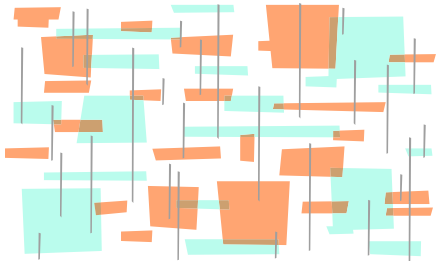
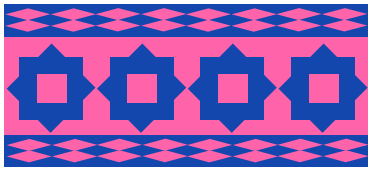
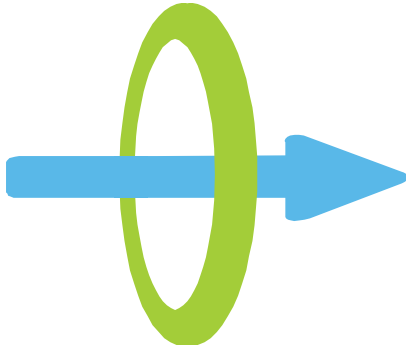
CS 1
Introduction to Computer Programming

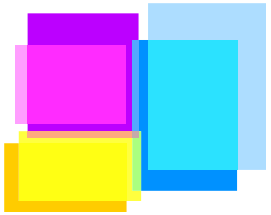
Lecture 11: October 29, 2012

Testing and Graphics









Last time

- Binary and hexadecimal numbers
- Dictionaries

Today

- Testing your code
- Introduction to computer graphics
  - continued next class
- Keyword arguments to functions

Testing your code

- Code that has never been tested should be considered wrong *by definition*
- Once code is written, the first thing that should be done is to test it
- Different ways to go about this
  - informally
  - systematically

Informal testing

- Informal testing means to run the code interactively
  - on whatever examples come to mind
- Once you're done, what can you say?
  - "It seems to work OK"
- This is rarely good enough

Systematic testing

- Systematic testing means to have some set of *test cases* that you run to test your code *automatically*
- If you change your code, can re-run the test cases easily to see if you broke anything

Exhaustive testing?

- No amount of testing can guarantee that your code is 100% free of bugs
- "Exhaustive testing" (testing for every single possible bug) has been called "Exhausting testing"
- Better strategy: when a bug comes up, write a new test case
  - So it won't come up again!
  - Get better *code coverage* over time

Unit tests

- Tests that apply to a particular module are usually called *unit tests*
- They test the code in a module in isolation from all other code
- These are the easiest tests to write

Integration tests

- Tests that check if multiple modules work properly in combination are usually called *integration tests*
- These are more complicated, and we won't cover them in this course
- But with good enough unit tests, you can still eliminate huge numbers of bugs!

Testing in Python

- Testing code in Python is easy
- With the **`nose`** module, it's *really* easy!
- Need to understand:
  - the **`assert`** statement
  - **`if __name__ == '__main__': ...`**
  - How to write individual tests
  - How to write and run test modules

The `assert` statement

- **`assert`** is a special Python statement which is useful for both debugging and testing
- It tests whether a boolean expression is **`True`** or **`False`**
- If it's **`True`**, nothing happens
- If it's **`False`**, an error occurs

The `assert` statement

- Examples:

```
>>> assert True
```

[nothing happens]

```
>>> assert False
AssertionError
>>> assert 1 + 1 == 2
>>> assert 2 + 2 == 5
AssertionError
```

The `assert` statement

- Can also add a message to an `assert`:

```
>>> assert 1 + 1 == 2, 'addition test 1'
>>> assert 2 + 2 == 5, 'addition test 2'
AssertionError: addition test 2
```

- This is useful as documentation

Using `assert` for debugging

- `assert` is often used as a way to make functions self-checking:

```
def square_root(x):
    # code to compute the square root
    root = ...
    assert (abs(x - root * root) < 0.001)
    return root
```

Using `assert` for debugging

- Now, every time you use `square_root` it will check that the number it computed is the actual square root
  - within a tolerance (floating point math is never exact)
- Problems:
  - tests are mixed in with the regular code
  - tests slow down the running of the code

Using `assert` for unit testing

- Using `assert` this way is OK
- Another approach is to write the code without `assert`s, and then to write a separate *test module* to test each function you wrote separately
- Such test modules are *unit tests* (where the "unit" is a module)
- Before we get to that, we need to explain one more thing...

`__name__`

- Inside a module, the variable `__name__` is set to be
  - the name of the module (when the module is imported)
  - the special name `'__main__'` (when the module is run directly by Python)
- Let's see how this works

__name__

- Here's a simple module: **example.py**

```
# module: example.py
print 'My name is: %s' % __name__
```

- It defines a Python module called **example**
- When it's imported, this code will be run
- Let's import it from other Python code:

```
>>> import example
My name is: example
```

- Nothing strange so far...

`__name__`

- What happens when the file **`example.py`** is executed directly by Python instead of being imported?
  - *e.g.* at the terminal command line
  - or by loading into WingIDE and hitting the run button

```
% python example.py
My name is: __main__
```

- This says: **`example.py`** is the first thing executed by Python

`if __name__ == '__main__':`

- We can use this to define some code in a module which only executes if the module is the first thing Python executes:

```
# example.py
if __name__ == '__main__':
    print 'This is the main module.'
```

`if __name__ == '__main__':`

- Now, at the terminal command line (or after loading into WingIDE and hitting the Run button):

```
% python example.py
This is the main module.
```

`if __name__ == '__main__':`

- But when importing the module in the Python shell:

```
>>> import example
```

- Nothing happens!
- Can use this trick to execute some code *only* when a module is loaded as the main module

Writing test modules

- A test module has this form:

```
import nose
from <module to test> import *

def test_<function 1>:
    ...
def test_<function 2> :
    ...
if __name__ == '__main__':
    nose.runmodule()
```

Writing test modules

- Example module to test: **zero.py**

```
# zero.py
def first_zero(lst):
    '''Return the index of the first zero
    in a list, or -1 if no zeros.'''
    for i, e in enumerate(lst):
        if e == 0:
            return i
    return -1
```

Writing test functions

- Function to test `first_zero`:

```
def test_first_zero():
    assert first_zero([]) == -1
    assert first_zero([0]) == 0
    assert first_zero([1, 0]) == 1
    assert first_zero([1, 1, 1]) == -1
```

- If `first_zero` is correct, calling `test_first_zero` will do nothing
  - Otherwise, an error will occur
- Could add more tests if desired

The test module

- The test module: **test_zero.py**:

```
import nose
from zero import *

def test_first_zero():
    # as before

if __name__ == '__main__':
    nose.runmodule()
```

- That's it!

Running the test module

- Run `test_zero.py`:

```
% python test_zero.py
.
----------------------------------
Ran 1 test in 0.001s

OK
```

- Success!

Running the test module

- Can have multiple tests in a test module
  - typically one per function in the module being tested
- If a test fails, get output describing which test failed and at which line
- Test failures may indicate
  - a bug in the code
  - a bug in the tests!
- Either way, need to fix it

Summing up

- How the `nose` module actually runs all these tests has not been described
  - more advanced than you're ready for right now
- However, *using* `nose` is very simple
- Writing tests may seem tedious, but will save you *enormous* amounts of time on bigger programming projects
- Need to get comfortable with this now

Interlude

- *Star Wars!*
  - (a new take on a classic)

Topic 2

- Computer graphics!

What does "graphics" mean?

- Graphics is (loosely speaking) the process by which you create visual images on a computer screen
- Graphics also involves the process of *interacting* with these visual images in a meaningful fashion

Text-based programming

- The programming we've done so far has been *text-based*
- We've written games that work from the terminal (Mastermind), programs that read and write text files, etc.
- Text-based programming has a simple notion of...

User interface

- A *user interface* refers to how you (the user) interact with a program
- Text-based programs tend to have very simple user interfaces
- Programs that create and use graphics can have much more complex user interfaces

Text-based user interfaces

- A text-based program typically has one of two kinds of user interface:
  - *batch mode*
  - *interactive mode*

Batch mode

- A *batch mode* program is run without any user involvement
  - Example: compute and print π to 1000 decimal places
  - The computer computes a while and then prints out `3.1415926...` and finally halts
  - Once the program has started, the program's user just waits for the answer

Interactive mode

- An *interactive mode* program is run with the help of the user
  - Example: Mastermind game from lab 2
  - You enter a guess
  - The computer tells you how good it was
  - You enter another guess
  - *etc.* until you guess correctly
- You and the computer "take turns"

Graphical user interfaces

- Programs that do graphics usually don't fit into either of these categories

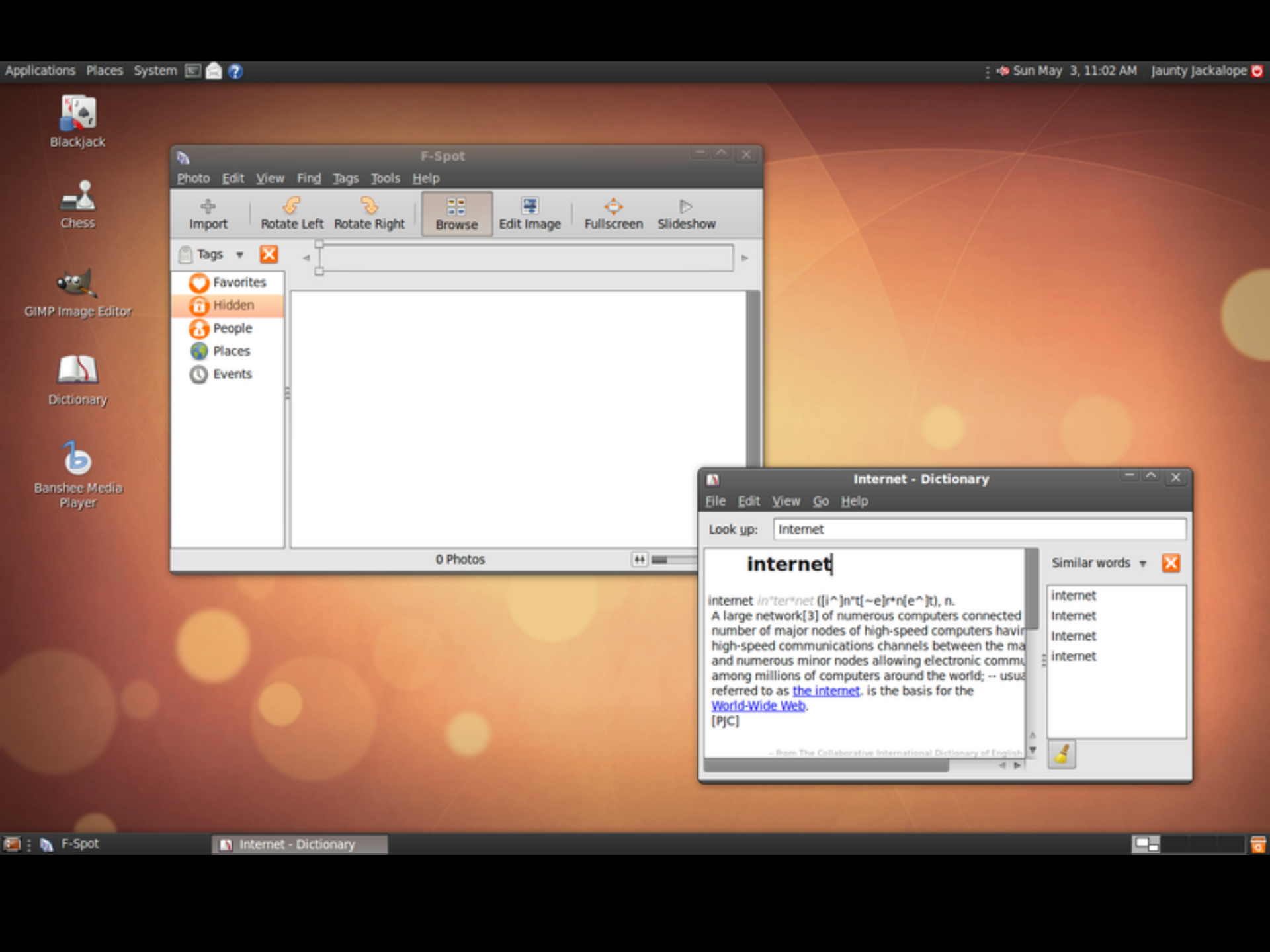
- Instead, they have a *graphical user interface* (GUI) which users interact with directly

Graphical user interfaces

- The program provides various visual entities (called *widgets*) that you can interact with
  - buttons, menus, sliders, scrollbars, etc.
  - drawing surfaces for drawing
- The program also displays output visually
  - images, animations, etc.

Example

- The "desktop" of a computer running Linux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Sun May 3, 11:02 AM Jaunty Jackalope
Blackjack
Chess
GIMP Image Editor
Dictionary
Banshee Media Player
F-Spot
Photo Edit View Find Tags Tools Help
Import Rotate Left Rotate Right Browse Edit Image Fullscreen Slideshow
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A large network[3] of numerous computers connected
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high-speed communications channels between the ma
and numerous minor nodes allowing electronic commu
among millions of computers around the world; -- usu
referred to as the internet, is the basis for the
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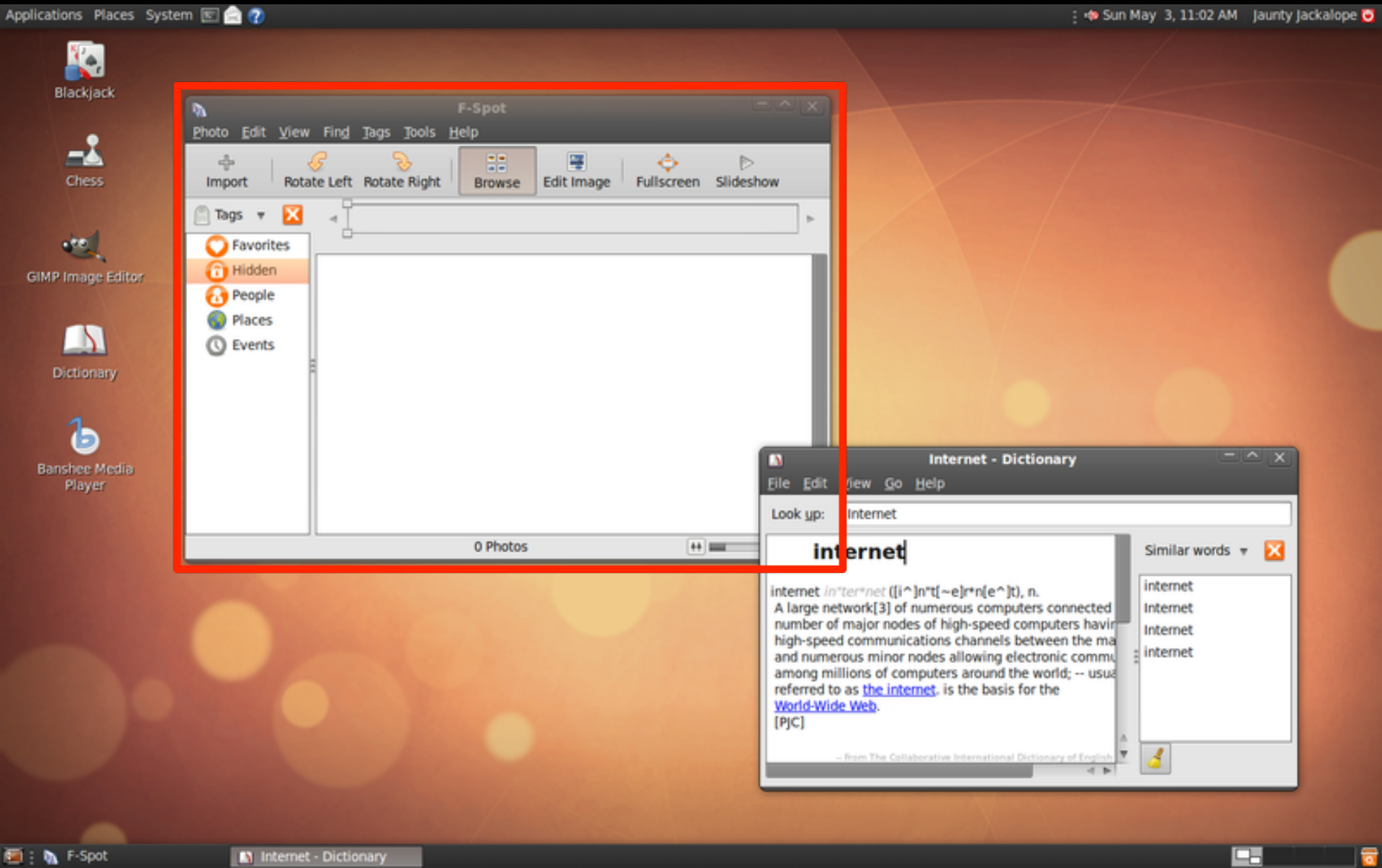
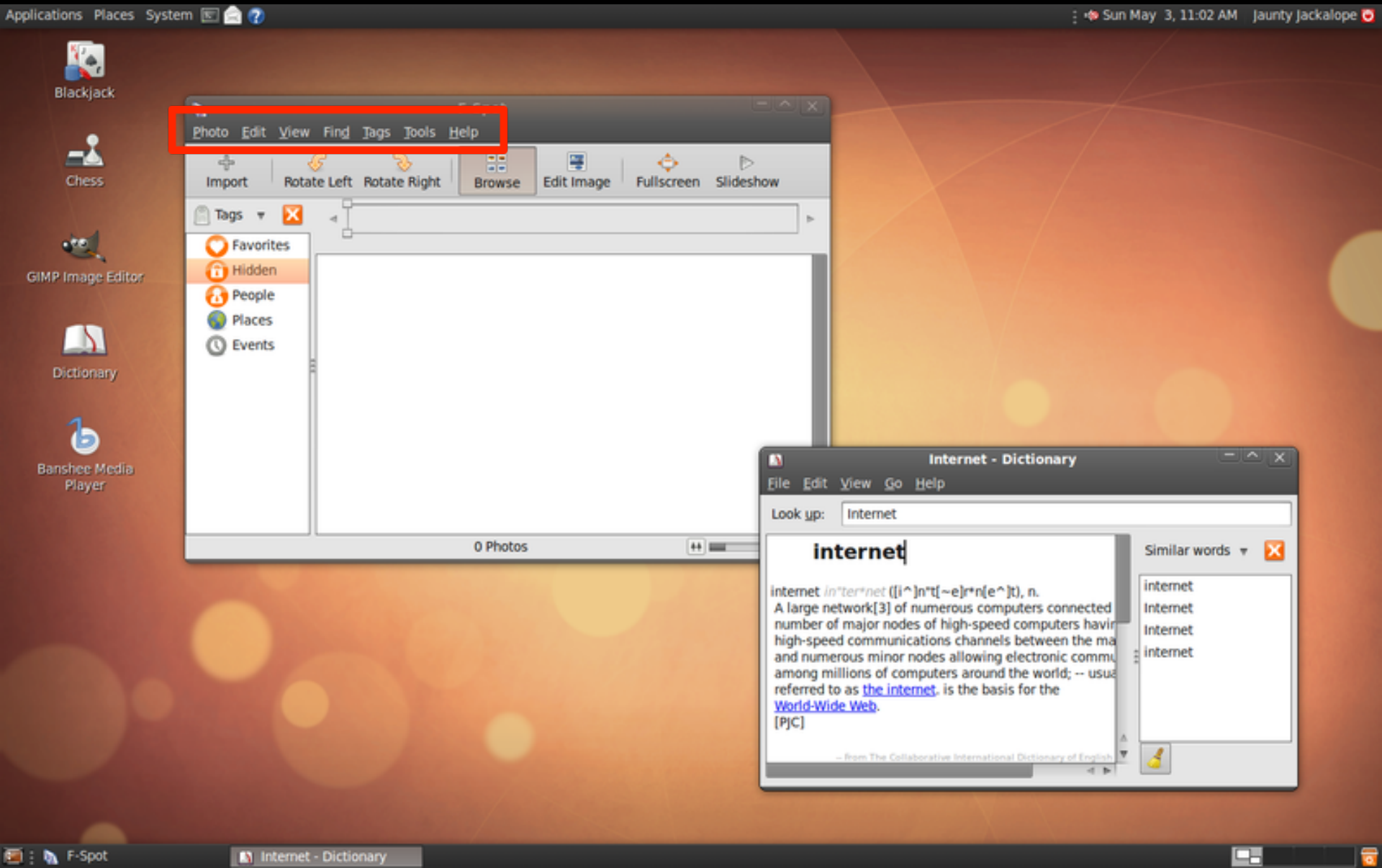
[PJC]
Similar words
internet
Internet
Internet
internet
F-Spot
Internet - Dictionary

Application (program)



Menu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Button

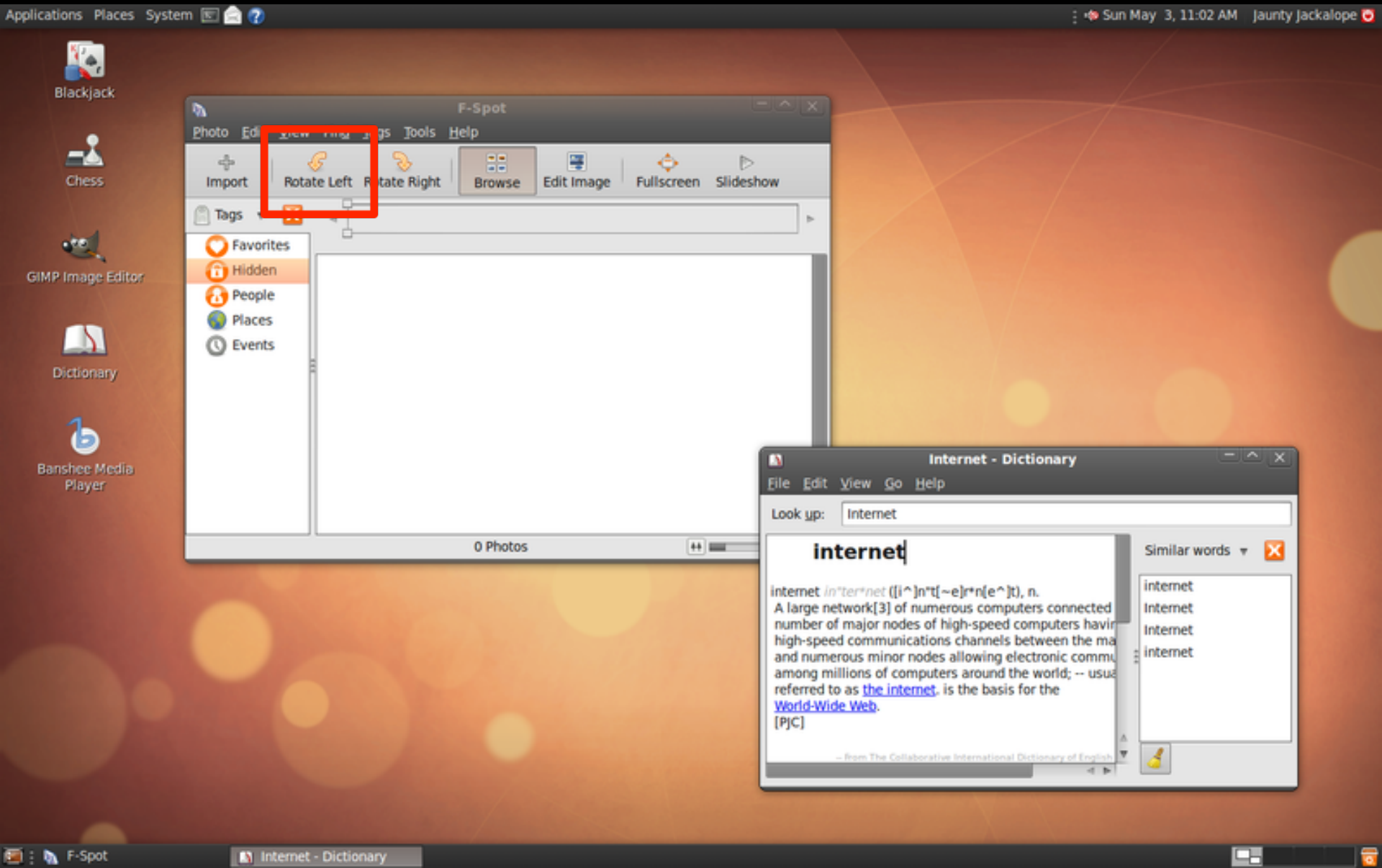
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Photo Edit View Tools Help
Import
Rotate Left
Rotate Right
Browse
Edit Image
Fullscreen
Slideshow
Tags
Favorites
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[PJC]
F-Spot
Internet - Dictionary

Graphical interfaces

- Graphical interfaces are so common today, we don't even notice them
  - unless they go wrong ;-)
- But their interfaces are very complex
- They are designed to make it feel "natural" for you to interact with the program

Event loop

- Typically, program will wait for the user (you) to activate one of its widgets
  - push a button, select a menu item, draw on a drawing surface etc.
- Then it will do something in response
- Then it will go back to waiting for you to do something again
- This process is called an *event loop*
  - your actions are the "events" the program is waiting for

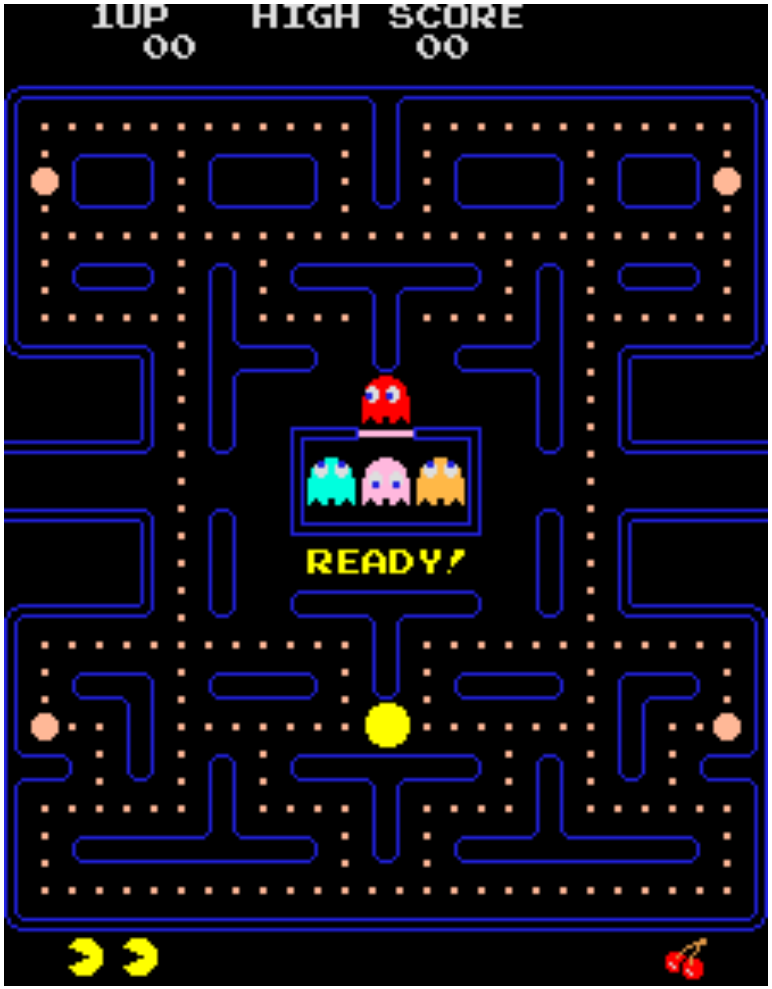
Programming GUIs

- Programming graphical user interfaces (GUIs) is somewhat laborious
  - (some people find it boring)
- The programmer must anticipate every reasonable thing the user might want to do with the program
  - then provide a graphical object (widget) to allow that to happen
- Good news: graphics programming is about more than this!

2-D and 3-D graphics

- Aside from graphical user interfaces, there are two other broad categories of graphics programming:
- 2-D (two-dimensional) graphics: drawing pictures (or animations) on a two-dimensional surface
- 3-D (three-dimensional) graphics: drawing pictures (or animations) to resemble three-dimensional objects

2-D graphics example



3-D graphics example

3-D graphics example

Today

- We will only be dealing with 2D graphics today
  - With a teensy bit of user interface thrown in for good measure
- We'll continue and expand our examples in later lectures

Python and graphics

- Many kinds of graphics libraries are available in Python
  - 2-D, 3-D, GUI, etc. (many of each)
- However, none are built-in
  - all require that you add the libraries to the basic Python installation
- Today, we'll look at the most commonly-used graphics library in Python

Tkinter

- The most common graphics library in Python is called **Tkinter**
  - perhaps because all the sensible, meaningful, pronounceable names were taken?
- It's a Python **inter**face to a system called "**Tk**" (which stands for "graphics **T**ool**k**it") written in a different language

Tkinter

- Tkinter provides a number of tools for writing programs that use graphics:
  - many GUI widgets
    - buttons, menus, labels, scrollbars etc.
  - a canvas widget on which arbitrary drawings can be created
    - using lines, circles, rectangles, ovals, images, text, etc.
  - ways to capture user interaction
    - key presses, mouse clicks, etc.

Tkinter

- We will concentrate on the canvas widget and drawing simple 2-D pictures
- We'll also show how to get a program to respond to actions (key presses) on the canvas

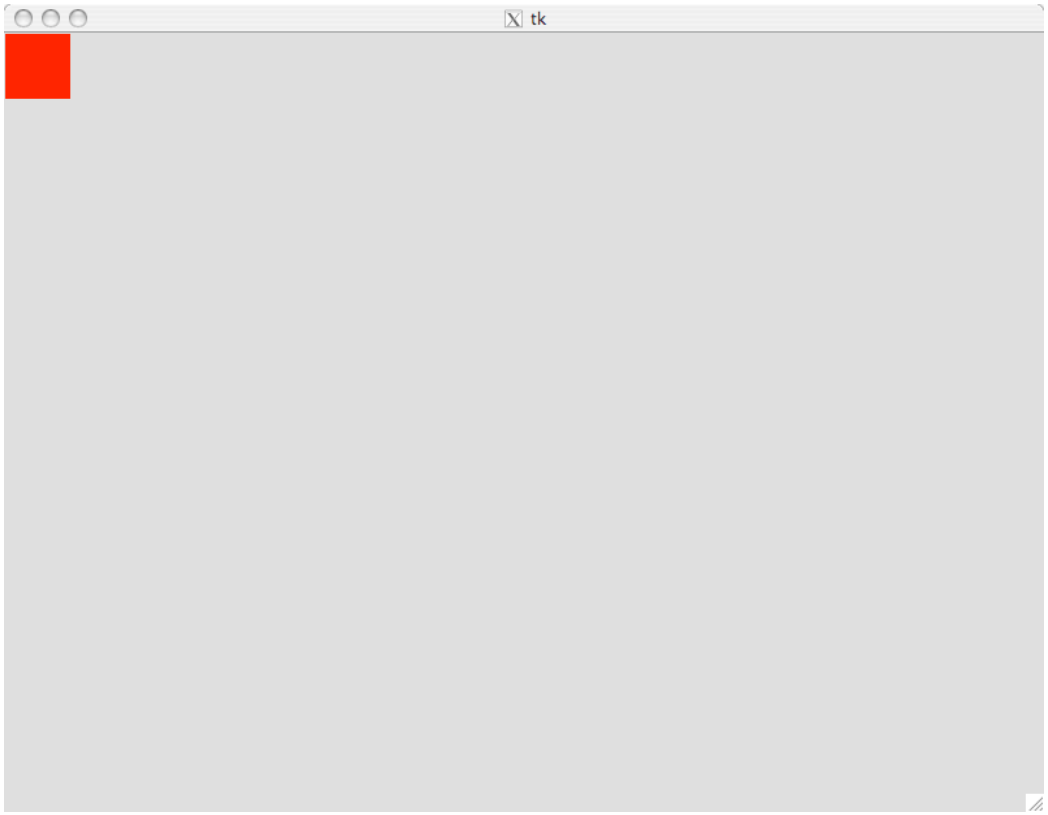
Simple `Tkinter` program

- In file **`tkinter1.py`**:

```
from Tkinter import *
root = Tk()
root.geometry('800x600')
c = Canvas(root, width=800, height=600)
c.pack()
r = c.create_rectangle(0, 0, 50, 50, \
                       fill='red', outline='red')
raw_input("Press <return> to quit")
```

Simple `Tkinter` program

- This program brings up a window with a red rectangle drawn in one corner:



Simple `Tkinter` program

- To understand how this works, we first have to understand
  1. pixel coordinates
  2. windows
  3. Python keyword arguments

Pixel coordinates

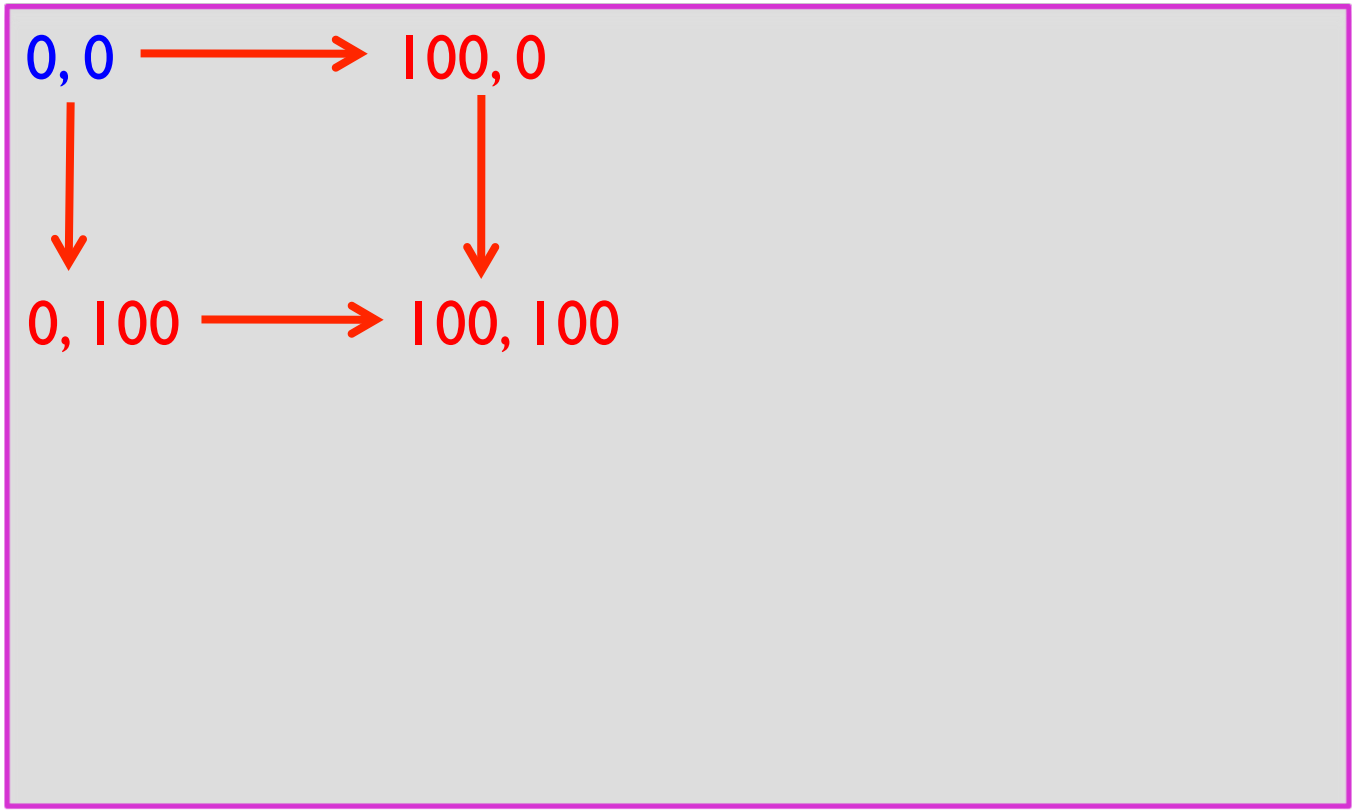
- To the computer, the entire screen is a 2-dimensional grid of tiny colored boxes called *pixels*
- Most computer screens have large numbers of pixels
  - *e.g.* 1440x900 pixels on this computer
  - or about 1.3 million pixels
- With millions of possible colors per pixel

Pixel coordinates

- The pixel in the upper left-hand corner is pixel (0, 0) (called the *origin*)
- The first pixel in the pair represents the horizontal dimension
  - so (100, 0) would be to the right of (0, 0)
- The second pixel in the pair represents the vertical dimension
  - so (0, 100) would be below (0, 0)

Pixel coordinates

- Visually:



Windows and pixels

- Most computers run multiple programs at one time, each in a separate *window*
- Pixel coordinates can be
  - absolute
  - relative to a particular window
- Absolute coordinates means the upper left-hand corner of the *monitor* is (0, 0)
- Relative means the upper left-hand corner of a *particular window* is (0, 0)
- Almost always use relative coordinates

Keyword arguments

- Last time, talked about dictionaries
  - store key/value pairs in a single data structure
  - keys are usually strings
- Python also allows functions to get key/value pairs as arguments to functions
  - as long as the key is a string
- All the key/value pairs are put into a dictionary before the function sees them

Keyword arguments

```
# Keyword argument example:
def foo(x, y, **kw):
    print x, y
    print kw

>>> foo(1, 2, width=100, height=200)
1 2
{ 'width' : 100, 'height' : 200 }
```

Keyword arguments

- In the definition of `foo`:

```
def foo(x, y, **kw):
```

- the `**kw` means that all the keyword arguments will be put into a dictionary called `kw`
- the `**kw` has to come at the *end* of the argument list
  - for boring technical reasons

Keyword arguments

- When calling the function `foo`:

```
foo(1, 2, width=100, height=200)
```

- the keyword arguments are `width` and `height`
- Inside the function `foo`, they get put into the `kw` dictionary, which becomes:

```
{ width: 100, height: 200 }
```

Keyword arguments

- Keyword arguments are useful in functions where you want to be able to specify arguments by name
- `Tkinter` uses keyword arguments a lot
- Usually the meaning is intuitive
  - *e.g.* `height` means height in pixels, `width` means width in pixels

Back to the example

- We had these lines:

```
from Tkinter import *
root = Tk()
root.geometry('800x600')
```

- Let's see what they mean...

Back to the example

```
from Tkinter import *
root = Tk()
root.geometry('800x600')
```

- This line means: import all names from the `Tkinter` module
- Use `from Tkinter import *` form because writing `Tkinter.<name>` for every name would be very tedious to write and to read

Back to the example

```
from Tkinter import *
root = Tk()
root.geometry('800x600')
```

- This line means: create the *root window* of the program
- This is the window in which all the other graphical components of the application will be placed
- It is a Python object, so has methods

Back to the example

```
from Tkinter import *
root = Tk()
root.geometry('800x600')
```

- This line calls the `geometry` method on the root object
- This line means: set the size of the root window to be `800` pixels wide (horizontal dimension) by `600` pixels deep (vertical dimension)

Back to the example

```
from Tkinter import *
root = Tk()
root.geometry('800x600')
```

- You could run this as a whole program
- If you did, a blank window of size 800 by 600 would appear on the screen and then go away almost immediately
- Need a way to make the screen stay up!

Back to the example

```
from Tkinter import *
root = Tk()
root.geometry('800x600')
raw_input('Press <return> to quit.')
```

- If this is the whole program, you get a blank window of size 800x600 which stays up until you press the return key in the terminal window

To be continued...

- Need to continue this next class
- Finish discussion of example program
- Also talk about *event handling*
  - how to make graphical programs respond to key presses, mouse clicks, etc.