Motivation for Dynamic Architectures

- Benefits of architecture-based development are well understood
  - particular benefit in large-scale development
- Safety- and mission-critical software systems often cannot be shut down and restarted for upgrades
  - undesirable delays
  - increased cost
  - unacceptable risk
  - → air traffic control
  - → telephone switching
  - → 24x7 public information systems,
- Runtime modification is a key aspect of these systems
  - this support should be provided at the level of architecture

What Are “Dynamic Architectures?”

- Architecture is not an executable artifact
- Two possibilities
  - *simulate* system execution at the architectural level
  - reflect architecture modifications in *executing system*
- Support for architectural dynamism
  - constrained dynamism
    - all changes to the architecture must be known *a priori*
  - unconstrained architectural dynamism
    - any changes are allowed in principle
    - → the validity of the changes must be ensured at runtime

Aspects of Dynamic Software Architectures

- Modeling dynamic architectures
  - languages for describing dynamically evolving software architectures
  - *enable* runtime changes
- Specifying dynamic changes
  - architecture modification languages
  - *specify* runtime changes
- Governing change
  - restricting runtime change to preserve system integrity
- Runtime tool support
  - tools for constructing dynamic systems from architectures
  - tools for supporting runtime changes

Modeling Dynamism in Architectures

- ADLs that support dynamism
  - most support constrained dynamism
  - C2 and Weaves support unconstrained dynamism
- Approaches to constrained dynamism
  - parameterized instantiation of architectural elements
  - component/connector replication
  - conditional reconnection
  - special architectural modification events
- Approaches to unconstrained dynamism
  - addition
  - removal
  - replacement
  - reconnection
  - → requires real-time analysis

Constrained Dynamism

- ADLs provide modeling support
  - → enactment requires tools
- Example — Darwin
  - runtime component replication via dynamic instantiation

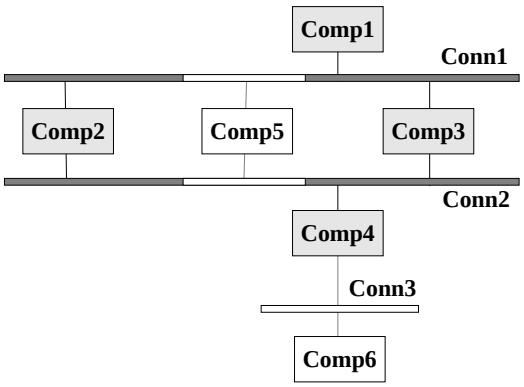
```
provide create_inst<dyn data>;
bind create_inst -- dyn comp;
```

  - component deletion/rebinding by interpreting scripts
- Example — Rapide
  - runtime reconnection via conditional operators

```
?A : Airplane; -- Airplanes contain outgoing event Radio
?M : Msg;
SFO : Control_Center;
    . . .
connections
    ?A.Radio(?M) Where ?A.InRange(SFO)
        ||> SFO.Receive(?M);;
```


Unconstrained Dynamism

- ADLs' underlying semantics provide support
  - → enactment requires tools
  - → requires on-the-fly analysis
- Achievable by
  - minimal element interdependencies
  - flexible connectors
  - untyped data
- Example — C2



Specifying Dynamic Changes

- ADLs describe architectures
  - used for analysis and system generation
  - include planned dynamic behavior
- Architecture modification languages (AMLs) describe changes to architectural descriptions
  - introduce unplanned changes to deployed systems
  - require active agent facilities to effect architectural changes in the system
    - difficult task in general
    - more tractable in implementation constraining approaches

→ An entire architectural description may be produced with an AML

AML Example

newArchitecture(A1);
A1.**addComponent**(C1);
A1.**addComponent**(C2);
A1.**addComponent**(C3);
A1.**addConnector**(B1);
A1.**addConnector**(B2);
A1.**attach**(C1,B1);
A1.**attach**(B1,C2);
A1.**attach**(C2,B2);
A1.**attach**(B2,C3);
A1.**attach**(B1,B2);
A1.**addComponent**(C4);
A1.**addConnector**(B3);
A1.**attach**(B3,C4);
A1.**detach**(B1,B2);
A1.**attach**(C2,B3);
A1.**detach**(C2,B2);
A1.**removeComponent**(C3);
A1.**removeConnector**(B2);

Governing Dynamic Architectural Changes

- Placing constraints on allowed changes
  - structural
  - syntactic
  - semantic
- Numerous possibilities for specifying constraints
  - imperative via predicates
    - e.g., Require (connect A B)
      Prohibit (connect A C)
  - declarative
    - e.g., *Forall* c1,c2 *in* sys.Comps *@ Exists* b *in* sys.Conns *@* Attached(c1,b) *and* Attached(c2,b)
  - event patterns
  - communication protocols

Tool Support for Dynamism

- Tools to facilitate use of dynamic software architectures
  - APIs, event mechanisms
- Construction of systems that exhibit dynamic properties
- Enactment of AML-like commands in running systems
- Analysis of dynamic changes
  - change the model, analyze it, enact changes in the system
- Generation of code needed to effect dynamic changes
  - glue code, new connectors, new components
- Provision of mechanisms that provide low-level support for dynamism
  - e.g., access to OS services, DLLs, PL-specific dynamic features

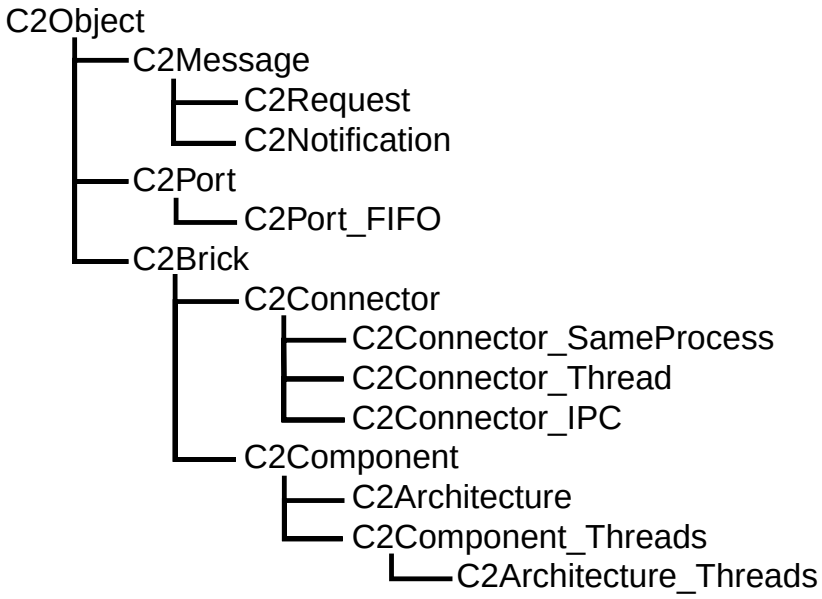
ArchShell
A Tool for Supporting Architectural Dynamism

- Allows C2-style architectures to be constructed, executed, monitored, and modified interactively
- Implements AML commands for component/connector
  - addition — *addComponent*, *addConnector*
  - removal — *removeComponent*, *removeConnector*
  - (re)connection — *weld*, *unweld*
- Built on top of the C2 implementation infrastructure
  - depends on the infrastructure to enable dynamic changes
- Similar to a UNIX command shell (e.g., csh)
  - allows interactive system construction
- Different from a UNIX shell
  - supports architecture modification during runtime

C2 Implementation Infrastructure

- Simple, extensible framework of abstract classes for C2 concepts
  - components
  - connectors
  - communication ports
  - messages
- Implements interconnection and communication protocols
- Enables rapid construction of C2-style applications
  - allows developers to focus on application-level issues
- Implemented in Java, C++, and Ada (partially)
  - you will use the Java framework for *Homework 3c*

C2 Class Framework



Java Framework — Message

- Messages parameters are Java hashtables
  - notification vs. request
- Methods
  - ***name*** — returns message name
  - ***setName*** — sets message name
  - ***type*** — returns message type
  - ***setType*** — sets message type
  - ***addParameter*** — adds parameter to message
  - ***removeParameter*** — removes parameter from message
  - ***getParameter*** — retrieves parameter value
  - ***hasParameter*** — checks if message has given parameter
  - ***setAllParameters*** — sets all message parameters at once
  - ***getAllParameters*** — returns parameter hashtable
  - ***clone***

Java Framework — Port

- Abstract class
- Methods
  - ***belongsTo*** — returns brick to which port belongs or (re)assigns port to brick
  - ***Link —*** accesses port to which *this* is linked
  - ***weld*** — welds *this* to another port
- FIFOPort is a kind of port
- FIFOPort Methods
  - ***receive*** — add message to incoming queue and notify brick
  - ***selectNextIncomingMessage*** — from incoming queue
  - ***selectNextOutgoingMessage*** — from outgoing queue
  - ***send*** — remove message from outgoing queue and transfer to its link's incoming queue

Java Framework — Brick

- Methods
  - ***start*** — starts the brick running; must be invoked first
  - ***isStarted*** — checks if brick has started
  - ***finish*** — immediately stop brick's execution
  - ***timeStep*** — abstract method invoked periodically to allow the brick to execute

Java Framework — Component

- Methods
  - ***bottomPort*** — returns component's bottom port
  - ***topPort*** — returns component's top port
  - ***send*** — messages to components above and below
  - ***timeStep*** — process an incoming message from each port
  - ***handle*** — abstract methods invoked by *timeStep* for handling notifications and requests
- Declaring new components
  - inherit from *Component*
  - define *handle* methods
- Using new components
  - create an instance
  - call its *start* method

Java Framework — Connector

- C2 connectors have *context-reflective* interfaces
  - ***add*** ***Top*** ***remove*** ***Bottom*** ***Port***
- Methods
  - ***topPortAt*** — returns top port at specified index
  - ***bottomPortAt*** — returns bottom port at specified index
  - ***topPorts*** — returns list of connector's top ports
  - ***bottomPorts*** — returns list connector's bottom ports
  - ***handle*** — methods for processing requests and notifications
  - ***send*** — broadcast message to all bricks above or below *this*
  - ***timeStep*** — process an incoming message from each port
- Declaring new connectors
  - inherit from *Connector*
  - override *handle* methods — message filtering
  - override *send* methods — message routing

Java Framework — [Brick]Thread

- Each brick runs in its own thread of control
- Implemented with a semaphore
- Methods
  - ***start*** — starts the thread running
  - ***finish*** — stops the execution of the thread
  - ***finished*** — checks if the brick is idle
  - ***run*** — called when thread created; processes messages or waits for them
  - ***newMessage*** — invoked when brick receives new message; sets semaphore to wake up brick's thread

Java Framework — Architecture

- Methods
  - ***start*** — starts all bricks in the architecture
  - ***run*** — assigns *timeSteps* to all bricks in the architecture
  - ***finish*** — finishes all bricks in the architecture
  - ***finished*** — checks if all bricks have finished executing
  - ***add[Brick]*** — adds brick to architecture
  - ***remove[Brick]*** — removes brick from architecture
  - ***Components*** — returns vector of components in *this*
  - ***Connectors*** — returns vector of connectors in *this*
  - ***detach[Side]*** — detaches all attached bricks on given side
  - ***detach[Brick]*** — detaches all bricks from both sides
  - ***weld*** — attaches two or more bricks to each other
  - ***unweld*** — detaches two or more bricks from each other

C2 Graphics Binding

- Existing toolkits essentially issue notifications...
  - "the user has typed the 'x' key"
- ...and respond to requests
  - "draw a line from (x_1,y_1) to (x_2,y_2)"
- Toolkits conceptually at the bottom of a C2 architecture
  - receive notifications
  - issue requests
- A C2 graphics binding is an *adaptor* to the toolkit

Java Framework — *GraphicsBinding*

- Subclass of *ComponentThread*
  - C2 notifications → AWT calls
  - user-generated events → C2 requests
- Current support
  - frames
  - panels
  - lists
  - buttons
  - text fields
  - arcs
  - lines
  - ovals
  - rectangles
  - text strings
- Each supported element has an associated "C2" class
  - may or may not extend AWT class
  - exports needed interface
  - can be extended
- No AWT layout managers are used

GraphicsBinding Methods (1)

- ***handle*** — handles C2 notifications received from above
- ***send*** — sends C2 requests up the architecture
- ***CreateObject*** — creates screen object
- ***ModifyObject*** — modifies screen object
- ***DestroyObject*** — destroys screen object
- ***createViewport*** — creates C2 viewport (AWT Frame)
- ***destroyViewport*** — destroys C2 viewport (AWT Frame)
- ***clearViewport*** — clears C2 viewport
- ***addPanel*** — creates C2 panel (AWT Panel)
- ***clearPanel*** — clears C2 panel

GraphicsBinding Methods (2)

- ***addList*** — adds list to container
- ***appendListItem*** — appends item to end of list
- ***addListItem*** — adds item to list at given location
- ***removeListItem*** — remove item at given location from list
- ***replaceListItem*** — replaces item at given location with new item
- (***de***)***selectListItem*** — marks list item as (de)selected
- ***clearListItems*** — clears all items from list
- ***addTextField*** — adds text field to container
- ***eraseTextField*** — clears text field
- ***setTextField*** — sets text field's value
- ***getTextField*** — retrieves text field's value
- ***addButton*** — adds button to container (panel or viewport)

GraphicsBinding Methods (3)

- ***line*** — draws a line in container
- ***arc*** — draws arc in container
- ***oval*** — draws oval in container
- ***rectangle*** — draws rectangle in container
- ***text*** — draws text string in container
- ***shutdown*** — exits current application

Notification Handling in *GraphicsBinding*

```
if (message_name.equalsIgnoreCase("ButtonAdded"))
{
    int x = ((Integer)n.getParameter("x")).intValue();
    int y = ((Integer)n.getParameter("y")).intValue();
    int width = ((Integer)n.getParameter("width")).intValue();
    int height = ((Integer)n.getParameter("height")).intValue();
    Color foreground = toColor((String)n.getParameter("foreground"));
    Color background = toColor((String)n.getParameter("background"));
    String id = (String)n.getParameter("label");
    String parent_id = (String)n.getParameter("parent_id");

    Container c = containerByID(parent_id);
        if (c.getClass().getName().equals("c2.comp.graphics.C2Viewport"))
            addButton((C2Viewport)c, x, y, width, height, id, foreground, background);
        else
            addButton((C2Panel)c, x, y, width, height, id, foreground, background);
}
```

Extending *GraphicsBinding*

- Define or modify “C2” class associated with (new) graphics element
  - constructors
  - accessors
  - modifiers
- Expand C2Viewport and C2Panel classes
  - events and actions needed by new element
  - requests sent up the architecture
- Expand the *GraphicsBinding handle* method
  - notifications received to operate on new element
  - element’s C2 class methods invoked in response