Game Engine Programming

GMT Master Program
Utrecht University

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Course code: INFOMGEP
Credits: 7.5 ECTS

Lecture #1

Part I: Introduction to C++

Introduction to C++

- Extension of C language
  - Bjarne Stroustrup (Bell Labs, 80's) 'C with classes'
- Open programming language
  - No owner, no central website, no official documentation except the ISO standard (1998)
  - Code compiled for a specific platform
  - Recent compilers have a high conformity with the standard but
    - A valid C++ code may not compiled if it uses advanced features not implemented in the compiler
    - An invalid C++ code may compiled with non rigorous compilers

Compilers

- Open source
  - GCC, Open Watcom ...
- Commercial products
  - Borland, Microsoft, SGI, Sun ...

- The standard specifies only the language (syntax) and its library
  - Compiler specific versions of network management, multi-task, UI, graphics ...
  - Compatibility / portability issues

What’s inside?

- Low-level manipulation of data
  - Pointer, memory usage ...
- Higher modeling functionalities
  - Reference, exception, class, template ...
- Programming techniques
  - OO, procedural and generic

- Suitable for large programs with high performance requirements

C++ vs. other languages

- Java
  - Compiled (vs. interpreted), separated declaration and definition, memory management
- C#
  - Multiple inheritance, separated declaration and definition, lower-level control
- Which language to use?
  - In industry 90% of the decision from financial issues

And in game engines?

- C++ is still an industry standard
  - Many games are programmed in C++ or use (prior) libraries written in C++
- Mostly, game companies use C++ for building their games
  - Object lifetime and memory management is often necessary
  - C++ allows for both high- and low-level coding
  - A lot of libraries and code is available
- Java is rarely used for games
  - But a lot of development is going on for Java3D, jMonkey engine and Java Scene Graphs
- C# is used in combination with XNA to produce Xbox games, Flash technology in casual games etc.

Lecture #1

Part II: C++ basics

Game Over!

```
#include <iostream>

using namespace std;

int main(int argc, char* argv[]) {
   // This program prints Game Over!
   cout << "Game Over!" << endl;
   return 0;
}
```

Game Over!

- The `#include <iostream>` directive loads the iostream library used for printing and reading data from the keyboard
- Comments are introduced by // (one line) or by /* and */ (multi-lines)
- The `using namespace std;` simply means that we will directly use functions/objects from the package called "std"

Game Over!

- The parameter `argc` gives the number of arguments (including the name of the program) and `argv` gives them in an array
  - `argc` and `argv` are optional
- The `cout` instruction prints data in the standard output (console)
- The returned value of the main program is
  - 0 if the program terminates normally
  - Non-zero for abnormal termination

Primitive types

- C++ has 5 primitive types
  - int, float, double, char and bool (true / false)
- C++ has no String class
  - Use array of ‘char’ or STL string (next lecture)
- In many libraries, ‘NULL’ is defined as macro for ‘0’ to increase readability

Using variables

- Normal variable

```
int a;
```

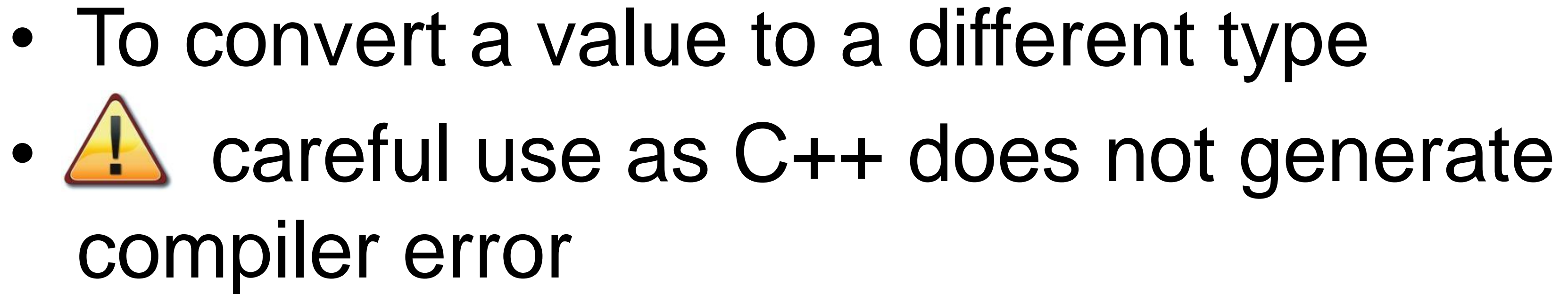
- Reference to a variable (address of)

```
int a = 2;
int & b = a; // reference
```

- Pointer to a variable (value pointed by)

```
int a = 2;
int * c = & a; // pointer
```

Explicit casting

- To convert a value to a different type
-  careful use as C++ does not generate compiler error

```
int x = 5; int y = 2; double z = 5.0;

double a = x / y; // a equals 2

double b = z / y; // b equals 2.5

double c = double(x)/double(y); // c equals 2.5
```

Operators

- Assignment to set a value to a variable
  - = ⚠ not the math equal and usually does not create compile-time error!
- Classical arithmetical operations
  - +, -, /, *,%
- Compound assignments
  - +=, -= ...
  - value += increase means value = value + increase
- Increase, decrease
  - ++ and --
  - a++ ⬄ a+=1 ⬄ a = a +1
    - a++ returns the value before increment
    - ++a returns the value after increment

Relational and logical operators

operator	description
!x	Returns false if x is true and vice-versa
x < y	Returns true if x is **less than** y
x > y	Returns true if x is **greater than** y
x <= y	Returns true if x is **less than or equal to** y
x >= y	Returns true if x is **greater than or equal to** y
x == y	Returns true if x and y are **equal**
x != y	Returns true if x and y are **not equal**
x && y	Returns true only if **both** x and y are **true**
x ^^ y	Returns true if **either** x or y is **true** (not both)
x || y	Returns true if **one** of x or y is **true** (or both)

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Control structures

- Conditional structure
  - the if-else statement
- Iteration structure
  - the while loop
  - the do-while loop
  - the for loop
- Jump structure
  - the break statement
  - the continue statement
  - the goto statement
- Selective structure
  - the switch statement

The if-else statement

- To execute a block only if a condition is fulfilled [otherwise execute another block]

```
if (condition) {block1;} [else {block2;}]
```

- Example

```
if (player_number > 0) {
   InitializeGameForPlayers(player_number);
   StartGame();
}
else WaitForMorePlayers();
```

The while loop

- To repeat a block while a condition is fulfilled

```
while (condition) {block;}
```

- Example

```
while (player_number <= 0) {
   player_number = GetMorePlayers();
}
```

The do-while loop

- Same as while loop except that the condition is evaluated after the execution of the block

```
do {block;} while (condition);
```

- Example

```
do {
   player_number = GetMorePlayers();
}
while (player_number <= 0);
```

The for loop

- To repeat a block a certain number of times

```
for ([initialization]; condition; [statement]) {block;}
```

- Example

```
cout << “Respawn in 10 seconds: ”;
for (int n = 10; n > 0; n--) {
   cout << n << “ ”;
   WaitOneSecond();
}
Respawn();
```

The brake statement

- To leave a loop even if the condition for its end is not fulfilled
- Example

```
cout << "Respawn in 10 seconds: ";
for (int n = 10; n > 0; n--) {
   cout << n << " ";
   WaitOneSecond();
   if (NeedToAbord()) {
        cout << "countdown aborted!" << endl;
        break;
   }
}
Respawn();
```

The continue statement

- To skip the rest of the block causing the jump to the start of the next iteration
- Example

```
cout << “Respawn in 10 seconds: ”;
for (int n = 10; n > 0; n--) {
   cout << n << “ ”;
   if (NeedToSkipThatSecond()) continue;
   else WaitOneSecond();
}
Respawn();
```

The goto statement

- To make an absolute jump to another point in the program identified by a label
  - the label must be located in the current function
- Example

```
cout << “Respawn in 10 seconds: ”;
int n = 10;
loop:
cout << n << “ ”;
n--;
if (n>0) goto loop;
Respawn();
```

The switch statement

- To check several possible constant values for an expression and execute blocks
- Example

```
switch (option) {
   case 'a':
   case 'b':
   case 'c':
        cout << "Normal menu option" << endl;
        ExecuteOption(option);
        break;
   case '?':
        cout << "Help option" << endl;
        ShowHelp();
        break;
   default:
        cout << "Invalid option!" << endl;
}
```

Scope

- Variables are accessible in the block in which they are defined

```
if (x == 12) {
   double z = 48.7;
}
cout << z << endl; // output?
```

```
for (int i = 0; i < 10; i++) {
   cout << i << endl;
}
cout << i << endl; // output?
```

Standard Input / Output

- Using the C++ iostream library

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

- Print on the standard output (screen)

```
cout << "Welcome " << PlayerName << endl;
```

- Read from the standard input (keyboard)

```
int PlayerAge;
cout << "Please enter your age.";
cin >> PlayerAge;
```

Reading lines

- cin extraction stops reading as soon as it finds a blank space character
- Function getline to get the line in a string

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

int main () {
   string Quest;
   cout << "What is your quest?" << endl;
   getline(cin, Quest);
   cout << Quest << " is also my quest! Let's team up!";
   return 0;
}
```

Reading numerical values

- To perform extraction or insertion operations to convert strings to numerical values and vice-versa

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

int main () {
   string inputString;
   int PlayerGold, PlayerSilver;
   cout << "How much gold and silver coins do you have?" << endl;
   getline(cin, inputString);
   stringstream(inputString) >> PlayerGold >> PlayerSilver;
   cout << "Can you give me " << PlayerGold / 2 << " gold coins?";
   return 0;
}
```

File Input / Output

- To read a file

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

int main() {
   string line;
   ifstream myfile("GameSaved.txt");
   if (myfile.is_open()) { // accessing file?
        while ( !myfile.eof() ) { // parsing file
             getline(myfile,line); // reading line-by-line
             cout << line << endl;
        }
        myfile.close();
   }
   else cout << "Unable to open file";
   return 0;
}
```

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File Input / Output

- To write a file

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

int main() {
   int PlayerLifes = 3;
   ofstream myfile("GameSaved.txt");
   if (myfile.is_open()) { // accessing file?
       myfile << "Game saved file" << endl;
       myfile << "Current lifes " << PlayerLifes << endl;
       myfile.close();
   }
   else cout << "Unable to open file";
   return 0;
}
```

Functions

- A function is a group of statements that is executed when it is called from some point of the program

```
type name ([parameter1, parameter2, ...]) {block;}
```

  - type is the type of the data returned by the function
  - name is the identifier of the function
  - parameters (data type followed by an identifier) act within the function as local variables
  - block is the function's body

Functions

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

int subtraction (int a, int b) {
   int r;
   r = a - b;
   return r; // or return a - b;
}

int main() {
   int x = 5, y = 3, z;
   z = subtraction(7,2);
   cout << "The first result is " << z << '\n';
   cout << "The second result is " << subtraction(7,2) << '\n';
   cout << "The third result is " << subtraction(x,y) << '\n';
   z = 4 + subtraction (x,y);
   cout << "The fourth result is " << z << '\n';
   return 0;
}
```

void functions

- Functions with no parameters and/or no return type (procedures)

```
void AVoidReturnFunction (int a) {
   int b = a + 1;
}
```

```
int AVoidParameterFunction (void) {
   int b = 1;
   return b;
}
```

```
void AVoidReturnAndParameterFunction () {
   int b = 1;
}
```

Modifying function

- Parameters are copies of the values but never the variables themselves
  - Modifications to them within the function will not have any effect on the values outside it
  - But if you want a modification, use a reference to the variable

Modifying function

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

void PreviousAndNext (int x, int& prev, int& next) {
   prev = x-1;
   next = x+1;
}

int main () {
   int x=100; int y=15; int z=8;
   PreviousAndNext(x, y, z);
   cout << "Previous=" << y << ", Next=" << z;
   return 0;
}
```

Create data types

- Data structures
- Union of types
- Enumeration of types
- Definition of types

Data structures

- A data structure is a group of data elements (not necessarily of the same type) grouped together under one name

```
struct structure_name {
   member_type1 member_name1;
   member_type2 member_name2;
   member_type3 member_name3; ...
} object_names;
```

- Examples

```
struct PlayerState {
   bool alive;
   int amno;
} State1, State2;
```

```
struct PlayerState {
   bool alive;
   int amno;
};
PlayerState State1;
PlayerState State2, State3;
```

Data structures

- Manipulation of the members with the dot operator

```
if (State1.alive && State2.alive && !State3.alive) {
    State1.amno += State3.amno / 2;
    State2.amno += State3.amno / 2;
    State3.amno = 0;
}
```

- Structures can be nested

```
struct Player {
   float posx, posy;
   PlayerState state;
};
Player player1;
if (player1.posx == 0.0) player1.state.amno = 0;
```

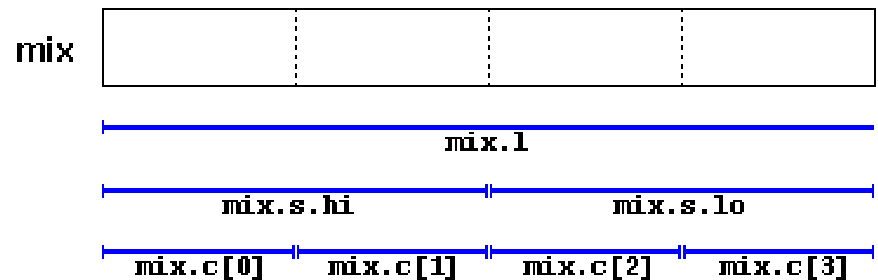
Union of types

- Allow one same portion of memory to be accessed as different data types

```
union union_name {
   member_type1 member_name1;
   member_type2 member_name2;
   member_type3 member_name3; ...
} object_names;
```

- Example

```
union mix_t {
   double l;
   struct {
        int hi;
        int lo;
    } s;
   char c[4];
} mix;
```



Enumeration of types

- Create new data types to contain something different that is not limited to the values that fundamental data types may take

```
enum enumeration_name {
   value1,
   value2, ...
} object_names;
```

- Example

```
enum GameState {InMenu, Paused, Running};
```

```
GameState currentState = InMenu;
while (!playerReady) update();
currentState = Running;
```

Definition of type

- Definition of your own types based on other existing data types

```
typedef existing_type new_type_name ;
```

- Example

```
typedef char C;
typedef unsigned int WORD;
typedef char field [50];

C mychar, anotherchar;
WORD myword;
field name;
```

End of lecture #1

Next lecture

Array, pointer, dynamic memory, string and OO basics