Lecture 22

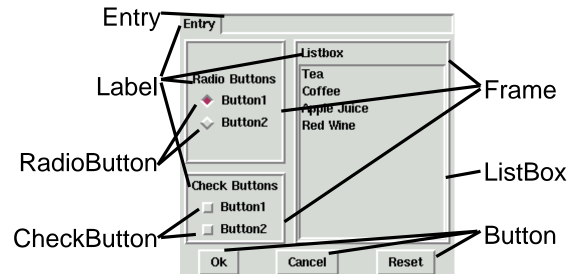
More on GUI and Extending Python

We will learn a bit more about GUI application. After that we will try to combine the benefits of C++ and Python.

References:

- Manpages of Tk: `http://dev.scriptics.com/man/tcl8.3.2/-TkCmd/contents.htm`
- An introduction to Tkinter: `http://www.pythonware.com/library/-an-introduction-to-tkinter.htm`
- Tkinter Life Preserver: `http://www.python.org/doc/life-pre-server/index.html`

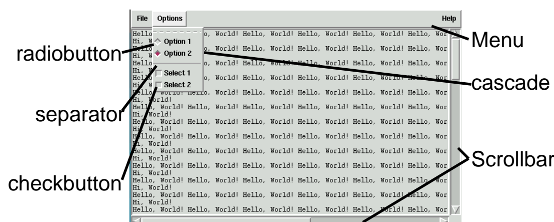
Available widgets (eg1.py)



Try to figure out how the program associate a variable to the radio button.

Note also how frames are used to put a grid within another grid.

More available widgets (eg2.py)

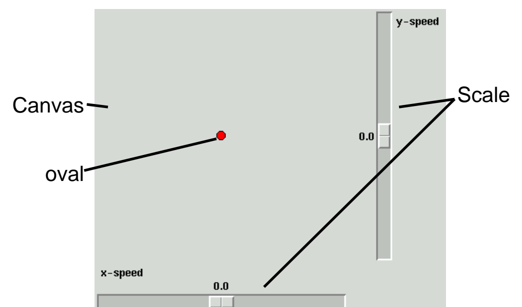


The text widget and the scrollbars are connected.

When a Scrollbar is dragged, the handler specified in the command option of Scrollbar notifies the text widget.

When the text changes, the handlers specified in xscrollcommand and yscrollcommand options of text notifies the scrollbar.

Even more available widgets (eg3.py)



This also demonstrates how to make a event to occur some time after the current time (using mainwin.after(time_in_minisecond, handler)).

More about events

- So far we have seen one type of events: those **triggered by a button** when it is pressed.
- Such commands are available for buttons, check buttons, radio buttons, scroll bars, scales and menu entries.
- But even **when the widget does not provide a command**, we might want to know whether something happen on it.
- We can **bind an 'event'** to a widget.

```
def process_entry(event):
    print myentry.get()

myentry = Entry()
# Bind to <Return> event, i.e., when somebody press Return
myentry.bind('<Return>', process_entry)
```


Available events

A large number of events are available ('man n bind' to see all). Some more important ones:

<Button-1>, <ButtonRelease-1>, <DoubleButton-1>
Mouse button 1 is pressed, released or double-clicked.

<Enter>, <Leave>	The pointer enters/leaves a widget.
<Configure>	The widget size is changed.
<Key>-a	The key 'a' is pressed.
<Shift-Up>	Shift-up is pressed.

The event is a map contains the following keys:

widget	The triggering widget.
x, y	The pointer position when the event is triggered.
width, height	Width and height of new window size.
num, char	The button number or key that is pressed.

What's next for Tkinter

This quick overview omit many features of Tkinter. E.g.,

- Two other **geometry managers** are available. The **pack** manager gives one side of its area to a widget each time. The **place** manager allows widgets to be put to absolute coordinates.
- Some **standard dialogs**: tkMessageBox, tkColorChooser, FileDialog.
- You can create two types of non-widget images: **bitmap** and **photoimage**, which respectively stores a black/white and color image.
- We can set an **idle command**, which is executed whenever there is nothing to do in the mainloop.
- A **Drag-and-drop** protocol is defined. Look at Tkdnd.py.
- Even more widgets are available if you install the **"Pmw"** package. More image operations are available with **PIL** (Python Imaging Library).

Combining Python with C++: why?

We want to write most of our code in a scripting language like Python.

But **Python alone is not good enough** for all computing needs:

- Some **libraries** are only available in C++.
- You cannot touch the **internals** of the machines, e.g., deal with I/O ports, make system calls, etc., in Python.
- Some needed **data types** are unavailable in Python.
- Sometimes you need **efficiency** that is not provided by Python.

In these cases, we still want most of our code to be in a scripting language, but **we must write part of our code to produce machine code**.

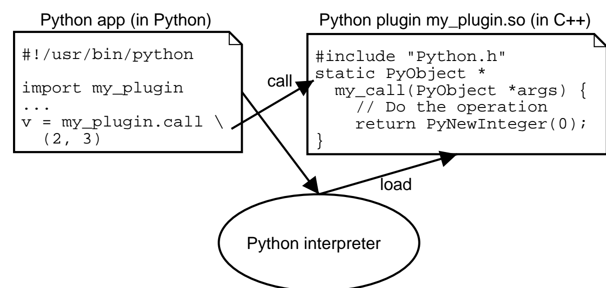
That is, we want the benefits of **both** the flexibility and efficiency of C++, and the ease of use and user configurability of Python.

What can we do

There are two completely different approach to combine two languages.

Extending Python	Embedding Python
Write the application as a Python script, which import some **C++ plugins** to perform functions unavailable in standard Python.	Write the application in C++, but runs a **Python interpreter** in it. The C++ program defines some functions that can be called from the Python interpreter.
Works best if Python is already "nearly good enough" for the application. The plugin provides the missing pieces.	Works best if Python is not good enough, but we want to allow users to configure or write scripts for our program using Python.
Examples: Tkinter, PIL, numeric library, etc.	**Examples**: Apache python-plugin, Gimp python-plugin, etc.

Extending Python: The concepts



When the **import** Python statement is executed, the Python interpreter tries to find a module or plugin with the appropriate name.

The **plugin** then registers some functions to Python so that the script can call them later.

Writing a C++ function to be called from Python

As an example, we will write a function that returns the i-th Fibonacci number. (In reality we will do this in Python instead.) The function:

```
#include "Python.h"
static PyObject *get_fib(PyObject *self, PyObject *args) {
    int arg, ret = 0;
    // Interesting place 1
    if (!PyArg_ParseTuple(args, "i", &arg))
        return 0;  // Error!  Propagate by returning NULL.
    if (arg ≥ 0) {
        int last = 1;
        for (int i = 0; i < arg; ++i)
            { int temp = ret; ret += last; last = temp; }
    }
    // Interesting place 2
    return PyInt_FromLong(ret);
}
```


Reading the arguments

There are two interesting things in the code, which communicate values between our Python plugin to the Python script.

- A Python-callable function gets 2 or 3 Python objects as arguments.
- The first argument is useful only for class functions. Ignore it now.
- The second argument is a **tuple** containing some *position arguments*.
- The third argument is a **dictionary** containing *keyword arguments*.
- In most cases, we can **parse** the tuple by using *PyArg_ParseTuple*.
- The function is called with the **tuple**, a **format string** telling what type of arguments are expected, and then some pointers to variables that are to hold the parsed values.
- You can concatenate format chars, e.g. "ii" = two integers expected.

Making out the result

The function must return a Python Object to the Python script. If we don't need to pass anything, at least we need to pass Py_None.

To create a value, we have two ways:

- Call *Py_BuildValue*. It is very similar to *Py_ParseTuple*: a **format string** tells what to make, followed by some arguments. E.g.:

  Py_BuildValue(*"i"*, 20)   // Create a Python integer of 20

  Multiple format chars results in tuples. E.g., *Py_BuildValue*(*"ii"*, 5, 10).

- Call a Python function that create a **specific type** of object. E.g.:

  PyInt_FromLong(20)   // The same

Usually we can use the first method, but if we need to build a sequence or dictionary of unknown number of elements, we need the second.

Registering with Python interpreter

When Python loads a plugin, **it calls a C function** in the plugin called initXXX, where XXX is the plugin's name. If it's "fibo", we write

```
extern "C" void initfibo() {
    Py_InitModule("fibo", FiboMethods);
}
```

Here FiboMethods is an array that **tells Python what methods we want to be available to Python scripts**:

```
static PyMethodDef FiboMethods[] = {              // Do this before initfibo()!
    { "get_fib", get_fib, METH_VARARGS },         // No keyword arguments
    { NULL, NULL }                                // No more Python functions
};
```

This tells that we want to expose the C++ *get_fib* function to Python scripts, using the name "*fibo.get_fib*" in Python.

Setup.in and compiling

Now that we have the plugin source, we can build it. We can write a Makefile to do it, but actually Python provide an easier way.

From the Python installation directory "/usr/lib/python1.5/conf", copy the file "Makefile.pre.in" to the current directory. Create a file called "Setup.in" like this:

```
*shared*
EC=fibo
CCC=g++
fibo fibo.cc
```

which is a partial Makefile. Then type `make -f Makefile.pre.in boot` and then `make`.

This free us from remembering whether to use which compiler options like -G, -Xlinker, … to build the shared object.

Using the plugin

Using the plugin is easy. A simple script:

```
import fibo
print fibo.get_fib(10)
```

If you pass it some wrong arguments (e.g., fibo.get_fib('a')), you get error from the PyArg_ParseTuple function.

In general, returning a NULL value means that there is an error.

Reference counting

Once you do a bit more than just creating new Python values and return, you start needing to take care about Python's garbage collector.

- Python use a **reference counting** mechanism to collect garbage.
- A new object (e.g., using Py_BuildValue) has a reference count of 1.
- We increment/decrement the count by Py_INCREF/Py_DECREF. **When the reference count of an object becomes 0, it is deleted.**
- When you don't need a Python object, call Py_DECREF, not delete.
- If you get an object without creating it, and then want to return it, increment the reference count.
- Example: to return Py_None, you need *Py_INCREF*(*Py_None*); before **return** *Py_None*;.

Conclusion and exercise

- We can combine the benefits of C++ and Python by either extending Python by plugin or embedding Python in a C++ application.
- To create a plugin, we need to define a C++ function taking python objects, define an array of exposed functions, and make an init function.
- Python provide an easy way to build the plugin using make.
- We load a plugin from Python just like we import a Python module.
- Python uses reference counting to clean-up objects that are no longer available.

Exercise: The source of the lecture contains a directory fibo, which in turn contains the source code in this lecture fibo.cc and Setup.in. Try to build the plugin and use it.