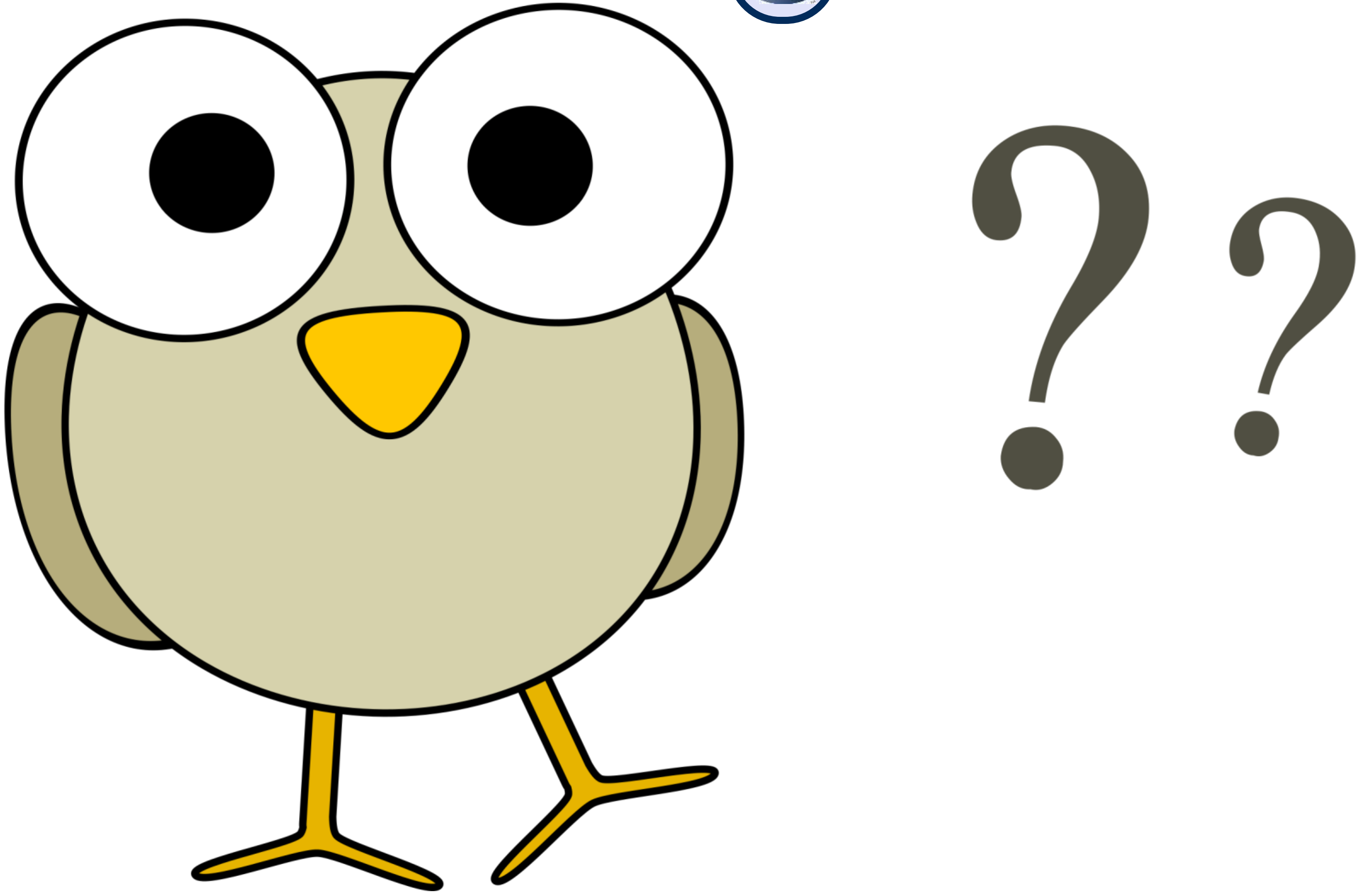
CSCI 200: Foundational Programming Concepts & Design Lecture 27

Making & Using
Libraries

Previously in CSCI 200

- Inheritance
  - Child class inherits members from Parent class

Questions?



Learning Outcomes For Today

- Explain what a library archive is
- Discuss reasons why headers & implementations can be bundled into a library archive and distributed
- Build and install a third-party library (SFML) to use within a C++ program (to display graphics)

On Tap For Today

- Using Libraries
- The SFML Library
- Practice

On Tap For Today

- Using Libraries
- The SFML Library
- Practice

Warehouse

```
#include "Box.h"
#include <vector>

class Warehouse {
public:
   ...
private:
   std::vector<Box*> *_pBoxen;
   ...
};
```

Warehouse

```
#include "Box.h"
#include <vector>

class Warehouse {
public:
   ...
private:
   std::vector<Box*> *_pBoxen;
   ...
};
```

- Where is **`Box.h`** header file located?

Warehouse

```
#include "Box.h"
#include <vector>

class Warehouse {
public:
   ...
private:
   std::vector<Box*> *_pBoxen;
   ...
};
```

- Where is **`Box.h`** header file located?
  - Alongside **`Warehouse.h`**

Warehouse

```
#include "Box.h"
#include <vector>

class Warehouse {
public:
   ...
private:
   std::vector<Box*> *_pBoxen;
   ...
};
```

- Where is **`vector`** header file located?

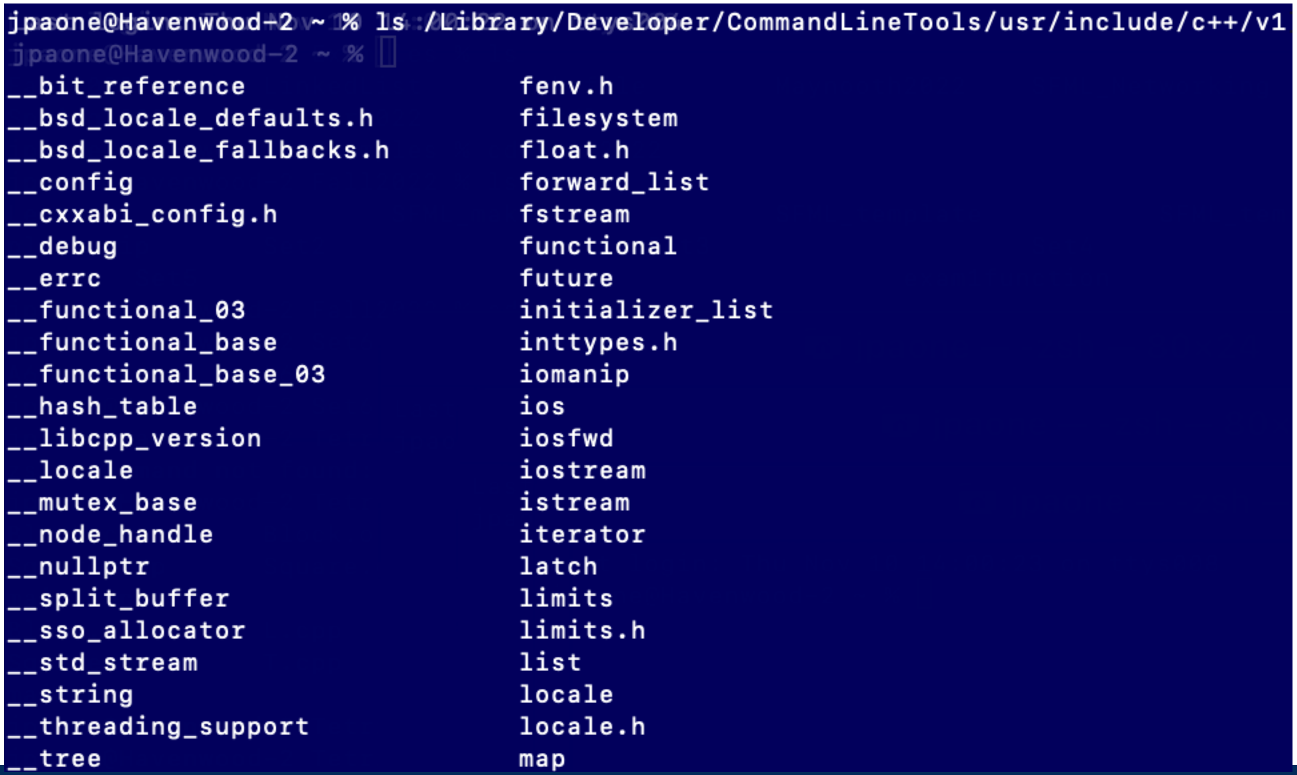
Including Headers

```
#include "LocalHeader.h"


#include <SystemHeader.h>
```

Finding System Headers

- Windows: Inside MinGW hierarchy
- OS X: Inside XCode hierarchy



```
jpaone@Havenwood-2 ~ % ls /Library/Developer/CommandLineTools/usr/include/c++/v1
jpaone@Havenwood-2 ~ %
__bit_reference                fenv.h
__bsd_locale_defaults.h        filesystem
__bsd_locale_fallbacks.h       float.h
__config                       forward_list
__cxxabi_config.h              fstream
__debug                        functional
__errc                         future
__functional_03                initializer_list
__functional_base              inttypes.h
__functional_base_03           iomanip
__hash_table                   ios
__libcpp_version               iosfwd
__locale                       iostream
__mutex_base                   istream
__node_handle                  iterator
__nullptr                      latch
__split_buffer                 limits
__sso_allocator                limits.h
__std_stream                   list
__string                       locale
__threading_support            locale.h
__tree                         map
```

Warehouse

```
#include "Box.h"
#include <vector>

class Warehouse {
public:
   ...
private:
   std::vector<Box*> *_pBoxen;
   ...
};
```

- Where is **`Box`** implementation located?

Warehouse

```
#include "Box.h"
#include <vector>

class Warehouse {
public:
   ...
private:
   std::vector<Box*> *_pBoxen;
   ...
};
```

- Where is **`Box`** implementation located?
  - Alongside in **`Box.cpp`**

Warehouse

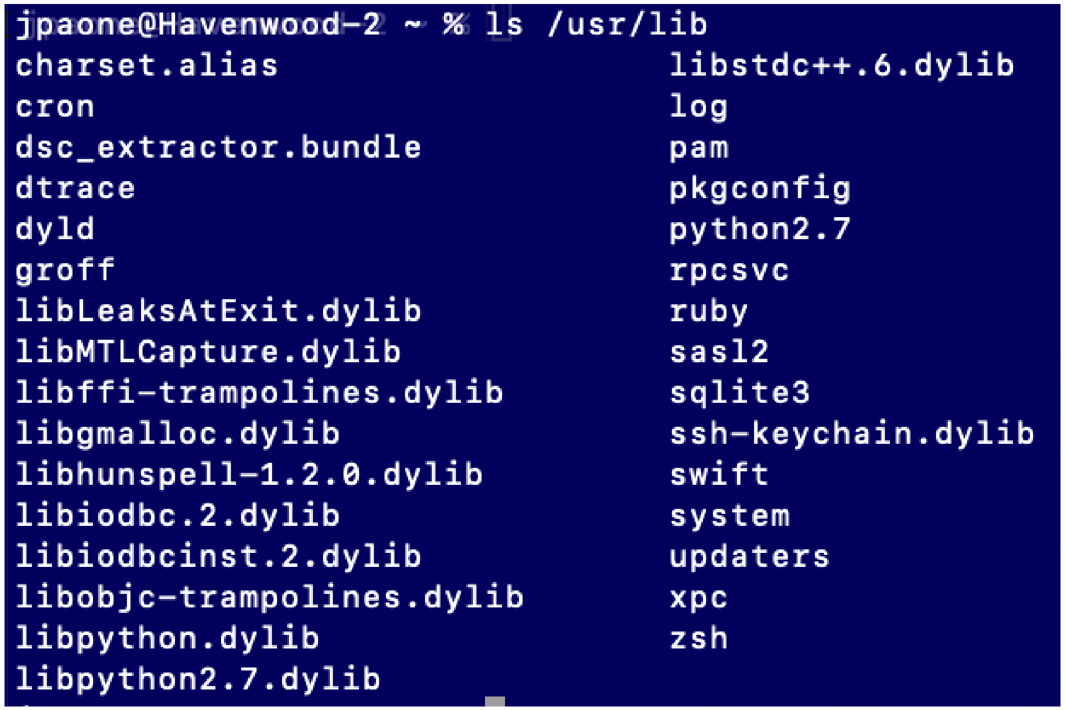
```
#include "Box.h"
#include <vector>

class Warehouse {
public:
   ...
private:
   std::vector<Box*> *_pBoxen;
   ...
};
```

- Where is **`vector`** implementation located?

Finding System Libraries

- Again, from MinGW / XCode
- `libstdc++` contains the C++ Standard Libraries



```
jpaone@Havenwood-2 ~ % ls /usr/lib
charset.alias                     libstdc++.6.dylib
cron                              log
dsc_extractor.bundle              pam
dtrace                            pkgconfig
dyld                              python2.7
groff                             rpcsvc
libLeaksAtExit.dylib              ruby
libMTLCapture.dylib               sasl2
libffi-trampolines.dylib          sqlite3
libgmalloc.dylib                  ssh-keychain.dylib
libhunspell-1.2.0.dylib           swift
libiodbc.2.dylib                  system
libiodbcinst.2.dylib              updaters
libobjc-trampolines.dylib         xpc
libpython.dylib                   zsh
libpython2.7.dylib
```

Archive File

- What's a library archive file?
  - Collection of object files

- What's an object file?
  - Compiled binary representation of C++ source code

Why Use Archive Files As Libraries?

- Single source of truth / Reuse
  - Headers & Implementations live in one place for ALL programs to access & use
- Distribution
  - Share a stable version of classes/functions for others to use

Distribution

1. Share header files
   - Serves as form of documentation for interface that is available
   - Necessary for other programs to include to be able to compile with your declared components

2. Share precompiled object files
   - Implementation doesn’t change (compile once, use many)
   - Abstract (& hide) details of implementation (may contain proprietary algorithm)

Header Best Practices

- Headers should be minimal, only include what is absolutely necessary for interface
- Don’t include any headers in your header that aren’t required in that file
  - Anything that can go into source file should
- Don’t use `using namespace` which forces others to as well

Informing the Compiler

- Tell the compiler where to look for header files

- Compiler command template

```
$(CXX) $(CFLAGS) -o $(OBJ_NAME) -c $(SRC_NAME) -I$(INC_PATH)
```

- For instance

```
g++ -Wall -g -std=c++17 -o main.o -c main.cpp -IZ:\CSCI200\include
```

- Specify location in Makefile

Informing the Linker

- Tell the linker where to look for library files
- Linker command template

```
$(CXX) -o $(TARGET_NAME) $(OBJECT_NAMES) -L$(LIB_PATH) $(LIBS)
```

- For instance

```
g++ -o SFMLExample.exe main.o -LZ:\CSCI200\lib -lsfml-system
```

- Specify location and libraries in Makefile

Makefile Updates

```
# customize your build
TARGET = TestLibrary
SRC_FILES = main.cpp
CXX = g++
CXXFLAGS = -Wall -Wextra -Wpedantic -g -std=c++17
INC_PATH = Z:\CSCI200\include # location where headers are
LIB_PATH = Z:\CSCI200\lib     # location where archive files are
LIBS = -lTestLib              # name of archive file to load
# do not edit below here
OBJECTS = ${SRC_FILES:.cpp=.o}
DEL = ...
all: ${TARGET}
${TARGET}: ${OBJECTS}
    ${CXX} -o $@ $^ -L${LIB_PATH} ${LIBS}
.cpp.o:
    ${CXX} ${CXXFLAGS} -o $@ -c $< -I${INC_PATH}
clean:
    ${DEL} ${TARGET} ${OBJECTS}
```

On Tap For Today

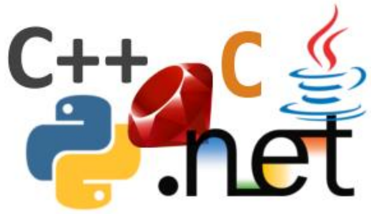
- Using Libraries
- The SFML Library
- Practice

SFML

- Simple & Fast Multimedia Library

Multimedia

Multiplatform



Multilanguage

What is SFML?

- http://www.sfml-dev.org
- Multimedia = Graphics & Audio
- Used for:
  - Games
  - Data Visualization
  - Networking
  - And much much more!

SFML Libraries

- SFML source code download consists of:
  - `SFML-3.0.2/`
    - `include/`
    - `lib/`
    - *`Bunch of other stuff`*
- Need to copy the
  - header files from `include/`
  - library files from `lib/`
- This is the start of Lab4C

Important Version Note

- Using v3.0.2 for this semester
  - Make sure any tutorials, references, resources are using v3.0 and not v2.6 or earlier

SFML Header

- Include like any other library file

```
#include <SFML/Graphics.hpp>
```

- Provides functions and complex data types that are used to display graphics

- (Other SFML headers exist as needed)

Sample SFML Program

```cpp
#include <SFML/Graphics.hpp>

int main() {
  // add File I/O commands here so they occur once!
  sf::Vector2u windowSize(640, 640);
  sf::RenderWindow window( sf::VideoMode( windowSize ),
                           "Window Title" ); // create & open a window
  while( window.isOpen() ) {
    window.clear();  // clear the existing contents of the window
    // add drawing commands here so they draw every frame
    window.display();// display the window on screen
    // check for user interaction
    while( const std::optional event = window.pollEvent() ) {
      if( event->is<sf::Event::Closed>() ) { // user press window X
        window.close(); // close the window
      }
    }
  }
  return 0;
}
```

Drawing Shapes

- Circle

```
sf::CircleShape circ;
circ.setRadius( 20.f );
circ.setPosition( sf::Vector2f(45.f, 90.f) );
circ.setFillColor( sf::Color::Yellow );
window.draw( circ );
```

- Rectangle

```
sf::RectangleShape rect;
rect.setSize( sf::Vector2f(150.f, 75.f) );
rect.setPosition( sf::Vector2f(115.f, 120.f) );
rect.setFillColor( sf::Color::Blue );
window.draw( rect );
```

Adding Color

- Use the `setFillColor()` function
- Use the `setOutlineColor()` and `setOutlineThickness()` functions

- Several options:
  - Built-in values: `sf::Color::`***Red***, `sf::Color::`***Green***, etc.
  - Custom value: `sf::Color(` *red*, *green*, *blue* `)`

Drawing Text: Part I

- First, we need to load a font to use
- And make sure it loaded properly

```
sf::Font myFont;
if( !myFont.openFromFile( "data/arial.ttf" ) ) {
  cerr << "Could not load font" << endl;
  return -1;
}
```

Drawing Text: Part II

- Now set up our Text object using the font

```
Text myLabel( myFont );
```

- Make use of text functions to set properties

```
myLabel.setString( "Hello World!" );

myLabel.setFillColor( sf::Color::Green );

myLabel.setPosition( sf::Vector2f(400.f, 150.f) );
```

- And tell window to draw it

```
window.draw( myLabel );
```

Displaying a Picture: Part I

- First, load the image into memory
  - Like text, we needed to load the font into memory

```
sf::Texture myTexture;
if( !myTexture.loadFromFile( "data/bubble.png" ) ) {
    cerr << "Could not load image" << endl;
    return -2;
}
```

Displaying a Picture: Part II

- Now add it to a Sprite and draw!
  - Sprite is like RectangleShape with a picture
  - Ta Da!

```
sf::Sprite mySprite( myTexture );
mySprite.setPosition( sf::Vector2f(200.f, 250.f) );
mySprite.setScale( sf::Vector2f(0.3f, 0.3f) );
mySprite.setColor( sf::Color::Green );
window.draw( mySprite );
```

Animation: Part I

- Need to store position as a variable

```
sf::Vector2f spritePos(0.f, 0.f);

while( window.isOpen() ) {
  // in draw loop
  mySprite.setPosition( spritePos );
  window.draw( mySprite );
}
```

Animation: Part II

- Each iteration of draw loop = one frame

```
#include <SFML/System/Clock.hpp>

// before draw loop

sf::Vector2f spritePos(0.f, 0.f);

sf::Clock programClock;
sf::Time lastTime = programClock.getElapsedTime();

while( window.isOpen() ) {

  // in draw loop
  mySprite.setPosition( spritePos );
  window.draw( mySprite );

  sf::Time currTime = programClock.getElapsedTime();
  if( (currTime - lastTime).asMilliseconds() > THRESHOLD ) {
    spritePos.x += dx;
    spritePos.y += dy;
    lastTime = currTime;
  }

}
```

Interaction = Event Handling

- Ways user can interact
  - Via keyboard
    - Key press
    - Key release
  - Via mouse
    - Button press
    - Button release
    - Mouse movement
  - And others (window minimize, lose focus, etc.)

Keyboard Interaction

- Can have user close window via keyboard

```
// in draw loop
while( std::optional event = window.pollEvent() ) {
  if( const sf::Event::KeyPressed * keyPressed =
                event->getIf<sf::Event::KeyPressed>() ) {
    if( keyPressed->scancode == sf::Keyboard::Scan::Q ) {
      window.close();
    }
  }
}
```

Mouse Clicks

- Have sprite jump to mouse click location

```
// in draw loop
while( std::optional event = window.pollEvent() ) {
  if( const sf::Event::MouseButtonPressed * mouseButtonPressed =
                    event->getIf<sf::Event::MouseButtonPressed>() ) {
    // mouseButtonPressed->button   - which button was pressed
    // mouseButtonPressed->position - mouse location when press occurred
  }
}
```

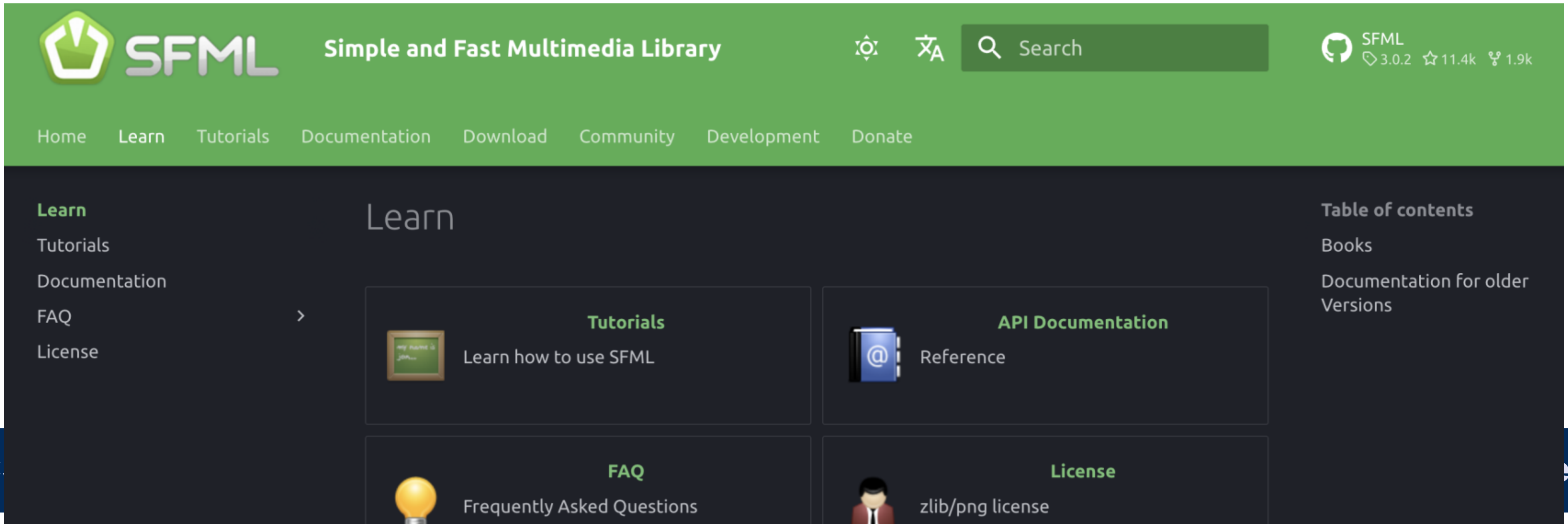
Event Handling

- Check all event types

```
while( std::optional event = window.pollEvent() ) {
  if( event->is<sf::Event::Closed>() ) {
    // close window
  } else if( const sf::Event::KeyPressed * keyPressed =
                 event->getIf<sf::Event::KeyPressed>() ) {
    // do something based on which key is pressed
  } else if( const sf::Event::MouseButtonPressed * mouseButtonPressed =
                 event->getIf<sf::Event::MouseButtonPressed>() ) {
    // do something based on mouse click location/button
  }
  // check other events that could occur
}
```

SFML Documentation

- Tutorials: https://www.sfml-dev.org/tutorials/3.0/
- API Documentation: https://www.sfml-dev.org/documentation/3.0.2/
- FAQ: https://www.sfml-dev.org/faq.php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Documentation for older Versions

Building Against SFML – Makefile

```
# if not placed in system folders
# location where SFML headers are
INC_PATH = Z:\CSCI200\include
# location where SFML archive files are
LIB_PATH = Z:\CSCI200\lib

# name of archive files to load
LIBS = -lsfml-window -lsfml-graphics -lsfml-system -lsfml-audio -lsfml-network
```

On Tap For Today

- Using Libraries
- The SFML Library
- Practice

To Do For Next Time

- L4C
  - Build and install SFML on your machine
  - OS dependent but cross-platform
  - YMMV – ask for help on Ed!
- A4
  - Draw balls bouncing around the screen
  - Add/remove balls
- Ask for help on Ed about setting up SFML!