Rangify New Algorithms

I. Motivation and Scope

This paper complements P0896 by adding rangified overloads for some of the non-parallel additions to `<algorithm>` since C++14, from whence the Ranges TS took its algorithms: `for_each_n, clamp, sample, shift_left, shift_right`.

The additions are straightforward and require no new concepts or classes. The motivation is to increase the chance of the proposal going through and the new rangified overloads to make it into C++20 in the San Diego meeting: the required LEWG review is expected to be minimal, and hopefully LWG would have enough time to go over the wording of the new overloads, similar to the wording review of P0896.

This paper does not provide rangified overloads for the rest of the additions to `<algorithm>` since C++14: `compare_3way, lexicographical_compare_3way, search(range, searcher)`, as those probably do require adding new concepts and classes and would require non-trivial LEWG design review. The rangified overloads for these will be provided in a separate proposal.

II. Impact On the Standard

This is a pure library extension of the Standard (after P0896 is merged).

III. Proposed Wording

24.2 Header `<algorithm> synopsis [algorithm.syn]

```cpp
// 24.6.4, for_each
[...
template<class InputIterator, class Size, class Function>
  constexpr InputIterator for_each_n(InputIterator first, Size n, Function f);
template<class ExecutionPolicy, class ForwardIterator, class Size, class Function>
  ForwardIterator for_each_n(ExecutionPolicy&& exec, // see
  [algorithms.parallel.overloads]
  ForwardIterator first, Size n, Function f);
```
24.6.12, sample

template<class PopulationIterator, class SampleIterator,
class Distance, class UniformRandomBitGenerator>
SampleIterator sample(PopulationIterator first, PopulationIterator last,
SampleIterator out, Distance n,
UniformRandomBitGenerator&& g);

namespace ranges {
  template<class I, class O>
  using sample_result = copy_result<I, O>;

  template<InputIterator I, Sentinel<I> S, WeaklyIncrementable O, class Gen>
  requires (ForwardIterator<I> | RandomAccessIterator<O>) &&
           IndirectCopyable<I, O> &&
           UniformRandomBitGenerator<remove_reference_t<Gen>>
  sample_result<I, O>
  sample(I first, S last, O out, iter_difference_t<I> n, Gen&& g);

  template<InputRange Rng, WeaklyIncrementable O, class Gen>
  requires (ForwardRange<Rng> | RandomAccessIterator<O>) &&
           IndirectCopyable<iterator_t<Rng>, O> &&
           UniformRandomBitGenerator<remove_reference_t<Gen>>
  sample_result<I, O>
  sample(Rng&& rng, O out, iter_difference_t<iterator_t<Rng>> n, Gen&&
         g);
}

24.6.14, shift

template<class ForwardIterator>
constexpr ForwardIterator
shift_left(ForwardIterator first, ForwardIterator last,
typename iterator_traits<ForwardIterator>::difference_type n);

template<class ExecutionPolicy, class ForwardIterator>
ForwardIterator
shift_left(ExecutionPolicy&& exec, // see [algorithms.parallel.overloads]
ForwardIterator first, ForwardIterator last,
typename iterator_traits<ForwardIterator>::difference_type n);

namespace ranges {
  template<Permutable I, Sentinel<I> S>
  constexpr subrange<I>
  shift_left(I first, S last, iter_difference_t<I> n);

  template<ForwardRange Rng>
  requires Permutable<iterator_t<Rng>>
  constexpr safe_subrange_t<Rng>
  shift_left(Rng&& rng, iter_difference_t<iterator_t<Rng>> n);
namespace ranges {
    template<class ForwardIterator>
    constexpr ForwardIterator
    shift_right(ForwardIterator first, ForwardIterator last,
                typename iterator_traits<ForwardIterator>::difference_type
                n);
    template<class ExecutionPolicy, class ForwardIterator>
    ForwardIterator
    shift_right(ExecutionPolicy&& exec, // see [algorithms.parallel.overloads]
                ForwardIterator first, ForwardIterator last,
                typename iterator_traits<ForwardIterator>::difference_type
                n);
}

namespace ranges {
    template<Permutable I, Sentinel<I> S>
    constexpr subrange<I>
    shift_right(I first, S last, iter_difference_t<I> n);
    template<ForwardRange Rng>
    requires Permutable<iterator_t<Rng>>
    constexpr safe_subrange_t<Rng>
    shift_right(Rng&& rng, iter_difference_t<iterator_t<Rng>> n);
}

namespace ranges {
    template<class T>
    constexpr const T& clamp(const T& v, const T& lo, const T& hi);
    template<class T, class Compare>
    constexpr const T& clamp(const T& v, const T& lo, const T& hi, Compare
                            comp);
    namespace ranges {
        template<class T, class Proj = identity,
                 IndirectStrictWeakOrder<projected<const T*, Proj>> Comp = ranges::less>>
        constexpr const T& clamp(const T& v, const T& lo, const T& hi, Comp comp = Comp{}, Proj proj = Proj{});
    }
}

24.7.9, bounded value

namespace ranges {
    template<InputIterator I, Sentinel<I> S, class Proj = identity,
             IndirectUnaryInvocable<projected<const I*, Proj>> Fun>
    constexpr for_each_result<I, Fun>
    for_each_n(I first, iter_difference_t<I> n, Fun f, Proj proj = Proj{});
    template<InputRange Rng, class Proj = identity,
             IndirectlyUnaryInvocable<projected<iterator_t<Rng>, Proj>> Fun>
    ...

[...]  

Remarks: If \( f \) returns a result, the result is ignored. Implementations do not have the
freedom granted under [algorithms.parallel.exec] to make arbitrary copies of elements
from the input sequence.
constexpr for_each_result<safe_iterator_t<Rng>, Fun>
    for_each_n(I first, iter_difference_t<iterator_t<Rng>> n, Fun f, Proj
    proj = Proj{});
}

Requires: \texttt{n} \geq 0.

Effects: Calls \texttt{invoke(f, \texttt{invoke(proj, \ast i)})} for every iterator \texttt{i} in the range \texttt{[first, first + n)} in order. [Note: If the result of \texttt{invoke(proj, \ast i)} is a mutable reference, \texttt{f} may apply non-constant functions. — end note ]

Returns: \{first + n, std::move(f)\}

Remarks: If \texttt{f} returns a result, the result is ignored.

24.6.12 Sample [alg.random.sample]

template<class PopulationIterator, class SampleIterator,
    class Distance, class UniformRandomBitGenerator>
    SampleIterator sample(PopulationIterator first, PopulationIterator last,
    SampleIterator out, Distance n,
    UniformRandomBitGenerator&& g);

namespace ranges {
    template<InputIterator I, Sentinel<I> S, WeaklyIncrementable O, class Gen>
        requires (ForwardIterator<I> || RandomAccessIterator<O>) &&
            IndirectlyCopyable<I, O> &&
            UniformRandomBitGenerator<remove_reference_t<Gen>>
        sample_result<I, O>
            sample(I first, S last, O out, iter_difference_t<I> n, Gen&& g);
    template<InputRange Rng, WeaklyIncrementable O, class Gen>
        requires (ForwardRange<Rng> || RandomAccessIterator<O>) &&
            IndirectlyCopyable<iterator_t<Rng>, O> &&
            UniformRandomBitGenerator<remove_reference_t<Gen>>
        sample_result<iterator_t<Rng>, O>
            sample(Rng&& rng, O out, iter_difference_t<iterator_t<Rng>> n, Gen&&
                g);
}

Requires:
— \texttt{out} shall not be in the range \texttt{[first, last)}.

For the overloads in namespace \texttt{std}:
— \texttt{PopulationIterator} shall satisfy the \texttt{Cpp17InputIterator} requirements (22.2.3).
— \texttt{SampleIterator} shall satisfy the \texttt{Cpp17OutputIterator} requirements (22.2.4).
— \texttt{SampleIterator} shall satisfy the \texttt{Cpp17RandomAccessIterator} requirements (22.2.7) unless \texttt{PopulationIterator} satisfies the
**Cpp17ForwardIterator** requirements (22.2.5).

- PopulationIterator’s value type shall be writable (22.2.1) to out.
- Distance shall be an integer type.
- `remove_reference_t<UniformRandomBitGenerator>` shall satisfy the requirements of a random number generator type (24.7.2.3) whose return type is convertible to Distance.
- out shall not be in the range [first, last).

**Effects:** Copies \( \min(\text{last} - \text{first}, n) \) elements (the sample) from \([\text{first}, \text{last})\) (the population) to out such that each possible sample has equal probability of appearance. [Note: Algorithms that obtain such effects include selection sampling and reservoir sampling. —end note]

**Returns:** Let SAMPLE_END be the end of the resulting sample range. 
- SAMPLE_END for the overloads in namespace std, or
- \{last, SAMPLE_END\} for the overloads in namespace ranges.

**Complexity:** \( O(\text{last} - \text{first}) \).

**Remarks:**
- For the overloads in namespace std, stable if and only if PopulationIterator satisfies the Cpp17ForwardIterator requirements. For the overloads in namespace ranges, stable if and only if I models ForwardIterator.
- To the extent that the implementation of this function makes use of random numbers, the object referenced by g shall serve as the implementation’s source of randomness.

### 24.6.14 Shift [alg.shift]

```cpp
template<class ForwardIterator>
constexpr ForwardIterator
shift_left(ForwardIterator first, ForwardIterator last,
          typename iterator_traits<ForwardIterator>::difference_type n);

template<class ExecutionPolicy, class ForwardIterator>
ForwardIterator
shift_left(ExecutionPolicy&& exec, ForwardIterator first,
          ForwardIterator last,
          typename iterator_traits<ForwardIterator>::difference_type n);

namespace ranges {
    template<Permutable I, Sentinel<I> S>
    constexpr subrange<I>
    shift_left(I first, S last, iter_difference_t<I> n);

    template<ForwardRange Rng>
    ...}
```
`requires Permutable<iterator_t<Rng>>
constexpr safe_subrange_t<Rng>
    shift_left(Rng&& rng, iter_difference_t<iterator_t<Rng>> n);
}

Requires: For the overloads in namespace std, the type of *first shall meet the Cpp17MoveAssignable requirements ([tab:moveassignable]).

Effects: If `n <= 0` or `n >= last - first`, does nothing. Otherwise, moves the element from position `first + n + i` into position `first + i` for each non-negative integer `i < (last - first) - n`. In the first overload case for the overloads with no ExecutionPolicy, does so in order starting from `i = 0` and proceeding to `i = (last - first) - n - 1`.

Returns: Let `NEW_LAST` be `first + (last - first - n)` if `n` is positive and `n < last - first`, otherwise `first` if `n` is positive, otherwise `last`:
- `NEW_LAST` for the overloads in namespace std, or
- `{first, NEW_LAST}` for the overloads in namespace ranges.

Complexity: At most `(last - first) - n` assignments.

```cpp
template<class ForwardIterator>
constexpr ForwardIterator
    shift_right(ForwardIterator first, ForwardIterator last,
                typename iterator_traits<ForwardIterator>::difference_type n);

template<class ExecutionPolicy, class ForwardIterator>
ForwardIterator
    shift_right(ExecutionPolicy&& exec, ForwardIterator first,
                ForwardIterator last,
                typename iterator_traits<ForwardIterator>::difference_type n);
```

```cpp
class ranges {
    template<Permutable I, Sentinel<I> S>
        constexpr subrange<I>
            shift_right(I first, S last, iter_difference_t<I> n);

template<ForwardRange Rng>
    requires Permutable<iterator_t<Rng>>
        constexpr safe_subrange_t<Rng>
            shift_right(Rng&& rng, iter_difference_t<iterator_t<Rng>> n);
};
```

Requires: For the overloads in namespace std, the type of *first shall meet the Cpp17MoveAssignable requirements ([tab:moveassignable]), and ForwardIterator shall meet the Cpp17BidirectionalIterator requirements.
(\[bidirectional.iterators\]) or the \textit{Cpp17ValueSwappable} \([\text{swappable.requirements}]\) requirements.

\textbf{Effects:} If \(n <= 0 \text{ or } n >= \text{last} - \text{first}\), does nothing. Otherwise, moves the element from position \(\text{first} + i\) into position \(\text{first} + n + i\) for each non-negative integer \(i < (\text{last} - \text{first}) - n\). In the first overload case, if \(\text{ForwardIterator}\) meets the \textit{Cpp17BidirectionalIterator} requirements \([\text{bidirectional.iterators}]\), does so in order starting from \(i = (\text{last} - \text{first}) - n - 1\) and proceeding to \(i = 0\) if:

\begin{itemize}
  \item \texttt{ForwardIterator} meets the \textit{Cpp17BidirectionalIterator} requirements \([\text{bidirectional.iterators}]\), does so in order starting from \(i = (\text{last} - \text{first}) - n - 1\) and proceeding to \(i = 0\) for the overload in namespace \texttt{std} with no \texttt{ExecutionPolicy}, or
  \item \texttt{decltype(first)} models \textit{BidirectionalIterator}, for the overloads in namespace \texttt{ranges}.
\end{itemize}

\textbf{Returns:} Let \texttt{NEW\_FIRST} be \(\text{first} + n\) if \(n\) is positive and \(n < \text{last} - \text{first}\), otherwise \(\text{last} + n\) if \(n\) is positive, otherwise \(\text{first}\):

\begin{itemize}
  \item \texttt{NEW\_FIRST} for the overloads in namespace \texttt{std}, or
  \item \{\texttt{NEW\_FIRST}, \texttt{last}\} for the overloads in namespace \texttt{ranges}.
\end{itemize}

\textbf{Complexity:} At most \((\text{last} - \text{first}) - n\) assignments or swaps.

\textbf{24.7.9 Bounded value [alg.clamp]}

\begin{verbatim}
template<class T>
  constexpr const T& clamp(const T& v, const T& lo, const T& hi);

template<class T, class Compare>
  constexpr const T& clamp(const T& v, const T& lo, const T& hi, Compare comp);

namespace ranges {
  template<class T, class Proj = identity, class Comp = ranges::less<>>
    constexpr const T& clamp(const T& v, const T& lo, const T& hi, Comp comp
                        = Comp{}, Proj proj = Proj{});
}
\end{verbatim}

\textbf{Requires:} The value of \(\texttt{lo}\) shall be no greater than \(\texttt{hi}\). For the first form, type \(T\) shall be \textit{Cpp17LessThanComparable} \([\text{tab:lessthancomparable}]\).

\textbf{Returns:} \(\texttt{lo}\) if \(v\) is less than \(\texttt{lo}\), \(\texttt{hi}\) if \(\texttt{hi}\) is less than \(v\), otherwise \(v\).
[Note: If NaN is avoided, T can be a floating-point type. —end note]

Complexity: At most two comparisons and three applications of any projection.

IV. Revision History
- R0, 7.10.18 - Initial revision

V. Acknowledgements
- Special thanks to Casey Carter for his guidance.