Achieving System Qualities Through Software Architecture II

The meaning of “design”
Modules and the module structure

Qualities Established in Architecture

<table>
<thead>
<tr>
<th>Behavioral (observable)</th>
<th>Developmental Qualities</th>
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</thead>
<tbody>
<tr>
<td>Performance</td>
<td>Modifiability (ease of change)</td>
</tr>
<tr>
<td>Security</td>
<td>Portability</td>
</tr>
<tr>
<td>Availability</td>
<td>Reusability</td>
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<tr>
<td>Reliability</td>
<td>Ease of integration</td>
</tr>
<tr>
<td>Usability</td>
<td>Understandability</td>
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Properties resulting from the properties of components, connectors and interfaces that exist at run time.

Properties resulting from the properties components, connectors and interfaces that exist at design time whether or not they have any distinct run-time manifestation.

Functionality, Architecture, and Quality Attributes

- Functionality and quality attributes are orthogonal
- Achieving quality attributes must be considered throughout design, implementation, and deployment
- Satisfactory results depends on:
  - Getting the big picture (architecture) right
  - Then getting the details (implementation) right
Example: Performance

- Ex: Performance depends on
  - How much inter-component communication is necessary (Arch)
  - What functionality has been allocated to each component (Arch)
  - How shared resources are allocated (Arch)
  - The choice of algorithms to implement functionality (Non-arch)
  - How algorithms are coded (Non-arch)

Product Development Cycle and Architecture

Goal: Keep architectural design decisions in sync with developmental goals
- ConOps <-> Req <-> Design
- Traceability to code
- Mechanisms for maintaining "intellectual control"

Software Engineering Architecture

- Goal is to keep developmental goals and architectural capabilities in sync
- Proceed from an understanding of desired qualities to an acceptable system design
  - Balance of stakeholder priorities and constraints
  - Requires making design tradeoffs
  - Documentation must communicate how this is accomplished
Implications for the Development Process

Implies need to address architectural concerns in the development process:
- Understanding the “business case” for the system
- Understanding the quality requirements
- Designing the architecture
  - Representing and communicating the architecture
  - Analyzing or evaluating the architecture
  - Implementing the system based on the architecture
- Ensuring the implementation conforms to the architecture

What is “design?”

Meaning of “Design”

- What does it mean to say that we are going to “design the software?”
- What is the basis for making a design decision?
- How do we know when we are done?
- If we did a good job? What makes a good design?
The Design Space

- A Design: is (a representation of) a solution to a problem
  - Represents a set of choices
  - Must navigate through possibilities
  - Invariably requires tradeoffs
  - Possible choices are limited by assumptions and constraints
  - Must be ISO 2000 compliant, legacy compatible, etc.
  - Some designs are better than others (notion of good design)

Problem Space

Possible Solutions

Good Solutions (designs)

Design Constraints

Our design

Design Means…

- Design Goals: the purpose of design is to solve some problem in a context of assumptions and constraints
  - Solution: acceptable balance of system qualities
  - Assumptions: what must be true of the design
  - Constraints: what should not be true
- Process: design proceeds through a sequence of decisions
  - A good decision brings us closer to the design goals
  - An idealized design process systematically makes good decisions
  - Any real design process is chaotic
- Good Design: by definition a good design is one that satisfies the design goals

Elements of Architectural Design

- Design goals
  - What are we trying to accomplish in the decomposition?
- Relevant Structure
  - How to we capture and communicate design decisions?
  - Which structures should we use?
- Decomposition principles
  - How do we distinguish good design decisions?
  - What decomposition (design) principles support the objectives?
- Evaluation criteria
  - How do I tell a good design from a bad one?
Which structures should we use?

- Choice of structure depends the specific design goals
  - Compare to architectural blueprints
- Choose minimal set of structures that
  - Make key design issues visible
  - Communicate key design decisions

<table>
<thead>
<tr>
<th>Structure</th>
<th>Components</th>
<th>Interfaces</th>
<th>Relationships</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calls/Structure</td>
<td>Programs (methods, services)</td>
<td>Program interface and parameter declarations</td>
<td>Schedules with parameters (A calls B)</td>
</tr>
<tr>
<td>Data Flow</td>
<td>Functional tasks</td>
<td>Data types or structures</td>
<td>Sends data to</td>
</tr>
<tr>
<td>Process</td>
<td>Sequential program (process, thread, task)</td>
<td>Scheduling and synchronization constraints</td>
<td>Runs concurrently, left, excludes, precedes</td>
</tr>
</tbody>
</table>

Some Key Architectural Structures

- Module Structure
  - Decomposition of the system into work assignments or information hiding modules
  - Most influential design time structure
    - Modifiability, work assignments, maintainability, reusability, understandability, etc.
- Uses Structure
  - Determine which modules may use one another’s services
  - Determines subsetability, ease of integration (e.g. for increments)
- Process Structure
  - Decomposition of the runtime code into threads of control
  - Determines potential concurrency, real-time behavior

Designing the Module Structure
Modularization

• For any large, complex system, must divide the coding into work assignments (WBS)
• Each work assignment is called a "module"
• Properties of a "good" module structure
  – Parts can be designed independently
  – Parts can be tested independently
  – Parts can be changed independently
  – Integration goes smoothly

Modularization Goals

• Reduces complexity, improves manageability
• Coding
  – Can write modules with little knowledge of other modules
  – Replace modules without reassembling the whole system
• Managerial
  – Allows concurrent development
  – Avoids "Mythical Man Month" effect ("adding people to a late software project makes it later")
• Flexibility/Maintainability
  – Anticipated changes affect only a small number of modules
  – Can calculate the impact and cost of change
• Review/communicate
  – Can understand or review the system one module at a time

Notional Modules

- Problem
- Interface
  - Encapsulated
- Interface
  - Encapsulated
- Interface
  - Encapsulated
- Interface
  - Encapsulated
What is a module?

- Concept due to David Parnas (conceptual basis for objects)
- A module is characterized by two things:
  - Its interface: services that the module provides to other parts of the systems
  - Its secrets: what the module hides (encapsulates). Design/implementation decisions that other parts of the system should not depend on
- Modules are abstract, design-time entities
  - Modules are "black boxes" – specifies the visible properties but not the implementation
  - May, or may not, directly correspond to programming components like classes/objects
    - E.g., one module may be implemented by several objects

A Simple Module

- A simple integer stack
  - push: push integer on stack top
  - pop: remove top element
  - top: get value of top element

What information is on the interface?
- What are the secrets?
- What information is missing?
- Why is this an abstraction?
Why these properties?

Module Implementer
- The specification tells me exactly what capabilities my module must provide to users
- I am free to implement it any way I want to
- I am free to change the implementation if needed as long as I don’t change the interface

Module User
- The specification tells me how to use the module’s services correctly
- I do not need to know anything about the implementation details to write my code
- If the implementation changes, my code stays the same

Key idea: the abstract interface specification defines a contract between a module’s developer and its users that allows each to proceed independently

Is a module a class/object?
- The programming language concepts of classes and objects are based on Parnas’ concept of modules
- To separate design-time concerns from coding issues, however, *they are not the same thing*
  - A module must be a work assignment at design time, does not dictate run-time structures
  - Coder free to implement with a different class structure as long as the interface capabilities are provided
  - Coder free to make changes as long as the interface does not change
- In simple cases, we will often implement each module as a class/object

Questions?