Lecture 1 Basic C++

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Animation Software Engineering

- Using C++ to develop Graphics application
- Develop 2D / 3D Applications and Tools
- Use OpenGL for Real-time applications
- Develop Algorithms for graphics simulations
- Output files to Renderman for High Quality production level graphics
- Write tools to help with the Graphics Production Pipeline

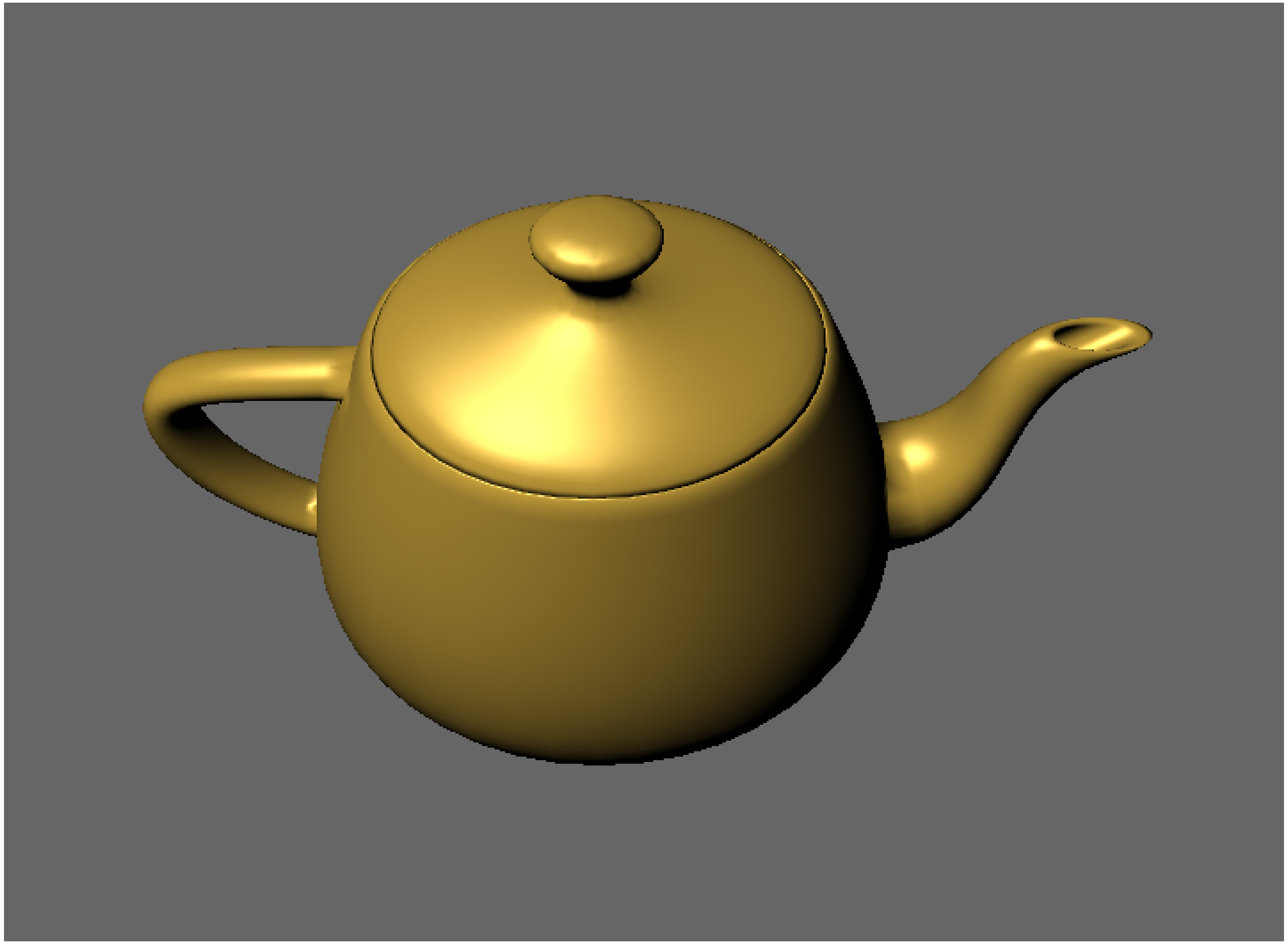
What we will use

- C++ using the clang++ compiler (and also g++) and other tools
- Doxygen for documenting our code
- OpenGL
- QtCreator IDE and Qt for GUI applications
- Loads of external libraries (OpenGL, Qt, Boost, Bullet)
- git and git-hub for versions control and code submission

NCCA Graphics Library(ngl::)

- As part of the course we will be using the NCCA Graphics Library (ngl::)
- This contains many C++ classes to aid the development of 3D applications
- Basic Maths elements such as Vectors and Matrix
- Colour, Points, Image (for textures)
- A Virtual Camera for viewing
- This will be used in all code and may be extended for other needs, changes to the lib are then fed back

ngl

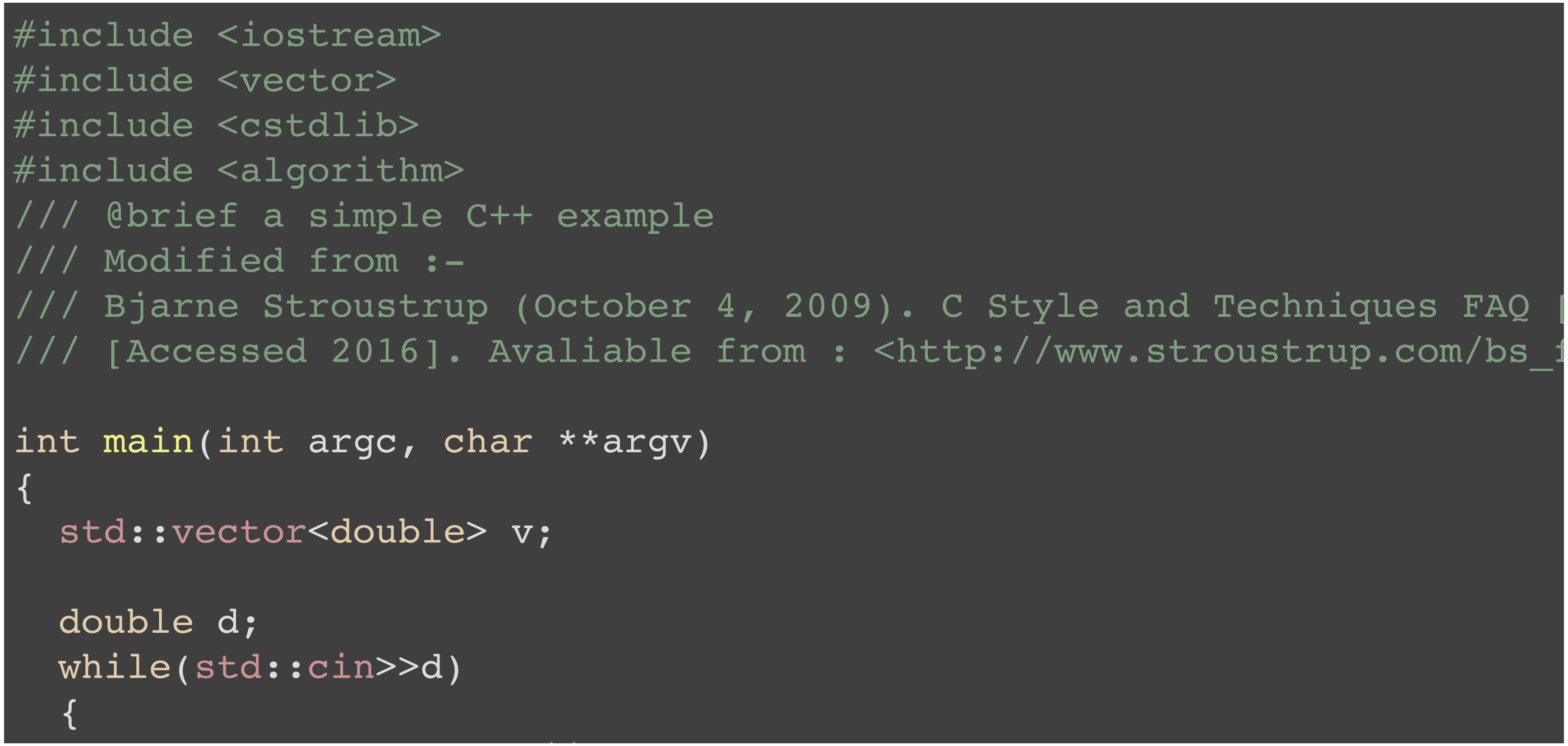


fullscreen

WebGL Debug

```
just attached PhongVertex 34
just attached PhongFragment 35
```

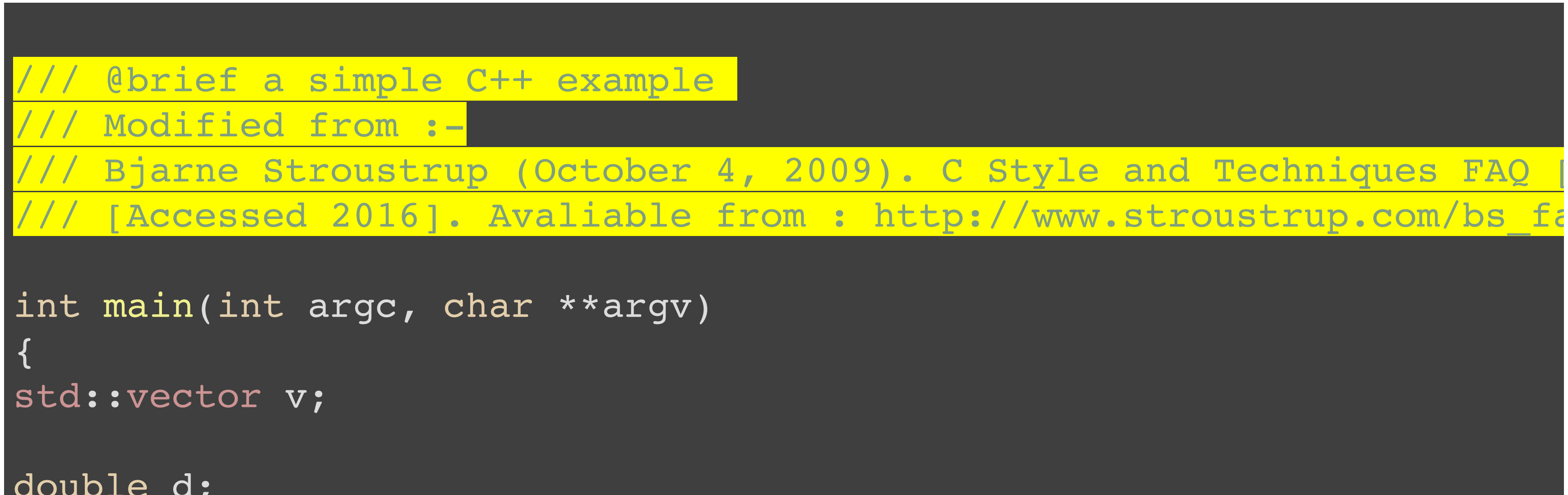
Citing code in your work



```
#include <iostream>
#include <vector>
#include <cstdlib>
#include <algorithm>
/// @brief a simple C++ example
/// Modified from :-
/// Bjarne Stroustrup (October 4, 2009). C Style and Techniques FAQ [
/// [Accessed 2016]. Avaliable from : <http://www.stroustrup.com/bs_f

int main(int argc, char **argv)
{
  std::vector<double> v;

  double d;
  while(std::cin>>d)
  {
```

Citing Code

- The previous example was taken and modified from a website
- We need to cite this source in the code to avoid any notion of plagiarism.
- To do this we use the standard Harvard referencing format



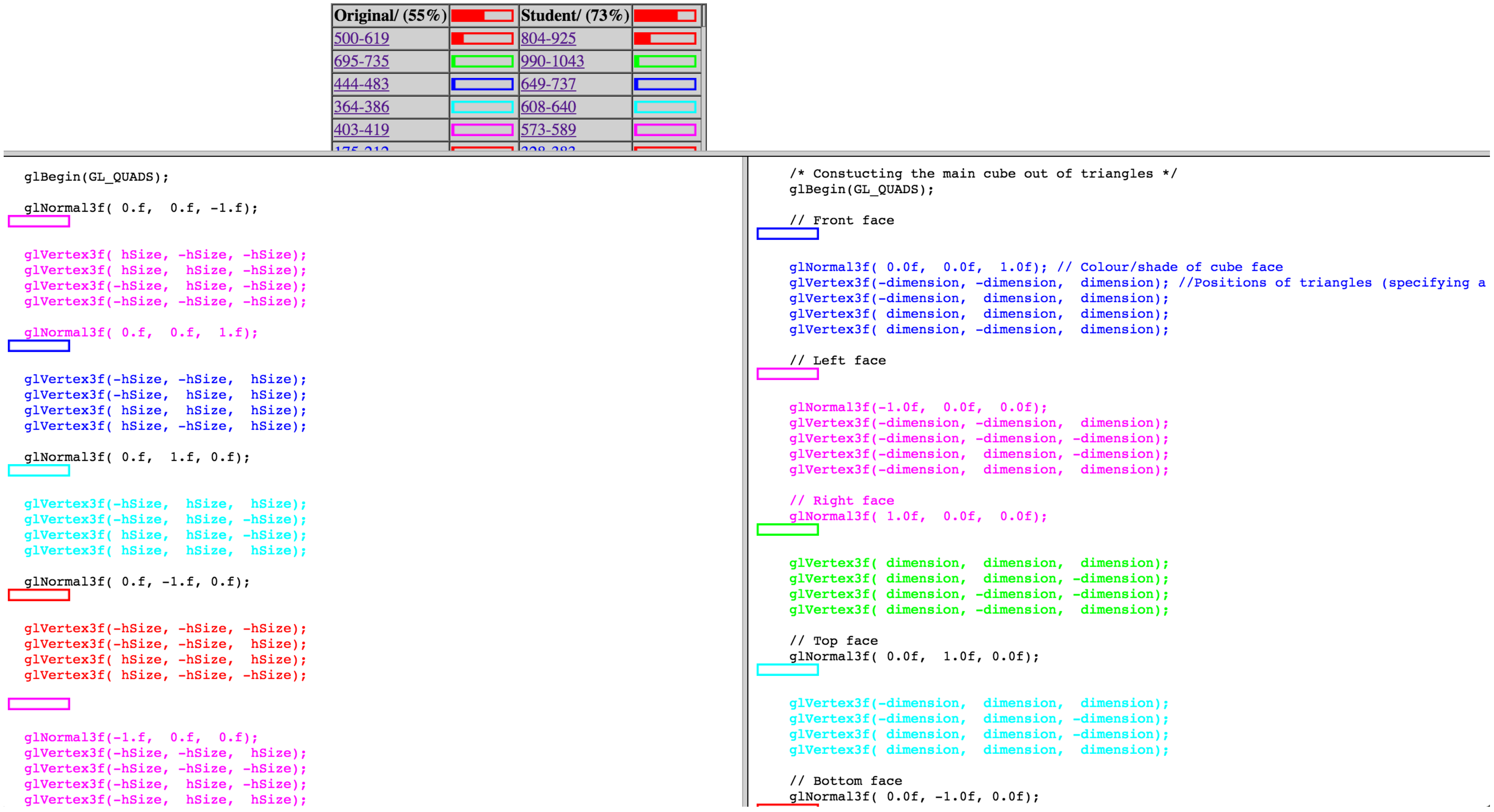
```
/// @brief a simple C++ example
/// Modified from :-
/// Bjarne Stroustrup (October 4, 2009). C Style and Techniques FAQ [
/// [Accessed 2016]. Avaliable from : http://www.stroustrup.com/bs_fa

int main(int argc, char **argv)
{
std::vector v;

double d;
double d;
while(std::cin>>d)
{
  v.push_back(d);     // read elements
}
if (!std::cin.eof())
```

Citing a small section of code

- If you use a small section of code do the following
- Cite at the beginning of the code section
- at the end of the section mark as end of citation

```
/// The following section is from :-
/// Dan Sunday (2006) Intersections of Rays, Segments Planes and Tria
/// Accessed [2010]
/// Avaliable from // see http://softsurfer.com/Archive/algorithm_010
ngl::Vec3 n=ngl::calcNormal(m_v0,m_v1,m_v2);
float a = -n.dot(tvec);
float b = n.dot(dir);
float r=a/b;
/// End Citation
```

Say hello to moss



Original/ (55%)	🟥	Student/ (73%)	🟥
500-619	🟥	804-925	🟥
695-735	🟩	990-1043	🟩
444-483	🟦	649-737	🟦
364-386	▭	608-640	▭
403-419	▭	573-589	▭
175-212	🟥	328-382	🟥

```
glBegin(GL_QUADS);

glNormal3f( 0.f,  0.f, -1.f);


glVertex3f( hSize, -hSize, -hSize);
glVertex3f( hSize,  hSize, -hSize);
glVertex3f(-hSize,  hSize, -hSize);
glVertex3f(-hSize, -hSize, -hSize);

glNormal3f( 0.f,  0.f,  1.f);


glVertex3f(-hSize, -hSize,  hSize);
glVertex3f(-hSize,  hSize,  hSize);
glVertex3f( hSize,  hSize,  hSize);
glVertex3f( hSize, -hSize,  hSize);

glNormal3f( 0.f,  1.f, 0.f);


glVertex3f(-hSize,  hSize,  hSize);
glVertex3f(-hSize,  hSize, -hSize);
glVertex3f( hSize,  hSize, -hSize);
glVertex3f( hSize,  hSize,  hSize);

glNormal3f( 0.f, -1.f, 0.f);


glVertex3f(-hSize, -hSize, -hSize);
glVertex3f(-hSize, -hSize,  hSize);
glVertex3f( hSize, -hSize,  hSize);
glVertex3f( hSize, -hSize, -hSize);



glNormal3f(-1.f,  0.f,  0.f);
glVertex3f(-hSize, -hSize,  hSize);
glVertex3f(-hSize, -hSize, -hSize);
glVertex3f(-hSize,  hSize, -hSize);
glVertex3f(-hSize,  hSize,  hSize);
```

```
/* Constucting the main cube out of triangles */
glBegin(GL_QUADS);

// Front face


glNormal3f( 0.0f,  0.0f,  1.0f); // Colour/shade of cube face
glVertex3f(-dimension, -dimension,  dimension); //Positions of triangles (specifying a
glVertex3f(-dimension,  dimension,  dimension);
glVertex3f( dimension,  dimension,  dimension);
glVertex3f( dimension, -dimension,  dimension);

// Left face


glNormal3f(-1.0f,  0.0f,  0.0f);
glVertex3f(-dimension, -dimension,  dimension);
glVertex3f(-dimension, -dimension, -dimension);
glVertex3f(-dimension,  dimension, -dimension);
glVertex3f(-dimension,  dimension,  dimension);

// Right face
glNormal3f( 1.0f,  0.0f,  0.0f);


glVertex3f( dimension,  dimension,  dimension);
glVertex3f( dimension,  dimension, -dimension);
glVertex3f( dimension, -dimension, -dimension);
glVertex3f( dimension, -dimension,  dimension);

// Top face
glNormal3f( 0.0f,  1.0f, 0.0f);


glVertex3f(-dimension,  dimension,  dimension);
glVertex3f(-dimension,  dimension, -dimension);
glVertex3f( dimension,  dimension, -dimension);
glVertex3f( dimension,  dimension,  dimension);

// Bottom face
glNormal3f( 0.0f, -1.0f, 0.0f);
```

NCCA Coding Standard

- The coding standard includes more details on how to cite code as well as other rules
- This helps us integrate code with existing projects
- Helps staff to understand code quicker when debugging and fixing problems
- Is good practice for the future (most companies use standards)
- We can also use tools to help with this.

CPP Core Guidelines

- The C++ Core Guidelines are a set of tried-and-true guidelines, rules, and best practices about coding in C++
- I will relate to these when talking about code.
- A very useful set of rules to follow

The inevitable helloWorld.cpp

```cpp
#include <iostream>
using namespace std;
int main()
{
  cout<<"Hello World"<<endl;
  return 0;
}
```

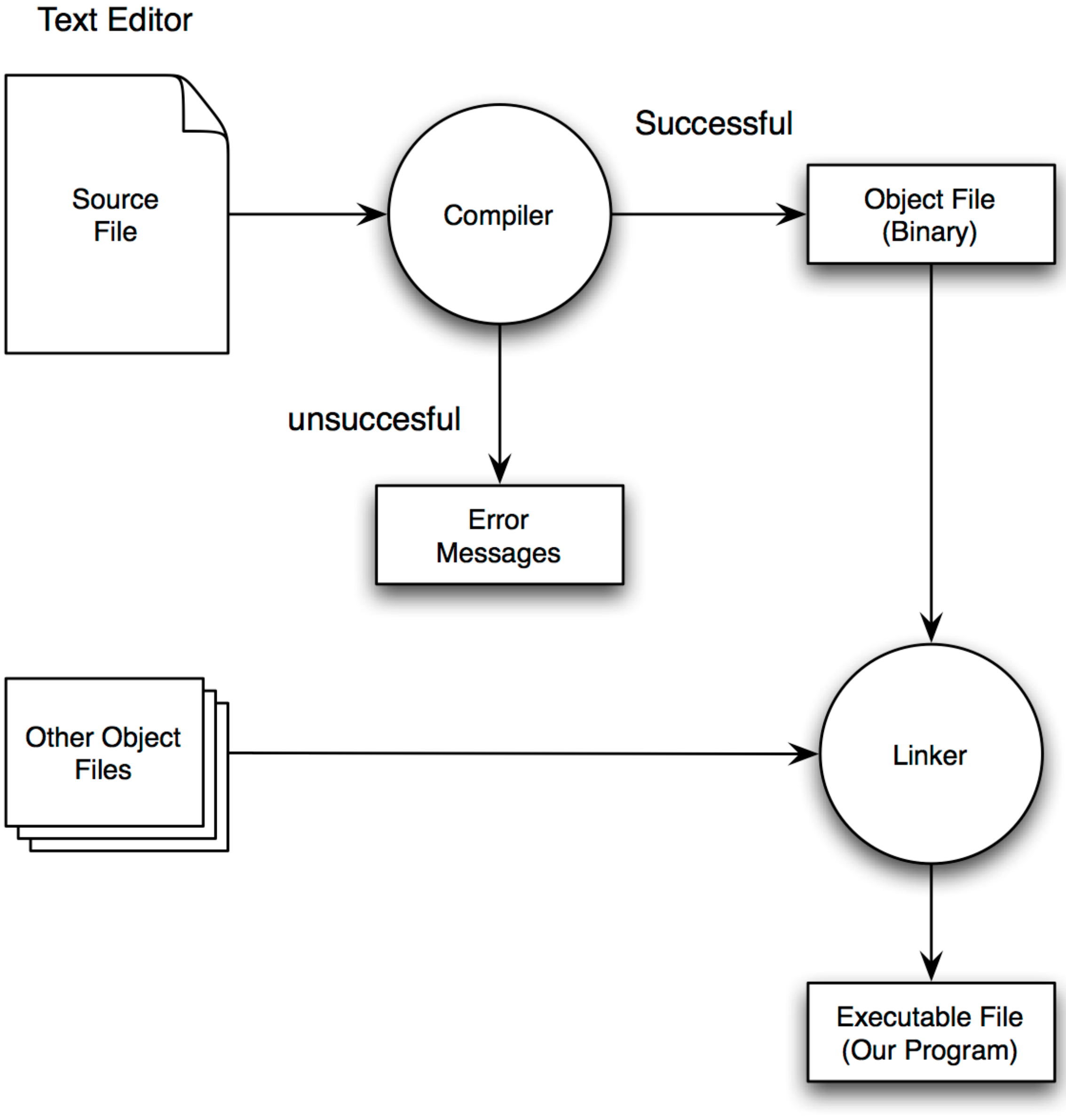
That version is bad!

- Usually the normal version everyone is taught
- many problems and doesn't follow the core guidelines
  - avoid endl
  - `using namespace std;` imports all of std
  - what does return 0 mean?
  - always better to be explicit in code see the Zen of python

This is better

```
#include <iostream>
#include <cstdlib>
int main()
{
  std::cout<<"Hello World\n";
  return EXIT_SUCCESS;
}
```

The compilation process



Compile

```
clang++ -g -Wall -std=c++11 HelloWorld.cpp -o HelloWorld
```

```
g++ -g -Wall -std=c++11 HelloWorld.cpp -o HelloWorld
```

- flags control the compiler function
  - -g turn on debug information
  - -Wall enable all warnings
  - -std=c++11 turn on c++ 11
  - -o output name (default if not used a.out)

clang++ vs g++

- clang++ is a modern C++ compiler based on the llvm architecture.
- It has the best error reporting and diagnostics of the two compilers
- both now fully support c++ 11 and some of C++ 14
- some ABI elements are compatible however mixing both compilers is usually problematic
- However this is also true of different version of the same compiler.
    - On mac clang is default, however some support is missing (such as OpenMP)

C++ Programming “In the Large”

- Typically at undergraduate level you have written small programs individually.
- This is not a true reflection of the real world software engineering process (but the best way to initially learn programming).
- As complexity of outputs grow we need to work in a different way.
- This presents us with a set of new issued to be solved.

Program Libraries

- Large programs - developed by teams
- Program = set of modules (files)
- Function interfaces - defined using library files.
- Libraries give us code reuse across programs (good thing!)
- However we need to have available
  - Header Files & Implementation files
  - Compiled Library Files.

Single File Inclusion

- header files define interfaces for functions, structures, unions and classes
- They may also define variables, however if this header file is then included in more than one module the linker will complain as the same variable is defined twice.
- To overcome this problem we can use Single File Inclusion

Single File Inclusion

- The traditional way of doing this is as follows
  - Use the name of the Header file as an identifier for the pre-processor and create a unique `#define` name
  - place a `#include` directive in the code to define the module name
  - If the `#define` does not exist then it will be included if it does there is no need to include it again.

Single File Inclusion

```
#ifndef WINDOWPARAMS_H_
#define WINDOWPARAMS_H_

  struct WinParams
  {
  int spinXFace=0;
  int spinYFace=0;
  int origX=0;
  int origY=0;
  int origXPos=0;
  int origYPos=0;
  int width=1024;
  int height=720;
  bool rotate=false;
  bool translate=false;
  };
```

#pragma once

- #pragma is a compiler directive
- #pragma once can be used at the top of an include file instead of the include guard
- whilst it is supported by both clang++ and g++ it is usually best to avoid
- good discussion here

Code as Modules

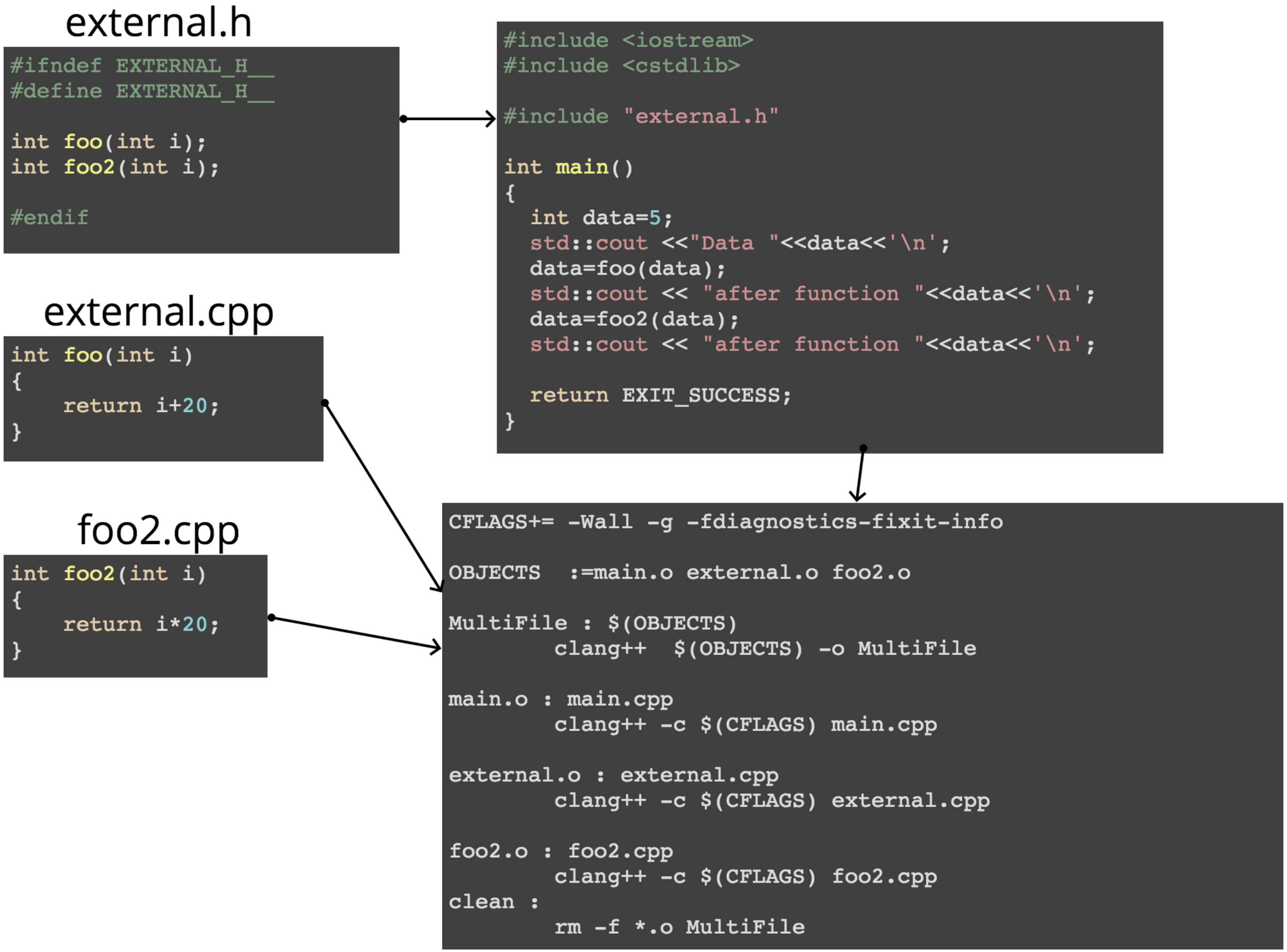
- In C and C++ it is easier to manage large programs by splitting them into source modules
- With C++ we create classes which contain all the functionality required of the thing we are going to represent.
- Teams can then work on different modules and combine them to produce a final program
- This may be done at the level of a single program with many modules or a small program with external libraries
- C++ 17 will have full module support and some compilers already have this in experimental systems ts

Separate Compilation

> *"A [C] program may reside in one or more source files. Source Files may be compiled separately and loaded together, along with previously compiled functions from libraries"*

(Kernighan & Ritchie The C programming Language)

Separate Compilation



external.h

```
#ifndef EXTERNAL_H__
#define EXTERNAL_H__

int foo(int i);
int foo2(int i);

#endif
```

external.cpp

```
int foo(int i)
{
    return i+20;
}
```

foo2.cpp

```
int foo2(int i)
{
    return i*20;
}
```

```
#include <iostream>
#include <cstdlib>

#include "external.h"

int main()
{
  int data=5;
  std::cout <<"Data "<<data<<'\n';
  data=foo(data);
  std::cout << "after function "<<data<<'\n';
  data=foo2(data);
  std::cout << "after function "<<data<<'\n';

  return EXIT_SUCCESS;
}
```

```
CFLAGS+= -Wall -g -fdiagnostics-fixit-info

OBJECTS  :=main.o external.o foo2.o

MultiFile : $(OBJECTS)
        clang++  $(OBJECTS) -o MultiFile

main.o : main.cpp
        clang++ -c $(CFLAGS) main.cpp

external.o : external.cpp
        clang++ -c $(CFLAGS) external.cpp

foo2.o : foo2.cpp
        clang++ -c $(CFLAGS) foo2.cpp
clean :
        rm -f *.o MultiFile
```

The Build process

```
clang++ -c -Wall -g -std=c++11 main.cpp
clang++ -c -Wall -g -std=c++11 external.cpp
clang++ -c -Wall -g -std=c++11 foo2.cpp
clang++  main.o external.o foo2.o -o MultiFile
```

Automating the Build process

- As you can see the build process is fairly simple but would require a lot of typing once we have more than a few source files.
- If we are using external libraries and other .h files more flags need to be added to the compilation line
- This means the process can become very involved after a while
- Luckily their are a number of standard build tools we can use to automate the process.

Makefiles

- As you can see the build process is fairly simple but would require a lot of typing once we have more than a few source files.
- If we are using external libraries and other .h files more flags need to be added to the compilation line
- This means the process can become very involved after a while
- Luckily their are a number of standard build tools we can use to automate the process.

Makefile

```
CFLAGS+= -Wall -g -std=c++11

OBJECTS  :=main.o external.o foo2.o

MultiFile : $(OBJECTS)
  clang++  $(OBJECTS) -o MultiFile

main.o : main.cpp
  clang++ -c $(CFLAGS) main.cpp

external.o : external.cpp
  clang++ -c $(CFLAGS) external.cpp

foo2.o : foo2.cpp
  clang++ -c $(CFLAGS) foo2.cpp
clean :
```

```
make -f Makefile.linux
```

Make

- By default make will look in the current directory for a file called Makefile
- We can use a different name for the file and use the -f command line argument to specify it.
- In this case the demo uses Makefile.linux as cmake and qmake which we shall see next will generate a Makefile and overwrite this one

Makefiles

- Makefiles can be complicated to generate especially for large projects
- The syntax and whitespace rules can be problematic
- Best to use a meta language / tool to generate the Makefiles
- We will use two
  - qmake (part of Qt)
  - cmake (which is very common in VFX development)

qmake

- Is a system which allows the automatic generation of Makefiles from within the Qt development environment
- It reads a file called a .pro file (Qt Project) and will then generate the Makefile for us
- This .pro file is also used by the QtCreator IDE as the main project development system

qmake

```
# We are not using Qt for this project so remove the depends
CONFIG-=qt
# We want a simple console app so remove bundles form mac
macx:CONFIG-=app_bundle
#TARGET is the name of the exe
TARGET=Multifile
SOURCES+= external.cpp foo2.cpp main.cpp
HEADERS+= external.h
```

```
qmake
make
```

cmake

> *“CMake is an extensible, open-source system that manages the build process in an operating system and a compiler-independent manner”*

- It also uses a meta language to generate a makefile
- Many open source projects use this (especially some of big animation packages such as OSL, OpenEXR etc etc)
- Uses a file called CMakeLists.txt to generate a makefile

cmake

```
cmake_minimum_required(VERSION 2.8.11)
# Name of the project
set(PROJECT_NAME MultiFile)
project(${PROJECT_NAME})

set(SOURCES external.cpp foo2.cpp main.cpp external.h )
add_executable(${PROJECT_NAME} ${SOURCES})
```

```
cmake CMakeLists.txt
make
```

references

- Budd, T 2002 “An introduction to Object Oriented programming” 3rd Edition. Addison Wesley
- Parsons, David. “Object Oriented Programming with C++” Thomson Learning; 2nd edition 8 Nov 2000
- Priess B. “Data Structures and Algorithms with Object-Oriented Design Patterns in C++” Wiley 1998
- Eckel B. “Thinking in C++, 2nd ed. Volume 1” Prentice Hall 2000