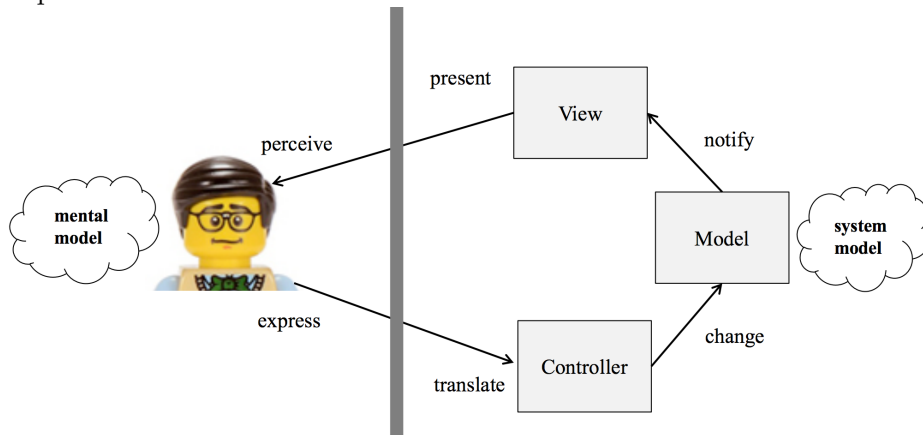


CS 349 Midterm Review

Background & History

- **User interface:**

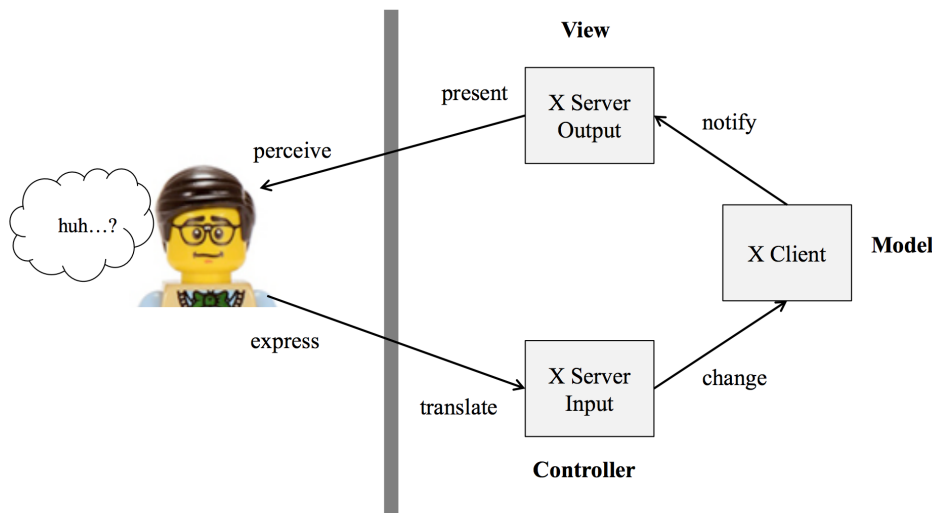
- The place where a person expresses intention to an artifact, and the artifact presents feedback to the person
- The way people (mental model) and technology (system model) interact
- Represented as MVC:



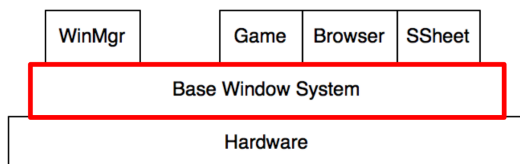
- **Interface:** external presentation (visual, physical, auditory) to the user
 - e.g. controls
- **Interaction:** actions invoked by user and corresponding responses (behaviour)
 - e.g. action and dialog
- Batch interfaces (1945-1965)
 - Sets of instructions fed via punch cards; only used by highly trained individuals
- Conversationalist interface (1965-1985+)
 - Text-based feedback and input; I/O is in system language, not task language
- Graphic user interface (1984+)
 - **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
- X11 architecture
 - 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

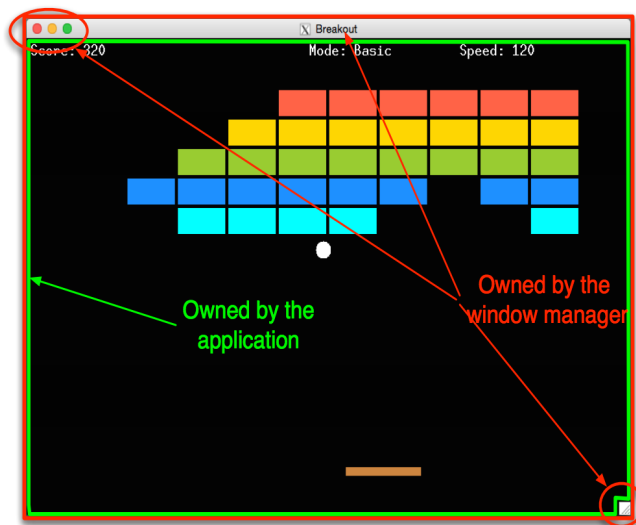


- Structure of an X program (application is run on the X client):
 - Perform client initialization
 - Connect to X server (e.g. `XOpenDisplay()`, `XCreateWindow()`)
 - Perform X related initialization (e.g. create graphic contexts with `XCreateGC()`; put window on the screen with `XMapRaised()`)
 - Event loop
 - Get next event from server (e.g. `XNextEvent()`)
 - Handle event (e.g. `XLookupKeysym()`)
 - Send draw request to server (e.g. flush output buffer with `XFlush()`)
 - Close down connection to X server (e.g. `XCloseDisplay()`)
 - Perform client cleanup
- 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)
 - The WM owns each application's window itself (while application owns the canvas)
 - i.e. application developers usually cannot change the window style
 - 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
 - XSetClipMask(), XSetClipRectangles()
 - Only exposed area is repainted – more efficient
 - **Painter's Algorithm**: draw shapes in layers from back to front to create composite shapes
 - Displayable class with abstract `paint()` method; implement `paint()` in each subclass
 - Draw list of `Displayables` from back to front, clear screen on every repaint
- **Events & animation**
 - Objective: need to map input from real-world devices to actions within a system
 - **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

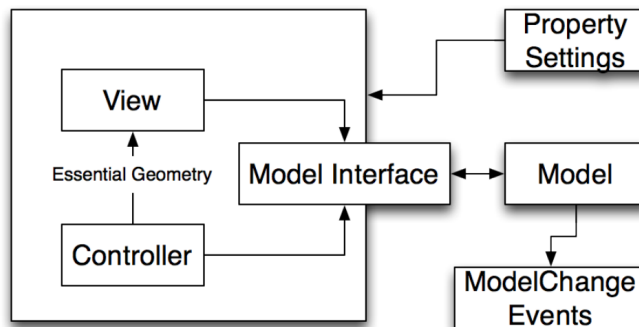
- Events are pushed into an event queue by the BWS (i.e. event capture)
- Implementation in X11:
 - Use `XSelectInput()` and event masks (e.g. `KeyPressMask` etc.) to register/subscribe to types of events
 - ◇ Filters out unneeded events
 - Use `XNextEvent()` to dequeue the next event; *may block if no events*
 - ◇ Use `XPending()` to check for # of events before dequeuing
 - 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)

Widgets & Events

- **Widgets:** parts of an interface that have their own behaviour
 - Control their own appearance; receive and handle their own events
 - Widgets toolkit defines a set of GUI components
 - Design goals:
 - Complete – covers wide range of functionality
 - Consistent – look-and-feel across components
 - Customizable – developers can extend functionality
 - Consistent behaviour of components helps users anticipate how the interface will react, and promotes easier *discoverability* of features

Heavyweight widgets: <ul style="list-style-type: none"> • Wrappers around OS's native GUI & windowing system • e.g. Java AWT 	Lightweight widgets: <ul style="list-style-type: none"> • OS provides top-level window in which widgets are drawn • Toolkit is responsible to passing events to widgets
Advantages: <ul style="list-style-type: none"> • Events passed directly to OS/BWS • Preserves the OS look-and-feel 	Advantages: <ul style="list-style-type: none"> • Consistent look-and-feel across platforms • Consistent widget set across platforms • Allows for highly optimized widgets
Disadvantages: <ul style="list-style-type: none"> • OS-specific programming • Small set of common widgets across different platforms 	Disadvantages: <ul style="list-style-type: none"> • 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.*



- Model is abstracted into an interface/abstract class for more code reuse and customizability
 - Interface may provide many accessors, mutators & event-firing functions to be implemented by the custom widgets, allowing for easy manipulation of custom data
- Essential geometry is computed by the view; controller interacts with it

- Event dispatch → event handling → notifying view & windowing system (MVC)
- **Event dispatch:** dequeuing 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
 - Widget can process the event or pass to its parent
 - e.g. widget belongs in a group/container – may be better for container 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
 - Widget can process the event or pass to child component
 - 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; dragging scrollbar but mouse moves out of scrollbar
- **Focus dispatch** – events dispatched to widget that has keyboard/mouse focus
 - 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:

- BWS has visibility to all widgets
- Can use top-down or bottom-up dispatch

Lightweight toolkits:

- BWS only has visibility to application window
- Toolkit then dispatches event to widget
- 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

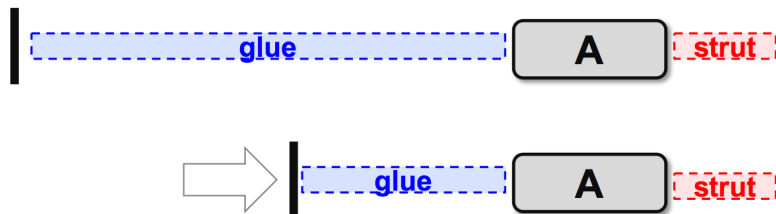

```
this.addListener(new Listener() { // implement all methods });
```
 - Adapter pattern – widget class holds adapter objects (class with boilerplate implementations)
 - ◇ Custom adapter only needs to extend methods that are used


```
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

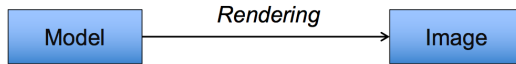
- **Dynamic layout** – dynamically adjusts screen composition; provides spatial layout for widgets in a container
 - Handles container resize by adjusting location, size, visibility or look-and-feel of widgets
- **Adaptive/responsive layout** – may go beyond spatial layout in order to adapt to different device sizes
- 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 on contained widgets
 - Bottom-up algorithm – query each child widget for preferred size, then set size for parent
 - e.g. `BoxLayout`, `FlowLayout`
 - Variable intrinsic size – widget size depends on both parent and contained widgets
 - Bottom-up & top-down algorithm
 - e.g. `GridBagLayout`, `BorderLayout`
 - Struts and Springs – layout specified by constraints and anchors
 - Strut widgets are fixed in size; spring/glue widgets stretch to fill space
 - e.g. `SpringLayout`



Graphics & Transformations

- **2D graphics:**

- Shape model – data needed to draw a shape (array of points, colour, location etc.)
- Rendering – using the properties to create an image to be displayed on the screen

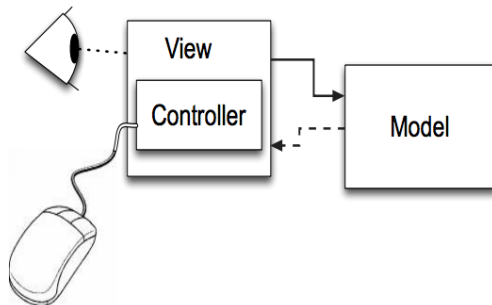


- **NOTE:** origin is located at the top-left when discussing graphics & transformations
- Selection paradigms:
 - Click selection (for lines) – find closest line segment to mouse position
 - Check distance from mouse to each line segment using vector projection
 - Count as “selection” for distance under a certain threshold
 - Click selection (for closed shapes) – check if mouse position is within shape
 - For complex polygons, draw a ray extending from the point & count the # of intersections with the polygon’s boundary
 - If odd # of intersections, the point is within the polygon; if even #, it is not
- **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 2×2 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:** calculates all transformations using 3×3 matrix
$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & t_x \\ 0 & 1 & t_y \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos(\Theta) & -\sin(\Theta) & 0 \\ \sin(\Theta) & \cos(\Theta) & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} s_x & 0 & 0 \\ 0 & s_y & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$
 - Transformations are applied right to left \leftarrow
- **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)
 - 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)

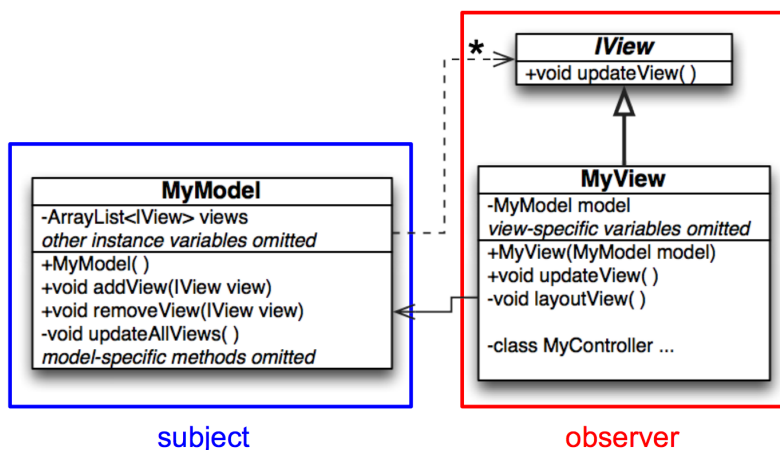
- Allows specification of object in its own coordinate system (e.g. relative to parent)
- Simplifies repositioning of object after change (e.g. moving an object in animation)
- Coordinates given by events need to be transformed as they traverse the interactor tree
 - e.g. for inside tests/hit detection, mouse event coordinates must be transformed into a model's local coordinates
 - Transforming mouse \rightarrow model coordinates
 - Only one transformation (of the mouse event) – take the inverse of model's affine matrix
 - Transforming model \rightarrow 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
- Devices are mostly focused on text & positional input
- **Text input**
 - QWERTY has many *perceived* problems:
 - Many common combinations require inefficient finger movements
 - Most typing is done with left hand
 - Most typing is *not* done on the home row
 - 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 aesthetics – 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)