Fusion 2.1

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Preface

“Algorithms + Data Structures = Programs.”

--Niklaus Wirth

Description

Fusion is a library for working with heterogenous collections of data, commonly referred to as tuples. A set of containers (vector, list, set and map) is provided, along with views that provide a transformed presentation of their underlying data. Collectively the containers and views are referred to as sequences, and Fusion has a suite of algorithms that operate upon the various sequence types, using an iterator concept that binds everything together.

The architecture is modeled after MPL which in turn is modeled after STL. It is named "fusion" because the library is a "fusion" of compile time metaprogramming with runtime programming.

Motivation

Tuples are powerful beasts. After having developed two significant projects (Spirit and Phoenix) that relied heavily metaprogramming, it became apparent that tuples are a powerful means to simplify otherwise tricky tasks; especially those that require a combination of metaprogramming and manipulation of heterogenous data types with values. While MPL is an extremely powerful metaprogramming tool, MPL focuses on type manipulation only. Ultimately, you'll have to map these types to real values to make them useful in the runtime world where all the real action takes place.

As Spirit and Phoenix evolved, patterns and idioms related to tuple manipulation emerged. Soon, it became clear that those patterns and idioms were best assembled in a tuples algorithms library. David Abrahams outlined such a scheme in 2002. At that time, it just so happened that Spirit and Phoenix had an adhoc collection of tuple manipulation and traversal routines. It was an instant *AHA!* moment.

How to use this manual

Some icons are used to mark certain topics indicative of their relevance. These icons precede some text to indicate:

Table 1. Icons

Icon	Name	Meaning
ⓘ	Note	Information provided is auxiliary but will give the reader a deeper insight into a specific topic. May be skipped.
⚠	Alert	Information provided is of utmost importance.
◆	Caution	A mild warning.
☞	Tip	A potentially useful and helpful piece of information.

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Support

Please direct all questions to Spirit's mailing list. You can subscribe to the Spirit Mailing List. The mailing list has a searchable archive. A search link to this archive is provided in Spirit's home page. You may also read and post messages to the mailing list through Spirit General NNTP news portal (thanks to Gmane). The news group mirrors the mailing list. Here is a link to the archives: http://news.gmane.org/gmane.comp.parsers.spirit.general.

Introduction

An advantage other languages such as Python and Lisp/ Scheme, ML and Haskell, etc., over C++ is the ability to have heterogeneous containers that can hold arbitrary element types. All the containers in the standard library can only hold a specific type. A `vector<int>` can only hold `int`s. A `list<X>` can only hold elements of type `X`, and so on.

True, you can use inheritance to make the containers hold different types, related through subclassing. However, you have to hold the objects through a pointer or smart reference of some sort. Doing this, you'll have to rely on virtual functions to provide polymorphic behavior since the actual type is erased as soon as you store a pointer to a derived class to a pointer to its base. The held objects must be related: you cannot hold objects of unrelated types such as `char`, `int`, `class X`, `float`, etc. Oh sure you can use something like Boost.Any to hold arbitrary types, but then you pay more in terms of runtime costs and due to the fact that you practically erased all type information, you'll have to perform dangerous casts to get back the original type.

The Boost.Tuple library written by Jaakko Jarvi provides heterogeneous containers in C++. The `tuple` is a basic data structure that can hold heterogeneous types. It's a good first step, but it's not complete. What's missing are the algorithms. It's nice that we can store and retrieve data to and from tuples, pass them around as arguments and return types. As it is, the Boost.Tuple facility is already very useful. Yet, as soon as you use it more often, usage patterns emerge. Eventually, you collect these patterns into algorithm libraries.

Hmmm, kinda reminds us of STL right? Right! Can you imagine how it would be like if you used STL without the algorithms? Everyone will have to reinvent their own *algorithm* wheels.

Fusion is a library and a framework similar to both STL and the boost MPL. The structure is modeled after MPL, which is modeled after STL. It is named "fusion" because the library is reminiscent of the "fusion" of compile time meta-programming with runtime programming. The library inherently has some interesting flavors and characteristics of both MPL and STL. It lives in the twilight zone between compile time meta-programming and run time programming. STL containers work on values. MPL containers work on types. Fusion containers work on both types and values.

Unlike MPL, Fusion algorithms are lazy and non sequence-type preserving. What does that mean? It means that when you operate on a sequence through a Fusion algorithm that returns a sequence, the sequence returned may not be of the same class as the original. This is by design. Runtime efficiency is given a high priority. Like MPL, and unlike STL, fusion algorithms are functional in nature such that algorithms are non mutating (no side effects). However, due to the high cost of returning full sequences such as vectors and lists, *Views* are returned from Fusion algorithms instead. For example, the `transform` algorithm does not actually return a transformed version of the original sequence. `transform` returns a `transform_view`. This view holds a reference to the original sequence plus the transform function. Iteration over the `transform_view` will apply the transform function over the sequence elements on demand. This *lazy* evaluation scheme allows us to chain as many algorithms as we want without incurring a high runtime penalty.

The *lazy* evaluation scheme where algorithms return views allows operations such as `push_back` to be totally generic. In Fusion, `push_back` is actually a generic algorithm that works on all sequences. Given an input sequence `s` and a value `x`, Fusion's `push_back` algorithm simply returns a `joint_view`: a view that holds a reference to the original sequence `s` and the value `x`. Functions that were once sequence specific and need to be implemented N times over N different sequences are now implemented only once.

Fusion provides full round compatibility with MPL. Fusion sequences are fully conforming MPL sequences and MPL sequences are fully compatible with Fusion. You can work with Fusion sequences on MPL if you wish to work solely on types [1]. In MPL, Fusion sequences follow MPL's sequence-type preserving semantics (i.e. algorithms preserve the original sequence type. e.g. transforming a vector returns a vector). You can also convert from an MPL sequence to a Fusion sequence. For example, there are times when it is convenient to work solely on MPL using pure MPL sequences, then, convert them to Fusion sequences as a final step before actual instantiation of real runtime objects with data. You have the best of both worlds.

[1] Choose MPL over fusion when doing pure type calculations. Once the static type calculation is finished, you can instantiate a fusion sequence (see Conversion) for the runtime part.

Quick Start

I assume the reader is already familiar with tuples (Boost.Tuple) and its ancestor `std::pair`. The tuple is a generalization of `std::pair` for multiple heterogeneous elements (triples, quadruples, etc.). The tuple is more or less a synonym for fusion's `vector`.

For starters, we shall include all of Fusion's Sequence(s) [2]:

```
#include <boost/fusion/sequence.hpp>
#include <boost/fusion/include/sequence.hpp>
```

Let's begin with a `vector` [3]:

```
vector<int, char, std::string> stuff(1, 'x', "howdy");
int i = at_c<0>(stuff);
char ch = at_c<1>(stuff);
std::string s = at_c<2>(stuff);
```

Just replace `tuple` for `vector` and `get` for `at_c` and this is exactly like Boost.Tuple. Actually, either names can be used interchangeably. Yet, the similarity ends there. You can do a lot more with Fusion `vector` or `tuple`. Let's see some examples.

Print the vector as XML

First, let's include the algorithms:

```
#include <boost/fusion/algorithm.hpp>
#include <boost/fusion/include/algorithm.hpp>
```

Now, let's write a function object that prints XML of the form <type>data</type> for each member in the tuple.

```
struct print_xml
{
    template <typename T>
    void operator()(T const& x) const
    {
        std::cout
            << '<' << typeid(x).name() << '>'
            << x
            << "</" << typeid(x).name() << '>'
            ;
    }
};
```

Now, finally:

```
for_each(stuff, print_xml());
```

That's it! `for_each` is a fusion algorithm. It is a generic algorithm similar to STL's. It iterates over the sequence and calls a user supplied function. In our case, it calls `print_xml`'s `operator()` for each element in `stuff`.

[2] There are finer grained header files available if you wish to have more control over which components to include (see section Organization for details).
[3] Unless otherwise noted, components are in namespace `boost::fusion`. For the sake of simplicity, code in this quick start implies `using` directives for the fusion components we will be using.

Caution

The result of `typeid(x).name()` is platform specific. The code here is just for exposition. Of course you already know that :-)

`for_each` is generic. With `print_xml`, you can use it to print just about any Fusion Sequence.

Print only pointers

Let's get a little cleverer. Say we wish to write a *generic* function that takes in an arbitrary sequence and XML prints only those elements which are pointers. Ah, easy. First, let's include the `is_pointer` boost type trait:

```
#include <boost/type_traits/is_pointer.hpp>
```

Then, simply:

```
template <typename Sequence>
void xml_print_pointers(Sequence const& seq)
{
    for_each(filter_if<boost::is_pointer<_> >(seq), print_xml());
}
```

`filter_if` is another Fusion algorithm. It returns a `filter_view`, a conforming Fusion sequence. This view reflects only those elements that pass the given predicate. In this case, the predicate is `boost::is_pointer<_>`. This "filtered view" is then passed to the `for_each` algorithm, which then prints the "filtered view" as XML.

Easy, right?

Associative tuples

Ok, moving on...

Apart from `vector`, fusion has a couple of other sequence types to choose from. Each sequence has its own characteristics. We have `list`, `set`, `map`, plus a multitude of `views` that provide various ways to present the sequences.

Fusion's `map` associate types with elements. It can be used as a cleverer replacement of the `struct`. Example:

```
namespace fields
{
    struct name;
    struct age;
}

typedef map<
    fusion::pair<fields::name, std::string>
  , fusion::pair<fields::age, int> >
person;
```

`map` is an associative sequence. Its elements are Fusion pairs which differ somewhat from `std::pair`. Fusion pairs only contain one member, with the type of their second template parameter. The first type parameter of the pair is used as an index to the associated element in the sequence. For example, given a `a_person` of type, `person`, you can do:

```
using namespace fields;
std::string person_name = at_key<name>(a_person);
int person_age = at_key<age>(a_person);
```

Why go through all this trouble, you say? Well, for one, unlike the `struct`, we are dealing with a generic data structure. There are a multitude of facilities available at your disposal provided out of the box with fusion or written by others. With these facilities, introspection comes for free, for example. We can write one serialization function (well, two, if you consider loading and saving) that will work for all your fusion `map`s. Example:

```
struct saver
{
    template <typename Pair>
    void operator()(Pair const& data) const
    {
        some_archive << data.second;
    }
};

template <typename Stuff>
void save(Stuff const& stuff)
{
    for_each(stuff, saver());
}
```

The `save` function is generic and will work for all types of `stuff` regardless if it is a `person`, a `dog` or a whole `alternate_universe`.

Tip of the Iceberg

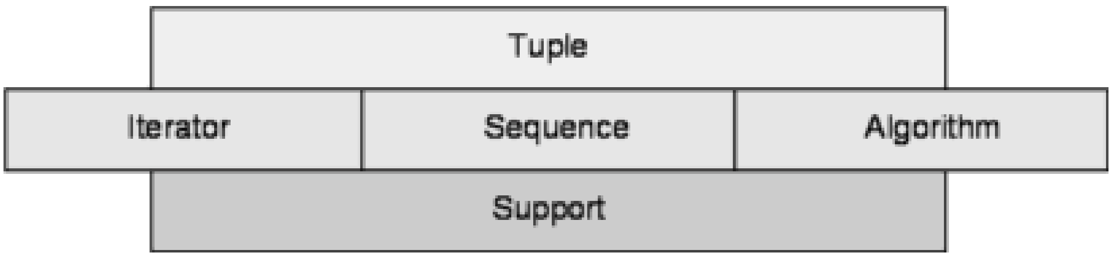
And... we've barely scratched the surface! You can compose and expand the data structures, remove elements from the structures, find specific data types, query the elements, filter out types for inspection, transform data structures, etc. What you've seen is just the tip of the iceberg.

Organization

The library is organized into layers of modules, with each module addressing a particular area of responsibility. A module may not depend on modules in higher layers.

The library is organized in three layers:

Layers



The entire library is found in the `"boost/fusion"` directory. Modules are organized in directories. Each module has its own header file placed in the same directory with the actual module-directory. For example, there exists `"boost/fusion/support.hpp"` in the same directory as "boost/fusion/support". Everything, except those found inside "detail" directories, is public.

There is also a `"boost/fusion/include/"` directory that contains all the headers to all the components and modules. If you are unsure where to find a specific component or module, or don't want to fuss with hierarchy and nesting, use this.

The library is header-only. There is no need to build object files to link against.

Directory

- tuple
- algorithm
  - iteration
  - query
  - transformation
- adapted
  - array
  - mpl
  - boost::tuple
  - std_pair
  - struct
  - variant
- view
  - filter_view
  - iterator_range
  - joint_view

  - reverse_view
  - single_view
  - transform_view
  - zip_view
- container
  - deque
  - list
  - map
  - set
  - vector
  - generation
- mpl
- functional
- sequence
  - comparison
  - intrinsic
  - io
- iterator
- support

Example

If, for example, you want to use `list`, depending on the granularity that you desire, you may do so by including one of

```
#include <boost/fusion/container.hpp>
#include <boost/fusion/include/container.hpp>
#include <boost/fusion/container/list.hpp>
#include <boost/fusion/include/list.hpp>
```

The first includes all containers The second includes only `list` [4].

[4] Modules may contain smaller components. Header file information for each component will be provided as part of the component's documentation.

Support

A couple of classes and metafunctions provide basic support for Fusion.

is_sequence

Description

Metafunction that evaluates to `mpl::true_` if a certain type `T` is a conforming Fusion Sequence, `mpl::false_` otherwise. This may be specialized to accomodate clients which provide Fusion conforming sequences.

Synopsis

```
namespace traits
{
    template <typename T>
    struct is_sequence
    {
        typedef unspecified type;
    };
}
```

Parameters

Parameter	Requirement	Description
`T`	Any type	The type to query.

Expression Semantics

```
typedef traits::is_sequence<T>::type c;
```

Return type: An MPL Boolean Constant.

Semantics: Metafunction that evaluates to `mpl::true_` if a certain type `T` is a conforming Fusion sequence, `mpl::false_` otherwise.

Header

```
#include <boost/fusion/support/is_sequence.hpp>
#include <boost/fusion/include/is_sequence.hpp>
```

Example

```
BOOST_MPL_ASSERT_NOT(( traits::is_sequence< std::vector<int> > ));
BOOST_MPL_ASSERT_NOT(( is_sequence< int > ));
BOOST_MPL_ASSERT(( traits::is_sequence<list<> > ));
BOOST_MPL_ASSERT(( traits::is_sequence<list<int> > ));
BOOST_MPL_ASSERT(( traits::is_sequence<vector<> > ));
BOOST_MPL_ASSERT(( traits::is_sequence<vector<int> > ));
```

is_view

Description

Metafunction that evaluates to `mpl::true_` if a certain type `T` is a conforming Fusion View, `mpl::false_` otherwise. A view is a specialized sequence that does not actually contain data. Views hold sequences which may be other views. In general, views are held by other views by value, while non-views are held by other views by reference. `is_view` may be specialized to accomodate clients providing Fusion conforming views.

Synopsis

```
namespace traits
{
    template <typename T>
    struct is_view
    {
        typedef unspecified type;
    };
}
```

Parameters

Parameter	Requirement	Description
`T`	Any type	The type to query.

Expression Semantics

```
typedef traits::is_view<T>::type c;
```

Return type: An MPL Boolean Constant.

Semantics: Metafunction that evaluates to `mpl::true_` if a certain type `T` is a conforming Fusion view, `mpl::false_` otherwise.

Header

```
#include <boost/fusion/support/is_view.hpp>
#include <boost/fusion/include/is_view.hpp>
```

Example

```
BOOST_MPL_ASSERT_NOT(( traits::is_view<std::vector<int> > ));
BOOST_MPL_ASSERT_NOT(( traits::is_view<int> ));

using boost::mpl::_
using boost::is_pointer;
typedef vector<int*, char, long*, bool, double> vector_type;
typedef filter_view<vector_type, is_pointer<_> > filter_view_type;
BOOST_MPL_ASSERT(( traits::is_view<filter_view_type> ));
```

tag_of

Description

All conforming Fusion sequences and iterators have an associated tag type. The purpose of the tag is to enable *tag dispatching* from Intrinsic functions to implementations appropriate for the type.

This metafunction may be specialized to accomodate clients providing Fusion conforming sequences.

Synopsis

```
namespace traits
{
    template<typename Sequence>
    struct tag_of
    {
        typedef unspecified type;
    };
}
```

Parameters

Parameter	Requirement	Description
`T`	Any type	The type to query.

Expression Semantics

```
typedef traits::tag_of<T>::type tag;
```

Return type: Any type.

Semantics: Returns the tag type associated with `T`.

Header

```
#include <boost/fusion/support/tag_of.hpp>
#include <boost/fusion/include/tag_of.hpp>
```

Example

```
typedef traits::tag_of<list<> >::type tag1;
typedef traits::tag_of<list<int> >::type tag2;
typedef traits::tag_of<vector<> >::type tag3;
typedef traits::tag_of<vector<int> >::type tag4;

BOOST_MPL_ASSERT((boost::is_same<tag1, tag2>));
BOOST_MPL_ASSERT((boost::is_same<tag3, tag4>));
```

category_of

Description

A metafunction that establishes the conceptual classification of a particular Sequence or Iterator (see Iterator Concepts and Sequence Concepts).

Synopsis

```
namespace traits
{
    template <typename T>
    struct category_of
    {
        typedef unspecified type;
    };
}
```

Parameters

Parameter	Requirement	Description
T	Any type	The type to query.

Expression Semantics

```
typedef traits::category_of<T>::type category;
```

Return type:

The return type is derived from one of:

```
namespace boost { namespace fusion
{
    struct incrementable_traversal_tag {};

    struct single_pass_traversal_tag
        : incrementable_traversal_tag {};

    struct forward_traversal_tag
        : single_pass_traversal_tag {};

    struct bidirectional_traversal_tag
        : forward_traversal_tag {};

    struct random_access_traversal_tag
        : bidirectional_traversal_tag {};
}}
```

And optionally from:

```
namespace boost { namespace fusion
{
    struct associative_tag {};
}}
```

Semantics: Establishes the conceptual classification of a particular Sequence or Iterator.

Header

```
#include <boost/fusion/support/category_of.hpp>
#include <boost/fusion/include/category_of.hpp>
```

Example

```
using boost::is_base_of;
typedef traits::category_of<list<> >::type list_category;
typedef traits::category_of<vector<> >::type vector_category;
BOOST_MPL_ASSERT(( is_base_of<forward_traversal_tag, list_category> ));
BOOST_MPL_ASSERT(( is_base_of<random_access_traversal_tag, vector_category> ));
```

deduce

Description

Metafunction to apply *element conversion* to the full argument type.

It removes references to `const`, references to array types are kept, even if the array is `const`. Reference wrappers are removed (see `boost::ref`).

Header

```
#include <boost/fusion/support/deduce.hpp>
#include <boost/fusion/include/deduce.hpp>
```

Synopsis

```
namespace traits
{
    template <typename T>
    struct deduce
    {
        typedef unspecified type;
    };
}
```

Example

```
template <typename T>
struct holder
{
    typename traits::deduce<T const &>::type element;

    holder(T const & a)
      : element(a)
    { }
};

template <typename T>
holder<T> make_holder(T const & a)
{
    return holder<T>(a);
}
```

See also

- `deduce_sequence`

deduce_sequence

Description

Applies *element conversion* to each element in a Forward Sequence. The resulting type is a Random Access Sequence that provides a converting constructor accepting the original type as its argument.

Header

```
#include <boost/fusion/support/deduce_sequence.hpp>
#include <boost/fusion/include/deduce_sequence.hpp>
```

Synopsis

```
namespace traits
{
    template <class Sequence>
    struct deduce_sequence
    {
        typedef unspecified type;
    };
}
```

Example

```
template <class Seq>
struct holder
{
    typename traits::deduce_sequence<Seq>::type element;

    holder(Seq const & a)
      : element(a)
    { }
};

template <typename T0, typename T1>
holder< vector<T0 const &, T1 const &> >
make_holder(T0 const & a0, T1 const & a1)
{
    typedef vector<T0 const &, T1 const &> arg_vec_t;
    return holder<arg_vec_t>( arg_vec_t(a0,a1) );
}
```

See also

- `deduce`

pair

Description

Fusion `pair` type is a half runtime pair. A half runtime pair is similar to a `std::pair`, but, unlike `std::pair`, the first type does not have data. It is used as elements in `map`s, for example.

Synopsis

```
template <typename First, typename Second>
struct pair;

namespace result_of
{
    template <typename Pair>
    struct first;

    template <typename Pair>
    struct second;

    template <typename First, typename Second>
    struct make_pair;
}

template <typename First, typename Second>
typename result_of::make_pair<First,Second>::type
make_pair(Second const &);
```

Template parameters

Parameter	Description
First	The first type. This is purely a type. No data is held.
Second	The second type. This contains data.

Notation

`P`	Fusion pair type
`p`, `p2`	Fusion pairs
`F`, `S`	Arbitrary types
`s`	Value of type `S`
`o`	Output stream
`i`	Input stream

Expression Semantics

Expression	Semantics
`P::first_type`	The type of the first template parameter, `F`, equivalent to `result_of::first<P>::type`.
`P::second_type`	The type of the second template parameter, `S`, equivalent to `result_of::second<P>::type`.
`P()`	Default construction.
`P(s)`	Construct a pair given value for the second type, `s`.
`P(p2)`	Copy constructs a pair from another pair, `p2`.
`p.second`	Get the data from `p1`.
`p = p2`	Assigns a pair, `p1`, from another pair, `p2`.
make_pair<F>(s)	Make a pair given the first type, `F`, and a value for the second type, `s`. The second type assumes the type of `s`
`o << p`	Output `p` to output stream, `o`.
`i >> p`	Input `p` from input stream, `i`.
`p == p2`	Tests two pairs for equality.
`p != p2`	Tests two pairs for inequality.

Header

```
#include <boost/fusion/support/pair.hpp>
#include <boost/fusion/include/pair.hpp>
```

Example

```
pair<int, char> p('X');
std::cout << p << std::endl;
std::cout << make_pair<int>('X') << std::endl;
assert((p == make_pair<int>('X')));
```

Iterator

Like MPL and STL, iterators are a fundamental concept in Fusion. As with MPL and STL iterators describe positions, and provide access to data within an underlying Sequence.

Header

```
#include <boost/fusion/iterator.hpp>
#include <boost/fusion/include/iterator.hpp>
```

Concepts

Fusion iterators are divided into different traversal categories. Forward Iterator is the most basic concept. Bidirectional Iterator is a refinement of Forward Iterator. Random Access Iterator is a refinement of Bidirectional Iterator. Associative Iterator is a refinement of Forward Iterator, Bidirectional Iterator or Random Access Iterator.

Forward Iterator

Description

A Forward Iterator traverses a Sequence allowing movement in only one direction through it's elements, one element at a time.

Notation

`i`, `j`	Forward Iterators
`I`, `J`	Forward Iterator types
`M`	An MPL integral constant
`N`	An integral constant

Expression requirements

A type models Forward Iterator if, in addition to being CopyConstructable, the following expressions are valid:

Expression	Return type	Runtime Complexity
`next(i)`	Forward Iterator	Constant
`i == j`	Convertible to bool	Constant
`i != j`	Convertible to bool	Constant
`advance_c<N>(i)`	Forward Iterator	Constant
`advance<M>(i)`	Forward Iterator	Constant
`distance(i, j)`	`result_of::distance<I, J>::type`	Constant
`deref(i)`	`result_of::deref<I>::type`	Constant
`*i`	`result_of::deref<I>::type`	Constant

Meta Expressions

Expression	Compile Time Complexity
`result_of::next<I>::type`	Amortized constant time
`result_of::equal_to<I, J>::type`	Amortized constant time
`result_of::advance_c<I, N>::type`	Linear
`result_of::advance<I ,M>::type`	Linear
`result_of::distance<I ,J>::type`	Linear
`result_of::deref<I>::type`	Amortized constant time
`result_of::value_of<I>::type`	Amortized constant time

Expression Semantics

[table [[Expression] [Semantics]] [[`next(i)`] [An iterator to the element following `i`]] [[`i == j`] [Iterator equality comparison]] [[`i != j`] [Iterator inequality comparison]] [[`advance_c<N>(i)`] [An iterator n elements after `i` in the sequence]] [[`advance<M>(i)`] [Equivalent to `advance_c<M::value>(i)`]] [[`distance(i, j)`] [The number of elements between `i` and `j`]] [[`deref(i)`] [The element at position`i`]] [[`*i`] [Equivalent to `deref(i)`]]]

Invariants

The following invariants always hold:

- `!(i == j) == (i != j)`
- `next(i) == advance_c<1>(i)`
- `distance(i, advance_c<N>(i)) == N`
- Using `next` to traverse the sequence will never return to a previously seen position
- `deref(i)` is equivalent to `*i`
- If `i == j` then `*i` is equivalent to `*j`

Models

- `std::pair` iterator
- `boost::array` iterator
- `vector` iterator
- `cons` iterator
- `list` iterator
- `set` iterator
- `map` iterator
- `single_view` iterator
- `filter_view` iterator

- `iterator_range` iterator
- `joint_view` iterator
- `transform_view` iterator
- `reverse_view` iterator

Bidirectional Iterator

Description

A Bidirectional Iterator traverses a Sequence allowing movement in either direction one element at a time.

Notation

`i`	A Bidirectional Iterator
`I`	A Bidirectional Iterator type
`M`	An MPL integral constant
`N`	An integral constant

Refinement of

Forward Iterator

Expression requirements

In addition to the requirements defined in Forward Iterator, the following expressions must be valid:

Expression	Return type	Runtime Complexity
`next(i)`	Bidirectional Iterator	Constant
`prior(i)`	Bidirectional Iterator	Constant
`advance_c<N>(i)`	Bidirectional Iterator	Constant
`advance<M>(i)`	Bidirectional Iterator	Constant

Meta Expressions

Expression	Compile Time Complexity
`result_of::prior<I>::type`	Amortized constant time

Expression Semantics

The semantics of an expression are defined only where they differ from, or are not defined in Forward Iterator

Expression	Semantics
`prior(i)`	An iterator to the element preceding `i`

Invariants

In addition to the invariants of Forward Iterator, the following invariants always hold:

- `prior(next(i)) == i && prior(next(i)) == next(prior(i))`
- `prior(i) == advance_c<-1>(i)`
- Using `prior` to traverse a sequence will never return a previously seen position

Models

- `std::pair` iterator
- `boost::array` iterator
- `vector` iterator
- `single_view` iterator
- `iterator_range` (where adapted sequence is a Bidirectional Sequence)
- `transform_view` (where adapted sequence is a Bidirectional Sequence)
- `reverse_view`

Random Access Iterator

Description

A Random Access Iterator traverses a Sequence moving in either direction, permitting efficient arbitrary distance movements back and forward through the sequence.

Notation

`i`, `j`	Random Access Iterators
`I`, `J`	Random Access Iterator types
`M`	An MPL integral constant
`N`	An integral constant

Refinement of

Bidirectional Iterator

Expression requirements

In addition to the requirements defined in Bidirectional Iterator, the following expressions must be valid:

Expression	Return type	Runtime Complexity
`next(i)`	Random Access Iterator	Constant
`prior(i)`	Random Access Iterator	Constant
`advance_c<N>(i)`	Random Access Iterator	Constant
`advance<M>(i)`	Random Access Iterator	Constant

Meta Expressions

Expression	Compile Time Complexity
`result_of::advance_c<I, N>::type`	Amortized constant time
`result_of::advance<I, M>::type`	Amortized constant time
`result_of::distance<I ,J>::type`	Amortized constant time

Models

- `vector` iterator
- `std::pair` iterator
- `boost::array` iterator
- `single_view` iterator
- `iterator_range` iterator (where adapted sequence is a Random Access Sequence)
- `transform_view` iterator (where adapted sequence is a Random Access Sequence)
- `reverse_view` iterator (where adapted sequence is a Random Access Sequence)

Associative Iterator

Description

An Associative Iterator provides additional semantics to obtain the properties of the element of an associative forward, bidirectional or random access sequence.

Notation

`i`	Associative Iterator
`I`	Associative Iterator type

Refinement of

Forward Iterator, Bidirectional Iterator or Random Access Iterator

Expression requirements

In addition to the requirements defined in Forward Iterator, Bidirectional Iterator or Random Access Iterator the following expressions must be valid:

Expression	Return type	Runtime Complexity
`deref_data(i)`	`result_of::deref_data<I>::type`	Constant

Meta Expressions

Expression	Compile Time Complexity
`result_of::key_of<I>::type`	Amortized constant time
`result_of::value_of_data<I>::type`	Amortized constant time
`result_of::deref_data<I>::type`	Amortized constant time

Models

- `map` iterator
- `set` iterator
- `filter_view` iterator (where adapted sequence is an Associative Sequence and a Forward Sequence)
- `iterator_range` iterator (where adapted iterators are Associative Iterators)
- `joint_view` iterator (where adapted sequences are Associative Sequences and Forward Sequences)
- `reverse_view` iterator (where adapted sequence is an Associative Sequence and a Bidirectional Sequence)

Functions

Fusion provides functions for manipulating iterators, analogous to the similar functions from the MPL library.

deref

Description

Deferences an iterator.

Synopsis

```
template<
    typename I
    >
typename result_of::deref<I>::type deref(I const& i);
```

Table 2. Parameters

Parameter	Requirement	Description
`i`	Model of Forward Iterator	Operation's argument

Expression Semantics

```
deref(i);
```

Return type: `result_of::deref<I>::type`

Semantics: Dereferences the iterator `i`.

Header

```
#include <boost/fusion/iterator/deref.hpp>
#include <boost/fusion/include/deref.hpp>
```

Example

```
typedef vector<int,int&> vec;

int i(0);
vec v(1,i);
assert(deref(begin(v)) == 1);
assert(deref(next(begin(v))) == 0);
assert(&(deref(next(begin(v)))) == &i);
```

next

Description

Moves an iterator 1 position forwards.

Synopsis

```
template<
    typename I
    >
typename result_of::next<I>::type next(I const& i);
```

Table 3. Parameters

Parameter	Requirement	Description
`i`	Model of Forward Iterator	Operation's argument

Expression Semantics

```
next(i);
```

Return type: A model of the same iterator concept as `i`.

Semantics: Returns an iterator to the next element after `i`.

Header

```
#include <boost/fusion/iterator/next.hpp>
#include <boost/fusion/include/next.hpp>
```

Example

```
typedef vector<int,int,int> vec;

vec v(1,2,3);
assert(deref(begin(v)) == 1);
assert(deref(next(begin(v))) == 2);
assert(deref(next(next(begin(v)))) == 3);
```

prior

Description

Moves an iterator 1 position backwards.

Synopsis

```
template<
    typename I
    >
typename result_of::prior<I>::type prior(I const& i);
```

Table 4. Parameters

Parameter	Requirement	Description
`i`	Model of Bidirectional Iterator	Operation's argument

Expression Semantics

```
prior(i);
```

Return type: A model of the same iterator concept as `i`.

Semantics: Returns an iterator to the element prior to `i`.

Header

```
#include <boost/fusion/iterator/prior.hpp>
#include <boost/fusion/include/prior.hpp>
```

Example

```
typedef vector<int,int> vec;

vec v(1,2);
assert(deref(next(begin(v))) == 2);
assert(deref(prior(next(begin(v)))) == 1);
```

distance

Description

Returns the distance between 2 iterators.

Synopsis

```
template<
    typename I,
    typename J
    >
typename result_of::distance<I, J>::type distance(I const& i, J const& j);
```

Table 5. Parameters

Parameter	Requirement	Description
`i`, `j`	Models of Forward Iterator into the same sequence	The start and end points of the distance to be measured

Expression Semantics

```
distance(i,j);
```

Return type: `int`

Semantics: Returns the distance between iterators `i` and `j`.

Header

```
#include <boost/fusion/iterator/distance.hpp>
#include <boost/fusion/include/distance.hpp>
```

Example

```
typedef vector<int,int,int> vec;

vec v(1,2,3);
assert(distance(begin(v), next(next(begin(v)))) == 2);
```

advance

Description

Moves an iterator by a specified distance.

Synopsis

```
template<
    typename I,
    typename M
    >
typename result_of::advance<I, M>::type advance(I const& i);
```

Table 6. Parameters

Parameter	Requirement	Description
`i`	Model of Forward Iterator	Iterator to move relative to
`N`	An MPL Integral Constant	Number of positions to move

Expression Semantics

```
advance<M>(i);
```

Return type: A model of the same iterator concept as `i`.

Semantics: Returns an iterator to the element `M` positions from `i`. If `i` is a Bidirectional Iterator then `M` may be negative.

Header

```
#include <boost/fusion/iterator/advance.hpp>
#include <boost/fusion/include/advance.hpp>
```

Example

```
typedef vector<int,int,int> vec;

vec v(1,2,3);
assert(deref(advance<mpl::int_<2> >(begin(v))) == 3);
```

advance_c

Description

Moves an iterator by a specified distance.

Synopsis

```
template<
    typename I,
    int N
    >
typename result_of::advance_c<I, N>::type advance_c(I const& i);
```

Table 7. Parameters

Parameter	Requirement	Description
`i`	Model of Forward Iterator	Iterator to move relative to
`N`	Integer constant	Number of positions to move

Expression Semantics

```
advance_c<N>(i);
```

Return type: A model of the same iterator concept as `i`.

Semantics: Returns an iterator to the element `N` positions from `i`. If `i` is a Bidirectional Iterator then `N` may be negative.

Header

```
#include <boost/fusion/iterator/advance.hpp>
#include <boost/fusion/include/advance.hpp>
```

Example

```
typedef vector<int,int,int> vec;

vec v(1,2,3);
assert(deref(advance_c<2>(begin(v))) == 3);
```

deref_data

Description

Deferences the data property associated with the element referenced by an associative iterator.

Synopsis

```
template<
    typename I
    >
typename result_of::deref_data<I>::type deref(I const& i);
```

Table 8. Parameters

Parameter	Requirement	Description
i	Model of Associative Iterator	Operation's argument

Expression Semantics

```
deref_data(i);
```

Return type: `result_of::deref_data<I>::type`

Semantics: Dereferences the data property associated with the element referenced by an associative iterator `i`.

Header

```
#include <boost/fusion/iterator/deref_data.hpp>
#include <boost/fusion/include/deref_data.hpp>
```

Example

```
typedef map<pair<float,int&> > map;

int i(0);
map m(1.0f,i);
assert(deref_data(begin(m)) == 0);
assert(&(deref_data(begin(m))) == &i);
```

Operator

Overloaded operators are provided to provide a more natural syntax for dereferencing iterators, and comparing them for equality.

Operator *

Description

Dereferences an iterator.

Synopsis

```
template<
    typename I
    >
typename result_of::deref<I>::type operator*(unspecified<I> const& i);
```

Table 9. Parameters

Parameter	Requirement	Description
`i`	Model of Forward Iterator	Operation's argument

Expression Semantics

```
*i
```

Return type: Equivalent to the return type of `deref(i)`.

Semantics: Equivalent to `deref(i)`.

Header

```
#include <boost/fusion/iterator/deref.hpp>
#include <boost/fusion/include/deref.hpp>
```

Example

```
typedef vector<int,int&> vec;

int i(0);
vec v(1,i);
assert(*begin(v) == 1);
assert(*next(begin(v)) == 0);
assert(&(*next(begin(v))) == &i);
```

Operator ==

Description

Compares 2 iterators for equality.

Synopsis

```
template<
    typename I,
    typename J
    >
unspecified operator==(I const& i, J const& i);
```

Table 10. Parameters

Parameter	Requirement	Description
`i`, `j`	Any fusion iterators	Operation's arguments

Expression Semantics

```
i == j
```

Return type: Convertible to `bool`.

Semantics: Equivalent to `result_of::equal_to<I,J>::value` where `I` and `J` are the types of `i` and `j` respectively.

Header

```
#include <boost/fusion/iterator/equal_to.hpp>
#include <boost/fusion/include/equal_to.hpp>
```

Operator !=

Description

Compares 2 iterators for inequality.

Synopsis

```
template<
    typename I,
    typename J
    >
unspecified operator==(I const& i, J const& i);
```

Table 11. Parameters

Parameter	Requirement	Description
`i`, `j`	Any fusion iterators	Operation's arguments

Expression Semantics

Return type: Convertible to `bool`.

Semantics: Equivalent to `!result_of::equal_to<I,J>::value` where `I` and `J` are the types of `i` and `j` respectively.

Header

```
#include <boost/fusion/iterator/equal_to.hpp>
#include <boost/fusion/include/equal_to.hpp>
```

Metafunctions

value_of

Description

Returns the type stored at the position of an iterator.

Synopsis

```
template<
    typename I
    >
struct value_of
{
    typedef unspecified type;
};
```

Table 12. Parameters

Parameter	Requirement	Description
`I`	Model of Forward Iterator	Operation's argument

Expression Semantics

```
result_of::value_of<I>::type
```

Return type: Any type

Semantics: Returns the type stored in a sequence at iterator position `I`.

Header

```
#include <boost/fusion/iterator/value_of.hpp>
#include <boost/fusion/include/value_of.hpp>
```

Example

```
typedef vector<int,int&,const int&> vec;
typedef result_of::begin<vec>::type first;
typedef result_of::next<first>::type second;
typedef result_of::next<second>::type third;

BOOST_MPL_ASSERT((boost::is_same<result_of::value_of<first>::type, int>));
BOOST_MPL_ASSERT((boost::is_same<result_of::value_of<second>::type, int&>));
BOOST_MPL_ASSERT((boost::is_same<result_of::value_of<third>::type, const int&>));
```

deref

Description

Returns the type that will be returned by dereferencing an iterator.

Synopsis

```
template<
    typename I
    >
struct deref
{
    typedef unspecified type;
};
```

Table 13. Parameters

Parameter	Requirement	Description
`I`	Model of Forward Iterator	Operation's argument

Expression Semantics

```
result_of::deref<I>::type
```

Return type: Any type

Semantics: Returns the result of dereferencing an iterator of type `I`.

Header

```
#include <boost/fusion/iterator/deref.hpp>
#include <boost/fusion/include/deref.hpp>
```

Example

```
typedef vector<int,int&> vec;
typedef const vec const_vec;
typedef result_of::begin<vec>::type first;
typedef result_of::next<first>::type second;

typedef result_of::begin<const_vec>::type const_first;
typedef result_of::next<const_first>::type const_second;

BOOST_MPL_ASSERT((boost::is_same<result_of::deref<first>::type, int&>));
BOOST_MPL_ASSERT((boost::is_same<result_of::deref<second>::type, int&>));
```

next

Description

Returns the type of the next iterator in a sequence.

Synposis

```
template<
    typename I
    >
struct next
{
    typedef unspecified type;
};
```

Table 14. Parameters

Parameter	Requirement	Description
`I`	Model of Forward Iterator	Operation's argument

Expression Semantics

```
result_of::next<I>::type
```

Return type: A model of the same iterator concept as `I`.

Semantics: Returns an iterator to the next element in the sequence after `I`.

Header

```
#include <boost/fusion/iterator/next.hpp>
#include <boost/fusion/include/next.hpp>
```

Example

```
typedef vector<int,double> vec;
typedef result_of::next<result_of::begin<vec>::type>::type second;

BOOST_MPL_ASSERT((boost::is_same<result_of::value_of<second>::type, double>));
```

prior

Description

Returns the type of the previous iterator in a sequence.

Synopsis

```
template<
    typename I
    >
struct prior
{
    typedef unspecified type;
};
```

Table 15. Parameters

Parameter	Requirement	Description
`I`	Model of Bidirectional Iterator	Operation's argument

Expression Semantics

```
result_of::prior<I>::type
```

Return type: A model of the same iterator concept as `I`.

Semantics: Returns an iterator to the previous element in the sequence before `I`.

Header

```
#include <boost/fusion/iterator/prior.hpp>
#include <boost/fusion/include/prior.hpp>
```

Example

```
typedef vector<int,double> vec;
typedef result_of::next<result_of::begin<vec>::type>::type second;

BOOST_MPL_ASSERT((boost::is_same<result_of::value_of<second>::type, double>));

typedef result_of::prior<second>::type first;
BOOST_MPL_ASSERT((boost::is_same<result_of::value_of<first>::type, int>));
```

equal_to

Description

Returns a true-valued MPL Integral Constant if `I` and `J` are equal.

Synopsis

```
template<
    typename I,
    typename J
    >
struct equal_to
{
    typedef unspecified type;
};
```

Table 16. Parameters

Parameter	Requirement	Description
`I`, `J`	Any fusion iterators	Operation's arguments

Expression Semantics

```
result_of::equal_to<I, J>::type
```

Return type: A model of MPL Integral Constant.

Semantics: Returns `boost::mpl::true_` if `I` and `J` are iterators to the same position. Returns `boost::mpl::false_` otherwise.

Header

```
#include <boost/fusion/iterator/equal_to.hpp>
#include <boost/fusion/include/equal_to.hpp>
```

Example

```
typedef vector<int,double> vec;
typedef result_of::begin<vec>::type first;
typedef result_of::end<vec>::type last;
BOOST_MPL_ASSERT((result_of::equal_to<first, first>));
BOOST_MPL_ASSERT_NOT((result_of::equal_to<first,last>));
```

distance

Description

Returns the distance between two iterators.

Synopsis

```
template<
    typename I,
    typename J
    >
struct distance
{
    typedef unspecified type;
};
```

Table 17. Parameters

Parameter	Requirement	Description
I, J	Models of Forward Iterator into the same sequence	The start and end points of the distance to be measured

Expression Semantics

```
result_of::distance<I, J>::type
```

Return type: A model of MPL Integral Constant.

Semantics: Returns the distance between iterators of types I and J.

Header

```
#include <boost/fusion/iterator/distance.hpp>
#include <boost/fusion/include/distance.hpp>
```

Example

```
typedef vector<int,double,char> vec;
typedef result_of::begin<vec>::type first;
typedef result_of::next<first>::type second;
typedef result_of::next<second>::type third;
typedef result_of::distance<first,third>::type dist;

BOOST_MPL_ASSERT_RELATION(dist::value, ==, 2);
```

advance

Description

Moves an iterator a specified distance.

Synopsis

```
template<
    typename I,
    typename M
    >
struct advance
{
    typedef unspecified type;
};
```

Table 18. Parameters

Parameter	Requirement	Description
`I`	Model of Forward Iterator	Iterator to move relative to
`M`	Model of MPL Integral Constant	Number of positions to move

Expression Semantics

```
result_of::advance<I,M>::type
```

Return type: A model of the same iterator concept as `I`.

Semantics: Returns an iterator a distance `M` from `I`. If `I` is a Bidirectional Iterator then `M` may be negative.

Header

```
#include <boost/fusion/iterator/advance.hpp>
#include <boost/fusion/include/advance.hpp>
```

Example

```
typedef vector<int,double,char> vec;
typedef result_of::begin<vec>::type first;
typedef result_of::next<first>::type second;
typedef result_of::next<second>::type third;

BOOST_MPL_ASSERT((result_of::equal_to<result_of::ad↵
vance<first, boost::mpl::int_<2> >::type, third>));
```

advance_c

Description

Moves an iterator by a specified distance.

Synopsis

```
template<
    typename I,
    int N
    >
struct advance_c
{
    typedef unspecified type;
};
```

Table 19. Parameters

Parameter	Requirement	Description
`I`	Model of Forward Iterator	Iterator to move relative to
`N`	Integer constant	Number of positions to move

Expression Semantics

```
result_of::advance_c<I, N>::type
```

Return type: A model of the same iterator concept as `I`.

Semantics: Returns an iterator a distance `N` from `I`. If `I` is a Bidirectional Iterator then `N` may be negative. Equivalent to `result_of::advance<I, boost::mpl::int_<N> >::type`.

Header

```
#include <boost/fusion/iterator/advance.hpp>
#include <boost/fusion/include/advance.hpp>
```

Example

```
typedef vector<int,double,char> vec;
typedef result_of::begin<vec>::type first;
typedef result_of::next<first>::type second;
typedef result_of::next<second>::type third;

BOOST_MPL_ASSERT((result_of::equal_to<result_of::advance_c<first, 2>::type, third>));
```

key_of

Description

Returns the key type associated with the element referenced by an associative iterator.

Synopsis

```
template<
    typename I
    >
struct key_of
{
    typedef unspecified type;
};
```

Table 20. Parameters

Parameter	Requirement	Description
`I`	Model of Associative Iterator	Operation's argument

Expression Semantics

```
result_of::key_of<I>::type
```

Return type: Any type

Semantics: Returns the key type associated with the element referenced by an associative iterator `I`.

Header

```
#include <boost/fusion/iterator/key_of.hpp>
#include <boost/fusion/include/key_of.hpp>
```

Example

```
typedef map<pair<float,int> > vec;
typedef result_of::begin<vec>::type first;

BOOST_MPL_ASSERT((boost::is_same<result_of::key_of<first>::type, float>));
```

value_of_data

Description

Returns the type of the data property associated with the element referenced by an associative iterator references.

Synopsis

```
template<
    typename I
    >
struct value_of_data
{
    typedef unspecified type;
};
```

Table 21. Parameters

Parameter	Requirement	Description
`I`	Model of Associative Iterator	Operation's argument

Expression Semantics

```
result_of::value_of_data<I>::type
```

Return type: Any type

Semantics: Returns the type of the data property associated with the element referenced by an associative iterator `I`.

Header

```
#include <boost/fusion/iterator/value_of_data.hpp>
#include <boost/fusion/include/value_of_data.hpp>
```

Example

```
typedef map<pair<float,int> > vec;
typedef result_of::begin<vec>::type first;

BOOST_MPL_ASSERT((boost::is_same<result_of::value_of_data<first>::type, int>));
```

deref_data

Description

Returns the type that will be returned by dereferencing the data property referenced by an associative iterator.

Synposis

```
template<
    typename I
    >
struct deref_data
{
    typedef unspecified type;
};
```

Table 22. Parameters

Parameter	Requirement	Description
`I`	Model of Associative Iterator	Operation's argument

Expression Semantics

```
result_of::deref_data<I>::type
```

Return type: Any type

Semantics: Returns the result of dereferencing the data property referenced by an associative iterator of type `I`.

Header

```
#include <boosta/fusion/iterator/deref_data.hpp>
#include <boost/fusion/include/deref_data.hpp>
```

Example

```
typedef map<pair<float,int> > map;
typedef result_of::begin<vec>::type first;

BOOST_MPL_ASSERT((boost::is_same<result_of::deref_data<first>::type, int&>));
```

Sequence

Like MPL, the Sequence is a fundamental concept in Fusion. A Sequence may or may not actually store or contain data. Container are sequences that hold data. Views, on the other hand, are sequences that do not store any data. Instead, they are proxies that impart an alternative presentation over another sequence. All models of Sequence have an associated Iterator type that can be used to iterate through the Sequence's elements.

Header

```
#include <boost/fusion/sequence.hpp>
#include <boost/fusion/include/sequence.hpp>
```

Concepts

Fusion Sequences are organized into a hierarchy of concepts.

Traversal

Fusion's sequence traversal related concepts parallel Fusion's Iterator Concepts. Forward Sequence is the most basic concept. Bidirectional Sequence is a refinement of Forward Sequence. Random Access Sequence is a refinement of Bidirectional Sequence. These concepts pertain to sequence traversal.

Associativity

The Associative Sequence concept is orthogonal to traversal. An Associative Sequence allows efficient retrieval of elements based on keys.

Forward Sequence

Description

A Forward Sequence is a Sequence whose elements are arranged in a definite order. The ordering is guaranteed not to change from iteration to iteration. The requirement of a definite ordering allows the definition of element-by-element equality (if the container's element type is Equality Comparable) and of lexicographical ordering (if the container's element type is LessThan Comparable).

Notation

`s`	A Forward Sequence
`S`	A Forward Sequence type
`o`	An arbitrary object
`e`	A Sequence element

Valid Expressions

For any Forward Sequence the following expressions must be valid:

Expression	Return type	Type Requirements	Runtime Complexity
`begin(s)`	Forward Iterator		Constant
`end(s)`	Forward Iterator		Constant
`size(s)`	MPL Integral Constant. Convertible to int.		Constant
`empty(s)`	MPL Boolean Constant. Convertible to bool.		Constant
`front(s)`	Any type		Constant
`front(s) = o`	Any type	`s` is mutable and `e = o`, where `e` is the first element in the sequence, is a valid expression.	Constant

Result Type Expressions

Expression	Compile Time Complexity
`result_of::begin<S>::type`	Amortized constant time
`result_of::end<S>::type`	Amortized constant time
`result_of::size<S>::type`	Unspecified
`result_of::empty<S>::type`	Constant time
`result_of::front<S>::type`	Amortized constant time

Expression Semantics

Expression	Semantics
`begin(s)`	An iterator to the first element of the sequence; see `begin`.
`end(s)`	A past-the-end iterator to the sequence; see `end`.
`size(s)`	The size of the sequence; see `size`.
`empty(s)`	A boolean Integral Constant `c` such that `c::value == true` if and only if the sequence is empty; see `empty`.
`front(s)`	The first element in the sequence; see `front`.

Invariants

For any Forward Sequence s the following invariants always hold:

- `[begin(s), end(s))` is always a valid range.
- An Algorithm that iterates through the range `[begin(s), end(s))` will pass through every element of `s` exactly once.
- `begin(s)` is identical to `end(s))` if and only if `s` is empty.

- Two different iterations through `s` will access its elements in the same order.

Models

- `std::pair`
- `boost::array`
- `vector`
- `cons`
- `list`
- `set`
- `map`
- `single_view`
- `filter_view`
- `iterator_range`
- `joint_view`
- `transform_view`
- `reverse_view`
- `zip_view`

Bidirectional Sequence

Description

A Bidirectional Sequence is a Forward Sequence whose iterators model Bidirectional Iterator.

Refinement of

Forward Sequence

Notation

`s`	A Forward Sequence
`S`	A Forward Sequence type
`o`	An arbitrary object
`e`	A Sequence element

Valid Expressions

In addition to the requirements defined in Forward Sequence, for any Bidirectional Sequence the following must be met:

Expression	Return type	Type Requirements	Runtime Complexity
`begin(s)`	Bidirectional Iterator		Constant
`end(s)`	Bidirectional Iterator		Constant
`back(s)`	Any type		Constant
`back(s) = o`	Any type	`s` is mutable and `e = o`, where `e` is the first element in the sequence, is a valid expression.	Constant

Result Type Expressions

Expression	Compile Time Complexity
`result_of::begin<S>::type`	Amortized constant time
`result_of::end<S>::type`	Amortized constant time
`result_of::back<S>::type`	Amortized constant time

Expression Semantics

The semantics of an expression are defined only where they differ from, or are not defined in Forward Sequence.

Expression	Semantics
`back(s)`	The last element in the sequence; see `back`.

Models

- `std::pair`
- `boost::array`
- `vector`
- `reverse_view`
- `single_view`
- `iterator_range` (where adapted sequence is a Bidirectional Sequence)
- `transform_view` (where adapted sequence is a Bidirectional Sequence)
- `zip_view` (where adapted sequences are models of Bidirectional Sequence)

Random Access Sequence

Description

A Random Access Sequence is a Bidirectional Sequence whose iterators model Random Access Iterator. It guarantees constant time access to arbitrary sequence elements.

Refinement of

Bidirectional Sequence

Notation

`s`	A Random Access Sequence
`S`	A Random Access Sequence type
`N`	An MPL Integral Constant
`o`	An arbitrary object
`e`	A Sequence element

Valid Expressions

In addition to the requirements defined in Bidirectional Sequence, for any Random Access Sequence the following must be met:

Expression	Return type	Type Requirements	Runtime Complexity
`begin(s)`	Random Access Iterator		Constant
`end(s)`	Random Access Iterator		Constant
`at<N>(s)`	Any type		Constant
`at<N>(s) = o`	Any type	`s` is mutable and `e = o`, where `e` is the first element in the sequence, is a valid expression.	Constant

Result Type Expressions

Expression	Compile Time Complexity
`result_of::begin<S>::type`	Amortized constant time
`result_of::end<S>::type`	Amortized constant time
`result_of::at<S, N>::type`	Amortized constant time
`result_of::value_at<S, N>::type`	Amortized constant time

`result_of::at<S, N>` returns the actual type returned by `at<N>(s)`. In most cases, this is a reference. Hence, there is no way to know the exact element type using `result_of::at<S, N>`.The element at `N` may actually be a reference to begin with. For this purpose, you can use `result_of::value_at<S, N>`.

Expression Semantics

The semantics of an expression are defined only where they differ from, or are not defined in Bidirectional Sequence.

Expression	Semantics
`at<N>(s)`	The Nth element from the beginning of the sequence; see `at`.

Models

- `std::pair`

- `boost::array`
- `vector`
- `reverse_view`
- `single_view`
- `iterator_range` (where adapted sequence is a Random Access Sequence)
- `transform_view` (where adapted sequence is a Random Access Sequence)
- `zip_view` (where adapted sequences are models of Random Access Sequence)

Associative Sequence

Description

An Associative Sequence allows efficient retrieval of elements based on keys. Like associative sequences in MPL, and unlike associative containers in STL, Fusion associative sequences have no implied ordering relation. Instead, type identity is used to impose an equivalence relation on keys.

Notation

`s`	An Associative Sequence
`S`	An Associative Sequence type
`K`	An arbitrary *key* type
`o`	An arbitrary object
`e`	A Sequence element

Valid Expressions

For any Associative Sequence the following expressions must be valid:

Expression	Return type	Type Requirements	Runtime Complexity
`has_key<K>(s)`	MPL Boolean Constant. Convertible to bool.		Constant
`at_key<K>(s)`	Any type		Constant
`at_key<K>(s) = o`	Any type	`s` is mutable and `e = o`, where `e` is the first element in the sequence, is a valid expression.	Constant

Result Type Expressions

Expression	Compile Time Complexity
`result_of::has_key<S, K>::type`	Amortized constant time
`result_of::at_key<S, K>::type`	Amortized constant time
`result_of::value_at_key<S, K>::type`	Amortized constant time

result_of::at_key<S, K> returns the actual type returned by at_key<K>(s). In most cases, this is a reference. Hence, there is no way to know the exact element type using result_of::at_key<S, K>.The element at K may actually be a reference to begin with. For this purpose, you can use result_of::value_at_key<S, N>.

Expression Semantics

Expression	Semantics
has_key<K>(s)	A boolean Integral Constant c such that c::value == true if and only if there is one or more elements with the key k in s; see has_key.
at_key<K>(s)	The element associated with the key K in the sequence s; see at.

Models

- set
- map
- filter_view (where adapted sequence is an Associative Sequence and a Forward Sequence)
- iterator_range (where adapted iterators are Associative Iterators)
- joint_view (where adapted sequences are Associative Sequences and Forward Sequences)
- reverse_view (where adapted sequence is an Associative Sequence and a Bidirectional Sequence)

Intrinsic

Intrinsic form the essential interface of every Fusion Sequence. STL counterparts of these functions are usually implemented as member functions. Intrinsic functions, unlike Algorithms, are not generic across the full Sequence repertoire. They need to be implemented for each Fusion Sequence[5].

Header

```
#include <boost/fusion/sequence/intrinsic.hpp>
#include <boost/fusion/include/intrinsic.hpp>
```

Functions

begin

Description

Returns an iterator pointing to the first element in the sequence.

[5] In practice, many of intrinsic functions have default implementations that will work in majority of cases

Synopsis

```
template <typename Sequence>
typename result_of::begin<Sequence>::type
begin(Sequence& seq);

template <typename Sequence>
typename result_of::begin<Sequence const>::type
begin(Sequence const& seq);
```

Parameters

Parameter	Requirement	Description
`seq`	Model of Forward Sequence	The sequence we wish to get an iterator from.

Expression Semantics

```
begin(seq);
```

Return type:

- A model of Forward Iterator if `seq` is a Forward Sequence else, Bidirectional Iterator if `seq` is a Bidirectional Sequence else, Random Access Iterator if `seq` is a Random Access Sequence.
- A model of Associative Iterator if `seq` is an Associative Sequence.

Semantics: Returns an iterator pointing to the first element in the sequence.

Header

```
#include <boost/fusion/sequence/intrinsic/begin.hpp>
#include <boost/fusion/include/begin.hpp>
```

Example

```
vector<int, int, int> v(1, 2, 3);
assert(deref(begin(v)) == 1);
```

end

Description

Returns an iterator pointing to one element past the end of the sequence.

Synopsis

```
template <typename Sequence>
typename result_of::end<Sequence>::type
end(Sequence& seq);

template <typename Sequence>
typename result_of::end<Sequence const>::type
end(Sequence const& seq);
```

Parameters

Parameter	Requirement	Description
`seq`	Model of Forward Sequence	The sequence we wish to get an iterator from.

Expression Semantics

```
end(seq);
```

Return type:

- A model of Forward Iterator if `seq` is a Forward Sequence else, Bidirectional Iterator if `seq` is a Bidirectional Sequence else, Random Access Iterator if `seq` is a Random Access Sequence.
- A model of Associative Iterator if `seq` is an Associative Sequence.

Semantics: Returns an iterator pointing to one element past the end of the sequence.

Header

```
#include <boost/fusion/sequence/intrinsic/end.hpp>
#include <boost/fusion/include/end.hpp>
```

Example

```
vector<int, int, int> v(1, 2, 3);
assert(deref(prior(end(v))) == 3);
```

empty

Description

Returns a type convertible to `bool` that evaluates to `true` if the sequence is empty, else, evaluates to `false`.

Synopsis

```
template <typename Sequence>
typename result_of::empty<Sequence>::type
empty(Sequence const& seq);
```

Parameters

Parameter	Requirement	Description
`seq`	Model of Forward Sequence	The sequence we wish to investigate.

Expression Semantics

```
empty(seq);
```

Return type: Convertible to `bool`.

Semantics: Evaluates to `true` if the sequence is empty, else, evaluates to `false`.

Header

```
#include <boost/fusion/sequence/intrinsic/empty.hpp>
#include <boost/fusion/include/empty.hpp>
```

Example

```
vector<int, int, int> v(1, 2, 3);
assert(empty(v) == false);
```

front

Description

Returns the first element in the sequence.

Synopsis

```
template <typename Sequence>
typename result_of::front<Sequence>::type
front(Sequence& seq);

template <typename Sequence>
typename result_of::front<Sequence const>::type
front(Sequence const& seq);
```

Parameters

Parameter	Requirement	Description
`seq`	Model of Forward Sequence	The sequence we wish to investigate.

Expression Semantics

```
front(seq);
```

Return type: Returns a reference to the first element in the sequence `seq` if `seq` is mutable and `e = o`, where `e` is the first element in the sequence, is a valid expression. Else, returns a type convertable to the first element in the sequence.

Precondition: `empty(seq) == false`

Semantics: Returns the first element in the sequence.

Header

```
#include <boost/fusion/sequence/intrinsic/front.hpp>
#include <boost/fusion/include/front.hpp>
```

Example

```
vector<int, int, int> v(1, 2, 3);
assert(front(v) == 1);
```

back

Description

Returns the last element in the sequence.

Synopsis

```
template <typename Sequence>
typename result_of::back<Sequence>::type
back(Sequence& seq);

template <typename Sequence>
typename result_of::back<Sequence const>::type
back(Sequence const& seq);
```

Parameters

Parameter	Requirement	Description
`seq`	Model of Bidirectional Sequence	The sequence we wish to investigate.

Expression Semantics

```
back(seq);
```

Return type: Returns a reference to the last element in the sequence `seq` if `seq` is mutable and `e = o`, where `e` is the last element in the sequence, is a valid expression. Else, returns a type convertable to the last element in the sequence.

Precondition: `empty(seq) == false`

Semantics: Returns the last element in the sequence.

Header

```
#include <boost/fusion/sequence/intrinsic/back.hpp>
#include <boost/fusion/include/back.hpp>
```

Example

```
vector<int, int, int> v(1, 2, 3);
assert(back(v) == 3);
```

size

Description

Returns a type convertible to `int` that evaluates the number of elements in the sequence.

Synopsis

```
template <typename Sequence>
typename result_of::size<Sequence>::type
size(Sequence const& seq);
```

Parameters

Parameter	Requirement	Description
seq	Model of Forward Sequence	The sequence we wish to investigate.

Expression Semantics

```
size(seq);
```

Return type: Convertible to `int`.

Semantics: Returns the number of elements in the sequence.

Header

```
#include <boost/fusion/sequence/intrinsic/size.hpp>
#include <boost/fusion/include/size.hpp>
```

Example

```
vector<int, int, int> v(1, 2, 3);
assert(size(v) == 3);
```

at

Description

Returns the N-th element from the beginning of the sequence.

Synopsis

```
template <typename N, typename Sequence>
typename result_of::at<Sequence, N>::type
at(Sequence& seq);

template <typename N, typename Sequence>
typename result_of::at<Sequence const, N>::type
at(Sequence const& seq);
```

Parameters

Parameter	Requirement	Description
seq	Model of Random Access Sequence	The sequence we wish to investigate.
N	An MPL Integral Constant	An index from the beginning of the sequence.

Expression Semantics

```
at<N>(seq);
```

Return type: Returns a reference to the N-th element from the beginning of the sequence `seq` if `seq` is mutable and `e = o`, where `e` is the N-th element from the beginning of the sequence, is a valid expression. Else, returns a type convertable to the N-th element from the beginning of the sequence.

Precondition: `0 <= N::value < size(s)`

Semantics: Equivalent to

```
deref(advance<N>(begin(s)))
```

Header

```
#include <boost/fusion/sequence/intrinsic/at.hpp>
#include <boost/fusion/include/at.hpp>
```

Example

```
vector<int, int, int> v(1, 2, 3);
assert(at<mpl::int_<1> >(v) == 2);
```

at_c

Description

Returns the N-th element from the beginning of the sequence.

Synopsis

```
template <int N, typename Sequence>
typename result_of::at_c<Sequence, N>::type
at_c(Sequence& seq);

template <int N, typename Sequence>
typename result_of::at_c<Sequence const, N>::type
at_c(Sequence const& seq);
```

Parameters

Parameter	Requirement	Description
`seq`	Model of Random Access Sequence	The sequence we wish to investigate.
`N`	An integral constant	An index from the beginning of the sequence.

Expression Semantics

```
at_c<N>(seq);
```

Return type: Returns a reference to the N-th element from the beginning of the sequence `seq` if `seq` is mutable and `e = o`, where `e` is the N-th element from the beginning of the sequence, is a valid expression. Else, returns a type convertable to the N-th element from the beginning of the sequence.

Precondition: `0 <= N < size(s)`

Semantics: Equivalent to

```
deref(advance<N>(begin(s)))
```

Header

```
#include <boost/fusion/sequence/intrinsic/at_c.hpp>
#include <boost/fusion/include/at_c.hpp>
```

Example

```
vector<int, int, int> v(1, 2, 3);
assert(at_c<1>(v) == 2);
```

has_key

Description

Returns a type convertible to `bool` that evaluates to `true` if the sequence contains an element associated with a Key, else, evaluates to `false`.

Synopsis

```
template <typename Key, typename Sequence>
typename result_of::has_key<Sequence, Key>::type
has_key(Sequence const& seq);
```

Parameters

Parameter	Requirement	Description
`seq`	Model of Associative Sequence	The sequence we wish to investigate.
`Key`	Any type	The queried key.

Expression Semantics

```
has_key<Key>(seq);
```

Return type: Convertible to `bool`.

Semantics: Evaluates to `true` if the sequence contains an element associated with Key, else, evaluates to `false`.

Header

```
#include <boost/fusion/sequence/intrinsic/has_key.hpp>
#include <boost/fusion/include/has_key.hpp>
```

Example

```
set<int, char, bool> s(1, 'x', true);
assert(has_key<char>(s) == true);
```

at_key

Description

Returns the element associated with a Key from the sequence.

Synopsis

```
template <typename Key, typename Sequence>
typename result_of::at_key<Sequence, Key>::type
at_key(Sequence& seq);

template <typename Key, typename Sequence>
typename result_of::at_key<Sequence const, Key>::type
at_key(Sequence const& seq);
```

Parameters

Parameter	Requirement	Description
`seq`	Model of Associative Sequence	The sequence we wish to investigate.
`Key`	Any type	The queried key.

Expression Semantics

```
at_key<Key>(seq);
```

Return type: Returns a reference to the element associated with Key from the sequence `seq` if `seq` is mutable and `e = o`, where `e` is the element associated with Key, is a valid expression. Else, returns a type convertable to the element associated with Key.

Precondition: `has_key<Key>(seq) == true`

Semantics: Returns the element associated with Key.

Header

```
#include <boost/fusion/sequence/intrinsic/at_key.hpp>
#include <boost/fusion/include/at_key.hpp>
```

Example

```
set<int, char, bool> s(1, 'x', true);
assert(at_key<char>(s) == 'x');
```

swap

Description

Performs an element by element swap of the elements in 2 sequences.

Synopsis

```
template<typename Seq1, typename Seq2>
void swap(Seq1& seq1, Seq2& seq2);
```

Parameters

Parameters	Requirement	Description
`seq1`, `seq2`	Models of Forward Sequence	The sequences whos elements we wish to swap.

Expression Semantics

```
swap(seq1, seq2);
```

Return type: `void`

Precondition: `size(seq1) == size(seq2)`

Semantics: Calls `swap(a1, b1)` for corresponding elements in `seq1` and `seq2`.

/sequence/intrinsic/swap.hpp>

Example

```
vector<int, std::string> v1(1, "hello"), v2(2, "world");
swap(v1, v2);
assert(v1 == make_vector(2, "world"));
assert(v2 == make_vector(1, "hello"));
```

Metafunctions

begin

Description

Returns the result type of `begin`.

Synopsis

```
template<typename Seq>
struct begin
{
    typedef unspecified type;
};
```

Table 23. Parameters

Parameter	Requirement	Description
`Seq`	A model of Forward Sequence	Argument sequence

Expression Semantics

```
result_of::begin<Seq>::type
```

Return type:

- A model of Forward Iterator if `seq` is a Forward Sequence else, Bidirectional Iterator if `seq` is a Bidirectional Sequence else, Random Access Iterator if `seq` is a Random Access Sequence.

- A model of Associative Iterator if `seq` is an Associative Sequence.

Semantics: Returns the type of an iterator to the first element of `Seq`.

Header

```
#include <boost/fusion/sequence/intrinsic/begin.hpp>
#include <boost/fusion/include/begin.hpp>
```

Example

```
typedef vector<int> vec;
typedef result_of::begin<vec>::type it;
BOOST_MPL_ASSERT((boost::is_same<result_of::deref<it>::type, int&>))
```

end

Description

Returns the result type of `end`.

Synopsis

```
template<typename Seq>
struct end
{
    typedef unspecified type;
};
```

Table 24. Parameters

Parameter	**Requirement**	**Description**
`Seq`	A model of Forward Sequence	Argument sequence

Expression Semantics

```
result_of::end<Seq>::type
```

Return type:

- A model of Forward Iterator if `seq` is a Forward Sequence else, Bidirectional Iterator if `seq` is a Bidirectional Sequence else, Random Access Iterator if `seq` is a Random Access Sequence.
- A model of Associative Iterator if `seq` is an Associative Sequence.

Semantics: Returns the type of an iterator one past the end of `Seq`.

Header

```
#include <boost/fusion/sequence/intrinsic/end.hpp>
#include <boost/fusion/include/end.hpp>
```

Example

```
typedef vector<int> vec;
typedef result_of::prior<result_of::end<vec>::type>::type first;
BOOST_MPL_ASSERT((result_of::equal_to<first, result_of::begin<vec>::type>))
```

empty

Description

Returns the result type of `empty`.

Synopsis

```
template<typename Seq>
struct empty
{
    typedef unspecified type;
};
```

Table 25. Parameters

Parameter	Requirement	Description
`Seq`	A model of Forward Sequence	Argument sequence

Expression Semantics

```
result_of::empty<Seq>::type
```

Return type: An MPL Integral Constant

Semantics: Returns `mpl::true_` if `Seq` has zero elements, `mpl::false_` otherwise.

Header

```
#include <boost/fusion/sequence/intrinsic/empty.hpp>
#include <boost/fusion/include/empty.hpp>
```

Example

```
typedef vector<> empty_vec;
typedef vector<int,float,char> vec;

BOOST_MPL_ASSERT((result_of::empty<empty_vec>));
BOOST_MPL_ASSERT_NOT((result_of::empty<vec>));
```

front

Description

Returns the result type of `front`.

Synopsis

```
template<typename Seq>
struct front
{
    typedef unspecified type;
};
```

Table 26. Parameters

Parameter	Requirement	Description
`Seq`	A model of Forward Sequence	Argument sequence

Expression Semantics

```
result_of::front<Seq>::type
```

Return type: Any type

Semantics: The type returned by dereferencing an iterator to the first element in `Seq`. Equivalent to `result_of::deref<result_of::begin<Seq>::type>::type`.

Header

```
#include <boost/fusion/sequence/intrinsic/front.hpp>
#include <boost/fusion/include/front.hpp>
```

Example

```
typedef vector<int,char> vec;
BOOST_MPL_ASSERT((boost::is_same<result_of::front<vec>::type, int&>));
```

back

Description

Returns the result type of `back`.

Synopsis

```
template<typename Seq>
struct back
{
    typedef unspecified type;
};
```

Table 27. Parameters

Parameter	Requirement	Description
`Seq`	A model of Forward Sequence	Argument sequence

Expression Semantics

```
result_of::back<Seq>::type
```

Return type: Any type

Semantics: The type returned by dereferencing an iterator to the last element in the sequence. Equivalent to `result_of::deref<result_of::prior<result_of::end<Seq>::type>::type>::type`.

Header

```
#include <boost/fusion/sequence/intrinsic/back.hpp>
#include <boost/fusion/include/back.hpp>
```

Example

```
typedef vector<int,char> vec;
BOOST_MPL_ASSERT((boost::is_same<result_of::back<vec>::type, char&>));
```

size

Description

Returns the result type of `size`.

Synopsis

```
template<typename Seq>
struct size
{
    typedef unspecified type;
};
```

Table 28. Parameters

Parameter	Requirement	Description
`Seq`	A model of Forward Sequence	Argument sequence

Expression Semantics

```
result_of::size<Seq>::type
```

Return type: An MPL Integral Constant.

Semantics: Returns the number of elements in `Seq`.

Header

```
#include <boost/fusion/sequence/intrinsic/size.hpp>
#include <boost/fusion/include/size.hpp>
```

Example

```
typedef vector<int,float,char> vec;
typedef result_of::size<vec>::type size_mpl_integral_constant;
BOOST_MPL_ASSERT_RELATION(size_mpl_integral_constant::value, ==, 3);
```

at

Description

Returns the result type of `at`[6].

Synopsis

```
template<
    typename Seq,
    typename N>
struct at
{
    typedef unspecified type;
};
```

Table 29. Parameters

Parameter	Requirement	Description
`Seq`	A model of Random Access Sequence	Argument sequence
`N`	An MPL Integral Constant	Index of element

Expression Semantics

```
result_of::at<Seq, N>::type
```

Return type: Any type.

Semantics: Returns the result type of using `at` to access the `N`th element of `Seq`.

Header

```
#include <boost/fusion/sequence/intrinsic/at.hpp>
#include <boost/fusion/include/at.hpp>
```

Example

```
typedef vector<int,float,char> vec;
BOOST_MPL_ASSERT((boost::is_same<result_of::at<vec, boost::mpl::int_<1> >::type, float&>));
```

[6] `result_of::at` reflects the actual return type of the function `at`. Sequence(s) typically return references to its elements via the `at` function. If you want to get the actual element type, use `result_of::value_at`

at_c

Description

Returns the result type of `at_c`[7].

Synopsis

```
template<
    typename Seq,
    int M>
struct at_c
{
    typedef unspecified type;
};
```

Table 30. Parameters

Parameter	Requirement	Description
`Seq`	A model of Random Access Sequence	Argument sequence
`M`	Positive integer index	Index of element

Expression Semantics

```
result_of::at_c<Seq, M>::type
```

Return type: Any type

Semantics: Returns the result type of using `at_c` to access the `M`th element of `Seq`.

Header

```
#include <boost/fusion/sequence/intrinsic/at.hpp>
#include <boost/fusion/include/at.hpp>
```

Example

```
typedef vector<int,float,char> vec;
BOOST_MPL_ASSERT((boost::is_same<result_of::at_c<vec, 1>::type, float&>));
```

value_at

Description

Returns the actual type at a given index from the Sequence.

[7] `result_of::at_c` reflects the actual return type of the function `at_c`. Sequence(s) typically return references to its elements via the `at_c` function. If you want to get the actual element type, use `result_of::value_at_c`

Synopsis

```
template<
    typename Seq,
    typename N>
struct value_at
{
    typedef unspecified type;
};
```

Table 31. Parameters

Parameter	Requirement	Description
`Seq`	A model of Random Access Sequence	Argument sequence
`N`	An MPL Integral Constant	Index of element

Expression Semantics

```
result_of::value_at<Seq, N>::type
```

Return type: Any type.

Semantics: Returns the actual type at the `N`th element of `Seq`.

Header

```
#include <boost/fusion/sequence/intrinsic/value_at.hpp>
#include <boost/fusion/include/value_at.hpp>
```

Example

```
typedef vector<int,float,char> vec;
BOOST_MPL_ASSERT((boost::is_same<result_of::value_at<vec, boost::mpl::int_<1> >::type, float>));
```

value_at_c

Description

Returns the actual type at a given index from the Sequence.

Synopsis

```
template<
    typename Seq,
    int M>
struct value_at_c
{
    typedef unspecified type;
};
```

Table 32. Parameters

Parameter	Requirement	Description
`Seq`	A model of Random Access Sequence	Argument sequence
`M`	Positive integer index	Index of element

Expression Semantics

```
result_of::value_at_c<Seq, M>::type
```

Return type: Any type

Semantics: Returns the actual type at the `M`th element of `Seq`.

Header

```
#include <boost/fusion/sequence/intrinsic/value_at.hpp>
#include <boost/fusion/include/value_at.hpp>
```

Example

```
typedef vector<int,float,char> vec;
BOOST_MPL_ASSERT((boost::is_same<result_of::value_at_c<vec, 1>::type, float>));
```

has_key

Description

Returns the result type of `has_key`.

Synopsis

```
template<
    typename Seq,
    typename Key>
struct has_key
{
    typedef unspecified type;
};
```

Table 33. Parameters

Parameter	Requirement	Description
`Seq`	A model of Associative Sequence	Argument sequence
`Key`	Any type	Key type

Expression Semantics

```
result_of::has_key<Seq, Key>::type
```

Return type: An MPL Integral Constant.

Semantics: Returns `mpl::true_` if `Seq` contains an element with key type `Key`, returns `mpl::false_` otherwise.

Header

```
#include <boost/fusion/sequence/intrinsic/has_key.hpp>
#include <boost/fusion/include/has_key.hpp>
```

Example

```
typedef map<pair<int, char>, pair<char, char>, pair<double, char> > mymap;
BOOST_MPL_ASSERT((result_of::has_key<mymap, int>));
BOOST_MPL_ASSERT_NOT((result_of::has_key<mymap, void*>));
```

at_key

Description

Returns the result type of `at_key`[8].

Synopsis

```
template<
    typename Seq,
    typename Key>
struct at_key
{
    typedef unspecified type;
};
```

Table 34. Parameters

Parameter	Requirement	Description
`Seq`	A model of Associative Sequence	Argument sequence
`Key`	Any type	Key type

Expression Semantics

```
result_of::at_key<Seq, Key>::type
```

Return type: Any type.

Semantics: Returns the result of using `at_key` to access the element with key type `Key` in `Seq`.

Header

```
#include <boost/fusion/sequence/intrinsic/at_key.hpp>
#include <boost/fusion/include/at_key.hpp>
```

[8] `result_of::at_key` reflects the actual return type of the function `at_key`. __sequence__s typically return references to its elements via the `at_key` function. If you want to get the actual element type, use `result_of::value_at_key`

Example

```
typedef map<pair<int, char>, pair<char, char>, pair<double, char> > mymap;
BOOST_MPL_ASSERT((boost::is_same<result_of::at_key<mymap, int>::type, char&>));
```

value_at_key

Description

Returns the actual element type associated with a Key from the Sequence.

Synopsis

```
template<
    typename Seq,
    typename Key>
struct value_at_key
{
    typedef unspecified type;
};
```

Table 35. Parameters

Parameter	Requirement	Description
`Seq`	A model of Associative Sequence	Argument sequence
`Key`	Any type	Key type

Expression Semantics

```
result_of::value_at_key<Seq, Key>::type
```

Return type: Any type.

Semantics: Returns the actual element type associated with key type `Key` in `Seq`.

Header

```
#include <boost/fusion/sequence/intrinsic/value_at_key.hpp>
#include <boost/fusion/include/value_at_key.hpp>
```

Example

```
typedef map<pair<int, char>, pair<char, char>, pair<double, char> > mymap;
BOOST_MPL_ASSERT((boost::is_same<result_of::at_key<mymap, int>::type, char>));
```

swap

Description

Returns the return type of swap.

Synopsis

```
template<typename Seq1, typename Seq2>
struct swap
{
    typedef void type;
};
```

Table 36. Parameters

Parameters	Requirement	Description
`Seq1`, `Seq2`	Models of Forward Sequence	The sequences being swapped

Expression Semantics

```
result_of::swap<Seq1, Seq2>::type
```

Return type: `void`.

Semantics: Always returns `void`.

Header

```
#include <boost/fusion/sequence/intrinsic/swap.hpp>
#include <boost/fusion/include/swap.hpp>
```

Operator

These operators, like the Algorithms, work generically on all Fusion sequences. All conforming Fusion sequences automatically get these operators for free.

I/O

The I/O operators: `<<` and `>>` work generically on all Fusion sequences. The I/O operators are overloaded in namespace `boost::fusion`[9]

The `operator<<` has been overloaded for generic output streams such that Sequence(s) are output by recursively calling `operator<<` for each element. Analogously, the global `operator>>` has been overloaded to extract Sequence(s) from generic input streams by recursively calling `operator>>` for each element.

The default delimiter between the elements is space, and the Sequence is enclosed in parenthesis. For Example:

```
vector<float, int, std::string> a(1.0f, 2, std::string("Howdy folks!");
cout << a;
```

outputs the `vector` as: (1.0 2 Howdy folks!)

The library defines three manipulators for changing the default behavior:

Manipulators

`tuple_open(arg)`	Defines the character that is output before the first element.

[9] __sequences__ and Views residing in different namespaces will have to either provide their own I/O operators (possibly forwarding to fusion's I/O operators) or hoist fusion's I/O operators (using declaration), in their own namespaces for proper argument dependent lookup.

`tuple_close(arg)`	Defines the character that is output after the last element.
`tuple_delimiter(arg)`	Defines the delimiter character between elements.

The argument to `tuple_open`, `tuple_close` and `tuple_delimiter` may be a `char`, `wchar_t`, a C-string, or a wide C-string.

Example:

```
std::cout << tuple_open('[') << tuple_close(']') << tuple_delimiter(", ") << a;
```

outputs the same `vector`, a as: [1.0, 2, Howdy folks!]

The same manipulators work with `operator>>` and `istream` as well. Suppose the `std::cin` stream contains the following data:

```
(1 2 3) [4:5]
```

The code:

```
vector<int, int, int> i;
vector<int, int> j;

std::cin >> i;
std::cin >> set_open('[') >> set_close(']') >> set_delimiter(':');
std::cin >> j;
```

reads the data into the `vector`(s) `i` and `j`.

Note that extracting Sequence(s) with `std::string` or C-style string elements does not generally work, since the streamed Sequence representation may not be unambiguously parseable.

Header

```
#include <boost/fusion/sequence/io.hpp>
#include <boost/fusion/include/io.hpp>
```

in

Description

Read a Sequence from an input stream.

Synopsis

```
template <typename IStream, typename Sequence>
IStream&
operator>>(IStream& is, Sequence& seq);
```

Parameters

Parameter	Requirement	Description
is	An input stream.	Stream to extract information from.
seq	A Sequence.	The sequence to read.

Expression Semantics

```
is >> seq
```

Return type: IStream&

Semantics: For each element, `e`, in sequence, `seq`, call `is >> e`.

Header

```
#include <boost/fusion/sequence/io/in.hpp>
#include <boost/fusion/include/in.hpp>
```

Example

```
vector<int, std::string, char> v;
std::cin >> v;
```

out

Description

Write a Sequence to an output stream.

Synopsis

```
template <typename OStream, typename Sequence>
OStream&
operator<<(OStream& os, Sequence& seq);
```

Parameters

Parameter	Requirement	Description
os	An output stream.	Stream to write information to.
seq	A Sequence.	The sequence to write.

Expression Semantics

```
os << seq
```

Return type: OStream&

Semantics: For each element, `e`, in sequence, `seq`, call `os << e`.

Header

```
#include <boost/fusion/sequence/io/out.hpp>
#include <boost/fusion/include/out.hpp>
```

Example

```
std::cout << make_vector(123, "Hello", 'x') << std::endl;
```

Comparison

The Comparison operators: ==, !=, <, <=, >= and >= work generically on all Fusion sequences. Comparison operators are "short-circuited": elementary comparisons start from the first elements and are performed only until the result is clear.

Header

```
#include <boost/fusion/sequence/comparison.hpp>
#include <boost/fusion/include/comparison.hpp>
```

equal

Description

Compare two sequences for equality.

Synopsis

```
template <typename Seq1, typename Seq2>
bool
operator==(Seq1 const& a, Seq2 const& b);
```

Parameters

Parameter	Requirement	Description
`a, b`	Instances of Sequence	Sequence(s) to compare

Expression Semantics

```
a == b
```

Return type: `bool`

Requirements:

For each element, `e1`, in sequence `a`, and for each element, `e2`, in sequence `b`, `a == b` is a valid expression returning a type that is convertible to bool.

An attempt to compare two Sequences of different lengths results in a compile time error.

Semantics:

For each element, `e1`, in sequence `a`, and for each element, `e2`, in sequence `b`, `e1 == e2` returns true. For any 2 zero length __sequence__s, e and f, e == f returns true.

Header

```
#include <boost/fusion/sequence/comparison/equal_to.hpp>
#include <boost/fusion/include/equal_to.hpp>
```

Example

```
vector<int, char> v1(5, 'a');
vector<int, char> v2(5, 'a');
assert(v1 == v2);
```

not equal

Compare two sequences for inequality.

Synopsis

```
template <typename Seq1, typename Seq2>
bool
operator!=(Seq1 const& a, Seq2 const& b);
```

Parameters

Parameter	Requirement	Description
`a, b`	Instances of Sequence	Sequence(s) to compare

Expression Semantics

```
a != b
```

Return type: `bool`

Requirements:

For each element, `e1`, in sequence `a`, and for each element, `e2`, in sequence `b`, `a == b` is a valid expression returning a type that is convertible to bool.

An attempt to compare two Sequences of different lengths results in a compile time error.

Semantics:

Returns !(a == b).

Header

```
#include <boost/fusion/sequence/comparison/not_equal_to.hpp>
#include <boost/fusion/include/not_equal_to.hpp>
```

Example

```
vector<int, char> v3(5, 'b');
vector<int, char> t4(2, 'a');
assert(v1 != v3);
assert(v1 != t4);
assert(!(v1 != v2));
```

less than

Lexicographically compare two sequences.

Synopsis

```
template <typename Seq1, typename Seq2>
bool
operator<(Seq1 const& a, Seq2 const& b);
```

Parameters

Parameter	Requirement	Description
`a, b`	Instances of Sequence	Sequence(s) to compare

Expression Semantics

```
a < b
```

Return type: `bool`

Requirements:

For each element, `e1`, in sequence `a`, and for each element, `e2`, in sequence `b`, `a < b` is a valid expression returning a type that is convertible to bool.

An attempt to compare two Sequences of different lengths results in a compile time error.

Semantics: Returns the lexicographical comparison of between `a` and `b`.

Header

```
#include <boost/fusion/sequence/comparison/less.hpp>
#include <boost/fusion/include/less.hpp>
```

Example

```
vector<int, float> v1(4, 3.3f);
vector<short, float> v2(5, 3.3f);
vector<long, double> v3(5, 4.4);
assert(v1 < v2);
assert(v2 < v3);
```

less than equal

Lexicographically compare two sequences.

Synopsis

```
template <typename Seq1, typename Seq2>
bool
operator<=(Seq1 const& a, Seq2 const& b);
```

Parameters

Parameter	Requirement	Description
`a, b`	Instances of Sequence	Sequence(s) to compare

Expression Semantics

```
a <= b
```

Return type: `bool`

Requirements:

For each element, `e1`, in sequence `a`, and for each element, `e2`, in sequence `b`, `a < b` is a valid expression returning a type that is convertible to bool.

An attempt to compare two Sequences of different lengths results in a compile time error.

Semantics: Returns !(b < a).

Header

```
#include <boost/fusion/sequence/comparison/less_equal.hpp>
#include <boost/fusion/include/less_equal.hpp>
```

Example

```
vector<int, float> v1(4, 3.3f);
vector<short, float> v2(5, 3.3f);
vector<long, double> v3(5, 4.4);
assert(v1 <= v2);
assert(v2 <= v3);
```

greater than

Lexicographically compare two sequences.

Synopsis

```
template <typename Seq1, typename Seq2>
bool
operator>(Seq1 const& a, Seq2 const& b);
```

Parameters

Parameter	Requirement	Description
`a, b`	Instances of Sequence	Sequence(s) to compare

Expression Semantics

```
a > b
```

Return type: `bool`

Requirements:

For each element, `e1`, in sequence `a`, and for each element, `e2`, in sequence `b`, `a < b` is a valid expression returning a type that is convertible to bool.

An attempt to compare two Sequences of different lengths results in a compile time error.

Semantics: Returns b < a.

Header

```
#include <boost/fusion/sequence/comparison/less_equal.hpp>
#include <boost/fusion/include/less_equal.hpp>
```

Example

```
vector<int, float> v1(4, 3.3f);
vector<short, float> v2(5, 3.3f);
vector<long, double> v3(5, 4.4);
assert(v2 > v1);
assert(v3 > v2);
```

greater than equal

Lexicographically compare two sequences.

Synopsis

```
template <typename Seq1, typename Seq2>
bool
operator>=(Seq1 const& a, Seq2 const& b);
```

Parameters

Parameter	Requirement	Description
`a, b`	Instances of Sequence	Sequence(s) to compare

Expression Semantics

```
a >= b
```

Return type: `bool`

Requirements:

For each element, `e1`, in sequence `a`, and for each element, `e2`, in sequence `b`, `a < b` is a valid expression returning a type that is convertible to bool.

An attempt to compare two Sequences of different lengths results in a compile time error.

Semantics: Returns !(a < b).

Header

```
#include <boost/fusion/sequence/comparison/greater_equal.hpp>
#include <boost/fusion/include/greater_equal.hpp>
```

Example

```
vector<int, float> v1(4, 3.3f);
vector<short, float> v2(5, 3.3f);
vector<long, double> v3(5, 4.4);
assert(v2 >= v1);
assert(v3 >= v2);
```

Container

Fusion provides a few predefined sequences out of the box. These *containers* actually hold heterogenously typed data; unlike Views. These containers are more or less counterparts of those in STL.

Header

```
#include <boost/fusion/container.hpp>
#include <boost/fusion/include/container.hpp>
```

vector

Description

`vector` is a Random Access Sequence of heterogenous typed data structured as a simple `struct` where each element is held as a member variable. `vector` is the simplest of the Fusion sequence container (a vector with N elements is just a struct with N members), and in many cases the most efficient.

Header

```
#include <boost/fusion/container/vector.hpp>
#include <boost/fusion/include/vector.hpp>
#include <boost/fusion/container/vector/vector_fwd.hpp>
#include <boost/fusion/include/vector_fwd.hpp>

// numbered forms
#include <boost/fusion/container/vector/vector10.hpp>
#include <boost/fusion/include/vector10.hpp>
#include <boost/fusion/container/vector/vector20.hpp>
#include <boost/fusion/include/vector20.hpp>
#include <boost/fusion/container/vector/vector30.hpp>
#include <boost/fusion/include/vector30.hpp>
#include <boost/fusion/container/vector/vector40.hpp>
#include <boost/fusion/include/vector40.hpp>
#include <boost/fusion/container/vector/vector50.hpp>
#include <boost/fusion/include/vector50.hpp>
```

Synopsis

Numbered forms

```
struct vector0;

template <typename T0>
struct vector1;

template <typename T0, typename T1>
struct vector2;

template <typename T0, typename T1, typename T2>
struct vector3;

...

template <typename T0, typename T1, typename T2..., typename TN>
struct vectorN;
```

Variadic form

```
template <
    typename T0 = unspecified
  , typename T1 = unspecified
  , typename T2 = unspecified
    ...
  , typename TN = unspecified
>
struct vector;
```

The numbered form accepts the exact number of elements. Example:

```
vector3<int, char, double>
```

The variadic form accepts `0` to `FUSION_MAX_VECTOR_SIZE` elements, where `FUSION_MAX_VECTOR_SIZE` is a user definable predefined maximum that defaults to `10`. Example:

```
vector<int, char, double>
```

You may define the preprocessor constant `FUSION_MAX_VECTOR_SIZE` before including any Fusion header to change the default. Example:

```
#define FUSION_MAX_VECTOR_SIZE 20
```

Template parameters

Parameter	Description	Default
`T0`...`TN`	Element types	*unspecified*

Model of

- Random Access Sequence

Notation

`v`	Instance of `vector`
`V`	A `vector` type
`e0`...`en`	Heterogeneous values
`s`	A Forward Sequence

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in Random Access Sequence.

Expression	Semantics
`V()`	Creates a vector with default constructed elements.
`V(e0, e1,... en)`	Creates a vector with elements `e0`...`en`.
`V(s)`	Copy constructs a vector from a Forward Sequence, `s`.
`v = s`	Assigns to a vector, `v`, from a Forward Sequence, `s`.

Example

```
vector<int, float> v(12, 5.5f);
std::cout << at_c<0>(v) << std::endl;
std::cout << at_c<1>(v) << std::endl;
```

cons

Description

`cons` is a simple Forward Sequence. It is a lisp style recursive list structure where `car` is the *head* and `cdr` is the *tail*: usually another cons structure or `nil`: the empty list. Fusion's `list` is built on top of this more primitive data structure. It is more efficient than `vector` when the target sequence is constructed piecemeal (a data at a time). The runtime cost of access to each element is peculiarly constant (see Recursive Inlined Functions).

Header

```
#include <boost/fusion/container/list/cons.hpp>
#include <boost/fusion/include/cons.hpp>
```

Synopsis

```
template <typename Car, typename Cdr = nil>
struct cons;
```

Template parameters

Parameter	Description	Default
`Car`	Head type	
`Cdr`	Tail type	`nil`

Model of

- Forward Sequence

Notation

`nil`	An empty `cons`
`C`	A `cons` type
`l`, `l2`	Instances of `cons`

`car`	An arbitrary data
`cdr`	Another `cons` list
`s`	A Forward Sequence
`N`	An MPL Integral Constant

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in Forward Sequence.

Expression	Semantics
`nil()`	Creates an empty list.
`C()`	Creates a cons with default constructed elements.
`C(car)`	Creates a cons with `car` head and default constructed tail.
`C(car, cdr)`	Creates a cons with `car` head and `cdr` tail.
`C(s)`	Copy constructs a cons from a Forward Sequence, `s`.
`l = s`	Assigns to a cons, `l`, from a Forward Sequence, `s`.
`at<N>(l)`	The Nth element from the beginning of the sequence; see `at`.

`at<N>(l)` is provided for convenience and compatibility with the original Boost.Tuple library, despite `cons` being a Forward Sequence only (`at` is supposed to be a Random Access Sequence requirement). The runtime complexity of `at` is constant (see Recursive Inlined Functions).

Example

```
cons<int, cons<float> > l(12, cons<float>(5.5f));
std::cout << at_c<0>(l) << std::endl;
std::cout << at_c<1>(l) << std::endl;
```

list

Description

`list` is a Forward Sequence of heterogenous typed data built on top of `cons`. It is more efficient than `vector` when the target sequence is constructed piecemeal (a data at a time). The runtime cost of access to each element is peculiarly constant (see Recursive Inlined Functions).

Header

```
#include <boost/fusion/container/list.hpp>
#include <boost/fusion/include/list.hpp>
#include <boost/fusion/container/list/list_fwd.hpp>
#include <boost/fusion/include/list_fwd.hpp>
```

Synopsis

```
template <
    typename T0 = unspecified
  , typename T1 = unspecified
  , typename T2 = unspecified
    ...
  , typename TN = unspecified
>
struct list;
```

The variadic class interface accepts `0` to `FUSION_MAX_LIST_SIZE` elements, where `FUSION_MAX_LIST_SIZE` is a user definable predefined maximum that defaults to `10`. Example:

```
list<int, char, double>
```

You may define the preprocessor constant `FUSION_MAX_LIST_SIZE` before including any Fusion header to change the default. Example:

```
#define FUSION_MAX_LIST_SIZE 20
```

Template parameters

Parameter	Description	Default
`T0`...`TN`	Element types	*unspecified*

Model of

- Forward Sequence

Notation

`L`	A `list` type
`l`	An instance of `list`
`e0`...`en`	Heterogeneous values
`s`	A Forward Sequence
`N`	An MPL Integral Constant

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in Forward Sequence.

Expression	Semantics
`L()`	Creates a list with default constructed elements.
`L(e0, e1,... en)`	Creates a list with elements `e0`...`en`.
`L(s)`	Copy constructs a list from a Forward Sequence, `s`.
`l = s`	Assigns to a list, `l`, from a Forward Sequence, `s`.
`at<N>(l)`	The Nth element from the beginning of the sequence; see `at`.

> `at<n>(l)` is provided for convenience and compatibility with the original Boost.Tuple library, despite `list` being a Forward Sequence only (`at` is supposed to be a Random Access Sequence requirement). The runtime complexity of `at` is constant (see Recursive Inlined Functions).

Example

```
list<int, float> l(12, 5.5f);
std::cout << at_c<0>(l) << std::endl;
std::cout << at_c<1>(l) << std::endl;
```

deque

Description

`deque` is a simple Bidirectional Sequence that supports constant-time insertion and removal of elements at both ends. Like the `list` and `cons`, `deque` is more efficient than `vector` (especially at compile time) when the target sequence is constructed piecemeal (a data at a time, e.g. when constructing expression templates). Like the `list` and `cons`, runtime cost of access to each element is peculiarly constant (see Recursive Inlined Functions).

Element insertion and removal are done by special `deque` helper classes `front_extended_deque` and `back_extended_deque`.

Header

```
#include <boost/fusion/container/deque.hpp>
#include <boost/fusion/include/deque.hpp>
#include <boost/fusion/container/list/deque_fwd.hpp>
#include <boost/fusion/include/deque_fwd.hpp>
```

Synopsis

```
template <typename ...Elements>
struct deque;
```

For C++11 compilers, the variadic class interface has no upper bound.

For C++03 compilers, the variadic class interface accepts `0` to `FUSION_MAX_DEQUE_SIZE` elements, where `FUSION_MAX_DEQUE_SIZE` is a user definable predefined maximum that defaults to `10`. Example:

```
deque<int, char, double>
```

You may define the preprocessor constant `FUSION_MAX_DEQUE_SIZE` before including any Fusion header to change the default. Example:

```
#define FUSION_MAX_DEQUE_SIZE 20
```

Template parameters

Parameter	Description	Default
`Elements`	Element types	

Model of

- Bidirectional Sequence

Notation

`D`	A `deque` type
`d`, `d2`	Instances of `deque`
`e0`...`en`	Heterogeneous values
`s`	A Forward Sequence
`N`	An MPL Integral Constant

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in Bidirectional Sequence.

Expression	Semantics
`D()`	Creates a deque with default constructed elements.
`D(e0, e1,... en)`	Creates a deque with elements `e0`...`en`.
`D(s)`	Copy constructs a deque from a Forward Sequence, `s`.
`d = s`	Assigns to a deque, `d`, from a Forward Sequence, `s`.
`at<N>(d)`	The Nth element from the beginning of the sequence; see `at`.

`at<N>(d)` is provided for convenience, despite `deque` being a Bidirectional Sequence only (`at` is supposed to be a Random Access Sequence requirement). The runtime complexity of `at` is constant (see Recursive Inlined Functions). `deque` element access utilizes operator overloading with argument dependent lookup (ADL) of the proper element getter function given a static constant index parameter. Interestingly, with modern C++ compilers, this lookup is very fast and rivals recursive template instantiations in compile time-speed, so much so that `deque` relies on ADL for all element access (indexing) as well as iteration.

Example

```
deque<int, float> d(12, 5.5f);
std::cout << at_c<0>(d) << std::endl;
std::cout << at_c<1>(d) << std::endl;
```

front_extended_deque

Description

`front_extended_deque` allows a `deque` to be front extended. It shares the same properties as the `deque`.

Header

```
See deque
```

Synopsis

```
template <typename Deque, typename T>
struct front_extended_deque;
```

Template parameters

Parameter	Description	Default
`Deque`	Deque type	
`T`	Element type	

`Deque` can be a `deque`, a `front_extended_deque` or a `back_extended_deque`

Model of

- Bidirectional Sequence

Notation

`D`	A `front_extended_deque` type
`e`	Heterogeneous value
`N`	An MPL Integral Constant

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in Bidirectional Sequence.

Expression	Semantics
`D(d, e)`	Extend `d` prepending `e` to its front.
`at<N>(d)`	The Nth element from the beginning of the sequence; see `at`.

See deque for further details.

Example

```
typedef deque<int, float> initial_deque;
initial_deque d(12, 5.5f);
front_extended_deque<initial_deque, int> d2(d, 999);
std::cout << at_c<0>(d2) << std::endl;
std::cout << at_c<1>(d2) << std::endl;
std::cout << at_c<2>(d2) << std::endl;
```

back_extended_deque

Description

back_extended_deque allows a deque to be back extended. It shares the same properties as the deque.

Header

```
See deque
```

Synopsis

```
template <typename Deque, typename T>
struct back_extended_deque;
```

Template parameters

Parameter	Description	Default
Deque	Deque type	
T	Element type	

Deque can be a deque, a back_extended_deque or a back_extended_deque

Model of

- Bidirectional Sequence

Notation

D	A back_extended_deque type
e	Heterogeneous value
N	An MPL Integral Constant

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in Bidirectional Sequence.

Expression	Semantics
`D(d, e)`	Extend `d` prepending `e` to its back.
`at<N>(d)`	The Nth element from the beginning of the sequence; see `at`.

See `deque` for further details.

Example

```
typedef deque<int, float> initial_deque;
initial_deque d(12, 5.5f);
back_extended_deque<initial_deque, int> d2(d, 999);
std::cout << at_c<0>(d2) << std::endl;
std::cout << at_c<1>(d2) << std::endl;
std::cout << at_c<2>(d2) << std::endl;
```

set

Description

set is an Associative Sequence of heteregenous typed data elements. Type identity is used to impose an equivalence relation on keys. The element's type is its key. A set may contain at most one element for each key. Membership testing and element key lookup has constant runtime complexity (see Overloaded Functions).

Header

```
#include <boost/fusion/container/set.hpp>
#include <boost/fusion/include/set.hpp>
#include <boost/fusion/container/set/set_fwd.hpp>
#include <boost/fusion/include/set_fwd.hpp>
```

Synopsis

```
template <
    typename T0 = unspecified
  , typename T1 = unspecified
  , typename T2 = unspecified
    ...
  , typename TN = unspecified
>
struct set;
```

The variadic class interface accepts `0` to `FUSION_MAX_SET_SIZE` elements, where `FUSION_MAX_SET_SIZE` is a user definable predefined maximum that defaults to `10`. Example:

```
set<int, char, double>
```

You may define the preprocessor constant `FUSION_MAX_SET_SIZE` before including any Fusion header to change the default. Example:

```
#define FUSION_MAX_SET_SIZE 20
```

Template parameters

Parameter	Description	Default
`T0...TN`	Element types	*unspecified*

Model of

- Associative Sequence
- Forward Sequence

Notation

`S`	A `set` type
`s`	An instance of `set`
`e0...en`	Heterogeneous values
`fs`	A Forward Sequence

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in Random Access Sequence and Associative Sequence.

Expression	Semantics
`S()`	Creates a set with default constructed elements.
`S(e0, e1,... en)`	Creates a set with elements `e0...en`.
`S(fs)`	Copy constructs a set from a Forward Sequence `fs`.
`s = fs`	Assigns to a set, `s`, from a Forward Sequence `fs`.

Example

```
typedef set<int, float> S;
S s(12, 5.5f);
std::cout << at_key<int>(s) << std::endl;
std::cout << at_key<float>(s) << std::endl;
std::cout << result_of::has_key<S, double>::value << std::endl;
```

map

Description

map is an Associative Sequence of heteregenous typed data elements. Each element is a key/data pair (see `fusion::pair`) where the key has no data (type only). Type identity is used to impose an equivalence relation on keys. A map may contain at most one element for each key. Membership testing and element key lookup has constant runtime complexity (see Overloaded Functions).

Header

```
#include <boost/fusion/container/map.hpp>
#include <boost/fusion/include/map.hpp>
#include <boost/fusion/container/map/map_fwd.hpp>
#include <boost/fusion/include/map_fwd.hpp>
```

Synopsis

```
template <
    typename T0 = unspecified
  , typename T1 = unspecified
  , typename T2 = unspecified
    ...
  , typename TN = unspecified
>
struct map;
```

The variadic class interface accepts `0` to `FUSION_MAX_MAP_SIZE` elements, where `FUSION_MAX_MAP_SIZE` is a user definable predefined maximum that defaults to `10`. Example:

```
map<pair<int, char>, pair<char, char>, pair<double, char> >
```

You may define the preprocessor constant `FUSION_MAX_MAP_SIZE` before including any Fusion header to change the default. Example:

```
#define FUSION_MAX_MAP_SIZE 20
```

Template parameters

Parameter	**Description**	**Default**
`T0`...`TN`	Element types	*unspecified*

Model of

- Associative Sequence
- Forward Sequence

Notation

`M`	A `map` type
`m`	An instance of `map`
`e0`...`en`	Heterogeneous key/value pairs (see `fusion::pair`)
`s`	A Forward Sequence

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in Random Access Sequence and Associative Sequence.

Expression	Semantics
`M()`	Creates a map with default constructed elements.
`M(e0, e1,... en)`	Creates a map with element pairs `e0`...`en`.
`M(s)`	Copy constructs a map from a Forward Sequence `s`.
`m = s`	Assigns to a map, `m`, from a Forward Sequence `s`.

Example

```
typedef map<
    pair<int, char>
  , pair<double, std::string> >
map_type;

map_type m(
    make_pair<int>('X')
  , make_pair<double>("Men"));

std::cout << at_key<int>(m) << std::endl;
std::cout << at_key<double>(m) << std::endl;
```

Generation

These are the functions that you can use to generate various forms of Container from elemental values.

Header

```
#include <boost/fusion/container/generation.hpp>
#include <boost/fusion/include/generation.hpp>
```

Functions

make_list

Description

Create a `list` from one or more values.

Synopsis

```
template <typename T0, typename T1,... typename TN>
typename result_of::make_list<T0, T1,... TN>::type
make_list(T0 const& x0, T1 const& x1... TN const& xN);
```

The variadic function accepts `0` to `FUSION_MAX_LIST_SIZE` elements, where `FUSION_MAX_LIST_SIZE` is a user definable predefined maximum that defaults to `10`. You may define the preprocessor constant `FUSION_MAX_LIST_SIZE` before including any Fusion header to change the default. Example:

```
#define FUSION_MAX_LIST_SIZE 20
```

Parameters

Parameter	Requirement	Description
`x0, x1,... xN`	Instances of `T0, T1,... TN`	The arguments to `make_list`

Expression Semantics

```
make_list(x0, x1,... xN);
```

Return type: `result_of::make_list<T0, T1,... TN>::type`

Semantics: Create a `list` from `x0, x1,... xN`.

Header

```
#include <boost/fusion/container/generation/make_list.hpp>
#include <boost/fusion/include/make_list.hpp>
```

Example

```
make_list(123, "hello", 12.5)
```

See also

`boost::ref`

make_cons

Description

Create a `cons` from `car` (*head*) and optional `cdr` (*tail*).

Synopsis

```
template <typename Car>
typename result_of::make_cons<Car>::type
make_cons(Car const& car);

template <typename Car, typename Cdr>
typename result_of::make_cons<Car, Cdr>::type
make_cons(Car const& car, Cdr const& cdr);
```

Parameters

Parameter	Requirement	Description
`car`	Instance of `Car`	The list's head
`cdr`	Instance of `Cdr`	The list's tail (optional)

Expression Semantics

```
make_cons(car, cdr);
```

Return type: `result_of::make_cons<Car, Cdr>::type` or `result_of::make_cons<Car>::type`

Semantics: Create a `cons` from `car` (*head*) and optional `cdr` (*tail*).

Header

```
#include <boost/fusion/container/generation/make_cons.hpp>
#include <boost/fusion/include/make_cons.hpp>
```

Example

```
make_cons('x', make_cons(123))
```

See also

`boost::ref`

make_vector

Description

Create a `vector` from one or more values.

Synopsis

```
template <typename T0, typename T1,... typename TN>
typename result_of::make_vector<T0, T1,... TN>::type
make_vector(T0 const& x0, T1 const& x1... TN const& xN);
```

The variadic function accepts `0` to `FUSION_MAX_VECTOR_SIZE` elements, where `FUSION_MAX_VECTOR_SIZE` is a user definable predefined maximum that defaults to `10`. You may define the preprocessor constant `FUSION_MAX_VECTOR_SIZE` before including any Fusion header to change the default. Example:

```
#define FUSION_MAX_VECTOR_SIZE 20
```

Parameters

Parameter	Requirement	Description
`x0, x1,... xN`	Instances of `T0, T1,... TN`	The arguments to `make_vector`

Expression Semantics

```
make_vector(x0, x1,... xN);
```

Return type: `result_of::make_vector<T0, T1,... TN>::type`

Semantics: Create a `vector` from `x0, x1,... xN`.

Header

```
#include <boost/fusion/container/generation/make_vector.hpp>
#include <boost/fusion/include/make_vector.hpp>
```

Example

```
make_vector(123, "hello", 12.5)
```

See also

`boost::ref`

make_deque

Description

Create a `deque` from one or more values.

Synopsis

```
template <typename ...Elements>
typename result_of::make_deque<Elements...>::type
make_deque(Elements const&... elements);
```

For C++11 compilers, the variadic function interface has no upper bound.

For C++11 compilers, the variadic function accepts `0` to `FUSION_MAX_DEQUE_SIZE` elements, where `FUSION_MAX_DEQUE_SIZE` is a user definable predefined maximum that defaults to `10`. You may define the preprocessor constant `FUSION_MAX_DEQUE_SIZE` before including any Fusion header to change the default. Example:

```
#define FUSION_MAX_DEQUE_SIZE 20
```

Parameters

Parameter	Description	Description
`elements`	Instances of `Elements`	The arguments to `make_deque`

Expression Semantics

```
make_deque(elements...);
```

Return type: `result_of::make_deque<Elements...>::type`

Semantics: Create a `deque` from `elements...`.

Header

```
#include <boost/fusion/container/generation/make_deque.hpp>
#include <boost/fusion/include/make_deque.hpp>
```

Example

```
make_deque(123, "hello", 12.5)
```

See also

`boost::ref`

make_set

Description

Create a `set` from one or more values.

Synopsis

```
template <typename T0, typename T1,... typename TN>
typename result_of::make_set<T0, T1,... TN>::type
make_set(T0 const& x0, T1 const& x1... TN const& xN);
```

The variadic function accepts `0` to `FUSION_MAX_SET_SIZE` elements, where `FUSION_MAX_SET_SIZE` is a user definable predefined maximum that defaults to `10`. You may define the preprocessor constant `FUSION_MAX_SET_SIZE` before including any Fusion header to change the default. Example:

```
#define FUSION_MAX_SET_SIZE 20
```

Parameters

Parameter	Requirement	Description
`x0, x1,... xN`	Instances of `T0, T1,... TN`	The arguments to `make_set`

Expression Semantics

```
make_set(x0, x1,... xN);
```

Return type: `result_of::make_set<T0, T1,... TN>::type`

Semantics: Create a `set` from `x0, x1,... xN`.

Precondition: There may be no duplicate key types.

Header

```
#include <boost/fusion/container/generation/make_set.hpp>
#include <boost/fusion/include/make_set.hpp>
```

Example

```
make_set(123, "hello", 12.5)
```

See also

`boost::ref`

make_map

Description

Create a `map` from one or more key/data pairs.

Synopsis

```
template <
    typename K0, typename K1,... typename KN
  , typename T0, typename T1,... typename TN>
typename result_of::make_map<K0, K0,... KN, T0, T1,... TN>::type
make_map(T0 const& x0, T1 const& x1... TN const& xN);
```

The variadic function accepts `0` to `FUSION_MAX_MAP_SIZE` elements, where `FUSION_MAX_MAP_SIZE` is a user definable predefined maximum that defaults to `10`. You may define the preprocessor constant `FUSION_MAX_MAP_SIZE` before including any Fusion header to change the default. Example:

```
#define FUSION_MAX_MAP_SIZE 20
```

Parameters

Parameter	Requirement	Description
`K0, K1,... KN`	The key types	Keys associated with `x0, x1,... xN`
`x0, x1,... xN`	Instances of `T0, T1,... TN`	The arguments to `make_map`

Expression Semantics

```
make_map<K0, K1,... KN>(x0, x1,... xN);
```

Return type: `result_of::make_map<K0, K0,... KN, T0, T1,... TN>::type`

Semantics: Create a `map` from `K0, K1,... KN` keys and `x0, x1,... xN` data.

Precondition: There may be no duplicate key types.

Header

```
#include <boost/fusion/container/generation/make_map.hpp>
#include <boost/fusion/include/make_map.hpp>
```

Example

```
make_map<int, double>('X', "Men")
```

See also

`boost::ref`, `fusion::pair`

Tiers

Tiers are sequences, where all elements are non-const reference types. They are constructed with a call to a couple of *tie* function templates. The succeeding sections document the various *tier* flavors.

- `list_tie`
- `vector_tie`
- `map_tie`

- `deque_tie`

Example:

```
int i; char c; double d;
  ...
vector_tie(i, c, a);
```

The `vector_tie` function creates a `vector` of type `vector<int&, char&, double&>`. The same result could be achieved with the call `make_vector(ref(i), ref(c), ref(a))` [10].

A *tie* can be used to 'unpack' another tuple into variables. E.g.:

```
int i; char c; double d;
vector_tie(i, c, d) = make_vector(1,'a', 5.5);
std::cout << i << " " <<  c << " " << d;
```

This code prints 1 a 5.5 to the standard output stream. A sequence unpacking operation like this is found for example in ML and Python. It is convenient when calling functions which return sequences.

Ignore

There is also an object called *ignore* which allows you to ignore an element assigned by a sequence. The idea is that a function may return a sequence, only part of which you are interested in. For example:

```
char c;
vector_tie(ignore, c) = make_vector(1, 'a');
```

list_tie

Description

Constructs a tie using a `list` sequence.

Synopsis

```
template <typename T0, typename T1,... typename TN>
list<T0&, T1&,... TN&>
list_tie(T0& x0, T1& x1... TN& xN);
```

The variadic function accepts `0` to `FUSION_MAX_LIST_SIZE` elements, where `FUSION_MAX_LIST_SIZE` is a user definable predefined maximum that defaults to `10`. You may define the preprocessor constant `FUSION_MAX_LIST_SIZE` before including any Fusion header to change the default. Example:

```
#define FUSION_MAX_LIST_SIZE 20
```

Parameters

Parameter	Requirement	Description
`x0, x1,... xN`	Instances of `T0, T1,... TN`	The arguments to `list_tie`

[10] see Boost.Ref for details about `ref`

Expression Semantics

```
list_tie(x0, x1,... xN);
```

Return type: `list`<T0&, T1&,... TN&>

Semantics: Create a `list` of references from `x0, x1,... xN`.

Header

```
#include <boost/fusion/container/generation/list_tie.hpp>
#include <boost/fusion/include/list_tie.hpp>
```

Example

```
int i = 123;
double d = 123.456;
list_tie(i, d)
```

vector_tie

Description

Constructs a tie using a `vector` sequence.

Synopsis

```
template <typename T0, typename T1,... typename TN>
vector<T0&, T1&,... TN&>
vector_tie(T0& x0, T1& x1... TN& xN);
```

The variadic function accepts `0` to `FUSION_MAX_VECTOR_SIZE` elements, where `FUSION_MAX_VECTOR_SIZE` is a user definable predefined maximum that defaults to `10`. You may define the preprocessor constant `FUSION_MAX_VECTOR_SIZE` before including any Fusion header to change the default. Example:

```
#define FUSION_MAX_VECTOR_SIZE 20
```

Parameters

Parameter	Requirement	Description
`x0, x1,... xN`	Instances of `T0, T1,... TN`	The arguments to `vector_tie`

Expression Semantics

```
vector_tie(x0, x1,... xN);
```

Return type: `vector`<T0&, T1&,... TN&>

Semantics: Create a `vector` of references from `x0, x1,... xN`.

Header

```
#include <boost/fusion/container/generation/vector_tie.hpp>
#include <boost/fusion/include/vector_tie.hpp>
```

Example

```
int i = 123;
double d = 123.456;
vector_tie(i, d)
```

map_tie

Description

Constructs a tie using a `map` sequence.

Synopsis

```
template <typename K0, typename K1,... typename KN, typename D0, typename D1,... typename DN>
map<pair<K0, D0&>, pair<K1, D1&>,... pair<KN, DN&> >
map_tie(D0& d0, D1& d1... DN& dN);
```

The variadic function accepts `0` to `FUSION_MAX_MAP_SIZE` elements, where `FUSION_MAX_MAP_SIZE` is a user definable predefined maximum that defaults to `10`, and a corresponding number of key types. You may define the preprocessor constant `FUSION_MAX_MAP_SIZE` before including any Fusion header to change the default. Example:

```
#define FUSION_MAX_MAP_SIZE 20
```

Parameters

Parameter	Requirement	Description
`K0, K1,... KN`	Any type	The key types associated with each of the `x1,x2,...,xN` values
`x0, x1,... xN`	Instances of `T0, T1,... TN`	The arguments to `map_tie`

Expression Semantics

```
map_tie<K0, K1,... KN>(x0, x1,... xN);
```

Return type: `map`<`pair`<K0, D0&>, `pair`<K1, D1&>,... `pair`<KN, DN&> >

Semantics: Create a `map` of references from `x0, x1,... xN` with keys `K0, K1,... KN`

Header

```
#include <boost/fusion/container/generation/map_tie.hpp>
#include <boost/fusion/include/map_tie.hpp>
```

Example

```
struct int_key;
struct double_key;
...
int i = 123;
double d = 123.456;
map_tie<int_key, double_key>(i, d)
```

deque_tie

Description

Constructs a tie using a deque sequence.

Synopsis

```
template <typename ...Elements>
deque<Elements&...>
deque_tie(Elements&... elements);
```

For C++11 compilers, the variadic function interface has no upper bound.

For C++03 compilers, the variadic function accepts `0` to `FUSION_MAX_DEQUE_SIZE` elements, where `FUSION_MAX_DEQUE_SIZE` is a user definable predefined maximum that defaults to `10`. You may define the preprocessor constant `FUSION_MAX_DEQUE_SIZE` before including any Fusion header to change the default. Example:

```
#define FUSION_MAX_DEQUE_SIZE 20
```

Parameters

Parameter	Description	Description
`elements`	Instances of `Elements`	The arguments to `deque_tie`

Expression Semantics

```
deque_tie(elements...);
```

Return type: deque<Elements&...>

Semantics: Create a deque of references from `elements...`.

Header

```
#include <boost/fusion/container/generation/deque_tie.hpp>
#include <boost/fusion/include/deque_tie.hpp>
```

Example

```
int i = 123;
double d = 123.456;
deque_tie(i, d)
```

MetaFunctions

make_list

Description

Returns the result type of `make_list`.

Synopsis

```
template <typename T0, typename T1,... typename TN>
struct make_list;
```

The variadic function accepts `0` to `FUSION_MAX_LIST_SIZE` elements, where `FUSION_MAX_LIST_SIZE` is a user definable predefined maximum that defaults to `10`. You may define the preprocessor constant `FUSION_MAX_LIST_SIZE` before including any Fusion header to change the default. Example:

```
#define FUSION_MAX_LIST_SIZE 20
```

Parameters

Parameter	Requirement	Description
`T0, T1,... TN`	Any type	Template arguments to `make_list`

Expression Semantics

```
result_of::make_list<T0, T1,... TN>::type
```

Return type: A `list` with elements of types converted following the rules for *element conversion*.

Semantics: Create a `list` from `T0, T1,... TN`.

Header

```
#include <boost/fusion/container/generation/make_list.hpp>
#include <boost/fusion/include/make_list.hpp>
```

Example

```
result_of::make_list<int, const char(&)[7], double>::type
```

make_cons

Description

Returns the result type of `make_cons`.

Synopsis

```
template <typename Car, typename Cdr = nil>
struct make_cons;
```

Parameters

Parameter	Requirement	Description
`Car`	Any type	The list's head type
`Cdr`	A `cons`	The list's tail type (optional)

Expression Semantics

```
result_of::make_cons<Car, Cdr>::type
```

Return type: A `cons` with head element, `Car`, of type converted following the rules for *element conversion*, and tail, `Cdr`.

Semantics: Create a `cons` from `Car` (*head*) and optional `Cdr` (*tail*).

Header

```
#include <boost/fusion/container/generation/make_cons.hpp>
#include <boost/fusion/include/make_cons.hpp>
```

Example

```
result_of::make_cons<char, result_of::make_cons<int>::type>::type
```

make_vector

Description

Returns the result type of `make_vector`.

Synopsis

```
template <typename T0, typename T1,... typename TN>
struct make_vector;
```

The variadic function accepts `0` to `FUSION_MAX_VECTOR_SIZE` elements, where `FUSION_MAX_VECTOR_SIZE` is a user definable predefined maximum that defaults to `10`. You may define the preprocessor constant `FUSION_MAX_VECTOR_SIZE` before including any Fusion header to change the default. Example:

```
#define FUSION_MAX_VECTOR_SIZE 20
```

Parameters

Parameter	Requirement	Description
`T0, T1,... TN`	Any type	Template arguments to `make_vector`

Expression Semantics

```
result_of::make_vector<T0, T1,... TN>::type
```

Return type: A `vector` with elements of types converted following the rules for *element conversion*.

Semantics: Create a `vector` from `T0, T1,... TN`.

Header

```
#include <boost/fusion/container/generation/make_list.hpp>
#include <boost/fusion/include/make_list.hpp>
```

Example

```
result_of::make_vector<int, const char(&)[7], double>::type
```

make_deque

Description

Returns the result type of `make_deque`.

Synopsis

```
template <typename ...Elements>
struct make_deque;
```

For C++11 compilers, the variadic template interface has no upper bound.

For C++03 The variadic function accepts `0` to `FUSION_MAX_DEQUE_SIZE` elements, where `FUSION_MAX_DEQUE_SIZE` is a user definable predefined maximum that defaults to `10`. You may define the preprocessor constant `FUSION_MAX_DEQUE_SIZE` before including any Fusion header to change the default. Example:

```
#define FUSION_MAX_DEQUE_SIZE 20
```

Parameters

Parameter	Requirement	Description
`Elements`	Variadic template types	Template arguments to `make_deque`

Expression Semantics

```
result_of::make_deque<Elements...>::type
```

Return type: A `deque` with elements of types converted following the rules for *element conversion*.

Semantics: Create a `deque` from `Elements...`.

Header

```
#include <boost/fusion/container/generation/make_deque.hpp>
#include <boost/fusion/include/make_deque.hpp>
```

Example

```
result_of::make_deque<int, const char(&)[7], double>::type
```

make_set

Description

Returns the result type of `make_set`.

Synopsis

```
template <typename T0, typename T1,... typename TN>
struct make_set;
```

The variadic function accepts `0` to `FUSION_MAX_SET_SIZE` elements, where `FUSION_MAX_SET_SIZE` is a user definable predefined maximum that defaults to `10`. You may define the preprocessor constant `FUSION_MAX_SET_SIZE` before including any Fusion header to change the default. Example:

```
#define FUSION_MAX_SET_SIZE 20
```

Parameters

Parameter	Requirement	Description
`T0, T1,... TN`	Any type	The arguments to `make_set`

Expression Semantics

```
result_of::make_set<T0, T1,... TN>::type
```

Return type: A `set` with elements of types converted following the rules for *element conversion*.

Semantics: Create a `set` from `T0, T1,... TN`.

Precondition: There may be no duplicate key types.

Header

```
#include <boost/fusion/container/generation/make_set.hpp>
#include <boost/fusion/include/make_set.hpp>
```

Example

```
result_of::make_set<int, char, double>::type
```

make_map

Description

Returns the result type of `make_map`.

Synopsis

```
template <
    typename K0, typename K1,... typename KN
  , typename T0, typename T1,... typename TN>
struct make_map;
```

The variadic function accepts `0` to `FUSION_MAX_MAP_SIZE` elements, where `FUSION_MAX_MAP_SIZE` is a user definable predefined maximum that defaults to `10`. You may define the preprocessor constant `FUSION_MAX_MAP_SIZE` before including any Fusion header to change the default. Example:

```
#define FUSION_MAX_MAP_SIZE 20
```

Parameters

Parameter	Requirement	Description
`K0, K1,... KN`	Any type	Keys associated with `T0, T1,... TN`
`T0, T1,... TN`	Any type	Data associated with keys `K0, K1,... KN`

Expression Semantics

```
resulf_of::make_map<K0, K1,... KN, T0, T1,... TN>::type;
```

Return type: `result_of::make_map<K0, K0,... KN, T0, T1,... TN>::type`

Semantics: A `map` with `fusion::pair` elements where the `second_type` is converted following the rules for *element conversion*.

Precondition: There may be no duplicate key types.

Header

```
#include <boost/fusion/container/generation/make_map.hpp>
#include <boost/fusion/include/make_map.hpp>
```

Example

```
result_of::make_map<int, double, char, double>::type
```

See also

`fusion::pair`

list_tie

Description

Returns the result type of `list_tie`.

Synopsis

```
template <typename T0, typename T1,... typename TN>
struct list_tie;
```

The variadic function accepts `0` to `FUSION_MAX_LIST_SIZE` elements, where `FUSION_MAX_LIST_SIZE` is a user definable predefined maximum that defaults to `10`. You may define the preprocessor constant `FUSION_MAX_LIST_SIZE` before including any Fusion header to change the default. Example:

```
#define FUSION_MAX_LIST_SIZE 20
```

Parameters

Parameter	Requirement	Description
`T0, T1,... TN`	Any type	The arguments to `list_tie`

Expression Semantics

```
result_of::list_tie<T0, T1,... TN>::type;
```

Return type: `list`<T0&, T1&,... TN&>

Semantics: Create a `list` of references from `T0, T1,... TN`.

Header

```
#include <boost/fusion/container/generation/list_tie.hpp>
#include <boost/fusion/include/list_tie.hpp>
```

Example

```
result_of::list_tie<int, double>::type
```

vector_tie

Description

Returns the result type of `vector_tie`.

Synopsis

```
template <typename T0, typename T1,... typename TN>
struct vector_tie;
```

The variadic function accepts `0` to `FUSION_MAX_VECTOR_SIZE` elements, where `FUSION_MAX_VECTOR_SIZE` is a user definable predefined maximum that defaults to `10`. You may define the preprocessor constant `FUSION_MAX_VECTOR_SIZE` before including any Fusion header to change the default. Example:

```
#define FUSION_MAX_VECTOR_SIZE 20
```

Parameters

Parameter	Requirement	Description
`T0, T1,... TN`	Any type	The arguments to `vector_tie`

Expression Semantics

```
result_of::vector_tie<T0, T1,... TN>::type;
```

Return type: `vector`<T0&, T1&,... TN&>

Semantics: Create a `vector` of references from `T0, T1,... TN`.

Header

```
#include <boost/fusion/container/generation/vector_tie.hpp>
#include <boost/fusion/include/vector_tie.hpp>
```

Example

```
result_of::vector_tie<int, double>::type
```

deque_tie

Description

Returns the result type of `deque_tie`.

Synopsis

```
template <typename ...Elements>
struct deque_tie;
```

For C++11 compilers, the variadic template interface has no upper bound.

For C++03 compilers, the variadic function accepts `0` to `FUSION_MAX_DEQUE_SIZE` elements, where `FUSION_MAX_DEQUE_SIZE` is a user definable predefined maximum that defaults to `10`. You may define the preprocessor constant `FUSION_MAX_DEQUE_SIZE` before including any Fusion header to change the default. Example:

```
#define FUSION_MAX_DEQUE_SIZE 20
```

Parameters

Parameter	Requirement	Description
`Elements`	Variadic template types	Template arguments to `deque_tie`

Expression Semantics

```
result_of::deque_tie<Elements...>::type;
```

Return type: `deque`<Elements&...>

Semantics: Create a `deque` of references from `Elements...`.

Header

```
#include <boost/fusion/container/generation/deque_tie.hpp>
#include <boost/fusion/include/deque_tie.hpp>
```

Example

```
result_of::deque_tie<int, double>::type
```

map_tie

Description

Returns the result type of `map_tie`.

Synopsis

```
template <typename K0, typename K1,... typename KN, typename D0, typename D1,... typename DN>
struct map_tie;
```

The variadic function accepts `0` to `FUSION_MAX_MAP_SIZE` elements, where `FUSION_MAX_MAP_SIZE` is a user definable predefined maximum that defaults to `10`. You may define the preprocessor constant `FUSION_MAX_MAP_SIZE` before including any Fusion header to change the default. Example:

```
#define FUSION_MAX_MAP_SIZE 20
```

Parameters

Parameter	**Requirement**	**Description**
`K0, K1,... KN`	Any type	The key types for `map_tie`
`D0, D1,... DN`	Any type	The arguments types for `map_tie`

Expression Semantics

```
result_of::map_tie<K0, K1,... KN, D0, D1,... DN>::type;
```

Return type: `map`<`pair`<K0, D0&>, `pair`<K1, D1&>,... `pair`<KN, DN&> >

Semantics: Create a `map` of references from `D0, D1,... DN` with keys `K0, K1,... KN`

Header

```
#include <boost/fusion/container/generation/map_tie.hpp>
#include <boost/fusion/include/map_tie.hpp>
```

Example

```
struct int_key;
struct double_key;
...
result_of::map_tie<int_key, double_key, int, double>::type
```

Conversion

All fusion sequences can be converted to one of the Container types using one of these conversion functions.

Header

```
#include <boost/fusion/include/convert.hpp>
```

Functions

as_list

Description

Convert a fusion sequence to a `list`.

Synopsis

```
template <typename Sequence>
typename result_of::as_list<Sequence>::type
as_list(Sequence& seq);

template <typename Sequence>
typename result_of::as_list<Sequence const>::type
as_list(Sequence const& seq);
```

Parameters

Parameter	Requirement	Description
seq	An instance of Sequence	The sequence to convert.

Expression Semantics

```
as_list(seq);
```

Return type: `result_of::as_list<Sequence>::type`

Semantics: Convert a fusion sequence, `seq`, to a `list`.

Header

```
#include <boost/fusion/container/list/convert.hpp>
#include <boost/fusion/include/as_list.hpp>
```

Example

```
as_list(make_vector('x', 123, "hello"))
```

as_vector

Description

Convert a fusion sequence to a `vector`.

Synopsis

```
template <typename Sequence>
typename result_of::as_vector<Sequence>::type
as_vector(Sequence& seq);

template <typename Sequence>
typename result_of::as_vector<Sequence const>::type
as_vector(Sequence const& seq);
```

Parameters

Parameter	Requirement	Description
seq	An instance of Sequence	The sequence to convert.

Expression Semantics

```
as_vector(seq);
```

Return type: `result_of::as_vector<Sequence>::type`

Semantics: Convert a fusion sequence, `seq`, to a `vector`.

Header

```
#include <boost/fusion/container/vector/convert.hpp>
#include <boost/fusion/include/as_vector.hpp>
```

Example

```
as_vector(make_list('x', 123, "hello"))
```

as_deque

Description

Convert a fusion sequence to a `deque`.

Synopsis

```
template <typename Sequence>
typename result_of::as_deque<Sequence>::type
as_deque(Sequence& seq);

template <typename Sequence>
typename result_of::as_deque<Sequence const>::type
as_deque(Sequence const& seq);
```

Parameters

Parameter	Requirement	Description
`seq`	An instance of Sequence	The sequence to convert.

Expression Semantics

```
as_deque(seq);
```

Return type: __result_of_as_deque__`<Sequence>::type`

Semantics: Convert a fusion sequence, `seq`, to a `deque`.

Header

```
#include <boost/fusion/container/deque/convert.hpp>
#include <boost/fusion/include/as_deque.hpp>
```

Example

```
as_deque(make_vector('x', 123, "hello"))
```

as_set

Description

Convert a fusion sequence to a `set`.

Synopsis

```
template <typename Sequence>
typename result_of::as_set<Sequence>::type
as_set(Sequence& seq);

template <typename Sequence>
typename result_of::as_set<Sequence const>::type
as_set(Sequence const& seq);
```

Parameters

Parameter	Requirement	Description
`seq`	An instance of Sequence	The sequence to convert.

Expression Semantics

```
as_set(seq);
```

Return type: `result_of::as_set<Sequence>::type`

Semantics: Convert a fusion sequence, `seq`, to a `set`.

Precondition: There may be no duplicate key types.

Header

```
#include <boost/fusion/container/set/convert.hpp>
#include <boost/fusion/include/as_set.hpp>
```

Example

```
as_set(make_vector('x', 123, "hello"))
```

as_map

Description

Convert a fusion sequence to a `map`.

Synopsis

```
template <typename Sequence>
typename result_of::as_map<Sequence>::type
as_map(Sequence& seq);

template <typename Sequence>
typename result_of::as_map<Sequence const>::type
as_map(Sequence const& seq);
```

Parameters

Parameter	Requirement	Description
seq	An instance of Sequence	The sequence to convert.

Expression Semantics

```
as_map(seq);
```

Return type: result_of::as_map<Sequence>::type

Semantics: Convert a fusion sequence, seq, to a map.

Precondition: The elements of the sequence are assumed to be __fusion_pair__s. There may be no duplicate fusion::pair key types.

Header

```
#include <boost/fusion/container/map/convert.hpp>
#include <boost/fusion/include/as_map.hpp>
```

Example

```
as_map(make_vector(
    make_pair<int>('X')
  , make_pair<double>("Men")))
```

Metafunctions

as_list

Description

Returns the result type of as_list.

Synopsis

```
template <typename Sequence>
struct as_list;
```

Parameters

Parameter	Requirement	Description
Sequence	A fusion Sequence	The sequence type to convert.

Expression Semantics

```
result_of::as_list<Sequence>::type;
```

Return type: A list with same elements as the input sequence, Sequence.

Semantics: Convert a fusion sequence, Sequence, to a list.

Header

```
#include <boost/fusion/container/list/convert.hpp>
#include <boost/fusion/include/as_list.hpp>
```

Example

```
result_of::as_list<vector<char, int> >::type
```

as_vector

Description

Returns the result type of `as_vector`.

Synopsis

```
template <typename Sequence>
struct as_vector;
```

Parameters

Parameter	Requirement	Description
`Sequence`	A fusion Sequence	The sequence to convert.

Expression Semantics

```
result_of::as_vector<Sequence>::type;
```

Return type: A `vector` with same elements as the input sequence, `Sequence`.

Semantics: Convert a fusion sequence, `Sequence`, to a `vector`.

Header

```
#include <boost/fusion/container/vector/convert.hpp>
#include <boost/fusion/include/as_vector.hpp>
```

Example

```
result_of::as_vector<list<char, int> >::type
```

as_deque

Description

Returns the result type of __as_deque__.

Synopsis

```
template <typename Sequence>
struct as_deque;
```

Parameters

Parameter	Requirement	Description
Sequence	A fusion Sequence	The sequence type to convert.

Expression Semantics

```
result_of::as_deque<Sequence>::type;
```

Return type: A `deque` with same elements as the input sequence, `Sequence`.

Semantics: Convert a fusion sequence, `Sequence`, to a `deque`.

Header

```
#include <boost/fusion/container/deque/convert.hpp>
#include <boost/fusion/include/as_deque.hpp>
```

Example

```
result_of::as_deque<vector<char, int> >::type
```

as_set

Description

Returns the result type of `as_set`.

Synopsis

```
template <typename Sequence>
struct as_set;
```

Parameters

Parameter	Requirement	Description
Sequence	A fusion Sequence	The sequence to convert.

Expression Semantics

```
result_of::as_set<Sequence>::type;
```

Return type: A `set` with same elements as the input sequence, `Sequence`.

Semantics: Convert a fusion sequence, `Sequence`, to a `set`.

Precondition: There may be no duplicate key types.

Header

```
#include <boost/fusion/container/set/convert.hpp>
#include <boost/fusion/include/as_set.hpp>
```

Example

```
result_of::as_set<vector<char, int> >::type
```

as_map

Description

Returns the result type of `as_map`.

Synopsis

```
template <typename Sequence>
struct as_map;
```

Parameters

Parameter	Requirement	Description
`Sequence`	A fusion Sequence	The sequence to convert.

Expression Semantics

```
result_of::as_map<Sequence>::type;
```

Return type: A `map` with same elements as the input sequence, `Sequence`.

Semantics: Convert a fusion sequence, `Sequence`, to a `map`.

Precondition: The elements of the sequence are assumed to be __fusion_pair__s. There may be no duplicate `fusion::pair` key types.

Header

```
#include <boost/fusion/container/map/convert.hpp>
#include <boost/fusion/include/as_map.hpp>
```

Example

```
result_of::as_map<vector<
    fusion::pair<int, char>
  , fusion::pair<double, std::string> > >::type
```

View

Views are sequences that do not actually contain data, but instead impart an alternative presentation over the data from one or more underlying sequences. Views are proxies. They provide an efficient yet purely functional way to work on potentially expensive sequence operations. Views are inherently lazy. Their elements are only computed on demand only when the elements of the underlying sequence(s) are actually accessed. Views' lazy nature make them very cheap to copy and be passed around by value.

Header

```
#include <boost/fusion/view.hpp>
#include <boost/fusion/include/view.hpp>
```

single_view

`single_view` is a view into a value as a single element sequence.

Header

```
#include <boost/fusion/view/single_view.hpp>
#include <boost/fusion/include/single_view.hpp>
```

Synopsis

```
template <typename T>
struct single_view;
```

Template parameters

Parameter	Description	Default
`T`	Any type	

Model of

- Random Access Sequence

Notation

`S`	A `single_view` type
`s`, `s2`	Instances of `single_view`
`x`	An instance of `T`

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in Random Access Sequence.

Expression	Semantics
`S(x)`	Creates a `single_view` from `x`.
`S(s)`	Copy constructs a `single_view` from another `single_view`, `s`.
`s = s2`	Assigns to a `single_view`, `s`, from another `single_view`, `s2`.

Example

```
single_view<int> view(3);
std::cout << view << std::endl;
```

filter_view

Description

`filter_view` is a view into a subset of its underlying sequence's elements satisfying a given predicate (an MPL metafunction). The `filter_view` presents only those elements for which its predicate evaluates to `mpl::true_`.

Header

```
#include <boost/fusion/view/filter_view.hpp>
#include <boost/fusion/include/filter_view.hpp>
```

Synopsis

```
template <typename Sequence, typename Pred>
struct filter_view;
```

Template parameters

Parameter	Description	Default
`Sequence`	A Forward Sequence	
`Pred`	Unary Metafunction returning an `mpl::bool_`	

Model of

- Forward Sequence
- Associative Sequence if `Sequence` implements the Associative Sequence model.

Notation

`F`	A `filter_view` type
`f`, `f2`	Instances of `filter_view`
`s`	A Forward Sequence

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in the implemented models.

Expression	Semantics
`F(s)`	Creates a `filter_view` given a sequence, `s`.
`F(f)`	Copy constructs a `filter_view` from another `filter_view`, `f`.
`f = f2`	Assigns to a `filter_view`, `f`, from another `filter_view`, `f2`.

Example

```
using boost::mpl::_;
using boost::mpl::not_;
using boost::is_class;

typedef vector<std::string, char, long, bool, double> vector_type;

vector_type v("a-string", '@', 987654, true, 6.6);
filter_view<vector_type const, not_<is_class<_> > > view(v);
std::cout << view << std::endl;
```

iterator_range

Description

`iterator_range` presents a sub-range of its underlying sequence delimited by a pair of iterators.

Header

```
#include <boost/fusion/view/iterator_range.hpp>
#include <boost/fusion/include/iterator_range.hpp>
```

Synopsis

```
template <typename First, typename Last>
struct iterator_range;
```

Template parameters

Parameter	Description	Default
`First`	A fusion Iterator	
`Last`	A fusion Iterator	

Model of

- Forward Sequence, Bidirectional Sequence or Random Access Sequence depending on the traversal characteristics (see Sequence Traversal Concept) of its underlying sequence.

- Associative Sequence if `First` and `Last` implement the Associative Iterator model.

Notation

`IR`	An `iterator_range` type
`f`	An instance of `First`
`l`	An instance of `Last`
`ir`, `ir2`	Instances of `iterator_range`

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in the implemented models.

Expression	Semantics
`IR(f, l)`	Creates an `iterator_range` given iterators, `f` and `l`.
`IR(ir)`	Copy constructs an `iterator_range` from another `iterator_range`, `ir`.
`ir = ir2`	Assigns to a `iterator_range`, `ir`, from another `iterator_range`, `ir2`.

Example

```
char const* s = "Ruby";
typedef vector<int, char, double, char const*> vector_type;
vector_type vec(1, 'x', 3.3, s);

typedef result_of::begin<vector_type>::type A;
typedef result_of::end<vector_type>::type B;
typedef result_of::next<A>::type C;
typedef result_of::prior<B>::type D;

C c(vec);
D d(vec);

iterator_range<C, D> range(c, d);
std::cout << range << std::endl;
```

joint_view

Description

`joint_view` presents a view which is a concatenation of two sequences.

Header

```
#include <boost/fusion/view/joint_view.hpp>
#include <boost/fusion/include/joint_view.hpp>
```

Synopsis

```
template <typename Sequence1, typename Sequence2>
struct joint_view;
```

Template parameters

Parameter	Description	Default
`Sequence1`	A Forward Sequence	
`Sequence2`	A Forward Sequence	

Model of

- Forward Sequence
- Associative Sequence if `Sequence1` and `Sequence2` implement the Associative Sequence model.

Notation

`JV`	A `joint_view` type
`s1`	An instance of `Sequence1`
`s2`	An instance of `Sequence2`
`jv`, `jv2`	Instances of `joint_view`

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in the implemented models.

Expression	Semantics
`JV(s1, s2)`	Creates a `joint_view` given sequences, `s1` and `s2`.
`JV(jv)`	Copy constructs a `joint_view` from another `joint_view`, `jv`.
`jv = jv2`	Assigns to a `joint_view`, `jv`, from another `joint_view`, `jv2`.

Example

```
vector<int, char> v1(3, 'x');
vector<std::string, int> v2("hello", 123);
joint_view<
    vector<int, char>
  , vector<std::string, int>
> view(v1, v2);
std::cout << view << std::endl;
```

zip_view

Description

`zip_view` presents a view which iterates over a collection of Sequence(s) in parallel. A `zip_view` is constructed from a Sequence of references to the component __sequence__s.

Header

```
#include <boost/fusion/view/zip_view.hpp>
#include <boost/fusion/include/zip_view.hpp>
```

Synopsis

```
template <typename Sequences>
struct zip_view;
```

Template parameters

Parameter	Description	Default
`Sequences`	A Forward Sequence of references to other Fusion __sequence__s	

Model of

- Forward Sequence, Bidirectional Sequence or Random Access Sequence depending on the traversal characteristics (see Sequence Traversal Concept) of its underlying sequence.

Notation

`ZV`	A `zip_view` type
`s`	An instance of `Sequences`
`zv1`, `zv2`	Instances of `ZV`

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in Forward Sequence.

Expression	Semantics
`ZV(s)`	Creates a `zip_view` given a sequence of references to the component __sequence__s.
`ZV(zv1)`	Copy constructs a `zip_view` from another `zip_view`, `zv`.
`zv1 = zv2`	Assigns to a `zip_view`, `zv`, from another `zip_view`, `zv2`.

Example

```
typedef vector<int,int> vec1;
typedef vector<char,char> vec2;
vec1 v1(1,2);
vec2 v2('a','b');
typedef vector<vec1&, vec2&> sequences;
std::cout << zip_view<sequences>(sequences(v1, v2)) << std::endl; // ((1 a) (2 b))
```

transform_view

The unary version of `transform_view` presents a view of its underlying sequence given a unary function object or function pointer. The binary version of `transform_view` presents a view of 2 underlying sequences, given a binary function object or function pointer. The `transform_view` inherits the traversal characteristics (see Sequence Traversal Concept) of its underlying sequence or sequences.

Header

```
#include <boost/fusion/view/transform_view.hpp>
#include <boost/fusion/include/transform_view.hpp>
```

Synopsis

Unary Version

```
template <typename Sequence, typename F1>
struct transform_view;
```

Binary Version

```
template <typename Sequence1, typename Sequence2, typename F2>
struct transform_view;
```

Template parameters

Parameter	Description	Default
`Sequence`	A Forward Sequence	
`Sequence1`	A Forward Sequence	
`Sequence2`	A Forward Sequence	
`F1`	A unary function object or function pointer. `boost::result_of<F1(E)>::type` is the return type of an instance of `F1` when called with a value of each element type `E` in the input sequence.	
`F2`	A binary function object or function pointer. `boost::result_of<F2(E1, E2)>::type` is the return type of an instance of `F2` when called with a value of each corresponding pair of element type `E1` and `E2` in the input sequences.	

Model of

- Forward Sequence, Bidirectional Sequence or Random Access Sequence depending on the traversal characteristics (see Sequence Traversal Concept) of its underlying sequence.

Notation

`TV`	A `transform_view` type
`BTV`	A binary `transform_view` type
`UTV`	A unary `transform_view` type
`f1`	An instance of `F1`
`f2`	An instance of `F2`
`s`	An instance of `Sequence`
`s1`	An instance of `Sequence1`
`s2`	An instance of `Sequence2`
`tv`, `tv2`	Instances of `transform_view`

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in Forward Sequence, Bidirectional Sequence or Random Access Sequence depending on the traversal characteristics (see Sequence Traversal Concept) of its underlying sequence or sequences.

Expression	Semantics
`UTV(s, f1)`	Creates a unary `transform_view` given sequence, `s` and unary function object or function pointer, `f1`.
`BTV(s1, s2, f2)`	Creates a binary `transform_view` given sequences, `s1` and `s2` and binary function object or function pointer, `f2`.
`TV(tv)`	Copy constructs a `transform_view` from another `transform_view`, `tv`.
`tv = tv2`	Assigns to a `transform_view`, `tv`, from another `transform_view`, `tv2`.

Example

```
struct square
{
    template<typename Sig>
    struct result;

    template<typename U>
    struct result<square(U)>
    : remove_reference<U>
    {};

    template <typename T>
    T operator()(T x) const
    {
        return x * x;
    }
};

typedef vector<int, short, double> vector_type;
vector_type vec(2, 5, 3.3);

transform_view<vector_type, square> transform(vec, square());
std::cout << transform << std::endl;
```

reverse_view

`reverse_view` presents a reversed view of underlying sequence. The first element will be its last and the last element will be its first.

Header

```
#include <boost/fusion/view/reverse_view.hpp>
#include <boost/fusion/include/reverse_view.hpp>
```

Synopsis

```
template <typename Sequence>
struct reverse_view;
```

Template parameters

Parameter	Description	Default
`Sequence`	A Bidirectional Sequence	

Model of

- A model of Bidirectional Sequence if `Sequence` is a Bidirectional Sequence else, Random Access Sequence if `Sequence` is a Random Access Sequence.
- Associative Sequence if `Sequence` implements the Associative Sequence model.

Notation

`RV`	A `reverse_view` type
`s`	An instance of `Sequence`
`rv`, `rv2`	Instances of `reverse_view`

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in the implemented models.

Expression	Semantics
`RV(s)`	Creates a unary `reverse_view` given sequence, `s`.
`RV(rv)`	Copy constructs a `reverse_view` from another `reverse_view`, `rv`.
`rv = rv2`	Assigns to a `reverse_view`, `rv`, from another `reverse_view`, `rv2`.

Example

```
typedef vector<int, short, double> vector_type;
vector_type vec(2, 5, 3.3);

reverse_view<vector_type> reverse(vec);
std::cout << reverse << std::endl;
```

nview

Description

`nview` presents a view which iterates over a given Sequence in a specified order. An `nview` is constructed from an arbitrary Sequence and a list of indicies specifying the elements to iterate over.

Header

```
#include <boost/fusion/view/nview.hpp>
#include <boost/fusion/include/nview.hpp>
```

Synopsis

```
template <typename Sequence, typename Indicies>
struct nview;

template <typename Sequence, int I1, int I2 = -1, ...>
typename result_of::nview<Sequence, I1, I2, ...>::type
as_nview(Sequence& s);
```

Template parameters

Parameter	Description	Default
`Sequence`	An arbitrary Fusion Forward Sequence	
`Indicies`	A `mpl::vector_c<int, ...>` holding the indicies defining the required iteration order.	
`I1`, `I2`, `I3`...	A list of integers specifying the required iteration order.	`INT_MAX` for `I2`, `I3`...

Model of

- Random Access Sequence (see Sequence Traversal Concept)

Notation

`NV`	A `nview` type
`s`	An instance of `Sequences`
`nv1`, `nv2`	Instances of `NV`

Expression Semantics

Semantics of an expression is defined only where it differs from, or is not defined in Random Access Sequence.

Expression	Semantics
`NV(s)`	Creates an `nview` given a sequence and a list of indicies.
`NV(nv1)`	Copy constructs an `nview` from another `nview`, `nv1`.
`nv1 = nv2`	Assigns to an `nview`, `nv1`, from another `nview`, `nv2`.

The `nview` internally stores a Fusion `vector` of references to the elements of the original Fusion Sequence

Example

```
typedef vector<int, char, double> vec;
typedef mpl::vector_c<int, 2, 1, 0, 2, 0> indicies;

vec v1(1, 'c', 2.0);

std::cout << nview<vec, indicies>(v1) << std::endl; // (2.0 c 1 2.0 1)
std::cout << as_nview<2, 1, 1, 0>(v1) << std::endl; // (2.0 c c 1)
```

repetitive_view

Description

`repetitive_view` presents a view which iterates over a given Sequence repeatedly. Because a `repetitive_view` has infinite length, it can only be used when some external condition determines the end. Thus, initializing a fixed length sequence with a `repetitive_view` is okay, but printing a `repetitive_view` to `std::cout` is not.

Header

```
#include <boost/fusion/view/repetitive_view.hpp>
#include <boost/fusion/include/repetitive_view.hpp>
```

Synopsis

```
template <typename Sequence>
struct repetitive_view;
```

Template parameters

Parameter	Description	Default
`Sequence`	An arbitrary Fusion Forward Sequence	

Notation

`RV`	A `repetitive_view` type
`s`	An instance of `Sequences`
`rv`, `rv1`, `rv2`	Instances of `RV`

Expression Semantics

Expression	Return Type	Semantics
`RV(s)`		Creates an `repetitive_view` given the underlying sequence.
`RV(rv1)`		Copy constructs an `repetitive_view` from another `repetitive_view`, `rv1`.
`rv1 = rv2`		Assigns to a `repetitive_view`, `rv1`, from another `repetitive_view`, `rv2`.
`begin(rv)`	Forward Iterator	
`end(rv)`	Forward Iterator	Creates an unreachable iterator (since the sequnce is infinite)

Result Type Expressions

Expression
`result_of::begin<RV>::type`
`result_of::end<RV>::type`

Example

```
typedef vector<int, char, double> vec1;
typedef vector<int, char, double, int, char> vec2;

vec1 v1(1, 'c', 2.0);
vec2 v2(repetitive_view<vec1>(v1));

std::cout << v2 << std::endl; // 1, 'c', 2.0, 1, 'c'
```

Adapted

Fusion provides a couple of adapters for other sequences such as arrays, `std::pair`, MPL sequences, and `boost::array`. These adapters are written using Fusion's non-intrusive Extension mechanism. If you wish to use these sequences with fusion, simply include the necessary files and they will be regarded as first-class, fully conforming fusion sequences.

Fusion also provides various schemes to make it easy for the user to adapt various data structures, non-intrusively, as full fledged Fusion sequences.

Header

```
#include <boost/fusion/adapted.hpp>
#include <boost/fusion/include/adapted.hpp>
```

Fusion sequences may also be adapted as fully conforming MPL sequences (see Intrinsics). That way, we can have 2-way adaptation to and from MPL and Fusion. To make Fusion sequences fully conforming MPL sequences, include:

```
#include <boost/fusion/mpl.hpp>
```

If you want bi-directional adaptation to and from MPL and Fusion, simply include:

```
#include <boost/fusion/include/mpl.hpp>
```

The header includes all the necessary headers.

Array

This module provides adapters for arrays. Including the module header makes any array a fully conforming Random Access Sequence.

Header

```
#include <boost/fusion/adapted/array.hpp>
#include <boost/fusion/include/array.hpp>
```

Model of

- Random Access Sequence

Example

```
int arr[3] = {1,2,3};

std::cout << *begin(arr) << std::endl;
std::cout << *next(begin(arr)) << std::endl;
std::cout << *advance_c<2>(begin(arr)) << std::endl;
std::cout << *prior(end(arr)) << std::endl;
std::cout << at_c<2>(arr) << std::endl;
```

std::pair

This module provides adapters for `std::pair`. Including the module header makes `std::pair` a fully conforming Random Access Sequence.

Header

```
#include <boost/fusion/adapted/std_pair.hpp>
#include <boost/fusion/include/std_pair.hpp>
```

Model of

- Random Access Sequence

Example

```
std::pair<int, std::string> p(123, "Hola!!!");
std::cout << at_c<0>(p) << std::endl;
std::cout << at_c<1>(p) << std::endl;
std::cout << p << std::endl;
```

See also

`std::pair`, `TR1 and std::pair`

mpl sequence

This module provides adapters for MPL sequences. Including the module header makes all MPL sequences fully conforming fusion sequences.

Header

```
#include <boost/fusion/adapted/mpl.hpp>
#include <boost/fusion/include/mpl.hpp>
```

Model of

- Forward Sequence (If the MPL sequence is a forward sequence.)
- Bidirectional Sequence (If the MPL sequence is a bidirectional sequence.)
- Random Access Sequence (If the MPL sequence is a random access sequence.)

Example

```
mpl::vector_c<int, 123, 456> vec_c;
fusion::vector2<int, long> v(vec_c);
std::cout << at_c<0>(v) << std::endl;
std::cout << at_c<1>(v) << std::endl;

v = mpl::vector_c<int, 456, 789>();
std::cout << at_c<0>(v) << std::endl;
std::cout << at_c<1>(v) << std::endl;
```

See also

MPL

boost::array

This module provides adapters for `boost::array`. Including the module header makes `boost::array` a fully conforming Random Access Sequence.

Header

```
#include <boost/fusion/adapted/boost_array.hpp>
#include <boost/fusion/include/boost_array.hpp>
```

Model of

- Random Access Sequence

Example

```
boost::array<int,3> arr = {{1,2,3}};

std::cout << *begin(arr) << std::endl;
std::cout << *next(begin(arr)) << std::endl;
std::cout << *advance_c<2>(begin(arr)) << std::endl;
std::cout << *prior(end(arr)) << std::endl;
std::cout << at_c<2>(arr) << std::endl;
```

See also

Boost.Array Library

boost::tuple

This module provides adapters for `boost::tuple`. Including the module header makes `boost::tuple` a fully conforming Forward Sequence.

Header

```
#include <boost/fusion/adapted/boost_tuple.hpp>
#include <boost/fusion/include/boost_tuple.hpp>
```

Model of

- Forward Sequence

Example

```
boost::tuple<int,std::string> example_tuple(101, "hello");
std::cout << *boost::fusion::begin(example_tuple) << '\n';
std::cout << *boost::fusion::next(boost::fusion::begin(example_tuple)) << '\n';
```

See also

Boost.Tuple Library

BOOST_FUSION_ADAPT_STRUCT

Description

BOOST_FUSION_ADAPT_STRUCT is a macro that can be used to generate all the necessary boilerplate to make an arbitrary struct a model of Random Access Sequence.

Synopsis

```
BOOST_FUSION_ADAPT_STRUCT(
    struct_name,
    (member_type0, member_name0)
    (member_type1, member_name1)
    ...
    )
```

Semantics

The above macro generates the necessary code to adapt `struct_name` as a model of Random Access Sequence. The sequence of `(member_typeN, member_nameN)` pairs declares the type and names of each of the struct members that are part of the sequence.

The macro should be used at global scope, and `struct_name` should be the fully namespace qualified name of the struct to be adapted.

Header

```
#include <boost/fusion/adapted/struct/adapt_struct.hpp>
#include <boost/fusion/include/adapt_struct.hpp>
```

Example

```
namespace demo
{
    struct employee
    {
        std::string name;
        int age;
    };
}

// demo::employee is now a Fusion sequence
BOOST_FUSION_ADAPT_STRUCT(
    demo::employee,
    (std::string, name)
    (int, age))
```

BOOST_FUSION_ADAPT_TPL_STRUCT

Description

BOOST_FUSION_ADAPT_TPL_STRUCT is a macro that can be used to generate all the necessary boilerplate to make an arbitrary template struct a model of Random Access Sequence.

Synopsis

```
BOOST_FUSION_ADAPT_TPL_STRUCT(
    (template_param0)(template_param1)...,
    (struct_name) (specialization_param0)(specialization_param1)...,
    (member_type0, member_name0)
    (member_type1, member_name1)
    ...
    )
```

Semantics

The above macro generates the necessary code to adapt `struct_name` or an arbitrary specialization of `struct_name` as a model of Random Access Sequence. The sequence `(template_param0)(template_param1)...` declares the names of the template type parameters used. The sequence `(specialization_param0)(specialization_param1)...` declares the template parameters of the actual specialization of `struct_name` that is adapted as a fusion sequence. The sequence of `(member_typeN, member_nameN)` pairs declares the type and names of each of the struct members that are part of the sequence.

The macro should be used at global scope, and `struct_name` should be the fully namespace qualified name of the struct to be adapted.

Header

```
#include <boost/fusion/adapted/struct/adapt_struct.hpp>
#include <boost/fusion/include/adapt_struct.hpp>
```

Example

```
namespace demo
{
    template<typename Name, typename Age>
    struct employee
    {
        Name name;
        Age age;
    };
}

// Any instantiated demo::employee is now a Fusion sequence
BOOST_FUSION_ADAPT_TPL_STRUCT(
    (Name)(Age),
    (demo::employee) (Name)(Age),
    (Name, name)
    (Age, age))
```

BOOST_FUSION_ADAPT_STRUCT_NAMED

Description

BOOST_FUSION_ADAPT_STRUCT_NAMED and BOOST_FUSION_ADAPT_STRUCT_NAMED_NS are macros that can be used to generate all the necessary boilerplate to make an arbitrary struct a model of Random Access Sequence. The given struct is adapted using the given name.

Synopsis

```
BOOST_FUSION_ADAPT_STRUCT_NAMED(
    struct_name, adapted_name,
    (member_type0, member_name0)
    (member_type1, member_name1)
    ...
    )

BOOST_FUSION_ADAPT_STRUCT_NAMED_NS(
    struct_name,
    (namespace0)(namespace1)...,
    adapted_name,
    (member_type0, member_name0)
    (member_type1, member_name1)
    ...
    )
```

Semantics

The above macros generate the necessary code to adapt `struct_name` as a model of Random Access Sequence while using `adapted_name` as the name of the adapted struct. The sequence `(namespace0)(namespace1)...` declares the namespace for `adapted_name`. It yields to a fully qualified name for `adapted_name` of `namespace0::namespace1::... adapted_name`. If an empty namespace sequence is given (that is a macro that expands to nothing), the adapted view is placed in the global namespace. If no namespace sequence is given (i.e. `BOOST_FUSION_ADAPT_STRUCT_NAMED`), the adapted view is placed in the namespace `boost::fusion::adapted`. The sequence of `(member_typeN, member_nameN)` pairs declares the type and names of each of the struct members that are part of the sequence.

The macros should be used at global scope, and `struct_name` should be the fully namespace qualified name of the struct to be converted.

Header

```
#include <boost/fusion/adapted/struct/adapt_struct_named.hpp>
#include <boost/fusion/include/adapt_struct_named.hpp>
```

Example

```
namespace demo
{
    struct employee
    {
        std::string name;
        int age;
    };
}

// boost::fusion::adapted::adapted_employee is now a Fusion sequence
// referring to demo::employee
BOOST_FUSION_ADAPT_STRUCT_NAMED(
    demo::employee, adapted_employee,
    (std::string, name)
    (int, age))
```

BOOST_FUSION_ADAPT_ASSOC_STRUCT

Description

BOOST_FUSION_ADAPT_ASSOC_STRUCT is a macro that can be used to generate all the necessary boilerplate to make an arbitrary struct a model of Random Access Sequence and Associative Sequence.

Synopsis

```
BOOST_FUSION_ADAPT_ASSOC_STRUCT(
    struct_name,
    (member_type0, member_name0, key_type0)
    (member_type1, member_name1, key_type1)
    ...
    )
```

Semantics

The above macro generates the necessary code to adapt `struct_name` as a model of Random Access Sequence and Associative Sequence. The sequence of `(member_typeN, member_nameN, key_typeN)` triples declares the type, name and key type of each of the struct members that are part of the sequence.

The macro should be used at global scope, and `struct_name` should be the fully namespace qualified name of the struct to be adapted.

Header

```
#include <boost/fusion/adapted/struct/adapt_assoc_struct.hpp>
#include <boost/fusion/include/adapt_assoc_struct.hpp>
```

Example

```
namespace demo
{
    struct employee
    {
        std::string name;
        int age;
    };
}

namespace keys
{
    struct name;
    struct age;
}

// demo::employee is now a Fusion sequence.
// It is also an associative sequence with
// keys keys::name and keys::age present.
BOOST_FUSION_ADAPT_ASSOC_STRUCT(
    demo::employee,
    (std::string, name, keys::name)
    (int, age, keys::age))
```

BOOST_FUSION_ADAPT_ASSOC_TPL_STRUCT

Description

BOOST_FUSION_ADAPT_ASSOC_TPL_STRUCT is a macro that can be used to generate all the necessary boilerplate to make an arbitrary template struct a model of Random Access Sequence and Associative Sequence.

Synopsis

```
BOOST_FUSION_ADAPT_ASSOC_TPL_STRUCT(
    (template_param0)(template_param1)...,
    (struct_name) (specialization_param0)(specialization_param1)...,
    (member_type0, member_name0, key_type0)
    (member_type1, member_name1, key_type1)
    ...
    )
```

Semantics

The above macro generates the necessary code to adapt `struct_name` or an arbitrary specialization of `struct_name` as a model of Random Access Sequence and Associative Sequence. The sequence `(template_param0)(template_param1)...` declares the names of the template type parameters used. The sequence `(specialization_param0)(specialization_param1)...` declares the template parameters of the actual specialization of `struct_name` that is adapted as a fusion sequence. The sequence of `(member_typeN, member_nameN, key_typeN)` triples declares the type, name and key type of each of the struct members that are part of the sequence.

The macro should be used at global scope, and `struct_name` should be the fully namespace qualified name of the struct to be adapted.

Header

```
#include <boost/fusion/adapted/struct/adapt_assoc_struct.hpp>
#include <boost/fusion/include/adapt_assoc_struct.hpp>
```

Example

```
namespace demo
{
    template<typename Name, typename Age>
    struct employee
    {
        Name name;
        Age age;
    };
}

namespace keys
{
    struct name;
    struct age;
}

// Any instantiated demo::employee is now a Fusion sequence.
// It is also an associative sequence with
// keys keys::name and keys::age present.
BOOST_FUSION_ADAPT_ASSOC_TPL_STRUCT(
    (Name)(Age),
    (demo::employee) (Name)(Age),
    (Name, name, keys::name)
    (Age, age, keys::age))
```

BOOST_FUSION_ADAPT_ASSOC_STRUCT_NAMED

Description

BOOST_FUSION_ADAPT_ASSOC_STRUCT_NAMED and BOOST_FUSION_ADAPT_ASSOC_STRUCT_NAMED_NS are macros that can be used to generate all the necessary boilerplate to make an arbitrary struct a model of Random Access Sequence and Associative Sequence. The given struct is adapted using the given name.

Synopsis

```
BOOST_FUSION_ADAPT_ASSOC_STRUCT_NAMED(
    struct_name, adapted_name,
    (member_type0, member_name0, key_type0)
    (member_type1, member_name1, key_type1)
    ...
    )

BOOST_FUSION_ADAPT_ASSOC_STRUCT_NAMED_NS(
    struct_name,
    (namespace0)(namespace1)...,
    adapted_name,
    (member_type0, member_name0, key_type0)
    (member_type1, member_name1, key_type1)
    ...
    )
```

Semantics

The above macros generate the necessary code to adapt `struct_name` as a model of Random Access Sequence and Associative Sequence while using `adapted_name` as the name of the adapted struct. The sequence `(namespace0)(namespace1)...` declares the namespace for `adapted_name`. It yields to a fully qualified name for `adapted_name` of `namespace0::namespace1::... adapted_name`. If an empty namespace sequence is given (that is a macro that expands to nothing), the adapted view is placed in the global namespace. If no namespace sequence is given (i.e. `BOOST_FUSION_ADAPT_STRUCT_ASSOC_NAMED`), the adapted view is placed in the namespace `boost::fusion::adapted`. The sequence of `(member_typeN, member_nameN, key_typeN)` triples declares the type, name and key type of each of the struct members that are part of the sequence.

The macros should be used at global scope, and `struct_name` should be the fully namespace qualified name of the struct to be converted.

Header

```
#include <boost/fusion/adapted/struct/adapt_assoc_struct_named.hpp>
#include <boost/fusion/include/adapt_assoc_struct_named.hpp>
```

Example

```
namespace demo
{
    struct employee
    {
        std::string name;
        int age;
    };
}

namespace keys
{
    struct name;
    struct age;
}

// boost::fusion::adapted::adapted_employee is now a Fusion sequence
// referring to demo::employee
BOOST_FUSION_ADAPT_ASSOC_STRUCT_NAMED(
    demo::employee, adapted_employee,
    (std::string, name, keys::name)
    (int, age, keys::age))
```

BOOST_FUSION_ADAPT_ADT

BOOST_FUSION_ADAPT_ADT is a macro than can be used to generate all the necessary boilerplate to adapt an arbitrary class type as a model of Random Access Sequence.

Synopsis

```
BOOST_FUSION_ADAPT_ADT(
    type_name,
    (attribute_type0, attribute_const_type0, get_expr0, set_expr0)
    (attribute_type1, attribute_const_type1, get_expr1, set_expr1)
    ...
    )
```

Expression Semantics

The above macro generates the necessary code to adapt `type_name` as a model of Random Access Sequence. The sequence of `(attribute_typeN, attribute_const_typeN, get_exprN, set_exprN)` quadruples declares the types, const types, get-expressions and set-expressions of the elements that are part of the adapted fusion sequence. `get_exprN` is the expression that is invoked to get the *N*th element of an instance of `type_name`. This expression may access a variable named `obj` of type `type_name&` or `type_name const&` which represents the underlying instance of `type_name`. `attribute_typeN` and `attribute_const_typeN` may specify the types that `get_exprN` denotes to. `set_exprN` is the expression that is invoked to set the *N*th element of an instance of `type_name`. This expression may access variables named `obj` of type `type_name&`, which represent the corresponding instance of `type_name`, and `val` of an arbitrary const-qualified reference template type parameter `Val`, which represents the right operand of the assignment expression.

The actual return type of fusion's intrinsic sequence access (meta-)functions when in invoked with (an instance of) `type_name` is a proxy type. This type is implicitly convertible to the attribute type via `get_exprN` and forwards assignment to the underlying element via `set_exprN`. The value type (that is the type returned by `result_of::value_of`, `result_of::value_at` and `result_of::value_at_c`) of the *N*th element is `attribute_typeN` with const-qualifier and reference removed.

The macro should be used at global scope, and `type_name` should be the fully namespace qualified name of the class type to be adapted.

Header

```
#include <boost/fusion/adapted/adt/adapt_adt.hpp>
#include <boost/fusion/include/adapt_adt.hpp>
```

Example

```
namespace demo
{
    struct employee
    {
    private:
        std::string name;
        int age;

    public:
        void set_name(std::string const& n)
        {
            name=n;
        }

        void set_age(int a)
        {
            age=a;
        }

        std::string const& get_name()const
        {
            return name;
        }

        int get_age()const
        {
            return age;
        }
    };
}

BOOST_FUSION_ADAPT_ADT(
    demo::employee,
    (std::string const&, std::string const&, obj.get_name(), obj.set_name(val))
    (int, int, obj.get_age(), obj.set_age(val)))

demo::employee e;
front(e)="Edward Norton";
back(e)=41;
//Prints 'Edward Norton is 41 years old'
std::cout << e.get_name() << " is " << e.get_age() << " years old" << std::endl;
```

See also

`adt_attribute_proxy`

BOOST_FUSION_ADAPT_TPL_ADT

BOOST_FUSION_ADAPT_TPL_ADT is a macro than can be used to generate all the necessary boilerplate to adapt an arbitrary template class type as a model of Random Access Sequence.

Synopsis

```
BOOST_FUSION_ADAPT_TPL_ADT(
    (template_param0)(template_param1)...,
    (type_name) (specialization_param0)(specialization_param1)...,
    (attribute_type0, attribute_const_type0, get_expr0, set_expr0)
    (attribute_type1, attribute_const_type1, get_expr1, set_expr1)
    ...
    )
```

Expression Semantics

The above macro generates the necessary code to adapt `type_name` or an arbitrary specialization of `type_name` as a model of Random Access Sequence. The sequence `(template_param0)(template_param1)...` declares the names of the template type parameters used. The sequence `(specialization_param0)(specialization_param1)...` declares the template parameters of the actual specialization of `type_name` that is adapted as a fusion sequence. The sequence of `(attribute_typeN, attribute_const_typeN, get_exprN, set_exprN)` quadruples declares the types, const types, get-expressions and set-expressions of the elements that are part of the adapted fusion sequence. `get_exprN` is the expression that is invoked to get the *N*th element of an instance of `type_name`. This expression may access a variable named `obj` of type `type_name&` or `type_name const&` which represents the underlying instance of `type_name`. `attribute_typeN` and `attribute_const_typeN` may specify the types that `get_exprN` denotes to. `set_exprN` is the expression that is invoked to set the *N*th element of an instance of `type_name`. This expression may access variables named `obj` of type `type_name&`, which represent the corresponding instance of `type_name`, and `val` of an arbitrary const-qualified reference template type parameter `Val`, which represents the right operand of the assignment expression.

The actual return type of fusion's intrinsic sequence access (meta-)functions when in invoked with (an instance of) `type_name` is a proxy type. This type is implicitly convertible to the attribute type via `get_exprN` and forwards assignment to the underlying element via `set_exprN`. The value type (that is the type returned by `result_of::value_of`, `result_of::value_at` and `result_of::value_at_c`) of the *N*th element is `attribute_typeN` with const-qualifier and reference removed.

The macro should be used at global scope, and `type_name` should be the fully namespace qualified name of the template class type to be adapted.

Header

```
#include <boost/fusion/adapted/adt/adapt_adt.hpp>
#include <boost/fusion/include/adapt_adt.hpp>
```

Example

```
namespace demo
{
    template<typename Name, typename Age>
    struct employee
    {
    private:
        Name name;
        Age age;

    public:
        void set_name(Name const& n)
        {
            name=n;
        }

        void set_age(Age const& a)
        {
            age=a;
        }

        Name const& get_name()const
        {
            return name;
        }

        Age const& get_age()const
        {
            return age;
        }
    };
}

BOOST_FUSION_ADAPT_TPL_ADT(
    (Name)(Age),
    (demo::employee) (Name)(Age),
    (Name const&, Name const&, obj.get_name(), obj.set_name(val))
    (Age const&, Age const&, obj.get_age(), obj.set_age(val)))

demo::employee<std::string, int> e;
boost::fusion::front(e)="Edward Norton";
boost::fusion::back(e)=41;
//Prints 'Edward Norton is 41 years old'
std::cout << e.get_name() << " is " << e.get_age() << " years old" << std::endl;
```

See also

`adt_attribute_proxy`

BOOST_FUSION_ADAPT_ASSOC_ADT

BOOST_FUSION_ADAPT_ASSOC_ADT is a macro than can be used to generate all the necessary boilerplate to adapt an arbitrary class type as a model of Random Access Sequence and Associative Sequence.

Synopsis

```
BOOST_FUSION_ADAPT_ASSOC_ADT(
    type_name,
    (attribute_type0, attribute_const_type0, get_expr0, set_expr0, key_type0)
    (attribute_type1, attribute_const_type1, get_expr1, set_expr1, key_type1)
    ...
    )
```

Expression Semantics

The above macro generates the necessary code to adapt `type_name` as a model of Random Access Sequence and Associative Sequence. The sequence of `(attribute_typeN, attribute_const_typeN, get_exprN, set_exprN, key_typeN)` 5-tuples declares the types, const types, get-expressions, set-expressions and key types of the elements that are part of the adapted fusion sequence. `get_exprN` is the expression that is invoked to get the *N*th element of an instance of `type_name`. This expression may access a variable named `obj` of type `type_name&` or `type_name const&` which represents the underlying instance of `type_name`. `attribute_typeN` and `attribute_const_typeN` may specify the types that `get_exprN` denotes to. `set_exprN` is the expression that is invoked to set the *N*th element of an instance of `type_name`. This expression may access variables named `obj` of type `type_name&`, which represent the corresponding instance of `type_name`, and `val` of an arbitrary const-qualified reference template type parameter `Val`, which represents the right operand of the assignment expression.

The actual return type of fusion's intrinsic sequence access (meta-)functions when in invoked with (an instance of) `type_name` is a proxy type. This type is implicitly convertible to the attribute type via `get_exprN` and forwards assignment to the underlying element via `set_exprN`. The value type (that is the type returned by `result_of::value_of`, `result_of::value_of_data`, `result_of::value_at`, `result_of::value_at_c` and `result_of::value_at_key`) of the *N*th element is `attribute_typeN` with const-qualifier and reference removed.

The macro should be used at global scope, and `type_name` should be the fully namespace qualified name of the class type to be adapted.

Header

```
#include <boost/fusion/adapted/adt/adapt_assoc_adt.hpp>
#include <boost/fusion/include/adapt_assoc_adt.hpp>
```

Example

```
namespace demo
{
    struct employee
    {
    private:
        std::string name;
        int age;

    public:
        void set_name(std::string const& n)
        {
            name=n;
        }

        void set_age(int a)
        {
            age=a;
        }

        std::string const& get_name()const
        {
            return name;
        }

        int get_age()const
        {
            return age;
        }
    };
}

namespace keys
{
    struct name;
    struct age;
}

BOOST_FUSION_ADAPT_ASSOC_ADT(
    demo::employee,
    (std::string const&, std::string const&, obj.get_name(), obj.set_name(val), keys::name)
    (int, int, obj.get_age(), obj.set_age(val), keys::age))

demo::employee e;
at_key<keys::name>(e)="Edward Norton";
at_key<keys::age>(e)=41;
//Prints 'Edward Norton is 41 years old'
std::cout << e.get_name() << " is " << e.get_age() << " years old" << std::endl;
```

See also

`adt_attribute_proxy`

BOOST_FUSION_ADAPT_ASSOC_TPL_ADT

BOOST_FUSION_ADAPT_ASSOC_TPL_ADT is a macro than can be used to generate all the necessary boilerplate to adapt an arbitrary template class type as a model of Random Access Sequence and Associative Sequence.

Synopsis

```
BOOST_FUSION_ADAPT_ASSOC_TPL_ADT(
    (template_param0)(template_param1)...,
    (type_name) (specialization_param0)(specialization_param1)...,
    (attribute_type0, attribute_const_type0, get_expr0, set_expr0, key_type0)
    (attribute_type1, attribute_const_type1, get_expr1, set_expr1, key_type1)
    ...
    )
```

Expression Semantics

The above macro generates the necessary code to adapt `type_name` or an arbitrary specialization of `type_name` as a model of Random Access Sequence and Associative Sequence. The sequence `(template_param0)(template_param1)...` declares the names of the template type parameters used. The sequence `(specialization_param0)(specialization_param1)...` declares the template parameters of the actual specialization of `type_name` that is adapted as a fusion sequence. The sequence of `(attribute_typeN, attribute_const_typeN, get_exprN, set_exprN, key_typeN)` 5-tuples declares the types, const types, get-expressions, set-expressions and key types of the elements that are part of the adapted fusion sequence. `get_exprN` is the expression that is invoked to get the *N*th element of an instance of `type_name`. This expression may access a variable named `obj` of type `type_name&` or `type_name const&` which represents the underlying instance of `type_name`. `attribute_typeN` and `attribute_const_typeN` may specify the types that `get_exprN` denotes to. `set_exprN` is the expression that is invoked to set the *N*th element of an instance of `type_name`. This expression may access variables named `obj` of type `type_name&`, which represent the corresponding instance of `type_name`, and `val` of an arbitrary const-qualified reference template type parameter `Val`, which represents the right operand of the assignment expression.

The actual return type of fusion's intrinsic sequence access (meta-)functions when in invoked with (an instance of) `type_name` is a proxy type. This type is implicitly convertible to the attribute type via `get_exprN` and forwards assignment to the underlying element via `set_exprN`. The value type (that is the type returned by `result_of::value_of`, `result_of::value_of_data`, `result_of::value_at`, `result_of::value_at_c` and `result_of::value_at_key`) of the *N*th element is `attribute_typeN` with const-qualifier and reference removed.

The macro should be used at global scope, and `type_name` should be the fully namespace qualified name of the template class type to be adapted.

Header

```
#include <boost/fusion/adapted/adt/adapt_assoc_adt.hpp>
#include <boost/fusion/include/adapt_assoc_adt.hpp>
```

Example

```
namespace demo
{
    template<typename Name, typename Age>
    struct employee
    {
    private:
        Name name;
        Age age;

    public:
        void set_name(Name const& n)
        {
            name=n;
        }

        void set_age(Age const& a)
        {
            age=a;
        }

        Name const& get_name()const
        {
            return name;
        }

        Age const& get_age()const
        {
            return age;
        }
    };
}

namespace keys
{
    struct name;
    struct age;
}

BOOST_FUSION_ADAPT_ASSOC_TPL_ADT(
    (Name)(Age),
    (demo::employee) (Name)(Age),
    (Name const&, Name const&, obj.get_name(), obj.set_name(val), keys::name)
    (Age const&, Age const&, obj.get_age(), obj.set_age(val), keys::age))

demo::employee<std::string, int> e;
at_key<keys::name>(e)="Edward Norton";
at_key<keys::age>(e)=41;
//Prints 'Edward Norton is 41 years old'
std::cout << e.get_name() << " is " << e.get_age() << " years old" << std::endl;
```

See also

`adt_attribute_proxy`

BOOST_FUSION_DEFINE_STRUCT

BOOST_FUSION_DEFINE_STRUCT is a macro that can be used to generate all the necessary boilerplate to define and adapt an arbitrary struct as a model of Random Access Sequence.

Synopsis

```
BOOST_FUSION_DEFINE_STRUCT(
    (namespace0)(namespace1)...,
    struct_name,
    (member_type0, member_name0)
    (member_type1, member_name1)
    ...
    )
```

Notation

`str`	An instance of `struct_name`
`e0`...`en`	Heterogeneous values
`fs`	A Forward Sequence

Expression Semantics

The above macro generates the necessary code that defines and adapts `struct_name` as a model of Random Access Sequence. The sequence `(namespace0)(namespace1)...` declares the namespace for `struct_name`. It yields to a fully qualified name for `struct_name` of `namespace0::namespace1::... struct_name`. If an empty namespace sequence is given (that is a macro that expands to nothing), the struct is placed in the global namespace. The sequence of `(member_typeN, member_nameN)` pairs declares the type and names of each of the struct members that are part of the sequence.

The macro should be used at global scope. Semantics of an expression is defined only where it differs from, or is not defined in Random Access Sequence.

Expression	Semantics
`struct_name()`	Creates an instance of `struct_name` with default constructed elements.
`struct_name(e0, e1,... en)`	Creates an instance of `struct_name` with elements `e0`...`en`.
`struct_name(fs)`	Copy constructs an instance of `struct_name` from a Forward Sequence `fs`.
`str = fs`	Assigns from a Forward Sequence `fs`.
`str.member_nameN`	Access of struct member `member_nameN`

Header

```
#include <boost/fusion/adapted/struct/define_struct.hpp>
#include <boost/fusion/include/define_struct.hpp>
```

Example

```
// demo::employee is a Fusion sequence
BOOST_FUSION_DEFINE_STRUCT(
    (demo), employee,
    (std::string, name)
    (int, age))
```

BOOST_FUSION_DEFINE_TPL_STRUCT

Description

BOOST_FUSION_DEFINE_TPL_STRUCT is a macro that can be used to generate all the necessary boilerplate to define and adapt an arbitrary template struct as a model of Random Access Sequence.

Synopsis

```
BOOST_FUSION_DEFINE_TPL_STRUCT(
    (template_param0)(template_param1)...,
    (namespace0)(namespace1)...,
    struct_name,
    (member_type0, member_name0)
    (member_type1, member_name1)
    ...
    )
```

Notation

`Str`	An instantiated `struct_name`
`str`	An instance of `Str`
`e0`...`en`	Heterogeneous values
`fs`	A Forward Sequence

Expression Semantics

The above macro generates the necessary code that defines and adapts `struct_name` as a model of Random Access Sequence. The sequence `(template_param0)(template_param1)...` declares the names of the template type parameters used. The sequence `(namespace0)(namespace1)...` declares the namespace for `struct_name`. It yields to a fully qualified name for `struct_name` of `namespace0::namespace1::... struct_name`. If an empty namespace sequence is given (that is a macro that expands to nothing), the struct is placed in the global namespace. The sequence of `(member_typeN, member_nameN)` pairs declares the type and names of each of the struct members that are part of the sequence.

The macro should be used at global scope. Semantics of an expression is defined only where it differs from, or is not defined in Random Access Sequence.

Expression	Semantics
`Str()`	Creates an instance of `Str` with default constructed elements.
`Str(e0, e1,... en)`	Creates an instance of `Str` with elements `e0`...`en`.
`Str(fs)`	Copy constructs an instance of `Str` from a Forward Sequence `fs`.
`str = fs`	Assigns from a Forward Sequence `fs`.
`str.member_nameN`	Access of struct member `member_nameN`

Header

```
#include <boost/fusion/adapted/struct/define_struct.hpp>
#include <boost/fusion/include/define_struct.hpp>
```

Example

```
// Any instantiated demo::employee is a Fusion sequence
BOOST_FUSION_DEFINE_TPL_STRUCT(
    (Name)(Age), (demo), employee,
    (Name, name)
    (Age, age))
```

BOOST_FUSION_DEFINE_STRUCT_INLINE

Description

BOOST_FUSION_DEFINE_STRUCT_INLINE is a macro that can be used to generate all the necessary boilerplate to define and adapt an arbitrary struct as a model of Random Access Sequence. Unlike BOOST_FUSION_DEFINE_STRUCT, it can be used at class or namespace scope.

Synopsis

```
BOOST_FUSION_DEFINE_STRUCT_INLINE(
    struct_name,
    (member_type0, member_name0)
    (member_type1, member_name1)
    ...
    )
```

Expression Semantics

The semantics of BOOST_FUSION_DEFINE_STRUCT_INLINE are identical to those of BOOST_FUSION_DEFINE_STRUCT, with two differences:

1. BOOST_FUSION_DEFINE_STRUCT_INLINE can be used at class or namespace scope, and thus does not take a namespace list parameter.

2. The structure generated by BOOST_FUSION_DEFINE_STRUCT_INLINE has a base class, and is thus not POD in C++03.

Header

```
#include <boost/fusion/adapted/struct/define_struct_inline.hpp>
#include <boost/fusion/include/define_struct_inline.hpp>
```

Example

```
// enclosing::employee is a Fusion sequence
class enclosing
{
    BOOST_FUSION_DEFINE_STRUCT_INLINE(
        employee,
        (std::string, name)
        (int, age))
};
```

BOOST_FUSION_DEFINE_TPL_STRUCT_INLINE

Description

BOOST_FUSION_DEFINE_TPL_STRUCT_INLINE is a macro that can be used to generate all the necessary boilerplate to define and adapt an arbitrary template struct as a model of Random Access Sequence. Unlike BOOST_FUSION_DEFINE_TPL_STRUCT, it can be used at class or namespace scope.

Synopsis

```
BOOST_FUSION_DEFINE_TPL_STRUCT_INLINE(
    (template_param0)(template_param1)...,
    struct_name,
    (member_type0, member_name0)
    (member_type1, member_name1)
    ...
    )
```

Expression Semantics

The semantics of BOOST_FUSION_DEFINE_TPL_STRUCT_INLINE are identical to those of BOOST_FUSION_DEFINE_TPL_STRUCT, with two differences:

1. BOOST_FUSION_DEFINE_TPL_STRUCT_INLINE can be used at class or namespace scope, and thus does not take a namespace list parameter.

2. The structure generated by BOOST_FUSION_DEFINE_TPL_STRUCT_INLINE has a base class, and is thus not POD in C++03.

Header

```
#include <boost/fusion/adapted/struct/define_struct_inline.hpp>
#include <boost/fusion/include/define_struct_inline.hpp>
```

Example

```
// Any instantiated enclosing::employee is a Fusion sequence
class enclosing
{
    BOOST_FUSION_DEFINE_TPL_STRUCT(
        (Name)(Age), employee,
        (Name, name)
        (Age, age))
};
```

BOOST_FUSION_DEFINE_ASSOC_STRUCT

Description

BOOST_FUSION_DEFINE_ASSOC_STRUCT is a macro that can be used to generate all the necessary boilerplate to define and adapt an arbitrary struct as a model of Random Access Sequence and Associative Sequence.

Synopsis

```
BOOST_FUSION_DEFINE_ASSOC_STRUCT(
    (namespace0)(namespace1)...,
    struct_name,
    (member_type0, member_name0, key_type0)
    (member_type1, member_name1, key_type1)
    ...
    )
```

Notation

`str`	An instance of `struct_name`
`e0`...`en`	Heterogeneous values
`fs`	A Forward Sequence

Expression Semantics

The above macro generates the necessary code that defines and adapts `struct_name` as a model of Random Access Sequence and Associative Sequence. The sequence `(namespace0)(namespace1)...` declares the namespace for `struct_name`. It yields to a fully qualified name for `struct_name` of `namespace0::namespace1::... struct_name`. If an empty namespace sequence is given (that is a macro that expands to nothing), the struct is placed in the global namespace. The sequence of `(member_typeN, member_nameN, key_typeN)` triples declares the type, name and key type of each of the struct members that are part of the sequence.

The macro should be used at global scope. Semantics of an expression is defined only where it differs from, or is not defined in Random Access Sequence and Associative Sequence.

Expression	Semantics
`struct_name()`	Creates an instance of `struct_name` with default constructed elements.
`struct_name(e0, e1,... en)`	Creates an instance of `struct_name` with elements `e0`...`en`.
`struct_name(fs)`	Copy constructs an instance of `struct_name` from a Forward Sequence `fs`.
`str = fs`	Assigns from a Forward Sequence `fs`.
`str.member_nameN`	Access of struct member `member_nameN`

Header

```
#include <boost/fusion/adapted/struct/define_assoc_struct.hpp>
#include <boost/fusion/include/define_assoc_struct.hpp>
```

Example

```
namespace keys
{
    struct name;
    struct age;
}

// demo::employee is a Fusion sequence
BOOST_FUSION_DEFINE_ASSOC_STRUCT(
    (demo), employee,
    (std::string, name, keys::name)
    (int, age, keys::age))
```

BOOST_FUSION_DEFINE_ASSOC_TPL_STRUCT

Description

BOOST_FUSION_DEFINE_ASSOC_TPL_STRUCT is a macro that can be used to generate all the necessary boilerplate to define and adapt an arbitrary template struct as a model of Random Access Sequence and Associative Sequence.

Synopsis

```
BOOST_FUSION_DEFINE_ASSOC_TPL_STRUCT(
    (template_param0)(template_param1)...,
    (namespace0)(namespace1)...,
    struct_name,
    (member_type0, member_name0, key_type0)
    (member_type1, member_name1, key_type1)
    ...
    )
```

Notation

`Str`	An instantiated `struct_name`
`str`	An instance of `Str`
`e0...en`	Heterogeneous values
`fs`	A Forward Sequence

Expression Semantics

The above macro generates the necessary code that defines and adapts `struct_name` as a model of Random Access Sequence and Associative Sequence. The sequence `(template_param0)(template_param1)...` declares the names of the template type parameters used. The sequence `(namespace0)(namespace1)...` declares the namespace for `struct_name`. It yields to a fully qualified name for `struct_name` of `namespace0::namespace1::... struct_name`. If an empty namespace sequence is given (that is a macro that expands to nothing), the struct is placed in the global namespace. The sequence of `(member_typeN, member_nameN, key_typeN)` triples declares the type, name and key type of each of the struct members that are part of the sequence.

The macro should be used at global scope. Semantics of an expression is defined only where it differs from, or is not defined in Random Access Sequence and Associative Sequence.

Expression	Semantics
`Str()`	Creates an instance of `Str` with default constructed elements.
`Str(e0, e1,... en)`	Creates an instance of `Str` with elements `e0`...`en`.
`Str(fs)`	Copy constructs an instance of `Str` from a Forward Sequence `fs`.
`str = fs`	Assigns from a Forward Sequence `fs`.
`str.member_nameN`	Access of struct member `member_nameN`

Header

```
#include <boost/fusion/adapted/struct/define_assoc_struct.hpp>
#include <boost/fusion/include/define_assoc_struct.hpp>
```

Example

```
namespace keys
{
    struct name;
    struct age;
}

// Any instantiated demo::employee is a Fusion sequence
BOOST_FUSION_DEFINE_ASSOC_TPL_STRUCT(
    (Name)(Age), (demo), employee,
    (Name, name, keys::name)
    (Age, age, keys::age))
```

Algorithm

Lazy Evaluation

Unlike MPL, Fusion algorithms are lazy[11] and non sequence-type preserving [12]. This is by design. Runtime efficiency is given a high priority. Like MPL, and unlike STL, fusion algorithms are mostly functional in nature such that algorithms are non mutating (no side effects). However, due to the high cost of returning full sequences such as vectors and lists, *Views* are returned from Fusion algorithms instead. For example, the `transform` algorithm does not actually return a transformed version of the original sequence. `transform` returns a `transform_view`. This view holds a reference to the original sequence plus the transform function. Iteration over the `transform_view` will apply the transform function over the sequence elements on demand. This *lazy* evaluation scheme allows us to chain as many algorithms as we want without incurring a high runtime penalty.

Sequence Extension

The *lazy* evaluation scheme where Algorithms return Views also allows operations such as `push_back` to be totally generic. In Fusion, `push_back` is actually a generic algorithm that works on all sequences. Given an input sequence `s` and a value `x`, Fusion's `push_back` algorithm simply returns a `joint_view`: a view that holds a reference to the original sequence `s` and the value `x`. Functions that were once sequence specific and need to be implemented N times over N different sequences are now implemented only once. That is to say that Fusion sequences are cheaply extensible.

To regain the original sequence, Conversion functions are provided. You may use one of the Conversion functions to convert back to the original sequence type.

Header

```
#include <boost/fusion/algorithm.hpp>
#include <boost/fusion/include/algorithm.hpp>
```

Auxiliary

The auxiliary algorithms provide the utility algorithms for sequences.

Header

```
#include <boost/fusion/algorithm/auxiliary.hpp>
#include <boost/fusion/include/auxiliary.hpp>
```

Functions

copy

Description

Copy a sequence `src` to a sequence `dest`. It is also used to convert sequence into other.

Synopsis

```
template <typename Seq1, typename Seq2>
void copy(Seq1 const& src, Seq2& dest);
```

[11] Except for some special cases such as `for_each` and `copy` which are inherently imperative algorithms.
[12] What does that mean? It means that when you operate on a sequence through a Fusion algorithm that returns a sequence, the sequence returned may not be of the same class as the original

Table 37. Parameters

Parameter	Requirement	Description
`src`	A model of Forward Sequence, all elements contained in the `src` sequence should be convertible into the element contained in the `dest` sequence.	Operation's argument
`dest`	A model of Forward Sequence, `e2 = e1` is valid expression for each pair of elements `e1` of `src` and `e2` of `dest`.	Operation's argument

Expression Semantics

```
copy(src, dest);
```

Return type: `void`

Semantics: `e2 = e1` for each element `e1` in `src` and `e2` in `dest`.

Complexity

Linear, exactly `result_of::size<Sequence>::value`.

Header

```
#include <boost/fusion/algorithm/auxiliary/copy.hpp>
#include <boost/fusion/include/copy.hpp>
```

Example

```
vector<int,int> vec(1,2);
list<int,int> ls;
copy(vec, ls);
assert(ls == make_list(1,2));
```

Iteration

The iteration algorithms provide the fundamental algorithms for traversing a sequence repeatedly applying an operation to its elements.

Header

```
#include <boost/fusion/algorithm/iteration.hpp>
#include <boost/fusion/include/iteration.hpp>
```

Functions

fold

Description

For a sequence `seq`, initial state `initial_state`, and binary function object or function pointer `f`, `fold` returns the result of the repeated application of binary `f` to the result of the previous `f` invocation (`inital_state` if it is the first call) and each element of `seq`.

Synopsis

```
template<
    typename Sequence,
    typename State,
    typename F
    >
typename result_of::fold<Sequence, State const, F>::type fold(
    Sequence& seq, State const& initial_state, F f);

template<
    typename Sequence,
    typename State,
    typename F
    >
typename result_of::fold<Sequence const, State const, F>::type fold(
    Sequence const& seq, State const& initial_state, F f);
```

Table 38. Parameters

Parameter	Requirement	Description
`seq`	A model of Forward Sequence	Operation's argument
`initial_state`	Any type	Initial state
`f`	`f(s,e)` with return type `boost::result_of<F(S,E)>::type` for current state `s` of type `S`, and for each element `e` of type `E` in `seq`	Operation's argument

Expression Semantics

```
fold(seq, initial_state, f);
```

Return type: Any type

Semantics: Equivalent to `f(... f(f(initial_state,e1),e2) ...eN)` where `e1 ...eN` are the consecutive elements of `seq`.

Complexity

Linear, exactly `result_of::size<Sequence>::value` applications of `f`.

Header

```
#include <boost/fusion/algorithm/iteration/fold.hpp>
#include <boost/fusion/include/fold.hpp>
```

Example

```
struct make_string
{
    typedef std::string result_type;

    template<typename T>
    std::string operator()(const std::string& str, const T& t) const
    {
        return str + boost::lexical_cast<std::string>(t);
    }
};
...
const vector<int,int> vec(1,2);
assert(fold(vec,std::string(""), make_string()) == "12");
```

reverse_fold

Description

For a sequence `seq`, initial state `initial_state`, and binary function object or function pointer `f`, `reverse_fold` returns the result of the repeated application of binary `f` to the result of the previous `f` invocation (`inital_state` if it is the first call) and each element of `seq`.

Synopsis

```
template<
    typename Sequence,
    typename State,
    typename F
    >
typename result_of::reverse_fold<Sequence, State const, F>::type reverse_fold(
    Sequence& seq, State const& initial_state, F f);

template<
    typename Sequence,
    typename State,
    typename F
    >
typename result_of::reverse_fold<Sequence const, State const, F>::type reverse_fold(
    Sequence const& seq, State const& initial_state, F f);
```

Table 39. Parameters

Parameter	Requirement	Description
`seq`	A model of Bidirectional Sequence	Operation's argument
`initial_state`	Any type	Initial state
`f`	`f(s,e)` with return type `boost::result_of<F(S,E)>::type` for current state `s` of type `S`, and for each element `e` of type `E` in `seq`	Operation's argument

Expression Semantics

```
reverse_fold(seq, initial_state, f);
```

Return type: Any type

Semantics: Equivalent to `f(... f(f(initial_state,eN),eN-1) ...e1)` where `e1 ...eN` are the consecutive elements of `seq`.

Complexity

Linear, exactly `result_of::size<Sequence>::value` applications of `f`.

Header

```
#include <boost/fusion/algorithm/iteration/reverse_fold.hpp>
#include <boost/fusion/include/reverse_fold.hpp>
```

Example

```
struct make_string
{
    typedef std::string result_type;

    template<typename T>
    std::string operator()(const std::string& str, const T& t) const
    {
        return str + boost::lexical_cast<std::string>(t);
    }
};
...
const vector<int,int> vec(1,2);
assert(reverse_fold(vec,std::string(""), make_string()) == "21");
```

iter_fold

Description

For a sequence `seq`, initial state `initial_state`, and binary function object or function pointer `f`, `iter_fold` returns the result of the repeated application of binary `f` to the result of the previous `f` invocation (`inital_state` if it is the first call) and iterators on each element of `seq`.

Synopsis

```
template<
    typename Sequence,
    typename State,
    typename F
    >
typename result_of::iter_fold<Sequence, State const, F>::type iter_fold(
    Sequence& seq, State const& initial_state, F f);

template<
    typename Sequence,
    typename State,
    typename F
    >
typename result_of::iter_fold<Sequence const, State const, F>::type iter_fold(
    Sequence const& seq, State const& initial_state, F f);
```

Table 40. Parameters

Parameter	Requirement	Description
`seq`	A model of Forward Sequence	Operation's argument
`initial_state`	Any type	Initial state
`f`	`f(s,it)` with return type `boost::result_of<F(S,It)>::type` for current state `s` of type `S`, and for each iterator `it` of type `It` on an element of `seq`	Operation's argument

Expression Semantics

```
iter_fold(seq, initial_state, f);
```

Return type: Any type

Semantics: Equivalent to `f(... f(f(initial_state,it1),it2) ...itN)` where `it1 ...itN` are consecutive iterators on the elements of `seq`.

Complexity

Linear, exactly `result_of::size<Sequence>::value` applications of `f`.

Header

```
#include <boost/fusion/algorithm/iteration/iter_fold.hpp>
#include <boost/fusion/include/iter_fold.hpp>
```

Example

```
struct make_string
{
    typedef std::string result_type;

    template<typename T>
    std::string operator()(const std::string& str, const T& t) const
    {
        return str + boost::lexical_cast<std::string>(deref(t));
    }
};
...
const vector<int,int> vec(1,2);
assert(iter_fold(vec,std::string(""), make_string()) == "12");
```

reverse_iter_fold

Description

For a sequence `seq`, initial state `initial_state`, and binary function object or function pointer `f`, `reverse_iter_fold` returns the result of the repeated application of binary `f` to the result of the previous `f` invocation (`inital_state` if it is the first call) and iterators on each element of `seq`.

Synopsis

```
template<
    typename Sequence,
    typename State,
    typename F
    >
typename result_of::reverse_iter_fold<Sequence, State const, F>::type reverse_iter_fold(
    Sequence& seq, State const& initial_state, F f);

template<
    typename Sequence,
    typename State,
    typename F
    >
typename result_of::reverse_iter_fold<Sequence const, State const, F>::type reverse_iter_fold(
    Sequence const& seq, State const& initial_state, F f);
```

Table 41. Parameters

Parameter	Requirement	Description
`seq`	A model of Bidirectional Sequence	Operation's argument
`initial_state`	Any type	Initial state
`f`	`f(s,it)` with return type `boost::result_of<F(S,It)>::type` for current state `s` of type `S`, and for each iterator `it` of type `It` on an element of `seq`	Operation's argument

Expression Semantics

```
reverse_iter_fold(seq, initial_state, f);
```

Return type: Any type

Semantics: Equivalent to `f(... f(f(initial_state,itN),itN-1) ...it1)` where `it1 ...itN` are consecutive iterators on the elements of `seq`.

Complexity

Linear, exactly `result_of::size<Sequence>::value` applications of `f`.

Header

```
#include <boost/fusion/algorithm/iteration/reverse_iter_fold.hpp>
#include <boost/fusion/include/reverse_iter_fold.hpp>
```

Example

```
struct make_string
{
    typedef std::string result_type;

    template<typename T>
    std::string operator()(const std::string& str, const T& t) const
    {
        return str + boost::lexical_cast<std::string>(deref(t));
    }
};
...
const vector<int,int> vec(1,2);
assert(reverse_iter_fold(vec,std::string(""), make_string()) == "21");
```

accumulate

Description

For a sequence `seq`, initial state `initial_state`, and binary function object or function pointer `f`, `accumulate` returns the result of the repeated application of binary `f` to the result of the previous `f` invocation (`inital_state` if it is the first call) and each element of `seq`.

Synopsis

```
template<
    typename Sequence,
    typename State,
    typename F
    >
typename result_of::accumulate<Sequence, State const, F>::type accumulate(
    Sequence& seq, State const& initial_state, F f);

template<
    typename Sequence,
    typename State,
    typename F
    >
typename result_of::accumulate<Sequence const, State const, F>::type accumulate(
    Sequence const& seq, State const& initial_state, F f);
```

Table 42. Parameters

Parameter	Requirement	Description
`seq`	A model of Forward Sequence	Operation's argument
`initial_state`	Any type	Initial state
`f`	`f(s,e)` with return type `boost::result_of<F(S,E)>::type` for current state `s` of type `S`, and for each element `e` of type `E` in `seq`	Operation's argument

Expression Semantics

```
accumulate(seq, initial_state, f);
```

Return type: Any type

Semantics: Equivalent to `f(... f(f(initial_state,e1),e2) ...eN)` where `e1 ...eN` are the consecutive elements of `seq`.

Complexity

Linear, exactly `result_of::size<Sequence>::value` applications of `f`.

Header

```
#include <boost/fusion/algorithm/iteration/accumulate.hpp>
#include <boost/fusion/include/accumulate.hpp>
```

Example

```
struct make_string
{
    typedef std::string result_type;

    template<typename T>
    std::string operator()(const std::string& str, const T& t) const
    {
        return str + boost::lexical_cast<std::string>(t);
    }
};
...
const vector<int,int> vec(1,2);
assert(accumulate(vec,std::string(""), make_string()) == "12");
```

for_each

Description

Applies a unary function object to each element of a sequence.

Synopsis

```
template<
    typename Sequence,
    typename F
    >
typename result_of::for_each<Sequence, F>::type for_each(
    Sequence& seq, F f);
```

Table 43. Parameters

Parameter	Requirement	Description
`seq`	A model of Forward Sequence, `f(e)` must be a valid expression for each element `e` in `seq`	Operation's argument
`f`	A unary Regular Callable Object	Operation's argument

Expression Semantics

```
for_each(seq, f);
```

Return type: `void`

Semantics: Calls `f(e)` for each element `e` in `seq`.

Complexity

Linear, exactly `result_of::size<Sequence>::value` applications of `f`.

Header

```
#include <boost/fusion/algorithm/iteration/for_each.hpp>
#include <boost/fusion/include/for_each.hpp>
```

Example

```
struct increment
{
    template<typename T>
    void operator()(T& t) const
    {
        ++t;
    }
};
...
vector<int,int> vec(1,2);
for_each(vec, increment());
assert(vec == make_vector(2,3));
```

Metafunctions

fold

Description

Returns the result type of `fold`.

Synopsis

```
template<
    typename Sequence,
    typename State,
    typename F>
struct fold
{
    typedef unspecified type;
};
```

Table 44. Parameters

Parameter	Requirement	Description
`Sequence`	A model of Forward Sequence	The sequence to iterate
`State`	Any type	The initial state for the first application of `F`
`F`	`boost::result_of<F(S,E)>::type` is the return type of `f(s,e)` with current state `s` of type `S`, and an element `e` of type `E` in `seq`	The operation to be applied on traversal

Expression Semantics

```
fold<Sequence, State, F>::type
```

Return type: Any type

Semantics: Returns the result of applying `fold` to a sequence of type `Sequence`, with an initial state of type `State` and binary function object or function pointer of type `F`.

Complexity

Linear, exactly `result_of::size<Sequence>::value` applications of `F`.

Header

```
#include <boost/fusion/algorithm/iteration/fold.hpp>
#include <boost/fusion/include/fold.hpp>
```

reverse_fold

Description

Returns the result type of `reverse_fold`.

Synopsis

```
template<
    typename Sequence,
    typename State,
    typename F>
struct reverse_fold
{
    typedef unspecified type;
};
```

Table 45. Parameters

Parameter	Requirement	Description
`Sequence`	A model of Bidirectional Sequence	The sequence to iterate
`State`	Any type	The initial state for the first application of `F`
`F`	`boost::result_of<F(S,E)>::type` is the return type of `f(s,e)` with current state `s` of type `S`, and an element `e` of type `E` in `seq`	The operation to be applied on traversal

Expression Semantics

```
reverse_fold<Sequence, State, F>::type
```

Return type: Any type

Semantics: Returns the result of applying `reverse_fold` to a sequence of type `Sequence`, with an initial state of type `State` and binary function object or function pointer of type `F`.

Complexity

Linear, exactly `result_of::size<Sequence>::value` applications of `F`.

Header

```
#include <boost/fusion/algorithm/iteration/reverse_fold.hpp>
#include <boost/fusion/include/reverse_fold.hpp>
```

iter_fold

Description

Returns the result type of `iter_fold`.

Synopsis

```
template<
    typename Sequence,
    typename State,
    typename F>
struct iter_fold
{
    typedef unspecified type;
};
```

Table 46. Parameters

Parameter	Requirement	Description
`Sequence`	A model of Forward Sequence	The sequence to iterate
`State`	Any type	The initial state for the first application of `F`
`F`	`boost::result_of<F(S,It)>::type` is the return type of `f(s,it)` with current state `s` of type `S`, and an iterator `it` of type `It` on an element of `seq`	The operation to be applied on traversal

Expression Semantics

```
iter_fold<Sequence, State, F>::type
```

Return type: Any type

Semantics: Returns the result of applying `iter_fold` to a sequence of type `Sequence`, with an initial state of type `State` and binary function object or function pointer of type `F`.

Complexity

Linear, exactly `result_of::size<Sequence>::value` applications of `F`.

Header

```
#include <boost/fusion/algorithm/iteration/iter_fold.hpp>
#include <boost/fusion/include/iter_fold.hpp>
```

reverse_iter_fold

Description

Returns the result type of `reverse_iter_fold`.

Synopsis

```
template<
    typename Sequence,
    typename State,
    typename F>
struct reverse_iter_fold
{
    typedef unspecified type;
};
```

Table 47. Parameters

Parameter	Requirement	Description
`Sequence`	A model of Bidirectional Sequence	The sequence to iterate
`State`	Any type	The initial state for the first application of `F`
`F`	`boost::result_of<F(S,It)>::type` is the return type of `f(s,it)` with current state `s` of type `S`, and an iterator `it` of type `It` on an element of `seq`	The operation to be applied on traversal

Expression Semantics

```
reverse_iter_fold<Sequence, State, F>::type
```

Return type: Any type

Semantics: Returns the result of applying `reverse_iter_fold` to a sequence of type `Sequence`, with an initial state of type `State` and binary function object or function pointer of type `F`.

Complexity

Linear, exactly `result_of::size<Sequence>::value` applications of `F`.

Header

```
#include <boost/fusion/algorithm/iteration/reverse_iter_fold.hpp>
#include <boost/fusion/include/reverse_iter_fold.hpp>
```

accumulate

Description

Returns the result type of `accumulate`.

Synopsis

```
template<
    typename Sequence,
    typename State,
    typename F>
struct accumulate
{
    typedef unspecified type;
};
```

Table 48. Parameters

Parameter	Requirement	Description
Sequence	A model of Forward Sequence	The sequence to iterate
State	Any type	The initial state for the first application of F
F	boost::result_of<F(S,E)>::type is the return type of f(s,e) with current state s of type S, and an element e of type E in seq	The operation to be applied on traversal

Expression Semantics

```
accumulate<Sequence, State, F>::type
```

Return type: Any type

Semantics: Returns the result of applying accumulate to a sequence of type Sequence, with an initial state of type State and binary function object or function pointer of type F.

Complexity

Linear, exactly result_of::size<Sequence>::value applications of F.

Header

```
#include <boost/fusion/algorithm/iteration/accumulate.hpp>
#include <boost/fusion/include/accumulate.hpp>
```

for_each

A metafunction returning the result type of applying for_each to a sequence. The return type of for_each is always void.

Description

Synopsis

```
template<
    typename Sequence,
    typename F
>
struct for_each
{
    typedef void type;
};
```

Table 49. Parameters

Parameter	Requirement	Description
Sequence	A model of Forward Sequence	Operation's argument
F	Any type	Operation's argument

Expression Semantics

```
result_of::for_each<Sequence, F>::type
```

Return type: `void`.

Semantics: Returns the return type of `for_each` for a sequence of type `Sequence` and a unary function object `F`. The return type is always `void`.

Complexity

Constant.

Header

```
#include <boost/fusion/algorithm/iteration/for_each.hpp>
#include <boost/fusion/include/for_each.hpp>
```

Query

The query algorithms provide support for searching and analyzing sequences.

Header

```
#include <boost/fusion/algorithm/query.hpp>
#include <boost/fusion/include/query.hpp>
```

Functions

any

Description

For a sequence `seq` and unary function object `f`, `any` returns true if `f` returns true for at least one element of `seq`.

Synopsis

```
template<
    typename Sequence,
    typename F
    >
typename result_of::any<Sequence,F>::type any(
    Sequence const& seq, F f);
```

Table 50. Parameters

Parameter	Requirement	Description
`seq`	A model of Forward Sequence, `f(e)` must be a valid expression, convertible to `bool`, for each element `e` in `seq`	The sequence to search
`f`	A unary function object	The search predicate

Expression semantics

```
any(seq, f);
```

Return type: `bool`

Semantics: Returns true if and only if `f(e)` evaluates to `true` for some element `e` in `seq`.

Complexity

Linear. At most `result_of::size<Sequence>::value` comparisons.

Header

```
#include <boost/fusion/algorithm/query/any.hpp>
#include <boost/fusion/include/any.hpp>
```

Example

```
struct odd
{
    template<typename T>
    bool operator()(T t) const
    {
        return t % 2;
    }
};
...
assert(any(make_vector(1,2), odd()));
assert(!any(make_vector(2,4), odd()));
```

all

Description

For a sequence `seq` and unary function object `f`, `all` returns true if `f` returns true for every element of `seq`.

Synopsis

```
template<
    typename Sequence,
    typename F
    >
typename result_of::all<Sequence,F>::type all(
    Sequence const& seq, F f);
```

Table 51. Parameters

Parameter	Requirement	Description
`seq`	A model of Forward Sequence, `f(e)` is a valid expression, convertible to `bool`, for every element `e` in `seq`	The sequence to search
`f`	A unary function object	The search predicate

Expression Semantics

```
all(seq, f);
```

Return type: `bool`

Semantics: Returns true if and only if `f(e)` evaluates to `true` for every element `e` in `seq`.

Complexity

Linear. At most `result_of::size<Sequence>::value` comparisons.

Header

```
#include <boost/fusion/algorithm/query/all.hpp>
#include <boost/fusion/include/all.hpp>
```

Example

```
struct odd
{
    template<typename T>
    bool operator()(T t) const
    {
        return t % 2;
    }
};
...
assert(all(make_vector(1,3), odd()));
assert(!all(make_vector(1,2), odd()));
```

none

Description

For a sequence `seq` and unary function object `f`, `none` returns true if `f` returns false for every element of `seq`.

Synopsis

```
template<
    typename Sequence,
    typename F
    >
typename result_of::none<Sequence,F>::type none(
    Sequence const& seq, F f);
```

Table 52. Parameters

Parameter	Requirement	Description
`seq`	A model of Forward Sequence, `f(e)` is a valid expression, convertible to `bool`, for every element `e` in `seq`	The sequence to search
`f`	A unary function object	The search predicate

Expression Semantics

```
none(seq, f);
```

Return type: `bool`

Semantics: Returns true if and only if `f(e)` evaluates to `false` for every element `e` in `seq`. Result equivalent to `!any(seq, f)`.

Complexity

Linear. At most `result_of::size<Sequence>::value` comparisons.

Header

```
#include <boost/fusion/algorithm/query/none.hpp>
#include <boost/fusion/include/none.hpp>
```

Example

```
struct odd
{
    template<typename T>
    bool operator()(T t) const
    {
        return t % 2;
    }
};
...
assert(none(make_vector(2,4), odd()));
assert(!none(make_vector(1,2), odd()));
```

find

Description

Finds the first element of a given type within a sequence.

Synopsis

```
template<
    typename T,
    typename Sequence
    >
unspecified find(Sequence const& seq);

template<
    typename T,
    typename Sequence
    >
unspecified find(Sequence& seq);
```

Table 53. Parameters

Parameter	Requirement	Description
`seq`	A model of Forward Sequence	The sequence to search
`T`	Any type	The type to search for

Expression Semantics

```
find<T>(seq)
```

Return type: A model of the same iterator category as the iterators of `seq`.

Semantics: Returns an iterator to the first element of `seq` of type `T`, or `end(seq)` if there is no such element. Equivalent to `find_if<boost::is_same<_, T> >(seq)`

Complexity

Linear. At most `result_of::size<Sequence>::value` comparisons.

Header

```
#include <boost/fusion/algorithm/query/find.hpp>
#include <boost/fusion/include/find.hpp>
```

Example

```
const vector<char,int> vec('a','0');
assert(*find<int>(vec) == '0');
assert(find<double>(vec) == end(vec));
```

find_if

Finds the first element within a sequence with a type for which a given MPL Lambda Expression evaluates to `boost::mpl::true_`.

Description

Synopsis

```
template<
    typename F,
    typename Sequence
    >
unspecified find_if(Sequence const& seq);

template<
    typename F,
    typename Sequence
    >
unspecified find_if(Sequence& seq);
```

Table 54. Parameters

Parameter	Requirement	Description
`seq`	A model of Forward Sequence	The sequence to search
`F`	A unary MPL Lambda Expression	The search predicate

Expression Semantics

```
find_if<F>(seq)
```

Return type: An iterator of the same iterator category as the iterators of `seq`.

Semantics: Returns the first element of `seq` for which MPL Lambda Expression `F` evaluates to `boost::mpl::true_`, or `end(seq)` if there is no such element.

Complexity

Linear. At most `result_of::size<Sequence>::value` comparisons.

1. include <boost/fusion/algorithm/query/find_if.hpp>

2. include <boost/fusion/include/find_if.hpp>

Example

```
const vector<double,int> vec(1.0,2);
assert(*find_if<is_integral<mpl::_> >(vec) == 2);
assert(find_if<is_class<mpl::_> >(vec) == end(vec));
```

count

Description

Returns the number of elements of a given type within a sequence.

Synopsis

```
template<
    typename Sequence,
    typename T
    >
typename result_of::count<Sequence, T>::type count(
    Sequence const& seq, T const& t);
```

Table 55. Parameters

Parameter	Requirement	Description
`seq`	A model of Forward Sequence, `e == t` must be a valid expression, convertible to `bool`, for each element `e` in `seq`	The sequence to search
`T`	Any type	The type to count

Expression Semantics

```
count(seq, t);
```

Return type: `int`

Semantics: Returns the number of elements of type `T` and equal to `t` in `seq`.

Complexity

Linear. At most `result_of::size<Sequence>::value` comparisons.

Header

```
#include <boost/fusion/algorithm/query/count.hpp>
#include <boost/fusion/include/count.hpp>
```

Example

```
const vector<double,int,int> vec(1.0,2,3);
assert(count(vec,2) == 1);
```

count_if

Description

Returns the number of elements within a sequence with a type for which a given unary function object evaluates to `true`.

Synopsis

```
template<
    typename Sequence,
    typename F
    >
typename result_of::count_if<Sequence, F>::type count_if(
    Sequence const& seq, F f);
```

Table 56. Parameters

Parameter	Requirement	Description
`seq`	A model of Forward Sequence, `f(e)` is a valid expression, convertible to `bool`, for each element `e` in `seq`	The sequence to search
`f`	A unary function object	The search predicate

Expression Semantics

```
count_if(seq, f)
```

Return type: `int`

Semantics: Returns the number of elements in `seq` where `f` evaluates to `true`.

Complexity

Linear. At most `result_of::size<Sequence>::value` comparisons.

Header

```
#include <boost/fusion/algorithm/query/count_if.hpp>
#include <boost/fusion/include/count_if.hpp>
```

Example

```
const vector<int,int,int> vec(1,2,3);
assert(count_if(vec,odd()) == 2);
```

Metafunctions

any

Description

A metafunction returning the result type of `any`.

Synopsis

```
template<
    typename Sequence,
    typename F
    >
struct any
{
    typedef bool type;
};
```

Table 57. Parameters

Parameter	Requirement	Description
`Sequence`	A model of Forward Sequence	Operation's argument
`F`	A model of unary Polymorphic Function Object	Operation's argument

Expression Semantics

```
result_of::any<Sequence, F>::type
```

Return type: `bool`.

Semantics: Returns the return type of `any` given a sequence of type `Sequence` and a unary Polymorphic Function Object of type `F`. The return type is always `bool`.

Complexity

Constant.

Header

```
#include <boost/fusion/algorithm/query/any.hpp>
#include <boost/fusion/include/any.hpp>
```

all

Description

A metafunction returning the result type of `all`.

Synopsis

```
template<
    typename Sequence,
    typename F
    >
struct all
{
    typedef bool type;
};
```

Table 58. Parameters

Parameter	**Requirement**	**Description**
`Sequence`	A model of Forward Sequence	Operation's argument
`F`	A model of unary Polymorphic Function Object	Operation's argument

Expression Semantics

```
result_of::all<Sequence, F>::type
```

Return type: `bool`.

Semantics: Returns the return type of `all` given a sequence of type `Sequence` and a unary Polymorphic Function Object of type `F`. The return type is always `bool`.

Complexity

Constant.

Header

```
#include <boost/fusion/algorithm/query/all.hpp>
#include <boost/fusion/include/all.hpp>
```

none

Description

A metafunction returning the result type of `none`.

Synopsis

```
template<
    typename Sequence,
    typename F
    >
struct none
{
    typedef bool type;
};
```

Table 59. Parameters

Parameter	Requirement	Description
`Sequence`	A model of Forward Sequence	Operation's argument
`F`	A model of unary Polymorphic Function Object	Operation's argument

Expression Semantics

```
result_of::none<Sequence, F>::type
```

Return type: `bool`.

Semantics: Returns the return type of `none` given a sequence of type `Sequence` and a unary Polymorphic Function Object of type `F`. The return type is always `bool`.

Complexity

Constant.

Header

```
#include <boost/fusion/algorithm/query/none.hpp>
#include <boost/fusion/include/none.hpp>
```

find

Description

Returns the result type of `find`, given the sequence and search types.

Synopsis

```
template<
    typename Sequence,
    typename T
    >
struct find
{
    typedef unspecified type;
};
```

Table 60. Parameters

Parameter	Requirement	Description
`Sequence`	Model of Forward Sequence	Operation's argument
`T`	Any type	Operation's argument

Expression Semantics

```
result_of::find<Sequence, T>::type
```

Return type: A model of the same iterator category as the iterators of `Sequence`.

Semantics: Returns an iterator to the first element of type `T` in `Sequence`, or `result_of::end<Sequence>::type` if there is no such element.

Complexity

Linear, at most `result_of::size<Sequence>::value` comparisons.

Header

```
#include <boost/fusion/algorithm/query/find.hpp>
#include <boost/fusion/include/find.hpp>
```

find_if

Description

Returns the result type of `find_if` given the sequence and predicate types.

Synopsis

```
template<
    typename Sequence,
    typename Pred
    >
struct find_if
{
    typedef unspecified type;
};
```

Table 61. Parameters

Parameter	Requirement	Description
`Sequence`	A model of Forward Sequence	Operation's argument
`Pred`	A model of MPL Lambda Expression	Operation's arguments

Expression Semantics

```
result_of::find_if<Sequence, Pred>::type
```

Return type: A model of the same iterator category as the iterators of `Sequence`.

Semantics: Returns an iterator to the first element in `Sequence` for which `Pred` evaluates to true. Returns `result_of::end<Sequence>::type` if there is no such element.

Complexity

Linear. At most `result_of::size<Sequence>::value` comparisons.

Header

```
#include <boost/fusion/algorithm/query/find_if.hpp>
#include <boost/fusion/include/find_if.hpp>
```

count

Description

A metafunction that returns the result type of `count` given the sequence and search types.

Synopsis

```
template<
    typename Sequence,
    typename T
    >
struct count
{
    typedef int type;
};
```

Table 62. Parameters

Parameter	Requirement	heading Description
`Sequence`	A model of Forward Sequence	Operation's argument
`T`	Any type	Operation's argument

Expression Semantics

```
result_of::count<T>::type
```

Return type: `int`.

Semantics: Returns the return type of `count`. The return type is always `int`.

Complexity

Constant.

Header

```
#include <boost/fusion/algorithm/query/count.hpp>
#include <boost/fusion/include/count.hpp>
```

count_if

Description

A metafunction that returns the result type of `count_if` given the sequence and predicate types.

Synopsis

```
template<
    typename Sequence,
    typename Pred
    >
struct count_if
{
    typedef int type;
};
```

Table 63. Parameters

Parameter	Requirement	Description
`Sequence`	A model of Forward Sequence	Operation's argument
`Pred`	A unary function object	Operation's argument

Expression Semantics

```
result_of::count_if<Sequence, Pred>::type
```

Return type: `int`.

Semantics: Returns the return type of `count_if`. The return type is always `int`.

Complexity

Constant.

Header

```
#include <boost/fusion/algorithm/query/count_if.hpp>
#include <boost/fusion/include/count_if.hpp>
```

Transformation

The transformation algorithms create new sequences out of existing sequences by performing some sort of transformation. In reality the new sequences are views onto the data in the original sequences.

Note

As the transformation algorithms return views onto their input arguments, it is important that the lifetime of the input arguments is greater than the period during which you wish to use the results.

Header

```
#include <boost/fusion/algorithm/transformation.hpp>
#include <boost/fusion/include/transformation.hpp>
```

Functions

filter

Description

For a given sequence, filter returns a new sequences containing only the elements of a specified type.

Synopsis

```
template<
    typename T,
    typename Sequence
    >
typename result_of::filter<Sequence const, T>::type filter(Sequence const& seq);
```

Table 64. Parameters

Parameter	Requirement	Description
`seq`	A model of Forward Sequence	Operation's argument
`T`	Any type	The type to retain

Expression Semantics

```
filter<T>(seq);
```

Return type:

- A model of Forward Sequence.
- A model of Associative Sequence if `seq` implements the Associative Sequence model.

Semantics: Returns a sequence containing all the elements of `seq` of type `T`. Equivalent to `filter_if<boost::same_type<_, T> >(seq)`.

Complexity

Constant. Returns a view which is lazily evaluated.

Header

```
#include <boost/fusion/algorithm/transformation/filter.hpp>
#include <boost/fusion/include/filter.hpp>
```

Example

```
const vector<int,int,long,long> vec(1,2,3,4);
assert(filter<int>(vec) == make_vector(1,2));
```

filter_if

Description

For a given sequence, `filter_if` returns a new sequences containing only the elements with types for which a given MPL Lambda Expression evaluates to `boost::mpl::true_`.

Synopsis

```
template<
    typename Pred,
    typename Sequence
    >
typename result_of::filter_if<Sequence const, Pred>::type filter_if(Sequence const& seq);
```

Table 65. Parameters

Parameter	Requirement	Description
`seq`	A model of Forward Sequence	Operation's argument
`Pred`	A unary MPL Lambda Expression	The predicate to filter by

Expression Semantics

```
filter_if<Pred>(seq);
```

Return type:

- A model of Forward Sequence.
- A model of Associative Sequence if `seq` implements the Associative Sequence model.

Semantics: Returns a sequence containing all the elements of `seq` with types for which `Pred` evaluates to `boost::mpl::true_`. The order of the retained elements is the same as in the original sequence.

Complexity

Constant. Returns a view which is lazily evaluated.

Header

```
#include <boost/fusion/algorithm/transformation/filter_if.hpp>
#include <boost/fusion/include/filter_if.hpp>
```

Example

```
const vector<int,int,double,double> vec(1,2,3.0,4.0);
assert(filter_if<is_integral<mpl::_> >(vec) == make_vector(1,2));
```

transform

Description

For a sequence `seq` and function object or function pointer `f`, `transform` returns a new sequence with elements created by applying `f(e)` to each element of `e` of `seq`.

Unary version synopsis

```
template<
    typename Sequence,
    typename F
    >
typename result_of::transform<Sequence const, F>::type transform(
    Sequence const& seq, F f);
```

Table 66. Parameters

Parameter	Requirement	Description
`seq`	A model of Forward Sequence	Operation's argument
`f`	`f(e)` is a valid expression for each element `e` of `seq`. `boost::result_of<F(E)>::type` is the return type of `f` when called with a value of each element type `E`.	Transformation function

Expression Semantics

```
transform(seq, f);
```

Return type: A model of Forward Sequence

Semantics: Returns a new sequence, containing the return values of `f(e)` for each element `e` within `seq`.

Binary version synopsis

```
template<
    typename Sequence1,
    typename Sequence2,
    typename F
    >
typename result_of::transform<Sequence1 const, Sequence2 const, F>::type transform(
    Sequence1 const& seq1, Sequence2 const& seq2, F f);
```

Table 67. Parameters

Parameter	Requirement	Description
`seq1`	A model of Forward Sequence	Operation's argument
`seq2`	A model of Forward Sequence	Operation's argument
`f`	`f(e1,e2)` is a valid expression for each pair of elements `e1` of `seq1` and `e2` of `seq2`. `boost::result_of<F(E1,E2)>::type` is the return type of `f` when called with elements of type `E1` and `E2`	Transformation function

Return type: A model of Forward Sequence.

Semantics: Returns a new sequence, containing the return values of `f(e1, e2)` for each pair of elements `e1` and `e2` within `seq1` and `seq2` respectively.

Complexity

Constant. Returns a view which is lazily evaluated.

Header

```
#include <boost/fusion/algorithm/transformation/transform.hpp>
#include <boost/fusion/include/transform.hpp>
```

Example

```
struct triple
{
    typedef int result_type;

    int operator()(int t) const
    {
        return t * 3;
    };
};
...
assert(transform(make_vector(1,2,3), triple()) == make_vector(3,6,9));
```

replace

Description

Replaces each value within a sequence of a given type and value with a new value.

Synopsis

```
template<
    typename Sequence,
    typename T
    >
typename result_of::replace<Sequence const, T>::type replace(
    Sequence const& seq, T const& old_value, T const& new_value);
```

Table 68. Parameters

Parameter	Requirement	Description
`seq`	A model of Forward Sequence, `e == old_value` is a valid expression, convertible to `bool`, for each element `e` in `seq` with type convertible to `T`	Operation's argument
`old_value`	Any type	Value to replace
`new_value`	Any type	Replacement value

Expression Semantics

```
replace(seq, old_value, new_value);
```

Return type: A model of Forward Sequence.

Semantics: Returns a new sequence with all the values of `seq` with `new_value` assigned to elements with the same type and equal to `old_value`.

Complexity

Constant. Returns a view which is lazily evaluated.

Header

```
#include <boost/fusion/algorithm/transformation/replace.hpp>
#include <boost/fusion/include/replace.hpp>
```

Example

```
assert(replace(make_vector(1,2), 2, 3) == make_vector(1,3));
```

replace_if

Description

Replaces each element of a given sequence for which an unary function object evaluates to `true` replaced with a new value.

Synopsis

```
template<
    typename Sequence,
    typename F,
    typename T>
typename result_of::replace_if<Sequence const, F, T>::type replace_if(
    Sequence const& seq, F f, T const& new_value);
```

Table 69. Parameters

Parameter	Requirement	Description
`seq`	A model of Forward Sequence	Operation's argument
`f`	A function object for which `f(e)` is a valid expression, convertible to `bool`, for each element `e` in `seq`	Operation's argument
`new_value`	Any type	Replacement value

Expression Semantics

```
replace_if(seq, f, new_value);
```

Return type: A model of Forward Sequence.

Semantics: Returns a new sequence with all the elements of `seq`, with `new_value` assigned to each element for which `f` evaluates to `true`.

Complexity

Constant. Returns a view which is lazily evaluated.

Header

```
#include <boost/fusion/algorithm/transformation/replace_if.hpp>
#include <boost/fusion/include/replace_if.hpp>
```

Example

```
struct odd
{
    template<typename T>
    bool operator()(T t) const
    {
        return t % 2;
    }
};
...
assert(replace_if(make_vector(1,2), odd(), 3) == make_vector(3,2));
```

remove

Description

Returns a new sequence, with all the elements of the original sequence, except those of a given type.

Synopsis

```
template<
    typename T,
    typename Sequence
    >
typename result_of::remove<Sequence const, T>::type replace(Sequence const& seq);
```

Table 70. Parameters

Parameter	Requirement	Description
`seq`	A model of Forward Sequence	Operation's argument
`T`	Any type	Type to remove

Expression Semantics

```
remove<T>(seq);
```

Return type:

- A model of Forward Sequence.
- A model of Associative Sequence if `Sequence` implements the Associative Sequence model.

Semantics: Returns a new sequence, containing all the elements of `seq`, in their original order, except those of type `T`. Equivalent to `remove_if<boost::is_same<_,T> >(seq)`.

Complexity

Constant. Returns a view which is lazily evaluated.

Header

```
#include <boost/fusion/algorithm/transformation/remove.hpp>
#include <boost/fusion/include/remove.hpp>
```

Example

```
const vector<int,double> vec(1,2.0);
assert(remove<double>(vec) == make_vector(1));
```

remove_if

Description

Returns a new sequence, containing all the elements of the original except those where a given unary function object evaluates to `true`.

Synopsis

```
template<
    typename Pred,
    typename Sequence
    >
typename result_of::remove_if<Sequence const, Pred>::type remove_if(Sequence const& seq);
```

Table 71. Parameters

Parameter	Requirement	Description
`seq`	A model of Forward Sequence	Operation's argument
`Pred`	A model of unary MPL Lambda Expression	Removal predicate

Expression Semantics

```
remove_if<Pred>(seq);
```

Return type:

- A model of Forward Sequence.
- A model of Associative Sequence if `seq` implements the Associative Sequence model.

Semantics: Returns a new sequence, containing all the elements of `seq`, in their original order, except those elements with types for which `Pred` evaluates to `boost::mpl::true_`. Equivalent to `filter<boost::mpl::not_<Pred> >(seq)`.

Complexity

Constant. Returns a view which is lazily evaluated.

Header

```
#include <boost/fusion/algorithm/transformation/remove_if.hpp>
#include <boost/fusion/include/remove_if.hpp>
```

Example

```
const vector<int,double> vec(1,2.0);
assert(remove_if<is_floating_point<mpl::_> >(vec) == make_vector(1));
```

reverse

Description

Returns a new sequence with the elements of the original in reverse order.

Synopsis

```
template<
    typename Sequence
    >
typename result_of::reverse<Sequence const>::type reverse(Sequence const& seq);
```

Table 72. Parameters

Parameter	Requirement	Description
`seq`	A model of Bidirectional Sequence	Operation's argument

Expression Semantics

```
reverse(seq);
```

Return type:

- A model of Bidirectional Sequence if `seq` is a Bidirectional Sequence else, Random Access Sequence if `seq` is a Random Access Sequence.
- A model of Associative Sequence if `seq` implements the Associative Sequence model.

Semantics: Returns a new sequence containing all the elements of `seq` in reverse order.

Complexity

Constant. Returns a view which is lazily evaluated.

Header

```
#include <boost/fusion/algorithm/transformation/reverse.hpp>
#include <boost/fusion/include/reverse.hpp>
```

Example

```
assert(reverse(make_vector(1,2,3)) == make_vector(3,2,1));
```

clear

Description

`clear` returns an empty sequence.

Synopsis

```
template<
    typename Sequence
    >
typename result_of::clear<Sequence const>::type clear(Sequence const& seq);
```

Table 73. Parameters

Parameter	Requirement	Description
`seq`	A model of Forward Sequence	Operation's argument

Expression Semantics

```
clear(seq);
```

Return type: A model of Forward Sequence.

Expression Semantics: Returns a sequence with no elements.

Complexity

Constant.

Header

```
#include <boost/fusion/algorithm/transformation/clear.hpp>
#include <boost/fusion/include/clear.hpp>
```

Example

```
assert(clear(make_vector(1,2,3)) == make_vector());
```

erase

Description

Returns a new sequence, containing all the elements of the original except those at a specified iterator, or between two iterators.

Synopsis

```
template<
    typename Sequence,
    typename First
    >
typename result_of::erase<Sequence const, First>::type erase(
    Sequence const& seq, First const& it1);

template<
    typename Sequence,
    typename First,
    typename Last
    >
typename result_of::erase<Sequence const, First, Last>::type erase(
    Sequence const& seq, First const& it1, Last const& it2);
```

Table 74. Parameters

Parameters	Requirement	Description
`seq`	A model of Forward Sequence	Operation's argument
`it1`	A model of Forward Iterator	Iterator into `seq`
`it2`	A model of Forward Iterator	Iterator into `seq` after `it1`

Expression Semantics

```
erase(seq, pos);
```

Return type:

- A model of Forward Sequence.
- A model of Associative Sequence if `seq` implements the Associative Sequence model.

Semantics: Returns a new sequence, containing all the elements of `seq` except the element at `pos`.

```
erase(seq, first, last);
```

Return type:

- A model of Forward Sequence.
- A model of Associative Sequence if `seq` implements the Associative Sequence model.

Semantics: Returns a new sequence, with all the elements of `seq`, in their original order, except those in the range [`first`,`last`).

Complexity

Constant. Returns a view which is lazily evaluated.

Header

```
#include <boost/fusion/algorithm/transformation/erase.hpp>
#include <boost/fusion/include/erase.hpp>
```

Example

```
const vector<int, double, char> vec(1, 2.0, 'c');
assert(erase(vec, next(begin(vec))) == make_vector(1, 'c'));
assert(erase(vec, next(begin(vec)), end(vec)) == make_vector(1));
```

erase_key

Description

For an associative] Forward Sequence `seq`, returns a associative] Forward Sequence containing all the elements of the original except those with a given key.

Synopsis

```
template<
    typename Key,
    typename Sequence
    >
typename result_of::erase_key<Sequence const, Key>::type erase_key(Sequence const& seq);
```

Table 75. Parameters

Parameter	Requirement	Description
`seq`	A model of Forward Sequence and Associative Sequence	Operation's argument
`Key`	Any type	Key to erase

Expression Semantics

```
erase_key<Key>(seq);
```

Return type: A model of Forward Sequence and Associative Sequence.

Semantics: Returns a new sequence, containing all the elements of `seq`, except those with key `Key`.

Complexity

Constant. Returns a view which is lazily evaluated.

Header

```
#include <boost/fusion/algorithm/transformation/erase_key.hpp>
#include <boost/fusion/include/erase_key.hpp>
```

Example

```
assert(erase_key<int>(make_map<int, long>('a', 'b')) == make_map<long>('b'));
```

insert

Description

Returns a new sequence with all the elements of the original, an a new element inserted the position described by a given iterator.

Synopsis

```
template<
    typename Sequence,
    typename Pos,
    typename T
    >
typename result_of::insert<Sequence const, Pos, T>::type insert(
    Sequence const& seq, Pos const& pos, T const& t);
```

Table 76. Parameters

Parameter	Requirement	Description
`seq`	A model of Forward Sequence	Operation's argument
`pos`	A model of Forward Iterator	The position to insert at
`t`	Any type	The value to insert

Expression Semantics

```
insert(seq, p, t);
```

Return type:

- A model of Forward Sequence.

Semantics: Returns a new sequence, containing all the elements of `seq`, in their original order, and a new element with the type and value of `t` inserted at iterator `pos`.

Complexity

Constant. Returns a view which is lazily evaluated.

Header

```
#include <boost/fusion/algorithm/transformation/insert.hpp>
#include <boost/fusion/include/insert.hpp>
```

Example

```
const vector<int,int> vec(1,2);
assert(insert(vec, next(begin(vec)), 3) == make_vector(1,3,2));
```

insert_range

Description

Returns a new sequence with another sequence inserted at a specified iterator.

Synposis

```
template<
    typename Sequence,
    typename Pos,
    typename Range
    >
typename result_of::insert_range<Sequence const, Pos, Range>::type insert_range(
    Sequence const& seq, Pos const& pos, Range const& range);
```

Table 77. Parameters

Parameter	Requirement	Description
`seq`	A model of Forward Sequence	Operation's argument
`pos`	A model of Forward Iterator	The position to insert at
`range`	A model of Forward Sequence	Range to insert

Expression Semantics

```
insert_range(seq, pos, range);
```

Return type:

- A model of Forward Sequence.
- A model of Associative Sequence if `seq` implements the Associative Sequence model.

Semantics: Returns a new sequence, containing all the elements of `seq`, and the elements of `range` inserted at iterator `pos`. All elements retaining their ordering from the orignal sequences.

Complexity

Constant. Returns a view which is lazily evaluated.

Header

```
#include <boost/fusion/algorithm/transformation/insert_range.hpp>
#include <boost/fusion/include/insert_range.hpp>
```

Example

```
const vector<int,int> vec(1,2);
assert(insert_range(vec, next(begin(vec)), make_vector(3,4)) == make_vector(1,3,4,2));
```

join

Description

Takes 2 sequences and returns a sequence containing the elements of the first followed by the elements of the second.

Synopsis

```
template<
    typename LhSequence,
    typename RhSequence>
typename result_of::join<LhSequence, RhSequence>::type join(Lh↵
Sequence const& lhs, RhSequence const& rhs);
```

Table 78. Parameters

Parameter	Requirement	Description
`lhs`	A model of Forward Sequence	Operation's argument
`rhs`	A model of Forward Sequence	Operation's argument

Expression Semantics

```
join(lhs, rhs);
```

Return type:

- A model of Forward Sequence.
- A model of Associative Sequence if `lhs` and `rhs` implement the Associative Sequence model.

Semantics: Returns a sequence containing all the elements of `lhs` followed by all the elements of `rhs`. The order of the elements is preserved.

Complexity

Constant. Returns a view which is lazily evaluated.

Header

```
#include <boost/fusion/algorithm/transformation/join.hpp>
#include <boost/fusion/include/join.hpp>
```

Example

```
vector<int,char> v1(1, 'a');
vector<int,char> v2(2, 'b');
assert(join(v1, v2) == make_vector(1,'a',2,'b'));
```

zip

Description

Zips sequences together to form a single sequence, whos members are tuples of the members of the component sequences.

Synopsis

```
template<
    typename Sequence1,
    typename Sequence2,
    ...
    typename SequenceN
    >
typename result_of::zip<Sequence1, Sequence2, ... SequenceN>::type
zip(Sequence1 const& seq1, Sequence2 const& seq2, ... SequenceN const& seqN);
```

Table 79. Parameters

Parameter	Requirement	Description
`seq1` to `seqN`	Each sequence is a model of Forward Sequence.	Operation's argument

Expression Semantics

```
zip(seq1, seq2, ... seqN);
```

Return type: A model of Forward Sequence.

Semantics: Returns a sequence containing tuples of elements from sequences `seq1` to `seqN`. For example, applying zip to tuples `(1, 2, 3)` and `('a', 'b', 'c')` would return `((1, 'a'),(2, 'b'),(3, 'c'))`

Complexity

Constant. Returns a view which is lazily evaluated.

Header

```
#include <boost/fusion/algorithm/transformation/zip.hpp>
#include <boost/fusion/include/zip.hpp>
```

Example

```
vector<int,char> v1(1, 'a');
vector<int,char> v2(2, 'b');
assert(zip(v1, v2) == make_vector(make_vector(1, 2),make_vector('a', 'b'));
```

pop_back

Description

Returns a new sequence, with the last element of the original removed.

Synopsis

```
template<
    typename Sequence
    >
typename result_of::pop_back<Sequence const>::type pop_back(Sequence const& seq);
```

Table 80. Parameters

Parameter	Requirement	Description
`seq`	A model of Forward Sequence	Operation's argument

Expression Semantics

```
pop_back(seq);
```

Return type:

- A model of Forward Sequence.
- A model of Associative Sequence if `seq` implements the Associative Sequence model.

Semantics: Returns a new sequence containing all the elements of `seq`, except the last element. The elements in the new sequence are in the same order as they were in `seq`.

Complexity

Constant. Returns a view which is lazily evaluated.

Header

```
#include <boost/fusion/algorithm/transformation/pop_back.hpp>
#include <boost/fusion/include/pop_back.hpp>
```

Example

```
assert(___pop_back__(make_vector(1,2,3)) == make_vector(1,2));
```

pop_front

Description

Returns a new sequence, with the first element of the original removed.

Synopsis

```
template<
    typename Sequence
    >
typename result_of::pop_front<Sequence const>::type pop_front(Sequence const& seq);
```

Table 81. Parameters

Parameter	Requirement	Description
`seq`	A model of Forward Sequence	Operation's argument

Expression Semantics

```
pop_front(seq);
```

Return type:

- A model of Forward Sequence.
- A model of Associative Sequence if `seq` implements the Associative Sequence model.

Semantics: Returns a new sequence containing all the elements of `seq`, except the first element. The elements in the new sequence are in the same order as they were in `seq`.

Complexity

Constant. Returns a view which is lazily evaluated.

Header

```
#include <boost/fusion/algorithm/transformation/pop_front.hpp>
#include <boost/fusion/include/pop_front.hpp>
```

Example

```
assert(pop_front(make_vector(1,2,3)) == make_vector(2,3));
```

push_back

Description

Returns a new sequence with an element added at the end.

Synopsis

```
template<
    typename Sequence,
    typename T
    >
typename result_of::push_back<Sequence, T>::type push_back(
    Sequence const& seq, T const& t);
```

Table 82. Parameters

Parameter	Requirement	Description
`seq`	A model of Forward Sequence	Operation's argument
`t`	Any type	The value to add to the end

Expression Semantics

```
push_back(seq, t);
```

Return type:

- A model of Forward Sequence.

Semantics: Returns a new sequence, containing all the elements of `seq`, and new element `t` appended to the end. The elements are in the same order as they were in `seq`.

Complexity

Constant. Returns a view which is lazily evaluated.

Header

```
#include <boost/fusion/algorithm/transformation/push_back.hpp>
#include <boost/fusion/include/push_back.hpp>
```

Example

```
assert(push_back(make_vector(1,2,3),4) == make_vector(1,2,3,4));
```

push_front

Description

Returns a new sequence with an element added at the beginning.

Synopsis

```
template<
    typename Sequence,
    typename T
    >
typename result_of::push_front<Sequence, T>::type push_front(
    Sequence const& seq, T const& t);
```

Table 83. Parameters

Parameter	Requirement	Description
`seq`	A model of Forward Sequence	Operation's argument
`t`	Any type	The value to add to the beginning

Expression Semantics

```
push_back(seq, t);
```

Return type:

- A model of Forward Sequence.

Semantics: Returns a new sequence, containing all the elements of `seq`, and new element `t` appended to the beginning. The elements are in the same order as they were in `seq`.

Complexity

Constant. Returns a view which is lazily evaluated.

Header

```
#include <boost/fusion/algorithm/transformation/push_front.hpp>
#include <boost/fusion/include/push_front.hpp>
```

Example

```
assert(push_front(make_vector(1,2,3),0) == make_vector(0,1,2,3));
```

Metafunctions

filter

Description

Returns the result type of `filter` given the sequence type and type to retain.

Synopsis

```
template<
    typename Sequence,
    typename T
    >
struct filter
{
    typedef unspecified type;
};
```

Table 84. Parameter

Parameter	Requirement	Description
`Sequence`	A model of Forward Sequence	Operation's argument
`T`	Any type	Type to retain

Expression Semantics

```
result_of::filter<Sequence, T>::type
```

Return type:

- A model of Forward Sequence.
- A model of Associative Sequence if `Sequence` implements the Associative Sequence model.

Semantics: Returns a sequence containing the elements of `Sequence` that are of type `T`. Equivalent to `result_of::filter_if<Sequence, boost::is_same<mpl::_, T> >::type`.

Complexity

Constant.

Header

```
#include <boost/fusion/algorithm/transformation/filter.hpp>
#include <boost/fusion/include/filter.hpp>
```

filter_if

Description

Returns the result type of `filter_if` given the sequence and unary MPL Lambda Expression predicate type.

Synopsis

```
template<
    typename Sequence,
    typename Pred
    >
struct filter_if
{
    typedef unspecified type;
};
```

Table 85. Parameter

Parameter	Requirement	Description
`Sequence`	A model of Forward Sequence	Operation's argument
`Pred`	A unary MPL Lambda Expression	Type to retain

Expression Semantics

```
result_of::filter_if<Sequence, Pred>::type
```

Return type:

- A model of Forward Sequence.
- A model of Associative Sequence if `Sequence` implements the Associative Sequence model.

Semantics: Returns a sequence containing the elements of `Sequence` for which `Pred` evaluates to `boost::mpl::true_`.

Complexity

Constant.

Header

```
#include <boost/fusion/algorithm/transformation/filter_if.hpp>
#include <boost/fusion/include/filter_if.hpp>
```

transform

Description

For a sequence `seq` and function object or function pointer `f`, `transform` returns a new sequence with elements created by applying `f(e)` to each element of `e` of `seq`.

Unary version synopsis

```
template<
    typename Sequence,
    typename F
    >
typename result_of::transform<Sequence const, F>::type transform(
    Sequence const& seq, F f);
```

Table 86. Parameters

Parameter	Requirement	Description
`seq`	A model of Forward Sequence	Operation's argument
`f`	`f(e)` is a valid expression for each element `e` of `seq`. `boost::result_of<F(E)>::type` is the return type of `f` when called with a value of each element type `E`.	Transformation function

Expression Semantics

```
transform(seq, f);
```

Return type:

- A model of Forward Sequence
- A model of Associative Sequence if `Sequence` implements the Associative Sequence model.

Semantics: Returns a new sequence, containing the return values of `f(e)` for each element `e` within `seq`.

Binary version synopsis

```
template<
    typename Sequence1,
    typename Sequence2,
    typename F
    >
typename result_of::transform<Sequence1 const, Sequence2 const, F>::type transform(
    Sequence1 const& seq1, Sequence2 const& seq2, F f);
```

Table 87. Parameters

Parameter	Requirement	Description
`seq1`	A model of Forward Sequence	Operation's argument
`seq2`	A model of Forward Sequence	Operation's argument
`f`	`f(e1,e2)` is a valid expression for each pair of elements `e1` of `seq1` and `e2` of `seq2`. `boost::result_of<F(E1,E2)>::type` is the return type of `f` when called with elements of type `E1` and `E2`	Transformation function

Return type: A model of Forward Sequence.

Semantics: Returns a new sequence, containing the return values of `f(e1, e2)` for each pair of elements `e1` and `e2` within `seq1` and `seq2` respectively.

Complexity

Constant. Returns a view which is lazily evaluated.

Header

```
#include <boost/fusion/algorithm/transformation/transform.hpp>
#include <boost/fusion/include/transform.hpp>
```

Example

```
struct triple
{
    typedef int result_type;

    int operator()(int t) const
    {
        return t * 3;
    };
};
...
assert(transform(make_vector(1,2,3), triple()) == make_vector(3,6,9));
```

replace

Description

Returns the result type of `replace`, given the types of the input sequence and element to replace.

Synopsis

```
template<
    typename Sequence,
    typename T
    >
struct replace
{
    typedef unspecified type;
};
```

Table 88. Parameters

Parameter	Requirement	Description
`Sequence`	A model of Forward Sequence	Operation's argument
`T`	Any type	The type of the search and replacement objects

Expression Semantics

```
result_of::replace<Sequence,T>::type
```

Return type: A model of Forward Sequence.

Semantics: Returns the return type of `replace`.

Complexity

Constant.

Header

```
#include <boost/fusion/algorithm/transformation/replace.hpp>
#include <boost/fusion/include/replace.hpp>
```

replace_if

Description

Returns the result type of `replace_if`, given the types of the sequence, Polymorphic Function Object predicate and replacement object.

Synopsis

```
template<
    typename Sequence,
    typename F,
    typename T>
struct replace_if
{
    typedef unspecified type;
};
```

Table 89. Parameters

Parameter	Requirement	Description
`Sequence`	A model of Forward Sequence	Operation's argument
`F`	A model of unary Polymorphic Function Object	Replacement predicate
`T`	Any type	The type of the replacement object

Expression Semantics

```
result_of::replace_if<Sequence,F,T>::type
```

Return type: A model of Forward Sequence.

Semantics: Returns the return type of `replace_if`.

Complexity

Constant.

Header

```
#include <boost/fusion/algorithm/transformation/replace_if.hpp>
#include <boost/fusion/include/replace_if.hpp>
```

remove

Description

Returns the result type of `remove`, given the sequence and removal types.

Synopsis

```
template<
    typename Sequence,
    typename T
    >
struct remove
{
    typedef unspecified type;
};
```

Table 90. Parameters

Parameter	Requirement	Description
`Sequence`	A model of Forward Sequence	Operation's argument
`T`	Any type	Remove elements of this type

Expression Semantics

```
result_of::remove<Sequence, T>::type
```

Return type:

- A model of Forward Sequence.
- A model of Associative Sequence if `Sequence` implements the Associative Sequence model.

Semantics: Returns a sequence containing the elements of `Sequence` not of type `T`. Equivalent to `result_of::replace_if<Sequence, boost::is_same<mpl::_, T> >::type`.

Complexity

Constant.

Header

```
#include <boost/fusion/algorithm/transformation/remove.hpp>
#include <boost/fusion/include/remove.hpp>
```

remove_if

Description

Returns the result type of `remove_if`, given the input sequence and unary MPL Lambda Expression predicate types.

Synopsis

```
template<
    typename Sequence,
    typename Pred
    >
struct remove_if
{
    typedef unspecified type;
};
```

Table 91. Parameters

Parameter	Requirement	Description
`Sequence`	A model of Forward Sequence	Operation's argument
`Pred`	A model of unary MPL Lambda Expression	Remove elements which evaluate to `boost::mpl::true_`

Expression Semantics

```
result_of::remove_if<Sequence, Pred>::type
```

Return type:

- A model of Forward Sequence.
- A model of Associative Sequence if `Sequence` implements the Associative Sequence model.

Semantics: Returns a sequence containing the elements of `Sequence` for which `Pred` evaluates to `boost::mpl::false_`.

Complexity

Constant.

Header

```
#include <boost/fusion/algorithm/transformation/remove_if.hpp>
#include <boost/fusion/include/remove_if.hpp>
```

reverse

Description

Returns the result type of `reverse`, given the input sequence type.

Synopsis

```
template<
    typename Sequence
    >
struct reverse
{
    typedef unspecified type;
};
```

Table 92. Parameters

Parameter	Requirement	Description
`Sequence`	A model of Bidirectional Sequence	Operation's argument

Expression Semantics

```
result_of::reverse<Sequence>::type
```

Return type:

- A model of Bidirectional Sequence if `Sequence` is a Bidirectional Sequence else, Random Access Sequence if `Sequence` is a Random Access Sequence.
- A model of Associative Sequence if `Sequence` implements the Associative Sequence model.

Semantics: Returns a sequence with the elements in the reverse order to `Sequence`.

Complexity

Constant.

Header

```
#include <boost/fusion/algorithm/transformation/reverse.hpp>
#include <boost/fusion/include/reverse.hpp>
```

clear

Description

Returns the result type of `clear`, given the input sequence type.

Synopsis

```
template<
    typename Sequence
    >
struct clear
{
    typedef unspecified type;
};
```

Table 93. Parameters

Parameter	Requirement	Description
`Sequence`	Any type	Operation's argument

Expression Semantics

```
result_of::clear<Sequence>::type
```

Return type: A model of Forward Sequence.

Semantics: Returns an empty sequence.

Complexity

Constant.

Header

```
#include <boost/fusion/algorithm/transformation/clear.hpp>
#include <boost/fusion/include/clear.hpp>
```

erase

Returns the result type of `erase`, given the input sequence and range delimiting iterator types.

Description

Synopsis

```
template<
    typename Sequence,
    typename It1,
    typename It2 = unspecified>
struct erase
{
    typedef unspecified type;
};
```

Table 94. Parameters

Parameter	Requirement	Description
`Sequence`	A model of Forward Sequence	Operation's argument
`It1`	A model of Forward Iterator	Operation's argument
`It2`	A model of Forward Iterator	Operation's argument

Expression Semantics

```
result_of::erase<Sequence, It1>::type
```

Return type:

- A model of Forward Sequence.
- A model of Associative Sequence if `Sequence` implements the Associative Sequence model.

Semantics: Returns a new sequence with the element at `It1` removed.

```
result_of::erase<Sequence, It1, It2>::type
```

Return type: A model of Forward Sequence.

Semantics: Returns a new sequence with the elements between `It1` and `It2` removed.

Complexity

Constant.

Header

```
#include <boost/fusion/algorithm/transformation/erase.hpp>
#include <boost/fusion/include/erase.hpp>
```

erase_key

Description

Returns the result type of `erase_key`, given the sequence and key types.

Synopsis

```
template<
    typename Sequence,
    typename Key
    >
struct erase_key
{
    typedef unspecified type;
};
```

Table 95. Parameters

Parameter	Requirement	Description
`Sequence`	A model of Forward Sequence and Associative Sequence	Operation's argument
`Key`	Any type	Key type

Expression Semantics

```
result_of::erase_key<Sequence, Key>::type
```

Return type: A model of Forward Sequence and Associative Sequence.

Semantics: Returns a sequence with the elements of `Sequence`, except those with key `Key`.

Complexity

Constant.

Header

```
#include <boost/fusion/algorithm/transformation/erase_key.hpp>
#include <boost/fusion/include/erase_key.hpp>
```

insert

Description

Returns the result type of `insert`, given the sequence, position iterator and insertion types.

Synopsis

```
template<
    typename Sequence,
    typename Position,
    typename T
    >
struct insert
{
    typedef unspecified type;
};
```

Table 96. Parameters

Parameter	**Requirement**	**Description**
`Sequence`	A model of Forward Sequence	Operation's argument
`Position`	A model of Forward Iterator	Operation's argument
`T`	Any type	Operation's argument

Expression Semantics

```
result_of::insert<Sequence, Position, T>::type
```

Return type:

- A model of Forward Sequence.

Semantics: Returns a sequence with an element of type `T` inserted at position `Position` in `Sequence`.

Complexity

Constant.

Header

```
#include <boost/fusion/algorithm/transformation/insert.hpp>
#include <boost/fusion/include/insert.hpp>
```

insert_range

Description

Returns the result type of `insert_range`, given the input sequence, position iterator and insertion range types.

Synopsis

```
template<
    typename Sequence,
    typename Position,
    typename Range
    >
struct insert_range
{
    typedef unspecified type;
};
```

Table 97. Parameters

Parameter	Requirement	Description
`Sequence`	A model of Forward Sequence	Operation's argument
`Position`	A model of Forward Iterator	Operation's argument
`Range`	A model of Forward Sequence	Operation's argument

Expression Semantics

```
result_of::insert_range<Sequence, Position, Range>::type
```

Return type:

- A model of Forward Sequence.
- A model of Associative Sequence if `Sequence` implements the Associative Sequence model.

Semantics: Returns a sequence with the elements of `Range` inserted at position `Position` into `Sequence`.

Complexity

Constant.

Header

```
#include <boost/fusion/algorithm/transformation/insert_range.hpp>
#include <boost/fusion/include/insert_range.hpp>
```

join

Description

Returns the result of joining 2 sequences, given the sequence types.

Synopsis

```
template<
    typename LhSequence,
    typename RhSequence
    >
struct join
{
    typedef unspecified type;
};
```

Expression Semantics

```
result_of::join<LhSequence, RhSequence>::type
```

Return type:

- A model of Forward Sequence.
- A model of Associative Sequence if `LhSequence` amd `RhSequence` implement the Associative Sequence model.

Semantics: Returns a sequence containing the elements of `LhSequence` followed by the elements of `RhSequence`. The order of the elements in the 2 sequences is preserved.

Complexity

Constant.

Header

```
#include <boost/fusion/algorithm/transformation/join.hpp>
#include <boost/fusion/include/join.hpp>
```

zip

Description

Zips sequences together to form a single sequence, whos members are tuples of the members of the component sequences.

Synopsis

```
template<
    typename Sequence1,
    typename Sequence2,
    ...
    typename SequenceN
    >
struct zip
{
    typedef unspecified type;
};
```

Expression Semantics

```
result_of::zip<Sequence1, Sequence2, ... SequenceN>::type
```

Return type: A model of the most restrictive traversal category of sequences `Sequence1` to `SequenceN`.

Semantics: Return a sequence containing tuples of elements from each sequence. For example, applying zip to tuples `(1, 2, 3)` and `('a', 'b', 'c')` would return `((1, 'a'),(2, 'b'),(3, 'c'))`

Complexity

Constant.

Header

```
#include <boost/fusion/algorithm/transformation/zip.hpp>
#include <boost/fusion/include/zip.hpp>
```

pop_back

Description

Returns the result type of `pop_back`, given the input sequence type.

Synopsis

```
template<
    typename Sequence
    >
struct pop_back
{
    typedef unspecified type;
};
```

Table 98. Parameters

Parameter	Requirement	Description
`Sequence`	A model of Forward Sequence	Operation's argument

Expression Semantics

```
result_of::pop_back<Sequence>::type
```

Return type:

- A model of Forward Sequence.
- A model of Associative Sequence if `Sequence` implements the Associative Sequence model.

Semantics: Returns a sequence with all the elements of `Sequence` except the last element.

Complexity

Constant.

Header

```
#include <boost/fusion/algorithm/transformation/pop_back.hpp>
#include <boost/fusion/include/pop_back.hpp>
```

pop_front

Description

Returns the result type of `pop_front`, given the input sequence type.

Synopsis

```
template<
    typename Sequence
    >
struct pop_front
{
    typedef unspecified type;
};
```

Table 99. Parameters

Parameter	Requirement	Description
`Sequence`	A model of Forward Sequence	Operation's argument

Expression Semantics

```
result_of::pop_front<Sequence>::type
```

Return type:

- A model of Forward Sequence.
- A model of Associative Sequence if `Sequence` implements the Associative Sequence model.

Semantics: Returns a sequence with all the elements of `Sequence` except the first element.

Complexity

Constant.

Header

```
#include <boost/fusion/algorithm/transformation/pop_front.hpp>
#include <boost/fusion/include/pop_front.hpp>
```

push_back

Description

Returns the result type of `push_back`, given the types of the input sequence and element to push.

Synopsis

```
template<
    typename Sequence,
    typename T
    >
struct push_back
{
    typedef unspecified type;
};
```

Table 100. Parameters

Parameter	Requirement	Description
`Sequence`	A model of Forward Sequence	Operation's argument
`T`	Any type	Operation's argument

Expression Semantics

```
result_of::push_back<Sequence, T>::type
```

Return type:

- A model of Forward Sequence.

Semantics: Returns a sequence with the elements of `Sequence` and an element of type `T` added to the end.

Complexity

Constant.

Header

```
#include <boost/fusion/algorithm/transformation/push_back.hpp>
#include <boost/fusion/include/push_back.hpp>
```

push_front

Description

Returns the result type of `push_front`, given the types of the input sequence and element to push.

Synopsis

```
template<
    typename Sequence,
    typename T
    >
struct push_front
{
    typedef unspecified type;
};
```

Table 101. Parameters

Parameter	Requirement	Description
`Sequence`	A model of Forward Sequence	Operation's argument
`T`	Any type	Operation's argument

Expression Semantics

```
result_of::push_front<Sequence, T>::type
```

Return type:

- A model of Forward Sequence.

Semantics: Returns a sequence with the elements of `Sequence` and an element of type `T` added to the beginning.

Complexity

Constant.

Header

```
#include <boost/fusion/algorithm/transformation/push_front.hpp>
#include <boost/fusion/include/push_front.hpp>
```

Tuple

The TR1 technical report describes extensions to the C++ standard library. Many of these extensions will be considered for the next iteration of the C++ standard. TR1 describes a tuple type, and support for treating `std::pair` as a type of tuple.

Fusion provides full support for the TR1 Tuple interface, and the extended uses of `std::pair` described in the TR1 document.

Class template tuple

Fusion's implementation of the TR1 Tuple is also a fusion Forward Sequence. As such the fusion tuple type provides a lot of functionality beyond that required by TR1.

Currently tuple is basically a synonym for `vector`, although this may be changed in future releases of fusion.

Synopsis

```
template<
    typename T1 = unspecified,
    typename T2 = unspecified,
    ...
    typename TN = unspecified>
class tuple;
```

/tuple.hpp>

Construction

Description

The TR1 Tuple type provides a default constructor, a constructor that takes initializers for all of its elements, a copy constructor, and a converting copy constructor. The details of the various constructors are described in this section.

Specification

Notation

`T1 ... TN`, `U1 ... UN`	Tuple element types
`P1 ... PN`	Parameter types
`Ti`, `Ui`	The type of the `i`th element of a tuple
`Pi`	The type of the `i`th parameter

```
tuple();
```

Requirements: Each `Ti` is default constructable.

Semantics: Default initializes each element of the tuple.

```
tuple(P1,P2,...,PN);
```

Requirements: Each `Pi` is `Ti` if `Ti` is a reference type, `const Ti&` otherwise.

Semantics: Copy initializes each element with the corresponding parameter.

```
tuple(const tuple& t);
```

Requirements: Each `Ti` should be copy constructable.

Semantics: Copy constructs each element of `*this` with the corresponding element of `t`.

```
template<typename U1, typename U2, ..., typename UN>
tuple(const tuple<U1, U2, ..., UN>& t);
```

Requirements: Each `Ti` shall be constructible from the corresponding `Ui`.

Semantics: Constructs each element of `*this` with the corresponding element of `t`.

Tuple creation functions

Description

TR1 describes 2 utility functions for creating __tr1__tuple__s. `make_tuple` builds a tuple out of it's argument list, and `tie` builds a tuple of references to it's arguments. The details of these creation functions are described in this section.

Specification

```
template<typename T1, typename T2, ..., typename TN>
tuple<V1, V2, ..., VN> make_tuple(const T1& t1, const T2& t2, ..., const TN& tn);
```

Where `Vi` is `X&` if the cv-unqualified type `Ti` is `reference_wrapper<X>`, otherwise `Vi` is `Ti`.

Returns: `tuple<V1, V2, ..., VN>(t1, t2, ..., tN)`

```
template<typename T1, typename T2, ..., typename TN>
tuple<T1&, T2&, ..., TN&> tie(T1& t1, T2& t2, ..., TN& tn);
```

Returns: tuple<T1&, T2&, ..., TN&>(t1, t2, ..., tN). When argument `ti` is `ignore`, assigning any value to the corresponding tuple element has has no effect.

Tuple helper classes

Description

The TR1 Tuple provides 2 helper traits, for compile time access to the tuple size, and the element types.

Specification

```
tuple_size<T>::value
```

Requires: `T` is any fusion sequence type, including `tuple`.

Type: MPL Integral Constant

Value: The number of elements in the sequence. Equivalent to `result_of::size<T>::type`.

```
tuple_element<I, T>::type
```

Requires: `T` is any fusion sequence type, including `tuple`. `0 <= I < N` or the program is ill formed.

Value: The type of the `I`th element of `T`. Equivalent to `result_of::value_at<I,T>::type`.

Element access

Description

The TR1 Tuple provides the `get` function to provide access to it's elements by zero based numeric index.

Specification

```
template<int I, T>
RJ get(T& t);
```

Requires: `0 < I <= N`. The program is ill formed if `I` is out of bounds. `T` is any fusion sequence type, including `tuple`.

Return type: `RJ` is equivalent to `result_of::at_c<I,T>::type`.

Returns: A reference to the `I`th element of `T`.

```
template<int I, typename T>
PJ get(T const& t);
```

Requires: `0 < I <= N`. The program is ill formed if `I` is out of bounds. `T` is any fusion sequence type, including `tuple`.

Return type: `PJ` is equivalent to `result_of::at_c<I,T>::type`.

Returns: A const reference to the `I`th element of `T`.

Relational operators

Description

The TR1 Tuple provides the standard boolean relational operators.

Specification

Notation

`T1 ... TN`, `U1 ... UN`	Tuple element types
`P1 ... PN`	Parameter types
`Ti`, `Ui`	The type of the `i`th element of a tuple
`Pi`	The type of the `i`th parameter

```
template<typename T1, typename T2, ..., typename TN,
         typename U1, typename U2, ..., typename UN>
bool operator==(
    const tuple<T1, T2, ..., TN>& lhs,
    const tuple<U1, U2, ..., UN>& rhs);
```

Requirements: For all `i`, `1 <= i < N`, `get<i>(lhs) == get<i>(rhs)` is a valid expression returning a type that is convertible to `bool`.

Semantics: Returns `true` if and only if `get<i>(lhs) == get<i>(rhs)` for all `i`. For any 2 zero length tuples `e` and `f`, `e == f` returns `true`.

```
template<typename T1, typename T2, ..., typename TN,
         typename U1, typename U2, ..., typename UN>
bool operator<(
    const tuple<T1, T2, ..., TN>& lhs,
    const tuple<U1, U2, ..., UN>& rhs);
```

Requirements: For all `i`, `1 <= i < N`, `get<i>(lhs) < get<i>(rhs)` is a valid expression returning a type that is convertible to `bool`.

Semantics: Returns the lexicographical comparison of between `lhs` and `rhs`.

```
template<typename T1, typename T2, ..., typename TN,
         typename U1, typename U2, ..., typename UN>
bool operator!=(
    const tuple<T1, T2, ..., TN>& lhs,
    const tuple<U1, U2, ..., UN>& rhs);
```

Requirements: For all `i`, `1 <= i < N`, `get<i>(lhs) == get<i>(rhs)` is a valid expression returning a type that is convertible to `bool`.

Semantics: Returns `!(lhs == rhs)`.

```
template<typename T1, typename T2, ..., typename TN,
         typename U1, typename U2, ..., typename UN>
bool operator<=(
    const tuple<T1, T2, ..., TN>& lhs,
    const tuple<U1, U2, ..., UN>& rhs);
```

Requirements: For all `i`, `1 <= i < N`, `get<i>(rhs) < get<i>(lhs)` is a valid expression returning a type that is convertible to `bool`.

Semantics: Returns `!(rhs < lhs)`

```
template<typename T1, typename T2, ..., typename TN,
         typename U1, typename U2, ..., typename UN>
bool operator>(
    const tuple<T1, T2, ..., TN>& lhs,
    const tuple<U1, U2, ..., UN>& rhs);
```

Requirements: For all `i`, `1 <= i < N`, `get<i>(rhs) < get<i>(lhs)` is a valid expression returning a type that is convertible to `bool`.

Semantics: Returns `rhs < lhs`.

```
template<typename T1, typename T2, ..., typename TN,
         typename U1, typename U2, ..., typename UN>
bool operator>=(
    const tuple<T1, T2, ..., TN>& lhs,
    const tuple<U1, U2, ..., UN>& rhs);
```

Requirements: For all `i`, `1 <= i < N`, `get<i>(lhs) < get<i>(rhs)` is a valid expression returning a type that is convertible to `bool`.

Semantics: Returns `!(lhs < rhs)`.

Pairs

Description

The TR1 Tuple interface is specified to provide uniform access to `std::pair` as if it were a 2 element tuple.

Specification

```
tuple_size<std::pair<T1, T2> >::value
```

Type: An MPL Integral Constant

Value: Returns 2, the number of elements in a pair.

```
tuple_element<0, std::pair<T1, T2> >::type
```

Type: `T1`

Value: Returns the type of the first element of the pair

```
tuple_element<1, std::pair<T1, T2> >::type
```

Type: `T2`

Value: Returns thetype of the second element of the pair

```
template<int I, typename T1, typename T2>
P& get(std::pair<T1, T2>& pr);

template<int I, typename T1, typename T2>
const P& get(const std::pair<T1, T2>& pr);
```

Type: If `I == 0` `P` is `T1`, else if `I == 1` `P` is `T2` else the program is ill-formed.

[*Returns: `pr.first` if `I == 0` else `pr.second`.

Extension

The Full Extension Mechanism

The Fusion library is designed to be extensible, new sequences types can easily be added. In fact, the library support for `std::pair`, `boost::array` and MPL sequences is entirely provided using the extension mechanism.

The process for adding a new sequence type to Fusion is:

1. Enable the *tag dispatching* mechanism used by Fusion for your sequence type
2. Design an iterator type for the sequence
3. Provide specialized behaviour for the intrinsic operations of the new Fusion sequence

Our example

In order to illustrate enabling a new sequence type for use with Fusion, we are going to use the type:

```
namespace example
{
    struct example_struct
    {
        std::string name;
        int age;
        example_struct(
            const std::string& n,
            int a)
            : name(n), age(a)
        {}
    };
}
```

We are going to pretend that this type has been provided by a 3rd party library, and therefore cannot be modified. We shall work through all the necessary steps to enable `example_struct` to serve as an Associative Sequence as described in the Quick Start guide.

Enabling Tag Dispatching

The Fusion extensibility mechanism uses *tag dispatching* to call the correct code for a given sequence type. In order to exploit the tag dispatching mechanism we must first declare a new tag type for the mechanism to use. For example:

```
namespace example {
    struct example_sequence_tag; // Only definition needed
}
```

Next we need to enable the `traits::tag_of` metafunction to return our newly chosen tag type for operations involving our sequence. This is done by specializing `traits::tag_of` for our sequence type.

```
#include <boost/fusion/support/tag_of_fwd.hpp>
#include <boost/fusion/include/tag_of_fwd.hpp>

namespace boost { namespace fusion { namespace traits {
    template<>
    struct tag_of<example_struct>
    {
        typedef example::example_sequence_tag type;
    };
}}}
```

`traits::tag_of` also has a second template argument, that can be used in conjuction with `boost::enable_if` to provide tag support for groups of related types. This feature is not necessary for our sequence, but for an example see the code in:

```
#include <boost/fusion/adapted/array/tag_of.hpp>
#include <boost/fusion/include/tag_of.hpp>
```

Designing a suitable iterator

We need an iterator to describe positions, and provide access to the data within our sequence. As it is straightforward to do, we are going to provide a random access iterator in our example.

We will use a simple design, in which the 2 members of `example_struct` are given numbered indices, 0 for `name` and 1 for `age` respectively.

```
template<typename Struct, int Pos>
struct example_struct_iterator
    : boost::fusion::iterator_base<example_struct_iterator<Struct, Pos> >
{
    BOOST_STATIC_ASSERT(Pos >=0 && Pos < 3);
    typedef Struct struct_type;
    typedef boost::mpl::int_<Pos> index;
    typedef boost::fusion::random_access_traversal_tag category;

    example_struct_iterator(Struct& str)
        : struct_(str) {}

    Struct& struct_;
};
```

A quick summary of the details of our iterator:

1. The iterator is parameterized by the type it is iterating over, and the index of the current element.
2. The typedefs `struct_type` and `index` provide convenient access to information we will need later in the implementation.
3. The typedef `category` allows the `traits::category_of` metafunction to establish the traversal category of the iterator.
4. The constructor stores a reference to the `example_struct` being iterated over.

We also need to enable *tag dispatching* for our iterator type, with another specialization of `traits::tag_of`.

In isolation, the iterator implementation is pretty dry. Things should become clearer as we add features to our implementation.

A first couple of instructive features

To start with, we will get the `result_of::value_of` metafunction working. To do this, we provide a specialization of the `boost::fusion::extension::value_of_impl` template for our iterator's tag type.

```
template<>
struct value_of_impl<example::example_struct_iterator_tag>
{
    template<typename Iterator>
    struct apply;

    template<typename Struct>
    struct apply<example::example_struct_iterator<Struct, 0> >
    {
        typedef std::string type;
    };

    template<typename Struct>
    struct apply<example::example_struct_iterator<Struct, 1> >
    {
        typedef int type;
    };
};
```

The implementation itself is pretty simple, it just uses 2 partial specializations to provide the type of the 2 different members of `example_struct`, based on the index of the iterator.

To understand how `value_of_impl` is used by the library we will look at the implementation of `result_of::value_of`:

```
template <typename Iterator>
struct value_of
    : extension::value_of_impl<typename detail::tag_of<Iterator>::type>::
        template apply<Iterator>
{};
```

So `result_of::value_of` uses *tag dispatching* to select an MPL Metafunction Class to provide its functionality. You will notice this pattern throughout the implementation of Fusion.

Ok, lets enable dereferencing of our iterator. In this case we must provide a suitable specialization of `deref_impl`.

```
template<>
struct deref_impl<example::example_struct_iterator_tag>
{
    template<typename Iterator>
    struct apply;

    template<typename Struct>
    struct apply<example::example_struct_iterator<Struct, 0> >
    {
        typedef typename mpl::if_<
            is_const<Struct>, std::string const&, std::string&>::type type;

        static type
        call(example::example_struct_iterator<Struct, 0> const& it)
        {
            return it.struct_.name;
        }
    };

    template<typename Struct>
    struct apply<example::example_struct_iterator<Struct, 1> >
    {
        typedef typename mpl::if_<
            is_const<Struct>, int const&, int&>::type type;

        static type
        call(example::example_struct_iterator<Struct, 1> const& it)
        {
                return it.struct_.age;
            }
        };
    };
}
```

The use of `deref_impl` is very similar to that of `value_of_impl`, but it also provides some runtime functionality this time via the `call` static member function. To see how `deref_impl` is used, lets have a look at the implementation of `deref`:

```
namespace result_of
{
    template <typename Iterator>
    struct deref
        : extension::deref_impl<typename detail::tag_of<Iterator>::type>::
            template apply<Iterator>
    {};
}

template <typename Iterator>
typename result_of::deref<Iterator>::type
deref(Iterator const& i)
{
    typedef result_of::deref<Iterator> deref_meta;
    return deref_meta::call(i);
}
```

So again `result_of::deref` uses *tag dispatching* in exactly the same way as the `result_of::value_of` implementation. The runtime functionality used by `deref` is provided by the `call` static function of the selected MPL Metafunction Class.

The actual implementation of `deref_impl` is slightly more complex than that of `value_of_impl`. We also need to implement the `call` function, which returns a reference to the appropriate member of the underlying sequence. We also require a little bit of metaprogramming to return `const` references if the underlying sequence is const.

Note

Although there is a fair amount of left to do to produce a fully fledged Fusion sequence, `result_of::value_of` and `deref` illustrate all the signficant concepts required. The remainder of the process is very repetitive, simply requiring implementation of a suitable `xxxx_impl` for each feature `xxxx`.

Implementing the remaining iterator functionality

Ok, now we have seen the way `result_of::value_of` and `deref` work, everything else will work in pretty much the same way. Lets start with forward iteration, by providing a `next_impl`:

```
template<>
struct next_impl<example::example_struct_iterator_tag>
{
    template<typename Iterator>
    struct apply
    {
        typedef typename Iterator::struct_type struct_type;
        typedef typename Iterator::index index;
        typedef example::example_struct_iterator<struct_type, index::value + 1> type;

        static type
        call(Iterator const& i)
        {
             return type(i.struct_);
        }
    };
};
```

This should be very familiar from our `deref_impl` implementation, we will be using this approach again and again now. Our design is simply to increment the `index` counter to move on to the next element. The various other iterator manipulations we need to perform will all just involve simple calculations with the `index` variables.

We also need to provide a suitable `equal_to_impl` so that iterators can be correctly compared. A Bidirectional Iterator will also need an implementation of `prior_impl`. For a Random Access Iterator `distance_impl` and `advance_impl` also need to be provided in order to satisfy the necessary complexity guarantees. As our iterator is a Random Access Iterator we will have to implement all of these functions.

Full implementations of `prior_impl`, `advance_impl`, `distance_impl` and `equal_to_impl` are provided in the example code.

Implementing the intrinsic functions of the sequence

In order that Fusion can correctly identify our sequence as a Fusion sequence, we need to enable `is_sequence` for our sequence type. As usual we just create an `impl` type specialized for our sequence tag:

```
template<>
struct is_sequence_impl<example::example_sequence_tag>
{
    template<typename T>
    struct apply : mpl::true_ {};
};
```

We've some similar formalities to complete, providing `category_of_impl` so Fusion can correctly identify our sequence type, and `is_view_impl` so Fusion can correctly identify our sequence as not being a View type. Implementations are provide in the example code.

Now we've completed some formalities, on to more interesting features. Lets get `begin` working so that we can get an iterator to start accessing the data in our sequence.

```
template<>
struct begin_impl<example::example_sequence_tag>
{
    template<typename Sequence>
    struct apply
    {
        typedef example::example_struct_iterator<Sequence, 0> type;

        static type
        call(Sequence& seq)
        {
            return type(seq);
        }
    };
};
```

The implementation uses the same ideas we have applied throughout, in this case we are just creating one of the iterators we developed earlier, pointing to the first element in the sequence. The implementation of `end` is very similar, and is provided in the example code.

For our Random Access Sequence we will also need to implement `size_impl`, `value_at_impl` and `at_impl`.

Enabling our type as an associative sequence

In order for `example_struct` to serve as an associative forward sequence, we need to adapt the traversal category of our sequence and our iterator accordingly and enable 3 intrinsic sequence lookup features, `at_key`, __value_at_key__ and `has_key`. We also need to enable 3 iterator lookup features, `result_of::key_of`, `result_of::value_of_data` and `deref_data`.

To implement `at_key_impl` we need to associate the `fields::name` and `fields::age` types described in the Quick Start guide with the appropriate members of `example_struct`. Our implementation is as follows:

```
template<>
struct at_key_impl<example::example_sequence_tag>
{
    template<typename Sequence, typename Key>
    struct apply;

    template<typename Sequence>
    struct apply<Sequence, fields::name>
    {
        typedef typename mpl::if_<
            is_const<Sequence>,
            std::string const&,
            std::string&>::type type;

        static type
        call(Sequence& seq)
        {
            return seq.name;
        };
    };

    template<typename Sequence>
    struct apply<Sequence, fields::age>
    {
        typedef typename mpl::if_<
            is_const<Sequence>,
            int const&,
            int&>::type type;

        static type
        call(Sequence& seq)
        {
            return seq.age;
        };
    };
};
```

Its all very similar to the implementations we've seen previously, such as `deref_impl` and `value_of_impl`. Instead of identifying the members by index or position, we are now selecting them using the types `fields::name` and `fields::age`. The implementations of the other functions are equally straightforward, and are provided in the example code.

Summary

We've now worked through the entire process for adding a new random access sequence and we've also enabled our type to serve as an associative sequence. The implementation was slightly longwinded, but followed a simple repeating pattern.

The support for `std::pair`, MPL sequences, and `boost::array` all use the same approach, and provide additional examples of the approach for a variety of types.

Sequence Facade

Description

The `sequence_facade` template provides an intrusive mechanism for producing a conforming Fusion sequence.

Synopsis

```
template<typename Derived, typename TravesalTag, typename IsView = mpl::false_>
struct sequence_facade;
```

Usage

The user of `sequence_facade` derives his sequence type from a specialization of `sequence_facade` and passes the derived sequence type as the first template parameter. The second template parameter should be the traversal category of the sequence being implemented. The 3rd parameter should be set to `mpl::true_` if the sequence is a view.

The user must the implement the key expressions required by their sequence type.

Table 102. Parameters

Name	Description
`sequence`, `Seq`	A type derived from `sequence_facade`
`N`	An MPL Integral Constant

Table 103. Key Expressions

Expression	Result
`sequence::template begin<Seq>::type`	The type of an iterator to the beginning of a sequence of type `Seq`
`sequence::template begin<Seq>::call(seq)`	An iterator to the beginning of sequence `seq`
`sequence::template end<Seq>::type`	The type of an iterator to the end of a sequence of type `Seq`
`sequence::template end<Seq>::call(seq)`	An iterator to the end of sequence `seq`
`sequence::template size<Seq>::type`	The size of a sequence of type `Seq` as an MPL Integral Constant
`sequence::template size<Seq>::call(seq)`	The size of sequence `seq`
`sequence::template empty<Seq>::type`	Returns `mpl::true_` if `Seq` has zero elements, `mpl::false_` otherwise.
`sequence::template empty<Seq>::call`	Returns a type convertible to `bool` that evaluates to true if the sequence is empty, else, evaluates to false.
`sequence::template at<Seq, N>::type`	The type of element `N` in a sequence of type `Seq`
`sequence::template at<Seq, N>::call(seq)`	Element `N` in sequence `seq`
`sequence::template value_at<Sequence, N>::type`	The type of the `N`th element in a sequence of type `Seq`

Include

```
#include <boost/fusion/sequence/sequence_facade.hpp>
#include <boost/fusion/include/sequence_facade.hpp>
```

Example

A full working example using `sequence_facade` is provided in triple.cpp in the extension examples.

Iterator Facade

Description

The `iterator_facade` template provides an intrusive mechanism for producing a conforming Fusion iterator.

Synopsis

```
template<typename Derived, typename TravesalTag>
struct iterator_facade;
```

Usage

The user of iterator_facade derives his iterator type from a specialization of iterator_facade and passes the derived iterator type as the first template parameter. The second template parameter should be the traversal category of the iterator being implemented.

The user must the implement the key expressions required by their iterator type.

Table 104. Parameters

Name	Description
`iterator`, `It`, `It1`, `It2`	A type derived from `iterator_facade`
`N`	An MPL Integral Constant

Table 105. Key Expressions

Expression	Result	Default
`iterator::template value_of<It>::type`	The element stored at iterator position `It`	None
`iterator::template deref<It>::type`	The type returned when dereferencing an iterator of type `It`	None
`iterator::template deref<It>::call(it)`	Dereferences iterator `it`	None
`iterator::template next<It>::type`	The type of the next element from `It`	None
`iterator::template next<It>::call(it)`	The next iterator after `it`	None
`iterator::template prior<It>::type`	The type of the next element from `It`	None
`iterator::template prior<It>::call(it)`	The next iterator after `it`	None
`iterator::template advance<It, N>::type`	The type of an iterator advanced `N` elements from `It`	Implemented in terms of `next` and `prior`
`iterator::template advance<It, N>::call(it)`	An iterator advanced `N` elements from `it`	Implemented in terms of `next` and `prior`
`iterator::template distance<It1, It2>::type`	The distance between iterators of type `It1` and `It2` as an MPL Integral Constant	None
`iterator::template distance<It1, It2>::call(it1, it2)`	The distance between iterator `it1` and `it2`	None
`iterator::template equal_to<It1, It2>::type`	Returns `mpl::true_` if `It1` is equal to `It2`, `mpl::false_` otherwise.	`boost::same_type<It1, It2>::type`
`iterator::template equal_to<It1, It2>::call(it1, it2)`	Returns a type convertible to `bool` that evaluates to `true` if `It1` is equal to `It2`, `false` otherwise.	`boost::same_type<It1, It2>::type()`
`iterator::template key_of<It>::type`	The key type associated with the element from `It`	None
`iterator::template value_of_data<It>::type`	The type of the data property associated with the element from `It`	None
`iterator::template deref_data<It>::type`	The type that will be returned by dereferencing the data property of the element from `It`	None
`iterator::template deref_data<It>::call(it)`	Deferences the data property associated with the element referenced by `it`	None

Header

```
#include <boost/fusion/iterator/iterator_facade.hpp>
#include <boost/fusion/include/iterator_facade.hpp>
```

Example

A full working example using `iterator_facade` is provided in triple.cpp in the extension examples.

Functional

Components to call functions and function objects and to make Fusion code callable through a function object interface.

Header

```
#include <boost/fusion/functional.hpp>
```

Fused and unfused forms

What is a function call?

```
f (a,b,c)
```

It is a name and a tuple written next to each other, left-to-right.

Although the C++ syntax does not allow to replace `(a,b,c)` with some Fusion Sequence, introducing yet another function provides a solution:

```
invoke(f,my_sequence)
```

Alternatively it is possible to apply a simple transformation to `f` in order to achieve the same effect:

```
f tuple <=> f' (tuple)
```

Now, `f'` is an unary function that takes the arguments to `f` as a tuple; `f'` is the *fused* form of `f`. Reading the above equivalence right-to-left to get the inverse transformation, `f` is the *unfused* form of `f'`.

Calling functions and function objects

Having generic C++ code call back arbitrary functions provided by the client used to be a heavily repetitive task, as different functions can differ in arity, invocation syntax and other properties that might be part of the type. Transporting arguments as Fusion sequences and factoring out the invocation makes Fusion algorithms applicable to function arguments and also reduces the problem to one invocation syntax and a fixed arity (instead of an arbitrary number of arbitrary arguments times several syntactic variants times additional properties).

Transforming an unfused function into its fused counterpart allows n-ary calls from an algorithm that invokes an unary Polymorphic Function Object with Sequence arguments.

The library provides several function templates to invoke different kinds of functions and adapters to transform them into fused form, respectively. Every variant has a corresponding generator function template that returns an adapter instance for the given argument.

Constructors can be called applying Boost.Functional/Factory.

Making Fusion code callable through a function object interface

Transforming a fused function into its unfused counterpart allows to create function objects to accept arbitrary calls. In other words, an unary function object can be implemented instead of (maybe heavily overloaded) function templates or function call operators.

The library provides both a strictly typed and a generic variant for this transformation. The latter should be used in combination with Boost.Functional/Forward to attack The Forwarding Problem.

Both variants have a corresponding generator function template that returns an adapter instance for the given argument.

Concepts

Callable Object

Description

A pointer to a function, a pointer to member function, a pointer to member data, or a class type whose objects can appear immediately to the left of a function call operator.

Models

- function pointer types
- member (function or data) pointer types
- all kinds of function objects

Examples

```
& a_free_function
& a_class::a_static_member_function
& a_class::a_nonstatic_data_member
& a_class::a_nonstatic_member_function
std::less<int>()
// using namespace boost;
bind(std::less<int>(), _1, 5)
lambda::_1 += lambda::_2;
fusion::make_fused_function_object(std::less<int>())
```

Regular Callable Object

Description

A non-member-pointer Callable Object type: A pointer to a function or a class type whose objects can appear immediately to the left of a function call operator.

Refinement of

- Callable Object

Notation

`F`	A possibly const qualified Deferred Callable Object type
`f`	An object or reference to an object of type F
`A1 ...AN`	Argument types
`a1 ...aN`	Objects or references to objects with types `A1 ...AN`

Expression requirements

Expression	Return Type	Runtime Complexity
`f(a1, ...aN)`	Unspecified	Unspecified

Models

- function pointer types

- all kinds of function objects

Examples

```
& a_free_function
& a_class::a_static_member_function
std::less<int>()
// using namespace boost;
bind(std::less<int>(), _1, 5)
lambda::_1 += lambda::_2;
fusion::make_fused_function_object(std::less<int>())
```

Deferred Callable Object

Description

Callable Object types that work with Boost.ResultOf to determine the result of a call.

Refinement of

- Callable Object

> note Once C++ supports the `decltype` keyword, all models of Callable Object will also be models of Deferred Callable Object, because function objects won't need client-side support for `result_of`.

Notation

`F`	A possibly const qualified Deferred Callable Object type
`A1 ...AN`	Argument types
`a1 ...aN`	Objects or references to objects with types `A1 ...AN`
`T1 ...TN`	`Ti` is `Ai &` if `ai` is an LValue, same as `Ai`, otherwise

Expression requirements

Expression	Type
`boost::result_of< F(T1 ...TN) >::type`	Result of a call with `A1 ...AN`-typed arguments

Models

- Polymorphic Function Object types
- member (function or data) pointer types

Examples

```
& a_free_function
& a_class::a_static_member_function
& a_class::a_nonstatic_data_member
& a_class::a_nonstatic_member_function
std::less<int>()
// using namespace boost;
bind(std::less<int>(), _1, 5)
// Note: Boost.Lambda expressions don't work with __boost_result_of__
fusion::make_fused_function_object(std::less<int>())
```

Polymorphic Function Object

Description

A non-member-pointer Deferred Callable Object type.

Refinement of

- Regular Callable Object
- Deferred Callable Object

Notation

`F`	A possibly const-qualified Polymorphic Function Object type
`f`	An object or reference to an object of type F
`A1 ...AN`	Argument types
`a1 ...aN`	Objects or references to objects with types `A1 ...AN`
`T1 ...TN`	`Ti` is `Ai &` if `ai` is an LValue, same as `Ai`, otherwise

Expression requirements

Expression	Return Type	Runtime Complexity
`f(a1, ...aN)`	`result_of< F(T1, ...TN) >::type`	Unspecified

Models

- function pointers
- function objects of the Standard Library
- all Fusion functional adapters

Examples

```
& a_free_function
& a_class::a_static_member_function
std::less<int>()
// using namespace boost;
bind(std::less<int>(), _1, 5)
// Note: Boost.Lambda expressions don't work with __boost_result_of__
fusion::make_fused_function_object(std::less<int>())
```

Invocation

Functions

invoke

Description

Calls a Deferred Callable Object with the arguments from a Sequence.

The first template parameter can be specialized explicitly to avoid copying and/or to control the const qualification of a function object.

If the target function is a pointer to a class members, the corresponding object can be specified as a reference, pointer, or smart pointer. In case of the latter, a freestanding `get_pointer` function must be defined (Boost provides this function for `std::auto_ptr` and `boost::shared_ptr`).

Constructors can be called applying Boost.Functional/Factory.

Synopsis

```
template<
    typename Function,
    class Sequence
    >
typename result_of::invoke<Function, Sequence>::type
invoke(Function f, Sequence & s);

template<
    typename Function,
    class Sequence
    >
typename result_of::invoke<Function, Sequence const>::type
invoke(Function f, Sequence const & s);
```

Parameters

Parameter	Requirement	Description
`f`	A Deferred Callable Object	The function to call.
`s`	A Forward Sequence	The arguments.

Expression Semantics

```
invoke(f,s);
```

Return type: Return type of `f` when invoked with the elements in `s` as its arguments.

Semantics: Invokes `f` with the elements in `s` as arguments and returns the result of the call expression.

Header

```
#include <boost/fusion/functional/invocation/invoke.hpp>
```

Example

```
std::plus<int> add;
assert(invoke(add,make_vector(1,1)) == 2);
```

See also

- `invoke_procedure`
- `invoke_function_object`
- `result_of::invoke`

- `fused`
- `make_fused`

invoke_procedure

Description

Calls a Callable Object with the arguments from a Sequence. The result of the call is ignored.

The first template parameter can be specialized explicitly to avoid copying and/or to control the const qualification of a function object.

For pointers to class members corresponding object can be specified as a reference, pointer, or smart pointer. In case of the latter, a freestanding `get_pointer` function must be defined (Boost provides this function for `std::auto_ptr` and `boost::shared_ptr`).

The target function must not be a pointer to a member object (dereferencing such a pointer without returning anything does not make sense, so it isn't implemented).

Synopsis

```
template<
    typename Function,
    class Sequence
    >
typename result_of::invoke_procedure<Function, Sequence>::type
invoke_procedure(Function f, Sequence & s);

template<
    typename Function,
    class Sequence
    >
typename result_of::invoke_procedure<Function, Sequence const>::type
invoke_procedure(Function f, Sequence const & s);
```

Parameters

Parameter	Requirement	Description
`f`	Model of Callable Object	The function to call.
`s`	Model of Forward Sequence	The arguments.

Expression Semantics

```
invoke_procedure(f,s);
```

Return type: `void`

Semantics: Invokes `f` with the elements in `s` as arguments.

Header

```
#include <booost/fusion/functional/invocation/invoke_procedure.hpp>
```

Example

```
vector<int,int> v(1,2);
using namespace boost::lambda;
invoke_procedure(_1 += _2, v);
assert(front(v) == 3);
```

See also

- `invoke`
- `invoke_function_object`
- `result_of::invoke_procedure`
- `fused_procedure`
- `make_fused_procedure`

invoke_function_object

Description

Calls a Polymorphic Function Object with the arguments from a Sequence.

The first template parameter can be specialized explicitly to avoid copying and/or to control the const qualification of a function object.

Constructors can be called applying Boost.Functional/Factory.

Synopsis

```
template<
    typename Function,
    class Sequence
    >
typename result_of::invoke_function_object<Function, Sequence>::type
invoke_function_object(Function f, Sequence & s);

template<
    typename Function,
    class Sequence
    >
typename result_of::invoke_function_object<Function, Sequence const>::type
invoke_function_object(Function f, Sequence const & s);
```

Parameters

Parameter	Requirement	Description
`f`	Model of Polymorphic Function Object	The function object to call.
`s`	Model of Forward Sequence	The arguments.

Expression Semantics

```
invoke_function_object(f,s);
```

Return type: Return type of `f` when invoked with the elements in `s` as its arguments.

Semantics: Invokes `f` with the elements in `s` as arguments and returns the result of the call expression.

Header

```
#include <boost/fusion/functional/invocation/invoke_function_object.hpp>
```

Example

```
struct sub
{
    template <typename Sig>
    struct result;

    template <class Self, typename T>
    struct result< Self(T,T) >
    { typedef typename remove_reference<T>::type type; };

    template<typename T>
    T operator()(T lhs, T rhs) const
    {
        return lhs - rhs;
    }
};

void try_it()
{
    sub f;
    assert(f(2,1) == invoke_function_object(f,make_vector(2,1)));
}
```

See also

- `invoke`
- `invoke_procedure`
- `result_of::invoke_function_object`
- `fused_function_object`
- `make_fused_function_object`

Metafunctions

invoke

Description

Returns the result type of `invoke`.

Synopsis

```
namespace result_of
{
    template<
        typename Function,
        class Sequence
        >
    struct invoke
    {
        typedef unspecified type;
    };
}
```

See also

- invoke
- fused

invoke_procedure

Description

Returns the result type of invoke_procedure.

Synopsis

```
namespace result_of
{
    template<
        typename Function,
        class Sequence
        >
    struct invoke_procedure
    {
        typedef unspecified type;
    };
}
```

See also

- invoke_procedure
- fused_procedure

invoke_function_object

Description

Returns the result type of invoke_function_object.

Synopsis

```
namespace result_of
{
    template<
        class Function,
        class Sequence
        >
    struct invoke_function_object
    {
        typedef unspecified type;
    };
}
```

See also

- `invoke_function_object`
- `fused_function_object`

Limits

Header

```
#include <boost/fusion/functional/invocation/limits.hpp>
```

Macros

The following macros can be defined to change the maximum arity. The default is 6.

- BOOST_FUSION_INVOKE_MAX_ARITY
- BOOST_FUSION_INVOKE_PROCEDURE_MAX_ARITY
- BOOST_FUSION_INVOKE_FUNCTION_OBJECT_MAX_ARITY

Adapters

Function object templates to transform a particular target function.

fused

Description

An unary Polymorphic Function Object adapter template for Deferred Callable Object target functions. It takes a Forward Sequence that contains the arguments for the target function.

The type of the target function is allowed to be const qualified or a reference. Const qualification is preserved and propagated appropriately (in other words, only const versions of `operator()` can be used for a target function object that is const or, if the target function object is held by value, the adapter is const - these semantics have nothing to do with the const qualification of a member function, which is referring to the type of object pointed to by `this` which is specified with the first element in the sequence passed to the adapter).

If the target function is a pointer to a class members, the corresponding object can be specified as a reference, pointer, or smart pointer. In case of the latter, a freestanding `get_pointer` function must be defined (Boost provides this function for `std::auto_ptr` and `boost::shared_ptr`).

Header

```
#include <boost/fusion/functional/adapter/fused.hpp>
```

Synopsis

```
template <typename Function>
class fused;
```

Template parameters

Parameter	Description	Default
`Function`	A Deferred Callable Object	

Model of

- Polymorphic Function Object
- Deferred Callable Object

Notation

`R` A possibly const qualified Deferred Callable Object type or reference type thereof

`r` An object convertible to `R`

`s` A Sequence of arguments that are accepted by `r`

`f` An instance of `fused<R>`

Expression Semantics

Expression	Semantics
`fused<R>(r)`	Creates a fused function as described above, initializes the target function with `r`.
`fused<R>()`	Creates a fused function as described above, attempts to use `R`'s default constructor.
`f(s)`	Calls `r` with the elements in `s` as its arguments.

Example

```
fused< std::plus<long> > f;
assert(f(make_vector(1,2l)) == 3l);
```

See also

- `fused_procedure`
- `fused_function_object`
- `invoke`
- `make_fused`

- deduce

fused_procedure

Description

An unary Polymorphic Function Object adapter template for Callable Object target functions. It takes a Forward Sequence that contains the arguments for the target function.

The result is discarded and the adapter's return type is `void`.

The type of the target function is allowed to be const qualified or a reference. Const qualification is preserved and propagated appropriately (in other words, only const versions of `operator()` can be used for a target function object that is const or, if the target function object is held by value, the adapter is const - these semantics have nothing to do with the const qualification of a member function, which is referring to the type of object pointed to by `this` which is specified with the first element in the sequence passed to the adapter).

If the target function is a pointer to a members function, the corresponding object can be specified as a reference, pointer, or smart pointer. In case of the latter, a freestanding `get_pointer` function must be defined (Boost provides this function for `std::auto_ptr` and `boost::shared_ptr`).

The target function must not be a pointer to a member object (dereferencing such a pointer without returning anything does not make sense, so this case is not implemented).

Header

```
#include <boost/fusion/functional/adapter/fused_procedure.hpp>
```

Synopsis

```
template <typename Function>
class fused_procedure;
```

Template parameters

Parameter	Description	Default
`Function`	Callable Object type	

Model of

- Polymorphic Function Object
- Deferred Callable Object

Notation

`R` A possibly const qualified Callable Object type or reference type thereof

`r` An object convertible to `R`

`s` A Sequence of arguments that are accepted by `r`

`f` An instance of `fused<R>`

Expression Semantics

Expression	Semantics
`fused_procedure<R>(r)`	Creates a fused function as described above, initializes the target function with `r`.
`fused_procedure<R>()`	Creates a fused function as described above, attempts to use `R`'s default constructor.
`f(s)`	Calls `r` with the elements in `s` as its arguments.

Example

```
template<class SequenceOfSequences, class Func>
void n_ary_for_each(SequenceOfSequences const & s, Func const & f)
{
    for_each(zip_view<SequenceOfSequences>(s),
        fused_procedure<Func const &>(f));
}

void try_it()
{
    vector<int,float> a(2,2.0f);
    vector<int,float> b(1,1.5f);
    using namespace boost::lambda;
    n_ary_for_each(vector_tie(a,b), _1 -= _2);
    assert(a == make_vector(1,0.5f));
}
```

See also

- `fused`
- `fused_function_object`
- `invoke_procedure`
- `make_fused_procedure`

fused_function_object

Description

An unary Polymorphic Function Object adapter template for a Polymorphic Function Object target function. It takes a Forward Sequence that contains the arguments for the target function.

The type of the target function is allowed to be const qualified or a reference. Const qualification is preserved and propagated appropriately (in other words, only const versions of `operator()` can be used for an target function object that is const or, if the target function object is held by value, the adapter is const).

Header

```
#include <boost/fusion/functional/adapter/fused_function_object.hpp>
```

Synopsis

```
template <class Function>
class fused_function_object;
```

Template parameters

Parameter	Description	Default
`Function`	Polymorphic Function Object type	

Model of

- Polymorphic Function Object
- Deferred Callable Object

Notation

`R`	A possibly const qualified Polymorphic Function Object type or reference type thereof
`r`	An object convertible to `R`
`s`	A Sequence of arguments that are accepted by `r`
`f`	An instance of `fused<R>`

Expression Semantics

Expression	Semantics
`fused_function_object<R>(r)`	Creates a fused function as described above, initializes the target function with `r`.
`fused_function_object<R>()`	Creates a fused function as described above, attempts to use `R`'s default constructor.
`f(s)`	Calls `r` with the elements in `s` as its arguments.

Example

```
template<class SeqOfSeqs, class Func>
typename result_of::transform< zip_view<SeqOfSeqs> const,
    fused_function_object<Func const &> >::type
n_ary_transform(SeqOfSeqs const & s, Func const & f)
{
    return transform(zip_view<SeqOfSeqs>(s),
        fused_function_object<Func const &>(f));
}

struct sub
{
    template <typename Sig>
    struct result;

    template <class Self, typename T>
    struct result< Self(T,T) >
    { typedef typename remove_reference<T>::type type; };

    template<typename T>
    T operator()(T lhs, T rhs) const
    {
        return lhs - rhs;
    }
};

void try_it()
{
    vector<int,float> a(2,2.0f);
    vector<int,float> b(1,1.5f);
    vector<int,float> c(1,0.5f);
    assert(c == n_ary_transform(vector_tie(a,b), sub()));
}
```

See also

- `fused`
- `fused_procedure`
- `invoke_function_object`
- `make_fused_function_object`
- `deduce`

unfused

Description

An n-ary Polymorphic Function Object adapter template for an unary Polymorphic Function Object target function. When called, its arguments are bundled to a Random Access Sequence of references that is passed to the target function object.

The nullary overload of the call operator can be removed by setting the second template parameter to `false`, which is very useful if the result type computation would result in a compile error, otherwise (nullary call operator's prototypes can't be templates and thus are instantiated as early as the class template).

Only LValue arguments are accepted. To overcome this limitation, apply Boost.Functional/Forward.

The type of the target function is allowed to be const qualified or a reference. Const qualification is preserved and propagated appropriately. In other words, only const versions of `operator()` can be used if the target function object is const - or, in case the target function object is held by value, the adapter is const.

Header

```
#include <boost/fusion/functional/adapter/unfused.hpp>
```

Synopsis

```
template <class Function, bool AllowNullary = true>
class unfused;
```

Template parameters

Parameter	Description	Default
`Function`	A unary Polymorphic Function Object	
`AllowNullary`	Boolean constant	true

Model of

- Polymorphic Function Object
- Deferred Callable Object

Notation

`F`	A possibly const qualified, unary Polymorphic Function Object type or reference type thereof
`f`	An object convertible to `F`
`UL`	The type `unfused<F>`
`ul`	An instance of `UL`, initialized with `f`
`a0`...`aN`	Arguments to `ul`

Expression Semantics

Expression	Semantics
`UL(f)`	Creates a fused function as described above, initializes the target function with `f`.
`UL()`	Creates a fused function as described above, attempts to use `F`'s default constructor.
`ul(a0`...`aN)`	Calls `f` with a Sequence that contains references to the arguments `a0`...`aN`.

Example

```
struct fused_incrementer
{
    template <class Seq>
    struct result
    {
        typedef void type;
    };

    template <class Seq>
    void operator()(Seq const & s) const
    {
        for_each(s,++boost::lambda::_1);
    }
};

void try_it()
{
    unfused<fused_incrementer> increment;
    int a = 2; char b = 'X';
    increment(a,b);
    assert(a == 3 && b == 'Y');
}
```

See also

- `unfused_typed`
- `make_unfused`

unfused_typed

Description

An n-ary Polymorphic Function Object adapter template for an unary Polymorphic Function Object target function. When called, its arguments are bundled to a Random Access Sequence that is passed to the target function object.

The call operators of esulting function objects are strictly typed (in other words, non-templatized) with the types from a Sequence.

The type of the target function is allowed to be const qualified or a reference. Const qualification is preserved and propagated appropriately (in other words, only const versions of `operator()` can be used if the target function object is const - or, in case the target function object is held by value, the adapter is const).

For Microsoft Visual C++ 7.1 (Visual Studio 2003) the detection of the Function Object's const qualification easily causes an internal error. Therefore the adapter is always treated as if it was const.

If the type sequence passed to this template contains non-reference elements, the element is copied only once - the call operator's signature is optimized automatically to avoid by-value parameters.

Header

```
#include <boost/fusion/functional/adapter/unfused_typed.hpp>
```

Synopsis

```
template <class Function, class Sequence>
class unfused_typed;
```

Template parameters

Parameter	Description	Default
`Function`	A unary Polymorphic Function Object	
`Sequence`	A Sequence	

Model of

- Polymorphic Function Object
- Deferred Callable Object

Notation

`F`	A possibly const qualified, unary Polymorphic Function Object type or reference type thereof
`f`	An object convertible to `F`
`S`	A Sequence of parameter types
`UT`	The type `unfused_typed<F,S>`
`ut`	An instance of `UT`, initialized with `f`
`a0`...`aN`	Arguments to `ut`, convertible to the types in `S`

Expression Semantics

Expression	Semantics
`UT(f)`	Creates a fused function as described above, initializes the target function with `f`.
`UT()`	Creates a fused function as described above, attempts to use `F`'s default constructor.
`ut(a0`...`aN)`	Calls `f` with an instance of `S` (or a subsequence of `S` starting at the first element, if fewer arguments are given and the overload hasn't been disabled) initialized with `a0`...`aN`.

Example

```
struct add_assign // applies operator+=
{
    typedef void result_type; // for simplicity

    template <typename T>
    void operator()(T & lhs, T const & rhs) const
    {
        lhs += rhs;
    }
};

template <class Tie>
class fused_parallel_adder
{
    Tie tie_dest;
public:
    explicit fused_parallel_adder(Tie const & dest)
        : tie_dest(dest)
    { }

    typedef void result_type;

    template <class Seq>
    void operator()(Seq const & s) const
    {
        for_each( zip(tie_dest,s), fused<add_assign>() );
    }
};

// accepts a tie and creates a typed function object from it
struct fused_parallel_adder_maker
{
    template <typename Sig>
    struct result;

    template <class Self, class Seq>
    struct result< Self(Seq) >
    {
        typedef typename remove_reference<Seq>::type seq;

        typedef unfused_typed< fused_parallel_adder<seq>,
            typename mpl::transform<seq, remove_reference<_> >::type > type;
    };

    template <class Seq>
    typename result< void(Seq) >::type operator()(Seq const & tie)
    {
        return typename result< void(Seq) >::type(
            fused_parallel_adder<Seq>(tie) );
    }
};
unfused<fused_parallel_adder_maker> parallel_add;

void try_it()
{
    int a = 2; char b = 'X';
    // the second call is strictly typed with the types deduced from the
    // first call
    parallel_add(a,b)(3,2);
    parallel_add(a,b)(3);
    parallel_add(a,b)();
    assert(a == 8 && b == 'Z');
}
```

See also

- `unfused`
- `deduce`
- `deduce_sequence`

Limits

Header

```
#include <boost/fusion/functional/adapter/limits.hpp>
```

Macros

The following macros can be defined to change the maximum arity. The value used for these macros must not exceed `FUSION_MAX_VECTOR_SIZE`. The default is 6.

- BOOST_FUSION_UNFUSED_MAX_ARITY
- BOOST_FUSION_UNFUSED_TYPE_MAX_ARITY

Generation

Functions

make_fused

Description

Creates a `fused` adapter for a given Deferred Callable Object. The usual *element conversion* is applied to the target function.

Synopsis

```
template <typename F>
inline typename make_fused<F>::type
make_fused(F const & f);
```

Parameters

Parameter	Requirement	Description
`f`	Model of Deferred Callable Object	The function to transform.

Expression Semantics

```
make_fused(f);
```

Return type: A specialization of `fused`.

Semantics: Returns a `fused` adapter for `f`.

Header

```
#include <boost/fusion/functional/generation/make_fused.hpp>
#include <boost/fusion/include/make_fused.hpp>
```

Example

```
float sub(float a, float b) { return a - b; }

void try_it()
{
    vector<int,float> a(2,2.0f);
    vector<int,float> b(1,1.5f);
    vector<float,float> c(1.0f,0.5f);
    assert(c == transform(zip(a,b), make_fused(& sub)));
    assert(c == transform(zip(a,b), make_fused(std::minus<float>())));
}
```

See also

- `fused`
- `deduce`
- `make_fused`

make_fused_procedure

Description

Creates a `fused_procedure` adapter for a given Deferred Callable Object. The usual *element conversion* applied to the target function.

Synopsis

```
template <typename F>
inline typename make_fused_procedure<F>::type
make_fused_procedure(F const & f);
```

Parameters

Parameter	Requirement	Description
`f`	Model of Callable Object	The function to transform.

Expression Semantics

```
make_fused_procedure(f);
```

Return type: A specialization of `fused_procedure`.

Semantics: Returns a `fused_procedure` adapter for `f`.

Header

```
#include <boost/fusion/functional/generation/make_fused_procedure.hpp>
#include <boost/fusion/include/make_fused_procedure.hpp>
```

Example

```
vector<int,int,int> v(1,2,3);
using namespace boost::lambda;
make_fused_procedure(_1 += _2 - _3)(v);
assert(front(v) == 0);
```

See also

- `fused_procedure`
- `deduce`
- `make_fused_procedure`

make_fused_function_object

Description

Creates a `fused_function_object` adapter for a given Deferred Callable Object. The usual *element conversion* is applied to the target function.

Synopsis

```
template <typename F>
inline typename make_fused_function_object<F>::type
make_fused_function_object(F const & f);
```

Parameters

Parameter	Requirement	Description
`f`	Model of Polymorphic Function Object	The function to transform.

Expression Semantics

```
make_fused_function_object(f);
```

Return type: A specialization of `fused_function_object`.

Semantics: Returns a `fused_function_object` adapter for `f`.

Header

```
#include <boost/fusion/functional/generation/make_fused_function_object.hpp>
#include <boost/fusion/include/make_fused_function_object.hpp>
```

Example

```
struct sub
{
    template <typename Sig>
    struct result;

    template <class Self, typename T>
    struct result< Self(T,T) >
    { typedef typename remove_reference<T>::type type; };

    template<typename T>
    T operator()(T lhs, T rhs) const
    {
        return lhs - rhs;
    }
};

void try_it()
{
    vector<int,float> a(2,2.0f);
    vector<int,float> b(1,1.5f);
    vector<int,float> c(1,0.5f);
    assert(c == transform(zip(a,b), make_fused_function_object(sub())));
}
```

See also

- `fused_function_object`
- `deduce`
- `make_fused_function_object`

make_unfused

Description

Creates a `unfused` adapter for a given, unary Polymorphic Function Object. The usual *element conversion* is applied to the target function.

Synopsis

```
template <typename F>
inline typename make_unfused<F>::type
make_unfused(F const & f);
```

Parameters

Parameter	Requirement	Description
`f`	Model of Polymorphic Function Object	The function to transform.

Expression Semantics

```
make_unfused(f);
```

Return type: A specialization of `unfused`.

Semantics: Returns a `unfused` adapter for `f`.

Header

```
#include <boost/fusion/functional/generation/make_unfused.hpp>
#include <boost/fusion/include/make_unfused.hpp>
```

Example

```
struct fused_incrementer
{
    template <class Seq>
    struct result
    {
        typedef void type;
    };

    template <class Seq>
    void operator()(Seq const & s) const
    {
        for_each(s,++boost::lambda::_1);
    }
};

void try_it()
{
    int a = 2; char b = 'X';
    make_unfused(fused_incrementer())(a,b);
    assert(a == 3 && b == 'Y');
}
```

See also

- `unfused`
- `deduce`
- `make_unfused`

Metafunctions

make_fused

Description

Returns the result type of `make_fused`.

Header

```
#include <boost/fusion/functional/generation/make_fused.hpp>
#include <boost/fusion/include/make_fused.hpp>
```

Synopsis

```
namespace result_of
{
    template<typename Function>
    struct make_fused
    {
        typedef unspecified type;
    };
}
```

See also

- `make_fused`

make_fused_procedure

Description

Returns the result type of `make_fused_procedure`.

Header

```
#include <boost/fusion/functional/generation/make_fused_procedure.hpp>
#include <boost/fusion/include/make_fused_procedure.hpp>
```

Synopsis

```
namespace result_of
{
    template<typename Function>
    struct make_fused_procedure
    {
        typedef unspecified type;
    };
}
```

See also

- `make_fused_procedure`

make_fused_function_object

Description

Returns the result type of `make_fused_function_object`.

Header

```
#include <boost/fusion/functional/generation/make_fused_function_object.hpp>
#include <boost/fusion/include/make_fused_function_object.hpp>
```

Synopsis

```
namespace result_of
{
    template<typename Function>
    struct make_fused_function_object
    {
        typedef unspecified type;
    };
}
```

See also

- `make_fused_function_object`

make_unfused

Description

Returns the result type of `make_unfused`.

Header

```
#include <boost/fusion/functional/generation/make_unfused.hpp>
#include <boost/fusion/include/make_unfused.hpp>
```

Synopsis

```
namespace result_of
{
    template<typename Function>
    struct make_unfused
    {
        typedef unspecified type;
    };
}
```

See also

- `make_unfused`

Notes

Recursive Inlined Functions

An interesting peculiarity of functions like `at` when applied to a Forward Sequence like `list` is that what could have been linear runtime complexity effectively becomes constant O(1) due to compiler optimization of C++ inlined functions, however deeply recursive (up to a certain compiler limit of course). Compile time complexity remains linear.

Overloaded Functions

Associative sequences use function overloading to implement membership testing and type associated key lookup. This amounts to constant runtime and amortized constant compile time complexities. There is an overloaded function, `f(k)`, for each key *type* `k`. The compiler chooses the appropriate function given a key, `k`.

Tag Dispatching

Tag dispatching is a generic programming technique for selecting template specializations. There are typically 3 components involved in the tag dispatching mechanism:

1. A type for which an appropriate template specialization is required
2. A metafunction that associates the type with a tag type
3. A template that is specialized for the tag type

For example, the fusion `result_of::begin` metafunction is implemented as follows:

```
template <typename Sequence>
struct begin
{
    typedef typename
        result_of::begin_impl<typename traits::tag_of<Sequence>::type>::
        template apply<Sequence>::type
    type;
};
```

In the case:

1. `Sequence` is the type for which a suitable implementation of `result_of::begin_impl` is required
2. `traits::tag_of` is the metafunction that associates `Sequence` with an appropriate tag
3. `result_of::begin_impl` is the template which is specialized to provide an implementation for each tag type

Extensibility

Unlike MPL, there is no extensibe sequence concept in fusion. This does not mean that Fusion sequences are not extensible. In fact, all Fusion sequences are inherently extensible. It is just that the manner of sequence extension in Fusion is diferent from both STL and MPL on account of the lazy nature of fusion Algorithms. STL containers extend themselves in place though member functions such as `push_back` and `insert`. MPL sequences, on the other hand, are extended through "intrinsic" functions that actually return whole sequences. MPL is purely functional and can not have side effects. For example, MPL's `push_back` does not actually mutate an `mpl::vector`. It can't do that. Instead, it returns an extended `mpl::vector`.

Like MPL, Fusion too is purely functional and can not have side effects. With runtime efficiency in mind, Fusion sequences are extended through generic functions that return Views. Views are sequences that do not actually contain data, but instead impart an alternative presentation over the data from one or more underlying sequences. Views are proxies. They provide an efficient yet purely functional way to work on potentially expensive sequence operations. For example, given a `vector`, Fusion's `push_back` returns a joint_view, instead of an actual extended vector. A joint_view holds a reference to the original sequence plus the appended data --making it very cheap to pass around.

Element Conversion

Functions that take in elemental values to form sequences (e.g. make_list) convert their arguments to something suitable to be stored as a sequence element. In general, the element types are stored as plain values. Example:

```
make_list(1, 'x')
```

returns a list<int, char>.

There are a few exceptions, however.

Arrays:

Array arguments are deduced to reference to const types. For example [13]:

```
make_list("Donald", "Daisy")
```

creates a list of type

```
list<const char (&)[7], const char (&)[6]>
```

Function pointers:

Function pointers are deduced to the plain non-reference type (i.e. to plain function pointer). Example:

```
void f(int i);
  ...
make_list(&f);
```

creates a list of type

```
list<void (*)(int)>
```

boost::ref

Fusion's generation functions (e.g. make_list) by default stores the element types as plain non-reference types. Example:

```
void foo(const A& a, B& b) {
    ...
    make_list(a, b)
```

creates a list of type

```
list<A, B>
```

Sometimes the plain non-reference type is not desired. You can use `boost::ref` and `boost::cref` to store references or const references (respectively) instead. The mechanism does not compromise const correctness since a const object wrapped with ref results in a tuple element with const reference type (see the fifth code line below). Examples:

[13] Note that the type of a string literal is an array of const characters, not `const char*`. To get make_list to create a list with an element of a non-const array type one must use the `ref` wrapper (see boost::ref).

For example:

```
A a; B b; const A ca = a;
make_list(cref(a), b);          // creates list<const A&, B>
make_list(ref(a), b);           // creates list<A&, B>
make_list(ref(a), cref(b));     // creates list<A&, const B&>
make_list(cref(ca));            // creates list<const A&>
make_list(ref(ca));             // creates list<const A&>
```

See Boost.Ref for details.

adt_attribute_proxy

To adapt arbitrary data types that do not allow direct access to their members, but allow indirect access via expressions (such as invocations of get- and set-methods), fusion's `BOOST_FUSION_ADAPT_`*`xxx`*`ADT`*`xxx`*-family (e.g. `BOOST_FUSION_ADAPT_ADT`) may be used. To bypass the restriction of not having actual lvalues that represent the elements of the fusion sequence, but rather a sequence of paired expressions that access the elements, the actual return type of fusion's intrinsic sequence access functions (`at`, `at_c`, `at_key`, `deref`, and `deref_data`) is a proxy type, an instance of `adt_attribute_proxy`, that encapsulates these expressions.

`adt_attribute_proxy` is defined in the namespace `boost::fusion::extension` and has three template arguments:

```
namespace boost { namespace fusion { namespace extension
{
    template<
        typename Type
      , int Index
      , bool Const
    >
    struct adt_attribute_proxy;
}}}
```

When adapting a class type, `adt_attribute_proxy` is specialized for every element of the adapted sequence, with `Type` being the class type that is adapted, `Index` the 0-based indices of the elements, and `Const` both `true` and `false`. The return type of fusion's intrinsic sequence access functions for the *N*th element of an adapted class type `type_name` is `adt_attribute_proxy<type_name, `*`N`*`, `*`Const`*`>`, with *`Const`* being `true` for constant instances of `type_name` and `false` for non-constant ones.

Notation

`type_name`	The type to be adapted, with M attributes
`inst`	Object of type `type_name`
`const_inst`	Object of type `type_name const`
`(attribute_type`*`N`*`, attribute_const_type`*`N`*`, get_expr`*`N`*`, set_expr`*`N`*`)`	Attribute descriptor of the *N*th attribute of `type_name` as passed to the adaption macro, 0≤*N*<M
`proxy_type`*`N`*	`adt_attribute_proxy<type_name, `*`N`*`, false>` with *N* being an integral constant, 0≤*N*<M
`const_proxy_type`*`N`*	`adt_attribute_proxy<type_name, `*`N`*`, true>` with *N* being an integral constant, 0≤*N*<M
`proxy`*`N`*	Object of type `proxy_type`*`N`*
`const_proxy`*`N`*	Object of type `const_proxy_type`*`N`*

Expression Semantics

Expression	Semantics
`proxy_typeN(inst)`	Creates an instance of `proxy_typeN` with underlying object `inst`
`const_proxy_typeN(const_inst)`	Creates an instance of `const_proxy_typeN` with underlying object `const_inst`
`proxy_typeN::type`	Another name for `attribute_typeN`
`const_proxy_typeN::type`	Another name for `const_attribute_typeN`
`proxyN=t`	Invokes `set_exprN`, with `t` being an arbitrary object. `set_exprN` may access the variables named `obj` of type `type_name&`, which represent the corresponding instance of `type_name`, and `val` of an arbitrary const-qualified reference template type parameter `Val`, which represents `t`.
`proxyN.get()`	Invokes `get_exprN` and forwards its return value. `get_exprN` may access the variable named `obj` of type `type_name&` which represents the underlying instance of `type_name`. `attribute_typeN` may specify the type that `get_exprN` denotes to.
`const_proxyN.get()`	Invokes `get_exprN` and forwards its return value. `get_exprN` may access the variable named `obj` of type `type_name const&` which represents the underlying instance of `type_name`. `attribute_const_typeN` may specify the type that `get_exprN` denotes to.

Additionally, `proxy_typeN` and `const_proxy_typeN` are copy constructible, copy assignable and implicitly convertible to `proxy_typeN::type` or `const_proxy_typeN::type`.

Tip

To avoid the pitfalls of the proxy type, an arbitrary class type may also be adapted directly using fusion's intrinsic extension mechanism.

Change log

This section summarizes significant changes to the Fusion library.

- Sep 27, 2006: Added `boost::tuple` support. (Joel de Guzman)
- Nov 17, 2006: Added `boost::variant` support. (Joel de Guzman)
- Feb 15, 2007: Added functional module. (Tobias Schwinger)
- April 2, 2007: Added struct adapter. (Joel de Guzman)
- May 8, 2007: Added associative struct adapter. (Dan Marsden)
- Dec 20, 2007: Removed `boost::variant` support. After thorough investigation, I think now that the move to make variant a fusion sequence is rather quirky. A variant will always have a size==1 regardless of the number of types it can contain and there's no way to know at compile time what it contains. Iterating over its types is simply wrong. All these imply that the variant is **not** a fusion sequence. (Joel de Guzman)
- Oct 12, 2009: The accumulator is the first argument to the functor of `fold` and `accumulate`. (Christopher Schmidt)
- Oct 30, 2009: Added support for associative iterators and views. (Christopher Schmidt)
- March 1, 2010: Added `BOOST_FUSION_ADAPT_STRUCT_NAMED` and `BOOST_FUSION_ADAPT_STRUCT_NAMED_NS` (Hartmut Kaiser)
- April 4, 2010: Added array support, `BOOST_FUSION_ADAPT_TPL_STRUCT`, `BOOST_FUSION_ADAPT_ASSOC_TPL_STRUCT`, `BOOST_FUSION_ADAPT_ASSOC_STRUCT_NAMED` and `BOOST_FUSION_ADAPT_ASSOC_STRUCT_NAMED_NS` (Christopher Schmidt)
- April 5, 2010: Added `BOOST_FUSION_DEFINE_STRUCT`, `BOOST_FUSION_DEFINE_TPL_STRUCT`, `BOOST_FUSION_DEFINE_ASSOC_STRUCT` and `BOOST_FUSION_DEFINE_ASSOC_TPL_STRUCT` (Christopher Schmidt)
- June 18, 2010: Added `reverse_fold`, `iter_fold` and `reverse_iter_fold` (Christopher Schmidt)
- October 7, 2010: Added `BOOST_FUSION_ADAPT_ADT`, `BOOST_FUSION_ADAPT_TPL_ADT`, `BOOST_FUSION_ADAPT_ASSOC_ADT` and `BOOST_FUSION_ADAPT_ASSOC_TPL_ADT` (Joel de Guzman, Hartmut Kaiser and Christopher Schmidt)
- August 29, 2011: Added support for segmented sequences and iterators (Eric Niebler)
- September 16, 2011: Added preprocessed files (using wave) to speed up compilation (Joel de Guzman)
- October 8, 2011: Added adaptor for std::tuple (Joel de Guzman)

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