Designing Interactive Systems II

Computer Science Graduate Programme SS 2010

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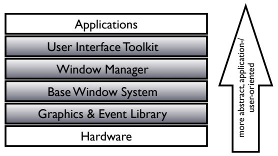
Today: Window Systems *Part I*

- Window System Requirements
- 4-Layer Model
- Graphics and Event Library



Window Systems: Basic Tasks

- Basic window system tasks:
  - Input handling: Pass user input to appropriate application
  - Output handling: Visualize application output in windows
  - Window management: Manage and provide user controls for windows
  - *This is roughly what our Simple Reference Window System will be implementing*

Window Systems: Requirements

- Independent of hardware and operating system
- Legacy (text-based) software support (virt. terminals)
- No noticeable delays (few ms) for basic operations (edit text, move window); 5+ redraws/s for cursor
- Customizable look&feel for user preferences
- Applications doing input/output in parallel
- Small resource overhead per window, fast graphics
- Support for keyboard and graphical input device
- Optional: Distribution, 3-D graphics, gesture, audio,...

In-Class Exercise: Window Systems Criteria

- In groups of 2, brainstorm criteria that you would look at when judging a new window system
- We will compile the answers in class afterwards

Window Systems: Criteria

- Availability (platforms supported)
- Productivity (for application development)
- Parallelism
  - external: parallel user input for several applications possible
  - internal: applications as actual parallel processes
- Performance
  - Basic operations on main resources (window, screen, net), user input latency—up to 90% of processing power for UI
- Graphics model (RasterOp vs. vector)

Window Systems: Criteria

- Appearance (Look & Feel, exchangeable?)
- Extensibility of WS (in source code or at runtime)
- Adaptability (localization, customization)
  - At runtime; e.g., via User Interface Languages (UILs)
- Resource sharing (e.g., fonts)
- Distribution (of window system layers over network)
- API structure (procedural vs. OO)
- API comfort (number and complexity of supplied toolkit, support for new components)

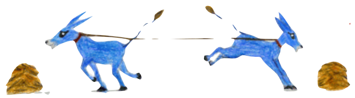
Window Systems: Criteria

- Independence (of application and interaction logic inside programs written for the WS)
- IAC (inter-application communication support)
  - User-initiated, e.g., Cut&Paste

Technique	Selection	Clipboard	DDE	OLE
Duration	short	short	medium	long
Data types	special	special	special	any
Directed	yes	no	yes	no
Relation	1:1	m:1:n	1:1	m:n
Abstraction	low	low	medium	high

Window Systems: Conflict

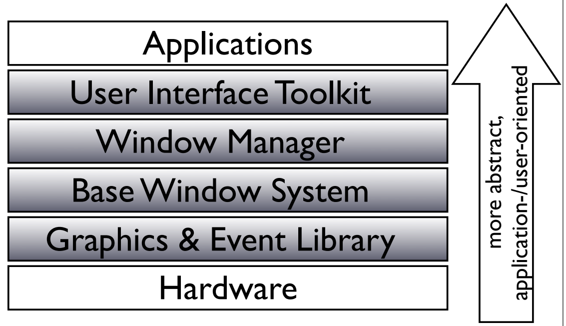
- WS developer wants: elegant design, portability
- App developer wants: Simple but powerful API
- User wants: immediate usability+malleability for experts



- Partially conflicting goals
- Architecture model shows if/how and where to solve
- Real systems show sample points in tradeoff space

The 4-Layer Model of Window System Architectures

- Layering of virtual machines
- Good reference model
- Existing systems often fuzzier
- Where is the OS?
- Where is the user?
    - physical vs. abstract communication
    - See ISO/OSI model



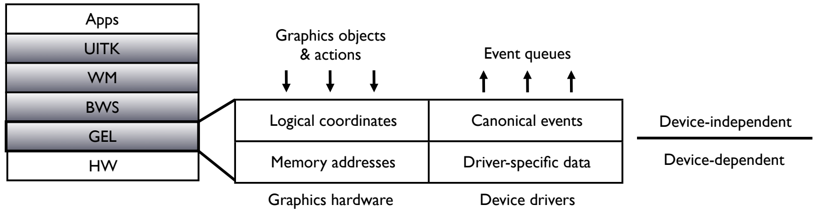
The 4-Layer Model of Window System Architectures

- UI Toolkit (a.k.a. Construction Set)
    - Offers standard user interface objects (widgets)
- Window Manager
    - Implements user interface to window functions
- Base Window System
    - Provide logical abstractions from physical resources (e.g., windows, mouse actions)
- Graphics & Event Library (implements graphics model)
    - high-performance graphics output functions for apps, register user input actions, draw cursor

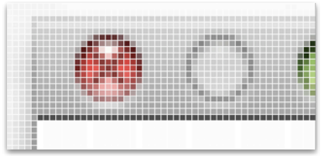
A Note On Gosling's Model

- Same overall structure
- But certain smaller differences
    - E.g., defines certain parts of the GEL to be part of the BWS
    - Written with NeWS in mind
- We will follow the model presented here
    - More general
    - 5 years newer
    - Includes Gosling's and other models

Graphics & Event Library



- Device-dependent sublayer to optimize for hardware
- Device-independent sublayer hides HW vs. SW implementation (virtual machine)



The RasterOp Model

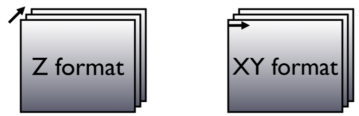
- Original graphics model
- Suited to bitmap displays with linear video memory
  - Adresses individual pixels directly
  - Fast transfer of memory blocks (a.k.a. bitblt: bit block transfer)
- Absolute integer screen coordinate system
  - Resolution problem
- Simple screen operations (the XOR trick,...)
  - But break down with color screens

The Vector Model

- API uses normalized coordinate system
  - Device-dependent transformation inside layer
  - Advantage: units are not pixels of specific device anymore
  - Applications can output same image data to various screens and printer, always get best possible resolution (no "jaggies")
- Originally implemented using Display PostScript
  - Included arbitrary clipping regions
  - a.k.a. "Stencil/Paint Model"

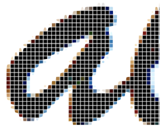
Graphics Library Objects: Canvas

- Memory areas with coordinate system and memory-to-pixel mapping
- Defined by: Start address, size, bit depth, logical arrangement in memory (only relevant for pixmaps)
  - Z format (consecutive bytes per pixel, easy pixel access)
  - XY format (consecutive bytes per plane, easy color access)



Graphics Library Objects: Output Objects

- Elementary
  - Directly rendered by graphics hardware
  - E.g., Circle, line, raster image



- Complex
  - Broken down by software into elementary objects to render
  - Example: Fonts
    - Broken down into raster images (bitmap/raster/image font, quick but jagged when scaled)
    - Or broken down into outline curves (scalable/outline/vector fonts, scalable but slower)
    - Real fonts do not scale arithmetically!

Graphics Library Objects: Graphics Contexts

- Status of the (virtual) graphics processor
- Bundle of graphical attributes to output objects
- E.g., line thickness, font, color table
- Goal: reduce parameters to pass when calling graphics operations
- Not always provided on this level

Graphics Library: Actions

- Output (Render) actions for objects described above
- Three "memory modes"
  - Direct/Immediate Drawing
    - Render into display memory and forget
  - Command-Buffered/Structured Drawing, Display List Mode
    - Create list of objects to draw
    - May be hierarchically organized and/or prioritized
    - Complex but very efficient for sparse objects
  - Data-Buffered Drawing
    - Draw into window and in parallel into "backup" in memory
    - Memory-intensive but simple, efficient for dense objects

Graphics Library: Actions

- Who has to do redraw?
  - Buffered modes: GEL can redraw, needs trigger
  - Immediate mode: application needs to redraw (may implement buffer or display list technique itself)
  - Mouse cursor is always redrawn by GEL (performance)
    - Unless own display layer for cursor (alpha channel)
    - Triggered by event part of GEL
  - Clipping is usually done by GEL (performance)

Event Library: Objects

- Events
  - Driver-specific: physical coordinates, timestamp, device-specific event code, in device-specific format
  - Canonical: logical screen coordinates, timestamp, global event code, in window system wide unified format
  - Event Library mediates between mouse/kbd/tablet/... drivers and window-based event handling system by doing this unification
- Queue
  - EL offers one event queue per device

Event Library: Actions

- Drivers deliver device-specific events interrupt-driven into buffers with timestamps
- EL cycles driver buffers, reads events, puts unified events into 1 queue per device (all queues equal format)
- Update mouse cursor without referring to higher layers

GEL: Extensions

- GL: Offer new graphics objects/actions (performance)
- EL: Support new devices
- How extensible is the GEL?
  - Most systems: Not accessible to application developer
  - GEL as library: extensible only with access to source code (X11)
  - GEL access via interpreted language: extensible at runtime (NeWS)
    - NeWS example: Download PostScript code into GEL to draw triangles, gridlines, patterns,...

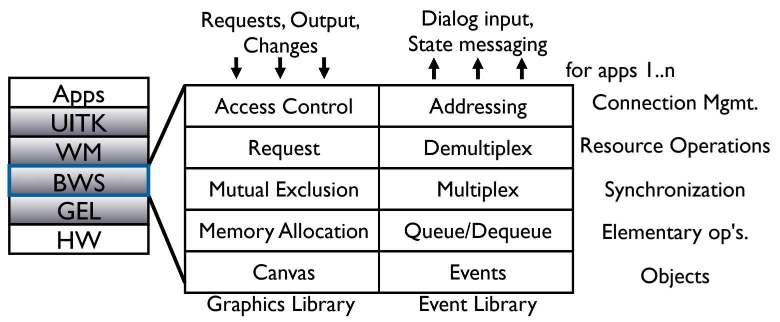
Summary

- 4-layer model
- Graphics & Event Library
  - Hides hardware and OS aspects
  - Offers virtual graphics/event machine
  - Often in same address space as Base Window System
  - Many GEL objects have peer objects on higher levels
    - E.g., windows have canvas

Base Window System: Tasks

- Provide mechanisms for operations on WS-wide data structures
- Manage shared resources - ensure consistency
- Core of the WS
- Most fundamental differences in structure between different systems
    - user process with GEL, part of OS, privileged process
- In general, *1* WS with k terminals, n applications, m objects (windows, fonts) per app (*l* WS if distributed)

Base Window System: Structure



Base Window System: Objects

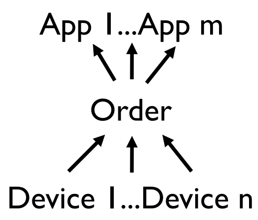
- Windows, canvas, graphics contexts, events
- Requested explicitly from applications (except events), but managed by BWS—why?
    - Manage scarce resources for performance & efficiency
    - Applications share resources
    - Consistency and synchronization
- Real vs. virtual resources
    - (Video) memory, mouse, keyboard, usually also network
    - Applications only see "their" virtual resources

Windows & Canvas

- Components:
    - Owner (application originally requesting the window)
    - Users (reference list of IDs of all applications temporary aiming to work with the window)
    - Size, depth, border, origin
    - State variables (visible, active,...)
- Canvas
    - =Window without state; not visible
- Operations:
    - Drawing in application coordinate system
    - State changes (make (in)visible, make (in)valid,...)

Events

- Components:
  - Event type
  - Time stamp
  - Type-specific data
  - Location
  - Window
  - Application
- Event Processing:
  - Collect (multiplex) from device queues
  - Order by time stamp, determine application & window
  - Distribute (demultiplex) to application event queues



Events

- BWS can generate events itself based on window states (e.g., "needs restoring") or certain incoming event patterns (replace two clicks by double-click), and insert them into queue

Fonts

- Increasingly offered by GEL (performance), but managed here
  - Load completely into virtual memory, or
  - Load each component into real memory, or
  - Load completely into real memory
- Components
  - Application owner, other apps using it (as with windows)
    - Typically shared as read-only → owner "just another user"
  - Name, measurements (font size, kerning, ligatures,...)
  - Data field per character containing its graphical shape

Graphics Context

- Graphics Context Components
  - Owner app, user apps
  - Graphics attributes (line thickness, color index, copy function,...)
  - Text attributes (color, skew, direction, copy function,...)
  - Color table reference
- GEL: 1 Graphics context at any time, BWS: many
  - Only one of them active (loaded into GEL) at any time

Color Tables

- Components
  - Owner app, user apps
  - Data fields for each color entry
    - RGB, HSV, YIQ,...
- Fault tolerance
  - BWS should hold defaults for all its object type parameters to allow underspecified requests
  - BWS should map illegal object requests (missing fonts,...) to legal ones (close replacement font,...)

Communication Bandwidth

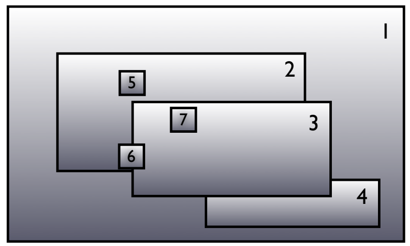
- WS needs to talk to other apps across network
  - Typically on top of ISO/OSI layer 4 connection (TCP/IP,...)
  - But requires some layer 5 services (priority, bandwidth,...)
  - Usually full-duplex, custom protocol with efficient coding
  - Exchange of character and image data, often in bursts
  - Each application expects own virtual connection
- ➢ Bandwidth is scarce resource
- Components of a Connection object:
  - Partner (IP+process,...), ID, parameters, encoding, message class (priority,...)
  - Elementary operations: decode, (de)compress, checksum,...
  - Optional operations: manage connection, address service

BWS: Actions

- Basic set of operations for all object types
  - Allocate, deallocate
- Other elementary operations for certain types
  - Read and write events to and from event queues
  - Filtering events for applications
- How to manage window collection in BWS?
  - Tree (all child windows are inside their parent window)
  - Why? → Visibility, Event routing
    - Remember: on the BWS level, all UI objects are windows—not just document windows of applications!

In-Class Exercise

- Determine a valid tree structure for the window arrangement shown below



Shared Resources

- Reasons for sharing resources: Scarcity, collaboration
- Problems: Competition, consistency
- Solution: Use “users” list of objects
  - Add operations to check list, add/remove users to object
  - Deallocate if list empty or owner asks for it
- How does BWS handle application requests?
  - Avoid overlapping requests through internal synchronization
  - Use semaphores, monitors, message queues

Synchronization Options

- Synchronize at BWS entrance
  - One app request entering the BWS is carried out in full before next request is processed (simple but potential delays)
- Synchronize on individual objects
  - Apps can run in parallel using (preemptive) multitasking
  - Operations on BWS objects are protected with monitors
    - Each object is monitor, verify if available before entering
    - high internal parallelism but complex, introduces overhead

OS Integration

- Single address space
  - No process concept, collaborative control (stability?)
  - “Window multitasking” through procedure calls (cooperation on common stack)
  - Xerox Star, Apple Mac OS Classic, MS Windows 3.x
- BWS in kernel
  - Apps are individual processes in user address space
  - BWS & GEL are parts of kernel in system address space
  - Each BWS (runtime library) call is kernel entry (expensive but handled with kernel priority)
  - Communication via shared memory, sync via kernel

OS Integration

- BWS as user process
  - BWS loses privileges, is user-level server for client apps, Communication via Inter-Process Communication (IPC)
    - Single-thread server (“secretary”): no internal parallelism, sync by entry
    - Server with specialized threads (“team”): each thread handles specific server subtask, shared BWS objects are protected using monitors
    - Multi-server architecture: Several separate servers for different tasks (font server, speech recognition and synthesizing server,... — see distributed window systems)

Summary

- BWS works with device- and OS-independent abstractions (only very general assumptions about OS)
- Supports system security and consistency through encapsulation and synchronization
  - map n apps with virtual resource requirements to 1 hardware
- Offers basic API for higher levels (comparable to our Simple Reference Window System)
  - Where are window controls, menus, icons, masks, ...?