Learning Objectives

- Formally define software architecture
- Distinguish prescriptive Versus descriptive architectures
- List the causes and types of architectural degradation, and the challenges of architecture recovery
- Understand elements of software architecture and differentiate between components and connectors
- Delineate the role of architectural styles and patterns in a software architecture
What is Software Architecture?

- **Definition:**
  - A software system’s architecture is the set of *principal design decisions* about the system
  - Software architecture is the blueprint for a software system’s construction and evolution
  - Design decisions encompass every facet of the system under development
    - Structure
    - Behavior
    - Interaction
    - Non-functional properties
Examples of Design Decisions

- System Structure (e.g., central component)
- Functional behaviour (e.g., sequence of operations)
- Interactions (e.g., event notifications)
- Non-functional properties (e.g., no single point of failure)
- System’s Implementation (e.g., Using Java Swing toolkit)
What is “Principal”? 

- “Principal” implies a degree of importance that grants a design decision “architectural status”
  - It implies that not all design decisions are architectural
  - That is, they do not necessarily impact a system’s architecture
- How one defines “principal” will depend on what the stakeholders define as the system goals
Temporal Aspect

- Design decisions are and unmade over a system’s lifetime → Architecture has a temporal aspect

- At any given point in time the system has only one architecture

- A system’s architecture will change over time
  - Architectures can be forked, converge etc.
  - Typically many related architectures are in play
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Prescriptive vs. Descriptive Architecture

- A system’s *prescriptive architecture* captures the design decisions made prior to the system’s construction
  - It is the *as-conceived* or *as-intended* architecture
- A system’s *descriptive architecture* describes how the system has been built
  - It is the *as-implemented* or *as-realized* architecture
Prescriptive vs. Descriptive
Prescriptive vs. Descriptive

- Which architecture is “correct”?
- Are the two architectures consistent with one another?
- What criteria are used to establish the consistency between the two architectures?
- On what information is the answer to the preceding questions based?
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Architectural Evolution

- When a system evolves, ideally its prescriptive architecture is modified first.
- In practice, the system – and thus its descriptive architecture – is often directly modified.
- This happens because of:
  - Developer sloppiness
  - Perception of short deadlines which prevent thinking through and documenting
  - Lack of documented prescriptive architecture
  - Need or desire for code optimizations
  - Inadequate techniques or tool support
Architectural Degradation

- Two related concepts
  - Architectural drift
  - Architectural erosion

- *Architectural drift* is the introduction of principal design decisions into a system’s descriptive architecture that are not included in, encompassed by, or implied by the prescriptive architecture but which do not violate any of the prescriptive architecture’s design decisions.

- *Architectural erosion* is the introduction of architectural design decisions into a system’s descriptive architecture that violate its prescriptive architecture.
Architectural Drift or Erosion?
Architectural Recovery

- If architectural degradation is allowed to occur, one will be forced to *recover* the system’s architecture sooner or later.

- *Architectural recovery* is the process of determining a software system’s architecture from its implementation-level artifacts.

- Implementation-level artifacts can be:
  - Source code
  - Executable files
  - Java `.class` files
Can you recover this architecture?
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Software Architecture’s Elements

- A software system’s architecture typically is not (and should not be) a uniform monolith
- A software system’s architecture should be a composition and interplay of different elements
  - Processing
  - Data, also referred as information or state
  - Interaction
Components

- Elements that encapsulate processing and data in a system’s architecture are referred to as software components.

**Definition**

- A software component is an architectural entity that:
  - encapsulates a subset of the system’s functionality and/or data
  - restricts access to that subset via an explicitly defined interface
  - has explicitly defined dependencies on its required execution context

- Components typically provide application-specific services
Examples of Components

- Application-specific components
  - Examples: Cargo, warehouse, vehicle

- Limited reuse components
  - Examples: Web servers, clocks, connections

- Reusable components
  - Examples: GUI components, class and math libraries
Connectors

- In complex systems *interaction* may become more important and challenging than the functionality of the individual components

**Definition**
- A *software connector* is an architectural building block tasked with effecting and regulating interactions among components

- In many software systems connectors are usually simple procedure calls or shared data accesses
- Connectors typically provide application-independent interaction facilities
  - Can be described independently of the components
Examples of Connectors

- Procedure call connectors
- Shared memory connectors
- Message passing connectors
- Streaming connectors
- Distribution connectors
- Wrapper/adaptor connectors
Configurations

- Components and connectors are composed in a specific way in a given system’s architecture to accomplish that system’s objective

**Definition**

- An *architectural configuration*, or topology, is a set of specific associations between the components and connectors of a software system’s architecture
An Example Configuration
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Architectural Styles

- Certain design choices regularly result in solutions with superior properties
  - Compared to other possible alternatives, solutions such as this are more elegant, effective, efficient, dependable, evolvable, scalable, and so on

- **Definition**
  - An *architectural style* is a named collection of architectural design decisions that:
    - are applicable in a given development context
    - constrain architectural design decisions that are specific to a particular system within that context
    - elicit beneficial qualities in each resulting system
Architectural Style: Example

- REST style (Representational State Transfer) – HTTP
  - Uniform Interface between clients and servers
  - Stateless: No client context stored on server between requests. All state is carried in the request URL.
  - Clients should be able to cache responses to requests
  - Layered architecture: Clients cannot tell if they are connected directly to the server or thro’ a proxy
  - Code on demand (optional): Server should be able to extend the client’s functionality thro’ client-side scripts
Architectural Patterns

- **Definition**
  - An *architectural pattern* is a set of architectural design decisions that are applicable to a recurring design problem, and parameterized to account for different software development contexts in which that problem appears.

- A widely used pattern in modern distributed systems is the *three-tiered system* pattern:
  - Science
  - Banking
  - E-commerce
  - Reservation systems
Three-Tiered Pattern

- Front Tier
  - Contains the user interface functionality to access the system’s services
- Middle Tier
  - Contains the application’s major functionality
- Back Tier
  - Contains the application’s data access and storage functionality
Differences between Style and Pattern

- **Style**
  - Provides a set of guiding principles in adopting solutions
  - Requires considerable effort to apply. Architect needs to justify the design choices based on the architectural style.

- **Pattern**
  - Provides concrete solutions, although parameterized to the specific problem.
  - Requires very little manual effort or justification to apply.
  - Usually applies to specific systems (e.g., GUI-based systems)
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Architectural Models, Views, and Visualizations

- **Architecture Model**
  - An artifact documenting some or all of the architectural design decisions about a system

- **Architecture Visualization**
  - A way of depicting some or all of the architectural design decisions about a system to a stakeholder

- **Architecture View/Perspective**
  - A subset of related architectural design decisions
  - Typically pertain to a cross-cutting functionality
Architectural Visualization: Example

Graphical Diagram

Textual descriptions

```java
component DataStore{
    provide landerValues;
}

component Calculation{
    require landerValues;
    provide calculationService;
}

component UserInterface{
    require calculationService;
    require landerValues;
}

component LunarLander{
    inst
    U: UserInterface;
    C: Calculation;
    D: DataStore;
    bind
    C.landerValues -- D.landerValues;
    U.landerValues -- D.landerValues;
    U.calculationService -- C.calculationService;
}
```
Architectural Views: Example

Structural View

Deployment View
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