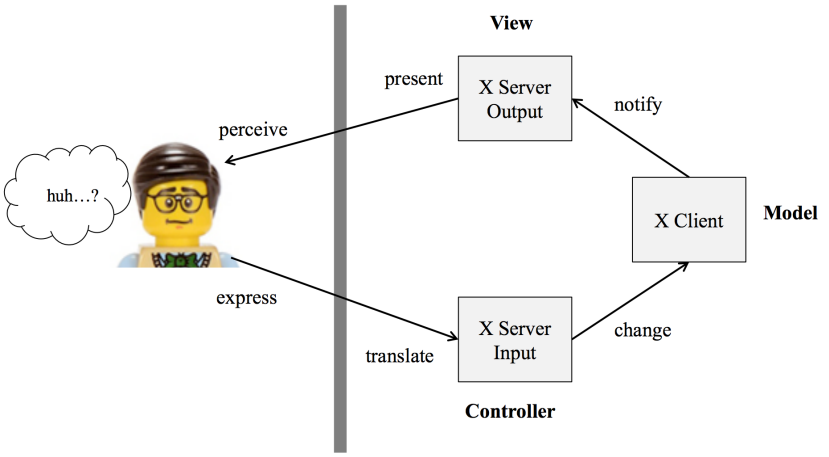
# CS 349 Midterm Review

## Background & History

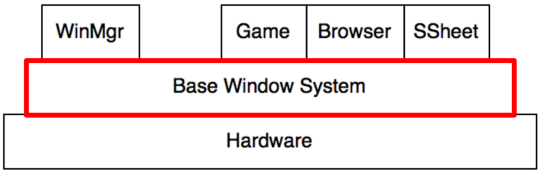
- **User interface**:
  - The place where a person expresses intention to an artifact, and the artifact presents feedback to the person
  - The way people (mental model) ↔ technology (system model) interact
- **Interface**: external presentation (visual, physical, auditory) to the user
- **Interaction**: actions invoked by user and corresponding responses (behaviour)
- Batch interfaces (1945-1965)
  - Sets of instructions fed via punch cards; only used by highly trained individuals
- Conversationalist interface (1965-1985+)
  - Text-based feedback and input; I/O is in system language, not task language
- Graphic user interface (1984+)
  - High resolution graphics display, standard keyboard, & pointing device
  - **WIMP interface**: windows, icons, menus & pointer
  - Benefits of GUI:
    - Keeps the user in control
    - Emphasize recognition (discovery of options) over recall (memorizing commands)
    - Uses metaphor; makes interaction language closer to user's language
- Notable people:
  - Vannevar Bush – conceptualized the memex, a desk with integrated display, input, and data storage
  - Ivan Sutherland – created the Sketchpad, an early graphical interface with a light pen and direct manipulation
  - Douglas Engelbart – invented the mouse, introduced copy/paste
  - Alan Kay – worked on the Xerox Star, first commercial computer with GUI

## Windowing Systems & X11

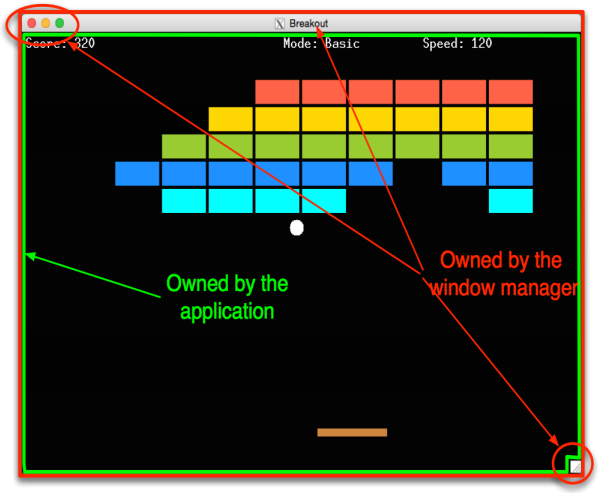
- **Windowing system**: provides input, output, and window management capabilities to the OS
- **X Windows (X11)**:
  - Standard windowing system for Unix-based systems
  - X Client handles all application logic
  - X Server handles all user input & display output
  - There may be many clients – each client is an application; server draws all clients onto one screen and reads all input




- X11 is a **base windowing system**:




  - A standard/protocol for creating windows, low-level graphical output, and user input
  - Does not specify the style of each application's UI
  - Provides each application with a window and manages its access
  - Each application (only) owns a canvas; shielded from details such as visibility, other windows
  - Some design goals of X11/BWS:
    - Display- & device- independent
    - Supports multiple overlapping & resizable windows
    - A display may have multiple screens (monitors) and a window may span multiple screens
    - High-performance, high-quality text, 2D graphic & imaging
- **Window manager**:
  - Provides interactive components (e.g. menus, close button, resizing)
  - Separation of the WM from the BWS enables many alternative "look and feels"



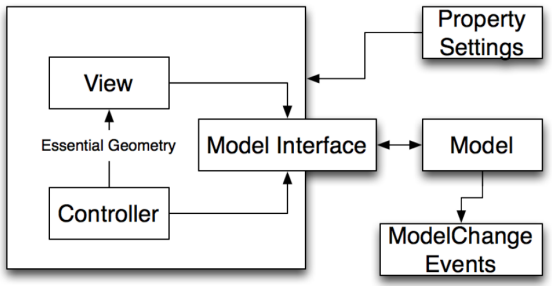
- **Drawing**
  - Three conceptual drawing models:
    - Pixel (e.g. images)
    - Stroke (e.g. lines, outlines of shapes)
    - Region (e.g. text, filled shapes)
  - X11 uses graphics contexts to store drawing options/parameters – stored on X server
  - **Clipping**: exposing only a particular region (specified by a mask) of an underlying image
    - Only exposed area is repainted – more efficient
  - **Painter's Algorithm**: draw shapes in layers from back to front to create composite shapes

## Widgets

- **Widgets**: parts of an interface that have their own behaviour
  - Control their own appearance; recieve and handle their own events
  - Design goals:
    - Complete – covers wide range of functionality
    - Consistent – look-and-feel across components
    - Customizable – developers can extend functionality

| **Heavyweight widgets**: | **Lightweight widgets**: |
|---|---|
| • Wrappers around OS's native GUI & windowing system<br>• e.g. Java AWT | • OS provides top-level window in which widgets are drawn<br>• Toolkit is responsible to passing events to widgets |
| Advantages:<br>• Events passed directly to OS/BWS<br>• Preserves the OS look-and-feel | Advantages:<br>• Consistent look-and-feel across platforms<br>• Consistent widget set across platforms |
| Disadvantages:<br>• OS-specific programming<br>• Small set of common widgets across different platforms | Disadvantages:<br>• May appear "non-native" |

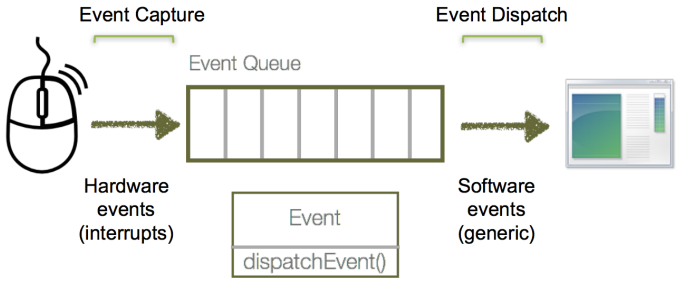
- Widgets as logical input devices




  - Characteristics:
    - Model manipulated by the widget (e.g. number, text)
    - Events generated by the widget (e.g. changed)
    - Properties (behaviour and appearance) of the widget (e.g. colour, size, allowed values)
    - e.g. radio button: model = *Boolean*; events = *changed*; properties = *size, colour etc.*

## Events

- **Event-driven programming**: flow of program is determined by events such as user input (key press, mouse click, input focus change) or messages from other programs/threads
  - Objective: need to map input from real-word devices → actions within a system
  - Events are pushed into an event queue by the BWS (i.e. event capture)
  - Implementation in X11:
    - Use `XSelectInput()` and event masks to register/subscribe to types of events & filter out unneeded events
    - Use `XNextEvent()` to dequeue the next event; *may block if no events*
      - Use `XPending()` to check for # of events before dequeueing
    - Should dequeue *all events* before repainting to avoid input lag
    - Should subtract time spent in event loop from `sleep()` to maintain consistent FPS
    - Should draw all images to a *buffer* (`XCreatePixmap()`), then copy the buffer onto the screen in one go (`XCopyArea()`) (aka. double buffering)
      - Avoids displaying an intermediate image (i.e. flickering)




- **Event dispatch**: dequeueing events from event queue and pushing to appropriate applications
- **Interactor tree** – hierarchy of containers and their nested widgets
- **Positional dispatch** – input sent to widget under mouse cursor location
  - Bottom-up dispatch:
    - Event is routed to leaf (lowest) widget in interactor tree; can pass to parent
      - e.g. sometimes may be better for the container of a widget to handle the event
    - Advantage: event does not have to traverse through entire tree to arrive at widget
  - Top-down dispatch:
    - Event is routed to highest-level node that contains mouse cursor; can pass to child
    - Advantages:
      - Parent widget can enforce policies (e.g. make children view-only)
      - Easy event logging (as it traverses down through the tree)
  - Pure positional dispatch can be problematic
    - e.g. mouse-down inside a button, mouse-up outside
    - e.g. dragging scrollbar but mouse moves out of scrollbar
- **Focus dispatch**
  - At most one widget each can be in keyboard & mouse focus at a given time
  - Focus dispatch also needs positional dispatch to change focus (i.e. mouse click)
  - Accelerator keys (i.e. keyboard shortcuts) can bypass focus dispatch – they're handled before

widget receives events

| **Heavyweight toolkits**: | **Lightweight toolkits**: |
|---|---|
| • BWS has visibility to all widgets<br>• Can use top-down or bottom-up dispatch | • BWS only has visibility to application window<br>• Toolkit then dispatches event to widget<br>• Can only use top-down dispatch |

- **Event handling**: interpreting events in widget's application code
  - Design goals of event-code binding:
    - Easy to understand
    - Easy to implement
    - Easy to debug
    - Good performance
  - Event loop & switch statement (X11):
    - All events are consumed in one event loop
    - Switch statement selects the appropriate code for each event
    - Downsides: switch statement needs to encompass every type of event (too many!)
  - Inheritance binding (Java, OS X):
    - Events are dispatched to base widget class with predefined event handling methods
    - Child widget overrides methods with custom behaviour
    - Downsides:
      - Event handling code in application logic (child widget) – no separation of concerns
      - Difficult to add new events
  - Listener binding (Java):
    - Interface binding – widget class implements event listener interfaces

      ```
      public class A implements Listener { // implement all methods }
      ```

    - Object binding – widget class holds listener objects (implement listener interface as a nested class)
      - Event handling & application code are decoupled

      ```
      this.addListener(new Listener() { // implement all methods });
      ```

    - Adapter pattern – widget class holds adapter objects (class with boilerplate implementations)
      - Custom adapter only needs to extend methods that are used

      ```
      this.addListener(new ListenerAdapter() { // override some methods });
      ```

  - Delegate binding (.NET):
    - Delegates "point" to a method (or methods); invoking delegate calls all associated methods

      ```
      delegate = object.Method1; delegate += object.Method2; delegate(args);
      ```

## Layouts

- **Dynamic layout** – dynamically adjusts screen composition
  - Provides spatial layout for widgets in a container
  - Handles container resize by adjusting location, size, visibility or look-and-feel of widgets
- Widgets may define constraints for size (e.g. min, preferred, max), position (e.g. anchors)
- Layout managers provide algorithms to size & position widgets
- **Composite pattern** – group/container of widgets and individual widgets are treated uniformly
  - Widgets are organized in a tree hierarchy
- **Strategy pattern** – abstract out the algorithm so that it can be changed at run-time
  - Layout manager can employ different layout strategies
- Types of layouts:
  - Fixed – widgets have fixed size & position
    - e.g. set `LayoutManager` to null
  - Intrinsic size – parent widget's size depends *solely* on contained widgets
    - Bottom-up approach – query each child widget for exact size, then set size for parent
    - e.g. `BoxLayout`, `FlowLayout`
  - Variable intrinsic size – widget size depends on both parent and contained widgets' preferred sizes
    - Both bottom-up & top-down approach
    - e.g. `GridBagLayout`, `BorderLayout`
  - Struts and Springs – layout specified by contraints and anchors
    - Strut widgets are fixed in size; spring/glue widgets stretch to fill space
    - e.g. `SpringLayout`

## Graphics & Transformations

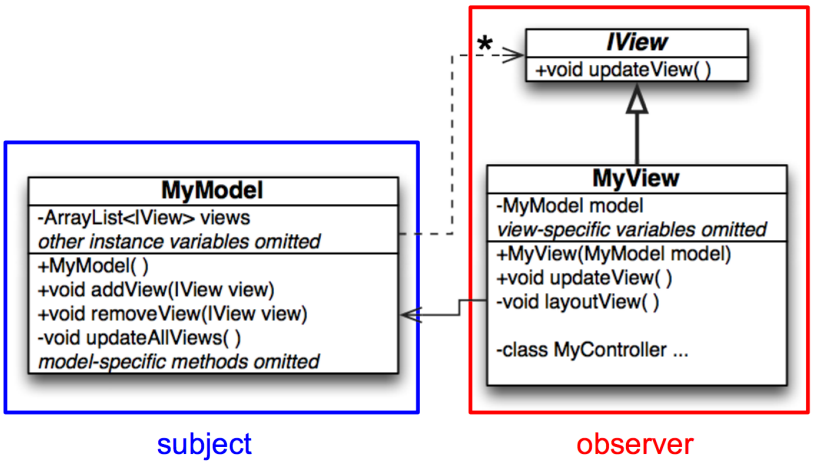
- **NOTE**: origin is located at the top-left when discussing graphics & transformations
- **Shape model** – data needed to draw a primitive shape (array of points, colour, location etc.)
- **Affine transformations**:
  - Translation: add scalar to $x$ and/or $y$ component
  - Scaling: multiply $x$ and/or $y$ components by scalars
  - Rotation (about the origin): $x' = x\cos(\Theta) - y\sin(\Theta)$, $y' = x\sin(\Theta) + y\cos(\Theta)$
  - Order of operations: scale $\rightarrow$ rotate $\rightarrow$ translate
    - $x' = s_x(x\cos(\Theta) - y\sin(\Theta)) + t_x$
    - $y' = s_y(x\sin(\Theta) + y\cos(\Theta)) + t_y$
    - Since scaling & rotation are about the origin, should translate to origin first, and translate back after scaling/rotation
  - Translation can't be done using $2 \times 2$ matrix – use homogeneous coordinates
    - $[x, y, w]$ represents a point at $[x/w, y/w]$; e.g. $[1, 2, 1] = [2, 4, 2]$
  - **Affine transformation matrix** (transformations are applied right to left $\leftarrow$)

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & t_x \\ 0 & 1 & t_y \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos(\Theta) & -\sin(\Theta) & 0 \\ \sin(\Theta) & \cos(\Theta) & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} s_x & 0 & 0 \\ 0 & s_y & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

- **Scene graph** – each component has a transformation matrix & draws its child components relative to itself
  - The interactor tree is a type of scene graph
  - Each component has a transformation matrix (describes its location relative to parent)
    - Each componnt paints itself, then
    - Combine its matrix with child component's matrix, and tells child to paint itself using combined matrix
- Benefits of geometric manipulation:
  - Allows reuse of objects (create multiple instances via transformations)
  - Allows specification of object in its own coordinate system (e.g. relative to parent)
  - Simplifies repositioning of object after change (e.g. moving an object in animation)
- Coordinates given by events need to be transformed as they traverse the interactor tree
  - e.g. for inside tests/hit detection, mouse event coordinates must be transformed into a model's local coordinates
  - Transforming mouse → model coordinates
    - Only one transformation (of the mouse event) – take the inverse of model's affine matrix
  - Transforming model → mouse coordinates
    - Many transformations (of all objects in the scene) in order to find which one the mouse is inside of

## Model-View-Controller

- **MVC** – multiple views *loosely coupled* with the underlying data model
  - Developed for Smalltalk-80 by Trygve Reenskaug
  - Tight coupling of data & presentation prevents easy modification and extension
  - Separation of concerns enables:
    - Alternate forms of interaction/presentation with the same data
    - Multiple, simultaneous views of data
    - Easy testing of data manipulations that are independent of the UI
  - View & controller can access the model through its interface; model only knows about the view
    - Controller → (notifies) → Model
    - View → (queries) → Model
    - Model → (updates) → View
    - Controller & view are tightly coupled in practice
      - Controller is just part of the view class that calls the model's interface based on input
- MVC is an instance of the **observer pattern**
  - Allows objects to communicate without knowing each others' specific types
  - In Java, the view implements `Observer` (like `IView`); model extends `Observable`




## Input

- Computer input can be classified by sensing method (e.g. mechanical, motion, contact), continuous vs. discrete, degrees of freedom
- Specific vs. general input
  - Specific inputs are optimized for certain tasks (but can't do others); general inputs can be adapted to many tasks (but lack accuracy/optimization)
- **Text input**
  - QWERTY has many *perceived* inefficiencies; Dvorak attempts to address these problems, but actual difference in speed is discernible
  - Portability (smaller, lower-profile keys) of keyboards also interfere with typing performance
  - Soft/virtual keyboards lack haptic feedback, but improves aethestics – good for when the amount of input is limited
- **Positional input**
  - Isometric (force) vs. isotonic (displacement) sensing
    - Device senses displacement (mouse) or force (joystick)
  - Position vs. rate control
    - Change in input device maps to change in position (mouse) or speed (joystick)
    - Usually, isometric → rate, isotonic → position
  - Absolute vs. relative position
    - 1:1 mapping between input & output position (touchscreen) or non-1:1 mapping (mouse)
  - Direct vs. indirect contact
    - Input takes place on the same surface as output (touchscreen) or on a different surface (mouse)
  - Dimensions sensed – 1 (dial) vs. 2 (mouse) vs. 3 (Wiimote)
  - Control-display gain = ratio between the movement speeds of pointer on screen & physical mouse
- **Keystroke Level Model** (KLM):
  - Use operators to estimate how long an input task should take
    - Keystroke (K), pointing (P), mouse button press (B), hand move between mouse & keyboard (H), mental preparation (M)

        - M is only needed when user needs to think, e.g. initiate a task, make a decision, or if they are a novice
    - Advantages:
        - Easy to model; can be done before an interface is actually built
    - Disadvantages:
        - Estimates can be out of date or inherently variable
        - Doesn't model errors and learning time
- **Fitts' Law**:
    - Predictive model for 2D pointing time, especially robust for modelling human hand movements
    - In general, longer distance & smaller target → longer time

$$MT = a + b \log\left(\frac{D}{W} + 1\right)$$

        - $MT$ = movement time
        - $D$ = distance from starting point ↔ centre of target
        - $W$ = constraining size (e.g. width) of target
        - $a, b$ = some parameters of the input device
        - $b$ = index of performance ($IP$) $\approx MT/ID$
        - $\log(D/W + 1)$ = index of difficulty ($ID$)
    - Visual space: how something appears to move on-screen
    - Motor space: how movement feels relative to input
    - Cursor speeds can be manipulated to make objects seem bigger in motor space (stickier)
- **Steering Law**:
    - When steering through a path between boundaries (e.g. context menus):

$$T = b\frac{D}{W}$$

    - Time to travel a complex path = sum of the times taken to travel each small path
    - When steering between boundaries, distance & width have greater influence on difficulty

## Direct Manipulation

- **Domain objects** – object of interest; data/attribute (model)
- **Interaction instrument** – used by user to manipulate domain objects
    - In turn manipulated through physical actions by user
- Spatial activation – instrument put under user control due to cursor movement
    - Cost = cursor movement distance
- Temporal activation – instrument put under user control due to some former action; enters a state
    - Cost = sequence of previous actions/steps required
- Degree of indirection:
    - Spatial offset (e.g. object follows mouse drag) & temporal offsets (e.g. immediate response)
- Degree of integration:
    - Degrees of freedom of the instrument vs. input device

    - e.g. 2D mouse + 1D scrollbar (higher degree) vs. 2D mouse + 3D model (lower degree)
- Degree of compatibility:
    - Similarity between physical action on instrument vs. response in object
    - e.g. dragging (high similarity) vs. dialog box (low similarity)
- **Direction manipulation** attempts to make user actions resemble real-world actions on objects
    - Visible & continuous representation of the domain objects and actions
    - Objects are manipulated by physical actions, e.g. clicking/dragging
    - Effects of operations on objects are immediately visible
    - Actions should be reversible
    - Allows users to feel like they are interacting directly with domain objects rather than an interface

- DM feature: **Undo/Redo**
    - Enables exploratory learning; lets the user recover from errors
    - Design decisions:
        - Undoable actions
        - UI state after undo
        - Granularity
        - Scope
    - Forward undo – apply CRs (change records) forwards from some baseline document
    - Reverse undo – save reverse CRs and apply them in reverse
    - Memento pattern – save snapshots of (entire or incremental) document state
    - Command pattern – save commands (or reverse commands)
    - e.g. Java uses reverse undo + command
        - User issues command → push onto undo stack, clear redo stack
        - Undo → pop from undo, perform reverse command, push onto redo
        - Redo → pop from redo, perform command, push onto undo

- DM feature: **Clipboard**
    - Cut + paste/drag + drop allows for easy data transfer within and between applications
    - Copy → paste format may be different (e.g. many image formats)
        - Application indicates what formats the data on clipboard is available in
    - For large amounts of data, may put a reference on clipboard instead (instead of making a copy)
        - Saves memory
        - But must create a copy if data is changed, or application is closed
    - Owned/maintained by the window system, not individual applications

## Responsiveness

- Responsiveness $\neq$ performance
  - Performance = computations per unit time
  - Responsiveness = compliance with human time requirements (deadlines)

## Touch Interfaces