Identifying Design Principles II

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Announcements
Final project

Design new visualization method
- Pose problem, Implement creative solution

Deliverables
- Implementation of solution
- 8-12 page paper in format of conference paper submission
- 1 or 2 design discussion presentations

Schedule
- Project proposal: 10/27
- Project presentation: 11/10, 11/12
- Final paper and presentation: TBD, likely 12/1-12/5

Grading
- Groups of up to 3 people, graded individually
- Clearly report responsibilities of each member

Identifying Design Principles
Good Design Improves Effectiveness

| London Underground [Beck 33] | Geographic version of map |

Design principle:
- Straighten lines to emphasize sequence of stops

Technique used to emphasize/de-emphasize information
Approach

Identify design principles
- Cognition and perception

Instantiate design principles
- Principles become constraints that guide an optimization process

Route Maps

Route maps

Assembly instructions
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

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
Road Layout

Choose road lengths and orientations

Before road layout

After road layout
Road Layout

Choose road lengths and orientations

![Road Layout Image]

Road Layout Constraints

**Length**
- Ensure all roads visible
- Maintain ordering by length

![Road Layout Constraints]

**Orientation**
- Maintain original orientation

**Topological errors**
- Prevent false
- Prevent missing
- Ensure separation

**Overall route shape**
- Maintain endpoint direction
- Maintain endpoint distance

\[(L_{\text{min}} - l(r_i) / L_{\text{min}})^2 * W_{\text{small}}\]  
\[W_{\text{shuffle}}\]

\[|\alpha_{\text{curr}}(r_i) - \alpha_{\text{orig}}(r_i)| * W_{\text{orient}}\]

\[\min(d_{\text{origin}}, d_{\text{dest}}) * W_{\text{false}}\]
\[d * W_{\text{missing}}\]
\[\min(d_{\text{ext}}, E) * W_{\text{ext}}\]

\[|\alpha_{\text{curr}}(v) - \alpha_{\text{orig}}(v)| * W_{\text{enddir}}\]
\[|d_{\text{curr}}(v) - d_{\text{orig}}(v)| * W_{\text{enddist}}\]
Balancing the Constraints

Prioritize scores by importance
1. Prevent topological errors
2. Ensure all roads visible
3. Maintain original orientation
4. Maintain ordering by length
5. Maintain overall route shape

Priorities set based on usability tests
- Users given maps containing errors
- Rated which errors most confusing

Label Layout
Find overlap-free position for each label
Context Layout

Place cross-streets and exit signs if possible

Bellevue to Seattle
Cross-Country Route

**System Performance**

*7727 routes*  (sampled over 1 day at MapBlast!)

- Median distance: 52.5 miles
- Median number turning points: 13
- Median computation time: 0.7 sec

- Short roads: 5.4%
- False intersections: 0.3%
- Missing intersections: 0.2%

- Label-label overlap: 0.5%
- Label-road overlap: 11.7%
Results

Beta version 6 months
- 150,000 maps served

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

At peak
- Deployed at: mappoint.com
- Served 750,000 maps/day
- Taken offline in fall 2011

Original Design

Layout
- Map and text close together
- Overview and destination maps for more content
Limited Resolution PDA

Next Steps: Wedding Maps

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

1st Ave. and 19th Ave. NW, Seattle WA

http://www.bing.com/maps/explore/#/c7pvw1whdkp6ggvw (Requires Windows, IE, Silverlight)

Roads selected from input

1st Ave. and 19th Ave. NW, Seattle WA

http://www.bing.com/maps/explore/#/c7pvw1whdkp6ggvw (Requires Windows, IE, Silverlight)
Evergreen Ave., Boston MA

http://www.bing.com/maps/explore/#/c7pvw1whdkp6ggvv (Requires Windows, IE, Silverlight)

635 Soda Hall, Berkeley CA
Previous Work

Planning
- Choose sequence of assembly operations
- Robotics / AI / Mechanical Engineering
  [Wolter 89], [de Mello 91], [Wilson 92], [Romney 95]

Presentation
- Visually convey assembly operations
- Visualization / Computer Graphics
  [Seligmann 91], [Rist 94], [Butz 97], [Strothotte 98]

Jointly optimize plan and presentation

Geometric Analysis [Romney 95]

Input Parts

Blocking Graph
Geometric Assembly Planning

Many Geometrically Valid Sequences

How do we choose the best sequence?
Identifying Design Principles

Stage 1: Production
Stage 2: Preference
Stage 3: Comprehension

Spatial Ability Tests

Mental Rotation [Vandenberg 78]
Navigation [Money 78]

Separate high and low spatial ability
Stage 1: Production

- 43 Participants
- Assemble TV Stand without instructions
- Write instructions for novice assembler

Stage 1: Mean completion time

- Low spatial: 12.76 minutes
- High spatial: 7.29 minutes
Stage 1: Instructions produced

- Almost all contained diagrams 98%
- Text redundant with diagrams 62%

Stage 1: Errors in instructions

- Errors in low spatial instructions 86%
- Errors in high spatial instructions 12%
Stage 1: Errors in instructions

- Errors in low spatial instructions: 86%
- Errors in high spatial instructions: 12%

Stage 1: Classes of Diagrams

- Parts menu to differentiate parts
- Structural diagrams depict completed step
- Action diagrams show assembly action/operation
Stage 1: Action diagrams

- High spatial
  - More action diagrams
  - More 3D diagrams
  - Less text

![Mean number per set graph](image)

Stage 2: Preference

- 21 Participants
- Assemble TV Stand without instructions
- Rated 39 sets of redrawn instructions
Stage 2: Highest Rated

- Ratings similar across all participants
- Spatial ability does not affect preference

Stage 3: Comprehension

- 44 Participants
- Given 1 of 4 instruction sets from Stage 2
- Assemble TV stand using instructions

Set 1: Text + Action

Set 3: Parts menu + Structural + Action
Stage 3: Results

- No difference in assembly time by condition
- Instruction consultations: Low 8.9  High 7.1
- Box picture consultations: Low 9.1  High 3.4

Comments
- Should show relevant parts and attachments
- Structural diagrams and exploded view hard to use
- Text not very useful

Design Principles

Step-by-Step
Action diagrams
Good visibility

TV stand instructions generated by our system
Input

Geometry: Parts in assembled configuration
Orientations: Default viewpoint/orientation
Preferred orientation for each part

Groupings: Fasteners, significant parts, similar actions, symmetry

Assembled geometry in default orientation

Parts grouped as fasteners and significant parts

Find best assembly sequence
- Planning: Geometric feasibility
- Presentation: Visibility

All parts → Search → Subdivide Steps → Reorientation → Step-by-step assembly sequence

Valid
Valid
Invalid
Computing Visibility

\[ \text{Area}(P,Q) = \# \text{ red pixels} \]
\[ \text{Area of top not occluded by sides} \]

\[ \text{Area}(P) = \# \text{ red pixels} \]
\[ \text{Area of top alone} \]

\[ \text{Vis}(P,Q) = \frac{\text{Area}(P,Q)}{\text{Area}(P)} \]
\[ \% \text{ pixels that remain visible when sides are included} \]

Visibility Constraints

1. Parts being attached \( R \)
   - Check that each part is visible
   \[ \min_{r \in R} (\text{Vis}(r, R-r)) \cdot W_R \]

2. Previously attached parts \( A \)
   - Check that context is visible
   \[ \text{Vis}(A, R) \cdot W_A \]

3. Future unattached parts \( U \)
   - Check that future parts will be visible
   \[ \min_{u \in U} (\text{Vis}(u, R)) \cdot W_U \]
**Lego Car**

Input model

**Bookcase**

Input model
Sequentially add parts

- Least visible to most visible
- Distance to viewer

Reorientation

Set preferred orientation
If poor visibility try alternate orientations
Action Diagrams

Choose Direction
Build Stacks
Place Guidelines

Subdivide Steps
Search
Reorientation

Step-by-step assembly sequence
Step-by-step assembly diagrams

Bookcase

1
2
3
4
5
6
7
8
9
10

9 Parts
Design: 48s
Test Object

![Diagram of a test object with 25 parts and a design time of 53s.]

Evaluation

- 30 Participants
- Given 1 of 3 instruction sets: factory, hand-drawn, computer
- Assemble TV stand using instructions
Factory

Hand-drawn

1. Score the following on each side as shown in the picture. (This should have two of 1-inch boards, like the one for the door.)

2. Place the smaller side upright on the surface such that the unmarked surface faces up and the two boards facing up with the marking face up. Surprise the two marked edges of the board have the other direction.

3. Place a white plastic and each of the hidden side of the door or board.

4. Place the board to frame the two pieces. Again, note the dimension must be the same dimension as the marked edge of the board board.

5. Take the sanding way board and score to keep clean. Make sure the sanding face up and the other side that has the dust direction is also direction.

6. Place the sanding board and line to mark that all of the boards lined up the picture.
Computer Generated

1. Factory
2. Hand-drawn
3. Computer
4. Mean time to assemble (min)
5. Factory 1.6
6. Hand-drawn 0.6
7. Computer 0.5
8. Task rated easiest in computer condition

Results

Mean time to assemble (min)

Factory 18.9
Hand-drawn 16.0
Computer 10.2

Errors: Factory 1.6 Hand-drawn 0.6 Computer 0.5
Task rated easiest in computer condition
Summary

Identification of design principles
- Production
- Preference
- Comprehension

Instantiation of design principles

Validation of design principles