zip and enumerate iterators

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1 Main Page 1

1.1 Python-like Zip and Enumerate Iterators . . . 1

1.1.1 Properties . . . 1

1.1.2 Doxygen Documentation . . . 1

1.1.3 Code Examples . . . 1

2 Namespace Documentation 2

2.1 iterators Namespace Reference . . . 2

2.1.1 Detailed Description . . . 3

2.1.2 Function Documentation . . . 3

2.2 iterators::impl Namespace Reference . . . 5

2.2.1 Detailed Description . . . 6

2.2.2 Function Documentation . . . 6

2.3 iterators::impl::traits Namespace Reference . . . 7

2.3.1 Detailed Description . . . 8

3 Class Documentation 8

3.1 iterators::impl::CounterIterator< T > Struct Template Reference . . . 8

3.1.1 Detailed Description . . . 10

3.1.2 Constructor & Destructor Documentation . . . 10

3.1.3 Member Function Documentation . . . 11

3.1.4 Friends And Related Function Documentation . . . 16

3.2 iterators::impl::CounterRange< T > Struct Template Reference . . . 17

3.2.1 Detailed Description . . . 17

3.2.2 Constructor & Destructor Documentation . . . 17

3.2.3 Member Function Documentation . . . 18

3.3 iterators::impl::SynthesizedOperators< Impl > Struct Template Reference . . . 18

3.3.1 Detailed Description . . . 19

3.3.2 Member Function Documentation . . . 20

3.3.3 Friends And Related Function Documentation . . . 22

3.4 iterators::impl::Unreachable Struct Reference . . . 24

3.4.1 Detailed Description . . . 24

3.5 iterators::impl::ZipIterator< Iterators > Class Template Reference . . . 24

3.5.1 Detailed Description . . . 26

3.5.2 Member Function Documentation . . . 26

3.5.3 Friends And Related Function Documentation . . . 34

3.6 iterators::impl::ZipView< Iterable > Struct Template Reference . . . 34

3.6.1 Detailed Description . . . 35

3.6.2 Constructor & Destructor Documentation . . . 35

3.6.3 Member Function Documentation . . . 36

3.6.4 Friends And Related Function Documentation . . . 38

4 File Documentation 39

4.1 Iterators.hpp File Reference 39
4.1.1 Detailed Description 41
4.1.2 Macro Definition Documentation 41

Index **43**

1 Main Page

1.1 Python-like Zip and Enumerate Iterators

C++-implementation of Python-like zip- and enumerate-iterators which can be used in range-based for loops along with structured bindings to iterate over multiple containers at the same time. Requires C++17.

1.1.1 Properties

The `zip`-class is a container-wrapper for arbitrary iterable containers. It provides the member functions `begin()` and `end()` enabling it to be used in range-based for loops to iterate over multiple containers at the same time. The `enuerate`-function is a special case of `zip` and uses a "counting container" (similar to `std::ranges::iota`) to provide an index. Additionally, const-versions exist which do not allow the manipulation of the container elements.

1.1.2 Doxygen Documentation

- HTML
- PDF

1.1.3 Code Examples

The syntax is mostly similar to Python:

```
#include <vector>
#include <list>
#include "Iterators.hpp"
using namespace iterators;
std::list<std::string> strings{"a", "b", "c"};
std::vector<int> numbers{1, 2, 3};
for (auto [string, number] : zip(strings, numbers)) {
    // 'string' and 'number' are references to the container element
    string += std::to_string(number);
}
// now 'strings' contains {"a1", "b2", "c3"}
```

The for loop uses so called `ZipIterator`s which point to tuples which in turn contain references to the container elements. Therefore, no copying occurs and manipulation of the container elements is possible. Observe that the structured binding captures by value (since the values are themselves references).

If you want to prohibit manipulation, you can use `const_zip`

```
using namespace iterators;
std::list<std::string> strings{"a", "b", "c"};
std::vector<int> numbers{1, 2, 3};
for (auto [string, number] : const_zip(strings, numbers)) {
    // string += std::to_string(number);  error, string is readonly!
```

```
    std::cout « string « " " « number « std::endl;
}
```

Additionally, you can use `zip_i` to manually zip iterators or pointers:

```
using namespace iterators;
std::list<std::string> strings{"a", "b", "c"};
std::vector<int> numbers{1, 2, 3};
auto zipBegin = zip_i(strings.begin(), numbers.begin());
auto zipEnd = zip_i(strings.end(), numbers.end());
while (zipBegin != zipEnd) {
    auto [s, num] = *zipBegin;
    // ...
    ++zipBegin;
}
```

`ZipIterators` support the same operations as the least powerful underlying iterator. For example, if you zip a random access iterator (e.g. from `std::vector`) and a bidirectional iterator (e.g. from `std::list`), then the resulting `ZipIterator` will only support bidirectional iteration but no random access.

As in Python, the shortest range decides the overall range:

```
using namespace iterators;
std::list<std::string> strings{"a", "b", "c"};
std::vector<int> numbers{1, 2, 3, 4, 5, 6};
for (auto [string, number] : zip(strings, numbers)) {
    std::cout « string « " " « number « " | "
}
// prints a 1 | b 2 | c 3 |
```

The `enumerate`-function works similarly.

```
using namespace iterators;
std::list<std::string> strings{"a", "b", "c"};
for (auto [index, string] : enumerate(strings)) {
    string += std::to_string(index);
}
// now 'strings' contains {"a0", "b1", "c2"}
```

Also, an optional offset can be specified:

```
for (auto [index, string] : enumerate(strings, 4)) { // index starts from 4
    ...
}
```

And as with `zip`, a const version (`const_enumerate`) exists.

In case temporary containers are used, `zip` and `enumerate` will take ownership of the containers to guarantee well-defined memory access.

```
for (auto [index, number] : enumerate(std::array{53, 21, 17})) {
    // enumerate takes ownership of the array. The elements
    // can safely be accessed and manipulated
}
```

2 Namespace Documentation

2.1 iterators Namespace Reference

namespace containing zip and enumerate functions

Namespaces

- impl

  namespace containing structures and helpers used to implement zip and enumerate. Normally there is no need to use any of its members directly

Functions

- template<typename ... Iterators>
  constexpr auto zip_i (Iterators ...iterators) -> impl::ZipIterator< std::tuple< Iterators... >>
- template<typename ... Iterable>
  constexpr auto zip (Iterable &&...iterable)
- template<typename ... Iterable>
  constexpr auto const_zip (Iterable &&...iterable)
- template<typename Container , typename T = std::size_t>
  constexpr auto enumerate (Container &&container, T start=T(0), T increment=T(1))
- template<typename Container , typename T = std::size_t>
  constexpr auto const_enumerate (Container &&container, T start=T(0), T increment=T(1))

2.1.1 Detailed Description

namespace containing zip and enumerate functions

2.1.2 Function Documentation

2.1.2.1 const_enumerate()

```
template<typename Container , typename T = std::size_t>
constexpr auto iterators::const_enumerate (
            Container && container,
            T start = T(0),
            T increment = T(1) )  [constexpr]
```

enumerate variant that does not allow manipulation of the container elements

Function that can be used in range based loops to emulate the enumerate iterator from python.

Template Parameters

Container	Container type that supports iteration
T	type of enumerate counter (default std::size_t)

Parameters

container	Source container
start	Optional index offset (default 0)
increment	Optional index increment (default 1)

Returns

impl::ZipView that provides begin and end members to be used in range based for-loops.

2.1.2.2 const_zip() `template<typename ... Iterable>`

```
constexpr auto iterators::const_zip (
            Iterable &&... iterable ) [constexpr]
```

Zip variant that does not allow manipulation of the container elements

Function that can be used in range based loops to emulate the zip iterator from python. As in python: if the passed containers have different lengths, the container with the least items decides the overall range

Template Parameters

Iterable	Container types that support iteration

Parameters

iterable	Arbitrary number of containers

Returns

impl::ZipView class that provides begin and end members to be used in range based for-loops

2.1.2.3 enumerate() `template<typename Container , typename T = std::size_t>`

```
constexpr auto iterators::enumerate (
            Container && container,
            T start = T(0),
            T increment = T(1) ) [constexpr]
```

Function that can be used in range based loops to emulate the enumerate iterator from python.

Template Parameters

Container	Container type that supports iteration
T	type of enumerate counter (default std::size_t)

Parameters

container	Source container
start	Optional index offset (default 0)
increment	Optional index increment (default 1)

Returns

impl::ZipView that provides begin and end members to be used in range based for-loops.

2.1.2.4 zip() `template<typename ... Iterable>`

```
constexpr auto iterators::zip (
            Iterable &&... iterable ) [constexpr]
```

Function that can be used in range based loops to emulate the zip iterator from python. As in python: if the passed containers have different lengths, the container with the least items decides the overall range

Template Parameters

Iterable	Container types that support iteration

Parameters

iterable	Arbitrary number of containers

Returns

impl::ZipView class that provides begin and end members to be used in range based for-loops

2.1.2.5 zip_i() `template<typename ... Iterators>`

```
constexpr auto iterators::zip_i (
            Iterators ... iterators ) -> impl::ZipIterator<std::tuple<Iterators...>>  [constexpr]
```

Function that is used to create a impl::ZipIterator from an arbitrary number of iterators

Template Parameters

Iterators	type of iterators

Parameters

iterators	arbitrary number of iterators

Returns

impl::ZipIterator

Note

ZipIterators have the same iterator category as the least powerful underlying operator. This means that for example, zipping a random access iterator and a bidirectional iterator only yields a bidirectional impl::ZipIterator

2.2 iterators::impl Namespace Reference

namespace containing structures and helpers used to implement zip and enumerate. Normally there is no need to use any of its members directly

Namespaces

- traits

  namespace containing type traits used in implementation of zip and enumerate

Classes

- struct SynthesizedOperators

  CRTP-class that provides additional pointer arithmetic operators synthesized from basic operators.
- class ZipIterator

  Class combining multiple iterators into one. Use it to iterate over multiple ranges at the same time.
- struct ZipView

  Zip-view that provides begin() and end() member functions. Use to loop over multiple ranges at the same time using ranged based for-loops.
- struct Unreachable

  represents the unreachable end of an infinite sequence
- struct CounterIterator

  Iterator of an infinite sequence of numbers. Simply increments an internal counter.
- struct CounterRange

  Represents an infinite range of numbers.

Functions

- template<typename T >
  constexpr T sgn (T val) noexcept

2.2.1 Detailed Description

namespace containing structures and helpers used to implement zip and enumerate. Normally there is no need to use any of its members directly

2.2.2 Function Documentation

2.2.2.1 sgn() `template<typename T >`

```
constexpr T iterators::impl::sgn (
            T val )  [constexpr], [noexcept]
```

Signum function

Template Parameters

T	arbitrary scalar type

Parameters

val	function argument

Returns

+1 if val >= 0, -1 else

2.3 iterators::impl::traits Namespace Reference

namespace containing type traits used in implementation of zip and enumerate

Classes

- struct **is_container**
- struct **is_container**< **T, std::void_t**< **decltype(std::begin(std::declval**< **T** >**()), std::end(std::declval**< **T** >**()))**> >
- struct **is_dereferencible**
- struct **is_dereferencible**< **T, std::void_t**< **decltype(**∗**std::declval**< **T** >**())**> >
- struct **is_dereferencible**< **std::tuple**< **Ts...** >**, void** >
- struct **is_incrementable**
- struct **is_incrementable**< **T, std::void_t**< **decltype(++REFERENCE(T))**> >
- struct **is_incrementable**< **std::tuple**< **Ts...** >**, void** >
- struct **dereference**
- struct **dereference**< **T, true** >
- struct **values**
- struct **values**< **std::tuple**< **Ts...** > >
- struct **iterator_category_value**
- struct **iterator_category_value**< **T, std::void_t**< **typename std::iterator_traits**< **T** >**::iterator_category** > >
- struct **iterator_category_from_value**
- struct **iterator_category_from_value**< **0** >
- struct **minimum_category**
- struct **minimum_category**< **std::tuple**< **Ts...** > >
- struct **is_random_accessible**
- struct **is_random_accessible**< **T, std::void_t**< **typename std::iterator_traits**< **T** >**::iterator_category** > >
- struct **is_random_accessible**< **std::tuple**< **Ts...** >**, std::void_t**< **value_to_type_t**< **minimum_category_v**< **std::tuple**< **Ts...** > > > > > >
- struct **is_bidirectional**
- struct **is_bidirectional**< **T, std::void_t**< **typename std::iterator_traits**< **T** >**::iterator_category** > >
- struct **is_bidirectional**< **std::tuple**< **Ts...** >**, std::void_t**< **value_to_type_t**< **minimum_category_v**< **std::tuple**< **Ts...** > > > > > >
- struct **has_size**
- struct **has_size**< **T, std::void_t**< **decltype(std::size(std::declval**< **std::remove_reference_t**< **T** >>**()))**> >
- struct **has_size**< **std::tuple**< **Ts...** > >

Typedefs

- template<bool Cond, typename T >
  using **reference_if_t** = std::conditional_t< Cond, std::add_lvalue_reference_t< T >, T >
- template<bool Cond, typename T >
  using **const_if_t** = std::conditional_t< Cond, std::add_const_t< T >, T >
- template<typename T >
  using **dereference_t** = typename dereference< T, is_dereferencible_v< T > >::type
- template<typename T >
  using **values_t** = typename values< T >::type

Variables

- template<typename T >
  constexpr bool **is_container_v** = is_container<T>::value
- template<typename T >
  constexpr bool **is_dereferencible_v** = is_dereferencible<T>::value
- template<typename T >
  constexpr bool **is_incrementable_v** = is_incrementable<T>::value
- template<typename T >
  constexpr std::size_t **minimum_category_v** = minimum_category<T>::value
- template<typename T >
  constexpr bool **is_random_accessible_v** = is_random_accessible<T>::value
- template<typename T >
  constexpr bool **is_bidirectional_v** = is_bidirectional<T>::value
- template<typename T >
  constexpr bool **has_size_v** = has_size<T>::value

2.3.1 Detailed Description

namespace containing type traits used in implementation of zip and enumerate

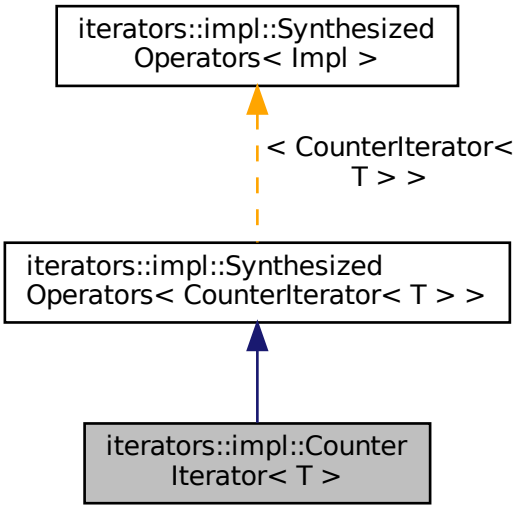
3 Class Documentation

3.1 iterators::impl::CounterIterator< T > Struct Template Reference

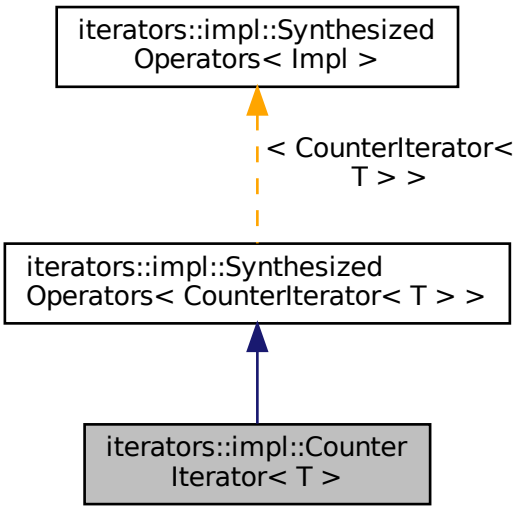
Iterator of an infinite sequence of numbers. Simply increments an internal counter.

`#include <Iterators.hpp>`

Inheritance diagram for iterators::impl::CounterIterator< T >:



Collaboration diagram for iterators::impl::CounterIterator< T >:



Public Types

- using **value_type** = T

- using **reference** = T
- using **pointer** = void
- using **iterator_category** = std::random_access_iterator_tag
- using **difference_type** = std::ptrdiff_t

Public Member Functions

- constexpr CounterIterator (T begin, T increment=T(1)) noexcept
- constexpr CounterIterator & operator++ () noexcept
- constexpr CounterIterator & operator-- () noexcept
- constexpr CounterIterator & operator+= (difference_type n) noexcept
- constexpr CounterIterator & operator-= (difference_type n) noexcept
- constexpr difference_type operator- (const CounterIterator &other) const noexcept
- constexpr bool operator== (const CounterIterator &other) const noexcept
- constexpr bool operator< (const CounterIterator &other) const noexcept
- constexpr bool operator> (const CounterIterator &other) const noexcept
- constexpr T operator* () const noexcept
- constexpr auto operator[ ] (typename Implementation::difference_type n) const noexcept(noexcept(*(std::declval< CounterIterator< T > >()+n)))
- constexpr CounterIterator< T > operator++ (int) noexcept(noexcept(++std::declval< CounterIterator< T > >()) &&std::is_nothrow_copy_constructible_v< CounterIterator< T > >)
- constexpr CounterIterator< T > operator-- (int) noexcept(noexcept(--std::declval< CounterIterator< T > >()) &&std::is_nothrow_copy_constructible_v< CounterIterator< T > >)
- constexpr bool operator!= (const T &other) const noexcept(noexcept(INSTANCE_OF_IMPL==other))
- constexpr bool operator<= (const T &rhs) const noexcept(noexcept(INSTANCE_OF_IMPL > rhs))
- constexpr bool operator>= (const T &rhs) const noexcept(noexcept(INSTANCE_OF_IMPL< rhs))

Friends

- constexpr friend bool operator== (const CounterIterator &, Unreachable) noexcept
- constexpr friend bool operator== (Unreachable, const CounterIterator &) noexcept
- constexpr friend bool **operator!=** (Unreachable, const CounterIterator &) noexcept

3.1.1 Detailed Description

template<typename T>
struct iterators::impl::CounterIterator< T >

Iterator of an infinite sequence of numbers. Simply increments an internal counter.

Template Parameters

Type	of the counter (most of the time this is `std::size_t`)

3.1.2 Constructor & Destructor Documentation

3.1.2.1 CounterIterator() `template<typename T >`

```
constexpr iterators::impl::CounterIterator< T >::CounterIterator (
            T begin,
            T increment = T(1) )  [inline], [explicit], [constexpr], [noexcept]
```

CTor.

Parameters

begin	start of number sequence
increment	step size (default is 1)

Note

Depending on the template type T, increment can also be negative.

3.1.3 Member Function Documentation

3.1.3.1 operator"!=() `constexpr bool iterators::impl::SynthesizedOperators< CounterIterator< T > >::operator!= (`

```
            const T & other ) const  [inline], [constexpr], [noexcept], [inherited]
```

Inequality comparison

Template Parameters

T	type of right hand side
Implementation	SFINAE helper, do not specify explicitly

Parameters

other	right hand side

Returns

true if this is not equal to other

3.1.3.2 operator*() `template<typename T >`

```
constexpr T iterators::impl::CounterIterator< T >::operator* ( ) const  [inline], [constexpr],
[noexcept]
```

Produces the counter value

Returns

value of internal counter

3.1.3.3 operator++() [1/2] template<typename T >

constexpr CounterIterator& iterators::impl::CounterIterator< T >::operator++ ( ) [inline], [constexpr], [noexcept]

Increments value by increment

Returns

reference to this

3.1.3.4 operator++() [2/2] constexpr CounterIterator< T > iterators::impl::SynthesizedOperators< CounterIterator< T > >::operator++ (int) [inline], [constexpr], [noexcept], [inherited]

Postfix increment. Synthesized from prefix increment

Template Parameters

Implementation	SFINAE helper, do not specify explicitly

Returns

Instance of Impl

3.1.3.5 operator+=() template<typename T >

constexpr CounterIterator& iterators::impl::CounterIterator< T >::operator+= (difference_type *n*) [inline], [constexpr], [noexcept]

Compound assignment increment. Increments value by n times increment

Parameters

n	number of steps

Returns

reference to this

3.1.3.6 operator-() template<typename T >

constexpr difference_type iterators::impl::CounterIterator< T >::operator- (const CounterIterator< T > & *other*) const [inline], [constexpr], [noexcept]

Difference between two CounterIterators

Parameters

other	right hand side

Returns

integer `n` with the smallest possible absolute value such that `other + n <= *this`

Note

When other has the same increment as `*this`, then the returned value is guaranteed to fulfil `other + n == *this`. In the following example, this is not the case:

```
CounterIterator a(8, 1);
CounterIterator b(4, 3);
auto diff = a - b; // yields 1 since b + 1 <= a
```

3.1.3.7 operator--() [1/2] template<typename T >

`constexpr CounterIterator& iterators::impl::CounterIterator< T >::operator-- ( ) [inline], [constexpr], [noexcept]`

Decrements value by increment

Returns

reference to this

3.1.3.8 operator--() [2/2] constexpr CounterIterator< T > iterators::impl::SynthesizedOperators< CounterIterator< T > >::operator-- (

`int ) [inline], [constexpr], [noexcept], [inherited]`

Postfix decrement. Synthesized from prefix decrement

Template Parameters

Implementation	SFINAE helper, do not specify explicitly

Returns

Instance of Impl

3.1.3.9 operator-=() template<typename T >

`constexpr CounterIterator& iterators::impl::CounterIterator< T >::operator-= ( difference_type n ) [inline], [constexpr], [noexcept]`

Compound assignment decrement. Increments value by n times increment

Parameters

n	number of steps

Returns

reference to this

3.1.3.10 operator<() `template<typename T >`

```
constexpr bool iterators::impl::CounterIterator< T >::operator< (
            const CounterIterator< T > & other ) const  [inline], [constexpr], [noexcept]
```

Less comparison of internal counters with respect to increment of this instance

Parameters

other	right hand side

Returns

true if
`sgn(increment) **this < *other sgn(increment)`

where `sgn` is the signum function

Note

If increment is negative then both sides of the inequality are multiplied with -1. For example: let `it1 = 5` and `it2 = -2` be two CounterIterators where `it1` has negative increment. Then `it1 < it2` is true.

3.1.3.11 operator<=() `constexpr bool iterators::impl::SynthesizedOperators< CounterIterator< T > >::operator<= (`

```
            const T & rhs ) const  [inline], [constexpr], [noexcept], [inherited]
```

Less than or equal comparison

Template Parameters

T	type of right hand side
Implementation	SFINAE helper, do not specify explicitly

Parameters

other	right hand side

Returns

true if this is not greater than other

3.1.3.12 operator==() `template<typename T >`

```
constexpr bool iterators::impl::CounterIterator< T >::operator== (
            const CounterIterator< T > & other ) const  [inline], [constexpr], [noexcept]
```

Equality comparison.

Parameters

other	right hand side

Returns

true if counter of left and right hand side are equal

3.1.3.13 operator>() `template<typename T >`

```
constexpr bool iterators::impl::CounterIterator< T >::operator> (
            const CounterIterator< T > & other ) const  [inline], [constexpr], [noexcept]
```

Greater comparison of internal counters with respect to increment of this instance

Parameters

other	right hand side

Returns

true if
`sgn(increment) **this > *other sgn(increment)`
where `sgn` is the signum

Note

If increment is negative then both sides of the inequality are multiplied with -1. For example: let `it1 = 5` and `it2 = -2` be two CounterIterators where `it1` has negative increment. Then `it1 > it2` is false.

3.1.3.14 operator>=() `constexpr bool iterators::impl::SynthesizedOperators< CounterIterator< T > >::operator>= (`

```
            const T & rhs ) const  [inline], [constexpr], [noexcept], [inherited]
```

Greater than or equal comparison

Template Parameters

T	type of right hand side
Implementation	SFINAE helper, do not specify explicitly

Parameters

other	right hand side

Returns

true if this is not less than other

3.1.3.15 operator[]() `constexpr auto iterators::impl::SynthesizedOperators< CounterIterator< T > >::operator[] ( typename Implementation::difference_type n ) const [inline], [constexpr], [noexcept], [inherited]`

Array subscript operator

Template Parameters

Implementation	SFINAE helper, do not specify explicitly

Parameters

n	index

Returns

∗(∗this + n)

3.1.4 Friends And Related Function Documentation

3.1.4.1 operator== [1/2] `template<typename T > constexpr friend bool operator== ( const CounterIterator< T > & , Unreachable ) [friend]`

Equality comparison with Unreachable sentinel

Returns

false

3.1.4.2 operator== [2/2] template<typename T >

```
constexpr friend bool operator== (
            Unreachable ,
            const CounterIterator< T > &  )  [friend]
```

Equality comparison with Unreachable sentinel

Returns

false

The documentation for this struct was generated from the following file:

- Iterators.hpp

3.2 iterators::impl::CounterRange< T > Struct Template Reference

Represents an infinite range of numbers.

`#include <Iterators.hpp>`

Public Member Functions

- constexpr CounterRange (T start, T increment) noexcept
- constexpr CounterIterator< T > begin () const noexcept

Static Public Member Functions

- static constexpr Unreachable end () noexcept

3.2.1 Detailed Description

template<typename T = std::size_t>
struct iterators::impl::CounterRange< T >

Represents an infinite range of numbers.

Template Parameters

T	type of number range

3.2.2 Constructor & Destructor Documentation

3.2.2.1 CounterRange() template<typename T = std::size_t>

```
constexpr iterators::impl::CounterRange< T >::CounterRange (
            T start,
            T increment )  [inline], [explicit], [constexpr], [noexcept]
```

CTor

Parameters

start	start of the range
increment	step size

Note

Depending on the template type T, increment can also be negative.

3.2.3 Member Function Documentation

3.2.3.1 begin() template<typename T = std::size_t>

```
constexpr CounterIterator<T> iterators::impl::CounterRange< T >::begin ( ) const  [inline],
[constexpr], [noexcept]
```

Returns

CounterIterator representing the beginning of the sequence

3.2.3.2 end() template<typename T = std::size_t>

```
static constexpr Unreachable iterators::impl::CounterRange< T >::end ( )  [inline], [static],
[constexpr], [noexcept]
```

Returns

Sentinel object representing the unreachable end of the sequence

The documentation for this struct was generated from the following file:

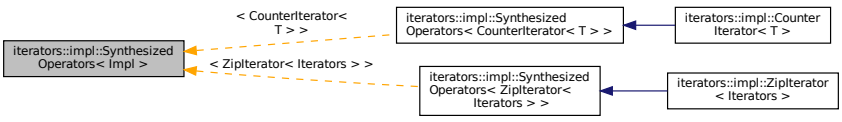
- Iterators.hpp

3.3 iterators::impl::SynthesizedOperators< Impl > Struct Template Reference

CRTP-class that provides additional pointer arithmetic operators synthesized from basic operators.

`#include <Iterators.hpp>`

Inheritance diagram for iterators::impl::SynthesizedOperators< Impl >:



Public Member Functions

- template<REQUIRES_IMPL(Impl, *(INSTANCE_OF_IMPL+INSTANCE_OF(typename Implementation::difference_type))) >
  constexpr auto operator[ ] (typename Implementation::difference_type n) const noexcept(noexcept(*(std↩
  ::declval< Impl >()+n)))
- template<REQUIRES_IMPL(Impl,++INSTANCE_OF_IMPL) >
  constexpr Impl operator++ (int) noexcept(noexcept(++std::declval< Impl >()) &&std::is_nothrow_copy_↩
  constructible_v< Impl >)
- template<REQUIRES_IMPL(Impl, --INSTANCE_OF_IMPL) >
  constexpr Impl operator-- (int) noexcept(noexcept(--std::declval< Impl >()) &&std::is_nothrow_copy_↩
  constructible_v< Impl >)
- template<typename T , REQUIRES_IMPL(Impl, INSTANCE_OF_IMPL==INSTANCE_OF(T)) >
  constexpr bool operator!= (const T &other) const noexcept(noexcept(INSTANCE_OF_IMPL==other))
- template<typename T , REQUIRES_IMPL(Impl, INSTANCE_OF_IMPL > INSTANCE_OF(T)) >
  constexpr bool operator<= (const T &rhs) const noexcept(noexcept(INSTANCE_OF_IMPL > rhs))
- template<typename T , REQUIRES_IMPL(Impl, INSTANCE_OF_IMPL< INSTANCE_OF(T)) >
  constexpr bool operator>= (const T &rhs) const noexcept(noexcept(INSTANCE_OF_IMPL< rhs))

Friends

- template<REQUIRES_IMPL(Impl, INSTANCE_OF_IMPL+=INSTANCE_OF(typename Implementation::difference_type)) >
  constexpr friend auto operator+ (Impl it, typename Implementation::difference_type n) noexcept(noexcept(std↩
  ::declval< Impl >()+=n))
- template<REQUIRES_IMPL(Impl, INSTANCE_OF_IMPL+=INSTANCE_OF(typename Implementation::difference_type)) >
  constexpr friend auto operator+ (typename Implementation::difference_type n, Impl it) noexcept(noexcept(std↩
  ::declval< Impl >()+=n))
- template<REQUIRES_IMPL(Impl, INSTANCE_OF_IMPL -=INSTANCE_OF(typename Implementation::difference_type)) >
  constexpr friend auto operator- (Impl it, typename Implementation::difference_type n) noexcept(noexcept(std↩
  ::declval< Impl >() -=n))

3.3.1 Detailed Description

template<typename Impl>
struct iterators::impl::SynthesizedOperators< Impl >

CRTP-class that provides additional pointer arithmetic operators synthesized from basic operators.

Adds the following operators

- postfix increment and decrement (requires the respective prefix operators)
- array subscript operator[] (requires operator+ and dereference operator)
- binary arithmetic operators (requires compound assignment operators)
- inequality comparison (requires operator==)
- less than or equal comparison (requires operator>)
- greater than or equal comparison (requires operator<)

Template Parameters

Impl	Base class

3.3.2 Member Function Documentation

3.3.2.1 operator"!=() template<typename Impl >

```
template<typename T , REQUIRES_IMPL(Impl, INSTANCE_OF_IMPL==INSTANCE_OF(T)) >
constexpr bool iterators::impl::SynthesizedOperators< Impl >::operator!= (
            const T & other ) const  [inline], [constexpr], [noexcept]
```

Inequality comparison

Template Parameters

T	type of right hand side
Implementation	SFINAE helper, do not specify explicitly

Parameters

other	right hand side

Returns

true if this is not equal to other

3.3.2.2 operator++() template<typename Impl >

```
template<REQUIRES_IMPL(Impl,++INSTANCE_OF_IMPL) >
constexpr Impl iterators::impl::SynthesizedOperators< Impl >::operator++ (
            int  )  [inline], [constexpr], [noexcept]
```

Postfix increment. Synthesized from prefix increment

Template Parameters

Implementation	SFINAE helper, do not specify explicitly

Returns

Instance of Impl

3.3.2.3 operator--() template<typename Impl >

```
template<REQUIRES_IMPL(Impl, --INSTANCE_OF_IMPL) >
constexpr Impl iterators::impl::SynthesizedOperators< Impl >::operator-- (
            int  )  [inline], [constexpr], [noexcept]
```

Postfix decrement. Synthesized from prefix decrement

Template Parameters

Implementation	SFINAE helper, do not specify explicitly

Returns

Instance of Impl

3.3.2.4 operator<=()

```
template<typename Impl >
template<typename T , REQUIRES_IMPL(Impl, INSTANCE_OF_IMPL > INSTANCE_OF(T)) >
constexpr bool iterators::impl::SynthesizedOperators< Impl >::operator<= (
            const T & rhs ) const  [inline], [constexpr], [noexcept]
```

Less than or equal comparison

Template Parameters

T	type of right hand side
Implementation	SFINAE helper, do not specify explicitly

Parameters

other	right hand side

Returns

true if this is not greater than other

3.3.2.5 operator>=()

```
template<typename Impl >
template<typename T , REQUIRES_IMPL(Impl, INSTANCE_OF_IMPL< INSTANCE_OF(T)) >
constexpr bool iterators::impl::SynthesizedOperators< Impl >::operator>= (
            const T & rhs ) const  [inline], [constexpr], [noexcept]
```

Greater than or equal comparison

Template Parameters

T	type of right hand side
Implementation	SFINAE helper, do not specify explicitly

Parameters

other	right hand side

Returns

true if this is not less than other

3.3.2.6 operator[]() `template<typename Impl >`

```
template<REQUIRES_IMPL(Impl, *(INSTANCE_OF_IMPL+INSTANCE_OF(typename Implementation::difference↩
_type))) >
constexpr auto iterators::impl::SynthesizedOperators< Impl >::operator[] (
            typename Implementation::difference_type n ) const  [inline], [constexpr], [noexcept]
```

Array subscript operator

Template Parameters

Implementation	SFINAE helper, do not specify explicitly

Parameters

n	index

Returns

∗(∗this + n)

3.3.3 Friends And Related Function Documentation

3.3.3.1 operator+ [1/2] `template<typename Impl >`

```
template<REQUIRES_IMPL(Impl, INSTANCE_OF_IMPL+=INSTANCE_OF(typename Implementation::difference↩
_type)) >
constexpr friend auto operator+ (
            Impl it,
            typename Implementation::difference_type n )  [friend]
```

Binary +plus operator. Synthesized from compound assignment operator+=

Template Parameters

Implementation	SFINAE helper, do not specify explicitly

Parameters

it	left hand side
n	right hand side

Returns

Instance of Impl

3.3.3.2 operator+ [2/2] template<typename Impl >

```
template<REQUIRES_IMPL(Impl, INSTANCE_OF_IMPL+=INSTANCE_OF(typename Implementation::difference↩
_type)) >
constexpr friend auto operator+ (
            typename Implementation::difference_type n,
            Impl it )  [friend]
```

Binary +plus operator. Synthesized from compound assignment operator+=

Template Parameters

Implementation	SFINAE helper, do not specify explicitly

Parameters

n	left hand side
it	right hand side

Returns

Instance of Impl

3.3.3.3 operator- template<typename Impl >

```
template<REQUIRES_IMPL(Impl, INSTANCE_OF_IMPL -=INSTANCE_OF(typename Implementation::difference↩
_type)) >
constexpr friend auto operator- (
            Impl it,
            typename Implementation::difference_type n )  [friend]
```

Binary minus operator. Synthesized from compound assignment operator-=

Template Parameters

Implementation	SFINAE helper, do not specify explicitly

Parameters

it	left hand side
n	right hand side

Returns

Instance of Impl

The documentation for this struct was generated from the following file:

- Iterators.hpp

3.4 iterators::impl::Unreachable Struct Reference

represents the unreachable end of an infinite sequence

`#include <Iterators.hpp>`

3.4.1 Detailed Description

represents the unreachable end of an infinite sequence

The documentation for this struct was generated from the following file:

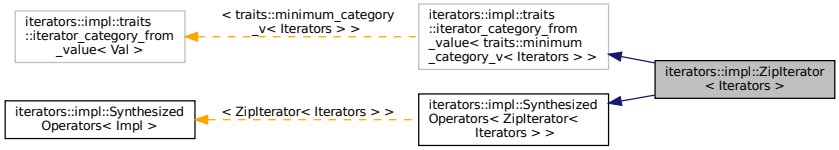
- Iterators.hpp

3.5 iterators::impl::ZipIterator< Iterators > Class Template Reference

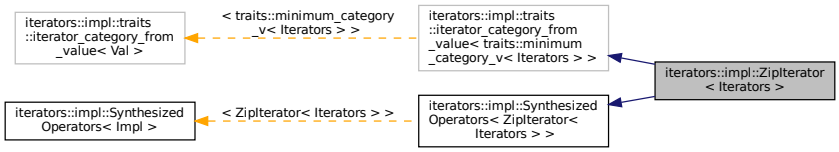
Class combining multiple iterators into one. Use it to iterate over multiple ranges at the same time.

`#include <Iterators.hpp>`

Inheritance diagram for iterators::impl::ZipIterator< Iterators >:



Collaboration diagram for iterators::impl::ZipIterator< Iterators >:



Public Types

- using **value_type** = traits::values_t< Iterators >
- using **reference** = value_type
- using **pointer** = void
- using **difference_type** = std::ptrdiff_t

Public Member Functions

- constexpr **ZipIterator** (const Iterators &iterators) noexcept(std::is_nothrow_copy_constructible_v< Iterators >)
- template<typename ... Its>
  constexpr **ZipIterator** (Its &&...its)
- template<typename Its = Iterators, typename = std::enable_if_t<traits::is_incrementable_v<Its>>>
  constexpr ZipIterator & operator++ () noexcept(traits::is_nothrow_incrementible_v< Iterators >)
- template<typename Its , REQUIRES(ZipIterator::oneEqual(INSTANCE_OF(Iterators), INSTANCE_OF(Its))) >
  constexpr bool operator== (const ZipIterator< Its > &other) const noexcept(noexcept(ZipIterator::oneEqual(std::declval< Iterators >(), other.getIterators())))
- template<typename Its = Iterators, typename = std::enable_if_t<traits::is_dereferencible_v<Its>>>
  constexpr auto operator* () const noexcept(traits::is_nothrow_dereferencible_v< Iterators >)
- constexpr auto getIterators () const noexcept -> const Iterators &
- constexpr auto operator[ ] (typename Implementation::difference_type n) const noexcept(noexcept(*(std::declval< ZipIterator< Iterators > >()+n)))
- constexpr ZipIterator< Iterators > operator++ (int) noexcept(noexcept(++std::declval< ZipIterator< Iterators > >()) &&std::is_nothrow_copy_constructible_v< ZipIterator< Iterators > >)
- constexpr ZipIterator< Iterators > operator-- (int) noexcept(noexcept(--std::declval< ZipIterator< Iterators > >()) &&std::is_nothrow_copy_constructible_v< ZipIterator< Iterators > >)
- constexpr bool operator!= (const T &other) const noexcept(noexcept(INSTANCE_OF_IMPL==other))
- constexpr bool operator<= (const T &rhs) const noexcept(noexcept(INSTANCE_OF_IMPL > rhs))
- constexpr bool operator>= (const T &rhs) const noexcept(noexcept(INSTANCE_OF_IMPL< rhs))

bidirectional iteration

the following operators are only available if all underlying iterators support bidirectional access

- template<bool IsBidirectional = traits::is_bidirectional_v<Iterators>>
  constexpr auto operator-- () noexcept(traits::is_nothrow_decrementible_v< Iterators >) -> std::enable_if_t< IsBidirectional, ZipIterator & >

random access operators

the following operators are only available if all underlying iterators support random access

- template<bool IsRandomAccessible = traits::is_random_accessible_v<Iterators>>
  constexpr auto operator+= (difference_type n) noexcept(traits::is_nothrow_compound_assignable_plus_v< Iterators >) -> std::enable_if_t< IsRandomAccessible, ZipIterator & >
- template<bool IsRandomAccessible = traits::is_random_accessible_v<Iterators>>
  constexpr auto operator-= (difference_type n) noexcept(traits::is_nothrow_compound_assignable_minus_v< Iterators >) -> std::enable_if_t< IsRandomAccessible, ZipIterator & >
- template<typename Its , bool IsRandomAccessible = traits::is_random_accessible_v<Iterators>, REQUIRES(ZipIterator::minDifference(INSTANCE_OF(Iterators), INSTANCE_OF(Its))) >
  constexpr auto operator- (const ZipIterator< Its > &other) const -> std::enable_if_t< IsRandomAccessible, difference_type >
- template<typename Its , bool IsRandomAccessible = traits::is_random_accessible_v<Iterators>, REQUIRES(ZipIterator::allLess(INSTANCE_OF(Iterators), INSTANCE_OF(Its))) >
  constexpr auto operator< (const ZipIterator< Its > &other) const noexcept(noexcept(ZipIterator::allLess(INSTANCE_OF(Iterators), INSTANCE_OF(Its)))) -> std::enable_if_t< IsRandomAccessible, bool >
- template<typename Its , bool IsRandomAccessible = traits::is_random_accessible_v<Iterators>, REQUIRES(ZipIterator::allGreater(INSTANCE_OF(Iterators), INSTANCE_OF(Its))) >
  constexpr auto operator> (const ZipIterator< Its > &other) const noexcept(noexcept(ZipIterator::allGreater(INSTANCE_OF(Iterators), INSTANCE_OF(Its)))) -> std::enable_if_t< IsRandomAccessible, bool >

Related Functions

(Note that these are not member functions.)

- template<typename ... Iterators>
  constexpr auto zip_i (Iterators ...iterators) -> impl::ZipIterator< std::tuple< Iterators... >>

3.5.1 Detailed Description

template<typename Iterators>
class iterators::impl::ZipIterator< Iterators >

Class combining multiple iterators into one. Use it to iterate over multiple ranges at the same time.

ZipIterators only support the operators of the least powerful underling iterator. Zipping a random access iterator (e.g. from std::vector) and a bidirectional iterator (e.g. from std::list) results in a bidirectional iterator. All operators are SFINAE friendly.

ZipIterators return a tuple of references to the range elements. When using structured bindings, no additional reference binding is necessary.

Let `z` be a ZipIterator composed from two `std::vector<int>`

```
auto [val1, val2] = *z; // val1 and val2 are references to the vector elements
val1 = 17; // this will change the respective value in the first vector
```

Template Parameters

Iterators	Underlying iterator types

3.5.2 Member Function Documentation

3.5.2.1 getIterators() `template<typename Iterators >`

`constexpr auto iterators::impl::ZipIterator< Iterators >::getIterators ( ) const -> const Iterators& [inline], [constexpr], [noexcept]`

Getter for underlying iterators

Returns

Const reference to underlying iterators

3.5.2.2 operator"!=() `constexpr bool iterators::impl::SynthesizedOperators< ZipIterator< Iterators > >::operator!= (`

`const T & other ) const [inline], [constexpr], [noexcept], [inherited]`

Inequality comparison

Template Parameters

T	type of right hand side
Implementation	SFINAE helper, do not specify explicitly

Parameters

other	right hand side

Returns

true if this is not equal to other

3.5.2.3 operator*() `template<typename Iterators >`

```
template<typename Its = Iterators, typename = std::enable_if_t<traits::is_dereferencible_v<↩
Its>>>
constexpr auto iterators::impl::ZipIterator< Iterators >::operator* ( ) const  [inline], [constexpr],
[noexcept]
```

Dereferences all underlying iterators and returns a tuple of the resulting range reference types

Template Parameters

Its	SFINAE guard, do not specify

Returns

tuple of references to range elements

3.5.2.4 operator++() [1/2] `template<typename Iterators >`

```
template<typename Its = Iterators, typename = std::enable_if_t<traits::is_incrementable_v<↩
Its>>>
constexpr ZipIterator& iterators::impl::ZipIterator< Iterators >::operator++ ( )  [inline],
[constexpr], [noexcept]
```

Increments all underlying iterators by one

Template Parameters

Its	SFINAE guard, do not specify

Returns

reference to this

3.5.2.5 operator++() [2/2]

```
constexpr ZipIterator< Iterators > iterators::impl::SynthesizedOperators< ZipIterator< Iterators > >::operator++ (
            int  )  [inline], [constexpr], [noexcept], [inherited]
```

Postfix increment. Synthesized from prefix increment

Template Parameters

Implementation	SFINAE helper, do not specify explicitly

Returns

Instance of Impl

3.5.2.6 operator+=()

```
template<typename Iterators >
template<bool IsRandomAccessible = traits::is_random_accessible_v<Iterators>>
constexpr auto iterators::impl::ZipIterator< Iterators >::operator+= (
            difference_type n ) -> std::enable_if_t<IsRandomAccessible, ZipIterator &>   [inline], [constexpr], [noexcept]
```

Compound assignment increment. Increments all underlying iterators by n. Only available if all underlying iterators support at least random access

Template Parameters

IsRandomAccessible	SFINAE guard, do not specify

Parameters

n	increment

Returns

reference to this

3.5.2.7 operator-()

```
template<typename Iterators >
template<typename Its , bool IsRandomAccessible = traits::is_random_accessible_v<Iterators>,
REQUIRES( ZipIterator::minDifference(INSTANCE_OF(Iterators), INSTANCE_OF(Its))) >
constexpr auto iterators::impl::ZipIterator< Iterators >::operator- (
            const ZipIterator< Its > & other ) const -> std::enable_if_t<IsRandomAccessible, difference_type>   [inline], [constexpr]
```

Returns the minimum pairwise difference n between all underlying iterators of ∗this and other, such that (other + n) == ∗this Only available if all underlying iterators support at least random access

Template Parameters

Its	Iterator types of right hand side
IsRandomAccessible	SFINAE guard, do not specify

Parameters

other	right hand side

Returns

integer n such that (other + n) == ∗this

3.5.2.8 operator--() [1/2]

```
template<typename Iterators >
template<bool IsBidirectional = traits::is_bidirectional_v<Iterators>>
constexpr auto iterators::impl::ZipIterator< Iterators >::operator-- ( ) -> std::enable_if_↩
t<IsBidirectional, ZipIterator &>  [inline], [constexpr], [noexcept]
```

Decrements all underlying iterators by one. Only available if all iterators support at least bidirectional access

Template Parameters

IsBidirectional	SFINAE guard, do not specify

Returns

reference to this

3.5.2.9 operator--() [2/2]

```
constexpr ZipIterator< Iterators > iterators::impl::SynthesizedOperators<
ZipIterator< Iterators > >::operator-- (
            int  )  [inline], [constexpr], [noexcept], [inherited]
```

Postfix decrement. Synthesized from prefix decrement

Template Parameters

Implementation	SFINAE helper, do not specify explicitly

Returns

Instance of Impl

3.5.2.10 operator-=() `template<typename Iterators >`

```
template<bool IsRandomAccessible = traits::is_random_accessible_v<Iterators>>
constexpr auto iterators::impl::ZipIterator< Iterators >::operator-= (
            difference_type n ) -> std::enable_if_t<IsRandomAccessible, ZipIterator &>   [inline],
[constexpr], [noexcept]
```

Compound assignment decrement. Decrements all underlying iterators by n. Only available if all underlying iterators support at least random access

Template Parameters

IsRandomAccessible	SFINAE guard, do not specify

Parameters

n	decrement

Returns

reference to this

3.5.2.11 operator<() `template<typename Iterators >`

```
template<typename Its , bool IsRandomAccessible = traits::is_random_accessible_v<Iterators>,
REQUIRES( ZipIterator::allLess(INSTANCE_OF(Iterators), INSTANCE_OF(Its))) >
constexpr auto iterators::impl::ZipIterator< Iterators >::operator< (
            const ZipIterator< Its > & other ) const -> std::enable_if_t<IsRandomAccessible,
bool>   [inline], [constexpr], [noexcept]
```

Pairwise less comparison of underlying iterators Only available if all underlying iterators support at least random access

Template Parameters

Its	Iterator types of right hand side
IsRandomAccessible	SFINAE guard, do not specify

Parameters

other	right hand side

Returns

true if all underlying iterators compare less to the corresponding iterators from other

3.5.2.12 operator<=() constexpr bool iterators::impl::SynthesizedOperators< ZipIterator< Iterators > >::operator<= (const T & *rhs*) const [inline], [constexpr], [noexcept], [inherited]

Less than or equal comparison

Template Parameters

T	type of right hand side
Implementation	SFINAE helper, do not specify explicitly

Parameters

other	right hand side

Returns

true if this is not greater than other

3.5.2.13 operator==() template<typename Iterators > template<typename Its , REQUIRES(ZipIterator::oneEqual(INSTANCE_OF(Iterators), INSTANCE_OF(Its))) > constexpr bool iterators::impl::ZipIterator< Iterators >::operator== (const ZipIterator< Its > & *other*) const [inline], [constexpr], [noexcept]

Pairwise equality comparison of underlying iterators

Template Parameters

Its	Iterator types of right hand side

Parameters

other	right hand side

Returns

true if at least one underlying iterator compares equal to the corresponding iterator from other

3.5.2.14 operator>() template<typename Iterators > template<typename Its , bool IsRandomAccessible = traits::is_random_accessible_v<Iterators>, REQUIRES(ZipIterator::allGreater(INSTANCE_OF(Iterators), INSTANCE_OF(Its))) > constexpr auto iterators::impl::ZipIterator< Iterators >::operator> (const ZipIterator< Its > & *other*) const -> std::enable_if_t<IsRandomAccessible, bool> [inline], [constexpr], [noexcept]

Pairwise grater comparison of underlying iterators Only available if all underlying iterators support at least random access

Template Parameters

Its	Iterator types of right hand side
IsRandomAccessible	SFINAE guard, do not specify

Parameters

other	right hand side

Returns

true if all underlying iterators compare greater to the corresponding iterators from other

3.5.2.15 operator>=()

`constexpr bool iterators::impl::SynthesizedOperators< ZipIterator< Iterators > >::operator>= ( const T & rhs ) const [inline], [constexpr], [noexcept], [inherited]`

Greater than or equal comparison

Template Parameters

T	type of right hand side
Implementation	SFINAE helper, do not specify explicitly

Parameters

other	right hand side

Returns

true if this is not less than other

3.5.2.16 operator[]()

`constexpr auto iterators::impl::SynthesizedOperators< ZipIterator< Iterators > >::operator[] ( typename Implementation::difference_type n ) const [inline], [constexpr], [noexcept], [inherited]`

Array subscript operator

Template Parameters

Implementation	SFINAE helper, do not specify explicitly

Parameters

n	index

Returns

∗(∗this + n)

3.5.3 Friends And Related Function Documentation

3.5.3.1 zip_i() `template<typename ... Iterators>`

```
constexpr auto zip_i (
            Iterators ... iterators ) -> impl::ZipIterator<std::tuple<Iterators...>>   [related]
```

Function that is used to create a impl::ZipIterator from an arbitrary number of iterators

Template Parameters

Iterators	type of iterators

Parameters

iterators	arbitrary number of iterators

Returns

impl::ZipIterator

Note

ZipIterators have the same iterator category as the least powerful underlying operator. This means that for example, zipping a random access iterator and a bidirectional iterator only yields a bidirectional impl::ZipIterator

The documentation for this class was generated from the following file:

- Iterators.hpp

3.6 iterators::impl::ZipView< Iterable > Struct Template Reference

Zip-view that provides begin() and end() member functions. Use to loop over multiple ranges at the same time using ranged based for-loops.

`#include <Iterators.hpp>`

Public Member Functions

- template<typename ... Container>
  constexpr ZipView (Container &&...containers)
- constexpr auto begin ()
- constexpr auto end ()
- constexpr auto begin () const
- constexpr auto end () const
- template<bool IsRandomAccess = traits::is_random_accessible_v<IteratorTuple>, typename = std::enable_if_t<IsRandom↩Access>>
  constexpr auto operator[] (std::size_t index)
- template<bool IsRandomAccess = traits::is_random_accessible_v<CIteratorTuple>, typename = std::enable_if_t<IsRandom↩Access>>
  constexpr auto operator[] (std::size_t index) const
- template<bool HasSize = traits::has_size_v<ContainerTuple>>
  constexpr auto size () const -> std::enable_if_t< HasSize, std::size_t >

Related Functions

(Note that these are not member functions.)

- template<typename ... Iterable>
  constexpr auto zip (Iterable &&...iterable)
- template<typename Container , typename T = std::size_t>
  constexpr auto enumerate (Container &&container, T start=T(0), T increment=T(1))

3.6.1 Detailed Description

template<typename ... Iterable>
struct iterators::impl::ZipView< Iterable >

Zip-view that provides begin() and end() member functions. Use to loop over multiple ranges at the same time using ranged based for-loops.

Ranges are captured by lvalue reference, no copying occurs. Temporaries are allowed as well in which case storage is moved into the zip-view.

Template Parameters

Iterable	Underlying range types

3.6.2 Constructor & Destructor Documentation

3.6.2.1 ZipView() `template<typename ... Iterable>` `template<typename ... Container>`

```
constexpr iterators::impl::ZipView< Iterable >::ZipView (
            Container &&...  containers )  [inline], [explicit], [constexpr]
```

CTor. Binds reference to ranges or takes ownership in case of rvalue references

Template Parameters

Container	range types

Parameters

containers	arbitrary number of ranges

3.6.3 Member Function Documentation

3.6.3.1 begin() [1/2] template<typename ... Iterable>

```
constexpr auto iterators::impl::ZipView< Iterable >::begin ( )  [inline], [constexpr]
```

Returns a ZipIterator to the first elements of the underlying ranges

Returns

ZipIterator created by invoking std::begin on all underlying ranges

3.6.3.2 begin() [2/2] template<typename ... Iterable>

```
constexpr auto iterators::impl::ZipView< Iterable >::begin ( ) const  [inline], [constexpr]
```

Returns a ZipIterator to the first elements of the underlying ranges

Returns

ZipIterator created by invoking std::begin on all underlying ranges

Note

returns a ZipIterator that does not allow changing the ranges' elements

3.6.3.3 end() [1/2] template<typename ... Iterable>

```
constexpr auto iterators::impl::ZipView< Iterable >::end ( )  [inline], [constexpr]
```

Returns a ZipIterator to the elements following the last elements of the the underlying ranges

Returns

ZipIterator created by invoking std::end on all underlying ranges

3.6.3.4 end() [2/2] template<typename ... Iterable>

```
constexpr auto iterators::impl::ZipView< Iterable >::end ( ) const  [inline], [constexpr]
```

Returns a ZipIterator to the elements following the last elements of the the underlying ranges

Returns

ZipIterator created by invoking std::end on all underlying ranges

3.6.3.5 operator[]() [1/2] template<typename ... Iterable>

```
template<bool IsRandomAccess = traits::is_random_accessible_v<IteratorTuple>, typename =
std::enable_if_t<IsRandomAccess>>
constexpr auto iterators::impl::ZipView< Iterable >::operator[] (
            std::size_t index )  [inline], [constexpr]
```

Array subscript operator (no bounds are checked)

Template Parameters

IsRandomAccess	SFINAE helper, do not specify explicitly

Parameters

index	index

Returns

zip view element at given index

3.6.3.6 operator[]() [2/2] template<typename ... Iterable>

```
template<bool IsRandomAccess = traits::is_random_accessible_v<CIteratorTuple>, typename =
std::enable_if_t<IsRandomAccess>>
constexpr auto iterators::impl::ZipView< Iterable >::operator[] (
            std::size_t index ) const  [inline], [constexpr]
```

Array subscript operator (no bounds are checked)

Template Parameters

IsRandomAccess	SFINAE helper, do not specify explicitly

Parameters

index	index

Returns

zip view element at given index

3.6.3.7 size() `template<typename ... Iterable>`

```
template<bool HasSize = traits::has_size_v<ContainerTuple>>
constexpr auto iterators::impl::ZipView< Iterable >::size ( ) const -> std::enable_if_t<Has↩
Size, std::size_t>   [inline], [constexpr]
```

Returns the smallest size of all containers. Only available if all containers know their size

Template Parameters

HasSize	SFINAE guard, do not specify explicitly

Returns

smallest size of all containers

3.6.4 Friends And Related Function Documentation

3.6.4.1 enumerate() `template<typename Container , typename T = std::size_t>`

```
constexpr auto enumerate (
            Container && container,
            T start = T(0),
            T increment = T(1) )  [related]
```

Function that can be used in range based loops to emulate the enumerate iterator from python.

Template Parameters

Container	Container type that supports iteration
T	type of enumerate counter (default std::size_t)

Parameters

container	Source container
start	Optional index offset (default 0)
increment	Optional index increment (default 1)

Returns

impl::ZipView that provides begin and end members to be used in range based for-loops.

3.6.4.2 zip() `template<typename ... Iterable>`

```
constexpr auto zip (
            Iterable &&... iterable ) [related]
```

Function that can be used in range based loops to emulate the zip iterator from python. As in python: if the passed containers have different lengths, the container with the least items decides the overall range

Template Parameters

Iterable	Container types that support iteration

Parameters

iterable	Arbitrary number of containers

Returns

impl::ZipView class that provides begin and end members to be used in range based for-loops

The documentation for this struct was generated from the following file:

- Iterators.hpp

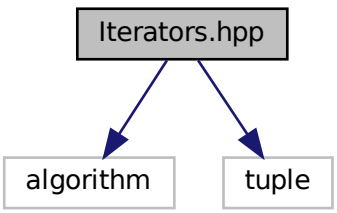
4 File Documentation

4.1 Iterators.hpp File Reference

This file contains the definitions of Python-like zip- and enumerate-functions. They can be used in range based for-loops to loop over multiple ranges at the same time, or to index a range while looping respectively.

```
#include <algorithm>
#include <tuple>
```

Include dependency graph for Iterators.hpp:



Classes

- struct iterators::impl::SynthesizedOperators< Impl >

  CRTP-class that provides additional pointer arithmetic operators synthesized from basic operators.
- class iterators::impl::ZipIterator< Iterators >

  Class combining multiple iterators into one. Use it to iterate over multiple ranges at the same time.
- struct iterators::impl::ZipView< Iterable >

  Zip-view that provides begin() and end() member functions. Use to loop over multiple ranges at the same time using ranged based for-loops.
- struct iterators::impl::Unreachable

  represents the unreachable end of an infinite sequence
- struct iterators::impl::CounterIterator< T >

  Iterator of an infinite sequence of numbers. Simply increments an internal counter.
- struct iterators::impl::CounterRange< T >

  Represents an infinite range of numbers.

Namespaces

- iterators

  namespace containing zip and enumerate functions
- iterators::impl

  namespace containing structures and helpers used to implement zip and enumerate. Normally there is no need to use any of its members directly
- iterators::impl::traits

  namespace containing type traits used in implementation of zip and enumerate

Macros

- #define **REFERENCE**(TYPE) std::declval<std::add_lvalue_reference_t<TYPE>>()
- #define **ALL_NOEXCEPT**(OP, NAME)
- #define **ELEMENT1** std::get<Idx>(tuple1)
- #define **ELEMENT2** std::get<Idx>(tuple2)
- #define **BINARY_TUPLE_FOR_EACH**(OPERATION, NAME)
- #define **BINARY_TUPLE_FOR_EACH_FOLD**(OPERATION, COMBINATOR, NAME) BINARY_TUPLE_↩ FOR_EACH(((OPERATION) COMBINATOR ...), NAME)
- #define **TYPE_MAP_DEFAULT**
- #define **TYPE_MAP**(TYPE, VALUE)
- #define **TYPE_MAP_ALIAS**
- #define **INSTANCE_OF**(TYPENAME) std::declval<TYPENAME>()
- #define **INSTANCE_OF_IMPL** INSTANCE_OF(Implementation)
- #define **REQUIRES_IMPL**(TYPENAME, EXPRESSION) typename Implementation = TYPENAME, typename = std::void_t<decltype(EXPRESSION)>
- #define **REQUIRES**(EXPRESSION) typename = std::void_t<decltype(EXPRESSION)>

Typedefs

- template<bool Cond, typename T >
  using **iterators::impl::traits::reference_if_t** = std::conditional_t< Cond, std::add_lvalue_reference_t< T >, T >
- template<bool Cond, typename T >
  using **iterators::impl::traits::const_if_t** = std::conditional_t< Cond, std::add_const_t< T >, T >
- template<typename T >
  using **iterators::impl::traits::dereference_t** = typename dereference< T, is_dereferencible_v< T > >::type
- template<typename T >
  using **iterators::impl::traits::values_t** = typename values< T >::type

Functions

- template<typename T >
  constexpr T iterators::impl::sgn (T val) noexcept
- template<typename ... Iterators>
  constexpr auto iterators::zip_i (Iterators ...iterators) -> impl::ZipIterator< std::tuple< Iterators... >>
- template<typename ... Iterable>
  constexpr auto iterators::zip (Iterable &&...iterable)
- template<typename ... Iterable>
  constexpr auto iterators::const_zip (Iterable &&...iterable)
- template<typename Container , typename T = std::size_t>
  constexpr auto iterators::enumerate (Container &&container, T start=T(0), T increment=T(1))
- template<typename Container , typename T = std::size_t>
  constexpr auto iterators::const_enumerate (Container &&container, T start=T(0), T increment=T(1))

Variables

- template<typename T >
  constexpr bool **iterators::impl::traits::is_container_v** = is_container<T>::value
- template<typename T >
  constexpr bool **iterators::impl::traits::is_dereferencible_v** = is_dereferencible<T>::value
- template<typename T >
  constexpr bool **iterators::impl::traits::is_incrementable_v** = is_incrementable<T>::value
- template<typename T >
  constexpr std::size_t **iterators::impl::traits::minimum_category_v** = minimum_category<T>::value
- template<typename T >
  constexpr bool **iterators::impl::traits::is_random_accessible_v** = is_random_accessible<T>::value
- template<typename T >
  constexpr bool **iterators::impl::traits::is_bidirectional_v** = is_bidirectional<T>::value
- template<typename T >
  constexpr bool **iterators::impl::traits::has_size_v** = has_size<T>::value

4.1.1 Detailed Description

This file contains the definitions of Python-like zip- and enumerate-functions. They can be used in range based for-loops to loop over multiple ranges at the same time, or to index a range while looping respectively.

Author

tim Luchterhand

Date

10.09.21

4.1.2 Macro Definition Documentation

4.1.2.1 ALL_NOEXCEPT #define ALL_NOEXCEPT(

OP,

NAME)

Value:

```
template<typename T> \
struct NAME { \
    static constexpr bool value = false; \
}; \
template<typename ...Ts> \
struct NAME <std::tuple<Ts...» { \
    static constexpr bool value = (... && noexcept(OP)); \
};                \
template<typename T> \
inline constexpr bool NAME##_v = NAME<T>::value;
```

4.1.2.2 BINARY_TUPLE_FOR_EACH #define BINARY_TUPLE_FOR_EACH(

OPERATION,

NAME)

Value:

```
template<typename Tuple1, typename Tuple2, std::size_t ...Idx> \
static constexpr auto NAME##Impl(const Tuple1 &tuple1, const Tuple2 &tuple2,
std::index_sequence<Idx...>) \
noexcept(noexcept((OPERATION))) -> decltype(OPERATION) { \
    return (OPERATION); \
} \
template<typename Tuple1, typename Tuple2> \
static constexpr auto NAME(const Tuple1 &tuple1, const Tuple2 &tuple2) \
noexcept(noexcept(NAME##Impl(tuple1, tuple2, std::make_index_sequence<std::tuple_size_v<Tuple1»{}))) \
-> decltype(NAME##Impl(tuple1, tuple2, std::make_index_sequence<std::tuple_size_v<Tuple1»{})) { \
    static_assert(std::tuple_size_v<Tuple1> == std::tuple_size_v<Tuple2>); \
    return NAME##Impl(tuple1, tuple2, std::make_index_sequence<std::tuple_size_v<Tuple1»{}); \
}
```

4.1.2.3 TYPE_MAP #define TYPE_MAP(

TYPE,

VALUE)

Value:

```
template<>            \
struct type_to_value<TYPE> { \
    static constexpr std::size_t value = VALUE; \
};                    \
template<>            \
struct value_to_type<VALUE>{ \
    static_assert(VALUE != 0, "0 is a reserved value"); \
    using type = TYPE;\
};
```

4.1.2.4 TYPE_MAP_ALIAS #define TYPE_MAP_ALIAS

Value:

```
template<typename T> \
constexpr inline std::size_t type_to_value_v = type_to_value<T>::value; \
template<std::size_t V>                                                  \
using value_to_type_t = typename value_to_type<V>::type;
```

4.1.2.5 TYPE_MAP_DEFAULT #define TYPE_MAP_DEFAULT

Value:

```
template<typename> \
struct type_to_value {}; \
template<std::size_t>    \
struct value_to_type {};
```

Index

ALL_NOEXCEPT
    Iterators.hpp, 41

begin
    iterators::impl::CounterRange< T >, 18
    iterators::impl::ZipView< Iterable >, 36
BINARY_TUPLE_FOR_EACH
    Iterators.hpp, 42

const_enumerate
    iterators, 3
const_zip
    iterators, 3
CounterIterator
    iterators::impl::CounterIterator< T >, 10
CounterRange
    iterators::impl::CounterRange< T >, 17

end
    iterators::impl::CounterRange< T >, 18
    iterators::impl::ZipView< Iterable >, 36
enumerate
    iterators, 4
    iterators::impl::ZipView< Iterable >, 38

getIterators
    iterators::impl::ZipIterator< Iterators >, 26

iterators, 2
    const_enumerate, 3
    const_zip, 3
    enumerate, 4
    zip, 4
    zip_i, 5
Iterators.hpp, 39
    ALL_NOEXCEPT, 41
    BINARY_TUPLE_FOR_EACH, 42
    TYPE_MAP, 42
    TYPE_MAP_ALIAS, 42
    TYPE_MAP_DEFAULT, 42
iterators::impl, 5
    sgn, 6
iterators::impl::CounterIterator< T >, 8
    CounterIterator, 10
    operator!=, 11
    operator<, 14
    operator<=, 14
    operator>, 15
    operator>=, 15
    operator*, 11
    operator++, 11, 12
    operator+=, 12
    operator-, 12
    operator--, 13
    operator-=, 13
    operator==, 15, 16
    operator[], 16
iterators::impl::CounterRange< T >, 17
    begin, 18
    CounterRange, 17
    end, 18
iterators::impl::SynthesizedOperators< Impl >, 18
    operator!=, 20
    operator<=, 21
    operator>=, 21
    operator+, 22, 23
    operator++, 20
    operator-, 23
    operator--, 20
    operator[], 22
iterators::impl::traits, 7
iterators::impl::Unreachable, 24
iterators::impl::ZipIterator< Iterators >, 24
    getIterators, 26
    operator!=, 26
    operator<, 30
    operator<=, 30
    operator>, 31
    operator>=, 33
    operator*, 27
    operator++, 27, 28
    operator+=, 28
    operator-, 28
    operator--, 29
    operator-=, 29
    operator==, 31
    operator[], 33
    zip_i, 34
iterators::impl::ZipView< Iterable >, 34
    begin, 36
    end, 36
    enumerate, 38
    operator[], 37
    size, 38
    zip, 38
    ZipView, 35

operator!=
    iterators::impl::CounterIterator< T >, 11
    iterators::impl::SynthesizedOperators< Impl >, 20
    iterators::impl::ZipIterator< Iterators >, 26
operator<
    iterators::impl::CounterIterator< T >, 14
    iterators::impl::ZipIterator< Iterators >, 30
operator<=
    iterators::impl::CounterIterator< T >, 14
    iterators::impl::SynthesizedOperators< Impl >, 21
    iterators::impl::ZipIterator< Iterators >, 30
operator>
    iterators::impl::CounterIterator< T >, 15
    iterators::impl::ZipIterator< Iterators >, 31

operator>=
iterators::impl::CounterIterator< T >, 15
iterators::impl::SynthesizedOperators< Impl >, 21
iterators::impl::ZipIterator< Iterators >, 33
operator*
iterators::impl::CounterIterator< T >, 11
iterators::impl::ZipIterator< Iterators >, 27
operator+
iterators::impl::SynthesizedOperators< Impl >, 22, 23
operator++
iterators::impl::CounterIterator< T >, 11, 12
iterators::impl::SynthesizedOperators< Impl >, 20
iterators::impl::ZipIterator< Iterators >, 27, 28
operator+=
iterators::impl::CounterIterator< T >, 12
iterators::impl::ZipIterator< Iterators >, 28
operator-
iterators::impl::CounterIterator< T >, 12
iterators::impl::SynthesizedOperators< Impl >, 23
iterators::impl::ZipIterator< Iterators >, 28
operator--
iterators::impl::CounterIterator< T >, 13
iterators::impl::SynthesizedOperators< Impl >, 20
iterators::impl::ZipIterator< Iterators >, 29
operator-=
iterators::impl::CounterIterator< T >, 13
iterators::impl::ZipIterator< Iterators >, 29
operator==
iterators::impl::CounterIterator< T >, 15, 16
iterators::impl::ZipIterator< Iterators >, 31
operator[]
iterators::impl::CounterIterator< T >, 16
iterators::impl::SynthesizedOperators< Impl >, 22
iterators::impl::ZipIterator< Iterators >, 33
iterators::impl::ZipView< Iterable >, 37

sgn
iterators::impl, 6
size
iterators::impl::ZipView< Iterable >, 38

TYPE_MAP
Iterators.hpp, 42
TYPE_MAP_ALIAS
Iterators.hpp, 42
TYPE_MAP_DEFAULT
Iterators.hpp, 42

zip
iterators, 4
iterators::impl::ZipView< Iterable >, 38
zip_i
iterators, 5
iterators::impl::ZipIterator< Iterators >, 34
ZipView
iterators::impl::ZipView< Iterable >, 35