

views::enumerate

Document #: P2164R1
Date: 2020-06-29
Project: Programming Language C++
Audience: LEWG
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

R1

- Fix the index type

Tony tables

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

```
struct __result {  
    difference_type index;  
    reference value;  
};
```

This design was previously discussed by LEWGI in the context of [?]

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;

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

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

```

```

public:
    using iterator_category = typename iterator_traits<iterator_t<Base>>::iterator_category;
    using reference = result;
    using value_type = result;
    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 result{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 result{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<!Const> 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>