Lecture 4

ADT Set, Map, Dictionary. Iterators

TDDD86: DALP

Utskriftsversion av Lecture in *Data Structures, Algorithms and Programming Paradigms*
September 6th, 2023

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4.1

Content

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1 Symbol table

Symbol table

- Abstraction of key-value pairs
  - *Submit* a value with the specified key
  - Given a key, *search* by the corresponding values

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1.1 Abstract datatype

ADT Set

- Storage of keys
- Typical operations:
  - size() the number of keys
  - isEmpty() returns true if there are no keys
  - contains(k) returns **true** if k is used in the container, otherwise **false**
  - put(k) add k to the container
  - remove(k) remove k from the container

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ADT Map

- Storage of pairs (*key*, *value*) with at most one pair per key. More than one key may map to the same value!
- Typical operations:
  - size() number of pairs in the map
  - isEmpty() checks if the map is empty
  - get(k) returns the value associated with k or **null** if the key is not in the map
  - put(k, v) add (k, v) to the container and returns **null** if k is new; otherwise replace the value with v and returns the old value
  - remove(k) remove the pair (k, v) and return v; return **null** if the key is not in the map

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ADT Dictionary

- Storage of pairs (*key*, *value*), possibly several pairs per key Contains the relationship between a key and one or several values!
- Typical operations:
  - size() number of elements
  - isEmpty() check if the container is empty
  - find(k) returns any item with k or **null** if there are none
  - findAll(k) return a list of value with key k
  - insert(k,v) add (k,v) and return the new entry
  - remove(k,v) remove (k,v) and returns the value; return **null** if there are no matching pair
  - entries() returns a list of all entries

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1.2 Associative container i C++

pair class

Class for storing pairs — for example, used by all map-containers.

- has a helper function `make_pair` to create a pair object

```
vector< pair<int, string> > v;
int    i = 4711;
string s = "foobar";
v.push_back(make_pair(i, s));  // exactly like pair<int, string>(i, s);
```

- it is easy to access the pair content:

```
pair<int, string> myPair;
myPair.first = 4711;
myPair.second = "foobar";
```

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Associative container

Quick access to data based on *key search*

- In the following associative containers keys are in order — iterating over them follow the ordering of the key

```
map      multimap      set      multiset
```

- *set-containers* stores only a key
- *map-containers* store key-values pairs - using `pair` to store a key and the associated value
- non-multi variant allows for a *unique* key
- Moreover, there are corresponding unordered associative container:

```
unordered_map   unordered_multimap   unordered_set   unordered_multiset
```

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Associative containers — operations

Storlek, kapacitet	**map**	**multimap**	**set**	**multiset**
`n = a.size()`	•	•	•	•
`n = a.max_size()`	•	•	•	•
`b = a.empty()`	•	•	•	•

Jämförelse	**map**	**multimap**	**set**	**multiset**
`==   !=`	•	•	•	•
`<   <=   >   >=`	•	•	•	•

Elementåtkomst	**map**	**multimap**	**set**	**multiset**
`x = a[k]`	•			
`x = a.at(k)`	•			

Anm: om ett element med nyckel k inte finns i en map, skapas det av **operator**[], med det associerade värdet defaultinitierat. En referens till det associerade värdet returneras och kan användas för att tilldela ett värde.

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Associative containers — operations

Modifierare	map	multimap	set	multiset	
`pair<iterator, bool> p = a.insert(x);`	•		•		**1, 3**
`it = a.insert(x)`		•		•	**1**
`it = a.insert(pos, x)`	•	•	•	•	**1**
`a.insert(first, last)`	•	•	•	•	
`a.insert( { x, y, z } )`	•	•	•	•	
`pair<iterator, bool> p = a.emplace(`*args*`);`	•		•		**2, 3**
`it = a.emplace(`*args*`)`		•		•	**2**
`it = a.emplace_hint(pos, `*args*`)`	•	•	•	•	**2**
`a.erase(it)`	•	•	•	•	
`n = a.erase(k)`	•	•	•	•	
`a.erase(first, last)`	•	•	•	•	
`a1.swap(a2)`	•	•	•	•	
`a.clear()`	•	•	•	•	

1) i fallen `map` och `multimap` har x typen pair (nyckel–värde)

2) i fallen `map` och `multimap` ska *args* var värden motsvarande ett nyckel–värde-par

3) använd hellre **auto**

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Associative containers — operations

Map- och set-operationer	map	multimap	set	multiset	
`it = a.find(k)`	•	•	•	•	
`n = a.count(k)`	•	•	•	•	
`it = a.lower_bound(k)`	•	•	•	•	
`it = a.upper_bound(k)`	•	•	•	•	
`pair<iter, iter> p = a.equal_range(k);`	•	•	•	•	**1**

Specialiserad operation				
`swap(a1, a2)`	•	•	•	•

1) använd hellre **auto**

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Exercise — count unique word

- Write a program that counts the number of unique words in a large text file

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Exercise — count words

- Write a program that determines which words are most common in a large text file

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Exercise — anagram

- Write a program that computes the largest amount of anagrams from a dictionary

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2 Iterators

Iterators

Can be seen as a pointer that can point to elements in a container and know how to move between elements

- Container iterator
  - point to an element in the container
  - each container class has its own iterator
- Stream iterator
  - bound to a stream
  - allows us to read from and write to streams using iterator operations
- insert iterator
  - bound to an iterator

  - used to insert into the iterator
- move iterator
  - element values are moved from the source to the destination, instead of being copied - source elements zeroed typically
- past-the-end iterator
  - a special iterator value indicating the end of a container, a stream or other type of range of values
  - primarily used to compare with other iterators: “Have we reached the end?”

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Iterators

- access to the element with * or -> (like a pointer)
- many operations on containers use iterators as arguments and/or return an iterator
- almost all algorithms use iterator for operation on containers and other datastructure, including streams
- improper use of an iterators can lead to execution errors, such as “segmentation fault”

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Container iterator

Each type of container has its own specific iterator implementation:

- Containers have the following types:
  - *iterator* iterates from the beginning to the end of a container
  - *const_iterator* can be used to read but not modify
  - *reverse_iterator* iterates from the end to the beginning of a container
  - *const_reverse_iterator*
- Here are the functions to return iterators: begin(), end(), cbegin(), cend(), rbegin(), rend(), crbegin(), crend()
- Example:

```
for(vector<int>::const_iterator it = v.cbegin(); it != v.cend(); ++it)
{
  cout << *it << '␣';
}
```

- If nothing should be changed during the operation, use the const version

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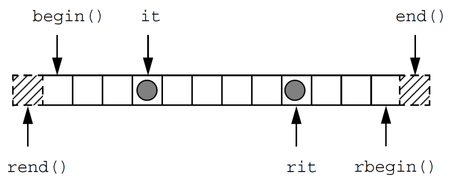
Iterator position



- Reverse iterator vs normal iterator:

```
for(vector<int>::const_reverse_iterator it = v.crbegin();
    it != v.crend(); ++it)
{
  cout << *it << '␣';
}
// Equivalent to:
for(vector<int>::const_iterator it = v.cend(); it != v.cbegin(); --it)
{
  cout << *(it-1) << '␣';
}
```

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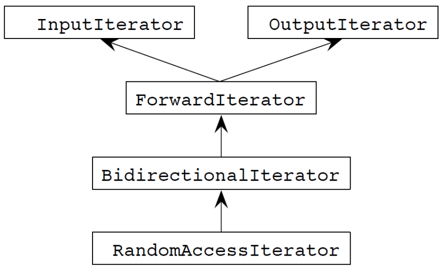
Iterator category

An iterator "points" to a value. All operators supports `++it` and `it++`
Different applications require different iterators. There is a hierarchy among iterator categories:



- `InputIterator`: can be referenced to read value.
- `OutputIterator`: can be referenced for writing a value.
- `ForwardIterator`: can both read and write.
- `BidirectionalIterator`: can move back and forth.
- `RandomAccessIterator`: allow pointer arithmetic and arbitrary index.

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Operations on iterators

Förutom kopiering och tilldelning finns följande operationer för de olika iteratorkategorierna:

	Input	**Output**	**Forward**	**Bidirectional**	**Random Access**
`==  !=`	Ja	Ja	Ja	Ja	Ja
`*`	Läs	Skriv	Läs + Skriv	Läs + Skriv	Läs + Skriv
`->`	Läs	Skriv	Läs + Skriv	Läs + Skriv	Läs + Skriv
`++`	Ja	Ja	Ja	Ja	Ja
`--`	–	–	–	Ja	Ja
`+  +=  -  -=`	–	–	–	–	Ja
`<  <=  >  >=`	–	–	–	–	Ja
it`[`*n*`]`	–	–	–	–	Ja
`advance(`*it*`, `*n*`)`	Ja	–	Ja	Ja	Ja
`distance(`*it1*`, `*it2*`)`	Ja	–	Ja	Ja	Ja
			`forward_list` *de oordnade associativa containrarna*	`list` `set multiset` `map multimap`	`vector` `deque` `array`

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Example — iterator operations

Vissa iteratoroperationer nedan kräver *random access*-iteratorer.

```
int a[]{ 1, 2, 3, 4, 5, 6, 7, 8, 9 };                    // a är en pekare till första elementet

vector<int> v1{ begin(a), end(a) };                      // "range access"-funktioner (<iterator>)

vector<int> v2{ v1.begin(), v1.end() };

vector<int>::iterator first    = v1.begin();
vector<int>::iterator past_end = v1.end();

cout << *first << '\n';                                                        // avreferering

cout << *(past_end - 1) << '\n';                                               // aritmetik

cout << past_end - first << '\n';                                              // avstånd

cout << first[5] << '\n';                                                      // indexering

vector<int>::iterator it{ first };                                             // kopiering

vector<int>::iterator middle = v2.begin() + (v2.end() - v2.begin()) / 2;       // tilldelning

v2.erase(middle, v2.end());
```

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