
Boost.Accumulators

Eric Niebler

Copyright © 2005, 2006 Eric Niebler

Distributed under the Boost Software License, Version 1.0. (See accompanying file LICENSE_1_0.txt or copy at http://www.boost.org/LICENSE_1_0.txt)

Table of Contents

Preface	4
User's Guide	5
The Accumulators Framework	5
Using <code>accumulator_set<></code>	7
Extracting Results	8
Passing Optional Parameters	9
Weighted Samples	10
Numeric Operators Sub-Library	11
Extending the Accumulators Framework	11
Defining a New Accumulator	11
Defining a New Feature	15
Defining a New Extractor	16
Controlling Dependencies	17
Specializing Numeric Operators	18
Concepts	20
The Statistical Accumulators Library	20
count	21
covariance	21
density	22
error_of<mean>	23
extended_p_square	24
extended_p_square_quantile <i>and variants</i>	25
kurtosis	27
max	28
mean <i>and variants</i>	28
median <i>and variants</i>	31
min	32
moment	33
p_square_cumulative_distribution	34
p_square_quantile <i>and variants</i>	35
peaks_over_threshold <i>and variants</i>	36
pot_quantile <i>and variants</i>	37
pot_tail_mean	40
rolling_count	40
rolling_sum	41
rolling_mean	42
skewness	43
sum <i>and variants</i>	44
tail	45
coherent_tail_mean	46
non_coherent_tail_mean	47
tail_quantile	48
tail_variate	50
tail_variate_means <i>and variants</i>	52

variance <i>and variants</i>	55
weighted_covariance	56
weighted_density	57
weighted_extended_p_square	58
weighted_kurtosis	60
weighted_mean <i>and variants</i>	61
weighted_median <i>and variants</i>	63
weighted_moment	64
weighted_p_square_cumulative_distribution	65
weighted_p_square_quantile <i>and variants</i>	68
weighted_peaks_over_threshold <i>and variants</i>	70
weighted_skewness	71
weighted_sum <i>and variants</i>	72
non_coherent_weighted_tail_mean	73
weighted_tail_quantile	75
weighted_tail_variate_means <i>and variants</i>	76
weighted_variance <i>and variants</i>	80
Acknowledgements	82
Reference	83
Accumulators Framework Reference	83
Header <boost/accumulators/accumulators.hpp>	83
Header <boost/accumulators/accumulators_fwd.hpp>	83
Header <boost/accumulators/framework/accumulator_base.hpp>	92
Header <boost/accumulators/framework/accumulator_concept.hpp>	94
Header <boost/accumulators/framework/accumulator_set.hpp>	94
Header <boost/accumulators/framework/accumulators/droppable_accumulator.hpp>	95
Header <boost/accumulators/framework/accumulators/external_accumulator.hpp>	96
Header <boost/accumulators/framework/accumulators/reference_accumulator.hpp>	97
Header <boost/accumulators/framework/accumulators/value_accumulator.hpp>	99
Header <boost/accumulators/framework/depends_on.hpp>	100
Header <boost/accumulators/framework/extractor.hpp>	100
Header <boost/accumulators/framework/features.hpp>	100
Header <boost/accumulators/framework/parameters/accumulator.hpp>	100
Header <boost/accumulators/framework/parameters/sample.hpp>	101
Header <boost/accumulators/framework/parameters/weight.hpp>	101
Header <boost/accumulators/framework/parameters/weights.hpp>	102
Statistics Library Reference	103
Header <boost/accumulators/statistics.hpp>	103
Header <boost/accumulators/statistics/count.hpp>	103
Header <boost/accumulators/statistics/covariance.hpp>	105
Header <boost/accumulators/statistics/density.hpp>	108
Header <boost/accumulators/statistics/error_of.hpp>	109
Header <boost/accumulators/statistics/error_of_mean.hpp>	110
Header <boost/accumulators/statistics/extended_p_square.hpp>	111
Header <boost/accumulators/statistics/extended_p_square_quantile.hpp>	113
Header <boost/accumulators/statistics/kurtosis.hpp>	118
Header <boost/accumulators/statistics/max.hpp>	119
Header <boost/accumulators/statistics/mean.hpp>	120
Header <boost/accumulators/statistics/median.hpp>	127
Header <boost/accumulators/statistics/min.hpp>	132
Header <boost/accumulators/statistics/moment.hpp>	133
Header <boost/accumulators/statistics/p_square_cumul_dist.hpp>	134
Header <boost/accumulators/statistics/p_square_quantile.hpp>	135
Header <boost/accumulators/statistics/peaks_over_threshold.hpp>	137
Header <boost/accumulators/statistics/pot_quantile.hpp>	142
Header <boost/accumulators/statistics/pot_tail_mean.hpp>	145
Header <boost/accumulators/statistics/rolling_count.hpp>	148
Header <boost/accumulators/statistics/rolling_mean.hpp>	149

Header <boost/accumulators/statistics/rolling_sum.hpp>	150
Header <boost/accumulators/statistics/rolling_window.hpp>	151
Header <boost/accumulators/statistics/skewness.hpp>	152
Header <boost/accumulators/statistics/stats.hpp>	153
Header <boost/accumulators/statistics/sum.hpp>	154
Header <boost/accumulators/statistics/sum_kahan.hpp>	156
Header <boost/accumulators/statistics/tail.hpp>	160
Header <boost/accumulators/statistics/tail_mean.hpp>	162
Header <boost/accumulators/statistics/tail_quantile.hpp>	164
Header <boost/accumulators/statistics/tail_variate.hpp>	166
Header <boost/accumulators/statistics/tail_variate_means.hpp>	168
Header <boost/accumulators/statistics/times2_iterator.hpp>	172
Header <boost/accumulators/statistics/variance.hpp>	172
Header <boost/accumulators/statistics/variates/covariate.hpp>	175
Header <boost/accumulators/statistics/weighted_covariance.hpp>	176
Header <boost/accumulators/statistics/weighted_density.hpp>	177
Header <boost/accumulators/statistics/weighted_extended_p_square.hpp>	178
Header <boost/accumulators/statistics/weighted_kurtosis.hpp>	179
Header <boost/accumulators/statistics/weighted_mean.hpp>	180
Header <boost/accumulators/statistics/weighted_median.hpp>	182
Header <boost/accumulators/statistics/weighted_moment.hpp>	184
Header <boost/accumulators/statistics/weighted_p_square_cumul_dist.hpp>	184
Header <boost/accumulators/statistics/weighted_p_square_quantile.hpp>	185
Header <boost/accumulators/statistics/weighted_peaks_over_threshold.hpp>	187
Header <boost/accumulators/statistics/weighted_skewness.hpp>	188
Header <boost/accumulators/statistics/weighted_sum.hpp>	189
Header <boost/accumulators/statistics/weighted_sum_kahan.hpp>	190
Header <boost/accumulators/statistics/weighted_tail_mean.hpp>	192
Header <boost/accumulators/statistics/weighted_tail_quantile.hpp>	192
Header <boost/accumulators/statistics/weighted_tail_variate_means.hpp>	193
Header <boost/accumulators/statistics/weighted_variance.hpp>	195
Header <boost/accumulators/statistics/with_error.hpp>	197
Header <boost/accumulators/statistics_fwd.hpp>	197
Numeric Operators Library Reference	261
Header <boost/accumulators/numeric/functional.hpp>	261
Header <boost/accumulators/numeric/functional/complex.hpp>	297
Header <boost/accumulators/numeric/functional/valarray.hpp>	298
Header <boost/accumulators/numeric/functional/vector.hpp>	303

Preface

“It is better to be approximately right than exactly wrong.”
-- *Old adage*

Description

Boost.Accumulators is both a library for incremental statistical computation as well as an extensible framework for incremental calculation in general. The library deals primarily with the concept of an *accumulator*, which is a primitive computational entity that accepts data one sample at a time and maintains some internal state. These accumulators may offload some of their computations on other accumulators, on which they depend. Accumulators are grouped within an *accumulator set*. Boost.Accumulators resolves the inter-dependencies between accumulators in a set and ensures that accumulators are processed in the proper order.

User's Guide

This section describes how to use the Boost.Accumulators framework to create new accumulators and how to use the existing statistical accumulators to perform incremental statistical computation. For detailed information regarding specific components in Boost.Accumulators, check the [Reference](#) section.

Hello, World!

Below is a complete example of how to use the Accumulators Framework and the Statistical Accumulators to perform an incremental statistical calculation. It calculates the mean and 2nd moment of a sequence of doubles.

```
#include <iostream>
#include <boost/accumulators/accumulators.hpp>
#include <boost/accumulators/statistics/stats.hpp>
#include <boost/accumulators/statistics/mean.hpp>
#include <boost/accumulators/statistics/moment.hpp>
using namespace boost::accumulators;

int main()
{
    // Define an accumulator set for calculating the mean and the
    // 2nd moment ...
    accumulator_set<double, stats<tag::mean, tag::moment<2> > > acc;

    // push in some data ...
    acc(1.2);
    acc(2.3);
    acc(3.4);
    acc(4.5);

    // Display the results ...
    std::cout << "Mean:   " << mean(acc) << std::endl;
    std::cout << "Moment: " << accumulators::moment<2>(acc) << std::endl;

    return 0;
}
```

This program displays the following:

```
Mean:   2.85
Moment: 9.635
```

The Accumulators Framework

The Accumulators Framework is framework for performing incremental calculations. Usage of the framework follows the following pattern:

- Users build a computational object, called an `accumulator_set<>`, by selecting the computations in which they are interested, or authoring their own computational primitives which fit within the framework.
- Users push data into the `accumulator_set<>` object one sample at a time.
- The `accumulator_set<>` computes the requested quantities in the most efficient method possible, resolving dependencies between requested calculations, possibly cacheing intermediate results.

The Accumulators Framework defines the utilities needed for defining primitive computational elements, called *accumulators*. It also provides the `accumulator_set<>` type, described above.

Terminology

The following terms are used in the rest of the documentation.

Sample	A datum that is pushed into an <code>accumulator_set<></code> . The type of the sample is the <i>sample type</i> .
Weight	An optional scalar value passed along with the sample specifying the weight of the sample. Conceptually, each sample is multiplied with its weight. The type of the weight is the <i>weight type</i> .
Feature	An abstract primitive computational entity. When defining an <code>accumulator_set<></code> , users specify the features in which they are interested, and the <code>accumulator_set<></code> figures out which <i>accumulators</i> would best provide those features. Features may depend on other features. If they do, the accumulator set figures out which accumulators to add to satisfy the dependencies.
Accumulator	A concrete primitive computational entity. An accumulator is a concrete implementation of a feature. It satisfies exactly one abstract feature. Several different accumulators may provide the same feature, but may represent different implementation strategies.
Accumulator Set	A collection of accumulators. An accumulator set is specified with a sample type and a list of features. The accumulator set uses this information to generate an ordered set of accumulators depending on the feature dependency graph. An accumulator set accepts samples one datum at a time, propagating them to each accumulator in order. At any point, results can be extracted from the accumulator set.
Extractor	A function or function object that can be used to extract a result from an <code>accumulator_set<></code> .

Overview

Here is a list of the important types and functions in the Accumulator Framework and a brief description of each.

Table 1. Accumulators Toolbox

Tool	Description
<code>accumulator_set<></code>	This is the most important type in the Accumulators Framework. It is a collection of accumulators. A datum pushed into an <code>accumulator_set<></code> is forwarded to each accumulator, in an order determined by the dependency relationships between the accumulators. Computational results can be extracted from an accumulator at any time.
<code>depends_on<></code>	Used to specify which other features a feature depends on.
<code>feature_of<></code>	Trait used to tell the Accumulators Framework that, for the purpose of feature-based dependency resolution, one feature should be treated the same as another.
<code>as_feature<></code>	Used to create an alias for a feature. For example, if there are two features, <code>fast_X</code> and <code>accurate_X</code> , they can be mapped to <code>X(fast)</code> and <code>X(accurate)</code> with <code>as_feature<></code> . This is just syntactic sugar.
<code>features<></code>	An MPL sequence. We can use <code>features<></code> as the second template parameter when declaring an <code>accumulator_set<></code> .
<code>external<></code>	Used when declaring an <code>accumulator_set<></code> . If the weight type is specified with <code>external<></code> , then the weight accumulators are assumed to reside in a separate accumulator set which will be passed in with a named parameter.
<code>extractor<></code>	A class template useful for creating an extractor function object. It is parameterized on a feature, and it has member functions for extracting from an <code>accumulator_set<></code> the result corresponding to that feature.

Using `accumulator_set<>`

Our tour of the `accumulator_set<>` class template begins with the forward declaration:

```
template< typename Sample, typename Features, typename Weight = void >
struct accumulator_set;
```

The template parameters have the following meaning:

Sample The type of the data that will be accumulated.

Features An [MPL](#) sequence of features to be calculated.

Weight The type of the (optional) weight paramter.

For example, the following line declares an `accumulator_set<>` that will accept a sequence of doubles one at a time and calculate the min and mean:

```
accumulator_set< double, features< tag::min, tag::mean > > acc;
```

Notice that we use the `features<>` template to specify a list of features to be calculated. `features<>` is an [MPL](#) sequence of features.

**Note**

`features<>` is a synonym of `mpl::vector<>`. In fact, we could use `mpl::vector<>` or any MPL sequence if we prefer, and the meaning would be the same.

Once we have defined an `accumulator_set<>`, we can then push data into it, and it will calculate the quantities you requested, as shown below.

```
// push some data into the accumulator_set ...
acc(1.2);
acc(2.3);
acc(3.4);
```

Since `accumulator_set<>` defines its accumulate function to be the function call operator, we might be tempted to use an `accumulator_set<>` as a UnaryFunction to a standard algorithm such as `std::for_each`. That's fine as long as we keep in mind that the standard algorithms take UnaryFunction objects by value, which involves making a copy of the `accumulator_set<>` object. Consider the following:

```
// The data for which we wish to calculate statistical properties:
std::vector< double > data( /* stuff */ );

// The accumulator set which will calculate the properties for us:
accumulator_set< double, features< tag::min, tag::mean > > acc;

// Use std::for_each to accumulate the statistical properties:
acc = std::for_each( data.begin(), data.end(), acc );
```

Notice how we must assign the return value of `std::for_each` back to the `accumulator_set<>`. This works, but some accumulators are not cheap to copy. For example, the `tail` and `tail_variate<>` accumulators must store a `std::vector<>`, so copying these accumulators involves a dynamic allocation. We might be better off in this case passing the accumulator by reference, with the help of `boost::bind()` and `boost::ref()`. See below:

```
// The data for which we wish to calculate statistical properties:
std::vector< double > data( /* stuff */ );

// The accumulator set which will calculate the properties for us:
accumulator_set< double, features< tag::tail<left> > > acc(
    tag::tail<left>::cache_size = 4 );

// Use std::for_each to accumulate the statistical properties:
std::for_each( data.begin(), data.end(), bind<void>( ref(acc), _1 ) );
```

Notice now that we don't care about the return value of `std::for_each()` anymore because `std::for_each()` is modifying `acc` directly.

**Note**

To use `boost::bind()` and `boost::ref()`, you must `#include <boost/bind.hpp>` and `<boost/ref.hpp>`

Extracting Results

Once we have declared an `accumulator_set<>` and pushed data into it, we need to be able to extract results from it. For each feature we can add to an `accumulator_set<>`, there is a corresponding extractor for fetching its result. Usually, the extractor has the same name as the feature, but in a different namespace. For example, if we accumulate the `tag::min` and `tag::max` features, we can extract the results with the `min` and `max` extractors, as follows:


```
// Calculate the minimum and maximum for a sequence of integers.
accumulator_set< int, features< tag::min, tag::max > > acc;
acc( 2 );
acc( -1 );
acc( 1 );

// This displays "(-1, 2)"
std::cout << '(' << min( acc ) << ", " << max( acc ) << ")\n";
```

The extractors are all declared in the `boost::accumulators::extract` namespace, but they are brought into the `boost::accumulators` namespace with a `using` declaration.



Tip

On the Windows platform, `min` and `max` are preprocessor macros defined in `WinDef.h`. To use the `min` and `max` extractors, you should either compile with `NOMINMAX` defined, or you should invoke the extractors like: `(min)(acc)` and `(max)(acc)`. The parentheses keep the macro from being invoked.

Another way to extract a result from an `accumulator_set<>` is with the `extract_result()` function. This can be more convenient if there isn't an extractor object handy for a certain feature. The line above which displays results could equally be written as:

```
// This displays "(-1, 2)"
std::cout << '(' << extract_result< tag::min >( acc )
          << ", " << extract_result< tag::max >( acc ) << ")\n";
```

Finally, we can define our own extractor using the `extractor<>` class template. For instance, another way to avoid the `min`/`max` macro business would be to define extractors with names that don't conflict with the macros, like this:

```
extractor< tag::min > min_;
extractor< tag::min > max_;

// This displays "(-1, 2)"
std::cout << '(' << min_( acc ) << ", " << max_( acc ) << ")\n";
```

Passing Optional Parameters

Some accumulators need initialization parameters. In addition, perhaps some auxiliary information needs to be passed into the `accumulator_set<>` along with each sample. Boost.Accumulators handles these cases with named parameters from the [Boost.Parameter](#) library.

For example, consider the `tail` and `tail_variate<>` features. `tail` keeps an ordered list of the largest N samples, where N can be specified at construction time. Also, the `tail_variate<>` feature, which depends on `tail`, keeps track of some data that is covariate with the N samples tracked by `tail`. The code below shows how this all works, and is described in more detail below.

```
// Define a feature for tracking covariate data
typedef tag::tail_variate< int, tag::covariate1, left > my_tail_variate_tag;

// This will calculate the left tail and my_tail_variate_tag for N == 2
// using the tag::tail<left>::cache_size named parameter
accumulator_set< double, features< my_tail_variate_tag > > acc(
    tag::tail<left>::cache_size = 2 );

// push in some samples and some covariates by using
// the covariate1 named parameter
acc( 1.2, covariate1 = 12 );
acc( 2.3, covariate1 = -23 );
acc( 3.4, covariate1 = 34 );
acc( 4.5, covariate1 = -45 );

// Define an extractor for the my_tail_variate_tag feature
extractor< my_tail_variate_tag > my_tail_variate;

// Write the tail statistic to std::cout. This will print "4.5, 3.4, "
std::ostream_iterator< double > dout( std::cout, ", " );
std::copy( tail( acc ).begin(), tail( acc ).end(), dout );

// Write the tail_variate statistic to std::cout. This will print "-45, 34, "
std::ostream_iterator< int > iout( std::cout, ", " );
std::copy( my_tail_variate( acc ).begin(), my_tail_variate( acc ).end(), iout );
```

There are several things to note about the code above. First, notice that we didn't have to request that the `tail` feature be calculated. That is implicit because the `tail_variate<>` feature depends on the `tail` feature. Next, notice how the `acc` object is initialized: `acc(tag::tail<left>::cache_size = 2)`. Here, `cache_size` is a named parameter. It is used to tell the `tail` and `tail_variate<>` accumulators how many samples and covariates to store. Conceptually, every construction parameter is made available to every accumulator in an accumulator set.

We also use a named parameter to pass covariate data into the accumulator set along with the samples. As with the constructor parameters, all parameters to the `accumulate` function are made available to all the accumulators in the set. In this case, only the accumulator for the `my_tail_variate` feature would be interested in the value of the `covariate1` named parameter.

We can make one final observation about the example above. Since `tail` and `tail_variate<>` are multi-valued features, the result we extract for them is represented as an iterator range. That is why we can say `tail(acc).begin()` and `tail(acc).end()`.

Even the extractors can accept named parameters. In a bit, we'll see a situation where that is useful.

Weighted Samples

Some accumulators, statistical accumulators in particular, deal with data that are *weighted*. Each sample pushed into the accumulator has an associated weight, by which the sample is conceptually multiplied. The Statistical Accumulators Library provides an assortment of these weighted statistical accumulators. And many unweighted statistical accumulators have weighted variants. For instance, the weighted variant of the `sum` accumulator is called `weighted_sum`, and is calculated by accumulating all the samples multiplied by their weights.

To declare an `accumulator_set<>` that accepts weighted samples, you must specify the type of the weight parameter as the 3rd template parameter, as follows:

```
// 3rd template parameter 'int' means this is a weighted
// accumulator set where the weights have type 'int'
accumulator_set< int, features< tag::sum >, int > acc;
```

When you specify a weight, all the accumulators in the set are replaced with their weighted equivalents. For example, the above `accumulator_set<>` declaration is equivalent to the following:

```
// Since we specified a weight, tag::sum becomes tag::weighted_sum
accumulator_set< int, features< tag::weighted_sum >, int > acc;
```

When passing samples to the accumulator set, you must also specify the weight of each sample. You can do that with the `weight` named parameter, as follows:

```
acc(1, weight = 2); // 1 * 2
acc(2, weight = 4); // 2 * 4
acc(3, weight = 6); // + 3 * 6
                    // -----
                    // =      28
```

You can then extract the result with the `sum()` extractor, as follows:

```
// This prints "28"
std::cout << sum(acc) << std::endl;
```



Note

When working with weighted statistical accumulators from the Statistical Accumulators Library, be sure to include the appropriate header. For instance, `weighted_sum` is defined in `<boost/accumulators/statistics/weighted_sum.hpp>`.

Numeric Operators Sub-Library

This section describes the function objects in the `boost::numeric` namespace, which is a sub-library that provides function objects and meta-functions corresponding to the infix operators in C++.

In the `boost::numeric::operators` namespace are additional operator overloads for some useful operations not provided by the standard library, such as multiplication of a `std::complex<>` with a scalar.

In the `boost::numeric::functional` namespace are function object equivalents of the infix operators. These function object types are heterogeneous, and so are more general than the standard ones found in the `<functional>` header. They use the `Boost.Typeof` library to deduce the return types of the infix expressions they evaluate. In addition, they look within the `boost::numeric::operators` namespace to consider any additional overloads that might be defined there.

In the `boost::numeric` namespace are global polymorphic function objects corresponding to the function object types defined in the `boost::numeric::functional` namespace. For example, `boost::numeric::plus(a, b)` is equivalent to `boost::numeric::functional::plus<A, B>()(a, b)`, and both are equivalent to using namespace `boost::numeric::operators`; `a + b`;

The Numeric Operators Sub-Library also gives several ways to sub-class and a way to sub-class and specialize operations. One way uses tag dispatching on the types of the operands. The other way is based on the compile-time properties of the operands.

Extending the Accumulators Framework

This section describes how to extend the Accumulators Framework by defining new accumulators, features and extractors. Also covered are how to control the dependency resolution of features within an accumulator set.

Defining a New Accumulator

All new accumulators must satisfy the [Accumulator Concept](#). Below is a sample class that satisfies the accumulator concept, which simply sums the values of all samples passed into it.

```
#include <boost/accumulators/framework/accumulator_base.hpp>
#include <boost/accumulators/framework/parameters/sample.hpp>

namespace boost {
namespace accumulators {
namespace impl {
// Putting your accumulators in the
// impl namespace has some
// advantages. See below.

template<typename Sample>
struct sum_accumulator
: accumulator_base
{
    typedef Sample result_type;
    // The type returned by result() below.

    template<typename Args>
    sum_accumulator(Args const & args)
    : sum(args[sample | Sample()])
    {
        // The constructor takes an argument pack.
        // Maybe there is an initial value in the
        // argument pack. ('sample' is defined in
        // sample.hpp, included above.)
    }

    template<typename Args>
    void operator ()(Args const & args)
    {
        // The accumulate function is the function
        // call operator, and it also accepts an
        // argument pack.
        this->sum += args[sample];
    }

    result_type result(dont_care) const
    {
        // The result function will also be passed
        // an argument pack, but we don't use it here,
        // so we use "dont_care" as the argument type.
        return this->sum;
    }
private:
    Sample sum;
};
}}}
```

Much of the above should be pretty self-explanatory, except for the use of argument packs which may be confusing if you have never used the [Boost.Parameter](#) library before. An argument pack is a cluster of values, each of which can be accessed with a key. So `args[sample]` extracts from the pack the value associated with the `sample` key. And the cryptic `args[sample | Sample()]` evaluates to the value associated with the `sample` key if it exists, or a default-constructed `Sample` if it doesn't.

The example above demonstrates the most common attributes of an accumulator. There are other optional member functions that have special meaning. In particular:

Optional Accumulator Member Functions

`on_drop(Args)` Defines an action to be taken when this accumulator is dropped. See the section on [Droppable Accumulators](#).

Accessing Other Accumulators in the Set

Some accumulators depend on other accumulators within the same accumulator set. In those cases, it is necessary to be able to access those other accumulators. To make this possible, the `accumulator_set<>` passes a reference to itself when invoking the member functions of its contained accumulators. It can be accessed by using the special `accumulator` key with the argument pack. Consider how we might implement `mean_accumulator`:

```
// Mean == (Sum / Count)
template<typename Sample>
struct mean_accumulator : accumulator_base
{
    typedef Sample result_type;
    mean_accumulator(dont_care) {}

    template<typename Args>
    result_type result(Args const &args) const
    {
        return sum(args[accumulator]) / count(args[accumulator]);
    }
};
```

mean depends on the `sum` and `count` accumulators. (We'll see in the next section how to specify these dependencies.) The result of the mean accumulator is merely the result of the sum accumulator divided by the result of the count accumulator. Consider how we write that: `sum(args[accumulator]) / count(args[accumulator])`. The expression `args[accumulator]` evaluates to a reference to the `accumulator_set<>` that contains this `mean_accumulator`. It also contains the `sum` and `count` accumulators, and we can access their results with the extractors defined for those features: `sum` and `count`.



Note

Accumulators that inherit from `accumulator_base` get an empty operator `()`, so accumulators like `mean_accumulator` above need not define one.

All the member functions that accept an argument pack have access to the enclosing `accumulator_set<>` via the `accumulator` key, including the constructor. The accumulators within the set are constructed in an order determined by their interdependencies. As a result, it is safe for an accumulator to access one on which it depends during construction.

Infix Notation and the Numeric Operators Sub-Library

Although not necessary, it can be a good idea to put your accumulator implementations in the `boost::accumulators::impl` namespace. This namespace pulls in any operators defined in the `boost::numeric::operators` namespace with a `using` directive. The Numeric Operators Sub-Library defines some additional overloads that will make your accumulators work with all sorts of data types.

Consider `mean_accumulator` defined above. It divides the sum of the samples by the count. The type of the count is `std::size_t`. What if the sample type doesn't define division by `std::size_t`? That's the case for `std::complex<>`. You might think that if the sample type is `std::complex<>`, the code would not work, but in fact it does. That's because Numeric Operators Sub-Library defines an overloaded operator `/` for `std::complex<>` and `std::size_t`. This operator is defined in the `boost::numeric::operators` namespace and will be found within the `boost::accumulators::impl` namespace. That's why it's a good idea to put your accumulators there.

Droppable Accumulators

The term "droppable" refers to an accumulator that can be removed from the `accumulator_set<>`. You can request that an accumulator be made droppable by using the `droppable<>` class template.

```
// calculate sum and count, make sum droppable:
accumulator_set< double, features< tag::count, droppable<tag::sum> > > acc;

// add some data
acc(3.0);
acc(2.0);

// drop the sum (sum is 5 here)
acc.drop<tag::sum>();

// add more data
acc(1.0);

// This will display "3" and "5"
std::cout << count(acc) << ' ' << sum(acc);
```

Any accumulators that get added to an accumulator set in order to satisfy dependencies on droppable accumulators are themselves droppable. Consider the following accumulator:

```
// Sum is not droppable. Mean is droppable. Count, brought in to
// satisfy mean's dependencies, is implicitly droppable, too.
accumulator_set< double, features< tag::sum, droppable<tag::mean> > > acc;
```

mean depends on sum and count. Since mean is droppable, so too is count. However, we have explicitly requested that sum be not droppable, so it isn't. Had we left tag::sum out of the above declaration, the sum accumulator would have been implicitly droppable.

A droppable accumulator is reference counted, and is only really dropped after all the accumulators that depend on it have been dropped. This can lead to some surprising behavior in some situations.

```
// calculate sum and mean, make mean droppable.
accumulator_set< double, features< tag::sum, droppable<tag::mean> > > acc;

// add some data
acc(1.0);
acc(2.0);

// drop the mean. mean's reference count
// drops to 0, so it's really dropped. So
// too, count's reference count drops to 0
// and is really dropped.
acc.drop<tag::mean>();

// add more data. Sum continues to accumulate!
acc(3.0);

// This will display "6 2 3"
std::cout << sum(acc) << ' '
          << count(acc) << ' '
          << mean(acc);
```

Note that at the point at which mean is dropped, sum is 3, count is 2, and therefore mean is 1.5. But since sum continues to accumulate even after mean has been dropped, the value of mean continues to change. If you want to remember the value of mean at the point it is dropped, you should save its value into a local variable.

The following rules more precisely specify how droppable and non-droppable accumulators behave within an accumulator set.

- There are two types of accumulators: droppable and non-droppable. The default is non-droppable.
- For any feature *x*, both *x* and `droppable<X>` satisfy the *x* dependency.

- If feature `x` depends on `y` and `z`, then `droppable<x>` depends on `droppable<y>` and `droppable<z>`.
- All accumulators have `add_ref()` and `drop()` member functions.
- For non-droppable accumulators, `drop()` is a no-op, and `add_ref()` invokes `add_ref()` on all accumulators corresponding to the features upon which the current accumulator depends.
- Droppable accumulators have a reference count and define `add_ref()` and `drop()` to manipulate the reference count.
- For droppable accumulators, `add_ref()` increments the accumulator's reference count, and also `add_ref()`'s the accumulators corresponding to the features upon which the current accumulator depends.
- For droppable accumulators, `drop()` decrements the accumulator's reference count, and also `drop()`'s the accumulators corresponding to the features upon which the current accumulator depends.
- The `accumulator_set` constructor walks the list of **user-specified** features and `add_ref()`'s the accumulator that corresponds to each of them. (Note: that means that an accumulator that is not user-specified but in the set merely to satisfy a dependency will be dropped as soon as all its dependencies have been dropped. Ones that have been user specified are not dropped until their dependencies have been dropped **and** the user has explicitly dropped the accumulator.)
- Droppable accumulators check their reference count in their `accumulate` member function. If the reference count is 0, the function is a no-op.
- Users are not allowed to drop a feature that is not user-specified and marked as droppable.

And as an optimization:

- If the user specifies the non-droppable feature `x`, which depends on `y` and `z`, then the accumulators for `y` and `z` can be safely made non-droppable, as well as any accumulators on which they depend.

Defining a New Feature

Once we have implemented an accumulator, we must define a feature for it so that users can specify the feature when declaring an `accumulator_set<>`. We typically put the features into a nested namespace, so that later we can define an extractor of the same name. All features must satisfy the [Feature Concept](#). Using `depends_on<>` makes satisfying the concept simple. Below is an example of a feature definition.

```
namespace boost { namespace accumulators { namespace tag {  
  
    struct mean                                // Features should inherit from  
    : depends_on< count, sum >                // depends_on<> to specify dependencies  
    {  
        // Define a nested typedef called 'impl' that specifies which  
        // accumulator implements this feature.  
        typedef accumulators::impl::mean_accumulator< mpl::_1 > impl;  
    };  
  
}}}
```

The only two things we must do to define the `mean` feature is to specify the dependencies with `depends_on<>` and define the nested `impl` typedef. Even features that have no dependencies should inherit from `depends_on<>`. The nested `impl` type must be an [MPL Lambda Expression](#). The result of `mpl::apply< impl, sample-type, weight-type >::type` must be the type of the accumulator that implements this feature. The use of [MPL placeholders](#) like `mpl::_1` make it especially easy to make a template such as `mean_accumulator<>` an [MPL Lambda Expression](#). Here, `mpl::_1` will be replaced with the sample type. Had we used `mpl::_2`, it would have been replaced with the weight type.

What about accumulator types that are not templates? If you have a `foo_accumulator` which is a plain struct and not a template, you could turn it into an [MPL Lambda Expression](#) using `mpl::always<>`, like this:

```
// An MPL lambda expression that always evaluates to
// foo_accumulator:
typedef mpl::always< foo_accumulator > impl;
```

If you are ever unsure, or if you are not comfortable with MPL lambda expressions, you could always define `impl` explicitly:

```
// Same as 'typedef mpl::always< foo_accumulator > impl;'
struct impl
{
    template< typename Sample, typename Weight >
    struct apply
    {
        typedef foo_accumulator type;
    };
};
```

Here, `impl` is a binary [MPL Metafunction Class](#), which is a kind of [MPL Lambda Expression](#). The nested `apply<>` template is part of the metafunction class protocol and tells MPL how to build the accumulator type given the sample and weight types.

All features must also provide a nested `is_weight_accumulator` typedef. It must be either `mpl::true_` or `mpl::false_`. [depends_on<>](#) provides a default of `mpl::false_` for all features that inherit from it, but that can be overridden (or hidden, technically speaking) in the derived type. When the feature represents an accumulation of information about the weights instead of the samples, we can mark this feature as such with `typedef mpl::true_ is_weight_accumulator;`. The weight accumulators are made external if the weight type is specified using the `external<>` template.

Defining a New Extractor

Now that we have an accumulator and a feature, the only thing lacking is a way to get results from the accumulator set. The Accumulators Framework provides the `extractor<>` class template to make it simple to define an extractor for your feature. Here's an extractor for the mean feature we defined above:

```
namespace boost {
namespace accumulators {
namespace extract {
    // By convention, we put extractors
    // in the 'extract' namespace

    extractor< tag::mean > const mean = {}; // Simply define our extractor with
                                           // our feature tag, like this.
}
using extract::mean; // Pull the extractor into the
                    // enclosing namespace.
}
```

Once defined, the mean extractor can be used to extract the result of the `tag::mean` feature from an `accumulator_set<>`.

Parameterized features complicate this simple picture. Consider the `moment` feature, for calculating the N -th moment, where N is specified as a template parameter:

```
// An accumulator set for calculating the N-th moment, for N == 2 ...
accumulator_set< double, features< tag::moment<2> > > acc;

// ... add some data ...

// Display the 2nd moment ...
std::cout << "2nd moment is " << accumulators::moment<2>(acc) << std::endl;
```

In the expression `accumulators::moment<2>(acc)`, what is `moment`? It cannot be an object -- the syntax of C++ will not allow it. Clearly, if we want to provide this syntax, we must make `moment` a function template. Here's what the definition of the `moment` extractor looks like:


```
namespace boost {
namespace accumulators {
namespace extract {
    // By convention, we put extractors
    // in the 'extract' namespace

    template<int N, typename AccumulatorSet>
    typename mpl::apply<AccumulatorSet, tag::moment<N> >::type::result_type
    moment(AccumulatorSet const &acc)
    {
        return extract_result<tag::moment<N> >(acc);
    }
}
using extract::moment;
// Pull the extractor into the
// enclosing namespace.
}
```

The return type deserves some explanation. Every `accumulator_set<>` type is actually a unary [MPL Metafunction Class](#). When you `mpl::apply<>` an `accumulator_set<>` and a feature, the result is the type of the accumulator within the set that implements that feature. And every accumulator provides a nested `result_type` typedef that tells what its return type is. The extractor simply delegates its work to the `extract_result()` function.

Controlling Dependencies

The feature-based dependency resolution of the Accumulators Framework is designed to allow multiple different implementation strategies for each feature. For instance, two different accumulators may calculate the same quantity with different rounding modes, or using different algorithms with different size/speed tradeoffs. Other accumulators that depend on that quantity shouldn't care how it's calculated. The Accumulators Framework handles this by allowing several different accumulators satisfy the same feature.

Aliasing feature dependencies with `feature_of<>`

Imagine that you would like to implement the hypothetical *fubar* statistic, and that you know two ways to calculate fubar on a bunch of samples: an accurate but slow calculation and an approximate but fast calculation. You might opt to make the accurate calculation the default, so you implement two accumulators and call them `impl::fubar_impl` and `impl::fast_fubar_impl`. You would also define the `tag::fubar` and `tag::fast_fubar` features as described [above](#). Now, you would like to inform the Accumulators Framework that these two features are the same from the point of view of dependency resolution. You can do that with `feature_of<>`, as follows:

```
namespace boost { namespace accumulators
{
    // For the purposes of feature-based dependency resolution,
    // fast_fubar provides the same feature as fubar
    template<>
    struct feature_of<tag::fast_fubar>
        : feature_of<tag::fubar>
    {
    };
}
```

The above code instructs the Accumulators Framework that, if another accumulator in the set depends on the `tag::fubar` feature, the `tag::fast_fubar` feature is an acceptable substitute.

Registering feature variants with `as_feature<>`

You may have noticed that some feature variants in the Accumulators Framework can be specified with a nicer syntax. For instance, instead of `tag::mean` and `tag::immediate_mean` you can specify them with `tag::mean(lazy)` and `tag::mean(immediate)` respectively. These are merely aliases, but the syntax makes the relationship between the two clearer. You can create these feature aliases with the `as_feature<>` trait. Given the fubar example above, you might decide to alias `tag::fubar(accurate)` with `tag::fubar` and `tag::fubar(fast)` with `tag::fast_fubar`. You would do that as follows:

```
namespace boost { namespace accumulators
{
    struct fast {};           // OK to leave these tags empty
    struct accurate {};

    template<>
    struct as_feature<tag::fubar(accurate)>
    {
        typedef tag::fubar type;
    };

    template<>
    struct as_feature<tag::fubar(fast)>
    {
        typedef tag::fast_fubar type;
    };
}}
```

Once you have done this, users of your fubar accumulator can request the `tag::fubar(fast)` and `tag::fubar(accurate)` features when defining their `accumulator_sets` and get the correct accumulator.

Specializing Numeric Operators

This section describes how to adapt third-party numeric types to work with the Accumulator Framework.

Rather than relying on the built-in operators, the Accumulators Framework relies on functions and operator overloads defined in the [Numeric Operators Sub-Library](#) for many of its numeric operations. This is so that it is possible to assign non-standard meanings to arithmetic operations. For instance, when calculating an average by dividing two integers, the standard integer division behavior would be mathematically incorrect for most statistical quantities. So rather than use `x / y`, the Accumulators Framework uses `numeric::average(x, y)`, which does floating-point division even if both `x` and `y` are integers.

Another example where the Numeric Operators Sub-Library is useful is when a type does not define the operator overloads required to use it for some statistical calculations. For instance, `std::vector<>` does not overload any arithmetic operators, yet it may be useful to use `std::vector<>` as a sample or variate type. The Numeric Operators Sub-Library defines the necessary operator overloads in the `boost::numeric::operators` namespace, which is brought into scope by the Accumulators Framework with a `using` directive.

Numeric Function Objects and Tag Dispatching

How are the numeric function object defined by the Numeric Operators Sub-Library made to work with types such as `std::vector<>`? The free functions in the `boost::numeric` namespace are implemented in terms of the function objects in the `boost::numeric::functional` namespace, so to make `boost::numeric::average()` do something sensible with a `std::vector<>`, for instance, we'll need to partially specialize the `boost::numeric::functional::average<>` function object.

The functional objects make use of a technique known as *tag dispatching* to select the proper implementation for the given operands. It works as follows:

```
namespace boost { namespace numeric { namespace functional
{
    // Metafunction for looking up the tag associated with
    // a given numeric type T.
    template<typename T>
    struct tag
    {
        // by default, all types have void as a tag type
        typedef void type;
    };

    // Forward declaration looks up the tag types of each operand
    template<
        typename Left
        , typename Right
        , typename LeftTag = typename tag<Left>::type
        , typename RightTag = typename tag<Right>::type
    >
    struct average;
}}}
```

If you have some user-defined type `MyDouble` for which you would like to customize the behavior of `numeric::average()`, you would specialize `numeric::functional::average<>` by first defining a tag type, as shown below:

```
namespace boost { namespace numeric { namespace functional
{
    // Tag type for MyDouble
    struct MyDoubleTag {};

    // Specialize tag<> for MyDouble.
    // This only needs to be done once.
    template<>
    struct tag<MyDouble>
    {
        typedef MyDoubleTag type;
    };

    // Specify how to divide a MyDouble by an integral count
    template<typename Left, typename Right>
    struct average<Left, Right, MyDoubleTag, void>
    {
        // Define the type of the result
        typedef ... result_type;

        result_type operator()(Left & left, Right & right) const
        {
            return ...;
        }
    };
}}}
```

Once you have done this, `numeric::average()` will use your specialization of `numeric::functional::average<>` when the first argument is a `MyDouble` object. All of the function objects in the Numeric Operators Sub-Library can be customized in a similar fashion.

Concepts

Accumulator Concept

In the following table, `Acc` is the type of an accumulator, `acc` and `acc2` are objects of type `Acc`, and `args` is the name of an argument pack from the [Boost.Parameter](#) library.

Table 2. Accumulator Requirements

Expression	Return type	Assertion / Note / Pre- / Post-condition
<code>Acc::result_type</code>	<i>implementation defined</i>	The type returned by <code>Acc::result()</code> .
<code>Acc acc(args)</code>	none	Construct from an argument pack.
<code>Acc acc(acc2)</code>	none	Post: <code>acc.result(args)</code> is equivalent to <code>acc2.result(args)</code>
<code>acc(args)</code>	<i>unspecified</i>	
<code>acc.on_drop(args)</code>	<i>unspecified</i>	
<code>acc.result(args)</code>	<code>Acc::result_type</code>	

Feature Concept

In the following table, `F` is the type of a feature and `S` is some scalar type.

Table 3. Feature Requirements

Expression	Return type	Assertion / Note / Pre- / Post-condition
<code>F::dependencies</code>	<i>unspecified</i>	An MPL sequence of other features on which which <code>F</code> depends.
<code>F::is_weight_accumulator</code>	<code>mpl::true_</code> or <code>mpl::false_</code>	<code>mpl::true_</code> if the accumulator for this feature should be made external when the weight type for the accumulator set is <code>external<S></code> , <code>mpl::false_</code> otherwise.
<code>F::impl</code>	<i>unspecified</i>	An MPL Lambda Expression that returns the type of the accumulator that implements this feature when passed a sample type and a weight type.

The Statistical Accumulators Library

The Statistical Accumulators Library defines accumulators for incremental statistical computations. It is built on top of [The Accumulator Framework](#).

count

The `count` feature is a simple counter that tracks the number of samples pushed into the accumulator set.

Result Type

```
std::size_t
```

Depends On

none

Variants

none

Initialization Parameters

none

Accumulator Parameters

none

Extractor Parameters

none

Accumulator Complexity

O(1)

Extractor Complexity

O(1)

Header

```
#include <boost/accumulators/statistics/count.hpp>
```

Example

```
accumulator_set<int, features<tag::count> > acc;
acc(0);
acc(0);
acc(0);
assert(3 == count(acc));
```

See also

- `count_impl`

covariance

The `covariance` feature is an iterative Monte Carlo estimator for the covariance. It is specified as `tag::covariance<variate-type, variate-tag>`.

Result Type

```
numeric::functional::outer_product<
    numeric::functional::average<sample-type, std::size_t>::result_type,
    numeric::functional::average<variate-type, std::size_t>::result_type>::result_type
```

Depends On

`count`
`mean`
`mean_of_variates<variate-type, variate-tag>`

Variants

`abstract_covariance`

Initialization Parameters

none

Accumulator Parameters	<i>variate-tag</i>
Extractor Parameters	<i>none</i>
Accumulator Complexity	TODO
Extractor Complexity	O(1)

Headers

```
#include <boost/accumulators/statistics/covariance.hpp>
#include <boost/accumulators/statistics/variates/covariate.hpp>
```

Example

```
accumulator_set<double, stats<tag::covariance<double, tag::covariate1> > > acc;
acc(1., covariate1 = 2.);
acc(1., covariate1 = 4.);
acc(2., covariate1 = 3.);
acc(6., covariate1 = 1.);
assert(covariance(acc) == -1.75);
```

See also

- [covariance_impl](#)
- [count](#)
- [mean](#)

density

The `tag::density` feature returns a histogram of the sample distribution. For more implementation details, see [density_impl](#).

Result Type

```
iterator_range<
    std::vector<
        std::pair<
            numeric::functional::average<sample-
type, std::size_t>::result_type
            , numeric::functional::average<sample-
type, std::size_t>::result_type
        >
    >::iterator
>
```

Depends On	count min max
Variants	<i>none</i>
Initialization Parameters	density::cache_size density::num_bins
Accumulator Parameters	<i>none</i>
Extractor Parameters	<i>none</i>

Accumulator Complexity	TODO
Extractor Complexity	$O(N)$, when N is <code>density::num_bins</code>

Header

```
#include <boost/accumulators/statistics/density.hpp>
```

Note

Results from the `density` accumulator can only be extracted after the number of samples meets or exceeds the cache size.

See also

- [density_impl](#)
- [count](#)
- [min](#)
- [max](#)

error_of<mean>

The `error_of<mean>` feature calculates the error of the mean feature. It is equal to `sqrt(variance / (count - 1))`.

Result Type

```
numeric::functional::average<sample-type, std::size_t>::result_type
```

Depends On	<code>count</code> <code>variance</code>
Variants	<code>error_of<immediate_mean></code>
Initialization Parameters	<i>none</i>
Accumulator Parameters	<i>none</i>
Extractor Parameters	<i>none</i>
Accumulator Complexity	TODO
Extractor Complexity	$O(1)$

Header

```
#include <boost/accumulators/statistics/error_of.hpp>
#include <boost/accumulators/statistics/error_of_mean.hpp>
```

Example

```
accumulator_set<double, stats<tag::error_of<tag::mean> > > acc;
acc(1.1);
acc(1.2);
acc(1.3);
assert(0.057735 == error_of<tag::mean>(acc));
```

See also

- [error_of_mean_impl](#)
- [count](#)
- [variance](#)

extended_p_square

Multiple quantile estimation with the extended P^2 algorithm. For further details, see [extended_p_square_impl](#).

Result Type

```
boost::iterator_range<
    implementation-defined
>
```

Depends On

[count](#)

Variants

none

Initialization Parameters

`tag::extended_p_square::probabilities`

Accumulator Parameters

none

Extractor Parameters

none

Accumulator Complexity

TODO

Extractor Complexity

$O(1)$

Header

```
#include <boost/accumulators/statistics/extended_p_square.hpp>
```

Example

```
boost::array<double> probs = {0.001,0.01,0.1,0.25,0.5,0.75,0.9,0.99,0.999};
accumulator_set<double, stats<tag::extended_p_square> >
    acc(tag::extended_p_square::probabilities = probs);

boost::lagged_fibonacci607 rng; // a random number generator
for (int i=0; i<10000; ++i)
    acc(rng());

BOOST_CHECK_CLOSE(extended_p_square(acc)[0], probs[0], 25);
BOOST_CHECK_CLOSE(extended_p_square(acc)[1], probs[1], 10);
BOOST_CHECK_CLOSE(extended_p_square(acc)[2], probs[2], 5);

for (std::size_t i=3; i < probs.size(); ++i)
{
    BOOST_CHECK_CLOSE(extended_p_square(acc)[i], probs[i], 2);
}
```

See also

- [extended_p_square_impl](#)
- [count](#)

extended_p_square_quantile and variants

Quantile estimation using the extended P^2 algorithm for weighted and unweighted samples. By default, the calculation is linear and unweighted, but quadratic and weighted variants are also provided. For further implementation details, see [extended_p_square_quantile_impl](#).

All the variants share the `tag::quantile` feature and can be extracted using the `quantile()` extractor.

Result Type

```
numeric::functional::average<sample-type, std::size_t>::result_type
```

Depends On

weighted variants depend on `weighted_extended_p_square`
unweighted variants depend on `extended_p_square`

Variants

`extended_p_square_quantile_quadratic`
`weighted_extended_p_square_quantile`
`weighted_extended_p_square_quantile_quadratic`

Initialization Parameters

`tag::extended_p_square::probabilities`

Accumulator Parameters

weight for the weighted variants

Extractor Parameters

`quantile_probability`

Accumulator Complexity

TODO

Extractor Complexity

$O(N)$ where N is the count of probabilities.

Header

```
#include <boost/accumulators/statistics/extended_p_square_quantile.hpp>
```

Example

```
typedef accumulator_set<double, stats<tag::extended_p_square_quantile> >
    accumulator_t;
typedef accumulator_set<double, stats<tag::weighted_extended_p_square_quantile>, double >
    accumulator_t_weighted;
typedef accumulator_set<double, stats<tag::extended_p_square_quantile(quadratic)> >
    accumulator_t_quadratic;
typedef accumulator_set<double, stats<tag::weighted_extended_p_square_quantile(quadratic)
ic)>, double >
    accumulator_t_weighted_quadratic;

// tolerance
double epsilon = 1;

// a random number generator
boost::lagged_fibonacci607 rng;

boost::array<double> probs = { 0.990, 0.991, 0.992, 0.993, 0.994,
                               0.995, 0.996, 0.997, 0.998, 0.999 };
accumulator_t acc(extended_p_square_probabilities = probs);
accumulator_t_weighted acc_weighted(extended_p_square_probabilities = probs);
accumulator_t_quadratic acc2(extended_p_square_probabilities = probs);
accumulator_t_weighted_quadratic acc_weighted2(extended_p_square_probabilities = probs);

for (int i=0; i<10000; ++i)
{
    double sample = rng();
    acc(sample);
    acc2(sample);
    acc_weighted(sample, weight = 1.);
    acc_weighted2(sample, weight = 1.);
}

for (std::size_t i = 0; i < probs.size() - 1; ++i)
{
    BOOST_CHECK_CLOSE(
        quantile(acc, quantile_probability = 0.99025 + i*0.001)
        , 0.99025 + i*0.001
        , epsilon
    );
    BOOST_CHECK_CLOSE(
        quantile(acc2, quantile_probability = 0.99025 + i*0.001)
        , 0.99025 + i*0.001
        , epsilon
    );
    BOOST_CHECK_CLOSE(
        quantile(acc_weighted, quantile_probability = 0.99025 + i*0.001)
        , 0.99025 + i*0.001
        , epsilon
    );
    BOOST_CHECK_CLOSE(
        quantile(acc_weighted2, quantile_probability = 0.99025 + i*0.001)
        , 0.99025 + i*0.001
        , epsilon
    );
}
```

See also

- [extended_p_square_quantile_impl](#)
- [extended_p_square](#)
- [weighted_extended_p_square](#)

kurtosis

The kurtosis of a sample distribution is defined as the ratio of the 4th central moment and the square of the 2nd central moment (the variance) of the samples, minus 3. The term -3 is added in order to ensure that the normal distribution has zero kurtosis. For more implementation details, see [kurtosis_impl](#)

Result Type

```
numeric::functional::average<sample-type, sample-type>::result_type
```

Depends On

```
mean  
moment<2>  
moment<3>  
moment<4>
```

Variants

none

Initialization Parameters

none

Accumulator Parameters

none

Extractor Parameters

none

Accumulator Complexity

O(1)

Extractor Complexity

O(1)

Header

```
#include <boost/accumulators/statistics/kurtosis.hpp>
```

Example

```
accumulator_set<int, stats<tag::kurtosis > > acc;  
  
acc(2);  
acc(7);  
acc(4);  
acc(9);  
acc(3);  
  
BOOST_CHECK_EQUAL( mean(acc), 5 );  
BOOST_CHECK_EQUAL( accumulators::moment<2>(acc), 159./5. );  
BOOST_CHECK_EQUAL( accumulators::moment<3>(acc), 1171./5. );  
BOOST_CHECK_EQUAL( accumulators::moment<4>(acc), 1863 );  
BOOST_CHECK_CLOSE( kurtosis(acc), -1.39965397924, 1e-6 );
```

See also

- [kurtosis_impl](#)
- [mean](#)
- [moment](#)

max

Calculates the maximum value of all the samples.

Result Type

sample-type

Depends On

none

Variants

none

Initialization Parameters

none

Accumulator Parameters

none

Extractor Parameters

none

Accumulator Complexity

O(1)

Extractor Complexity

O(1)

Header

```
#include <boost/accumulators/statistics/max.hpp>
```

Example

```
accumulator_set<int, stats<tag::max> > acc;

acc(1);
BOOST_CHECK_EQUAL(1, (max)(acc));

acc(0);
BOOST_CHECK_EQUAL(1, (max)(acc));

acc(2);
BOOST_CHECK_EQUAL(2, (max)(acc));
```

See also

- [max_impl](#)

mean and variants

Calculates the mean of samples, weights or variates. The calculation is either lazy (in the result extractor), or immediate (in the accumulator). The lazy implementation is the default. For more implementation details, see [mean_impl](#) or [immediate_mean_impl](#)

Result Type

For samples,	<code>numeric::functional::average<sample-type,</code>
<code>std::size_t>::result_type</code>	
For weights,	<code>numeric::functional::average<weight-type,</code>
<code>std::size_t>::result_type</code>	
For variates,	<code>numeric::functional::average<variate-type,</code>
<code>std::size_t>::result_type</code>	

Depends On

count
The lazy mean of samples depends on sum
The lazy mean of weights depends on sum_of_weights
The lazy mean of variates depends on sum_of_variates<>

Variants	<code>mean_of_weights</code> <code>mean_of_variates<variate-type, variate-tag></code> <code>immediate_mean</code> <code>immediate_mean_of_weights</code> <code>immediate_mean_of_variates<variate-type, variate-tag></code>
Initialization Parameters	<i>none</i>
Accumulator Parameters	<i>none</i>
Extractor Parameters	<i>none</i>
Accumulator Complexity	O(1)
Extractor Complexity	O(1)

Header

```
#include <boost/accumulators/statistics/mean.hpp>
```

Example

```
accumulator_set<
    int
    , stats<
        tag::mean
        , tag::mean_of_weights
        , tag::mean_of_variates<int, tag::covariate1>
    >
    , int
> acc;

acc(1, weight = 2, covariate1 = 3);
BOOST_CHECK_CLOSE(1., mean(acc), 1e-5);
BOOST_CHECK_EQUAL(1u, count(acc));
BOOST_CHECK_EQUAL(2, sum(acc));
BOOST_CHECK_CLOSE(2., mean_of_weights(acc), 1e-5);
BOOST_CHECK_CLOSE(3., (accumulators::mean_of_variates<int, tag::covariate1>(acc)), 1e-5);

acc(0, weight = 4, covariate1 = 4);
BOOST_CHECK_CLOSE(0.3333333333333333, mean(acc), 1e-5);
BOOST_CHECK_EQUAL(2u, count(acc));
BOOST_CHECK_EQUAL(2, sum(acc));
BOOST_CHECK_CLOSE(3., mean_of_weights(acc), 1e-5);
BOOST_CHECK_CLOSE(3.5, (accumulators::mean_of_variates<int, tag::covariate1>(acc)), 1e-5);

acc(2, weight = 9, covariate1 = 8);
BOOST_CHECK_CLOSE(1.3333333333333333, mean(acc), 1e-5);
BOOST_CHECK_EQUAL(3u, count(acc));
BOOST_CHECK_EQUAL(20, sum(acc));
BOOST_CHECK_CLOSE(5., mean_of_weights(acc), 1e-5);
BOOST_CHECK_CLOSE(5., (accumulators::mean_of_variates<int, tag::covariate1>(acc)), 1e-5);

accumulator_set<
    int
    , stats<
        tag::mean(immediate)
        , tag::mean_of_weights(immediate)
        , tag::mean_of_variates<int, tag::covariate1>(immediate)
    >
    , int
> acc2;

acc2(1, weight = 2, covariate1 = 3);
BOOST_CHECK_CLOSE(1., mean(acc2), 1e-5);
BOOST_CHECK_EQUAL(1u, count(acc2));
BOOST_CHECK_CLOSE(2., mean_of_weights(acc2), 1e-5);
BOOST_CHECK_CLOSE(3., (accumulators::mean_of_variates<int, tag::covariate1>(acc2)), 1e-5);

acc2(0, weight = 4, covariate1 = 4);
BOOST_CHECK_CLOSE(0.3333333333333333, mean(acc2), 1e-5);
BOOST_CHECK_EQUAL(2u, count(acc2));
BOOST_CHECK_CLOSE(3., mean_of_weights(acc2), 1e-5);
BOOST_CHECK_CLOSE(3.5, (accumulators::mean_of_variates<int, tag::covariate1>(acc2)), 1e-5);

acc2(2, weight = 9, covariate1 = 8);
BOOST_CHECK_CLOSE(1.3333333333333333, mean(acc2), 1e-5);
BOOST_CHECK_EQUAL(3u, count(acc2));
BOOST_CHECK_CLOSE(5., mean_of_weights(acc2), 1e-5);
BOOST_CHECK_CLOSE(5., (accumulators::mean_of_variates<int, tag::covariate1>(acc2)), 1e-5);
```

See also

- [mean_impl](#)

- [immediate_mean_impl](#)
- [count](#)
- [sum](#)

median and variants

Median estimation based on the P^2 quantile estimator, the density estimator, or the P^2 cumulative distribution estimator. For more implementation details, see [median_impl](#), [with_density_median_impl](#), and [with_p_square_cumulative_distribution_median_impl](#).

The three median accumulators all satisfy the `tag::median` feature, and can all be extracted with the `median()` extractor.

Result Type

```
numeric::functional::average<sample-type, std::size_t>::result_type
```

Depends On

`median` depends on `p_square_quantile_for_median`
`with_density_median` depends on `count` and `density`
`with_p_square_cumulative_distribution_median` depends on `p_square_cumulative_distribution`

Variants

`with_density_median`
`with_p_square_cumulative_distribution_median`

Initialization Parameters

`with_density_median` requires `tag::density::cache_size` and `tag::density::num_bins`
`with_p_square_cumulative_distribution_median` requires `tag::p_square_cumulative_distribution::num_cells`

Accumulator Parameters

none

Extractor Parameters

none

Accumulator Complexity

TODO

Extractor Complexity

TODO

Header

```
#include <boost/accumulators/statistics/median.hpp>
```

Example

```
// two random number generators
double mu = 1.;
boost::lagged_fibonacci607 rng;
boost::normal_distribution<> mean_sigma(mu,1);
boost::variate_generator<boost::lagged_fibonacci607&, boost::normal_distribution<> >
    normal(rng, mean_sigma);

accumulator_set<double, stats<tag::median(with_p_square_quantile) > > acc;
accumulator_set<double, stats<tag::median(with_density) > >
    acc_dens( density_cache_size = 10000, density_num_bins = 1000 );
accumulator_set<double, stats<tag::median(with_p_square_cumulative_distribution) > >
    acc_cdist( p_square_cumulative_distribution_num_cells = 100 );

for (std::size_t i=0; i<100000; ++i)
{
    double sample = normal();
    acc(sample);
    acc_dens(sample);
    acc_cdist(sample);
}

BOOST_CHECK_CLOSE(1., median(acc), 1.);
BOOST_CHECK_CLOSE(1., median(acc_dens), 1.);
BOOST_CHECK_CLOSE(1., median(acc_cdist), 3.);
```

See also

- [median_impl](#)
- [with_density_median_impl](#)
- [with_p_square_cumulative_distribution_median_impl](#)
- [count](#)
- [p_square_quantile](#)
- [p_square_cumulative_distribution](#)

min

Calculates the minimum value of all the samples.

Result Type

sample-type

Depends On *none*

Variants *none*

Initialization Parameters *none*

Accumulator Parameters *none*

Extractor Parameters *none*

Accumulator Complexity O(1)

Extractor Complexity O(1)

Header


```
#include <boost/accumulators/statistics/min.hpp>
```

Example

```
accumulator_set<int, stats<tag::min> > acc;

acc(1);
BOOST_CHECK_EQUAL(1, (min)(acc));

acc(0);
BOOST_CHECK_EQUAL(0, (min)(acc));

acc(2);
BOOST_CHECK_EQUAL(0, (min)(acc));
```

See also

- [min_impl](#)

moment

Calculates the N-th moment of the samples, which is defined as the sum of the N-th power of the samples over the count of samples.

Result Type

```
numeric::functional::average<sample-type, std::size_t>::result_type
```

Depends On	count
Variants	<i>none</i>
Initialization Parameters	<i>none</i>
Accumulator Parameters	<i>none</i>
Extractor Parameters	<i>none</i>
Accumulator Complexity	O(1)
Extractor Complexity	O(1)

Header

```
#include <boost/accumulators/statistics/moment.hpp>
```

Example

```
accumulator_set<int, stats<tag::moment<2> > > acc1;

acc1(2); //    4
acc1(4); //   16
acc1(5); // + 25
        // = 45 / 3 = 15

BOOST_CHECK_CLOSE(15., accumulators::moment<2>(acc1), 1e-5);

accumulator_set<int, stats<tag::moment<5> > > acc2;

acc2(2); //    32
acc2(3); //   243
acc2(4); //  1024
acc2(5); // + 3125
        // = 4424 / 4 = 1106

BOOST_CHECK_CLOSE(1106., accumulators::moment<5>(acc2), 1e-5);
```

See also

- [moment_impl](#)
- [count](#)

p_square_cumulative_distribution

Histogram calculation of the cumulative distribution with the p^2 algorithm. For more implementation details, see [p_square_cumulative_distribution_impl](#)

Result Type

```
iterator_range<
    std::vector<
        std::pair<
            numeric::functional::average<sample-
type, std::size_t>::result_type
            , numeric::functional::average<sample-
type, std::size_t>::result_type
        >
    >::iterator
>
```

Depends On	<code>count</code>
Variants	<i>none</i>
Initialization Parameters	<code>tag::p_square_cumulative_distribution::num_cells</code>
Accumulator Parameters	<i>none</i>
Extractor Parameters	<i>none</i>
Accumulator Complexity	TODO
Extractor Complexity	$O(N)$ where N is <code>num_cells</code>

Header

```
#include <boost/accumulators/statistics/p_square_cumul_dist.hpp>
```

Example

```
// tolerance in %
double epsilon = 3;

typedef accumulator_set<double, stats<tag::p_square_cumulative_distribution> > accumulator_t;

accumulator_t acc(tag::p_square_cumulative_distribution::num_cells = 100);

// two random number generators
boost::lagged_fibonacci607 rng;
boost::normal_distribution<> mean_sigma(0,1);
boost::variate_generator<boost::lagged_fibonacci607&, boost::normal_distribution<> > normal(rng, mean_sigma);

for (std::size_t i=0; i<100000; ++i)
{
    acc(normal());
}

typedef iterator_range<std::vector<std::pair<double, double> >::iterator > histogram_type;
histogram_type histogram = p_square_cumulative_distribution(acc);

for (std::size_t i = 0; i < histogram.size(); ++i)
{
    // problem with small results: epsilon is relative (in percent), not absolute!
    if ( histogram[i].second > 0.001 )
        BOOST_CHECK_CLOSE( 0.5 * (1.0 + erf( histogram[i].first / sqrt(2.0) )), histogram[i].second, epsilon );
}
```

See also

- [p_square_cumulative_distribution_impl](#)
- [count](#)

p_square_quantile and variants

Single quantile estimation with the P^2 algorithm. For more implementation details, see [p_square_quantile_impl](#)

Result Type

```
numeric::functional::average<sample-type, std::size_t>::result_type
```

Depends On

count

Variants

p_square_quantile_for_median

Initialization Parameters

quantile_probability, which defaults to 0.5. (Note: for p_square_quantile_for_median, the quantile_probability parameter is ignored and is always 0.5.)

Accumulator Parameters

none

Extractor Parameters

none

Accumulator Complexity

TODO

Extractor Complexity

O(1)

Header

```
#include <boost/accumulators/statistics/p_square_quantile.hpp>
```

Example

```
typedef accumulator_set<double, stats<tag::p_square_quantile> > accumulator_t;

// tolerance in %
double epsilon = 1;

// a random number generator
boost::lagged_fibonacci607 rng;

accumulator_t acc0(quantile_probability = 0.001);
accumulator_t acc1(quantile_probability = 0.01 );
accumulator_t acc2(quantile_probability = 0.1  );
accumulator_t acc3(quantile_probability = 0.25 );
accumulator_t acc4(quantile_probability = 0.5  );
accumulator_t acc5(quantile_probability = 0.75 );
accumulator_t acc6(quantile_probability = 0.9  );
accumulator_t acc7(quantile_probability = 0.99 );
accumulator_t acc8(quantile_probability = 0.999);

for (int i=0; i<100000; ++i)
{
    double sample = rng();
    acc0(sample);
    acc1(sample);
    acc2(sample);
    acc3(sample);
    acc4(sample);
    acc5(sample);
    acc6(sample);
    acc7(sample);
    acc8(sample);
}

BOOST_CHECK_CLOSE( p_square_quantile(acc0), 0.001, 15*epsilon );
BOOST_CHECK_CLOSE( p_square_quantile(acc1), 0.01 , 5*epsilon );
BOOST_CHECK_CLOSE( p_square_quantile(acc2), 0.1  , epsilon );
BOOST_CHECK_CLOSE( p_square_quantile(acc3), 0.25 , epsilon );
BOOST_CHECK_CLOSE( p_square_quantile(acc4), 0.5  , epsilon );
BOOST_CHECK_CLOSE( p_square_quantile(acc5), 0.75 , epsilon );
BOOST_CHECK_CLOSE( p_square_quantile(acc6), 0.9  , epsilon );
BOOST_CHECK_CLOSE( p_square_quantile(acc7), 0.99 , epsilon );
BOOST_CHECK_CLOSE( p_square_quantile(acc8), 0.999, epsilon );
```

See also

- [p_square_quantile_impl](#)
- [count](#)

peaks_over_threshold and variants

Peaks Over Threshold method for quantile and tail mean estimation. For implementation details, see [peaks_over_threshold_impl](#) and [peaks_over_threshold_prob_impl](#).

Both `tag::peaks_over_threshold` and `tag::peaks_over_threshold_prob<>` satisfy the `tag::abstract_peaks_over_threshold` feature, and can be extracted with the `peaks_over_threshold()` extractor. The result is a 3-tuple representing the fit parameters `u_bar`, `beta_bar` and `xi_hat`.

Result Type

```
boost::tuple<
    numeric::functional::average<sample-type, std::size_t>::result_type // u_bar
    , numeric::functional::average<sample-type, std::size_t>::result_type // beta_bar
    , numeric::functional::average<sample-type, std::size_t>::result_type // xi_hat
>
```

Depends On`count`In addition, `tag::peaks_over_threshold_prob<>` depends on `tail<left-or-right>`**Variants**`peaks_over_threshold_prob<left-or-right>`**Initialization Parameters**`tag::peaks_over_threshold::threshold_value``tag::peaks_over_threshold_prob::threshold_probability``tag::tail<left-or-right>::cache_size`**Accumulator Parameters***none***Extractor Parameters***none***Accumulator Complexity**

TODO

Extractor Complexity

TODO

Header

```
#include <boost/accumulators/statistics/peaks_over_threshold.hpp>
```

ExampleSee example for [pot_quantile](#).**See also**

- [peaks_over_threshold_impl](#)
- [peaks_over_threshold_prob_impl](#)
- [count](#)
- [tail](#)
- [pot_quantile](#)
- [pot_tail_mean](#)

[pot_quantile and variants](#)

Quantile estimation based on Peaks over Threshold method (for both left and right tails). For implementation details, see [pot_quantile_impl](#).

Both `tag::pot_quantile<left-or-right>` and `tag::pot_quantile_prob<left-or-right>` satisfy the `tag::quantile` feature and can be extracted using the `quantile()` extractor.

Result Type

```
numeric::functional::average<sample-type, std::size_t>::result_type
```

Depends On

```
pot_quantile<left-or-right> depends on peaks_over_threshold<left-or-right>
pot_quantile_prob<left-or-right> depends on
peaks_over_threshold_prob<left-or-right>
```

Variants

```
pot_quantile_prob<left-or-right>
```

Initialization Parameters

```
tag::peaks_over_threshold::threshold_value
tag::peaks_over_threshold_prob::threshold_probability
tag::tail<left-or-right>::cache_size
```

Accumulator Parameters

```
none
```

Extractor Parameters

```
quantile_probability
```

Accumulator Complexity

```
TODO
```

Extractor Complexity

```
TODO
```

Header

```
#include <boost/accumulators/statistics/pot_quantile.hpp>
```

Example

```
// tolerance in %
double epsilon = 1.;

double alpha = 0.999;
double threshold_probability = 0.99;
double threshold = 3.;

// two random number generators
boost::lagged_fibonacci607 rng;
boost::normal_distribution<> mean_sigma(0,1);
boost::exponential_distribution<> lambda(1);
boost::variate_generator<boost::lagged_fibonacci607&, boost::normal_distribution<> > normal(rng, mean_sigma);
boost::variate_generator<boost::lagged_fibonacci607&, boost::exponential_distribution<> > exponential(rng, lambda);

accumulator_set<double, stats<tag::pot_quantile<right>(with_threshold_value)> > acc1(
    tag::peaks_over_threshold::threshold_value = threshold
);
accumulator_set<double, stats<tag::pot_quantile<right>(with_threshold_probability)> > acc2(
    tag::tail<right>::cache_size = 2000
    , tag::peaks_over_threshold_prob::threshold_probability = threshold_probability
);

threshold_probability = 0.995;
threshold = 5.;

accumulator_set<double, stats<tag::pot_quantile<right>(with_threshold_value)> > acc3(
    tag::peaks_over_threshold::threshold_value = threshold
);
accumulator_set<double, stats<tag::pot_quantile<right>(with_threshold_probability)> > acc4(
    tag::tail<right>::cache_size = 2000
    , tag::peaks_over_threshold_prob::threshold_probability = threshold_probability
);

for (std::size_t i = 0; i < 100000; ++i)
{
    double sample = normal();
    acc1(sample);
    acc2(sample);
}

for (std::size_t i = 0; i < 100000; ++i)
{
    double sample = exponential();
    acc3(sample);
    acc4(sample);
}

BOOST_CHECK_CLOSE( quantile(acc1, quantile_probability = alpha), 3.090232, epsilon );
BOOST_CHECK_CLOSE( quantile(acc2, quantile_probability = alpha), 3.090232, epsilon );

BOOST_CHECK_CLOSE( quantile(acc3, quantile_probability = alpha), 6.908, epsilon );
BOOST_CHECK_CLOSE( quantile(acc4, quantile_probability = alpha), 6.908, epsilon );
```

See also

- [pot_quantile_impl](#)
- [peaks_over_threshold](#)

pot_tail_mean

Estimation of the (coherent) tail mean based on the peaks over threshold method (for both left and right tails). For implementation details, see [pot_tail_mean_impl](#).

Both `tag::pot_tail_mean<left-or-right>` and `tag::pot_tail_mean_prob<left-or-right>` satisfy the `tag::tail_mean` feature and can be extracted using the `tail_mean()` extractor.

Result Type

```
numeric::functional::average<sample-type, std::size_t>::result_type
```

Depends On

`pot_tail_mean<left-or-right>` depends on `peaks_over_threshold<left-or-right>` and `pot_quantile<left-or-right>`
`pot_tail_mean_prob<left-or-right>` depends on `peaks_over_threshold_prob<left-or-right>` and `pot_quantile_prob<left-or-right>`

Variants

`pot_tail_mean_prob<left-or-right>`

Initialization Parameters

`tag::peaks_over_threshold::threshold_value`
`tag::peaks_over_threshold_prob::threshold_probability`
`tag::tail<left-or-right>::cache_size`

Accumulator Parameters

none

Extractor Parameters

`quantile_probability`

Accumulator Complexity

TODO

Extractor Complexity

TODO

Header

```
#include <boost/accumulators/statistics/pot_tail_mean.hpp>
```

Example

```
// TODO
```

See also

- [pot_tail_mean_impl](#)
- [peaks_over_threshold](#)
- [pot_quantile](#)

rolling_count

The rolling count is the current number of elements in the rolling window.

Result Type

```
std::size_t
```

Depends On

`rolling_window_plus1`

Variants	<i>none</i>
Initialization Parameters	<code>tag::rolling_window::window_size</code>
Accumulator Parameters	<i>none</i>
Extractor Parameters	<i>none</i>
Accumulator Complexity	$O(1)$
Extractor Complexity	$O(1)$

Header

```
#include <boost/accumulators/statistics/rolling_count.hpp>
```

Example

```
accumulator_set<int, stats<tag::rolling_count> > acc(tag::rolling_window::window_size = 3);

BOOST_CHECK_EQUAL(0u, rolling_count(acc));

acc(1);
BOOST_CHECK_EQUAL(1u, rolling_count(acc));

acc(1);
BOOST_CHECK_EQUAL(2u, rolling_count(acc));

acc(1);
BOOST_CHECK_EQUAL(3u, rolling_count(acc));

acc(1);
BOOST_CHECK_EQUAL(3u, rolling_count(acc));

acc(1);
BOOST_CHECK_EQUAL(3u, rolling_count(acc));
```

See also

- [rolling_count_impl](#)

rolling_sum

The rolling sum is the sum of the last N samples.

Result Type	<i>sample-type</i>
-------------	--------------------

Depends On	<code>rolling_window_plus1</code>
Variants	<i>none</i>
Initialization Parameters	<code>tag::rolling_window::window_size</code>
Accumulator Parameters	<i>none</i>
Extractor Parameters	<i>none</i>
Accumulator Complexity	$O(1)$

Extractor Complexity $O(1)$

Header

```
#include <boost/accumulators/statistics/rolling_sum.hpp>
```

Example

```
accumulator_set<int, stats<tag::rolling_sum> > acc(tag::rolling_window::window_size = 3);

BOOST_CHECK_EQUAL(0, rolling_sum(acc));

acc(1);
BOOST_CHECK_EQUAL(1, rolling_sum(acc));

acc(2);
BOOST_CHECK_EQUAL(3, rolling_sum(acc));

acc(3);
BOOST_CHECK_EQUAL(6, rolling_sum(acc));

acc(4);
BOOST_CHECK_EQUAL(9, rolling_sum(acc));

acc(5);
BOOST_CHECK_EQUAL(12, rolling_sum(acc));
```

See also

- [rolling_sum_impl](#)

rolling_mean

The rolling mean is the mean over the last N samples. It is computed by dividing the rolling sum by the rolling count.

Result Type

```
numeric::functional::average<sample-type, std::size_t>::result_type
```

Depends On	rolling_sum rolling_count
Variants	<i>none</i>
Initialization Parameters	tag::rolling_window::window_size
Accumulator Parameters	<i>none</i>
Extractor Parameters	<i>none</i>
Accumulator Complexity	$O(1)$
Extractor Complexity	$O(1)$

Header

```
#include <boost/accumulators/statistics/rolling_mean.hpp>
```

Example

```
accumulator_set<int, stats<tag::rolling_mean> > acc(tag::rolling_window::window_size = 5);

acc(1);
acc(2);
acc(3);

BOOST_CHECK_CLOSE( rolling_mean(acc), 2.0, 1e-6 );

acc(4);
acc(5);
acc(6);
acc(7);

BOOST_CHECK_CLOSE( rolling_mean(acc), 5.0, 1e-6 );
```

See also

- [rolling_mean_impl](#)

skewness

The skewness of a sample distribution is defined as the ratio of the 3rd central moment and the 3/2-th power of the 2nd central moment (the variance) of the samples. For implementation details, see [skewness_impl](#).

Result Type

```
numeric::functional::average<sample-type, sample-type>::result_type
```

Depends On

```
mean
moment<2>
moment<3>
```

Variants

none

Initialization Parameters

none

Accumulator Parameters

none

Extractor Parameters

none

Accumulator Complexity

O(1)

Extractor Complexity

O(1)

Header

```
#include <boost/accumulators/statistics/skewness.hpp>
```

Example

```
accumulator_set<int, stats<tag::skewness > > acc2;

acc2(2);
acc2(7);
acc2(4);
acc2(9);
acc2(3);

BOOST_CHECK_EQUAL( mean(acc2), 5 );
BOOST_CHECK_EQUAL( accumulators::moment<2>(acc2), 159./5. );
BOOST_CHECK_EQUAL( accumulators::moment<3>(acc2), 1171./5. );
BOOST_CHECK_CLOSE( skewness(acc2), 0.406040288214, 1e-6 );
```

See also

- [skewness_impl](#)
- [mean](#)
- [moment](#)

sum and variants

For summing the samples, weights or variates. The default implementation uses the standard sum operation, but variants using the Kahan summation algorithm are also provided.

Result Type	<i>sample-type</i> for summing samples <i>weight-type</i> for summing weights <i>variate-type</i> for summing variates
Depends On	<i>none</i>
Variants	<code>tag::sum</code> <code>tag::sum_of_weights</code> <code>tag::sum_of_variates<variate-type, variate-tag></code> <code>tag::sum_kahan</code> (a.k.a. <code>tag::sum(kahan)</code>) <code>tag::sum_of_weights_kahan</code> (a.k.a. <code>tag::sum_of_weights(kahan)</code>) <code>tag::sum_of_variates_kahan<variate-type, variate-tag></code>
Initialization Parameters	<i>none</i>
Accumulator Parameters	<i>weight</i> for summing weights <i>variate-tag</i> for summing variates
Extractor Parameters	<i>none</i>
Accumulator Complexity	O(1). Note that the Kahan sum performs four floating-point sum operations per accumulated value, whereas the naive sum performs only one.
Extractor Complexity	O(1)

Header

```
#include <boost/accumulators/statistics/sum.hpp>
#include <boost/accumulators/statistics/sum_kahan.hpp>
```

Example

```
accumulator_set<
    int
    , stats<
        tag::sum
        , tag::sum_of_weights
        , tag::sum_of_variates<int, tag::covariate1>
    >
    , int
> acc;

acc(1, weight = 2, covariate1 = 3);
BOOST_CHECK_EQUAL(2, sum(acc)); // weighted sample = 1 * 2
BOOST_CHECK_EQUAL(2, sum_of_weights(acc));
BOOST_CHECK_EQUAL(3, sum_of_variates(acc));

acc(2, weight = 4, covariate1 = 6);
BOOST_CHECK_EQUAL(10, sum(acc)); // weighted sample = 2 * 4
BOOST_CHECK_EQUAL(6, sum_of_weights(acc));
BOOST_CHECK_EQUAL(9, sum_of_variates(acc));

acc(3, weight = 6, covariate1 = 9);
BOOST_CHECK_EQUAL(28, sum(acc)); // weighted sample = 3 * 6
BOOST_CHECK_EQUAL(12, sum_of_weights(acc));
BOOST_CHECK_EQUAL(18, sum_of_variates(acc));

// demonstrate Kahan summation
accumulator_set<float, stats<tag::sum_kahan> > acc;
BOOST_CHECK_EQUAL(0.0f, sum_kahan(acc));
for (size_t i = 0; i < 1e6; ++i) {
    acc(1e-6f);
}
BOOST_CHECK_EQUAL(1.0f, sum_kahan(acc));
```

See also

- [sum_impl](#)
- [sum_kahan_impl](#)

tail

Tracks the largest or smallest N values. `tag::tail<right>` tracks the largest N, and `tag::tail<left>` tracks the smallest. The parameter N is specified with the `tag::tail<left-or-right>::cache_size` initialization parameter. For implementation details, see [tail_impl](#).

Both `tag::tail<left>` and `tag::tail<right>` satisfy the `tag::abstract_tail` feature and can be extracted with the `tail()` extractor.

Result Type

```
boost::iterator_range<
    boost::reverse_iterator<
        boost::permutation_iterator<
            std::vector<sample-type>::const_iterator // samples
            , std::vector<std::size_t>::iterator      // indices
        >
    >
>
```

Depends On

none

Variants

`abstract_tail`

Initialization Parameters	<code>tag::tail<left-or-right>::cache_size</code>
Accumulator Parameters	<i>none</i>
Extractor Parameters	<i>none</i>
Accumulator Complexity	$O(\log N)$, where N is the cache size
Extractor Complexity	$O(N \log N)$, where N is the cache size

Header

```
#include <boost/accumulators/statistics/tail.hpp>
```

Example

See the Example for [tail_variate](#).

See also

- [tail_impl](#)
- [tail_variate](#)

coherent_tail_mean

Estimation of the coherent tail mean based on order statistics (for both left and right tails). The left coherent tail mean feature is `tag::coherent_tail_mean<left>`, and the right coherent tail mean feature is `tag::coherent_tail_mean<right>`. They both share the `tag::tail_mean` feature and can be extracted with the `tail_mean()` extractor. For more implementation details, see [coherent_tail_mean_impl](#)

Result Type

```
numeric::functional::average<sample-type, std::size_t>::result_type
```

Depends On	<code>count</code> <code>quantile</code> <code>non_coherent_tail_mean<left-or-right></code>
------------	---

Variants	<i>none</i>
----------	-------------

Initialization Parameters	<code>tag::tail<left-or-right>::cache_size</code>
Accumulator Parameters	<i>none</i>
Extractor Parameters	<code>quantile_probability</code>
Accumulator Complexity	$O(\log N)$, where N is the cache size
Extractor Complexity	$O(N \log N)$, where N is the cache size

Header

```
#include <boost/accumulators/statistics/tail_mean.hpp>
```

Example

See the example for [non_coherent_tail_mean](#).

See also

- [coherent_tail_mean_impl](#)
- [count](#)
- [extended_p_square_quantile](#)
- [pot_quantile](#)
- [tail_quantile](#)
- [non_coherent_tail_mean](#)

non_coherent_tail_mean

Estimation of the (non-coherent) tail mean based on order statistics (for both left and right tails). The left non-coherent tail mean feature is `tag::non_coherent_tail_mean<left>`, and the right non-coherent tail mean feature is `tag::non_coherent_tail_mean<right>`. They both share the `tag::abstract_non_coherent_tail_mean` feature and can be extracted with the `non_coherent_tail_mean()` extractor. For more implementation details, see [non_coherent_tail_mean_impl](#)

Result Type

```
numeric::functional::average<sample-type, std::size_t>::result_type
```

Depends On

```
count  
tail<left-or-right>
```

Variants

```
abstract_non_coherent_tail_mean
```

Initialization Parameters

```
tag::tail<left-or-right>::cache_size
```

Accumulator Parameters

```
none
```

Extractor Parameters

```
quantile_probability
```

Accumulator Complexity

```
O(log N), where N is the cache size
```

Extractor Complexity

```
O(N log N), where N is the cache size
```

Header

```
#include <boost/accumulators/statistics/tail_mean.hpp>
```

Example

```
// tolerance in %
double epsilon = 1;

std::size_t n = 100000; // number of MC steps
std::size_t c = 10000; // cache size

typedef accumulator_set<double, stats<tag::non_coher,
ent_tail_mean<right>, tag::tail_quantile<right> > > accumulator_t_right1;
typedef accumulator_set<double, stats<tag::non_coher,
ent_tail_mean<left>, tag::tail_quantile<left> > > accumulator_t_left1;
typedef accumulator_set<double, stats<tag::coher,
ent_tail_mean<right>, tag::tail_quantile<right> > > accumulator_t_right2;
typedef accumulator_set<double, stats<tag::coher,
ent_tail_mean<left>, tag::tail_quantile<left> > > accumulator_t_left2;

accumulator_t_right1 acc0( right_tail_cache_size = c );
accumulator_t_left1 acc1( left_tail_cache_size = c );
accumulator_t_right2 acc2( right_tail_cache_size = c );
accumulator_t_left2 acc3( left_tail_cache_size = c );

// a random number generator
boost::lagged_fibonacci607 rng;

for (std::size_t i = 0; i < n; ++i)
{
    double sample = rng();
    acc0(sample);
    acc1(sample);
    acc2(sample);
    acc3(sample);
}

// check uniform distribution
BOOST_CHECK_CLOSE( non_coherent_tail_mean(acc0, quantile_probability = 0.95), 0.975, epsilon );
BOOST_CHECK_CLOSE( non_coherent_tail_mean(acc0, quantile_probability = 0.975), 0.9875, epsilon );
BOOST_CHECK_CLOSE( non_coherent_tail_mean(acc0, quantile_probability = 0.99), 0.995, epsilon );
BOOST_CHECK_CLOSE( non_coherent_tail_mean(acc0, quantile_probability = 0.999), 0.9995, epsilon );
BOOST_CHECK_CLOSE( non_coherent_tail_mean(acc1, quantile_probability = 0.05), 0.025, epsilon );
BOOST_CHECK_CLOSE( non_coherent_tail_mean(acc1, quantile_probability = 0.025), 0.0125, epsilon );
BOOST_CHECK_CLOSE( non_coherent_tail_mean(acc1, quantile_probability = 0.01), 0.005, 5 );
BOOST_CHECK_CLOSE( non_coherent_tail_mean(acc1, quantile_probability = 0.001), 0.0005, 10 );
BOOST_CHECK_CLOSE( tail_mean(acc2, quantile_probability = 0.95), 0.975, epsilon );
BOOST_CHECK_CLOSE( tail_mean(acc2, quantile_probability = 0.975), 0.9875, epsilon );
BOOST_CHECK_CLOSE( tail_mean(acc2, quantile_probability = 0.99), 0.995, epsilon );
BOOST_CHECK_CLOSE( tail_mean(acc2, quantile_probability = 0.999), 0.9995, epsilon );
BOOST_CHECK_CLOSE( tail_mean(acc3, quantile_probability = 0.05), 0.025, epsilon );
BOOST_CHECK_CLOSE( tail_mean(acc3, quantile_probability = 0.025), 0.0125, epsilon );
BOOST_CHECK_CLOSE( tail_mean(acc3, quantile_probability = 0.01), 0.005, 5 );
BOOST_CHECK_CLOSE( tail_mean(acc3, quantile_probability = 0.001), 0.0005, 10 );
```

See also

- [non_coherent_tail_mean_impl](#)
- [count](#)
- [tail](#)

tail_quantile

Tail quantile estimation based on order statistics (for both left and right tails). The left tail quantile feature is `tag::tail_quantile<left>`, and the right tail quantile feature is `tag::tail_quantile<right>`. They both share the

`tag::quantile` feature and can be extracted with the `quantile()` extractor. For more implementation details, see [tail_quantile_impl](#)

Result Type

sample-type

Depends On

`count`
`tail<left-or-right>`

Variants

none

Initialization Parameters

`tag::tail<left-or-right>::cache_size`

Accumulator Parameters

none

Extractor Parameters

`quantile_probability`

Accumulator Complexity

$O(\log N)$, where N is the cache size

Extractor Complexity

$O(N \log N)$, where N is the cache size

Header

```
#include <boost/accumulators/statistics/tail_quantile.hpp>
```

Example

```

// tolerance in %
double epsilon = 1;

std::size_t n = 100000; // number of MC steps
std::size_t c = 10000; // cache size

typedef accumulator_set<double, stats<tag::tail_quantile<right> > > accumulator_t_right;
typedef accumulator_set<double, stats<tag::tail_quantile<left> > > accumulator_t_left;

accumulator_t_right acc0( tag::tail<right>::cache_size = c );
accumulator_t_right acc1( tag::tail<right>::cache_size = c );
accumulator_t_left  acc2( tag::tail<left>::cache_size = c );
accumulator_t_left  acc3( tag::tail<left>::cache_size = c );

// two random number generators
boost::lagged_fibonacci607 rng;
boost::normal_distribution<> mean_sigma(0,1);
boost::variate_generator<boost::lagged_fibonacci607&, boost::normal_distribution<> > normal(
rng, mean_sigma);

for (std::size_t i = 0; i < n; ++i)
{
    double sample1 = rng();
    double sample2 = normal();
    acc0(sample1);
    acc1(sample2);
    acc2(sample1);
    acc3(sample2);
}

// check uniform distribution
BOOST_CHECK_CLOSE( quantile(acc0, quantile_probability = 0.95 ), 0.95, epsilon );
BOOST_CHECK_CLOSE( quantile(acc0, quantile_probability = 0.975), 0.975, epsilon );
BOOST_CHECK_CLOSE( quantile(acc0, quantile_probability = 0.99 ), 0.99, epsilon );
BOOST_CHECK_CLOSE( quantile(acc0, quantile_probability = 0.999), 0.999, epsilon );
BOOST_CHECK_CLOSE( quantile(acc2, quantile_probability = 0.05 ), 0.05, 2 );
BOOST_CHECK_CLOSE( quantile(acc2, quantile_probability = 0.025), 0.025, 2 );
BOOST_CHECK_CLOSE( quantile(acc2, quantile_probability = 0.01 ), 0.01, 3 );
BOOST_CHECK_CLOSE( quantile(acc2, quantile_probability = 0.001), 0.001, 20 );

// check standard normal distribution
BOOST_CHECK_CLOSE( quantile(acc1, quantile_probability = 0.975), 1.959963, epsilon );
BOOST_CHECK_CLOSE( quantile(acc1, quantile_probability = 0.999), 3.090232, epsilon );
BOOST_CHECK_CLOSE( quantile(acc3, quantile_probability = 0.025), -1.959963, epsilon );
BOOST_CHECK_CLOSE( quantile(acc3, quantile_probability = 0.001), -3.090232, epsilon );

```

See also

- [tail_quantile_impl](#)
- [count](#)
- [tail](#)

tail_variate

Tracks the covariates of largest or smallest *N* samples. `tag::tail_variate<variate-type, variate-tag, right>` tracks the covariate associated with *variate-tag* for the largest *N*, and `tag::tail_variate<variate-type, variate-tag, left>` for the smallest. The parameter *N* is specified with the `tag::tail<left-or-right>::cache_size` initialization parameter. For implementation details, see [tail_variate_impl](#).

Both `tag::tail_variate<variate-type, variate-tag, right>` and `tag::tail_variate<variate-type, variate-tag, left>` satisfy the `tag::abstract_tail_variate` feature and can be extracted with the `tail_variate()` extractor.

Result Type

```
boost::iterator_range<
    boost::reverse_iterator<
        boost::permutation_iterator<
            std::vector<variate-type>::const_iterator // variates
            , std::vector<std::size_t>::iterator       // indices
        >
    >
>
```

Depends On	<code>tail<left-or-right></code>
Variants	<code>abstract_tail_variate</code>
Initialization Parameters	<code>tag::tail<left-or-right>::cache_size</code>
Accumulator Parameters	<i>none</i>
Extractor Parameters	<i>none</i>
Accumulator Complexity	$O(\log N)$, where N is the cache size
Extractor Complexity	$O(N \log N)$, where N is the cache size

Header

```
#include <boost/accumulators/statistics/tail_variate.hpp>
```

Example

```
accumulator_set<int, stats<tag::tail_variate<int, tag::covariate1, right> > > acc(
    tag::tail<right>::cache_size = 4
);

acc(8, covariate1 = 3);
CHECK_RANGE_EQUAL(tail(acc), {8});
CHECK_RANGE_EQUAL(tail_variate(acc), {3});

acc(16, covariate1 = 1);
CHECK_RANGE_EQUAL(tail(acc), {16, 8});
CHECK_RANGE_EQUAL(tail_variate(acc), {1, 3});

acc(12, covariate1 = 4);
CHECK_RANGE_EQUAL(tail(acc), {16, 12, 8});
CHECK_RANGE_EQUAL(tail_variate(acc), {1, 4, 3});

acc(24, covariate1 = 5);
CHECK_RANGE_EQUAL(tail(acc), {24, 16, 12, 8});
CHECK_RANGE_EQUAL(tail_variate(acc), {5, 1, 4, 3});

acc(1, covariate1 = 9);
CHECK_RANGE_EQUAL(tail(acc), {24, 16, 12, 8});
CHECK_RANGE_EQUAL(tail_variate(acc), {5, 1, 4, 3});

acc(9, covariate1 = 7);
CHECK_RANGE_EQUAL(tail(acc), {24, 16, 12, 9});
CHECK_RANGE_EQUAL(tail_variate(acc), {5, 1, 4, 7});
```

See also

- [tail_variate_impl](#)
- [tail](#)

tail_variate_means and variants

Estimation of the absolute and relative tail variate means (for both left and right tails). The absolute tail variate means has the feature `tag::absolute_tail_variate_means<left-or-right, variate-type, variate-tag>` and the relative tail variate mean has the feature `tag::relative_tail_variate_means<left-or-right, variate-type, variate-tag>`. All absolute tail variate mean features share the `tag::abstract_absolute_tail_variate_means` feature and can be extracted with the `tail_variate_means()` extractor. All the relative tail variate mean features share the `tag::abstract_relative_tail_variate_means` feature and can be extracted with the `relative_tail_variate_means()` extractor.

For more implementation details, see [tail_variate_means_impl](#)

Result Type

```
boost::iterator_range<
    std::vector<
        numeric::functional::average<sample-
type, std::size_t>::result_type
    >::iterator
>
```

Depends On

```
non_coherent_tail_mean<left-or-right>
tail_variate<variate-type, variate-tag, left-or-right>
```

Variants

```
tag::absolute_tail_variate_means<left-or-right, variate-type, variate-
tag>
tag::relative_tail_variate_means<left-or-right, variate-type, variate-
tag>
```

Initialization Parameters

```
tag::tail<left-or-right>::cache_size
```

Accumulator Parameters

```
none
```

Extractor Parameters

```
quantile_probability
```

Accumulator Complexity

```
O(log N), where N is the cache size
```

Extractor Complexity

```
O(N log N), where N is the cache size
```

Header

```
#include <boost/accumulators/statistics/tail_variate_means.hpp>
```

Example

```
std::size_t c = 5; // cache size

typedef double variate_type;
typedef std::vector<variate_type> variate_set_type;

typedef accumulator_set<double, stats<
    tag::tail_variate_means<right, variate_set_type, tag::covariatel>(relative)>, tag::tail<right> >
    accumulator_t1;

typedef accumulator_set<double, stats<
    tag::tail_variate_means<right, variate_set_type, tag::covariatel>(absolute)>, tag::tail<right> >
    accumulator_t2;

typedef accumulator_set<double, stats<
    tag::tail_variate_means<left, variate_set_type, tag::covariatel>(relative)>, tag::tail<left> >
    accumulator_t3;

typedef accumulator_set<double, stats<
    tag::tail_variate_means<left, variate_set_type, tag::covariatel>(absolute)>, tag::tail<left> >
    accumulator_t4;

accumulator_t1 acc1( right_tail_cache_size = c );
accumulator_t2 acc2( right_tail_cache_size = c );
accumulator_t3 acc3( left_tail_cache_size = c );
accumulator_t4 acc4( left_tail_cache_size = c );

variate_set_type cov1, cov2, cov3, cov4, cov5;
double c1[] = { 10., 20., 30., 40. }; // 100
double c2[] = { 26., 4., 17., 3. }; // 50
double c3[] = { 46., 64., 40., 50. }; // 200
double c4[] = { 1., 3., 70., 6. }; // 80
double c5[] = { 2., 2., 2., 14. }; // 20
cov1.assign(c1, c1 + sizeof(c1)/sizeof(variate_type));
cov2.assign(c2, c2 + sizeof(c2)/sizeof(variate_type));
cov3.assign(c3, c3 + sizeof(c3)/sizeof(variate_type));
cov4.assign(c4, c4 + sizeof(c4)/sizeof(variate_type));
cov5.assign(c5, c5 + sizeof(c5)/sizeof(variate_type));

acc1(100., covariatel = cov1);
acc1( 50., covariatel = cov2);
acc1(200., covariatel = cov3);
acc1( 80., covariatel = cov4);
acc1( 20., covariatel = cov5);

acc2(100., covariatel = cov1);
acc2( 50., covariatel = cov2);
acc2(200., covariatel = cov3);
acc2( 80., covariatel = cov4);
acc2( 20., covariatel = cov5);

acc3(100., covariatel = cov1);
acc3( 50., covariatel = cov2);
acc3(200., covariatel = cov3);
acc3( 80., covariatel = cov4);
acc3( 20., covariatel = cov5);

acc4(100., covariatel = cov1);
acc4( 50., covariatel = cov2);
acc4(200., covariatel = cov3);
acc4( 80., covariatel = cov4);
acc4( 20., covariatel = cov5);
```

```

// check relative risk contributions
BOOST_CHECK_EQUAL( *(relative_tail_variate_means(acc1, quantile_probability = 0.7).begin()
), 14./75. ); // (10 + 46) / 300 = 14/75
BOOST_CHECK_EQUAL( *(relative_tail_variate_means(acc1, quantile_probability = 0.7).begin() + 1),
7./25. ); // (20 + 64) / 300 = 7/25
BOOST_CHECK_EQUAL( *(relative_tail_variate_means(acc1, quantile_probability = 0.7).begin() + 2),
7./30. ); // (30 + 40) / 300 = 7/30
BOOST_CHECK_EQUAL( *(relative_tail_variate_means(acc1, quantile_probability = 0.7).begin() + 3),
3./10. ); // (40 + 50) / 300 = 3/10
BOOST_CHECK_EQUAL( *(relative_tail_variate_means(acc3, quantile_probability = 0.3).begin()
), 14./35. ); // (26 + 2) / 70 = 14/35
BOOST_CHECK_EQUAL( *(relative_tail_variate_means(acc3, quantile_probability = 0.3).begin() + 1),
3./35. ); // (4 + 2) / 70 = 3/35
BOOST_CHECK_EQUAL( *(relative_tail_variate_means(acc3, quantile_probability = 0.3).begin() + 2),
19./70. ); // (17 + 2) / 70 = 19/70
BOOST_CHECK_EQUAL( *(relative_tail_variate_means(acc3, quantile_probability = 0.3).begin() + 3),
17./70. ); // (3 + 14) / 70 = 17/70

// check absolute risk contributions
BOOST_CHECK_EQUAL( *(tail_variate_means(acc2, quantile_probability = 0.7).begin()
), 28 ); // (10 + 46) / 2 = 28
BOOST_CHECK_EQUAL( *(tail_variate_means(acc2, quantile_probability = 0.7).begin() + 1),
42 ); // (20 + 64) / 2 = 42
BOOST_CHECK_EQUAL( *(tail_variate_means(acc2, quantile_probability = 0.7).begin() + 2),
35 ); // (30 + 40) / 2 = 35
BOOST_CHECK_EQUAL( *(tail_variate_means(acc2, quantile_probability = 0.7).begin() + 3),
45 ); // (40 + 50) / 2 = 45
BOOST_CHECK_EQUAL( *(tail_variate_means(acc4, quantile_probability = 0.3).begin()
), 14 ); // (26 + 2) / 2 = 14
BOOST_CHECK_EQUAL( *(tail_variate_means(acc4, quantile_probability = 0.3).begin() + 1),
3 ); // (4 + 2) / 2 = 3
BOOST_CHECK_EQUAL( *(tail_variate_means(acc4, quantile_probability = 0.3).begin() + 2),
9.5 ); // (17 + 2) / 2 = 9.5
BOOST_CHECK_EQUAL( *(tail_variate_means(acc4, quantile_probability = 0.3).begin() + 3),
8.5 ); // (3 + 14) / 2 = 8.5

// check relative risk contributions
BOOST_CHECK_EQUAL( *(relative_tail_variate_means(acc1, quantile_probability = 0.9).begin()
), 23./100. ); // 46/200 = 23/100
BOOST_CHECK_EQUAL( *(relative_tail_variate_means(acc1, quantile_probability = 0.9).begin() + 1),
8./25. ); // 64/200 = 8/25
BOOST_CHECK_EQUAL( *(relative_tail_variate_means(acc1, quantile_probability = 0.9).begin() + 2),
1./5. ); // 40/200 = 1/5
BOOST_CHECK_EQUAL( *(relative_tail_variate_means(acc1, quantile_probability = 0.9).begin() + 3),
1./4. ); // 50/200 = 1/4
BOOST_CHECK_EQUAL( *(relative_tail_variate_means(acc3, quantile_probability = 0.1).begin()
), 1./10. ); // 2/ 20 = 1/10
BOOST_CHECK_EQUAL( *(relative_tail_variate_means(acc3, quantile_probability = 0.1).begin() + 1),
1./10. ); // 2/ 20 = 1/10
BOOST_CHECK_EQUAL( *(relative_tail_variate_means(acc3, quantile_probability = 0.1).begin() + 2),
1./10. ); // 2/ 20 = 1/10
BOOST_CHECK_EQUAL( *(relative_tail_variate_means(acc3, quantile_probability = 0.1).begin() + 3),
7./10. ); // 14/ 20 = 7/10

// check absolute risk contributions
BOOST_CHECK_EQUAL( *(tail_variate_means(acc2, quantile_probability = 0.9).begin()
), 46 ); // 46
BOOST_CHECK_EQUAL( *(tail_variate_means(acc2, quantile_probability = 0.9).begin() + 1),
64 ); // 64
BOOST_CHECK_EQUAL( *(tail_variate_means(acc2, quantile_probability = 0.9).begin() + 2),
40 ); // 40
BOOST_CHECK_EQUAL( *(tail_variate_means(acc2, quantile_probability = 0.9).begin() + 3),
50 ); // 50
BOOST_CHECK_EQUAL( *(tail_variate_means(acc4, quantile_probability = 0.1).begin()
), 2 ); // 2

```

```
BOOST_CHECK_EQUAL( *(tail_variate_means(acc4, quantile_probability = 0.1).begin() + 1), 2 ); // ↴  
2  
BOOST_CHECK_EQUAL( *(tail_variate_means(acc4, quantile_probability = 0.1).begin() + 2), 2 ); // ↴  
2  
BOOST_CHECK_EQUAL( *(tail_variate_means(acc4, quantile_probability = 0.1).begin() + 3), 14 ); // 14
```

See also

- [tail_variate_means_impl](#)
- [non_coherent_tail_mean](#)
- [tail_variate](#)

variance and variants

Lazy or iterative calculation of the variance. The lazy calculation is associated with the `tag::lazy_variance` feature, and the iterative calculation with the `tag::variance` feature. Both can be extracted using the `tag::variance()` extractor. For more implementation details, see [lazy_variance_impl](#) and [variance_impl](#)

Result Type

```
numeric::functional::average<sample-type, std::size_t>::result_type
```

Depends On

`tag::lazy_variance` depends on `tag::moment<2>` and `tag::mean`
`tag::variance` depends on `tag::count` and `tag::immediate_mean`

Variants

`tag::lazy_variance` (a.k.a. `tag::variance(lazy)`)
`tag::variance` (a.k.a. `tag::variance(immediate)`)

Initialization Parameters

none

Accumulator Parameters

none

Extractor Parameters

none

Accumulator Complexity

O(1)

Extractor Complexity

O(1)

Header

```
#include <boost/accumulators/statistics/variance.hpp>
```

Example

```
// lazy variance
accumulator_set<int, stats<tag::variance(lazy)> > acc1;

acc1(1);
acc1(2);
acc1(3);
acc1(4);
acc1(5);

BOOST_CHECK_EQUAL(5u, count(acc1));
BOOST_CHECK_CLOSE(3., mean(acc1), 1e-5);
BOOST_CHECK_CLOSE(11., accumulators::moment<2>(acc1), 1e-5);
BOOST_CHECK_CLOSE(2., variance(acc1), 1e-5);

// immediate variance
accumulator_set<int, stats<tag::variance> > acc2;

acc2(1);
acc2(2);
acc2(3);
acc2(4);
acc2(5);

BOOST_CHECK_EQUAL(5u, count(acc2));
BOOST_CHECK_CLOSE(3., mean(acc2), 1e-5);
BOOST_CHECK_CLOSE(2., variance(acc2), 1e-5);
```

See also

- [lazy_variance_impl](#)
- [variance_impl](#)
- [count](#)
- [mean](#)
- [moment](#)

weighted_covariance

An iterative Monte Carlo estimator for the weighted covariance. The feature is specified as `tag::weighted_covariance<variate-type, variate-tag>` and is extracted with the `weighted_variate()` extractor. For more implementation details, see [weighted_covariance_impl](#)

Result Type

```
numeric::functional::outer_product<
    numeric::functional::multiplies<
        weight-type
    , numeric::functional::average<sample-
type, std::size_t>::result_type
    >::result_type
    , numeric::functional::multiplies<
        weight-type
    , numeric::functional::average<variate-
type, std::size_t>::result_type
    >::result_type
>
```

Depends On

`count`
`sum_of_weights`

	<code>weighted_mean</code> <code>weighted_mean_of_variates<variate-type, variate-tag></code>
Variants	<code>abstract_weighted_covariance</code>
Initialization Parameters	<i>none</i>
Accumulator Parameters	<code>weight</code> <code>variate-tag</code>
Extractor Parameters	<i>none</i>
Accumulator Complexity	$O(1)$
Extractor Complexity	$O(1)$

Header

```
#include <boost/accumulators/statistics/weighted_covariance.hpp>
```

Example

```
accumulator_set<double, stats<tag::weighted_covariance<double, tag::covariate1> >, double > acc;  
  
acc(1., weight = 1.1, covariate1 = 2.);  
acc(1., weight = 2.2, covariate1 = 4.);  
acc(2., weight = 3.3, covariate1 = 3.);  
acc(6., weight = 4.4, covariate1 = 1.);  
  
double epsilon = 1e-6;  
BOOST_CHECK_CLOSE(weighted_covariance(acc), -2.39, epsilon);
```

See also

- [weighted_covariance_impl](#)
- [count](#)
- [sum](#)
- [weighted_mean](#)

weighted_density

The `tag::weighted_density` feature returns a histogram of the weighted sample distribution. For more implementation details, see [weighted_density_impl](#).

Result Type

```
iterator_range<  
    std::vector<  
        std::pair<  
            numeric::functional::average<weight-  
type, std::size_t>::result_type  
            , numeric::functional::average<weight-  
type, std::size_t>::result_type  
        >  
    >::iterator  
>
```

Depends On `count`

	<code>sum_of_weights</code> <code>min</code> <code>max</code>
Variants	<i>none</i>
Initialization Parameters	<code>tag::weighted_density::cache_size</code> <code>tag::weighted_density::num_bins</code>
Accumulator Parameters	<code>weight</code>
Extractor Parameters	<i>none</i>
Accumulator Complexity	TODO
Extractor Complexity	O(N), when N is <code>weighted_density::num_bins</code>

Header

```
#include <boost/accumulators/statistics/weighted_density.hpp>
```

See also

- [weighted_density_impl](#)
- [count](#)
- [sum](#)
- [min](#)
- [max](#)

weighted_extended_p_square

Multiple quantile estimation with the extended P^2 algorithm for weighted samples. For further details, see [weighted_extended_p_square_impl](#).

Result Type

```
boost::iterator_range<  
    implementation-defined  
>
```

Depends On	<code>count</code> <code>sum_of_weights</code>
Variants	<i>none</i>
Initialization Parameters	<code>tag::weighted_extended_p_square::probabilities</code>
Accumulator Parameters	<code>weight</code>
Extractor Parameters	<i>none</i>
Accumulator Complexity	TODO
Extractor Complexity	O(1)

Header

```
#include <boost/accumulators/statistics/weighted_extended_p_square.hpp>
```

Example

```
typedef accumulator_set<double, stats<tag::weighted_extended_p_square>, double> accumulator_t;

// tolerance in %
double epsilon = 1;

// some random number generators
double mu1 = -1.0;
double mu2 = 1.0;
boost::lagged_fibonacci607 rng;
boost::normal_distribution<> mean_signal(mu1, 1);
boost::normal_distribution<> mean_sigma2(mu2, 1);
boost::variate_generator<boost::lagged_fibonacci607&, boost::normal_distribution<> > nor1(
    rng, mean_signal);
boost::variate_generator<boost::lagged_fibonacci607&, boost::normal_distribution<> > nor2(
    rng, mean_sigma2);

std::vector<double> probs_uniform, probs_normal1, probs_normal2, probs_normal_exact1, probs_normal_exact2;

double p1[] = { /*0.001,*/ 0.01, 0.1, 0.5, 0.9, 0.99, 0.999 };
probs_uniform.assign(p1, p1 + sizeof(p1) / sizeof(double));

double p2[] = { 0.001, 0.025 };
double p3[] = { 0.975, 0.999 };
probs_normal1.assign(p2, p2 + sizeof(p2) / sizeof(double));
probs_normal2.assign(p3, p3 + sizeof(p3) / sizeof(double));

double p4[] = { -3.090232, -1.959963 };
double p5[] = { 1.959963, 3.090232 };
probs_normal_exact1.assign(p4, p4 + sizeof(p4) / sizeof(double));
probs_normal_exact2.assign(p5, p5 + sizeof(p5) / sizeof(double));

accumulator_t acc_uniform(tag::weighted_extended_p_square::probabilities = probs_uniform);
accumulator_t acc_normal1(tag::weighted_extended_p_square::probabilities = probs_normal1);
accumulator_t acc_normal2(tag::weighted_extended_p_square::probabilities = probs_normal2);

for (std::size_t i = 0; i < 100000; ++i)
{
    acc_uniform(rng(), weight = 1.);

    double sample1 = normal1();
    double sample2 = normal2();
    acc_normal1(sample1, weight = std::exp(-mu1 * (sample1 - 0.5 * mu1)));
    acc_normal2(sample2, weight = std::exp(-mu2 * (sample2 - 0.5 * mu2)));
}

// check for uniform distribution
for (std::size_t i = 0; i < probs_uniform.size(); ++i)
{
    BOOST_CHECK_CLOSE(weighted_extended_p_square(acc_uniform)[i], probs_uniform[i], epsilon);
}

// check for standard normal distribution
for (std::size_t i = 0; i < probs_normal1.size(); ++i)
{
    BOOST_CHECK_CLOSE(weighted_extended_p_square(acc_normal1)[i], probs_normal_exact1[i], epsilon);
    BOOST_CHECK_CLOSE(weighted_extended_p_square(acc_normal2)[i], probs_normal_exact2[i], epsilon);
}
```

See also

- [weighted_extended_p_square_impl](#)
- [count](#)
- [sum](#)

weighted_kurtosis

The kurtosis of a sample distribution is defined as the ratio of the 4th central moment and the square of the 2nd central moment (the variance) of the samples, minus 3. The term -3 is added in order to ensure that the normal distribution has zero kurtosis. For more implementation details, see [weighted_kurtosis_impl](#)

Result Type

```
numeric::functional::average<
    numeric::functional::multiplies<sample-type, weight-type>::result_type
    , numeric::functional::multiplies<sample-type, weight-type>::result_type
>::result_type
```

Depends On

```
weighted_mean
weighted_moment<2>
weighted_moment<3>
weighted_moment<4>
```

Variants

none

Initialization Parameters

none

Accumulator Parameters

none

Extractor Parameters

none

Accumulator Complexity

O(1)

Extractor Complexity

O(1)

Header

```
#include <boost/accumulators/statistics/weighted_kurtosis.hpp>
```

Example

```
accumulator_set<int, stats<tag::weighted_kurtosis>, int > acc2;

acc2(2, weight = 4);
acc2(7, weight = 1);
acc2(4, weight = 3);
acc2(9, weight = 1);
acc2(3, weight = 2);

BOOST_CHECK_EQUAL( weighted_mean(acc2), 42./11. );
BOOST_CHECK_EQUAL( accumulators::weighted_moment<2>(acc2), 212./11. );
BOOST_CHECK_EQUAL( accumulators::weighted_moment<3>(acc2), 1350./11. );
BOOST_CHECK_EQUAL( accumulators::weighted_moment<4>(acc2), 9956./11. );
BOOST_CHECK_CLOSE( weighted_kurtosis(acc2), 0.58137026432, 1e-6 );
```

See also

- [weighted_kurtosis_impl](#)
- [weighted_mean](#)
- [weighted_moment](#)

weighted_mean and variants

Calculates the weighted mean of samples or variates. The calculation is either lazy (in the result extractor), or immediate (in the accumulator). The lazy implementation is the default. For more implementation details, see [weighted_mean_impl](#) or [immediate_weighted_mean_impl](#)

Result Type	For samples, <code>numeric::functional::average<numeric::functional::multiplies<sample-type, weight-type>::result_type, weight-type>::result_type</code> For variates, <code>numeric::functional::average<numeric::functional::multiplies<variate-type, weight-type>::result_type, weight-type>::result_type</code>
Depends On	<code>sum_of_weights</code> The lazy mean of samples depends on <code>weighted_sum</code> The lazy mean of variates depends on <code>weighted_sum_of_variates<></code>
Variants	<code>weighted_mean_of_variates<variate-type, variate-tag></code> <code>immediate_weighted_mean</code> <code>immediate_weighted_mean_of_variates<variate-type, variate-tag></code>
Initialization Parameters	<i>none</i>
Accumulator Parameters	<i>none</i>
Extractor Parameters	<i>none</i>
Accumulator Complexity	O(1)
Extractor Complexity	O(1)

Header

```
#include <boost/accumulators/statistics/weighted_mean.hpp>
```

Example

```
accumulator_set<
    int
    , stats<
        tag::weighted_mean
        , tag::weighted_mean_of_variates<int, tag::covariate1>
    >
    , int
> acc;

acc(10, weight = 2, covariate1 = 7);           // 20
BOOST_CHECK_EQUAL(2, sum_of_weights(acc));    //
//
acc(6, weight = 3, covariate1 = 8);           // 18
BOOST_CHECK_EQUAL(5, sum_of_weights(acc));    //
//
acc(4, weight = 4, covariate1 = 9);           // 16
BOOST_CHECK_EQUAL(9, sum_of_weights(acc));    //
//
acc(6, weight = 5, covariate1 = 6);           //+ 30
BOOST_CHECK_EQUAL(14, sum_of_weights(acc));   //
//= 84 / 14 = 6

BOOST_CHECK_EQUAL(6., weighted_mean(acc));
BOOST_CHECK_EQUAL(52./7., (accumulators::weighted_mean_of_variates<int, tag::covariate1>(acc)));

accumulator_set<
    int
    , stats<
        tag::weighted_mean(immediate)
        , tag::weighted_mean_of_variates<int, tag::covariate1>(immediate)
    >
    , int
> acc2;

acc2(10, weight = 2, covariate1 = 7);         // 20
BOOST_CHECK_EQUAL(2, sum_of_weights(acc2));  //
//
acc2(6, weight = 3, covariate1 = 8);         // 18
BOOST_CHECK_EQUAL(5, sum_of_weights(acc2));  //
//
acc2(4, weight = 4, covariate1 = 9);         // 16
BOOST_CHECK_EQUAL(9, sum_of_weights(acc2));  //
//
acc2(6, weight = 5, covariate1 = 6);         //+ 30
BOOST_CHECK_EQUAL(14, sum_of_weights(acc2)); //
//= 84 / 14 = 6

BOOST_CHECK_EQUAL(6., weighted_mean(acc2));
BOOST_CHECK_EQUAL(52./7., (accumulators::weighted_mean_of_variates<int, tag::covariate1>(acc2)));
```

See also

- [weighted_mean_impl](#)
- [immediate_weighted_mean_impl](#)
- [weighted_sum](#)
- [sum](#)

weighted_median and variants

Median estimation for weighted samples based on the P^2 quantile estimator, the density estimator, or the P^2 cumulative distribution estimator. For more implementation details, see [weighted_median_impl](#), [with_weighted_density_median_impl](#), and [with_weighted_p_square_cumulative_distribution_median_impl](#).

The three median accumulators all satisfy the `tag::weighted_median` feature, and can all be extracted with the `weighted_median()` extractor.

Result Type

```
numeric::functional::average<sample-type, std::size_t>::result_type
```

Depends On

`weighted_median` depends on `weighted_p_square_quantile_for_median`
`with_weighted_density_median` depends on `count` and `weighted_density`
`with_weighted_p_square_cumulative_distribution_median` depends on `weighted_p_square_cumulative_distribution`

Variants

`with_weighted_density_median` (a.k.a. `weighted_median(with_weighted_density)`)
`with_weighted_p_square_cumulative_distribution_median` (a.k.a. `weighted_median(with_weighted_p_square_cumulative_distribution)`)

Initialization Parameters

`with_weighted_density_median` requires `tag::weighted_density::cache_size` and `tag::weighted_density::num_bins`
`with_weighted_p_square_cumulative_distribution_median` requires `tag::weighted_p_square_cumulative_distribution::num_cells`

Accumulator Parameters

`weight`

Extractor Parameters

none

Accumulator Complexity

TODO

Extractor Complexity

TODO

Header

```
#include <boost/accumulators/statistics/weighted_median.hpp>
```

Example

```
// Median estimation of normal distribution N(1,1) using samples from a narrow normal distribution N(1,0.01)
// The weights equal to the likelihood ratio of the corresponding samples

// two random number generators
double mu = 1.;
double sigma_narrow = 0.01;
double sigma = 1.;
boost::lagged_fibonacci607 rng;
boost::normal_distribution<> mean_sigma_narrow(mu, sigma_narrow);
boost::variate_generator<boost::lagged_fibonacci607&, boost::normal_distribution<> > normal_narrow(rng, mean_sigma_narrow);

accumulator_set<double, stats<tag::weighted_median>> acc(
    with_weighted_p_square_quantile) >, double > acc;
accumulator_set<double, stats<tag::weighted_median>> acc_dens(
    tag::weighted_density::cache_size = 10000, tag::weighted_density::num_bins = 1000) >, double >
accumulator_set<double, stats<tag::weighted_median>> acc_cdist(
    tag::weighted_p_square_cumulative_distribution::num_cells = 100) >, double >

for (std::size_t i=0; i<100000; ++i)
{
    double sample = normal_narrow();
    acc(sample, weight = std::exp(0.5 * (sample - mu) * (sample - mu) * (1./sigma_narrow/sigma_narrow - 1./sigma/sigma)));
    acc_dens(sample, weight = std::exp(0.5 * (sample - mu) * (sample - mu) * (1./sigma_narrow/sigma_narrow - 1./sigma/sigma)));
    acc_cdist(sample, weight = std::exp(0.5 * (sample - mu) * (sample - mu) * (1./sigma_narrow/sigma_narrow - 1./sigma/sigma)));
}

BOOST_CHECK_CLOSE(1., weighted_median(acc), 1e-1);
BOOST_CHECK_CLOSE(1., weighted_median(acc_dens), 1e-1);
BOOST_CHECK_CLOSE(1., weighted_median(acc_cdist), 1e-1);
```

See also

- [weighted_median_impl](#)
- [with_weighted_density_median_impl](#)
- [with_weighted_p_square_cumulative_distribution_median_impl](#)
- [count](#)
- [weighted_p_square_quantile](#)
- [weighted_p_square_cumulative_distribution](#)

weighted_moment

Calculates the N-th moment of the weighted samples, which is defined as the sum of the weighted N-th power of the samples over the sum of the weights.

Result Type

```
numeric::functional::average<
    numeric::functional::multiplies<sample-type, weight-type>::result_type,
    weight_type
>::result_type
```


Depends On	count sum_of_weights
Variants	<i>none</i>
Initialization Parameters	<i>none</i>
Accumulator Parameters	weight
Extractor Parameters	<i>none</i>
Accumulator Complexity	O(1)
Extractor Complexity	O(1)

Header

```
#include <boost/accumulators/statistics/weighted_moment.hpp>
```

Example

```
accumulator_set<double, stats<tag::weighted_moment<2> >, double> acc2;  
accumulator_set<double, stats<tag::weighted_moment<7> >, double> acc7;  
  
acc2(2.1, weight = 0.7);  
acc2(2.7, weight = 1.4);  
acc2(1.8, weight = 0.9);  
  
acc7(2.1, weight = 0.7);  
acc7(2.7, weight = 1.4);  
acc7(1.8, weight = 0.9);  
  
BOOST_CHECK_CLOSE(5.403, accumulators::weighted_moment<2>(acc2), 1e-5);  
BOOST_CHECK_CLOSE(548.54182, accumulators::weighted_moment<7>(acc7), 1e-5);
```

See also

- [weighted_moment_impl](#)
- [count](#)
- [sum](#)

weighted_p_square_cumulative_distribution

Histogram calculation of the cumulative distribution with the P^2 algorithm for weighted samples. For more implementation details, see [weighted_p_square_cumulative_distribution_impl](#)

Result Type

```
iterator_range<  
    std::vector<  
        std::pair<  
            numeric::functional::averaging, numeric::functional::averaging  
        >, numeric::functional::averaging, numeric::functional::averaging  
    >  
>::iterator  
>
```

where `weighted_sample` is `numeric::functional::multiplies<sample-type, weight-type>::result_type`

Depends On	<code>count</code> <code>sum_or_weights</code>
Variants	<i>none</i>
Initialization Parameters	<code>tag::weighted_p_square_cumulative_distribution::num_cells</code>
Accumulator Parameters	<code>weight</code>
Extractor Parameters	<i>none</i>
Accumulator Complexity	TODO
Extractor Complexity	$O(N)$ where <code>N</code> is <code>num_cells</code>

Header

```
#include <boost/accumulators/statistics/weighted_p_square_cumul_dist.hpp>
```

Example

```
// tolerance in %
double epsilon = 4;

typedef accumulator_set<double, stats<tag::weighted_p_square_cumulative_distribution>, double > accu-
accumulator_t;

accumulator_t acc_upper(tag::weighted_p_square_cumulative_distribution::num_cells = 100);
accumulator_t acc_lower(tag::weighted_p_square_cumulative_distribution::num_cells = 100);

// two random number generators
double mu_upper = 1.0;
double mu_lower = -1.0;
boost::lagged_fibonacci607 rng;
boost::normal_distribution<> mean_sigma_upper(mu_upper,1);
boost::normal_distribution<> mean_sigma_lower(mu_lower,1);
boost::variate_generator<boost::lagged_fibonacci607&, boost::normal_distribution<> > normal_up-
per(rng, mean_sigma_upper);
boost::variate_generator<boost::lagged_fibonacci607&, boost::normal_distribution<> > nor-
mal_lower(rng, mean_sigma_lower);

for (std::size_t i=0; i<100000; ++i)
{
    double sample = normal_upper();
    acc_upper(sample, weight = std::exp(-mu_upper * (sample - 0.5 * mu_upper)));
}

for (std::size_t i=0; i<100000; ++i)
{
    double sample = normal_lower();
    acc_lower(sample, weight = std::exp(-mu_lower * (sample - 0.5 * mu_lower)));
}

typedef iterator_range<std::vector<std::pair<double, double> >::iterator > histogram_type;
histogram_type histogram_upper = weighted_p_square_cumulative_distribution(acc_upper);
histogram_type histogram_lower = weighted_p_square_cumulative_distribution(acc_lower);

// Note that applying importance sampling results in a region of the distribution
// to be estimated more accurately and another region to be estimated less accurately
// than without importance sampling, i.e., with unweighted samples

for (std::size_t i = 0; i < histogram_upper.size(); ++i)
{
    // problem with small results: epsilon is relative (in percent), not absolute!

    // check upper region of distribution
    if ( histogram_upper[i].second > 0.1 )
        BOOST_CHECK_CLOSE( 0.5 * (1.0 + erf( histogram_upper[i].first / sqrt(2.0) )), histogram_up-
per[i].second, epsilon );
    // check lower region of distribution
    if ( histogram_lower[i].second < -0.1 )
        BOOST_CHECK_CLOSE( 0.5 * (1.0 + erf( histogram_lower[i].first / sqrt(2.0) )), histo-
gram_lower[i].second, epsilon );
}
```

See also

- [weighted_p_square_cumulative_distribution_impl](#)
- [count](#)
- [sum](#)

weighted_p_square_quantile *and variants*

Single quantile estimation with the P^2 algorithm. For more implementation details, see [weighted_p_square_quantile_impl](#)

Result Type

```
numeric::functional::average<
    numeric::functional::multiplies<sample-type, weight-type>::result_type
    , std::size_t
>::result_type
```

Depends On

count
sum_of_weights

Variants

weighted_p_square_quantile_for_median

Initialization Parameters

quantile_probability, which defaults to 0.5. (Note: for weighted_p_square_quantile_for_median, the quantile_probability parameter is ignored and is always 0.5.)

Accumulator Parameters

weight

Extractor Parameters

none

Accumulator Complexity

TODO

Extractor Complexity

O(1)

Header

```
#include <boost/accumulators/statistics/weighted_p_square_quantile.hpp>
```

Example

```
typedef accumulator_set<double, stats<tag::weighted_p_square_quantile>, double> accumulator_t;

// tolerance in %
double epsilon = 1;

// some random number generators
double mu4 = -1.0;
double mu5 = -1.0;
double mu6 = 1.0;
double mu7 = 1.0;
boost::lagged_fibonacci607 rng;
boost::normal_distribution<> mean_sigma4(mu4, 1);
boost::normal_distribution<> mean_sigma5(mu5, 1);
boost::normal_distribution<> mean_sigma6(mu6, 1);
boost::normal_distribution<> mean_sigma7(mu7, 1);
boost::variate_generator<boost::lagged_fibonacci607&, boost::normal_distribution<> > norJ
mal4(rng, mean_sigma4);
boost::variate_generator<boost::lagged_fibonacci607&, boost::normal_distribution<> > norJ
mal5(rng, mean_sigma5);
boost::variate_generator<boost::lagged_fibonacci607&, boost::normal_distribution<> > norJ
mal6(rng, mean_sigma6);
boost::variate_generator<boost::lagged_fibonacci607&, boost::normal_distribution<> > norJ
mal7(rng, mean_sigma7);

accumulator_t acc0(quantile_probability = 0.001);
accumulator_t acc1(quantile_probability = 0.025);
accumulator_t acc2(quantile_probability = 0.975);
accumulator_t acc3(quantile_probability = 0.999);

accumulator_t acc4(quantile_probability = 0.001);
accumulator_t acc5(quantile_probability = 0.025);
accumulator_t acc6(quantile_probability = 0.975);
accumulator_t acc7(quantile_probability = 0.999);

for (std::size_t i=0; i<100000; ++i)
{
    double sample = rng();
    acc0(sample, weight = 1.);
    acc1(sample, weight = 1.);
    acc2(sample, weight = 1.);
    acc3(sample, weight = 1.);

    double sample4 = normal4();
    double sample5 = normal5();
    double sample6 = normal6();
    double sample7 = normal7();
    acc4(sample4, weight = std::exp(-mu4 * (sample4 - 0.5 * mu4)));
    acc5(sample5, weight = std::exp(-mu5 * (sample5 - 0.5 * mu5)));
    acc6(sample6, weight = std::exp(-mu6 * (sample6 - 0.5 * mu6)));
    acc7(sample7, weight = std::exp(-mu7 * (sample7 - 0.5 * mu7)));
}

// check for uniform distribution with weight = 1
BOOST_CHECK_CLOSE( weighted_p_square_quantile(acc0), 0.001, 15 );
BOOST_CHECK_CLOSE( weighted_p_square_quantile(acc1), 0.025, 5 );
BOOST_CHECK_CLOSE( weighted_p_square_quantile(acc2), 0.975, epsilon );
BOOST_CHECK_CLOSE( weighted_p_square_quantile(acc3), 0.999, epsilon );
```

```
// check for shifted standard normal distribution ("importance sampling")
BOOST_CHECK_CLOSE( weighted_p_square_quantile(acc4), -3.090232, epsilon );
BOOST_CHECK_CLOSE( weighted_p_square_quantile(acc5), -1.959963, epsilon );
BOOST_CHECK_CLOSE( weighted_p_square_quantile(acc6),  1.959963, epsilon );
BOOST_CHECK_CLOSE( weighted_p_square_quantile(acc7),  3.090232, epsilon );
```

See also

- [weighted_p_square_quantile_impl](#)
- [count](#)
- [sum](#)

weighted_peaks_over_threshold and variants

Weighted peaks over threshold method for weighted quantile and weighted tail mean estimation. For more implementation details, see [weighted_peaks_over_threshold_impl](#) and [weighted_peaks_over_threshold_prob_impl](#).

Both `tag::weighted_peaks_over_threshold<left-or-right>` and `tag::weighted_peaks_over_threshold_prob<left-or-right>` satisfy the `tag::weighted_peaks_over_threshold<left-or-right>` feature and can be extracted using the `weighted_peaks_over_threshold()` extractor.

Result Type `tuple<float_type, float_type, float_type>` where `float_type` is

```
numeric::functional::average<
    numeric::functional::multiplies<sample-type, weight-type>::result_type
    , std::size_t
>::result_type
```

Depends On `weighted_peaks_over_threshold<left-or-right>` depends on `sum_of_weights`
`weighted_peaks_over_threshold_prob<left-or-right>` depends on `sum_of_weights` and `tail_weights<left-or-right>`

Variants `weighted_peaks_over_threshold_prob`

Initialization Parameters
`tag::peaks_over_threshold::threshold_value`
`tag::peaks_over_threshold_prob::threshold_probability`
`tag::tail<left-or-right>::cache_size`

Accumulator Parameters `weight`

Extractor Parameters `none`

Accumulator Complexity `TODO`

Extractor Complexity `O(1)`

Header

```
#include <boost/accumulators/statistics/weighted_peaks_over_threshold.hpp>
```

See also

- [weighted_peaks_over_threshold_impl](#)

- [weighted_peaks_over_threshold_prob_impl](#)
- [sum](#)
- [tail](#)

weighted_skewness

The skewness of a sample distribution is defined as the ratio of the 3rd central moment and the $3/2$ -th power of the 2nd central moment (the variance) of the samples. The skewness estimator for weighted samples is formally identical to the estimator for unweighted samples, except that the weighted counterparts of all measures it depends on are to be taken.

For implementation details, see [weighted_skewness_impl](#).

Result Type

```
numeric::functional::average<
    numeric::functional::multiplies<sample-type, weight-type>::result_type
, numeric::functional::multiplies<sample-type, weight-type>::result_type
>::result_type
```

Depends On

```
weighted_mean
weighted_moment<2>
weighted_moment<3>
```

Variants

none

Initialization Parameters

none

Accumulator Parameters

weight

Extractor Parameters

none

Accumulator Complexity

$O(1)$

Extractor Complexity

$O(1)$

Header

```
#include <boost/accumulators/statistics/weighted_skewness.hpp>
```

Example

```
accumulator_set<int, stats<tag::weighted_skewness>, int > acc2;

acc2(2, weight = 4);
acc2(7, weight = 1);
acc2(4, weight = 3);
acc2(9, weight = 1);
acc2(3, weight = 2);

BOOST_CHECK_EQUAL( weighted_mean(acc2), 42./11. );
BOOST_CHECK_EQUAL( accumulators::weighted_moment<2>(acc2), 212./11. );
BOOST_CHECK_EQUAL( accumulators::weighted_moment<3>(acc2), 1350./11. );
BOOST_CHECK_CLOSE( weighted_skewness(acc2), 1.30708406282, 1e-6 );
```

See also

- [weighted_skewness_impl](#)
- [weighted_mean](#)
- [weighted_moment](#)

weighted_sum and variants

For summing the weighted samples or variates. All of the `tag::weighted_sum_of_variates<>` features can be extracted with the `weighted_sum_of_variates()` extractor. Variants that implement the Kahan summation algorithm are also provided.

Result Type	<code>numeric::functional::multiplies<sample-type, weight-type>::result_type</code> for summing weighted samples <code>numeric::functional::multiplies<variate-type, weight-type>::result_type</code> for summing weighted variates
Depends On	<i>none</i>
Variants	<code>tag::weighted_sum</code> <code>tag::weighted_sum_of_variates<variate-type, variate-tag></code> <code>tag::weighted_sum_kahan</code> (a.k.a. <code>tag::weighted_sum(kahan)</code>) <code>tag::weighted_sum_of_variates_kahan<variate-type, variate-tag></code>
Initialization Parameters	<i>none</i>
Accumulator Parameters	<code>weight</code> <code>variate-tag</code> for summing variates
Extractor Parameters	<i>none</i>
Accumulator Complexity	O(1). Note that the Kahan sum performs four floating-point sum operations per accumulated value, whereas the naive sum performs only one.
Extractor Complexity	O(1)

Header

```
#include <boost/accumulators/statistics/weighted_sum.hpp>
#include <boost/accumulators/statistics/weighted_sum_kahan.hpp>
```

Example


```
accumulator_set<int, stats<tag::weighted_sum, tag::weighted_sum_of_variates<int, tag::covariate1> >, int> acc;

acc(1, weight = 2, covariate1 = 3);
BOOST_CHECK_EQUAL(2, weighted_sum(acc));
BOOST_CHECK_EQUAL(6, weighted_sum_of_variates(acc));

acc(2, weight = 3, covariate1 = 6);
BOOST_CHECK_EQUAL(8, weighted_sum(acc));
BOOST_CHECK_EQUAL(24, weighted_sum_of_variates(acc));

acc(4, weight = 6, covariate1 = 9);
BOOST_CHECK_EQUAL(32, weighted_sum(acc));
BOOST_CHECK_EQUAL(78, weighted_sum_of_variates(acc));

// demonstrate weighted Kahan summation
accumulator_set<float, stats<tag::weighted_sum_kahan>, float > acc;
BOOST_CHECK_EQUAL(0.0f, weighted_sum_kahan(acc));
for (size_t i = 0; i < 1e6; ++i) {
    acc(1.0f, weight = 1e-6f);
}
BOOST_CHECK_EQUAL(1.0f, weighted_sum_kahan(acc));
```

See also

- [weighted_sum_impl](#)
- [weighted_sum_kahan_impl](#)

non_coherent_weighted_tail_mean

Estimation of the (non-coherent) weighted tail mean based on order statistics (for both left and right tails). The left non-coherent weighted tail mean feature is `tag::non_coherent_weighted_tail_mean<left>`, and the right non-coherent weighted tail mean feature is `tag::non_coherent_weighted_tail_mean<right>`. They both share the `tag::abstract_non_coherent_tail_mean` feature with the unweighted non-coherent tail mean accumulators and can be extracted with either the `non_coherent_tail_mean()` or the `non_coherent_weighted_tail_mean()` extractors. For more implementation details, see [non_coherent_weighted_tail_mean_impl](#).

Result Type

```
numeric::functional::average<
    numeric::functional::multiplies<sample-type, weight-type>::result_type
    , std::size_t
>::result_type
```

Depends On

`sum_of_weights`
`tail_weights<left-or-right>`

Variants

`abstract_non_coherent_tail_mean`

Initialization Parameters

`tag::tail<left-or-right>::cache_size`

Accumulator Parameters

none

Extractor Parameters

`quantile_probability`

Accumulator Complexity

$O(\log N)$, where N is the cache size

Extractor Complexity

$O(N \log N)$, where N is the cache size

Header

```
#include <boost/accumulators/statistics/weighted_tail_mean.hpp>
```

Example

```
// tolerance in %
double epsilon = 1;

std::size_t n = 100000; // number of MC steps
std::size_t c = 25000; // cache size

accumulator_set<double, stats<tag::non_coherent_weighted_tail_mean<right> >, double >
    acc0( right_tail_cache_size = c );
accumulator_set<double, stats<tag::non_coherent_weighted_tail_mean<left> >, double >
    acc1( left_tail_cache_size = c );

// random number generators
boost::lagged_fibonacci607 rng;

for (std::size_t i = 0; i < n; ++i)
{
    double smpl = std::sqrt(rng());
    acc0(smpl, weight = 1./smpl);
}

for (std::size_t i = 0; i < n; ++i)
{
    double smpl = rng();
    acc1(smpl*smpl, weight = smpl);
}

// check uniform distribution
BOOST_CHECK_CLOSE( non_coherent_weighted_tail_mean(acc0, quantile_probability = 0.95), 0.975, epsilon );
BOOST_CHECK_CLOSE( non_coherent_weighted_tail_mean(acc0, quantile_probability = 0.975), 0.9875, epsilon );
BOOST_CHECK_CLOSE( non_coherent_weighted_tail_mean(acc0, quantile_probability = 0.99), 0.995, epsilon );
BOOST_CHECK_CLOSE( non_coherent_weighted_tail_mean(acc0, quantile_probability = 0.999), 0.9995, epsilon );
BOOST_CHECK_CLOSE( non_coherent_weighted_tail_mean(acc1, quantile_probability = 0.05), 0.025, epsilon );
BOOST_CHECK_CLOSE( non_coherent_weighted_tail_mean(acc1, quantile_probability = 0.025), 0.0125, epsilon );
BOOST_CHECK_CLOSE( non_coherent_weighted_tail_mean(acc1, quantile_probability = 0.01), 0.005, epsilon );
BOOST_CHECK_CLOSE( non_coherent_weighted_tail_mean(acc1, quantile_probability = 0.001), 0.0005, 5*epsilon );
```

See also

- [non_coherent_weighted_tail_mean_impl](#)
- [sum](#)
- [tail](#)

weighted_tail_quantile

Tail quantile estimation based on order statistics of weighted samples (for both left and right tails). The left weighted tail quantile feature is `tag::weighted_tail_quantile<left>`, and the right weighted tail quantile feature is `tag::weighted_tail_quantile<right>`. They both share the `tag::quantile` feature with the unweighted tail quantile accumulators and can be extracted with either the `quantile()` or the `weighted_tail_quantile()` extractors. For more implementation details, see [weighted_tail_quantile_impl](#)

Result Type

`sample-type`

Depends On

`sum_of_weights`
`tail_weights<left-or-right>`

Variants

none

Initialization Parameters

`tag::tail<left-or-right>::cache_size`

Accumulator Parameters

none

Extractor Parameters

`quantile_probability`

Accumulator Complexity

$O(\log N)$, where N is the cache size

Extractor Complexity

$O(N \log N)$, where N is the cache size

Header

```
#include <boost/accumulators/statistics/weighted_tail_quantile.hpp>
```

Example

```
// tolerance in %
double epsilon = 1;

std::size_t n = 100000; // number of MC steps
std::size_t c = 20000; // cache size

double mu1 = 1.0;
double mu2 = -1.0;
boost::lagged_fibonacci607 rng;
boost::normal_distribution<> mean_signal(mu1,1);
boost::normal_distribution<> mean_sigma2(mu2,1);
boost::variate_generator<boost::lagged_fibonacci607&, boost::normal_distribution<> > nor1(
    rng, mean_signal);
boost::variate_generator<boost::lagged_fibonacci607&, boost::normal_distribution<> > nor2(
    rng, mean_sigma2);

accumulator_set<double, stats<tag::weighted_tail_quantile<right> >, double>
    acc1(right_tail_cache_size = c);

accumulator_set<double, stats<tag::weighted_tail_quantile<left> >, double>
    acc2(left_tail_cache_size = c);

for (std::size_t i = 0; i < n; ++i)
{
    double sample1 = nor1();
    double sample2 = nor2();
    acc1(sample1, weight = std::exp(-mu1 * (sample1 - 0.5 * mu1)));
    acc2(sample2, weight = std::exp(-mu2 * (sample2 - 0.5 * mu2)));
}

// check standard normal distribution
BOOST_CHECK_CLOSE( quantile(acc1, quantile_probability = 0.975), 1.959963, epsilon );
BOOST_CHECK_CLOSE( quantile(acc1, quantile_probability = 0.999), 3.090232, epsilon );
BOOST_CHECK_CLOSE( quantile(acc2, quantile_probability = 0.025), -1.959963, epsilon );
BOOST_CHECK_CLOSE( quantile(acc2, quantile_probability = 0.001), -3.090232, epsilon );
```

See also

- [weighted_tail_quantile_impl](#)
- [sum](#)
- [tail](#)

weighted_tail_variate_means and variants

Estimation of the absolute and relative weighted tail variate means (for both left and right tails) The absolute weighted tail variate means has the feature `tag::absolute_weighted_tail_variate_means<left-or-right, variate-type, variate-tag>` and the relative weighted tail variate mean has the feature `tag::relative_weighted_tail_variate_means<left-or-right, variate-type, variate-tag>`. All absolute weighted tail variate mean features share the `tag::abstract_absolute_tail_variate_means` feature with their unweighted variants and can be extracted with the `tail_variate_means()` and `weighted_tail_variate_means()` extractors. All the relative weighted tail variate mean features share the `tag::abstract_relative_tail_variate_means` feature with their unweighted variants and can be extracted with either the `relative_tail_variate_means()` or `relative_weighted_tail_variate_means()` extractors.

For more implementation details, see [weighted_tail_variate_means_impl](#)

Result Type

```
boost::iterator_range<
    numeric::functional::average<
        numeric::functional::multiplies<variate-type, weight-
type>::result_type
        , weight-type
    >::result_type::iterator
>
```

Depends On

```
non_coherent_weighted_tail_mean<left-or-right>
tail_variate<variate-type, variate-tag, left-or-right>
tail_weights<left-or-right>
```

Variants

```
tag::absolute_weighted_tail_variate_means<left-or-right, variate-type,
variate-tag>
tag::relative_weighted_tail_variate_means<left-or-right, variate-type,
variate-tag>
```

Initialization Parameters

```
tag::tail<left-or-right>::cache_size
```

Accumulator Parameters

```
none
```

Extractor Parameters

```
quantile_probability
```

Accumulator Complexity

$O(\log N)$, where N is the cache size

Extractor Complexity

$O(N \log N)$, where N is the cache size

Header

```
#include <boost/accumulators/statistics/weighted_tail_variate_means.hpp>
```

Example

```

std::size_t c = 5; // cache size

typedef double variate_type;
typedef std::vector<variate_type> variate_set_type;

accumulator_set<double, stats<tag::weighted_tail_variate_means<right, variate_set_type, tag::covariatel>(relative)>, double >
    acc1( right_tail_cache_size = c );
accumulator_set<double, stats<tag::weighted_tail_variate_means<right, variate_set_type, tag::covariatel>(absolute)>, double >
    acc2( right_tail_cache_size = c );
accumulator_set<double, stats<tag::weighted_tail_variate_means<left, variate_set_type, tag::covariatel>(relative)>, double >
    acc3( left_tail_cache_size = c );
accumulator_set<double, stats<tag::weighted_tail_variate_means<left, variate_set_type, tag::covariatel>(absolute)>, double >
    acc4( left_tail_cache_size = c );

variate_set_type cov1, cov2, cov3, cov4, cov5;
double c1[] = { 10., 20., 30., 40. }; // 100
double c2[] = { 26., 4., 17., 3. }; // 50
double c3[] = { 46., 64., 40., 50. }; // 200
double c4[] = { 1., 3., 70., 6. }; // 80
double c5[] = { 2., 2., 2., 14. }; // 20
cov1.assign(c1, c1 + sizeof(c1)/sizeof(variate_type));
cov2.assign(c2, c2 + sizeof(c2)/sizeof(variate_type));
cov3.assign(c3, c3 + sizeof(c3)/sizeof(variate_type));
cov4.assign(c4, c4 + sizeof(c4)/sizeof(variate_type));
cov5.assign(c5, c5 + sizeof(c5)/sizeof(variate_type));

acc1(100., weight = 0.8, covariatel = cov1);
acc1( 50., weight = 0.9, covariatel = cov2);
acc1(200., weight = 1.0, covariatel = cov3);
acc1( 80., weight = 1.1, covariatel = cov4);
acc1( 20., weight = 1.2, covariatel = cov5);

acc2(100., weight = 0.8, covariatel = cov1);
acc2( 50., weight = 0.9, covariatel = cov2);
acc2(200., weight = 1.0, covariatel = cov3);
acc2( 80., weight = 1.1, covariatel = cov4);
acc2( 20., weight = 1.2, covariatel = cov5);

acc3(100., weight = 0.8, covariatel = cov1);
acc3( 50., weight = 0.9, covariatel = cov2);
acc3(200., weight = 1.0, covariatel = cov3);
acc3( 80., weight = 1.1, covariatel = cov4);
acc3( 20., weight = 1.2, covariatel = cov5);

acc4(100., weight = 0.8, covariatel = cov1);
acc4( 50., weight = 0.9, covariatel = cov2);
acc4(200., weight = 1.0, covariatel = cov3);
acc4( 80., weight = 1.1, covariatel = cov4);
acc4( 20., weight = 1.2, covariatel = cov5);

// check relative risk contributions
BOOST_CHECK_EQUAL( *(relative_weighted_tail_variate_means(acc1, quantile_probability = 0.7).begin()
    ), (0.8*10 + 1.0*46)/(0.8*100 + 1.0*200) );
BOOST_CHECK_EQUAL( *(relative_weighted_tail_variate_means(acc1, quantile_probability = 0.7).begin()
    + 1), (0.8*20 + 1.0*64)/(0.8*100 + 1.0*200) );
BOOST_CHECK_EQUAL( *(relative_weighted_tail_variate_means(acc1, quantile_probability = 0.7).begin()
    + 2), (0.8*30 + 1.0*40)/(0.8*100 + 1.0*200) );
BOOST_CHECK_EQUAL( *(relative_weighted_tail_variate_means(acc1, quantile_probability = 0.7).begin()
    + 3), (0.8*40 + 1.0*50)/(0.8*100 + 1.0*200) );

```

```

BOOST_CHECK_EQUAL( *(relative_weighted_tail_variate_means(acc3, quantile_probability = 0.3).begin()
gin()      ), (0.9*26 + 1.2*2)/(0.9*50 + 1.2*20) );
BOOST_CHECK_EQUAL( *(relative_weighted_tail_variate_means(acc3, quantile_probability = 0.3).begin()
gin() + 1), (0.9*4 + 1.2*2)/(0.9*50 + 1.2*20) );
BOOST_CHECK_EQUAL( *(relative_weighted_tail_variate_means(acc3, quantile_probability = 0.3).begin()
gin() + 2), (0.9*17 + 1.2*2)/(0.9*50 + 1.2*20) );
BOOST_CHECK_EQUAL( *(relative_weighted_tail_variate_means(acc3, quantile_probability = 0.3).begin()
gin() + 3), (0.9*3 + 1.2*14)/(0.9*50 + 1.2*20) );

// check absolute risk contributions
BOOST_CHECK_EQUAL( *(weighted_tail_variate_means(acc2, quantile_probability = 0.7).begin()
), (0.8*10 + 1.0*46)/1.8 );
BOOST_CHECK_EQUAL( *(weighted_tail_variate_means(acc2, quantile_probability = 0.7).begin()
gin() + 1), (0.8*20 + 1.0*64)/1.8 );
BOOST_CHECK_EQUAL( *(weighted_tail_variate_means(acc2, quantile_probability = 0.7).begin()
gin() + 2), (0.8*30 + 1.0*40)/1.8 );
BOOST_CHECK_EQUAL( *(weighted_tail_variate_means(acc2, quantile_probability = 0.7).begin()
gin() + 3), (0.8*40 + 1.0*50)/1.8 );
BOOST_CHECK_EQUAL( *(weighted_tail_variate_means(acc4, quantile_probability = 0.3).begin()
), (0.9*26 + 1.2*2)/2.1 );
BOOST_CHECK_EQUAL( *(weighted_tail_variate_means(acc4, quantile_probability = 0.3).begin()
gin() + 1), (0.9*4 + 1.2*2)/2.1 );
BOOST_CHECK_EQUAL( *(weighted_tail_variate_means(acc4, quantile_probability = 0.3).begin()
gin() + 2), (0.9*17 + 1.2*2)/2.1 );
BOOST_CHECK_EQUAL( *(weighted_tail_variate_means(acc4, quantile_probability = 0.3).begin()
gin() + 3), (0.9*3 + 1.2*14)/2.1 );

// check relative risk contributions
BOOST_CHECK_EQUAL( *(relative_weighted_tail_variate_means(acc1, quantile_probability = 0.9).begin()
gin()      ), 1.0*46/(1.0*200) );
BOOST_CHECK_EQUAL( *(relative_weighted_tail_variate_means(acc1, quantile_probability = 0.9).begin()
gin() + 1), 1.0*64/(1.0*200) );
BOOST_CHECK_EQUAL( *(relative_weighted_tail_variate_means(acc1, quantile_probability = 0.9).begin()
gin() + 2), 1.0*40/(1.0*200) );
BOOST_CHECK_EQUAL( *(relative_weighted_tail_variate_means(acc1, quantile_probability = 0.9).begin()
gin() + 3), 1.0*50/(1.0*200) );
BOOST_CHECK_EQUAL( *(relative_weighted_tail_variate_means(acc3, quantile_probability = 0.1).begin()
gin()      ), 1.2*2/(1.2*20) );
BOOST_CHECK_EQUAL( *(relative_weighted_tail_variate_means(acc3, quantile_probability = 0.1).begin()
gin() + 1), 1.2*2/(1.2*20) );
BOOST_CHECK_EQUAL( *(relative_weighted_tail_variate_means(acc3, quantile_probability = 0.1).begin()
gin() + 2), 1.2*2/(1.2*20) );
BOOST_CHECK_EQUAL( *(relative_weighted_tail_variate_means(acc3, quantile_probability = 0.1).begin()
gin() + 3), 1.2*14/(1.2*20) );

// check absolute risk contributions
BOOST_CHECK_EQUAL( *(weighted_tail_variate_means(acc2, quantile_probability = 0.9).begin()
), 1.0*46/1.0 );
BOOST_CHECK_EQUAL( *(weighted_tail_variate_means(acc2, quantile_probability = 0.9).begin()
gin() + 1), 1.0*64/1.0 );
BOOST_CHECK_EQUAL( *(weighted_tail_variate_means(acc2, quantile_probability = 0.9).begin()
gin() + 2), 1.0*40/1.0 );
BOOST_CHECK_EQUAL( *(weighted_tail_variate_means(acc2, quantile_probability = 0.9).begin()
gin() + 3), 1.0*50/1.0 );
BOOST_CHECK_EQUAL( *(weighted_tail_variate_means(acc4, quantile_probability = 0.1).begin()
), 1.2*2/1.2 );
BOOST_CHECK_EQUAL( *(weighted_tail_variate_means(acc4, quantile_probability = 0.1).begin()
gin() + 1), 1.2*2/1.2 );
BOOST_CHECK_EQUAL( *(weighted_tail_variate_means(acc4, quantile_probability = 0.1).begin()
gin() + 2), 1.2*2/1.2 );
BOOST_CHECK_EQUAL( *(weighted_tail_variate_means(acc4, quantile_probability = 0.1).begin()
gin() + 3), 1.2*14/1.2 );

```

See also

- [weighted_tail_variate_means_impl](#)
- [non_coherent_weighted_tail_mean](#)
- [tail_variate](#)
- [tail](#)

weighted_variance and variants

Lazy or iterative calculation of the weighted variance. The lazy calculation is associated with the `tag::lazy_weighted_variance` feature, and the iterative calculation with the `tag::weighted_variance` feature. Both can be extracted using the `tag::weighted_variance()` extractor. For more implementation details, see [lazy_weighted_variance_impl](#) and [weighted_variance_impl](#)

Result Type

```
numeric::functional::average<
    numeric::functional::multiplies<sample-type, weight-type>::result_type
    , std::size_t
>::result_type
```

Depends On

`tag::lazy_weighted_variance` depends on `tag::weighted_moment<2>` and `tag::weighted_mean`
`tag::weighted_variance` depends on `tag::count` and `tag::immediate_weighted_mean`

Variants

`tag::lazy_weighted_variance` (a.k.a. `tag::weighted_variance(lazy)`)
`tag::weighted_variance` (a.k.a. `tag::weighted_variance(immediate)`)

Initialization Parameters

none

Accumulator Parameters

`weight`

Extractor Parameters

none

Accumulator Complexity

O(1)

Extractor Complexity

O(1)

Header

```
#include <boost/accumulators/statistics/weighted_variance.hpp>
```

Example


```
// lazy weighted_variance
accumulator_set<int, stats<tag::weighted_variance(lazy)>, int> acc1;

acc1(1, weight = 2);    // 2
acc1(2, weight = 3);    // 6
acc1(3, weight = 1);    // 3
acc1(4, weight = 4);    // 16
acc1(5, weight = 1);    // 5

// weighted_mean = (2+6+3+16+5) / (2+3+1+4+1) = 32 / 11 = 2.9090909090909090909090909090909
BOOST_CHECK_EQUAL(5u, count(acc1));
BOOST_CHECK_CLOSE(2.9090909, weighted_mean(acc1), 1e-5);
BOOST_CHECK_CLOSE(10.1818182, accumulators::weighted_moment<2>(acc1), 1e-5);
BOOST_CHECK_CLOSE(1.7190083, weighted_variance(acc1), 1e-5);

// immediate weighted_variance
accumulator_set<int, stats<tag::weighted_variance>, int> acc2;

acc2(1, weight = 2);
acc2(2, weight = 3);
acc2(3, weight = 1);
acc2(4, weight = 4);
acc2(5, weight = 1);

BOOST_CHECK_EQUAL(5u, count(acc2));
BOOST_CHECK_CLOSE(2.9090909, weighted_mean(acc2), 1e-5);
BOOST_CHECK_CLOSE(1.7190083, weighted_variance(acc2), 1e-5);

// check lazy and immediate variance with random numbers

// two random number generators
boost::lagged_fibonacci607 rng;
boost::normal_distribution<> mean_sigma(0,1);
boost::variate_generator<boost::lagged_fibonacci607&, boost::normal_distribution<> > normal(rng, mean_sigma);

accumulator_set<double, stats<tag::weighted_variance>, double> acc_lazy;
accumulator_set<double, stats<tag::weighted_variance(immediate)>, double> acc_immediate;

for (std::size_t i=0; i<10000; ++i)
{
    double value = normal();
    acc_lazy(value, weight = rng());
    acc_immediate(value, weight = rng());
}

BOOST_CHECK_CLOSE(1., weighted_variance(acc_lazy), 1.);
BOOST_CHECK_CLOSE(1., weighted_variance(acc_immediate), 1.);
```

See also

- [lazy_weighted_variance_impl](#)
- [weighted_variance_impl](#)
- [count](#)
- [weighted_mean](#)
- [weighted_moment](#)

Acknowledgements

Boost.Accumulators represents the efforts of many individuals. I would like to thank Daniel Egloff of [Zürcher Kantonalbank](#) for helping to conceive the library and realize its implementation. I would also like to thank David Abrahams and Matthias Troyer for their key contributions to the design of the library. Many thanks are due to Michael Gauckler and Olivier Gygi, who, along with Daniel Egloff, implemented many of the statistical accumulators.

I would also like to thank Simon West for all his assistance maintaining Boost.Accumulators.

Finally, I would like to thank [Zürcher Kantonalbank](#) for sponsoring the work on Boost.Accumulators and graciously donating it to the community.

Reference

Accumulators Framework Reference

Header <boost/accumulators/accumulators.hpp>

Includes all of the Accumulators Framework

Header <boost/accumulators/accumulators_fwd.hpp>

```
BOOST_ACCUMULATORS_MAX_FEATURES
BOOST_ACCUMULATORS_MAX_ARGS
BOOST_ACCUMULATORS_PROTO_DISABLE_IF_IS_CONST(T)
BOOST_ACCUMULATORS_GCC_VERSION
BOOST_ACCUMULATORS_IGNORE_GLOBAL(X)
BOOST_PARAMETER_NESTED_KEYWORD(tag_namespace, name, alias)
```

```
namespace boost {
    namespace accumulators {
        template<typename Accumulator> struct droppable_accumulator_base;
        template<typename Accumulator> struct droppable_accumulator;
        template<typename Accumulator> struct with_cached_result;
        template<typename Sample, typename Features, typename Weight = void>
            struct accumulator_set;
        template<typename Feature> struct extractor;
        template<typename Feature> struct feature_of;
        template<typename Feature> struct as_feature;
        template<typename Feature> struct as_weighted_feature;
        template<BOOST_PP_ENUM_PARAMS_WITH_A_DEFAULT(BOOST_ACCUMULATORS_MAX_FEATURES, typename Feature, mpl::na) >
            struct depends_on;
        template<BOOST_PP_ENUM_PARAMS_WITH_A_DEFAULT(BOOST_ACCUMULATORS_MAX_FEATURES, typename Feature, mpl::na) >
            struct features;
        template<typename Feature, typename AccumulatorSet>
            mpl::apply< AccumulatorSet, Feature >::type::result_type
            extract_result(AccumulatorSet const & acc);
        template<typename Feature, typename AccumulatorSet, typename A1>
            mpl::apply< AccumulatorSet, Feature >::type::result_type
            extract_result(AccumulatorSet const & acc, A1 const & a1);
        namespace impl {
        }
        namespace tag {
            template<typename ValueType, typename Tag> struct value;
            template<typename Tag> struct value_tag;
            template<typename Referent, typename Tag> struct reference;
            template<typename Tag> struct reference_tag;
            template<typename Type, typename Tag = void,
                    typename AccumulatorSet = void>
                struct external;
            template<typename Feature> struct droppable;
        }
    }
}
```

Struct template value

boost::accumulators::tag::value

Synopsis

```
// In header: <boost/accumulators/accumulators_fwd.hpp>

template<typename ValueType, typename Tag>
struct value : public boost::accumulators::depends_on<> {
};
```

Struct template value_tag

boost::accumulators::tag::value_tag

Synopsis

```
// In header: <boost/accumulators/accumulators_fwd.hpp>

template<typename Tag>
struct value_tag {
};
```

Struct template reference

boost::accumulators::tag::reference

Synopsis

```
// In header: <boost/accumulators/accumulators_fwd.hpp>

template<typename Referent, typename Tag>
struct reference : public boost::accumulators::depends_on<> {
};
```

Struct template reference_tag

boost::accumulators::tag::reference_tag

Synopsis

```
// In header: <boost/accumulators/accumulators_fwd.hpp>

template<typename Tag>
struct reference_tag {
};
```

Struct template external

boost::accumulators::tag::external

Synopsis

```
// In header: <boost/accumulators/accumulators_fwd.hpp>

template<typename Type, typename Tag = void, typename AccumulatorSet = void>
struct external :
    public boost::accumulators::depends_on< reference< AccumulatorSet, Tag > >
{
};
```

Struct template droppable

boost::accumulators::tag::droppable

Synopsis

```
// In header: <boost/accumulators/accumulators_fwd.hpp>

template<typename Feature>
struct droppable : public as_feature::type< Feature > {
};
```

Struct template droppable_accumulator_base

boost::accumulators::droppable_accumulator_base

Synopsis

```
// In header: <boost/accumulators/accumulators_fwd.hpp>

template<typename Accumulator>
struct droppable_accumulator_base : public Accumulator {
    // construct/copy/destruct
    template<typename Args> droppable_accumulator_base(Args const &);
    droppable_accumulator_base(droppable_accumulator_base const &);

    // public member functions
    template<typename Args> void operator()(Args const &);
    template<typename Args> void add_ref(Args const &);
    template<typename Args> void drop(Args const &);
    bool is_dropped() const;
};
```

Description

droppable_accumulator_base public construct/copy/destruct

1.

```
template<typename Args> droppable_accumulator_base(Args const & args);
```
2.

```
droppable_accumulator_base(droppable_accumulator_base const & that);
```

droppable_accumulator_base public member functions

1.

```
template<typename Args> void operator()(Args const & args);
```
2.

```
template<typename Args> void add_ref(Args const &);
```
3.

```
template<typename Args> void drop(Args const & args);
```
4.

```
bool is_dropped() const;
```

Struct template droppable_accumulator

boost::accumulators::droppable_accumulator

Synopsis

```
// In header: <boost/accumulators/accumulators_fwd.hpp>

template<typename Accumulator>
struct droppable_accumulator :
    public boost::accumulators::droppable_accumulator_base< Accumulator >
{
    // construct/copy/destroy
    template<typename Args> droppable_accumulator(Args const &);
    droppable_accumulator(droppable_accumulator const &);
};
```

Description**droppable_accumulator public construct/copy/destroy**

1.

```
template<typename Args> droppable_accumulator(Args const & args);
```
2.

```
droppable_accumulator(droppable_accumulator const & that);
```

Struct template with_cached_result

boost::accumulators::with_cached_result

Synopsis

```
// In header: <boost/accumulators/accumulators_fwd.hpp>

template<typename Accumulator>
struct with_cached_result : public Accumulator {
    // construct/copy/destruct
    template<typename Args> with_cached_result(Args const &);
    with_cached_result(with_cached_result const &);
    with_cached_result& operator=(with_cached_result const &);
    ~with_cached_result();

    // public member functions
    template<typename Args> void on_drop(Args const &);
    template<typename Args> result_type result(Args const &) const;

    // private member functions
    void set(result_type const &);
    result_type const & get() const;
    bool has_result() const;
};
```

Description

with_cached_result public construct/copy/destruct

1. `template<typename Args> with_cached_result(Args const & args);`
2. `with_cached_result(with_cached_result const & that);`
3. `with_cached_result& operator=(with_cached_result const &);`
4. `~with_cached_result();`

with_cached_result public member functions

1. `template<typename Args> void on_drop(Args const & args);`
2. `template<typename Args> result_type result(Args const & args) const;`

with_cached_result private member functions

1. `void set(result_type const & r);`
2. `result_type const & get() const;`

```
3.  bool has_result() const;
```

Struct template accumulator_set

boost::accumulators::accumulator_set — A set of accumulators.

Synopsis

```
// In header: <boost/accumulators/accumulators_fwd.hpp>

template<typename Sample, typename Features, typename Weight = void>
struct accumulator_set {
    // construct/copy/destruct
    template<typename A1> explicit accumulator_set(A1 const &);

    // public member functions
    template<typename UnaryFunction> void visit(UnaryFunction const &);
    template<typename FilterPred, typename UnaryFunction>
        void visit_if(UnaryFunction const &);
    void operator()();
    template<typename A1> void operator()(A1 const &);
    template<typename Feature> apply< Feature >::type & extract();
    template<typename Feature> apply< Feature >::type const & extract() const;
    template<typename Feature> void drop();
};
```

Description

[accumulator_set](#) resolves the dependencies between features and ensures that the accumulators in the set are updated in the proper order.

[accumulator_set](#) provides a general mechanism to visit the accumulators in the set in order, with or without a filter. You can also fetch a reference to an accumulator that corresponds to a feature.

accumulator_set public construct/copy/destruct

```
1.  template<typename A1> explicit accumulator_set(A1 const & a1);
```

This is an overloaded member function, provided for convenience. It differs from the above function only in what argument(s) it accepts.

Parameters: a1 Optional named parameter to be passed to all the accumulators

accumulator_set public member functions

```
1.  template<typename UnaryFunction> void visit(UnaryFunction const & func);
```

Visitation

Parameters: func UnaryFunction which is invoked with each accumulator in turn.

```
2.  template<typename FilterPred, typename UnaryFunction>
    void visit_if(UnaryFunction const & func);
```

Conditional visitation

Parameters: func UnaryFunction which is invoked with each accumulator in turn, provided the accumulator satisfies the MPL predicate FilterPred.

3. `void operator()();`

Accumulation

4. `template<typename A1> void operator()(A1 const & a1);`

5. `template<typename Feature> apply< Feature >::type & extract();`

Extraction

6. `template<typename Feature> apply< Feature >::type const & extract() const;`

This is an overloaded member function, provided for convenience. It differs from the above function only in what argument(s) it accepts.

7. `template<typename Feature> void drop();`

Drop

Struct template extractor

boost::accumulators::extractor

Synopsis

```
// In header: <boost/accumulators/accumulators_fwd.hpp>

template<typename Feature>
struct extractor {

    // public member functions
    template<typename Arg1> unspecified operator()(Arg1 const &) const;
    template<typename AccumulatorSet, typename A1>
        unspecified operator()(AccumulatorSet const &, A1 const &) const;
    template<typename AccumulatorSet, typename A1, typename A2, ... >
        unspecified operator()(AccumulatorSet const &, A1 const &, A2 const &,
                                ...);
};
```

Description

Extracts the result associated with Feature from the specified [accumulator_set](#).

extractor public member functions

1. `template<typename Arg1> unspecified operator()(Arg1 const & arg1) const;`

Extract the result associated with Feature from the accumulator set

2. `template<typename AccumulatorSet, typename A1>
 unspecified operator()(AccumulatorSet const & acc, A1 const & a1) const;`

This is an overloaded member function, provided for convenience. It differs from the above function only in what argument(s) it accepts.

Parameters: a1 Optional named parameter to be passed to the accumulator's result() function.

3.

```
template<typename AccumulatorSet, typename A1, typename A2, ... >
    unspecified operator()(AccumulatorSet const & acc, A1 const & a1,
                          A2 const & a2, ...);
```

This is an overloaded member function, provided for convenience. It differs from the above function only in what argument(s) it accepts.

Struct template feature_of

boost::accumulators::feature_of

Synopsis

```
// In header: <boost/accumulators/accumulators_fwd.hpp>

template<typename Feature>
struct feature_of {
};
```

Struct template as_feature

boost::accumulators::as_feature

Synopsis

```
// In header: <boost/accumulators/accumulators_fwd.hpp>

template<typename Feature>
struct as_feature {
};
```

Struct template as_weighted_feature

boost::accumulators::as_weighted_feature

Synopsis

```
// In header: <boost/accumulators/accumulators_fwd.hpp>

template<typename Feature>
struct as_weighted_feature {
};
```

Struct template depends_on

boost::accumulators::depends_on

Synopsis

```
// In header: <boost/accumulators/accumulators_fwd.hpp>

template<BOOST_PP_ENUM_PARAMS_WITH_A_DEFAULT(BOOST_ACCUMULATORS_MAX_FEATURES, typename Feature, mpl::na) >
struct depends_on {
};
```

Description

`depends_on`

Struct template features

`boost::accumulators::features`

Synopsis

```
// In header: <boost/accumulators/accumulators_fwd.hpp>

template<BOOST_PP_ENUM_PARAMS_WITH_A_DEFAULT(BOOST_ACCUMULATORS_MAX_FEATURES, typename Feature, mpl::na) >
struct features : public mpl::vector< Feature1, Feature2, ... > {
};
```

Macro BOOST_ACCUMULATORS_MAX_FEATURES

`BOOST_ACCUMULATORS_MAX_FEATURES`

Synopsis

```
// In header: <boost/accumulators/accumulators_fwd.hpp>

BOOST_ACCUMULATORS_MAX_FEATURES
```

Description

The maximum number of accumulators that may be put in an `accumulator_set`. Defaults to `BOOST_MPL_LIMIT_VECTOR_SIZE` (which defaults to 20).

Macro BOOST_ACCUMULATORS_MAX_ARGS

`BOOST_ACCUMULATORS_MAX_ARGS`

Synopsis

```
// In header: <boost/accumulators/accumulators_fwd.hpp>

BOOST_ACCUMULATORS_MAX_ARGS
```

Description

The maximum number of arguments that may be specified to an `accumulator_set`'s accumulation function. Defaults to 15.

Macro BOOST_ACCUMULATORS_PROTO_DISABLE_IF_IS_CONST

BOOST_ACCUMULATORS_PROTO_DISABLE_IF_IS_CONST

Synopsis

```
// In header: <boost/accumulators/accumulators_fwd.hpp>

BOOST_ACCUMULATORS_PROTO_DISABLE_IF_IS_CONST(T)
```

Macro BOOST_ACCUMULATORS_GCC_VERSION

BOOST_ACCUMULATORS_GCC_VERSION

Synopsis

```
// In header: <boost/accumulators/accumulators_fwd.hpp>

BOOST_ACCUMULATORS_GCC_VERSION
```

Macro BOOST_ACCUMULATORS_IGNORE_GLOBAL

BOOST_ACCUMULATORS_IGNORE_GLOBAL

Synopsis

```
// In header: <boost/accumulators/accumulators_fwd.hpp>

BOOST_ACCUMULATORS_IGNORE_GLOBAL(X)
```

Macro BOOST_PARAMETER_NESTED_KEYWORD

BOOST_PARAMETER_NESTED_KEYWORD

Synopsis

```
// In header: <boost/accumulators/accumulators_fwd.hpp>

BOOST_PARAMETER_NESTED_KEYWORD(tag_namespace, name, alias)
```

Header <boost/accumulators/framework/accumulator_base.hpp>

```
namespace boost {
    namespace accumulators {
        struct dont_care;
        struct accumulator_base;
    }
}
```

Struct dont_care

boost::accumulators::dont_care

Synopsis

```
// In header: <boost/accumulators/framework/accumulator_base.hpp>

struct dont_care {
    // construct/copy/destruct
    template<typename Args> dont_care(Args const &);
};
```

Description

dont_care public construct/copy/destruct

1.

```
template<typename Args> dont_care(Args const &);
```

Struct accumulator_base

boost::accumulators::accumulator_base

Synopsis

```
// In header: <boost/accumulators/framework/accumulator_base.hpp>

struct accumulator_base {
    // types
    typedef mpl::false_ is_droppable;

    // public member functions
    unspecified operator()(dont_care);
    unspecified add_ref(dont_care);
    unspecified drop(dont_care);
    unspecified on_drop(dont_care);
};
```

Description

accumulator_base public member functions

1.

```
unspecified operator()(dont_care);
```
2.

```
unspecified add_ref(dont_care);
```
3.

```
unspecified drop(dont_care);
```

4. `unspecified on_drop(dont_care);`

Header <boost/accumulators/framework/accumulator_concept.hpp>

```
namespace boost {  
    namespace accumulators {  
        template<typename Stat> struct accumulator_concept;  
    }  
}
```

Struct template accumulator_concept

boost::accumulators::accumulator_concept

Synopsis

```
// In header: <boost/accumulators/framework/accumulator_concept.hpp>  
  
template<typename Stat>  
struct accumulator_concept {  
  
    // public member functions  
    void constraints();  
  
    // public data members  
    Stat stat;  
};
```

Description

accumulator_concept public member functions

1. `void constraints();`

Header <boost/accumulators/framework/accumulator_set.hpp>

```
namespace boost {  
    namespace accumulators {  
        template<typename Feature, typename AccumulatorSet>  
            mpl::apply< AccumulatorSet, Feature >::type &  
            find_accumulator(AccumulatorSet &acc BOOST_ACCUMULATORS_PROTO_DISABLE_IF_IS_CONST);  
    }  
}
```

Header `<boost/accumulators/framework/accumulators/droppable_accumulator.hpp>`

```
namespace boost {
  namespace accumulators {
    template<typename Feature> struct as_feature<tag::droppable< Feature >>;
    template<typename Feature>
      struct as_weighted_feature<tag::droppable< Feature >>;
    template<typename Feature> struct feature_of<tag::droppable< Feature >>;
    namespace tag {
      template<typename Feature> struct as_droppable;

      template<typename Feature> struct as_droppable<droppable< Feature >>;
    }
  }
}
```

Struct template `as_droppable`

`boost::accumulators::tag::as_droppable`

Synopsis

```
// In header: <boost/accumulators/framework/accumulators/droppable_accumulator.hpp>

template<typename Feature>
struct as_droppable {
  // types
  typedef droppable< Feature > type;
};
```

Struct template `as_droppable<droppable< Feature >>`

`boost::accumulators::tag::as_droppable<droppable< Feature >>`

Synopsis

```
// In header: <boost/accumulators/framework/accumulators/droppable_accumulator.hpp>

template<typename Feature>
struct as_droppable<droppable< Feature >> {
  // types
  typedef droppable< Feature > type;
};
```

Struct template `as_feature<tag::droppable< Feature >>`

`boost::accumulators::as_feature<tag::droppable< Feature >>`

Synopsis

```
// In header: <boost/accumulators/framework/accumulators/droppable_accumulator.hpp>

template<typename Feature>
struct as_feature<tag::droppable< Feature >> {
    // types
    typedef tag::droppable< typename as_feature< Feature >::type > type;
};
```

Struct template `as_weighted_feature<tag::droppable< Feature >>`

`boost::accumulators::as_weighted_feature<tag::droppable< Feature >>`

Synopsis

```
// In header: <boost/accumulators/framework/accumulators/droppable_accumulator.hpp>

template<typename Feature>
struct as_weighted_feature<tag::droppable< Feature >> {
    // types
    typedef tag::droppable< typename as_weighted_feature< Feature >::type > type;
};
```

Struct template `feature_of<tag::droppable< Feature >>`

`boost::accumulators::feature_of<tag::droppable< Feature >>`

Synopsis

```
// In header: <boost/accumulators/framework/accumulators/droppable_accumulator.hpp>

template<typename Feature>
struct feature_of<tag::droppable< Feature >> : public boost::accumulators::feature_of< Feature > {
};
```

Header `<boost/accumulators/framework/accumulators/external_accumulator.hpp>`

```
namespace boost {
    namespace accumulators {
        template<typename Feature, typename Tag, typename AccumulatorSet>
        struct feature_of<tag::external< Feature, Tag, AccumulatorSet >>;
        namespace impl {
        }
        namespace tag {
            template<typename Feature, typename Tag>
            struct external<Feature, Tag, void>;
        }
    }
}
```


Struct template `external<Feature, Tag, void>`

`boost::accumulators::tag::external<Feature, Tag, void>`

Synopsis

```
// In header: <boost/accumulators/framework/accumulators/external_accumulator.hpp>

template<typename Feature, typename Tag>
struct external<Feature, Tag, void> : public boost::accumulators::depends_on<> {
    // types
    typedef unspecified impl;
};
```

Struct template `feature_of<tag::external< Feature, Tag, AccumulatorSet >>`

`boost::accumulators::feature_of<tag::external< Feature, Tag, AccumulatorSet >>`

Synopsis

```
// In header: <boost/accumulators/framework/accumulators/external_accumulator.hpp>

template<typename Feature, typename Tag, typename AccumulatorSet>
struct feature_of<tag::external< Feature, Tag, AccumulatorSet >> : public boost::accumulators::feature_of< Feature > {
};
```

Header `<boost/accumulators/framework/accumulators/reference_accumulator.hpp>`

```
namespace boost {
    namespace accumulators {
        template<typename ValueType, typename Tag>
        struct feature_of<tag::reference< ValueType, Tag >>;
        namespace extract {
        }
        namespace impl {
            template<typename Referent, typename Tag> struct reference_accumulator_impl;
        }
        namespace tag {
        }
    }
}
```

Struct template `reference_accumulator_impl`

`boost::accumulators::impl::reference_accumulator_impl`

Synopsis

```
// In header: <boost/accumulators/framework/accumulators/reference_accumulator.hpp>

template<typename Referent, typename Tag>
struct reference_accumulator_impl :
    public boost::accumulators::accumulator_base
{
    // types
    typedef Referent & result_type;

    // construct/copy/destruct
    template<typename Args> reference_accumulator_impl(Args const &);

    // public member functions
    result_type result(dont_care) const;
};
```

Description

reference_accumulator_impl public construct/copy/destruct

```
1. template<typename Args> reference_accumulator_impl(Args const & args);
```

reference_accumulator_impl public member functions

```
1. result_type result(dont_care) const;
```

Struct template **feature_of<tag::reference< ValueType, Tag >>**

boost::accumulators::feature_of<tag::reference< ValueType, Tag >>

Synopsis

```
// In header: <boost/accumulators/framework/accumulators/reference_accumulator.hpp>

template<typename ValueType, typename Tag>
struct feature_of<tag::reference< ValueType, Tag >> :
    public boost::accumulators::feature_of< tag::reference_tag< Tag > >
{
};
```

Header <[boost/accumulators/framework/accumulators/value_accumulator.hpp](#)>

```
namespace boost {
  namespace accumulators {
    template<typename ValueType, typename Tag>
      struct feature_of<tag::value< ValueType, Tag >>;
    namespace extract {
    }
    namespace impl {
      template<typename ValueType, typename Tag> struct value_accumulator_impl;
    }
    namespace tag {
    }
  }
}
```

Struct template value_accumulator_impl

boost::accumulators::impl::value_accumulator_impl

Synopsis

```
// In header: <boost/accumulators/framework/accumulators/value_accumulator.hpp>

template<typename ValueType, typename Tag>
struct value_accumulator_impl : public boost::accumulators::accumulator_base {
  // types
  typedef ValueType result_type;

  // construct/copy/destruct
  template<typename Args> value_accumulator_impl(Args const &);

  // public member functions
  result_type result(dont_care) const;
};
```

Description**value_accumulator_impl public construct/copy/destruct**

1. `template<typename Args> value_accumulator_impl(Args const & args);`

value_accumulator_impl public member functions

1. `result_type result(dont_care) const;`

Struct template feature_of<tag::value< ValueType, Tag >>

boost::accumulators::feature_of<tag::value< ValueType, Tag >>

Synopsis

```
// In header: <boost/accumulators/framework/accumulators/value_accumulator.hpp>

template<typename ValueType, typename Tag>
struct feature_of<tag::value< ValueType, Tag >> :
    public boost::accumulators::feature_of< tag::value_tag< Tag > >
{
};
```

Header <[boost/accumulators/framework/depends_on.hpp](#)>

Header <[boost/accumulators/framework/extractor.hpp](#)>

```
BOOST_ACCUMULATORS_DEFINE_EXTRACTOR(Tag, Feature, ParamSeq)
```

Macro **BOOST_ACCUMULATORS_DEFINE_EXTRACTOR**

BOOST_ACCUMULATORS_DEFINE_EXTRACTOR

Synopsis

```
// In header: <boost/accumulators/framework/extractor.hpp>

BOOST_ACCUMULATORS_DEFINE_EXTRACTOR(Tag, Feature, ParamSeq)
```

Header <[boost/accumulators/framework/features.hpp](#)>

Header <[boost/accumulators/framework/parameters/accumulator.hpp](#)>

```
namespace boost {
    namespace accumulators {
        boost::parameter::keyword< tag::accumulator > const accumulator;
        namespace tag {
            struct accumulator;
        }
    }
}
```

Struct accumulator

boost::accumulators::tag::accumulator

Synopsis

```
// In header: <boost/accumulators/framework/parameters/accumulator.hpp>

struct accumulator {
};
```

Global accumulator

boost::accumulators::accumulator

Synopsis

```
// In header: <boost/accumulators/framework/parameters/accumulator.hpp>

boost::parameter::keyword< tag::accumulator > const accumulator;
```

Header <boost/accumulators/framework/parameters/sample.hpp>

```
namespace boost {
    namespace accumulators {
        boost::parameter::keyword< tag::sample > const sample;
        namespace tag {
            struct sample;
        }
    }
}
```

Struct sample

boost::accumulators::tag::sample

Synopsis

```
// In header: <boost/accumulators/framework/parameters/sample.hpp>

struct sample {
};
```

Global sample

boost::accumulators::sample

Synopsis

```
// In header: <boost/accumulators/framework/parameters/sample.hpp>

boost::parameter::keyword< tag::sample > const sample;
```

Header <boost/accumulators/framework/parameters/weight.hpp>

```
namespace boost {
    namespace accumulators {
        boost::parameter::keyword< tag::weight > const weight;
        namespace tag {
            struct weight;
        }
    }
}
```

Struct weight

boost::accumulators::tag::weight

Synopsis

```
// In header: <boost/accumulators/framework/parameters/weight.hpp>

struct weight {
};
```

Global weight

boost::accumulators::weight

Synopsis

```
// In header: <boost/accumulators/framework/parameters/weight.hpp>

boost::parameter::keyword< tag::weight > const weight;
```

Header <boost/accumulators/framework/parameters/weights.hpp>

```
namespace boost {
  namespace accumulators {
    boost::parameter::keyword< tag::weights > const weights;
    namespace tag {
      struct weights;
    }
  }
}
```

Struct weights

boost::accumulators::tag::weights

Synopsis

```
// In header: <boost/accumulators/framework/parameters/weights.hpp>

struct weights {
};
```

Global weights

boost::accumulators::weights

Synopsis

```
// In header: <boost/accumulators/framework/parameters/weights.hpp>

boost::parameter::keyword< tag::weights > const weights;
```

Statistics Library Reference

Header <boost/accumulators/statistics.hpp>

Includes all of the Statistical Accumulators Library

Header <boost/accumulators/statistics/count.hpp>

```
namespace boost {
  namespace accumulators {
    namespace extract {
      extractor< tag::count > const count;
    }
    namespace impl {
      struct count_impl;
    }
    namespace tag {
      struct count;
    }
  }
}
```

Global count

boost::accumulators::extract::count

Synopsis

```
// In header: <boost/accumulators/statistics/count.hpp>

extractor< tag::count > const count;
```

Struct count_impl

boost::accumulators::impl::count_impl

Synopsis

```
// In header: <boost/accumulators/statistics/count.hpp>

struct count_impl : public accumulator_base {
    // types
    typedef std::size_t result_type;

    // construct/copy/destruct
    count_impl(dont_care);

    // public member functions
    void operator()(dont_care);
    result_type result(dont_care) const;
};
```

Description

count_impl public construct/copy/destruct

1. `count_impl(dont_care);`

count_impl public member functions

1. `void operator()(dont_care);`

2. `result_type result(dont_care) const;`

Struct count

`boost::accumulators::tag::count`

Synopsis

```
// In header: <boost/accumulators/statistics/count.hpp>

struct count : public boost::accumulators::depends_on<> {
};
```


Header `<boost/accumulators/statistics/covariance.hpp>`

```
namespace boost {
  namespace accumulators {
    template<typename VariateType, typename VariateTag>
      struct feature_of<tag::covariance< VariateType, VariateTag >>;
    template<typename VariateType, typename VariateTag>
      struct as_weighted_feature<tag::covariance< VariateType, VariateTag >>;
    template<typename VariateType, typename VariateTag>
      struct feature_of<tag::weighted_covariance< VariateType, VariateTag >>;
    namespace extract {
      extractor< tag::abstract_covariance > const covariance;
    }
    namespace impl {
    }
    namespace tag {
      struct abstract_covariance;
    }
  }
  namespace numeric {
    namespace functional {
      template<typename Left, typename Right, typename EnableIf = void>
        struct outer_product_base;
      template<typename Left, typename Right,
        typename LeftTag = typename tag<Left>::type,
        typename RightTag = typename tag<Right>::type>
        struct outer_product;

      template<typename Left, typename Right>
        struct outer_product<Left, Right, std_vector_tag, std_vector_tag>;
    }
    namespace op {
      struct outer_product;
    }
  }
}
```

Global covariance

boost::accumulators::extract::covariance

Synopsis

```
// In header: <boost/accumulators/statistics/covariance.hpp>

extractor< tag::abstract_covariance > const covariance;
```

Struct abstract_covariance

boost::accumulators::tag::abstract_covariance

Synopsis

```
// In header: <boost/accumulators/statistics/covariance.hpp>

struct abstract_covariance : public boost::accumulators::depends_on<> {
};
```

Struct template `feature_of<tag::covariance< VariateType, VariateTag >>`

`boost::accumulators::feature_of<tag::covariance< VariateType, VariateTag >>`

Synopsis

```
// In header: <boost/accumulators/statistics/covariance.hpp>

template<typename VariateType, typename VariateTag>
struct feature_of<tag::covariance< VariateType, VariateTag >> :
    public boost::accumulators::feature_of< tag::abstract_covariance >
{
};
```

Struct template `as_weighted_feature<tag::covariance< VariateType, VariateTag >>`

`boost::accumulators::as_weighted_feature<tag::covariance< VariateType, VariateTag >>`

Synopsis

```
// In header: <boost/accumulators/statistics/covariance.hpp>

template<typename VariateType, typename VariateTag>
struct as_weighted_feature<tag::covariance< VariateType, VariateTag >> {
    // types
    typedef tag::weighted_covariance< VariateType, VariateTag > type;
};
```

Struct template `feature_of<tag::weighted_covariance< VariateType, VariateTag >>`

`boost::accumulators::feature_of<tag::weighted_covariance< VariateType, VariateTag >>`

Synopsis

```
// In header: <boost/accumulators/statistics/covariance.hpp>

template<typename VariateType, typename VariateTag>
struct feature_of<tag::weighted_covariance< VariateType, VariateTag >> : public boost::accumulators::feature_of< tag::covariance< VariateType, VariateTag > >
{
};
```

Struct template `outer_product_base`

`boost::numeric::functional::outer_product_base`

Synopsis

```
// In header: <boost/accumulators/statistics/covariance.hpp>

template<typename Left, typename Right, typename EnableIf = void>
struct outer_product_base : public functional::multiplies< Left, Right > {
};
```

Struct template outer_product

boost::numeric::functional::outer_product

Synopsis

```
// In header: <boost/accumulators/statistics/covariance.hpp>

template<typename Left, typename Right,
        typename LeftTag = typename tag<Left>::type,
        typename RightTag = typename tag<Right>::type>
struct outer_product :
    public boost::numeric::functional::outer_product_base< Left, Right, void >
{
};
```

Struct template outer_product<Left, Right, std_vector_tag, std_vector_tag>

boost::numeric::functional::outer_product<Left, Right, std_vector_tag, std_vector_tag>

Synopsis

```
// In header: <boost/accumulators/statistics/covariance.hpp>

template<typename Left, typename Right>
struct outer_product<Left, Right, std_vector_tag, std_vector_tag> : public std::binary_function<
Left, Right, ublas::matrix< functional::multiplies< Left::value_type, Right::value_type >::result_type > >
{
    // types
    typedef ublas::matrix< typename functional::multiplies< typename Left::value_type, typename
Right::value_type >::result_type > result_type;

    // public member functions
    result_type operator()(Left &, Right &) const;
};
```

Description

outer_product public member functions

1.

```
result_type operator()(Left & left, Right & right) const;
```

Struct outer_product

boost::numeric::op::outer_product

Synopsis

```
// In header: <boost/accumulators/statistics/covariance.hpp>

struct outer_product {
};
```

Header <boost/accumulators/statistics/density.hpp>

```
namespace boost {
  namespace accumulators {
    template<> struct as_weighted_feature<tag::density>;
    template<> struct feature_of<tag::weighted_density>;
    namespace extract {
      extractor< tag::density > const density;
    }
    namespace impl {
    }
    namespace tag {
      struct density;
    }
  }
}
```

Global density

boost::accumulators::extract::density

Synopsis

```
// In header: <boost/accumulators/statistics/density.hpp>

extractor< tag::density > const density;
```

Struct density

boost::accumulators::tag::density

Synopsis

```
// In header: <boost/accumulators/statistics/density.hpp>

struct density : public boost::accumulators::depends_on< count, min, max >,
                public density_cache_size,
                public density_num_bins
{
  // public data members
  static boost::parameter::keyword< density_cache_size > const cache_size;
  static boost::parameter::keyword< density_num_bins > const num_bins;
};
```

Description

density public public data members

```
1. static boost::parameter::keyword< density_cache_size > const cache_size;
```

tag::density::cache_size named parameter tag::density::num_bins named parameter

Struct as_weighted_feature<tag::density>

boost::accumulators::as_weighted_feature<tag::density>

Synopsis

```
// In header: <boost/accumulators/statistics/density.hpp>

struct as_weighted_feature<tag::density> {
    // types
    typedef tag::weighted_density type;
};
```

Struct feature_of<tag::weighted_density>

boost::accumulators::feature_of<tag::weighted_density>

Synopsis

```
// In header: <boost/accumulators/statistics/density.hpp>

struct feature_of<tag::weighted_density> : public boost::accumulators::feature_of< tag::density > {
};
```

Header <boost/accumulators/statistics/error_of.hpp>

```
namespace boost {
    namespace accumulators {
        template<typename Feature> struct as_feature<tag::error_of< Feature >>;
        template<typename Feature>
            struct as_weighted_feature<tag::error_of< Feature >>;
        namespace extract {
        }
        namespace impl {
        }
        namespace tag {
        }
    }
}
```

Struct template as_feature<tag::error_of< Feature >>

boost::accumulators::as_feature<tag::error_of< Feature >>

Synopsis

```
// In header: <boost/accumulators/statistics/error_of.hpp>

template<typename Feature>
struct as_feature<tag::error_of< Feature >> {
    // types
    typedef tag::error_of< typename as_feature< Feature >::type > type;
};
```

Struct template `as_weighted_feature<tag::error_of< Feature >>`

`boost::accumulators::as_weighted_feature<tag::error_of< Feature >>`

Synopsis

```
// In header: <boost/accumulators/statistics/error_of.hpp>

template<typename Feature>
struct as_weighted_feature<tag::error_of< Feature >> {
    // types
    typedef tag::error_of< typename as_weighted_feature< Feature >::type > type;
};
```

Header `<boost/accumulators/statistics/error_of_mean.hpp>`

Struct `error_of<mean>`

`boost::accumulators::tag::error_of<mean>`

Synopsis

```
// In header: <boost/accumulators/statistics/error_of_mean.hpp>

struct error_of<mean> :
    public boost::accumulators::depends_on< lazy_variance, count >
{
};
```

Struct `error_of<immediate_mean>`

`boost::accumulators::tag::error_of<immediate_mean>`

Synopsis

```
// In header: <boost/accumulators/statistics/error_of_mean.hpp>

struct error_of<immediate_mean> : public boost::accumulators::depends_on< variance, count > {
};
```

Header `<boost/accumulators/statistics/extended_p_square.hpp>`

```
namespace boost {
  namespace accumulators {
    template<> struct as_weighted_feature<tag::extended_p_square>;
    template<> struct feature_of<tag::weighted_extended_p_square>;
    namespace extract {
      extractor< tag::extended_p_square > const extended_p_square;
    }
    namespace impl {
    }
    namespace tag {
      struct extended_p_square;
    }
  }
}
```

Global `extended_p_square`

`boost::accumulators::extract::extended_p_square`

Synopsis

```
// In header: <boost/accumulators/statistics/extended_p_square.hpp>

extractor< tag::extended_p_square > const extended_p_square;
```

Struct `extended_p_square`

`boost::accumulators::tag::extended_p_square`

Synopsis

```
// In header: <boost/accumulators/statistics/extended_p_square.hpp>

struct extended_p_square : public boost::accumulators::depends_on< count >,
                          public extended_p_square_probabilities
{
  // types
  typedef accumulators::impl::extended_p_square_impl< mpl::_1 > impl;

  // public data members
  static boost::parameter::keyword< tag::probabilities > const probabilities; // tag::extended_p_square::probabilities named parameter
};
```

Struct `as_weighted_feature<tag::extended_p_square>`

`boost::accumulators::as_weighted_feature<tag::extended_p_square>`

Synopsis

```
// In header: <boost/accumulators/statistics/extended_p_square.hpp>

struct as_weighted_feature<tag::extended_p_square> {
    // types
    typedef tag::weighted_extended_p_square type;
};
```

Struct feature_of<tag::weighted_extended_p_square>

boost::accumulators::feature_of<tag::weighted_extended_p_square>

Synopsis

```
// In header: <boost/accumulators/statistics/extended_p_square.hpp>

struct feature_of<tag::weighted_extended_p_square> :
    public boost::accumulators::feature_of< tag::extended_p_square >
{
};
```


Header `<boost/accumulators/statistics/extended_p_square_quantile.hpp>`

```
namespace boost {
    namespace accumulators {
        template<> struct as_feature<tag::extended_p_square_quantile(linear)>;
        template<> struct as_feature<tag::extended_p_square_quantile(quadratic)>;
        template<>
            struct as_feature<tag::weighted_extended_p_square_quantile(linear)>;
        template<>
            struct as_feature<tag::weighted_extended_p_square_quantile(quadratic)>;
        template<> struct feature_of<tag::extended_p_square_quantile>;
        template<> struct feature_of<tag::extended_p_square_quantile_quadratic>;
        template<> struct as_weighted_feature<tag::extended_p_square_quantile>;
        template<> struct feature_of<tag::weighted_extended_p_square_quantile>;
        template<>
            struct as_weighted_feature<tag::extended_p_square_quantile_quadratic>;
        template<>
            struct feature_of<tag::weighted_extended_p_square_quantile_quadratic>;
        namespace extract {
            extractor< tag::extended_p_square_quantile > const extended_p_square_quantile;
            extractor< tag::extended_p_square_quantile_quadratic > const extended_p_square_quantile_quadra
            tic;
            extractor< tag::weighted_extended_p_square_quantile > const weighted_exten
            ded_p_square_quantile;
            extractor< tag::weighted_extended_p_square_quantile_quadratic > const weighted_exten
            ded_p_square_quantile_quadratic;
        }
        namespace impl {
        }
        namespace tag {
            struct extended_p_square_quantile;
            struct extended_p_square_quantile_quadratic;
            struct weighted_extended_p_square_quantile;
            struct weighted_extended_p_square_quantile_quadratic;
        }
    }
}
```

Global `extended_p_square_quantile`

`boost::accumulators::extract::extended_p_square_quantile`

Synopsis

```
// In header: <boost/accumulators/statistics/extended_p_square_quantile.hpp>

extractor< tag::extended_p_square_quantile > const extended_p_square_quantile;
```

Global `extended_p_square_quantile_quadratic`

`boost::accumulators::extract::extended_p_square_quantile_quadratic`

Synopsis

```
// In header: <boost/accumulators/statistics/extended_p_square_quantile.hpp>

extractor< tag::extended_p_square_quantile_quadratic > const extended_p_square_quantile_quadratic;
```

Global weighted_extended_p_square_quantile

boost::accumulators::extract::weighted_extended_p_square_quantile

Synopsis

```
// In header: <boost/accumulators/statistics/extended_p_square_quantile.hpp>

extractor< tag::weighted_extended_p_square_quantile > const weighted_extended_p_square_quantile;
```

Global weighted_extended_p_square_quantile_quadratic

boost::accumulators::extract::weighted_extended_p_square_quantile_quadratic

Synopsis

```
// In header: <boost/accumulators/statistics/extended_p_square_quantile.hpp>

extractor< tag::weighted_extended_p_square_quantile_quadratic > const weighted_extended_p_square_quantile_quadratic;
```

Struct extended_p_square_quantile

boost::accumulators::tag::extended_p_square_quantile

Synopsis

```
// In header: <boost/accumulators/statistics/extended_p_square_quantile.hpp>

struct extended_p_square_quantile :
    public boost::accumulators::depends_on< extended_p_square >
{
    // types
    typedef accumulators::impl::extended_p_square_quantile_impl< mpl::_1, unweighted, linear > impl;
};
```

Struct extended_p_square_quantile_quadratic

boost::accumulators::tag::extended_p_square_quantile_quadratic

Synopsis

```
// In header: <boost/accumulators/statistics/extended_p_square_quantile.hpp>

struct extended_p_square_quantile_quadratic :
    public boost::accumulators::depends_on< extended_p_square >
{
    // types
    typedef accumulators::impl::extended_p_square_quantile_impl< mpl::_1, unweighted, quadratic > impl;
};
```

Struct `weighted_extended_p_square_quantile`

`boost::accumulators::tag::weighted_extended_p_square_quantile`

Synopsis

```
// In header: <boost/accumulators/statistics/extended_p_square_quantile.hpp>

struct weighted_extended_p_square_quantile :
    public boost::accumulators::depends_on< weighted_extended_p_square >
{
    // types
    typedef accumulators::impl::extended_p_square_quantile_impl< mpl::_1, weighted, linear > impl;
};
```

Struct `weighted_extended_p_square_quantile_quadratic`

`boost::accumulators::tag::weighted_extended_p_square_quantile_quadratic`

Synopsis

```
// In header: <boost/accumulators/statistics/extended_p_square_quantile.hpp>

struct weighted_extended_p_square_quantile_quadratic :
    public boost::accumulators::depends_on< weighted_extended_p_square >
{
    // types
    typedef accumulators::impl::extended_p_square_quantile_impl< mpl::_1, weighted, quadratic > impl;
};
```

Struct `as_feature<tag::extended_p_square_quantile(linear)>`

`boost::accumulators::as_feature<tag::extended_p_square_quantile(linear)>`

Synopsis

```
// In header: <boost/accumulators/statistics/extended_p_square_quantile.hpp>

struct as_feature<tag::extended_p_square_quantile(linear)> {
    // types
    typedef tag::extended_p_square_quantile type;
};
```

Struct `as_feature<tag::extended_p_square_quantile(quadratic)>`

`boost::accumulators::as_feature<tag::extended_p_square_quantile(quadratic)>`

Synopsis

```
// In header: <boost/accumulators/statistics/extended_p_square_quantile.hpp>

struct as_feature<tag::extended_p_square_quantile(quadratic)> {
    // types
    typedef tag::extended_p_square_quantile_quadratic type;
};
```

Struct `as_feature<tag::weighted_extended_p_square_quantile(linear)>`

`boost::accumulators::as_feature<tag::weighted_extended_p_square_quantile(linear)>`

Synopsis

```
// In header: <boost/accumulators/statistics/extended_p_square_quantile.hpp>

struct as_feature<tag::weighted_extended_p_square_quantile(linear)> {
    // types
    typedef tag::weighted_extended_p_square_quantile type;
};
```

Struct `as_feature<tag::weighted_extended_p_square_quantile(quadratic)>`

`boost::accumulators::as_feature<tag::weighted_extended_p_square_quantile(quadratic)>`

Synopsis

```
// In header: <boost/accumulators/statistics/extended_p_square_quantile.hpp>

struct as_feature<tag::weighted_extended_p_square_quantile(quadratic)> {
    // types
    typedef tag::weighted_extended_p_square_quantile_quadratic type;
};
```

Struct `feature_of<tag::extended_p_square_quantile>`

`boost::accumulators::feature_of<tag::extended_p_square_quantile>`

Synopsis

```
// In header: <boost/accumulators/statistics/extended_p_square_quantile.hpp>

struct feature_of<tag::extended_p_square_quantile> : public boost::accumulators::feature_of<tag::quantile> {
};
```

Struct `feature_of<tag::extended_p_square_quantile_quadratic>``boost::accumulators::feature_of<tag::extended_p_square_quantile_quadratic>`**Synopsis**

```
// In header: <boost/accumulators/statistics/extended_p_square_quantile.hpp>

struct feature_of<tag::extended_p_square_quantile_quadratic> : public boost::accumulators::feature_of< tag::quantile > {
};
```

Struct `as_weighted_feature<tag::extended_p_square_quantile>``boost::accumulators::as_weighted_feature<tag::extended_p_square_quantile>`**Synopsis**

```
// In header: <boost/accumulators/statistics/extended_p_square_quantile.hpp>

struct as_weighted_feature<tag::extended_p_square_quantile> {
    // types
    typedef tag::weighted_extended_p_square_quantile type;
};
```

Struct `feature_of<tag::weighted_extended_p_square_quantile>``boost::accumulators::feature_of<tag::weighted_extended_p_square_quantile>`**Synopsis**

```
// In header: <boost/accumulators/statistics/extended_p_square_quantile.hpp>

struct feature_of<tag::weighted_extended_p_square_quantile> :
    public boost::accumulators::feature_of< tag::extended_p_square_quantile >
{
};
```

Struct `as_weighted_feature<tag::extended_p_square_quantile_quadratic>``boost::accumulators::as_weighted_feature<tag::extended_p_square_quantile_quadratic>`**Synopsis**

```
// In header: <boost/accumulators/statistics/extended_p_square_quantile.hpp>

struct as_weighted_feature<tag::extended_p_square_quantile_quadratic> {
    // types
    typedef tag::weighted_extended_p_square_quantile_quadratic type;
};
```

Struct `feature_of<tag::weighted_extended_p_square_quantile_quadratic>`

`boost::accumulators::feature_of<tag::weighted_extended_p_square_quantile_quadratic>`

Synopsis

```
// In header: <boost/accumulators/statistics/extended_p_square_quantile.hpp>

struct feature_of<tag::weighted_extended_p_square_quantile_quadratic> : public boost::accumulator
s::feature_of< tag::extended_p_square_quantile_quadratic >
{
};
```

Header `<boost/accumulators/statistics/kurtosis.hpp>`

```
namespace boost {
  namespace accumulators {
    template<> struct as_weighted_feature<tag::kurtosis>;
    template<> struct feature_of<tag::weighted_kurtosis>;
    namespace extract {
      extractor< tag::kurtosis > const kurtosis;
    }
    namespace impl {
    }
    namespace tag {
      struct kurtosis;
    }
  }
}
```

Global kurtosis

`boost::accumulators::extract::kurtosis`

Synopsis

```
// In header: <boost/accumulators/statistics/kurtosis.hpp>

extractor< tag::kurtosis > const kurtosis;
```

Struct kurtosis

`boost::accumulators::tag::kurtosis`

Synopsis

```
// In header: <boost/accumulators/statistics/kurtosis.hpp>

struct kurtosis : public boost::accumulators::depends_on< mean, moment< 2 >, moment< 3 >, mo
ment< 4 > >
{
};
```

Struct `as_weighted_feature<tag::kurtosis>`

`boost::accumulators::as_weighted_feature<tag::kurtosis>`

Synopsis

```
// In header: <boost/accumulators/statistics/kurtosis.hpp>

struct as_weighted_feature<tag::kurtosis> {
    // types
    typedef tag::weighted_kurtosis type;
};
```

Struct `feature_of<tag::weighted_kurtosis>`

`boost::accumulators::feature_of<tag::weighted_kurtosis>`

Synopsis

```
// In header: <boost/accumulators/statistics/kurtosis.hpp>

struct feature_of<tag::weighted_kurtosis> : public boost::accumulators::feature_of< tag::kurtosis,
is > {
};
```

Header `<boost/accumulators/statistics/max.hpp>`

```
namespace boost {
    namespace accumulators {
        namespace extract {
            extractor< tag::max > const max;
        }
        namespace impl {
        }
        namespace tag {
            struct max;
        }
    }
}
```

Global `max`

`boost::accumulators::extract::max`

Synopsis

```
// In header: <boost/accumulators/statistics/max.hpp>

extractor< tag::max > const max;
```

Struct max

boost::accumulators::tag::max

Synopsis

```
// In header: <boost/accumulators/statistics/max.hpp>

struct max : public boost::accumulators::depends_on<> {
};
```

Header <boost/accumulators/statistics/mean.hpp>

```
namespace boost {
namespace accumulators {
template<> struct as_feature<tag::mean(lazy)>;
template<> struct as_feature<tag::mean(immediate)>;
template<> struct as_feature<tag::mean_of_weights(lazy)>;
template<> struct as_feature<tag::mean_of_weights(immediate)>;
template<typename VariateType, typename VariateTag>
    struct as_feature<tag::mean_of_variates< VariateType, VariateTag >(lazy)>;
template<typename VariateType, typename VariateTag>
    struct as_feature<tag::mean_of_variates< VariateType, VariateTag >(immediate)>;
template<> struct feature_of<tag::immediate_mean>;
template<> struct feature_of<tag::immediate_mean_of_weights>;
template<typename VariateType, typename VariateTag>
    struct feature_of<tag::immediate_mean_of_variates< VariateType, VariateTag >>;
template<> struct as_weighted_feature<tag::mean>;
template<> struct feature_of<tag::weighted_mean>;
template<> struct as_weighted_feature<tag::immediate_mean>;
template<> struct feature_of<tag::immediate_weighted_mean>;
template<typename VariateType, typename VariateTag>
    struct as_weighted_feature<tag::mean_of_variates< VariateType, VariateTag >>;
template<typename VariateType, typename VariateTag>
    struct feature_of<tag::weighted_mean_of_variates< VariateType, VariateTag >>;
template<typename VariateType, typename VariateTag>
    struct as_weighted_feature<tag::immediate_mean_of_variates< VariateType, VariateTag >>;
template<typename VariateType, typename VariateTag>
    struct feature_of<tag::immediate_weighted_mean_of_variates< VariateType, VariateTag >>;
namespace extract {
    extractor< tag::mean > const mean;
    extractor< tag::mean_of_weights > const mean_of_weights;
}
namespace impl {
}
namespace tag {
    struct mean;
    struct immediate_mean;
    struct mean_of_weights;
    struct immediate_mean_of_weights;
}
}
```

Global mean

boost::accumulators::extract::mean

Synopsis

```
// In header: <boost/accumulators/statistics/mean.hpp>

extractor< tag::mean > const mean;
```

Global mean_of_weights

boost::accumulators::extract::mean_of_weights

Synopsis

```
// In header: <boost/accumulators/statistics/mean.hpp>

extractor< tag::mean_of_weights > const mean_of_weights;
```

Struct mean

boost::accumulators::tag::mean

Synopsis

```
// In header: <boost/accumulators/statistics/mean.hpp>

struct mean : public boost::accumulators::depends_on< count, sum > {
};
```

Struct immediate_mean

boost::accumulators::tag::immediate_mean

Synopsis

```
// In header: <boost/accumulators/statistics/mean.hpp>

struct immediate_mean : public boost::accumulators::depends_on< count > {
};
```

Struct mean_of_weights

boost::accumulators::tag::mean_of_weights

Synopsis

```
// In header: <boost/accumulators/statistics/mean.hpp>

struct mean_of_weights :
    public boost::accumulators::depends_on< count, sum_of_weights >
{
    // types
    typedef mpl::true_ is_weight_accumulator;
};
```

Struct immediate_mean_of_weights

boost::accumulators::tag::immediate_mean_of_weights

Synopsis

```
// In header: <boost/accumulators/statistics/mean.hpp>

struct immediate_mean_of_weights :
    public boost::accumulators::depends_on< count >
{
    // types
    typedef mpl::true_ is_weight_accumulator;
};
```

Struct as_feature<tag::mean(lazy)>

boost::accumulators::as_feature<tag::mean(lazy)>

Synopsis

```
// In header: <boost/accumulators/statistics/mean.hpp>

struct as_feature<tag::mean(lazy)> {
    // types
    typedef tag::mean type;
};
```

Struct as_feature<tag::mean(immediate)>

boost::accumulators::as_feature<tag::mean(immediate)>

Synopsis

```
// In header: <boost/accumulators/statistics/mean.hpp>

struct as_feature<tag::mean(immediate)> {
    // types
    typedef tag::immediate_mean type;
};
```

Struct `as_feature<tag::mean_of_weights(lazy)>`

`boost::accumulators::as_feature<tag::mean_of_weights(lazy)>`

Synopsis

```
// In header: <boost/accumulators/statistics/mean.hpp>

struct as_feature<tag::mean_of_weights(lazy)> {
    // types
    typedef tag::mean_of_weights type;
};
```

Struct `as_feature<tag::mean_of_weights(immediate)>`

`boost::accumulators::as_feature<tag::mean_of_weights(immediate)>`

Synopsis

```
// In header: <boost/accumulators/statistics/mean.hpp>

struct as_feature<tag::mean_of_weights(immediate)> {
    // types
    typedef tag::immediate_mean_of_weights type;
};
```

Struct template `as_feature<tag::mean_of_variates< VariateType, VariateTag >(lazy)>`

`boost::accumulators::as_feature<tag::mean_of_variates< VariateType, VariateTag >(lazy)>`

Synopsis

```
// In header: <boost/accumulators/statistics/mean.hpp>

template<typename VariateType, typename VariateTag>
struct as_feature<tag::mean_of_variates< VariateType, VariateTag >(lazy)> {
    // types
    typedef tag::mean_of_variates< VariateType, VariateTag > type;
};
```

Struct template as_feature<tag::mean_of_variates< VariateType, VariateTag >(immediate)>

boost::accumulators::as_feature<tag::mean_of_variates< VariateType, VariateTag >(immediate)>

Synopsis

```
// In header: <boost/accumulators/statistics/mean.hpp>

template<typename VariateType, typename VariateTag>
struct as_feature<tag::mean_of_variates< VariateType, VariateTag >(immediate)> {
    // types
    typedef tag::immediate_mean_of_variates< VariateType, VariateTag > type;
};
```

Struct feature_of<tag::immediate_mean>

boost::accumulators::feature_of<tag::immediate_mean>

Synopsis

```
// In header: <boost/accumulators/statistics/mean.hpp>

struct feature_of<tag::immediate_mean> : public boost::accumulators::feature_of< tag::mean > {
};
```

Struct feature_of<tag::immediate_mean_of_weights>

boost::accumulators::feature_of<tag::immediate_mean_of_weights>

Synopsis

```
// In header: <boost/accumulators/statistics/mean.hpp>

struct feature_of<tag::immediate_mean_of_weights> :
    public boost::accumulators::feature_of< tag::mean_of_weights >
{
};
```

Struct template feature_of<tag::immediate_mean_of_variates< VariateType, VariateTag >>

boost::accumulators::feature_of<tag::immediate_mean_of_variates< VariateType, VariateTag >>

Synopsis

```
// In header: <boost/accumulators/statistics/mean.hpp>

template<typename VariateType, typename VariateTag>
struct feature_of<tag::immediate_mean_of_variates< VariateType, VariateTag >> : public boost::ac-
cumulators::feature_of< tag::mean_of_variates< VariateType, VariateTag > >
{
};
```

Struct `as_weighted_feature<tag::mean>``boost::accumulators::as_weighted_feature<tag::mean>`**Synopsis**

```
// In header: <boost/accumulators/statistics/mean.hpp>

struct as_weighted_feature<tag::mean> {
    // types
    typedef tag::weighted_mean type;
};
```

Struct `feature_of<tag::weighted_mean>``boost::accumulators::feature_of<tag::weighted_mean>`**Synopsis**

```
// In header: <boost/accumulators/statistics/mean.hpp>

struct feature_of<tag::weighted_mean> : public boost::accumulators::feature_of< tag::mean > {
};
```

Struct `as_weighted_feature<tag::immediate_mean>``boost::accumulators::as_weighted_feature<tag::immediate_mean>`**Synopsis**

```
// In header: <boost/accumulators/statistics/mean.hpp>

struct as_weighted_feature<tag::immediate_mean> {
    // types
    typedef tag::immediate_weighted_mean type;
};
```

Struct `feature_of<tag::immediate_weighted_mean>``boost::accumulators::feature_of<tag::immediate_weighted_mean>`**Synopsis**

```
// In header: <boost/accumulators/statistics/mean.hpp>

struct feature_of<tag::immediate_weighted_mean> :
    public boost::accumulators::feature_of< tag::immediate_mean >
{
};
```

Struct template `as_weighted_feature<tag::mean_of_variates< VariateType, VariateTag >>`

`boost::accumulators::as_weighted_feature<tag::mean_of_variates< VariateType, VariateTag >>`

Synopsis

```
// In header: <boost/accumulators/statistics/mean.hpp>

template<typename VariateType, typename VariateTag>
struct as_weighted_feature<tag::mean_of_variates< VariateType, VariateTag >> {
    // types
    typedef tag::weighted_mean_of_variates< VariateType, VariateTag > type;
};
```

Struct template `feature_of<tag::weighted_mean_of_variates< VariateType, VariateTag >>`

`boost::accumulators::feature_of<tag::weighted_mean_of_variates< VariateType, VariateTag >>`

Synopsis

```
// In header: <boost/accumulators/statistics/mean.hpp>

template<typename VariateType, typename VariateTag>
struct feature_of<tag::weighted_mean_of_variates< VariateType, VariateTag >> : public boost::ac-
cumulators::feature_of< tag::mean_of_variates< VariateType, VariateTag > >
{
};
```

Struct template `as_weighted_feature<tag::immediate_mean_of_variates< VariateType, VariateTag >>`

`boost::accumulators::as_weighted_feature<tag::immediate_mean_of_variates< VariateType, VariateTag >>`

Synopsis

```
// In header: <boost/accumulators/statistics/mean.hpp>

template<typename VariateType, typename VariateTag>
struct as_weighted_feature<tag::immediate_mean_of_variates< VariateType, VariateTag >> {
    // types
    typedef tag::immediate_weighted_mean_of_variates< VariateType, VariateTag > type;
};
```

Struct template `feature_of<tag::immediate_weighted_mean_of_variates< VariateType, VariateTag >>`

`boost::accumulators::feature_of<tag::immediate_weighted_mean_of_variates< VariateType, VariateTag >>`

Synopsis

```
// In header: <boost/accumulators/statistics/mean.hpp>

template<typename VariateType, typename VariateTag>
struct feature_of<tag::immediate_weighted_mean_of_variates< VariateType, VariateTag >> : public
    boost::accumulators::feature_of< tag::immediate_mean_of_variates< VariateType, VariateTag >
    > >
{
};
```

Header <boost/accumulators/statistics/median.hpp>

```
namespace boost {
    namespace accumulators {
        template<> struct as_feature<tag::median(with_p_square_quantile)>;
        template<> struct as_feature<tag::median(with_density)>;
        template<>
            struct as_feature<tag::median(with_p_square_cumulative_distribution)>;
        template<> struct feature_of<tag::with_density_median>;
        template<>
            struct feature_of<tag::with_p_square_cumulative_distribution_median>;
        template<> struct as_weighted_feature<tag::median>;
        template<> struct feature_of<tag::weighted_median>;
        template<> struct as_weighted_feature<tag::with_density_median>;
        template<> struct feature_of<tag::with_density_weighted_median>;
        template<>
            struct as_weighted_feature<tag::with_p_square_cumulative_distribution_median>;
        template<>
            struct feature_of<tag::with_p_square_cumulative_distribution_weighted_median>;
        namespace extract {
            extractor< tag::median > const median;
            extractor< tag::with_density_median > const with_density_median;
            extractor< tag::with_p_square_cumulative_distribution_median > const with_p_square_cumulative_distribution_median;
        }
        namespace impl {
        }
        namespace tag {
            struct median;
            struct with_density_median;
            struct with_p_square_cumulative_distribution_median;
        }
    }
}
```

Global median

boost::accumulators::extract::median

Synopsis

```
// In header: <boost/accumulators/statistics/median.hpp>

extractor< tag::median > const median;
```

Global with_density_median

boost::accumulators::extract::with_density_median

Synopsis

```
// In header: <boost/accumulators/statistics/median.hpp>

extractor< tag::with_density_median > const with_density_median;
```

Global with_p_square_cumulative_distribution_median

boost::accumulators::extract::with_p_square_cumulative_distribution_median

Synopsis

```
// In header: <boost/accumulators/statistics/median.hpp>

extractor< tag::with_p_square_cumulative_distribution_median > const with_p_square_cumulative_distribution_median;
```

Struct median

boost::accumulators::tag::median

Synopsis

```
// In header: <boost/accumulators/statistics/median.hpp>

struct median :
    public boost::accumulators::depends_on< p_square_quantile_for_median >
{
};
```

Struct with_density_median

boost::accumulators::tag::with_density_median

Synopsis

```
// In header: <boost/accumulators/statistics/median.hpp>

struct with_density_median :
    public boost::accumulators::depends_on< count, density >
{
};
```

Struct with_p_square_cumulative_distribution_median

boost::accumulators::tag::with_p_square_cumulative_distribution_median

Synopsis

```
// In header: <boost/accumulators/statistics/median.hpp>

struct with_p_square_cumulative_distribution_median :
    public boost::accumulators::depends_on< p_square_cumulative_distribution >
{
};
```

Struct `as_feature<tag::median(with_p_square_quantile)>`

`boost::accumulators::as_feature<tag::median(with_p_square_quantile)>`

Synopsis

```
// In header: <boost/accumulators/statistics/median.hpp>

struct as_feature<tag::median(with_p_square_quantile)> {
    // types
    typedef tag::median type;
};
```

Struct `as_feature<tag::median(with_density)>`

`boost::accumulators::as_feature<tag::median(with_density)>`

Synopsis

```
// In header: <boost/accumulators/statistics/median.hpp>

struct as_feature<tag::median(with_density)> {
    // types
    typedef tag::with_density_median type;
};
```

Struct `as_feature<tag::median(with_p_square_cumulative_distribution)>`

`boost::accumulators::as_feature<tag::median(with_p_square_cumulative_distribution)>`

Synopsis

```
// In header: <boost/accumulators/statistics/median.hpp>

struct as_feature<tag::median(with_p_square_cumulative_distribution)> {
    // types
    typedef tag::with_p_square_cumulative_distribution_median type;
};
```

Struct feature_of<tag::with_density_median>

boost::accumulators::feature_of<tag::with_density_median>

Synopsis

```
// In header: <boost/accumulators/statistics/median.hpp>

struct feature_of<tag::with_density_median> : public boost::accumulators::feature_of< tag::medi-
an > {
};
```

Struct feature_of<tag::with_p_square_cumulative_distribution_median>

boost::accumulators::feature_of<tag::with_p_square_cumulative_distribution_median>

Synopsis

```
// In header: <boost/accumulators/statistics/median.hpp>

struct feature_of<tag::with_p_square_cumulative_distribution_median> : public boost::accumulat-
ors::feature_of< tag::median > {
};
```

Struct as_weighted_feature<tag::median>

boost::accumulators::as_weighted_feature<tag::median>

Synopsis

```
// In header: <boost/accumulators/statistics/median.hpp>

struct as_weighted_feature<tag::median> {
    // types
    typedef tag::weighted_median type;
};
```

Struct feature_of<tag::weighted_median>

boost::accumulators::feature_of<tag::weighted_median>

Synopsis

```
// In header: <boost/accumulators/statistics/median.hpp>

struct feature_of<tag::weighted_median> : public boost::accumulators::feature_of< tag::median > {
};
```

Struct `as_weighted_feature<tag::with_density_median>``boost::accumulators::as_weighted_feature<tag::with_density_median>`**Synopsis**

```
// In header: <boost/accumulators/statistics/median.hpp>

struct as_weighted_feature<tag::with_density_median> {
    // types
    typedef tag::with_density_weighted_median type;
};
```

Struct `feature_of<tag::with_density_weighted_median>``boost::accumulators::feature_of<tag::with_density_weighted_median>`**Synopsis**

```
// In header: <boost/accumulators/statistics/median.hpp>

struct feature_of<tag::with_density_weighted_median> :
    public boost::accumulators::feature_of< tag::with_density_median >
{
};
```

Struct `as_weighted_feature<tag::with_p_square_cumulative_distribution_median>``boost::accumulators::as_weighted_feature<tag::with_p_square_cumulative_distribution_median>`**Synopsis**

```
// In header: <boost/accumulators/statistics/median.hpp>

struct as_weighted_feature<tag::with_p_square_cumulative_distribution_median> {
    // types
    typedef tag::with_p_square_cumulative_distribution_weighted_median type;
};
```

Struct `feature_of<tag::with_p_square_cumulative_distribution_weighted_median>``boost::accumulators::feature_of<tag::with_p_square_cumulative_distribution_weighted_median>`

Synopsis

```
// In header: <boost/accumulators/statistics/median.hpp>

struct feature_of<tag::with_p_square_cumulative_distribution_weighted_median> : public boost::ac-
cumulators::feature_of< tag::with_p_square_cumulative_distribution_median >
{
};
```

Header **<boost/accumulators/statistics/min.hpp>**

```
namespace boost {
  namespace accumulators {
    namespace extract {
      extractor< tag::min > const min;
    }
    namespace impl {
    }
    namespace tag {
      struct min;
    }
  }
}
```

Global min

boost::accumulators::extract::min

Synopsis

```
// In header: <boost/accumulators/statistics/min.hpp>

extractor< tag::min > const min;
```

Struct min

boost::accumulators::tag::min

Synopsis

```
// In header: <boost/accumulators/statistics/min.hpp>

struct min : public boost::accumulators::depends_on<> {
};
```

Header `<boost/accumulators/statistics/moment.hpp>`

```
namespace boost {
  namespace accumulators {
    template<int N> struct as_weighted_feature<tag::moment< N >>;
    template<int N> struct feature_of<tag::weighted_moment< N >>;
    namespace extract {
    }
    namespace impl {
    }
    namespace tag {
    }
  }
  namespace numeric {
  }
}
```

Struct template `as_weighted_feature<tag::moment< N >>`

`boost::accumulators::as_weighted_feature<tag::moment< N >>`

Synopsis

```
// In header: <boost/accumulators/statistics/moment.hpp>

template<int N>
struct as_weighted_feature<tag::moment< N >> {
  // types
  typedef tag::weighted_moment< N > type;
};
```

Struct template `feature_of<tag::weighted_moment< N >>`

`boost::accumulators::feature_of<tag::weighted_moment< N >>`

Synopsis

```
// In header: <boost/accumulators/statistics/moment.hpp>

template<int N>
struct feature_of<tag::weighted_moment< N >> :
  public boost::accumulators::feature_of< tag::moment< N > >
{
};
```

Header `<boost/accumulators/statistics/p_square_cumul_dist.hpp>`

```
namespace boost {
  namespace accumulators {
    template<>
    struct as_weighted_feature<tag::p_square_cumulative_distribution>;
    template<>
    struct feature_of<tag::weighted_p_square_cumulative_distribution>;
    namespace extract {
      extractor< tag::p_square_cumulative_distribution > const p_square_cumulative_distribution;
    }
    namespace impl {
    }
    namespace tag {
      struct p_square_cumulative_distribution;
    }
  }
}
```

Global `p_square_cumulative_distribution`

`boost::accumulators::extract::p_square_cumulative_distribution`

Synopsis

```
// In header: <boost/accumulators/statistics/p_square_cumul_dist.hpp>

extractor< tag::p_square_cumulative_distribution > const p_square_cumulative_distribution;
```

Struct `p_square_cumulative_distribution`

`boost::accumulators::tag::p_square_cumulative_distribution`

Synopsis

```
// In header: <boost/accumulators/statistics/p_square_cumul_dist.hpp>

struct p_square_cumulative_distribution : public boost::accumulators::depends_on< count >,
                                         public p_square_cumulative_distribution_num_cells
{
};
```

Struct `as_weighted_feature<tag::p_square_cumulative_distribution>`

`boost::accumulators::as_weighted_feature<tag::p_square_cumulative_distribution>`

Synopsis

```
// In header: <boost/accumulators/statistics/p_square_cumul_dist.hpp>

struct as_weighted_feature<tag::p_square_cumulative_distribution> {
    // types
    typedef tag::weighted_p_square_cumulative_distribution type;
};
```

Struct `feature_of<tag::weighted_p_square_cumulative_distribution>`

`boost::accumulators::feature_of<tag::weighted_p_square_cumulative_distribution>`

Synopsis

```
// In header: <boost/accumulators/statistics/p_square_cumul_dist.hpp>

struct feature_of<tag::weighted_p_square_cumulative_distribution> : public boost::accumulators::feature_of< tag::p_square_cumulative_distribution >
{
};
```

Header `<boost/accumulators/statistics/p_square_quantile.hpp>`

```
namespace boost {
    namespace accumulators {
        template<> struct as_weighted_feature<tag::p_square_quantile>;
        template<> struct feature_of<tag::weighted_p_square_quantile>;
        namespace extract {
            extractor< tag::p_square_quantile > const p_square_quantile;
            extractor< tag::p_square_quantile_for_median > const p_square_quantile_for_median;
        }
        namespace impl {
        }
        namespace tag {
            struct p_square_quantile;
            struct p_square_quantile_for_median;
        }
    }
}
```

Global `p_square_quantile`

`boost::accumulators::extract::p_square_quantile`

Synopsis

```
// In header: <boost/accumulators/statistics/p_square_quantile.hpp>

extractor< tag::p_square_quantile > const p_square_quantile;
```

Global p_square_quantile_for_median

boost::accumulators::extract::p_square_quantile_for_median

Synopsis

```
// In header: <boost/accumulators/statistics/p_square_quantile.hpp>

extractor< tag::p_square_quantile_for_median > const p_square_quantile_for_median;
```

Struct p_square_quantile

boost::accumulators::tag::p_square_quantile

Synopsis

```
// In header: <boost/accumulators/statistics/p_square_quantile.hpp>

struct p_square_quantile : public boost::accumulators::depends_on< count > {
};
```

Struct p_square_quantile_for_median

boost::accumulators::tag::p_square_quantile_for_median

Synopsis

```
// In header: <boost/accumulators/statistics/p_square_quantile.hpp>

struct p_square_quantile_for_median :
    public boost::accumulators::depends_on< count >
{
};
```

Struct as_weighted_feature<tag::p_square_quantile>

boost::accumulators::as_weighted_feature<tag::p_square_quantile>

Synopsis

```
// In header: <boost/accumulators/statistics/p_square_quantile.hpp>

struct as_weighted_feature<tag::p_square_quantile> {
    // types
    typedef tag::weighted_p_square_quantile type;
};
```

Struct feature_of<tag::weighted_p_square_quantile>

boost::accumulators::feature_of<tag::weighted_p_square_quantile>

Synopsis

```
// In header: <boost/accumulators/statistics/p_square_quantile.hpp>

struct feature_of<tag::weighted_p_square_quantile> :
    public boost::accumulators::feature_of< tag::p_square_quantile >
{
};
```

Header **<boost/accumulators/statistics/peaks_over_threshold.hpp>**

```
namespace boost {
    namespace accumulators {
        template<typename LeftRight>
            struct as_feature<tag::peaks_over_threshold< LeftRight >(with_threshold_value)>;
        template<typename LeftRight>
            struct as_feature<tag::peaks_over_threshold< LeftRight >(with_threshold_probability)>;
        template<typename LeftRight>
            struct feature_of<tag::peaks_over_threshold< LeftRight >>;
        template<typename LeftRight>
            struct feature_of<tag::peaks_over_threshold_prob< LeftRight >>;
        template<typename LeftRight>
            struct as_weighted_feature<tag::peaks_over_threshold< LeftRight >>;
        template<typename LeftRight>
            struct feature_of<tag::weighted_peaks_over_threshold< LeftRight >>;
        template<typename LeftRight>
            struct as_weighted_feature<tag::peaks_over_threshold_prob< LeftRight >>;
        template<typename LeftRight>
            struct feature_of<tag::weighted_peaks_over_threshold_prob< LeftRight >>;
        namespace extract {
            extractor< tag::abstract_peaks_over_threshold > const peaks_over_threshold;
        }
        namespace impl {
            template<typename Sample, typename LeftRight>
                struct peaks_over_threshold_impl;
        }
        namespace tag {
            struct abstract_peaks_over_threshold;
        }
    }
}
```

Global peaks_over_threshold

boost::accumulators::extract::peaks_over_threshold

Synopsis

```
// In header: <boost/accumulators/statistics/peaks_over_threshold.hpp>

extractor< tag::abstract_peaks_over_threshold > const peaks_over_threshold;
```

Struct template peaks_over_threshold_impl

boost::accumulators::impl::peaks_over_threshold_impl — Peaks over Threshold Method for Quantile and Tail Mean Estimation.

Synopsis

```
// In header: <boost/accumulators/statistics/peaks_over_threshold.hpp>

template<typename Sample, typename LeftRight>
struct peaks_over_threshold_impl : public accumulator_base {
    // types
    typedef numeric::functional::average< Sample, std::size_t >::result_type float_type;
    typedef boost::tuple< float_type, float_type, float_type > result_type;
    typedef mpl::int_< is_same< LeftRight, left >::value?-1:1 > sign;

    // construct/copy/destruct
    template<typename Args> peaks_over_threshold_impl(Args const &);

    // public member functions
    template<typename Args> void operator()(Args const &);
    template<typename Args> result_type result(Args const &) const;
};
```

Description

According to the theorem of Pickands-Balkema-de Haan, the distribution function $F_u(x)$ of the excesses x over some sufficiently high threshold u of a distribution function $F(x)$ may be approximated by a generalized Pareto distribution

Equation 1.

$$G_{\xi,\beta}(x) = \begin{cases} \beta^{-1} \left(1 + \frac{\xi x}{\beta}\right)^{-1/\xi-1} & \text{if } \xi \neq 0 \\ \beta^{-1} \exp\left(-\frac{x}{\beta}\right) & \text{if } \xi = 0, \end{cases}$$

with suitable parameters ξ and β that can be estimated, e.g., with the method of moments, cf. Hosking and Wallis (1987),

Equation 2.

$$\begin{aligned} \hat{\xi} &= \frac{1}{2} \left[1 - \frac{(\hat{\mu}-u)^2}{\hat{\sigma}^2} \right] \\ \hat{\beta} &= \frac{\hat{\mu}-u}{2} \left[\frac{(\hat{\mu}-u)^2}{\hat{\sigma}^2} + 1 \right], \end{aligned}$$

$\hat{\mu}$ and $\hat{\sigma}^2$ being the empirical mean and variance of the samples over the threshold u . Equivalently, the distribution function $F_u(x-u)$ of the exceedances $x-u$ can be approximated by $G_{\xi,\beta}(x-u) = G_{\xi,\beta,u}(x)$. Since for $x \geq u$ the distribution function $F(x)$ can be written as

Equation 3.

$$F(x) = [1 - \mathbb{P}(X \leq u)]F_u(x-u) + \mathbb{P}(X \leq u)$$

and the probability $\mathbb{P}(X \leq u)$ can be approximated by the empirical distribution function $F_n(u)$ evaluated at u , an estimator of $F(x)$ is given by

Equation 4.

$$\hat{F}(x) = [1 - F_n(u)]G_{\xi,\beta,u}(x) + F_n(u).$$

It can be shown that $\hat{F}(x)$ is a generalized Pareto distribution $G_{\xi,\beta,u}(x)$ with $\bar{\beta} = \beta[1 - F_n(u)]^\xi$ and $\bar{u} = u - \bar{\beta} \{[1 - F_n(u)]^{-\xi} - 1\} / \xi$. By inverting $\hat{F}(x)$, one obtains an estimator for the α -quantile,

Equation 5.

$$\hat{q}_\alpha = \hat{a} + \frac{\hat{\beta}}{\xi} [(1 - \alpha)^{-\xi} - 1],$$

and similarly an estimator for the (coherent) tail mean,

Equation 6.

$$\widehat{CTM}_\alpha = \hat{q}_\alpha - \frac{\hat{\beta}}{\xi - 1} (1 - \alpha)^{-\xi},$$

cf. McNeil and Frey (2000).

Note that in case extreme values of the left tail are fitted, the distribution is mirrored with respect to the y axis such that the left tail can be treated as a right tail. The computed fit parameters thus define the Pareto distribution that fits the mirrored left tail. When quantities like a quantile or a tail mean are computed using the fit parameters obtained from the mirrored data, the result is mirrored back, yielding the correct result.

For further details, see

J. R. M. Hosking and J. R. Wallis, Parameter and quantile estimation for the generalized Pareto distribution, *Technometrics*, Volume 29, 1987, p. 339-349

A. J. McNeil and R. Frey, Estimation of Tail-Related Risk Measures for Heteroscedastic Financial Time Series: an Extreme Value Approach, *Journal of Empirical Finance*, Volume 7, 2000, p. 271-300

peaks_over_threshold_impl public construct/copy/destruct

```
1. template<typename Args> peaks_over_threshold_impl(Args const & args);
```

peaks_over_threshold_impl public member functions

```
1. template<typename Args> void operator()(Args const & args);
```

```
2. template<typename Args> result_type result(Args const & args) const;
```

Struct abstract_peaks_over_threshold

boost::accumulators::tag::abstract_peaks_over_threshold

Synopsis

```
// In header: <boost/accumulators/statistics/peaks_over_threshold.hpp>

struct abstract_peaks_over_threshold :
    public boost::accumulators::depends_on<>
{
};
```

Struct template `as_feature<tag::peaks_over_threshold< LeftRight >(with_threshold_value)>`

`boost::accumulators::as_feature<tag::peaks_over_threshold< LeftRight >(with_threshold_value)>`

Synopsis

```
// In header: <boost/accumulators/statistics/peaks_over_threshold.hpp>

template<typename LeftRight>
struct as_feature<tag::peaks_over_threshold< LeftRight >(with_threshold_value)> {
    // types
    typedef tag::peaks_over_threshold< LeftRight > type;
};
```

Struct template `as_feature<tag::peaks_over_threshold< LeftRight >(with_threshold_probability)>`

`boost::accumulators::as_feature<tag::peaks_over_threshold< LeftRight >(with_threshold_probability)>`

Synopsis

```
// In header: <boost/accumulators/statistics/peaks_over_threshold.hpp>

template<typename LeftRight>
struct as_feature<tag::peaks_over_threshold< LeftRight >(with_threshold_probability)> {
    // types
    typedef tag::peaks_over_threshold_prob< LeftRight > type;
};
```

Struct template `feature_of<tag::peaks_over_threshold< LeftRight >>`

`boost::accumulators::feature_of<tag::peaks_over_threshold< LeftRight >>`

Synopsis

```
// In header: <boost/accumulators/statistics/peaks_over_threshold.hpp>

template<typename LeftRight>
struct feature_of<tag::peaks_over_threshold< LeftRight >> : public boost::accumulators::feature_of< tag::abstract_peaks_over_threshold >
{
};
```

Struct template `feature_of<tag::peaks_over_threshold_prob< LeftRight >>`

`boost::accumulators::feature_of<tag::peaks_over_threshold_prob< LeftRight >>`

Synopsis

```
// In header: <boost/accumulators/statistics/peaks_over_threshold.hpp>

template<typename LeftRight>
struct feature_of<tag::peaks_over_threshold_prob< LeftRight >> : public boost::accumulators::feature_of< tag::abstract_peaks_over_threshold >
{
};
```

Struct template as_weighted_feature<tag::peaks_over_threshold< LeftRight >>

boost::accumulators::as_weighted_feature<tag::peaks_over_threshold< LeftRight >>

Synopsis

```
// In header: <boost/accumulators/statistics/peaks_over_threshold.hpp>

template<typename LeftRight>
struct as_weighted_feature<tag::peaks_over_threshold< LeftRight >> {
    // types
    typedef tag::weighted_peaks_over_threshold< LeftRight > type;
};
```

Struct template feature_of<tag::weighted_peaks_over_threshold< LeftRight >>

boost::accumulators::feature_of<tag::weighted_peaks_over_threshold< LeftRight >>

Synopsis

```
// In header: <boost/accumulators/statistics/peaks_over_threshold.hpp>

template<typename LeftRight>
struct feature_of<tag::weighted_peaks_over_threshold< LeftRight >> : public boost::accumulators::feature_of< tag::peaks_over_threshold< LeftRight > >
{
};
```

Struct template as_weighted_feature<tag::peaks_over_threshold_prob< LeftRight >>

boost::accumulators::as_weighted_feature<tag::peaks_over_threshold_prob< LeftRight >>

Synopsis

```
// In header: <boost/accumulators/statistics/peaks_over_threshold.hpp>

template<typename LeftRight>
struct as_weighted_feature<tag::peaks_over_threshold_prob< LeftRight >> {
    // types
    typedef tag::weighted_peaks_over_threshold_prob< LeftRight > type;
};
```

Struct template feature_of<tag::weighted_peaks_over_threshold_prob< LeftRight >>

boost::accumulators::feature_of<tag::weighted_peaks_over_threshold_prob< LeftRight >>

Synopsis

```
// In header: <boost/accumulators/statistics/peaks_over_threshold.hpp>

template<typename LeftRight>
struct feature_of<tag::weighted_peaks_over_threshold_prob< LeftRight >> : public boost::accumulators::feature_of< tag::peaks_over_threshold_prob< LeftRight > >
{
};
```

Header <boost/accumulators/statistics/pot_quantile.hpp>

```
namespace boost {
  namespace accumulators {
    template<typename LeftRight>
      struct as_feature<tag::pot_quantile< LeftRight >(with_threshold_value)>;
    template<typename LeftRight>
      struct as_feature<tag::pot_quantile< LeftRight >(with_threshold_probability)>;
    template<typename LeftRight>
      struct as_feature<tag::weighted_pot_quantile< LeftRight >(with_threshold_value)>;
    template<typename LeftRight>
      struct as_feature<tag::weighted_pot_quantile< LeftRight >(with_threshold_probability)>;
    template<typename LeftRight>
      struct feature_of<tag::pot_quantile< LeftRight >>;
    template<typename LeftRight>
      struct feature_of<tag::pot_quantile_prob< LeftRight >>;
    template<typename LeftRight>
      struct as_weighted_feature<tag::pot_quantile< LeftRight >>;
    template<typename LeftRight>
      struct feature_of<tag::weighted_pot_quantile< LeftRight >>;
    template<typename LeftRight>
      struct as_weighted_feature<tag::pot_quantile_prob< LeftRight >>;
    template<typename LeftRight>
      struct feature_of<tag::weighted_pot_quantile_prob< LeftRight >>;
    namespace impl {
    }
    namespace tag {
    }
  }
}
```

Struct template as_feature<tag::pot_quantile< LeftRight >(with_threshold_value)>

boost::accumulators::as_feature<tag::pot_quantile< LeftRight >(with_threshold_value)>

Synopsis

```
// In header: <boost/accumulators/statistics/pot_quantile.hpp>

template<typename LeftRight>
struct as_feature<tag::pot_quantile< LeftRight >(with_threshold_value)> {
  // types
  typedef tag::pot_quantile< LeftRight > type;
};
```

Struct template as_feature<tag::pot_quantile< LeftRight >(with_threshold_probability)>

boost::accumulators::as_feature<tag::pot_quantile< LeftRight >(with_threshold_probability)>

Synopsis

```
// In header: <boost/accumulators/statistics/pot_quantile.hpp>

template<typename LeftRight>
struct as_feature<tag::pot_quantile< LeftRight >(with_threshold_probability)> {
    // types
    typedef tag::pot_quantile_prob< LeftRight > type;
};
```

Struct template as_feature<tag::weighted_pot_quantile< LeftRight >(with_threshold_value)>

boost::accumulators::as_feature<tag::weighted_pot_quantile< LeftRight >(with_threshold_value)>

Synopsis

```
// In header: <boost/accumulators/statistics/pot_quantile.hpp>

template<typename LeftRight>
struct as_feature<tag::weighted_pot_quantile< LeftRight >(with_threshold_value)> {
    // types
    typedef tag::weighted_pot_quantile< LeftRight > type;
};
```

Struct template as_feature<tag::weighted_pot_quantile< LeftRight >(with_threshold_probability)>

boost::accumulators::as_feature<tag::weighted_pot_quantile< LeftRight >(with_threshold_probability)>

Synopsis

```
// In header: <boost/accumulators/statistics/pot_quantile.hpp>

template<typename LeftRight>
struct as_feature<tag::weighted_pot_quantile< LeftRight >(with_threshold_probability)> {
    // types
    typedef tag::weighted_pot_quantile_prob< LeftRight > type;
};
```

Struct template feature_of<tag::pot_quantile< LeftRight >>

boost::accumulators::feature_of<tag::pot_quantile< LeftRight >>

Synopsis

```
// In header: <boost/accumulators/statistics/pot_quantile.hpp>

template<typename LeftRight>
struct feature_of<tag::pot_quantile< LeftRight >> : public boost::accumulators::fea
ture_of< tag::quantile > {
};
```

Struct template feature_of<tag::pot_quantile_prob< LeftRight >>

boost::accumulators::feature_of<tag::pot_quantile_prob< LeftRight >>

Synopsis

```
// In header: <boost/accumulators/statistics/pot_quantile.hpp>

template<typename LeftRight>
struct feature_of<tag::pot_quantile_prob< LeftRight >> : public boost::accumulators::fea
ture_of< tag::quantile > {
};
```

Struct template as_weighted_feature<tag::pot_quantile< LeftRight >>

boost::accumulators::as_weighted_feature<tag::pot_quantile< LeftRight >>

Synopsis

```
// In header: <boost/accumulators/statistics/pot_quantile.hpp>

template<typename LeftRight>
struct as_weighted_feature<tag::pot_quantile< LeftRight >> {
    // types
    typedef tag::weighted_pot_quantile< LeftRight > type;
};
```

Struct template feature_of<tag::weighted_pot_quantile< LeftRight >>

boost::accumulators::feature_of<tag::weighted_pot_quantile< LeftRight >>

Synopsis

```
// In header: <boost/accumulators/statistics/pot_quantile.hpp>

template<typename LeftRight>
struct feature_of<tag::weighted_pot_quantile< LeftRight >> :
    public boost::accumulators::feature_of< tag::pot_quantile< LeftRight > >
{
};
```

Struct template as_weighted_feature<tag::pot_quantile_prob< LeftRight >>

boost::accumulators::as_weighted_feature<tag::pot_quantile_prob< LeftRight >>

Synopsis

```
// In header: <boost/accumulators/statistics/pot_quantile.hpp>

template<typename LeftRight>
struct as_weighted_feature<tag::pot_quantile_prob< LeftRight >> {
    // types
    typedef tag::weighted_pot_quantile_prob< LeftRight > type;
};
```

Struct template feature_of<tag::weighted_pot_quantile_prob< LeftRight >>

boost::accumulators::feature_of<tag::weighted_pot_quantile_prob< LeftRight >>

Synopsis

```
// In header: <boost/accumulators/statistics/pot_quantile.hpp>

template<typename LeftRight>
struct feature_of<tag::weighted_pot_quantile_prob< LeftRight >> : public boost::accumulators::feature_of< tag::pot_quantile_prob< LeftRight > >
{
};
```

Header <boost/accumulators/statistics/pot_tail_mean.hpp>

```
namespace boost {
    namespace accumulators {
        template<typename LeftRight>
            struct as_feature<tag::pot_tail_mean< LeftRight >(with_threshold_value)>;
        template<typename LeftRight>
            struct as_feature<tag::pot_tail_mean< LeftRight >(with_threshold_probability)>;
        template<typename LeftRight>
            struct as_feature<tag::weighted_pot_tail_mean< LeftRight >(with_threshold_value)>;
        template<typename LeftRight>
            struct as_feature<tag::weighted_pot_tail_mean< LeftRight >(with_threshold_probability)>;
        template<typename LeftRight>
            struct feature_of<tag::pot_tail_mean< LeftRight >>;
        template<typename LeftRight>
            struct feature_of<tag::pot_tail_mean_prob< LeftRight >>;
        template<typename LeftRight>
            struct as_weighted_feature<tag::pot_tail_mean< LeftRight >>;
        template<typename LeftRight>
            struct feature_of<tag::weighted_pot_tail_mean< LeftRight >>;
        template<typename LeftRight>
            struct as_weighted_feature<tag::pot_tail_mean_prob< LeftRight >>;
        template<typename LeftRight>
            struct feature_of<tag::weighted_pot_tail_mean_prob< LeftRight >>;
        namespace impl {
        }
        namespace tag {
        }
    }
}
```

Struct template as_feature<tag::pot_tail_mean< LeftRight >(with_threshold_value)>

boost::accumulators::as_feature<tag::pot_tail_mean< LeftRight >(with_threshold_value)>

Synopsis

```
// In header: <boost/accumulators/statistics/pot_tail_mean.hpp>

template<typename LeftRight>
struct as_feature<tag::pot_tail_mean< LeftRight >(with_threshold_value)> {
    // types
    typedef tag::pot_tail_mean< LeftRight > type;
};
```

Struct template as_feature<tag::pot_tail_mean< LeftRight >(with_threshold_probability)>

boost::accumulators::as_feature<tag::pot_tail_mean< LeftRight >(with_threshold_probability)>

Synopsis

```
// In header: <boost/accumulators/statistics/pot_tail_mean.hpp>

template<typename LeftRight>
struct as_feature<tag::pot_tail_mean< LeftRight >(with_threshold_probability)> {
    // types
    typedef tag::pot_tail_mean_prob< LeftRight > type;
};
```

Struct template as_feature<tag::weighted_pot_tail_mean< LeftRight >(with_threshold_value)>

boost::accumulators::as_feature<tag::weighted_pot_tail_mean< LeftRight >(with_threshold_value)>

Synopsis

```
// In header: <boost/accumulators/statistics/pot_tail_mean.hpp>

template<typename LeftRight>
struct as_feature<tag::weighted_pot_tail_mean< LeftRight >(with_threshold_value)> {
    // types
    typedef tag::weighted_pot_tail_mean< LeftRight > type;
};
```

**Struct template as_feature<tag::weighted_pot_tail_mean< LeftRight
>(with_threshold_probability)>**

boost::accumulators::as_feature<tag::weighted_pot_tail_mean< LeftRight >(with_threshold_probability)>

Synopsis

```
// In header: <boost/accumulators/statistics/pot_tail_mean.hpp>

template<typename LeftRight>
struct as_feature<tag::weighted_pot_tail_mean< LeftRight >(with_threshold_probability)> {
    // types
    typedef tag::weighted_pot_tail_mean_prob< LeftRight > type;
};
```

Struct template feature_of<tag::pot_tail_mean< LeftRight >>

boost::accumulators::feature_of<tag::pot_tail_mean< LeftRight >>

Synopsis

```
// In header: <boost/accumulators/statistics/pot_tail_mean.hpp>

template<typename LeftRight>
struct feature_of<tag::pot_tail_mean< LeftRight >> : public boost::accumulators::fea-
ture_of< tag::tail_mean > {
};
```

Struct template feature_of<tag::pot_tail_mean_prob< LeftRight >>

boost::accumulators::feature_of<tag::pot_tail_mean_prob< LeftRight >>

Synopsis

```
// In header: <boost/accumulators/statistics/pot_tail_mean.hpp>

template<typename LeftRight>
struct feature_of<tag::pot_tail_mean_prob< LeftRight >> : public boost::accumulators::fea-
ture_of< tag::tail_mean > {
};
```

Struct template as_weighted_feature<tag::pot_tail_mean< LeftRight >>

boost::accumulators::as_weighted_feature<tag::pot_tail_mean< LeftRight >>

Synopsis

```
// In header: <boost/accumulators/statistics/pot_tail_mean.hpp>

template<typename LeftRight>
struct as_weighted_feature<tag::pot_tail_mean< LeftRight >> {
    // types
    typedef tag::weighted_pot_tail_mean< LeftRight > type;
};
```

Struct template feature_of<tag::weighted_pot_tail_mean< LeftRight >>

boost::accumulators::feature_of<tag::weighted_pot_tail_mean< LeftRight >>

Synopsis

```
// In header: <boost/accumulators/statistics/pot_tail_mean.hpp>

template<typename LeftRight>
struct feature_of<tag::weighted_pot_tail_mean< LeftRight >> :
    public boost::accumulators::feature_of< tag::pot_tail_mean< LeftRight > >
{
};
```

Struct template `as_weighted_feature<tag::pot_tail_mean_prob< LeftRight >>`

`boost::accumulators::as_weighted_feature<tag::pot_tail_mean_prob< LeftRight >>`

Synopsis

```
// In header: <boost/accumulators/statistics/pot_tail_mean.hpp>

template<typename LeftRight>
struct as_weighted_feature<tag::pot_tail_mean_prob< LeftRight >> {
    // types
    typedef tag::weighted_pot_tail_mean_prob< LeftRight > type;
};
```

Struct template `feature_of<tag::weighted_pot_tail_mean_prob< LeftRight >>`

`boost::accumulators::feature_of<tag::weighted_pot_tail_mean_prob< LeftRight >>`

Synopsis

```
// In header: <boost/accumulators/statistics/pot_tail_mean.hpp>

template<typename LeftRight>
struct feature_of<tag::weighted_pot_tail_mean_prob< LeftRight >> : public boost::accumulators::feature_of< tag::pot_tail_mean_prob< LeftRight > >
{
};
```

Header `<boost/accumulators/statistics/rolling_count.hpp>`

```
namespace boost {
    namespace accumulators {
        namespace extract {
            extractor< tag::rolling_count > const rolling_count;
        }
        namespace impl {
        }
        namespace tag {
            struct rolling_count;
        }
    }
}
```

Global rolling_count

boost::accumulators::extract::rolling_count

Synopsis

```
// In header: <boost/accumulators/statistics/rolling_count.hpp>

extractor< tag::rolling_count > const rolling_count;
```

Struct rolling_count

boost::accumulators::tag::rolling_count

Synopsis

```
// In header: <boost/accumulators/statistics/rolling_count.hpp>

struct rolling_count :
    public boost::accumulators::depends_on< rolling_window_plus1 >
{
    // public data members
    static boost::parameter::keyword< tag::rolling_window_size > const window_size; // ↵
    tag::rolling_window::window_size named parameter
};
```

Header <boost/accumulators/statistics/rolling_mean.hpp>

```
namespace boost {
    namespace accumulators {
        namespace extract {
            extractor< tag::rolling_mean > const rolling_mean;
        }
        namespace impl {
        }
        namespace tag {
            struct rolling_mean;
        }
    }
}
```

Global rolling_mean

boost::accumulators::extract::rolling_mean

Synopsis

```
// In header: <boost/accumulators/statistics/rolling_mean.hpp>

extractor< tag::rolling_mean > const rolling_mean;
```

Struct rolling_mean

boost::accumulators::tag::rolling_mean

Synopsis

```
// In header: <boost/accumulators/statistics/rolling_mean.hpp>

struct rolling_mean :
    public boost::accumulators::depends_on< rolling_sum, rolling_count >
{
    // public data members
    static boost::parameter::keyword< tag::rolling_window_size > const window_size; // ↵
    tag::rolling_window::window_size named parameter
};
```

Header <boost/accumulators/statistics/rolling_sum.hpp>

```
namespace boost {
    namespace accumulators {
        namespace extract {
            extractor< tag::rolling_sum > const rolling_sum;
        }
        namespace impl {
        }
        namespace tag {
            struct rolling_sum;
        }
    }
}
```

Global rolling_sum

boost::accumulators::extract::rolling_sum

Synopsis

```
// In header: <boost/accumulators/statistics/rolling_sum.hpp>

extractor< tag::rolling_sum > const rolling_sum;
```

Struct rolling_sum

boost::accumulators::tag::rolling_sum

Synopsis

```
// In header: <boost/accumulators/statistics/rolling_sum.hpp>

struct rolling_sum :
    public boost::accumulators::depends_on< rolling_window_plus1 >
{
    // public data members
    static boost::parameter::keyword< tag::rolling_window_size > const window_size; // ↓
    tag::rolling_window::window_size named parameter
};
```

Header <boost/accumulators/statistics/rolling_window.hpp>

```
namespace boost {
    namespace accumulators {
        namespace extract {
            extractor< tag::rolling_window_plus1 > const rolling_window_plus1;
            extractor< tag::rolling_window > const rolling_window;
        }
        namespace impl {
            template<typename Args>
            bool is_rolling_window_plus1_full(Args const & args);
        }
        namespace tag {
            struct rolling_window_plus1;
            struct rolling_window;
        }
    }
}
```

Global rolling_window_plus1

boost::accumulators::extract::rolling_window_plus1

Synopsis

```
// In header: <boost/accumulators/statistics/rolling_window.hpp>

extractor< tag::rolling_window_plus1 > const rolling_window_plus1;
```

Global rolling_window

boost::accumulators::extract::rolling_window

Synopsis

```
// In header: <boost/accumulators/statistics/rolling_window.hpp>

extractor< tag::rolling_window > const rolling_window;
```

Struct rolling_window_plus1

boost::accumulators::tag::rolling_window_plus1

Synopsis

```
// In header: <boost/accumulators/statistics/rolling_window.hpp>

struct rolling_window_plus1 :
    public boost::accumulators::depends_on<>, public rolling_window_size
{
    // public data members
    static boost::parameter::keyword< tag::rolling_window_size > const window_size; // ↵
    tag::rolling_window::size named parameter
};
```

Struct rolling_window

boost::accumulators::tag::rolling_window

Synopsis

```
// In header: <boost/accumulators/statistics/rolling_window.hpp>

struct rolling_window :
    public boost::accumulators::depends_on< rolling_window_plus1 >
{
    // public data members
    static boost::parameter::keyword< tag::rolling_window_size > const window_size; // ↵
    tag::rolling_window::size named parameter
};
```

Header <boost/accumulators/statistics/skewness.hpp>

```
namespace boost {
    namespace accumulators {
        template<> struct as_weighted_feature<tag::skewness>;
        template<> struct feature_of<tag::weighted_skewness>;
        namespace extract {
            extractor< tag::skewness > const skewness;
        }
        namespace impl {
        }
        namespace tag {
            struct skewness;
        }
    }
}
```

Global skewness

boost::accumulators::extract::skewness

Synopsis

```
// In header: <boost/accumulators/statistics/skewness.hpp>

extractor< tag::skewness > const skewness;
```

Struct skewness

boost::accumulators::tag::skewness

Synopsis

```
// In header: <boost/accumulators/statistics/skewness.hpp>

struct skewness :
    public boost::accumulators::depends_on< mean, moment< 2 >, moment< 3 > >
{
};
```

Struct as_weighted_feature<tag::skewness>

boost::accumulators::as_weighted_feature<tag::skewness>

Synopsis

```
// In header: <boost/accumulators/statistics/skewness.hpp>

struct as_weighted_feature<tag::skewness> {
    // types
    typedef tag::weighted_skewness type;
};
```

Struct feature_of<tag::weighted_skewness>

boost::accumulators::feature_of<tag::weighted_skewness>

Synopsis

```
// In header: <boost/accumulators/statistics/skewness.hpp>

struct feature_of<tag::weighted_skewness> : public boost::accumulators::feature_of< tag::skewness > {
};
```

Header <boost/accumulators/statistics/stats.hpp>

Contains the stats<> template.

Header `<boost/accumulators/statistics/sum.hpp>`

```
namespace boost {
  namespace accumulators {
    template<> struct as_weighted_feature<tag::sum>;
    template<> struct feature_of<tag::weighted_sum>;
    template<typename VariateType, typename VariateTag>
      struct feature_of<tag::sum_of_variates< VariateType, VariateTag >>;
    namespace extract {
      extractor< tag::sum > const sum;
      extractor< tag::sum_of_weights > const sum_of_weights;
      extractor< tag::abstract_sum_of_variates > const sum_of_variates;
    }
    namespace impl {
    }
    namespace tag {
      struct sum;
      struct sum_of_weights;
      struct abstract_sum_of_variates;
    }
  }
}
```

Global sum

boost::accumulators::extract::sum

Synopsis

```
// In header: <boost/accumulators/statistics/sum.hpp>

extractor< tag::sum > const sum;
```

Global sum_of_weights

boost::accumulators::extract::sum_of_weights

Synopsis

```
// In header: <boost/accumulators/statistics/sum.hpp>

extractor< tag::sum_of_weights > const sum_of_weights;
```

Global sum_of_variates

boost::accumulators::extract::sum_of_variates

Synopsis

```
// In header: <boost/accumulators/statistics/sum.hpp>

extractor< tag::abstract_sum_of_variates > const sum_of_variates;
```

Struct sum

boost::accumulators::tag::sum

Synopsis

```
// In header: <boost/accumulators/statistics/sum.hpp>

struct sum : public boost::accumulators::depends_on<> {
};
```

Struct sum_of_weights

boost::accumulators::tag::sum_of_weights

Synopsis

```
// In header: <boost/accumulators/statistics/sum.hpp>

struct sum_of_weights : public boost::accumulators::depends_on<> {
    // types
    typedef mpl::true_ is_weight_accumulator;
};
```

Struct abstract_sum_of_variates

boost::accumulators::tag::abstract_sum_of_variates

Synopsis

```
// In header: <boost/accumulators/statistics/sum.hpp>

struct abstract_sum_of_variates : public boost::accumulators::depends_on<> {
};
```

Struct as_weighted_feature<tag::sum>

boost::accumulators::as_weighted_feature<tag::sum>

Synopsis

```
// In header: <boost/accumulators/statistics/sum.hpp>

struct as_weighted_feature<tag::sum> {
    // types
    typedef tag::weighted_sum type;
};
```

Struct feature_of<tag::weighted_sum>

boost::accumulators::feature_of<tag::weighted_sum>

Synopsis

```
// In header: <boost/accumulators/statistics/sum.hpp>

struct feature_of<tag::weighted_sum> : public boost::accumulators::feature_of< tag::sum > {
};
```

Struct template feature_of<tag::sum_of_variates< VariateType, VariateTag >>

boost::accumulators::feature_of<tag::sum_of_variates< VariateType, VariateTag >>

Synopsis

```
// In header: <boost/accumulators/statistics/sum.hpp>

template<typename VariateType, typename VariateTag>
struct feature_of<tag::sum_of_variates< VariateType, VariateTag >> :
    public boost::accumulators::feature_of< tag::abstract_sum_of_variates >
{
};
```

Header <boost/accumulators/statistics/sum_kahan.hpp>

```
namespace boost {
    namespace accumulators {
        template<> struct as_feature<tag::sum(kahan)>;
        template<> struct as_feature<tag::sum_of_weights(kahan)>;
        template<> struct as_weighted_feature<tag::sum_kahan>;
        template<> struct feature_of<tag::weighted_sum_kahan>;
        template<> struct feature_of<tag::sum_kahan>;
        template<> struct feature_of<tag::sum_of_weights_kahan>;
        template<typename VariateType, typename VariateTag>
            struct feature_of<tag::sum_of_variates_kahan< VariateType, VariateTag >>;
        namespace extract {
            extractor< tag::sum_kahan > const sum_kahan;
            extractor< tag::sum_of_weights_kahan > const sum_of_weights_kahan;
            extractor< tag::abstract_sum_of_variates > const sum_of_variates_kahan;
        }
        namespace impl {
        }
        namespace tag {
            struct sum_kahan;
            struct sum_of_weights_kahan;
        }
    }
}
```

Global sum_kahan

boost::accumulators::extract::sum_kahan

Synopsis

```
// In header: <boost/accumulators/statistics/sum_kahan.hpp>

extractor< tag::sum_kahan > const sum_kahan;
```

Global sum_of_weights_kahan

boost::accumulators::extract::sum_of_weights_kahan

Synopsis

```
// In header: <boost/accumulators/statistics/sum_kahan.hpp>

extractor< tag::sum_of_weights_kahan > const sum_of_weights_kahan;
```

Global sum_of_variates_kahan

boost::accumulators::extract::sum_of_variates_kahan

Synopsis

```
// In header: <boost/accumulators/statistics/sum_kahan.hpp>

extractor< tag::abstract_sum_of_variates > const sum_of_variates_kahan;
```

Struct sum_kahan

boost::accumulators::tag::sum_kahan

Synopsis

```
// In header: <boost/accumulators/statistics/sum_kahan.hpp>

struct sum_kahan : public boost::accumulators::depends_on<> {
};
```

Struct sum_of_weights_kahan

boost::accumulators::tag::sum_of_weights_kahan

Synopsis

```
// In header: <boost/accumulators/statistics/sum_kahan.hpp>

struct sum_of_weights_kahan : public boost::accumulators::depends_on<> {
    // types
    typedef mpl::true_ is_weight_accumulator;
};
```

Struct `as_feature<tag::sum(kahan)>``boost::accumulators::as_feature<tag::sum(kahan)>`**Synopsis**

```
// In header: <boost/accumulators/statistics/sum_kahan.hpp>

struct as_feature<tag::sum(kahan)> {
    // types
    typedef tag::sum_kahan type;
};
```

Struct `as_feature<tag::sum_of_weights(kahan)>``boost::accumulators::as_feature<tag::sum_of_weights(kahan)>`**Synopsis**

```
// In header: <boost/accumulators/statistics/sum_kahan.hpp>

struct as_feature<tag::sum_of_weights(kahan)> {
    // types
    typedef tag::sum_of_weights_kahan type;
};
```

Struct `as_weighted_feature<tag::sum_kahan>``boost::accumulators::as_weighted_feature<tag::sum_kahan>`**Synopsis**

```
// In header: <boost/accumulators/statistics/sum_kahan.hpp>

struct as_weighted_feature<tag::sum_kahan> {
    // types
    typedef tag::weighted_sum_kahan type;
};
```

Struct `feature_of<tag::weighted_sum_kahan>``boost::accumulators::feature_of<tag::weighted_sum_kahan>`**Synopsis**

```
// In header: <boost/accumulators/statistics/sum_kahan.hpp>

struct feature_of<tag::weighted_sum_kahan> : public boost::accumulators::feature_of< tag::sum > {
};
```

Struct feature_of<tag::sum_kahan>

boost::accumulators::feature_of<tag::sum_kahan>

Synopsis

```
// In header: <boost/accumulators/statistics/sum_kahan.hpp>

struct feature_of<tag::sum_kahan> : public boost::accumulators::feature_of< tag::sum > {
};
```

Struct feature_of<tag::sum_of_weights_kahan>

boost::accumulators::feature_of<tag::sum_of_weights_kahan>

Synopsis

```
// In header: <boost/accumulators/statistics/sum_kahan.hpp>

struct feature_of<tag::sum_of_weights_kahan> :
    public boost::accumulators::feature_of< tag::sum_of_weights >
{
};
```

Struct template feature_of<tag::sum_of_variates_kahan< VariateType, VariateTag >>

boost::accumulators::feature_of<tag::sum_of_variates_kahan< VariateType, VariateTag >>

Synopsis

```
// In header: <boost/accumulators/statistics/sum_kahan.hpp>

template<typename VariateType, typename VariateTag>
struct feature_of<tag::sum_of_variates_kahan< VariateType, VariateTag >> :
    public boost::accumulators::feature_of< tag::abstract_sum_of_variates >
{
};
```

Header `<boost/accumulators/statistics/tail.hpp>`

```
namespace boost {
  namespace accumulators {
    template<typename T> struct tail_cache_size_named_arg;

    template<> struct tail_cache_size_named_arg<left>;
    template<> struct tail_cache_size_named_arg<right>;
    template<typename LeftRight> struct feature_of<tag::tail< LeftRight >>;
    namespace extract {
      extractor< tag::abstract_tail > const tail;
    }
    namespace impl {
    }
    namespace tag {
      struct abstract_tail;
    }
  }
}
```

Global tail

boost::accumulators::extract::tail

Synopsis

```
// In header: <boost/accumulators/statistics/tail.hpp>

extractor< tag::abstract_tail > const tail;
```

Struct abstract_tail

boost::accumulators::tag::abstract_tail

Synopsis

```
// In header: <boost/accumulators/statistics/tail.hpp>

struct abstract_tail : public boost::accumulators::depends_on<> {
};
```

Struct template tail_cache_size_named_arg

boost::accumulators::tail_cache_size_named_arg

Synopsis

```
// In header: <boost/accumulators/statistics/tail.hpp>

template<typename T>
struct tail_cache_size_named_arg {
};
```


Struct tail_cache_size_named_arg<left>

boost::accumulators::tail_cache_size_named_arg<left>

Synopsis

```
// In header: <boost/accumulators/statistics/tail.hpp>

struct tail_cache_size_named_arg<left> : public left_tail_cache_size {
};
```

Struct tail_cache_size_named_arg<right>

boost::accumulators::tail_cache_size_named_arg<right>

Synopsis

```
// In header: <boost/accumulators/statistics/tail.hpp>

struct tail_cache_size_named_arg<right> : public right_tail_cache_size {
};
```

Struct template feature_of<tag::tail< LeftRight >>

boost::accumulators::feature_of<tag::tail< LeftRight >>

Synopsis

```
// In header: <boost/accumulators/statistics/tail.hpp>

template<typename LeftRight>
struct feature_of<tag::tail< LeftRight >> :
    public boost::accumulators::feature_of< tag::abstract_tail >
{
};
```

Header `<boost/accumulators/statistics/tail_mean.hpp>`

```
namespace boost {
  namespace accumulators {
    template<typename LeftRight>
      struct feature_of<tag::coherent_tail_mean< LeftRight >>;
    template<typename LeftRight>
      struct feature_of<tag::non_coherent_tail_mean< LeftRight >>;
    template<typename LeftRight>
      struct as_weighted_feature<tag::non_coherent_tail_mean< LeftRight >>;
    template<typename LeftRight>
      struct feature_of<tag::non_coherent_weighted_tail_mean< LeftRight >>;
    namespace extract {
      extractor< tag::abstract_non_coherent_tail_mean > const non_coherent_tail_mean;
      extractor< tag::tail_mean > const coherent_tail_mean;
    }
    namespace impl {
    }
    namespace tag {
      struct abstract_non_coherent_tail_mean;
    }
  }
}
```

Global `non_coherent_tail_mean`

`boost::accumulators::extract::non_coherent_tail_mean`

Synopsis

```
// In header: <boost/accumulators/statistics/tail_mean.hpp>

extractor< tag::abstract_non_coherent_tail_mean > const non_coherent_tail_mean;
```

Global `coherent_tail_mean`

`boost::accumulators::extract::coherent_tail_mean`

Synopsis

```
// In header: <boost/accumulators/statistics/tail_mean.hpp>

extractor< tag::tail_mean > const coherent_tail_mean;
```

Struct `abstract_non_coherent_tail_mean`

`boost::accumulators::tag::abstract_non_coherent_tail_mean`

Synopsis

```
// In header: <boost/accumulators/statistics/tail_mean.hpp>

struct abstract_non_coherent_tail_mean :
    public boost::accumulators::depends_on<>
{
};
```

Struct template `feature_of<tag::coherent_tail_mean< LeftRight >>`

`boost::accumulators::feature_of<tag::coherent_tail_mean< LeftRight >>`

Synopsis

```
// In header: <boost/accumulators/statistics/tail_mean.hpp>

template<typename LeftRight>
struct feature_of<tag::coherent_tail_mean< LeftRight >> : public boost::accumulators::fea-
ture_of< tag::tail_mean > {
};
```

Struct template `feature_of<tag::non_coherent_tail_mean< LeftRight >>`

`boost::accumulators::feature_of<tag::non_coherent_tail_mean< LeftRight >>`

Synopsis

```
// In header: <boost/accumulators/statistics/tail_mean.hpp>

template<typename LeftRight>
struct feature_of<tag::non_coherent_tail_mean< LeftRight >> : public boost::accumulators::fea-
ture_of< tag::abstract_non_coherent_tail_mean >
{
};
```

Struct template `as_weighted_feature<tag::non_coherent_tail_mean< LeftRight >>`

`boost::accumulators::as_weighted_feature<tag::non_coherent_tail_mean< LeftRight >>`

Synopsis

```
// In header: <boost/accumulators/statistics/tail_mean.hpp>

template<typename LeftRight>
struct as_weighted_feature<tag::non_coherent_tail_mean< LeftRight >> {
    // types
    typedef tag::non_coherent_weighted_tail_mean< LeftRight > type;
};
```

Struct template feature_of<tag::non_coherent_weighted_tail_mean< LeftRight >>

boost::accumulators::feature_of<tag::non_coherent_weighted_tail_mean< LeftRight >>

Synopsis

```
// In header: <boost/accumulators/statistics/tail_mean.hpp>

template<typename LeftRight>
struct feature_of<tag::non_coherent_weighted_tail_mean< LeftRight >> : public boost::accumulators::feature_of< tag::non_coherent_tail_mean< LeftRight > >
{
};
```

Header <boost/accumulators/statistics/tail_quantile.hpp>

```
namespace boost {
  namespace accumulators {
    template<typename LeftRight>
      struct feature_of<tag::tail_quantile< LeftRight >>;
    template<typename LeftRight>
      struct as_weighted_feature<tag::tail_quantile< LeftRight >>;
    template<typename LeftRight>
      struct feature_of<tag::weighted_tail_quantile< LeftRight >>;
    namespace extract {
      extractor< tag::quantile > const tail_quantile;
    }
    namespace impl {
    }
    namespace tag {
    }
  }
}
```

Global tail_quantile

boost::accumulators::extract::tail_quantile

Synopsis

```
// In header: <boost/accumulators/statistics/tail_quantile.hpp>

extractor< tag::quantile > const tail_quantile;
```

Struct template feature_of<tag::tail_quantile< LeftRight >>

boost::accumulators::feature_of<tag::tail_quantile< LeftRight >>

Synopsis

```
// In header: <boost/accumulators/statistics/tail_quantile.hpp>

template<typename LeftRight>
struct feature_of<tag::tail_quantile< LeftRight >> : public boost::accumulators::fea-
ture_of< tag::quantile > {
};
```

Struct template as_weighted_feature<tag::tail_quantile< LeftRight >>

boost::accumulators::as_weighted_feature<tag::tail_quantile< LeftRight >>

Synopsis

```
// In header: <boost/accumulators/statistics/tail_quantile.hpp>

template<typename LeftRight>
struct as_weighted_feature<tag::tail_quantile< LeftRight >> {
    // types
    typedef tag::weighted_tail_quantile< LeftRight > type;
};
```

Struct template feature_of<tag::weighted_tail_quantile< LeftRight >>

boost::accumulators::feature_of<tag::weighted_tail_quantile< LeftRight >>

Synopsis

```
// In header: <boost/accumulators/statistics/tail_quantile.hpp>

template<typename LeftRight>
struct feature_of<tag::weighted_tail_quantile< LeftRight >> :
    public boost::accumulators::feature_of< tag::tail_quantile< LeftRight > >
{
};
```

Header `<boost/accumulators/statistics/tail_variate.hpp>`

```
namespace boost {
  namespace accumulators {
    template<typename VariateType, typename VariateTag, typename LeftRight>
      struct feature_of<tag::tail_variate< VariateType, VariateTag, LeftRight >>;
    template<typename LeftRight>
      struct feature_of<tag::tail_weights< LeftRight >>;
    namespace extract {
      extractor< tag::abstract_tail_variate > const tail_variate;
      extractor< tag::abstract_tail_weights > const tail_weights;
    }
    namespace impl {
    }
    namespace tag {
      struct abstract_tail_variate;
      struct abstract_tail_weights;
    }
  }
}
```

Global `tail_variate`

`boost::accumulators::extract::tail_variate`

Synopsis

```
// In header: <boost/accumulators/statistics/tail_variate.hpp>

extractor< tag::abstract_tail_variate > const tail_variate;
```

Global `tail_weights`

`boost::accumulators::extract::tail_weights`

Synopsis

```
// In header: <boost/accumulators/statistics/tail_variate.hpp>

extractor< tag::abstract_tail_weights > const tail_weights;
```

Struct `abstract_tail_variate`

`boost::accumulators::tag::abstract_tail_variate`

Synopsis

```
// In header: <boost/accumulators/statistics/tail_variate.hpp>

struct abstract_tail_variate : public boost::accumulators::depends_on<> {
};
```

Struct `abstract_tail_weights`

`boost::accumulators::tag::abstract_tail_weights`

Synopsis

```
// In header: <boost/accumulators/statistics/tail_variate.hpp>

struct abstract_tail_weights : public boost::accumulators::depends_on<> {
};
```

Struct template `feature_of<tag::tail_variate< VariateType, VariateTag, LeftRight >>`

`boost::accumulators::feature_of<tag::tail_variate< VariateType, VariateTag, LeftRight >>`

Synopsis

```
// In header: <boost/accumulators/statistics/tail_variate.hpp>

template<typename VariateType, typename VariateTag, typename LeftRight>
struct feature_of<tag::tail_variate< VariateType, VariateTag, LeftRight >> :
    public boost::accumulators::feature_of< tag::abstract_tail_variate >
{
};
```

Struct template `feature_of<tag::tail_weights< LeftRight >>`

`boost::accumulators::feature_of<tag::tail_weights< LeftRight >>`

Synopsis

```
// In header: <boost/accumulators/statistics/tail_variate.hpp>

template<typename LeftRight>
struct feature_of<tag::tail_weights< LeftRight >> {
    // types
    typedef tag::abstract_tail_weights type;
};
```

Header `<boost/accumulators/statistics/tail_variate_means.hpp>`

```
namespace boost {
    namespace accumulators {
        template<typename LeftRight, typename VariateType, typename VariateTag>
            struct as_feature<tag::tail_variate_means< LeftRight, VariateType, VariateTag >(absolute)>;
        template<typename LeftRight, typename VariateType, typename VariateTag>
            struct as_feature<tag::tail_variate_means< LeftRight, VariateType, VariateTag >(relative)>;
        template<typename LeftRight, typename VariateType, typename VariateTag>
            struct feature_of<tag::absolute_tail_variate_means< LeftRight, VariateType, VariateTag >>;
        template<typename LeftRight, typename VariateType, typename VariateTag>
            struct feature_of<tag::relative_tail_variate_means< LeftRight, VariateType, VariateTag >>;
        template<typename LeftRight, typename VariateType, typename VariateTag>
            struct as_weighted_feature<tag::absolute_tail_variate_means< LeftRight, VariateType, VariateTag >>;
        template<typename LeftRight, typename VariateType, typename VariateTag>
            struct feature_of<tag::absolute_weighted_tail_variate_means< LeftRight, VariateType, VariateTag >>;
        template<typename LeftRight, typename VariateType, typename VariateTag>
            struct as_weighted_feature<tag::relative_tail_variate_means< LeftRight, VariateType, VariateTag >>;
        template<typename LeftRight, typename VariateType, typename VariateTag>
            struct feature_of<tag::relative_weighted_tail_variate_means< LeftRight, VariateType, VariateTag >>;
        namespace extract {
            extractor< tag::abstract_absolute_tail_variate_means > const tail_variate_means;
            extractor< tag::abstract_relative_tail_variate_means > const relative_tail_variate_means;
        }
        namespace impl {
        }
        namespace tag {
            struct abstract_absolute_tail_variate_means;
            struct abstract_relative_tail_variate_means;
        }
    }
}
```

Global tail_variate_means

boost::accumulators::extract::tail_variate_means

Synopsis

```
// In header: <boost/accumulators/statistics/tail_variate_means.hpp>

extractor< tag::abstract_absolute_tail_variate_means > const tail_variate_means;
```

Global relative_tail_variate_means

boost::accumulators::extract::relative_tail_variate_means

Synopsis

```
// In header: <boost/accumulators/statistics/tail_variate_means.hpp>

extractor< tag::abstract_relative_tail_variate_means > const relative_tail_variate_means;
```


Struct `abstract_absolute_tail_variate_means`

`boost::accumulators::tag::abstract_absolute_tail_variate_means`

Synopsis

```
// In header: <boost/accumulators/statistics/tail_variate_means.hpp>

struct abstract_absolute_tail_variate_means :
    public boost::accumulators::depends_on<>
{
};
```

Struct `abstract_relative_tail_variate_means`

`boost::accumulators::tag::abstract_relative_tail_variate_means`

Synopsis

```
// In header: <boost/accumulators/statistics/tail_variate_means.hpp>

struct abstract_relative_tail_variate_means :
    public boost::accumulators::depends_on<>
{
};
```

Struct template `as_feature<tag::tail_variate_means< LeftRight, VariateType, VariateTag >(absolute)>`

`boost::accumulators::as_feature<tag::tail_variate_means< LeftRight, VariateType, VariateTag >(absolute)>`

Synopsis

```
// In header: <boost/accumulators/statistics/tail_variate_means.hpp>

template<typename LeftRight, typename VariateType, typename VariateTag>
struct as_feature<tag::tail_variate_means< LeftRight, VariateType, VariateTag >(absolute)> {
    // types
    typedef tag::absolute_tail_variate_means< LeftRight, VariateType, VariateTag > type;
};
```

Struct template `as_feature<tag::tail_variate_means< LeftRight, VariateType, VariateTag >(relative)>`

`boost::accumulators::as_feature<tag::tail_variate_means< LeftRight, VariateType, VariateTag >(relative)>`

Synopsis

```
// In header: <boost/accumulators/statistics/tail_variate_means.hpp>

template<typename LeftRight, typename VariateType, typename VariateTag>
struct as_feature<tag::tail_variate_means< LeftRight, VariateType, VariateTag >(relative)> {
    // types
    typedef tag::relative_tail_variate_means< LeftRight, VariateType, VariateTag > type;
};
```

Struct template feature_of<tag::absolute_tail_variate_means< LeftRight, VariateType, VariateTag >>

boost::accumulators::feature_of<tag::absolute_tail_variate_means< LeftRight, VariateType, VariateTag >>

Synopsis

```
// In header: <boost/accumulators/statistics/tail_variate_means.hpp>

template<typename LeftRight, typename VariateType, typename VariateTag>
struct feature_of<tag::absolute_tail_variate_means< LeftRight, VariateType, VariateTag >> : public
    boost::accumulators::feature_of< tag::abstract_absolute_tail_variate_means >
{
};
```

Struct template feature_of<tag::relative_tail_variate_means< LeftRight, VariateType, VariateTag >>

boost::accumulators::feature_of<tag::relative_tail_variate_means< LeftRight, VariateType, VariateTag >>

Synopsis

```
// In header: <boost/accumulators/statistics/tail_variate_means.hpp>

template<typename LeftRight, typename VariateType, typename VariateTag>
struct feature_of<tag::relative_tail_variate_means< LeftRight, VariateType, VariateTag >> : public
    boost::accumulators::feature_of< tag::abstract_relative_tail_variate_means >
{
};
```

Struct template as_weighted_feature<tag::absolute_tail_variate_means< LeftRight, VariateType, VariateTag >>

boost::accumulators::as_weighted_feature<tag::absolute_tail_variate_means< LeftRight, VariateType, VariateTag >>

Synopsis

```
// In header: <boost/accumulators/statistics/tail_variate_means.hpp>

template<typename LeftRight, typename VariateType, typename VariateTag>
struct as_weighted_feature<tag::absolute_tail_variate_means< LeftRight, VariateType, VariateTag >> {
    // types
    typedef tag::absolute_weighted_tail_variate_means< LeftRight, VariateType, VariateTag > type;
};
```

Struct template feature_of<tag::absolute_weighted_tail_variate_means< LeftRight, VariateType, VariateTag >>

boost::accumulators::feature_of<tag::absolute_weighted_tail_variate_means< LeftRight, VariateType, VariateTag >>

Synopsis

```
// In header: <boost/accumulators/statistics/tail_variate_means.hpp>

template<typename LeftRight, typename VariateType, typename VariateTag>
struct feature_of<tag::absolute_weighted_tail_variate_means< LeftRight, VariateType, VariateTag >> : public boost::accumulators::feature_of< tag::absolute_tail_variate_means< LeftRight, VariateType, VariateTag > > {
};
```

Struct template as_weighted_feature<tag::relative_tail_variate_means< LeftRight, VariateType, VariateTag >>

boost::accumulators::as_weighted_feature<tag::relative_tail_variate_means< LeftRight, VariateType, VariateTag >>

Synopsis

```
// In header: <boost/accumulators/statistics/tail_variate_means.hpp>

template<typename LeftRight, typename VariateType, typename VariateTag>
struct as_weighted_feature<tag::relative_tail_variate_means< LeftRight, VariateType, VariateTag >> {
    // types
    typedef tag::relative_weighted_tail_variate_means< LeftRight, VariateType, VariateTag > type;
};
```

Struct template feature_of<tag::relative_weighted_tail_variate_means< LeftRight, VariateType, VariateTag >>

boost::accumulators::feature_of<tag::relative_weighted_tail_variate_means< LeftRight, VariateType, VariateTag >>

Synopsis

```
// In header: <boost/accumulators/statistics/tail_variate_means.hpp>

template<typename LeftRight, typename VariateType, typename VariateTag>
struct feature_of<tag::relative_weighted_tail_variate_means< LeftRight, VariateType, VariateTag >> : public boost::accumulators::feature_of< tag::relative_tail_variate_means< LeftRight, VariateType, VariateTag > >
{
};
```

Header <[boost/accumulators/statistics/times2_iterator.hpp](#)>

Header <[boost/accumulators/statistics/variance.hpp](#)>

```
namespace boost {
  namespace accumulators {
    template<> struct as_feature<tag::variance(lazy)>;
    template<> struct as_feature<tag::variance(immediate)>;
    template<> struct feature_of<tag::lazy_variance>;
    template<> struct as_weighted_feature<tag::variance>;
    template<> struct feature_of<tag::weighted_variance>;
    template<> struct as_weighted_feature<tag::lazy_variance>;
    template<> struct feature_of<tag::lazy_weighted_variance>;
    namespace extract {
      extractor< tag::lazy_variance > const lazy_variance;
      extractor< tag::variance > const variance;
    }
    namespace impl {
    }
    namespace tag {
      struct lazy_variance;
      struct variance;
    }
  }
}
```

Global lazy_variance

boost::accumulators::extract::lazy_variance

Synopsis

```
// In header: <boost/accumulators/statistics/variance.hpp>

extractor< tag::lazy_variance > const lazy_variance;
```

Global variance

boost::accumulators::extract::variance

Synopsis

```
// In header: <boost/accumulators/statistics/variance.hpp>

extractor< tag::variance > const variance;
```

Struct lazy_variance

boost::accumulators::tag::lazy_variance

Synopsis

```
// In header: <boost/accumulators/statistics/variance.hpp>

struct lazy_variance :
    public boost::accumulators::depends_on< moment< 2 >, mean >
{
};
```

Struct variance

boost::accumulators::tag::variance

Synopsis

```
// In header: <boost/accumulators/statistics/variance.hpp>

struct variance :
    public boost::accumulators::depends_on< count, immediate_mean >
{
};
```

Struct as_feature<tag::variance(lazy)>

boost::accumulators::as_feature<tag::variance(lazy)>

Synopsis

```
// In header: <boost/accumulators/statistics/variance.hpp>

struct as_feature<tag::variance(lazy)> {
    // types
    typedef tag::lazy_variance type;
};
```

Struct as_feature<tag::variance(immediate)>

boost::accumulators::as_feature<tag::variance(immediate)>

Synopsis

```
// In header: <boost/accumulators/statistics/variance.hpp>

struct as_feature<tag::variance(immediate)> {
    // types
    typedef tag::variance type;
};
```

Struct feature_of<tag::lazy_variance>

boost::accumulators::feature_of<tag::lazy_variance>

Synopsis

```
// In header: <boost/accumulators/statistics/variance.hpp>

struct feature_of<tag::lazy_variance> : public boost::accumulators::feature_of< tag::variance > {
};
```

Struct as_weighted_feature<tag::variance>

boost::accumulators::as_weighted_feature<tag::variance>

Synopsis

```
// In header: <boost/accumulators/statistics/variance.hpp>

struct as_weighted_feature<tag::variance> {
    // types
    typedef tag::weighted_variance type;
};
```

Struct feature_of<tag::weighted_variance>

boost::accumulators::feature_of<tag::weighted_variance>

Synopsis

```
// In header: <boost/accumulators/statistics/variance.hpp>

struct feature_of<tag::weighted_variance> : public boost::accumulators::feature_of< tag::variance > {
};
```

Struct as_weighted_feature<tag::lazy_variance>

boost::accumulators::as_weighted_feature<tag::lazy_variance>

Synopsis

```
// In header: <boost/accumulators/statistics/variance.hpp>

struct as_weighted_feature<tag::lazy_variance> {
    // types
    typedef tag::lazy_weighted_variance type;
};
```

Struct feature_of<tag::lazy_weighted_variance>

boost::accumulators::feature_of<tag::lazy_weighted_variance>

Synopsis

```
// In header: <boost/accumulators/statistics/variance.hpp>

struct feature_of<tag::lazy_weighted_variance> :
    public boost::accumulators::feature_of< tag::lazy_variance >
{
};
```

Header <boost/accumulators/statistics/variates/covariate.hpp>

```
namespace boost {
    namespace accumulators {
        boost::parameter::keyword< tag::covariate1 > const covariate1;
        boost::parameter::keyword< tag::covariate2 > const covariate2;
        namespace tag {
            struct covariate1;
            struct covariate2;
        }
    }
}
```

Struct covariate1

boost::accumulators::tag::covariate1

Synopsis

```
// In header: <boost/accumulators/statistics/variates/covariate.hpp>

struct covariate1 {
};
```

Struct covariate2

boost::accumulators::tag::covariate2

Synopsis

```
// In header: <boost/accumulators/statistics/variates/covariate.hpp>

struct covariate2 {
};
```

Global covariate1

boost::accumulators::covariate1

Synopsis

```
// In header: <boost/accumulators/statistics/variates/covariate.hpp>

boost::parameter::keyword< tag::covariate1 > const covariate1;
```

Global covariate2

boost::accumulators::covariate2

Synopsis

```
// In header: <boost/accumulators/statistics/variates/covariate.hpp>

boost::parameter::keyword< tag::covariate2 > const covariate2;
```

Header <boost/accumulators/statistics/weighted_covariance.hpp>

Global weighted_covariance

boost::accumulators::extract::weighted_covariance

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_covariance.hpp>

extractor< tag::abstract_covariance > const weighted_covariance;
```


Header `<boost/accumulators/statistics/weighted_density.hpp>`

```
namespace boost {
  namespace accumulators {
    namespace extract {
      extractor< tag::density > const weighted_density;
    }
    namespace impl {
    }
    namespace tag {
      struct weighted_density;
    }
  }
}
```

Global `weighted_density`

`boost::accumulators::extract::weighted_density`

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_density.hpp>

extractor< tag::density > const weighted_density;
```

Struct `weighted_density`

`boost::accumulators::tag::weighted_density`

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_density.hpp>

struct weighted_density : public boost::accumulators::depends_on< count, sum_of_weights, min, max >,
                          public density_cache_size,
                          public density_num_bins
{
    // public data members
    static boost::parameter::keyword< density_cache_size > const cache_size;
    static boost::parameter::keyword< density_num_bins > const num_bins;
};
```

Header `<boost/accumulators/statistics/weighted_extended_p_square.hpp>`

```
namespace boost {
    namespace accumulators {
        namespace extract {
            extractor< tag::weighted_extended_p_square > const weighted_extended_p_square;
        }
        namespace impl {
        }
        namespace tag {
            struct weighted_extended_p_square;
        }
    }
}
```

Global `weighted_extended_p_square`

`boost::accumulators::extract::weighted_extended_p_square`

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_extended_p_square.hpp>

extractor< tag::weighted_extended_p_square > const weighted_extended_p_square;
```

Struct `weighted_extended_p_square`

`boost::accumulators::tag::weighted_extended_p_square`

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_extended_p_square.hpp>

struct weighted_extended_p_square : public boost::accumulators::depends_on< count, sum_of_weights >,
                                   public extended_p_square_probabilities
{
    // types
    typedef accumulators::impl::weighted_extended_p_square_impl< mpl::_1, mpl::_2 > impl;
};
```

Header `<boost/accumulators/statistics/weighted_kurtosis.hpp>`

```
namespace boost {
  namespace accumulators {
    namespace extract {
      extractor< tag::weighted_kurtosis > const weighted_kurtosis;
    }
    namespace impl {
    }
    namespace tag {
      struct weighted_kurtosis;
    }
  }
}
```

Global `weighted_kurtosis`

`boost::accumulators::extract::weighted_kurtosis`

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_kurtosis.hpp>

extractor< tag::weighted_kurtosis > const weighted_kurtosis;
```

Struct `weighted_kurtosis`

`boost::accumulators::tag::weighted_kurtosis`

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_kurtosis.hpp>

struct weighted_kurtosis : public boost::accumulators::depends_on< weighted_mean, weighted_moment< 2 >, weighted_moment< 3 >, weighted_moment< 4 > >
{
};
```

Header `<boost/accumulators/statistics/weighted_mean.hpp>`

```
namespace boost {
  namespace accumulators {
    template<> struct as_feature<tag::weighted_mean(lazy)>;
    template<> struct as_feature<tag::weighted_mean(immediate)>;
    template<typename VariateType, typename VariateTag>
      struct as_feature<tag::weighted_mean_of_variates< VariateType, VariateTag >(lazy)>;
    template<typename VariateType, typename VariateTag>
      struct as_feature<tag::weighted_mean_of_variates< VariateType, VariateTag >(immediate)>;
    namespace extract {
      extractor< tag::mean > const weighted_mean;
    }
    namespace impl {
    }
    namespace tag {
      struct weighted_mean;
      struct immediate_weighted_mean;
    }
  }
}
```

Global `weighted_mean`

`boost::accumulators::extract::weighted_mean`

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_mean.hpp>

extractor< tag::mean > const weighted_mean;
```

Struct `weighted_mean`

`boost::accumulators::tag::weighted_mean`

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_mean.hpp>

struct weighted_mean :
  public boost::accumulators::depends_on< sum_of_weights, weighted_sum >
{
};
```

Struct `immediate_weighted_mean`

`boost::accumulators::tag::immediate_weighted_mean`

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_mean.hpp>

struct immediate_weighted_mean :
    public boost::accumulators::depends_on< sum_of_weights >
{
};
```

Struct `as_feature<tag::weighted_mean(lazy)>`

`boost::accumulators::as_feature<tag::weighted_mean(lazy)>`

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_mean.hpp>

struct as_feature<tag::weighted_mean(lazy)> {
    // types
    typedef tag::weighted_mean type;
};
```

Struct `as_feature<tag::weighted_mean(immediate)>`

`boost::accumulators::as_feature<tag::weighted_mean(immediate)>`

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_mean.hpp>

struct as_feature<tag::weighted_mean(immediate)> {
    // types
    typedef tag::immediate_weighted_mean type;
};
```

Struct template `as_feature<tag::weighted_mean_of_variates<VariateType,VariateTag>(lazy)>`

`boost::accumulators::as_feature<tag::weighted_mean_of_variates<VariateType,VariateTag>(lazy)>`

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_mean.hpp>

template<typename VariateType, typename VariateTag>
struct as_feature<tag::weighted_mean_of_variates< VariateType, VariateTag >(lazy)> {
    // types
    typedef tag::weighted_mean_of_variates< VariateType, VariateTag > type;
};
```

Struct template `as_feature<tag::weighted_mean_of_variates< VariateType, VariateTag >(immediate)>`

`boost::accumulators::as_feature<tag::weighted_mean_of_variates< VariateType, VariateTag >(immediate)>`

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_mean.hpp>

template<typename VariateType, typename VariateTag>
struct as_feature<tag::weighted_mean_of_variates< VariateType, VariateTag >(immediate)> {
    // types
    typedef tag::immediate_weighted_mean_of_variates< VariateType, VariateTag > type;
};
```

Header `<boost/accumulators/statistics/weighted_median.hpp>`

```
namespace boost {
    namespace accumulators {
        template<> struct as_feature<tag::weighted_median(with_p_square_quantile)>;
        template<> struct as_feature<tag::weighted_median(with_density)>;
        template<>
            struct as_feature<tag::weighted_median(with_p_square_cumulative_distribution)>;
        namespace extract {
            extractor< tag::median > const weighted_median;
        }
        namespace impl {
        }
        namespace tag {
            struct weighted_median;
            struct with_density_weighted_median;
            struct with_p_square_cumulative_distribution_weighted_median;
        }
    }
}
```

Global `weighted_median`

`boost::accumulators::extract::weighted_median`

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_median.hpp>

extractor< tag::median > const weighted_median;
```

Struct `weighted_median`

`boost::accumulators::tag::weighted_median`

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_median.hpp>

struct weighted_median : public boost::accumulators::depends_on< weighted_p_square_quantile_for_med
dian >
{
};
```

Struct with_density_weighted_median

boost::accumulators::tag::with_density_weighted_median

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_median.hpp>

struct with_density_weighted_median :
    public boost::accumulators::depends_on< count, weighted_density >
{
};
```

Struct with_p_square_cumulative_distribution_weighted_median

boost::accumulators::tag::with_p_square_cumulative_distribution_weighted_median

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_median.hpp>

struct with_p_square_cumulative_distribution_weighted_median : public boost::accumulators::de
pend_s_on< weighted_p_square_cumulative_distribution >
{
};
```

Struct as_feature<tag::weighted_median(with_p_square_quantile)>

boost::accumulators::as_feature<tag::weighted_median(with_p_square_quantile)>

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_median.hpp>

struct as_feature<tag::weighted_median(with_p_square_quantile)> {
    // types
    typedef tag::weighted_median type;
};
```

Struct `as_feature<tag::weighted_median(with_density)>``boost::accumulators::as_feature<tag::weighted_median(with_density)>`**Synopsis**

```
// In header: <boost/accumulators/statistics/weighted_median.hpp>

struct as_feature<tag::weighted_median(with_density)> {
    // types
    typedef tag::with_density_weighted_median type;
};
```

Struct `as_feature<tag::weighted_median(with_p_square_cumulative_distribution)>``boost::accumulators::as_feature<tag::weighted_median(with_p_square_cumulative_distribution)>`**Synopsis**

```
// In header: <boost/accumulators/statistics/weighted_median.hpp>

struct as_feature<tag::weighted_median(with_p_square_cumulative_distribution)> {
    // types
    typedef tag::with_p_square_cumulative_distribution_weighted_median type;
};
```

Header `<boost/accumulators/statistics/weighted_moment.hpp>`**Header `<boost/accumulators/statistics/weighted_p_square_cumul_dist.hpp>`**

```
namespace boost {
    namespace accumulators {
        namespace extract {
            extractor< tag::weighted_p_square_cumulative_distribution > const weighted_p_square_cumulative_distribution;
        }
        namespace impl {
        }
        namespace tag {
            struct weighted_p_square_cumulative_distribution;
        }
    }
}
```

Global `weighted_p_square_cumulative_distribution``boost::accumulators::extract::weighted_p_square_cumulative_distribution`

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_p_square_cumul_dist.hpp>

extractor< tag::weighted_p_square_cumulative_distribution > const weighted_p_square_cumulative_distribution;
```

Struct `weighted_p_square_cumulative_distribution`

`boost::accumulators::tag::weighted_p_square_cumulative_distribution`

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_p_square_cumul_dist.hpp>

struct weighted_p_square_cumulative_distribution : public boost::accumulators::depends_on< count, sum_of_weights >,
                                                    public p_square_cumulative_distribution_num_cells
{
    // types
    typedef accumulators::impl::weighted_p_square_cumulative_distribution_impl< mpl::_1, mpl::_2 > impl;
};
```

Header `<boost/accumulators/statistics/weighted_p_square_quantile.hpp>`

```
namespace boost {
    namespace accumulators {
        namespace extract {
            extractor< tag::weighted_p_square_quantile > const weighted_p_square_quantile;
            extractor< tag::weighted_p_square_quantile_for_median > const weighted_p_square_quantile_for_median;
        }
        namespace impl {
        }
        namespace tag {
            struct weighted_p_square_quantile;
            struct weighted_p_square_quantile_for_median;
        }
    }
}
```

Global `weighted_p_square_quantile`

`boost::accumulators::extract::weighted_p_square_quantile`

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_p_square_quantile.hpp>

extractor< tag::weighted_p_square_quantile > const weighted_p_square_quantile;
```

Global weighted_p_square_quantile_for_median

boost::accumulators::extract::weighted_p_square_quantile_for_median

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_p_square_quantile.hpp>

extractor< tag::weighted_p_square_quantile_for_median > const weighted_p_square_quantile_for_me-
dian;
```

Struct weighted_p_square_quantile

boost::accumulators::tag::weighted_p_square_quantile

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_p_square_quantile.hpp>

struct weighted_p_square_quantile :
    public boost::accumulators::depends_on< count, sum_of_weights >
{
    // types
    typedef accumulators::impl::weighted_p_square_quantile_impl< mpl::_1, mpl::_2, regular > impl;
};
```

Struct weighted_p_square_quantile_for_median

boost::accumulators::tag::weighted_p_square_quantile_for_median

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_p_square_quantile.hpp>

struct weighted_p_square_quantile_for_median :
    public boost::accumulators::depends_on< count, sum_of_weights >
{
    // types
    typedef accumulators::impl::weighted_p_square_quantile_impl< mpl::_1, mpl::_2, for_median > impl;
};
```

Header <[boost/accumulators/statistics/weighted_peaks_over_threshold.hpp](#)>

```
namespace boost {
  namespace accumulators {
    template<typename LeftRight>
      struct as_feature<tag::weighted_peaks_over_threshold< LeftRight >(with_threshold_value)>;
    template<typename LeftRight>
      struct as_feature<tag::weighted_peaks_over_threshold< LeftRight >(with_threshold_probabil-
ity)>;
    namespace extract {
      extractor< tag::abstract_peaks_over_threshold > const weighted_peaks_over_threshold;
    }
    namespace impl {
    }
    namespace tag {
    }
  }
}
```

Global weighted_peaks_over_threshold

boost::accumulators::extract::weighted_peaks_over_threshold

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_peaks_over_threshold.hpp>

extractor< tag::abstract_peaks_over_threshold > const weighted_peaks_over_threshold;
```

Struct **template** **as_feature<tag::weighted_peaks_over_threshold<** **LeftRight**
>(with_threshold_value)>

boost::accumulators::as_feature<tag::weighted_peaks_over_threshold< LeftRight >(with_threshold_value)>

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_peaks_over_threshold.hpp>

template<typename LeftRight>
struct as_feature<tag::weighted_peaks_over_threshold< LeftRight >(with_threshold_value)> {
  // types
  typedef tag::weighted_peaks_over_threshold< LeftRight > type;
};
```

Struct **template** **as_feature<tag::weighted_peaks_over_threshold<** **LeftRight**
>(with_threshold_probability)>

boost::accumulators::as_feature<tag::weighted_peaks_over_threshold< LeftRight >(with_threshold_probability)>

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_peaks_over_threshold.hpp>

template<typename LeftRight>
struct as_feature<tag::weighted_peaks_over_threshold< LeftRight >(with_threshold_probability)> {
    // types
    typedef tag::weighted_peaks_over_threshold_prob< LeftRight > type;
};
```

Header **<boost/accumulators/statistics/weighted_skewness.hpp>**

```
namespace boost {
    namespace accumulators {
        namespace extract {
            extractor< tag::weighted_skewness > const weighted_skewness;
        }
        namespace impl {
        }
        namespace tag {
            struct weighted_skewness;
        }
    }
}
```

Global weighted_skewness

boost::accumulators::extract::weighted_skewness

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_skewness.hpp>

extractor< tag::weighted_skewness > const weighted_skewness;
```

Struct weighted_skewness

boost::accumulators::tag::weighted_skewness

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_skewness.hpp>

struct weighted_skewness : public boost::accumulators::depends_on< weighted_mean, weighted_moment< 2 >, weighted_moment< 3 > >
{
};
```

Header `<boost/accumulators/statistics/weighted_sum.hpp>`

```
namespace boost {
  namespace accumulators {
    template<typename VariateType, typename VariateTag>
      struct feature_of<tag::weighted_sum_of_variates< VariateType, VariateTag >>;
    namespace extract {
      extractor< tag::weighted_sum > const weighted_sum;
      extractor< tag::abstract_weighted_sum_of_variates > const weighted_sum_of_variates;
    }
    namespace impl {
    }
    namespace tag {
      struct weighted_sum;
      struct abstract_weighted_sum_of_variates;
    }
  }
}
```

Global `weighted_sum`

`boost::accumulators::extract::weighted_sum`

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_sum.hpp>

extractor< tag::weighted_sum > const weighted_sum;
```

Global `weighted_sum_of_variates`

`boost::accumulators::extract::weighted_sum_of_variates`

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_sum.hpp>

extractor< tag::abstract_weighted_sum_of_variates > const weighted_sum_of_variates;
```

Struct `weighted_sum`

`boost::accumulators::tag::weighted_sum`

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_sum.hpp>

struct weighted_sum : public boost::accumulators::depends_on<> {
};
```

Struct `abstract_weighted_sum_of_variates`

`boost::accumulators::tag::abstract_weighted_sum_of_variates`

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_sum.hpp>

struct abstract_weighted_sum_of_variates :
    public boost::accumulators::depends_on<>
{
};
```

Struct template `feature_of<tag::weighted_sum_of_variates< VariateType, VariateTag >>`

`boost::accumulators::feature_of<tag::weighted_sum_of_variates< VariateType, VariateTag >>`

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_sum.hpp>

template<typename VariateType, typename VariateTag>
struct feature_of<tag::weighted_sum_of_variates< VariateType, VariateTag >> : public boost::ac-
cumulators::feature_of< tag::abstract_weighted_sum_of_variates >
{
};
```

Header `<boost/accumulators/statistics/weighted_sum_kahan.hpp>`

```
namespace boost {
    namespace accumulators {
        template<> struct as_feature<tag::weighted_sum(kahan)>;
        template<typename VariateType, typename VariateTag>
            struct feature_of<tag::weighted_sum_of_variates_kahan< VariateType, VariateTag >>;
        namespace extract {
            extractor< tag::weighted_sum_kahan > const weighted_sum_kahan;
            extractor< tag::abstract_weighted_sum_of_variates > const weighted_sum_of_variates_kahan;
        }
        namespace impl {
        }
        namespace tag {
            struct weighted_sum_kahan;
            template<typename VariateType, typename VariateTag>
                struct weighted_sum_of_variates_kahan;
        }
    }
}
```

Global `weighted_sum_kahan`

`boost::accumulators::extract::weighted_sum_kahan`

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_sum_kahan.hpp>

extractor< tag::weighted_sum_kahan > const weighted_sum_kahan;
```

Global weighted_sum_of_variates_kahan

boost::accumulators::extract::weighted_sum_of_variates_kahan

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_sum_kahan.hpp>

extractor< tag::abstract_weighted_sum_of_variates > const weighted_sum_of_variates_kahan;
```

Struct weighted_sum_kahan

boost::accumulators::tag::weighted_sum_kahan

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_sum_kahan.hpp>

struct weighted_sum_kahan : public boost::accumulators::depends_on<> {
};
```

Struct template weighted_sum_of_variates_kahan

boost::accumulators::tag::weighted_sum_of_variates_kahan

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_sum_kahan.hpp>

template<typename VariateType, typename VariateTag>
struct weighted_sum_of_variates_kahan :
    public boost::accumulators::depends_on<>
{
};
```

Struct as_feature<tag::weighted_sum(kahan)>

boost::accumulators::as_feature<tag::weighted_sum(kahan)>

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_sum_kahan.hpp>

struct as_feature<tag::weighted_sum(kahan)> {
    // types
    typedef tag::weighted_sum_kahan type;
};
```

Struct template feature_of<tag::weighted_sum_of_variates_kahan< VariateType, VariateTag >>

boost::accumulators::feature_of<tag::weighted_sum_of_variates_kahan< VariateType, VariateTag >>

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_sum_kahan.hpp>

template<typename VariateType, typename VariateTag>
struct feature_of<tag::weighted_sum_of_variates_kahan< VariateType, VariateTag >> : public
    boost::accumulators::feature_of< tag::abstract_weighted_sum_of_variates >
{
};
```

Header <boost/accumulators/statistics/weighted_tail_mean.hpp>

Global non_coherent_weighted_tail_mean

boost::accumulators::extract::non_coherent_weighted_tail_mean

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_tail_mean.hpp>

extractor< tag::abstract_non_coherent_tail_mean > const non_coherent_weighted_tail_mean;
```

Header <boost/accumulators/statistics/weighted_tail_quantile.hpp>

Global weighted_tail_quantile

boost::accumulators::extract::weighted_tail_quantile

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_tail_quantile.hpp>

extractor< tag::quantile > const weighted_tail_quantile;
```


Header `<boost/accumulators/statistics/weighted_tail_variate_means.hpp>`

```
namespace boost {
    namespace accumulators {
        template<typename LeftRight, typename VariateType, typename VariateTag>
        struct as_feature<tag::weighted_tail_variate_means< LeftRight, VariateType, VariateTag >(absolute)>;
        template<typename LeftRight, typename VariateType, typename VariateTag>
        struct as_feature<tag::weighted_tail_variate_means< LeftRight, VariateType, VariateTag >(relative)>;
        namespace extract {
            extractor< tag::abstract_absolute_tail_variate_means > const weighted_tail_variate_means;
            extractor< tag::abstract_relative_tail_variate_means > const relative_weighted_tail_variate_means;
        }
        namespace impl {
        }
        namespace tag {
        }
    }
    namespace numeric {
        namespace functional {
            template<typename T, typename U> struct multiply_and_promote_to_double;
        }
    }
}
```

Global `weighted_tail_variate_means`

`boost::accumulators::extract::weighted_tail_variate_means`

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_tail_variate_means.hpp>

extractor< tag::abstract_absolute_tail_variate_means > const weighted_tail_variate_means;
```

Global `relative_weighted_tail_variate_means`

`boost::accumulators::extract::relative_weighted_tail_variate_means`

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_tail_variate_means.hpp>

extractor< tag::abstract_relative_tail_variate_means > const relative_weighted_tail_variate_means;
```

Struct `template as_feature<tag::weighted_tail_variate_means< LeftRight, VariateType, VariateTag >(absolute)>`

`boost::accumulators::as_feature<tag::weighted_tail_variate_means< LeftRight, VariateType, VariateTag >(absolute)>`

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_tail_variate_means.hpp>

template<typename LeftRight, typename VariateType, typename VariateTag>
struct as_feature<tag::weighted_tail_variate_means< LeftRight, VariateType, VariateTag >(absolute)> {
    // types
    typedef tag::absolute_weighted_tail_variate_means< LeftRight, VariateType, VariateTag > type;
};
```

Struct template as_feature<tag::weighted_tail_variate_means< LeftRight, VariateType, VariateTag >(relative)>

boost::accumulators::as_feature<tag::weighted_tail_variate_means< LeftRight, VariateType, VariateTag >(relative)>

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_tail_variate_means.hpp>

template<typename LeftRight, typename VariateType, typename VariateTag>
struct as_feature<tag::weighted_tail_variate_means< LeftRight, VariateType, VariateTag >(relative)> {
    // types
    typedef tag::relative_weighted_tail_variate_means< LeftRight, VariateType, VariateTag > type;
};
```

Struct template multiply_and_promote_to_double

boost::numeric::functional::multiply_and_promote_to_double

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_tail_variate_means.hpp>

template<typename T, typename U>
struct multiply_and_promote_to_double :
    public functional::multiplies< T, double const >
{
};
```

Header `<boost/accumulators/statistics/weighted_variance.hpp>`

```
namespace boost {
  namespace accumulators {
    template<> struct as_feature<tag::weighted_variance(lazy)>;
    template<> struct as_feature<tag::weighted_variance(immediate)>;
    namespace extract {
      extractor< tag::lazy_weighted_variance > const lazy_weighted_variance;
      extractor< tag::weighted_variance > const weighted_variance;
    }
    namespace impl {
    }
    namespace tag {
      struct lazy_weighted_variance;
      struct weighted_variance;
    }
  }
}
```

Global lazy_weighted_variance

boost::accumulators::extract::lazy_weighted_variance

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_variance.hpp>

extractor< tag::lazy_weighted_variance > const lazy_weighted_variance;
```

Global weighted_variance

boost::accumulators::extract::weighted_variance

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_variance.hpp>

extractor< tag::weighted_variance > const weighted_variance;
```

Struct lazy_weighted_variance

boost::accumulators::tag::lazy_weighted_variance

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_variance.hpp>

struct lazy_weighted_variance : public boost::accumulators::depends_on< weighted_moment< 2 >, lazy_weighted_mean >
{
};
```

Struct `weighted_variance`

`boost::accumulators::tag::weighted_variance`

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_variance.hpp>

struct weighted_variance :
    public boost::accumulators::depends_on< count, immediate_weighted_mean >
{
};
```

Struct `as_feature<tag::weighted_variance(lazy)>`

`boost::accumulators::as_feature<tag::weighted_variance(lazy)>`

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_variance.hpp>

struct as_feature<tag::weighted_variance(lazy)> {
    // types
    typedef tag::lazy_weighted_variance type;
};
```

Struct `as_feature<tag::weighted_variance(immediate)>`

`boost::accumulators::as_feature<tag::weighted_variance(immediate)>`

Synopsis

```
// In header: <boost/accumulators/statistics/weighted_variance.hpp>

struct as_feature<tag::weighted_variance(immediate)> {
    // types
    typedef tag::weighted_variance type;
};
```

Header <boost/accumulators/statistics/with_error.hpp>**Header <boost/accumulators/statistics_fwd.hpp>**

```
namespace boost {
    namespace accumulators {
        template<BOOST_PP_ENUM_PARAMS_WITH_A_DEFAULT(BOOST_ACCUMULATORS_MAX_FEATURES, typename Feature, mpl::na) >
            struct stats;
        template<BOOST_PP_ENUM_PARAMS_WITH_A_DEFAULT(BOOST_ACCUMULATORS_MAX_FEATURES, typename Feature, mpl::na) >
            struct with_error;
        struct lazy;
        struct immediate;
        struct right;
        struct left;
        struct absolute;
        struct relative;
        struct with_density;
        struct with_p_square_cumulative_distribution;
        struct with_p_square_quantile;
        struct with_threshold_value;
        struct with_threshold_probability;
        struct weighted;
        struct unweighted;
        struct linear;
        struct quadratic;
        struct regular;
        struct for_median;
        struct kahan;
    }
    namespace extract {
        extractor< tag::quantile > const quantile;
        extractor< tag::tail_mean > const tail_mean;
    }
    namespace impl {
        template<typename Sample, typename VariateType, typename VariateTag>
            struct covariance_impl;
        template<typename Sample> struct density_impl;
        template<typename Sample, typename Variance> struct error_of_mean_impl;
        template<typename Sample> struct extended_p_square_impl;
        template<typename Sample, typename Impl1, typename Impl2>
            struct extended_p_square_quantile_impl;
        template<typename Sample> struct kurtosis_impl;
        template<typename Sample> struct max_impl;
        template<typename Sample> struct median_impl;
        template<typename Sample> struct with_density_median_impl;
        template<typename Sample>
            struct with_p_square_cumulative_distribution_median_impl;
        template<typename Sample> struct min_impl;
        template<typename Sample, typename SumFeature = tag::sum> struct mean_impl;
        template<typename Sample, typename Tag = tag::sample>
            struct immediate_mean_impl;
        template<typename N, typename Sample> struct moment_impl;
        template<typename Sample, typename LeftRight>
            struct peaks_over_threshold_prob_impl;
        template<typename Sample, typename Impl, typename LeftRight>
            struct pot_quantile_impl;
        template<typename Sample, typename Impl, typename LeftRight>
            struct pot_tail_mean_impl;
        template<typename Sample> struct p_square_cumulative_distribution_impl;
        template<typename Sample, typename Impl> struct p_square_quantile_impl;
        template<typename Sample> struct skewness_impl;
    }
}
```

```
template<typename Sample, typename Tag = tag::sample> struct sum_impl;
template<typename Sample, typename Tag> struct sum_kahan_impl;
template<typename Sample, typename LeftRight> struct tail_impl;
template<typename Sample, typename LeftRight>
    struct coherent_tail_mean_impl;
template<typename Sample, typename LeftRight>
    struct non_coherent_tail_mean_impl;
template<typename Sample, typename LeftRight> struct tail_quantile_impl;
template<typename VariateType, typename VariateTag, typename LeftRight>
    struct tail_variate_impl;
template<typename Sample, typename Impl, typename LeftRight,
    typename VariateTag>
    struct tail_variate_means_impl;
template<typename Sample, typename MeanFeature> struct lazy_variance_impl;
template<typename Sample, typename MeanFeature, typename Tag>
    struct variance_impl;
template<typename Sample, typename Weight, typename VariateType,
    typename VariateTag>
    struct weighted_covariance_impl;
template<typename Sample, typename Weight> struct weighted_density_impl;
template<typename Sample, typename Weight> struct weighted_kurtosis_impl;
template<typename Sample> struct weighted_median_impl;
template<typename Sample> struct with_density_weighted_median_impl;
template<typename Sample, typename Weight>
    struct with_p_square_cumulative_distribution_weighted_median_impl;
template<typename Sample, typename Weight, typename Tag>
    struct weighted_mean_impl;
template<typename Sample, typename Weight, typename Tag>
    struct immediate_weighted_mean_impl;
template<typename Sample, typename Weight, typename LeftRight>
    struct weighted_peaks_over_threshold_impl;
template<typename Sample, typename Weight, typename LeftRight>
    struct weighted_peaks_over_threshold_prob_impl;
template<typename Sample, typename Weight>
    struct weighted_extended_p_square_impl;
template<typename N, typename Sample, typename Weight>
    struct weighted_moment_impl;
template<typename Sample, typename Weight>
    struct weighted_p_square_cumulative_distribution_impl;
template<typename Sample, typename Weight, typename Impl>
    struct weighted_p_square_quantile_impl;
template<typename Sample, typename Weight> struct weighted_skewness_impl;
template<typename Sample, typename Weight, typename Tag>
    struct weighted_sum_impl;
template<typename Sample, typename Weight, typename Tag>
    struct weighted_sum_kahan_impl;
template<typename Sample, typename Weight, typename LeftRight>
    struct non_coherent_weighted_tail_mean_impl;
template<typename Sample, typename Weight, typename LeftRight>
    struct weighted_tail_quantile_impl;
template<typename Sample, typename Weight, typename Impl,
    typename LeftRight, typename VariateType>
    struct weighted_tail_variate_means_impl;
template<typename Sample, typename Weight, typename MeanFeature>
    struct lazy_weighted_variance_impl;
template<typename Sample, typename Weight, typename MeanFeature,
    typename Tag>
    struct weighted_variance_impl;
template<typename Sample> struct rolling_window_plus1_impl;
template<typename Sample> struct rolling_window_impl;
template<typename Sample> struct rolling_sum_impl;
template<typename Sample> struct rolling_count_impl;
template<typename Sample> struct rolling_mean_impl;
```

```

}
namespace tag {
    struct quantile;
    struct tail_mean;
    template<typename VariateType, typename VariateTag> struct covariance;
    template<typename Feature> struct error_of;
    template<typename VariateType, typename VariateTag> struct mean_of_variates;
    template<typename VariateType, typename VariateTag>
        struct immediate_mean_of_variates;
    template<int N> struct moment;
    template<typename LeftRight> struct peaks_over_threshold;
    template<typename LeftRight> struct peaks_over_threshold_prob;
    template<typename LeftRight> struct pot_tail_mean;
    template<typename LeftRight> struct pot_tail_mean_prob;
    template<typename LeftRight> struct pot_quantile;
    template<typename LeftRight> struct pot_quantile_prob;
    template<typename VariateType, typename VariateTag> struct sum_of_variates;
    template<typename VariateType, typename VariateTag>
        struct sum_of_variates_kahan;
    template<typename LeftRight> struct tail;
    template<typename LeftRight> struct coherent_tail_mean;
    template<typename LeftRight> struct non_coherent_tail_mean;
    template<typename LeftRight> struct tail_quantile;
    template<typename VariateType, typename VariateTag, typename LeftRight>
        struct tail_variate;
    template<typename LeftRight> struct tail_weights;
    template<typename VariateType, typename VariateTag, typename LeftRight>
        struct right_tail_variate;
    template<typename VariateType, typename VariateTag, typename LeftRight>
        struct left_tail_variate;
    template<typename LeftRight, typename VariateType, typename VariateTag>
        struct tail_variate_means;
    template<typename LeftRight, typename VariateType, typename VariateTag>
        struct absolute_tail_variate_means;
    template<typename LeftRight, typename VariateType, typename VariateTag>
        struct relative_tail_variate_means;
    template<typename VariateType, typename VariateTag>
        struct weighted_covariance;
    template<typename VariateType, typename VariateTag>
        struct weighted_mean_of_variates;
    template<typename VariateType, typename VariateTag>
        struct immediate_weighted_mean_of_variates;
    template<int N> struct weighted_moment;
    template<typename LeftRight> struct weighted_peaks_over_threshold;
    template<typename LeftRight> struct weighted_peaks_over_threshold_prob;
    template<typename LeftRight> struct weighted_pot_quantile;
    template<typename LeftRight> struct weighted_pot_quantile_prob;
    template<typename LeftRight> struct weighted_pot_tail_mean;
    template<typename LeftRight> struct weighted_pot_tail_mean_prob;
    template<typename LeftRight> struct weighted_tail_quantile;
    template<typename LeftRight> struct non_coherent_weighted_tail_mean;
    template<typename LeftRight, typename VariateType, typename VariateTag>
        struct weighted_tail_variate_means;
    template<typename LeftRight, typename VariateType, typename VariateTag>
        struct absolute_weighted_tail_variate_means;
    template<typename LeftRight, typename VariateType, typename VariateTag>
        struct relative_weighted_tail_variate_means;
    template<typename VariateType, typename VariateTag>
        struct weighted_sum_of_variates;
}
}
}

```

Global quantile

boost::accumulators::extract::quantile

Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

extractor< tag::quantile > const quantile;
```

Global tail_mean

boost::accumulators::extract::tail_mean

Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

extractor< tag::tail_mean > const tail_mean;
```

Struct template covariance_impl

boost::accumulators::impl::covariance_impl — Covariance Estimator.

Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename VariateType, typename VariateTag>
struct covariance_impl : public accumulator_base {
    // construct/copy/destruct
    template<typename Args> covariance_impl(Args const &);

    // public member functions
    template<typename Args> void operator()(Args const &);
    result_type result(dont_care) const;
};
```

Description

An iterative Monte Carlo estimator for the covariance $\text{Cov}(\mathbf{X}, \mathbf{X}')$, where \mathbf{X} is a sample and \mathbf{X}' is a variate, is given by:

Equation 7.

$$\hat{c}_n = \frac{n-1}{n} \hat{c}_{n-1} + \frac{1}{n-1} (X_n - \hat{\mu}_n)(X'_n - \hat{\mu}'_n), \quad n \geq 2, \quad \hat{c}_1 = 0,$$

$\hat{\mu}_n$ and $\hat{\mu}'_n$ being the means of the samples and variates.

covariance_impl public construct/copy/destruct

1.

```
template<typename Args> covariance_impl(Args const & args);
```


covariance_impl public member functions

1.

```
template<typename Args> void operator()(Args const & args);
```
2.

```
result_type result(dont_care) const;
```

Struct template density_impl

boost::accumulators::impl::density_impl — Histogram density estimator.

Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample>
struct density_impl : public accumulator_base {
    // construct/copy/destroy
    template<typename Args> density_impl(Args const &);

    // public member functions
    template<typename Args> void operator()(Args const &);
    template<typename Args> result_type result(Args const &) const;
};
```

Description

The histogram density estimator returns a histogram of the sample distribution. The positions and sizes of the bins are determined using a specifiable number of cached samples (`cache_size`). The range between the minimum and the maximum of the cached samples is subdivided into a specifiable number of bins (`num_bins`) of same size. Additionally, an under- and an overflow bin is added to capture future under- and overflow samples. Once the bins are determined, the cached samples and all subsequent samples are added to the correct bins. At the end, a range of `std::pair` is return, where each pair contains the position of the bin (lower bound) and the samples count (normalized with the total number of samples).

density_impl public construct/copy/destroy

1.

```
template<typename Args> density_impl(Args const & args);
```

density_impl public member functions

1.

```
template<typename Args> void operator()(Args const & args);
```
2.

```
template<typename Args> result_type result(Args const & args) const;
```

Requires: The number of samples must meet or exceed the cache size

Struct template error_of_mean_impl

boost::accumulators::impl::error_of_mean_impl

Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename Variance>
struct error_of_mean_impl : public accumulator_base {
    // construct/copy/destruct
    error_of_mean_impl(dont_care);

    // public member functions
    template<typename Args> result_type result(Args const &) const;
};
```

Description

error_of_mean_impl public construct/copy/destruct

1. `error_of_mean_impl(dont_care);`

error_of_mean_impl public member functions

1. `template<typename Args> result_type result(Args const & args) const;`

Struct template `extended_p_square_impl`

`boost::accumulators::impl::extended_p_square_impl` — Multiple quantile estimation with the extended P^2 algorithm.

Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample>
struct extended_p_square_impl : public accumulator_base {
    // construct/copy/destruct
    template<typename Args> extended_p_square_impl(Args const &);

    // public member functions
    template<typename Args> void operator()(Args const &);
    result_type result(dont_care) const;
};
```

Description

Extended P^2 algorithm for estimation of several quantiles without storing samples. Assume that m quantiles $\xi_{p_1}, \dots, \xi_{p_m}$ are to be estimated. Instead of storing the whole sample cumulative distribution, the algorithm maintains only $m+2$ principal markers and $m+1$ middle markers, whose positions are updated with each sample and whose heights are adjusted (if necessary) using a piecewise-parabolic formula. The heights of these central markers are the current estimates of the quantiles and returned as an iterator range.

For further details, see

K. E. E. Raatikainen, Simultaneous estimation of several quantiles, *Simulation*, Volume 49, Number 4 (October), 1986, p. 159-164.

The extended P^2 algorithm generalizes the P^2 algorithm of

R. Jain and I. Chlamtac, The P^2 algorithm for dynamic calculation of quantiles and histograms without storing observations, Communications of the ACM, Volume 28 (October), Number 10, 1985, p. 1076-1085.

extended_p_square_impl public construct/copy/destruct

```
1. template<typename Args> extended_p_square_impl(Args const & args);
```

extended_p_square_impl public member functions

```
1. template<typename Args> void operator()(Args const & args);
```

```
2. result_type result(dont_care) const;
```

Struct template extended_p_square_quantile_impl

boost::accumulators::impl::extended_p_square_quantile_impl — Quantile estimation using the extended P^2 algorithm for weighted and unweighted samples.

Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename Impl1, typename Impl2>
struct extended_p_square_quantile_impl : public accumulator_base {
    // construct/copy/destruct
    template<typename Args> extended_p_square_quantile_impl(Args const &);

    // public member functions
    template<typename Args> result_type result(Args const &) const;
};
```

Description

Uses the quantile estimates calculated by the extended P^2 algorithm to compute intermediate quantile estimates by means of quadratic interpolation.

extended_p_square_quantile_impl public construct/copy/destruct

```
1. template<typename Args> extended_p_square_quantile_impl(Args const & args);
```

extended_p_square_quantile_impl public member functions

```
1. template<typename Args> result_type result(Args const & args) const;
```

Struct template kurtosis_impl

boost::accumulators::impl::kurtosis_impl — Kurtosis estimation.

Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample>
struct kurtosis_impl : public accumulator_base {
    // construct/copy/destroy
    kurtosis_impl(dont_care);

    // public member functions
    template<typename Args> result_type result(Args const &) const;
};
```

Description

The kurtosis of a sample distribution is defined as the ratio of the 4th central moment and the square of the 2nd central moment (the variance) of the samples, minus 3. The term -3 is added in order to ensure that the normal distribution has zero kurtosis. The kurtosis can also be expressed by the simple moments:

Equation 8.

$$\hat{g}_2 = \frac{\hat{m}_n^{(4)} - 4\hat{m}_n^{(3)}\hat{\mu}_n + 6\hat{m}_n^{(2)}\hat{\mu}_n^2 - 3\hat{\mu}_n^4}{\left(\hat{m}_n^{(2)} - \hat{\mu}_n^2\right)^2} - 3,$$

where $\hat{m}_n^{(i)}$ are the i -th moment and $\hat{\mu}_n$ the mean (first moment) of the n samples.

kurtosis_impl public construct/copy/destroy

1. `kurtosis_impl(dont_care);`

kurtosis_impl public member functions

1. `template<typename Args> result_type result(Args const & args) const;`

Struct template max_impl

boost::accumulators::impl::max_impl

Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample>
struct max_impl : public accumulator_base {
    // construct/copy/destroy
    template<typename Args> max_impl(Args const &);

    // public member functions
    template<typename Args> void operator()(Args const &);
    result_type result(dont_care) const;
};
```

Description

`max_impl` public construct/copy/destruct

```
1. template<typename Args> max_impl(Args const & args);
```

`max_impl` public member functions

```
1. template<typename Args> void operator()(Args const & args);

2. result_type result(dont_care) const;
```

Struct template `median_impl`

`boost::accumulators::impl::median_impl` — Median estimation based on the P^2 quantile estimator.

Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample>
struct median_impl : public accumulator_base {
    // construct/copy/destruct
    median_impl(dont_care);

    // public member functions
    template<typename Args> result_type result(Args const &) const;
};
```

Description

The P^2 algorithm is invoked with a quantile probability of 0.5.

`median_impl` public construct/copy/destruct

```
1. median_impl(dont_care);
```

`median_impl` public member functions

```
1. template<typename Args> result_type result(Args const & args) const;
```

Struct template with `density_median_impl`

`boost::accumulators::impl::with_density_median_impl` — Median estimation based on the density estimator.

Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample>
struct with_density_median_impl : public accumulator_base {
    // construct/copy/destroy
    template<typename Args> with_density_median_impl(Args const &);

    // public member functions
    void operator()(dont_care);
    template<typename Args> result_type result(Args const &) const;
};
```

Description

The algorithm determines the bin in which the $0.5 * cnt$ -th sample lies, cnt being the total number of samples. It returns the approximate horizontal position of this sample, based on a linear interpolation inside the bin.

`with_density_median_impl` public construct/copy/destroy

1.

```
template<typename Args> with_density_median_impl(Args const & args);
```

`with_density_median_impl` public member functions

1.

```
void operator()(dont_care);
```
2.

```
template<typename Args> result_type result(Args const & args) const;
```

Struct template `with_p_square_cumulative_distribution_median_impl`

`boost::accumulators::impl::with_p_square_cumulative_distribution_median_impl` — Median estimation based on the P^2 cumulative distribution estimator.

Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample>
struct with_p_square_cumulative_distribution_median_impl :
    public accumulator_base
{
    // construct/copy/destroy
    with_p_square_cumulative_distribution_median_impl(dont_care);

    // public member functions
    void operator()(dont_care);
    template<typename Args> result_type result(Args const &) const;
};
```

Description

The algorithm determines the first (leftmost) bin with a height exceeding 0.5. It returns the approximate horizontal position of where the cumulative distribution equals 0.5, based on a linear interpolation inside the bin.

with_p_square_cumulative_distribution_median_impl public construct/copy/destruct

```
1. with_p_square_cumulative_distribution_median_impl(dont_care);
```

with_p_square_cumulative_distribution_median_impl public member functions

```
1. void operator()(dont_care);
```

```
2. template<typename Args> result_type result(Args const & args) const;
```

Struct template min_impl

boost::accumulators::impl::min_impl

Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample>
struct min_impl : public accumulator_base {
    // construct/copy/destruct
    template<typename Args> min_impl(Args const &);

    // public member functions
    template<typename Args> void operator()(Args const &);
    result_type result(dont_care) const;
};
```

Description

min_impl public construct/copy/destruct

```
1. template<typename Args> min_impl(Args const & args);
```

min_impl public member functions

```
1. template<typename Args> void operator()(Args const & args);
```

```
2. result_type result(dont_care) const;
```

Struct template mean_impl

boost::accumulators::impl::mean_impl

Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename SumFeature = tag::sum>
struct mean_impl : public accumulator_base {
    // construct/copy/destroy
    mean_impl(dont_care);

    // public member functions
    template<typename Args> result_type result(Args const &) const;
};
```

Description

mean_impl public construct/copy/destroy

1. `mean_impl(dont_care);`

mean_impl public member functions

1. `template<typename Args> result_type result(Args const & args) const;`

Struct template `immediate_mean_impl`

`boost::accumulators::impl::immediate_mean_impl`

Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename Tag = tag::sample>
struct immediate_mean_impl : public accumulator_base {
    // construct/copy/destroy
    template<typename Args> immediate_mean_impl(Args const &);

    // public member functions
    template<typename Args> void operator()(Args const &);
    result_type result(dont_care) const;
};
```

Description

immediate_mean_impl public construct/copy/destroy

1. `template<typename Args> immediate_mean_impl(Args const & args);`

immediate_mean_impl public member functions

1. `template<typename Args> void operator()(Args const & args);`

2. `result_type result(dont_care) const;`

Struct template `moment_impl`

`boost::accumulators::impl::moment_impl`

Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename N, typename Sample>
struct moment_impl : public accumulator_base {
    // construct/copy/destruct
    template<typename Args> moment_impl(Args const &);

    // public member functions
    BOOST_MPL_ASSERT_RELATION(N::value, 0);
    template<typename Args> void operator()(Args const &);
    template<typename Args> result_type result(Args const &) const;
};
```

Description

`moment_impl` public construct/copy/destruct

1. `template<typename Args> moment_impl(Args const & args);`

`moment_impl` public member functions

1. `BOOST_MPL_ASSERT_RELATION(N::value, 0);`

2. `template<typename Args> void operator()(Args const & args);`

3. `template<typename Args> result_type result(Args const & args) const;`

Struct template `peaks_over_threshold_prob_impl`

`boost::accumulators::impl::peaks_over_threshold_prob_impl` — Peaks over Threshold Method for Quantile and Tail Mean Estimation.

Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename LeftRight>
struct peaks_over_threshold_prob_impl : public accumulator_base {
    // construct/copy/destruct
    template<typename Args> peaks_over_threshold_prob_impl(Args const &);

    // public member functions
    void operator()(dont_care);
    template<typename Args> result_type result(Args const &) const;
};
```

Description

See Also:

[peaks_over_threshold_impl](#)

peaks_over_threshold_prob_impl public construct/copy/destruct

1.

```
template<typename Args> peaks_over_threshold_prob_impl(Args const & args);
```

peaks_over_threshold_prob_impl public member functions

1.

```
void operator()(dont_care);
```
2.

```
template<typename Args> result_type result(Args const & args) const;
```

Struct template pot_quantile_impl

boost::accumulators::impl::pot_quantile_impl — Quantile Estimation based on Peaks over Threshold Method (for both left and right tails)

Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename Impl, typename LeftRight>
struct pot_quantile_impl : public accumulator_base {
    // construct/copy/destruct
    pot_quantile_impl(dont_care);

    // public member functions
    template<typename Args> result_type result(Args const &) const;
};
```

Description

Computes an estimate

Equation 9.

$$\hat{q}_\alpha = \hat{u} + \frac{\hat{\beta}}{\xi} [(1 - \alpha)^{-\xi} - 1]$$

for a right or left extreme quantile, \hat{u} , $\hat{\beta}$ and ξ being the parameters of the generalized Pareto distribution that approximates the right tail of the distribution (or the mirrored left tail, in case the left tail is used). In the latter case, the result is mirrored back, yielding the correct result.

pot_quantile_impl public construct/copy/destruct

```
1. pot_quantile_impl(dont_care);
```

pot_quantile_impl public member functions

```
1. template<typename Args> result_type result(Args const & args) const;
```

Struct template pot_tail_mean_impl

boost::accumulators::impl::pot_tail_mean_impl — Estimation of the (coherent) tail mean based on the peaks over threshold method (for both left and right tails)

Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename Impl, typename LeftRight>
struct pot_tail_mean_impl : public accumulator_base {
    // construct/copy/destruct
    pot_tail_mean_impl(dont_care);

    // public member functions
    template<typename Args> result_type result(Args const &) const;
};
```

Description

Computes an estimate for the (coherent) tail mean

Equation 10.

$$\widehat{CTM}_\alpha = \hat{q}_\alpha - \frac{\hat{\beta}}{\xi - 1} (1 - \alpha)^{-\xi},$$

where \hat{u} , $\hat{\beta}$ and ξ are the parameters of the generalized Pareto distribution that approximates the right tail of the distribution (or the mirrored left tail, in case the left tail is used). In the latter case, the result is mirrored back, yielding the correct result.

pot_tail_mean_impl public construct/copy/destruct

```
1. pot_tail_mean_impl(dont_care);
```

pot_tail_mean_impl public member functions

1.

```
template<typename Args> result_type result(Args const & args) const;
```

Struct template p_square_cumulative_distribution_impl

boost::accumulators::impl::p_square_cumulative_distribution_impl — Histogram calculation of the cumulative distribution with the P^2 algorithm.

Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample>
struct p_square_cumulative_distribution_impl : public accumulator_base {
    // construct/copy/destruct
    template<typename Args> p_square_cumulative_distribution_impl(Args const &);

    // public member functions
    template<typename Args> void operator()(Args const &);
    template<typename Args> result_type result(Args const &) const;
};
```

Description

A histogram of the sample cumulative distribution is computed dynamically without storing samples based on the P^2 algorithm. The returned histogram has a specifiable amount (num_cells) equiprobable (and not equal-sized) cells.

For further details, see

R. Jain and I. Chlamtac, The P^2 algorithm for dynamic calculation of quantiles and histograms without storing observations, Communications of the ACM, Volume 28 (October), Number 10, 1985, p. 1076-1085.

p_square_cumulative_distribution_impl public construct/copy/destruct

1.

```
template<typename Args>
    p_square_cumulative_distribution_impl(Args const & args);
```

p_square_cumulative_distribution_impl public member functions

1.

```
template<typename Args> void operator()(Args const & args);
```
2.

```
template<typename Args> result_type result(Args const & args) const;
```

Struct template p_square_quantile_impl

boost::accumulators::impl::p_square_quantile_impl — Single quantile estimation with the P^2 algorithm.

Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename Impl>
struct p_square_quantile_impl : public accumulator_base {
    // construct/copy/destroy
    template<typename Args> p_square_quantile_impl(Args const &);

    // public member functions
    template<typename Args> void operator()(Args const &);
    result_type result(dont_care) const;
};
```

Description

The P^2 algorithm estimates a quantile dynamically without storing samples. Instead of storing the whole sample cumulative distribution, only five points (markers) are stored. The heights of these markers are the minimum and the maximum of the samples and the current estimates of the $(p/2)$ -, p - and $(1+p)/2$ -quantiles. Their positions are equal to the number of samples that are smaller or equal to the markers. Each time a new samples is recorded, the positions of the markers are updated and if necessary their heights are adjusted using a piecewise- parabolic formula.

For further details, see

R. Jain and I. Chlamtac, The P^2 algorithm for dynamic calculation of quantiles and histograms without storing observations, Communications of the ACM, Volume 28 (October), Number 10, 1985, p. 1076-1085.

p_square_quantile_impl public construct/copy/destroy

```
1. template<typename Args> p_square_quantile_impl(Args const & args);
```

p_square_quantile_impl public member functions

```
1. template<typename Args> void operator()(Args const & args);
```

```
2. result_type result(dont_care) const;
```

Struct template skewness_impl

boost::accumulators::impl::skewness_impl — Skewness estimation.

Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample>
struct skewness_impl : public accumulator_base {
    // construct/copy/destruct
    skewness_impl(dont_care);

    // public member functions
    template<typename Args> result_type result(Args const &) const;
};
```

Description

The skewness of a sample distribution is defined as the ratio of the 3rd central moment and the $3/2$ -th power of the 2nd central moment (the variance) of the samples. The skewness can also be expressed by the simple moments:

Equation 11.

$$\hat{g}_1 = \frac{\hat{m}_n^{(3)} - 3\hat{m}_n^{(2)}\hat{\mu}_n + 2\hat{\mu}_n^3}{\left(\hat{m}_n^{(2)} - \hat{\mu}_n^2\right)^{3/2}}$$

where $\hat{m}_n^{(i)}$ are the i -th moment and $\hat{\mu}_n$ the mean (first moment) of the n samples.

skewness_impl public construct/copy/destruct

1. `skewness_impl(dont_care);`

skewness_impl public member functions

1. `template<typename Args> result_type result(Args const & args) const;`

Struct template sum_impl

boost::accumulators::impl::sum_impl

Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename Tag = tag::sample>
struct sum_impl : public accumulator_base {
    // construct/copy/destruct
    template<typename Args> sum_impl(Args const &);

    // public member functions
    template<typename Args> void operator()(Args const &);
    result_type result(dont_care) const;
};
```

Description

sum_impl public construct/copy/destruct

```
1. template<typename Args> sum_impl(Args const & args);
```

sum_impl public member functions

```
1. template<typename Args> void operator()(Args const & args);

2. result_type result(dont_care) const;
```

Struct template **sum_kahan_impl**

boost::accumulators::impl::sum_kahan_impl

Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename Tag>
struct sum_kahan_impl : public accumulator_base {
    // construct/copy/destruct
    template<typename Args> sum_kahan_impl(Args const &);

    // public member functions
    template<typename Args> void operator()(Args const &);
    result_type result(dont_care) const;
};
```

Description

sum_kahan_impl public construct/copy/destruct

```
1. template<typename Args> sum_kahan_impl(Args const & args);
```

Kahan summation algorithm.

The Kahan summation algorithm reduces the numerical error obtained with standard sequential sum.

sum_kahan_impl public member functions

```
1. template<typename Args> void operator()(Args const & args);

2. result_type result(dont_care) const;
```

Struct template **tail_impl**

boost::accumulators::impl::tail_impl

Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename LeftRight>
struct tail_impl : public accumulator_base {
    // construct/copy/destruct
    template<typename Args> tail_impl(Args const &);
    tail_impl(tail_impl const &);

    // public member functions
    BOOST_MPL_ASSERT((mpl::or_< is_same< LeftRight, right >, is_same< LeftRight, left > >));
    template<typename Args> void operator()(Args const &);
    result_type result(dont_care) const;

    // private member functions
    template<typename Args> void assign(Args const &, std::size_t);
};
```

Description

tail_impl public construct/copy/destruct

1. `template<typename Args> tail_impl(Args const & args);`

2. `tail_impl(tail_impl const & that);`

tail_impl public member functions

1. `BOOST_MPL_ASSERT((mpl::or_< is_same< LeftRight, right >, is_same< LeftRight, left > >));`

2. `template<typename Args> void operator()(Args const & args);`

3. `result_type result(dont_care) const;`

tail_impl private member functions

1. `template<typename Args> void assign(Args const & args, std::size_t index);`

Struct template **coherent_tail_mean_impl**

`boost::accumulators::impl::coherent_tail_mean_impl` — Estimation of the coherent tail mean based on order statistics (for both left and right tails)

Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename LeftRight>
struct coherent_tail_mean_impl : public accumulator_base {
    // construct/copy/destroy
    coherent_tail_mean_impl(dont_care);

    // public member functions
    template<typename Args> result_type result(Args const &) const;
};
```

Description

The coherent tail mean $\widehat{CTM}_{n,\alpha}(X)$ is equal to the non-coherent tail mean $\widehat{NCTM}_{n,\alpha}(X)$ plus a correction term that ensures coherence in case of non-continuous distributions.

Equation 12.

$$\widehat{CTM}_{n,\alpha}^{\text{right}}(X) = \widehat{NCTM}_{n,\alpha}^{\text{right}}(X) + \frac{1}{\lceil n(1-\alpha) \rceil} \hat{q}_{n,\alpha}(X) \left(1 - \alpha - \frac{1}{n} \lceil n(1-\alpha) \rceil \right)$$

Equation 13.

$$\widehat{CTM}_{n,\alpha}^{\text{left}}(X) = \widehat{NCTM}_{n,\alpha}^{\text{left}}(X) + \frac{1}{\lceil n\alpha \rceil} \hat{q}_{n,\alpha}(X) \left(\alpha - \frac{1}{n} \lceil n\alpha \rceil \right)$$

coherent_tail_mean_impl public construct/copy/destroy

```
1. coherent_tail_mean_impl(dont_care);
```

coherent_tail_mean_impl public member functions

```
1. template<typename Args> result_type result(Args const & args) const;
```

Struct template non_coherent_tail_mean_impl

boost::accumulators::impl::non_coherent_tail_mean_impl — Estimation of the (non-coherent) tail mean based on order statistics (for both left and right tails)

Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename LeftRight>
struct non_coherent_tail_mean_impl : public accumulator_base {
    // construct/copy/destroy
    non_coherent_tail_mean_impl(dont_care);

    // public member functions
    template<typename Args> result_type result(Args const &) const;
};
```

Description

An estimation of the non-coherent tail mean $\widehat{NCTM}_{n,\alpha}(X)$ is given by the mean of the $\lceil n\alpha \rceil$ smallest samples (left tail) or the mean of the $\lceil n(1-\alpha) \rceil$ largest samples (right tail), n being the total number of samples and α the quantile level:

Equation 14.

$$\widehat{NCTM}_{n,\alpha}^{\text{right}}(X) = \frac{1}{\lceil n(1-\alpha) \rceil} \sum_{i=\lceil \alpha n \rceil}^n X_{i:n}$$

Equation 15.

$$\widehat{NCTM}_{n,\alpha}^{\text{left}}(X) = \frac{1}{\lceil n\alpha \rceil} \sum_{i=1}^{\lceil \alpha n \rceil} X_{i:n}$$

It thus requires the caching of at least the $\lceil n\alpha \rceil$ smallest or the $\lceil n(1-\alpha) \rceil$ largest samples.

non_coherent_tail_mean_impl public construct/copy/destruct

```
1. non_coherent_tail_mean_impl(dont_care);
```

non_coherent_tail_mean_impl public member functions

```
1. template<typename Args> result_type result(Args const & args) const;
```

Struct template tail_quantile_impl

boost::accumulators::impl::tail_quantile_impl — Tail quantile estimation based on order statistics (for both left and right tails)

Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename LeftRight>
struct tail_quantile_impl : public accumulator_base {
    // construct/copy/destruct
    tail_quantile_impl(dont_care);

    // public member functions
    template<typename Args> result_type result(Args const &) const;
};
```

Description

The estimation of a tail quantile \hat{q} with level α based on order statistics requires the caching of at least the $\lceil n\alpha \rceil$ smallest or the $\lceil n(1-\alpha) \rceil$ largest samples, n being the total number of samples. The largest of the $\lceil n\alpha \rceil$ smallest samples or the smallest of the $\lceil n(1-\alpha) \rceil$ largest samples provides an estimate for the quantile:

Equation 16.

$$\hat{q}_{n,\alpha} = X_{\lceil \alpha n \rceil:n}$$

tail_quantile_impl public construct/copy/destruct

```
1. tail_quantile_impl(dont_care);
```

tail_quantile_impl public member functions

```
1. template<typename Args> result_type result(Args const & args) const;
```

Struct template tail_variate_impl

boost::accumulators::impl::tail_variate_impl

Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename VariateType, typename VariateTag, typename LeftRight>
struct tail_variate_impl : public accumulator_base {
    // construct/copy/destruct
    template<typename Args> tail_variate_impl(Args const &);

    // public member functions
    template<typename Args> void assign(Args const &, std::size_t);
    template<typename Args> result_type result(Args const &) const;

    // private member functions
    template<typename TailRng> result_type do_result(TailRng const &) const;
};
```

Description**tail_variate_impl public construct/copy/destruct**

```
1. template<typename Args> tail_variate_impl(Args const & args);
```

tail_variate_impl public member functions

```
1. template<typename Args> void assign(Args const & args, std::size_t index);
```

```
2. template<typename Args> result_type result(Args const & args) const;
```

tail_variate_impl private member functions

```
1. template<typename TailRng> result_type do_result(TailRng const & rng) const;
```

Struct template tail_variate_means_impl

boost::accumulators::impl::tail_variate_means_impl — Estimation of the absolute and relative tail variate means (for both left and right tails)

Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename Impl, typename LeftRight,
        typename VariateTag>
struct tail_variate_means_impl : public accumulator_base {
    // construct/copy/destruct
    tail_variate_means_impl(dont_care);

    // public member functions
    template<typename Args> result_type result(Args const &) const;
};
```

Description

For all j -th variates associated to the $\lceil n(1-\alpha) \rceil$ largest samples (or the $\lceil n(1-\alpha) \rceil$ smallest samples in case of the left tail), the absolute tail means $\widehat{ATM}_{n,\alpha}(X,j)$ are computed and returned as an iterator range. Alternatively, the relative tail means $\widehat{RTM}_{n,\alpha}(X,j)$ are returned, which are the absolute tail means normalized with the (non-coherent) sample tail mean $\widehat{NCTM}_{n,\alpha}(X)$.

Equation 17.

$$\widehat{ATM}_{n,\alpha}^{\text{right}}(X,j) = \frac{1}{\lceil n(1-\alpha) \rceil} \sum_{i=\lceil n\alpha \rceil}^n \xi_{j,i}$$

Equation 18.

$$\widehat{ATM}_{n,\alpha}^{\text{left}}(X,j) = \frac{1}{\lceil n\alpha \rceil} \sum_{i=1}^{\lceil n\alpha \rceil} \xi_{j,i}$$

Equation 19.

$$\widehat{RTM}_{n,\alpha}^{\text{right}}(X,j) = \frac{\sum_{i=\lceil n\alpha \rceil}^n \xi_{j,i}}{\lceil n(1-\alpha) \rceil \widehat{NCTM}_{n,\alpha}^{\text{right}}(X)}$$

Equation 20.

$$\widehat{RTM}_{n,\alpha}^{\text{left}}(X,j) = \frac{\sum_{i=1}^{\lceil n\alpha \rceil} \xi_{j,i}}{\lceil n\alpha \rceil \widehat{NCTM}_{n,\alpha}^{\text{left}}(X)}$$

tail_variate_means_impl public construct/copy/destruct

```
1. tail_variate_means_impl(dont_care);
```

tail_variate_means_impl public member functions

```
1. template<typename Args> result_type result(Args const & args) const;
```

Struct template lazy_variance_impl

boost::accumulators::impl::lazy_variance_impl — Lazy calculation of variance.

Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename MeanFeature>
struct lazy_variance_impl : public accumulator_base {
    // construct/copy/destruct
    lazy_variance_impl(dont_care);

    // public member functions
    template<typename Args> result_type result(Args const &) const;
};
```

Description

Default sample variance implementation based on the second moment $M_n^{(2)}$ moment<2>, mean and count.

Equation 21.

$$\sigma_n^2 = M_n^{(2)} - \mu_n^2.$$

where

Equation 22.

$$\mu_n = \frac{1}{n} \sum_{i=1}^n x_i.$$

is the estimate of the sample mean and n is the number of samples.

lazy_variance_impl public construct/copy/destruct

```
1. lazy_variance_impl(dont_care);
```

lazy_variance_impl public member functions

```
1. template<typename Args> result_type result(Args const & args) const;
```

Struct template variance_impl

boost::accumulators::impl::variance_impl — Iterative calculation of variance.

Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename MeanFeature, typename Tag>
struct variance_impl : public accumulator_base {
    // construct/copy/destruct
    template<typename Args> variance_impl(Args const &);

    // public member functions
    template<typename Args> void operator()(Args const &);
    result_type result(dont_care) const;
};
```

Description

Iterative calculation of sample variance σ_n^2 according to the formula

Equation 23.

$$\sigma_n^2 = \frac{1}{n} \sum_{i=1}^n (x_i - \mu_n)^2 = \frac{n-1}{n} \sigma_{n-1}^2 + \frac{1}{n-1} (x_n - \mu_n)^2.$$

where

Equation 24.

$$\mu_n = \frac{1}{n} \sum_{i=1}^n x_i.$$

is the estimate of the sample mean and n is the number of samples.

Note that the sample variance is not defined for $n \leq 1$.

A simplification can be obtained by the approximate recursion

Equation 25.

$$\sigma_n^2 \approx \frac{n-1}{n} \sigma_{n-1}^2 + \frac{1}{n} (x_n - \mu_n)^2.$$

because the difference

Equation 26.

$$\left(\frac{1}{n-1} - \frac{1}{n} \right) (x_n - \mu_n)^2 = \frac{1}{n(n-1)} (x_n - \mu_n)^2.$$

converges to zero as $n \rightarrow \infty$. However, for small n the difference can be non-negligible.

variance_impl public construct/copy/destruct

- ```
template<typename Args> variance_impl(Args const & args);
```

**variance\_impl public member functions**

1. 

```
template<typename Args> void operator()(Args const & args);
```
2. 

```
result_type result(dont_care) const;
```

**Struct template weighted\_covariance\_impl**

boost::accumulators::impl::weighted\_covariance\_impl — Weighted Covariance Estimator.

**Synopsis**

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename Weight, typename VariateType,
 typename VariateTag>
struct weighted_covariance_impl : public accumulator_base {
 // construct/copy/destroy
 template<typename Args> weighted_covariance_impl(Args const &);

 // public member functions
 template<typename Args> void operator()(Args const &);
 result_type result(dont_care) const;
};
```

**Description**

An iterative Monte Carlo estimator for the weighted covariance  $\text{Cov}(\mathbf{X}, \mathbf{X}')$ , where  $\mathbf{X}$  is a sample and  $\mathbf{X}'$  a variate, is given by:

**Equation 27.**

$$\hat{c}_n = \frac{\bar{w}_n - w_n}{\bar{w}_n} \hat{c}_{n-1} + \frac{w_n}{\bar{w}_n - w_n} (X_n - \hat{\mu}_n)(X'_n - \hat{\mu}'_n), \quad n \geq 2, \quad \hat{c}_1 = 0,$$

$\hat{\mu}_n$  and  $\hat{\mu}'_n$  being the weighted means of the samples and variates and  $\bar{w}_n$  the sum of the  $n$  first weights  $w_i$ .

**weighted\_covariance\_impl public construct/copy/destroy**

1. 

```
template<typename Args> weighted_covariance_impl(Args const & args);
```

**weighted\_covariance\_impl public member functions**

1. 

```
template<typename Args> void operator()(Args const & args);
```
2. 

```
result_type result(dont_care) const;
```

**Struct template weighted\_density\_impl**

boost::accumulators::impl::weighted\_density\_impl — Histogram density estimator for weighted samples.

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename Weight>
struct weighted_density_impl : public accumulator_base {
 // construct/copy/destruct
 template<typename Args> weighted_density_impl(Args const &);

 // public member functions
 template<typename Args> void operator()(Args const &);
 template<typename Args> result_type result(Args const &) const;
};
```

### Description

The histogram density estimator returns a histogram of the sample distribution. The positions and sizes of the bins are determined using a specifiable number of cached samples (`cache_size`). The range between the minimum and the maximum of the cached samples is subdivided into a specifiable number of bins (`num_bins`) of same size. Additionally, an under- and an overflow bin is added to capture future under- and overflow samples. Once the bins are determined, the cached samples and all subsequent samples are added to the correct bins. At the end, a range of `std::pair` is returned, where each pair contains the position of the bin (lower bound) and the sum of the weights (normalized with the sum of all weights).

#### `weighted_density_impl` public construct/copy/destruct

1. 

```
template<typename Args> weighted_density_impl(Args const & args);
```

#### `weighted_density_impl` public member functions

1. 

```
template<typename Args> void operator()(Args const & args);
```
2. 

```
template<typename Args> result_type result(Args const & args) const;
```

## Struct template `weighted_kurtosis_impl`

`boost::accumulators::impl::weighted_kurtosis_impl` — Kurtosis estimation for weighted samples.

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename Weight>
struct weighted_kurtosis_impl : public accumulator_base {
 // construct/copy/destruct
 weighted_kurtosis_impl(dont_care);

 // public member functions
 template<typename Args> result_type result(Args const &) const;
};
```



## Description

The kurtosis of a sample distribution is defined as the ratio of the 4th central moment and the square of the 2nd central moment (the variance) of the samples, minus 3. The term  $-3$  is added in order to ensure that the normal distribution has zero kurtosis. The kurtosis can also be expressed by the simple moments:

### Equation 28.

$$\hat{g}_2 = \frac{\hat{m}_n^{(4)} - 4\hat{m}_n^{(3)}\hat{\mu}_n + 6\hat{m}_n^{(2)}\hat{\mu}_n^2 - 3\hat{\mu}_n^4}{\left(\hat{m}_n^{(2)} - \hat{\mu}_n^2\right)^2} - 3,$$

where  $\hat{m}_n^{(i)}$  are the  $i$ -th moment and  $\hat{\mu}_n$  the mean (first moment) of the  $n$  samples.

The kurtosis estimator for weighted samples is formally identical to the estimator for unweighted samples, except that the weighted counterparts of all measures it depends on are to be taken.

#### weighted\_kurtosis\_impl public construct/copy/destruct

```
1. weighted_kurtosis_impl(dont_care);
```

#### weighted\_kurtosis\_impl public member functions

```
1. template<typename Args> result_type result(Args const & args) const;
```

## Struct template weighted\_median\_impl

boost::accumulators::impl::weighted\_median\_impl — Median estimation for weighted samples based on the  $P^2$  quantile estimator.

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample>
struct weighted_median_impl : public accumulator_base {
 // construct/copy/destruct
 weighted_median_impl(dont_care);

 // public member functions
 template<typename Args> result_type result(Args const &) const;
};
```

## Description

The  $P^2$  algorithm for weighted samples is invoked with a quantile probability of 0.5.

#### weighted\_median\_impl public construct/copy/destruct

```
1. weighted_median_impl(dont_care);
```

**weighted\_median\_impl public member functions**

1. 

```
template<typename Args> result_type result(Args const & args) const;
```

**Struct template with\_density\_weighted\_median\_impl**

boost::accumulators::impl::with\_density\_weighted\_median\_impl — Median estimation for weighted samples based on the density estimator.

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample>
struct with_density_weighted_median_impl : public accumulator_base {
 // construct/copy/destroy
 template<typename Args> with_density_weighted_median_impl(Args const &);

 // public member functions
 void operator()(dont_care);
 template<typename Args> result_type result(Args const &) const;
};
```

**Description**

The algorithm determines the bin in which the  $0.5 * cnt$ -th sample lies, *cnt* being the total number of samples. It returns the approximate horizontal position of this sample, based on a linear interpolation inside the bin.

**with\_density\_weighted\_median\_impl public construct/copy/destroy**

1. 

```
template<typename Args> with_density_weighted_median_impl(Args const & args);
```

**with\_density\_weighted\_median\_impl public member functions**

1. 

```
void operator()(dont_care);
```
2. 

```
template<typename Args> result_type result(Args const & args) const;
```

**Struct template with\_p\_square\_cumulative\_distribution\_weighted\_median\_impl**

boost::accumulators::impl::with\_p\_square\_cumulative\_distribution\_weighted\_median\_impl — Median estimation for weighted samples based on the  $P^2$  cumulative distribution estimator.

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename Weight>
struct with_p_square_cumulative_distribution_weighted_median_impl :
 public accumulator_base
{
 // construct/copy/destruct
 with_p_square_cumulative_distribution_weighted_median_impl(dont_care);

 // public member functions
 void operator()(dont_care);
 template<typename Args> result_type result(Args const &) const;
};
```

### Description

The algorithm determines the first (leftmost) bin with a height exceeding 0.5. It returns the approximate horizontal position of where the cumulative distribution equals 0.5, based on a linear interpolation inside the bin.

**with\_p\_square\_cumulative\_distribution\_weighted\_median\_impl public construct/copy/destruct**

1. `with_p_square_cumulative_distribution_weighted_median_impl(dont_care);`

**with\_p\_square\_cumulative\_distribution\_weighted\_median\_impl public member functions**

1. `void operator()(dont_care);`
2. `template<typename Args> result_type result(Args const & args) const;`

## Struct template weighted\_mean\_impl

boost::accumulators::impl::weighted\_mean\_impl

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename Weight, typename Tag>
struct weighted_mean_impl : public accumulator_base {
 // construct/copy/destruct
 weighted_mean_impl(dont_care);

 // public member functions
 template<typename Args> result_type result(Args const &) const;
};
```

## Description

**weighted\_mean\_impl** public construct/copy/destruct

```
1. weighted_mean_impl(dont_care);
```

**weighted\_mean\_impl** public member functions

```
1. template<typename Args> result_type result(Args const & args) const;
```

## Struct template immediate\_weighted\_mean\_impl

boost::accumulators::impl::immediate\_weighted\_mean\_impl

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename Weight, typename Tag>
struct immediate_weighted_mean_impl : public accumulator_base {
 // construct/copy/destruct
 template<typename Args> immediate_weighted_mean_impl(Args const &);

 // public member functions
 template<typename Args> void operator()(Args const &);
 result_type result(dont_care) const;
};
```

## Description

**immediate\_weighted\_mean\_impl** public construct/copy/destruct

```
1. template<typename Args> immediate_weighted_mean_impl(Args const & args);
```

**immediate\_weighted\_mean\_impl** public member functions

```
1. template<typename Args> void operator()(Args const & args);
```

```
2. result_type result(dont_care) const;
```

## Struct template weighted\_peaks\_over\_threshold\_impl

boost::accumulators::impl::weighted\_peaks\_over\_threshold\_impl — Weighted Peaks over Threshold Method for Weighted Quantile and Weighted Tail Mean Estimation.

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename Weight, typename LeftRight>
struct weighted_peaks_over_threshold_impl : public accumulator_base {
 // construct/copy/destruct
 template<typename Args> weighted_peaks_over_threshold_impl(Args const &);

 // public member functions
 template<typename Args> void operator()(Args const &);
 template<typename Args> result_type result(Args const &) const;
};
```

### Description

#### See Also:

[peaks\\_over\\_threshold\\_impl](#)

**weighted\_peaks\_over\_threshold\_impl public construct/copy/destruct**

1. 

```
template<typename Args> weighted_peaks_over_threshold_impl(Args const & args);
```

**weighted\_peaks\_over\_threshold\_impl public member functions**

1. 

```
template<typename Args> void operator()(Args const & args);
```
2. 

```
template<typename Args> result_type result(Args const & args) const;
```

## Struct template weighted\_peaks\_over\_threshold\_prob\_impl

boost::accumulators::impl::weighted\_peaks\_over\_threshold\_prob\_impl — Peaks over Threshold Method for Quantile and Tail Mean Estimation.

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename Weight, typename LeftRight>
struct weighted_peaks_over_threshold_prob_impl : public accumulator_base {
 // construct/copy/destruct
 template<typename Args>
 weighted_peaks_over_threshold_prob_impl(Args const &);

 // public member functions
 void operator()(dont_care);
 template<typename Args> result_type result(Args const &) const;
};
```

### Description

#### See Also:

### weighted\_peaks\_over\_threshold\_impl

**weighted\_peaks\_over\_threshold\_prob\_impl** public construct/copy/destruct

```
1. template<typename Args>
 weighted_peaks_over_threshold_prob_impl(Args const & args);
```

**weighted\_peaks\_over\_threshold\_prob\_impl** public member functions

```
1. void operator()(dont_care);
```

```
2. template<typename Args> result_type result(Args const & args) const;
```

## Struct template weighted\_extended\_p\_square\_impl

boost::accumulators::impl::weighted\_extended\_p\_square\_impl — Multiple quantile estimation with the extended  $P^2$  algorithm for weighted samples.

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename Weight>
struct weighted_extended_p_square_impl : public accumulator_base {
 // construct/copy/destruct
 template<typename Args> weighted_extended_p_square_impl(Args const &);

 // public member functions
 template<typename Args> void operator()(Args const &);
 result_type result(dont_care) const;
};
```

## Description

This version of the extended  $P^2$  algorithm extends the extended  $P^2$  algorithm to support weighted samples. The extended  $P^2$  algorithm dynamically estimates several quantiles without storing samples. Assume that  $m$  quantiles  $\xi_{p_1}, \dots, \xi_{p_m}$  are to be estimated. Instead of storing the whole sample cumulative distribution, the algorithm maintains only  $m + 2$  principal markers and  $m + 1$  middle markers, whose positions are updated with each sample and whose heights are adjusted (if necessary) using a piecewise-parabolic formula. The heights of the principal markers are the current estimates of the quantiles and are returned as an iterator range.

For further details, see

K. E. E. Raatikainen, Simultaneous estimation of several quantiles, Simulation, Volume 49, Number 4 (October), 1986, p. 159-164.

The extended  $P^2$  algorithm generalizes the  $P^2$  algorithm of

R. Jain and I. Chlamtac, The  $P^2$  algorithm for dynamic calculation of quantiles and histograms without storing observations, Communications of the ACM, Volume 28 (October), Number 10, 1985, p. 1076-1085.

**weighted\_extended\_p\_square\_impl** public construct/copy/destruct

```
1. template<typename Args> weighted_extended_p_square_impl(Args const & args);
```

**weighted\_extended\_p\_square\_impl public member functions**

1. 

```
template<typename Args> void operator()(Args const & args);
```
2. 

```
result_type result(dont_care) const;
```

**Struct template weighted\_moment\_impl**

boost::accumulators::impl::weighted\_moment\_impl

**Synopsis**

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename N, typename Sample, typename Weight>
struct weighted_moment_impl : public accumulator_base {
 // construct/copy/destruct
 template<typename Args> weighted_moment_impl(Args const &);

 // public member functions
 BOOST_MPL_ASSERT_RELATION(N::value, 0);
 template<typename Args> void operator()(Args const &);
 template<typename Args> result_type result(Args const &) const;
};
```

**Description****weighted\_moment\_impl public construct/copy/destruct**

1. 

```
template<typename Args> weighted_moment_impl(Args const & args);
```

**weighted\_moment\_impl public member functions**

1. 

```
BOOST_MPL_ASSERT_RELATION(N::value, 0);
```
2. 

```
template<typename Args> void operator()(Args const & args);
```
3. 

```
template<typename Args> result_type result(Args const & args) const;
```

**Struct template weighted\_p\_square\_cumulative\_distribution\_impl**

boost::accumulators::impl::weighted\_p\_square\_cumulative\_distribution\_impl — Histogram calculation of the cumulative distribution with the  $P^2$  algorithm for weighted samples.

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename Weight>
struct weighted_p_square_cumulative_distribution_impl :
 public accumulator_base
{
 // construct/copy/destruct
 template<typename Args>
 weighted_p_square_cumulative_distribution_impl(Args const &);

 // public member functions
 template<typename Args> void operator()(Args const &);
 template<typename Args> result_type result(Args const &) const;
};
```

### Description

A histogram of the sample cumulative distribution is computed dynamically without storing samples based on the  $P^2$  algorithm for weighted samples. The returned histogram has a specifiable amount (num\_cells) equiprobable (and not equal-sized) cells.

Note that applying importance sampling results in regions to be more and other regions to be less accurately estimated than without importance sampling, i.e., with unweighted samples.

For further details, see

R. Jain and I. Chlamtac, The  $P^2$  algorithm for dynamic calculation of quantiles and histograms without storing observations, Communications of the ACM, Volume 28 (October), Number 10, 1985, p. 1076-1085.

#### **weighted\_p\_square\_cumulative\_distribution\_impl public construct/copy/destruct**

1. 

```
template<typename Args>
 weighted_p_square_cumulative_distribution_impl(Args const & args);
```

#### **weighted\_p\_square\_cumulative\_distribution\_impl public member functions**

1. 

```
template<typename Args> void operator()(Args const & args);
```
2. 

```
template<typename Args> result_type result(Args const & args) const;
```

### Struct template **weighted\_p\_square\_quantile\_impl**

boost::accumulators::impl::weighted\_p\_square\_quantile\_impl — Single quantile estimation with the  $P^2$  algorithm for weighted samples.



## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename Weight, typename Impl>
struct weighted_p_square_quantile_impl : public accumulator_base {
 // construct/copy/destruct
 template<typename Args> weighted_p_square_quantile_impl(Args const &);

 // public member functions
 template<typename Args> void operator()(Args const &);
 result_type result(dont_care) const;
};
```

### Description

This version of the  $P^2$  algorithm extends the  $P^2$  algorithm to support weighted samples. The  $P^2$  algorithm estimates a quantile dynamically without storing samples. Instead of storing the whole sample cumulative distribution, only five points (markers) are stored. The heights of these markers are the minimum and the maximum of the samples and the current estimates of the  $(p/2)$ -,  $p$  - and  $(1+p)/2$  -quantiles. Their positions are equal to the number of samples that are smaller or equal to the markers. Each time a new sample is added, the positions of the markers are updated and if necessary their heights are adjusted using a piecewise- parabolic formula.

For further details, see

R. Jain and I. Chlamtac, The  $P^2$  algorithm for dynamic calculation of quantiles and histograms without storing observations, Communications of the ACM, Volume 28 (October), Number 10, 1985, p. 1076-1085.

#### **weighted\_p\_square\_quantile\_impl public construct/copy/destruct**

1. 

```
template<typename Args> weighted_p_square_quantile_impl(Args const & args);
```

#### **weighted\_p\_square\_quantile\_impl public member functions**

1. 

```
template<typename Args> void operator()(Args const & args);
```
2. 

```
result_type result(dont_care) const;
```

### **Struct template weighted\_skewness\_impl**

boost::accumulators::impl::weighted\_skewness\_impl — Skewness estimation for weighted samples.

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename Weight>
struct weighted_skewness_impl : public accumulator_base {
 // construct/copy/destruct
 weighted_skewness_impl(dont_care);

 // public member functions
 template<typename Args> result_type result(Args const &) const;
};
```

### Description

The skewness of a sample distribution is defined as the ratio of the 3rd central moment and the  $3/2$ -th power of the 2nd central moment (the variance) of the samples. The skewness can also be expressed by the simple moments:

### Equation 29.

$$\hat{g}_1 = \frac{\hat{m}_n^{(3)} - 3\hat{m}_n^{(2)}\hat{\mu}_n + 2\hat{\mu}_n^3}{\left(\hat{m}_n^{(2)} - \hat{\mu}_n^2\right)^{3/2}}$$

where  $\hat{m}_n^{(i)}$  are the  $i$ -th moment and  $\hat{\mu}_n$  the mean (first moment) of the  $n$  samples.

The skewness estimator for weighted samples is formally identical to the estimator for unweighted samples, except that the weighted counterparts of all measures it depends on are to be taken.

#### weighted\_skewness\_impl public construct/copy/destruct

1. `weighted_skewness_impl(dont_care);`

#### weighted\_skewness\_impl public member functions

1. `template<typename Args> result_type result(Args const & args) const;`

## Struct template weighted\_sum\_impl

boost::accumulators::impl::weighted\_sum\_impl

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename Weight, typename Tag>
struct weighted_sum_impl : public accumulator_base {
 // construct/copy/destruct
 template<typename Args> weighted_sum_impl(Args const &);

 // public member functions
 template<typename Args> void operator()(Args const &);
 result_type result(dont_care) const;
};
```

## Description

### **weighted\_sum\_impl public construct/copy/destruct**

```
1. template<typename Args> weighted_sum_impl(Args const & args);
```

### **weighted\_sum\_impl public member functions**

```
1. template<typename Args> void operator()(Args const & args);
```

```
2. result_type result(dont_care) const;
```

## Struct template weighted\_sum\_kahan\_impl

boost::accumulators::impl::weighted\_sum\_kahan\_impl

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename Weight, typename Tag>
struct weighted_sum_kahan_impl : public accumulator_base {
 // construct/copy/destruct
 template<typename Args> weighted_sum_kahan_impl(Args const &);

 // public member functions
 template<typename Args> void operator()(Args const &);
 result_type result(dont_care) const;
};
```

## Description

### **weighted\_sum\_kahan\_impl public construct/copy/destruct**

```
1. template<typename Args> weighted_sum_kahan_impl(Args const & args);
```

### **weighted\_sum\_kahan\_impl public member functions**

```
1. template<typename Args> void operator()(Args const & args);
```

```
2. result_type result(dont_care) const;
```

## Struct template non\_coherent\_weighted\_tail\_mean\_impl

boost::accumulators::impl::non\_coherent\_weighted\_tail\_mean\_impl — Estimation of the (non-coherent) weighted tail mean based on order statistics (for both left and right tails)

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename Weight, typename LeftRight>
struct non_coherent_weighted_tail_mean_impl : public accumulator_base {
 // construct/copy/destroy
 non_coherent_weighted_tail_mean_impl(dont_care);

 // public member functions
 template<typename Args> result_type result(Args const &) const;
};
```

### Description

An estimation of the non-coherent, weighted tail mean  $\widehat{NCTM}_{n,\alpha}(X)$  is given by the weighted mean of the

#### Equation 30.

$$\lambda = \inf \left\{ l \left| \frac{1}{\bar{w}_n} \sum_{i=1}^l w_i \geq \alpha \right. \right\}$$

smallest samples (left tail) or the weighted mean of the

#### Equation 31.

$$n+1-\rho = n+1 - \sup \left\{ r \left| \frac{1}{\bar{w}_n} \sum_{i=r}^n w_i \geq (1-\alpha) \right. \right\}$$

largest samples (right tail) above a quantile  $\hat{q}_\alpha$  of level  $\alpha$ ,  $n$  being the total number of sample and  $\bar{w}_n$  the sum of all  $n$  weights:

#### Equation 32.

$$\widehat{NCTM}_{n,\alpha}^{\text{left}}(X) = \frac{\sum_{i=1}^{\lambda} w_i X_{i:n}}{\sum_{i=1}^{\lambda} w_i},$$

#### Equation 33.

$$\widehat{NCTM}_{n,\alpha}^{\text{right}}(X) = \frac{\sum_{i=\rho}^n w_i X_{i:n}}{\sum_{i=\rho}^n w_i}.$$

**non\_coherent\_weighted\_tail\_mean\_impl public construct/copy/destroy**

```
1. non_coherent_weighted_tail_mean_impl(dont_care);
```

**non\_coherent\_weighted\_tail\_mean\_impl public member functions**

```
1. template<typename Args> result_type result(Args const & args) const;
```

### Struct template weighted\_tail\_quantile\_impl

boost::accumulators::impl::weighted\_tail\_quantile\_impl — Tail quantile estimation based on order statistics of weighted samples (for both left and right tails)

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename Weight, typename LeftRight>
struct weighted_tail_quantile_impl : public accumulator_base {
 // construct/copy/destruct
 weighted_tail_quantile_impl(dont_care);

 // public member functions
 template<typename Args> result_type result(Args const &) const;
};
```

### Description

An estimator  $\hat{q}$  of tail quantiles with level  $\alpha$  based on order statistics  $X_{1:n} \leq X_{2:n} \leq \dots \leq X_{n:n}$  of weighted samples are given by  $X_{\lambda:n}$  (left tail) and  $X_{\rho:n}$  (right tail), where

### Equation 34.

$$\lambda = \inf \left\{ l \left| \frac{1}{\bar{w}_n} \sum_{i=1}^l w_i \geq \alpha \right. \right\}$$

and

### Equation 35.

$$\rho = \sup \left\{ r \left| \frac{1}{\bar{w}_n} \sum_{i=r}^n w_i \geq (1 - \alpha) \right. \right\},$$

$n$  being the number of samples and  $\bar{w}_n$  the sum of all weights.

**weighted\_tail\_quantile\_impl public construct/copy/destruct**

```
1. weighted_tail_quantile_impl(dont_care);
```

**weighted\_tail\_quantile\_impl public member functions**

```
1. template<typename Args> result_type result(Args const & args) const;
```

## Struct template weighted\_tail\_variate\_means\_impl

boost::accumulators::impl::weighted\_tail\_variate\_means\_impl — Estimation of the absolute and relative weighted tail variate means (for both left and right tails)

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename Weight, typename Impl, typename LeftRight,
 typename VariateType>
struct weighted_tail_variate_means_impl : public accumulator_base {
 // construct/copy/destruct
 weighted_tail_variate_means_impl(dont_care);

 // public member functions
 template<typename Args> result_type result(Args const &) const;
};
```

### Description

For all  $j$ -th variates associated to the

#### Equation 36.

$$\lambda = \inf \left\{ l \left| \frac{1}{\bar{w}_n} \sum_{i=1}^l w_i \geq \alpha \right. \right\}$$

smallest samples (left tail) or the weighted mean of the

#### Equation 37.

$$n + 1 - \rho = n + 1 - \sup \left\{ r \left| \frac{1}{\bar{w}_n} \sum_{i=r}^n w_i \geq (1 - \alpha) \right. \right\}$$

largest samples (right tail), the absolute weighted tail means  $\widehat{ATM}_{n,\alpha}(X, j)$  are computed and returned as an iterator range. Alternatively, the relative weighted tail means  $\widehat{RTM}_{n,\alpha}(X, j)$  are returned, which are the absolute weighted tail means normalized with the weighted (non-coherent) sample tail mean  $\widehat{NCTM}_{n,\alpha}(X)$ .

#### Equation 38.

$$\widehat{ATM}_{n,\alpha}^{\text{right}}(X, j) = \frac{1}{\sum_{i=\rho}^n w_i} \sum_{i=\rho}^n w_i \xi_{j,i}$$

#### Equation 39.

$$\widehat{ATM}_{n,\alpha}^{\text{left}}(X, j) = \frac{1}{\sum_{i=1}^{\lambda} w_i} \sum_{i=1}^{\lambda} w_i \xi_{j,i}$$

#### Equation 40.

$$\widehat{RTM}_{n,\alpha}^{\text{right}}(X, j) = \frac{\sum_{i=\rho}^n w_i \xi_{j,i}}{\sum_{i=\rho}^n w_i \widehat{NCTM}_{n,\alpha}^{\text{right}}(X)}$$

#### Equation 41.

$$\widehat{RTM}_{n,\alpha}^{\text{left}}(X, j) = \frac{\sum_{i=1}^{\lambda} w_i \xi_{j,i}}{\sum_{i=1}^{\lambda} w_i \widehat{NCTM}_{n,\alpha}^{\text{left}}(X)}$$

**weighted\_tail\_variate\_means\_impl public construct/copy/destruct**

```
1. weighted_tail_variate_means_impl(dont_care);
```

**weighted\_tail\_variate\_means\_impl public member functions**

```
1. template<typename Args> result_type result(Args const & args) const;
```

**Struct template lazy\_weighted\_variance\_impl**

boost::accumulators::impl::lazy\_weighted\_variance\_impl — Lazy calculation of variance of weighted samples.

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename Weight, typename MeanFeature>
struct lazy_weighted_variance_impl : public accumulator_base {
 // construct/copy/destruct
 lazy_weighted_variance_impl(dont_care);

 // public member functions
 template<typename Args> result_type result(Args const &) const;
};
```

**Description**

The default implementation of the variance of weighted samples is based on the second moment  $\hat{m}_n^{(2)}$  (weighted\_moment<2>) and the mean  $\hat{\mu}_n$  (weighted\_mean):

**Equation 42.**

$$\hat{\sigma}_n^2 = \hat{m}_n^{(2)} - \hat{\mu}_n^2,$$

where  $n$  is the number of samples.

**lazy\_weighted\_variance\_impl public construct/copy/destruct**

```
1. lazy_weighted_variance_impl(dont_care);
```

**lazy\_weighted\_variance\_impl public member functions**

```
1. template<typename Args> result_type result(Args const & args) const;
```

**Struct template weighted\_variance\_impl**

boost::accumulators::impl::weighted\_variance\_impl — Iterative calculation of variance of weighted samples.

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample, typename Weight, typename MeanFeature, typename Tag>
struct weighted_variance_impl : public accumulator_base {
 // construct/copy/destruct
 template<typename Args> weighted_variance_impl(Args const &);

 // public member functions
 template<typename Args> void operator()(Args const &);
 result_type result(dont_care) const;
};
```

### Description

Iterative calculation of variance of weighted samples:

#### Equation 43.

$$\hat{\sigma}_n^2 = \frac{\bar{w}_n - w_n}{\bar{w}_n} \hat{\sigma}_{n-1}^2 + \frac{w_n}{\bar{w}_n - w_n} (x_n - \hat{\mu}_n)^2, \quad n \geq 2, \quad \hat{\sigma}_0^2 = 0.$$

where  $\bar{w}_n$  is the sum of the  $n$  weights  $w_i$  and  $\hat{\mu}_n$  the estimate of the mean of the weighted samples. Note that the sample variance is not defined for  $n \leq 1$ .

#### **weighted\_variance\_impl public construct/copy/destruct**

1. 

```
template<typename Args> weighted_variance_impl(Args const & args);
```

#### **weighted\_variance\_impl public member functions**

1. 

```
template<typename Args> void operator()(Args const & args);
```
2. 

```
result_type result(dont_care) const;
```

### Struct template rolling\_window\_plus1\_impl

boost::accumulators::impl::rolling\_window\_plus1\_impl



## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample>
struct rolling_window_plus1_impl : public accumulator_base {
 // construct/copy/destroy
 template<typename Args> rolling_window_plus1_impl(Args const &);
 rolling_window_plus1_impl(rolling_window_plus1_impl const &);
 rolling_window_plus1_impl& operator=(rolling_window_plus1_impl const &);

 // public member functions
 template<typename Args> void operator()(Args const &);
 bool full() const;
 result_type result(dont_care) const;
};
```

### Description

#### **rolling\_window\_plus1\_impl public construct/copy/destroy**

1. 

```
template<typename Args> rolling_window_plus1_impl(Args const & args);
```
2. 

```
rolling_window_plus1_impl(rolling_window_plus1_impl const & that);
```
3. 

```
rolling_window_plus1_impl& operator=(rolling_window_plus1_impl const & that);
```

#### **rolling\_window\_plus1\_impl public member functions**

1. 

```
template<typename Args> void operator()(Args const & args);
```
2. 

```
bool full() const;
```
3. 

```
result_type result(dont_care) const;
```

### Struct template rolling\_window\_impl

boost::accumulators::impl::rolling\_window\_impl

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample>
struct rolling_window_impl : public accumulator_base {
 // construct/copy/destruct
 rolling_window_impl(dont_care);

 // public member functions
 template<typename Args> result_type result(Args const &) const;
};
```

### Description

#### **rolling\_window\_impl public construct/copy/destruct**

1. `rolling_window_impl(dont_care);`

#### **rolling\_window\_impl public member functions**

1. `template<typename Args> result_type result(Args const & args) const;`

## Struct template rolling\_sum\_impl

boost::accumulators::impl::rolling\_sum\_impl

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample>
struct rolling_sum_impl : public accumulator_base {
 // construct/copy/destruct
 template<typename Args> rolling_sum_impl(Args const &);

 // public member functions
 template<typename Args> void operator()(Args const &);
 template<typename Args> result_type result(Args const &) const;
};
```

### Description

#### **rolling\_sum\_impl public construct/copy/destruct**

1. `template<typename Args> rolling_sum_impl(Args const & args);`

#### **rolling\_sum\_impl public member functions**

1. `template<typename Args> void operator()(Args const & args);`

2. `template<typename Args> result_type result(Args const & args) const;`

## Struct template `rolling_count_impl`

`boost::accumulators::impl::rolling_count_impl`

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample>
struct rolling_count_impl : public accumulator_base {
 // construct/copy/destruct
 rolling_count_impl(dont_care);

 // public member functions
 template<typename Args> result_type result(Args const &) const;
};
```

### Description

`rolling_count_impl` **public construct/copy/destruct**

1. `rolling_count_impl(dont_care);`

`rolling_count_impl` **public member functions**

1. `template<typename Args> result_type result(Args const & args) const;`

## Struct template `rolling_mean_impl`

`boost::accumulators::impl::rolling_mean_impl`

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Sample>
struct rolling_mean_impl : public accumulator_base {
 // construct/copy/destruct
 rolling_mean_impl(dont_care);

 // public member functions
 template<typename Args> result_type result(Args const &) const;
};
```

### Description

`rolling_mean_impl` **public construct/copy/destruct**

1. `rolling_mean_impl(dont_care);`

**rolling\_mean\_impl public member functions**

```
1. template<typename Args> result_type result(Args const & args) const;
```

**Struct quantile**

boost::accumulators::tag::quantile

**Synopsis**

```
// In header: <boost/accumulators/statistics_fwd.hpp>

struct quantile : public boost::accumulators::depends_on<> {
 // types
 typedef mpl::print< class ____MISSING_SPECIFIC_QUANTILE_FEATURE_IN_ACCUMULATOR_SET____ > impl;
};
```

**Struct tail\_mean**

boost::accumulators::tag::tail\_mean

**Synopsis**

```
// In header: <boost/accumulators/statistics_fwd.hpp>

struct tail_mean : public boost::accumulators::depends_on<> {
 // types
 typedef mpl::print< class ____MISSING_SPECIFIC_TAIL_MEAN_FEATURE_IN_ACCUMULATOR_SET____ > impl;
};
```

**Struct template covariance**

boost::accumulators::tag::covariance

**Synopsis**

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename VariateType, typename VariateTag>
struct covariance : public boost::accumulators::depends_on< count, mean, mean_of_variates< VariateType, VariateTag > > {
 {
};
```

**Struct template error\_of**

boost::accumulators::tag::error\_of

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename Feature>
struct error_of : public boost::accumulators::depends_on< Feature > {
};
```

### Struct template mean\_of\_variates

boost::accumulators::tag::mean\_of\_variates

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename VariateType, typename VariateTag>
struct mean_of_variates : public boost::accumulators::depends_on< count, sum_of_variates< VariateType, VariateTag > >
{
};
```

### Struct template immediate\_mean\_of\_variates

boost::accumulators::tag::immediate\_mean\_of\_variates

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename VariateType, typename VariateTag>
struct immediate_mean_of_variates :
 public boost::accumulators::depends_on< count >
{
};
```

### Struct template moment

boost::accumulators::tag::moment

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<int N>
struct moment : public boost::accumulators::depends_on< count > {
};
```

### Struct template peaks\_over\_threshold

boost::accumulators::tag::peaks\_over\_threshold

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename LeftRight>
struct peaks_over_threshold :
 public boost::accumulators::depends_on< count >, public pot_threshold_value
{
};
```

### Struct template peaks\_over\_threshold\_prob

boost::accumulators::tag::peaks\_over\_threshold\_prob

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename LeftRight>
struct peaks_over_threshold_prob : public boost::accumulators::depends_on< count, tail< LeftRight > >,
 public pot_threshold_probability
{
};
```

### Struct template pot\_tail\_mean

boost::accumulators::tag::pot\_tail\_mean

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename LeftRight>
struct pot_tail_mean : public boost::accumulators::depends_on< peaks_over_threshold< LeftRight >, pot_quantile< LeftRight > >
{
};
```

### Struct template pot\_tail\_mean\_prob

boost::accumulators::tag::pot\_tail\_mean\_prob

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename LeftRight>
struct pot_tail_mean_prob : public boost::accumulators::depends_on< peaks_over_threshold_prob< LeftRight >, pot_quantile_prob< LeftRight > >
{
};
```

## Struct template pot\_quantile

boost::accumulators::tag::pot\_quantile

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename LeftRight>
struct pot_quantile :
 public boost::accumulators::depends_on< peaks_over_threshold< LeftRight > >
{
};
```

## Struct template pot\_quantile\_prob

boost::accumulators::tag::pot\_quantile\_prob

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename LeftRight>
struct pot_quantile_prob : public boost::accumulators::depends_on< peaks_over_threshold_prob<
LeftRight > >
{
};
```

## Struct template sum\_of\_variates

boost::accumulators::tag::sum\_of\_variates

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename VariateType, typename VariateTag>
struct sum_of_variates : public boost::accumulators::depends_on<> {
};
```

## Struct template sum\_of\_variates\_kahan

boost::accumulators::tag::sum\_of\_variates\_kahan

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename VariateType, typename VariateTag>
struct sum_of_variates_kahan : public boost::accumulators::depends_on<> {
};
```

## Struct template tail

boost::accumulators::tag::tail

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename LeftRight>
struct tail : public boost::accumulators::depends_on<>,
 public boost::accumulators::tail_cache_size_named_arg< LeftRight >
{
};
```

## Struct template coherent\_tail\_mean

boost::accumulators::tag::coherent\_tail\_mean

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename LeftRight>
struct coherent_tail_mean : public boost::accumulators::depends_on< count, quantile, non_coherent_tail_mean< LeftRight > >
{
};
```

## Struct template non\_coherent\_tail\_mean

boost::accumulators::tag::non\_coherent\_tail\_mean

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename LeftRight>
struct non_coherent_tail_mean :
 public boost::accumulators::depends_on< count, tail< LeftRight > >
{
};
```

## Struct template tail\_quantile

boost::accumulators::tag::tail\_quantile



## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename LeftRight>
struct tail_quantile :
 public boost::accumulators::depends_on< count, tail< LeftRight > >
{
};
```

### Struct template tail\_variate

boost::accumulators::tag::tail\_variate

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename VariateType, typename VariateTag, typename LeftRight>
struct tail_variate :
 public boost::accumulators::depends_on< tail< LeftRight > >
{
};
```

### Struct template tail\_weights

boost::accumulators::tag::tail\_weights

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename LeftRight>
struct tail_weights :
 public boost::accumulators::depends_on< tail< LeftRight > >
{
};
```

### Struct template right\_tail\_variate

boost::accumulators::tag::right\_tail\_variate

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename VariateType, typename VariateTag, typename LeftRight>
struct right_tail_variate {
};
```

### Struct template left\_tail\_variate

boost::accumulators::tag::left\_tail\_variate

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename VariateType, typename VariateTag, typename LeftRight>
struct left_tail_variate {
};
```

### Struct template tail\_variate\_means

boost::accumulators::tag::tail\_variate\_means

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename LeftRight, typename VariateType, typename VariateTag>
struct tail_variate_means {
};
```

### Struct template absolute\_tail\_variate\_means

boost::accumulators::tag::absolute\_tail\_variate\_means

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename LeftRight, typename VariateType, typename VariateTag>
struct absolute_tail_variate_means : public boost::accumulators::depends_on< count, non_coherent_tail_mean< LeftRight >, tail_variate< VariateType, VariateTag, LeftRight > >
{
};
```

### Struct template relative\_tail\_variate\_means

boost::accumulators::tag::relative\_tail\_variate\_means

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename LeftRight, typename VariateType, typename VariateTag>
struct relative_tail_variate_means : public boost::accumulators::depends_on< count, non_coherent_tail_mean< LeftRight >, tail_variate< VariateType, VariateTag, LeftRight > >
{
};
```

### Struct template weighted\_covariance

boost::accumulators::tag::weighted\_covariance

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename VariateType, typename VariateTag>
struct weighted_covariance : public boost::accumulators::depends_on< count, sum_of_weights,
weighted_mean, weighted_mean_of_variates< VariateType, VariateTag > >
{
};
```

### Struct template weighted\_mean\_of\_variates

boost::accumulators::tag::weighted\_mean\_of\_variates

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename VariateType, typename VariateTag>
struct weighted_mean_of_variates : public boost::accumulators::depends_on< sum_of_weights,
weighted_sum_of_variates< VariateType, VariateTag > >
{
};
```

### Struct template immediate\_weighted\_mean\_of\_variates

boost::accumulators::tag::immediate\_weighted\_mean\_of\_variates

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename VariateType, typename VariateTag>
struct immediate_weighted_mean_of_variates :
 public boost::accumulators::depends_on< sum_of_weights >
{
};
```

### Struct template weighted\_moment

boost::accumulators::tag::weighted\_moment

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<int N>
struct weighted_moment :
 public boost::accumulators::depends_on< count, sum_of_weights >
{
};
```

## Struct template `weighted_peaks_over_threshold`

`boost::accumulators::tag::weighted_peaks_over_threshold`

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename LeftRight>
struct weighted_peaks_over_threshold : public boost::accumulators::depends_on< sum_of_weights >,
 public pot_threshold_value
{
};
```

## Struct template `weighted_peaks_over_threshold_prob`

`boost::accumulators::tag::weighted_peaks_over_threshold_prob`

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename LeftRight>
struct weighted_peaks_over_threshold_prob : public boost::accumulators::depends_on< ↵
sum_of_weights, tail_weights< LeftRight > >,
 public pot_threshold_probability
{
};
```

## Struct template `weighted_pot_quantile`

`boost::accumulators::tag::weighted_pot_quantile`

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename LeftRight>
struct weighted_pot_quantile : public boost::accumulators::depends_on< ↵
weighted_peaks_over_threshold< LeftRight > >
{
};
```

## Struct template `weighted_pot_quantile_prob`

`boost::accumulators::tag::weighted_pot_quantile_prob`

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename LeftRight>
struct weighted_pot_quantile_prob : public boost::accumulators::depends_on<
weighted_peaks_over_threshold_prob< LeftRight > >
{
};
```

### Struct template weighted\_pot\_tail\_mean

boost::accumulators::tag::weighted\_pot\_tail\_mean

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename LeftRight>
struct weighted_pot_tail_mean : public boost::accumulators::depends_on<
weighted_peaks_over_threshold< LeftRight >, weighted_pot_quantile< LeftRight > >
{
};
```

### Struct template weighted\_pot\_tail\_mean\_prob

boost::accumulators::tag::weighted\_pot\_tail\_mean\_prob

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename LeftRight>
struct weighted_pot_tail_mean_prob : public boost::accumulators::depends_on<
weighted_peaks_over_threshold_prob< LeftRight >, weighted_pot_quantile_prob< LeftRight > >
{
};
```

### Struct template weighted\_tail\_quantile

boost::accumulators::tag::weighted\_tail\_quantile

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename LeftRight>
struct weighted_tail_quantile : public boost::accumulators::depends_on< sum_of_weights,
tail_weights< LeftRight > >
{
};
```

## Struct template `non_coherent_weighted_tail_mean`

`boost::accumulators::tag::non_coherent_weighted_tail_mean`

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename LeftRight>
struct non_coherent_weighted_tail_mean : public boost::accumulators::depends_on< sum_of_weights, tail_weights< LeftRight > >
{
};
```

## Struct template `weighted_tail_variate_means`

`boost::accumulators::tag::weighted_tail_variate_means`

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename LeftRight, typename VariateType, typename VariateTag>
struct weighted_tail_variate_means {
};
```

## Struct template `absolute_weighted_tail_variate_means`

`boost::accumulators::tag::absolute_weighted_tail_variate_means`

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename LeftRight, typename VariateType, typename VariateTag>
struct absolute_weighted_tail_variate_means : public boost::accumulators::depends_on< non_coherent_weighted_tail_mean< LeftRight >, tail_variate< VariateType, VariateTag, LeftRight >, tail_weights< LeftRight > >
{
};
```

## Struct template `relative_weighted_tail_variate_means`

`boost::accumulators::tag::relative_weighted_tail_variate_means`

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename LeftRight, typename VariateType, typename VariateTag>
struct relative_weighted_tail_variate_means : public boost::accumulators::depends_on< non_coherent_weighted_tail_mean< LeftRight >, tail_variate< VariateType, VariateTag, LeftRight >, tail_weights< LeftRight > >
{
};
```

### Struct template weighted\_sum\_of\_variates

boost::accumulators::tag::weighted\_sum\_of\_variates

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<typename VariateType, typename VariateTag>
struct weighted_sum_of_variates : public boost::accumulators::depends_on<> {
};
```

### Struct template stats

boost::accumulators::stats

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<BOOST_PP_ENUM_PARAMS_WITH_A_DEFAULT(BOOST_ACCUMULATORS_MAX_FEATURES, typename Feature, mpl::na) >
struct stats : public mpl::vector< Stat1, Stat2,...> {
};
```

### Description

An MPL sequence of statistics.

### Struct template with\_error

boost::accumulators::with\_error

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

template<BOOST_PP_ENUM_PARAMS_WITH_A_DEFAULT(BOOST_ACCUMULATORS_MAX_FEATURES, typename Feature, mpl::na) >
struct with_error {
};
```

## Struct lazy

boost::accumulators::lazy

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

struct lazy {
};
```

## Struct immediate

boost::accumulators::immediate

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

struct immediate {
};
```

## Struct right

boost::accumulators::right

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

struct right {
};
```

## Struct left

boost::accumulators::left

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

struct left {
};
```

## Struct absolute

boost::accumulators::absolute



## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

struct absolute {
};
```

### Struct relative

boost::accumulators::relative

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

struct relative {
};
```

### Struct with\_density

boost::accumulators::with\_density

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

struct with_density {
};
```

### Struct with\_p\_square\_cumulative\_distribution

boost::accumulators::with\_p\_square\_cumulative\_distribution

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

struct with_p_square_cumulative_distribution {
};
```

### Struct with\_p\_square\_quantile

boost::accumulators::with\_p\_square\_quantile

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

struct with_p_square_quantile {
};
```

### Struct with\_threshold\_value

boost::accumulators::with\_threshold\_value

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

struct with_threshold_value {
};
```

### Struct with\_threshold\_probability

boost::accumulators::with\_threshold\_probability

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

struct with_threshold_probability {
};
```

### Struct weighted

boost::accumulators::weighted

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

struct weighted {
};
```

### Struct unweighted

boost::accumulators::unweighted

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

struct unweighted {
};
```

### Struct linear

boost::accumulators::linear

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

struct linear {
};
```

### Struct quadratic

boost::accumulators::quadratic

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

struct quadratic {
};
```

### Struct regular

boost::accumulators::regular

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

struct regular {
};
```

### Struct for\_median

boost::accumulators::for\_median

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

struct for_median {
};
```

### Struct kahan

boost::accumulators::kahan

## Synopsis

```
// In header: <boost/accumulators/statistics_fwd.hpp>

struct kahan {
};
```

# Numeric Operators Library Reference

## Header <boost/accumulators/numeric/functional.hpp>

```

namespace boost {
 namespace numeric {
 template<typename T> struct default_;
 template<typename T> struct one;
 template<typename T> struct zero;
 template<typename T> struct one_or_default;
 template<typename T> struct zero_or_default;
 template<typename To, typename From>
 lazy_disable_if< is_const< From >, mpl::if_< is_same< To, From >, To &, To > >::type
 promote(From & from);
 template<typename To, typename From>
 mpl::if_< is_same< To const, From const >, To const &, To const >::type
 promote(From const & from);
 }
 namespace functional {
 template<typename Left, typename Right> struct left_ref;
 template<typename Left, typename Right, typename EnableIf = void>
 struct plus_base;
 template<typename Left, typename Right,
 typename LeftTag = typename tag<Left>::type,
 typename RightTag = typename tag<Right>::type>
 struct plus;
 template<typename Left, typename Right, typename EnableIf = void>
 struct minus_base;
 template<typename Left, typename Right,
 typename LeftTag = typename tag<Left>::type,
 typename RightTag = typename tag<Right>::type>
 struct minus;
 template<typename Left, typename Right, typename EnableIf = void>
 struct multiplies_base;
 template<typename Left, typename Right,
 typename LeftTag = typename tag<Left>::type,
 typename RightTag = typename tag<Right>::type>
 struct multiplies;
 template<typename Left, typename Right, typename EnableIf = void>
 struct divides_base;
 template<typename Left, typename Right,
 typename LeftTag = typename tag<Left>::type,
 typename RightTag = typename tag<Right>::type>
 struct divides;
 template<typename Left, typename Right, typename EnableIf = void>
 struct modulus_base;
 template<typename Left, typename Right,
 typename LeftTag = typename tag<Left>::type,
 typename RightTag = typename tag<Right>::type>
 struct modulus;
 template<typename Left, typename Right, typename EnableIf = void>
 struct greater_base;
 template<typename Left, typename Right,
 typename LeftTag = typename tag<Left>::type,
 typename RightTag = typename tag<Right>::type>
 struct greater;
 template<typename Left, typename Right, typename EnableIf = void>
 struct greater_equal_base;
 template<typename Left, typename Right,
 typename LeftTag = typename tag<Left>::type,
 typename RightTag = typename tag<Right>::type>
 struct greater_equal;
 template<typename Left, typename Right, typename EnableIf = void>

```

```
 struct less_base;
template<typename Left, typename Right,
 typename LeftTag = typename tag<Left>::type,
 typename RightTag = typename tag<Right>::type>
 struct less;
template<typename Left, typename Right, typename EnableIf = void>
 struct less_equal_base;
template<typename Left, typename Right,
 typename LeftTag = typename tag<Left>::type,
 typename RightTag = typename tag<Right>::type>
 struct less_equal;
template<typename Left, typename Right, typename EnableIf = void>
 struct equal_to_base;
template<typename Left, typename Right,
 typename LeftTag = typename tag<Left>::type,
 typename RightTag = typename tag<Right>::type>
 struct equal_to;
template<typename Left, typename Right, typename EnableIf = void>
 struct not_equal_to_base;
template<typename Left, typename Right,
 typename LeftTag = typename tag<Left>::type,
 typename RightTag = typename tag<Right>::type>
 struct not_equal_to;
template<typename Left, typename Right, typename EnableIf = void>
 struct assign_base;
template<typename Left, typename Right,
 typename LeftTag = typename tag<Left>::type,
 typename RightTag = typename tag<Right>::type>
 struct assign;
template<typename Left, typename Right, typename EnableIf = void>
 struct plus_assign_base;
template<typename Left, typename Right,
 typename LeftTag = typename tag<Left>::type,
 typename RightTag = typename tag<Right>::type>
 struct plus_assign;
template<typename Left, typename Right, typename EnableIf = void>
 struct minus_assign_base;
template<typename Left, typename Right,
 typename LeftTag = typename tag<Left>::type,
 typename RightTag = typename tag<Right>::type>
 struct minus_assign;
template<typename Left, typename Right, typename EnableIf = void>
 struct multiplies_assign_base;
template<typename Left, typename Right,
 typename LeftTag = typename tag<Left>::type,
 typename RightTag = typename tag<Right>::type>
 struct multiplies_assign;
template<typename Left, typename Right, typename EnableIf = void>
 struct divides_assign_base;
template<typename Left, typename Right,
 typename LeftTag = typename tag<Left>::type,
 typename RightTag = typename tag<Right>::type>
 struct divides_assign;
template<typename Left, typename Right, typename EnableIf = void>
 struct modulus_assign_base;
template<typename Left, typename Right,
 typename LeftTag = typename tag<Left>::type,
 typename RightTag = typename tag<Right>::type>
 struct modulus_assign;
template<typename Arg, typename EnableIf = void> struct unary_plus_base;
template<typename Arg, typename Tag = typename tag<Arg>::type>
 struct unary_plus;
template<typename Arg, typename EnableIf = void> struct unary_minus_base;
```

```

template<typename Arg, typename Tag = typename tag<Arg>::type>
 struct unary_minus;
template<typename Arg, typename EnableIf = void> struct complement_base;
template<typename Arg, typename Tag = typename tag<Arg>::type>
 struct complement;
template<typename Arg, typename EnableIf = void> struct logical_not_base;
template<typename Arg, typename Tag = typename tag<Arg>::type>
 struct logical_not;
template<typename Left, typename Right, typename EnableIf>
 struct min_assign_base;
template<typename Left, typename Right, typename EnableIf>
 struct max_assign_base;
template<typename Left, typename Right, typename EnableIf>
 struct average_base;

template<typename Left, typename Right>
 struct average_base<Left, Right, typename enable_if< are_integral< Left, Right > >::type>;

template<typename To, typename From, typename EnableIf> struct promote_base;

template<typename ToFrom> struct promote_base<ToFrom, ToFrom, void>;

template<typename Arg, typename EnableIf> struct as_min_base;

template<typename Arg>
 struct as_min_base<Arg, typename enable_if< is_floating_point< Arg > >::type>;

template<typename Arg, typename EnableIf> struct as_max_base;
template<typename Arg, typename EnableIf> struct as_zero_base;
template<typename Arg, typename EnableIf> struct as_one_base;
template<typename To, typename From, typename ToTag, typename FromTag>
 struct promote;
template<typename Left, typename Right, typename LeftTag,
 typename RightTag>
 struct min_assign;
template<typename Left, typename Right, typename LeftTag,
 typename RightTag>
 struct max_assign;
template<typename Left, typename Right, typename LeftTag,
 typename RightTag>
 struct average;
template<typename Arg, typename Tag> struct as_min;
template<typename Arg, typename Tag> struct as_max;
template<typename Arg, typename Tag> struct as_zero;
template<typename Arg, typename Tag> struct as_one;
}

namespace op {
 struct plus;
 struct minus;
 struct multiplies;
 struct divides;
 struct modulus;
 struct greater;
 struct greater_equal;
 struct less;
 struct less_equal;
 struct equal_to;
 struct not_equal_to;
 struct assign;
 struct plus_assign;
 struct minus_assign;
 struct multiplies_assign;
 struct divides_assign;

```

```
 struct modulus_assign;
 struct unary_plus;
 struct unary_minus;
 struct complement;
 struct logical_not;
 template<typename To> struct promote;
 struct min_assign;
 struct max_assign;
 struct average;
 struct as_min;
 struct as_max;
 struct as_zero;
 struct as_one;
}
}
```

## Struct template left\_ref

boost::numeric::functional::left\_ref

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right>
struct left_ref {
 // types
 typedef Left & type;
};
```

## Struct template plus\_base

boost::numeric::functional::plus\_base

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right, typename EnableIf = void>
struct plus_base : public std::binary_function< Left, Right,
 typename std::result_of<Left >() + Left >()>
{
 // public member functions
 result_type operator()(Left &, Right &) const;
};
```

## Description

### plus\_base public member functions

1. `result_type operator()(Left & left, Right & right) const;`

Returns:      left + right



## Struct template plus

boost::numeric::functional::plus

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right,
 typename LeftTag = typename tag<Left>::type,
 typename RightTag = typename tag<Right>::type>
struct plus :
 public boost::numeric::functional::plus_base< Left, Right, void >
{
};
```

## Struct template minus\_base

boost::numeric::functional::minus\_base

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right, typename EnableIf = void>
struct minus_base : public std::binary_function< Left, Right,
 typeof(lvalue< Left >()-lvalue< Left >())>
{
 // public member functions
 result_type operator()(Left &, Right &) const;
};
```

### Description

#### minus\_base public member functions

1. 

```
result_type operator()(Left & left, Right & right) const;
```

Returns:      left - right

## Struct template minus

boost::numeric::functional::minus

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right,
 typename LeftTag = typename tag<Left>::type,
 typename RightTag = typename tag<Right>::type>
struct minus :
 public boost::numeric::functional::minus_base< Left, Right, void >
{
};
```

### Struct template multiplies\_base

boost::numeric::functional::multiplies\_base

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right, typename EnableIf = void>
struct multiplies_base : public std::binary_function< Left, Right,
 typename std::result_of<Left * Right>::type>
{
 // public member functions
 result_type operator()(Left &, Right &) const;
};
```

### Description

#### multiplies\_base public member functions

1. `result_type operator()(Left & left, Right & right) const;`

Returns:      left \* right

### Struct template multiplies

boost::numeric::functional::multiplies

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right,
 typename LeftTag = typename tag<Left>::type,
 typename RightTag = typename tag<Right>::type>
struct multiplies :
 public boost::numeric::functional::multiplies_base< Left, Right, void >
{
};
```

## Struct template divides\_base

boost::numeric::functional::divides\_base

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right, typename EnableIf = void>
struct divides_base : public std::binary_function< Left, Right, typeof(lvalue< Left >()/lvalue< Left >())>
{
 // public member functions
 result_type operator()(Left &, Right &) const;
};
```

### Description

#### divides\_base public member functions

1. 

```
result_type operator()(Left & left, Right & right) const;
```

Returns:      left / right

## Struct template divides

boost::numeric::functional::divides

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right,
 typename LeftTag = typename tag<Left>::type,
 typename RightTag = typename tag<Right>::type>
struct divides :
 public boost::numeric::functional::divides_base< Left, Right, void >
{
};
```

## Struct template modulus\_base

boost::numeric::functional::modulus\_base

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right, typename EnableIf = void>
struct modulus_base : public std::binary_function< Left, Right, typeof(lvalue< Left >() % lvalue<
Right >())>
{

 // public member functions
 result_type operator()(Left &, Right &) const;
};
```

### Description

#### **modulus\_base** public member functions

1. `result_type operator()(Left & left, Right & right) const;`

Returns:      left % right

### Struct template modulus

boost::numeric::functional::modulus

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right,
 typename LeftTag = typename tag<Left>::type,
 typename RightTag = typename tag<Right>::type>
struct modulus :
 public boost::numeric::functional::modulus_base< Left, Right, void >
{
};
```

### Struct template greater\_base

boost::numeric::functional::greater\_base

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right, typename EnableIf = void>
struct greater_base : public std::binary_function< Left, Right, typeof(lvalue< Left >() > lvalue<
Right >())>
{

 // public member functions
 result_type operator()(Left &, Right &) const;
};
```

## Description

### **greater\_base** public member functions

1. 

```
result_type operator()(Left & left, Right & right) const;
```

Returns:     left > right

## Struct template greater

boost::numeric::functional::greater

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right,
 typename LeftTag = typename tag<Left>::type,
 typename RightTag = typename tag<Right>::type>
struct greater :
 public boost::numeric::functional::greater_base< Left, Right, void >
{
};
```

## Struct template greater\_equal\_base

boost::numeric::functional::greater\_equal\_base

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right, typename EnableIf = void>
struct greater_equal_base : public std::binary_function< Left, Right,
 typeof(lvalue< Left >()) <= lvalue< Right >())>
{
 // public member functions
 result_type operator()(Left &, Right &) const;
};
```

## Description

### **greater\_equal\_base** public member functions

1. 

```
result_type operator()(Left & left, Right & right) const;
```

Returns:     left >= right

## Struct template greater\_equal

boost::numeric::functional::greater\_equal

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right,
 typename LeftTag = typename tag<Left>::type,
 typename RightTag = typename tag<Right>::type>
struct greater_equal :
 public boost::numeric::functional::greater_equal_base< Left, Right, void >
{
};
```

### Struct template less\_base

boost::numeric::functional::less\_base

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right, typename EnableIf = void>
struct less_base : public std::binary_function< Left, Right, typeof(lvalue< Left >()< lvalue< Left >()< Right >())>
{

 // public member functions
 result_type operator()(Left &, Right &) const;
};
```

### Description

#### less\_base public member functions

1. `result_type operator()(Left & left, Right & right) const;`

Returns:      left < right

### Struct template less

boost::numeric::functional::less

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right,
 typename LeftTag = typename tag<Left>::type,
 typename RightTag = typename tag<Right>::type>
struct less :
 public boost::numeric::functional::less_base< Left, Right, void >
{
};
```

## Struct template less\_equal\_base

boost::numeric::functional::less\_equal\_base

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right, typename EnableIf = void>
struct less_equal_base : public std::binary_function< Left, Right, typeof(lvalue< Left >() <= lvalue< Right >())>
{
 // public member functions
 result_type operator()(Left &, Right &) const;
};
```

### Description

#### less\_equal\_base public member functions

1. 

```
result_type operator()(Left & left, Right & right) const;
```

Returns:      left <= right

## Struct template less\_equal

boost::numeric::functional::less\_equal

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right,
 typename LeftTag = typename tag<Left>::type,
 typename RightTag = typename tag<Right>::type>
struct less_equal :
 public boost::numeric::functional::less_equal_base< Left, Right, void >
{
};
```

## Struct template equal\_to\_base

boost::numeric::functional::equal\_to\_base

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right, typename EnableIf = void>
struct equal_to_base : public std::binary_function< Left, Right, typeof(lvalue< Left >()=lvalue< Left >()> Right >())>
{
 // public member functions
 result_type operator()(Left &, Right &) const;
};
```

### Description

#### `equal_to_base` public member functions

1. `result_type operator()(Left & left, Right & right) const;`

Returns:      `left == right`

### Struct template `equal_to`

`boost::numeric::functional::equal_to`

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right,
 typename LeftTag = typename tag<Left>::type,
 typename RightTag = typename tag<Right>::type>
struct equal_to :
 public boost::numeric::functional::equal_to_base< Left, Right, void >
{
};
```

### Struct template `not_equal_to_base`

`boost::numeric::functional::not_equal_to_base`

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right, typename EnableIf = void>
struct not_equal_to_base : public std::binary_function< Left, Right, typeof(lvalue< Left >() != lvalue< Right >())>
{
 // public member functions
 result_type operator()(Left &, Right &) const;
};
```



## Description

### `not_equal_to_base` public member functions

```
1. result_type operator()(Left & left, Right & right) const;
```

Returns:     `left != right`

## Struct template `not_equal_to`

`boost::numeric::functional::not_equal_to`

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right,
 typename LeftTag = typename tag<Left>::type,
 typename RightTag = typename tag<Right>::type>
struct not_equal_to :
 public boost::numeric::functional::not_equal_to_base< Left, Right, void >
{
};
```

## Struct template `assign_base`

`boost::numeric::functional::assign_base`

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right, typename EnableIf = void>
struct assign_base : public std::binary_function< Left, Right,
 typename std::result_of<Left >()=lvalue< Left >()=lvalue< Left >()>
{
 // public member functions
 result_type operator()(Left &, Right &) const;
};
```

## Description

### `assign_base` public member functions

```
1. result_type operator()(Left & left, Right & right) const;
```

Returns:     `left = right`

## Struct template `assign`

`boost::numeric::functional::assign`

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right,
 typename LeftTag = typename tag<Left>::type,
 typename RightTag = typename tag<Right>::type>
struct assign :
 public boost::numeric::functional::assign_base< Left, Right, void >
{
};
```

### Struct template plus\_assign\_base

boost::numeric::functional::plus\_assign\_base

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right, typename EnableIf = void>
struct plus_assign_base : public std::binary_function< Left, Right,
 typename boost::numeric::functional::plus_assign_base::result_type>
{
 // public member functions
 result_type operator()(Left &, Right &) const;
};
```

### Description

#### plus\_assign\_base public member functions

1. `result_type operator()(Left & left, Right & right) const;`

Returns:      left += right

### Struct template plus\_assign

boost::numeric::functional::plus\_assign

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right,
 typename LeftTag = typename tag<Left>::type,
 typename RightTag = typename tag<Right>::type>
struct plus_assign :
 public boost::numeric::functional::plus_assign_base< Left, Right, void >
{
};
```

## Struct template minus\_assign\_base

boost::numeric::functional::minus\_assign\_base

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right, typename EnableIf = void>
struct minus_assign_base : public std::binary_function< Left, Right, typeof(lvalue< Left >()-
=lvalue< Right >())>
{
 // public member functions
 result_type operator()(Left &, Right &) const;
};
```

### Description

#### minus\_assign\_base public member functions

1. 

```
result_type operator()(Left & left, Right & right) const;
```

Returns:      left -= right

## Struct template minus\_assign

boost::numeric::functional::minus\_assign

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right,
 typename LeftTag = typename tag<Left>::type,
 typename RightTag = typename tag<Right>::type>
struct minus_assign :
 public boost::numeric::functional::minus_assign_base< Left, Right, void >
{
};
```

## Struct template multiplies\_assign\_base

boost::numeric::functional::multiplies\_assign\_base

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right, typename EnableIf = void>
struct multiplies_assign_base : public std::binary_function< Left, Right, typeof(lvalue< Left >())>
{
 // public member functions
 result_type operator()(Left &, Right &) const;
};
```

### Description

#### multiplies\_assign\_base public member functions

1. `result_type operator()(Left & left, Right & right) const;`

Returns:      left \*= right

### Struct template multiplies\_assign

boost::numeric::functional::multiplies\_assign

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right,
 typename LeftTag = typename tag<Left>::type,
 typename RightTag = typename tag<Right>::type>
struct multiplies_assign : public boost::numeric::functional::multiplies_assign_base< Left,
Right, void >
{
};
```

### Struct template divides\_assign\_base

boost::numeric::functional::divides\_assign\_base

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right, typename EnableIf = void>
struct divides_assign_base : public std::binary_function< Left, Right, typeof(lvalue< Left >())>
{
 // public member functions
 result_type operator()(Left &, Right &) const;
};
```

## Description

### `divides_assign_base` public member functions

```
1. result_type operator()(Left & left, Right & right) const;
```

Returns:      `left /= right`

## Struct template `divides_assign`

`boost::numeric::functional::divides_assign`

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right,
 typename LeftTag = typename tag<Left>::type,
 typename RightTag = typename tag<Right>::type>
struct divides_assign :
 public boost::numeric::functional::divides_assign_base< Left, Right, void >
{
};
```

## Struct template `modulus_assign_base`

`boost::numeric::functional::modulus_assign_base`

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right, typename EnableIf = void>
struct modulus_assign_base : public std::binary_function< Left, Right,
 typeof(lvalue< Left > >() %= lvalue< Right > >())>
{
 // public member functions
 result_type operator()(Left &, Right &) const;
};
```

## Description

### `modulus_assign_base` public member functions

```
1. result_type operator()(Left & left, Right & right) const;
```

Returns:      `left %= right`

## Struct template `modulus_assign`

`boost::numeric::functional::modulus_assign`

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right,
 typename LeftTag = typename tag<Left>::type,
 typename RightTag = typename tag<Right>::type>
struct modulus_assign :
 public boost::numeric::functional::modulus_assign_base< Left, Right, void >
{
};
```

### Struct template unary\_plus\_base

boost::numeric::functional::unary\_plus\_base

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Arg, typename EnableIf = void>
struct unary_plus_base :
 public std::unary_function< Arg, typeof(+lvalue< Arg >())>
{
 // public member functions
 result_type operator()(Arg &) const;
};
```

### Description

**unary\_plus\_base public member functions**

1. `result_type operator()(Arg & arg) const;`

Returns:      + arg

### Struct template unary\_plus

boost::numeric::functional::unary\_plus

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Arg, typename Tag = typename tag<Arg>::type>
struct unary_plus :
 public boost::numeric::functional::unary_plus_base< Arg, void >
{
};
```

### Struct template unary\_minus\_base

boost::numeric::functional::unary\_minus\_base

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Arg, typename EnableIf = void>
struct unary_minus_base :
 public std::unary_function< Arg, typeof(-lvalue< Arg >())>
{
 // public member functions
 result_type operator()(Arg &) const;
};
```

### Description

#### **unary\_minus\_base** public member functions

1. `result_type operator()(Arg & arg) const;`

Returns:      - arg

### Struct template unary\_minus

boost::numeric::functional::unary\_minus

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Arg, typename Tag = typename tag<Arg>::type>
struct unary_minus :
 public boost::numeric::functional::unary_minus_base< Arg, void >
{
};
```

### Struct template complement\_base

boost::numeric::functional::complement\_base

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Arg, typename EnableIf = void>
struct complement_base :
 public std::unary_function< Arg, typeof(~lvalue< Arg >())>
{
 // public member functions
 result_type operator()(Arg &) const;
};
```

## Description

**complement\_base** public member functions

```
1. result_type operator()(Arg & arg) const;
```

Returns:     ~ arg

## Struct template complement

boost::numeric::functional::complement

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Arg, typename Tag = typename tag<Arg>::type>
struct complement :
 public boost::numeric::functional::complement_base< Arg, void >
{
};
```

## Struct template logical\_not\_base

boost::numeric::functional::logical\_not\_base

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Arg, typename EnableIf = void>
struct logical_not_base :
 public std::unary_function< Arg, typeof(!lvalue< Arg >())>
{
 // public member functions
 result_type operator()(Arg &) const;
};
```

## Description

**logical\_not\_base** public member functions

```
1. result_type operator()(Arg & arg) const;
```

Returns:     ! arg

## Struct template logical\_not

boost::numeric::functional::logical\_not



## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Arg, typename Tag = typename tag<Arg>::type>
struct logical_not :
 public boost::numeric::functional::logical_not_base< Arg, void >
{
};
```

### Struct template min\_assign\_base

boost::numeric::functional::min\_assign\_base

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right, typename EnableIf>
struct min_assign_base : public std::binary_function< Left, Right, void > {

 // public member functions
 void operator()(Left &, Right &) const;
};
```

### Description

**min\_assign\_base** public member functions

1. 

```
void operator()(Left & left, Right & right) const;
```

### Struct template max\_assign\_base

boost::numeric::functional::max\_assign\_base

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right, typename EnableIf>
struct max_assign_base : public std::binary_function< Left, Right, void > {

 // public member functions
 void operator()(Left &, Right &) const;
};
```

### Description

**max\_assign\_base** public member functions

1. 

```
void operator()(Left & left, Right & right) const;
```

## Struct template average\_base

boost::numeric::functional::average\_base

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right, typename EnableIf>
struct average_base :
 public boost::numeric::functional::divides< Left, Right >
{
};
```

## Struct template average\_base<Left, Right, typename enable\_if< are\_integral< Left, Right > >::type>

boost::numeric::functional::average\_base<Left, Right, typename enable\_if< are\_integral< Left, Right > >::type>

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right>
struct average_base<Left, Right, typename enable_if< are_integral< Left, Right > >::type> :
 public boost::numeric::functional::divides< double const, double const >
{
};
```

## Struct template promote\_base

boost::numeric::functional::promote\_base

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename To, typename From, typename EnableIf>
struct promote_base : public std::unary_function< From, To > {

 // public member functions
 To operator()(From &) const;
};
```

## Description

**promote\_base** public member functions

1. To operator()(From & from) const;

## Struct template promote\_base<ToFrom, ToFrom, void>

boost::numeric::functional::promote\_base<ToFrom, ToFrom, void>

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename ToFrom>
struct promote_base<ToFrom, ToFrom, void> : public std::unary_function< ToFrom, ToFrom > {

 // public member functions
 ToFrom & operator()(ToFrom &);
};
```

### Description

**promote\_base** public member functions

1. `ToFrom & operator()(ToFrom & tofrom);`

## Struct template `as_min_base`

`boost::numeric::functional::as_min_base`

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Arg, typename EnableIf>
struct as_min_base :
 public std::unary_function< Arg, remove_const< Arg >::type >
{

 // public member functions
 BOOST_STATIC_ASSERT(std::numeric_limits< typename remove_const< Arg >::type >::is_specialized);
 remove_const< Arg >::type operator()(Arg &) const;
};
```

### Description

**as\_min\_base** public member functions

1. `BOOST_STATIC_ASSERT(std::numeric_limits< typename remove_const< Arg >::type >::is_specialized);`
2. `remove_const< Arg >::type operator()(Arg &) const;`

## Struct template `as_min_base<Arg, typename enable_if< is_floating_point< Arg > >::type>`

`boost::numeric::functional::as_min_base<Arg, typename enable_if< is_floating_point< Arg > >::type>`

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Arg>
struct as_min_base<Arg, typename enable_if< is_floating_point< Arg >>::type> :
{
 public std::unary_function< Arg, remove_const< Arg >::type> >

 // public member functions
 BOOST_STATIC_ASSERT(std::numeric_limits< typename remove_const< Arg >::type>>::is_specialized);
 remove_const< Arg >::type operator()(Arg &) const;
};
```

### Description

#### as\_min\_base public member functions

1. BOOST\_STATIC\_ASSERT(std::numeric\_limits< typename remove\_const< Arg >::type>>::is\_specialized);
2. remove\_const< Arg >::type operator()(Arg &) const;

## Struct template as\_max\_base

boost::numeric::functional::as\_max\_base

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Arg, typename EnableIf>
struct as_max_base :
{
 public std::unary_function< Arg, remove_const< Arg >::type> >

 // public member functions
 BOOST_STATIC_ASSERT(std::numeric_limits< typename remove_const< Arg >::type>>::is_specialized);
 remove_const< Arg >::type operator()(Arg &) const;
};
```

### Description

#### as\_max\_base public member functions

1. BOOST\_STATIC\_ASSERT(std::numeric\_limits< typename remove\_const< Arg >::type>>::is\_specialized);
2. remove\_const< Arg >::type operator()(Arg &) const;

## Struct template as\_zero\_base

boost::numeric::functional::as\_zero\_base

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Arg, typename EnableIf>
struct as_zero_base :
 public std::unary_function< Arg, remove_const< Arg >::type >
{
 // public member functions
 remove_const< Arg >::type operator()(Arg &) const;
};
```

### Description

#### as\_zero\_base public member functions

1. `remove_const< Arg >::type operator()(Arg &) const;`

## Struct template as\_one\_base

boost::numeric::functional::as\_one\_base

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Arg, typename EnableIf>
struct as_one_base :
 public std::unary_function< Arg, remove_const< Arg >::type >
{
 // public member functions
 remove_const< Arg >::type operator()(Arg &) const;
};
```

### Description

#### as\_one\_base public member functions

1. `remove_const< Arg >::type operator()(Arg &) const;`

## Struct template promote

boost::numeric::functional::promote

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename To, typename From, typename ToTag, typename FromTag>
struct promote :
 public boost::numeric::functional::promote_base< To, From, void >
{
};
```

### Struct template min\_assign

boost::numeric::functional::min\_assign

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right, typename LeftTag, typename RightTag>
struct min_assign :
 public boost::numeric::functional::min_assign_base< Left, Right, void >
{
};
```

### Struct template max\_assign

boost::numeric::functional::max\_assign

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right, typename LeftTag, typename RightTag>
struct max_assign :
 public boost::numeric::functional::max_assign_base< Left, Right, void >
{
};
```

### Struct template average

boost::numeric::functional::average

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Left, typename Right, typename LeftTag, typename RightTag>
struct average :
 public boost::numeric::functional::average_base< Left, Right, void >
{
};
```

## Struct template as\_min

boost::numeric::functional::as\_min

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Arg, typename Tag>
struct as_min : public boost::numeric::functional::as_min_base< Arg, void > {
};
```

## Struct template as\_max

boost::numeric::functional::as\_max

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Arg, typename Tag>
struct as_max : public boost::numeric::functional::as_max_base< Arg, void > {
};
```

## Struct template as\_zero

boost::numeric::functional::as\_zero

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Arg, typename Tag>
struct as_zero : public boost::numeric::functional::as_zero_base< Arg, void > {
};
```

## Struct template as\_one

boost::numeric::functional::as\_one

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename Arg, typename Tag>
struct as_one : public boost::numeric::functional::as_one_base< Arg, void > {
};
```

## Struct plus

boost::numeric::op::plus

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

struct plus {
};
```

### Struct minus

boost::numeric::op::minus

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

struct minus {
};
```

### Struct multiplies

boost::numeric::op::multiplies

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

struct multiplies {
};
```

### Struct divides

boost::numeric::op::divides

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

struct divides {
};
```

### Struct modulus

boost::numeric::op::modulus



## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

struct modulus {
};
```

### Struct greater

boost::numeric::op::greater

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

struct greater {
};
```

### Struct greater\_equal

boost::numeric::op::greater\_equal

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

struct greater_equal {
};
```

### Struct less

boost::numeric::op::less

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

struct less {
};
```

### Struct less\_equal

boost::numeric::op::less\_equal

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

struct less_equal {
};
```

### Struct equal\_to

boost::numeric::op::equal\_to

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

struct equal_to {
};
```

### Struct not\_equal\_to

boost::numeric::op::not\_equal\_to

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

struct not_equal_to {
};
```

### Struct assign

boost::numeric::op::assign

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

struct assign {
};
```

### Struct plus\_assign

boost::numeric::op::plus\_assign

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

struct plus_assign {
};
```

### Struct minus\_assign

boost::numeric::op::minus\_assign

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

struct minus_assign {
};
```

### Struct multiplies\_assign

boost::numeric::op::multiplies\_assign

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

struct multiplies_assign {
};
```

### Struct divides\_assign

boost::numeric::op::divides\_assign

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

struct divides_assign {
};
```

### Struct modulus\_assign

boost::numeric::op::modulus\_assign

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

struct modulus_assign {
};
```

### Struct unary\_plus

boost::numeric::op::unary\_plus

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

struct unary_plus {
};
```

### Struct unary\_minus

boost::numeric::op::unary\_minus

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

struct unary_minus {
};
```

### Struct complement

boost::numeric::op::complement

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

struct complement {
};
```

### Struct logical\_not

boost::numeric::op::logical\_not

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

struct logical_not {
};
```

### Struct template promote

boost::numeric::op::promote

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename To>
struct promote {
};
```

### Struct min\_assign

boost::numeric::op::min\_assign

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

struct min_assign {
};
```

### Struct max\_assign

boost::numeric::op::max\_assign

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

struct max_assign {
};
```

### Struct average

boost::numeric::op::average

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

struct average {
};
```

### Struct as\_min

boost::numeric::op::as\_min

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

struct as_min {
};
```

### Struct as\_max

boost::numeric::op::as\_max

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

struct as_max {
};
```

### Struct as\_zero

boost::numeric::op::as\_zero

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

struct as_zero {
};
```

### Struct as\_one

boost::numeric::op::as\_one

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

struct as_one {
};
```

### Struct template default\_

boost::numeric::default\_

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename T>
struct default_ {
 // types
 typedef T value_type;

 // public static functions

 // public member functions
 operator T const &() const;

 // public data members
 static T const value;
};
```

### Description

**default\_ public static functions**

**default\_ public member functions**

1. `operator T const &() const;`

### Struct template one

boost::numeric::one

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename T>
struct one {
 // types
 typedef one type;
 typedef T value_type;

 // public member functions
 operator T const &() const;

 // public data members
 static T const value;
};
```

### Description

**one** public member functions

1. `operator T const &() const;`

## Struct template zero

boost::numeric::zero

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename T>
struct zero {
 // types
 typedef zero type;
 typedef T value_type;

 // public member functions
 operator T const &() const;

 // public data members
 static T const value;
};
```

### Description

**zero** public member functions

1. `operator T const &() const;`

## Struct template one\_or\_default

boost::numeric::one\_or\_default



## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename T>
struct one_or_default :
 public mpl::if_::type< is_empty< T >, default_< T >, one< T > >
{
};
```

### Struct template zero\_or\_default

boost::numeric::zero\_or\_default

## Synopsis

```
// In header: <boost/accumulators/numeric/functional.hpp>

template<typename T>
struct zero_or_default :
 public mpl::if_::type< is_empty< T >, default_< T >, zero< T > >
{
};
```

### Header <boost/accumulators/numeric/functional/complex.hpp>

```
namespace boost {
 namespace numeric {
 namespace operators {
 template<typename T, typename U>
 disable_if< mpl::or_< is_same< T, U >, is_same< std::complex< T >, U > >, std::complex< T > >::type
 operator*(std::complex< T > ri, U const & u);
 template<typename T, typename U>
 disable_if< mpl::or_< is_same< T, U >, is_same< std::complex< T >, U > >, std::complex< T > >::type
 operator/(std::complex< T > ri, U const & u);
 }
 }
}
```

## Header `<boost/accumulators/numeric/functional/valarray.hpp>`

```

namespace boost {
 namespace numeric {
 namespace functional {
 template<typename T> struct tag<std::valarray< T >>;
 template<typename Left, typename Right>
 struct min_assign<Left, Right, std_valarray_tag, std_valarray_tag>;
 template<typename Left, typename Right>
 struct max_assign<Left, Right, std_valarray_tag, std_valarray_tag>;
 template<typename Left, typename Right, typename RightTag>
 struct average<Left, Right, std_valarray_tag, RightTag>;
 template<typename To, typename From>
 struct promote<To, From, std_valarray_tag, std_valarray_tag>;
 template<typename ToFrom>
 struct promote<ToFrom, ToFrom, std_valarray_tag, std_valarray_tag>;
 template<typename From> struct promote<bool, From, void, std_valarray_tag>;
 template<typename From>
 struct promote<bool const, From, void, std_valarray_tag>;
 template<typename T> struct as_min<T, std_valarray_tag>;
 template<typename T> struct as_max<T, std_valarray_tag>;
 template<typename T> struct as_zero<T, std_valarray_tag>;
 template<typename T> struct as_one<T, std_valarray_tag>;
 }
 namespace operators {
 template<typename Left, typename Right>
 unspecified operator/(std::valarray< Left > const & left,
 Right const & right);
 template<typename Left, typename Right>
 unspecified operator*(std::valarray< Left > const & left,
 Right const & right);
 template<typename Left, typename Right>
 unspecified operator+(std::valarray< Left > const & left,
 std::valarray< Right > const & right);
 }
 }
}

```

### Struct template `tag<std::valarray< T >>`

`boost::numeric::functional::tag<std::valarray< T >>`

## Synopsis

```

// In header: <boost/accumulators/numeric/functional/valarray.hpp>

template<typename T>
struct tag<std::valarray< T >> {
 // types
 typedef std_valarray_tag type;
};

```

### Struct template `min_assign<Left, Right, std_valarray_tag, std_valarray_tag>`

`boost::numeric::functional::min_assign<Left, Right, std_valarray_tag, std_valarray_tag>`

## Synopsis

```
// In header: <boost/accumulators/numeric/functional/valarray.hpp>

template<typename Left, typename Right>
struct min_assign<Left, Right, std_valarray_tag, std_valarray_tag> : public std::binary_function< Left, Right, void > {

 // public member functions
 void operator()(Left &, Right &) const;
};
```

### Description

**min\_assign** public member functions

1. 

```
void operator()(Left & left, Right & right) const;
```

## Struct template `max_assign<Left, Right, std_valarray_tag, std_valarray_tag>`

`boost::numeric::functional::max_assign<Left, Right, std_valarray_tag, std_valarray_tag>`

## Synopsis

```
// In header: <boost/accumulators/numeric/functional/valarray.hpp>

template<typename Left, typename Right>
struct max_assign<Left, Right, std_valarray_tag, std_valarray_tag> : public std::binary_function< Left, Right, void > {

 // public member functions
 void operator()(Left &, Right &) const;
};
```

### Description

**max\_assign** public member functions

1. 

```
void operator()(Left & left, Right & right) const;
```

## Struct template `average<Left, Right, std_valarray_tag, RightTag>`

`boost::numeric::functional::average<Left, Right, std_valarray_tag, RightTag>`

## Synopsis

```
// In header: <boost/accumulators/numeric/functional/valarray.hpp>

template<typename Left, typename Right, typename RightTag>
struct average<Left, Right, std_valarray_tag, RightTag> : public mpl::if_::type< are_integral< Left::value_type, Right >, divides< Left, double const >, divides< Left, Right > >
{
};
```

## Struct template `promote<To, From, std_valarray_tag, std_valarray_tag>`

`boost::numeric::functional::promote<To, From, std_valarray_tag, std_valarray_tag>`

## Synopsis

```
// In header: <boost/accumulators/numeric/functional/valarray.hpp>

template<typename To, typename From>
struct promote<To, From, std_valarray_tag, std_valarray_tag> : public std::unary_function< From, To > {

 // public member functions
 To operator()(From &) const;
};
```

### Description

`promote` public member functions

1. `To operator()(From & arr) const;`

## Struct template `promote<ToFrom, ToFrom, std_valarray_tag, std_valarray_tag>`

`boost::numeric::functional::promote<ToFrom, ToFrom, std_valarray_tag, std_valarray_tag>`

## Synopsis

```
// In header: <boost/accumulators/numeric/functional/valarray.hpp>

template<typename ToFrom>
struct promote<ToFrom, ToFrom, std_valarray_tag, std_valarray_tag> : public std::unary_function< ToFrom, ToFrom > {

 // public member functions
 ToFrom & operator()(ToFrom &) const;
};
```

### Description

`promote` public member functions

1. `ToFrom & operator()(ToFrom & tofrom) const;`

## Struct template `promote<bool, From, void, std_valarray_tag>`

`boost::numeric::functional::promote<bool, From, void, std_valarray_tag>`

## Synopsis

```
// In header: <boost/accumulators/numeric/functional/valarray.hpp>

template<typename From>
struct promote<bool, From, void, std_valarray_tag> : public std::unary_function< From, bool > {

 // public member functions
 bool operator()(From &) const;
};
```

### Description

**promote** public member functions

1. `bool operator()(From & arr) const;`

### Struct template `promote<bool const, From, void, std_valarray_tag>`

`boost::numeric::functional::promote<bool const, From, void, std_valarray_tag>`

## Synopsis

```
// In header: <boost/accumulators/numeric/functional/valarray.hpp>

template<typename From>
struct promote<bool const, From, void, std_valarray_tag> : public boost::numeric::functional::promote< bool, From, void, std_valarray_tag >
{
};
```

### Struct template `as_min<T, std_valarray_tag>`

`boost::numeric::functional::as_min<T, std_valarray_tag>`

## Synopsis

```
// In header: <boost/accumulators/numeric/functional/valarray.hpp>

template<typename T>
struct as_min<T, std_valarray_tag> : public std::unary_function< T, remove_const< T >::type > {

 // public member functions
 remove_const< T >::type operator()(T &) const;
};
```

### Description

**as\_min** public member functions

1. `remove_const< T >::type operator()(T & arr) const;`

## Struct template `as_max<T, std_valarray_tag>`

`boost::numeric::functional::as_max<T, std_valarray_tag>`

## Synopsis

```
// In header: <boost/accumulators/numeric/functional/valarray.hpp>

template<typename T>
struct as_max<T, std_valarray_tag> : public std::unary_function< T, remove_const< T >::type > {

 // public member functions
 remove_const< T >::type operator()(T &) const;
};
```

### Description

#### `as_max` public member functions

1. `remove_const< T >::type operator()(T & arr) const;`

## Struct template `as_zero<T, std_valarray_tag>`

`boost::numeric::functional::as_zero<T, std_valarray_tag>`

## Synopsis

```
// In header: <boost/accumulators/numeric/functional/valarray.hpp>

template<typename T>
struct as_zero<T, std_valarray_tag> : public std::unary_function< T, remove_const< T >::type > {

 // public member functions
 remove_const< T >::type operator()(T &) const;
};
```

### Description

#### `as_zero` public member functions

1. `remove_const< T >::type operator()(T & arr) const;`

## Struct template `as_one<T, std_valarray_tag>`

`boost::numeric::functional::as_one<T, std_valarray_tag>`

## Synopsis

```
// In header: <boost/accumulators/numeric/functional/valarray.hpp>

template<typename T>
struct as_one<T, std_valarray_tag> : public std::unary_function< T, remove_const< T >::type > {

 // public member functions
 remove_const< T >::type operator()(T &) const;
};
```

## Description

### as\_one public member functions

1. `remove_const< T >::type operator()(T & arr) const;`

## Header <boost/accumulators/numeric/functional/vector.hpp>

```
namespace boost {
 namespace numeric {
 namespace functional {
 template<typename T, typename A1> struct tag<std::vector< T, A1 >>;
 template<typename Left, typename Right>
 struct min_assign<Left, Right, std_vector_tag, std_vector_tag>;
 template<typename Left, typename Right>
 struct max_assign<Left, Right, std_vector_tag, std_vector_tag>;
 template<typename Left, typename Right>
 struct average<Left, Right, std_vector_tag, void>;
 template<typename To, typename From>
 struct promote<To, From, std_vector_tag, std_vector_tag>;
 template<typename ToFrom>
 struct promote<ToFrom, ToFrom, std_vector_tag, std_vector_tag>;
 template<typename T> struct as_min<T, std_vector_tag>;
 template<typename T> struct as_max<T, std_vector_tag>;
 template<typename T> struct as_zero<T, std_vector_tag>;
 template<typename T> struct as_one<T, std_vector_tag>;
 }
 namespace operators {
 template<typename Left, typename Right>
 unspecified operator/(std::vector< Left > const & left,
 Right const & right);
 template<typename Left, typename Right>
 std::vector< typename functional::divides< Left, Right >::result_type >
 operator/(std::vector< Left > const & left,
 std::vector< Right > const & right);
 template<typename Left, typename Right>
 unspecified operator*(std::vector< Left > const & left,
 Right const & right);
 template<typename Left, typename Right>
 unspecified operator*(Left const & left,
 std::vector< Right > const & right);
 template<typename Left, typename Right>
 std::vector< typename functional::multiplies< Left, Right >::result_type >
 operator*(std::vector< Left > const & left,
 std::vector< Right > const & right);
 template<typename Left, typename Right>
 std::vector< typename functional::plus< Left, Right >::result_type >
 operator+(std::vector< Left > const & left,
```

```

 std::vector< Right > const & right);
template<typename Left, typename Right>
 std::vector< typename functional::minus< Left, Right >::result_type >
 operator-(std::vector< Left > const & left,
 std::vector< Right > const & right);
template<typename Left>
 std::vector< Left > &
 operator+=(std::vector< Left > & left,
 std::vector< Left > const & right);
template<typename Arg>
 std::vector< typename functional::unary_minus< Arg >::result_type >
 operator-(std::vector< Arg > const & arg);
 }
}
}

```

## Struct template tag<std::vector<T, Al >>

boost::numeric::functional::tag<std::vector<T, Al >>

## Synopsis

```

// In header: <boost/accumulators/numeric/functional/vector.hpp>

template<typename T, typename Al>
struct tag<std::vector< T, Al >> {
 // types
 typedef std_vector_tag type;
};

```

## Struct template min\_assign<Left, Right, std\_vector\_tag, std\_vector\_tag>

boost::numeric::functional::min\_assign<Left, Right, std\_vector\_tag, std\_vector\_tag>

## Synopsis

```

// In header: <boost/accumulators/numeric/functional/vector.hpp>

template<typename Left, typename Right>
struct min_assign<Left, Right, std_vector_tag, std_vector_tag> : public std::binary_function< Left, Right, void > {

 // public member functions
 void operator()(Left &, Right &) const;
};

```

## Description

### min\_assign public member functions

1. `void operator()(Left & left, Right & right) const;`



## Struct template `max_assign<Left, Right, std_vector_tag, std_vector_tag>`

`boost::numeric::functional::max_assign<Left, Right, std_vector_tag, std_vector_tag>`

## Synopsis

```
// In header: <boost/accumulators/numeric/functional/vector.hpp>

template<typename Left, typename Right>
struct max_assign<Left, Right, std_vector_tag, std_vector_tag> : public std::binary_function<
 Left, Right, void > {

 // public member functions
 void operator()(Left &, Right &) const;
};
```

### Description

**max\_assign** public member functions

1. `void operator()(Left & left, Right & right) const;`

## Struct template `average<Left, Right, std_vector_tag, void>`

`boost::numeric::functional::average<Left, Right, std_vector_tag, void>`

## Synopsis

```
// In header: <boost/accumulators/numeric/functional/vector.hpp>

template<typename Left, typename Right>
struct average<Left, Right, std_vector_tag, void> : public mpl::if_::type< are_integral<
 Left::value_type, Right >, divides< Left, double const >, divides< Left, Right > >
{
};
```

## Struct template `promote<To, From, std_vector_tag, std_vector_tag>`

`boost::numeric::functional::promote<To, From, std_vector_tag, std_vector_tag>`

## Synopsis

```
// In header: <boost/accumulators/numeric/functional/vector.hpp>

template<typename To, typename From>
struct promote<To, From, std_vector_tag, std_vector_tag> : public std::unary_function< From, To > {

 // public member functions
 To operator()(From &) const;
};
```

## Description

**promote** public member functions

1. 

```
To operator()(From & arr) const;
```

## Struct template `promote<ToFrom, ToFrom, std_vector_tag, std_vector_tag>`

`boost::numeric::functional::promote<ToFrom, ToFrom, std_vector_tag, std_vector_tag>`

## Synopsis

```
// In header: <boost/accumulators/numeric/functional/vector.hpp>

template<typename ToFrom>
struct promote<ToFrom, ToFrom, std_vector_tag, std_vector_tag> : public std::unary_function< ToFrom, ToFrom > {

 // public member functions
 ToFrom & operator()(ToFrom &) const;
};
```

## Description

**promote** public member functions

1. 

```
ToFrom & operator()(ToFrom & tofrom) const;
```

## Struct template `as_min<T, std_vector_tag>`

`boost::numeric::functional::as_min<T, std_vector_tag>`

## Synopsis

```
// In header: <boost/accumulators/numeric/functional/vector.hpp>

template<typename T>
struct as_min<T, std_vector_tag> : public std::unary_function< T, remove_const< T >::type > {

 // public member functions
 remove_const< T >::type operator()(T &) const;
};
```

## Description

**as\_min** public member functions

1. 

```
remove_const< T >::type operator()(T & arr) const;
```

## Struct template `as_max<T, std_vector_tag>`

`boost::numeric::functional::as_max<T, std_vector_tag>`

## Synopsis

```
// In header: <boost/accumulators/numeric/functional/vector.hpp>

template<typename T>
struct as_max<T, std_vector_tag> : public std::unary_function< T, remove_const< T >::type > {

 // public member functions
 remove_const< T >::type operator()(T &) const;
};
```

### Description

#### as\_max public member functions

1. `remove_const< T >::type operator()(T & arr) const;`

## Struct template as\_zero<T, std\_vector\_tag>

boost::numeric::functional::as\_zero<T, std\_vector\_tag>

## Synopsis

```
// In header: <boost/accumulators/numeric/functional/vector.hpp>

template<typename T>
struct as_zero<T, std_vector_tag> : public std::unary_function< T, remove_const< T >::type > {

 // public member functions
 remove_const< T >::type operator()(T &) const;
};
```

### Description

#### as\_zero public member functions

1. `remove_const< T >::type operator()(T & arr) const;`

## Struct template as\_one<T, std\_vector\_tag>

boost::numeric::functional::as\_one<T, std\_vector\_tag>

## Synopsis

```
// In header: <boost/accumulators/numeric/functional/vector.hpp>

template<typename T>
struct as_one<T, std_vector_tag> : public std::unary_function< T, remove_const< T >::type > {

 // public member functions
 remove_const< T >::type operator()(T &) const;
};
```

**Description****as\_one** public member functions

1. 

```
remove_const< T >::type operator()(T & arr) const;
```