8th Advanced School on SCIENTIFIC VISUALIZATION

Advanced GUI development using Qt

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Agenda

- The Story of Qt
- Developing a Hello World Application
- Qt SDK
- Hands-On & Examples

Qt brief timeline

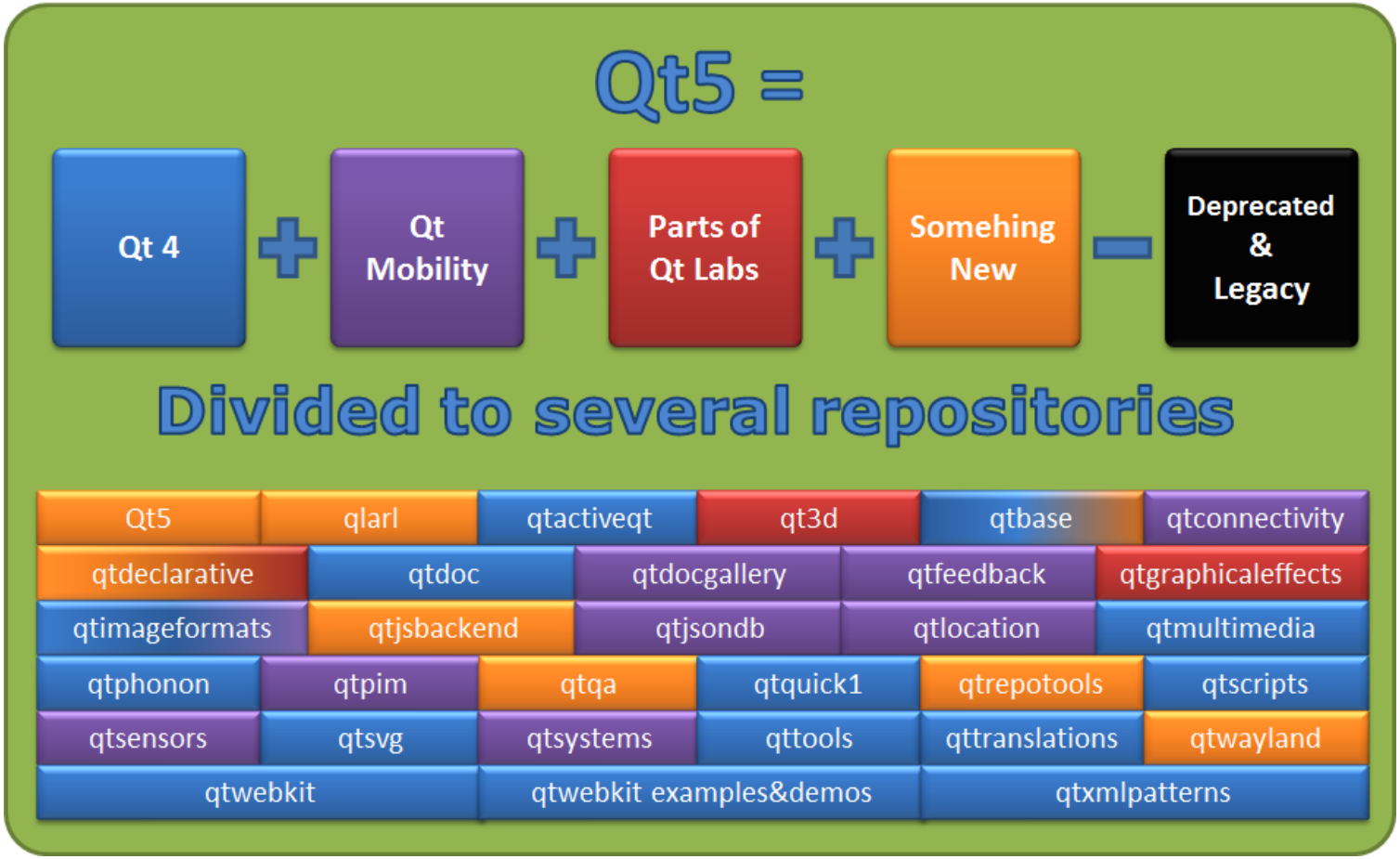
- Qt Development Frameworks founded in 1994
- Trolltech acquired by Nokia in 2008
- Qt Commercial business acquired by Digia in 2011
- Qt business acquired by Digia from Nokia in 2012
- Trusted by over 6,500 companies worldwide

- Qt: a cross-platform application and UI framework
- For desktop, mobile and embedded development
- Used by more than 350,000 commercial and open source developers
- Backed by Qt consulting, support and training

Why Qt

- Write code once to target multiple platforms
- Produce compact, high-performance applications
- Focus on innovation, not infrastructure coding
- Choose the license that fits you
  - Commercial, LGPL or GPL
- Count on professional services, support and training

Qt5 modules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“Hello world” in Qt /1 - Project files

Program consists of

- *main.cpp* - application code
- *helloworld.pro* - project file
  - lists source and header files
  - provides project configuration

“Hello world” in Qt /2

```
// main.cpp
#include <QtWidgets>
int main(int argc, char *argv[])
{
  QApplication app(argc, argv);
  QPushButton button("Hello world");
  button.show();
  return app.exec();
}
```

“Hello world” in Qt /3

```
# File: helloworld.pro
SOURCES = main.cpp
HEADERS += # No headers used
QT = core gui widgets
```

“Hello world” in Qt /4

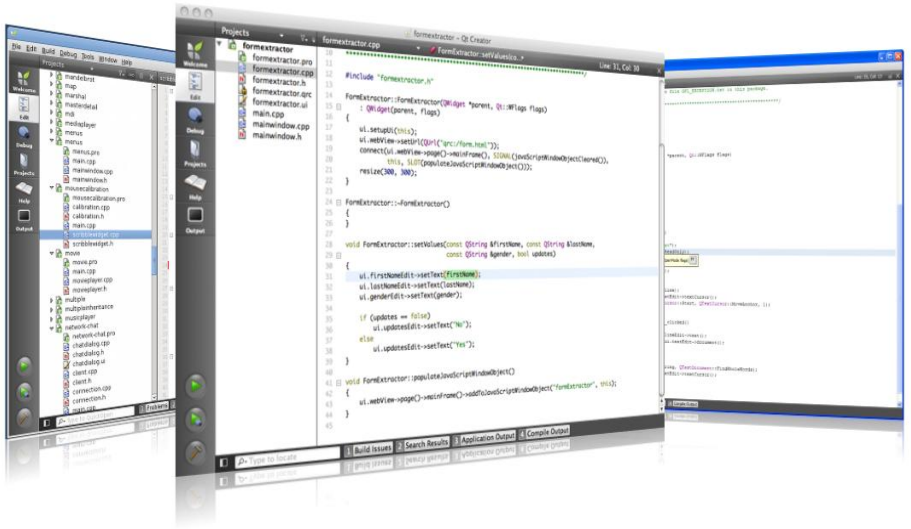
- qmake tool
- Creates cross-platform make-files

- Build project using qmake

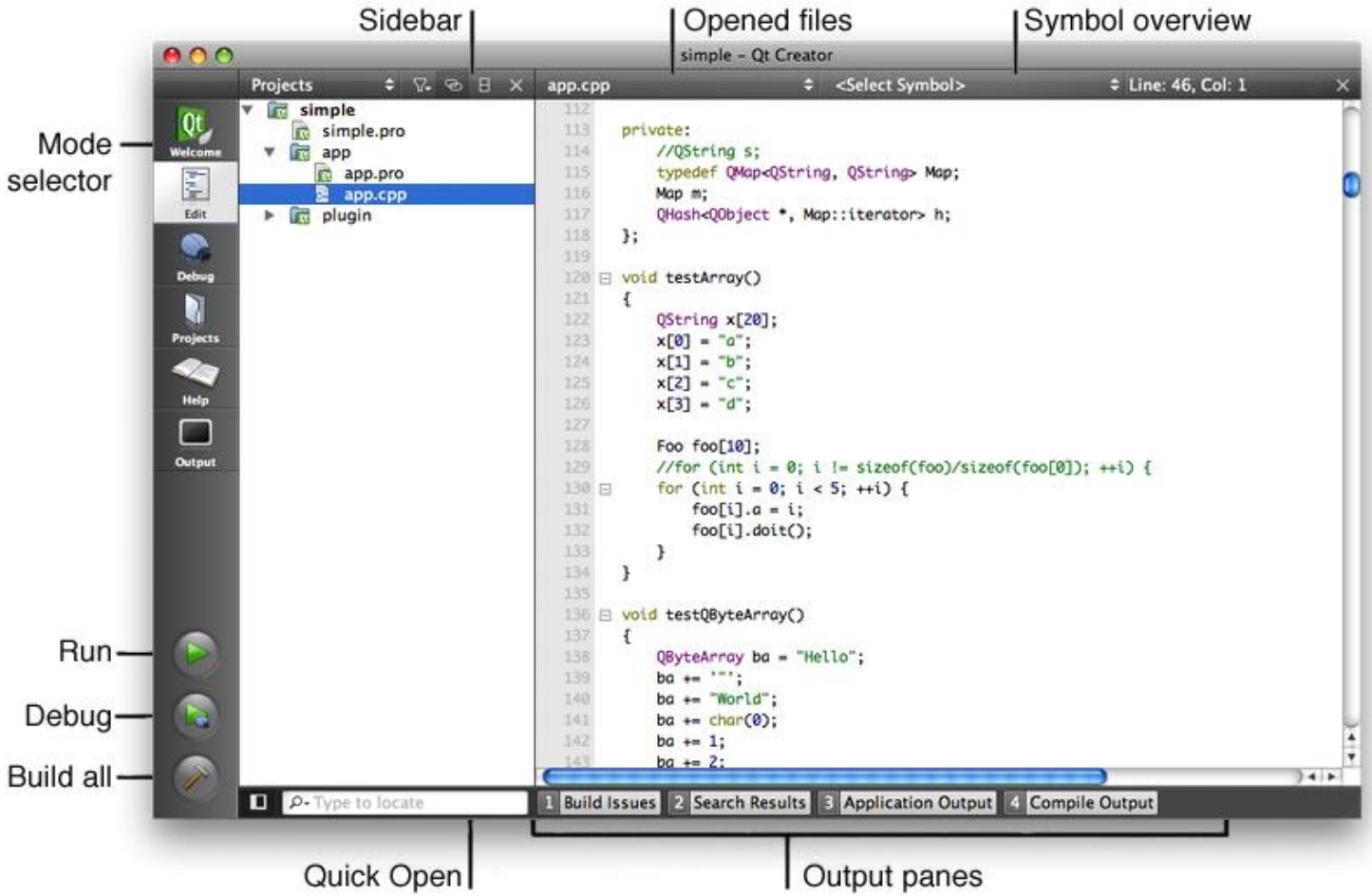
```
> cd helloworld
> qmake helloworld.pro # creates Makefile
> make # compiles and links application

> ./helloworld # executes application
```

QtCreator

- Advanced C++ code editor
- Integrated GUI layout and forms designer
- Project and build management tools
- Integrated, context-sensitive help system
- Visual debugger
- Rapid code navigation tools
- Supports multiple platforms



QtCreator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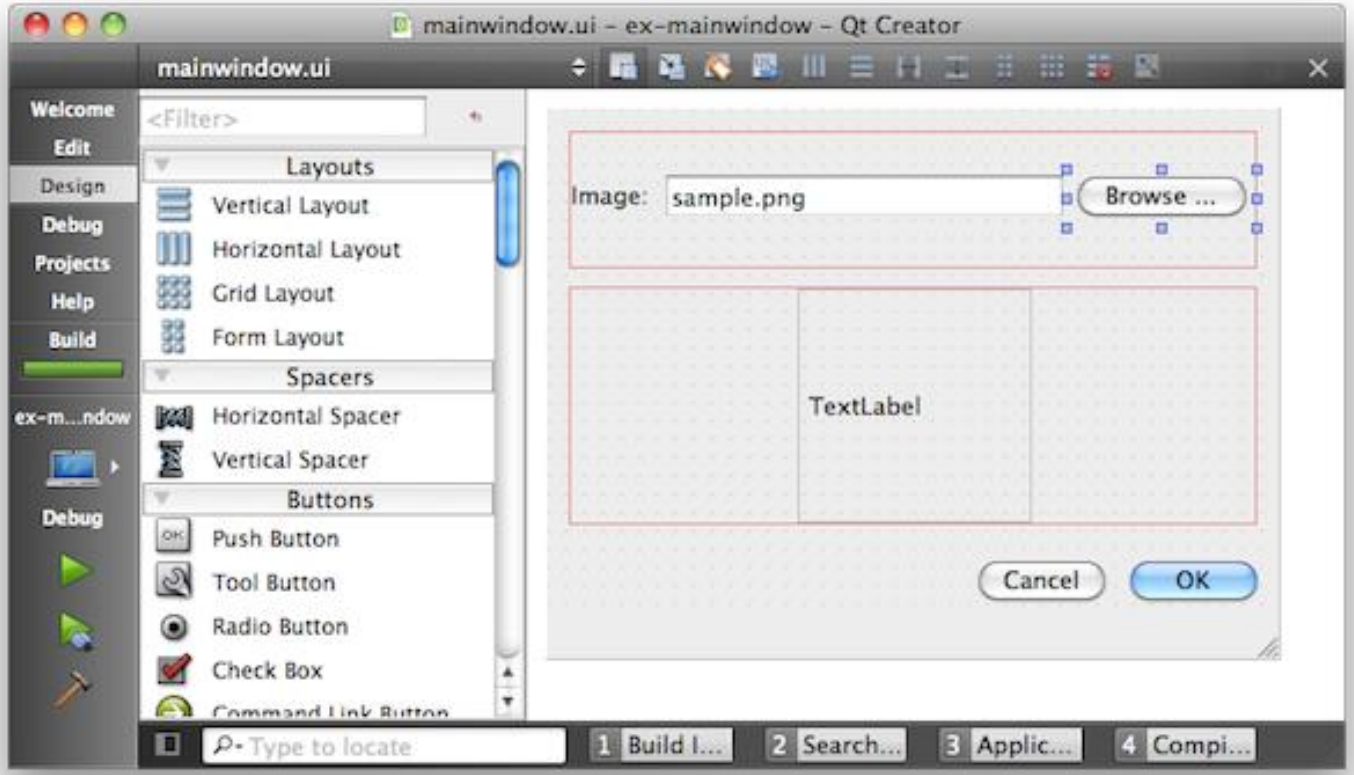
Qt Designer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Qt Object Communication

Object communication

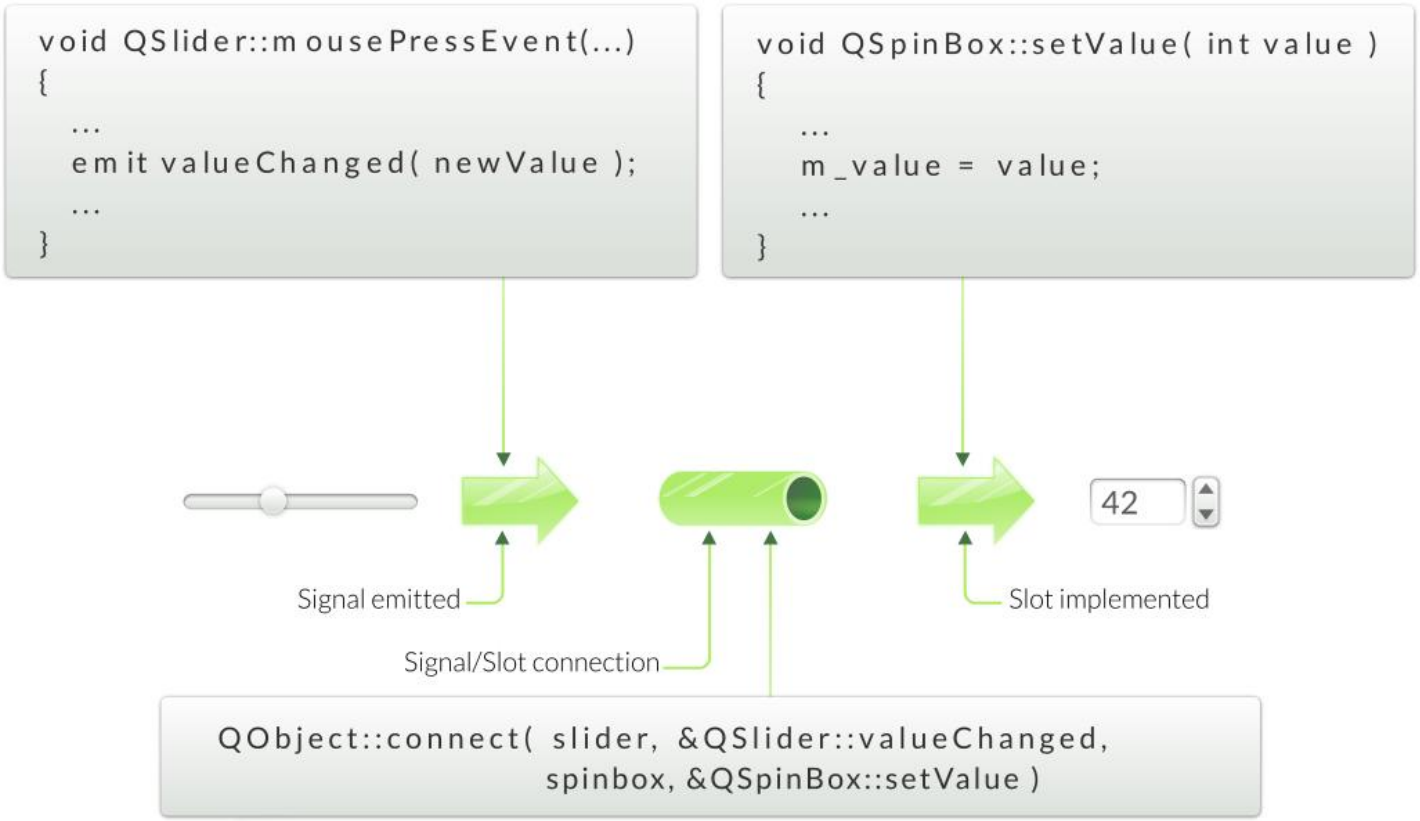
- Between objects
  Signals & Slots
- Between Qt and the application
  Events
- Between Objects on threads
  Signal & Slots + Events
- Between Applications
  DBus, QSharedMemory

Callbacks

General Problem
How do you get from "the user clicks a button" to your business logic?

- **Possible solutions**
  - Callbacks
    - Based on function pointers
    - Not type-safe
  - Observer Pattern (Listener)
    - Based on interface classes
    - Needs listener registration
    - Many interface classes
- **Qt uses**
  - Signals and slots for high-level (semantic) callbacks
  - Virtual methods for low-level (syntactic) events.

Signals & Slots



Connection variants

- Qt 4 style:

```
connect(slider, SIGNAL(valueChanged(int)),
        spinbox, SLOT(setValue(int)));
```

- Qt 5, using function pointers:

```
connect(slider, &QSlider::valueChanged,
        spinbox, &QSpinBox::setValue);
```

- Using non-member function:

  static void **printValue**(int value) {...}

```
connect( slider, &QSignal::valueChanged, &printValue );
```

Custom slots

- File: **myclass.h**

```
class MyClass : public QObject
{
    Q_OBJECT // marker for moc
    // ... your methods
    public slots:
    void setValue(int value); // a custom slot
};
```

- File: **myclass.cpp**

```
void MyClass::setValue(int value)
{
    // slot implementation
}
```

Custom signals

- File: **myclass.h**

```
class MyClass : public QObject
{
    Q_OBJECT // marker for moc
    // ... your methods
    signals:
    void valueChanged(int value); // a custom signal
};
```

- File: **myclass.cpp**

```
// No implementation for a signal
```

- Sending a signal

```
emit valueChanged(value);
```

About connections

Rule for Signal/Slot Connection

Can ignore arguments, but not create values from nothing

Signals		**Slot**
rangeChanged(int,int)	V	setRange(int,int)
	V	setValue(int)
	V	update()
valueChanged(int)	V	setValue(int)
	V	update()
	X	setRange(int,int)
	V	setValue(float)*
textChanged(QString)	X	setValue(int)

* Though not for Qt4 connection types

Variations of Signal/Slot Connections

Signal(s)	Connect to	Slot(s)
one	OK	many
many	OK	one
one	OK	another signal

- Signal to Signal connection

```
connect(bt,    SIGNAL(clicked()),
        this,  SIGNAL(okSignal()));
```

- **Not** allowed to name parameters

```
connect(m_slider, SIGNAL( valueChanged( int value ))
        this,     SLOT(setValue(int newValue )))
```

Event processing

Qt is an event-driven UI toolkit
QApplication::exec() runs the event loop

1) Generate Events
    - by input devices: keyboard, mouse, etc.
    - by Qt itself (e.g. timers)
2) Queue Events
    - by event loop
3) Dispatch Events
    - by QApplication to receiver: QObject
        - Key events sent to widget with focus
        - Mouse events sent to widget under cursor
4) Handle Events
    - by QObject event handler methods

Event handling

- `QObject::event(QEvent *event)`
  - Handles all events for this object
- Specialized event handlers for QWidget:
  - `mousePressEvent()` for mouse clicks
- Accepting an Event
  - `event->accept()` / `event->ignore()`
    - Accepts or ignores the event
    - Accepted is the default
- Event propagation
  - Happens if event is ignored
  - Might be propagated to parent widget

Event handling

- **QCloseEvent** delivered to top level widgets (windows)
- Accepting event allows window to close
- Ignoring event keeps window open

```
void MyWidget::closeEvent(QCloseEvent *event)
{
    if (maybeSave())
    {
        writeSettings();
        event->accept(); // close window
    }
    else
    {
        event->ignore(); // keep window
    }
}
```

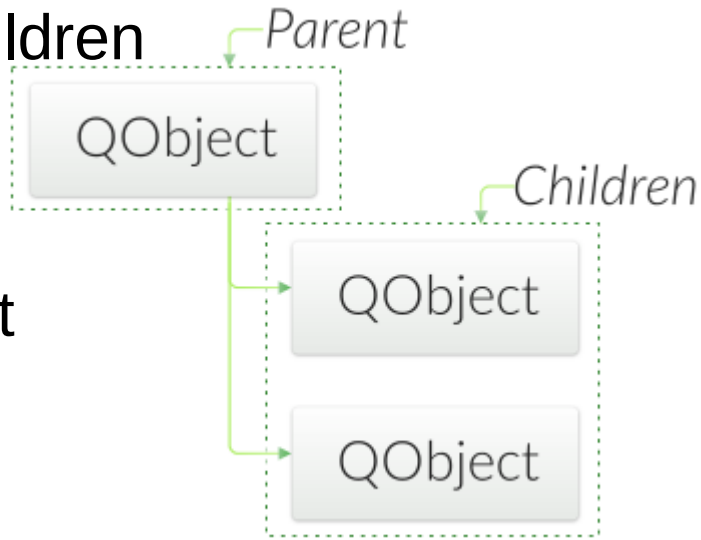
Core types

QObject

- QObject is the heart of Qt's object model
- Include these features:
  - Memory management
  - Object properties
  - Signals and slots
  - Event handling
- QObject has no visual representation

Object tree

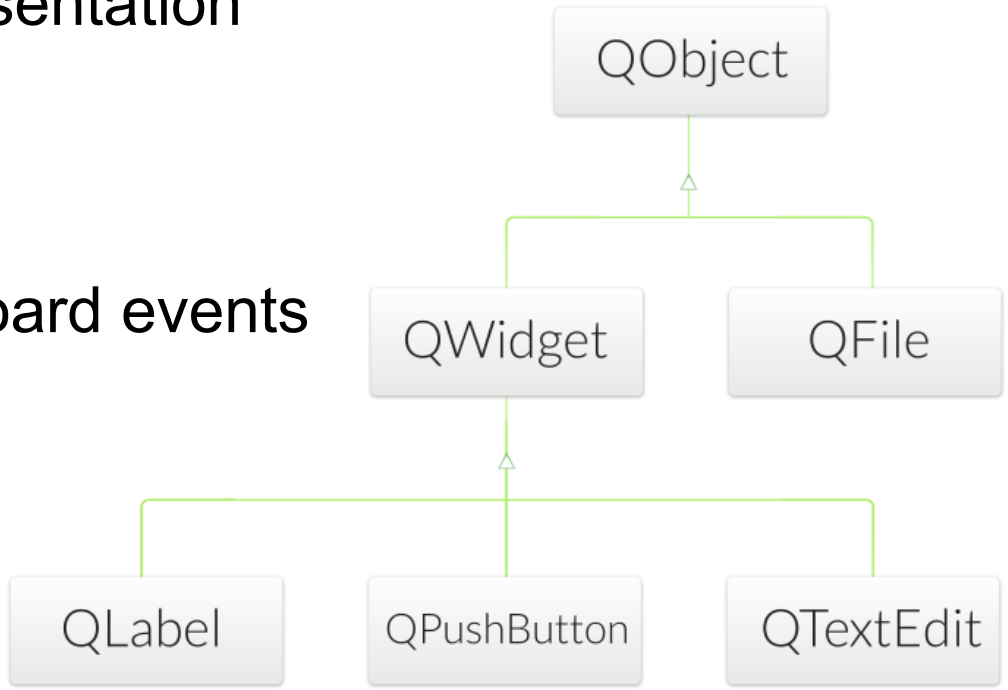
- QObjects organize themselves in object trees
  - Based on parent-child relationship
- `QObject(QObject *parent = 0)`
  - Parent adds object to list of children
  - Parent owns children
- Widget Centric
  - Used intensively with QtWidget



Note: Parent-child relationship is NOT inheritance

Qt's Widget Model - QWidget

- Derived from QObject
  - Adds visual representation
- Receives events
  - e.g. mouse, keyboard events
- Paints itself on screen
  - Using styles



Object Tree and QWidget

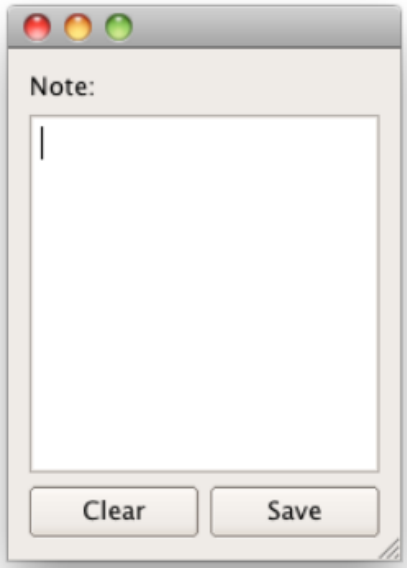
- `new QWidget(0)`
  - Widget with no parent = "window"
- QWidget's children
  - Positioned in parent's coordinate system
  - Clipped by parent's boundaries
- QWidget parent
  - Propagates state changes
  - hides/shows children when it is hidden/shown itself
  - enables/disables children when it is enabled/disabled itself

Widgets that contain other widgets

- Container Widget
  - Aggregates other child-widgets
- Use layouts for aggregation
  - **QHBoxLayout** and **QVBoxLayout**
  - Note: Layouts are not widgets
- Layout Process
  - Add widgets to layout
  - Layouts may be nested
  - Set layout on container widget

Example Container Widget

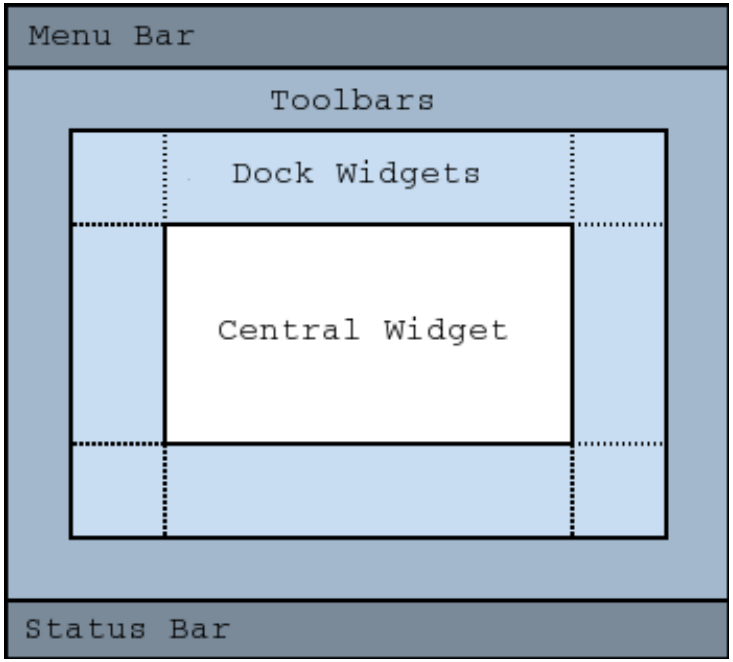
```
// container (window) widget creation
QWidget* container = new QWidget;
QLabel* label = new QLabel("Note:", container);
QTextEdit* edit = new QTextEdit(container);
QPushButton* clear = new QPushButton("Clear", container);
QPushButton* save = new QPushButton("Save", container);


// widget layout
QVBoxLayout* outer = new QVBoxLayout();
outer->addWidget(label);
outer->addWidget(edit);
QHBoxLayout* inner = new QHBoxLayout();
inner->addWidget(clear);
inner->addWidget(save);


container->setLayout(outer);
outer->addLayout(inner); // nesting layouts
```



Application creation

Main Window

- `QMainWindow`: main application window
- Has own layout
  - Central Widget
  - QMenuBar
  - QToolBar
  - QDockWidget
  - QStatusBar



- Central Widget
  - `QMainWindow::setCentralWidget( widget )`
  - Just any widget object

QAction

- Action is an abstract user interface command
- Emits signal triggered on execution
    - Connected slot performs action
- Added to menus, toolbar, key shortcuts
- Each performs same way
    - Regardless of user interface used

QAction /2

```
void MainWindow::setupActions()
{
    QAction* action = new QAction("Open ...", this);
    action->setIcon(QIcon(":/images/open.png"));
    action->setShortcut(QKeySequence::Open);
    action->setStatusTip("Open file");

    connect(action, SIGNAL(triggered()), SLOT(onOpen()));

    menu->addAction(action);
    toolbar->addAction(action);
}
```

Dialogs

QDialog

- Base class of dialog window widgets
- General Dialogs can have 2 modes:
  - **Modal dialog**
    - Remains in foreground, until closed
    - Blocks input to remaining application
    - Example: Configuration dialog
  - **Modeless dialog**
    - Operates independently in application
    - Example: Find/Search dialog

Modal dialog

- Modal dialog example

```
MyDialog dialog(this);
dialog.setMyInput(text);
if(dialog.exec() == Dialog::Accepted)
{
// exec blocks until user closes dialog
}
```

Modeless dialog

- Use show()
  - Displays dialog
  - Returns control to caller

```
void EditorWindow::find() {
    if (!m_findDialog) {
        m_findDialog = new FindDialog(this);
        connect(m_findDialog, SIGNAL(findNext()),
                              SLOT(onFindNext()));
    }
    m_findDialog->show(); // returns immediately
    m_findDialog->raise(); // on top of other windows
    m_findDialog->activateWindow(); // keyboard focus
}
```

Deploy your application

- Static Linking
  - Results in stand-alone executable
  - Only few files to deploy
  - Executables are large
  - No flexibility
  - You cannot deploy plugins
- Shared Libraries
  - Can deploy plugins
  - Qt libs shared between applications
  - Smaller, more flexible executables
  - More files to deploy
- Qt is by default compiled as shared library
- If Qt is pre-installed on system
  - Use shared libraries approach