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Helpful pointers for ContiguousIterator

1 Abstract

The support for contiguous iterators in the working draft is missing a useful feature: a mechanism to convert a contiguous iterator into a pointer that denotes the same object. This paper proposes that `std::to_address` be that mechanism.

Table 1 — Tony Table

Before	After
<pre>extern "C" int some_c_api(T* ptr, size_t size); template<ContiguousIterator I> int try_useful_things(I i, size_t n) { // Expects: [i, n) is a valid range if (n == 0) { // Oops - can't dereference past-the-end iterator throw something; } return some_c_api(addressof(*i), n); } template<ContiguousIterator I> int try_useful_things(I i, I j) { // Expects: [i, j) is a valid range if (i == j) { // Oops - can't dereference past-the-end iterator throw something; } return some_c_api(addressof(*i), addressof(*i) + (j - i)); }</pre>	<pre>extern "C" int some_c_api(T* ptr, size_t size); template<ContiguousIterator I> int try_useful_things(I i, size_t n) { // Expects: [i, n) is a valid range return some_c_api(to_address(i), n); } template<ContiguousIterator I> int try_useful_things(I i, I j) { // Expects: [i, j) is a valid range return some_c_api(to_address(i), to_address(j)); }</pre>

1.1 Revision History

1.1.1 Revision 0

— Initial revision.

2 Problem description

P0944R0 “Contiguous ranges” [1] proposed support for contiguous ranges and iterators, which was merged into P0896R4 “The One Ranges Proposal” [4] and then merged into the Working Draft. Neither P0944R0 nor P0896R4 proposed a means of obtaining a pointer to the element denoted by an arbitrary `ContiguousIterator`. At the time, the author was under the impression that such a mechanism had been a “third rail” for past contiguous iterator proposals [3], and that requiring such a mechanism would make it impossible to require

the iterators of the Standard Library containers to model `ContiguousIterator`. Those implementability concerns have since been rectified.

Note that obtaining a pointer value from a dereferenceable `ContiguousIterator` is trivial: `std::addressof(*i)` returns such a pointer value for a contiguous iterator `i`. Dereferencing a non-dereferenceable iterator is (unsurprisingly) not well-defined, so this mechanism isn't suitable for iterators not known to be dereferenceable. Obtaining a pointer value for the potentially non-dereferenceable iterator `j` that is the past-the-end iterator of a range `[i, j)` thus requires a different mechanism that is well-defined for past-the-end iterators. Ideally the mechanism would also be well-defined for dereferenceable iterators so it can be used uniformly.

P0653R2 “Utility to convert a pointer to a raw pointer” [2] added the function `std::to_address` ([[pointer.conversion](#)]) to the Standard Library which converts values of so-called “fancy” pointer types and standard smart pointer types to pointer values. In the interest of spelling similar things similarly, it seems a good idea to reuse this facility to convert `ContiguousIterators` to pointer values. In practice, that means that a type `I` must be a pointer type or

- specialize `pointer_traits<I>`, and
- implement `pointer_traits<I>::to_address`, or admit past-the-end (potentially non-dereferenceable) iterator values in `operator->()`.

3 Proposal

The basic proposal is to add a requirement to the `ContiguousIterator` concept that the expression `std::to_address(i)` for an lvalue `i` of type `const I` must

- be well-formed and yield a pointer of type `add_pointer_t<iter_reference_t<i>>`,
- be well-defined for both dereferenceable and past-the-end pointer values,
- yield a pointer value equal to `std::addressof(*i)` if `i` is dereferenceable, or equal to `std::addressof(*(i - 1))` if `i - 1` is dereferenceable.

Since dereferenceable `ContiguousIterators` always denote objects - their reference types are always lvalue references - they can always feasibly implement the `->` operator. `->` is useful in contexts where the value type of the iterator is concrete so we propose requiring it for all `ContiguousIterators`. [*Note*: Recall that the iterator concepts do not generally require `operator->` as do the “old” iterator requirements. — *end note*]

Now that there's a mechanism to retrieve a pointer from a potentially non-dereferenceable iterator, we can also cleanup the edge cases in `ranges::data` and `ranges::view_interface::data` which return `nullptr` for an empty `ContiguousRange` rather than unconditionally returning the pointer value that the `begin` iterator denotes.

4 Technical specifications

Change the [[iterator.concept.contiguous](#)] as follows:

```
template<class I>
concept ContiguousIterator =
    RandomAccessIterator<I> &&
    DerivedFrom<ITER_CONCEPT(I), contiguous_iterator_tag> &&
    is_lvalue_reference_v<iter_reference_t<I>> &&
    Same<iter_value_t<I>, remove_cvref_t<iter_reference_t<I>>>; &&
    requires(const I& i) {
        { to_address(i) } -> Same<add_pointer_t<iter_reference_t<I>>>;
    } &&
    (is_pointer_v<I> || requires(const I& i) {
        { i.operator->(); } -> Same<add_pointer_t<iter_reference_t<I>>>;
    });
```

² Let `a` and `b` be dereferenceable iterators and `c` a non-dereferenceable iterator of type `I` such that `b` is reachable from `a` and `c` is reachable from `b`, and let `D` be `iter_difference_t<I>`. The type `I`

models `ContiguousIterator` only if `addressof(*(a + D(b - a)))` is equal to `addressof(*a) + D(b - a)`.

- (2.1) — `to_address(b) == to_address(a) + D(b - a)`,
- (2.2) — `to_address(c) == to_address(a) + D(c - a)`, and
- (2.3) — if `I` is not a pointer type, `a.operator->() == to_address(a)`.

Change `[range.prim.data]` as follows:

- 1 The name `data` denotes a customization point object (`[customization.point.object]`). The expression `ranges::data(E)` for some subexpression `E` is expression-equivalent to:
- (1.1) — If `E` is an lvalue, `DECAY_COPY(E.data())` if it is a valid expression of pointer to object type.
 - (1.2) — Otherwise, if `ranges::begin(E)` is a valid expression whose type models `ContiguousIterator`, `to_address(ranges::begin(E))`.
`ranges::begin(E) == ranges::end(E) ? nullptr : addressof(*ranges::begin(E))`

except that `E` is evaluated only once.
 - (1.3) — Otherwise, `ranges::data(E)` is ill-formed.
- [...]

Change `[view.interface]` as follows:

```
namespace std::ranges {
    [...]

    template<class D>
        requires is_class_v<D> && Same<D, remove_cv_t<D>>
        class view_interface : public view_base {
            [...]

            constexpr auto data() requires ContiguousIterator<iterator_t<D>> {
                return ranges::empty(derived()) ? nullptr : addressof(*ranges::begin(derived()));
                return to_address(ranges::begin(derived()));
            }
            constexpr auto data() const
                requires Range<const D> && ContiguousIterator<iterator_t<const D>> {
                return ranges::empty(derived()) ? nullptr : addressof(*ranges::begin(derived()));
                return to_address(ranges::begin(derived()));
            }
        }

    [...]
}
```

Bibliography

- [1] Casey Carter. P0944R0: Contiguous ranges, 02 2018. <http://www.open-std.org/jtc1/sc22/wg21/docs/papers/2018/p0944r0.html>.
- [2] Glen Joseph Fernandes. P0653R2: Utility to convert a pointer to a raw pointer, 11 2017. <https://wg21.link/p0653r2>.
- [3] Nevin "==" Liber. N4183: Contiguous iterators: Pointer conversion and type trait, 10 2014. <https://wg21.link/n4183>.
- [4] Eric Niebler, Casey Carter, and Christopher Di Bella. P0896R4: The one ranges proposal, 11 2018. <http://www.open-std.org/jtc1/sc22/wg21/docs/papers/2018/p0896r4.pdf>.