C++

Containers

Introduction

- A container is an object that stores other objects (its elements) and that has methods to access its elements
- There are three important concepts:
  - The container type (sequence, associative container, container adaptors)
  - The type of objects contained (int, double, user defined class)
  - The operations on the containers (and their complexity)

Example

- We will illustrate how containers works (and can be implemented) by an example
- We will implement an array: i.e a sequence of homogeneous element
- Operations:
  - Assignment
  - Assignment and access to a random element

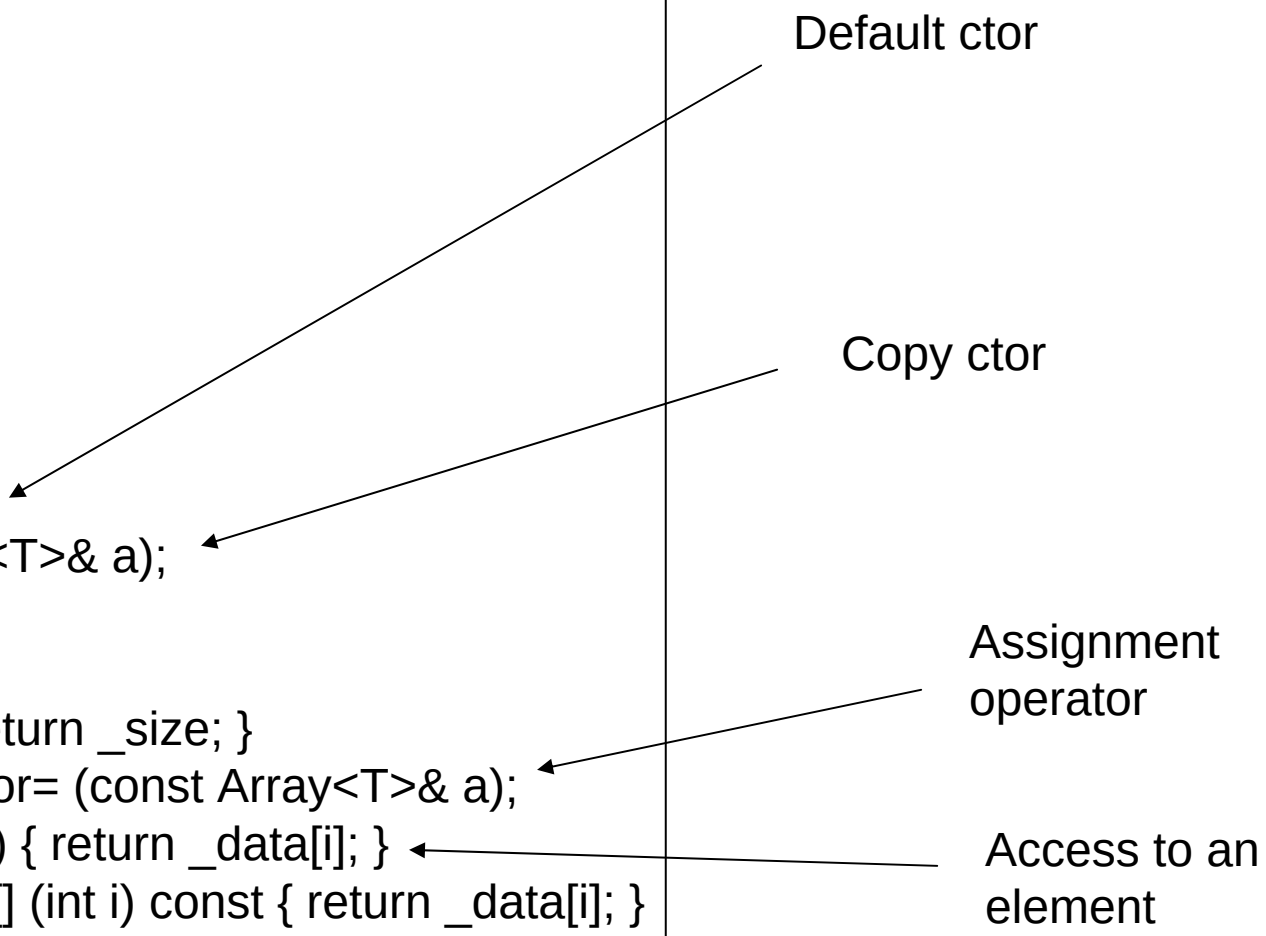
Example: Array

```
#ifndef ARRAY_H
#define ARRAY_H

template <class T>
Array {
 private:
  int _size;
  T* _data;
 public:
  Array(int sz=100);
  Array(const Array<T>& a);
  ~Array();

  int size() const { return _size; }
  Array<T>& operator= (const Array<T>& a);
  T& operator[] (int i) { return _data[i]; }
  const T& operator[] (int i) const { return _data[i]; }
};

#endif
```



Ctor and Dtor

```
template<class T>
Array<T>::Array(int sz) : _size(sz), _data(new T[sz]){}

template<class T>
Array<T>::Array(const Array<T>& a) : _size(a._size), _data(new T[a._size]) {
  for (int i=0; i < _size; i++) {
    _data[i] = a._data[i];
  }
}

template<class T>
Array<T>::~Array() {
  delete[] _data;
}
```

Copy Ctor: reminder

- Remember: if a class owns data (has member data which are pointer), then you should provide a copy constructor
- The default copy constructor does only bit-wise copy
- Example:

  Array<int> A;
  Array<int> B = A; // or B(A)
- With the default copy ctor, _data in B and A will point to the same location
- Deleting _data, for example in B dtor, will also delete the memory allocated for A._data and potentially create memory bugs

Assignment operator

- Let us look first at a wrong implementation of the assignment operator, we will then comment and fix it

```
template<class T>
Array<T>&
Array<T>::operator= (const Array<T>& a) {
  delete[] _data;
  _size = a._size;
  _data = new T[_size];
  for (int i =0; i < _size; i++){
     _data[i] = a._data[i];
  }
  return *this;
}
```

The problem is here

Assignment operator problem

- Suppose that we write:

```
Array<int> a;
a = a; // problem!
```

- Remember the lesson on assignment operator: we need to be careful about self-assignment

Assignment operator fixed

```
template<class T>
Array<T>&
Array<T>::operator= (const Array<T>& a) {
  if (this != &a) {
    delete[] _data;
    _size = a._size;
    _data = new T[_size];
    for (int i =0; i < _size; i++){
       _data[i] = a._data[i];
    }
  }
  return *this;
}
```

We can now write:
Array<int> a;
a = a;

Printing facilities

- Let us add some printing facilities for the class array
- We want to do:

  Array<int> a;

  cout << a << endl;

```
template <class T>
ostream&
operator<< (ostream& os, const Array<T>& a){
  for (int i = 0; i < a.size(); i++) {
     os << a[i] << " ";
  }
  return os;
}
```

Note: we already saw how to overload "<<" in the prev. lesson on op. overloading

Usage

```
#include <iostream>
#include <Array.h>

using namespace std;

int main() {
 Array<int> a(20);
 for(int i = 0; i < a.size(); i++) {
   a[i] = i; // call operator[]
 }
 cout << a << endl;

 Array<int> b = a; // copy ctor
 cout << b.size() << endl;

 Array<int> c(50);
 c = a; // assignment op
}
```

Remarks on operator[]

- There are two operator[] implementations in the class Array<T>:
  - template<class T> T& Array<T>::operator[] (int i);
  - template<class T> const T& Array<T>::operator[] (int i) const;
- Reason: suppose you want e.g. to pass a const Array to a function that will need to access some of the elements

Remarks on operator[]

```
template <class T>
T f (const Array<T>& a)
{
  T sum = 0;
  for (int i = 0; i < a.size(); i++)
    sum += a[i];
  return sum;
}
```

a is const

Elements of a are read only but not modified

Without the second form of operator[], this code would not compile.

Containers and the STL

- STL has 4 types of containers:
  - Sequences: list, vector, deque, …
  - Associative containers: set, map, multiset, hash,…
  - String
  - Container adaptors: stack, queue, priority_queue

Containers in the STL

- Sequences: variable sized container with elements arranged in a linear order; it supports insertion and removal of elements
- Available operations depends on the type of sequence: e.g. vector<T> allows random access by operator [], but not list<T>

Containers in the STL

- Associative container: it is a container of pairs <key, value> objects
- For some assoc. containers key==value (sets) while for others they are different (maps)
- Some assoc. cont. require unique key (set, map) while other not (multiset, multimap)
- Operation availables depends on the assoc. container

Container adaptors

- Container adaptor means that it is implemented on top of another container
- For example, the stack in the STL is defined as Stack<T, Sequence>
  - Sequence is the underlying container
  - By default deque is used
  - T is the type of the element
- Container adaptors provide a restricted subset of Container facilities