# Organization of User Interface Software

# Administration

- **Questions about assignments due and assignments assigned**

# What we will talk about

- Ways to organize UI code
- Different "models" of user interfaces as systems/programs
  - How they are structured and the parts that make them up
  - Conceptually and in practice
  - Separation of UI and rest of software = "semantics"

# Semantic

- Functionality of system; what can be expressed
- What information is needed for each operation on object
- What errors can occur
- Semantic vs. UI is key issue in UI tools
- "Semantic Feedback"
  - Depends on meaning of items
  - Example: only appropriate items highlight during drag

# Conceptual

- Key application concepts that must be understood by user
- User model
  - objects and classes of objects
  - Relationships among them
  - Operations on them
    - E.g. text editor
      - Objects = characters, files, paragraphs
      - Relationships = files contain paragraphs contain characters
      - Operations = insert, delete, etc.

# The User Interface

- Typically want to think of "UI" as only one component of an overall system
  - The part that "deals with the user"
  - Distinct from the "functional core" (AKA the "application")

# Separation of UI from "Appl"

- **Really good reasons to want separation of UI**
  **(in general: "separation of concerns")**
  - **Modularity (good software design)**
  - **Different expertise needed**
  - **Don't want to iterate the whole thing**

# Unfortunately this is typically very hard to do in practice

- More and more of interactive programs are tightly coupled to UI (in some cases everything)
  - Generally need to structure around user concepts
  - UI structure "sneaks into" application

# Separation of concerns is a central theme of UI organization

- A continual challenge
- A continual tension and tradeoff

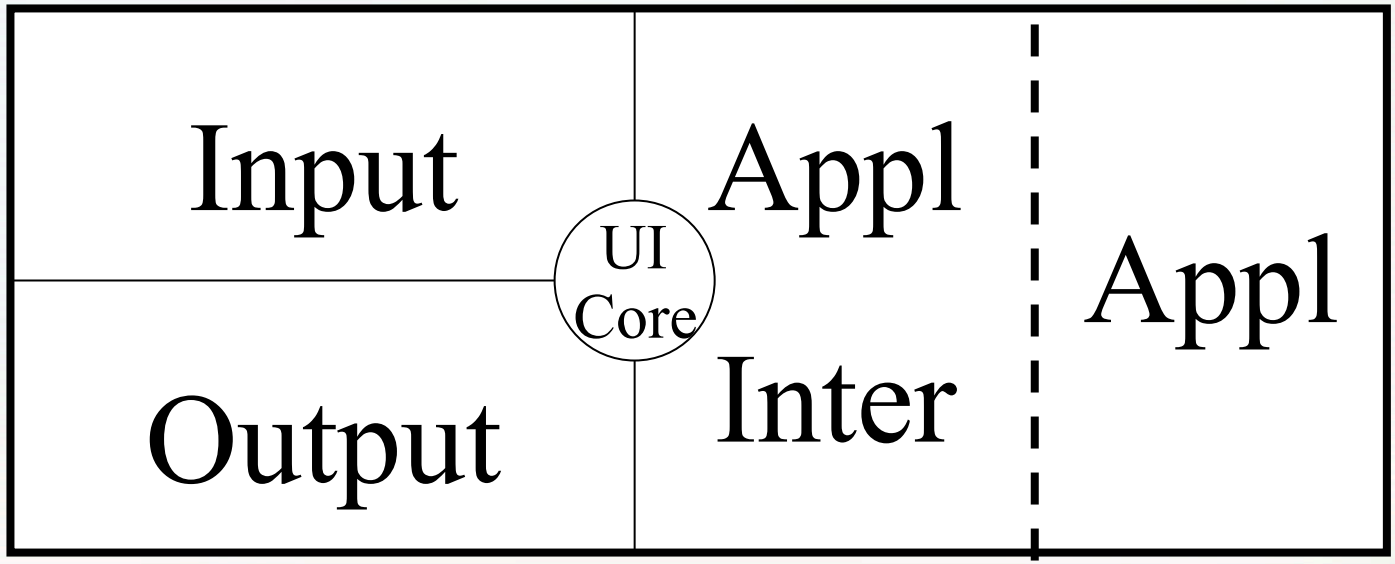
# UI tasks

- **So far have:**


- **Clearly more structure could be useful**

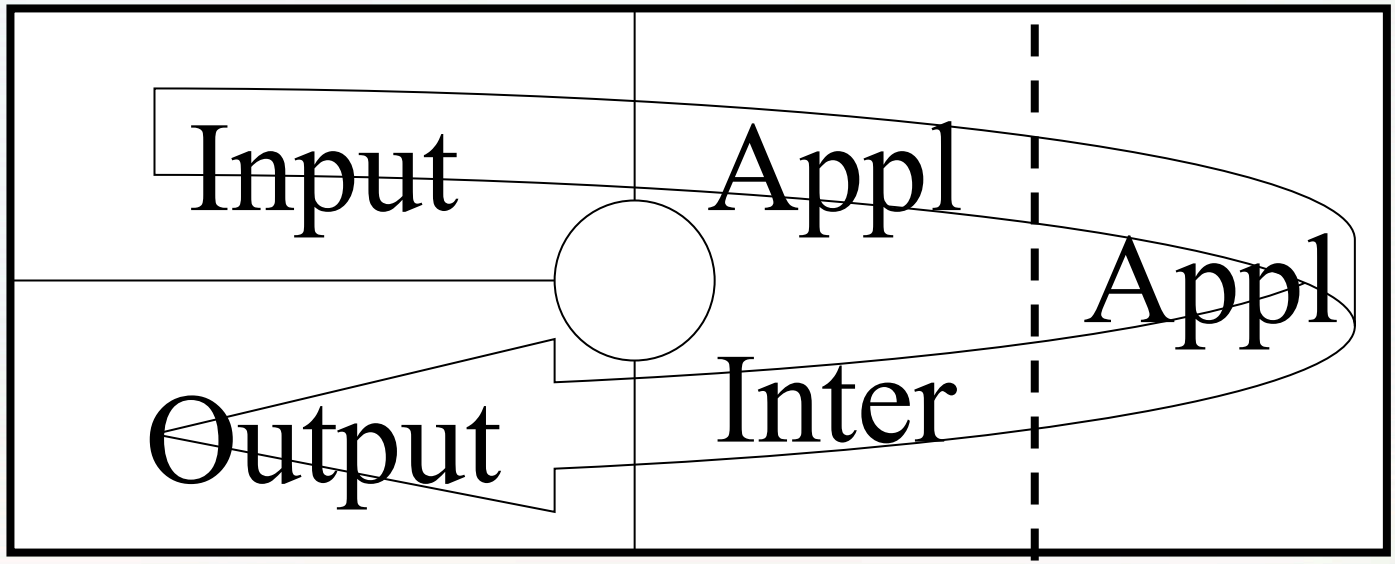
# UI tasks

- **Basic parts of UI**



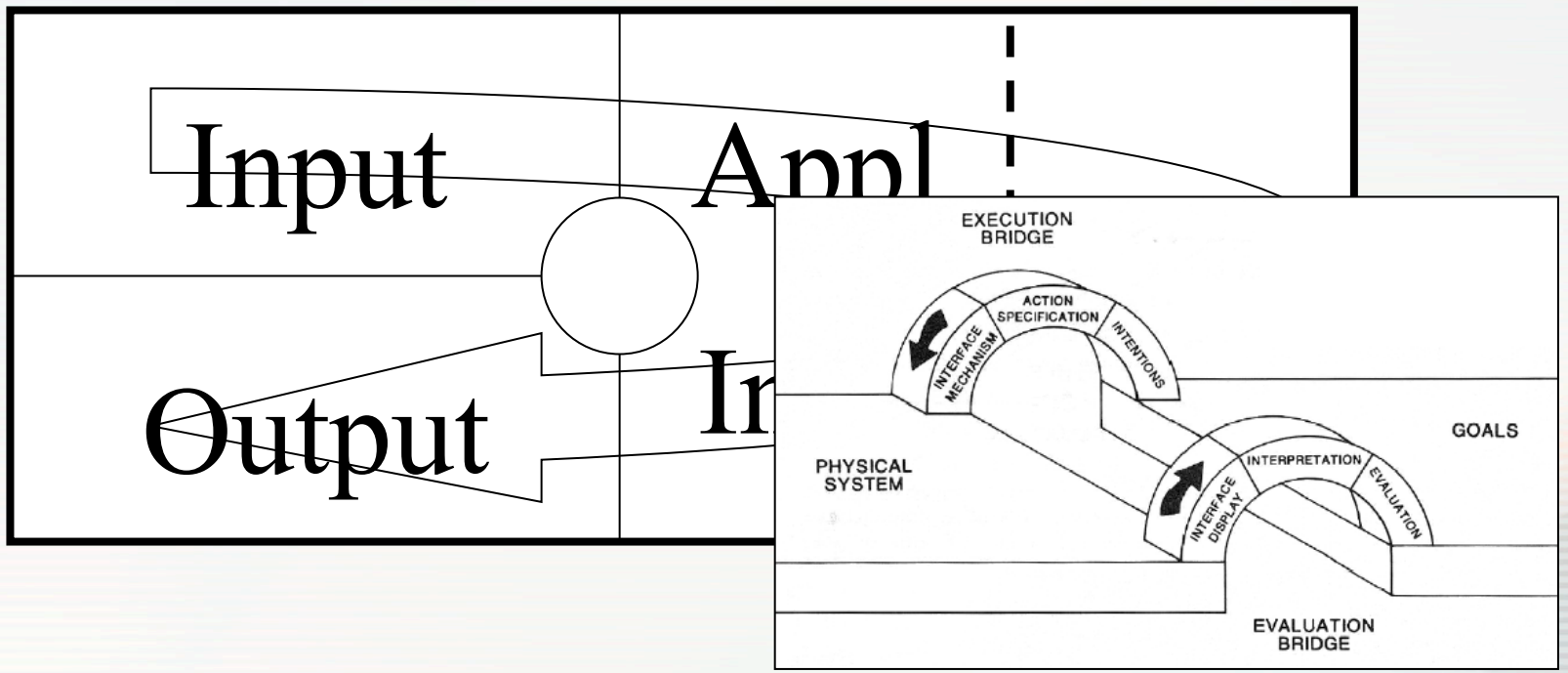
# UI tasks

- Basic flow



# UI tasks

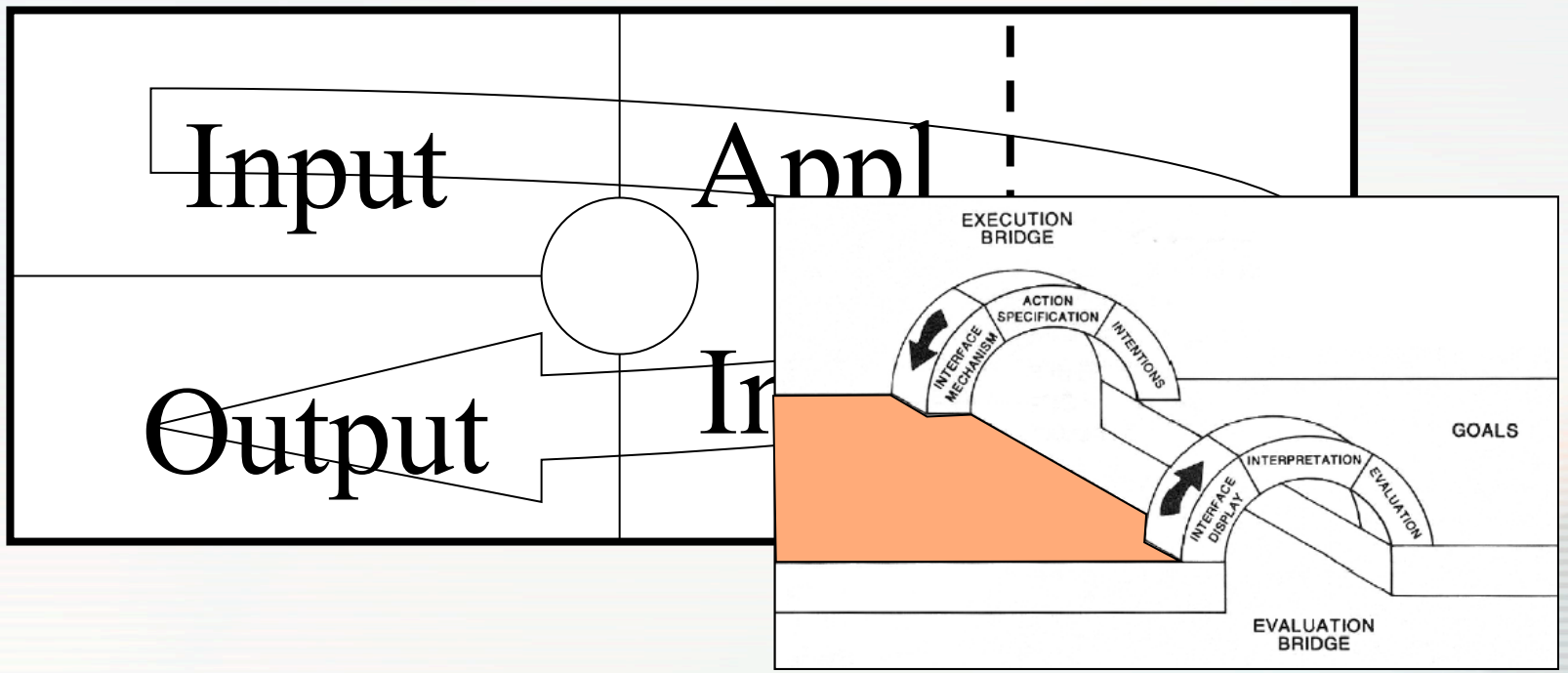
- Basic flow




Note relation to : Norman's 7 stages

# UI tasks

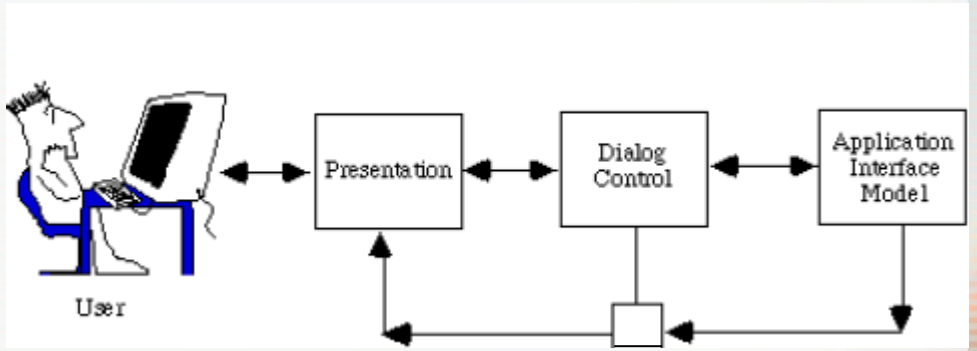
- Basic flow




Note relation to : Norman's 7 stages

# How do we connect these disparate parts into working whole

- Tempting to organize system modules around these boxes
  - One module for input, one for output, etc.
  - Has been tried

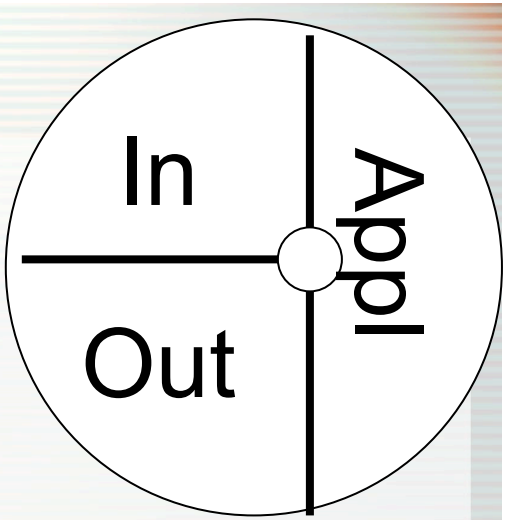



("Seeheim model" ~1983)
Didn't work real well

# Organizing UI as "3 big boxes" doesn't work well because...

- Modern ("direct manipulation") interfaces tend to be collections of quasi-independent agents
  - Each "object of interest" is separate (but still needs the 3 parts)
  - e.g. a button
    - has "button-like" screen appearance
    - acts on input in a "button-like" way
    - etc.

# Leads to object-based organization



# Object-oriented techniques

- Key features
  - Separation of "objects of interest" into encapsulated entities that implement that "object"
    - Store information about it
      - It's "state" ("properties" in Flex)
    - Provide implementation of actions on that data ("methods")
  - Combines data & action into one thing instead of traditional approach of data & procedures operating on it

# Object-oriented techniques

- **Key features**
  - **Abstract (& hide) the implementation details**
    - **Present "what" to outside world so that details of "how" can be changed w/o breaking other code**
      - **Classically no data access, only call methods**
    - **Reduces complexity by limiting dependencies**
    - **Example: Stack data structure**
      - **Just provide operations: push(), pop(), isEmpty()**
      - **Could be implemented with array or linked list**
      - **Can change implementation without breaking any code that uses stacks!**

# Object-oriented techniques

- Key features
  - Support reuse of code
    - Can base new code (new classes) on old code
  - Objects defined by a class
    - Represents of "type of thing"
    - Provides definition of methods appropriate to that type of thing
    - Provides implementation

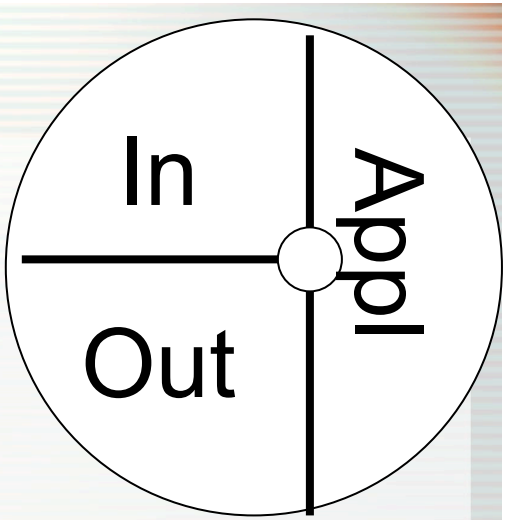
# Object-oriented techniques

- **Key features**
  - **Object created as an "instance" of the class**
    - **Object gets own storage and uses methods provided by class**
  - **New classes can be created by *specialization* of a class ("inheritance", "subclassing")**
    - **Selectively replace ("override") implementation of methods and other details "inherited" from another class ("superclass", "base class")**
    - **Substitutability: Object of subclass can be used anywhere object of superclass is expected**

# Object-oriented techniques

- Became popular along with GUIs, direct manipulation
- Buttons, sliders, icons, act like separate entities (→ objects)
  - Have internal state, persistence
  - React according to "what they are"
- OO was originally developed (SmallTalk) and became popular (C++) largely due to GUIs

# Leads to object-based organization



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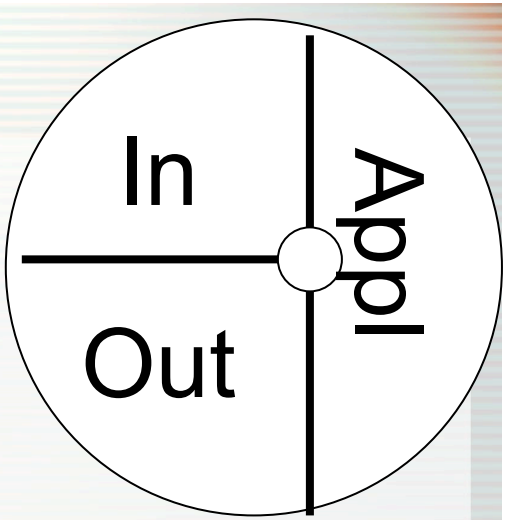
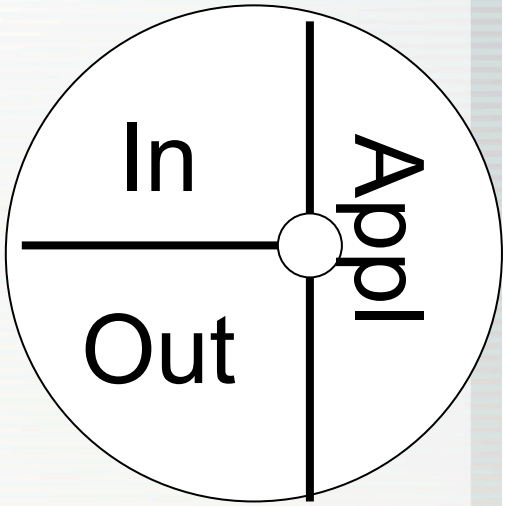



- Each object implements each aspect
  - In a way that reflects what it is

# Leads to object-based organization

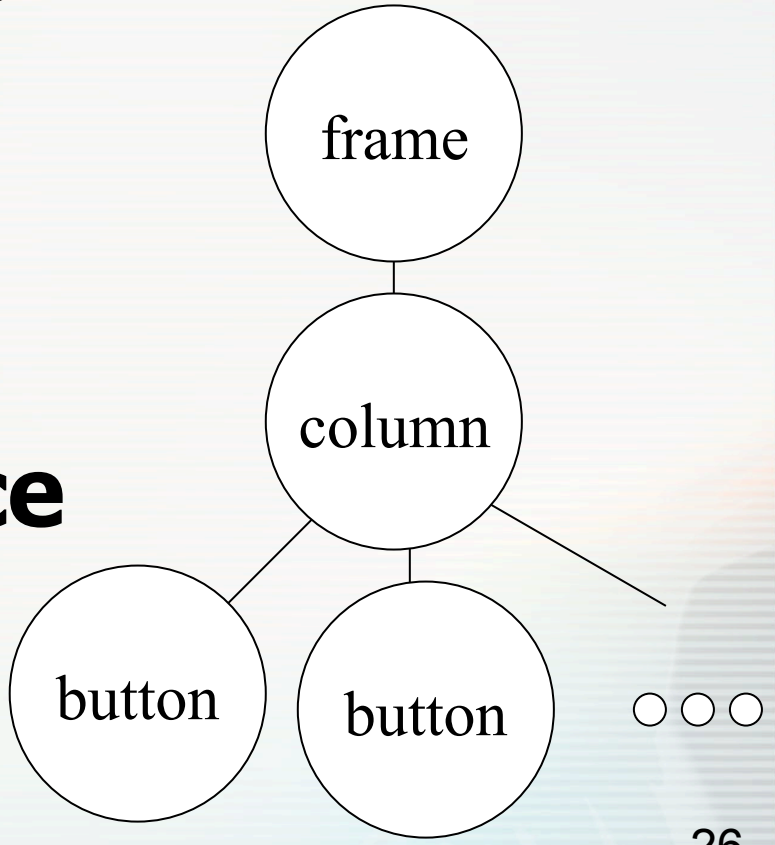



- **Objects organized hierarchically**
  - **Normally reflecting spatial containment relationships**

➡**"Component trees"**

# Component Trees

- Central concept for UI org
- Everything is done through this tree
  - Build an interface == build a tree
  - Change an interface == change a tree



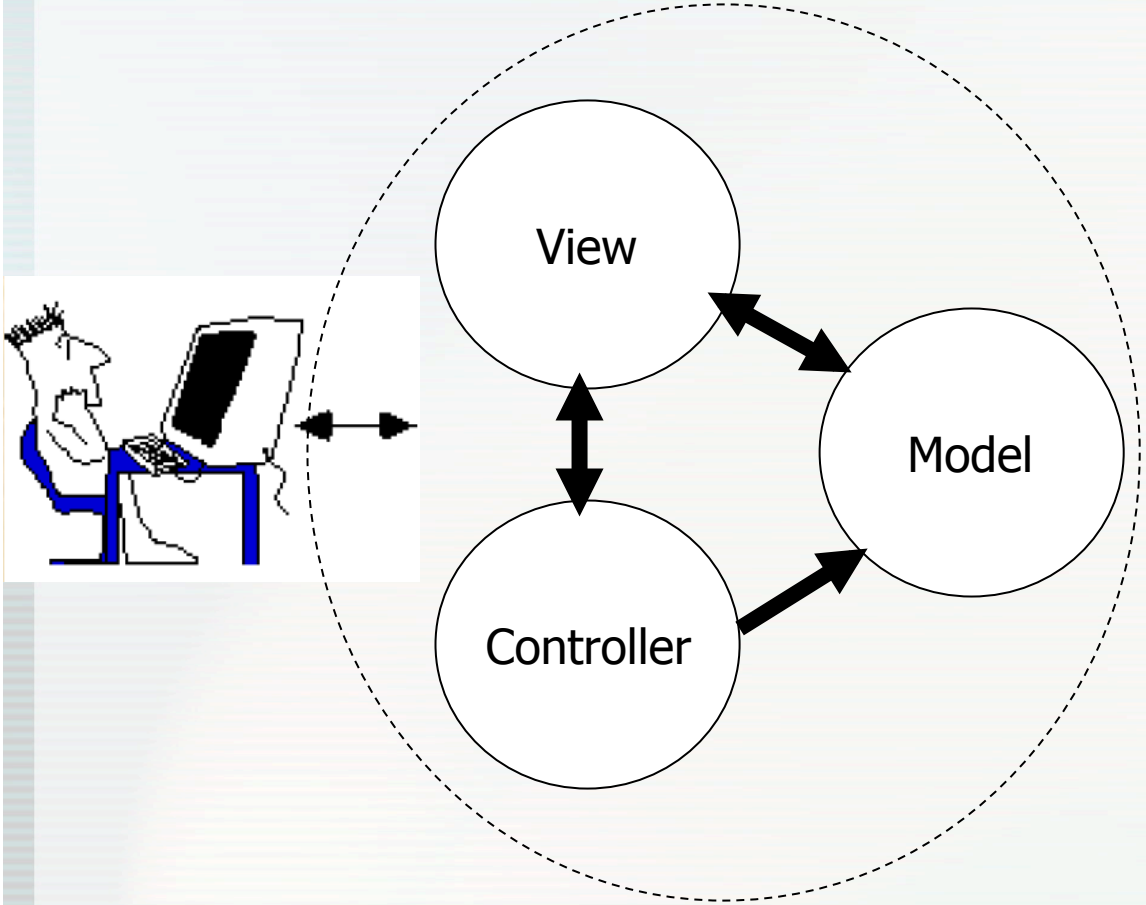
# Challenge: Separation of concerns

- Challenge is doing all this different stuff in a single object without creating a hopelessly large and complicated beast

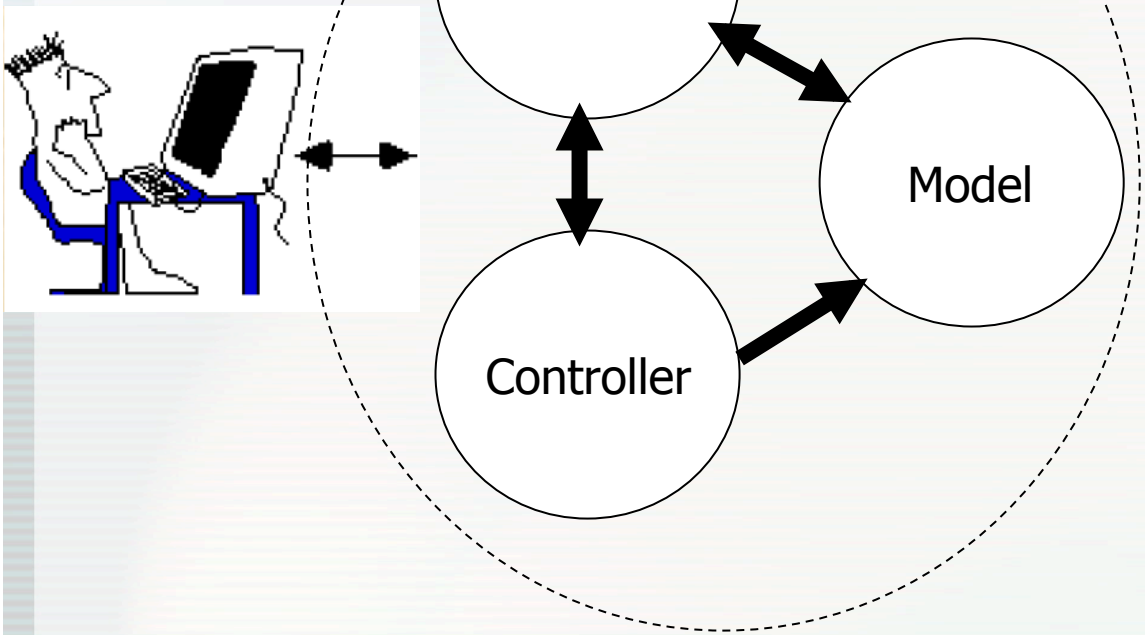
# One organizational approach

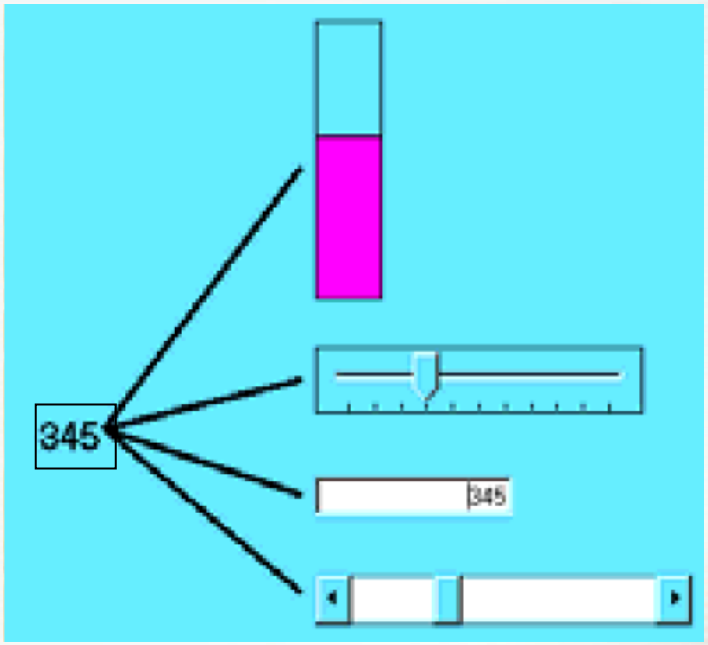
- Model-View-Controller (MVC)
  - Smalltalk ~1980
  - Idea: Separate out parts
    - output / presentation (View)
    - user input (Controller)
    - "semantics" / data (Model)
  - Goals
    - Different kinds of views and controllers for same model
    - Create (subclass?) a new model, then re-use existing views and controllers
    - Multiple views (and controllers) for one model

# MVC



# MVC



# MVC

- **Model**
  - **Can be simple as an integer for a counter, or string for an text entry box**
  - **Or as complex as a molecular simulator**
- **View**
  - **Everything graphical (output)**
  - **Layout, subviews, composites**
- **Controller**
  - **Schedule interactions with other VCs**

# MVC interaction cycle

- User operates input device
- Controller notifies model to change
- Model broadcasts change notifications to its dependent views
- Views schedules update of screen
  - May query model to get all details

# MVC issues

- Views and controllers tightly coupled
  - Rarely implemented separately in practice
- What is in each part?
- Complexity when we have sub-parts
  - Sub-views, sub-controllers, sub-models

# Exercise: MVC partitioning

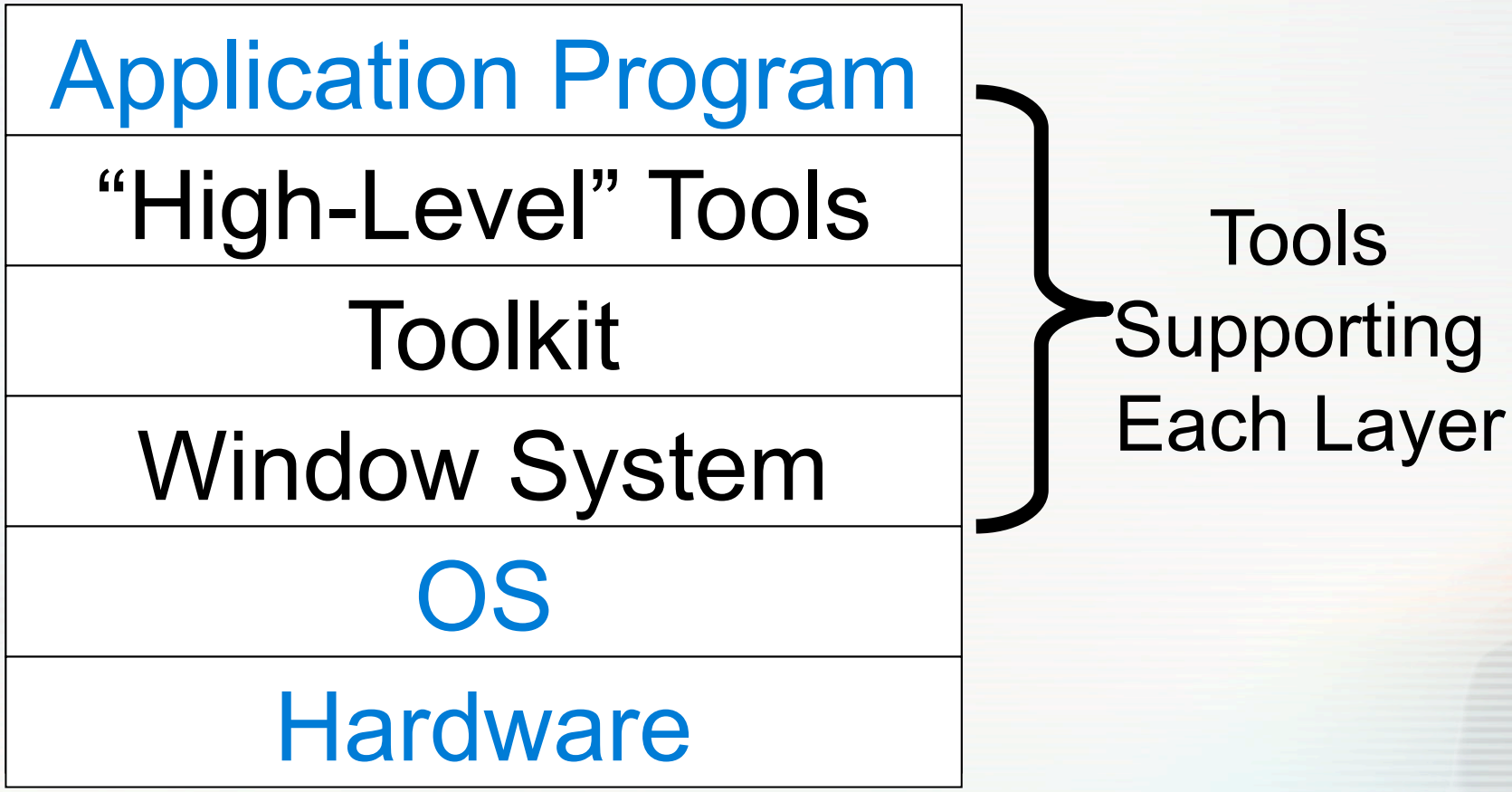
- File picker
- MP3 Player
- Text editor

# What do we have to help us implement UI systems?

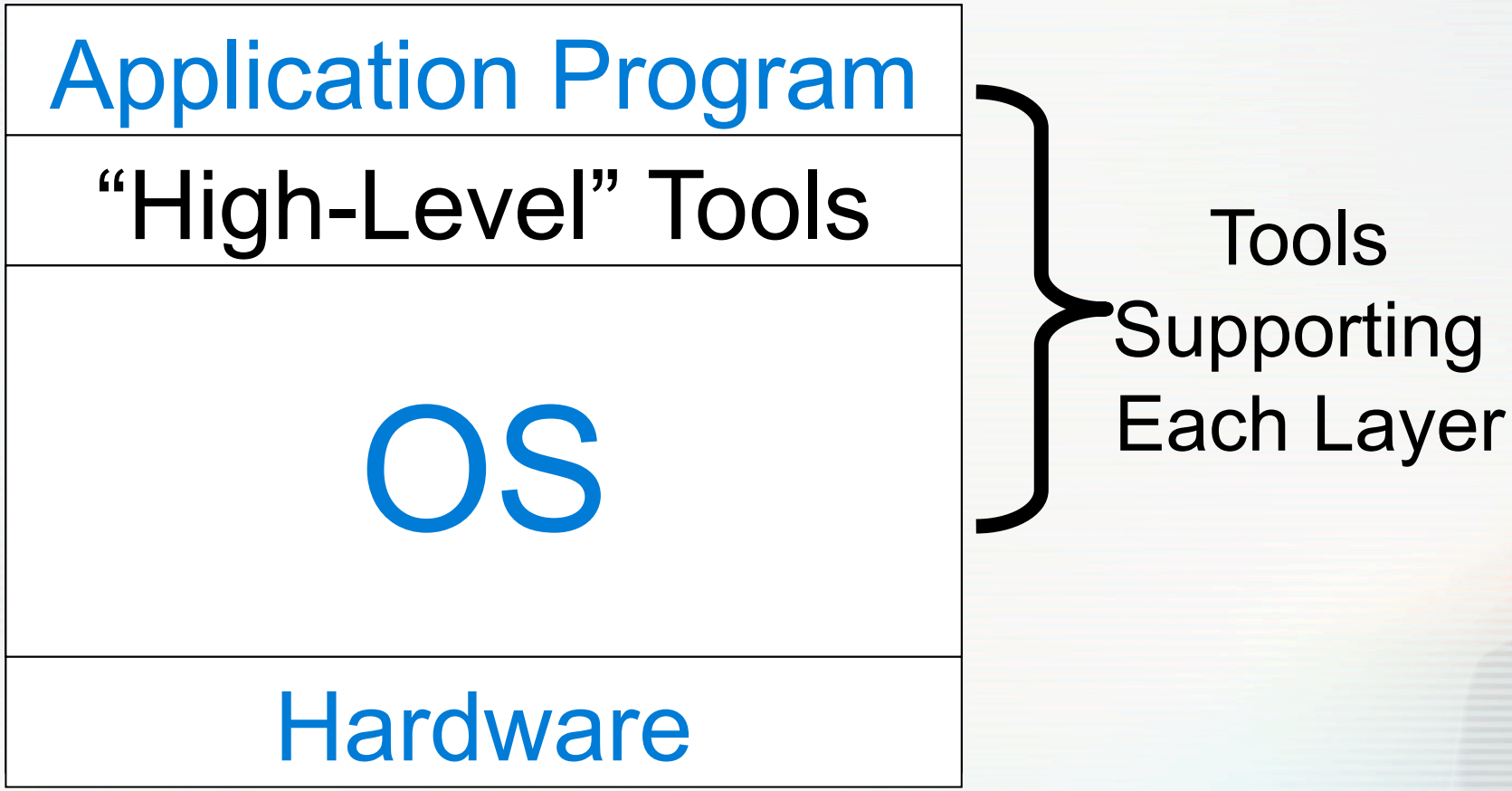
- Layered set of tools…

(A different way to slice concepts)

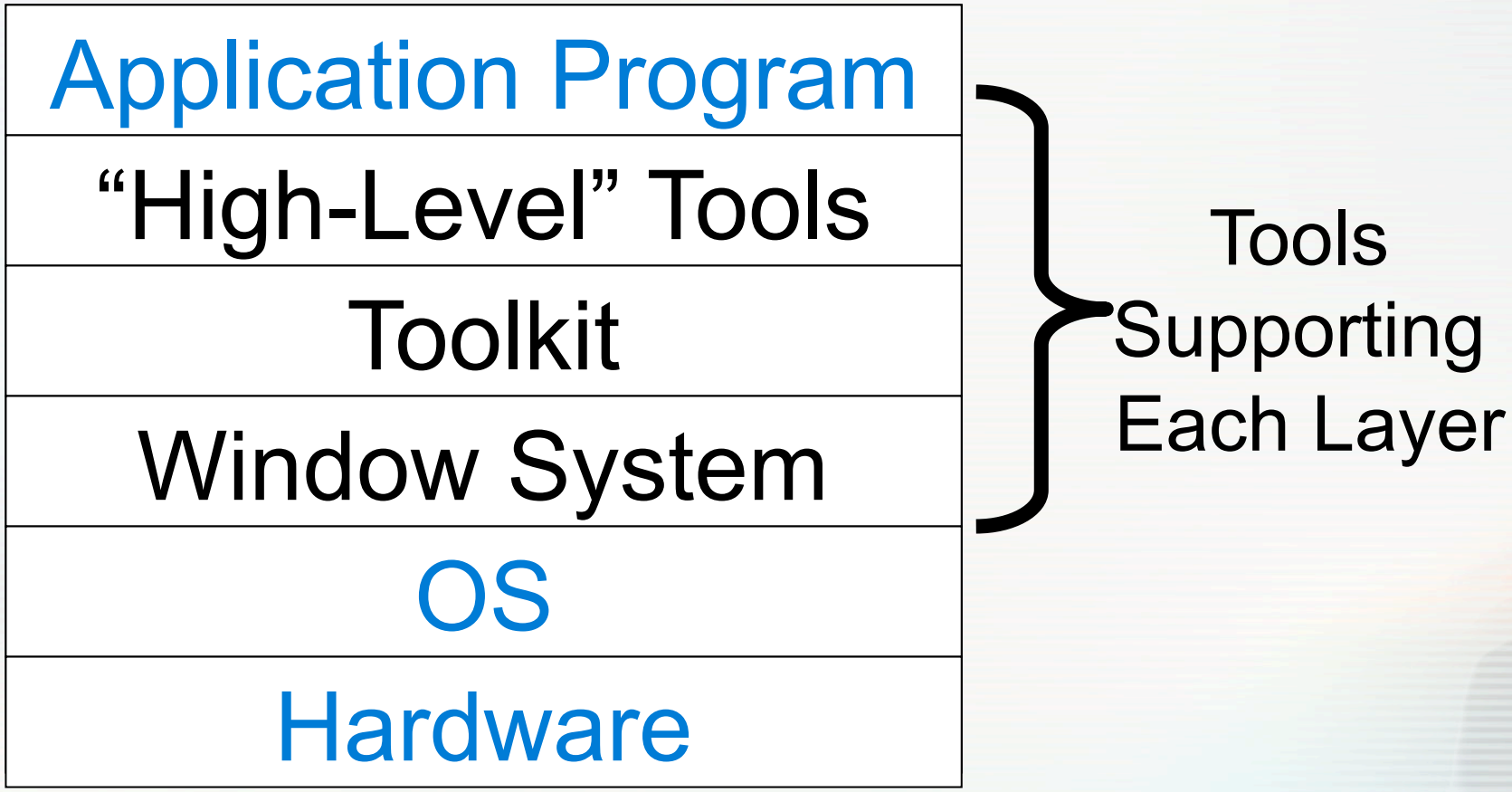
# Layers of UI Software



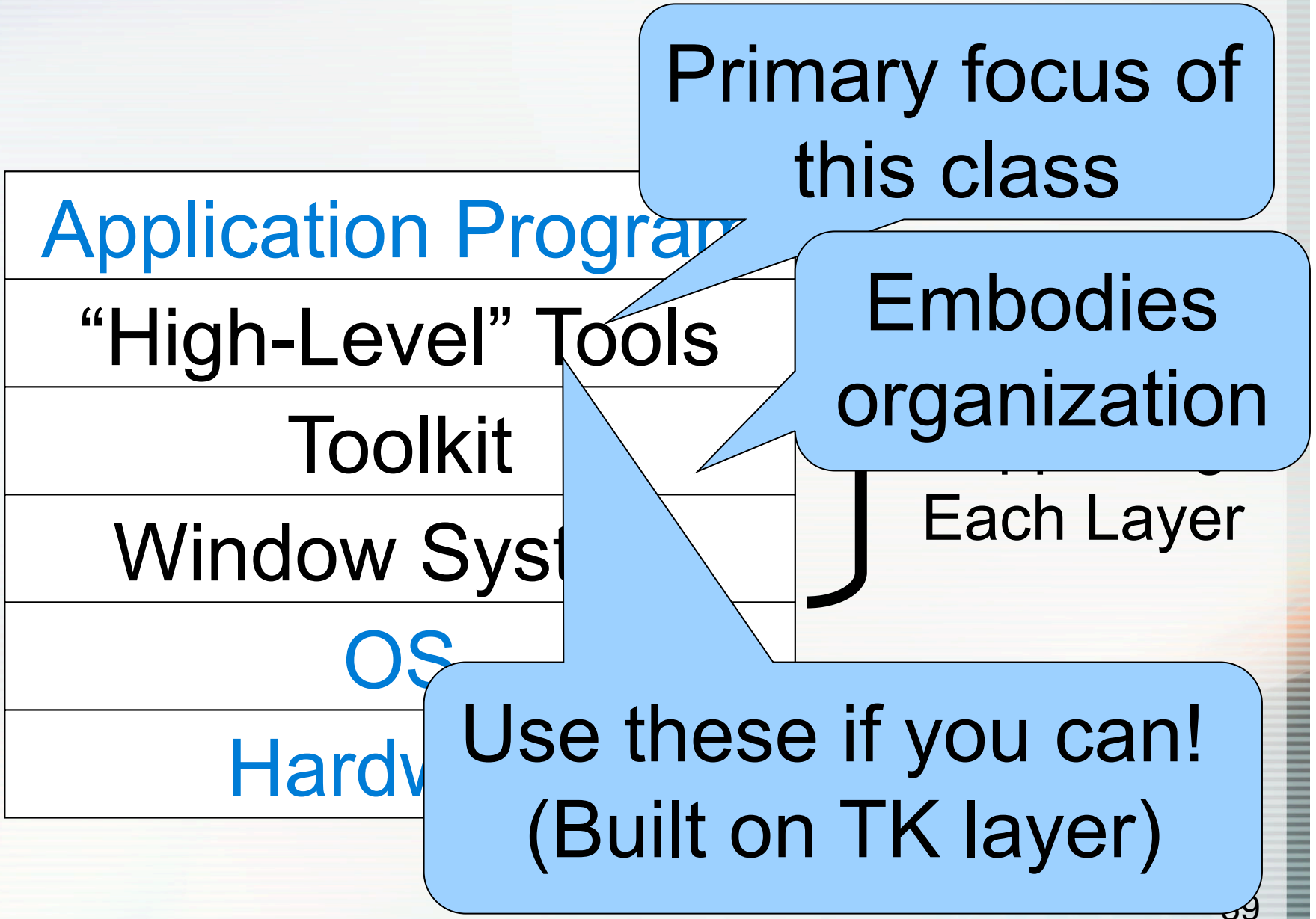
# Layers of UI Software as They Tend to Occur in Commercial Systems…



# Layers of UI Software



# Layers of UI Software



# Quick Look at the tools landscape

- Today's tools are highly successful
  - Window Managers, Toolkits, Interface Builders are ubiquitous
  - Most software built using them
  - Are based on many years of HCI research

# Window Systems

- Provides a virtual device abstraction
  - Each program can act as if it has a complete control over screen & input
  - Window system manages and controls multiple contexts, logically separated, but implemented together
    - Analogous to OS management of CPU and memory

# Window Managers (History)

- Multiple (tiled) windows in research systems of 1960's: NLS, etc.
- Overlapping in Alan Kay's thesis (1969)
- Smalltalk (1974) at Xerox PARC
- Successful because multiple windows help users manage scarce resources:
  - Screen space and input devices
  - Attention of users
  - Affordances for reminding and finding other work

# Windows, components

- "Window System"
  - Programming interface
  - Output graphics operations to draw clipped to a window
  - Input from mouse and keyboard to appropriate window
- "Window Manager"
  - User interface to windows themselves
  - Decorations on windows
  - Mouse and keyboard commands to control windows.

# Windows, cont.

- Many systems combine Window System and Window Manager
  - SunTools, Macintosh, MS Windows, NeXT
- Others allow different WM on same WS
  - X, NeWS
  - Allows diversity and user preference
- Also different WS on same hardware
  - SunTools, X, NeWS on Unix machines

# Window System: Output Model

- Graphics commands that the programs can use
- All must go through window system so they are always clipped
  - Usually can only draw with what the window system provides

# Window System: Output Model

- Oldest systems (SunTools, etc.) simple primitives
- Later (Macintosh, X Windows) more sophisticated
  - Filled polygons, splines, colors, clipping
  - Still, all 2-D objects
  - Extensions for 3D
- Newer systems (e.g., Java Swing) have quite sophisticated output model
  - Fully scalable, transparency, …

# Window System: Input Model

- How input from user is handled.
- Most only support keyboard and mouse
- All modern WS use similar model:
  - Events generated and passed to applications
    - "Event records" containing significant details of a user input action
      - type of input, x,y of mouse, time, etc.
    - Processed asynchronously (queued)

# A model for input handling Semantic-Syntactic-Lexical levels

- Comes from analogy to programming languages
  - Lexical:

    characters form symbols
    (keywords, operators, comments, etc.)
  - Syntactic:

    symbols organized by a grammar
    (into constructs: procedures etc.)
  - Semantic:

    meaning derived from constructs
    (so code can be generator or lang. interpreted)

# A model for input handling Semantic-Syntactic-Lexical levels

- For UI
  - Lexical: the basic inputs
    - Events: e.g., Mouse movements, button and key presses
    - Often consider interactions with basic interactors (e.g., button press, menu selection) to be at this level even though these may have more detailed syntax
  - Syntactic: what is current "state" of the system and what can happen next
    - In modern systems often expressed by showing certain dialogs or disabling menus, etc.
  - Semantic: translation to meaning in the form or actions carried out for the user
- Note: good conceptual model, not necessarily good implementation model

# Toolkits

- A library of components that can be manipulated by application programs.
- A component is a graphical object which can be manipulated by the user to input a certain type of value.
  - Also called "widget", "control", "interactor"
  - Menus, scroll bars, text entry fields, buttons, etc.
- Infrastructure for implementing and organizing components
  - E.g., managing component trees, redraw, input distribution, etc.
  - Sometimes called "intrinsics"
- Used directly only by programmers
  - Only a procedural interface.

# Toolkits (cont.)

- **Interface to applications is most typically done with "callback procedures"**
  - **Application says: "when this happens" (e.g., this button pressed), "call this routine"**
- **Issues with callbacks:**
  - **Can be hundreds or thousands distributed around system**
    - **Modularization compromised**
  - **Hard to deal with undo, etc.**

# Toolkit Advantages

- Consistent Look and Feel
  - Key insight of Macintosh toolbox
  - Path of least resistance was to be consistent
- Structuring the task
- Re-use of code
  - Just flat out a lot less work to use the toolkit library than to recreate

# But…

- Can be hard to use:
  - Very large libraries
    - Can end up as a complicated mess
    - Very large manuals
  - No help with when and how to call what

# Higher Level Tools

- Since toolkits are hard to use, higher-level support is helpful
  - Graphical layout tools
  - Higher-level frameworks
  - Older tools called "User Interface Management Systems"
- Successful research ⇒ industry

# Graphical / Interactive Tools

- **Create parts of UI by laying out components with a mouse**
  - **Examples: Menulay (1983), Trillium (1986), Jean-Marie Hullot from INRIA to NeXT**
  - **Now:** "Interface Builders"**, Visual Basic's layout editor, resource editors, "constructors"**

# Graphical Interactive Tools

- **Significant Advantages**
  - **Graphical parts done in an appropriate, graphical way**
  - **Accessible to non-programmers**

# Component Architectures

- **Create applications out of loosely coupled *components* which are separately developed and compiled**
  - **In UI software, each component controls an area of the screen**
  - **Example: drawing component handles picture inside a document**
- **Invented by Andrew research project at CMU (1988)**
- **Now: OLE, OpenDoc, Visual Basic Controls (VBX Controls), ActiveX, Java Beans**

# Higher Level Tools are Good

- Use them if you can

# But a bit of a warning:

- **Be aware of the path of least resistance**
- **Tools have Whorfian effects**
  - **Change the way you think**
  - **Change what is possible**
  - **➔Change what you design**

Whorf-Sapir Hypothesis
Benjamin Whorf

# Questions about the lecture or readings?