Introduction to Software Engineering

10. Software Architecture
Roadmap

> What is Software Architecture?
> Coupling and Cohesion
> Architectural styles:
  — Layered
  — Client-Server
  — Blackboard, Dataflow, ...
> Model-Driven Architecture
> UML diagrams for architectures
Sources

> *Objects, Components and Frameworks with UML*, D. D'Souza, A. Wills, Addison-Wesley, 1999
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What is Software Architecture?

A neat-looking drawing of some boxes, circles, and lines, laid out nicely in Powerpoint or Word, does not constitute an architecture.

— D’Souza & Wills
What is Software Architecture?

The architecture of a system consists of:

- the *structure(s) of its parts*
  - including design-time, test-time, and run-time hardware and software parts
- the *externally visible properties* of those parts
  - modules with interfaces, hardware units, objects
- the *relationships and constraints* between them

**in other words:**
The set of *design decisions* about any system (or subsystem) that keeps its implementors and maintainers from exercising “needless creativity”.
> Use a **3-tier client-server architecture**: all business logic must be in the middle tier, presentation and dialogue on the client, and data services on the server; that way you can scale the application server processing independently of persistent store.

> Use **Corba** for all distribution, using Corba event channels for notification and the Corba relationship service; do not use the Corba messaging service as it is not yet mature.
How Architecture Drives Implementation ...

> Use Collection Galore’s *collections* for representing any collections; by default use their List class, or document your reason otherwise.

> Use *Model-View-Controller* with an explicit ApplicationModel object to connect any UI to the business logic and objects.
Sub-systems, Modules and Components

> A **sub-system** is a system in its own right whose operation is *independent* of the services provided by other sub-systems.

> A **module** is a system component that *provides services* to other components but would not normally be considered as a separate system.

> A **component** is an *independently deliverable unit* of software that encapsulates its design and implementation and offers interfaces to the out-side, by which it may be composed with other components to form a larger whole.
Roadmap

What is Software Architecture?

Coupling and Cohesion

Architectural styles:
- Layered
- Client-Server
- Blackboard, Dataflow, ...

Model-Driven Architecture

UML diagrams for architectures
Cohesion is a measure of *how well the parts of a component “belong together”*.  

- Cohesion is *weak* if elements are bundled simply because they perform similar or related functions (e.g., `java.lang.Math`).  
- Cohesion is *strong* if all parts are needed for the functioning of other parts (e.g. `java.lang.String`).

— Strong cohesion *promotes maintainability* and adaptability by *limiting the scope of changes* to small numbers of components.

There are many definitions and interpretations of cohesion. *Most attempts to formally define it are inadequate!*
**Coupling** is a measure of the *strength of the interconnections* between system components.

> Coupling is **tight** between components if they depend heavily on one another, (e.g., there is a lot of communication between them).

> Coupling is **loose** if there are few dependencies between components.

— Loose coupling *promotes maintainability* and adaptability since *changes in one component are less likely to affect others.*
Tight Coupling

Subsystem A

Subsystem B

Subsystem C

Subsystem D

Shared data area
Loose Coupling

Subsystem A

A’s data

Subsystem B

B’s data

Subsystem A

D’s data

Subsystem A

C’s data
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Architectural Parallels

> Architects are the *technical interface* between the customer and the contractor building the system

> A bad architectural design for a building *cannot be rescued by good construction* — the same is true for software

> There are *specialized types* of building and software architects

> There are *schools or styles* of building and software architecture
An architectural style defines a family of systems in terms of a pattern of structural organization. More specifically, an architectural style defines a vocabulary of components and connector types, and a set of constraints on how they can be combined.

— Shaw and Garlan
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Layered Architectures

A **layered architecture** organises a system into a set of layers each of which provide a set of services to the layer “above”.

> Normally layers are *constrained* so elements only see
  — other elements in the same layer, or
  — elements of the layer below

> **Callbacks** may be used to communicate to higher layers

> Supports the *incremental development* of sub-systems in different layers.
  — When a layer interface changes, *only the adjacent layer is affected*
Version management system

- Version management
- Object management
- Database system
- Operating system
OSI reference model
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Client-Server Architectures

A client-server architecture distributes application logic and services respectively to a number of client and server sub-systems, each potentially running on a different machine and communicating through the network (e.g., by RPC).

**Advantages**

- *Distribution* of data is straightforward
- Makes effective use of networked systems. May require cheaper hardware
- Easy to add new servers or upgrade existing servers

**Disadvantages**

- No shared data model so sub-systems use different data organisation. Data interchange may be inefficient
- Redundant management in each server
- May require a central registry of names and services — it may be hard to find out what servers and services are available
Film and picture library

Client 1

Client 2

Client 3

Client 4

Wide area network

Video server

Music server

Photo server

Web server
Four-Tier Architectures

- Clients
  - Browser
  - Non-browser GUI

- Web server
  - Web Server
  - Servlet

- Business objects and components server
  - EJB Container
    - Enterprise JavaBean
  - Legacy Adaptor
    - Legacy System

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Blackboard Architectures

A blackboard architecture distributes application logic to a number of independent sub-systems, but manages all data in a single, shared repository (or “blackboard”).

**Advantages**

> Efficient way to share large amounts of data
> Sub-systems need not be concerned with how data is produced, backed up etc.
> Sharing model is published as the repository schema

**Disadvantages**

> Sub-systems must agree on a repository data model
> Data evolution is difficult and expensive
> No scope for specific management policies
> Difficult to distribute efficiently
CASE toolset architecture

Design editor

Code generator

Project repository

Design translator

Design analyzer

Report generator

Program editor

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In an event-driven architecture components perform services in reaction to external events generated by other components.

- In broadcast models an event is broadcast to all sub-systems. Any sub-system which can handle the event may do so.
- In interrupt-driven models real-time interrupts are detected by an interrupt handler and passed to some other component for processing.
Broadcast model

> Effective in *integrating sub-systems* on different computers in a network
> Can be implemented using a *publisher-subscriber* pattern:
  — Sub-systems register an interest in specific events
  — When these occur, control is transferred to the subscribed sub-systems
> *Control policy is not embedded* in the event and message handler. Sub-systems decide on events of interest to them
> However, sub-systems don’t know if or when an event will be handled
Selective Broadcasting

Subsystem 1

Subsystem 2

Subsystem 3

Subsystem 4

Event and message handler
Dataflow Models

In a dataflow architecture each component performs *functional transformations* on its inputs to produce outputs.

> Highly effective for *reducing latency* in parallel or distributed systems
  — No call/reply overhead
  — But, fast processes must wait for slower ones

> Not really suitable for *interactive systems*
  — Dataflows should be free of cycles
## Pipes and Filters

<table>
<thead>
<tr>
<th>Domain</th>
<th>Data source</th>
<th>Filter</th>
<th>Data sink</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unix</td>
<td>tar cf - .</td>
<td>gzip -9</td>
<td>rsh picasso dd</td>
</tr>
<tr>
<td>CGI</td>
<td>HTML Form</td>
<td>CGI Script</td>
<td>generated HTML page</td>
</tr>
</tbody>
</table>
Invoice Processing System

- **Invoices**
  - Read issued invoices

- **Payments**
  - Identify payments
  - Find payments due
  - Issue payment reminder

- **Receipts**
- **Reminders**

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Compilers as Dataflow Architectures

- Lexical analysis
- Syntactic analysis
- Semantic analysis
- Code generation

Symbol table
Compilers as Blackboard Architectures

- Lexical analysis
- Syntactic analysis
- Semantic analysis
- Abstract syntax tree
- Grammar definition
- Symbol table
- Output definition
- Repository
- Pretty printer
- Editor
- Optimizer
- Code generation
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The Vision of MDA

- software developer
- Platform Independent Model
- automatic translation

C. Atkinson, U Mannheim
MDA in a nutshell

- One unique Metametamodel (the MOF)
- An important library of compatible Metamodels, each defining a DSL
- Each of the models is defined in the language of its unique metamodel
The OMG/MDA Stack

The MOF

The UML metamodel ++

Some UML Models ++

Various usages of these models

"the real world"
Write Once, Run Anywhere
Model Once, Generate Anywhere

Multi-target code generation

PIM

Platform-Independent Model

etc.

data grid computing
pervasive computing
cluster computing

+ SVG, GML, Delphi, ASP, MySQL, PHP, etc.

CORBA
Java/EJB
C#/DotNet
Web/XML/SOAP

SMIL/Flash
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Decompose system into packages (containing any other UML element, incl. packages)
UML support: Deployment Diagram

Physical layout of run-time components on hardware nodes.

Figure 3-8. Deployment diagram (descriptor level)

Figure 3-9. Deployment diagram (instance level)
What you should know!

- How does software architecture constrain a system?
- How does choosing an architecture simplify design?
- What are coupling and cohesion?
- What is an architectural style?
- Why shouldn’t elements in a software layer “see” the layer above?
- What kinds of applications are suited to event-driven architectures?
Can you answer the following questions?

> What is meant by a “fat client” or a “thin client” in a 4-tier architecture?
> What kind of architectural styles are supported by the Java AWT? by RMI?
> How do callbacks reduce coupling between software layers?
> How would you implement a dataflow architecture in Java?
> Is it easier to understand a dataflow architecture or an event-driven one?
> What are the coupling and cohesion characteristics of each architectural style?
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