Outline

• What is a software architecture?
• What does an architecture look like?
• What is a good architecture?
• Properties of architectures
• Example architectures
Why architecture?

“Good software architecture makes the rest of the project easy.”
Steve McConnell, Survival Guide

“There are two ways of constructing a software design:
one way is to make it so simple that there are obviously no deficiencies;
the other is to make it so complicated that there are no obvious deficiencies.”
C.A.R. Hoare
The basic problem: From requirements to code

Requirements

?????

How do you bridge the gap between requirements and code?

Code
One answer:
Solve with inspiration

Requirements

a miracle happens

Code
A better answer: Solve with engineering

Requirements → Software Architecture

Software Architecture

Provides a high-level framework to build and evolve the system

Code
What does an architecture look like?
Box-and-arrow diagrams

Very common and hugely valuable. But, what does a box represent? an arrow? a layer? adjacent boxes?
Box and arrow diagrams redux

Very common and highly valuable.
But what does a box represent? An arrow? A layer? Adjacent boxes?
An architecture: components and connectors

• **Components** define the basic computations comprising the system and their behaviors
  – abstract data types, filters, etc.

• **Connectors** define the interconnections between components
  – procedure call, event announcement, asynchronous message sends, etc.

• The line between them may be fuzzy at times
  – Ex: A connector might (de)serialize data, but can it perform other, richer computations?
UML diagrams

• UML = universal modeling language
• A standardized way to describe (draw) architecture
  – Also implementation details such as subclassing, uses (dependences), and much more
• Widely used in industry
• Not the topic of this lecture
What is a good architecture?

• Satisfies functional and performance requirements
• Manages complexity
• Accommodates future change
• Is concerned with
  – reliability, safety, understandability, compatibility, robustness, ...
Divide and conquer

• Benefits of decomposition:
  – Decrease size of tasks
  – Support independent testing and analysis
  – Separate work assignments
  – Ease understanding

• Use of abstraction leads to modularity
  – Implementation techniques: information hiding, interfaces

• To achieve modularity, you need:
  – Strong cohesion within a component
  – Loose coupling between components
  – And these properties should be true at each level
An architecture helps with

System understanding: interactions between modules
Reuse: high-level view shows opportunity for reuse
Construction: breaks development down into work items; provides a path from requirements to code
Evolution: high-level view shows evolution path
Management: helps understand work items and track progress
Communication: provides vocabulary; a picture says 1000 words
Qualities of modular software

• decomposable
  – can be broken down into pieces

• composable
  – pieces are useful and can be combined

• understandable
  – one piece can be examined in isolation

• has continuity
  – change in reqs affects few modules

• protected / safe
  – an error affects few other modules
**Interface and implementation**

- **public interface**: data and behavior of the object that can be seen and executed externally by "client" code.

- **private implementation**: internal data and methods in the object, used to help implement the public interface, but cannot be directly accessed.

- **client**: code that uses your class/subsystem.

Example: *radio*

- public interface is the speaker, volume buttons, station dial.
- private implementation is the guts of the radio; the transistors, capacitors, voltage readings, frequencies, etc. that user should not see.
Properties of architecture

- Coupling
- Cohesion
- Style conformity
- Matching
Coupling (loose vs. tight)

- **Coupling**: the kind and quantity of interconnections among modules

- Modules that are loosely coupled (or uncoupled) are better than those that are tightly coupled

- The more tightly coupled two modules are, the harder it is to work with them separately
Tightly or loosely coupled?
Tightly or loosely coupled?
Cohesion (strong vs. weak)

- **Cohesion**: how closely the operations in a module are related

- Tight relationships improve clarity and understanding

- A class with good abstraction usually has strong internal cohesion

- No schizophrenic classes!
Strong or weak cohesion?

class Employee {

public:

…

FullName GetName() const;
Address GetAddress() const;
PhoneNumber GetWorkPhone() const;

…

bool IsJobClassificationValid(JobClassification jobClass);
bool IsZipCodeValid (Address address);
bool IsPhoneNumberValid (PhoneNumber phoneNumber);

…

SqlQuery GetQueryToCreateNewEmployee() const;
SqlQuery GetQueryToModifyEmployee() const;
SqlQuery GetQueryToRetrieveEmployee() const;

…

}
Style conformity: What is a style?

• An architectural style defines
  – The vocabulary of components and connectors for a family (style)
  – Constraints on the elements and their combination
    • Topological constraints (no cycles, register/announce relationships, etc.)
    • Execution constraints (timing, etc.)
• By choosing a style, one gets all the known properties of that style (for any architecture in that style)
  – For example: performance, lack of deadlock, ease of making particular classes of changes, etc.
An architectural style imposes constraints

• Pipes & filters
  – Pipes must compute local transformations
  – Filters must not share state with other filters
  – There must be no cycles
• If these constraints are violated, it’s not a pipe & filter system
  – One can’t tell this from a picture
  – One can formalize these constraints
The design and the reality

• The code is often less clean than the design

• The design is still useful
  – communication among team members
  – selected deviations can be explained more concisely and with clearer reasoning
Interface mismatch

• Mars orbiter loss

NASA lost a $125 million Mars orbiter because one engineering team used metric units while another used Imperial units
Architectural mismatch

• Some components are inherently incompatible
  – Assumptions about memory allocation, vs. custom allocator
  – Use of two frameworks (assumes it is `main`)
  – Library wants to operate first or last
  – Data formats
  – Assumed infrastructure
Architectural mismatch example

• Garlan, Allen, Ockerbloom tried to build a toolset to support software architecture definition from existing components
  – OODB (OBST)
  – graphical user interface toolkit (Interviews)
  – RPC mechanism (MIG/Mach RPC)
  – Event-based tool integration mechanism (Softbench)
• Failure: each piece worked, but they didn’t fit together
  – Excessive code size
  – Poor performance
  – Needed to modify out-of-the-box components (e.g., memory allocation)
  – Error-prone construction process
• Architecture should warn about such problems (& identify problems)
Views

A view illuminates a set of top-level design decisions

• how the system is composed of interacting parts
• where are the main pathways of interaction
• key properties of the parts
• information to allow high-level analysis and appraisal
Importance of views

Multiple views are needed to understand the different dimensions of systems.

- Functional Requirements
- Performance (execution) Requirements
- Packaging Requirements
- Installation Requirements

Booch
Web application (client-server)
Model-View-Controller

Separates:

- the application object (model)
- the way it is represented to the user (view)
- the way in which the user controls it (controller).
Pipe and filter

Pipe – passes the data

Filter – computes on the data

top | grep $USER | grep acrobat

Each stage of the pipeline acts independently of the others.
Can you think of a system based on this architecture?
Shared nothing architecture
Blackboard architectures

- The knowledge sources: separate, independent units of application dependent knowledge. No direct interaction among knowledge sources.
- The blackboard data structure: problem-solving state data. Knowledge sources make changes to the blackboard that lead incrementally to a solution to the problem.
- Control: driven entirely by state of blackboard. Knowledge sources respond opportunistically to changes in the blackboard.

Blackboard systems have traditionally been used for applications requiring complex interpretations of signal processing, such as speech and pattern recognition.
Hearsay-II: blackboard

Hearsay-II Instance of Blackboard

Software Architectures
Summary

• An architecture provides a high-level framework to build and evolve a software system.

• Strive for modularity: strong cohesion and loose coupling.

• Consider using existing architectural styles or patterns.