Poll Everywhere

PollEv.com/javabear text **javabear** to 22333

What is the (tight) space complexity of Dijkstra's algorithm?

```
while(!frontier.isEmpty()) {
   V v = frontier.remove();
   for (WeightedEdge<V> edge : v.outgoingEdges()) {
      V neighbor = edge.head();
      double dist = discovered.get(v.label()).distance() + edge.weight();
      if (!discovered.containsKey(neighbor.label())) {
         discovered.put(neighbor.label(), new PathInfo(dist, v.label()));
         frontier.add(neighbor, dist);
      } else if (discovered.get(neighbor.label()).distance > dist)  {
         discovered.put(neighbor.label(), new PathInfo(dist, v.label()));
         frontier.updatePriority(neighbor, dist);
}}}
```

both pqueue and map grow to size O(|V|)

O(1)

$O(1)$	**(A)**
$O(\|V\|)$	**(B)**
$O(\|V\| + \|E\|)$	**(C)**
$O(\|V\| \log \|V\|)$	**(D)**

Dijkstra's Algorithm Runtime Complexity

```
while(!frontier.isEmpty()) {                                   O(|V|) iterations
    V v = frontier.remove();                                   O(log|V|) · O(|V|)
    for (WeightedEdge<V> edge : v.outgoingEdges()) {           O(|E|) total iterations (across all outer loop iterations)
        V neighbor = edge.head();                              O(1) · O(|E|)
        double dist = discovered.get(v.label()).distance() + edge.weight();   O(1) · O(|E|)
        if (!discovered.containsKey(neighbor.label())) {       O(1) · O(|E|)
            discovered.put(neighbor.label(), new PathInfo(dist, v.label()));   O(1) · O(|V|)
            frontier.add(neighbor, dist);                      O(log|V|) · O(|V|)
        } else if (discovered.get(neighbor.label()).distance > dist)  {   O(1) · O(|E|)
            discovered.put(neighbor.label(), new PathInfo(dist, v.label()));   O(1) · O(|E|)
            frontier.updatePriority(neighbor, dist);           O(log|V|) · O(|E|)
}}}
```

O(|E| · log|V|)

Exam Reminders:

Prelim 2 is tonight, 7:30-9:00 !

Rooms assigned by first letter of your NetID:
Baker Lab 200 (a-p), 219 (q-s), 135 (t-z)

Bring your **Cornell ID Card** and a couple **writing utensils** (pencils, erasers, pens)
Exam is closed-book

More information and review materials linked on website / Ed

You've learned a lot so far! Time to show it off!

Lecture 24: Graphical User Interfaces

CS 2110

April 21, 2026

Today's Learning Outcomes

95. Categorize aspects of a GUI application as part of its *model*, *view*, or *controller*.

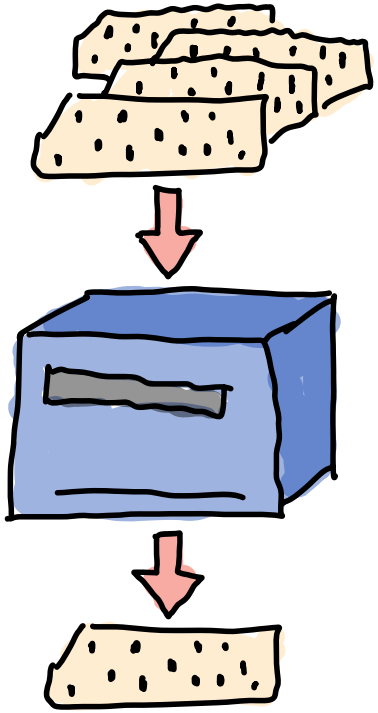
96. Write code to set up the component hierarchy of a graphical application given a mock-up of its design.

97. Describe the work performed by a layout manager and its interaction with elements in the component hierarchy.

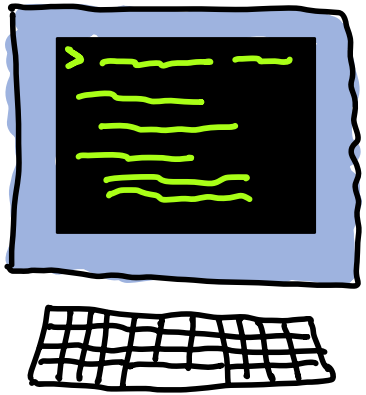
99. Write code that performs custom painting on graphical components.

Application Paradigms

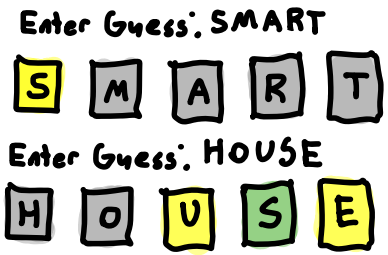
Batch Applications



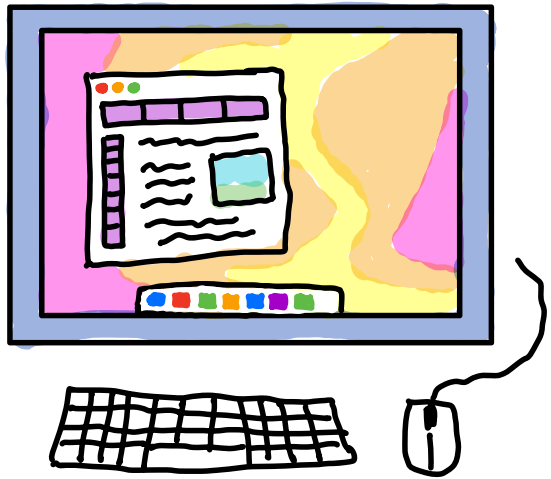
Command-Line Interfaces (CLI)



AI



Graphical User Interfaces (GUI)



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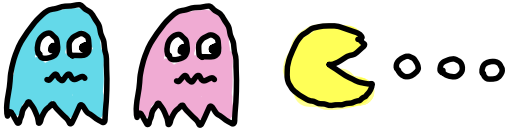
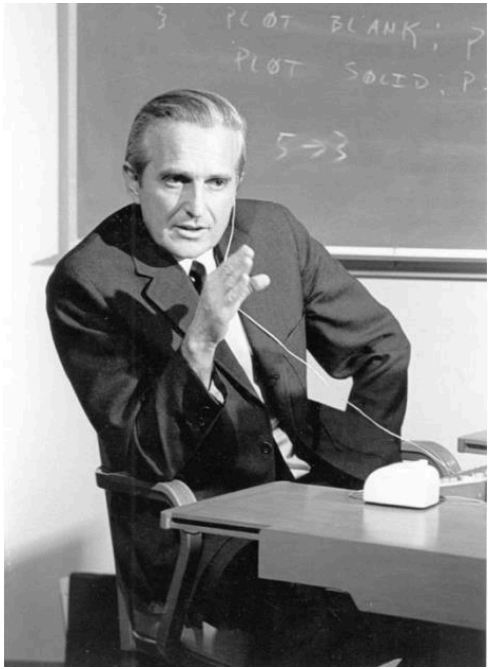


The *Mother of All Demos*: 1968

Foundation of "Personal Computing"

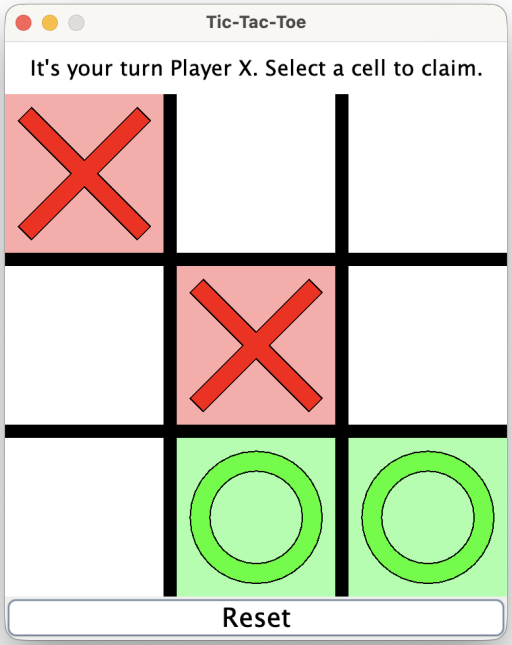
*"Computers can **augment** the capabilities of the human mind"*

- Computer mice
- Application windows
- Hyperlinks
- Word processors
- File menus
- Copy-paste
- Teleconferencing
- Document sharing



Douglas Engelbart

GUI Applications



Brainstorm: What new considerations are there to make a graphical application like this?

- Create window and show on screen
- Add window title
- Get close, minimize buttons to work
- Add label to top of window "body"
- Draw with different shapes, colors
- Add button
- Make button do something when clicked
- Keep track of board state, turns
- Let players select cells, then redraw screen
- ⋮

MVC Separation

We can divide a GUI application into three aspects:

Model

- State representation of the "back end" of the application
- variables
- objects
- interfaces
- invariants

* basically, everything we've done so far

View

- The collection of windows and widgets that display the state of the program to the user
- widget = graphical component that presents user info or way to interact with program
  - button
  - slider
  - image
  - textbox

(Today)

Controller

- Application logic that responds to user inputs or other events
- Requests updates of the model or the view

(Next Lecture)

Coding Demo: TicTacToe Model

GUI Frameworks

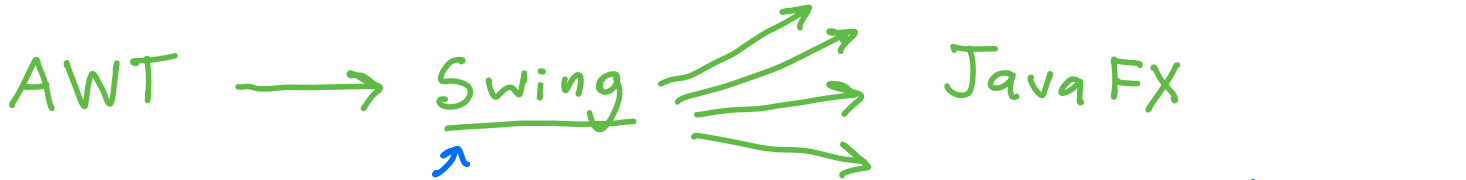
GUI applications are a lot more complicated than other programs we've written this semester

- Interaction with hardware and operating system
- Many layers of abstraction
- Good views need many interoperable + customizable widgets
- High coupling between parts of view + controller

Frameworks are large software libraries that we use to build GUIs.

Webdev: React, Angular, etc. build on top of HTML/CSS/Javascript

Java:



Coding Demo: The `JFrame` Class

Swing Widgets

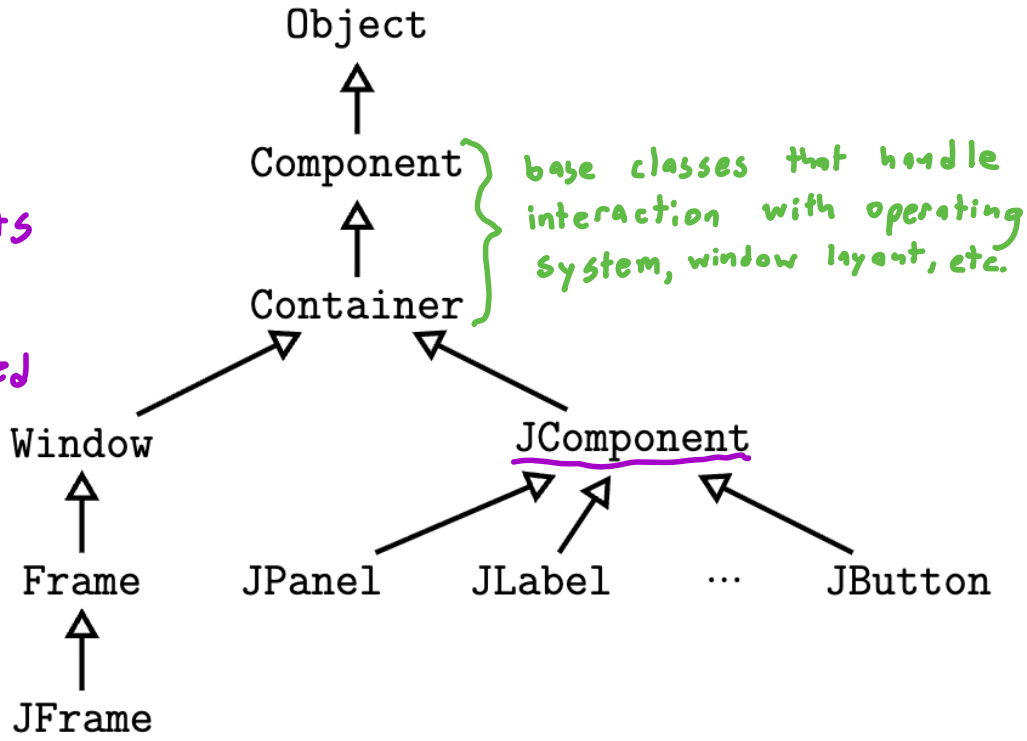
The JComponent class serves as the parent of all Swing widgets

Three main ones:

- JPanel holds + arranges other widgets
- JLabel displays formatted text
- JButton does some action when clicked

many others (checkbox, slider, text pane, ...)

GUI frameworks are one of the best examples of the benefits of deep inheritance hierarchies



Poll Everywhere

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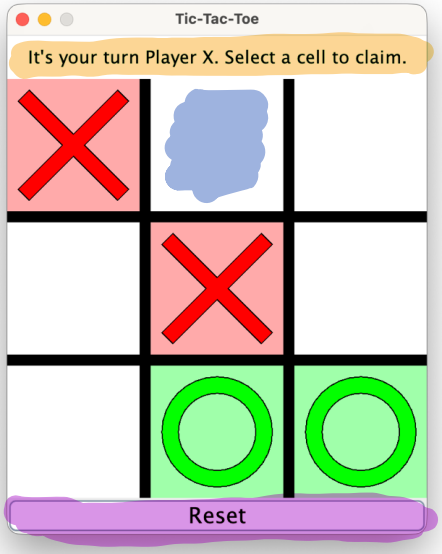
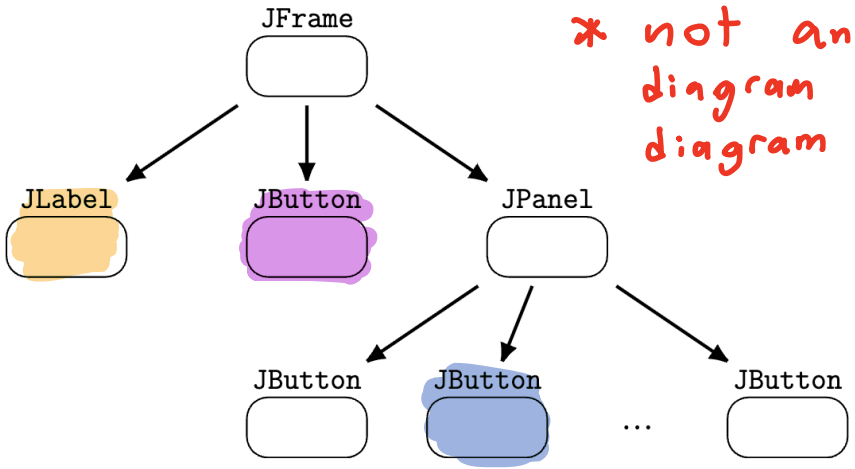
What is one consequence of the fact that all Swing widgets extend `JComponent`?

- Every widget must be drawn the same way overriding ✗ **(A)**
- It is impossible for third parties to make new Swing widgets ✗ **(B)**
- Every widget will support a common set of core behaviors **(C)**
- Widgets must override every method of JComponent ✗ **(D)**

The Component Hierarchy





* not an inheritance diagram or a node diagram

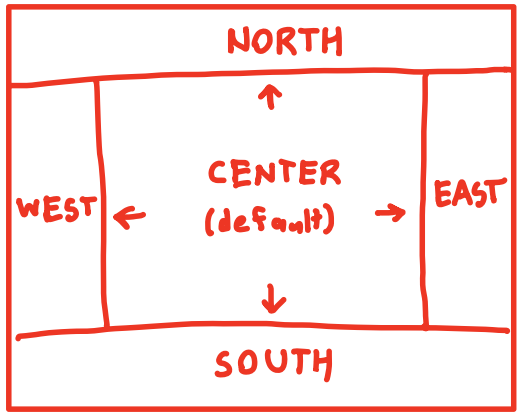
In this tree, children represent containment

- The frame contains a label, a button, and a panel with 9 more buttons

Layout Managers

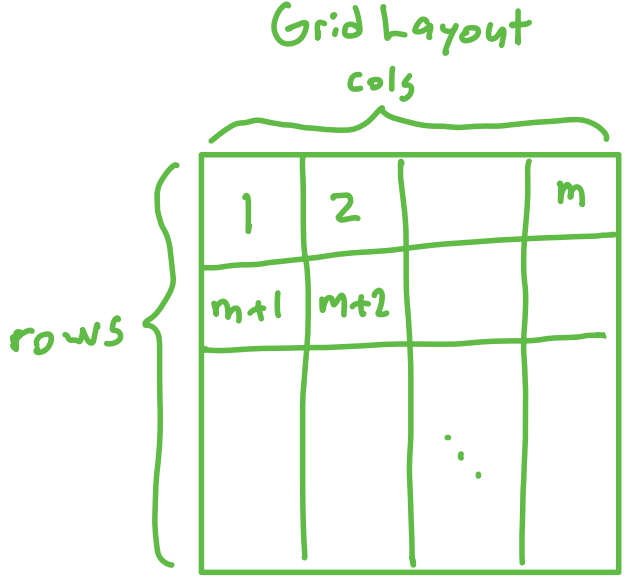
Separate objects associated with a Container that determine how to arrange its child components.
We'll consider two:

Border Layout
(JFrame default)



CENTER grows to fill frame

Grid Layout



All cells have same size

Call pack() on JFrame to ask layout manager to arrange components

Poll Everywhere

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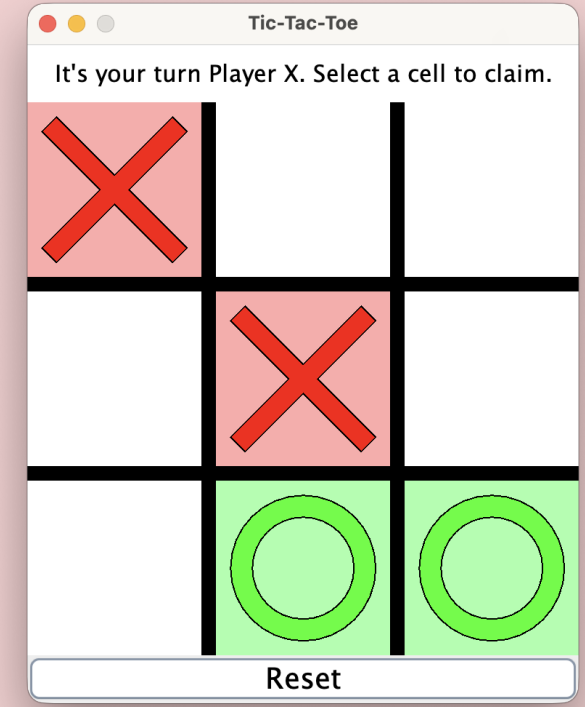
Which are the most appropriate choices of layout managers in our Tic-Tac-Toe game?



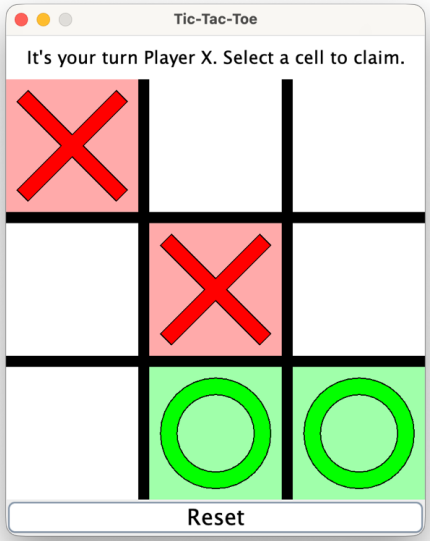
Frame: BorderLayout **Panel:** BorderLayout **(A)**

Frame: BorderLayout **Panel:** GridLayout **(B)**

Frame: GridLayout **Panel:** BorderLayout **(C)**

Frame: GridLayout **Panel:** GridLayout **(D)**

Coding Demo: Building out the View



- custom JComponent subclasses
- set LayoutManagers and use their contents to set positioning in add()
- call pack() at end of frame constructor

Connecting the View and Model

Multiple approaches

- Maintain the model in a separate class, accessible to all view components through alias references
  - Model has many methods to query and update state
  - Helps with separation of responsibilities in larger projects
  - Having model updates reflect in view requires observer pattern (next lecture)
- Store relevant bits of model within view classes
  - Sometimes leads to cleaner code when these are closely linked
  - Can get unwieldy in larger projects, but often easier in small ones

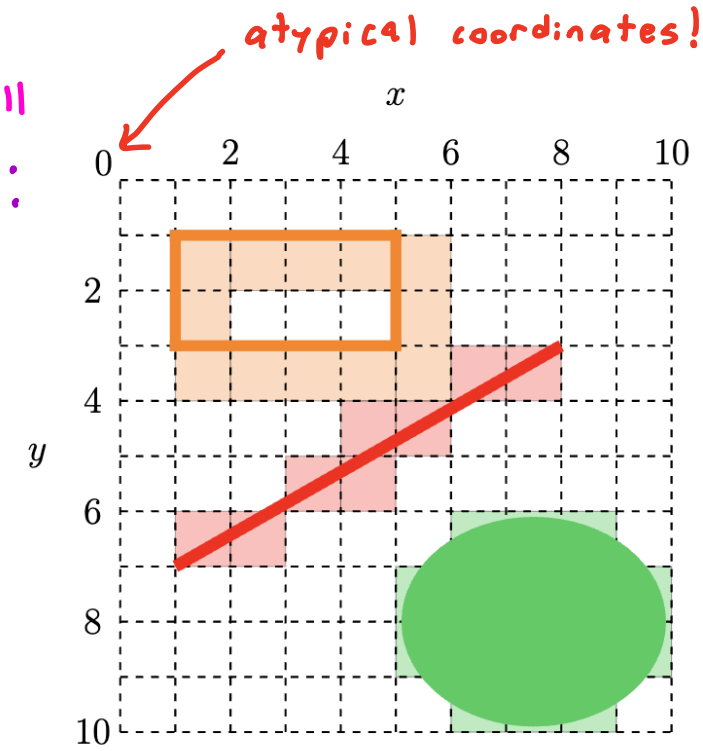
* we'll do a bit of both

Custom Painting

Override paintComponent() method
- first line must be super.paintComponent() call

Graphics object works like paint brush:
- setColor() "dips" into one color paint
- use draw___() and fill___() methods to add lines/shapes in that color

```
g.setColor(Color.RED);
g.drawLine(1,7,8,3);
g.setColor(Color.GREEN);
g.fillOval(5,6,5,4);
```



* Never call paintComponent() directly, instead call repaint()

Coding Demo: Painting Demo