# An Introduction to STL

# The C++ Standard Template Libraries

- In 1990, Alex Stepanov and Meng Lee of Hewlett Packard Laboratories extended C++ with a library of class and function templates which has come to be known as the STL.
- In 1994, STL was adopted as part of ANSI/ISO Standard C++.

# The C++ Standard Template Libraries

- STL had three basic components:
  - Containers

    Generic class templates for storing collection of data.
  - Algorithms

    Generic function templates for operating on containers.
  - Iterators

    Generalized 'smart' pointers that facilitate use of containers.

    They provide an interface that is needed for STL algorithms to operate on STL containers.
- **String abstraction was added during standardization.**

# Why use STL?

- STL offers an assortment of containers
- STL publicizes the time and storage complexity of its containers
- STL containers grow and shrink in size automatically
- STL provides built-in algorithms for processing containers
- STL provides iterators that make the containers and algorithms flexible and efficient.
- STL is extensible which means that users can add new containers and new algorithms such that:
  - STL algorithms can process STL containers as well as user defined containers
  - User defined algorithms can process STL containers as well user defined containers

# Strings

- In C we used char * to represent a string.
- The C++ standard library provides a common implementation of a string class abstraction named string.

# Hello World - C

```c
#include <stdio.h>

void main()
{
        // create string 'str' = "Hello world!"
        char *str = "Hello World!";

        printf("%s\n", str);
}
```

# Hello World – C++

```
#include <iostream>
#include <string>
using namespace std;

int main()
{
        // create string 'str' = "Hello world!"
        string str = "Hello World!";

        cout << str << endl;
        return 0;
}
```

# String

- To use the string type simply include its header file.

```
#include <string>
```

# Creating strings

```
string str = "some text";
```

or

```
string str("some text");
```

other ways:

```
string s1(7,'a');
string s2 = s1;
```

# string length

The length of string is returned by its `size()` operation.

```
#include <string>

string str = "something";
cout << "The size of "
     << str
     << "is " << str.size()
     << "characters." << endl;
```

# The size method

str.size() ???

In C we had structs containing only data, In C++, we have :

```
class string
{
        …
 public:
        …
        unsigned int size();
        …
};
```

# String concatenation

concatenating one string to another is done by the '+' operator.

```
string str1 = "Here ";
string str2 = "comes the sun";
string concat_str = str1 + str2;
```

# String comparison

To check if two strings are equal use the '==' operator.

```
string str1 = "Here ";
string str2 = "comes the sun";

if ( str1 == str2 )
      /* do something */
else
      /* do something else */
```

# String assignment

To assign one string to another use the "=" operator.

```
string str1 = "Sgt. Pappers";
string str2 = "lonely hearts club bend";
str2 = str1;
```

Now : str2 equals "Sgt. Pappers"

# What more ?

- Containers
- Algorithms

# Containers

Data structures that hold anything (other objects).

- list: doubly linked list.
- vector: similar to a C array, but dynamic.
- map: set of ordered key/value pairs.
- Set: set of ordered keys.

# Algorithms

generic functions that handle common tasks such as searching, sorting, comparing, and editing:

- find
- merge
- reverse
- sort
- and more: count, random shuffle, remove, Nth-element, rotate.

# Vector

- Provides an alternative to the built in array.
- A vector is self grown.
- Use It instead of the built in array!

# Defining a new vector

Syntax: `vector<of what>`

For example :

`vector<int>` - vector of integers.
`vector<string>` - vector of strings.
`vector<int * >` - vector of pointers to integers.
`vector<Shape>` - vector of Shape objects. Shape is a user defined class.

# Using Vector

- `#include <vector>`

- Two ways to use the vector type:
  1. Array style.
  2. STL style

# Using a Vector – Array Style

We mimic the use of built-in array.

```
void simple_example()
{
        const int N = 10;
        vector<int> ivec(N);
        for (int i=0; i < 10; ++i)
                cin >> ivec[i];

        int ia[N];
        for ( int j = 0; j < N; ++j)
                ia[j] = ivec[j];
}
```

# Using a vector - STL style

We define an empty vector

```
vector<string> svec;
```

we insert elements into the vector using the method push_back.

```
string word;
while ( cin >> word ) //the number of
                                words is unlimited. {
      svec.push_back(word);
}
```

# Insertion

```
void push_back(const T& x);
```

Inserts an element with value x at the end of the controlled sequence.

```
svec.push_back(str);
```

# Size

```
unsigned int size();
```

Returns the length of the controlled sequence (how many items it contains).

```
unsigned int size = svec.size();
```

# Class Exercise 1

Write a program that read integers from the user, sorts them, and print the result.

# Solving the problem

- Easy way to read input.
- A "place" to store the input
- A way to sort the stored input.

# Using STL

```
int main()
{
        int input;
        vector<int> ivec;

        /* rest of code */
}
```

# STL - Input

```
while ( cin >> input )
      ivec.push_back(input);
```

# STL - Sorting

```
sort(ivec.begin(), ivec.end());
```

Sort Prototype:

```
void  sort(Iterator first, Iterator  last);
```

# STL - Output

```
for ( int i = 0; i < ivec.size(); ++i )
      cout << ivec[i] << " ";
cout << endl;
```

Or (more recommended)

```
vector<int>::iterator it;
for ( it = ivec.begin(); it != ivec.end(); ++it )
      cout << *it << " ";
cout << endl;
```

# STL - Include files

```
#include <iostream>   // I/O
#include <vector>     // container
#include <algorithm> // sorting

//using namespace std;
```

# Putting it all together

```
int main() {
        int input;
        vector<int> ivec;

        // input
        while (cin >> input )
                ivec.push_back(input);

        // sorting
        sort(ivec.begin(), ivec.end());

        // output
        vector<int>::iterator it;
        for ( it = ivec.begin();
              it != ivec.end(); ++it ) {
                      cout << *it << " ";
        }
        cout << endl;

        return 0;
}
```

# Operations on vector

- iterator begin();
- iterator end();
- bool empty();
- void push_back(const T& x);
- iterator erase(iterator it);
- iterator erase(iterator first, iterator last);
- void clear();
- ….

# Standard C++ Library

Part II

# Last Time

- String abstraction
- Containers - vector

# Today

- Map
- pair
- copy algorithm

# Employee

```
class Employee {
public:
        // Constructors ...:
  Employee () {}
  Employee (const string& name) : _name(name) {}

        // Member functions ...:
  void set_salary(int salary) {_salary = salary; }
  int salary() const { return _salary; }
  void set_name(const string& name) { _name = name; }
  const string& name() const { return _name;}
        // …
private:
        int  _salary;
        string  _name;
};
```

# Locating an Employee

Save all employees in a vector.

When we need to find a specific employee:

go over all employees until you find one that its name matches the requested name.

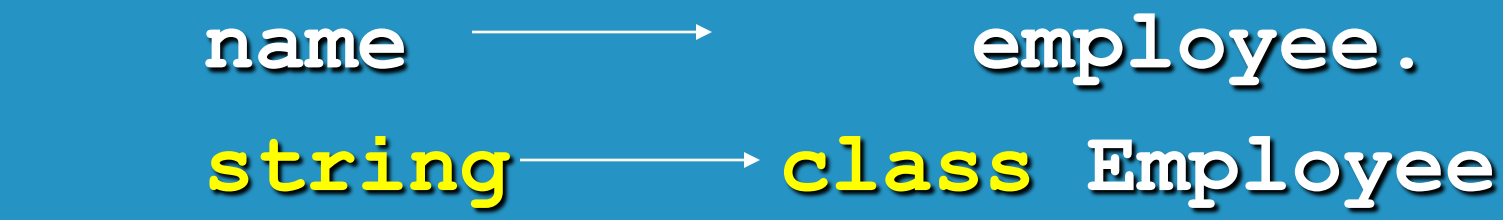
Bad solution - not efficient!

# Solution: Map – Associative Array

- Most useful when we want to store (and possibly modify) an associated value.
- We provide a **key/value pair**. The key serves as an **index** into the map, the value serves as the **data** to be stored.
- Insertion/find operation – **O(logn)**

# Using Map

Have a map, where the key will be the employee name and the value – the employee object.




```
map<string, Employee *> employees;
```

# Populating a Map

```
void main()
{
 map<string, Employee *> employees;
 string name("Eti");
 Employee *employee;

 employee = new Employee(name);

 //insetrion
 employees[name] = employee;
}
```

# Locating an Employee

```
map<string, Employee> employees;
```

Looking for an employee named Eti :

```
//find
Employee *eti = employees["Eti"];
//or
map<string, Employee *>::iterator iter =
employees.find("Eti");
```

The returned value is an iterator to map.
If "Eti" exists on map, it points to this value, otherwise, it returns the end() iterator of map.

# Iterating Across a Map

Printing all map contents.

```
map<string,Employee *>::iterator it;
for ( it = employees.begin();
        it != employees.end(); ++it )
{
     cout << ???
}
```

# Iterators

Provide a general way for accessing each element in sequential (vector, list) or associative (map, set) containers.

# Pointer Semantics

Let `iter` be an iterator then :

- `++iter` (or `iter++`)
  Advances the iterator to the next element
- `*iter` Returns the value of the element addressed by the iterator.

# Begin and End

Each container provide a **begin()** and **end()** member functions.

- **begin()** Returns an iterator that addresses the **first** element of the container.
- **end()** returns an iterator that addresses **1 past the last** element.

# Iterating Over Containers

Iterating over the elements of any container type.

```
for ( iter = container.begin();
      iter != container.end();
      ++iter )
{
     // do something with the element
}
```

# Map Iterators

```
map<key, value>::iterator iter;
```

What type of element iter does addresses?

- The key ?
- The value ?

It addresses a **key/value pair**.

# Pair

Stores a pair of objects, first of type $T_1$, and second of type $T_2$.

```
struct pair<T1, T2>
{
      T1 first;
      T2 second;
};
```

# Our Pair

In our example iter addresses a

```
pair<string, Employee *>
```

Element.

Accessing the name (key)

```
iter->first
```

Accessing the Employee* (value)

```
iter->second
```

# Printing the Salary

```
for ( iter = employees.begin();
      iter != employees.end();
      ++iter )
{
     cout << iter->first << " "
          << (iter->second)->salary();
}
```

# Example Output

alon 3300

dafna 10000

eyal 5000

nurit 6750

# Map Sorting Scheme

map holds its content sorted by key.

We would like to sort the map using another sorting scheme. (by salary)

# Map Sorting Problem

**Problem**:

Since map already holds the elements sorted, we can't sort them.

**Solution**:

Copy the elements to a container where we can control the sorting scheme.

# Copy

```
copy(Iterator first, Iterator last,
     Iterator where);
```

Copy from 'first' to 'last' into 'where'.

```
int ia[] = { 0, 1, 1, 2, 3, 5, 5, 8 };
vector<int> ivec1(ia, ia + 8 ), ivec2;
// ...
copy(ivec1.begin(),ivec1.end(),
     ivec2.begin() );
```

# The Problem

- `ivec2` has been allocated no space.
- The `copy` algorithm uses assignment to copy each element value.
- `copy` will fail, because there is no space available.

# The Solution: use back_inserter()

Causes the container's **push_back** operation to be invoked.

The argument to back_inserter is the container itself.

```
// ok. copy now inserts using
ivec2.push_back()
copy(ivec1.begin(),ivec1.end(),
     back_inserter(ivec2) );
```

# Inserter iterators.

Puts an algorithm into an "insert mode" rather than "over write mode".

`*iter =` causes an insertion at that position, (instead of overwriting).

# Employee copy

```
map<string, Employee *> employees;
vector< pair<string, Employee *> > evec;


copy( employees.begin(), employees.end(),
      back_inserter( evec ) );
```

Now it works!!!

# Sort

Formal definition :

```
void sort(Iterator first, Iterator last);
```

# Sort

```
sort( Iterator begin, Iterator end );
```

Example:

```
vector<int> ivec;

// Fill ivec with integers …

sort(ivec.begin(), ivec.end())
```

# Inside Sort

- Sort uses operator < to sort two elements.
- What happens when sorting is meaningful, but no operator < is defined ?

# The meaning of operator <

What does it mean to write :

```
pair<string, Employee *> p1, p2;
if ( p1 < p2 ) {
     …
}
```

# The meaning of operator <

No operator < is defined between two pairs.

How can we sort a vector of pairs ?

# Sorting Function

Define a function that knows how to sort these elements, and make the sort algorithm use it.

# lessThen Function

```
bool
lessThen(pair<string, Employee *> &l,
         pair<string, Employee *> &r )
{
     return (l.second)->Salary() <
                    (r.second)->Salary()
}
```

# Using lessThen

```
vector< pair<string, Employee *> > evec;

// Use lessThen to sort the vector.
sort(evec.begin(), evec.end(), lessThen);
```

pointer to function

# Sorted by Salary

alon 3300
eyal 5000
nurit 6750
dafna 10000

# Putting it all Together

```
bool lessThen( pair<…> &p1, pair<…> &p2 ) { … }

int main() {
    map<string, Employee *> employees;

    /* Populate the map. */
    vector< pair<string, Employee *> > employeeVec;
    copy( employees.begin(), employees.end(),
          back_inserter( employeeVec ) );

    sort( employeeVec.begin(), employeeVec.end(),
          lessThen );

    vector< pair<string, Employee *> >::iterator it;
    for ( it = …; it != employeeVec.end(); ++it ) {
        cout << (it->second)->getName() << " "
             << (it->second)->getSalary() << endl;
    }
    return 0;
}
```