Review

Previously in 3110:

• language features for modularity: modules, structures, signatures, abstract types, includes, functors
• aspects of modularity: namespaces, abstraction, code reuse

Today:

• architecture and of large programs
• (until after Prelim 1: no new language features) 🎉🎉🎉
ARCHITECTURE
Architecture

• Any large system must be divided into sub-systems
• Goal of **architectural analysis**: identify sub-systems, their interfaces, how they interact
• Architecture is the highest-level design of software system
Elements of architecture

• Code **components**
  – a unit of an executing system
  – e.g. a server, a database

• Externally visible **properties** of those components
  – aspects of its functionality
  – e.g., services provided, data maintained, performance characteristics

• **Relationships** among components
  – e.g., implemented-by, shares-data-with, independent-of
Why analyze architecture?

• **Understanding**
  – Communicate system design between implementers, testers, maintainers, clients, users
  – Reduce system to a few parts; abstract from details; simplify
    • Working memory: humans can pay attention to only a small number of things at a time (3 or 4? 7?)

• **Reuse**
  – Identify what components can be repurposed from other systems
  – Assembly line model: cheaply produce system out of stock components
    • e.g., web mashups, 3110 website

• **Construction**
  – Division of (independent) labor
  – How to add new features
Ex: Architecture of web survey system

Requirements:
• present multiple-choice questions to user
• collect and store answers
• present results-in-progress to user after they submit

box and arrow diagram, aka component and connector (C&C) diagram
New requirement: only some users are authorized to take survey; must authenticate users before they can register response
Ex: Architecture of web survey system

Examples of abstraction:
• No discussion of the code modules that make up components
• No details about the connectors (URLs, schema for SQL queries)

Examples of specification:
• Survey taker uses web browser
• Server must speak with all other components
Building blocks of architecture

Components:

• Computation elements or data stores

• Primarily from the view of run time: what happens while system is executing?

• Not necessarily from the view of compile time: how is code physically organized?
Building blocks of architecture

Connectors:

• Protocol: agreed upon means of communication
  – e.g., TCP, function call
• Topology could vary: binary, broadcast, ring, ...
Architectural patterns

• Architecture is a high-level creative activity, not a science

• Some common patterns:
  1. Pipe and filter
  2. Shared data
  3. Client–server
Ex 1: Pipe and filter architecture

- **Filter**: component that transforms data
  - receives data on input pipes
  - sends output data over pipes to other filters
  - might have >1 inputs, >1 outputs
  - each filter is independent of others and could operate concurrently

- **Pipe**: connector that relays data
  - unidirectional
  - does not change data
  - pipes handle storage, synchronization, rate of transfer, etc.
Ex 1: Pipe and filter architecture

MapReduce:

- Large amount of data comes in
  - e.g. documents whose words we want to index
- Split across multiple workers who concurrently process a block of data; output a map from keys to values
  - e.g. the key is a word, the value is the set of documents in which it appears
- Mapper outputs are shuffled to bring keys together at a worker
  - e.g., all the key-value pairs for a single word are brought together at a single worker
- Key-value pairs are reduced concurrently by workers; output new values
  - e.g., aggregate the sets of documents into a single set
- Values are combined into final output
  - e.g., the index: a map from all words to the set of documents in which they appear
Ex 1: Pipe and filter architecture

MapReduce as a pipe and filter architecture:
Ex 2: Shared data architecture

- **Data repository**: component that stores data
  - provides reliability, backup, access control
  - might be passive or might actively notify accessors about changes in data
- **Data accessor**: component that does computation with data
  - gets data from repository, computes, puts data back to repository
  - accessors do not directly communicate with one another
- **Interfaces**: connectors that gives read/write access to repository
Ex 2: Shared data architecture

PeopleSoft as a shared data architecture:

Student Center → PeopleSoft

PeopleSoft → Faculty Center

browser → browser
Ex 3: Client–server architecture

- **Server**: component that provides service/resources
  - When server provides a storage service, might reduce to shared data arch.
- **Client**: component that accesses service/resources
  - clients do not directly communicate with one another
  - clients need not be co-located with server
- **Channels**: connectors that allow client to make request, then server to return response
  - asymmetric: client can contact server, not vice-versa
  - (a)synchronous: client waits for response?
- Generalizes to *n-tier architecture*, in which server acts as client to another server, etc.
Ex 3: Client–server architecture

CMS as client-server architecture:

browser → CMS (http) → J2EE server (jdbc) → Oracle DBMS
Ex 3: Client–server architecture

CMS as client-server architecture:

browser

http

CMS

J2EE server

jdbc

Oracle DBMS

client–server
Ex 3: Client–server architecture

CMS as client-server architecture:
Ex 3: Client–server architecture

CMS as 3-tier architecture:

- **Client tier**: browser
- **Business tier**: CMS J2EE server
- **Database tier**: Oracle DBMS

Connections:
- **Client tier** to **Business tier** via **http**
- **Business tier** to **Database tier** via **jdbc**
Question

Which architecture best describes the Enigma cipher?

A. Pipe and filter
B. Shared data
C. Client–server
D. None of the above
E. YNOXQ
Question

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From architecture to design

• Architecture *is* a kind of design
  – focuses on highest level structure of system
  – based on principle of divide and conquer
• But architecture isn't about code per se
• As the *design process* iteratively proceeds, we get closer and closer to code
• *Design* as a phase of software development has a more specific connotation:
  – **System design:** decide what modules are needed, their specification, how they interact
  – **Detailed design:** decide how the modules themselves can be created such that they satisfy their specifications and can be implemented
Upcoming events

• [Wed] A2 due

This is architected.

THIS IS 3110
Acknowledgment

Parts of this lecture are based on this book: