

`views::enumerate`

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Reply-to: Corentin Jabot <corentin.jabot@gmail.com>

Abstract

We propose a view `enumerate` whose value type is a struct with 2 members `index` and `value` representing respectively the position and value of the elements in the adapted range.

Revisions

R3

- Typos and minor wording improvements

R2, following mailing list reviews

- Make `value_type` different from `reference` to match other views
- Remove inconsistencies between the wording and the description
- Add relevant includes and namespaces to the examples

R1

- Fix the index type

Tony tables

Before	After
<pre> std::vector days{"Mon", "Tue", "Wed", "Thu", "Fri", "Sat", "Sun"}; int idx = 0; for(const auto & d : days) { print("{} {} \n", idx, d); index++; } </pre>	<pre> #include <ranges> std::vector days{"Mon", "Tue", "Wed", "Thu", "Fri", "Sat", "Sun"}; for(const auto & [idx, d] : std::views::enumerate(days)) { print("{} {} \n", idx, d); } </pre>

Motivation

The impossibility to extract an index from a range-based for loop leads to the use of non-range based for loop, or the introduction of a variable in the outer scope. This is both more verbose and error-prone: in the example above, the type of `index` is incorrect.

`enumerate` is a library solution solving this problem, enabling the use of range-based for loops in more cases.

It also composes nicely with other range facilities: The following creates a map from a vector using the position of each element as key.

```
my_vector | views::enumerate | ranges::to<map>;
```

This feature exists in some form in Python, Rust, Go (backed into the language), and in many C++ libraries: `ranges-v3`, `folly`, `boost::ranges (indexed)`.

The existence of this feature or lack thereof is the subject of recurring stackoverflow questions.

Design

The result is a simple aggregate

Following the trend of using meaningful names instead of returning pairs or tuples, this proposal uses a simple aggregate return type. This design was previously discussed by LEWGI in Belfast in the context of [P1894R0](#) [?].

```

struct reference {
    count_type index;
    range_reference_t<Base> value;
};

```

`count_type` is defined as follow:

- `ranges::range_size_t<Base>` if `Base` models `ranges::sized_range`

- Otherwise, `make_unsigned_t<ranges::range_difference_t<Base>>`

This is consistent with `ranges-v3` and allows the view to support both sized and non sized ranges.

constness

The `index` is always `const`, `value` is conditionnally `const` like all other views

Performance

An optimizing compiler can generate the same machine code for `views::enumerate` as it would for an equivalent `for` loop. [Compiler Explorer](#)

Implementation

This proposal has been implemented ([Github](#)) There exist an implementation in `ranges-v3` (where the `enumerate` view uses `zip_with` and a pair value type).

Proposal

We propose a view `enumerate` whose value type is a struct with 2 members `index` and `value` representing respectively the position and value of the elements in the adapted range.

Wording

 **Enumerate view** [[range.enumerate](#)]

 **Overview** [[range.enumerate.overview](#)]

`enumerate_view` presents a view with a value type that represents both the position and value of the adapted view's value-type.

The name `views::enumerate` denotes a range adaptor object. Given the subexpressions `E` the expression `views::enumerate(E)` is expression-equivalent to `enumerate_view{E}`.

[*Example:*

```
vector<int> vec{ 1, 2, 3 };
for (auto [index, value] : enumerate(vec) )
    cout << index << ":" << value ' '; // prints: 0:1 1:2 2:3
```

— *end example*]



Class template `enumerate_view`

[range.enumerate.view]

```
namespace std::ranges {
    template<input_range V>
    requires view<V>
    class enumerate_view : public view_interface<enumerate_view<V>> {

    private:
        V base_ = {};

        template <bool Const>
        class iterator; // exposition only
        template <bool Const>
        struct sentinel; // exposition only

    public:

        constexpr enumerate_view() = default;
        constexpr enumerate_view(V base_);

        constexpr auto begin() requires (!simple_view<V>)
        { return iterator<false>(ranges::begin(base_), 0); }

        constexpr auto begin() const requires simple_view<V>
        { return iterator<true>(ranges::begin(base_), 0); }

        constexpr auto end()
        { return sentinel<false>{end(base_)}; }

        constexpr auto end()
        requires common_range<V> && sized_range<V>
        { return iterator<false>{ranges::end(base_),
            static_cast<range_difference_t<V>>(size()) }; }

        constexpr auto end() const
        requires range<const V>
        { return sentinel<true>{ranges::end(base_)}; }

        constexpr auto end() const
        requires common_range<const V> && sized_range<V>
        { return iterator<true>{ranges::end(base_),
            static_cast<range_difference_t<V>>(size())}; }

        constexpr auto size()
        requires sized_range<V>
        { return ranges::size(base_); }

        constexpr auto size() const
        requires sized_range<const V>
        { return ranges::size(base_); }
```

```

    constexpr V base() const & requires copy_constructible<V> { return base_; }
    constexpr V base() && { return move(base_); }
};
template<class R>
enumerate_view(R&&) -> enumerate_view<views::all_t<R>>;

```

```
constexpr enumerate_view(V base);
```

Effects: Initializes *base_* with move(*base*).



Class `enumerate_view::iterator`

[range.enumerate.iterator]

```

namespace std::ranges {
    template<input_range V>
    requires view<V>
    template<bool Const>
    class enumerate_view<V>::iterator {

        using Base = conditional_t<Const, const V, V>;
        using count_type = see below;

        iterator_t<Base> current_ = iterator_t<Base>();
        count_type pos_ = 0;

    public:
        using iterator_category = typename iterator_traits<iterator_t<Base>>::iterator_category;

        struct reference {
            const count_type index;
            range_reference_t<Base> value;
        };

        struct value_type {
            const count_type index;
            range_value_t<Base> value;
        };

        using difference_type = range_difference_t<Base>;

        iterator() = default;
        constexpr explicit iterator(iterator_t<Base> current, range_difference_t<Base> pos);
        constexpr iterator(iterator<!Const> i)
        requires Const && convertible_to<iterator_t<V>, iterator_t<Base>>;

        constexpr iterator_t<Base> base() const&
        requires copyable<iterator_t<Base>>;
        constexpr iterator_t<Base> base() &&;
    };
}

```

```

constexpr decltype(auto) operator*() const {
    return reference{pos_, *current_};
}

constexpr iterator& operator++();
constexpr void operator++(int) requires (!forward_range<Base>);
constexpr iterator operator++(int) requires forward_range<Base>;

constexpr iterator& operator--() requires bidirectional_range<Base>;
constexpr iterator operator--(int) requires bidirectional_range<Base>;

constexpr iterator& operator+=(difference_type x)
requires random_access_range<Base>;
constexpr iterator& operator-=(difference_type x)
requires random_access_range<Base>;

constexpr decltype(auto) operator[](difference_type n) const
requires random_access_range<Base>
{ return reference{static_cast<difference_type>(pos_ + n), *(current_ + n) }; }

friend constexpr bool operator==(const iterator& x, const iterator& y)
requires equality_comparable<iterator_t<Base>>;

friend constexpr bool operator<(const iterator& x, const iterator& y)
requires random_access_range<Base>;
friend constexpr bool operator>(const iterator& x, const iterator& y)
requires random_access_range<Base>;
friend constexpr bool operator<=(const iterator& x, const iterator& y)
requires random_access_range<Base>;
friend constexpr bool operator>=(const iterator& x, const iterator& y)
requires random_access_range<Base>;
friend constexpr auto operator<=>(const iterator& x, const iterator& y)
requires random_access_range<Base> && three_way_comparable<iterator_t<Base>>;

friend constexpr iterator operator+(const iterator& x, difference_type y)
requires random_access_range<Base>;
friend constexpr iterator operator+(difference_type x, const iterator& y)
requires random_access_range<Base>;
friend constexpr iterator operator-(const iterator& x, difference_type y)
requires random_access_range<Base>;
friend constexpr difference_type operator-(const iterator& x, const iterator& y)
requires random_access_range<Base>;
};
}

```

iterator::count_type is defined as follow:

- ranges::range_size_t<Base> if Base models ranges::sized_range
- Otherwise, make_unsigned_t<ranges::range_difference_t<Base>>

```
constexpr explicit iterator(iterator_t<Base> current, range_difference_t<Base> pos = 0);
```

Effects: Initializes `current_` with `move(current)` and `pos` with `static_cast<count_type>(pos)`.

```
constexpr iterator(iterator<!Const> i)
```

```
requires Const && convertible_to<iterator_t<V>, iterator_t<Base>>;
```

Effects: Initializes `current_` with `move(i.current_)` and `pos` with `i.pos_`.

```
constexpr iterator_t<Base> base() const&
```

```
requires copyable<iterator_t<Base>>;
```

Effects: Equivalent to: return `current_`;

```
constexpr iterator_t<Base> base() &&;
```

Effects: Equivalent to: return `move(current_)`;

```
constexpr iterator& operator++();
```

Effects: Equivalent to:

```
++pos;  
++current_;  
return *this;
```

```
constexpr void operator++(int) requires (!forward_range<Base>);
```

Effects: Equivalent to:

```
++pos;  
++current_;
```

```
constexpr iterator operator++(int) requires forward_range<Base>;
```

Effects: Equivalent to:

```
auto temp = *this;  
++pos;  
++current_;  
return temp;
```

```
constexpr iterator& operator--() requires bidirectional_range<Base>;
```

Effects: Equivalent to:

```
--pos_;  
--current_;  
return *this;
```

constexpr *iterator* operator--(int) requires *bidirectional_range*<*Base*>;

Effects: Equivalent to:

```
auto temp = *this;
--current_;
--pos_;
return temp;
```

constexpr *iterator*& operator+=(*difference_type* n);
requires *random_access_range*<*Base*>;

Effects: Equivalent to:

```
current_ += n;
pos_ += n;
return *this;
```

constexpr *iterator*& operator-=(*difference_type* n)
requires *random_access_range*<*Base*>;

Effects: Equivalent to:

```
current_ -= n;
pos_ -= n;
return *this;
```

friend constexpr bool operator==(const *iterator*& x, const *iterator*& y)
requires *equality_comparable*<*Base*>;

Effects: Equivalent to: return x.current_ == y.current_;

friend constexpr bool operator<(const *iterator*& x, const *iterator*& y)
requires *random_access_range*<*Base*>;

Effects: Equivalent to: return x.current_ < y.current_;

friend constexpr bool operator>(const *iterator*& x, const *iterator*& y)
requires *random_access_range*<*Base*>;

Effects: Equivalent to: return y < x;

friend constexpr bool operator<=(const *iterator*& x, const *iterator*& y)
requires *random_access_range*<*Base*>;

Effects: Equivalent to: return !(y < x);

friend constexpr bool operator>=(const *iterator*& x, const *iterator*& y)
requires *random_access_range*<*Base*>;

Effects: Equivalent to: return !(x < y);


```
friend constexpr auto operator<=>(const iterator& x, const iterator& y)
requires random_access_range<Base> && three_way_comparable<iterator_t<Base>>;
```

Effects: Equivalent to: return `x.current_ <=> y.current_;`

```
friend constexpr iterator operator+(const iterator& x, difference_type y)
requires random_access_range<Base>;
```

Effects: Equivalent to: return `iterator{x} += y;`

```
friend constexpr iterator operator+(difference_type x, const iterator& y)
requires random_access_range<Base>;
```

Effects: Equivalent to: return `y + x;`

```
constexpr iterator operator-(const iterator& x, difference_type y)
requires random_access_range<Base>;
```

Effects: Equivalent to: return `iterator{x} -= y;`

```
constexpr difference_type operator-(const iterator& x, const iterator& y)
requires random_access_range<Base>;
```

Effects: Equivalent to: return `x.current_ - y.current_;`



Class template `enumerate_view::sentinel`

[range.enumerate.sentinel]

```
namespace std::ranges {
    template<input_range V, size_t N>
    requires view<V>
    template<bool Const>
    class enumerate_view<V, N>::sentinel { // exposition only
    private:
        using Base = conditional_t<Const, const V, V>; // exposition only
        sentinel_t<Base> end_ = sentinel_t<Base>(); // exposition only
    public:
        sentinel() = default;
        constexpr explicit sentinel(sentinel_t<Base> end);
        constexpr sentinel(sentinel_t<Base> other)
        requires Const && convertible_to<sentinel_t<V>, sentinel_t<Base>>;

        constexpr sentinel_t<Base> base() const;

        friend constexpr bool operator==(const iterator<Const>& x, const sentinel& y);

        friend constexpr range_difference_t<Base>
        operator-(const iterator<Const>& x, const sentinel& y)
        requires sized_sentinel_for<sentinel_t<Base>, iterator_t<Base>>;

        friend constexpr range_difference_t<Base>
        operator-(const sentinel& x, const iterator<Const>& y)
        requires sized_sentinel_for<sentinel_t<Base>, iterator_t<Base>>;
    };
}
```

```
}
```

```
constexpr explicit sentinel(sentinel_t<Base> end);
```

Effects: Initializes `end_` with `end`.

```
constexpr sentinel(sentinel_t<!Const> other)
```

```
requires Const && convertible_to<sentinel_t<V>, sentinel_t<Base>>;
```

Effects: Initializes `end_` with `move(other.end_)`.

```
constexpr sentinel_t<Base> base() const;
```

Effects: Equivalent to: return `end_`;

```
friend constexpr bool operator==(const iterator<Const>& x, const sentinel& y);
```

Effects: Equivalent to: return `x.current_ == y.end_`;

```
friend constexpr range_difference_t<Base>
```

```
operator-(const iterator<Const>& x, const sentinel& y)
```

```
requires sized_sentinel_for<sentinel_t<Base>, iterator_t<Base>>;
```

Effects: Equivalent to: return `x.current_ - y.end_`;

```
friend constexpr range_difference_t<Base>
```

```
operator-(const sentinel& x, const iterator<Const>& y)
```

```
requires sized_sentinel_for<sentinel_t<Base>, iterator_t<Base>>;
```

Effects: Equivalent to: return `x.end_ - y.current_`;

References

[N4861] Richard Smith *Working Draft, Standard for Programming Language C++*
<https://wg21.link/N4861>