Design Principles for Visual Communication

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Users’ task:
- Understand how to get from point A to point B

Important information:
- Sequence of stops/interchanges along each line
Design Principles

London Underground [Beck 33]

Geographic version of map

Design principles:
- Straighten lines and evenly space stops to emphasize sequence of stops
- De-emphasize geographic shape of subway lines

Techniques used to emphasize/de-emphasize information
Phases of the Moon

Galileo’s drawings from 1616

http://galileo.rice.edu/sci/observations/moon.html
Design Principles

Users’ task:
- Understand shape of moon’s surface

Important information:
- Variation in illumination, especially along terminator

Design principles:
- Detail light/dark variation at terminator
- Reduce detail elsewhere

Galileo’s drawings from 1616
Torus Exploded View

Strange immersion of torus in 3-space

[Curtis 92]
Design Principles

Users’ task:
- Understand shape of torus

Important information:
- Silhouettes, curvature and self intersection features

Design principles:
- Explode and create holes to reveal internal features
- Use hatching and contrast to emphasize features
Procedure

1. Find most effective visualizations within domain

2. Analyze example visualizations to identify
   - Users’ tasks
   - Important information (perception/cognition)
   - Techniques used to emphasize/de-emphasize information

3. Instantiate principles in automated design algorithms
Tourist Maps
Goal
Goal

Input Data  Selection  Rendering  Tourist Map
Selection Principles: Map Cognition

Mental maps of cities based on 5 elements
- Landmarks
- Paths
- Edges
- Districts
- Nodes

*The Image of the City* [Lynch 60]
Types of Landmarks

[Semantic] Geary Theater
[Visual] Structural

[Sorrows 99]
Types of Landmarks

[Sorrows 99]

We compute quantitative scores in each category for each building.
Semantic Features

INPUT WEBPAGES

GOOGLE MAP API

<table>
<thead>
<tr>
<th>Name</th>
<th>Category</th>
<th>District</th>
<th>Rating</th>
<th>Address</th>
<th>Position</th>
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<tbody>
<tr>
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<td>Business Facility</td>
<td>North Beach</td>
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<td>Tourist Attraction</td>
<td>Golden Gate Park</td>
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</table>

Score based on user ratings
Visual Features

Color
- Choose representative color

Shape Complexity
- Non-rectangularity
- Angle variation

Height
- Distance from top to ground plane

Score based on local distinctiveness of features
Structural Features

Score based on importance of intersection or square
Combining Feature Scores

Semantic

Visual

Structural
Threshold Weighted Sum of Scores
Rendering Principle: Multiperspective

Streets
Prevent foreshortening distortion via orthographic projection

Landmarks
Choose projection to ensure visibility of street-side facades
Combine Multiple Views

Roads: Top-Down Orthographic  Buildings: Side Perspective
Result: Restaurants in San Francisco
Result: Shopping in San Francisco
Single Street View
Single Street View
Route Maps
Visualizing Routes
A Better Visualization
Cognition of Route Maps

Essential information

- Turning points
- Route topology

Secondary context information

- Local landmarks, cross streets, etc.
- Overview area landmarks, global shape

Exact geometry less important

- Not apprehended accurately
- Not drawn accurately

[Tversky 81] [Tufte 90] [Tversky 92] [MacEachren 95] [Denis 97] [Tversky 99]
Design Principles

- Exaggerate road length
- Regularize turning angles
- Simplify road shape
LineDrive

Hand-drawn route map

LineDrive route map
Map Design via Optimization

Set of graphic elements
- Roads, labels, cross-streets, ...

Choose visual attributes
- Position, orientation, size, ...
- Distortions increase flexibility

Develop constraints based on design principles

Simulated annealing
- Perturb: Form a layout
- Score: Evaluate quality
- Minimize score
DEMO
mappoint.com
Results

Beta version 6 months
- 150,000 maps served

2242 responses
- Replace standard 55.6%
- Use with standard 43.5%
- Prefer standard 0.9%

Current Status
- Deployed at: mappoint.com
- At peak: 750,000 maps/day
Next Steps: Wedding Maps

Hand-designed Wedding Map www.WeddingMaps.CC
Input map drawn to scale

Our result

1st Ave. and 19th Ave. NW, Seattle WA
1st Ave. and 19th Ave. NW, Seattle WA
Evergreen Ave., Boston MA
Shape & Detail Enhancement from Multi-Light Image Collections
Photograph captures appearance (color, texture) much the way we see it.

Shading and lighting in illustration clarifies shape and structural elements.
Silhouettes

- Constrains shape of surface → important shape cue
- Increase contrast at silhouettes to emphasize shape

[from Hodges 89]
Highlights and Shadows

- Remove distracting highlights and shadows
Creases, Ridges and Valleys

[Imhof 83]

- Sharp dark/light transitions to emphasize boundaries [www.shadedrelief.com]
Multiple Scales

- Blend between depictions at multiple scales  [www.shadedrelief.com]
Multiscale bilateral decomposition
Differences between successive levels
Emphasizing coarser scales
Increasing Strength of Details
Summary

1. Find most effective visualizations within domain

2. Analyze examples to identify
   - Users’ tasks
   - Important information
   - Techniques used to emphasize/de-emphasize information

3. Instantiate principles in automated design algorithms
Image-Based Exploded Views
Exploded view of the master cylinder
Design Principles

Clarify spatial relationships
- Direct manipulation  [Schneiderman 83]
- Animated transitions  [Woods 84] [Robertson 91] [Grossman 01]

Reduce visual clutter
- Interactive filtering  [Schneiderman 96] [MacEachren 97]
- Highlight most important information  [Tufte 83] [MacEachren 97]
Authoring Pipeline

Input  Segment  Stack  Fragment  Assign ordering  Annotate
Interactive Viewing

impeller
pump

stator

turbine

cover
Visualizing Buildings
Exploded View

Concept design for museum guide [Tufte 97]
Design Principles

Floorplans

Axonometric View

Floorplans + Front View

Use 3D exploded view [Fontaine 01]

External, axonometric perspective better than egocentric view

Single integrated 3D view better than multiple 2D floorplans
Generating an Exploded View

1. Geometric analysis - Find downward facing ceiling polygons
2. Place sectioning planes below ceilings
3. Multi-pass render each story separately
Works with Existing 3D Applications

Intercept and modify OpenGL stream
- Non-invasive [Mohr 01]
- Apply to existing OpenGL application without modification
Future: Enhanced Spectator Mode

Mock-up design
Future: Building Maps

Seattle Public Library [from Seattle Times 04]
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