Programming Abstraction in C++

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Chapter 4. Using Abstract Data Types

Outline

Introduction

Abstract data type (ADT): A type defined in terms of its behavior. (Rather than its representation, e.g., `char` is represented by codes.)

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Separating behavior from implementation

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- Flexibility. Implementation can be changed as long as the interface (behavior) remains the same.
- Security. Protect the implementation from the client.

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- Flexibility. Implementation can be changed as long as the interface (behavior) remains the same.
- Security. Protect the implementation from the client.

Seven classes:
Vector, Grid, Stack, Queue, Map, Lexicon, Scanner.

Outline

Vector class

A container class or collection class.
Interface

```
#include "vector.h"
```

A naming convention. For example: `grid.h`, `stack.h`.

Generalization of one-dimensional array type

- Variable size
- Effective size available
- Simple insert and delete
- Bound checking

Vector class (cont.)

Constructor

```
Vector<int> vec;
```

Specify the base type of a vector.

Vector class (cont.)

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Methods. Table 4-1, p. 127.

Example.

`vec.add(10)`, `vec.removeAt(0)`.

Vector class (cont.)

Constructor

```
Vector<int> vec;
```

Specify the base type of a vector.

Methods. Table 4-1, p. 127.

Example.

`vec.add(10)`, `vec.removeAt(0)`.

Question. How would you remove the last entry?

Idiom

Idiom: Going through a vector, p. 129

```
void PrintVector(Vector<int> & vec) {
    cout << "[";
    for (int i = 0; i < vec.size(); i++) {
        if (i > 0) cout << ", ";
        cout << vec[i];
    }
    cout << "]" << endl;
}
```

Note. Passing by reference.

Idiom

Idiom: Going through a vector, p. 129

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    for (int i = 0; i < vec.size(); i++) {
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}
```

Note. Passing by reference.

Question:

Can you pass `vec` by value (without the ampersand)? If you can, what are the differences?

Passing by reference

```
void AddArrayToVector(Vector<int> & vec,
                      int array[], int n) {
    for (int 1 = 0; i < n; i++) {
        vec.add(array[i]);
    }
}
```

Passing by reference

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void AddArrayToVector(Vector<int> & vec,
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    }
}
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Question:

Can you pass `vec` by value (without the ampersand)? If you can, what are the differences?

Almost always pass classes by reference.

Idiom

Idiom: Open a text file, p. 131

```
void AskUserForInputFile(string promt,
                         ifstream & infile) {
    while (true) {
        cout << prompt;
        string filename = GetLine();
        infile.open(filename.c_str());
        if (!infile.fail()) break;
        cout << "Unable to open " << filename << endl;
        infile.clear();
    }
}
```

Note. Don't forget `infile.close()` after reading/writing.

Idiom

Idiom: Open a text file, p. 131

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    }
}
```

Note. Don't forget `infile.close()` after reading/writing.

Study `revfile.cpp`, p. 130.

A text file as `lines`, an object of `Vector<string>`.

Outline

Grid class

Generalization of two-dimensional array.

- Variable dimensions.

Constructor

```
Grid<double> matrix(3,2);
```

Specify row and column dimensions, in addition to the base type.

Methods. Table 4-2, p. 132

Example

`CheckForWin` for the tic-tac-toe game, p. 133.

```
bool CheckForWin(Grid<char> & board, char mark) {
    for (int i = 0; i <3; i++) {
        if (CheckLine(board, mark, i, 0, 0, 1)) return true;
        if (CheckLine(board, mark, 0, i, 1, 0)) return true;
    }
    if (CheckLine(board, mark, 0, 0, 1, 1)) return true;
    return (CheckLine(board, mark, 2, 0, -1, 1));
}
```

- check rows
- check columns
- check diagonal
- check antidiagonal

Outline

Stack class

Behavior: Last in, first out (LIFO). Only the top is accessible to the client.

Fundamental operations: push, pop

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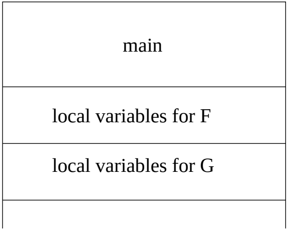
Applications. Nested function calls:

```
main() {
    call function F
}


function F() {
    call function G
}
```

Stack class (cont.)

Function G is called last and returns first.



Stack class (cont.)

Constructor

```
Stack<double> calculator;
```

Specify a base type.

Methods. Table 4-3, p. 135.

Stack class (cont.)

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Methods. Table 4-3, p. 135.

Example. Scientific calculator (HP C-13)

```
50.0 * 1.5 + 3.8 / 2.0
```

Reverse Polish notation (RPN):

50.0 [ENTER] 1.5 [*] 3.8 [ENTER] 2.0 [/] [+]

RPN and stack

When the ENTER button is pressed, the previous value is pushed on a stack.

When an operator button is pressed

- Pushing the previous value
- Popping two values
- Applying the operation to the two values
- Pushing the result on the stack

Example

50.0 ENTER 1.5 * 3.8 ENTER 2.0 / +

Stack content, p. 136.

Example

50.0 [ENTER] 1.5 [*] 3.8 [ENTER] 2.0 [/] [+]

Stack content, p. 136.

Question. What is the key sequence for

```
50.0 * (1.5 + 3.8) / 2.0
```

Think the stack content.

Example

50.0 [ENTER] 1.5 [*] 3.8 [ENTER] 2.0 [/] [+]

Stack content, p. 136.

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Think the stack content.

An RPN calculator simulator, pp. 137–138.

Outline

Queue class

Behavior. First in, first out (FIFO). Only the head and tail are accessible to the client.

Fundamental operations: enqueue, dequeue

Constructor

```
Queue<int> queue;
```

Methods. Table 4-4, p. 139.

Application. Printer queue.

Example

Check-out line simulation.

Models

- Discretize time to serialize events.
- Arrival process: Poisson distribution. Average probability of a customer arriving in a particular time interval.
  Parameter: `ARRIVAL_PROBABILITY`
  Implementation:
  `RandomChance(ARRIVAL_PROBABILITY)`
- Service time: Uniformly distributed within a range.
  Parameters: `MIN_SERVICE_TIME`, `MAX_SERVICE_TIME`
  Implementation: `RandomInteger(MIN_SERVICE_TIME, MAX_SERVICE_TIME)`

Check-out line simulation (cont.)

- Simulating time.

  Parameter: SIMULATION_TIME
  Implementation:

```
for (int t = 0; t < SIMULATION_TIME; t++) {
    if (RandomChance(ARRIVAL_PROBABILITY)) {
        queue.enqueue(t);
    }
    if (serviceTimeRemaining > 0) {
        serviceTimeRemaining--;
        if (serviceTimeRemaining == 0) nServed++;
    } else {
        totalWait = t - queue.dequeue();
        serviceTimeRemaining =
          RandomInteger(MIN_..., MAX_...);
    }
    totalLength += queue.size();
}
```

Outline

Map class

Behavior. An association between a key (tag) and an associated value (can be a complicated structure). A generalization of `Vector`.

Fundamental operations: put, get

Application. Symbol table, an association between a variable name and its value.

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Constructor

```
Map<double> symbolTable;
```

Note. The base type is the type of value, not tag.
For simplicity, the type of tag is always string.

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Methods. Table 4-5, p.147.

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For simplicity, the type of tag is always string.

Methods. Table 4-5, p.147.

Example. Airport codes. Figure 4-6, p. 150.

Outline

Lexicon class

Behavior. A list of alphabetically ordered words.

Fundamental operations: add, containsWord

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Constructors

```
Lexicon wordList;
Lexicon english("EnglishWords.dat");
```

Note. No parameterized type (always string)

Formats of the data file

- text file, list of words, one word per line
- precompiled data file

Lexicon class (cont.)

Methods. Table 4-6, p. 152.

Example. `twoletters.cpp`, p. 153.
Check every possible two-letter combinations (26^2), if it is contained in `EnglishWords.dat`.

Lexicon class (cont.)

Methods. Table 4-6, p. 152.

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Why Lexicon now that we have Map?

Lexicon class (cont.)

Methods. Table 4-6, p. 152.

Example. `twoletters.cpp`, p. 153.
Check every possible two-letter combinations (26^2), if it is contained in `EnglishWords.dat`.

Why Lexicon now that we have Map?

Efficiency.

Outline

Scanner class

Behavior. Divide up a string into tokens

- A sequence of consecutive alphanumeric characters, or
- A single-character string consisting of a space or punctuation mark.

Fundamental operation: hasMoreTokens, nextToken

Constructor

```
Scanner scanner;
```

No base type. (Always string.)

Methods. Table 4-7, p. 157.

Idiom

Idiom: Scan a file

```
ifstream infile;
Scanner scanner;

AskUserForInputFile("Input file: ", infile);
scanner.setInput(infile);
while (scanner.hasMoreTokens()) {
    string word = scanner.nextToken();
    ... do something with the token ...
}

infile.close();
```

Outline

Iterators

Iterator: A subclass (of `Vector`, `Grid`, `Map`, `Lexicon`, `Scanner`).

Behavior. Stepping through the elements of a collection class.

Fundamental operations: hasNext, next

Iterators (cont.)

Idiom: iterator, p. 158

```
Lexicon::Iterator iter = english.iterator();
while (iter.hasNext()) {
    string word = iter.next();
    ... code to work with the word ...
}
```

`Lexicon::Iterator` A subclass of `Lexicon`
`iter` An object of the class `Lexicon::Iterator`
`iter.next()` Returns a value of type string (`Lexicon`) or base type (`Vector` or `Grid` or `Map`).

foreach mechanism

Usage

Idiom: foreach

```
foreach (string word in english) {
    if (word.length() == 2) {
        cout << word << endl;
    }
}
```

foreach mechanism

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Idiom: foreach

```
foreach (string word in english) {
    if (word.length() == 2) {
        cout << word << endl;
    }
}
```

It is simple and easy to use, but you should understand the mechanism. The type of `word` (string) must match the base type of the class (Lexicon) of which `english` is an object.