LECTURE 17

GUI Programming

GUI PROGRAMMING

- Today, we're going to begin looking at how we can create GUIs (Graphical User Interfaces) in Python.

  So far, every application we've built has been console-based. If we want to create a user-friendly standalone application, we really must create a nice interface for it.

- As an example, we'll create an interface for the triangle peg game.

- First, let's see what packages are available to help us do this.

GUI PROGRAMMING IN PYTHON

There are a huge number of modules available to help you create an interface. Some of these include:

- Tkinter: wrapper around Tcl/Tk. Python's standard GUI.
- PyQt: bindings for the Qt application framework.
- wxPython: wrapper around wxWidgets C++ library.
- pyGTK: wrapper around GTK+.
- PyJamas/PyJamas Desktop
- etc.

CHOOSING A TOOLKIT

Toolkit	Important Points
Tkinter	- Limited theme support: "look" was relatively the same until recently. - Relatively limited widget options. - Bundled with Python since the beginning. - Most commonly used.
PyQt	- Limited licensing choices. - Very good docs - Very beautiful applications. - Huge! Both good and bad...
wxPython	- Very large user base. - Great widget selection. - Bad docs. - Not Python 3 compatible.
pyGTK	- Originally developed for GIMP. - Stable with a full selection of widgets. - Only offers theme-able native widgets on Windows + Linux. Mac lags behind somewhat. - Some quirks to work around (some C programming style).

PYQT

- In this class, we will be exploring basic GUI development with PyQt since it is a widely-used toolkit. However, the other mentioned options are all very good and it may be necessary to branch out depending on the complexity and/or needs of the application.

- First, we'll discuss some of the mechanics of GUI development. Afterwards, we could spend tons of class time learning about PyQt's ~1000 classes but we won't. What we'll do is build an application together and get familiar with the common parts of a PyQt application.

- As a note, we'll be using PyQt5 in this lecture.

GETTING PYQT5

- 1. Go to https://sourceforge.net/projects/pyqt/files/sip/ and grab sip-4.19.8.tar.gz.
- 2. Run the following commands to build and install SIP.

```
$ gunzip sip-4.19.8.tar.gz
$ tar -xvf sip-4.18.8.tar
$ cd sip-4.18.8/
$ python configure.py
$ make
$ sudo make install
```

GETTING PYQT5

- 1. Now go to https://sourceforge.net/projects/pyqt/files/PyQt5/ and grab PyQt5_gpl-5.10.1.tar.gz.
- 2. Run the following commands to build and install PyQt5.

```
$ gunzip PyQt5_gpl-5.10.1.tar.gz
$ tar -xvf PyQt5_gpl-5.10.1.tar
$ sudo apt-get install qt5-default
$ cd PyQt5_gpl-5.10.1
$ python configure.py
$ make          ← go get some coffee, this one will take a while!
$ sudo make install
```

- 3. Open up an interpreter and `import PyQt5` to make sure everything's working.

GUI PROGRAMMING IN PYQT

PyQt is a multi-platform GUI toolkit. It has approximately ~1000 classes divided into a set of ~38 modules. Among these are QtCore and QtGui – the most commonly used PyQt modules.

- **QtCore** contains the core classes, including the event loop and Qt's signal and slot mechanism. It also includes platform independent abstractions for animations, state machines, threads, mapped files, shared memory, regular expressions, and user and application settings.
- **QtGui** contains classes for windowing system integration, event handling, 2D graphics, basic imaging, fonts and text.
- **QtWidgets** contains classes that provide a set of UI elements to create classic desktop-style user interfaces.
- Besides these, there are other modules (like, QtNetwork and QtOpenGL) which focus on specific functionality.

GUI PROGRAMMING IN PYQT

- Programming a GUI is not that different than programming an object-oriented console application.

  What is different is that GUI programming involves the use of a *Toolkit* and GUI developers must follow the pattern of program design specified by the toolkit.

  As a developer, you should be familiar with the API and design rules of at least one toolkit – preferably one that is multiplatform with bindings in many languages!

GUI PROGRAMMING IN PYQT

- GUI programming necessarily means **object-oriented programming** with an **event-driven framework**. This should make sense: your job as a GUI developer is to create an application that responds to events.

  For instance, when a user clicks their mouse on a certain button, the program should do X. When the user presses enter in a text field, the program should do Y. You're defining the behavior of the program as a response to external events.

BASIC PYQT

- Let's dive right in by looking at an embarrassingly basic PyQt program.

```
from PyQt5 import QtWidgets

if __name__ == "__main__":
    app = QtWidgets.QApplication(sys.argv)
    main_window = QtWidgets.QWidget()
    main_window.show()
    app.exec_()
```

The QApplication class manages the application's control flow and main settings. It controls the main event loop through which all events are handled and scheduled. No matter how many windows there are, there is only one QApplication instance.

BASIC PYQT

- Let's dive right in by looking at an embarrassingly basic PyQt program.

```
from PyQt5 import QtWidgets

if __name__ == "__main__":
    app = QtWidgets.QApplication(sys.argv)
    main_window = QtWidgets.QWidget()
    main_window.show()
    app.exec_()
```

A **widget** is a control element which is visible and can be manipulated by the user. These include elements such as buttons, text fields, radio selections, etc.

If we create a basic widget QWidget instance without a parent widget, it automatically becomes a window.

BASIC PYQT

- Let's dive right in by looking at an embarrassingly basic PyQt program.

```
from PyQt5 import QtWidgets

if __name__ == "__main__":
    app = QtWidgets.QApplication(sys.argv)
    main_window = QtWidgets.QWidget()
    main_window.show()
    app.exec_()
```

QWidget implements a variety of methods for it and its derived classes. These include resize, move, setWindowTitle (for widgets with no parents), among many others.

Widgets and their children are created in memory and made visible with the show() method.

BASIC PYQT

- Let's dive right in by looking at an embarrassingly basic PyQt program.

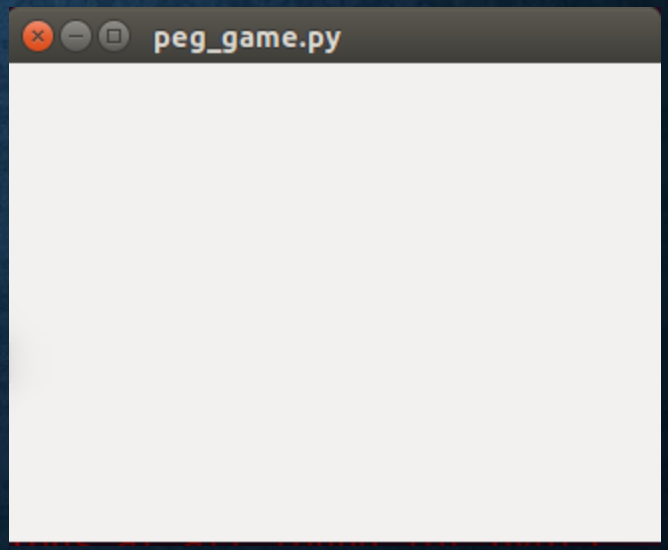
```
from PyQt5 import QtWidgets

if __name__ == "__main__":
    app = QtWidgets.QApplication(sys.argv)
    main_window = QtWidgets.QWidget()
    main_window.show()
    app.exec_()
```

Calling exec_() on our QApplication instance will start our main event loop.

BASIC PYQT

- Let's dive right in by looking at an embarrassingly basic PyQt program.

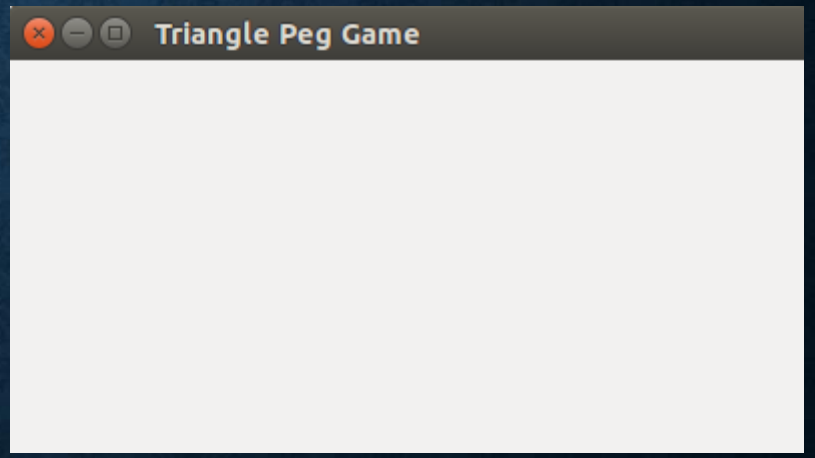
```
from PyQt5 import QtWidgets

if __name__ == "__main__":
    app = QtWidgets.QApplication(sys.argv)
    main_window = QtWidgets.QWidget()
    main_window.show()
    app.exec_()
```



BASIC PYQT

- Rather than the procedural approach we took before, we should try to define our interface in an object-oriented manner.

```
from PyQt5 import QtWidgets

class PegGameWindow(QtWidgets.QWidget):
    def __init__(self):
        QtWidgets.QWidget.__init__(self)
        self.setGeometry(200, 200, 400, 200)
        self.setWindowTitle('Triangle Peg Game')
        self.show()

if __name__ == "__main__":
    app = QtWidgets.QApplication(sys.argv)
    main_window = PegGameWindow()
    app.exec_()
```



QWIDGET

So, we can see that a parentless QWidget instance gives us a window, but the QWidget class is actually the base class for all UI elements. Some of the classes that inherit and extend QWidget include:

- QProgressBar
- QPushButton
- QCheckBox
- QScrollBar
- and many, *many more*

QWIDGET

- The QWidget class also defines some of the basic functionality common to all widgets.
- `QWidget.geometry()` **and** `Qwidget.setgeometry(x, y, w, h)`
- `QWidget.resize(w, h)`
- `QWidget.setParent(parent)`
- `QWidget.setToolTip(str)`, `QWidget.setStatusTip(str)`
- `QWidget.setPalette(palette)`

Check here for an exhaustive list. Not only is this not all of the methods defined – we're not even Including all the different *ways* you can call these methods!

BASIC PYQT


```
class PegGameWindow(QtWidgets.QWidget):
    def __init__(self):
        QtWidgets.QWidget.__init__(self)
        self.setGeometry(200, 200, 400, 200)
        self.setWindowTitle('Triangle Peg Game')
        self.setToolTip("Play the triangle peg game!")
        self.show()

if __name__ == "__main__":
    app = QtWidgets.QApplication(sys.argv)
    main_window = PegGameWindow()
    app.exec_()
```

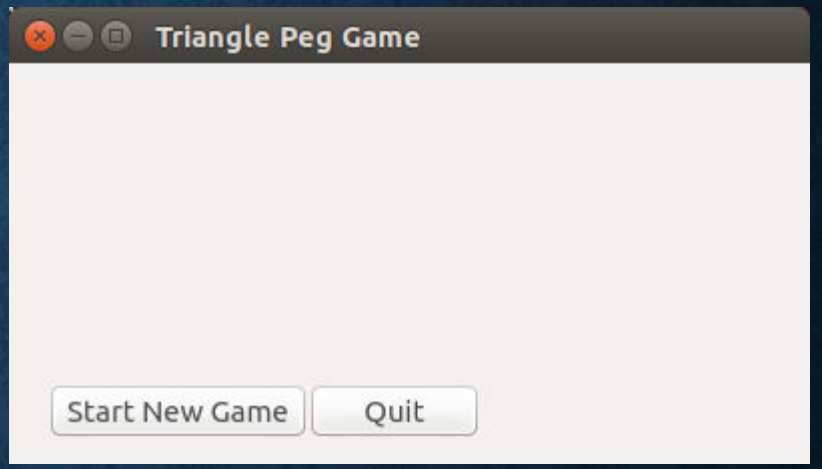
BASIC PYQT

- Let's make some buttons!

```
Class StartNewGameBtn(QtWidgets.QPushButton):
    def __init__(self, parent):
        QtWidgets.QPushButton.__init__(self, parent)
        self.setText("Start New Game")
        self.move(20,160)

class QuitBtn(QtWidgets.QPushButton):
    def __init__(self, parent):
        QtWidgets.QPushButton.__init__(self, parent)
        self.setText("Quit")
        self.move(150,160)
```

BASIC PYQT

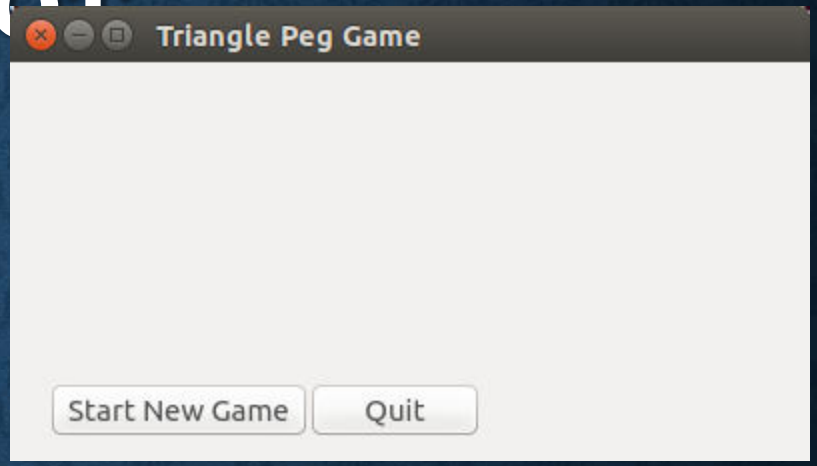
```
class PegGameWindow(QtWidgets.QWidget):
    def __init__(self):
        QtWidgets.QWidget.__init__(self)
        self.setup()
    def setup(self):
        self.setGeometry(200, 200, 400, 200)
        self.setWindowTitle('Triangle Peg Game')
        self.setToolTip("Play the triangle peg game!")
        self.new_button = StartNewGameBtn(self)
        self.quit_button = QuitBtn(self)
        self.show()
```



BASIC PYQT

Alternatively….

```
class PegGameWindow(QtWidgets.QWidget):
    def __init__(self):
        QtWidgets.QWidget.__init__(self)
        self.setup()

    def setup(self):
        self.setGeometry(200, 200, 400, 200)
        self.setWindowTitle('Triangle Peg Game')
        self.setToolTip("Play the triangle peg game!")
        self.new_button = QtWidgets.QPushButton("Start New Game", self)
        self.new_button.move(20, 160)
        self.quit_button = QtWidgets.QPushButton("Quit", self)
        self.quit_button.move(150, 160)
        self.show()
```



SIGNALS AND SLOTS

- PyQt5 makes use of a signal/slot mechanism for specifying the actions that should be taken when an event happens.
- A *signal* is emitted when a particular event occurs. Widgets already have many predefined signals, but you could also create custom signals on subclassed widgets.

Some common signals of `QPushButton` are:

- `QPushButton.clicked` – signal activated when button is pressed and then released while mouse is on button.
- `QPushButton.pressed` – signal activated when button is pressed.
- `QPushButton.released` – signal activated when button is released.

SIGNALS AND SLOTS

The example buttons we created earlier can be clicked, but nothing will happen. That's because we need to assign a *slot* to the signal.

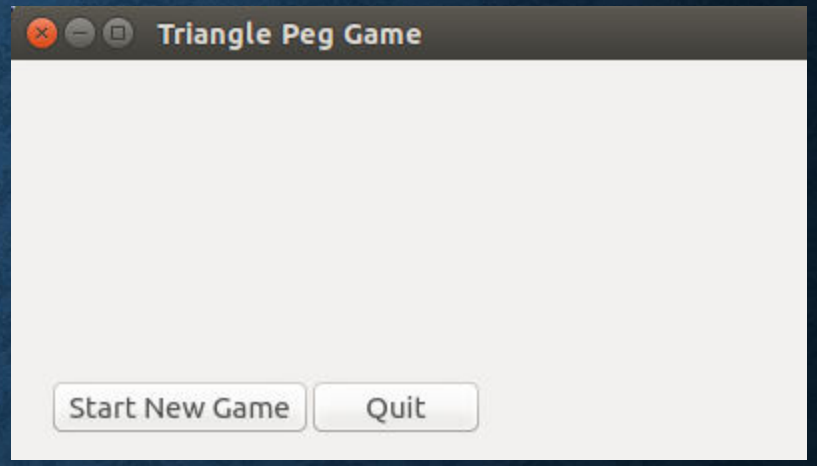
A slot is a function that is called in response to a particular signal. Widgets have many pre-defined slots, but because a slot can be any Python callable, we can easily define our own slots to define our reaction to the signal.

Let's try to make our Quit button exit the application. The slot we want to assign is:

```
QWidgets.qApp.quit()
```

Note that `QWidgets.qApp` is the `QApplication` instance running our program.

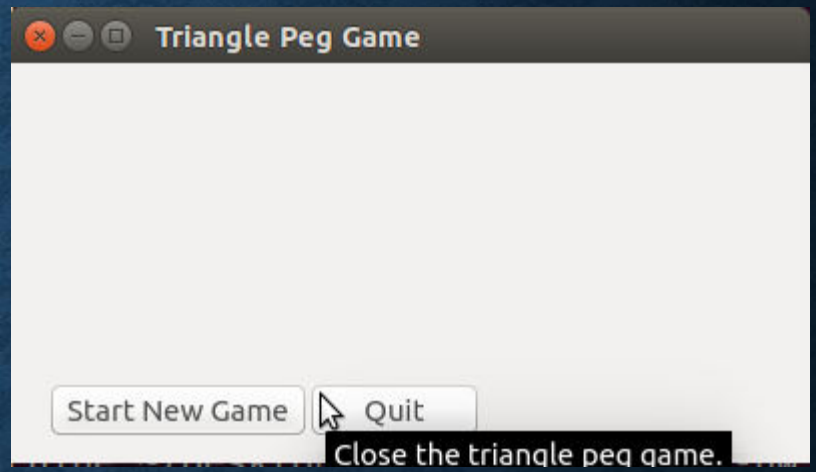
SIGNALS AND SLOTS




```
class QuitBtn(QtWidgets.QPushButton):
    def __init__(self, parent):
        QtWidgets.QPushButton.__init__(self, parent)
        self.setText("Quit")
        self.move(150,160)
        self.clicked.connect(QtWidgets.qApp.quit)
        self.setToolTip("Close the triangle peg game.")
```

Clicking quit now causes our window to close!

SIGNALS AND SLOTS




```
class QuitBtn(QtWidgets.QPushButton):
    def __init__(self, parent):
        QtWidgets.QPushButton.__init__(self, parent)
        self.setText("Quit")
        self.move(150,160)
        self.clicked.connect(QtWidgets.qApp.quit)
        self.setToolTip("Close the triangle peg game.")
```

Clicking quit now causes our window to close!

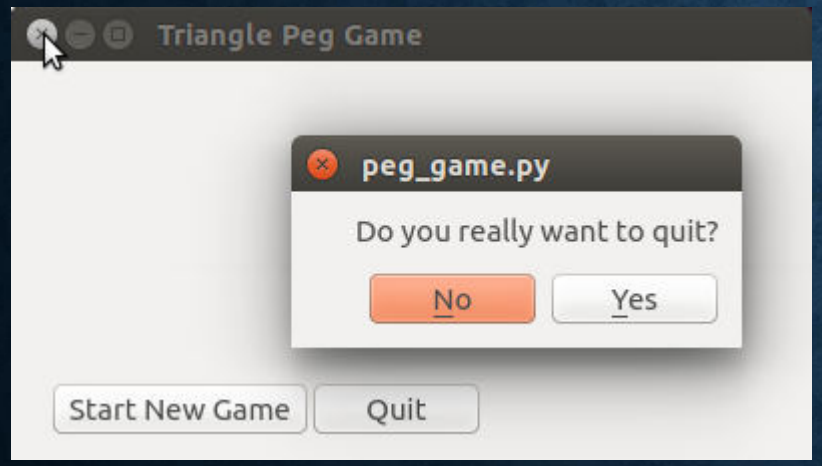
BASIC PYQT

We are also free to define the behavior of our application by overriding built-in methods.

For example, `QtWidgets.QWidget` has a method called `closeEvent()` which is called automatically with an instance of a window close request. By default, we just accept the request and close the window. Here, we'll override the function to ask if they're sure.

```
class PegGameWindow(QtWidgets.QWidget):
    def __init__(self):
        ...
    def setup(self):
        ...
    def closeEvent(self, event):
        reply = QuitMessage().exec_()
        if reply == QtWidgets.QMessageBox.Yes:
            event.accept()
        else:
            event.ignore()


class QuitMessage(QtWidgets.QMessageBox):
    def __init__(self):
        QtWidgets.QMessageBox.__init__(self)
        self.setText("Do you really want to quit?")
        self.addButton(self.No)
        self.addButton(self.Yes)
```

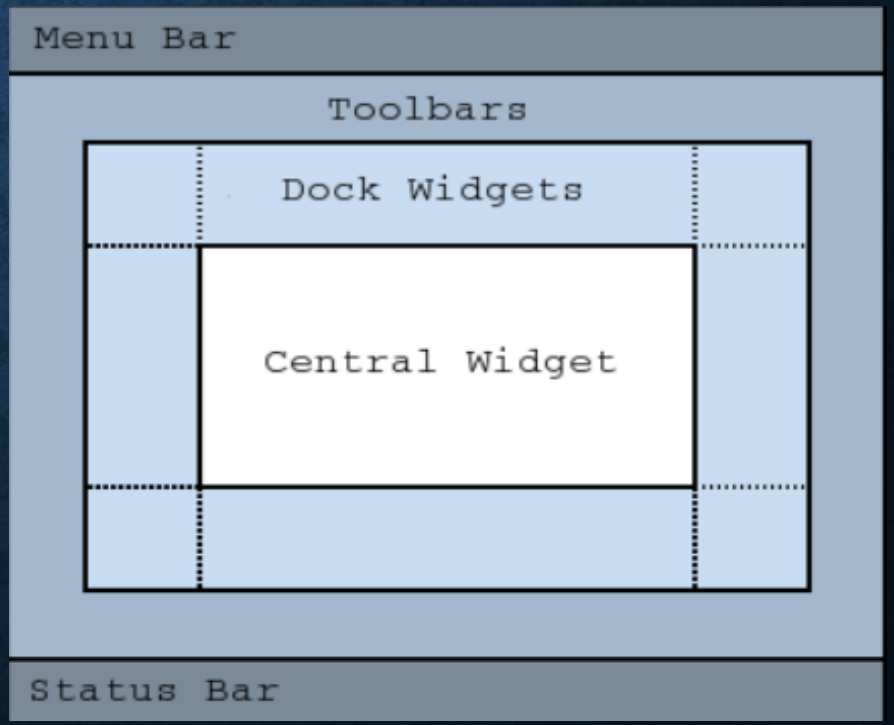
BASIC PYQT




```
class PegGameWindow(QtWidgets.QWidget):
    def __init__(self):
        ...
    def setup(self):
        ...
    def closeEvent(self, event):
        reply = QuitMessage().exec_()
        if reply == QtWidgets.QMessageBox.Yes:
            event.accept()
        else:
            event.ignore()


class QuitMessage(QtWidgets.QMessageBox):
    def __init__(self):
        QtWidgets.QMessageBox.__init__(self)
        self.setText("Do you really want to quit?")
        self.addButton(self.No)
        self.addButton(self.Yes)
```

QT MAIN WINDOW

- The `QtWidgets.QMainWindow` class provides a main application window. `QMainWindow` has its own layout as opposed to `QWidget` (but it inherits from `QWidget`).
- `QMainWindow` automatically makes room for:
- • `QToolBar`
- • `QDockWidget`
- • `QMenuBar`
- • `QStatusBar`
- • Any widget can occupy Central Widget.



BASIC PYQT

We're going to add a menu bar with a File > Exit action.

First, we create a `QAction` instance for exiting the application, for which the text is "Exit".

When the action is taken, we quit the application.

```
class PegGameWindow(QtWidgets.QMainWindow):
    def __init__(self):
        ...
    def setup(self):
        ...
        self.central_widget = QtWidgets.QWidget(self)
        self.new_button = StartNewGameBtn(self.central_widget)
        self.quit_button = QuitBtn(self.central_widget)
        self.setCentralWidget(self.central_widget)

        exit_action = QtWidgets.QAction('Exit', self)
        exit_action.triggered.connect(QtWidgets.qApp.quit)

        menu_bar = self.menuBar()
        file_menu = menu_bar.addMenu('File')
        file_menu.addAction(exit_action)

        self.show()
```

BASIC PYQT

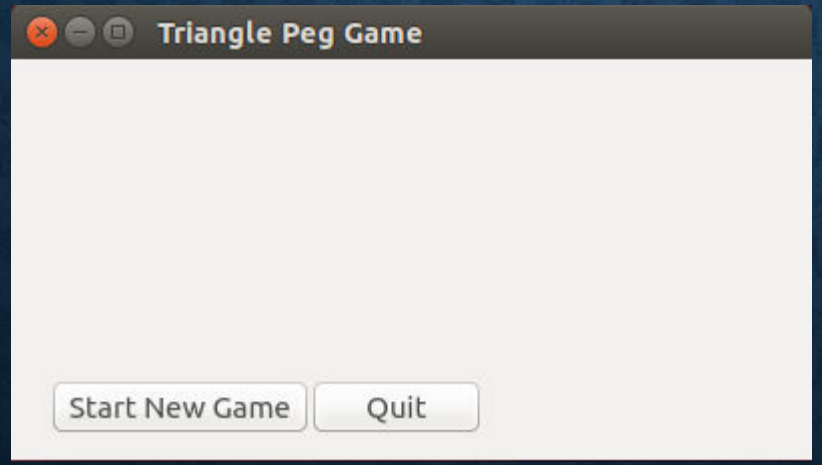
We reference the menu bar for our main window by calling menuBar(). This will also create and return an empty menu bar if there is none.

Then we add a new menu with the text "File". Then we add the Exit action to the File menu.

```
class PegGameWindow(QtWidgets.QMainWindow):
    def __init__(self):
        ...
    def setup(self):
        ...
        self.central_widget = QtWidgets.QWidget(self)
        new_button = StartNewGameBtn(self.central_widget)
        quit_button = QuitBtn(self.central_widget)
        self.setCentralWidget(self.central_widget)

        exit_action = QtWidgets.QAction('Exit', self)
        exit_action.triggered.connect(QtWidgets.qApp.quit)

        menu_bar = self.menuBar()
        file_menu = menu_bar.addMenu('File')
        file_menu.addAction(exit_action)

        self.show()
```

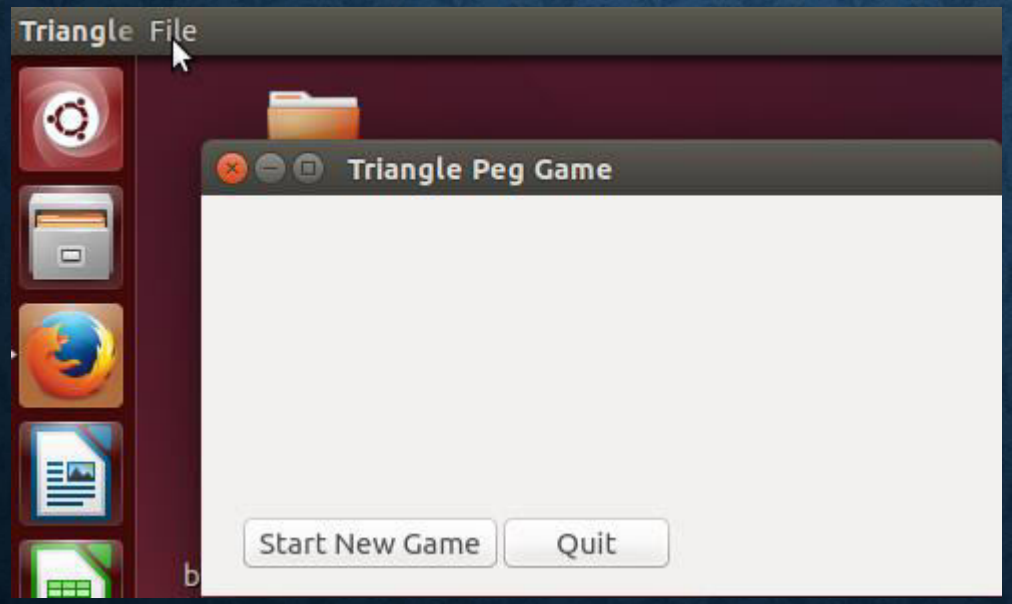
BASIC PYQT

- Where's our menu bar!?



BASIC PYQT

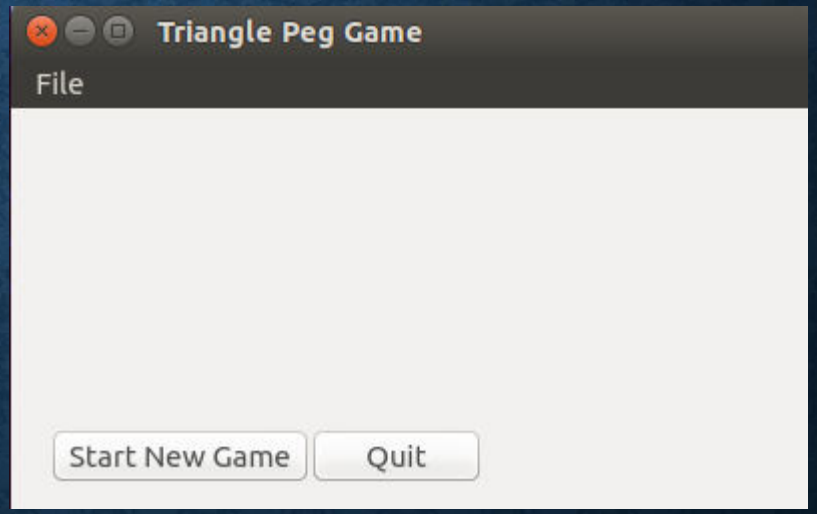
- Where's our menu bar!?



Very sneaky, Ubuntu…

BASIC PYQT

```
menu_bar = self.menuBar()
menu_bar.setNativeMenuBar(False)
file_menu = menu_bar.addMenu('File')
file_menu.addAction(exit_action)
```



LAYOUT MANAGEMENT

- Before we can add more components to our application, we need to talk about layout management in PyQt.

  The two options for managing the position of widgets are

- Absolute positioning
- Layout classes

  Absolute positioning is as simple as calling the `move()` method on a widget with some arguments that specify a position (x,y). This can be impractical for a few reasons. First, applications might look differently on different platforms (or even using different fonts) as they won't scale. Secondly, changes in layout will be much more tedious.

LAYOUT MANAGEMENT

Layout classes automatically position and resize widgets to accommodate space changes so that the look and feel is consistent.

Every `QWidget` subclass may have a layout specified which gives a widget control over:

- Positioning of child widgets.
- Sensible default sizes for widgets.
- Sensible minimum sizes for widgets.
- Resize handling.
- Automatic updates when contents change (font size, text or other contents of child widgets, hiding or showing a child widget, removal of child widgets).

LAYOUT MANAGEMENT

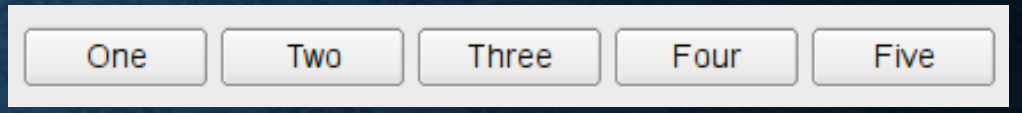
- There are a large number of layout classes but the most common include:
- Box Layout (`QBoxLayout`): lays out widgets in a horizontal row (`QHBoxLayout`) or vertical column (`QVBoxLayout`) from left-to-right or top-to-bottom.
- Grid Layout (`QGridLayout`): lays out widgets in a 2-D grid where widgets can occupy multiple cells.
- Form Layout (`QFormLayout`): layout class for managing forms. Creates a two-column form with labels on the left and fields on the right.

BOX LAYOUT

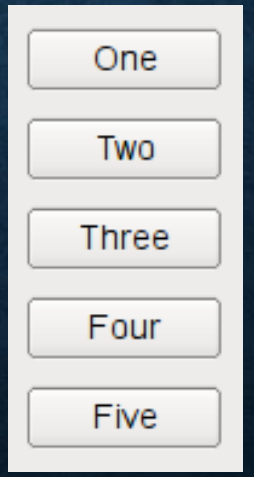
The `QBoxLayout` class lines up child widgets horizontally or vertically.

`QBoxLayout` will take a given space and divide it up into boxes that contain widgets.

- `QHBoxLayout` makes horizontal rows of boxes.



- `QVBoxLayout` makes vertical columns of boxes.



BOX LAYOUT

Once you create a box layout and attach it to a parent widget, the following methods are used to add child widgets and manage the space:

- `addWidget(widget, stretch=0)` to add a widget to the `QBoxLayout` and set the widget's stretch factor.
- `addSpacing(size)` to create an empty (non-stretchable) box with a particular size.
- `addStretch(stretch=0)` to create an empty, stretchable box.
- `addLayout(layout, stretch=0)` to add a box containing another `QLayout` to the row and set that layout's stretch factor.

Stretch factors indicate the relative amount of leftover space that should be allocated to a block.

GRID LAYOUT

- The Grid Layout class is the most universal, but we will use both Grid and Box layouts.

  A grid is represented with multiple rows and columns. Widgets can be attached to the grid by indicating the (row, column) space it should fill.

- Create a grid layout with `QtWidgets.QGridLayout()`.
- Attach widgets to the grid with `addWidget(`*`QWidget`*`, `*`row`*`, `*`column`*`)`.

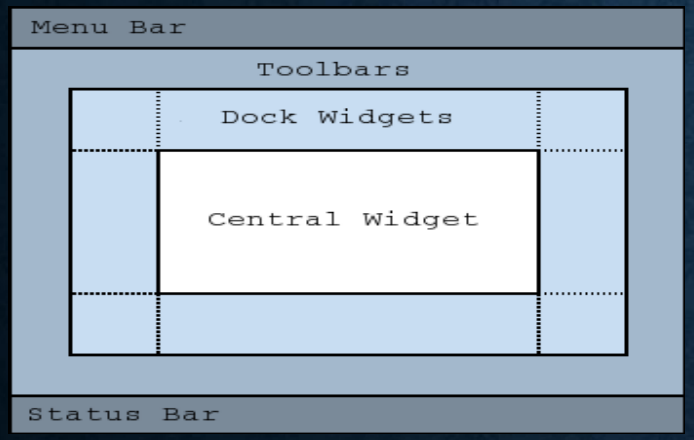
  You can also set the number of grid spaces that it should take up.

BASIC PYQT

Recall that `QMainWindow` includes a default layout for traditional GUI components like a menu bar, status bar, tool bar, etc. The focal point of the application is stored in the Central Widget of the layout.


```
class PegGameWindow(QtWidgets.QMainWindow):
    def __init__(self):
        ...
    def setup(self):
        ...
        self.central_widget = QtWidgets.QWidget(self)
        self.new_button = StartNewGameBtn(self.central_widget)
        self.quit_button = QuitBtn(self.central_widget)
        self.setCentralWidget(self.central_widget)

        exit_action = QtWidgets.QAction('Exit', self)
        exit_action.triggered.connect(QtWidgets.qApp.quit)

        menu_bar = self.menuBar()
        file_menu = menu_bar.addMenu('File')
        file_menu.addAction(exit_action)

        self.show()
```

BASIC PYQT



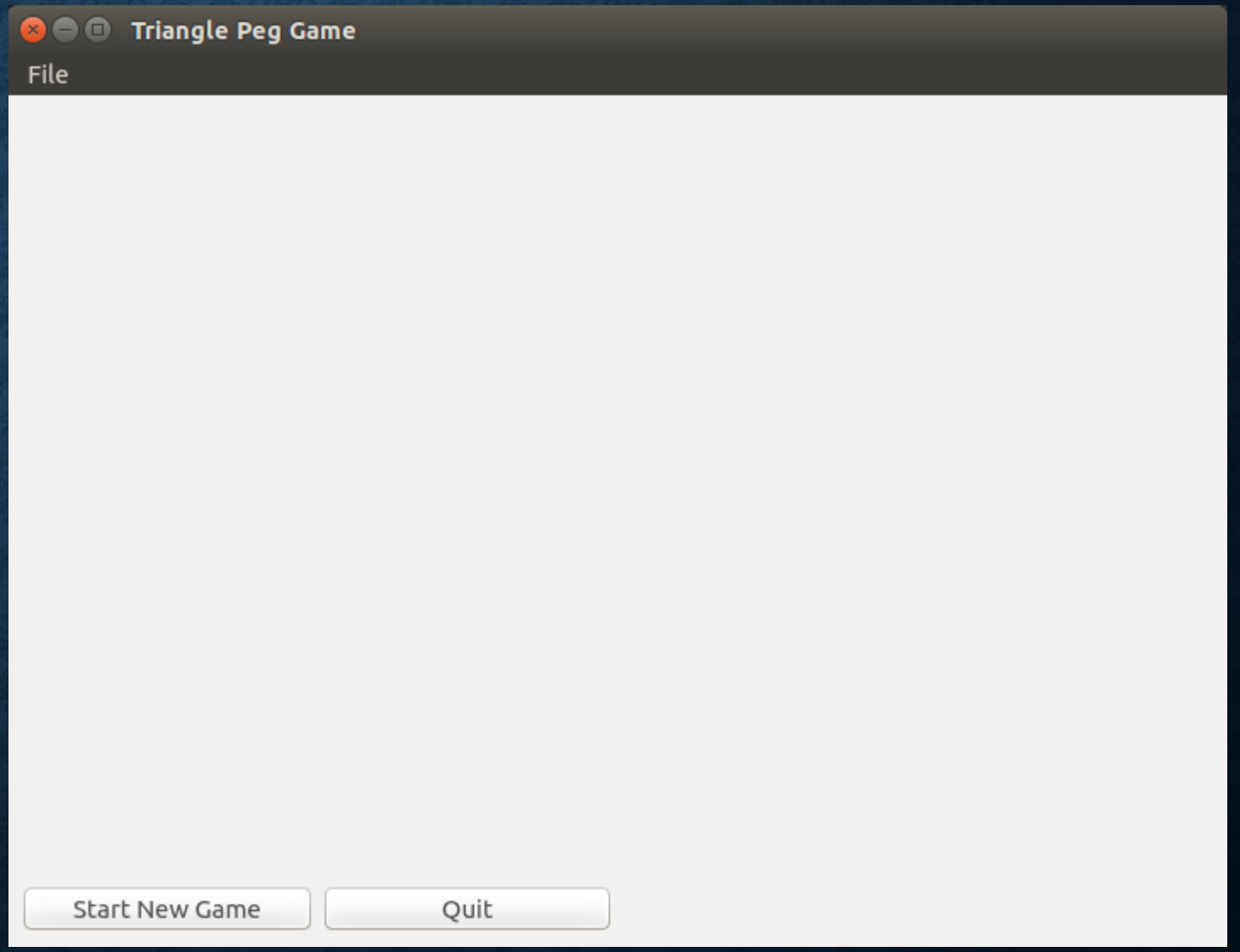

```
class PegGameWindow(QtWidgets.QMainWindow):
    def __init__(self):
        QtWidgets.QMainWindow.__init__(self)
        self.setup()

    def setup(self):
        self.setWindowTitle('Triangle Peg Game')
        self.setToolTip("Play the triangle peg game!")

        self.peg_game = PegGame(self)
        self.setCentralWidget(self.peg_game)
        ...
        self.show()
```

Let's really define what this central widget should look like. We'll create a new class called PegGame.

GRID LAYOUT

So what do we want PegGame to look like?

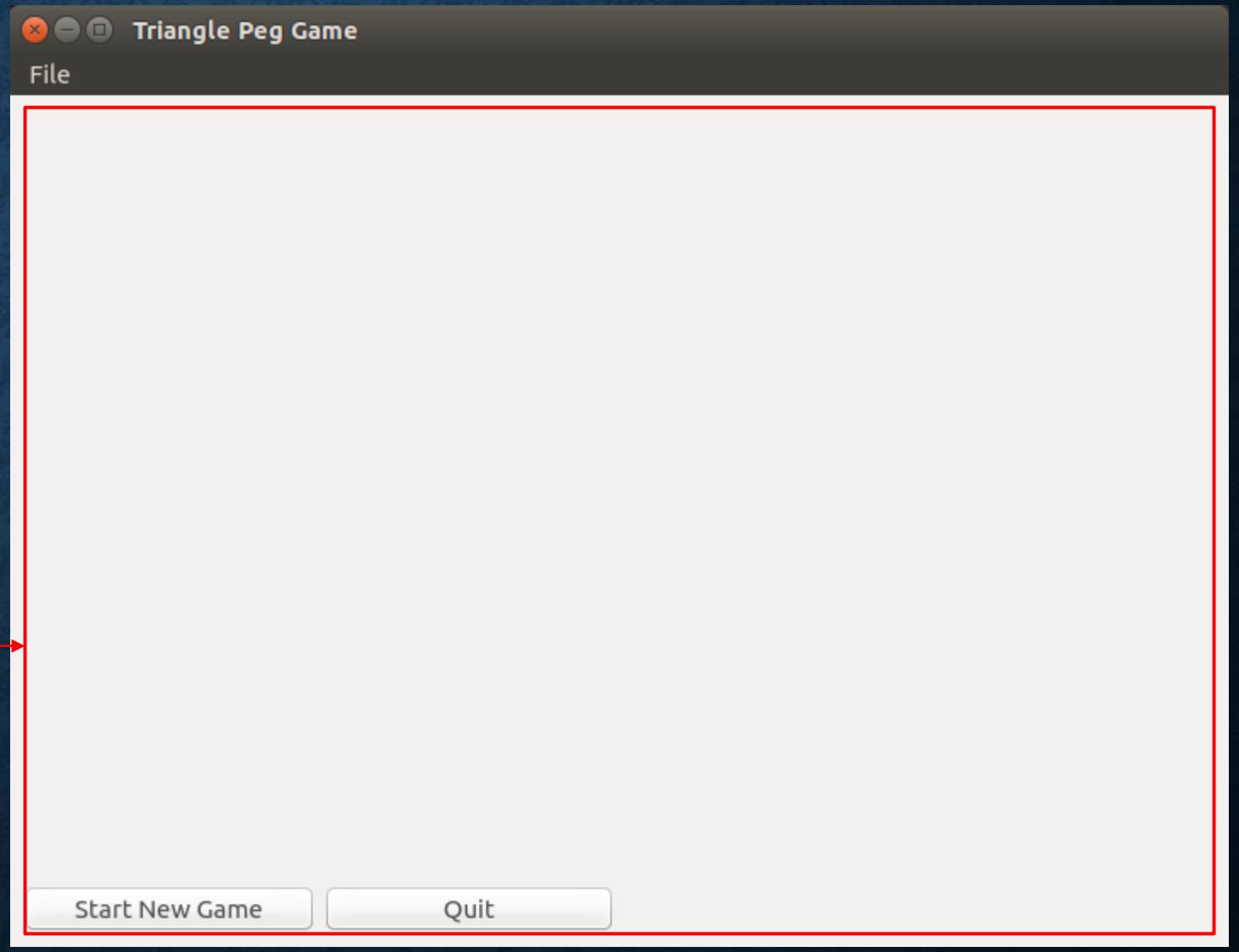
Well it's not too interesting. But let's point out the important details.



GRID LAYOUT

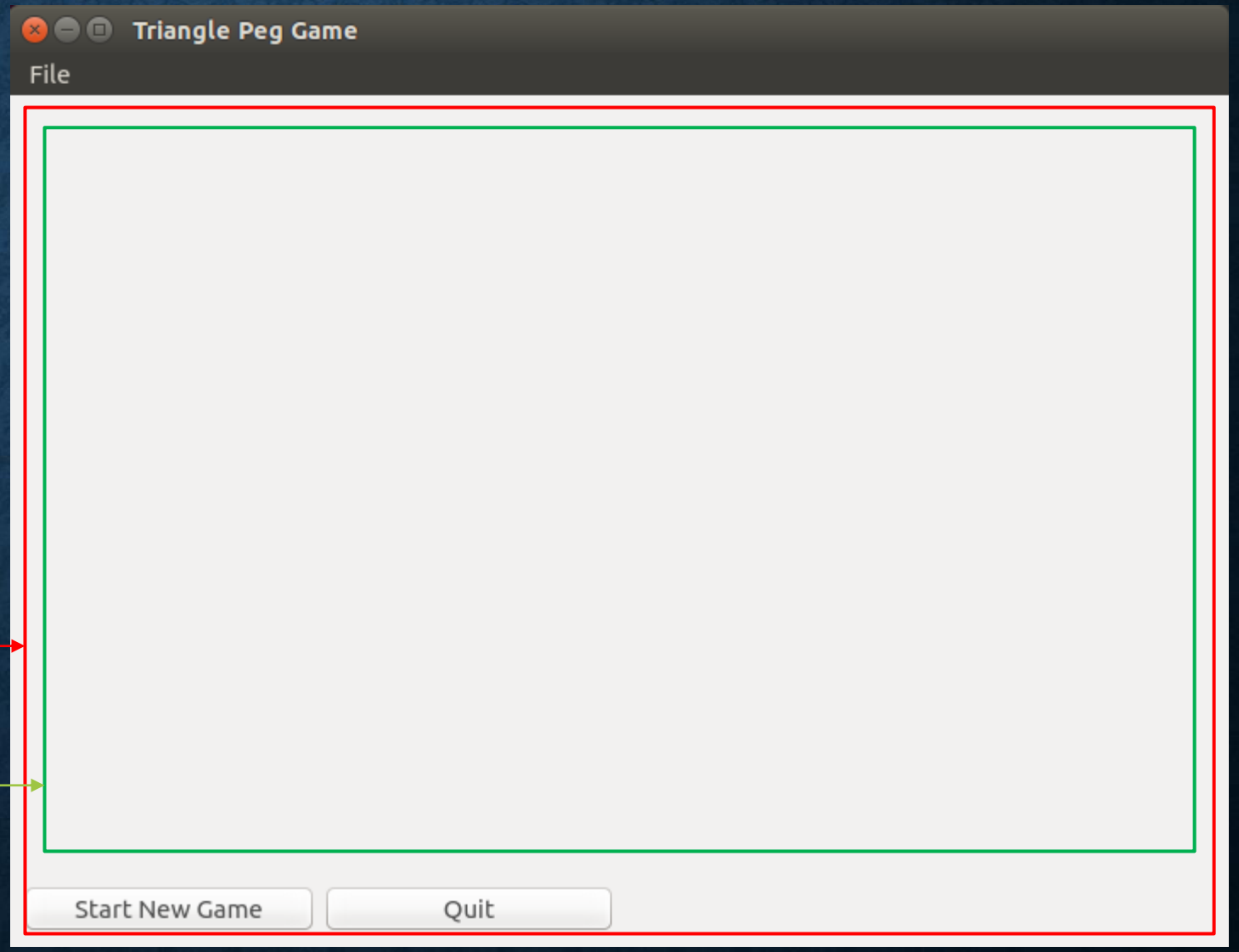
So what do we want PegGame to look like?

Well it's not too interesting. But let's point out the important details.



GRID LAYOUT

PegGame will contain three important components (at least, to start):
- PegBoard, which will house the board, pegs, etc.
- Start New Game Button
- Quit Button



GRID LAYOUT

So how do we define `PegGame`?

`PegGameWindow` has a built-in layout because it inherits from `QMainWindow`.

Our three components

`PegGame`, however, is a plain widget.
So we can associate a Grid layout with it.

```
class PegGame(QtWidgets.QWidget):
    def __init__(self, parent):
        QtWidgets.QWidget.__init__(self, parent)
        self.setup()

    def setup(self):
        self.board = PegBoard(self)
        self.new_btn = StartNewGameBtn(self)
        self.quit_btn = QuitBtn(self)
        self.grid = QtWidgets.QGridLayout()
        self.setLayout(self.grid)
        self.grid.addWidget(self.board, 1, 1, 1, 4)
        self.grid.addWidget(self.new_btn, 2, 1, 1, 1)
        self.grid.addWidget(self.quit_btn, 2, 2, 1, 1)
```

GRID LAYOUT

So how do we define `PegGame`?

```
class PegGame(QtWidgets.QWidget):
    def __init__(self, parent):
        QtWidgets.QWidget.__init__(self, parent)
        self.setup()

    def setup(self):
        self.board = PegBoard(self)
        self.new_btn = StartNewGameBtn(self)
        self.quit_btn = QuitBtn(self)
        self.grid = QtWidgets.QGridLayout()
        self.setLayout(self.grid)
        self.grid.addWidget(self.board, 1, 1, 1, 4)
        self.grid.addWidget(self.new_btn, 2, 1, 1, 1)
        self.grid.addWidget(self.quit_btn, 2, 2, 1, 1)
```

Creating and setting our grid layout

GRID LAYOUT

So how do we define `PegGame`?

```
class PegGame(QtWidgets.QWidget):
    def __init__(self, parent):
        QtWidgets.QWidget.__init__(self, parent)
        self.setup()

    def setup(self):
        self.board = PegBoard(self)
        self.new_btn = StartNewGameBtn(self)
        self.quit_btn = QuitBtn(self)
        self.grid = QtWidgets.QGridLayout()
        self.setLayout(self.grid)
        self.grid.addWidget(self.board, 1, 1, 1, 4)
        self.grid.addWidget(self.new_btn, 2, 1, 1, 1)
        self.grid.addWidget(self.quit_btn, 2, 2, 1, 1)
```

Adding our components to the grid layout.

row, column

GRID LAYOUT

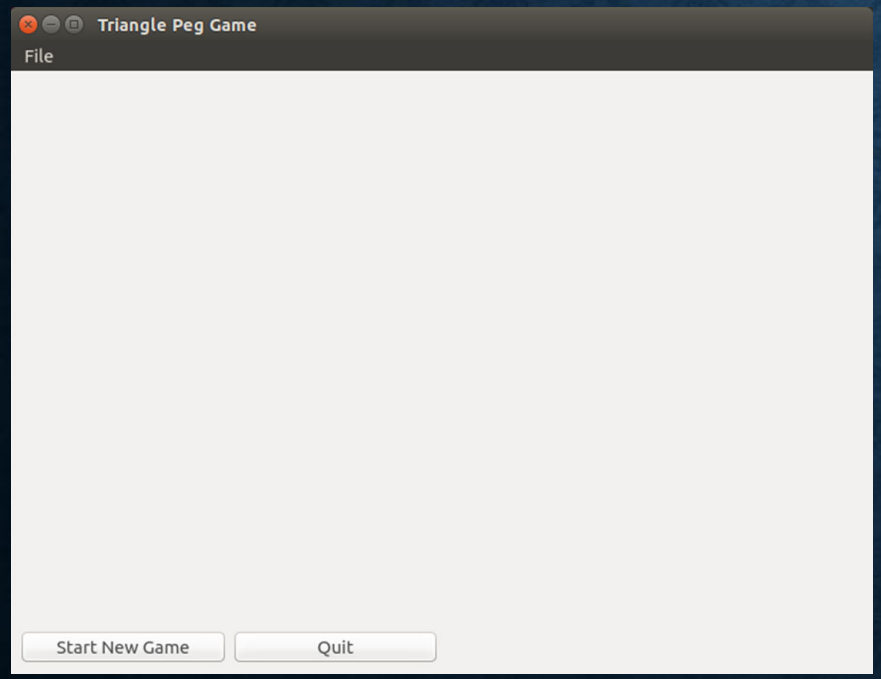
So how do we define `PegGame`?

```
class PegGame(QtWidgets.QWidget):
    def __init__(self, parent):
        QtWidgets.QWidget.__init__(self, parent)
        self.setup()

    def setup(self):
        self.board = PegBoard(self)
        self.new_btn = StartNewGameBtn(self)
        self.quit_btn = QuitBtn(self)
        self.grid = QtWidgets.QGridLayout()
        self.setLayout(self.grid)
        self.grid.addWidget(self.board, 1, 1, 1, 4)
        self.grid.addWidget(self.new_btn, 2, 1, 1, 1)
        self.grid.addWidget(self.quit_btn, 2, 2, 1, 1)
```

Adding our components to the grid layout.

height, width

GRID LAYOUT




```
class PegGame(QtWidgets.QWidget):
    def __init__(self, parent):
        QtWidgets.QWidget.__init__(self, parent)
        self.setup()

    def setup(self):
        self.board = PegBoard(self)
        self.new_btn = StartNewGameBtn(self)
        self.quit_btn = QuitBtn(self)
        self.grid = QtWidgets.QGridLayout()
        self.setLayout(self.grid)
        self.grid.addWidget(self.board, 1, 1, 1, 4)
        self.grid.addWidget(self.new_btn, 2, 1, 1, 1)
        self.grid.addWidget(self.quit_btn, 2, 2, 1, 1)
```

PEGBOARD

- So, what does the `PegBoard` look like so far?

```
class PegBoard(QtWidgets.QWidget):
    def __init__(self, parent):
        QtWidgets.QWidget.__init__(self, parent)
        self.setFixedSize(700, 460)
```

The parent we passed in was the `PegGame` instance that holds the `PegBoard`.

The `setFixedSize(`*`width, height`*`)` method gives us a convenient way to not only define a size for the `PegBoard` instance, but also set a lower bound on the size of the parent containers (`PegGame` and `PegGameWindow`).

PEGBOARD

- Here's our first goal: let's get a wooden triangle.

  To get this, we need to introduce the QPainter object.

QPAINTER

- The `QtGui.QPainter` class performs low-level painting on any object that inherits the `QtGui.QPaintDevice` class (e.g. `QWidget`, `QPixmap`, `QPicture`).

```
qp = QtGui.QPainter()
qp.begin(canvas)
...
qp.end()
```

- The most basic usage involves creating a QPainter instance, calling the begin method with the QPaintDevice to which we will be painting, and then calling the end method.

QPAINTER

```
qp = QtGui.QPainter()
qp.begin(canvas)
...
qp.end()
```

- So what can we do in those ellipses?
- Manipulate settings
  - `font()`, `brush()`, `pen()` give you access to the tools used to draw. Return `QFont`, `QBrush`, and `QPen` objects.
  - Also `setFont(`*font*`)`, `setBrush(`*brush*`)`, `setPen(`*pen*`)`.
- Draw
  - `drawEllipse()`, `drawPolygon()`, `drawImage()`, `drawLine()`, `drawPath()`, `drawPicture()`, `drawPie()`, etc…
  - If you can dream it, you can draw it. ☺

QPAINTER

- First thing to notice is the method name we're using: paintEvent.

  paintEvent is a method called automatically whenever the widget's appearance is updated. This includes when we first show the widget, but also when we request an update.

```
class PegBoard(QtWidgets.QWidget):
    def __init__(self, parent):
        QtWidgets.QWidget.__init__(self, parent)
        self.setFixedSize(700, 460)

    def paintEvent(self, event):
        points_list = [QtCore.QPoint(50,455),
                       QtCore.QPoint(650,455),
                       QtCore.QPoint(350,5)]
        triangle = QtGui.QPolygon(points_list)
        qp = QtGui.QPainter()
        qp.begin(self)
        qp.drawPolygon(triangle)
        qp.end()
```

QPAINTER

```
class PegBoard(QtWidgets.QWidget):
    def __init__(self, parent):
        QtWidgets.QWidget.__init__(self, parent)
        self.setFixedSize(700, 460)

    def paintEvent(self, event):
        points_list = [QtCore.QPoint(50,455),
                       QtCore.QPoint(650,455),
                       QtCore.QPoint(350,5)]
        triangle = QtGui.QPolygon(points_list)
        qp = QtGui.QPainter()
        qp.begin(self)
        qp.drawPolygon(triangle)
        qp.end()
```

We create a list of QPoint objects representing the vertices of our triangle.

QPAINTER

```
class PegBoard(QtWidgets.QWidget):
    def __init__(self, parent):
        QtWidgets.QWidget.__init__(self, parent)
        self.setFixedSize(700, 460)

    def paintEvent(self, event):
        points_list = [QtCore.QPoint(50,455),
                       QtCore.QPoint(650,455),
                       QtCore.QPoint(350,5)]
        triangle = QtGui.QPolygon(points_list)
        qp = QtGui.QPainter()
        qp.begin(self)
        qp.drawPolygon(triangle)
        qp.end()
```

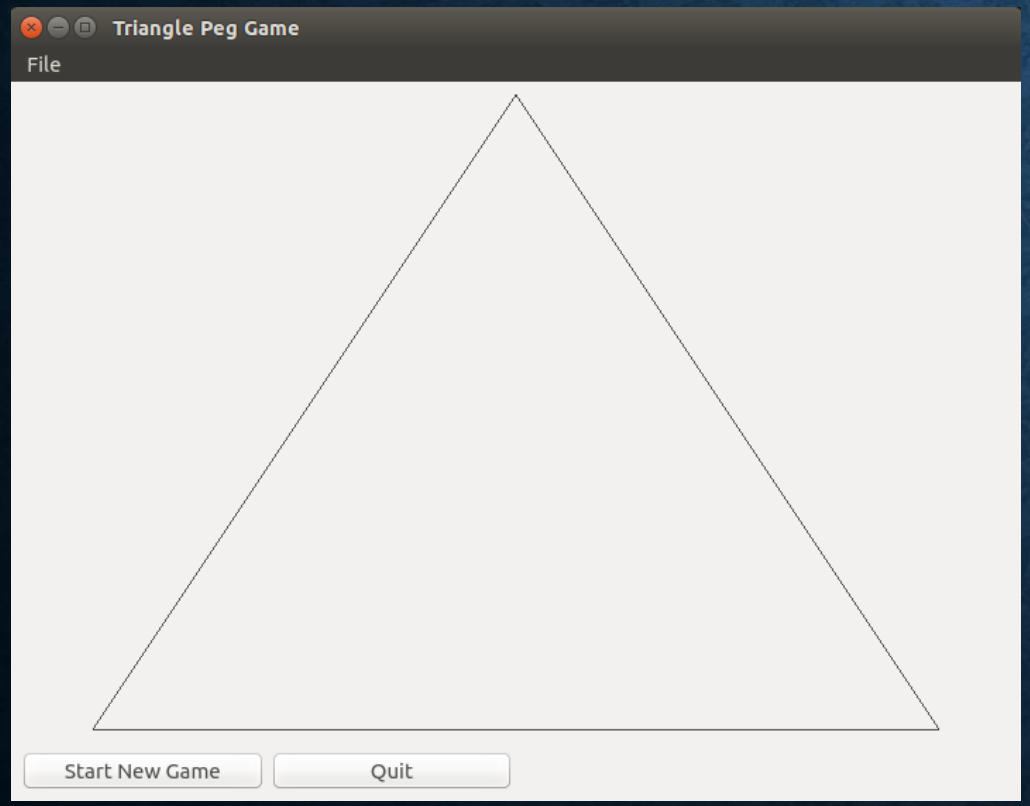
Using these points, we initialize a QPolygon object representing our triangle.

QPAINTER

```
class PegBoard(QtWidgets.QWidget):
    def __init__(self, parent):
        QtWidgets.QWidget.__init__(self, parent)
        self.setFixedSize(700, 460)

    def paintEvent(self, event):
        points_list = [QtCore.QPoint(50,455),
                       QtCore.QPoint(650,455),
                       QtCore.QPoint(350,5)]
        triangle = QtGui.QPolygon(points_list)
        qp = QtGui.QPainter()
        qp.begin(self)
        qp.drawPolygon(triangle)
        qp.end()
```

Finally, we create our QPainter, make the PegBoard instance our QPaintDevice and draw the triangle!

QPAINTER




```
class PegBoard(QtWidgets.QWidget):
    def __init__(self, parent):
        QtWidgets.QWidget.__init__(self, parent)
        self.setFixedSize(700, 460)

    def paintEvent(self, event):
        points_list = [QtCore.QPoint(50,455),
                       QtCore.QPoint(650,455),
                       QtCore.QPoint(350,5)]
        triangle = QtGui.QPolygon(points_list)
        qp = QtGui.QPainter()
        qp.begin(self)
        qp.drawPolygon(triangle)
        qp.end()
```

QPAINTER

- We want to make two changes: get rid of the black outline and apply a wood grain fill.

Grab the curren QPen object, set the color to transparent, and reset Qpen object.

Create a new QBrush object, set the texture image to a local picture of some wood. Set the QBrush object.

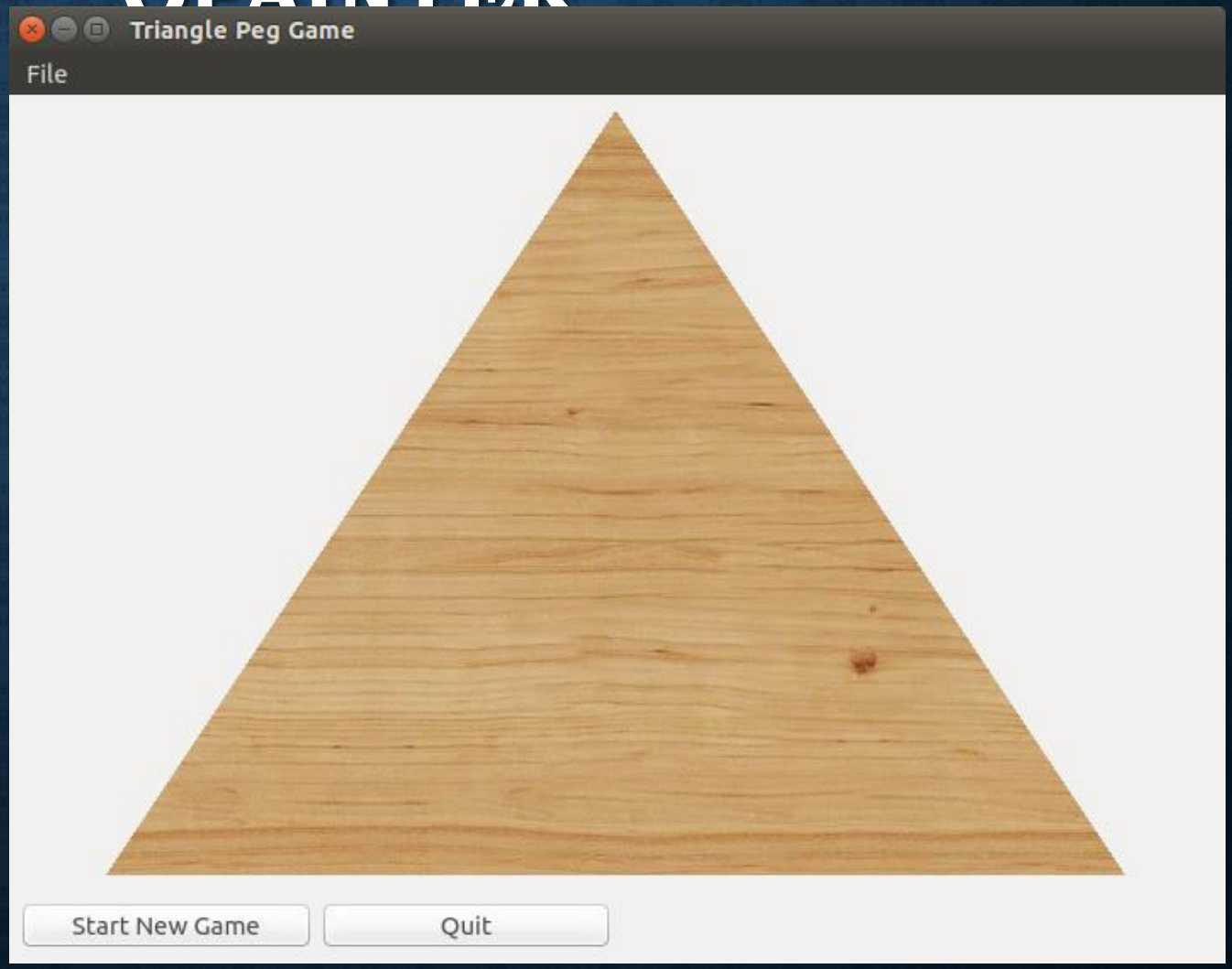
```
qp = QtGui.QPainter()
qp.begin(self)
pen = qp.pen()
pen.setColor(QtCore.Qt.transparent)
qp.setPen(pen)
brush = QtGui.QBrush()
brush.setTextureImage(QtGui.QImage('wood.jpg'))
qp.setBrush(brush)
qp.drawPolygon(triangle)
qp.end()
```

QPAINTER

Ok, so what if we want a black background?

Rather than drawing *on* the widget, that requires us to change the way the widget *draws itself*.

Specifically, we'll need to change the way the PegBoard widget displays.



QPALETTE

To do this, we need to introduce the idea of a `QPalette`.

The `QPalette` class contains color groups for each widget state. It describes how the widget should render itself on the screen for each state.

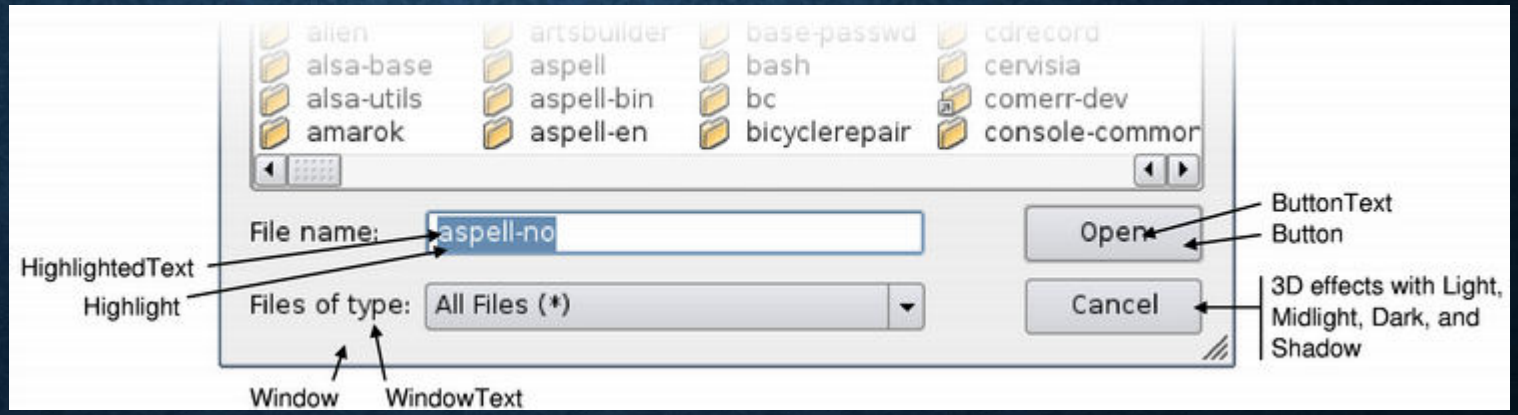
A palette consists of three color groups: *Active (keyboard focus)*, *Disabled (not in focus)*, and *Inactive (disabled)*. All widgets in Qt contain a palette and use their palette to draw themselves.

`QWidget`'s `palette()` method returns the currently used `QPalette` object and `setPalette(`*`palette`*`)` allows you to reassign the `QPalette` object being used.

QPALETTE

For each state of a widget, there are many roles of which we need to describe the look and feel. Each role has an assigned color and brush.

- Window
- Background
- WindowText
- Foreground
- Button
- Etc.



QPALETTE

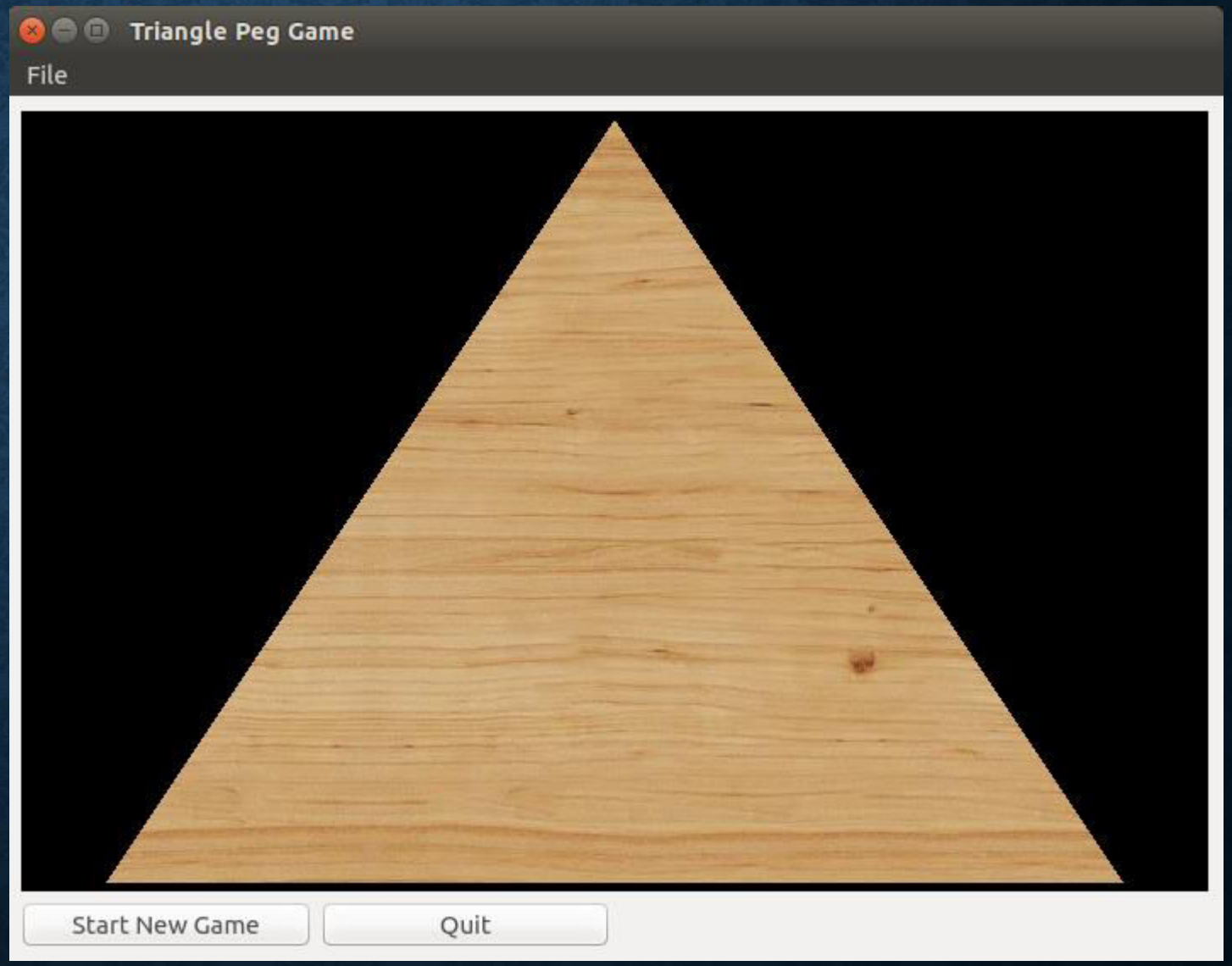
- Colors and brushes can be set for particular roles in any of a palette's color groups with `setColor()` for color and `setBrush()` for color, style, and texture.
- Calling, for example, `backgroundRole()` on a widget will return the current brush from the widget's palette that is being used to draw the role. You can also get this, and any other brush, as `palette.Background`.

QPALETTE

- Calling `palette()` on a `QWidget` object will return its currently associated `QPalette`.
  `QPalette` objects have a method `setColor()` which allows a `ColorRole` to be associated with a `QColor`.

  `setAutoFillBackground` toggles the filling in of the background, which is transparent by default.

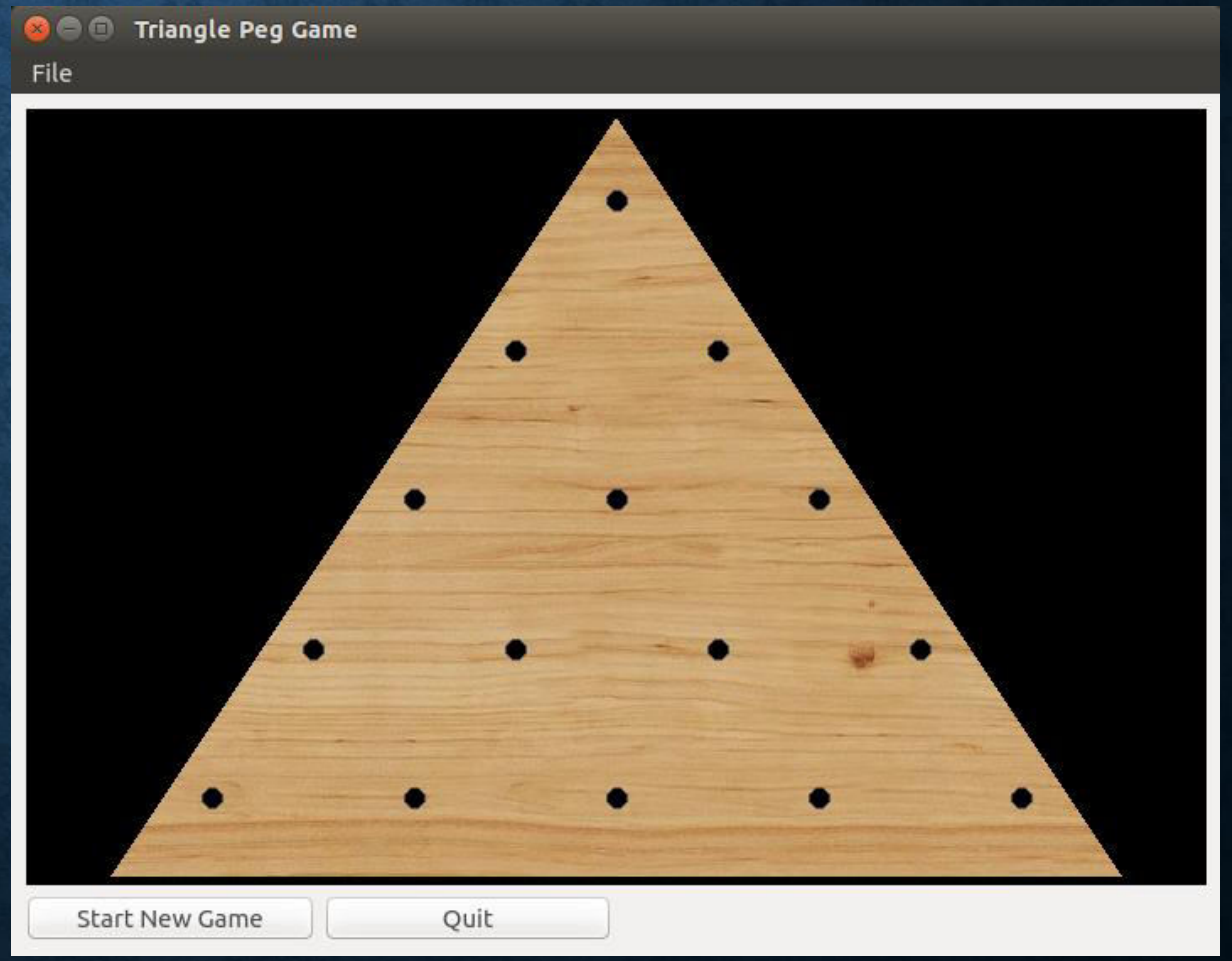
```
class PegBoard(QtWidgets.QWidget):
    def __init__(self, parent):
        QtWidgets.QWidget.__init__(self, parent)
        self.setFixedSize(700, 460)
        p = self.palette()
        p.setColor(self.backgroundRole(), QtGui.QColor(0, 0, 0, 255))
        self.setPalette(p)
        self.setAutoFillBackground(True)
```


Triangle Peg Game
File
Start New Game
Quit

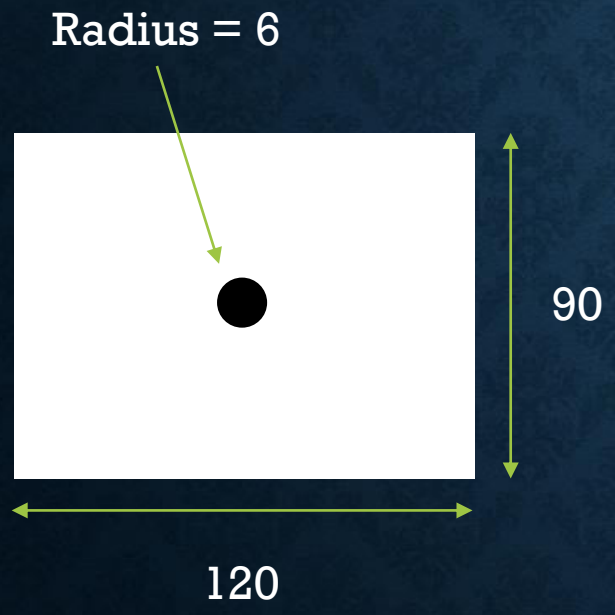
ADDING TO THE PEG BOARD

- Next is to add the peg holes to our peg board.

  We won't merely draw some dark circles on the board – we will create PegHole objects that can contain Peg objects. But let's just start with the PegHole definition.



PEG HOLES

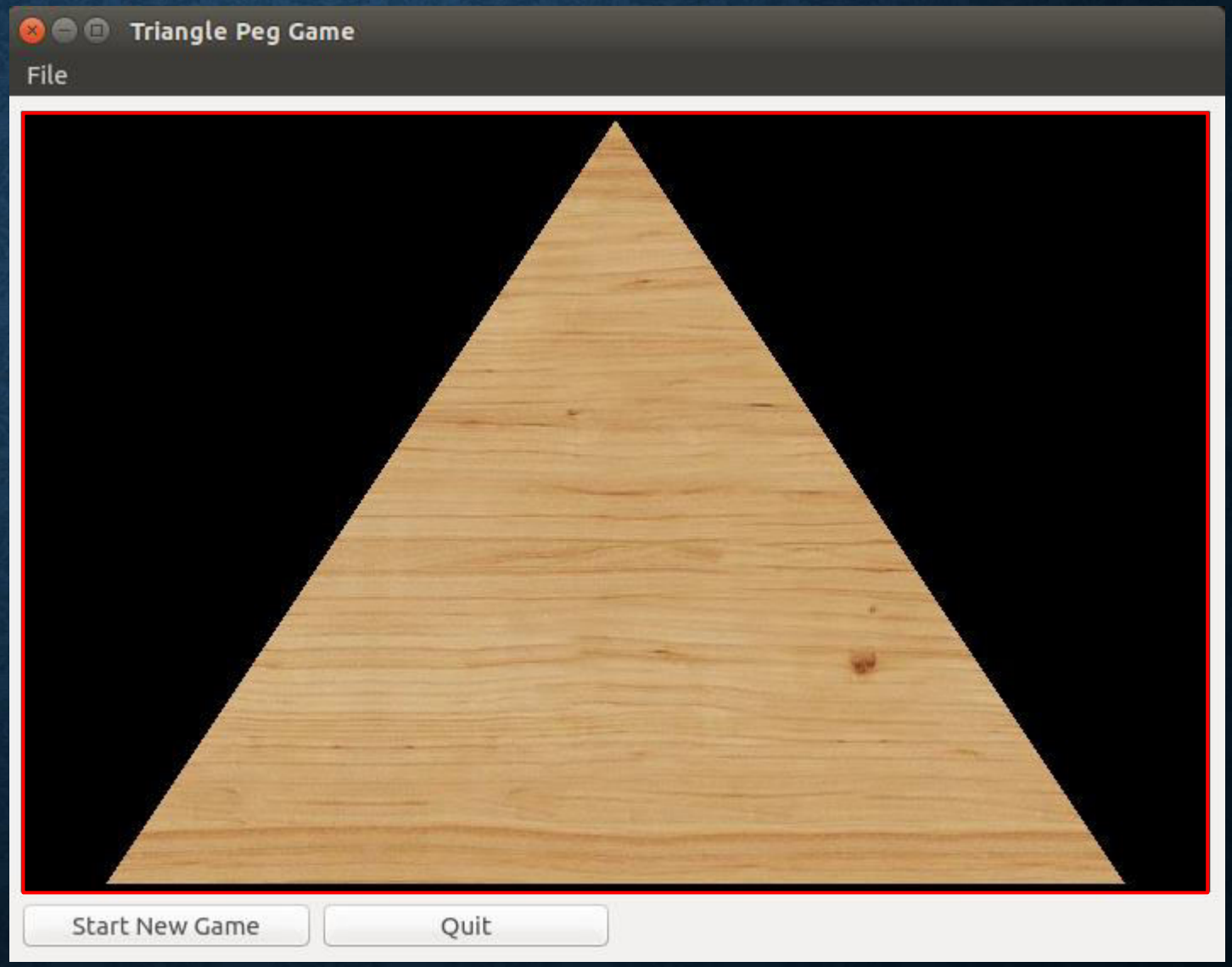


Note that our background is actually transparent!

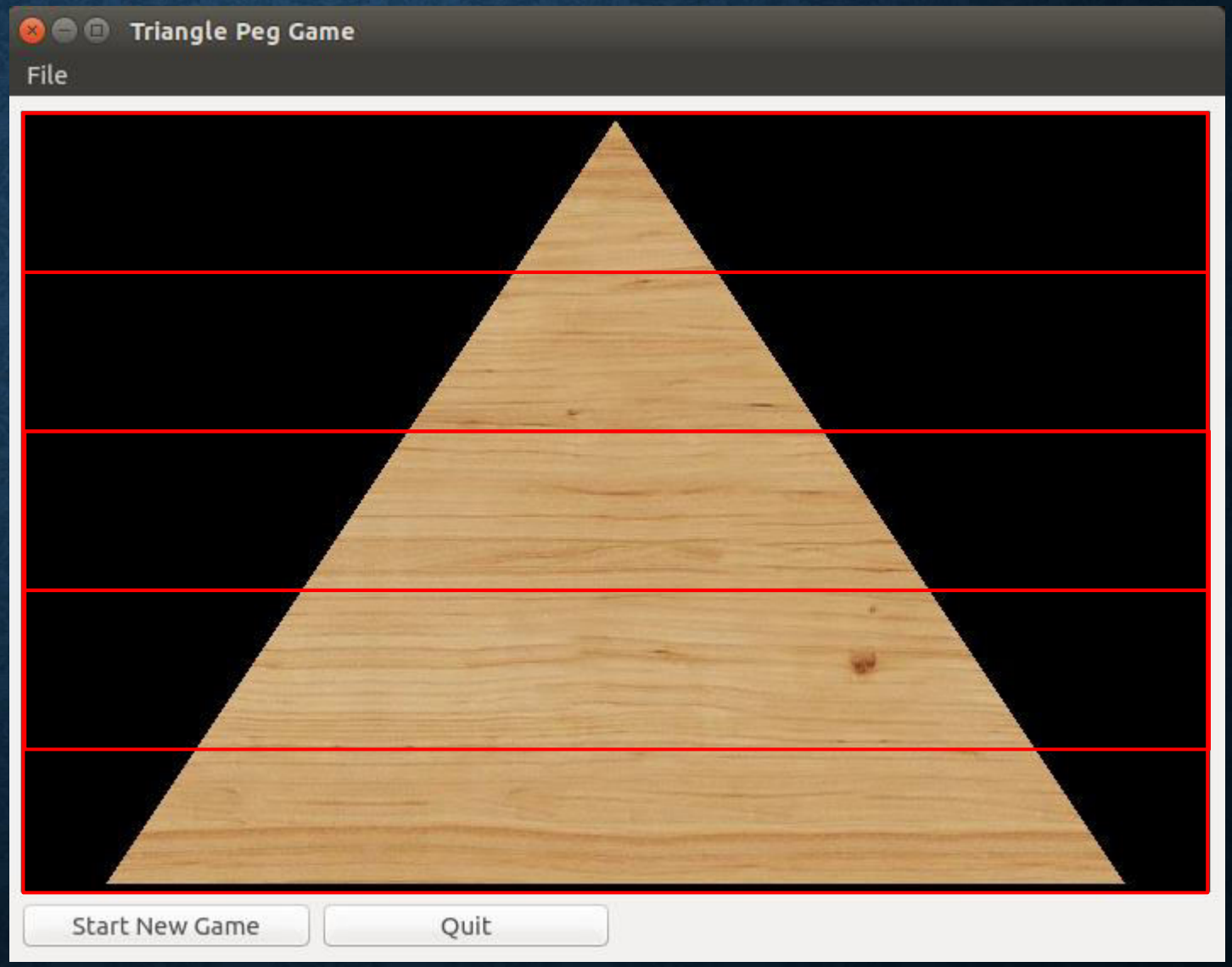
```
class PegHole(QtWidgets.QWidget):
    def __init__(self, parent):
        QtWidgets.QWidget.__init__(self, parent)
        self.grid = QtWidgets.QGridLayout()
        self.setLayout(self.grid)
        self.peg = None

    def paintEvent(self, event):
        qp = QtGui.QPainter()
        qp.begin(self)
        brush = QtGui.QBrush(QtCore.Qt.SolidPattern)
        qp.setBrush(brush)
        qp.drawEllipse(QtCore.QPointF(60, 45), 6, 6)
        qp.end()

    def minimumSizeHint(self):
        return QtCore.QSize(120, 90)
```

- Now, how do we place these things on our board?

  Start by creating a vertical box layout on the PegBoard.

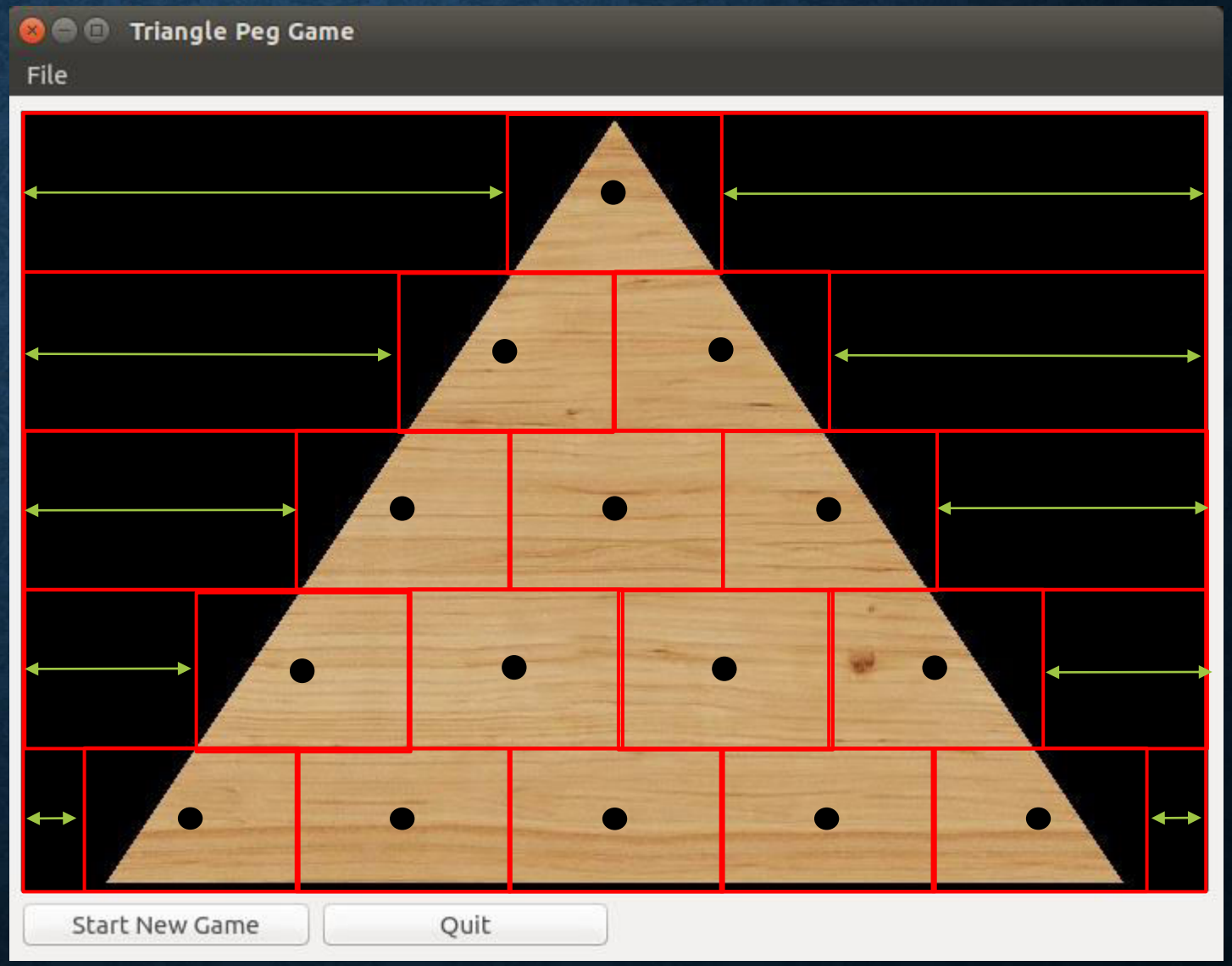


- Now, add 5 horizontal box layouts to the vertical box layout.



- In each horizontal box layout, add:

  - a very stretchy spacer.
  - the PegHole objects.
  - another very stretchy spacer.

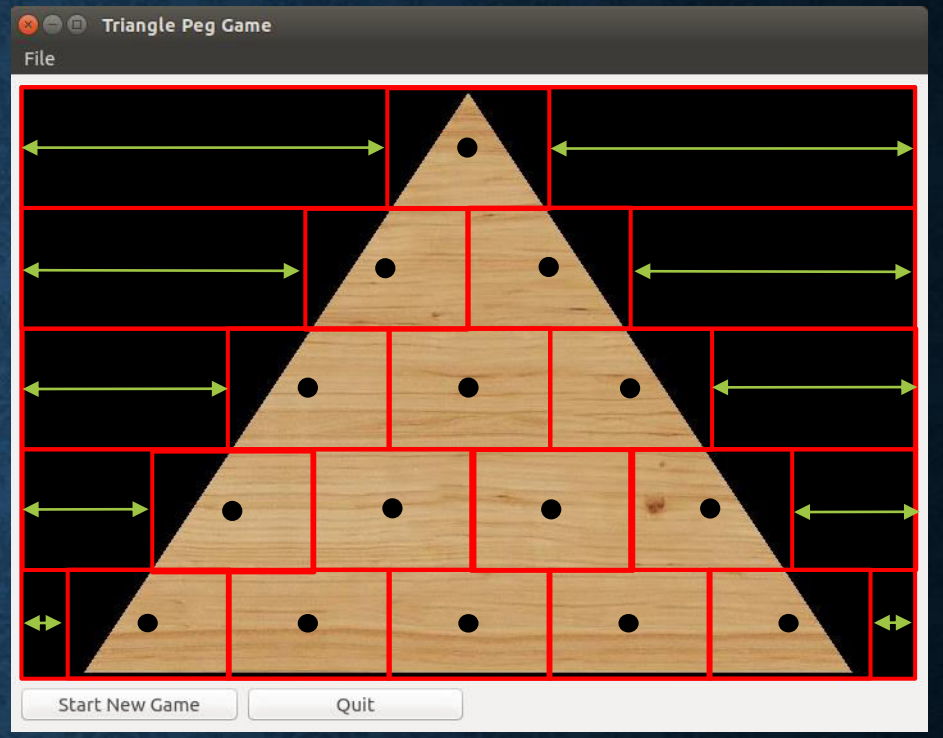


PEG HOLES


```
class PegBoard(QtWidgets.QWidget):
    def __init__(self, parent):
        QtWidgets.QWidget.__init__(self, parent)
        self.setFixedSize(700, 460)
        p = self.palette()
        p.setColor(self.backgroundRole(), QtGui.QColor(0, 0, 0, 255))
        self.setPalette(p)
        self.setAutoFillBackground(True)
        self.vbox = QtWidgets.QVBoxLayout()
        self.setLayout(self.vbox)
        self.vbox.setSpacing(0)
        self.place_holes()
```

Create a vertical box layout for the PegBoard instance. The `setSpacing` method allows us to manipulate the margins between widgets in the layout.

PEG HOLES




```
def place_holes(self):
    for row in range(0,5):
        rowLayout = QtWidgets.QHBoxLayout()
        self.vbox.addLayout(rowLayout)
        rowLayout.addStretch(1)
        for col in range(0,row+1):
            hole = PegHole(self)
            rowLayout.addWidget(hole, 0)
        rowLayout.addStretch(1)
```

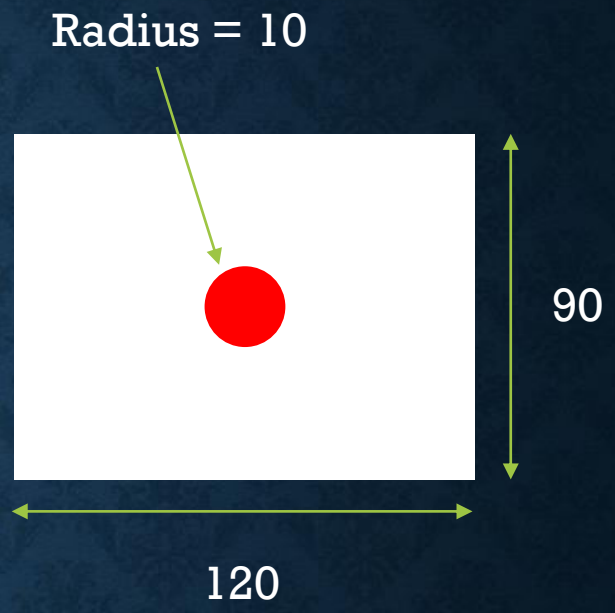
PEGS

- So, the next step is to create a Peg object.

  Keep in mind that PegHole objects are designed to house Peg objects and control their manipulation on the board.

```
class PegHole(QtWidgets.QWidget):
    def __init__(self, parent):
        QtWidgets.QWidget.__init__(self, parent)
        self.grid = QtWidgets.QGridLayout()
        self.setLayout(self.grid)
        self.peg = None
```

PEGS




```
class Peg(QtWidgets.QWidget):
    def __init__(self, parent):
        QtWidgets.QWidget.__init__(self, parent)
        self.resize(parent.size())

    def paintEvent(self, event):
        qp = QtGui.QPainter()
        qp.begin(self)
        brush = QtGui.QBrush(QtCore.Qt.SolidPattern)
        brush.setColor(QtCore.Qt.red)
        qp.setBrush(brush)
        qp.drawEllipse(QtCore.QPointF(self.width()/2,self.height()/2),10,10)
        qp.end()
```

Size is changed to match PegHole size.

PEGS

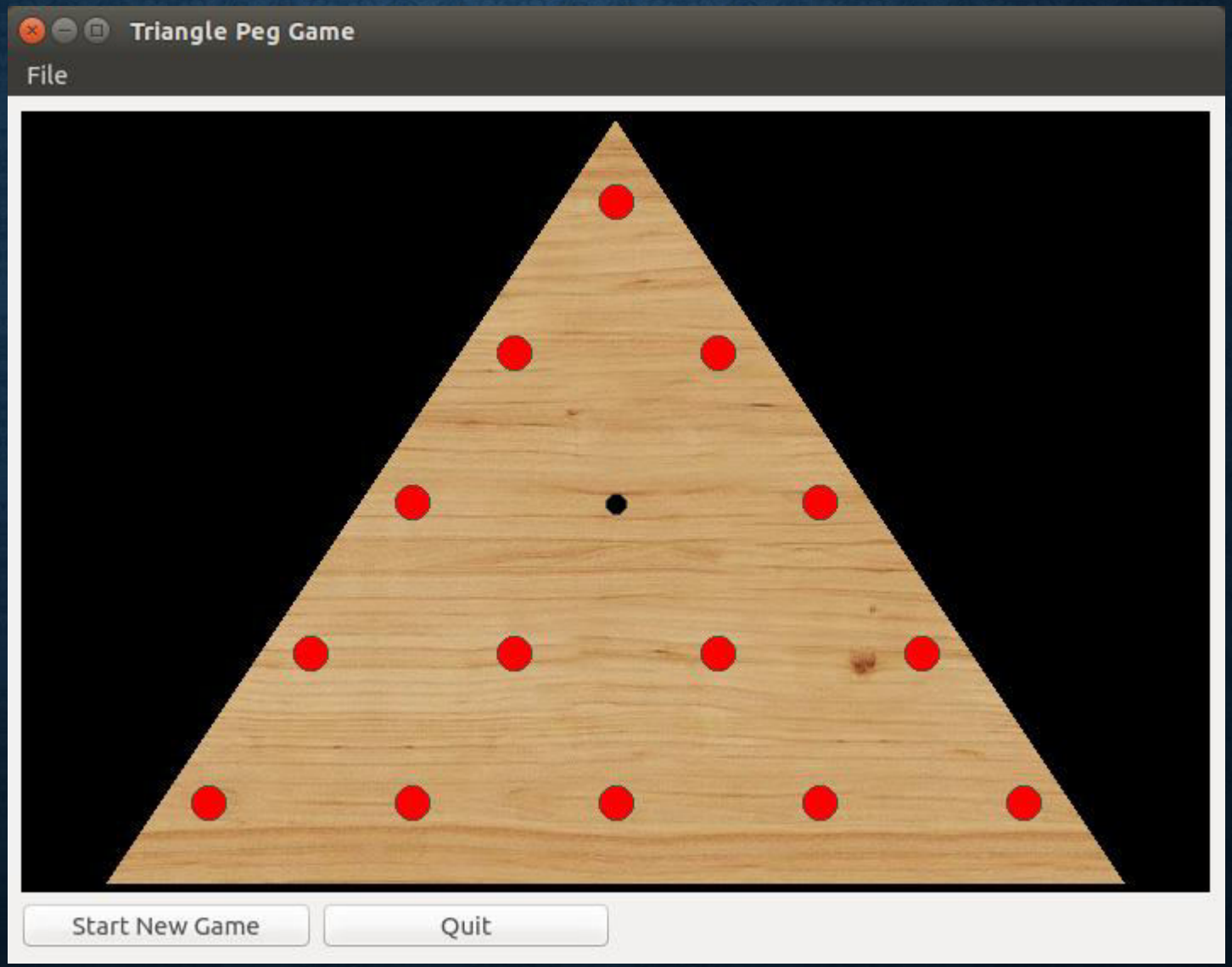
- Now, we add a method to our PegHole class which allows us to associate Peg instances with PegHole objects.

```
class PegHole(QtWidgets.QWidget):
    def __init__(self, parent):
        QtWidgets.QWidget.__init__(self, parent)
        self.grid = QtWidgets.QGridLayout()
        self.setLayout(self.grid)
        self.peg = None
    ...
    def addPeg(self):
        self.peg = Peg(self)
        self.grid.addWidget(self.peg)
```

PEGS

- And finally, we extend our PegBoard.place_holes method to associate Pegs with PegHoles.

```
def place_holes(self):
    for row in range(0,5):
        rowLayout = QtWidgets.QHBoxLayout()
        self.vbox.addLayout(rowLayout)
        rowLayout.addStretch(1)
        for col in range(0, row+1):
            hole = PegHole(self)
            rowLayout.addWidget(hole, 0)
            if (row, col) != (2,1):
                hole.addPeg()
        rowLayout.addStretch(1)
```


Triangle Peg Game
File
Start New Game
Quit

PEG MOVEMENT

- Now, the hard part. How do we describe the mechanics of moving the pegs? How does a user interact with the game board?

  We aren't going to concern ourselves with keeping score or enforcing legal movements yet. We just want to figure out *how* to move the pegs around.

- The most natural mechanism is probably drag-and-drop. We should be able to "pick up" pegs, move them with the mouse, and "drop" them into an empty hole.

DRAG AND DROP

- Drag and drop, a commonly implemented GUI interaction mechanism, centers around the `QDrag` object.
- The `QDrag` class supports MIME-based drag and drop transfer.
- MIME (Multiple Internet Mail Extensions) is a system originally designed to package arbitrary attachments to email. But this system is also commonly used to package arbitrary data with a `QDrag` object so we can send it anywhere in the application.

DRAG AND DROP

- There are two parts to a drag and drop action to be considered:

  - The drag source.

  - The drop target.

- Let's start with our drag source, the PegHole object.

DRAG SOURCE

A drag source is any object that creates a `QDrag` object when we interact with it. What does it mean to "interact"? Well, we could define it a couple of ways – here are some methods we could override to start a drag:

- `mousePressEvent(self, event)`
  - Called when the mouse is pressed down.
- `mouseReleaseEvent(self, event)`
  - Called when the mouse is released.
- `mouseMoveEvent(self, event)`
  - Called when the mouse is pressed down and moved.

DRAG SOURCE

```
class PegHole(QtWidgets.QWidget):
    def __init__(self, parent):
        QtWidgets.QWidget.__init__(self, parent)
        self.grid = QtWidgets.QGridLayout()
        self.setLayout(self.grid)
        self.peg = None

    def mousePressEvent(self, event):
        if not self.peg:
            QtWidgets.QWidget.mousePressEvent(self, event)
            return

        drag = QtGui.QDrag(self)
        drag.setMimeData(QtCore.QMimeData())
        dropAction = drag.exec_(QtCore.Qt.MoveAction)
```

Now, when we click on a PegHole object, we'll start the process of dragging… but only if there is a Peg object associated!

DRAG SOURCE

```
class PegHole(QtWidgets.QWidget):
    def __init__(self, parent):
        QtWidgets.QWidget.__init__(self, parent)
        self.grid = QtWidgets.QGridLayout()
        self.setLayout(self.grid)
        self.peg = None

    def mousePressEvent(self, event):
        if not self.peg:
            QtWidgets.QWidget.mousePressEvent(self, event)
            return

        drag = QtGui.QDrag(self)
        drag.setMimeData(QtCore.QMimeData())
        dropAction = drag.exec_(QtCore.Qt.MoveAction)
```

If there is no associated Peg object, simply call the basic mousePressEvent method and return.

DRAG SOURCE

```
class PegHole(QtWidgets.QWidget):
    def __init__(self, parent):
        QtWidgets.QWidget.__init__(self, parent)
        self.grid = QtWidgets.QGridLayout()
        self.setLayout(self.grid)
        self.peg = None

    def mousePressEvent(self, event):
        if not self.peg:
            QtWidgets.QWidget.mousePressEvent(self, event)
            return

        drag = QtGui.QDrag(self)
        drag.setMimeData(QtCore.QMimeData())
        dropAction = drag.exec_(QtCore.Qt.MoveAction)
```

If there is a Peg object, then start a drag by instantiating a new QDrag object.

DRAG SOURCE

```
class PegHole(QtWidgets.QWidget):
    def __init__(self, parent):
        QtWidgets.QWidget.__init__(self, parent)
        self.grid = QtWidgets.QGridLayout()
        self.setLayout(self.grid)
        self.peg = None

    def mousePressEvent(self, event):
        if not self.peg:
            QtWidgets.QWidget.mousePressEvent(self, event)
            return

        drag = QtGui.QDrag(self)
        drag.setMimeData(QtCore.QMimeData())
        dropAction = drag.exec_(QtCore.Qt.MoveAction)
```

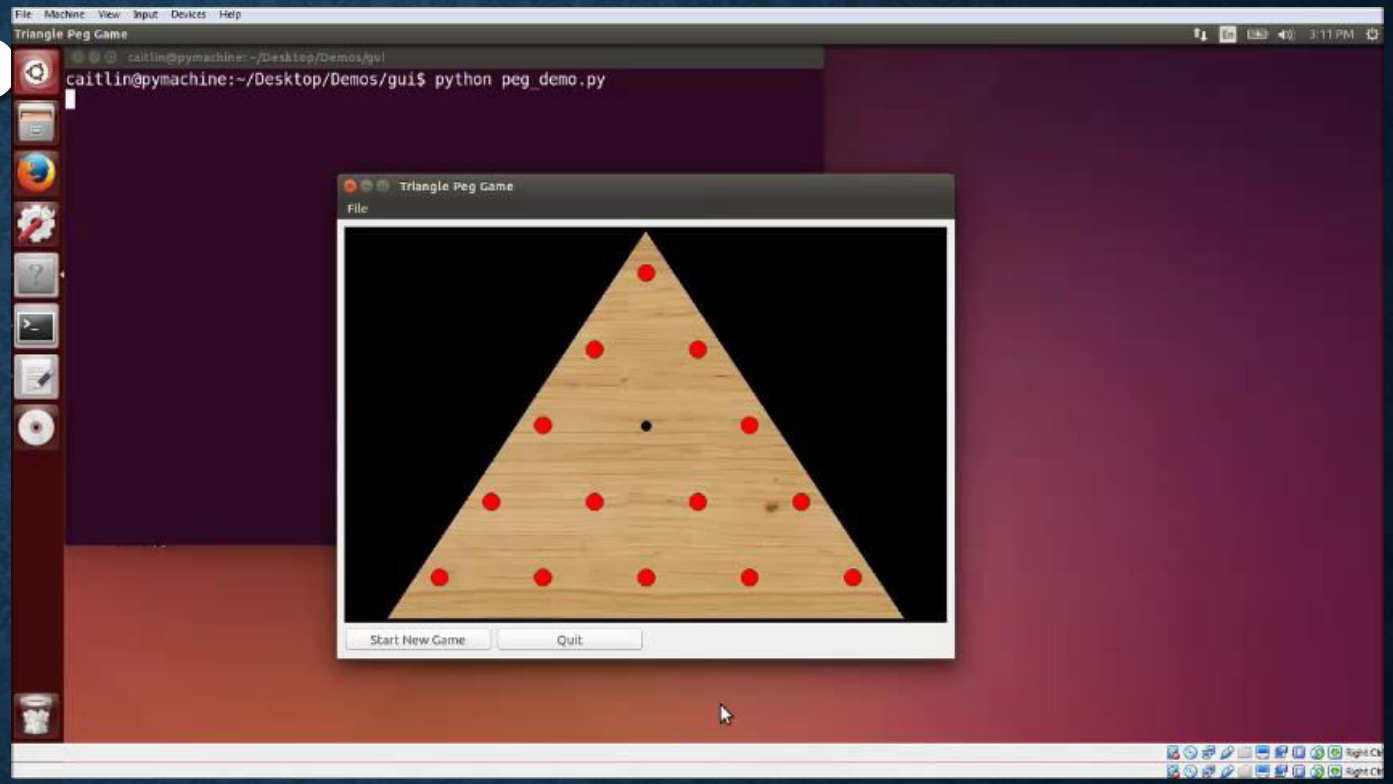
Associate a QMimeData object. This is required, but your QMimeData object is not required to hold anything significant.

DRAG SOURCE

```
class PegHole(QtWidgets.QWidget):
    def __init__(self, parent):
        QtWidgets.QWidget.__init__(self, parent)
        self.grid = QtWidgets.QGridLayout()
        self.setLayout(self.grid)
        self.peg = None

    def mousePressEvent(self, event):
        if not self.peg:
            QtWidgets.QWidget.mousePressEvent(self, event)
            return

        drag = QtGui.QDrag(self)
        drag.setMimeData(QtCore.QMimeData())
        dropAction = drag.exec_(QtCore.Qt.MoveAction)
```

Call the exec_() method on the QDrag object to start the drag and drop operation. This method returns a value indicating the drop action taken.

- So, what happens now?



Well, not much. We haven't defined what it looks like to drag the Peg and we haven't defined any drop targets. The only thing we can see for sure is that a drag event starts when the PegHole has an associated Peg, otherwise nothing happens.

DROP TARGET

Now, let's define a drop target. Since a PegHole is conceptually both the source of the Peg as well as the eventual destination of the Peg, we will also use a PegHole as our drop target. Drop targets have the following properties:

- Sets `self.setAcceptDrops(True)`.
- Implements the `dragEnterEvent(self, event)` method.
  - Called when a drag enters the target's area. Typically defined to either accept or reject the drag.
- Implements the `dropEvent(self, event)` method.
  - Called when the user releases the mouse button, "dropping" on the target.

DROP TARGET

Our PegHole now accepts drop requests

Allow the drag to enter the widget space and set the drop action to be whatever the QDrag object proposes (i.e. MoveAction).

```
class PegHole(QtWidgets.QWidget):
    def __init__(self, parent):
        QtWidgets.QWidget.__init__(self, parent)
        self.setAcceptDrops(True)
        self.grid = QtWidgets.QGridLayout()
        self.setLayout(self.grid)
        self.peg = None

    def dragEnterEvent(self, event):
        event.acceptProposedAction()

    def dropEvent(self, event):
        if not self.peg:
            self.addPeg()
            event.accept()
        else:
            event.ignore()
```

DROP TARGET

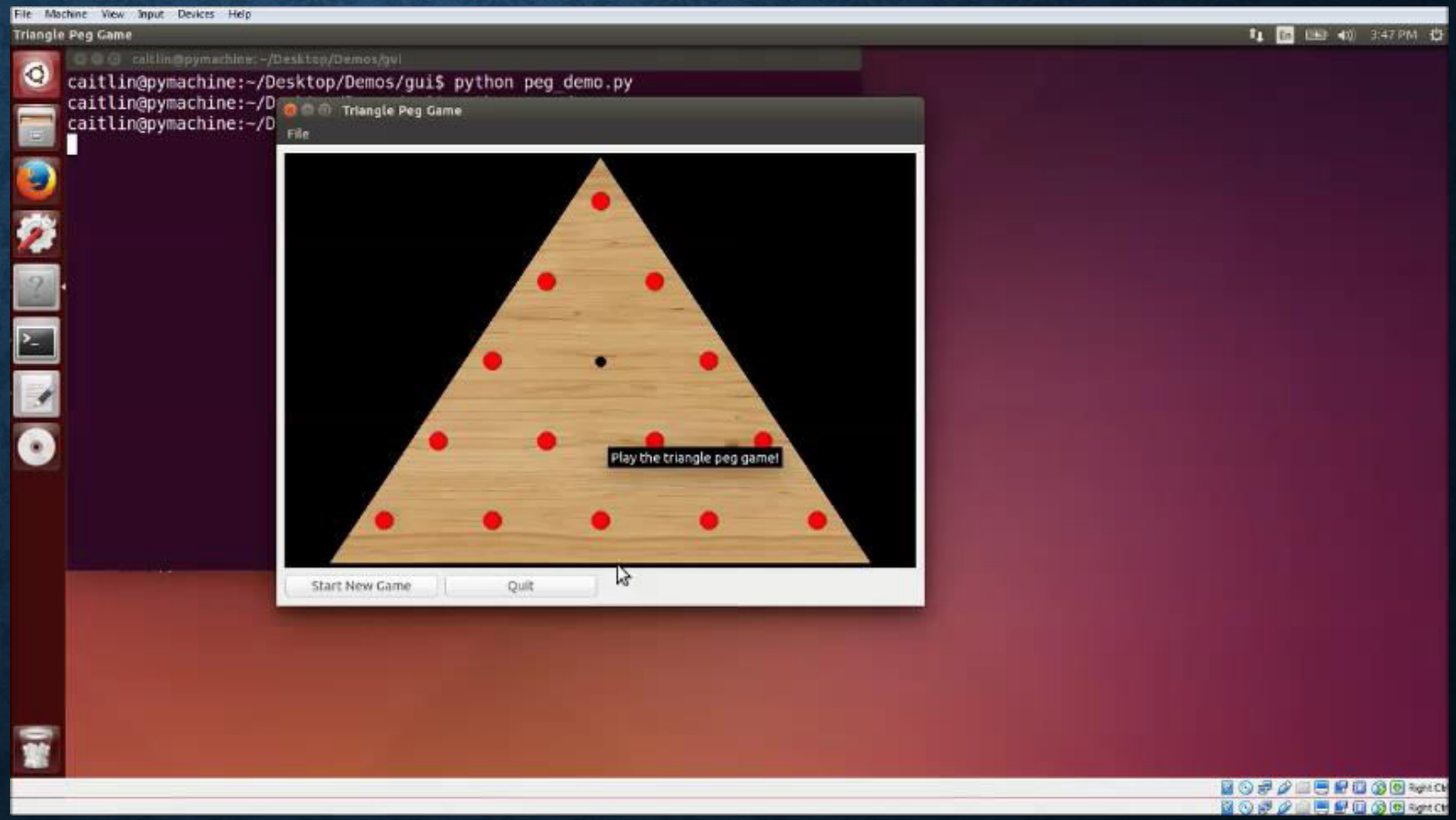
```
class PegHole(QtWidgets.QWidget):
    def __init__(self, parent):
        QtWidgets.QWidget.__init__(self, parent)
        self.setAcceptDrops(True)
        self.grid = QtWidgets.QGridLayout()
        self.setLayout(self.grid)
        self.peg = None

    def dragEnterEvent(self, event):
        event.acceptProposedAction()

    def dropEvent(self, event):
        if not self.peg:
            self.addPeg()
            event.accept()
        else:
            event.ignore()
```

Accept the drop and add a new Peg object if there is not already a Peg object associated.

DROP TARGET

- We can at least force a new Peg object to appear.

  But that does not delete the old Peg object nor describe what it means to drag from PegHole instance to PegHole instance.



DRAG SOURCE

- Back to the drag source….

```
def mousePressEvent(self, event):
    if not self.peg:
        QtWidgets.QWidget.mousePressEvent(self, event)
        return
```

Hide the peg temporarily →

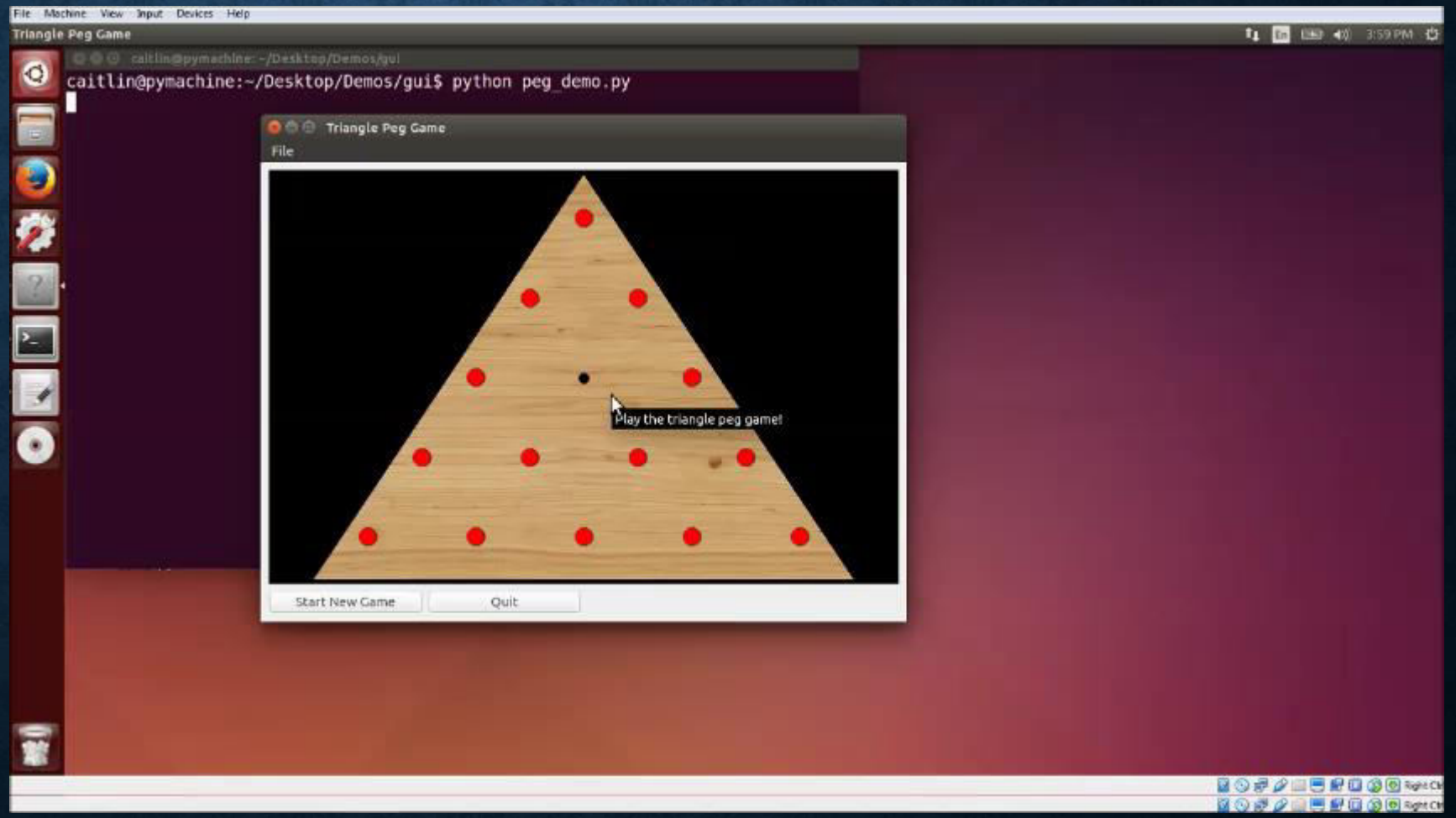
```
    self.peg.hide()
    drag = QtGui.QDrag(self)
    drag.setMimeData(QtCore.QMimeData())
    dropAction = drag.exec_(QtCore.Qt.MoveAction)
```

When "drop" happens, check whether drop was accepted or not. If so, delete Peg. Otherwise, show the Peg again.

```
    if dropAction:
        del(self.peg)
        self.peg = None
    else:
        self.peg.show()
```

DRAG AND DROP

- Ok, once again!



DRAG AND DROP

- But wouldn't it be so nice to *see* the Peg move?

We'll create an icon of the Peg and associate it with the `QDrag` object.

```
def mousePressEvent(self, event):
    if not self.peg:
        QtWidgets.QWidget.mousePressEvent(self, event)
        return

    self.peg.hide()
    drag = QtGui.QDrag(self)
    drag.setMimeData(QtCore.QMimeData())
    drag.setPixmap(self.peg_icon)
    drag.setHotSpot(self.peg_icon.rect().topLeft())
    dropAction = drag.exec_(QtCore.Qt.MoveAction)

    if dropAction:
        del(self.peg)
        self.peg = None
    else:
        self.peg.show()
```

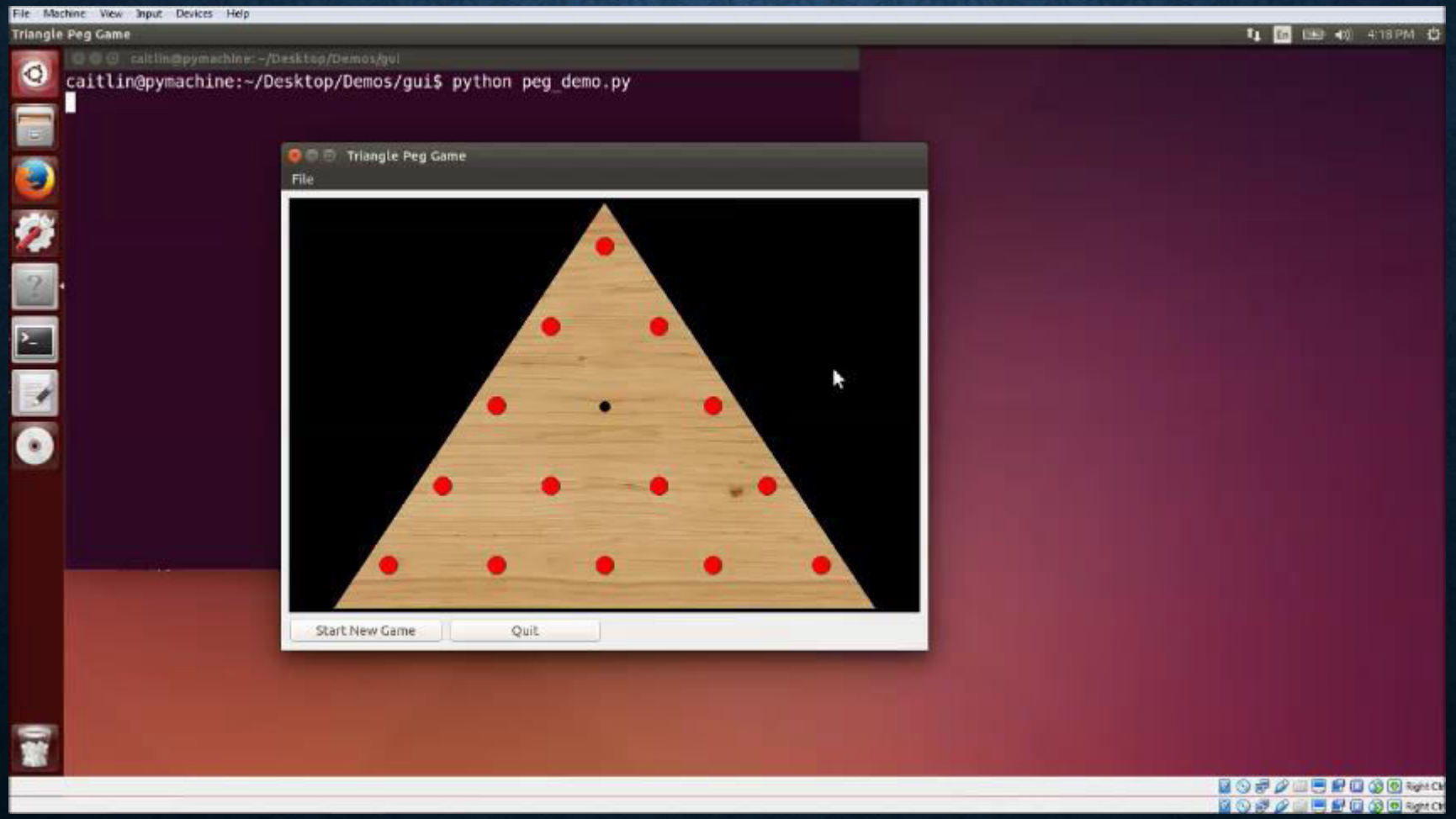
DRAG AND DROP

Now we have an icon that represents what a Peg looks like visually.

This is the visual we'll associate with the drag so that our user feels like they're moving the object in space.

```
class PegHole(QtWidgets.QWidget):
    def __init__(self, parent):
        QtWidgets.QWidget.__init__(self, parent)
        self.setAcceptDrops(True)
        self.grid = QtWidgets.QGridLayout()
        self.setLayout(self.grid)
        self.peg = None
        self.create_icon()

    def create_icon(self):
        self.peg_icon = QtGui.QPixmap(22, 22)
        self.peg_icon.fill(QtCore.Qt.transparent)
        qp = QtGui.QPainter()
        qp.begin(self.peg_icon)
        brush = QtGui.QBrush(QtCore.Qt.SolidPattern)
        brush.setColor(QtCore.Qt.red)
        qp.setBrush(brush)
        qp.drawEllipse(0, 0, 20, 20)
        qp.end()
```

DRAG AND DROP



ENFORCING RULES

So, we have the mechanics of movement. Now, all we need to do is enforce some rules. This comes down to two checks:

- Make sure destination is valid.
- Make sure "hopped" hole contains a Peg to be removed.

We're going to use the MIME mechanism to send information about our drag source to our drop target – this will help us decide whether to accept or not.

CHECKING DESTINATION

We first extend the PegHole class definition to accept its position as an argument. We pass in the row and column where it is placed on the board.

Furthermore, the PegBoard now maintains a list of its child widgets and an associated counter

```
class PegBoard(QtWidgets.QWidget):
    def __init__(self, parent):
        QtWidgets.QWidget.__init__(self, parent)
        self.holes = []
        ...
        self.place_holes()
        self.peg_count = len(self.holes)- 1

def place_holes(self):
    for row in range(0,5):
        row_list = []
        ...
        for col in range(0,row+1):
            hole = PegHole(self, row, col)
            ...
        rowLayout.addStretch(1)
        self.holes.append(row_list[:])
```

CHECKING DESTINATION

```
def mousePressEvent(self, event):
    if not self.peg:
        QtWidgets.QWidget.mousePressEvent(self, event)
        return

    self.peg_icon = self.create_icon()
    self.peg.hide()
    drag = QtGui.QDrag(self)
    data = QtCore.QMimeData()
    data.setText(pickle.dumps((self.row, self.col)))
    drag.setMimeData(data)
    drag.setPixmap(self.peg_icon)
    drag.setHotSpot(self.peg_icon.rect().topLeft())
    dropAction = drag.exec_(QtCore.Qt.MoveAction)

    ...
```

The `QMimeData` object associated with the `QDrag` object will now house some information – a pickled string holding the source's coordinates.

CHECKING DESTINATION

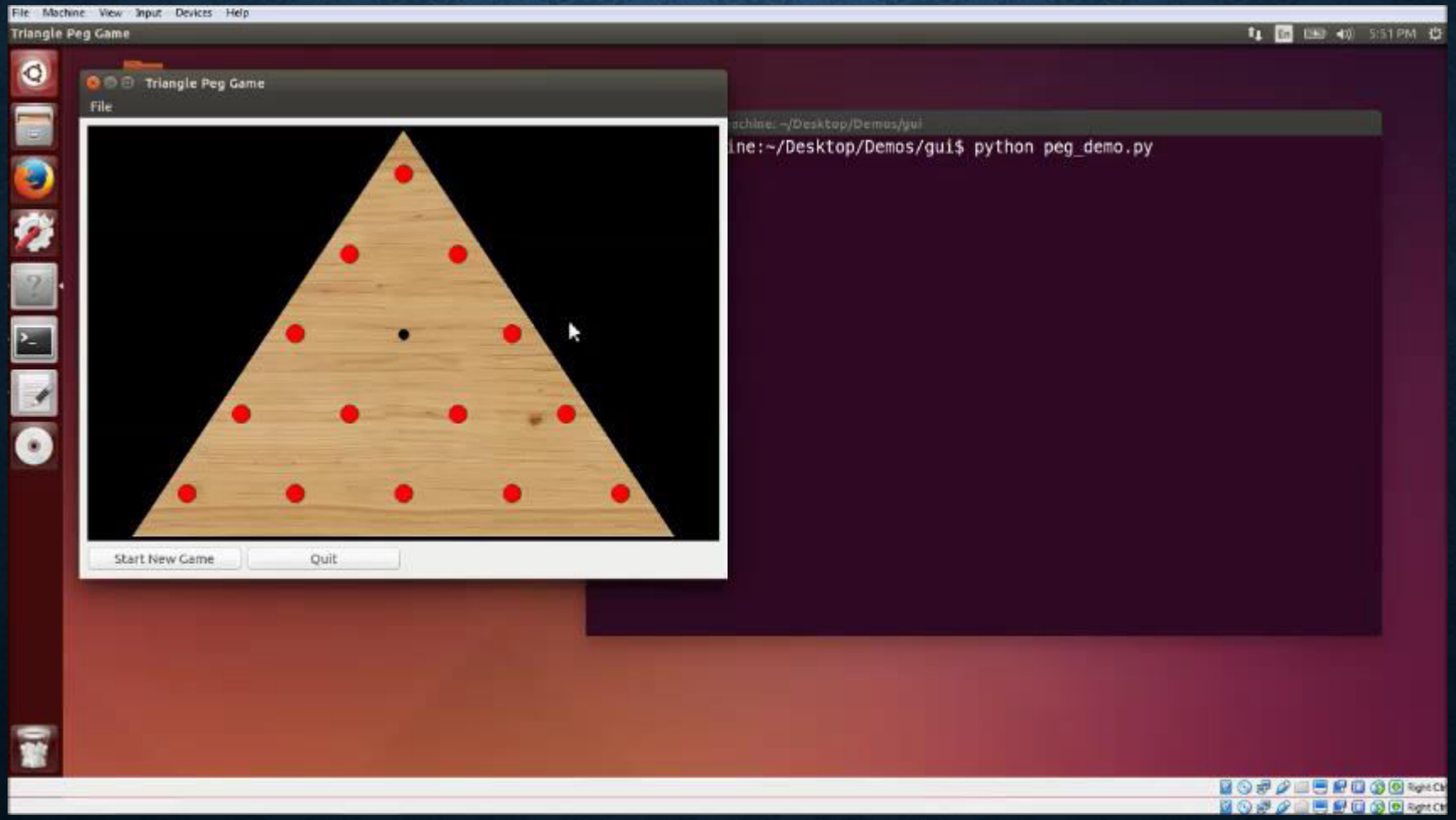
Only accept the drop request if the destination does not have a Peg *and* the source of the drag is valid.

```
def dropEvent(self, event):
    if not self.peg:
        row, col = pickle.loads(event.mimeData().text())
        if(self.check_valid(row, col)):
            self.addPeg()
            event.accept()
        else:
            event.ignore()
    else:
        event.ignore()
```

ENFORCING RULES

```
def check_valid(self, row, col):
    hopped = None
    # Calculate coordinates of skipped peg
    # and store as hopped
    if not hopped:
        return False

    if(self.parent.holes[hopped[0]][hopped[1]].peg):
        self.parent.holes[hopped[0]][hopped[1]].deletePeg()
        self.parent.peg_count -= 1
        return True
    else:
        return False
```

ENFORCING RULES



FURTHER READING

- Check out this link for a little tutorial on custom widgets.

- Check out this link for a small tetris game demo.