Identifying Design Principles

Maneesh Agrawala

CS 294-10: Visualization
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Last Time: Spatial Layout

Problem

Input: Set of graphic elements (scene description)
Goal: Select visual attributes for elements

- Position
- Orientation
- Size
- Color
- ...

Approaches

Direct rule-based methods
Constraint satisfaction
Optimization
Example-based methods

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
- 2 design discussion presentations

Schedule
- Project proposal: 3/14
- Project presentation: 4/4
- Final paper and presentation: TBD

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

Good Design Improves Effectiveness

London Underground \cite{Beck33}

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

Visualizing Routes

Route Maps
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

Request for Directions
Route Finding Service
Route Data
LineDrive
Shape Simplification
Road Layout
Label Layout
Context Layout
Decoration
Route Map
Road Layout

Choose road lengths and orientations

Before road layout

After road layout

Road Layout Constraints

Length
- Ensure all roads visible
- Maintain ordering by length

Orientation
- Maintain original orientation

Topological errors
- Prevent false
- Prevent missing
- Ensure separation

Overall route shape
- Maintain endpoint direction
- Maintain endpoint distance

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

Balancing the Constraints

Find overlap-free position for each label

Label Layout Score: 376.5426

Context Layout

Place cross-streets and exit signs if possible

Context Layout Score: 336.7560
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%

Current Status

- Deployed at: mappoint.com
- 750,000 maps/day

Original Design

Layout

- Map and text close together
- Overview and destination maps for more content

DEMO
mappoint.com
Limited Resolution PDA

Next Steps: Wedding Maps

Hand-designed Wedding Map www.WeddingMaps.CC

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

Input map drawn to scale

Our result

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

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

Roads selected from input

Our result

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

Evergreen Ave., Boston MA

Input map drawn to scale

Our result

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

2050 Gateway Place

Bing map

Our result

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

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], [Hart 94], [Butz 97], [Strothotte 98]

Jointly optimize plan and presentation
Geometric Analysis [Romney 95]

Input Parts

Blocking Graph

Geometric Assembly Planning

Valid

Valid

Valid

Invalid

Many Geometrically Valid Sequences

Valid

Valid

Valid

Valid

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 (min)
- High spatial: 7.29 (min)

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: Classes of Diagrams
- Parts menu to differentiate parts
- Structural diagrams depict completed step
- Action diagrams show assembly action/operation

Stage 1: Action diagrams
- Mean number per set
- High spatial: 2.67
- Low spatial: 0.64
- More action diagrams
- More 3D diagrams
- Less text
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

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

Input

- Geometry: Parts in assembled configuration
- Orientations: Default viewpoint / orientation
- Groupings: Fasteners, significant parts, similar actions, symmetry

TV stand instructions generated by our system
Find best assembly sequence

- Planning: Geometric feasibility
- Presentation: Visibility

Computing Visibility

Vis(P, Q) = \frac{\text{Area}(P, Q)}{\text{Area}(P)}

\% pixels that remain visible when sides are included

Area(P) = \# red pixels
Area of top alone

Area(P, Q) = \# red pixels
Area of top not occluded by sides

Visibility Constraints

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

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

3. Future unattached parts \( U \)
   - Check that future parts will be visible
   \[
   \min_{u \in U} \left( \text{Vis}(u, R) \right) \times W_u
   \]

Bookcase

Input model

Lego Car

Input model
Reorient
- Set preferred orientation
- If poor visibility try alternate orientations

Reorientation

Search

Subdivide Steps

Bookcase
9 Parts Design: 48s

Test Object
25 Parts Design: 53s

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

Factory
Results

<table>
<thead>
<tr>
<th></th>
<th>Factory</th>
<th>Hand-drawn</th>
<th>Computer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean time to assemble (min)</td>
<td>18.9</td>
<td>16.0</td>
<td>10.2</td>
</tr>
</tbody>
</table>

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