COMP2012H

Introduction
Background Assumptions

- This course assumes that you have taken COMP1003, COMP1004, COMP2011, COMP104H (prior to 2009-10) or an equivalent. The topics assumed are:
  - Basic loop constructs, e.g., for, while, repeat, etc.
  - Functions
  - Arrays
  - Basic I/O
  - Introduction to classes
  - Abstract Data Types
  - Linked Lists
  - Recursion
  - Dynamic Objects
Why Take This Course

You all know how to program, so why take this course?

• In your previous course you learned mostly “the C part” of C++ and can write “small” C++ programs.

• Most of the time you write code that is (almost) the same as code that’s been written many times before. How do you avoid wasting time “re-inventing the wheel”? How do you re-use coding effort?

• What if you need to write a large program and/or work with a team of other programmers? How do you maintain consistency across your large program or between the different coders?

• In this course you will learn the essence of Object Oriented Programming (OOP). The goal is to teach you how to design and code large software projects.
A Short “History” of Computing

• Early programming languages (e.g., Basic, Fortran) were unstructured. This allowed “spaghetti code” – code with a complex and tangled structure - with goto’s and gosub’s jumping all over the place. Almost impossible to understand.
Spaghetti Code

10 k =1
20 gosub 100
30 if y > 120 goto 60
40 k = k+1
50 goto 20
60 print k, y
70 stop
100 y = 3*k*k + 7*k -3
110 return

- Hard to follow the flow.
- Difficult to modify.
A Short “History” of Computing

• Early programming languages (e.g., Basic, Fortran) were **unstructured**. This allowed “**spaghetti code**” – code with a complex and tangled structure - with goto’s and gosub’s jumping all over the place. Almost impossible to understand.

• The abuses of spaghetti code led to **structured** programming languages to support **procedural programming (PP)** – e.g., Algol, Pascal, C.

• While well-written C is easier to understand, it’s still hard to write large, consistent code. This inspired researchers to borrow AI concepts (from knowledge representation, especially semantic networks) resulting in **object-oriented programming (OOP)** languages – e.g., Smalltalk, Simula, Lisp (CLOS), Eiffel, Objective C, C++, Java).

• Even with OOP, typically programmers still re-invent code instead of re-using it, often because OOP creates less efficient code. This led to **generic programming (GP)** – e.g., Lisp (CLOS), C++, and (sort of) the latest Java versions.
Procedural Programming (PP)

```c
int func(int j)
{
    return (3*j*j + 7*j -3);
}

int main()
{
    int k = 1;
    while (func(k) <= 120)
        k++;
    printf("%d\t%d\n", k, func(k));
    return (0);
}
```

• Loop constructs: for, while, repeat, do-while
• Program = a set of procedures/functions
• Focus is on code: how to get things done
Problems of PP

const int MAX ALTITUDE = 11000;
const int MAX SPEED = 960;
struct Airplane
{
    int altitude;
    int speed;
};
void takeoff(Airplane B747);
void descend(Airplane B747, int feet);

• Data and code are separated. Data is passive, code is active.

• There are usually some constraints on variables, e.g., altitude of airplane must be \( \geq 0 \) but less than some constant. Also, not all speeds are possible at all altitudes.
Example: Problems of PP

const int MAX_ALTITUDE = 11000;
const int MAX_SPEED = 960;
const MAX_RUNWAY_SPEED = 400;
const MIN_FLY_SPEED = 350;
struct Airplane
{
    int altitude;
    int speed;
};
void takeoff(Airplane B747)
{
    // initial state: speed == 0, altitude = 0
    B747.speed = (MAX_RUNWAY_SPEED + MIN_FLY_SPEED) / 2;
    // accelerate and climb to 1000 ft
    B747.altitude += 1000;
    B747.speed += 200;
    // cruising speed and altitude
    B747.altitude = MAX_ALTITUDE;
    B747.speed = MAX_SPEED;
}
void descend(Airplane B747, int feet);

• Question: How can constraints be enforced?
How to Maintain Data Consistency

- **Data/State Consistency**: Every time we change the value of a member of an Airplane structure we must check to make sure that the new value is valid with respect to the values of all of the other data items (members).

- A snapshot of the values of all of the data members of an object represents the **state** of the object.

- Ensuring data consistency is one of the major challenges in a (large) software project.

- This challenge becomes even more difficult when the program is modified and new constraints are added.
Example: Adding a New Data Member

```c
struct Airplane
{
    int altitude;
    int speed;

    bool flaps_out;
        // Flaps must be extended below a certain
        // speed to gain lift, but they must be
        // retracted before the speed gets too high;
        // otherwise they will be damaged
}
```

- How to ensure that flaps are not changed at wrong speed?
Solution(?): Maintain Data Consistency

```c
struct Airplane
{
  int altitude;
  int speed;
  bool flaps;
};

void set_speed(Airplane A, int new_speed)
{
  // make sure we don't violate any constraints
  // when changing the speed of the airplane
  // e.g., if altitude == 0 then Speed <= MAX_RUNWAY_SPEED
  // and flaps are not extended/retracted at inappropriate speeds
}
```

• One solution: Define a restricted set of functions that access the data members (of Airplane) to ensure data consistency (of speed, altitude and flaps).
Maintain Data Consistency (cont)

• For this to work, the rest of the program must use only these functions to change an Airplane's state, rather than changing the members directly.

• If we can enforce this, then modifying the Airplane structure is easier. We know that we only need to modify the restricted set of functions that directly access the members of the Airplane structure and make sure that they do not violate the new constraints.

• Since the rest of the program does not directly access the Airplane structure's members we do not have to worry about keeping the data consistent.
Maintain Data Consistency (cont)

• **Question**: How can we ensure that the *Airplane* structure’s members are only accessed by the restricted set of functions?

• **Answer**: In standard procedural programming languages we can't....
Object-Oriented Programming (at last)

- It would be very useful if we could make it impossible to access the Airplane structure directly, i.e., to force the rest of the program to use the restricted set of functions to access it.

- This observation leads to OOP.
  - In OOP the fundamental entity is the class.
  - In contrast with PP, in OOP objects are “alive”; they take care of their own internal state and “talk” with other objects.
  - In OOP there is little code outside of the class.
  - Instead of focusing on how to do things (implementation), classes tell the world what they can do (interface).
Example OOP Class + Function

class Airplane
{
public:
    void set_speed(int new_speed);
    void set_altitude(int new_altitude);
private:
    int altitude;
    int speed;
};

void some_function()
{
    Airplane marys_B747;
    marys_B747.set_speed(340);
    marys_B747.set_altitude(1500);
    marys_B747.speed = 5000; // ERROR: speed is private!!
}
Classes and Objects

- A **class** is a user-defined type representing a set of items with the same structure and behavior, e.g., Airplane.

- An **object** is a variable of a class type, e.g., marys_747. We also say marys_747 is an **instance** of the Airplane class.

- **Instantiation**: The process of creating an object (an instance of a class type) is called **instantiating** an object, e.g., Airplane marys_B747;

- Each object of a class has its **own** data members with their own values.

- All objects in the same class share a common set of member functions. **Example**: Airplane marys_B747, joes_DC10; marys_B747 and joes_DC10 have different speed and altitude values but share the set_speed and set_altitude functions.
Classes and Objects (cont)

• When calling a procedure in PP, we are simply “calling function X” or “calling X”.

• In OOP, we are formally “invoking method/operation/function X on object Y (where object Y is of class Z)”
  
  – e.g., invoking function `set_altitude` on object `marys_B747` of class `Airplane`. 
OOP Does Not Magically Impose Good Design

```cpp
struct Airplane
{
    int speed;
    int altitude;
};

// ... is the same as ...

class Airplane
{
public:
    int get_altitude { return altitude;}
    int get_speed() { return speed;}
    void set_speed(int x) { speed = x;}
    void set_altitude(int x) { altitude = x;}

private:
    int altitude;
    int speed;
};

• In fact, it can make things worse!!
```
Things That OOP Supports

- Data Abstraction (Abstract Data Type)
- Data Encapsulation (Data Hiding)
- Inheritance (Hierarchy Among Classes)

• With enough self-discipline, most OOP programming can be done in C or other PP languages.

• What makes an OOP language different is the support and enforcement of the above three concepts built into it.

• We will spend much of this semester learning and mastering the above concepts.
The Holy Grail: Reusable Code

• Designing reusable code in which modules can be reused as basic building blocks and plugged in where necessary has long been a dream.

• Code is reusable if:
  – It is easy to understand
  – It can be assumed to be correct
  – Its interface is clear
  – It requires no changes to be used in a new program

• When properly applied OOP and GP help us get closer to our goal of reusable code.