



Matplotlib for Python Developers

Sandro Tosi



Chapter No. 6 "Embedding Matplotlib in Qt 4"

In this package, you will find:

A Biography of the author of the book

A preview chapter from the book, Chapter NO.6 "Embedding Matplotlib in Qt 4"

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About the Author

Sandro Tosi was born in Firenze (Italy) in the early 80s, and graduated with a B.Sc. in Computer Science from the University of Firenze.

His personal passions for Linux, Python (and programming), and computer technology are luckily a part of his daily job, where he has gained a lot of experience in systems and applications management, database administration, as well as project management and development.

After having worked for five years as an EAI and an Application architect in an energy multinational, he's now working as a system administrator for an important European Internet company.

I'd like to thank Laura, who has assisted and supported me while writing this book.

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Matplotlib for Python Developers

This book is about Matplotlib, a Python package for 2D plotting that generates production quality graphs. Its variety of output formats, several chart types, and capability to run either interactively (from Python or IPython consoles) and non-interactively (useful, for example, when included into web applications), makes Matplotlib suitable for use in many different situations.

Matplotlib is a big package with several dependencies and having them all installed and running properly is the first step that needs to be taken. We provide some ways to have a system ready to explore Matplotlib. Then we start describing the basic functions required for plotting lines, exploring any useful or advanced commands for our plots until we come to the core of Matplotlib: the object-oriented interface. This is the root for the next big section of the book—embedding Matplotlib into GUI libraries applications. We cannot limit it only to desktop programs, so we show several methods to include Matplotlib into web sites using low level techniques for two well known web frameworks—Pylons and Django. Last but not the least, we present a number of real world examples of Matplotlib applications.

The core concept of the book is to present how to embed Matplotlib into Python applications, developed using the main GUI libraries: GTK+, Qt 4, and wxWidgets. However, we are by no means limiting ourselves to that. The step-by-step introduction to Matplotlib functions, the advanced details, the example with web frameworks, and several real-life use cases make the book suitable for anyone willing to learn or already working with Matplotlib.

What This Book Covers

Chapter 1—Introduction to Matplotlib introduces what Matplotlib is, describing its output formats and the interactions with graphical environments. Several ways to install Matplotlib are presented, along with its dependencies needed to have a correctly configured environment to get along with the book.

Chapter 2—Getting started with Matplotlib covers the first examples of Matplotlib usage. While still being basic, the examples show important aspects of Matplotlib like how to plot lines, legends, axes labels, axes grids, and how to save the finished plot. It also shows how to configure Matplotlib using its configuration files or directly into the code, and how to work profitably with IPython.

Chapter 3—Decorate Graphs with Plot Styles and Types discusses the additional plotting capabilities of Matplotlib: lines and points styles and ticks customizations. Several types of plots are discussed and covered: histograms, bars, pie charts, scatter plots, and more, along with the polar representation. It is also explained how to include textual information inside the plot.

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Chapter 4—Advanced Matplotlib examines some advanced (or not so common) topics like the object-oriented interface, how to include more subplots in a single plot or how to generate more figures, how to set one axis (or both) to logarithmic scale, and how to share one axis between two graphs in one plot. A consistent section is dedicated to plotting date information and all that comes with that. This chapter also shows the text properties that can be tuned in Matplotlib and how to use the LaTeX typesetting language. It also presents a section about contour plot and image plotting.

Chapter 5—Embedding Matplotlib in GTK+ guides us through the steps to embed Matplotlib inside a GTK+ program. Starting from embedding just the Figure and the Navigation toolbar, it will present how to use Glade to design a GUI and then embed Matplotlib into it. It also describes how to dynamically update a Matplotlib plot using the GTK+ capabilities.

Chapter 6—Embedding Matplotlib in Qt 4 explores how to include a Matplotlib figure into a Qt 4 GUI. It includes an example that uses Qt Designer to develop a GUI and how to use Matplotlib into it. What Qt 4 library provides for a real-time update of a Matplotlib plot is described here too.

Chapter 7—Embedding Matplotlib in wxWidgets shows what is needed to embed Matplotlib into a wxWidget graphical application. An important example is the one for a real-time plot update using a very efficient technique (borrowed from computer graphics), allowing for a high update rate. WxGlade is introduced, which guides us step-by-step through the process of wxWidgets GUI creation and where to include a Matplotlib plot.

Chapter 8—Matplotlib for the Web describes how to expose plots generated with Matplotlib on the Web. The first examples start from the lower ground, using CGI and the Apache `mod_python` module, technologies recommended only for limited or simple tasks. For a full web experience, two web frameworks are introduced, Pylons and Django, and a complete guide for the inclusion of Matplotlib with these frameworks is given.

Chapter 9—Matplotlib in the Real World takes Matplotlib and brings it into the real world examples field, guiding through several situations that might occur in the real life. The source code to plot the data extracted from a database, a web page, a parsed log file, and from a comma-separated file are described in full detail here. A couple of third-party tools using Matplotlib, NetworkX, and Mpmath, are described presenting some examples of their usage. A considerable section is dedicated to Basemap, a Matplotlib toolkit to draw geographical data.

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Embedding Matplotlib in Qt 4

There are several GUI libraries available, and one of the most famous is Qt. In this book, we will use Qt 4, the latest major version of this library. Unless explicitly mentioned, when we write Qt, we are referring to Qt 4.

We will follow the same progression as in the GTK+ chapter, and we will present the same examples, but this time written in Qt.

We believe that this method will allow us to directly compare the libraries, and it has the advantage of not leaving the "How would I write something with library X?" question unanswered.

During this chapter, we will see how to:

- Embed a Matplotlib `Figure` into a Qt widget
- Embed a `Figure` and navigation toolbar into a Qt widget
- Use events to update in real-time a Matplotlib plot
- Use Qt Designer to draw a GUI and then use it with Matplotlib in a simple Python application

We begin by giving an introduction to the library.

Brief introduction to Qt 4 and PyQt4

Qt is a cross-platform application development framework, widely used for graphical programs (GUI) but also for non-GUI tools.

Qt was developed by Trolltech (now owned by Nokia), and it's probably best known for being the foundation of the **K Desktop Environment (KDE)** for Linux.

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The Qt toolkit is a collection of classes to simplify the creation of programs. Qt is more than just a GUI toolkit; it includes components for abstractions of network sockets, threads, Unicode, regular expressions, SQL databases, SVG, OpenGL, and XML, as well as a fully functional web browser, a help system, a multimedia framework, and a rich collection of GUI widgets.

Qt is available on several platforms, in particular: Unix/Linux, Windows, Mac OS X, and also some embedded devices. As it uses the native APIs of the platform to render the Qt controls, applications developed with Qt have a look and feel which fits the running environment (without looking like *aliens* in it).

Though written in C++, Qt can also be used in several other programming languages, through language bindings available for Ruby, Java, Perl, and also Python with PyQt.

PyQt is a comprehensive set of Python bindings for the Qt framework. PyQt provides bindings for Qt 2 and Qt 3. PyQt4 is a separate set of bindings and covers the Qt 4 series of releases. We will use PyQt4 and references to PyQt should be considered to be referring to PyQt4.

PyQt brings together the Qt C++ cross-platform application framework and the cross-platform interpreted language, Python. An application written in Qt and PyQt often runs unchanged on all the supported platforms.

The Qt components are mapped to several Python submodules (where PyQt4 is the main module), and the most important are:

- The `QtCore` module, which contains the core non-GUI classes (for example, the event loop).
- The `QtGui` module, which contains the majority of the GUI classes.
- `QtOpenGL`, `QtScript` (JavaScript support), `QtSql` (SQL databases support), `QtSvg` (SVG file support), `QtTest` (unit testing support), `QtXml` (XML support), `QtNetwork` (for network programming), and several others. Note how many of these submodules provide functionalities that are already present in Python standard library.

Embedding a Matplotlib figure in a Qt window

We are going to see how to embed a Matplotlib `Figure` into a simple Qt window. We will first walk through the code and describe it, while presenting it as a whole at the end of the section (this presentation style will be used throughout the chapter).

Here is the beginning:

```
import sys
```

The module `sys` contains information and functions used to interact with the Python interpreter. In this case, we need it to access the command-line arguments passed to the Python script.

```
from PyQt4 import QtGui
```

We import the PyQt4 submodule, `QtGui` which contains the biggest part of the GUI classes, for example, all the basic GUI widgets are located in this module.

```
import numpy as np
```

The NumPy module is needed for our example graph.

```
from matplotlib.figure import Figure
```

Import the `Figure` Matplotlib object: this is the backend-independent representation of our plot.

```
from matplotlib.backends.backend_qt4agg \
import FigureCanvasQTAagg as FigureCanvas
```

Here we import from the `matplotlib.backends.backend_qt4agg` module the `FigureCanvasQTAagg` class, which is the backend-dependent figure canvas; it contains the backend-specific knowledge to render the `Figure` we've drawn to the Qt 4 backend.

Note that `FigureCanvasQTAagg`, other than being a Matplotlib class, is also a `QWidget` – the base class of all user interface objects (it simply represents an empty area). So this means we can treat `FigureCanvasQTAagg` like a pure Qt widget object, using it in the GUI window as we would do with buttons, text areas, and so on.

```
class Qt4MplCanvas(FigureCanvas):
```

We now define a new class, `Qt4MplCanvas`, to render our Matplotlib plot; it inherits from `FigureCanvas`, as well as from `QWidget`. Therefore, it can be used as a Qt element in the main window of our application.

```
def __init__(self):
    self.fig = Figure()
    self.axes = self.fig.add_subplot(111)
    self.x = np.arange(0.0, 3.0, 0.01)
    self.y = np.cos(2*np.pi*self.x)
    self.axes.plot(self.x, self.y)
```


In the `__init__` method, which is called upon class instantiation, we write the code to draw the graph.

```
FigureCanvas.__init__(self, self.fig)
```

We also instantiate the `FigureCanvas`, which is responsible for taking the Matplotlib `Figure` object, and render it in a Qt widget.

```
qApp = QtGui.QApplication(sys.argv)
```

This command creates the Qt application, initialized with the list of arguments given from the command line. This is a required parameter, and it's the reason we imported the `sys` module.

 Every PyQt4 application must create one and only one `QApplication` instance, no matter how many windows compose the application.

`QApplication` manages the GUI application's control flow and main settings. It's the place where the main event loop is executed, processing and dispatching to the widgets all the events coming from the window system and other sources.

It is also responsible for application initialization and finalization, handling most of the system-wide and application-wide settings.

Since `QApplication` handles the entire initialization phase, it must be created before any other objects related to the UI are created.

```
mpl = Qt4MplCanvas()
```

We can now instantiate the `Qt4MplCanvas`. A `QWidget` with no parent (like the one over here) is called a **window**. Consider the *parent* as the object where we want to put the widget; if it's `None`, then it's a main window. Otherwise, if we want to put the widget in a window, then we set the parent as a reference to that window.

```
mpl.show()
```

The `show()` method makes the widget visible on the screen.

```
sys.exit(qApp.exec_())
```


The command `qApp.exec_()` enters the Qt main event loop. Once `exit()` or `quit()` is called, it returns the relevant return code. Until the main loop is started, nothing is displayed on screen.

It's necessary to call this function as the main loop handles all events and signals coming from both the application widgets and from the window system; essentially, no user interaction can take place before it's called.

You may be wondering why there is an underscore in `exec_()`; the reason is simple: `exec()` is a reserved word in Python, thus the addition of the underscore to the `exec()` Qt method.

Wrapping it inside `sys.exit()` allows the Python script to exit with the same return code, informing the environment how the application ended (whether successfully or not).

Here is the complete source code:

```
# for command-line arguments
import sys

# Python Qt4 bindings for GUI objects
from PyQt4 import QtGui

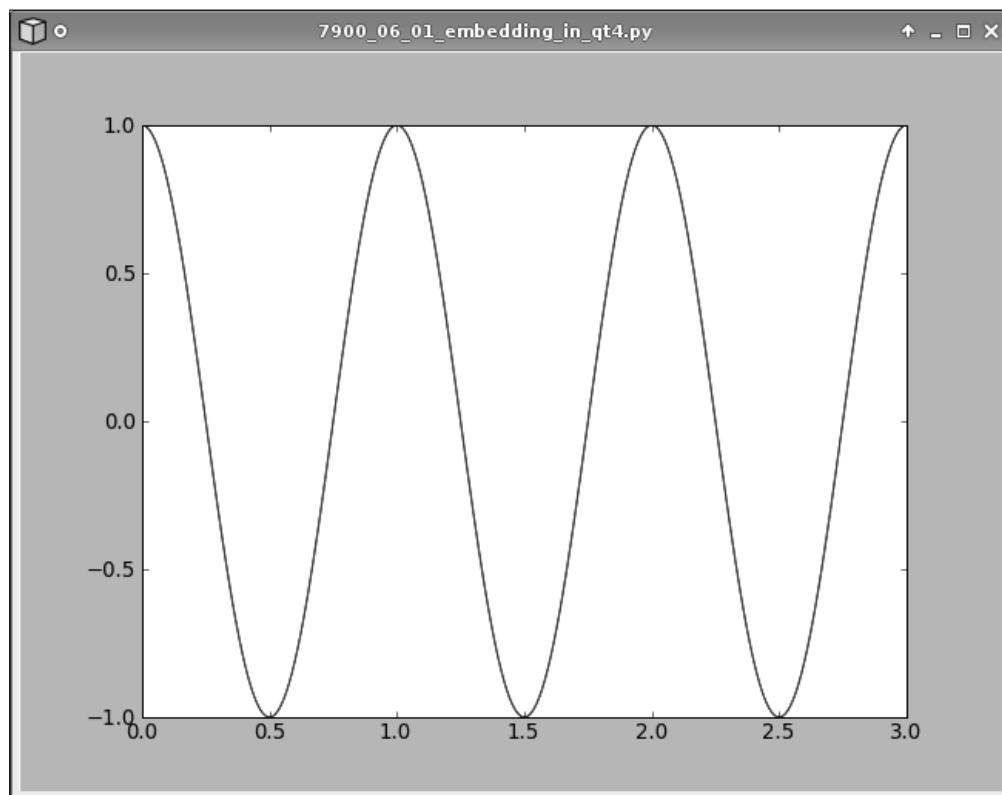
# Numpy functions for image creation
import numpy as np

# Matplotlib Figure object
from matplotlib.figure import Figure
# import the Qt4Agg FigureCanvas object, that binds Figure to
# Qt4Agg backend. It also inherits from QWidget
from matplotlib.backends.backend_qt4agg \
    import FigureCanvasQTAgg as FigureCanvas

class Qt4MplCanvas(FigureCanvas):
    """Class to represent the FigureCanvas widget"""
    def __init__(self):
        # Standard Matplotlib code to generate the plot
        self.fig = Figure()
        self.axes = self.fig.add_subplot(111)
        self.x = np.arange(0.0, 3.0, 0.01)
        self.y = np.cos(2*np.pi*self.x)
        self.axes.plot(self.x, self.y)
        # initialize the canvas where the Figure renders into
        FigureCanvas.__init__(self, self.fig)
```

```
# Create the GUI application
qApp = QtGui.QApplication(sys.argv)
# Create the Matplotlib widget
mpl = Qt4MplCanvas()
# show the widget
mpl.show()
# start the Qt main loop execution, exiting from this script
# with the same return code of Qt application
sys.exit(qApp.exec_())
```

Here is the screenshot from the running application:



Including a navigation toolbar

Here we're going to add the navigation toolbar to the Matplotlib plot to explore some additional aspects of Qt.

```
import sys
```

This is used for command-line argument retrieval.

```
from PyQt4 import QtGui
```

We now import the Qt 4 GUI widget's submodule.

```
import numpy as np
```

This is the usual NumPy import to generate the plot data.

```
from matplotlib.figure import Figure
from matplotlib.backends.backend_qt4agg \
    import FigureCanvasQTAff as FigureCanvas
from matplotlib.backends.backend_qt4agg \
    import NavigationToolbar2QTAff as NavigationToolbar
```

Here we import the Matplotlib Figure object along with the FigureCanvasQTAff and NavigationToolbar2QTAff. Note that the last two are Qt 4 specific and also inherit from QWidget, so they can be used as Qt objects in a QApplication.

```
class Qt4MplCanvas(FigureCanvas):
```

We now define a new class and as it inherits from FigureCanvas, it is also a QWidget that can be embedded into a Qt application.

```
def __init__(self, parent):
    self.fig = Figure()
    self.axes = self.fig.add_subplot(111)
    t = np.arange(0.0, 3.0, 0.01)
    s = np.cos(2*np.pi*t)
    self.axes.plot(t, s)
```

This is the usual code to draw a Matplotlib example graph.

```
FigureCanvas.__init__(self, self.fig)
```

We now initialize the FigureCanvas object, the Qt 4-specific figure canvas.

```
self.setParent(parent)
```

We set the parent of this widget to the parent parameter of `__init__`.

```
FigureCanvas.setSizePolicy(self,
                            QtGui.QSizePolicy.Expanding,
                            QtGui.QSizePolicy.Expanding)
```

The `setSizePolicy()` `QWidget` method is used to set the widget size behavior. We set it to be freely expandable so that we can resize the window and have the `Figure` be resized accordingly.

```
FigureCanvas.updateGeometry(self)
```

We need to call this method because we have changed the size policies, so we now notify the layout system of this change.

```
class ApplicationWindow(QtGui.QMainWindow):
```

We create another class that will be our main application window.

The `QMainWindow` class provides a framework to create the main windows of application user interfaces; it's common to subclass it, when defining our own window.

As we've seen in the previous example, there are other ways to create a visible window (we did it with a `QWidget` without a parent), but using `QMainWindow` is the best way to build a full-featured GUI application.

```
def __init__(self):
    QtGui.QMainWindow.__init__(self)
```

We call the constructor of the superclass, since we inherit from it. It's necessary to initialize the base class (to be able to use its functionalities) while initializing our own class.

```
self.setWindowTitle("Matplotlib Figure in a Qt4 Window With
NavigationToolbar")
```

We set the window title, as we expect a real application to have a title.

```
self.main_widget = QtGui.QWidget(self)
```

We create a widget that will be the main widget displayed by our application.

```
vbl = QtGui.QVBoxLayout(self.main_widget)
```

Here is a vertical box: vertical and horizontal boxes are used to group widgets together (on a vertical or horizontal layout) and allow size transformations on all of them. They are also called *geometry* or *layout managers*, since they are able to automatically position and adjust the widgets they contain.

The idea behind layout managers is to pack widgets into an area where their positions are relative to the other widgets and to the window. Resize the window, and the layout managers will automatically adjust the size and position of widgets to accommodate this change.

```
qmc = Qt4MplCanvas(self.main_widget)
ntb = NavigationToolbar(qmc, self.main_widget)
```

Now we have the two Matplotlib objects we're interested in—the figure canvas and the toolbar. Note how one of the toolbar parameters is the figure canvas.

```
vbl.addWidget(qmc)
vbl.addWidget(ntb)
```

So now we can pack these two widgets into the vertical box that will align widgets from top to bottom.

```
self.main_widget.setFocus()
```

We set the focus on our main widget.

```
self.setCentralWidget(self.main_widget)
```

We now define it as the **central widget**. `QApplication` has the concept of central widget that we can think of as the main part of the application. It is not the toolbar, the menu, or anything else, rather it is the actual main functional area of the application.

```
qApp = QtGui.QApplication(sys.argv)
```

We create the `QApplication` instance.

```
aw = ApplicationWindow()
```

We instantiate our main window.

```
aw.show()
```

We show the main window.

```
sys.exit(qApp.exec_())
```

and at the end, start the Qt 4 main events loop.

The whole code is :

```
# for command-line arguments
import sys

# Python Qt4 bindings for GUI objects
from PyQt4 import QtGui

# Numpy functions for image creation
```

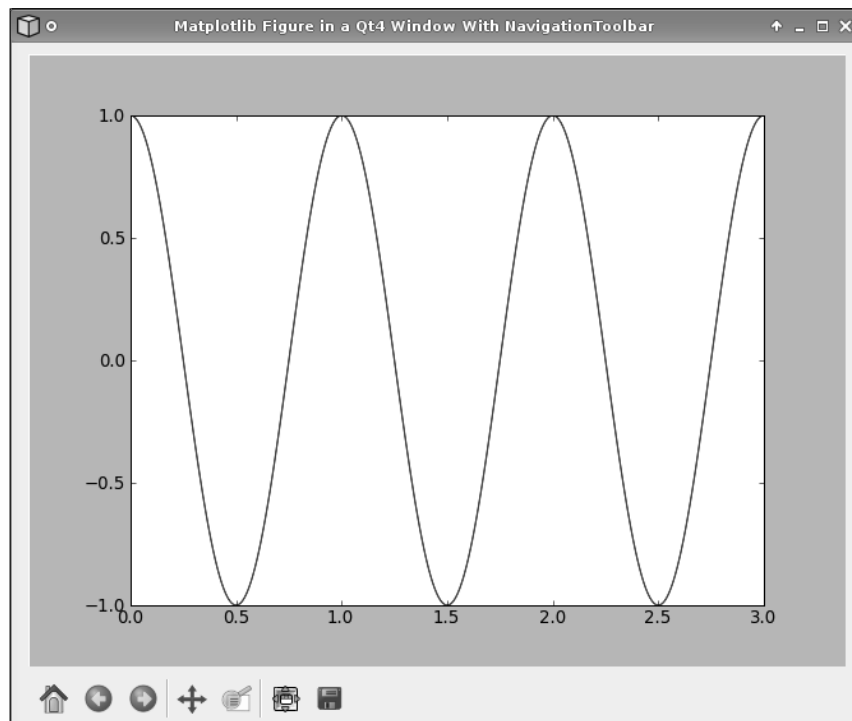
```
import numpy as np
# Matplotlib Figure object
from matplotlib.figure import Figure
# import the Qt4Agg FigureCanvas object, that binds Figure to
# Qt4Agg backend. It also inherits from QWidget
from matplotlib.backends.backend_qt4agg \
    import FigureCanvasQTAgg as FigureCanvas
# import the NavigationToolbar Qt4Agg widget
from matplotlib.backends.backend_qt4agg \
    import NavigationToolbar2QTAgg as NavigationToolbar
class Qt4MplCanvas(FigureCanvas):
    """Class to represent the FigureCanvas widget"""
    def __init__(self, parent):
        # plot definition
        self.fig = Figure()
        self.axes = self.fig.add_subplot(111)
        t = np.arange(0.0, 3.0, 0.01)
        s = np.cos(2*np.pi*t)
        self.axes.plot(t, s)
        # initialization of the canvas
        FigureCanvas.__init__(self, self.fig)
        # set the parent widget
        self.setParent(parent)
        # we define the widget as expandable
        FigureCanvas.setSizePolicy(self,
                                   QtGui.QSizePolicy.Expanding,
                                   QtGui.QSizePolicy.Expanding)
        # notify the system of updated policy
        FigureCanvas.updateGeometry(self)
class ApplicationWindow(QtGui.QMainWindow):
    """Example main window"""
    def __init__(self):
        # initialization of Qt MainWindow widget
        QtGui.QMainWindow.__init__(self)
        # set window title
        self.setWindowTitle("Matplotlib Figure in a Qt4 Window With
NavigationToolbar")
        # instantiate a widget, it will be the main one
        self.main_widget = QtGui.QWidget(self)
        # create a vertical box layout widget
        vbl = QtGui.QVBoxLayout(self.main_widget)
        # instantiate our Matplotlib canvas widget
```

```
qmc = Qt4MplCanvas(self.main_widget)
# instantiate the navigation toolbar
ntb = NavigationToolbar(qmc, self.main_widget)
# pack these widget into the vertical box
vbl.addWidget(qmc)
vbl.addWidget(ntb)

# set the focus on the main widget
self.main_widget.setFocus()
# set the central widget of MainWindow to main_widget
self.setCentralWidget(self.main_widget)

# create the GUI application
qApp = QtGui.QApplication(sys.argv)
# instantiate the ApplicationWindow widget
aw = ApplicationWindow()
# show the widget
aw.show()
# start the Qt main loop execution, exiting from this script
# with the same return code of Qt application
sys.exit(qApp.exec_())
```

When we execute this application, it will show something similar to:



Real-time update of a Matplotlib graph

In this section, we will present a simple application—a CPU usage monitor, where we will update the Matplotlib graph in real-time (once every second over a period of 30 seconds).

As there are several indicators of CPU usage in a modern operating system, we decided to restrict our graph to the four main ones:

- **user:** The time consumed by processes executed by the users of the machine
- **nice:** The time consumed by processes executed by users but with a lower priority
- **system:** The time consumed by system tasks
- **idle:** The time consumed waiting for something to execute

The ignored indicators contribute for just a minimal part of the CPU usage, so their exclusion doesn't disturb the validity of the example.

Of those four indicators, what we will plot is the percentage of each of them against the total CPU usage.

Here we start:

```
import sys
from PyQt4 import QtGui
```

These are the modules for command-line parameters and for Python bindings of the QtGui submodule.

```
from matplotlib.figure import Figure
from matplotlib.backends.backend_qt4agg \
    import FigureCanvasQTAgg as FigureCanvas
```

The classic Matplotlib import for the required objects.

```
import psutil as p
```

Python is full of modules that do almost everything we can think of, so for our example, we leverage an existing module—psutils.

psutil is a multiplatform module (available for Windows, Linux, and Mac OS X) that exports a common interface to access system information such as processes, memory, CPU, and so on. We will use its functionalities to obtain the CPU usage.

```
MAXITERS = 30
```


This is the total number of iterations we want to perform. Since we perform an iteration every second, the total number of iterations equals 30 seconds of CPU usage monitoring.

```
class CPUMonitor(FigureCanvas):
```

As usual, we define a class for the Matplotlib graph elaboration.

```
def __init__(self):
    self.before = self.prepare_cpu_usage()
```

In the initialization method, we save the current CPU usage information. The algorithm we will use to update the graph needs a *previous* set of values.

```
self.fig = Figure()
self.ax = self.fig.add_subplot(111)
```

The basic Matplotlib Figure and Axes initialization.

```
FigureCanvas.__init__(self, self.fig)
```

Initialization for the canvas, referring to the Figure object defined earlier.

```
self.ax.set_xlim(0, 30)
self.ax.set_ylim(0, 100)
self.ax.set_autoscale_on(False)
```

We set the limits for the X-axis (to have a 30 seconds interval) and for the Y-axis (the range of percentage usage), and then disable the autoscale feature. This will allow us to have a fixed dimension Axes, where the plot can be redrawn without resizing the figure.

```
self.user, self.nice, self.sys, self.idle = [], [], [], []
self.l_user, = self.ax.plot([],self.user, label='User %')
self.l_nice, = self.ax.plot([],self.nice, label='Nice %')
self.l_sys, = self.ax.plot([],self.sys, label='Sys %')
self.l_idle, = self.ax.plot([],self.idle, label='Idle %')
```

This draws a placeholder line for the four datasets that we will use. This is important because we now have the references to the four line objects, and we can dynamically update their information without generating a new object at every iteration.

```
self.ax.legend()
```

Here, we add a legend.

```
self.fig.canvas.draw()
```

The preceding line of code forces a draw of the canvas.

```
self.cnt = 0
```

We initialize the iterations counter to 0.

```
self.timerEvent(None)
```

We make an explicit call to the method that we will use to update the graph dynamically: this is a little trick used to speed up the visualization of the plot.

```
self.timer = self.startTimer(1000)
```

With this command, we start a timer object and save the reference to `self.timer`. `QTimer` is a class that triggers an event every n milliseconds (the interval is specified on instantiation).

In this case, our timer will generate an event every second, and we will use this event to update our graph.

The main loop (started by `exec_()`) processes the timer events (along with all the others) and delivers them to this widget.

```
def prepare_cpu_usage(self):
```

This function will take care of preparing the CPU usage information we need.

```
t = p.cpu_times()
```

We use the `psutil cpu_times()` method to retrieve the current CPU usage.

```
if hasattr(t, 'nice'):
    return [t.user, t.nice, t.system, t.idle]
else:
    # special case for Windows, without 'nice' value
    return [t.user, 0, t.system, t.idle]
```

We check if the `nice` attribute is available. On a Unix-like system, that attribute is present, so we can return the whole set of data. On Windows, where there is no distinction between `user` and `nice` processes, the attribute is missing, so we set its value to 0 while still returning the other indicators. The net result is that we have a cross-platform code able to run on Windows and on Unix-like systems.

```
def get_cpu_usage(self):
```

We define another function to take the values from `prepare_cpu_usage()` and compute the information needed for plotting.

```
now = self.prepare_cpu_usage()
```

We take the current CPU usage values.

```
delta = [now[i]-self.before[i] for i in range(len(now))]
```

Then we compute the deltas from the previous measurement to the current one. *Delta* is the Greek letter for *d* (from difference), commonly used when dealing with differences.

Values returned from `psutil.cpu_times()` are counters. They are monotonically increased from the moment the machine boots until it is turned off. What we're interested in is the amount of CPU taken by each of the four categories that we plot during the measurement interval. These commands do this evaluation.

```
total = sum(delta)
```

We compute the sum of the deltas.

```
self.before = now
```

We replace the `self.before` value with `now`, so at the next iteration, the current values will be used.

```
return [(100.0*dt)/total for dt in delta]
```

and we return the CPU usage percentage for our four categories. `dt/total` represents the fraction of the total time used by that category and multiplying it by `100.0` generates a percentage value.

```
def timerEvent(self, evt):
```

As said, events are an important part of Qt, and the main loop receives and dispatches them to the right widgets. A common way by which a widget processes events is by reimplementing *event handlers*.

In our example, `QTimer` object generates (at a regular rate of one event per second) a `QTimerEvent` that is sent to our widget (since it's the widget that started the timer).

To modify the widget behavior following the reception of an event, we need to define our own event handler, which in the case of a timer is called `timerEvent()`.

```
result = self.get_cpu_usage()
```

We get the current percentage values for CPU usage.

```
self.user.append(result[0])
self.nice.append(result[1])
self.sys.append(result[2])
self.idle.append(result[3])
```

We add them to the relevant datasets.

```
self.l_user.set_data(range(len(self.user)), self.user)
self.l_nice.set_data(range(len(self.nice)), self.nice)
self.l_sys.set_data(range(len(self.sys)), self.sys)
self.l_idle.set_data(range(len(self.idle)), self.idle)
```

Now, we replot the lines with the updated information. We have added one item to each indicator's list, and now we are updating the line objects to reflect the new data. Updating the lines instead of creating a completely new plot (or removing the old lines and adding new ones) is faster and does not create any annoying visual effect on the window.

```
self.fig.canvas.draw()
```

We force a redraw of the canvas to actually show the changed lines.

```
if self.cnt == MAXITERS:
```

then we have to check if we've performed all the iterations or not.

```
self.killTimer(self.timer)
```

Once we have completed all the iterations, we stop the timer by calling `killTimer()` and passing the timer reference that we had created and saved when creating `startTimer()`.

```
else:
    self.cnt += 1
```

Alternatively, we simply increment the counter and wait for the next timer event to occur.

```
app = QtGui.QApplication(sys.argv)
```

we now start the main part of the application, and as the first thing, we create our wrapper `QApplication` instance.

```
widget = CPUMonitor()
```

Here, we create our `CPUMonitor` widget.

```
widget.setWindowTitle("30 Seconds of CPU Usage Updated in RealTime")
```

we set the window title.

```
widget.show()
```

We show the widget.

```
sys.exit(app.exec_())
```

and at the end, we start the main loop.

Here is the full example code:

```
# for command-line arguments
import sys

# Python Qt4 bindings for GUI objects
from PyQt4 import QtGui

# Matplotlib Figure object
from matplotlib.figure import Figure
# import the Qt4Agg FigureCanvas object, that binds Figure to
# Qt4Agg backend. It also inherits from QWidget
from matplotlib.backends.backend_qt4agg \
    import FigureCanvasQTAgg as FigureCanvas

# used to obtain CPU usage information
import psutil as p

# Total number of iterations
MAXITERS = 30

class CPUMonitor(FigureCanvas):
    """Matplotlib Figure widget to display CPU utilization"""
    def __init__(self):
        # save the current CPU info (used by updating algorithm)
        self.before = self.prepare_cpu_usage()

        # first image setup
        self.fig = Figure()
        self.ax = self.fig.add_subplot(111)

        # initialization of the canvas
        FigureCanvas.__init__(self, self.fig)

        # set specific limits for X and Y axes
        self.ax.set_xlim(0, 30)
        self.ax.set_ylim(0, 100)

        # and disable figure-wide autoscale
```

```
self.ax.set_autoscale_on(False)

# generates first "empty" plots
self.user, self.nice, self.sys, self.idle = [], [], [], []

self.l_user, = self.ax.plot([],self.user, label='User %')
self.l_nice, = self.ax.plot([],self.nice, label='Nice %')
self.l_sys, = self.ax.plot([],self.sys, label='Sys %')
self.l_idle, = self.ax.plot([],self.idle, label='Idle %')

# add legend to plot
self.ax.legend()

# force a redraw of the Figure
self.fig.canvas.draw()

# initialize the iteration counter
self.cnt = 0

# call the update method (to speed-up visualization)
self.timerEvent(None)

# start timer, trigger event every 1000 millisecs (=1sec)
self.timer = self.startTimer(1000)

def prepare_cpu_usage(self):
    """helper function to return CPU usage info"""

    # get the CPU times using psutil module
    t = p.cpu_times()

    # return only the values we're interested in
    if hasattr(t, 'nice'):
        return [t.user, t.nice, t.system, t.idle]
    else:
        # special case for Windows, without 'nice' value
        return [t.user, 0, t.system, t.idle]
def get_cpu_usage(self):
    """Compute CPU usage comparing previous and current
measurements"""

    # take the current CPU usage information
    now = self.prepare_cpu_usage()
    # compute delta between current and previous measurements
```

```
delta = [now[i]-self.before[i] for i in range(len(now))]
# compute the total (needed for percentages calculation)
total = sum(delta)
# save the current measurement to before object
self.before = now
# return the percentage of CPU usage for our 4 categories
return [(100.0*dt)/total for dt in delta]

def timerEvent(self, evt):
    """Custom timerEvent code, called at timer event receive"""
    # get the cpu percentage usage
    result = self.get_cpu_usage()

    # append new data to the datasets
    self.user.append(result[0])
    self.nice.append(result[1])
    self.sys.append( result[2])
    self.idle.append(result[3])

    # update lines data using the lists with new data
    self.l_user.set_data(range(len(self.user)), self.user)
    self.l_nice.set_data(range(len(self.nice)), self.nice)
    self.l_sys.set_data( range(len(self.sys)), self.sys)
    self.l_idle.set_data(range(len(self.idle)), self.idle)

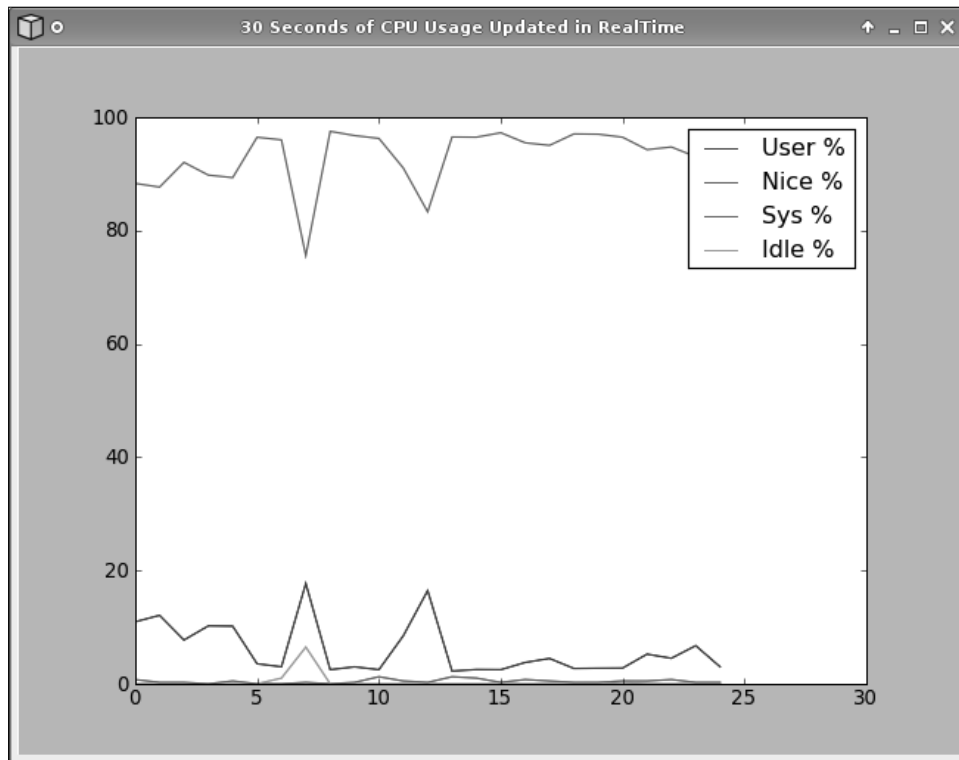
    # force a redraw of the Figure
    self.fig.canvas.draw()

    # if we've done all the iterations
    if self.cnt == MAXITERS:
        # stop the timer
        self.killTimer(self.timer)
    else:
        # else, we increment the counter
        self.cnt += 1

# create the GUI application
app = QtGui.QApplication(sys.argv)
# Create our Matplotlib widget
widget = CPUMonitor()
# set the window title
widget.setWindowTitle("30 Seconds of CPU Usage Updated in RealTime")
# show the widget
widget.show()
```

```
# start the Qt main loop execution, exiting from this script
# with the same return code of Qt application
sys.exit(app.exec_())
```

Here is a screenshot which was taken while running the preceding application:



At the top of the window, we can see the green line for the CPU usage of `nice` processes, down below there is the blue line for user CPU usage, and very near the 0 we have system time (in red) and idle time (in cyan) lines, barely visible. In Chapter 7, we will present a similar technique to update a plot in real time, but with a much higher throughput.

Embedding Matplotlib in a GUI made with Qt Designer

For simple examples, designing the GUI in the Python code can be good enough, but for more complex applications, this solution does not scale.

There are some tools to help you design the GUI for Qt, and one of the most commonly used is **Qt Designer**.

Similar to Glade, we can design the user interface part of the application using on-screen form and drag-and-drop interface. Then we can connect the widgets with the backend code, where we develop the logic of the application.

The core of our example application will be plotting the frequencies of occurrences of letters in a text file: we will count the number of times each letter of the English alphabet appears in a given file and then plot this information in a bar graph.

First, we will show how to design our GUI with Qt Designer, in particular, how to create a custom Matplotlib widget managed by an external Python source file. Then, we will convert that GUI into a Python code that we can use for our main program.

This example is made up of several source files:

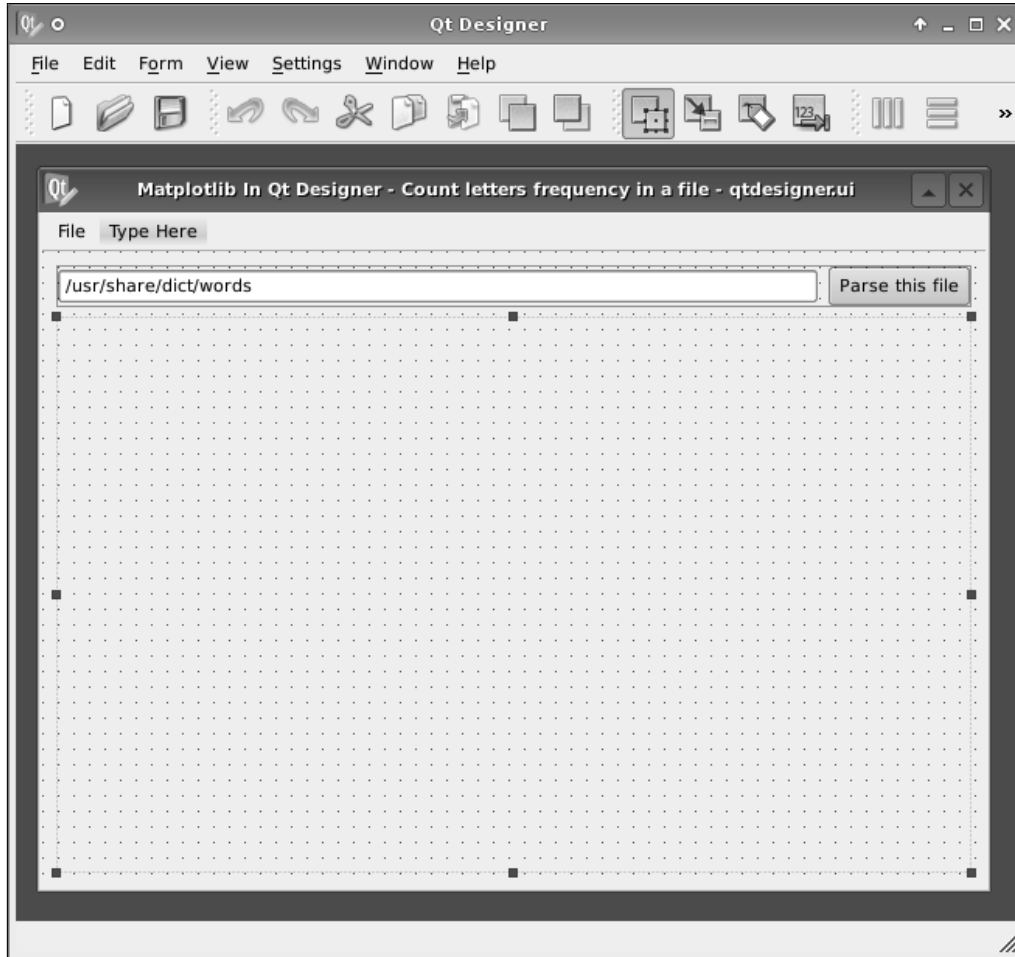
- `qtdesigner.ui`: UI file generated by Qt Designer
- `qtdesigner.py`: Python code generated from UI file
- `mplwidget.py`: Python code to control the custom Matplotlib widget
- `7900_06_04_qt_designer.py`: Main code used to execute the example

We start by looking at how we used the Qt Designer. This chapter is about Qt 4, so we have to use development tools for that version, for example, our Qt Designer is the one for Qt 4 (in particular, version 4.5.1).

Designing the GUI using Qt Designer

Once started, the Designer asks us what kind of form we want to design. For our purpose, we will create a *main window*. An empty window will show up, ready for designing the interface.

From that empty window, the final result will be:



Let's see how to achieve this.

First, rename the main window to **MplMainWindow**. Double-click on the widget in the **Object Inspector** to change its name. We will rename all the widgets to start with `mp1` to recall Matplotlib. Then, we can also remove the status bar (as we do not use it) from the **Object Inspector**.

At this point, we can start adding the widgets that will make up our GUI.

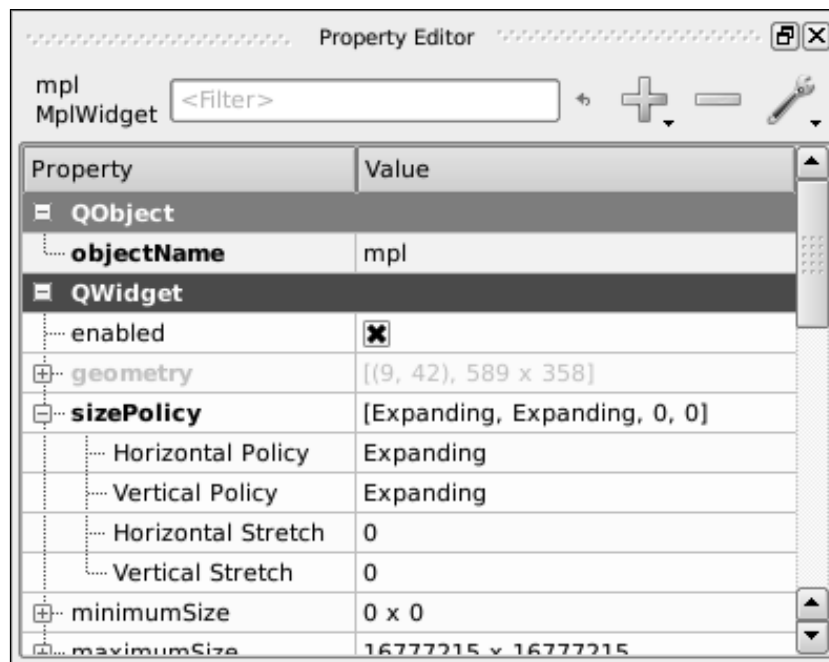
The use of layout managers is important to obtain a nice-looking GUI. So we will add a **Horizontal Layout** widget, and then we add a **Line Edit** and a **PUSH BUTTON** widget to it.

As you can see, the **Horizontal Layout** is just *dropped* in the window right where we dragged it, without a specific layout. Now that we have a widget in the main window, we can decide its global layout. Right-click on the main window widget in the **Object Inspector**, and choose **Lay Out Vertically** from the **Lay Out** submenu.

We can see that our **Horizontal Layout** widget is now expanded to fill the whole window.

Now, place a widget right below the **Horizontal Layout**. This will be our custom widget, where we will plot Matplotlib `Figure`. Each widget is resized to take only half of the window space, but we want to give all the space we can to the custom widget.

We can achieve this by changing the size policy properties of the widget. Click on the widget, and in the **Property editor**, look for the **sizePolicy** section. Set both the, **Horizontal Policy** and **Vertical Policy** properties to **Expanding**, and the widget will be expanded to take much more space (as we expected).

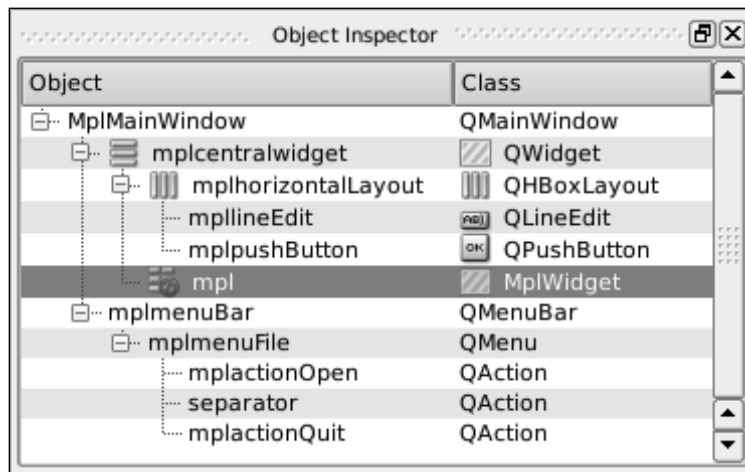


But how can we define the new widget as a custom widget? We have to *promote* it. This is the way to define a custom widget in Qt Designer:

Select the widget, right-click on it and select **Promote to...** and a window will pop up. This is where we will define our custom widget class name and the external library that manages it. We set **Promoted class name** to **MplWidget** to identify this as the widget for Matplotlib plotting, and **Header file** to **mplwidget**, that's the filename without the `.py` extension where we will write the Python code to govern its behavior. Add it to the promoted class, and finally promote the widget to it.

We have almost created the whole GUI, just another step left to go: add a menu with two items, one to select a file to parse and the other to close the application.

Let's see the widgets hierarchy showing the widgets names, their classes, and how they're related to each other:



Code to use the Qt Designer GUI

Now that we have our GUI ready, let's save it to a file, we chose the filename `qtdesigner.ui`. The UI file format is XML, so we have to convert it to Python code, using `pyuic4`: `pyuic4` generates Python code from the GUI designed with Qt 4 Designer.

The tool outputs the result to the terminal, so we have to redirect it into a file:

```
$ pyuic4 qtdesigner.ui > qtdesigner.py
```

If we look at the generated file, we can see that the code is structured as a single class that creates the GUI. On the last line we can see:

```
from mplwidget import MplWidget
Embed Matplotlib in Qt 4
```

This is the same name used in the **Header file** field when promoting the widget.

This import connects the custom widget with the external Python code that controls it; in our example, the file that contains that code is `mplwidget.py`.

So let's give it a look:

```
from PyQt4 import QtGui
from matplotlib.backends.backend_qt4agg \
    import FigureCanvasQTAff as FigureCanvas
from matplotlib.figure import Figure
```

These are the usual imports for the Qt GUI widgets: the Matplotlib Qt4Agg backend canvas and the Figure object.

```
class MplCanvas(FigureCanvas):
    def __init__(self):
        self.fig = Figure()
        self.ax = self.fig.add_subplot(111)
        FigureCanvas.__init__(self, self.fig)
        FigureCanvas.setSizePolicy(self,
                                   QtGui.QSizePolicy.Expanding,
                                   QtGui.QSizePolicy.Expanding)
        FigureCanvas.updateGeometry(self)
```

This is the class that represents the Matplotlib Figure for the Qt backend; nothing new, we've already seen it in the previous examples.

```
class MplWidget(QtGui.QWidget):
```

This is an important class: the name must match with the one used for the custom widget defined in Qt Designer UI file, as this will manage widget drawing. The code is quite similar to what we already saw:

```
def __init__(self, parent = None):
    QtGui.QWidget.__init__(self, parent)
```

Here, we initialize the widget.

```
self.canvas = MplCanvas()
```

We instantiate the Matplotlib canvas object.

```
self.vbl = QtGui.QVBoxLayout()
```

Here, we create a layout manager (in this case a vertical box).

```
self.vbl.addWidget(self.canvas)
```

We add the Matplotlib canvas to the layout manager.

```
self.setLayout(self.vbl)
```

Here, we delegate the layout handling to the `vbl` object.

The main program, `7900_06_04_qt_designer.py`, will glue all the code together to create our application. It will:

- Import the UI
- Define the code to compose the application logic
- Instantiate the `QApplication` with the window layout defined by our GUI
- Start the main loop

At the beginning, we have the import part (as usual):

```
from __future__ import with_statement
```

This helps to open the file easily.

```
import numpy as np
```

NumPy is needed for its array support.

```
import sys
```

For command-line arguments, it is needed for `QApplication` instantiation.

```
from PyQt4 import QtCore
from PyQt4 import QtGui
```

Here, we also import `QtCore`, the Qt submodules for non-GUI, low-level functions.

```
from qtdesigner import Ui_MplMainWindow
```

We import the main window designed with Qt Designer; the name of the main window in Designer is `MplMainWindow` and so `pyuic4` creates a class called `Ui_MplMainWindow` that we can now import to have access to the main window object.

```
class DesignerMainWindow(QtGui.QMainWindow, Ui_MplMainWindow):
```

We now define a class to merge the UI we have designed (with the Qt Designer) with the code to develop the application.

```
def __init__(self, parent = None):
    super(DesignerMainWindow, self).__init__(parent)
```

We initialize the superclass.

```
self.setupUi(self)
```

`setupUi()` is a method of `Ui_MplMainWindow`, created by `pyuic4` at conversion time. It is used to create the UI. The parameter is the widget in which the user interface is created.

```
QtCore.QObject.connect(self.mplpushButton, QtCore.SIGNAL("clicked()"), self.update_graph)
QtCore.QObject.connect(self.mplactionOpen, QtCore.SIGNAL('triggered()'), self.select_file)
QtCore.QObject.connect(self.mplactionQuit, QtCore.SIGNAL('triggered()'), QtGui.QApp, QtCore.SLOT("quit()"))
```

Here we need to introduce the concept of signals and slots.

Introduction to signals and slots

One of the fundamental (and most innovative) concepts in Qt is signals and slots.

They are a very elegant solution which was introduced by Qt to let widgets interact. **Signals** are emitted (sent) by an object that wants to notify the world that something interesting just happened (usually in response to a user interaction, such as a click), and by *connecting signals to slots*, the notification arrives to the slot of objects that are interested.

Slots are functions that respond to certain signals. When a signal is emitted, Qt executes all the slots that are connected to that signal.

We can also connect signals to other signals, creating a chain of notifications.

Signals and slots are primarily used for event handling, but they can also be used to let objects interact (keeping this fact *hidden* from them). Those objects know nothing about who emits the signals or where the slots are; it's all handled by Qt, so they are *loosely coupled*, resulting in more reusable components.

With the function `QtCore.QObject.connect()`, we connect a slot to a particular signal. The complementary function, `QtCore.QObject.disconnect()`, is used to remove the slot from the signal notification. If a signal isn't connected to a slot, nothing happens; the component that emits the signal does not know if the signal is being used or not.

The general line for `connect()` is:

```
QtCore.QObject.connect(objA, QtCore.SIGNAL("QtSig()"), objB, QtCore.SLOT("QtSlot()"))
```

It's made of four parameters:

- The sender, `objA` – the object emitting the signal
- The signal, `QtSig` – the signal emitted
- The receiver, `objB` – the object that will receive the signal
- The slot, `QtSlot` – the slot that will react to the signal

In case `objB` is `self`, then we can omit the third argument:

```
QtCore.QObject.connect(objA, QtCore.SIGNAL("QtSig()"), QtCore.SLOT("QtSlot()"))
```

`SIGNAL()` is used to refer a signal, while `SLOT()` is used to refer a slot. The strings passed to those functions are used to look up dictionaries of signals and slots into Qt engine, so we have to match the definition precisely.

PyQt allows any Python callable (functions mainly) to be used as a slot, not just Qt slots. This is done by simply referencing the callable. As Qt slots are implemented as class methods, they are also available as Python callables. Therefore, it is not usually necessary to use `QtCore.SLOT()` for Qt slots.

So, we will end up with a line like this one:

```
QtCore.QObject.connect(objA, QtCore.SIGNAL("QtSig()"), pyFunction)
```

In our example, we used both formats: `SLOT()` is used to connect the `quit()` slot of `qApp` to the `triggered()` signal of **Quit** menu item, while Python function references are used for button `clicked()` signal and **Open** menu item `triggered()` signal.

A note about the order of signals receiving: there is no fixed order for the arrival of signals at their destinations. If a signal is connected to more slots, then the slots are called in no particular order, every time the signal is emitted. Note that if two different signals are connected to two separated slots, then the slots are called in the order in which the signals are emitted.

Returning to the example

Getting back to where we stopped:

```
def select_file(self):
```

This is the function called when the menu item **Open** is selected.

```
file = QtGui.QFileDialog.getOpenFileName()
```


It creates a dialog to select a file, obtaining the selected file (if any).

```
if file:
    self.mpllineEdit.setText(file)
```

It saves the file to the **Line Edit** widget, but only if a file was selected in the dialog (think about what happens when we click on the **Cancel** button).

```
def parse_file(self, filename):
```

This function will take care of parsing the input file and extracting the information we will plot later.

```
    letters = {}
```

We define the dictionary that will hold the letters information.

```
    for i in range(97, 122 + 1):
        letters[chr(i)] = 0
```

we initialize that dictionary with all the lowercase English letters (identified in the ASCII table with numbers from 97 to 122) setting the value to 0.

```
    with open(filename) as f:
        for line in f:
            for char in line:
                # counts only letters
                if ord(char.lower()) in range(97, 122 + 1):
                    letters[char.lower()] += 1
```

For each line in the file and for each letter in that line, we check if it's a plain text letter, and in that case we increment the counter for it.

```
    k = sorted(letters.keys())
    v = [letters[ki] for ki in k]
    return k, v
```

At the end, we return the sorted dictionary keys with the related values.

```
def update_graph(self):
```

This function is called when the **mplPushButton** button is clicked and handles the graph update.

```
    l, v = self.parse_file(self.mpllineEdit.text())
```

First of all, we get the letters and their frequencies by passing the file set in the **Line Edit** widget to `parse_file()`.

```
    self.mpl.canvas.ax.clear()
```

Then we clear the `Axes` to ensure that the next plot will seem a completely new one, while we are reusing the same `Figure` and `Axes` instances.

```
self.mpl.canvas.ax.bar(np.arange(len(l))-0.25, v, width=0.5)
```

We plot a set of bars, one for each letter with the height set to the number of occurrences of that letter in the parsed file.

Note how we set up the bars: we shift their starting point by 0.25 to the left and the width is set to 0.5; this will result in bars centered on the X ticks.

```
self.mpl.canvas.ax.set_xlim(xmin=-0.25, xmax=len(l)-0.75)
```

We have to adjust the X limits. As said earlier, we shifted bars start by 0.25, so the minimum X value is -0.25; the maximum X value is `len(l) - 1` (the last tick position) but then we have to add 0.25 (half the bar width). With these limits, we have the bars perfectly fitting into the plot area.

```
self.mpl.canvas.ax.set_xticks(range(len(l)))
self.mpl.canvas.ax.set_xticklabels(l)
```

We set the X-axis ticks with their labels (the letters).

```
self.mpl.canvas.ax.get_yaxis().grid(True)
```

We draw a grid on the plot, but only for the Y-axis

```
self.mpl.canvas.draw()
```

Then we force a redraw of the canvas to show the changes we just did.

```
app = QtGui.QApplication(sys.argv)
```

As usual, we instantiate a `QApplication` to wrap our widget.

```
dmw = DesignerMainWindow()
```

we instantiate the main window.

```
dmw.show()
```

We show the main window.

```
sys.exit(app.exec_())
```

Then, we start the Qt main loop.

The complete source code for `mplwidget.py` is:

```
# Python Qt4 bindings for GUI objects
from PyQt4 import QtGui

# import the Qt4Agg FigureCanvas object, that binds Figure to
# Qt4Agg backend. It also inherits from QWidget
from matplotlib.backends.backend_qt4agg \
    import FigureCanvasQTAff as FigureCanvas

# Matplotlib Figure object
from matplotlib.figure import Figure

class MplCanvas(FigureCanvas):
    """Class to represent the FigureCanvas widget"""
    def __init__(self):
        # setup Matplotlib Figure and Axis
        self.fig = Figure()
        self.ax = self.fig.add_subplot(111)

        # initialization of the canvas
        FigureCanvas.__init__(self, self.fig)
        # we define the widget as expandable
        FigureCanvas.setSizePolicy(self,
                                   QtGui.QSizePolicy.Expanding,
                                   QtGui.QSizePolicy.Expanding)
        # notify the system of updated policy
        FigureCanvas.updateGeometry(self)

class MplWidget(QtGui.QWidget):
    """Widget defined in Qt Designer"""
    def __init__(self, parent = None):
        # initialization of Qt MainWindow widget
        QtGui.QWidget.__init__(self, parent)
        # set the canvas to the Matplotlib widget
        self.canvas = MplCanvas()
        # create a vertical box layout
        self.vbl = QtGui.QVBoxLayout()
        # add mpl widget to vertical box
        self.vbl.addWidget(self.canvas)
        # set the layout to th vertical box
        self.setLayout(self.vbl)
```

The whole source code for `7900_06_04_qt_designer.py` is:

```
# used to parse files more easily
from __future__ import with_statement

# Numpy module
import numpy as np

# for command-line arguments
import sys

# Qt4 bindings for core Qt functionalities (non-GUI)
from PyQt4 import QtCore
# Python Qt4 bindings for GUI objects
from PyQt4 import QtGui

# import the MainWindow widget from the converted .ui files
from qtdesigner import Ui_MplMainWindow

class DesignerMainWindow(QtGui.QMainWindow, Ui_MplMainWindow):
    """Customization for Qt Designer created window"""
    def __init__(self, parent = None):
        # initialization of the superclass
        super(DesignerMainWindow, self).__init__(parent)
        # setup the GUI --> function generated by pyuic4
        self.setupUi(self)

        # connect the signals with the slots
        QtCore.QObject.connect(self.mplpushButton, QtCore.
SIGNAL("clicked()"), self.update_graph)
        QtCore.QObject.connect(self.mplactionOpen, QtCore.
SIGNAL('triggered()'), self.select_file)
        QtCore.QObject.connect(self.mplactionQuit, QtCore.
SIGNAL('triggered()'), QtGui.qApp, QtCore.SLOT("quit()"))

    def select_file(self):
        """opens a file select dialog"""
        # open the dialog and get the selected file
        file = QtGui.QFileDialog.getOpenFileName()
        # if a file is selected
        if file:
            # update the lineEdit text with the selected filename
            self.mpllineEdit.setText(file)

    def parse_file(self, filename):
```

```
"""Parse a text file to extract letters frequencies"""
# dict initialization
letters = {}

# lower-case letter ordinal numbers
for i in range(97, 122 + 1):
    letters[chr(i)] = 0

# parse the input file
with open(filename) as f:
    for line in f:
        for char in line:
            # counts only letters
            if ord(char.lower()) in range(97, 122 + 1):
                letters[char.lower()] += 1

# compute the ordered list of keys and relative values
k = sorted(letters.keys())
v = [letters[ki] for ki in k]

return k, v

def update_graph(self):
    """Updates the graph with new letters frequencies"""

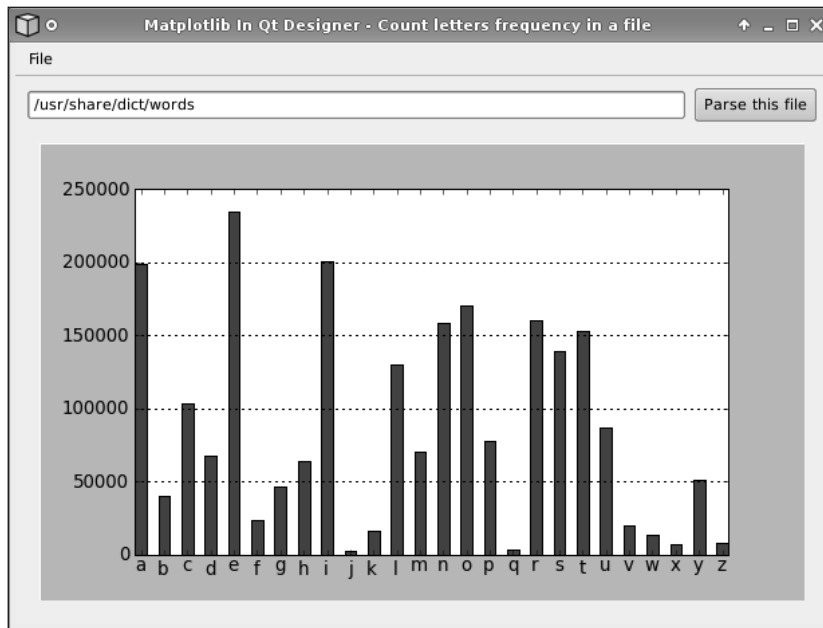
    # get the letters frequencies
    l, v = self.parse_file(self.mppllineEdit.text())

    # clear the Axes
    self.mpl.canvas.ax.clear()

    # draw a bar chart for letters and their frequencies
    # set width to 0.5 and shift bars of 0.25, to be centered
    self.mpl.canvas.ax.bar(np.arange(len(l))-0.25, v, width=0.5)
    # reset the X limits
    self.mpl.canvas.ax.set_xlim(xmin=-0.25, xmax=len(l)-0.75)
    # set the X ticks & ticklabel as the letters
    self.mpl.canvas.ax.set_xticks(range(len(l)))
    self.mpl.canvas.ax.set_xticklabels(l)
    # enable grid only on the Y axis
    self.mpl.canvas.ax.get_yaxis().grid(True)
    # force an image redraw
    self.mpl.canvas.draw()
```

```
# create the GUI application
app = QtGui.QApplication(sys.argv)
# instantiate the main window
dmw = DesignerMainWindow()
# show it
dmw.show()
# start the Qt main loop execution, exiting from this script
# with the same return code of Qt application
sys.exit(app.exec_())
```

A screenshot of the application running, where we can see a bar for each letter with heights corresponding to the number of occurrences of that letter in the file is as follows:



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Summary

In this chapter, we learned how to use Qt and Matplotlib together. Now we know how to:

- Embed a `Figure` in a `QWidget`
- Use layout manager to pack a `Figure` and navigation toolbar in a `QWidget`
- Create a timer, react to events, and update a Matplotlib graph accordingly
- Use Qt Designer to draw a simple GUI and then refer it into our Python code

We are now ready to learn about another GUI library, `wxWidgets`.

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