Last Class

- 3-tier model common.
- Sun’s version of 4-tier model not-common.
- N-tier model where Webserver and Application Server on separate equipment also common.
- Sun’s hardware business not strong.
  - Linux on cheap PCs most common servers
  - Microsoft desktops replacing Sun workstations
Last Class

- **Java**
  - Common in Server implementations
    - Example: Java Servlet implementing application logic in a banking application.
  - Often used to push simple applets onto client
  - Not common
    - For “big” desktop applications
    - Office Suite in Java not popular
  - *Microsoft is still in business...*
What could have Sun done?

- Compete on price with cheap PC servers running Linux?
- Sell a fat-client workstation that runs Windows and is price competitive with Dell, HP PCs, etc...
- Sell workstations at a price premium over PCs, focus on software reliability, run some Microsoft application, build brand cachet.
- Focus on Java based software and IT services for enterprises, withdraw from low-end hardware...
- Something else?
Architecture Example
Conceptualization

What is it you are trying to do?

Example Concept:

Small HHC for flight attendants.

HHC tells flight attendants which passengers are higher priority.

- Who paid the highest fares
- Who has been a more valuable customer in past

Flight attendant discriminates based on this

- Free drinks, meals, and pillows to valuable customers
- Ignore less valuable customers
Example Concept:
Architecture

- How do you begin to architect a solution for a problem like this?

- Break it into modules!
Architecture

HEADQUARTERS

Airline Dataserver

Airline Intranet

HHC Server

Wireless Link

HHC
HHC Architecture

When a module is composed of sub-modules, the architecture is **hierarchical**.
We are using a *layered architecture* as well.

- Allows reuse of previously built infrastructure.
Granularity tradeoff.

- How big should we make the modules
  - Many simple small ones
  - Or a few complicated big ones...

- This aspect of modularity is called **granularity**.

- Which is better?
HHC Server

- Again, we see layering and hierarchy.
- Between each module we specify an **interface**
Our architecture makes use of the existing interface of the airline database, so we don’t need to redesign it!
A simple interface: from within our HHC Server Architecture

Computation of key statistics

List of numbers

Compute Mean and Variance

Mean, Variance

HHC Application

Palm OS

Networking Infrastructure

Communication with HHC

Computation of key statistics

Communication with airline database
Interfaces

Interface specifications are often made precise by using **data types**.

- **Example type: float**
  - A number with a decimal place
  - Has a certain allowable range, and precision.
More on Data types

- Data passing an interface is often specified in terms of a limited number of standard data types.

- Data type = range of values and allowable manipulation.

- Data type does not presume a specific representation, to allow heterogeneous platforms.
  - Representation must be known when data passes a specific module interface.
Example data types

**Integer**
- “natural number between -32,767 and +32,768”
- Could be represented (in many ways) by 16 bits
  - since \(2^n = 65,536\)

**Float**
- “number of the form \(m \times 10^n/32768\), where \(m\) is in the range -32,767 to +32,768 and \(n\) is in the range -255 to +256”
- Could be represented by 16+8 = 24 bits
More data types

**Character**

- “values assuming a-z and A-Z plus space and punctuation marks”
  - could be represented by 7 or 8 bits

**Character string**

- “collection of $n$ characters, where $n$ is customizable”
  - could be represented by $7^\ast n$ bits
Compound data types

Programmer-defined composition of basic data types
Example:
Employee {
    String name;
    String address;
    Integer year_of_birth;
    etc.
}
Interfaces

PARAMETERS

N numbers of Float type

INTERFACE

Compute Mean and Variance

RETURNS

2 Numbers of float type that signify: Mean, Variance

Computation of key statistics
Implementation

Computation of key statistics

Module A

Module B

Compute Mean and Variance

Implementation 1:

\[ \text{MEAN} = \frac{1}{N} \sum_{i=1}^{N} x_i \]

\[ \text{VARIANCE} = \sum_{i=1}^{N} (x_i - \text{MEAN})^2 \]

- One module should not be concerned with other module's implementation
  - “Separation of concerns.”
- One module should see the other only through its interface - implementation details hidden.
  - Abstraction
Implementation

Computation of key statistics

Module A

Module B

Compute Mean and Variance

Implementation 2:

\[ \text{SUM} = \sum_{i=1}^{N} x_i \]

\[ \text{MEAN} = \frac{\text{SUM}}{N} \]

\[ \text{VARIANCE} = \sum_{i=1}^{N} (x_i - \text{MEAN})^2 \]

- Though different, this implementation is ok too.

- We can choose the implementation details however we want, as long as we comply with the agreed interface.
Implementation

Module A

Computation of key statistics

Module B

Compute Mean and Variance

Implementation 1:

\[
\text{SUM} = \sum_{i=1}^{N} x_i \\
\text{MEAN} = \frac{\text{SUM}}{N} \\
\text{VARIANCE} = \sum_{i=1}^{N} (x_i - \text{MEAN})^2
\]

“\text{I need to get the sum, I’ll just take it from B}”

- Should he use it?
  - NO!! Why??

- Either A should compute “SUM” himself, or sit down with B and redesign the interface
Encapsulation

- The designer of B might take measures to hide “SUM” from A so that A is not able to violate the agreed interface.

  - Example: B does not declare “SUM” as a global variable.

- Making a modules implementation details inaccessible to other modules is called **encapsulation**.
This simple interface example allows for only one action of module B.

- Action is “Compute mean and variance.”

Other examples are possible.
Possible software interface

Menu of actions

Example:

Action 1: Compute mean
Action 2: Compute variance
Action 3: Compute mode
Etc..
In addition to atomic actions, an interface may define protocols

- Protocol == finite sequence of actions required to achieve a higher level function

- One action can be shared by multiple protocols

- Multiple modules may participate in a protocol
Protocol Example

Hello: I’m the HHC of Airplane#1234
Hello: I’m the gate 32 server
These were the unruly passengers on last flight
“Passengers noted”

Tell me about the passengers of my next flight
Return Passenger Data

Tell me about the weather at my next destination.
Return Weather Data

(Might be passed As an array of a compound data type “passenger,” which in turn is composed of standard types like integer, and string)
Another Interface Example:
Automatic teller machine (ATM)

What is the interface between this machine and the customer?
Steps

Define available actions
Define, for each higher level function, a protocol

- Single action or a finite sequence of actions
Interface building blocks

Message on screen or printed
- Menu of actions or returns from an action
- Touch selection of action

Keypad
- Input parameters to an action

Card reader
- Authentication, input parameters

Money output slot
- Returns money
Action: authentication

Parameters
Internal functionality
Returns
Action: authentication

Parameters

- Identity (card in slot)
- Institution (card in slot)
- PIN (typed on keypad)

Internally, it contacts institution and matches against its database, institution noted for all subsequent actions (example of state)

Returns

- Screen message ("Invalid PIN" or menu of available actions)
Action: specify_account

Parameters
Internal functionality
Returns
Action: specify_account

Parameters

- Account (touch screen from menu of choices)

Internally, choice noted for all subsequent actions (another example of state)

Returns

- None
Action: amount

Parameters

- Dollars_and_cents (typed on keypad)

Internally, amount noted (another example of state)

Returns

- Success or failure (state dependent, for example for a withdraw failure when dollars_and_cents exceeds balance)
Protocol: cash_withdrawal

What is the sequence of actions?
Protocol: cash_withdrawal

1. Authentication
   - Failure

2. Choose objective
   - Other objectives

3. Account
   - No accounts

4. Amount
   - Balance exceeded!
More on layering

by
David G. Messerschmitt
Goals

Understand better

- how layering is used in the infrastructure
- how it contains complexity
- how it coordinates suppliers
- how it allows new capabilities to be added incrementally
Interaction of layers

Layer above is a client of the layer below

Each layer provides services to the layer above ....

....by utilizing the services of the layer below and adding capability

Layer below as a server to the layer above
Layering builds capability incrementally by adding to what exists.
Three types of software

Application

• Components and frameworks:

What is in common among applications

• Infrastructure:

Basic services (communication, storage, concurrency, presentation, etc.)
Part of Microsoft vs. DOJ dispute

Microsoft position

DOJ position

Application

Components and frameworks

Infrastructure
Major layers

- Network
- Operating system
- Middleware
- Application frameworks and components
- Applications
Data and information

Application
Deals with information

Assumes structure and interpretation

Infrastructure
Deals with data

Ignores structure and interpretation
The infrastructure should deal with data, or at most minimal structure and interpretation.

The application adds additional structure and interpretation.

This yields a separation of concerns.

Data and information in layers
Package = file, message

In the simplest case, the infrastructure deals with a package of data (non-standard terminology)

- collection of bits
- specified number and ordering

The objective of the infrastructure is to store and communicate packages while maintaining data integrity

File for storage, message for communication
Data integrity

Retain the

- values
- order
- number

of bits in a package
Example 1

Bob sends a letter to Alice

Bob

Envelope

US Postal Service

Shipping Container

US Postal Service

ABC Airlines

UK Royal Mail

Shipping Container

Envelope

Alice

Example 2

Web server → Web page → Web browser

Application

Operating system

Network

File system

File

Message

Fragmentation → Collection of packets → Assembly

HTML

Screen

Message
Example 3

HHC Server Application

Windows OS

Networking Infrastructure (Contains: TCP/IP, WiFi)

Passenger Information

HHC Client Application

Palm OS

Networking Infrastructure (Contains: TCP/IP, WiFi)

Collection of Packets
Example 3: Network Infrastructure Expanded

HHC Server Application

message

Windows OS

TCP transport layer

WiFi Link Layer

WiFi Physical Layer

Networking Infrastructure

Passenger Information

HHC Client Application

message

Palm OS

TCP transport layer

WiFi Link Layer

WiFi Physical Layer

Networking Infrastructure

Radio Signals

Packets

Packets
Example 4

HHC Server Application

Windows OS

Networking Infrastructure Layers within TCP/IP, WiFi

“Send me today’s flight information”

DBMS

Unix OS

Networking Infrastructure Layers within: TCP/IP, WiFi
Information in the infrastructure

Sometimes it is appropriate for the infrastructure to assume structure and interpretation for data

- to add capabilities widely useful to applications
- to help applications deal with heterogeneous platforms, where representations differ

At most, data types
Data and information

Application
Deals with information

Assumes structure and interpretation

Assumes standard data types

Infrastructure
Deals with data types