Binary Search

A fast search with a search time of O(log n) has been predefined in C++.

WE'LL COVER THE FOLLOWING

- Further information

The binary search algorithms use the fact that the ranges are already sorted. To search for an element, use `std::binary_search`. With `std::lower_bound`, we get an iterator for the first element, not smaller than the given value. With `std::upper_bound`, we get an iterator back for the first element which is bigger than the given value. `std:::equal_range` combines both algorithms.

If the container has n elements, we need on average $\mathbf{\log_2(n)}$ comparisons for the search. The binary search requires that we use the same comparison criterion that you used for sorting the container. By default, the comparison criterion is `std::less`, but we can adjust it. Our sorting criterion has to obey strict weak ordering. If not, the result is undefined.

If we have an unordered associative container, the methods of the unordered associative container are generally faster.

`std::binary_search`: Searches for the element `val` in the range.

```
bool binary_search(FwdIt first, FwdIt last, const T& val)
bool binary_search(FwdIt first, FwdIt last, const T& val, BiPre pre)
```

`lower_bound`: Returns the position of the first element of the range which is not smaller than `val`.

```
FwdIt lower_bound(FwdIt first, FwdIt last, const T& val)
FwdIt lower_bound(FwdIt first, FwdIt last, const T& val, BiPre pre)
```

`upper_bound`: Returns the position of the first element of the range which is bigger than `val`.

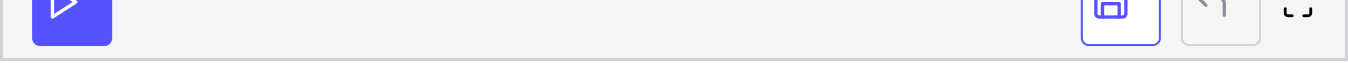
```
FwdIt upper_bound(FwdIt first, FwdIt last, const T& val)
FwdIt upper_bound(FwdIt first, FwdIt last, const T& val, BiPre pre)
```

`equal_range`: Returns the pair `std::lower_bound` and `std::upper_bound` for the element `val`.

```
pair<FwdIt, FwdIt> equal_range(FwdIt first, FwdIt last, const T& val)
pair<FwdIt, FwdIt> equal_range(FwdIt first, FwdIt last, const T& val, BiPre pre)
```

Finally, the code snippet:

```
#include <algorithm>
#include <cmath>
#include <iostream>
#include <vector>

bool isLessAbs(int a, int b){
  return std::abs(a) < std::abs(b);
}

int main(){

  std::cout << std::boolalpha << std::endl;

  std::vector<int> vec{-3, 0, -3, 2, -3, 5, -3, 7, -0, 6, -3, 5, -6, 8, 9, 0, 8, 7, -7, 8, 9,

  for ( auto v: vec ) std::cout << v << " ";

  std::sort(vec.begin(), vec.end(), isLessAbs);
  std::cout << std::endl;
  for ( auto v: vec ) std::cout << v << " ";

  std::cout << std::endl;

  std::cout << std::endl;
  std::cout << "std::binary_search(vec.begin(), vec.end(), -5, isLessAbs): " << std::binary_s
  std::cout << "std::binary_search(vec.begin(), vec.end(), 5, isLessAbs): " << std::binary_se

  auto pair= std::equal_range(vec.begin(), vec.end(), 3, isLessAbs);

  std::cout << std::endl;

  std::cout << "Position of first 3: " << std::distance(vec.begin(), pair.first) << std::endl
  std::cout << "Position of last 3: " << std::distance(vec.begin(), pair.second)-1 << std::en
  for ( auto threeIt= pair.first; threeIt != pair.second ; ++threeIt ) std::cout << *threeIt

  std::cout << "\n\n";

}
```



Binary search algorithms

Further information

- strict weak ordering
- unordered associative container

In the next lesson, we'll learn different ways of combining ranges.