`size_hint`: Eagerly reserving memory for not-quite-sized lazy ranges

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Abstract

This proposals adds a `ranges::size_hint` customization point object which allows `ranges::to` to reserve memory for non-sized ranges whose size can be approximated.

Revisions

R1

When SG-9 reviewed R0, Tim Song pointed out that `std::vector` and `std::string` call `std::distance` in their constructor (rather than calling `push_back` and reallocating themselves). This was not mentioned or considered at all in R0. R1 fixes this blattant omission.

If anything this makes the motivation stronger but it opens some interesting design questions.

SG-9 also pointed out that R0, despite being motivated by performance considerations failed to present any benchmarks. Benchmarks are now provided.

SG-9 also suggested that it would be useful for `sized_range` to subsume `approximately_sized_range`. This change has been applied.

Add a section on naming.

Motivation

You should know this proposal is secretly about Unicode.

Consider the string

`"In C++ ist es schwieriger, sich selbst in den fuß zu schießen."`

Its correct upper-case transformation is

`"IN C++ IST ES SCHWIERIGER, SICH SELBST IN DEN FUSS ZU SCHIESSEN".`

You will have observed that the transformed string is longer. 2 codepoints longer to be exact. This is because **ß** capitalizes as **SS**.

Now consider a hypothetical uppercase_view that transforms Unicode codepoints into their uppercase version. It might look like this:

```
U"In C++ ist es schwieriger, sich selbst in den fuß zu schießen."sv
    | views::uppercase
    | ranges::to<std::u32string>();
```

We do not have to know anything else about `views::uppercase` to know that it cannot be a `sized_range`.

In fact, it cannot be, for the same reason, a `random_access_range`. It will be, at best, a `bidirectional_range`. This means that in the above example, we cannot reserve memory in advance when constructing the output vector in `ranges::to`. So the implementation will

- for a forward range, call `distance`, in effect going over the view twice (unless the range is random access, which is never the case in the presence of Unicode algorithms) which for a Unicode algorithm is very expensive.
- for a non forward range, call `push_back` in a loop

But... only a couple thousand codepoints have a casing that is not their identity and of those only a few hundred might produce more than one codepoint. That's about 1% of the total number of allocated codepoints.

Most scripts not derived from Latin (for example CJK characters) do not even have a notion of case.

So the above example is massively pessimized because of a statistically unlikely scenario.

This is not just a problem with upper-casing. All casing transformations in Unicode have the same peculiarity. It also applies to all forms of Unicode Normalization (normalization can produce output strings that are longer, or shorter than the input) and text encoding and decoding, especially between UTF forms.

It is not possible to compute the size of the conversion from a string of length `L` from UTF-32 to UTF-8, but we know it will be at least `L`. And for some scripts, including English, it will be equal or very close to `L`.

We need a way to advertise "This range is about yea big" so that `ranges::to` and all the ranges constructors added by P1206R7 [2] can reduce the number of allocations they perform.

Design

To that end, we propose:

- a `ranges::size_hint` CPO
- a `approximately_sized_range` concept that checks whether a range supports `size_hint`

- the extension of many existing standard views so that they can forward the `size_hint` of their adapted view

`ranges::size_hint`

`ranges::size_hint` is a CPO that calls

- `ranges::size` for sized ranges
- the `size_hint` member function.
- the `size_hint` function found by adl.

Like `ranges::size` we mandate O(1) evaluation of `size_hint`. With this design, ranges that are sized are already `approximately_sized_range`, which avoids some duplication, undue complexity, and confusion. for example, we don't have to modify existing containers and views whose sized-ness does not depend on another view.

Usage

An implementation of `uppercase_view` might look like this

```
template <input_range V>
class uppercase_view {
    constexpr const V & base() const;
    constexpr auto begin() const;
    constexpr auto end() const;

    constexpr auto size_hint() requires approximately_sized_range<View> {
        return ranges::size_hint(base());
    }
    constexpr auto size_hint() const requires approximately_sized_range<const View> {
        return ranges::size_hint(base());
    }
};
```

IE, we assume `uppercase_view` will have approximatively the same size as the underlying range, even if it might be in rare cases slightly more. Note that `uppercase_view` would not provide a `size` method because it cannot determine its exact size.

Adapting existing views

Views that transform elements of their adapted view can just forward the `size_hint` of their underlying view. Nothing too complicated there. `drop`, `take`, `adjacent chunk`, `slide` and `stride` can also compute a `size_hint` the same way they compute their size.

`join` andf `split` cannot compute their size in O(1), so they do not provide a `size_hint`.

Views with predicate

take_while, drop_while and filter could, in theory, expose the size of their adapted range. however, this might lead to huge overallocation so, conservatively, these things do not expose a size_hint.

zip and cartesian_product

It would be reasonable for zip's size_hint to be the smallest size_hint amongst the adapted ranges that do have a size_hint. Similarly, it would make sense that the size_hint of cartesian_product would be the product of the size_hint of the ranges that do have one.

I think the correct way to do that might be to provide 3 overloads:

```
constexpr auto size_hint() requires (approximately_sized_range<Views> &&...);
constexpr auto size_hint() const requires (approximately_sized_range<const Views> &&...);
constexpr auto size_hint() const requires (!((approximately_sized_range<Views> ||
    approximately_sized_range<Views>) &&...));
```

Otherwise, the const and non-const overload could give different results.

As I'm not entirely certain what the best approach is, this paper does not make a change to zip or cartesian_product

ranges::to

ranges::to is sligtly modified to use ranges::size_hint instead of ranges::size. An implementation can also use size_hint in the various range constructors. User code could use that feature for similar purposes.

vector and string constructors

std::vector performs a single allocation on construction by calling distance first. It could only use size_hint on types that are Cpp17MoveInsertable (which is the case for Unicode algorithms), as reallocation would force items to be moved around. It may affect the performance of vector construction negatively when it is constructed from a forward range that is not sized, but for which calling distance is cheap, and size_hint is off enough that the reallocations are noticeable.

The proposed wording is currently silent on what happens to vector but we have 3 options:

- Require implementation to rely on size_hint when constructing a vector from a non-sized range of Cpp17MoveInsertable elements.

  A concern here is that custom allocators can't tell whether elements are move insertable because they are not required to be SFINAE-friendly. So, we could either only require calling size_hint for std::allocator only, or it would break vectors of non-movable types using a custom allocator.

Another solution is to check for `MoveConstructible` - which would still break the fringe case of types that are `MoveConstructible` and not `Cpp17MoveInsertable`. But there is consensus in SG-9 that those are fringe edge cases.

- Allowing implementations to do so without requiring it.

  Note that whether allocations are performed would be observable through whether the move constructor of each element is called or not (unless the elements are of trivial types (or are otherwise trivially relocatable P2786R0 [1])). Any effect resulting from a call to `std::distance` would not be performed.

  SG-9 had a preference for this option.

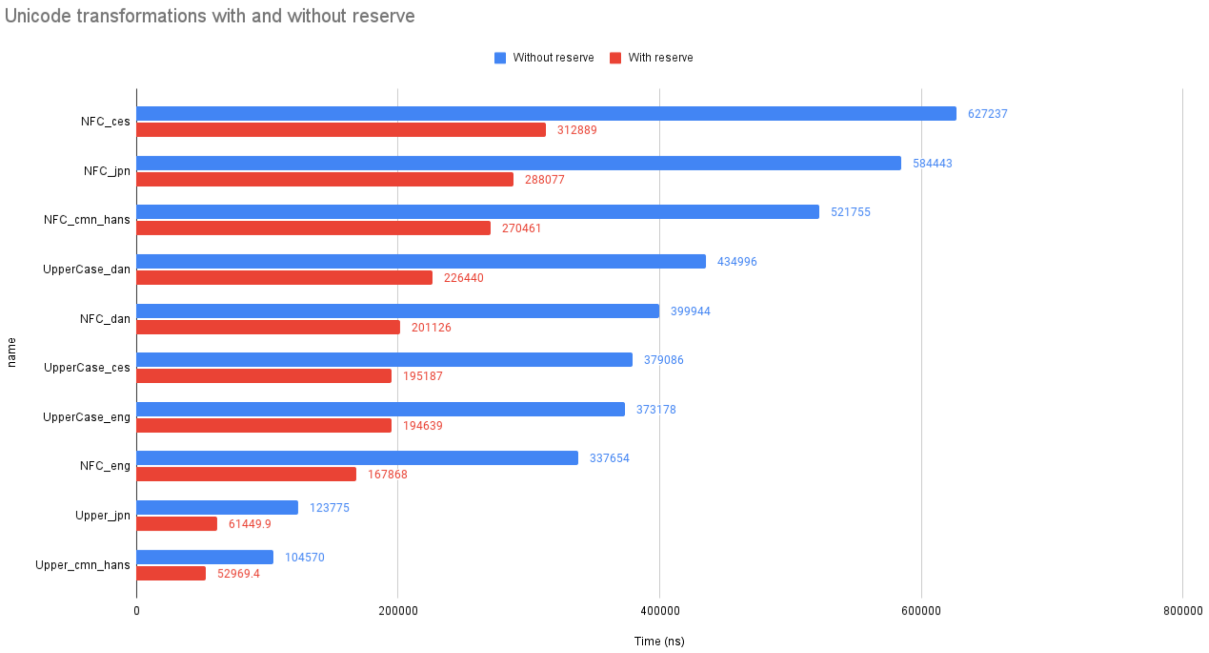
- In the presence of a `approximately_sized_range`, `ranges::to` could construct the container using reserve and insertions, instead of forwarding to the container constructor. The downside of this approach is that `ranges::to` would have different performance characteristics than container construction, which seems undesirable, and the optimization could not be applied to other operations such as `assign_range`/`insert_range`.

Benchmarks

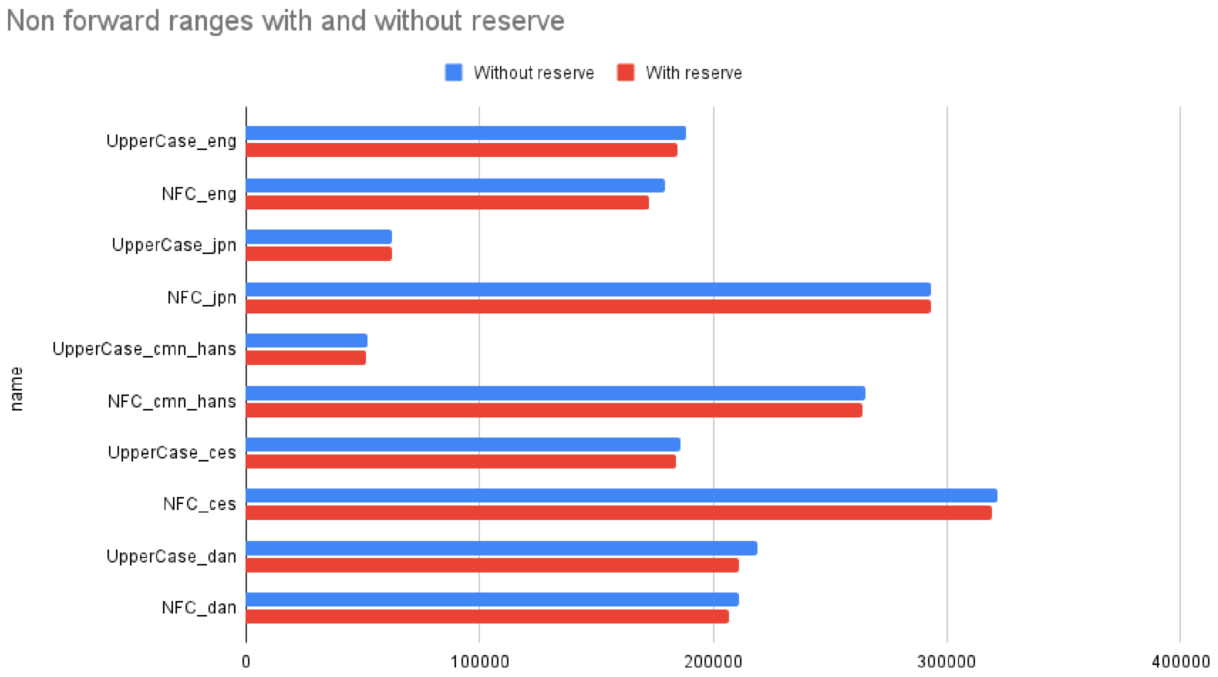
The following graph shows 2 Unicode normalization algorithms (Upper casing and NFC) for translations of the Universal Declaration of Human Rights in English, Danish, Japanese, and Chinese. Each such Transformation is performed twice:

- By reserving the number of elements of the pre-transformation text in the output container, emulating the proposed `size_hint`
- By constructing the output container directly without reserve (status quo behavior of `ranges::to`).

The graph shows that, for a forward range, reserving is consistently about twice as fast. This is consistent with the fact the range is traversed twice.



If the input range is non-forward, there is less difference on small datasets:



But as the data gets bigger and the number of allocations increases being able to reserve memory gets more noticeably impactful (performance delta of 5-10%).

Existing practices and alternatives considered

Rust has a similar facility in the iterator trait.

> **`fn size_hint(&self) -> (usize, Option<usize>)`**
> Returns the bounds on the remaining length of the iterator. Specifically, size_hint() returns a tuple where the first element is the lower bound, and the second element is the upper bound. The second half of the tuple that is returned is an Option<usize>. A None here means that either there is no known upper bound, or the upper bound is larger than usize.
>
> It is not enforced that an iterator implementation yields the declared number of elements. A buggy iterator may yield less than the lower bound or more than the upper bound of elements. size_hint() is primarily intended to be used for optimizations such as reserving space for the elements of the iterator, but must not be trusted to e.g., omit bounds checks in unsafe code. An incorrect implementation of size_hint() should not lead to memory safety violations. That said, the implementation should provide a correct estimation, because otherwise, it would be a violation of the trait's protocol.

However, that flexibility is not useful in practice: The upper bound is rarely used, and I'm told that using it in reserved was tried and led to performance regression. The complex return type seems to also create some confusion for rust users.

Naming

SG-9 had no strong preferences between the naming of the `size_hint` function. The two options considered are `size_hint` (which is nice because it reflects the fact that it's a function intended as a performance hint) and `approximate_size` (which is nice because it reflects the name of the `approximately_sized_range` concept). Both options being equally cromulent, we are happy to let LEWG pick their preference.

Wording

[*Editor's note:* Add the macro `__cpp_lib_ranges_zip` to `<version>` and `<ranges>`]

```
#define __cpp_lib_ranges_zip 2026XX (**placeholder**)
```

� Header `<ranges>` synopsis [ranges.syn]

```
#include <compare>              // see ??
#include <initializer_list>     // see ??
#include <iterator>             // see ??
```

```
namespace std::ranges {
inline namespace unspecified {
    // ??, range access
    inline constexpr unspecified begin = unspecified;    // freestanding
    inline constexpr unspecified end = unspecified;      // freestanding
    inline constexpr unspecified cbegin = unspecified;   // freestanding
    inline constexpr unspecified cend = unspecified;     // freestanding
    inline constexpr unspecified rbegin = unspecified;   // freestanding
    inline constexpr unspecified rend = unspecified;     // freestanding
    inline constexpr unspecified crbegin = unspecified;  // freestanding
    inline constexpr unspecified crend = unspecified;    // freestanding

    inline constexpr unspecified size = unspecified;    // freestanding
    inline constexpr unspecified size_hint = unspecified;  // freestanding
    inline constexpr unspecified ssize = unspecified;   // freestanding
    inline constexpr unspecified empty = unspecified;   // freestanding
    inline constexpr unspecified data = unspecified;    // freestanding
    inline constexpr unspecified cdata = unspecified;   // freestanding
}


template<class>
constexpr bool disable_sized_range = false; // freestanding

template<class T>
concept approximately_sized_range = see below;  // freestanding

template<class T>
concept sized_range = see below;   // freestanding

template<class T>
constexpr bool enable_view = see below;    // freestanding

}
```

[*Editor's note:* Insert after [range.prim.ssize]]

� ranges::size_hint [range.prim.size.hint]

The name `ranges::size_hint` denotes a customization point object [customization.point.object].

Given a subexpression `E` with type `T`, let `t` be an lvalue that denotes the reified object for `E`. Then:

- If `ranges::size(E)` is a valid expression, `ranges::size_hint(E)` is expression-equivalent to `ranges::size(E)`.
- Otherwise, if `auto(t.size_hint())` is a valid expression of integer-like type [iterator.concept.winc], `ranges::size_hint(E)` is expression-equivalent to `auto(t.size_hint())`.
- Otherwise, if `T` is a class or enumeration type and `auto(size_hint(t))` is a valid expression

of integer-like type where the meaning of `size_hint` is established as-if by performing argument-dependent lookup only [basic.lookup.argdep], then `ranges::size_hint(E)` is expression-equivalent to that expression.

- Otherwise, `ranges::size_hint(E)` is ill-formed.

[*Note:* Diagnosable ill-formed cases above result in substitution failure when `ranges::size_hint(E)` appears in the immediate context of a template instantiation. — *end note*]

[*Note:* Whenever `ranges::size_hint(E)` is a valid expression, its type is integer-like. — *end note*]

� Sized ranges [range.sized]

� Approximately sized ranges [range.approximately.sized]

The `approximately_sized_range` concept refines `range` with the requirement that an approximation of the number of elements in the range can be determined in amortized constant time using `ranges::size_hint`.

```
template<class T>
concept approximately_sized_range =
range<T> && requires(T& t) { ranges::size_hint(t); };
```

Given an lvalue `t` of type `remove_reference_t<T>`, `T` models `approximately_sized_range` only if `ranges::size_hint(t)` is amortized $\mathcal{O}(1)$, and does not modify `t`.

The `sized_range` concept refines ~~`range`~~ `approximately_sized_range` with the requirement that the number of elements in the range can be determined in amortized constant time using `ranges::size`.

```
template<class T>
concept sized_range =
~~range~~ approximately_sized_range<T> && requires(T& t) { ranges::size(t); };
```

Given an lvalue `t` of type `remove_reference_t<T>`, `T` models `sized_range` only if

- `ranges::size(t)` is amortized $\mathcal{O}(1)$, does not modify `t`, and is equal to `ranges::distance( ranges::begin(t), ranges::end(t))`, and
- if `iterator_t<T>` models `forward_iterator`, `ranges::size(t)` is well-defined regardless of the evaluation of `ranges::begin(t)`. [*Note:* `ranges::size(t)` is otherwise not required to be well-defined after evaluating `ranges::begin(t)`. For example, it is possible for `ranges::size(t)` to be well-defined for a `sized_range` whose iterator type does not model `forward_iterator` only if evaluated before the first call to `ranges::begin(t)`. — *end note*]

� `ranges::to` [range.utility.conv.to]

```
template<class C, input_range R, class... Args> requires (!view<C>)
```

```
constexpr C to(R&& r, Args&&... args);
```

Mandates: `C` is a cv-unqualified class type.

Returns: An object of type `C` constructed from the elements of `r` in the following manner:

- If `C` does not satisfy `input_range` or `convertible_to<range_reference_t<R>, range_value_t<C>>` is `true`:
  - If `constructible_from<C, R, Args...>` is `true`:

    ```
    C(std::forward<R>(r), std::forward<Args>(args)...)
    ```

  - Otherwise, if `constructible_from<C, from_range_t, R, Args...>` is `true`:

    ```
    C(from_range, std::forward<R>(r), std::forward<Args>(args)...)
    ```

  - Otherwise, if
    - `common_range<R>` is `true`,
    - the *qualified-id* `iterator_traits<iterator_t<R>>::iterator_category` is valid and denotes a type that models `derived_from<input_iterator_tag>`, and
    - `constructible_from<C, iterator_t<R>, sentinel_t<R>, Args...>` is `true`:

    ```
    C(ranges::begin(r), ranges::end(r), std::forward<Args>(args)...)
    ```

  - Otherwise, if
    - `constructible_from<C, Args...>` is `true`, and
    - *`container-insertable`*`<C, range_reference_t<R>>` is `true`:

    ```
    C c(std::forward<Args>(args)...);
    if constexpr (approximately_sized_range<R> && reservable-container<C>)
        c.reserve(static_cast<range_size_t<C>>(ranges::size_hint(r)));
    ranges::copy(r, container-inserter<range_reference_t<R>>(c));
    ```

- Otherwise, if `input_range<range_reference_t<R>>` is `true`:

  ```
  to<C>(r | views::transform([](auto&& elem) {
      return to<range_value_t<C>>(std::forward<decltype(elem)>(elem));
  }), std::forward<Args>(args)...);
  ```

- Otherwise, the program is ill-formed.

� Class template `ref_view` [range.ref.view]

`ref_view` is a view of the elements of some other range.

```
namespace std::ranges {
template<range R>
requires is_object_v<R>
class ref_view : public view_interface<ref_view<R>> {
    //...

    constexpr auto size() const requires sized_range<R>
    { return ranges::size(*r_); }


    constexpr auto size_hint() const requires approximately_sized_range<R>
    { return ranges::size_hint(*r_); }

    constexpr auto data() const requires contiguous_range<R>
    { return ranges::data(*r_); }
};
```

� Class template `owning_view` [range.owning.view]

`owning_view` is a move-only view of the elements of some other range.

```
namespace std::ranges {
template<range R>
requires movable<R> && (!is-initializer-list<R>) // see ??
class owning_view : public view_interface<owning_view<R>> {
    private:
    R r_ = R();         // exposition only

    public:
    owning_view() requires default_initializable<R> = default;
    constexpr owning_view(R&& t);

    owning_view(owning_view&&) = default;
    owning_view& operator=(owning_view&&) = default;

    //...

    constexpr auto size() requires sized_range<R>
    { return ranges::size(r_); }
    constexpr auto size() const requires sized_range<const R>
    { return ranges::size(r_); }

    constexpr auto size_hint() requires approximately_sized_range<R>
    { return ranges::size_hint(r_); }

    constexpr auto size_hint() const requires approximately_sized_range<const R>
    { return ranges::size_hint(r_); }

    constexpr auto data() requires contiguous_range<R>
    { return ranges::data(r_); }
    constexpr auto data() const requires contiguous_range<const R>
    { return ranges::data(r_); }
};
}
```

� Class template `as_rvalue_view` [range.as.rvalue.view]

```
namespace std::ranges {
template<view V>
requires input_range<V>
class as_rvalue_view : public view_interface<as_rvalue_view<V>> {
    V base_ = V();      // exposition only

    public:
    as_rvalue_view() requires default_initializable<V> = default;
    constexpr explicit as_rvalue_view(V base);

    //...

    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 auto size_hint() requires approximately_sized_range<V>
    { return ranges::size_hint(base_); }

    constexpr auto size_hint() const requires approximately_sized_range<const V>
    { return ranges::size_hint(base_); }
};

template<class R>
as_rvalue_view(R&&) -> as_rvalue_view<views::all_t<R>>;
}
```

� Class template `transform_view` [range.transform.view]

```
namespace std::ranges {
template<input_range V, move_constructible F>
requires view<V> && is_object_v<F> &&
regular_invocable<F&, range_reference_t<V>> &&
can-reference<invoke_result_t<F&, range_reference_t<V>>>
class transform_view : public view_interface<transform_view<V, F>> {
    //...

    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 auto size_hint() requires approximately_sized_range<V>
    { return ranges::size_hint(base_); }

    constexpr auto size_hint() const requires approximately_sized_range<const V>
    { return ranges::size_hint(base_); }
};

}
```

� Class template `take_view` [range.take.view]

```
namespace std::ranges {
template<view V>
class take_view : public view_interface<take_view<V>> {
    // ...
constexpr auto size() requires sized_range<V> {
    auto n = ranges::size(base_);
    return ranges::min(n, static_cast<decltype(n)>(count_));
}

constexpr auto size() const requires sized_range<const V> {
    auto n = ranges::size(base_);
    return ranges::min(n, static_cast<decltype(n)>(count_));
}

constexpr auto size_hint() requires approximately_sized_range<V> {
    auto n = ranges::size_hint(base_);
    return ranges::min(n, static_cast<decltype(n)>(count_));
}

constexpr auto size_hint() const requires approximately_sized_range<const V> {
    auto n = ranges::size_hint(base_);
    return ranges::min(n, static_cast<decltype(n)>(count_));
}

};

}
```

� Class template `drop_view` [range.drop.view]

```
namespace std::ranges {
template<view V>
///...

constexpr auto size() requires sized_range<V> {
    const auto s = ranges::size(base_);
    const auto c = static_cast<decltype(s)>(count_);
    return s < c ? 0 : s - c;
}

constexpr auto size() const requires sized_range<const V> {
    const auto s = ranges::size(base_);
    const auto c = static_cast<decltype(s)>(count_);
    return s < c ? 0 : s - c;
}
constexpr auto size_hint() requires approximately_sized_range<V> {
    const auto s = ranges::size_hint(base_);
    const auto c = static_cast<decltype(s)>(count_);
    return s < c ? 0 : s - c;
}

constexpr auto size_hint() const requires approximately_sized_range<const V> {
    const auto s = ranges::size_hint(base_);
    const auto c = static_cast<decltype(s)>(count_);
    return s < c ? 0 : s - c;
}


private:
V base_ = V();                              // exposition only
range_difference_t<V> count_ = 0;           // exposition only
};

}
```

� Class template common_view [range.common.view]

```
namespace std::ranges {
template<view V>
requires (!common_range<V> && copyable<iterator_t<V>>)
class common_view : public view_interface<common_view<V>> {
    // ...
    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 auto size_hint() requires approximately_sized_range<V>
    { return ranges::size_hint(base_); }

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

� Class template reverse_view [range.reverse.view]

```
namespace std::ranges {
template<view V>
requires bidirectional_range<V>
class reverse_view : public view_interface<reverse_view<V>> {
    ///...
    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 auto size_hint() requires approximately_sized_range<V>
    { return ranges::size_hint(base_); }

    constexpr auto size_hint() const requires approximately_sized_range<const V>
    { return ranges::size_hint(base_); }
};

}
```

� Class template `as_const_view` [range.as.const.view]

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

    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 auto size_hint() requires approximately_sized_range<V>
    { return ranges::size_hint(base_); }

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

� Class template `elements_view` [range.elements.view]

```
namespace std::ranges {
template<class T, size_t N>
concept has-tuple-element =                  // exposition only
tuple-like<T> && N < tuple_size_v<T>;

template<class T, size_t N>
concept returnable-element =                 // exposition only
is_reference_v<T> || move_constructible<tuple_element_t<N, T>>;

template<input_range V, size_t N>
requires view<V> && has-tuple-element<range_value_t<V>, N> &&
has-tuple-element<remove_reference_t<range_reference_t<V>>, N> &&
returnable-element<range_reference_t<V>, N>
class elements_view : public view_interface<elements_view<V, N>> {
    //...

    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 auto size_hint() requires approximately_sized_range<V>
    { return ranges::size_hint(base_); }

    constexpr auto size_hint() const requires approximately_sized_range<const V>
    { return ranges::size_hint(base_); }

    private:
    // ??, class template elements_view::iterator
    template<bool> class iterator;                          // exposition only

    // ??, class template elements_view::sentinel
    template<bool> class sentinel;                          // exposition only

    V base_ = V();                                          // exposition only
};
}
```

� Class template `enumerate_view` [range.enumerate.view]

```
namespace std::ranges {
template<view V>
requires range-with-movable-references<V>
class enumerate_view : public view_interface<enumerate_view<V>> {
     //...

    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 auto size_hint() requires approximately_sized_range<V>
    { return ranges::size_hint(base_); }

    constexpr auto size_hint() const requires approximately_sized_range<const V>
    { return ranges::size_hint(base_); }

    constexpr V base() const & requires copy_constructible<V> { return base_; }
    constexpr V base() && { return std::move(base_); }
};

template<class R>
enumerate_view(R&&) -> enumerate_view<views::all_t<R>>;
}
```

� Class template `adjacent_view` [range.adjacent.view]

```
namespace std::ranges {
template<forward_range V, size_t N>
requires view<V> && (N > 0)
class adjacent_view : public view_interface<adjacent_view<V, N>> {
    //...

    constexpr auto size() requires sized_range<V>;
    constexpr auto size() const requires sized_range<const V>;

    constexpr auto size_hint() requires approximately_sized_range<V>;
    constexpr auto size_hint() const requires approximately_sized_range<const V>;

};
}
```

```
    constexpr auto size() requires sized_range<V>;
    constexpr auto size() const requires sized_range<const V>;
```

Effects: Equivalent to:

```
using ST = decltype(ranges::size(base_));
using CT = common_type_t<ST, size_t>;
auto sz = static_cast<CT>(ranges::size(base_));
sz -= std::min<CT>(sz, N - 1);
return static_cast<ST>(sz);
```

```
    constexpr auto size_hint() requires approximately_sized_range<V>;
    constexpr auto size_hint() const requires approximately_sized_range<const V>;
```

Effects: Equivalent to:

```
using ST = decltype(ranges::size_hint(base_));
using CT = common_type_t<ST, size_t>;
auto sz = static_cast<CT>(ranges::size_hint(base_));
sz -= std::min<CT>(sz, N - 1);
return static_cast<ST>(sz);
```

� Class template `adjacent_transform_view` [range.adjacent.transform.view]

```
namespace std::ranges {
template<forward_range V, move_constructible F, size_t N>
requires view<V> && (N > 0) && is_object_v<F> &&
regular_invocable<F&, REPEAT(range_reference_t<V>, N)...> &&
can-reference<invoke_result_t<F&, REPEAT(range_reference_t<V>, N)...>>
class adjacent_transform_view : public view_interface<adjacent_transform_view<V, F, N>> {
    //...
    constexpr auto size() requires sized_range<InnerView> {
        return inner_.size();
    }
    constexpr auto size() const requires sized_range<const InnerView> {
        return inner_.size();
    }

    constexpr auto size_hint() requires approximately_sized_range<InnerView>
    { return inner_.size_hint(); }

    constexpr auto size_hint() const requires approximately_sized_range<const InnerView>
    { inner_.size_hint(); }
};
}
```

�   Class template `chunk_view` for input ranges   [range.chunk.view.input]

```
class chunk_view : public view_interface<chunk_view<V>> {
    //...
    constexpr auto size() requires sized_range<V>;
    constexpr auto size() const requires sized_range<const V>;
    constexpr auto size_hint() requires approximately_sized_range<V>;
    constexpr auto size_hint() const requires approximately_sized_range<const V>;
};
```

```
    constexpr auto size() requires sized_range<V>;
    constexpr auto size() const requires sized_range<const V>;
```

Effects: Equivalent to:

```
        return to-unsigned-like(div-ceil(ranges::distance(base_), n_));
```

```
    constexpr auto size_hint() requires approximately_sized_range<V>;
    constexpr auto size_hint() const requires approximately_sized_range<const V>;
```

Effects: Equivalent to:

```
        return to-unsigned-like(div-ceil(ranges::size_hint(base_), n_));
```

�   Class template `chunk_view` for forward ranges   [range.chunk.view.fwd]

```
namespace std::ranges {
template<view V>
requires forward_range<V>
class chunk_view<V> : public view_interface<chunk_view<V>> {
   //...
   constexpr auto size() requires sized_range<V>;
   constexpr auto size() const requires sized_range<const V>;
   constexpr auto size_hint() requires approximately_sized_range<V>;
   constexpr auto size_hint() const requires approximately_sized_range<const V>;
};
}
```

```
constexpr auto size() requires sized_range<V>;
constexpr auto size() const requires sized_range<const V>;
```

Effects: Equivalent to:

```
return to-unsigned-like(div-ceil(ranges::distance(base_), n_));
```

```
constexpr auto size_hint() requires approximately_sized_range<V>;
constexpr auto size_hint() const requires approximately_sized_range<const V>;
```

Effects: Equivalent to:

```
return to-unsigned-like(div-ceil(ranges::size_hint(base_), n_));
```

� Class template `slide_view` [range.slide.view]

```
namespace std::ranges {
template<forward_range V>
requires view<V>
class slide_view : public view_interface<slide_view<V>> {
    //...
    constexpr auto size() requires sized_range<V>;
    constexpr auto size() const requires sized_range<const V>;
    constexpr auto size_hint() requires approximately_sized_range<V>;
    constexpr auto size_hint() const requires approximately_sized_range<const V>;
};
}
```

```
constexpr auto size() requires sized_range<V>;
constexpr auto size() const requires sized_range<const V>;
```

Effects: Equivalent to:

```
auto sz = ranges::distance(base_) - n_ + 1;
if (sz < 0) sz = 0;
return to-unsigned-like(sz);
```

```
constexpr auto size_hint() requires approximately_sized_range<V>;
constexpr auto size_hint() const requires approximately_sized_range<const V>;
```

Effects: Equivalent to:

```
auto sz = static_cast<range_difference_t<R>>(ranges::size_hint(r)) - n_ + 1;
if (sz < 0) sz = 0;
return to-unsigned-like(sz);
```

� Class template `stride_view` [range.stride.view]

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

    constexpr auto size() requires sized_range<V>;
    constexpr auto size() const requires sized_range<const V>;
    constexpr auto size_hint() requires approximately_sized_range<V>;
    constexpr auto size_hint() const requires approximately_sized_range<const V>;
};
}
```

```
    constexpr auto size() requires sized_range<V>;
    constexpr auto size() const requires sized_range<const V>;
```

Effects: Equivalent to:

```
        return to-unsigned-like(div-ceil(ranges::distance(base_), stride_));
```

```
    constexpr auto size_hint() requires approximately_sized_range<V>;
    constexpr auto size_hint() const requires approximately_sized_range<const V>;
```

Effects: Equivalent to:

```
    return to-unsigned-like(div-ceil(ranges::size_hint(base_), stride_));
```

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References

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