Lecture 10: Architecture

Lecture goals

- Visualize structural models with deployment and interface diagrams
- Identify common architectural styles

System design

Design steps

- Given requirements, must **design** a system to meet them
    - System architecture
    - User experience
    - Program design
- Ideal: requirements are independent of design (avoid implementation bias)
- Reality: working on design clarifies requirements
    - Methodology should allow feedback (strength of iterative & agile methods)

Design principles

- Design is an especially creative part of the software development process
    - More a "craft" than a science
    - Many tools are available; must select appropriate ones for a given project
- Strive for **simplicity**
    - Use modeling, abstraction to (hopefully) find simple ways to achieve complex requirements
    - Designs should be easy to implement, test, and maintain
- Easy to use correctly, hard to use incorrectly
- Low coupling, high cohesion

What is architecture

- Brooks: **Conceptual integrity** is key to usability and maintainability; **architect** maintains conceptual integrity
- Johnson: The shared understanding that expert developers have of the system / The decisions you wish you could get right early in a project
- Sommerville: Dominant influence on **non-functional** system characteristics
- "Highest level" organization of system

Levels of abstraction

- Requirements
    - High level "what"
- Architecture

    - High-level "how"
    - Mid-level "what"
- Program design
    - Mid-level "how"
    - Low-level "what"
- Code
    - Low-level "how"

- Documentation for each step should respect its level of abstraction
    - Avoid biasing later steps
    - Avoid redundancy

Architectural considerations

- Infrastructure
    - Hardware
    - Operating systems
    - Virtualization
- Interfaces
    - Networks/buses
    - Protocols
- Services
    - Databases
    - Authentication
- Operations
    - Testing
    - Logging/monitoring
    - Backups
    - Rolling deployment
- Product line

Architectural models

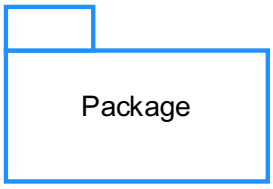
- Diagram **and** supporting specification
    - Be *specific* with notation
- Multiple perspectives
    - Conceptual
    - Static (subsystems)
    - Dynamic (data flow)
    - Physical (deployment)
- Appropriate level of detail
    - A single diagram should fit cleanly on one page
- Distinct from **program models**
    - Inheritance diagrams don’t show interactions

Subsystems

- Improve comprehensibility of system by decomposing into **subsystems**
- Group elements into subsystems to minimize coupling while maintaining cohesion
- **Coupling**: Dependencies *between* two subsystems
  - If coupling is high, can't change one without affecting the other
- **Cohesion**: Dependencies *within* a subsystem
  - High cohesion implies closely-related functionality

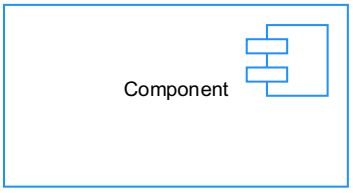
UML: Package

- General grouping of system elements
- Appropriate for denoting subsystem at conceptual level

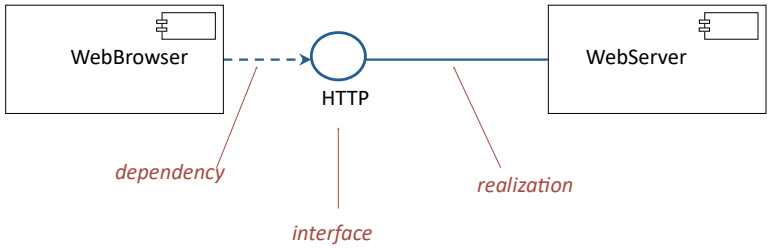


UML: Component

- Replaceable part of a system
  - Conforms to and realizes a set of interfaces
  - An implementation of a subsystem
  - Could be replaced by another component that realizes the same interfaces, and system would still function
- Distinct from classes
  - Classes may have fields, are assembled into programs
  - Components realize interfaces, are assembled into systems



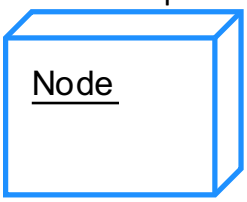
Interface diagram



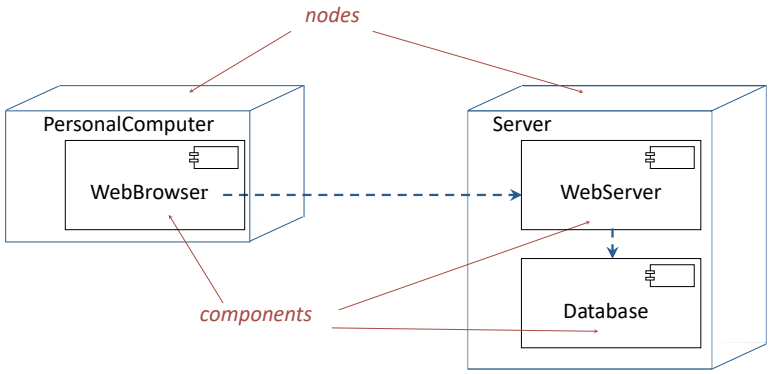
UML: Node

- Physical element that exists at runtime, provides a computational resource
  - Computer
  - Smartphone

    - Network router
- Components live on nodes



Deployment diagram



Deployment environments

- Development
- Production
- Staging
- (Acceptance testing)

Example: simulator

- Vehicle state propagated by integrator
- Integrated equations affected by **physics models**, **actuators**
- **Sensors** read vehicle state
- Sensors and actuators communicate with **controller** via **streams** and/or **registers**
- Register values aggregated by a **registry server** communicating with **registry clients**

Draw a conceptual diagram for this architecture

- Simulator process consists of integrator, models, sensors & actuators, and registry server
- Controller's registry client reads/writes controller's registers via shared memory
- Registry server communicates with clients via UDP
- Streams are sent via TCP
- Controller runs on virtual machine

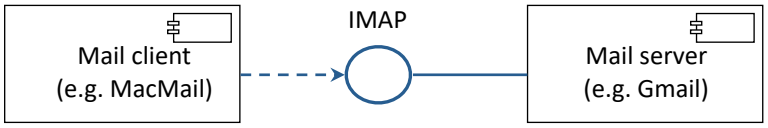
Draw a deployment and/or component diagram incorporating these details

Architectural styles

System architecture (or portion thereof) that recurs in many different applications

Client/sever

- Control flow in client and server are independent
- Communication follows a protocol
- If protocol is fixed, either side can be replaced independently
- Peer-to-peer: same component can act as both client and server



Example: X Window System (X11)

Layered

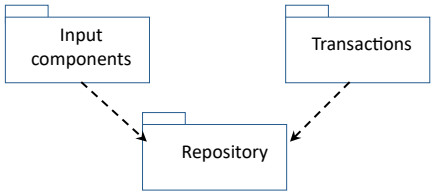
- Partition subsystems into stack of layers
  - Layer provides services to layer directly above
  - Layer relies on services to layer directly below
- Advantage: constrains coupling
- Danger: leaky abstractions
  - May need services of multiple lower layers

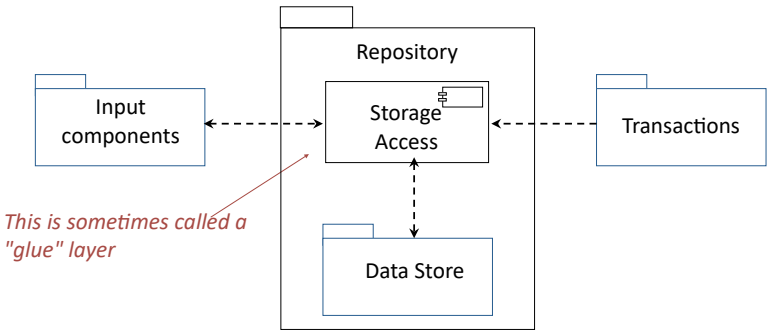
Pipe and filter

- Transformation components process inputs to produce outputs
  - Subsystems coupled via **data exchange**
  - Good match for data flow models
  - May be dynamically assembled
- Applications:
  - Streaming media
  - Graphics shaders
  - Signal processing
- Caveats:
  - Awkward to handle events (interactive systems)
  - Rate mismatches if branches merge

Repository

- Couple subsystems via **shared data**
  - Repository may need to support atomic transactions
- Advantages:
  - Components are independent (low coupling)
  - Centralized state storage (good for backups)
- Dangers:
  - Bottleneck / single point of failure



Flexibility through indirection

- Repository is highly coupled – difficult to change data store
- By defining higher-level storage access interface, data store is now lightly coupled