CS 160: User Interface Design

Result of HCI research:


http://www.omnigroup.com/products/omnigraphsketcher/videos/
Prototype Feedback

Pick up your group’s stack of feedback forms at the end of class!
### Topics

**Visualization**

- Why do we create visualizations?
- Data and image
- Estimating magnitude
- Deconstructions

**Design Patterns**
Why Do We Create Visualizations?
What is Visualization?

Definition [www.oed.com]

1. The action or fact of visualizing; the power or process of forming a mental picture or vision of something not actually present to the sight; a picture thus formed.

2. The action or process of rendering visible.
Examples
Why Do We Create Visualizations?
# Three Primary Functions

**Record information**
- Photographs, blueprints, ...

**Support reasoning about information (analyze)**
- Process and calculate
- Reason about data
- Feedback and interaction

**Convey information to others (present)**
- Share and persuade
- Collaborate and revise
- Emphasize important aspects of data
Record Information
Galileo’s drawings of the phases of the moon from 1616
http://galileo.rice.edu/sci/observations/moon.html
Gallop, Bay Horse “Daisy” [Muybridge 1884-86]
Other Recording Instruments

Marey’s sphygmograph [from Braun 83]
Support Reasoning
In 1864 John Snow plotted the position of each cholera case on a map. [from Tufte 83]
Data in Context: Cholera Outbreak

Used map to hypothesize that pump on Broad St. was the cause. [from Tufte 83]
## HISTORY OF O-RING DAMAGE ON SRM FIELD JOINTS

### Cross Sectional View

<table>
<thead>
<tr>
<th>SRM No.</th>
<th>Depth (in)</th>
<th>Affected Dia. (in)</th>
<th>Nominal Dia. (in)</th>
<th>Length of Heat Erosion (in)</th>
<th>Total Heat Affected Length (in)</th>
<th>Clocking Location (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>61A LH Center Field**</td>
<td>0.006</td>
<td>0.260</td>
<td>0.300</td>
<td>2.05</td>
<td>6.00</td>
<td>180</td>
</tr>
<tr>
<td>61A LH Forward Field</td>
<td>0.010</td>
<td>0.260</td>
<td>0.300</td>
<td>2.05</td>
<td>6.00</td>
<td>180</td>
</tr>
<tr>
<td>61B LH Center Field (prim)**</td>
<td>0.008</td>
<td>0.260</td>
<td>0.300</td>
<td>2.05</td>
<td>6.00</td>
<td>180</td>
</tr>
<tr>
<td>61B LH Center Field (sec)**</td>
<td>0.008</td>
<td>0.260</td>
<td>0.300</td>
<td>2.05</td>
<td>6.00</td>
<td>180</td>
</tr>
<tr>
<td>410 RH Forward Field</td>
<td>0.020</td>
<td>0.260</td>
<td>0.300</td>
<td>3.00</td>
<td>9.00</td>
<td>180</td>
</tr>
<tr>
<td>410 RH Alt Field</td>
<td>0.020</td>
<td>0.260</td>
<td>0.300</td>
<td>3.00</td>
<td>9.00</td>
<td>180</td>
</tr>
<tr>
<td>410 RH Forward Field</td>
<td>0.020</td>
<td>0.260</td>
<td>0.300</td>
<td>3.00</td>
<td>9.00</td>
<td>180</td>
</tr>
<tr>
<td>STS-2 RH Alt Field</td>
<td>0.053</td>
<td>0.260</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>90</td>
</tr>
</tbody>
</table>

*Not gas path detected in putty. Indication of heat on O-ring, but no damage.*

**Soot behind primary O-ring.

***Soot behind primary O-ring, heat affected secondary O-ring.

Clocking location of leak check port = 0 deg.

### OTHER SRM-15 FIELD JOINTS HAD NO BLOOMHOLE IN PUTTY AND NO SOOT NEAR OR BEYOND THE PRIMARY O-RING.

### SRM-22 FORWARD FIELD JOINT HAD PUTTY PATH TO PRIMARY O-RING, BUT NO O-RING EROSION AND NO SOOT BLOOMBY. OTHER SRM-22 FIELD JOINTS HAD NO BLOOMHOLES IN PUTTY.

---

### Blow By History

**SRM-15**

- **Worst Blow-By**
  - 2 Case Joints (30°), (110°) Arc
  - Much worse visually than SRM-22

**SRM-12**

- **Blow-By**
  - 2 CASE JOINTS (30-45°)

**SRM-17A, 15, 16A, 18, 23A, 24A**

- **Nozzle Blow-By**

### HISTORY OF O-RING TEMPERATURES (DEGREES F)

<table>
<thead>
<tr>
<th>MOTOR</th>
<th>MAT</th>
<th>AMB</th>
<th>O-RING</th>
<th>WIND</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM-1</td>
<td>68</td>
<td>36</td>
<td>47</td>
<td>10 MPH</td>
</tr>
<tr>
<td>DM-2</td>
<td>76</td>
<td>45</td>
<td>52</td>
<td>10 MPH</td>
</tr>
<tr>
<td>GM-3</td>
<td>72.5</td>
<td>40</td>
<td>48</td>
<td>10 MPH</td>
</tr>
<tr>
<td>GM-4</td>
<td>76</td>
<td>48</td>
<td>51</td>
<td>10 MPH</td>
</tr>
<tr>
<td>SRM-15</td>
<td>52</td>
<td>44</td>
<td>53</td>
<td>10 MPH</td>
</tr>
<tr>
<td>SRM-22</td>
<td>77</td>
<td>78</td>
<td>75</td>
<td>10 MPH</td>
</tr>
<tr>
<td>SRM-25</td>
<td>55</td>
<td>26</td>
<td>29</td>
<td>10 MPH</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>27</td>
<td>20 MPH</td>
</tr>
</tbody>
</table>
Make a Decision: Challenger

Visualizations by booster rocket manufacturer of damage to O-rings [Tufte 97]
Make a Decision: Challenger

Visualizations drawn by Tufte show how low temperatures damage O-rings [Tufte 97]
Convey Information to Others
Present Argument: Exports & Imports

Exports and Imports to and from Denmark & Norway from 1700 to 1780.

[Playfair 1786]
Tell Story: Most Powerful Brain?

<table>
<thead>
<tr>
<th>ID</th>
<th>Name</th>
<th>Body Weight</th>
<th>Brain Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lesser Short-tailed Shrew</td>
<td>5</td>
<td>0.14</td>
</tr>
<tr>
<td>2</td>
<td>Little Brown Bat</td>
<td>10</td>
<td>0.25</td>
</tr>
<tr>
<td>3</td>
<td>Mouse</td>
<td>23</td>
<td>0.3</td>
</tr>
<tr>
<td>4</td>
<td>Big Brown Bat</td>
<td>23</td>
<td>0.4</td>
</tr>
<tr>
<td>5</td>
<td>Musk Shrew</td>
<td>48</td>
<td>0.33</td>
</tr>
<tr>
<td>6</td>
<td>Star Nosed Mole</td>
<td>60</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Eastern American Mole</td>
<td>75</td>
<td>1.2</td>
</tr>
<tr>
<td>8</td>
<td>Ground Squirrel</td>
<td>101</td>
<td>4</td>
</tr>
<tr>
<td>9</td>
<td>Tree Shrew</td>
<td>104</td>
<td>2.5</td>
</tr>
<tr>
<td>10</td>
<td>Golden Hamster</td>
<td>120</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>Mole Rate</td>
<td>122</td>
<td>3</td>
</tr>
<tr>
<td>12</td>
<td>Galago</td>
<td>200</td>
<td>5</td>
</tr>
<tr>
<td>13</td>
<td>Rat</td>
<td>280</td>
<td>1.9</td>
</tr>
<tr>
<td>14</td>
<td>Chinchilla</td>
<td>425</td>
<td>6.4</td>
</tr>
<tr>
<td>15</td>
<td>Desert Hedgehog</td>
<td>550</td>
<td>2.4</td>
</tr>
<tr>
<td>16</td>
<td>Rock Hyrax (a)</td>
<td>750</td>
<td>12.3</td>
</tr>
<tr>
<td>17</td>
<td>European Hedgehog</td>
<td>785</td>
<td>3.5</td>
</tr>
<tr>
<td>18</td>
<td>Tenrec</td>
<td>900</td>
<td>2.6</td>
</tr>
<tr>
<td>19</td>
<td>Arctic Ground Squirrel</td>
<td>920</td>
<td>5.7</td>
</tr>
<tr>
<td>20</td>
<td>African Giant Pouched Rat</td>
<td>1000</td>
<td>6.6</td>
</tr>
<tr>
<td>21</td>
<td>Guinea Pig</td>
<td>1040</td>
<td>5.5</td>
</tr>
<tr>
<td>22</td>
<td>Mountain Beaver</td>
<td>1350</td>
<td>8.1</td>
</tr>
<tr>
<td>23</td>
<td>Slow Loris</td>
<td>1400</td>
<td>12.5</td>
</tr>
<tr>
<td>24</td>
<td>Genet</td>
<td>1410</td>
<td>17.5</td>
</tr>
<tr>
<td>25</td>
<td>Phalanger</td>
<td>1620</td>
<td>11.4</td>
</tr>
</tbody>
</table>
Tell Story: Most Powerful Brain?

The Dragons of Eden [Carl Sagan]
Tell Story: Most Powerful Brain?

The Elements of Graping Data [Cleveland]
Attention

“What information consumes is rather obvious: it consumes the attention of its recipients. Hence a wealth of information creates a poverty of attention, and a need to allocate that attention efficiently among the overabundance of information sources that might consume it.”

~Herb Simon
as quoted by Hal Varian
Scientific American
September 1995

[slide from PARC UIR group]
Data
Data Types

**Physical type (model)**
Characterized by storage format
Characterized by machine operations
Example:
  - bool, short, int32, float, double, string, …

**Abstract type**
Provide (conceptual) descriptions of the data
May be characterized by methods/attributes
May be organized into a hierarchy
Example:
  - nominal, ordinal, quantitative, …,
  - plants, animals, metazoans, …
Nominal, Ordinal & Quantitative

N - Nominal (labels)
Fruits: Apples, oranges, …

O - Ordered
Quality of meat: Grade A, AA, AAA

Q - Quantitative
Real numbers
Ordered, with measurable distances, or amounts
Dates: Jan, 19, 2006; Location: (LAT 33.98, LONG -118.45)
Physical measurement: Length, Mass, Temp, …

S. S. Stevens, On the theory of scales of measurements, 1946
Data model
32.5, 54.0, -17.3, …
floats

Conceptual model
Temperature

Data type
Burned vs. Not burned (N)
Hot, warm, cold (O)
Continuous range of values (Q)

[based on slide from Munzner]
Image

Jacques Bertin
Visual Variables

Position
Size
Value

Texture
Color
Orientation
Shape

Note: Bertin does not consider 3D or time
Note: Card and Mackinlay extend the number of vars.
1. A, B, C are distinguishable
2. B is between A and C.
3. BC is twice as long as AB.
4. ∴ Encode quantitative variables (Q)
Information in Color and Value

Value is perceived as ordered
∴ Encode ordinal variables (O)

∴ Encode continuous variables (Q) [not as well]

Hue is normally perceived as unordered
∴ Encode nominal variables (N) using color
Bertins’ “Levels of Organization”

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>O</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position</td>
<td>N</td>
<td>O</td>
<td>Q</td>
</tr>
<tr>
<td>Size</td>
<td>N</td>
<td>O</td>
<td>Q</td>
</tr>
<tr>
<td>Value</td>
<td>N</td>
<td>O</td>
<td>Q</td>
</tr>
<tr>
<td>Texture</td>
<td>N</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>Color</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orientation</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shape</td>
<td>N</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

N: Nominal  
O: Ordinal  
Q: Quantitative
Estimating Magnitude
Detecting Brightness

Which is brighter?
Detecting Brightness

Which is brighter?

(128, 128, 128) (144, 144, 144)
Just Noticeable Differences

JND (Weber’s Law)

$$\Delta S = k \frac{\Delta I}{I}$$

Ratios more important than magnitude

Most continuous variations perceived in discrete steps
Steven’s Power law

\[ S = I^p \]

\( p < 1 \) : underestimate
\( p > 1 \) : overestimate

[graph from Wilkinson 99, based on Stevens 61]
Exponents of Power Law

<table>
<thead>
<tr>
<th>Sensation</th>
<th>Exponent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loudness</td>
<td>0.6</td>
</tr>
<tr>
<td>Brightness</td>
<td>0.33</td>
</tr>
<tr>
<td>Smell</td>
<td>0.55 (Coffee) - 0.6 (Heptane)</td>
</tr>
<tr>
<td>Taste</td>
<td>0.6 (Saccharine) - 1.3 (Salt)</td>
</tr>
<tr>
<td>Temperature</td>
<td>1.0 (Cold) – 1.6 (Warm)</td>
</tr>
<tr>
<td>Vibration</td>
<td>0.6 (250 Hz) – 0.95 (60 Hz)</td>
</tr>
<tr>
<td>Duration</td>
<td>1.1</td>
</tr>
<tr>
<td>Pressure</td>
<td>1.1</td>
</tr>
<tr>
<td>Heaviness</td>
<td>1.45</td>
</tr>
<tr>
<td>Electric Shock</td>
<td>3.5</td>
</tr>
</tbody>
</table>

[Psychophysics of Sensory Function, Stevens 61]
WHAT YOU PAY, WHAT YOU GET

A comparison of Internet download speeds available to residential customers in the Triangle

- **$22**
  - EARTHLINK DIAL-UP: 56 kbps

- **$20/$25**
  - AT&T “LITE” DSL: 768 kbps
  - VERIZON “STARTER” DSL: 768 kbps

- **$33/$80**
  - AT&T “ULTRA” DSL: 1.5 Mbps
  - WILDBLUE AND HUGHESNET SATELLITE: 1.5 Mbps

- **$35/$38**
  - VERIZON “POWER” DSL: 3 Mbps
  - AT&T “XTREME” DSL: 3 Mbps

- **$43**
  - AT&T “XTREME 6.0” DSL: 6 Mbps

- **$43/$47**
  - VERIZON HIGHEST TIER DSL: 7 Mbps
  - TIME WARNER CABLE ROAD RUNNER: 7 Mbps

- **$35*/$57**
  - GREENLIGHT, a publicly owned utility offering fiber-to-the-home service to residents of Wilson (LOWEST TIER): 10 Mbps
  - TIME WARNER CABLE ROAD RUNNER “TURBO”: 10 Mbps

- **$300***
  - GREENLIGHT (HIGHEST TIER): 100 Mbps

*Speeds are shown in kilobits per second and Megabits per second.
1 Megabit=1,000 kilobits. Prices are monthly, long-term (not promotional), rounded to the nearest dollar.

*GREENLIGHT broadband available only when paired with TV and/or phone service.
Compare area of circles
Proportional Symbol Map
Newspaper Circulation

[Cartography: Thematic Map Design, Figure 8.8, p. 172, Dent, 96]
Apparent Magnitude Scaling

\[ S = 0.98A^{0.87} \]  [from Flannery 71]
Relative Magnitude Estimation

Most accurate
- Position (common) scale
- Position (non-aligned) scale
- Length
- Slope
- Angle
- Area
- Volume

Least accurate
- Color hue-saturation-density
Deconstructions
March 1998: Bert Ellis founds iXL. It is backed initially with money from Kelso & Co., a New York investment firm, and Ellis.

Dec. 18, 1999: iXL throws a big Christmas party, where Ellis predicts the stock will top $100 in 2000. Stock was trading at under $50 a share.


Jan. 11, 2001: iXL taps PricewaterhouseCoopers Chris Formant, 49, as CEO. He vows to turn iXL around.

Tuesday: iXL announces it will merge with rival Scient Corp., based in New York. Ellis becomes vice chairman of Scient.
Stock Chart

x-axis: time (Q)
y-axis: price (Q)
Exports and Imports [Playfair 1786]

Exports and Imports to and from Denmark & Norway from 1700 to 1780.
Exports and Imports [Playfair 1786]

x-axis: year (Q)
y-axis: currency (Q)
color: imports/exports (N)
color: positive/negative (O)
Map of the Market [Wattenberg 1998]

http://www.smartmoney.com/marketmap/
Map of the Market [Wattenberg 1998]

rectangle size: market cap (Q)
rectangle position: market sector (N), market cap (Q)
color hue: loss vs. gain (N, O)
color value: magnitude of loss or gain (Q)
Summary

We create visualizations to
Record information
Support reasoning about the information
Convey information to others

Choose the right mark for your data
Position good for N, O, Q, but Hue best only for N

With careful design it is possible to display many dimensions at once
Design Patterns
What Do Expert Designers Know?

An effective and flexible design is difficult to get “right” the first time.
Yet experienced designers do create good designs.
New designers are often overwhelmed by all the choices and options.
Do experienced designers know something inexperienced ones don’t?
Experts usually do not solve every problem from first principles; they reuse solutions that have worked in the past.
Good solutions are used again and again.
Such experience is part of what makes them experts.
Experiences can be recorded as design patterns.
What is a Design Pattern?

“Each pattern describes a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice.”

C. Alexander, A Pattern Language, 1977
What is a Design Pattern?

“Patterns communicate insights into design problems, capturing the essence of the problems and their solutions in a compact form. They describe the problem in depth, the rationale for the solution, and some of the trade-offs in applying the solution.”

D. Van Duyne et al., The Design of Sites, 2002
Hierarchy of Design Methods

Design Philosophy
Design Principles
Design Patterns
Design Idioms, Tips & Tricks

Abstract ➔ Concrete
History: Christopher Alexander

Professor of Architecture, UC Berkeley (since ‘63)

Influential books:
A Pattern Language
The Timeless Way of Building

ATC Talk on 5/2/11
7:30-9 pm
Sutardja Dai Auditorium
Alexander’s Pattern Format

1. Pattern Name
2. Context
3. Forces
4. Problem Statement
5. Solution (Sketch)
6. Other Patterns to Consider (hyperlinks!)
Example Pattern:

115 COURTYARDS WHICH LIVE**

The courtyards built in modern buildings are very often dead. They are intended to be private open spaces for people to use—but they end up unused, full of gravel and abstract sculptures.

There seem to be three distinct ways in which these courtyards fail.

1. There is too little ambiguity between indoors and outdoors...
2. There are not enough doors into the courtyard...
3. They are too enclosed...

Therefore:

Place every courtyard in such a way that there is a view out of it to some larger open space; place it so that at least two or three doors open from the building into it and so that the natural paths which connect these doors pass across the courtyard. And at one edge, beside a door, make a roofed veranda or a porch, which is continuous with both the inside and the courtyard.

Build the porch according to the patterns for ARCADE (119), GALLERY SURROUND (166), and SIX-FOOT BALCONY (167)…
The “Gang of Four” borrowed the pattern idea and applied it to software engineering.

Goal: Communicate OO software design problems and solutions
Intent

Ensure a class only has one instance, and provide a global point of access to it.

Motivation

It’s important for some classes to have exactly one instance. Although there can be many printers in a system, there should be only one printer spooler. There should be only one file system and one window manager. A digital filter will have one A/D converter. An accounting system will be dedicated to serving one company.

How do we ensure that a class has only one instance and that the instance is easily accessible? A global variable makes an object accessible, but it doesn’t keep you from instantiating multiple objects.

A better solution is to make the class itself responsible for keeping track of its sole instance. The class can ensure that no other instance can be created (by intercepting requests to create new objects), and it can provide a way to access the instance. This is the Singleton pattern.

Applicability

Use the Singleton pattern when

- there must be exactly one instance of a class, and it must be accessible to clients from a well-known access point.
- when the sole instance should be extensible by subclassing, and clients should be able to use an extended instance without modifying their code.

Structure

```
Singleton
static instance() { return uniqueInstance; }
static uniqueInstance

singletonData
```

Note that `instance` must be modified whenever you define a new subclass of `MazeFactory`. That might not be a problem in this application, but it might be for abstract factories defined in a framework.

A possible solution would be to use the registry approach described in the Implementation section. Dynamic linking could be useful here as well—it would keep the application from having to load all the subclasses that are not used.

Known Uses

An example of the Singleton pattern in Smalltalk-80 [Par90] is the set of changes to the code, which is ChangeSet `current`. A more subtle example is the relationship between classes and their `metaclasses`. A metaclass is the class of a class, and each metaclass has one instance. Metaclasses do not have names (except indirectly through their sole instance), but they keep track of their sole instance and will not normally create another.

The InterViews user interface toolkit [LCH+82] uses the Singleton pattern to access the unique instance of its Session and WidgetKit classes, among others. Session defines the application’s main event dispatch loop, stores the user’s database of stylistic preferences, and manages connections to one or more physical displays. WidgetKit is an Abstract Factory (B7) for defining the look and feel of user interface widgets. The `WidgetKit::instance()` operation determines the particular WidgetKit subclass that’s instantiated based on an environment variable that Session defines. A similar operation on Session determines whether monochrome or color displays are supported and configures the singleton Session instance accordingly.
Patterns in HCI

Borchers, 2001

Van Duyne et. al, 2002 (UC Berkeley EECS)

Tidwell 2005

Focus on Web, Desktop Apps
Example: Extras on Demand
Example: Extras on Demand

Description:
Show the most important content up front, but hide the rest. Let the user reach it via a single, simple gesture.

Context
There's too much stuff to be shown on the page, but some of it isn't very important. You'd rather have a simpler UI, but you have to put all this content somewhere.

Solution
[P]rune the UI down to its most commonly used, most important items. Put the remainder into their own page or section. Hide that section by default; on the newly simplified UI, put a clearly marked button or link to the remainder, such as "More Options." ...
Android Patterns

Five common patterns:
Dashboard
Action Bar
Search Bar
Quick Actions
Companion Widgets

Summary:

Expert designers don’t reinvent the wheel (frequently).
Patterns capture design knowledge: good solutions to frequently occurring problems.
Read up on Android design patterns and think about where you can adopt successful patterns in your project!
Next Time

Reading:

Question is on Piazzza.