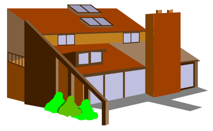
XIX. Software Architectures

Software Architectures
UML Packages
Client-Server vs Peer-to-Peer
Horizontal Layers and Vertical Partitions
3-Tier and 4-Tier Architectures
The Model-View-Controller Architecture
Broker Architectures for Distributed Systems

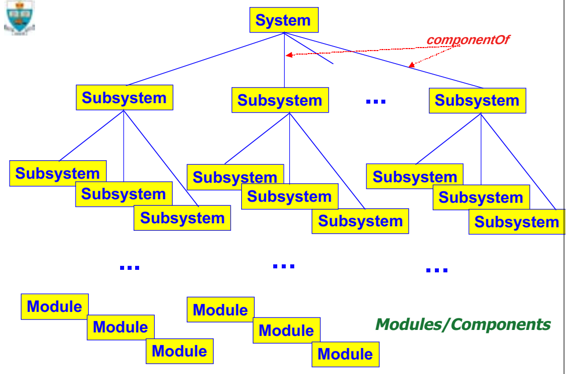


Software Architectures

- A software architecture defines the components of a software system and their inter-dependencies.
- For example, the ***client-server*** architecture consists of ***servers*** that support services, ***clients*** that use services.
- With such an architecture, I/O is placed on clients, running on PCs and workstations; data storage is assigned to a server, implemented in terms of a DBMS (e.g., DB2) and placed on a mainframe or mini. Consistency checking is located with the server, applications run on clients.
- ***Thick servers*** offer a lot of functionality, ***thin*** ones little.
- ***Thick clients*** have their own services, ***thin*** ones get almost everything from servers.

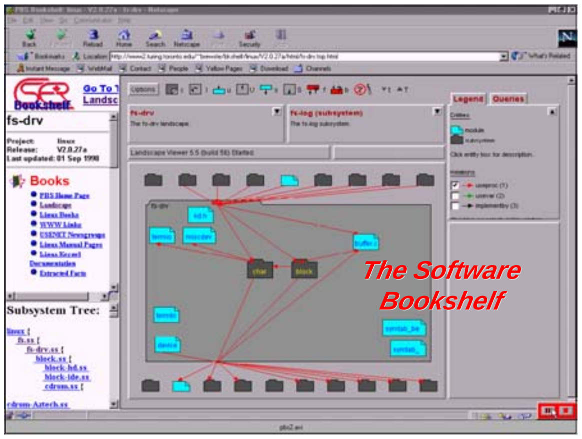
Subsystems

- A software ***subsystem*** is a component of a system or of another subsystem.
- ***Modules*** or ***components*** are atomic subsystems
- It's useful to subdivide software into subsystems
  - For better-managed software development;
  - For improved reuse (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 nodes represent subsystems/modules and the connectors represent *componentOf* relationships.
- There are many others kinds of connectors that can be used, such as:
  - ***Uses*** -- 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;



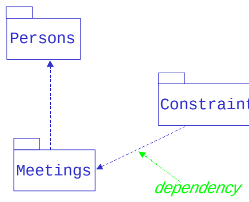
Architectural Styles

- It is useful to classify software architectures into classes of ***architectural styles***. For example, the client-server architecture discussed earlier is an architectural style.
- There are many architectural styles, e.g., pipes and filters, object-orientation, event-based, layered, repository-based, client-server, three-tier,...others…
- We discuss here some architectures that relate to object-oriented information systems.

Packages

- A package in UML is a grouping of elements which:
  - ✓ May be packages (e.g., subsystems or modules);
  - ✓ May be classes.
- Each element of a software architecture (subsystem, module or class) is owned by a single package.
- There are many criteria for decomposing a software system into packages:
  - ✓ Ownership -- who is responsible for what;
  - ✓ Application -- e.g., a university dept model may be partitioned into staff, courses, programmes,…
  - ✓ Clusters of classes used together, e.g., course, course description, instructor, student,…

A Package Diagram

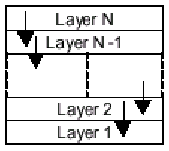


- A ***dependency*** means that if you change a class in one package (`Meetings`), you ***may*** have to change something in the other (`Constraints`).
- The concept is similar to compilation dependencies.
- It's desirable to minimize dependency cycles, if at all possible.

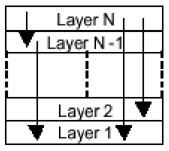
Decomposition into Subsystems

- A software system may be decomposed into ***horizontal layers***, and/or ***vertical partitions***.
- For a horizontal layer decomposition, each layer corresponds to one or more subsystems, and each layer uses services provided by the layers below it.
- Layered architectures have two forms:
  - ✓ ***closed architecture*** - each layer only uses services of the layer immediatebelow;
  - ✓ ***open architecture*** - a layer can use services from any lower layer.

Closed vs Open Layered Architecture



Closed architecture—messages may only be sent to the adjacent lower layer.



Open architecture—messages can be sent to any lower layer.

Closed vs Open Layered Architectures

- Closed layered architectures -- Minimize dependencies between layers and reduce the impact of a change to the interface of any one layer.
- Open layered architectures:
  - ✓ Lead to more compact code, since the services of all lower layers can be accessed directly without the need for extra program code to pass messages through each intervening layer;
  - ✓ Break the encapsulation of layers, increase dependencies between layers and increase the complexity of changes to the system.

Client Server Architectures

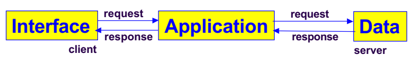
- A client server architecture consists of **service consumers** (clients) and **service providers** (servers). Clients and servers may or may not be running on dedicated machines.
- Information exchange between clients and servers is done through messages.
- Server establishes connection with each client (possibly several), accepts messages from connected clients and responds to each.

Protocols for Communication

- Service requests and responses are accomplished through one of the following standard protocols:
  - ✓ **Remote Procedure Call (RPC)** -- invoke remote procedure, results sent; RPC is widely supported;
  - ✓ **Remote Data Access (RDA)** -- invoked procedure is a database query; supported by DBMS vendors;
  - ✓ **Queued Message Processing** -- requests queued.

Three-Tier Architectures

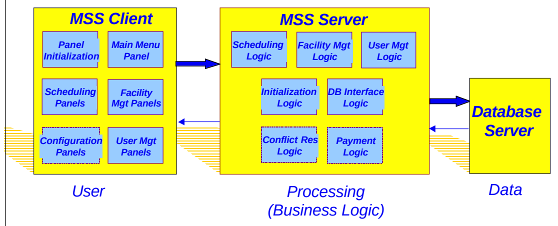
- Used widely in industry



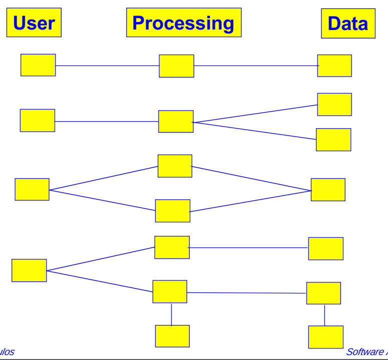
- Application layer may be placed with client (fat client) or the server (fat server), or split between them.
- For example, constraint checking may be done on the server side, other applications are run on the client side.

Example Three-Tier Architecture

- An architecture for a meeting scheduling system (MSS)



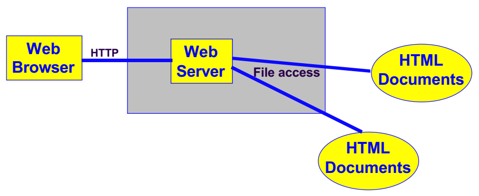
Many Possible Variations



Web-Based Software Architectures

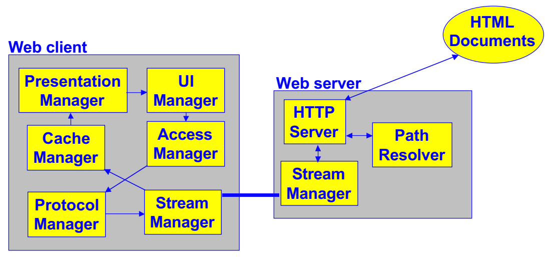
- These are client-server, based on WWW technologies.
- Elements of WWW technologies:
  - ✓ HTTP -- **HyperText Transfer Protocol**, used to transfer hypertext documents over the internet;
  - ✓ HTML -- **HyperText Markup Language**, used to define hypertext documents;
  - ✓ CGI -- **Common Gateway Interface** 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



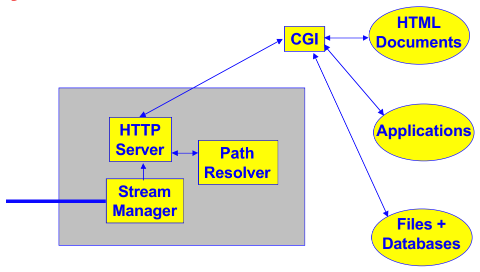
- This architecture basically retrieves and displays HTML documents that reside on the web server site.

More Detailed Static Architecture



- Arrows indicate data and/or control flow.

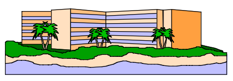
Dynamic HTML-Based Architecture



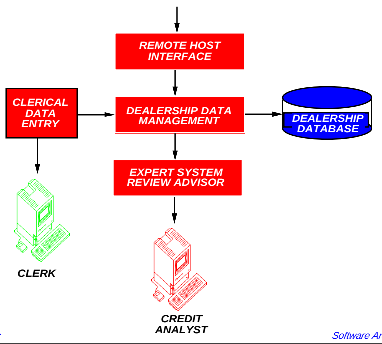
- The CGI gateway serves as demon which dispatches a request, dealt with by an application or a database server.

System Architecture Example

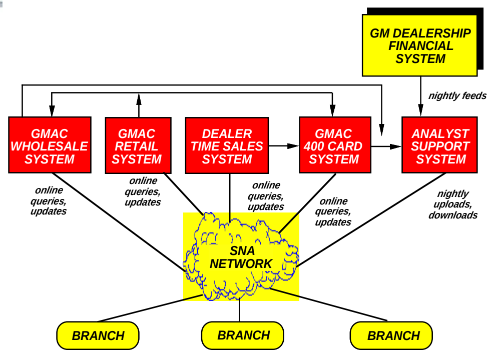
- ANALYST, General Motors Dealer Review Advisor.
- Assists credit analysts in 230 GM Acceptance Corporation branch offices analyzing dealership operations in order to decide on credit applications.
- Offers many benefits, including faster reviews, reduced training of personnel and consistency in decision-making.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



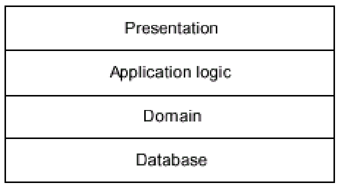
ANALYST Local Architecture



ANALYST Global Architecture



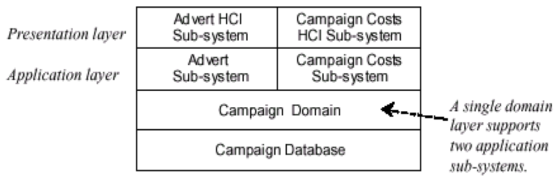
Four-Layer Architectures for Information Systems



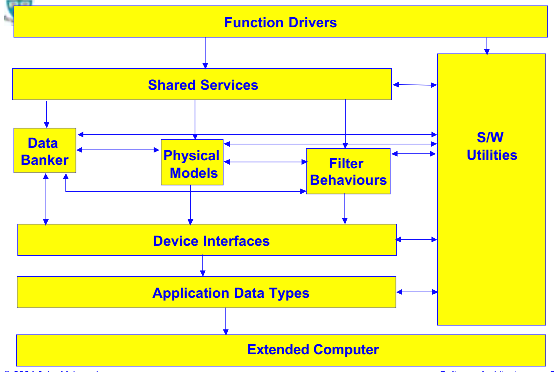
This is a variation of the 3-tier architecture we discussed earlier

Vertical Partitioning

- *Partition each layer into subsystems.*
- *Partitioning identifies **weakly coupled** subsystems within a layer.*
- *Each partition provides a self-contained service.*


Presentation layer
Application layer
Advert HCI Sub-system
Campaign Costs HCI Sub-system
Advert Sub-system
Campaign Costs Sub-system
Campaign Domain
Campaign Database
A single domain layer supports two application sub-systems.

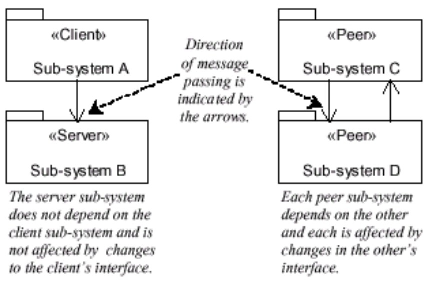
Architecture for the A-7E Aircraft



Notes on the A-7E Architecture

- *This is a "uses" architecture.*
- *Modules in different components of the architecture:*
  - ✓*Extended computer: virtual mem, parallelism, timer;*
  - ✓*Device interfaces: air data, audible signal device, Doppler radar set,…;*
  - ✓ *Function driving: flight information display, panel, ground test,…;*
  - ✓ *Application data types: numeric, state transition,…;*
  - ✓ *Data banker: singular values, complex event,…;*
  - ✓ *Physical model: aircraft motion, earth characteristics, human factors;*
  - ✓ *Software utilities: powerup,….*

Styles of Communication: Client-Server vs Peer-to-Peer


«Client»
Sub-system A
«Server»
Sub-system B
Direction of message passing is indicated by the arrows.
«Peer»
Sub-system C
«Peer»
Sub-system D
The server sub-system does not depend on the client sub-system and is not affected by changes to the client's interface.
Each peer sub-system depends on the other and each is affected by changes in the other's interface.

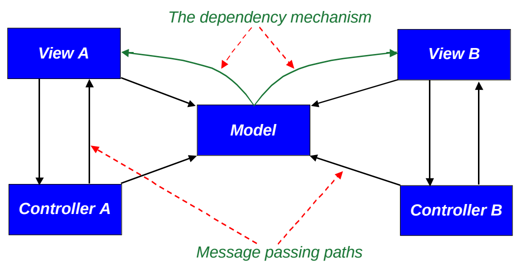
The Model View Controller (MVC) Architecture

- *First used with Smalltalk but has since become widely used as an architecture for object-oriented software.*
- *Capable of supporting user requirements that are presented through differing interface styles.*
- *Aids modifiability and portability. In particular, allows one to change the functionality related to one class (e.g., Courses), without changing others (e.g., DegreeProgrammes.) Also, makes it easier to port a system to different I/O devices.*
- *This architecture is best suited for software systems where user interfaces play an important role.*

The MVC Architecture

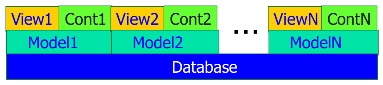
- Consists of subsystems classified into one of:
  - ✓ ***Model*** -- provides main functionality of application, is aware of dependent view and controller components.
  - ✓ ***View*** -- supports a particular style and format of presentation (output) of information to the user: Retrieves data from model and updates its presentations when data has been changed in one of the other views; creates its own controller;
  - ✓ ***Controller*** -- accepts user input in the form of events that trigger execution of operations within the model; these may cause model changes, and may trigger updates in all views to keep them up to date.
- ***Dependency Mechanism***: informs each view that the model data has changed, view must update itself.

Model View Controller (MVC)

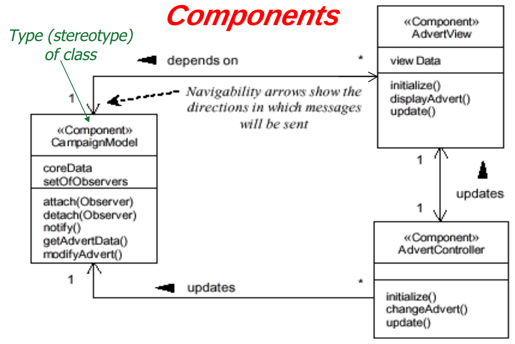


MVC as a Layered Architecture

- You can think of MVC architectures as a refinement of the presentation and application tiers of a 3-tier architecture.



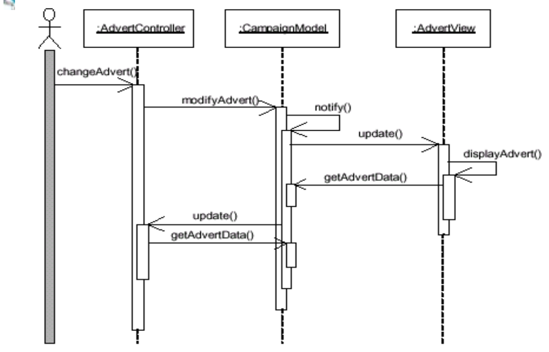
Responsibilities of MVC Components



Notes on MVC

- The operation *update()* in *AdvertView* and *AdvertController* trigger these components to request data from *CampaignModel*, which has no knowledge of how this information will be used.
- The *attach()* and *detach()* operations allow views and controllers to be added to/removed from *setOfObservers*.
- The *notify()* operation of a model causes all associated views and controllers to be updated.

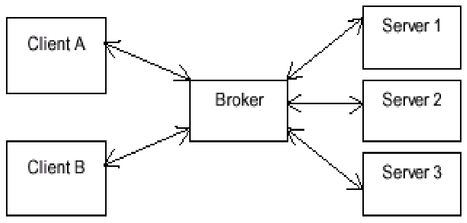
MVC Component Interaction



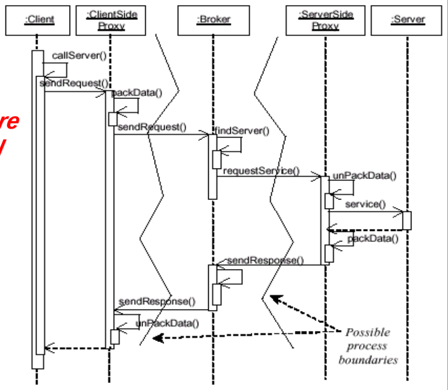
Broker Architectures for Distributed Systems

- A broker increases the flexibility of the system by decoupling the client and server components:
  - ✓ Each client sends its requests to the broker rather than communicating directly with the server component;
  - ✓ The broker then forwards the service request to an appropriate server.
- The client need not know where the server is locate (it may be in local or remote computer.)
- Only the broker needs to know the location of the servers that it handles.

Simplified Broker Architecture



Broker Architecture for Local Server



Proxies

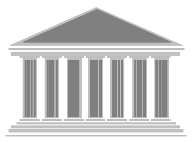
- Some classes (e.g., model classes like *Advert* and *Customer*) are “heavy-weight” in the sense that to create an instance, we need to access a database (…very expensive!).
- We would like to avoid creating instances of heavy-weight classes for as long as possible.
- A **proxy class** is associated to a heavy-weight class and has the same interface (allowable operations.)
- Proxy objects are created as needed and act like placeholders. When someone tries to operate on one e.g., access one of its attributes), the corresponding heavy-weight object is created.

Threading and Concurrency

- Each independent flow of control can be modelled as an active object that represents a process or thread that can initiate control activity.
  - ✓ A **process** is a heavyweight flow (known to the operating systems itself) that can execute concurrently with other processes
  - ✓ A **thread** is a lightweight flow that can execute concurrently with other threads within the same process.
- Dynamic design identifies concurrent system parts:
  - ✓ Sequence diagrams imply sequential threads;
  - ✓ State/activity diagrams model concurrent execution.

Summary

- Architectural **software** design focuses on the main components of a software system and how they inter-relate.
- Architectural software design is an important phase of the software development process, and can -- literally -- make or break a development project.



Additional Readings

- *[Booch99] Booch, G. Rumbaugh, J., Jacobson, I., The Unified Modeling Language User Guide. Chapter 22. Addison-Wesley.*
- *[Rumbaugh91] Rumbaugh, J et al. Object-Oriented Modeling and Design. Chapter 9, Prentice-Hall.*