Basic Object Design

C++ Object Oriented Programming

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NTOUCS

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Object Oriented Analysis/Design

- Object-Oriented Analysis (OOA)
  - What are the classes in the system?
  - What are the operations and attributes?
  - What are the inheritance relationships?
- Object-Oriented Design (OOD)
  - How do objects relate to other objects?
  - How is the system constructed with the objects?
- Object-Oriented Programming (OOP)

  How do you create the system using your particular object-oriented programming language?

OOA Identification	OOD Integration	OOP Implementation
What objects do I need to implement the system?	How do I integrate the objects to make the system work?	How do I use the programming lang. to create each object?

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Object Oriented Analysis/Design

⬦ There are generally four phases to the object-oriented analysis/design process:

  ✴ The <u>identification</u> of objects from the program specification.

  ✴ The <u>identification</u> of the attributes and behaviors of these objects.

  ✴ The <u>identification</u> of any super-classes.

  ✴ The specification of the behaviors of the identified classes.

Basic Object Design

Objects in general have two important properties:

1. State
2. Behaviour

Object States:

An object contains certain information about itself   e.g.

➢ a lecturer "knows" his name, address, age, courses he teach …

➢ a student "knows" his name, address, age, ID, courses studied …

➢ a lecture theatre "knows" its location, capacity etc.

The information that an object maintains determines its state. The individual components of information are known as the objects attributes.

Basic Object Design (cont'd)

Object Behaviour

Apart from maintaining information about itself, an object is also capable of performing certain actions. e.g.

- ➤ a lecturer can teach a class, grade assignments, set an examination paper
- ➤ a student can attend a lecture, complete an assignment, sit in an exam etc.

The actions that an object can perform are known as its behaviours.

When applying an object-orientated design to a problem specification we identify objects, record their states and specify their behaviours.

Specifying Good Objects

✧ Strong Cohesion

✧ Completeness and Convenience

✧ Consistency

✧ Loose Coupling

Cohesion

✧ A good class describes a single abstraction
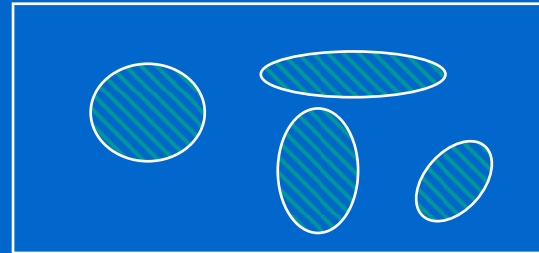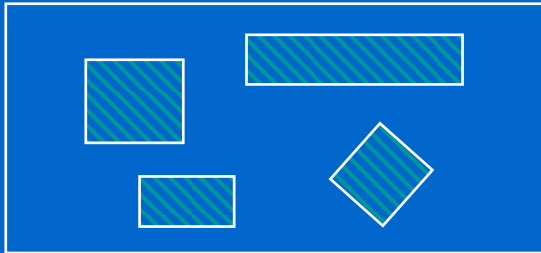
✧ Assume we are writing a networking email program

```
class Mail {
public:
    void sendMessage() const;
    void receiveMessage();
    void displayMessage() const;
    void processCommand();
    void getCommand();
private:
    char *m_message;
    char *m_command;
};
```

Why does this class lack cohesion?

✧ To achieve good cohesion, you must classify objects into groups with close functionalities.

Completeness and Convenience

- Every class must contain all necessary features.

  ```
  class String {
  public:
      String(char *inputData);
      void displayString() const;
      char getLetter(int slot) const;
      char getLength() const;
  private:
      char *m_string;
  };
  ```

  - Why is this class not complete?
  - What would be desirable but not essential features?

- The opposite problem is a class that is over-complete in the name of convenience.

  ```
  char getLetter(int slot) const;
  char getFirstLetter() const;
  char getLastLetter() const;
  char getPreviousLetter() const;
  char getNextLetter() const;
  char findLetter(char letter) const; // find first occurrence of letter
  char findLetterEnd(char letter) const; // finds last occurrence
  ```

  - A class stuffed with unnecessary features is not convenient.

Consistency

✧ Here is a very inconsistent class.

```
class Data {
public:
    Data(); ~Data();
    Data(char *name, int weight, int height);
    void setWeight(int weight);
    void setHeight(int height);
    int returnWeight();
    int getSize();
private:
    char *m_name;
    int m_weight;
    int m_length;
};
```

✧ This class is both inconsistent and unclear

Without these descriptions, it is hard to guess what functions of this class are about.

```
class Graphics {
    void drawLine(int x, int y); // absolute coordinate
    void movePen(int deltaX, int deltaY); // relative offsets
};
```

✦ drawLine() draws a line from the current pen position to the new coordinate (x, y) which is specified in *absolute* coordinates

✦ movePen() moves the pen from the current position by the amounts (x, y) which is specified in *relative* coordinates

Coupling

♦ Classes with many interconnections are *highly coupled.*
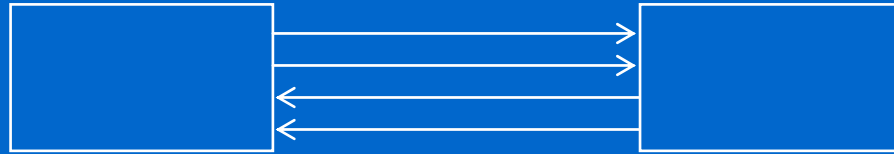

```
class Input { // returns data from file at location fileReferenceNum
public:
    double readFromFile(long &fileReferenceNum);
};

class Math { // returns sine or cosine of current data in file
public:
    double sine(Input source, long &fileReferenceNum);
    double cosine(Input source, long &fileReferenceNum);
};

void main() {
    Math mathObject;
    Input inputObject;
    long fileReferenceNum = 0; // do not forget initialization
    cout << mathObject.sine(inputObject, fileReferenceNum);
}
```

Reducing Coupling

◇ Encapsulation reduces coupling

```
class Input {
public:
    Input();                    // will set m_refNum to zero
    double readFromFile();  // will take care of m_refNum
private:
    int m_refNum;
};
void main() {
    Input inputObject;
    Math mathObject(inputObject);
    cout << mathObject.sine();
}
```

```
class Math {
public:
    Math(Input &);
    double sine();      // will handle m_data
    double cosine();    // automatically
private:
    Input m_data;
};
```

◇ Avoid passing a great amount of data across object boundaries. Object should provide abstract and simple services.

◇ As opposed to the data flow design of application programs, in which data flow between processing units, object oriented/based programming tries to design objects that keeps and handles data intelligently. Put all responsible objects together for accomplishing a specific work without looking into their detailed processed data.

Design Classes Before You Code It

✧ Before writing a large program, decide on your classes, what they do, and how they relate to other classes.

✧ CRC cards – Classes – Responsibilities, Collaborators

✧ Example

Class Math	
Responsibilities	Collaborators
Return sine of file data	Input
Return cosine of file data	Input

Class Input	
Responsibilities	Collaborators
Read next data from file	-

✧ What about the data members?
These are hashed out after all the CRC cards have been prepared.

Class Description

- An alternative approach to the CRC method

Name	Array
Purpose	Create a fixed-size array which protects against out of bounds and off by one errors.
Constructors	Default set the array to size 0 Non default sets the array to a size specified by the client
Destructors	Deletes the memory associated with the array
Operations Mutators Accessors	 Insert data into a specified slot Retrieve data from a specified slot
Fields	m_dataSize m_data

- Codes

```
class Array {
public:
    Array();
    Array(int arraySize);
    ~Array();
    void insertElement(int element, int slot);
    int getElement(int slot) const;
private:
    int m_dataSize;
    int *m_data;
};
```

Function Descriptions

✧ Each function should be completely specified before coding.

Prototype	int getElement(int slot) const;
Purpose	To return the integer in the array at position slot
Receives	The slot which the client would like to access. The first element in the array is slot 0.
Returns	The integer if the function succeeds, otherwise returns an error value specified as kError
Remarks	kError is currently set to 0.

✧ Alternatively, write the complete function documentation and prepare a skeleton function declaration

```
/*
 * function: getElement
 * Usage: value = getElement(slot);
 * ----------------------------------------
 * Returns the integer in the array corresponding to slot.
 * The first element is slot zero.  If the slot is out of range
 * kError is returned, which is currently zero.
 */
int Array::getElement(int slot) {
}
```

Discover Your Classes

- Bertrand Meyer in "Object-oriented Software Construction"

  "When software design is understood as operational modeling, object-oriented design is a natural approach: the world being modeled is made of objects – sensors, devices, airplanes, employees, paychecks, tax returns – and it is appropriate to organize the model around computer representations of theses objects. This is why object-oriented designers usually do not spend their time in academic discussions of methods to find objects: in the physical or abstract reality being modeled, the objects are just there for the picking! The software objects will simply reflect these external objects."

- How do the experts identify objects?

  "It's a Holy Grail. There is no panacea." by Bjarne Stroustrup

  "That's a fundamental question for which there is no easy answer." by R. Gabriel, designer of Common Lisp Object System (CLOS)

Object Discovery Techniques

- Real-world modeling:
    - Use objects in the application domain as the basis for objects in the system.
- Behavior modeling:
    - Determine the overall behaviors of the system (what it does).
    - Components which play significant roles in each behavior are objects.
- Scenario-based analysis:
    - Create scenarios of the system.
    - What are the required entities in each scenario?
- Grammatical analysis:
    - Write a natural language description of the system.
    - The nouns are the classes; the verbs are the methods.

Noun-Verb Analysis Example

- Program description (specification, highly abbreviated)

  "The program allows the user to assign students to sections based on the available times. Times are input by the teacher. Students rank times by preference (up to three allowed) using a form. All of the student inputs are collected into a central database. When the teacher indicates the database is complete, the final result is optimized so that no section has more than 12 students and each student has received the highest possible preference. The results are stored in a file showing which students have been assigned to which sections."

- Noun analysis: **students, sections, times, teacher, preferences, form, student inputs, database, results, output file**

  This can be simplified further to just these categories

  form, (section) times, database, results (optimization process), output file

- Possible classes: **optimization process, student, teacher, form, sections, database, output**

- Verb analysis: **assign students, input sections, rank by preference, collect into database, indicate database is complete, optimize results, store results in file**

Tentative Classes

- Assign verbs to nouns, that is, assign methods to classes. This is the usual classification problem.

- Ex: class Optimization   Possible collaborators: Database, File
          optimize data
          store in file

- Expect change:

  Designs always turn out to be wrong or incomplete, but having no design is worse. In a suitably encapsulated object system, it is easy to refactor. It is easy to create new objects and to reassign methods or data from one class to another class.

- Checking your design:

  Once you have the classes, rewrite the program description using the new terms and actions. If the description does not make sense, you have a bad design. If it does, you have a better and cleaner description. The model extracted will become gradually simpler.
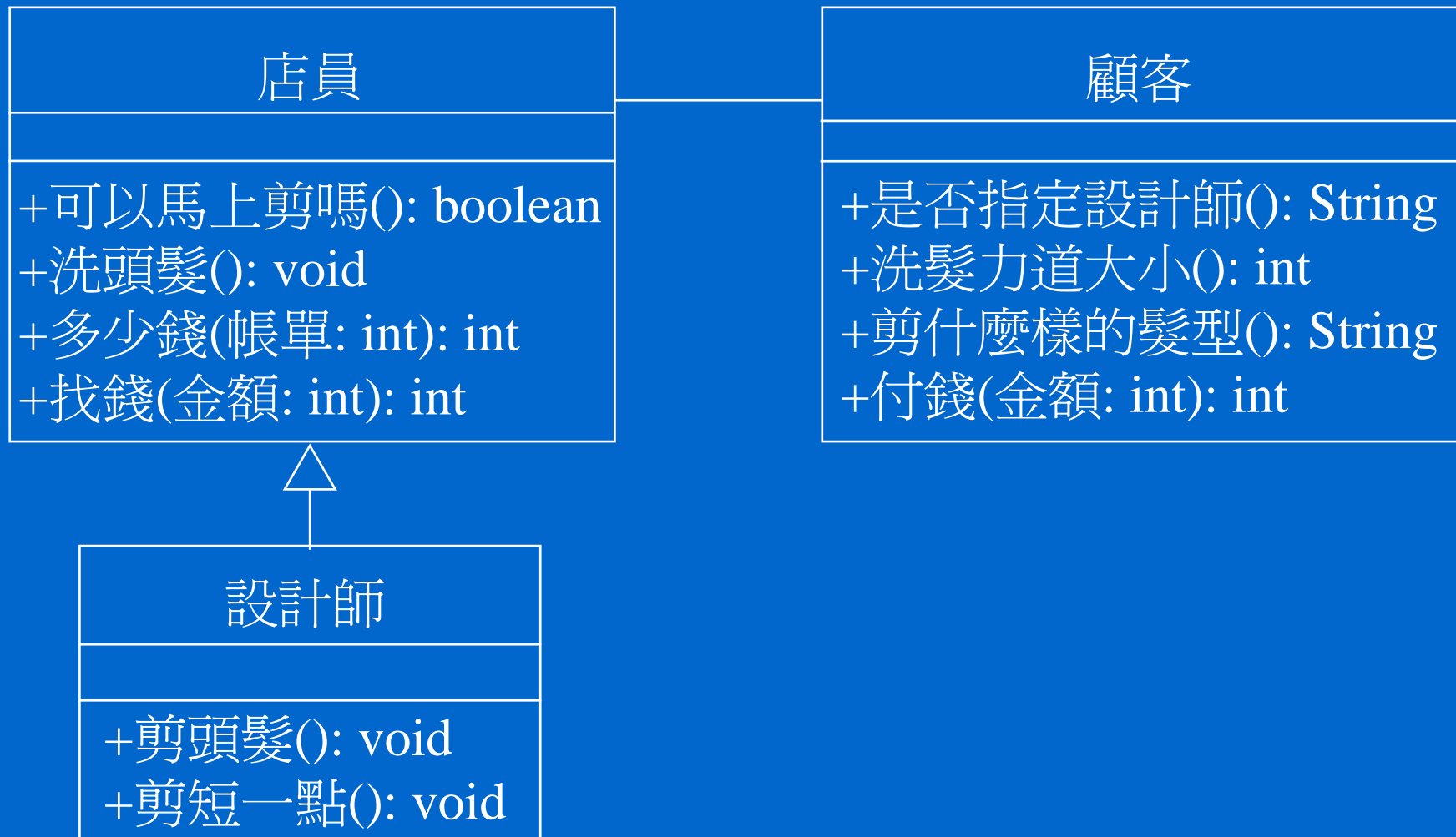
specification

design
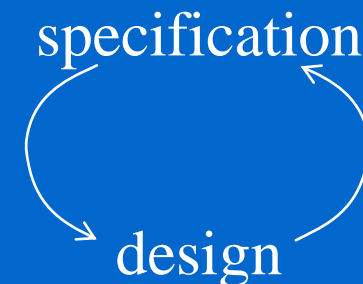
範例一

✧ 昨天我去剪頭髮，看到店裡的客人蠻多的，就問店員：現在可以馬上剪嗎？店員回答我：可以啊。在我坐下來後，店員走到我旁邊問我：你有指定的設計師嗎？我想了想回答他：沒有耶，都可以。隨後有一位帥哥來幫我洗頭髮，洗幾下之後，他就問我：這樣的力道可以嗎？本來想跟他說用力一點，但又怕太用力會抓破頭皮，所以就跟他說：很好。洗完頭後，另一位設計師來幫我剪頭髮，首先他問我說：你要剪什麼樣的髮型？我跟他說：剪短一點就好。其實目的是剪短一點可以再撐三四個月不用剪頭髮。他又問：短一點就好嗎？我當下覺得，他可能不清楚我說的短是多短，所以我就說：可以很短沒關係。剪完我滿意的長度的頭髮後，我拿著帳單去櫃檯買單，問店員多少錢？他回答我說：350元，於是我拿一千元給他找，他找我 650元，收下錢，我便踏著輕快的腳步回家去了。

範例一 (cont'd)

✧ 物件: 店員, 設計師, 顧客 (帳單)
✧ 類別圖:

```
┌─────────────────────────────┐          ┌─────────────────────────────┐
│            店員             │          │            顧客             │
├─────────────────────────────┤          ├─────────────────────────────┤
│                             │          │                             │
├─────────────────────────────┤──────────├─────────────────────────────┤
│ +可以馬上剪嗎(): boolean    │          │ +是否指定設計師(): String    │
│ +洗頭髮(): void             │          │ +洗髮力道大小(): int         │
│ +多少錢(帳單: int): int     │          │ +剪什麼樣的髮型(): String    │
│ +找錢(金額: int): int       │          │ +付錢(金額: int): int        │
└─────────────────────────────┘          └─────────────────────────────┘
              △
              │
┌─────────────────────────────┐
│            設計師           │
├─────────────────────────────┤
│                             │
├─────────────────────────────┤
│ +剪頭髮(): void             │
│ +剪短一點(): void           │
└─────────────────────────────┘
```

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範例二

✧ 賣場裡販賣各種電腦零件：主機板、記憶體、螢幕、**CPU**等等

✧ 顧客購買電腦零件，如果是會員可以打八折，但特價品不打折。
每週會選部分產品為特價品，特價方式有兩種：打八五折或買二送一。

✧ 店員薪水有兩種：時薪制與銷售額抽成計酬制。
 ★ 時薪制依照工作時數給錢，
 ★ 銷售額抽成計酬制根據賣出零件的價錢乘上一定的百分比為酬勞。

✧ 設計每次交易的金額、一天營業的總金額，以及兩個員工 - 一為銷售額抽成計酬制一為時薪制 – 一天的薪水。

範例二 (cont'd)