Replication of information requires knowledge of representation

Implications

Digitally represented information can be preserved over time or distance in its precise original form by occasional regeneration

- digital library
- digital telephony

Replication of data is easy and cheap

Implications (con’t)

- Replication of information requires knowledge of the structure and interpretation
  - Standardization or some other means
- Extreme supply economies of scale
- You can give away or sell and still retain
- Unauthorized replication or piracy relatively easy

Architecture

by

David G. Messerschmitt
What is Architecture?

How do you architect a solution?

Three elements of architecture

Decomposition
Organization
Functionality
Responsibility
Interaction
Cooperation

System examples

Let’s quickly look at some system decomposition examples
- Quick tour of information technology systems

Time sharing

Point-to-point wire
(no network)

ASCII terminal
(no graphics)

Mainframe
(database and application server)
Two-tier client/server

Three-tier client/server

System integration

1. Architecture
2. subsystem implementation
3. system integration
   Bring together subsystems and make them achieve desired system functionality
   - Testing
   - Modifications often needed

Emergence

Subsystems are
- specialized
- have simple functionality

Higher-level system functionality arises from the interaction of subsystems
Called: Emergence

e.g. airplane flies, but subsystems can’t

Why system decomposition?

- Divide and conquer approach to containing complexity
- Reuse
- Consonant with industry structure (unless system is to be supplied by one company)
- Others?

Networked computing infrastructure

by

David G. Messerschmitt
Layering

Elaboration or specialization

Services

Existing layers

Example of Layering: networking

Application

Messages

Transport

Packets

Network

Frames

Link

Bits

Physical

Software Layering

Application

Middleware

Operating System

Operating system functions

- Graphical user interface (client only)
- Hide details of equipment from the application
- Multitasking
- Resource management
  - Processing, memory, storage, etc
  - etc

Middleware Functions

- Capabilities that can be shared by many applications, but that is not part of OS
  - Example: Database Management System (DBMS)
- Hide details of OS from application
  - Java Virtual Machine
- More purposes we’ll talk about later.

What’s a database?

Database

- File with specified structure
- Example: relational table
### A Database

<table>
<thead>
<tr>
<th>Year</th>
<th>City</th>
<th>Accommodation</th>
<th>Tourists</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>Oakley</td>
<td>Bed&amp;Breakfast</td>
<td>14</td>
</tr>
<tr>
<td>2002</td>
<td>Oakley</td>
<td>Resort</td>
<td>350</td>
</tr>
<tr>
<td>2002</td>
<td>Oakland</td>
<td>Bed&amp;Breakfast</td>
<td>34</td>
</tr>
<tr>
<td>2002</td>
<td>Berkeley</td>
<td>Camping</td>
<td>120000</td>
</tr>
<tr>
<td>2002</td>
<td>Berkeley</td>
<td>Resort</td>
<td>340</td>
</tr>
<tr>
<td>2002</td>
<td>Albany</td>
<td>Camping</td>
<td>8790</td>
</tr>
<tr>
<td>2002</td>
<td>Albany</td>
<td>Bed&amp;Breakfast</td>
<td>3240</td>
</tr>
<tr>
<td>2002</td>
<td>Albany</td>
<td>Resort</td>
<td>215</td>
</tr>
<tr>
<td>2002</td>
<td>Oakland</td>
<td>Camping</td>
<td>100000</td>
</tr>
<tr>
<td>2002</td>
<td>Oakland</td>
<td>Resort</td>
<td>230</td>
</tr>
<tr>
<td>2002</td>
<td>Berkeley</td>
<td>Camping</td>
<td>115800</td>
</tr>
<tr>
<td>2002</td>
<td>Berkeley</td>
<td>Resort</td>
<td>390800</td>
</tr>
<tr>
<td>2003</td>
<td>Albany</td>
<td>Camping</td>
<td>8790</td>
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<tr>
<td>2003</td>
<td>Albany</td>
<td>Bed&amp;Breakfast</td>
<td>6750</td>
</tr>
<tr>
<td>2003</td>
<td>Berkeley</td>
<td>Bed&amp;Breakfast</td>
<td>3450</td>
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<tr>
<td>2003</td>
<td>Berkeley</td>
<td>Resort</td>
<td>419000</td>
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<tr>
<td>2003</td>
<td>Albany</td>
<td>Camping</td>
<td>7650</td>
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<tr>
<td>2003</td>
<td>Albany</td>
<td>Bed&amp;Breakfast</td>
<td>6750</td>
</tr>
</tbody>
</table>

### Storage Middleware example: DBMS

- **Database Management System (DBMS)**
  - Manage Multiple databases
  - Allow multiple applications to access common databases
  - Implement standard data “lookup” (query) functions.

### Client Server Example

**Client**

```
Client
```

**Server**

```
Server
```

```
<html><head><meta http-equiv="content-type" content="text/html; charset=UTF-8"><title>Google</title><style><!--body,td,a,p,.h{font-family:arial,sans-serif;}.h{font-size: 20px;}.q{color:#0000cc;}//-->…
```

```
Client Server Example – Layers Revealed
```

**Client**

```
Client
```

**Application Server**

```
Application Server
```

```
Clicks, keystrokes
```

```
What is Bob’s balance?
```

```
Balance $0.50
```

```
Shared data
```

```
What is Bob’s balance?
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$0.50
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