`views::enumerate`

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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.

Tony tables

Before	After

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

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 [1]

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>;

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

        iterator_t<Base> current_ = iterator_t<Base>();
        range_difference_t<Base> 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>;
    };
}
```

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

Effects: Initializes `current_` with `move(current)` and `pos` with `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 `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<!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<!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

[1] Andrew Tomazos. P1894R0: Proposal of std::upto, std::indices and std::enumerate. https://wg21.link/p1894r0, 10 2019.

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