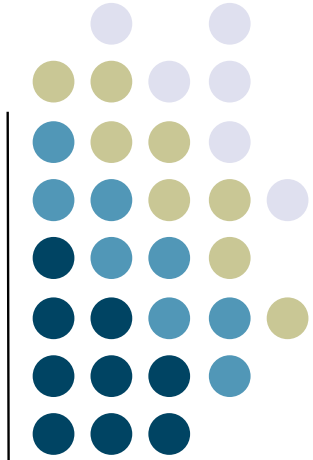
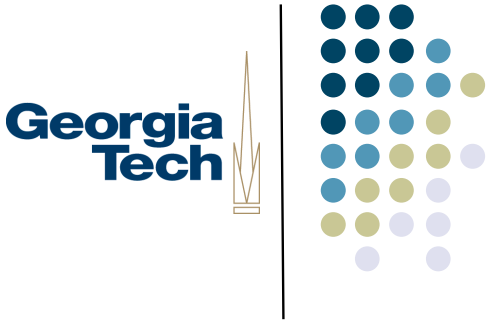
UI Software Organization



Georgia Tech

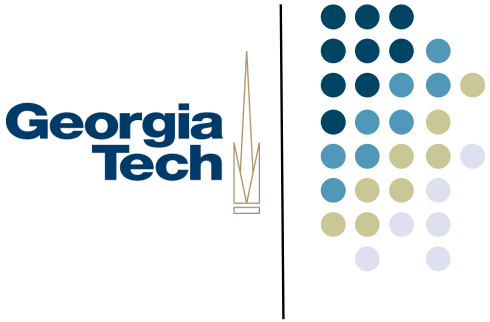
The user interface

- From previous class:
  - Generally want to think of the "UI" as only one component of the system
    - Deals with the user
    - Separate from the "functional core" (AKA, the "app")



Separation of Concerns

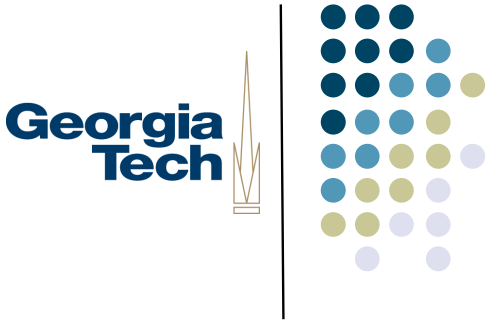
- There are good software engineering reasons to do this
  - Keep UI code separate from app code
  - Isolate changes
  - More modular implementation
  - Different expertise needed
  - Don't want to iterate the whole thing



In practice, very hard to do...

- More and more interactive programs are tightly coupled to the UI
  - Programs structured around UI concepts/flow
  - UI structure "sneaks into" application
- Not always bad...
  - Tight coupling can offer better feedback/performance

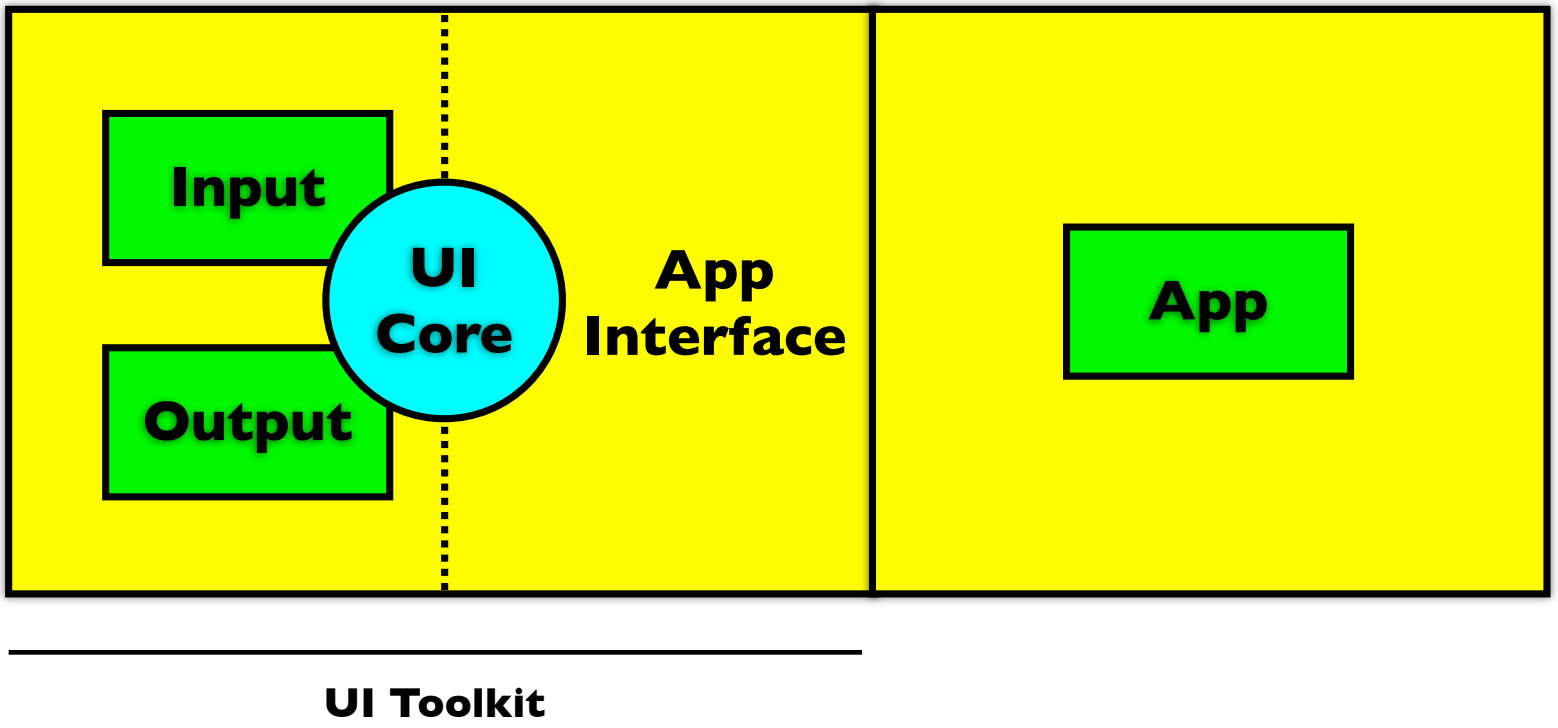
Separation of concerns is a central theme of UI organization



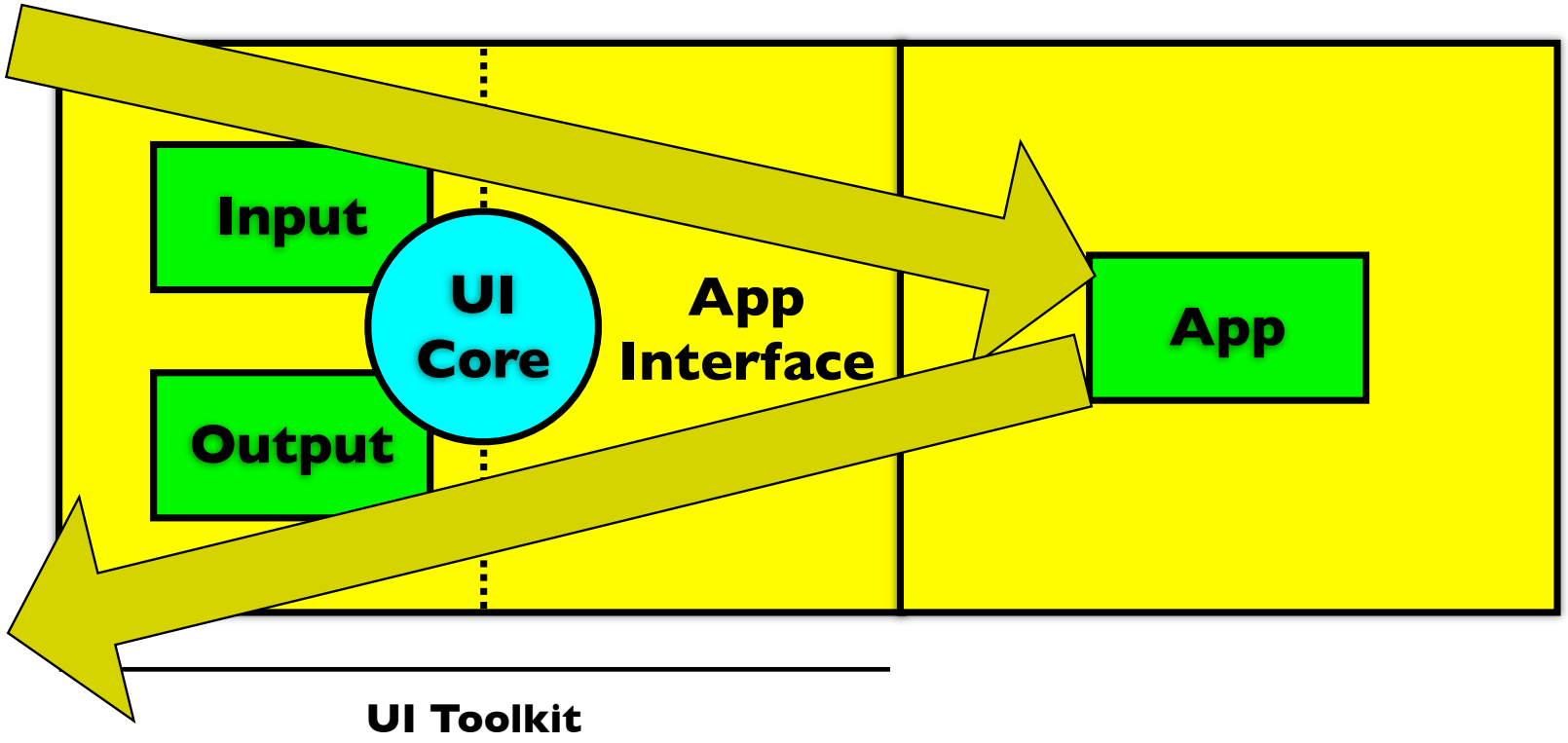
- A continual challenge
- A continual tension and tradeoff

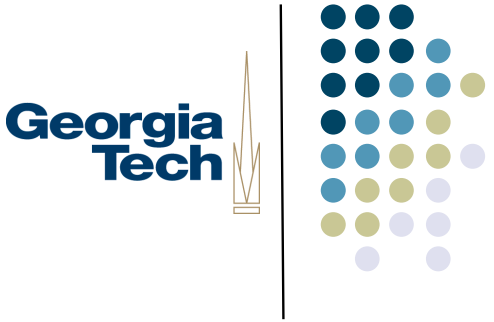
- Real separation of UI from application is almost a lost cause

Conceptual Overview of the UI



Basic UI Flow

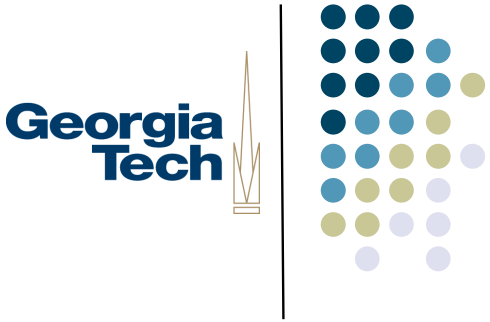




How would you architect this?

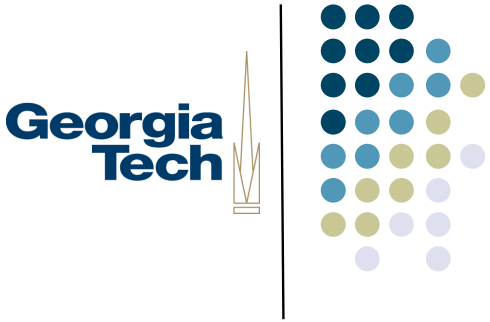
- Tempting to architect systems around these boxes
  - One module for input, one for output, etc.
  - Has been tried ("Seeheim model")
  - Didn't work well

Why "Big Box" architectures don't work well



- Modern ("direct manipulation") interfaces tend to be collections of quasi-independent agents
  - Each **interactor** ("object of interest" on the screen) is separable
  - Example: an on-screen button
    - Produces "button-like" output
    - Acts on input in a "button-like" way
    - Etc.

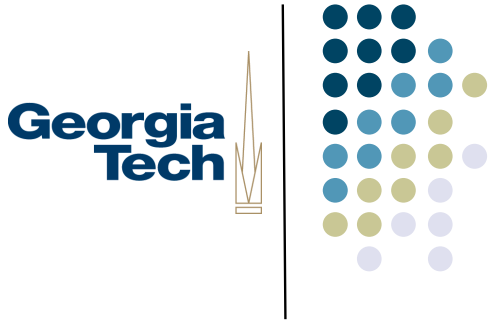
Leads to object-based architectures



- Each on-screen interactor corresponds to an object instance
  - Common methods for
    - Drawing output (button-like appearance)
    - Handling input (what happens when I click)
- Classes are organized into a subclassing hierarchy
  - Typically a top-level "Component" or "Widget" class that describes basic interactor capabilities
  - Leaf-node classes for the things you actually see on the screen (buttons, scrollbars, etc.)
  - Intermediate classes for common behaviors (text or mouse processing)
- Objects are organized hierarchically at runtime
  - Normally reflecting spatial containment relationships
  - NOTE: different than class hierarchy created at development time

- **Interactor trees**

Challenge: maintaining separation of concerns



- Trick is coming up with a separation that works quickly, simply, and extensibly
  - Even a single button may be hopelessly complex (pluggable looks-and-feels anyone?)
  - Needs to be extensible to new interactors
  - What's the right factoring for all this stuff?
- Will see some strategies later
- Basically: common O-O patterns to manage complexity

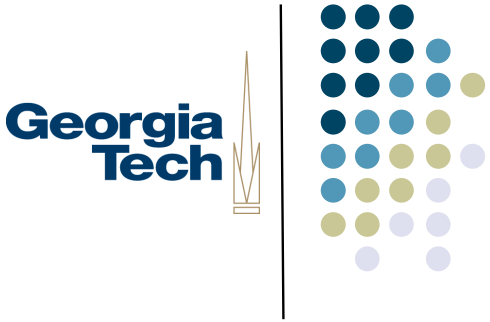
UI Toolkits

- System to provide development-time and runtime support for UIs
  - Core functionality
  - Input & output handling
  - Connecting to the application
- Also: specific interaction techniques
  - Library of interactors
  - Look and feel (sometimes pluggable)

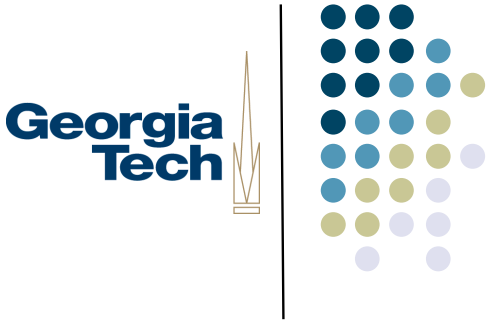
Categories of users

- Consumer
  - End-user, albeit indirectly
- Programmers
  - Interface designer
  - Application builder
  - Toolkit implementer/maintainer
  - Interactor writer
  - Tool builder
  - Expert end-user (through scripting)

Toolkit functionality in detail (Roadmap of topics)



- Core functions
  - Hierarchy management
    - Create, maintain, tear down tree of interactor objects
  - Geometry management
    - Dealing with coordinate systems
    - On-screen bounds of interactors
  - Interactor status/information management
    - Is this interactor visible? Is it active?

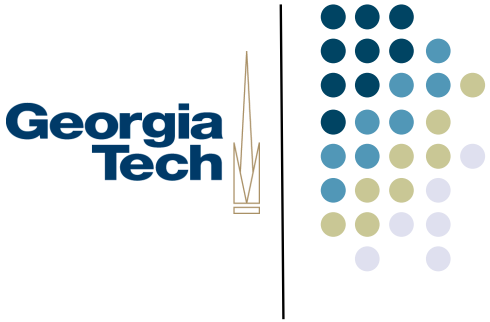


Toolkit functionality in detail

- Output
  - Layout
    - Establishing the size and position of each object
    - Both initially, and after a resize
  - (Re)drawing
  - Damage management
    - Knowing what needs to be redrawn
  - Localization and customization
    - We won't talk much about this...

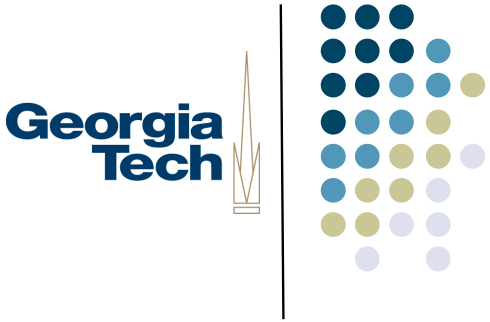
Toolkit functionality in detail

- Input
  - Picking
    - Figuring out what interactors are "under" a given screen point
  - Event dispatch, translation, handling
    - This is where a lot of the work goes



Toolkit functionality in detail

- Application interface
  - How the UI system connects with application code
    - Callbacks
    - Command objects
    - Undo models
    - ...

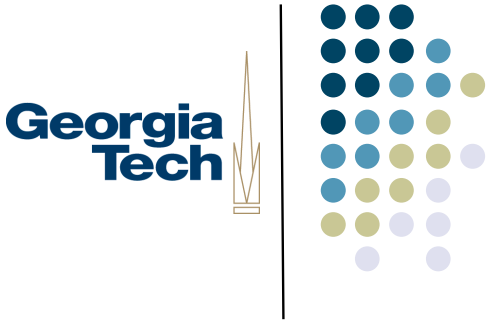


Example: Java Swing

- All functions of interactors encapsulated in base class
  - javax.swing.JComponent
  - All objects on-screen inherit from this class

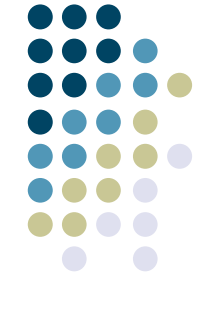
- Terminology:
  - interactor, widget, component, control, ...

Standard object-oriented approach



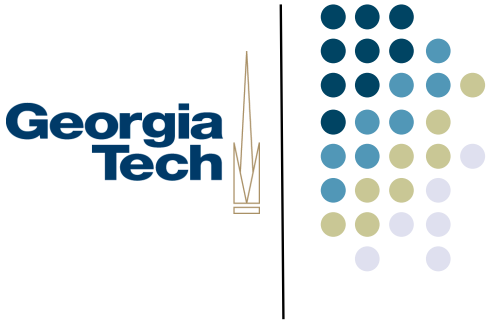
- Base class (or interface) defines the set of things that every interactor must do
  - e.g., public void paintComponent(Graphics g);
- Subclasses provide specific specialized implementations
  - Do the right drawing, input, etc., to be a button vs. a slider vs. ...

JComponent API defines methods for



- Hierarchy management
- Geometry management
- Object status management
- Layout
- (Re)drawing
- Damage management
- Picking

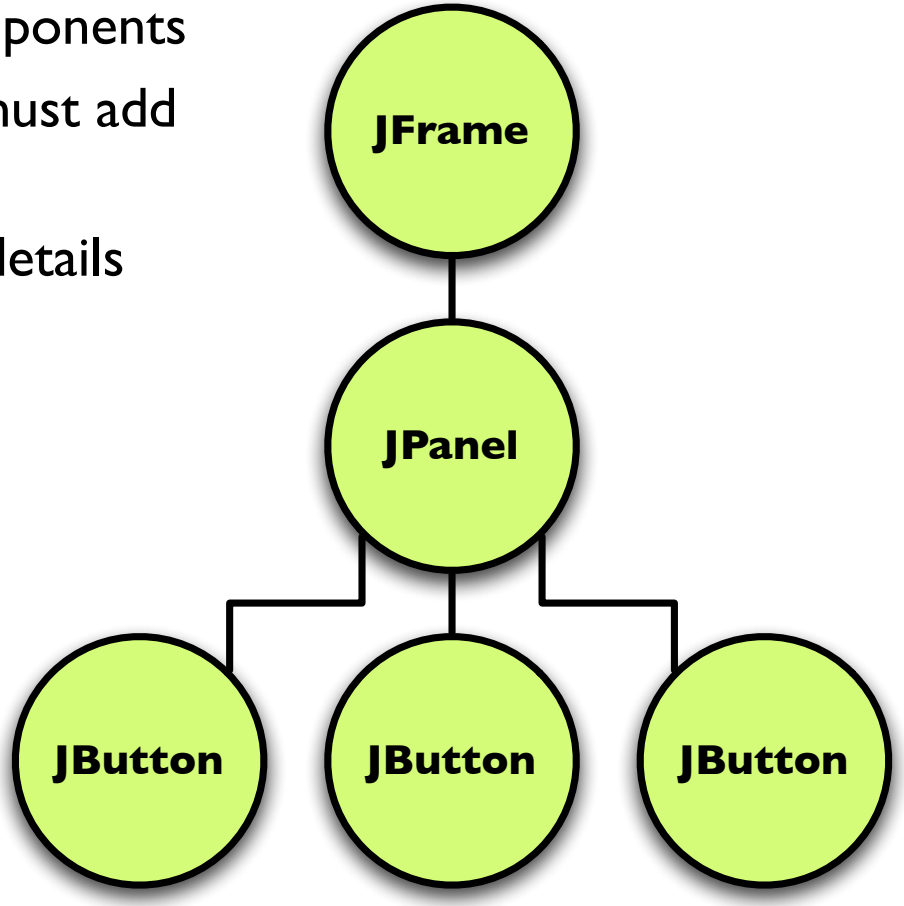
In subclasses and other parts of the toolkit:



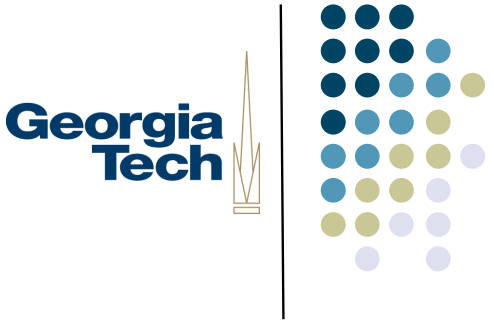
- Input dispatch and handling
- Application interface
- Pluggable looks and feels
- Undo support
- Accessibility

Hierarchy Management

- Swing interfaces are trees of components
- To make something appear, you must add it to the tree
- Swing takes care of many of the details from there
  - Screen redraw
  - Input dispatch

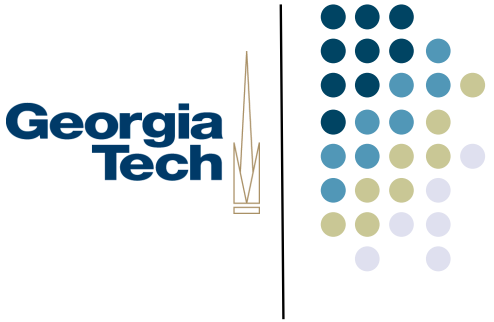


Hierarchy Management

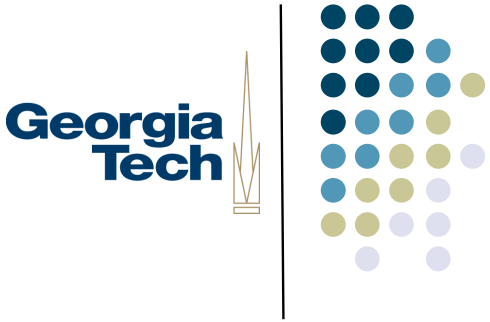


- Lots of methods for manipulating the tree
  - add(), remove(), removeAll(), getComponents(), getComponentCount(), isAncestorOf(), ...
- Common mistake
  - If nothing shows up on the screen, make sure you've added it!

Geometry Management

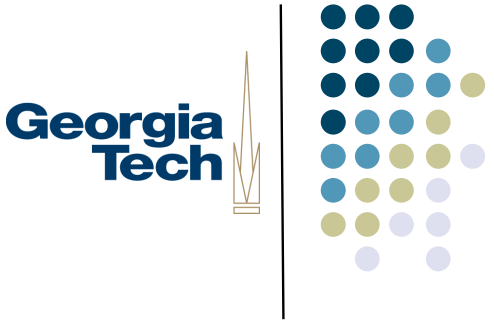


- Every component maintains its own geometry:
  - Bounding box: getX(), getY(), getWidth(), getHeight()
    - X,Y are relative to parent
    - i.e., 0,0 is at parent's top left corner
    - Other operations: setSize(), setLocation(), setBounds(), getSize(), getLocation(), getBounds()
  - All drawing happens within that box
    - System clips to bounding box
    - Including output of children!
  - Drawing is relative to top-left corner
    - Each component has its own coordinate system



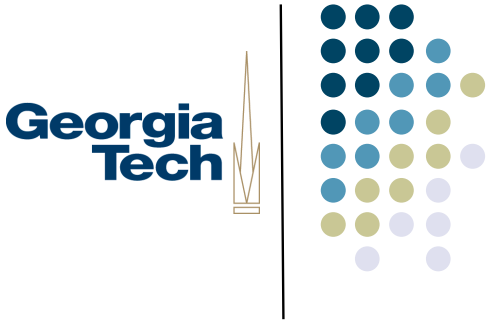
Object Status

- Each component maintains information about its "state"
  - isEnabled(), setEnabled()
  - isVisible(), setVisible()
- Lots of other methods of lesser importance



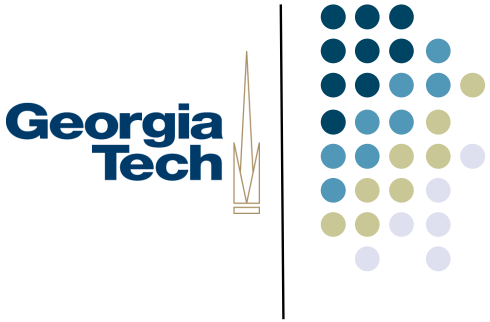
Each component handles:

- Layout (we'll talk about this later...)
- Drawing
  - Each component knows how to (re)create its appearance based on its current state
  - Responsible for painting three items, in order:
    1. Component
    2. Borders
    3. Children
  - paintComponent(), paintBorder(), paintChildren()
  - **These are the only places to draw on the screen!!!**
  - Automatically called by JComponent's paint() method, which is itself called by the Swing RepaintManager (figures out "damaged" regions)



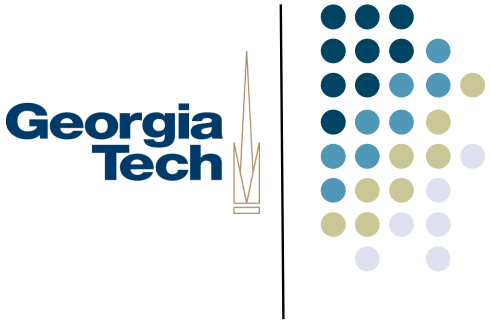
Damage Management

- Damage: areas of a component that need to be redrawn
  - Sometimes: computed automatically by Swing RepaintManager
    - e.g., if another window is dragged over your component, or your component is resized
  - Other times: you need to flag damage yourself to tell the system that something in your internal state has changes and your on-screen image may not be correct
    - e.g., your component needs to change the color of a displayed label
- Managing damage yourself:
  - repaint(Rectangle r)
  - Puts the indicated rectangle on the RepaintManager's queue of regions to be redrawn
- Terminology: *damage* is not a Swing term; generic



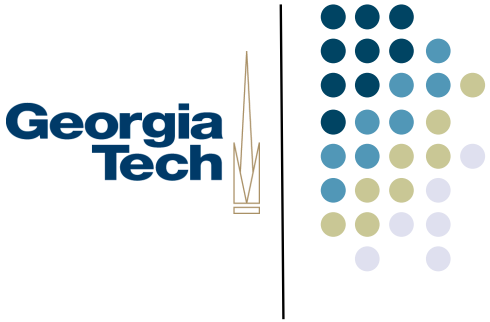
Picking

- Determine if a point is "inside" a component
  - contains(int x, int y)
  - Is the point inside the bounding box of this component (uses local coordinate system of component)
- Terminology: likewise, *picking* is not a Swing term



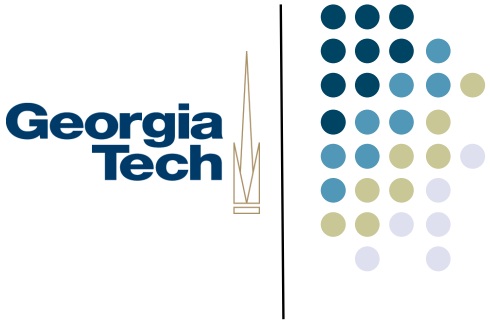
Other stuff

- Input (we'll talk about this later...)
- Application interface
  - Glue between component and application functionality
  - Not directly in component, but there is a convention for how to associate your functionality with a component
  - *Callbacks*: you register code with a component to say "call this code when something happens"
- Terminology: Swing uses the term *listener* for a piece of application code that will be called back in response to something happening
  - The code "listens for" something happening



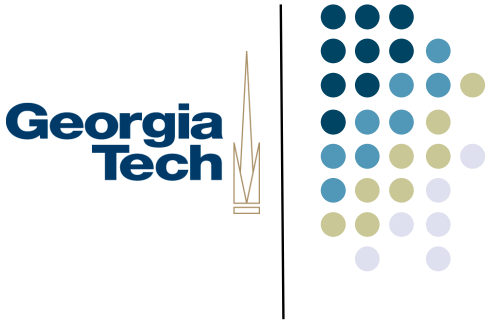
Listeners

- Any given component may have multiple situations in which it invokes a listener
  - Button pressed, list scrolled, list item selected
  - Different *types of listeners* representing different *types of things happening*
- Therefore, each component has a list of *listeners* for each situation
- Standardized names for accessing these lists
  - addPropertyChangeListener(), getPropertyChangeListeners(), removePropertyChangeListener()
  - addActionListener(), getActionListeners(), removeActionListener()



More on listeners

- There is generally a separate interface for each type of listener
  - PropertyChangeListener
  - ActionListener
- Your code must implement the appropriate listener interface *and* be registered with the list of appropriate list of listeners on the appropriate component
  - Example: button press causes listeners on the button's ActionListener list to be called
    - Define your code so that it implements ActionListener
    - Register it with the button using addActionListener()



Events

- Most listener interfaces define methods that take an *event object* that describes what just happened
- Separate classes of events for each listener interface
  - ActionListener: ActionEvent
  - MouseListener: MouseEvent
- Passed as a parameter containing details of what happened
  - e.g., MouseListener: mouse coordinates, whether it was pressed, released, etc.