XVIII. Software Architectures

Software Architectures
Subsystems, Modules and Connectors
Pipes and Filters, Object-Oriented, Layered,
Event-Driven, Repository-Based Architectures
Client Server Architectures
Web-Based Software Architectures
Examples

Subsystems
- A subsystem is a component of a system or of another subsystem.
- Modules are atomic subsystems (which are not further decomposed into subsystems.)
- It's useful to subdivide a software system into subsystems
  - For better-managed software development;
  - For improved reuse potential (through components);
  - For improved portability (platform-specific code isolated to particular subsystems);
  - For easier maintenance.
- Each subsystem has a well-defined interface with respect to the rest of the system.

Components and Connectors
- The architecture shown in the previous slide is one example of a software architecture where the nodes represent subsystems or modules and the connectors between them describe "componentOf" relationships.
- There are many others kinds of connectors that can be used, such as:
  - Usage -- one component uses data defined in another component;
  - Calls -- one component calls methods defined in another component;
  - I/O -- the output of one component is fed as input to another;

Software Architectures
- A software architecture defines the components of a software system and how they use each other's functionality and data.
- An example of a software architecture is the client-server architecture. Such an architecture consists of servers, which support some kind of service, and clients which request and use server services.
- With a client-server architecture, an information system need not be seen as a monolithic program.
- Instead, input/output functions can be placed on clients, running on PCs and workstations;
- Data storage is treated as a server, implemented in terms of a DBMS such as DB2, Ingres, Sybase or Oracle and placed on a mainframe or minicomputer;
- Consistency checking is located with the server;
- Applications are located with clients;
- Thick servers offer a lot of functionality, thin ones little;
- Thick clients have their own services, thin ones get almost everything from servers.

The Software Bookshelf
It is useful to classify software architectures into classes of architectural styles.

For example, the client-server architecture discussed earlier is an architectural style.

The styles we’ll discuss below are as follows:
- Pipes and filters;
- Object-Orientation;
- Event-Based;
- Layered;
- Repository-Based;
- Client-Server;
- Three-Tier;
- …more…

### Pipes and Filters

Each component has inputs and outputs. A component reads streams of data on its inputs and produces data on its outputs, continuously as data are coming in.

Components compute by performing local transformations on their inputs to produce their outputs and are termed filters. The connectors of components transmit the outputs of one component to the inputs of another and are termed pipes.

Unix supports a linear pipe and filter architecture called pipeline.

### Pipes and Filters: Strengths and Weaknesses

#### Strengths
- Makes it easy to understand overall function of the system as a composition of filter functions
- Encourages reuse of filters
- Facilitates maintenance
- Facilitates deadlock and throughput analysis

#### Weaknesses
- Often leads to batch-type processing
- Not good for interactive applications where you often want to do incremental computations, e.g., incremental display updates
- Can’t coordinate stream inputs
- Data transmission critical for system performance

### Data Abstraction and Object-Orientation

Data structures and their associated operations are encapsulated in an abstract data type (ADT) or object. The components of a system are instances of an ADT and they interact through procedure (or method) calls.

An object is responsible for preserving the integrity of its data structures and also these data structures are hidden from other objects.

Objects may operate concurrently or not

### Data Abstraction: Strengths and Weaknesses

#### Strengths
- Possible to change implementation of an object without affecting its clients
- Encourages decomposition of a problem into a number of interacting components/agents
- Encourages software reuse

#### Weaknesses
- For an object to interact with another, it must know its identity (not so for pipe/filter architectures)
- When the methods of an object change, so must all other objects that use this object

**Client-Server Architecture a special case of the Data Abstraction Architecture**

### Event-Based Architectures

Instead of invoking a procedure directly, a component can announce one or more events (such as arrival of data or execution of an operation).

- On <event> if <condition> then <action>
- On arrive(D) if D < a or D ≥ b then print("out of bounds")

Such procedures are also called triggers, actors or event-condition-action rules

An advantage of event-based invocation is that it encourages reuse; a component can be introduced in a system simply by registering it for the events of that system

A drawback is that sometimes event-based systems become quite unpredictable and hard to control.
Layered Systems

- A layered system is organized hierarchically, each layer serving the layer above. In some systems, inner layers are hidden in all but the adjacent outer layer.
- Best examples of layered software systems are layered communication protocols.
- Layered systems support design based on increasing levels of abstraction. However, not all systems can be structured in a layered fashion.

Event-Based Architecture for Data Integration

- Interface library (services, events)
- Rules set
- Rule engine
- KB schemas

Repository-Based Architectures

- A repository architecture consists of a central data structure (often a database) and a collection of independent components which operate on the central data structure.
- Examples of repository architectures include blackboard architectures, where a blackboard serves as communication centre for a collection of knowledge sources, and database systems serving several applications.
- Repositories are very important for data integration, are being introduced in a variety of applications, including software development, CAD etc.

Other Software Architectures

- Table-Driven Interpreters -- each interpreter offers a “virtual machine” to high layers of interpreters; special case of the layered architecture.
- Distributed Processes -- program consists of distributed components organized into a static or dynamic configuration; this is a special case of the object-oriented architecture.
- Main Program/Subroutine -- FORTRAN-style architecture.
- State-Transition Architecture -- system structured in terms of states, state transitions; useful architecture for real-time systems.

Client Server Architectures

- A client server architecture consists of components which are service consumers (clients) and service providers (servers).
- Clients and servers may or may not be running on dedicated machines.
- Information exchange between clients and servers is done through messages.
- Service requests and responses are accomplished through one of the following protocols:
  - Remote Procedure Call (RPC) -- client invokes a remotely located procedure, which is executed and the results sent to the client; RPC is widely supported.
  - Remote Data Access (RDA) -- here the invoked procedure is a database query (say, in SQL) and the response is an often large set of data, supported by DBMS vendors.
  - Queued Message Processing -- here requests are queued and processed whenever possible.
### Three-Tier Client Server Architectures

- Used widely in industry

**E.g., architecture for a meeting scheduling system (MSS)**

### Many Possible Variations

**User** → **Processing** → **Data**

### Web-Based Software Architectures

- These are client server too, but they are based on WWW technologies.
- Such architectures are becoming very popular because of static HTML-based applications, but also dynamic ones, such as those that involve Ecommerce.
  - HTTP - HyperText transfer Protocol, used to transfer hypertext documents over the internet;
  - HTML - HyperText Markup Language, used to define hypertext documents;
  - CGI - Common Gateway Interface is a program (e.g., a unix shell script, or a perl script)
  - CGI scripts are programs that reside on a web server and are executed with a click to retrieve data, generate graphics etc.

### Static HTML-Based Architecture

- This architecture basically retrieves and displays HTML documents that reside on the web server site.

### Dynamic HTML-Based Architecture

- The CGI gateway serves as deamon which dispatches a request, dealt with by an application or a database server.
**Document Interchange Example: ANALYST**

*General Motors Dealer Review Advisor*

- Assists credit analysts in 230 GM Acceptance Corporation branch offices analyzing dealership operations in order to decide on credit applications.
- Offers many benefits, including faster reviews, reduced training of personnel and consistency in decision-making.
- Uses an expert system, integrated into vast, conventional data processing architecture.

**ANALYST Architecture at a GMAC Branch**

**ANALYST Architecture: Global GM Perspective**

**A Layered Architecture for the A-7E Aircraft**

**Notes on the A-7E Architecture**

- This is a "uses" architecture, i.e., shows which component uses resources in another component.
- Modules in the different components of the architecture:
  - Extended computer: virtual memory module, parallelism module, time module
  - Device interfaces: air data module, audible signal device module, Doppler radar set module...
  - Function driving module: flight information display module, panel module, ground test module, ...
  - Application data types: numeric, state transition data types
  - Data banker module: singular values module, complex event module, ...
  - Physical model: aircraft motion module, earth characteristics module, human factors module
  - Software utilities: powerup module

**Summary**

- Architectural system design addresses issues of hardware and software location, interconnectivity; also distribution of I/O processes, data stores and application processes.
- Architectural system design is the most important step of system design and can, literally, make or break an information system development project.
Additional Reading