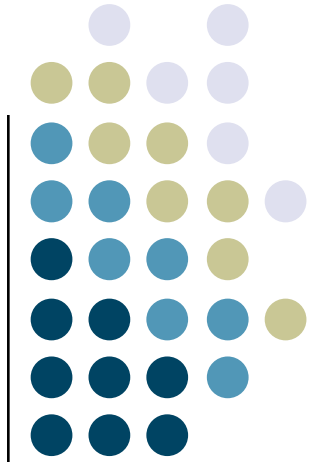
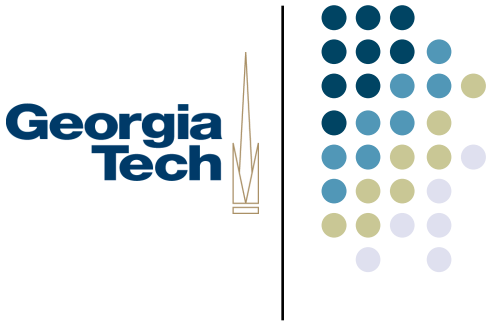
Asynchronous Programming

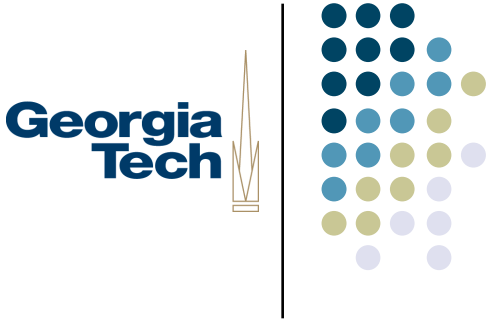


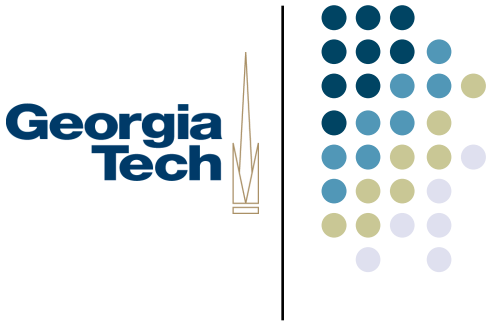


Turn-in Instructions

- A "main" file, called gui.py
  - See previous slides for how to make it "main"
  - I'll run it from the command line
- Put in a ZIP file, along with any additional needed files
- Name the ZIP file *your_last_name*.zip
- Send to me in email, along with details on:
  - Anything special I need to do to run it
  - What platform you developed/tested it on
  - Anything else you think I should know

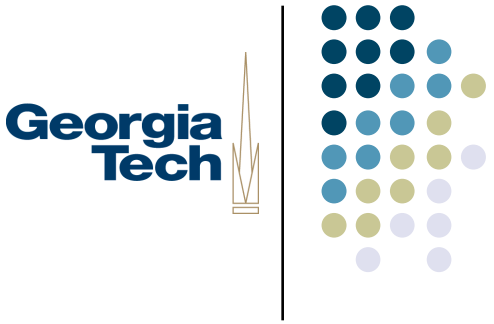
Asynchronous Programming





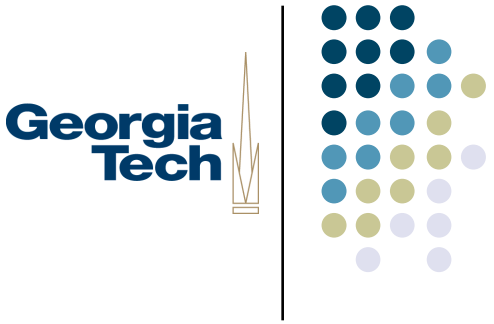
Asynchronous Programming

- Probably **the** most used idiom for interactive systems
- Why? *Interactions with the real world*
  - Must be prepared to respond to events external to your program
  - You don't know when these might occur
  - They may come from multiple sources (a user, remote users, sensors, hardware devices)
- Also, the single biggest mind-shift away from doing simple "straight line" programs
- A few canonical examples:
  - GUIs (responsive to mice, keyboard)
  - Systems that interact with hardware (*interrupts*)
  - Collaborative tools (multiple users, each doing their own thing)



Asynchrony and Modularity

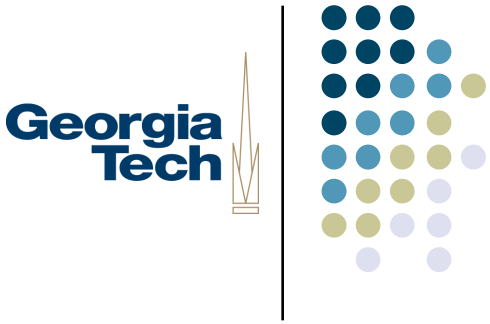
- First-time programmers:
  - Try to do everything "in line" in one flow of control
  - Works only for trivial problems
  - How would you do an "in line" program that needs to respond to multiple event sources?
    - *N.B.: It's actually possible. In fact, it's one of the ways that asynchronous programming works "under the hood." We'll talk about it later in the semester.*
- Asynchronous programming requires that you break your program down into pieces that are invoked independently whenever any external event happens
- *Modularity*



Modularity is a Good Thing

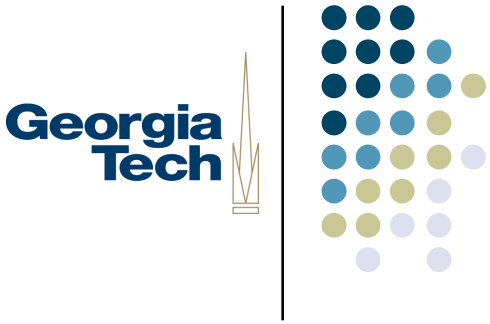
- Fortunately, modularity is a good goal *anyway*
  - Break apart code into more manageable chunks (abstraction)
  - Keep the entanglements between chunks as simple as possible (encapsulation)
    - Corollary: keep as few things global as possible
  - Treat each chunk as a "black box" that does a simple thing, and does it well (information hiding)
- Object-oriented programming is modularity on steroids (an oversimplification)
- Modularity is important when even *one* person is working on it
  - Easier to conceptualize the entire system; chunk behavior into building blocks, etc.

You can't make complexity go away completely, but you can learn techniques to manage it!



Thinking Asynchronously

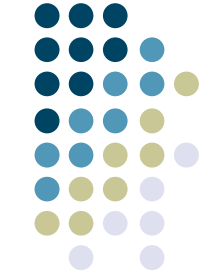
- Asynchronous: things can happen at arbitrary times
- Your program will probably have two types of code in it:
  - Set-up code, that gets the initial windows on the screen, does initialization, etc.
  - A collection of program chunks that respond to particular types of events that occur
- Some terminology:
  - An *event* is some external occurrence
  - The asynchronously-callable program chunks are *event handlers*
  - An *event dispatcher* is the thing that calls your event handlers; it is typically provided by the system (language, library, OS, ...)
- Your set-up code will *install* your various event handlers, so that the event dispatcher will know which ones to call
- Much of your program's logic will reside in the event handlers!



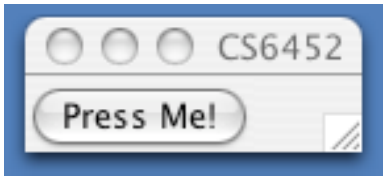
Common Idiom: GUI Callbacks

- In many GUI systems, event handlers are called *callbacks*
  - These are just functions that will be invoked when an event occurs
  - Typically, they take a predefined set of arguments (what event happened, etc.)
  - They are parts of your program that get *called back* when something happens
- How you associate your specific callback with a particular type of event depends on the particulars of the dispatch system

Example: GUI Callbacks in Jython with Swing



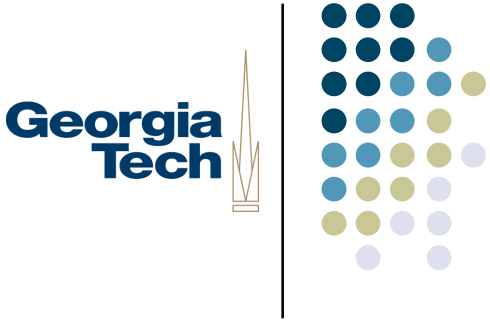
```
import javax.swing as swing

def callback(event):
    print "Button was pressed:", event

window = swing.JFrame("CS6452")
button = swing.JButton("Press Me!")

button.actionPerformed=callback
window.contentPane.add(button)

window.pack()
window.show()
```



Results:

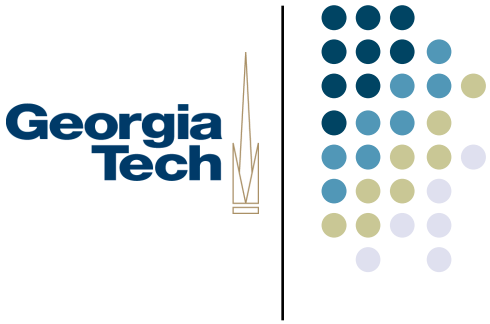
Button was pressed: java.awt.event.ActionEvent [ACTION_PERFORMED,cmd=Press Me!,when=72985371,modifiers=Button1] on javax.swing.JButton[, 0,0,87x29,layout=javax.swing.OverlayLayout,alignmentX=0.0,alignmentY=0.5,border=apple.laf.AquaButtonBorder@eb1670,flags=296,maximumSize=,minimumSize=,preferredSize=,defaultIcon=,disabledIcon=,disabledSelectedIcon=,margin=javax.swing.plaf.InsetsUIResource[top=3,left=14,bottom=3,right=14],paintBorder=true,paintFocus=true,pressedIcon=,rolloverEnabled=false,rolloverIcon=,rolloverSelectedIcon=,selectedIcon=,text=Press Me!,defaultCapable=true]

The Details of Event-Based Programming in Swing



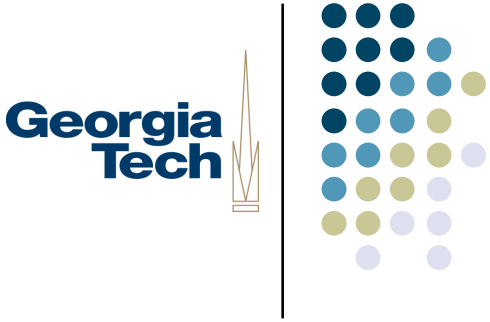
- In Swing, events are generated based on user input
  - Mouse clicks, movement, release
  - Key presses, releases
  - Combinations of all of the above
- Each widget gets to define what constitutes an event for it, and how callbacks will be associated with it
  - button.actionPerformed
  - list.valueChanged
- Any given widget may allow multiple kinds of callbacks to be associated with it
  - panel.mousePressed
  - panel.mouseReleased
  - panel.mouseClicked

The Details of Event-Based Programming in Swing (cont'd)



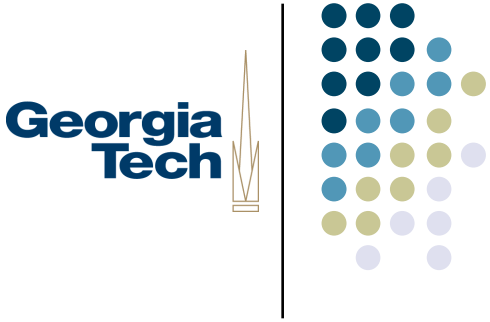
- Event dispatcher calls your code when the appropriate combination of user inputs occurs
- Passes an *event* argument to your code
- Specific details contained in the event depend on type of callback:
  - button.actionPerformed → ActionEvent
    - source: the widget that generated the event
    - timestamp: when the event occurred
    - modifiers: which keys were held down when the event occurred
  - list.valueChanged → ListSelectionEvent
    - firstIndex: first index of changed item
    - lastIndex: last index of changed item
  - To get specific details of any given event type, look at the Java documentation (http://java.sun.com/j2se/1.5.0/docs/api/) or ask me or the TA

The Details of Event-Based Programming in Swing (cont'd)



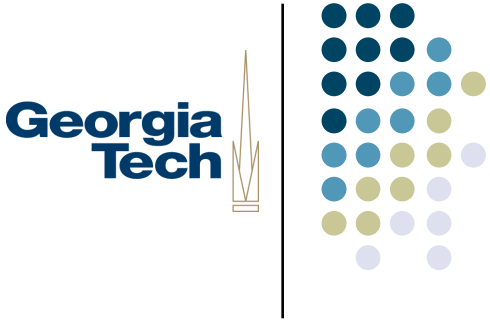
- You can call your callbacks yourself
  - They're just normal functions
  - Simulate what happens when user input occurs
- Make sure you return quickly from your event handlers!
  - The program is waiting until you finish so that it can continue running
  - Common signs of a non-returning callback:
    - Program appears to freeze
    - Program window doesn't redraw
    - Buttons become inactive

O-O and Asynchronous Programming



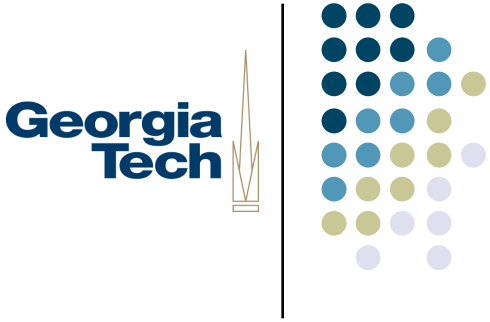
- Simple callbacks are a perfectly acceptable idiom; they're the "baseline" of asynchronous programming
- If you do much callback programming, though, you begin to notice some common patterns:
  - Often need to share some data across several related callbacks
  - Often need to keep track of what happened the last time you ran the callback
  - There's a group of variables and related functions that are used only by the callback

An Example



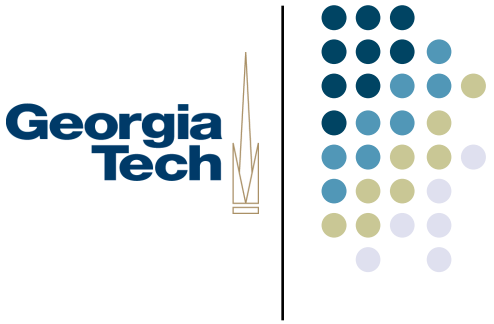

```
import javax.swing as swing

startx = 0
starty = 0

def pressCallback(event):
        global startx, starty
        startx = event.x
        starty = event.y

def releaseCallback(event):
        global startx, starty
        graphics = event.source.graphics
        graphics.drawLine(startx, starty, event.x, event.y)

if __name__ == "__main__":
        frame = swing.JFrame("Simple Drawing Program")
        canvas = swing.JPanel()
        canvas.preferredSize = (400, 400)
        frame.contentPane.add(canvas)
        frame.pack()
        frame.show()

        canvas.mousePressed = pressCallback
        canvas.mouseReleased = releaseCallback
```

O-O and Asynchronous Programming (cont'd)



- Last mouse-down position needs to be remembered until the next time the callback is invoked
  - Can't save in a local variable, as it will be reset each time the callback is invoked
- Option #1: keep all of this cross-callback information in global variables
- Why is this a bad idea?
  - The information is specific to the drawing callbacks; nothing else should use it
  - By making it global, you increase program clutter, and the mental cycles needed to manage it
  - Worse: you run the risk that someone (you?) will misunderstand what the global variables are for, and reuse them for something else

O-O and Asynchronous Programming (cont'd)



- The principle of data hiding:
  - Keep data as "close" to the behavior it controls as possible
  - Keep it inaccessible to everything else that doesn't need to use it
- The more of the inner workings of something you expose, the more likely it is to be used in the wrong way
- Option #2: object-oriented programming provides a nice way to handle this:
  - Each handler is an object that contains whatever information is necessary for it to execute properly
  - Internal state is not visible outside the handler object
  - Well-designed objects will allow the user to use them *only* in the way they were intended

Example of O-O Event Handling

```
import javax.swing as swing

class Draw:
    def __init__(self):
        frame = swing.JFrame("Simple Drawing Program")
        canvas = swing.JPanel()
        canvas.preferredSize = (400, 400)
        frame.contentPane.add(canvas)
        frame.pack()
        frame.show()

        eventHandler = EventHandler()
        canvas.mousePressed = eventHandler.pressCallback
        canvas.mouseReleased = eventHandler.releaseCallback


class EventHandler:
    def pressCallback(self, event):
        self.startx = event.x
        self.starty = event.y

    def releaseCallback(self, event):
        graphics = event.source.graphics
        graphics.drawLine(self.startx, self.starty, event.x, event.y)

if __name__ == "__main__":
    draw = Draw()
```

Example of O-O Event Handling

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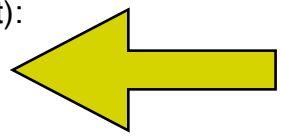
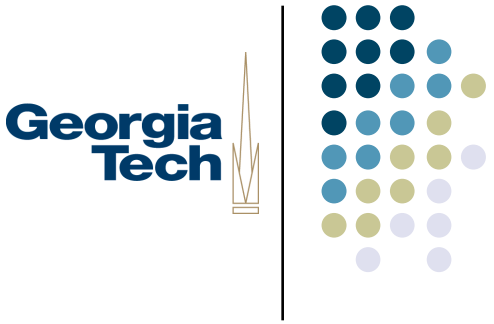


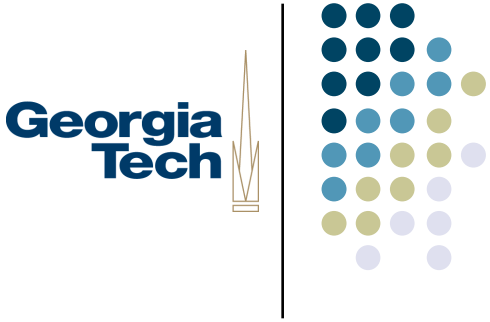
Record of last X,Y positions are stored in the EventHandler object. Not easily visible *outside* the object, easily shared among just these callbacks.

Objects As a Structuring Principle



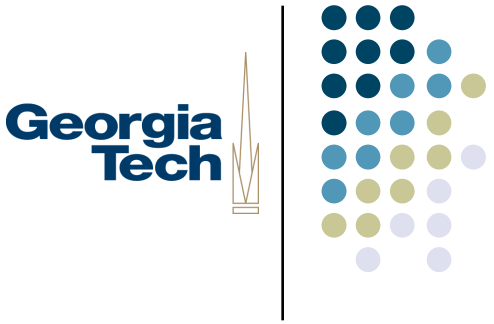
- Very often, the data in your program will have a natural structure
- In a drawing program, each drawing window will have its own contents, current mode, etc., that is not shared by any other open windows
  - All of this information can be grouped together into a *DrawingWindow* object
  - One *DrawingWindow* object per open window
  - No need to make the information needed by it global
- In a chat program, each ongoing chat has its own list of users, and its own message history
  - The user list, history, etc., could be grouped into a *Chat* object
  - One *Chat* object per ongoing chat
  - No need to make all of this information global

Creating Objects



- Where do new objects come from?
- In an event-driven program, they usually are created in response to events!
- Example:
  - User clicks "New Chat" button in GUI
  - Callback creates a new Chat object to represent the details of that chat

```
def newChat(event):
    chat = Chat()
    chat.users = [me, buddyList.selectedValue]
```

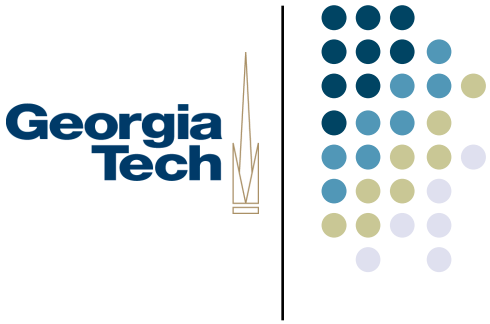


Managing Global State Effectively

- Some times, you really do need to store some stuff globally

```
allMyChats=[ ]
def newChat(event):
    chat = Chat()
    chat.users = [me, buddyList.selectedValue]
    allMyChats.append(chat)
```

- Useful idiom: keep track of objects through global data structure
  - Lists and Dictionaries are very helpful here
  - Use Lists for simple, ordered collection of stuff
  - Use Dictionaries when there's a natural *identifier* for stored objects
  - Extra bonus: since you update a collection by invoking a method on it (and not assigning to it), you avoid some of the scoping problems we talked about last week



Lab Time!