CSCI 104
Qt Intro

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Qt

- What is QT?
  - Pronounced “cute”
  - An cross-platform application development framework built by Nokia
  - A toolkit for building Graphical User Interfaces (GUIs)
  - GUI toolkits are composed of many classes including many widgets
    - "Widget" is GUI-lingo for a 'control' or graphical component that a user can interact with
- QT has bindings available for many languages
  - C++, Python, Ruby, Java, etc.
- We are using QT v4.8.1

QApplication

- Every major QT widget has its own header
  - See QPushButton in the example
- QApplication
  - The main class that controls all the default GUI behavior and manages application resources
  - Every QT GUI application **must** have a QApplication instance (**and only one**!)
  - QApplication parses the command line input and pulls out any display-related parameters
  - A QApplication must be created **before** any GUI-related features can be used

```
#include <QApplication>
#include <QPushButton>

int main(int argc, char *argv[])
{
 QApplication app(argc, argv);
 QPushButton button("Hello world!");

 button.show();
 return app.exec();
}
```

QPushButton

- QPushButton
  - A button object that you can click on
- QPushButton button("Hello World!");
  - Creates a clickable button on the GUI
  - We can only do this now that we already created a QApplication to handle all the backend stuff
  - The button is clickable just by nature
  - The button will have the text “Hello World” on it
  - There are all kinds of button function/display attributes we could set if we really wanted to
    - Color, Size, Text/Image, Animation, Border, etc.

```
#include <QApplication>
#include <QPushButton>

int main(int argc, char *argv[])
{
 QApplication app(argc, argv);
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 button.show();
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}
```

Display Widgets

- button.show();
  - Widgets are always invisible by default when they are created, you must call show() to display them
  - Calling show() on a widget also calls show on all the widgets it contains (all of its children)
    - Some widgets are merely containers for other widgets (i.e. a display grid that display other widgets in some tabular format)

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#include <QPushButton>

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 QPushButton button("Hello world!");

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}
```

Event-Driven Program Flow

- return app.exec();
  - At this point, main() passes control to the QT framework
  - exec() will not return until the window is terminated
- Question?
  - What happens to your code flow?
  - How do you get any other code to run?
  - Welcome to the world of event-driven programs
    - You write code (member functions) that is 'automatically' called/executed when an event occurs (e.g. click(), resize(), mouseOver(), …)
  - More on this later...

```
#include <QApplication>
#include <QPushButton>

int main(int argc, char *argv[])
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 button.show();
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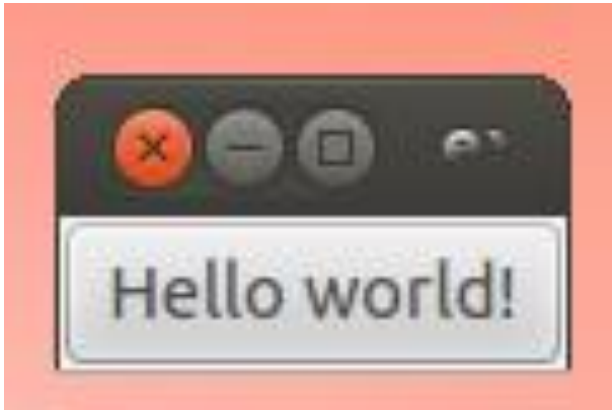
}
```

End Result

- All of this results in…




```
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#include <QPushButton>

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}
```

Compiling Qt Applications

- We can't just type 'g++ -o qtex qtex.cpp'. Why?
  - We have external dependencies that aren't part of standard C++
  - How will the compiler find the QT .h files?
  - How will the linker find the QT compiled code?
  - QT has to build Meta-Objects to handle communication between GUI pieces
  - The individual .cpp files need to compile and link separately in some cases
- 'make' and 'qmake' to the rescue
  - We've seen 'make' which helps us specify dependencies, compile order, and compiler commands
  - 'qmake' will examine code in the current directory and help to automatically generate a 'Makefile'

3-Step Qt Compiler Process

- Step 1: Generate a Qt project file with 'qmake'
  - $ qmake –project
  - The command will make Qt examine all the source code in the current directory and make a platform-independent project file (with a .pro extension) that specifies dependencies between your .h and .cpp files
- Step 2: Generate the platform dependent Makefile
  - $ qmake
  - This command will make QT read the .pro file from the current directory and generate a Makefile that contains all the commands for compiling the code and linking it with the QT libraries
- Step 3: Run 'make'
  - $ make
  - If you have any compiler or linker errors, this is the step in the process where you will see them
  - If you only need to recompile, you only need to use this particular step of the 3 step process

Qt Compilation Notes

- Keep each project in a separate directory (this is why we can run qmake with no arguments)
- If you add new .h or .cpp files, you need to re-run the entire compilation process (i.e. Make new .pro and Makefile files again)
- If your object needs slots or signals, then you MUST put it into separate .h and .cpp files
- If you're getting weird linker errors, try make clean or try rebuilding the .pro file and the Makefile
- You may notice that when you compile some projects with QT, it actually generate extra .cpp files
  - These extra files are generated by QT's **moc** (**Meta Object Compiler**)
  - QT makes extensive use of the preprocessor to generate code that makes things like its **signals** and **slots** mechanisms work
  - Don't bother changing these files. They'll just get overwritten next time you compile.

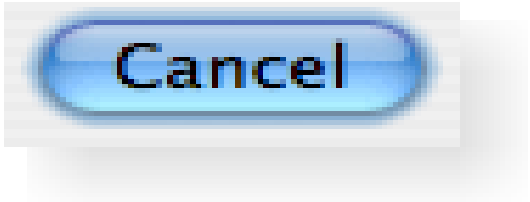
Qt Organization

- For your programming purposes, the QT windowing framework consists of three major parts (in reality, it's MUCH more complicated than this):
  - **Widgets**
  - **Layouts**
  - **Signals & Slots**

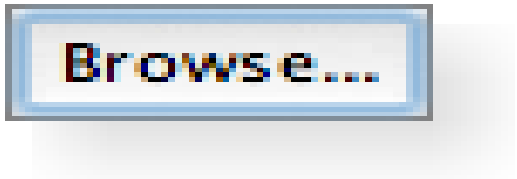
Qt Widgets

- What is a widget?
  - A user interface object that can process input, emit signals and draw graphics
  - A widget can be styled to have a vastly different appearance than its default
  - Most widgets generate signals that can be received by pieces of your code called slots
- QT comes pre-packaged with a ton of pre-made widgets to suit most of your GUI-building needs
  - Buttons, Containers, Menus, etc.

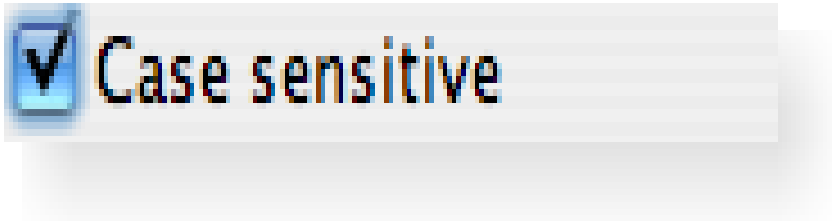
Qt Button Examples



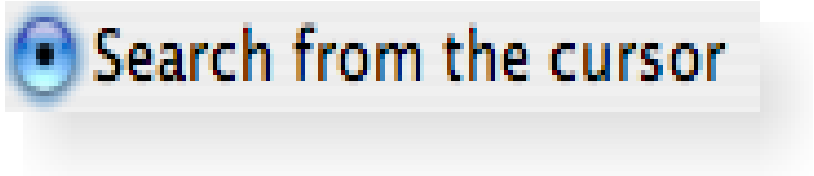
Push Buttons



Tool Buttons



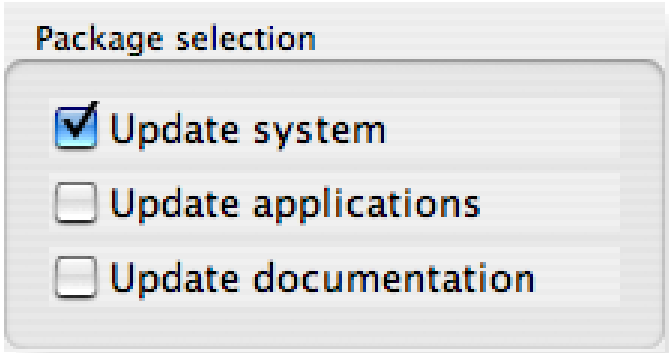
Checkboxes



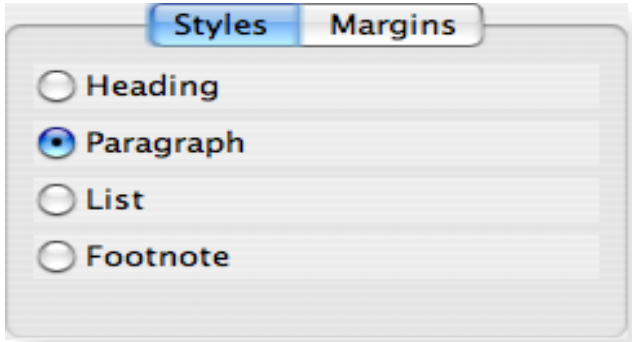
Radio Buttons

Images from http://doc.trolltech.com/4.3/gallery-macintosh.html

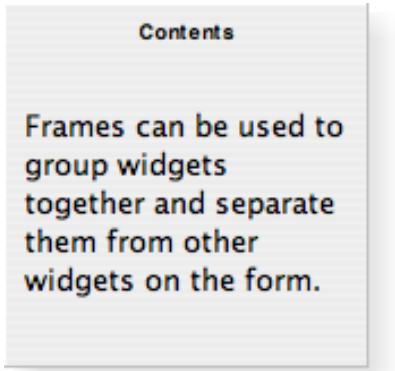
Container Examples



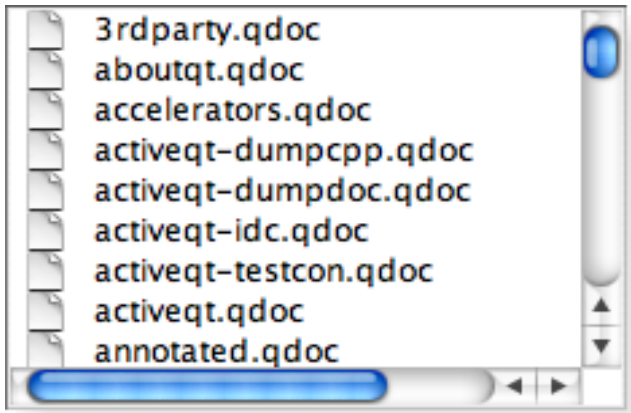
Group Boxes



Tabbed Displays



Frames



Scrolled Displays

Images from http://doc.trolltech.com/4.3/gallery-macintosh.html

User Input Widget Examples

Text Entry

Combo Boxes

Sliders

Spin Boxes

Calendars

Images from http://doc.trolltech.com/4.3/gallery-macintosh.html

Qt Layouts

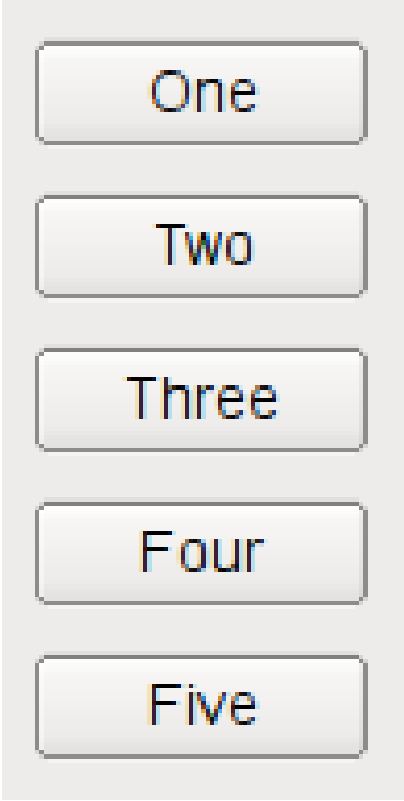
- What is a layout?
  - A layout describe how widgets are organized and positioned in a user interface
- The jobs of a QT layout
  - Positioning of widgets in GUI
  - Choosing sensible default and minimum sizes
  - Handling window resize events
  - Automatic updates when content changes
    - Font size, text or other widget changes
    - Add or removal of new widgets
    - Showing and hiding of existing widgets

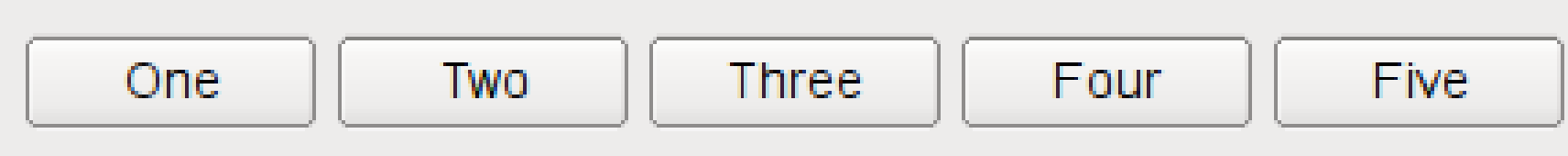
More About Layouts

- QT layouts and widgets share numerous parent/child relationships
  - **Widgets** can contain other **widgets** (usually in a layout)
  - **Widgets** can have one primary **layout** (which may contain many other child layouts)
  - **Layouts** can contain **widgets**
  - **Layouts** can contain other **layouts**
  - There can be a gigantic graph of parent and child relationships in a GUI
- The best way to make a complex layout is usually to combine many simpler layouts
- FYI: Getting a layout right is ***HARD***

Sample Layouts

- QVBoxLayout
  - Layout all children in a vertical column
  - (top to bottom or bottom to top)
- QHBoxLayout
  - Layout all children in a horizontal row
  - (left to right or right to left)





Images from http://qt.nokia.com/doc/4.5/layout.html

Layout Example Code

```
#include <QApplication>
#include <QPushButton>

int main(int argc, char *argv[])
{
  QApplication app(argc, argv);
  QWidget *window = new Qwidget;

  QPushButton *button1 = new QPushButton("One");
  QPushButton *button2 = new QPushButton("Two");
  QPushButton *button3 = new QpushButton("Three");

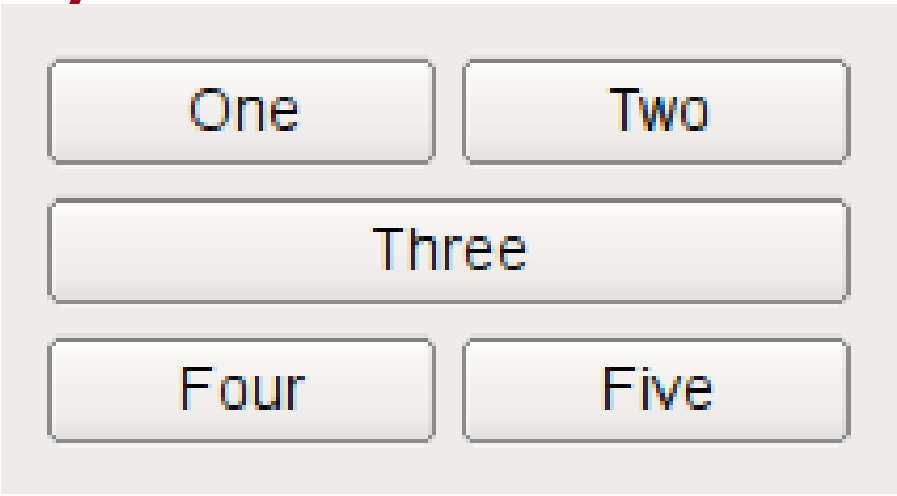
  QHBoxLayout *layout = new QHBoxLayout;
  layout->addWidget(button1);
  layout->addWidget(button2);
  layout->addWidget(button3);

  window->setLayout(layout);
  window->show();
  return app.exec();
}
```

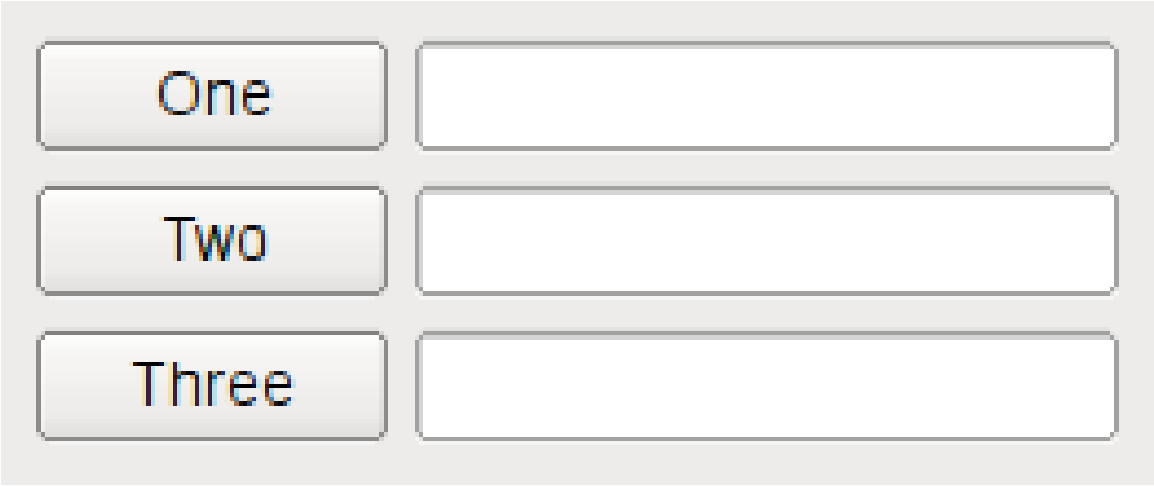
Code from http://qt.nokia.com/doc/4.5/layout.html

More Layouts

- QGridLayout
  - Layout widgets in a 2D grid
  - Widgets can span multiple rows/columns



- QFormLayout
  - Layout children in a 2-column descriptive label-field style.



Images from http://qt.nokia.com/doc/4.5/layout.html

Event-Based Programming

- GUI-based programs follow a different paradigm than basic command line programs
  - The window will sit there indefinitely until the user does something
  - Your code no longer functions on line-by-line flow, it is triggered by events
- In QT, all widgets are capable of firing events and receiving events
  - **Signals** are used to **notify (emit)** widgets of an event
  - **Slots** are used to **receive (listen for)** widget events
  - connect is used to tie together a signal & a slot
  - Signals & slots can have M-to-N connections

Qt Signals and Slots

- **Signals** and **Slots** provide communication between various object in your application
  - Often when one widget changes, you need another widget to know about it
- A **signal** emitter and a **slot** receiver never need to know about each other!
  - Widgets emit signals whether or not any other widgets are listening
    - e.g. **QPushButton** has a **clicked()** signal
  - Widgets slots listen for signals whether or not there are any being emitted
    - A slot is just a normal class member function!
    - e.g. Create a widget with a **handleClick()** slot

QT Signals & Slots

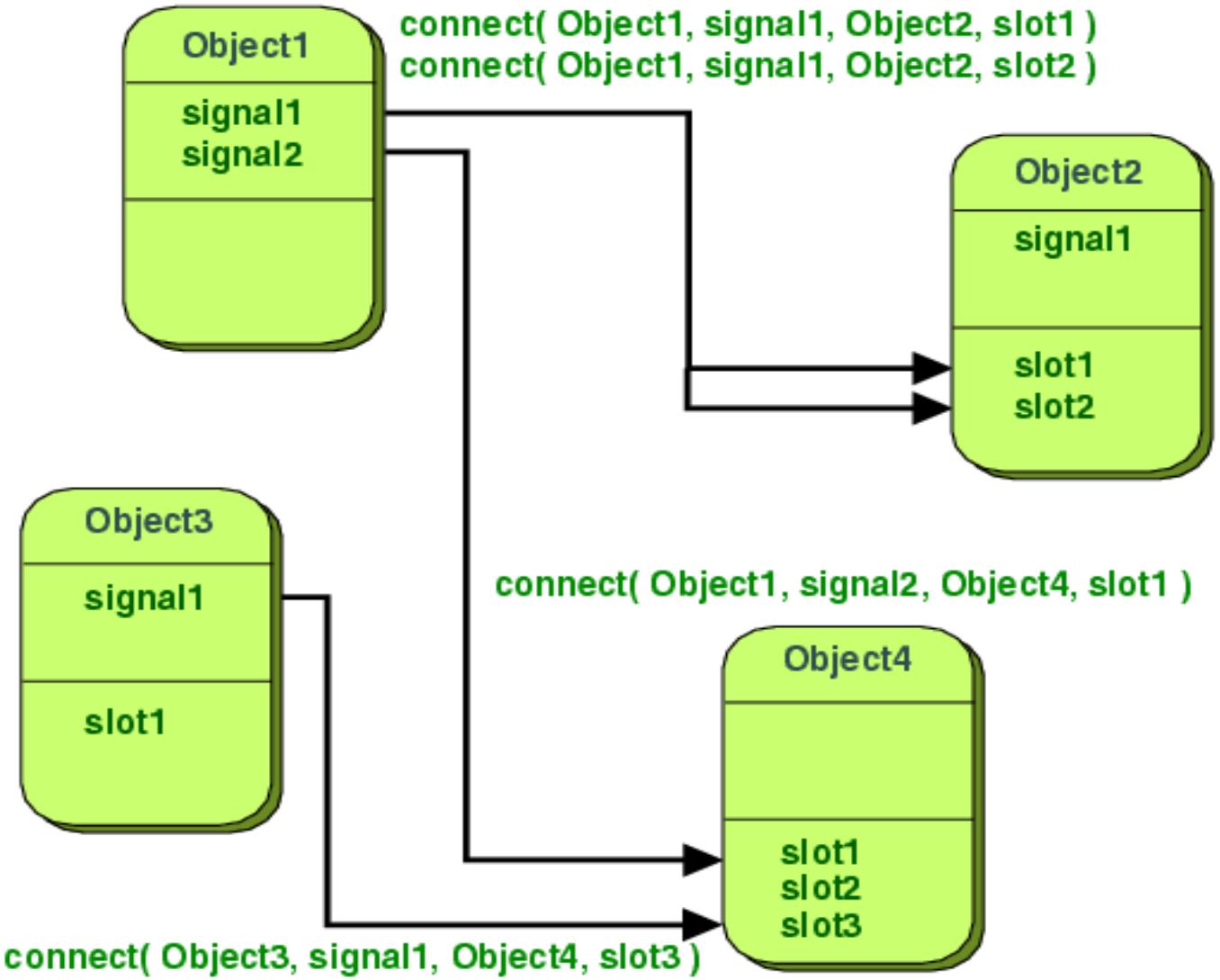


Image from http://doc.trolltech.com/4.6/signalsandslots.html

Qt Signal/Slot Example

```
#include <QApplication>
#include <QPushButton>
int main(int argc, char *argv[])
{
  QApplication app(argc, argv);
  QPushButton button("QUIT");

  //connect(object1 pointer, object1 signal,
  //              object2 pointer, object2 slot)
  QObject::connect(&button, SIGNAL(clicked()),
                   &app, SLOT(quit()));
  button.show();
  return app.exec();
}
```

Code from http://qt.nokia.com/doc/4.5/layout.html

QT Signals & Slots Summary

- Using event-driven programming in QT involves three major parts:
- 1. A widget with a **SIGNAL** to emit events when they occur (e.g. **clicked()** on QPushButton)
- 2. A widget with a **SLOT** to receive events that have been emitted (e.g. **quit()** on QApplication)
- 3. A **connect** statement to wire the signal and slot together so that when the signal is emitted, the slot receives it

Qt Tutorial

- A set of 14 example QT tutorials can all be found online here:

  http://doc.qt.digia.com/4.3/tutorial.html or

  http://web.njit.edu/all_topics/Prog_Lang_Docs/html/qt/tutorial.html

- Official? Qt Page
  - http://doc.qt.digia.com/stable/
  - http://qt-project.org/doc/qt-4.8/
- Other resources
  - http://www.zetcode.com/gui/qt4/

NEXT PART

Examples

- On your VM
  - Do a pull on your homework-resources repo and look for the qtex folder
  - OR
    - $ mkdir qtex
    - $ cd qtex
    - $ wget http://ee.usc.edu/~redekopp/cs104/qtex.tar
    - $ tar xvf qtex.tar
- 4 examples
  - Reflex (signals & slots)
  - Formex (Form example)
    - Inheritance…deriving new widgets
    - Layouts
  - Lec_ttt (Tic-Tac-Toe example)
  - Multiwin (Multi window example)

Reflex

- Hammer defines a signal function
  - A signal is a function that has no body
  - When you "call"/"emit" it, it will trigger other "connected" functions to be called
    - emit hit(hard)
- Knee defines a slot function
  - A slot function must match the prototype of the signal function that it will be connected to
  - You can do whatever you want in this function
- You must connect signals to slots via connect()
  - See reflex.cpp
- You can have multiple slot functions connected to 1 signal
  - Exercise: in reflex.cpp declare another 'knee' and connect it's reflex to the hammer's signal

Formex

- This program provides QLineEdit textboxes and buttons to prompt the user for their name and age and then saves that data out to a text file named 'data.txt'
- Think about layouts as tables within other tables
- http://doc.qt.io/qt-4.8/widgets-and-layouts.html

Layouts

- Four different layouts are commonly used
  - QVBoxLayout
  - QHBoxLayout
  - QFormLayout
  - QGridLayout
- Each widget (or derived class) can have only one Layout
  - Set by calling: widget->setLayout(*pointer to the layout)* method
- But a layout may contain either widgets or OTHER LAYOUTS in each of its entries
  - Set by calling: layout->addLayout(*pointer to child layout)*
  - Set by calling: layout->addWidget(*pointer to the child widget*)
- So for each widget think about whether you want to add items vertically or horizontally and pick a Vbox or Hbox Layout and then add child layouts within that context

More Notes

- Widgets have a virtual function sizeHint()
  - Qsize sizeHint() const;
  - If you want your widget to start at a particular size, add this to your class and simply have it return a Qsize object which is just pixel rows x columns
  - Qsize MYCLASS::sizeHint() const { return QSize(400, 400); }
- Defining your own signals
  - Signals go in the "signals:" section of your class
  - They are just prototypes (you don't write an implementation)
  - Use the 'emit' keyword followed by a "call" to this signal function
  - Whatever slot has been connected to this signal will in turn be called
- Events are not slots (think of them as "slots" that are pre-connected to certain actions/signals)
  - Just override them and usually call the BaseClass version

Tic-Tac-Toe Example

- $ cd lec_ttt
- Look up instructions on the 3 steps from our previous Qt lecture to setup and build/compile the project

Overall structure

- TTTButton models a single square in the grid and contains its type: Blank, Circle, Cross
- TTTBoard models the NxN tic-tac-toe grid
- TTT models the other controls of the game and UI

TTTButton

- Is a derived PushButton
- TTTButton models a single square in the grid and contains its type: Blank, Circle, Cross
  - setType() calls repaint()
  - Repaint() triggers paintEvent() which TTTButton overrides
- Examine TTTButton::paintEvent()
  - What if we don't call the base class version or change the ordering?

Q_OBJECT macro

- Helps Qt preprocessor define the .moc files (meta-objects)
  - If your class derives from a Qt widget/other GUI control or uses signals and slots you should place it in the definition
- Declare on a line (w/o a semicolon to follow)

TTTBoard

- Is derived from QWidget (because it contains other widgets, receives user input, and needs to be drawn/painted)
- Stores the TTT buttons and implements the move AI and win/lose/draw logic
- Examine GridLayout component which controls the display of the tic-tac-toe grid
- finished() signal (no definition)
  - Signals have no definitions in a .cpp file
  - Notice the emit statement in
- Connecting the clicks on buttons via buttonClicked
  - Notice the many-to-one relationship of TTT_Button::clicked() to TTT_Board::buttonClicked()
  - Look at buttonClicked() how do we determine which button was actually clicked?
- updateButtons
  - Notice setEnabled() call…What does that do?

TTT

- Models the overall UI and main window
- Is derived from QWidget (because it contains other widgets, receives user input, and needs to be drawn/painted)
- QVBoxLayout
  - Each widgeth is added via addWidget and gets slotted vertically
- QLabel: On screen text
- QComboBox
  - Items have an ID and a display string usually
  - Selected value from the user can be obtained with currentIndex()
- QPushButton
  - Notice we connect the signals and slots (some from TTT_Board, others from ourselves (i.e. TTT))
- newState() controls the string printed on the status label

main

- Instantiates a TTT widget and shows it (then enters the execution loop).

WIDGET REFERENCE

Overview

- The following slides represent a few commonly used widgets and some of their useful functions and signals
- Recall: A SLOT function can be called anytime as a normal function OR it can be connected as a SLOT (OR both)
- The online documentation for the Qt library is THE source to go to. Either google your widgets name or go here: http://qt-project.org/doc/qt-4.8/
  - http://doc.qt.io/qt-4.8/widgets-and-layouts.html

QLineEdit

- Provides a generic text box functionality
- Helpful methods
  - text()
    - Returns a QString of the text currently written in the textbox
    - Can convert a QString to a C++ string using toStdString()
  - setText(QString)
    - Changes the text displayed in the textbox to the argument provided
  - clear()
    - Deletes the text currently in the box

QComboBox

- Provides a DropDownBox functionality (list of items that can be displayed when you click the down array and then 1 item can be selected)
- Helpful methods
  - currentText()
    - Returns a QString of the selected item's text
  - addItem(QString)
    - Adds the string argument to the list of items to be displayed in the drop down box
- Useful Signals that you can connect to
  - currentIndexChanged(QString)
    - This signal will be emitted whenever a new item is selected in the drop down box…It will pass the text string of the newly selected item

QListWidget

- Provides a scrollable list of selectable text items
- Helpful Methods
  - clear()
    - Removes all the items in the list
  - insertItem(int pos, QString str)
    - Adds the text item, str, at position, pos, in the list
  - currentItem()
    - Returns a QListWidgetItem* of the currently selected item
  - item(int row)
    - Returns a QListWidgetItem* of the item on the row given by the argument
- Helpful signals
  - itemClicked(QListWidgetItem* item)
    - Will call connected SLOT functions whenever an item is clicked in the QListWidget and pass a pointer to the QListWidgetItem that was clicked.
    - You can retrieve the text of the clicked item by calling "`item->text()`"
- Other helpful functions
  - itemDoubleClicked(), removeItemWidget(), indexFromItem()

QPushButton

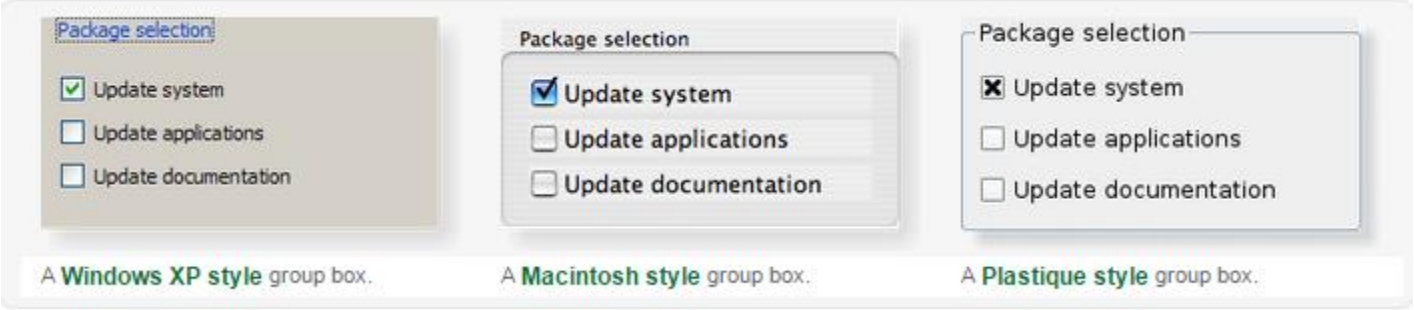
- Push/Command button functionality
- Helpful signals:
  - clicked()
    - Will call associated SLOT functions when clicked

QRadioButton

- Implements a 1-of-n selection…each radio button has an automatically associated text label to help the user
- All radio buttons with the same parent widget (usually a layout) will be mutually exclusive (only 1 can be on)
- Usually grouped radio buttons should be in a QGroupBox
  - setChecked(bool val)
    - Sets the radio button value to 'val' (true = on, false = off)

QGroupBox

- Provides a visual grouping of widgets in a boxed frame with a title
  - Title is the argument to the constructor of the QGroupBox
- Make a layout with everything you want to be in this framed area and then set the layout
  - QGroupBox* gb = new QGroupBox("Your Title")
  - // make a layout with all widgets you want in the framed area
  - gb->setLayout(your_layout);



http://qt-project.org/doc/qt-4.8/qgroupbox.html

QFormLayout

- Remember QFormLayout adds a text label and an arbitrary widget in a row-based layout

Other Useful Controls

- QCheckBox
  - Similar to radio buttons but without the restriction of 1-of-n being selected (many can be selected at a time)
- QTextEdit
  - For displaying multi-line text with auto line-wrapping, etc.