Identifying Design Principles

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CS 448B: 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
Rule-based timeline labeling

- Alternate above/below line
- Center labels with respect to point on line

Network of layout constraints

[TITLE ABOVE TEXT1
TITLE FULL PAGE WIDTH
TEXT1 LEFT OF PIC1
CAPTION1 BELOW PIC1
TEXT2 BELOW TEXT1]

Constraints

Network

Two possible layouts

[from Lok and Feiner 01]
Adaptive document layout [Jacobs 03]

Users authors templates which use one-way constraints to adapt to changes in page size

Optimization
**Simulated annealing**

\[
\text{currL} \leftarrow \text{Initialize()}
\]

\[
\text{while(! termination condition)}
\]

\[
\text{newL} \leftarrow \text{Perturb(currL)}
\]

\[
\text{currE} \leftarrow \text{Penalty(currL)}
\]

\[
\text{newE} \leftarrow \text{Penalty(newL)}
\]

\[
\text{if}((\text{newE} < \text{currE}) \text{ or } (\text{rand}(0,1) < e^{-\Delta E/T}))
\]

\[
\text{then } \text{currL} \leftarrow \text{newL}
\]

\[
\text{Decrease(T)}
\]

**Perturb:** Efficiently cover layout design space

**Penalty:** Describes desirable/undesirable layout features
Scene description

Geometry
- Pie slices
- Anchors for labels
- Labels
- Bounding boxes

Layout parameters
- Position (x, y)
- Leader line
- Word wrap
- Color
- Alignment
- Orientation
- Scale
Many dimensions → large space

- Position \((x, y)\)
- Leader line
- Word wrap
- Color
- Alignment
- Orientation
- Scale

2D x 50 labels → 100D space

Penalties

- Overlap & Distance
  - Label – anchor slice
  - Label – other slices
  - Label – label

- Leader lines
  - Length
  - Intersections

- Word Wrap

Annealing minimizes sum of all penalties
Overlap: Label – Anchor Slice

Avoid partial overlap: No penalty if fully inside /outside

Penalize partial overlap by overlap amount
Distance: Label – Anchor Slice

Ensure label near center of edge of anchor slice

Minimize distance $d$
Penalties

Overlap & Distance
- Label – anchor slice
- Label – other slices
- Label – label

Leader lines
- Length
- Intersections

Word Wrap

Annealing minimizes sum of all penalties

Demo
Pros and cons

Pros

- Much more flexible than linear constraint solving systems

Cons

- Can be relatively slow to converge
- Need to set penalty function parameters (weights)
- Difficult to encode desired layout in terms of mathematical penalty functions

Design principles

Sometimes specified in design books

- Tufte, Few, photography manuals, cartography books …
- Often specified at a high level
- Challenge is to transform principles into constraints or penalties

Cartographer Eduard Imhof’s labeling heuristics transformed into penalty functions for an optimization based point labeling system [Edmondson 97]
Example-Based Methods

Preference elicitation [Gajos and Weld 05]

Learn characteristics of good designs
- Generate designs based on a parameterized design space
- Ask designers if they are good or bad
- Learn good parameters values based on responses
Nonlinear Inverse Opt. [Vollick et al. 07]

Learn label layout style from single example

Example

Horizontal/Vertical

Parallel Leader Lines
Final project

Design new visualization method (e.g. software)
- Pose problem, Implement creative solution
- Design studies/evaluations less common but also possible (talk to us)

Deliverables
- Implementation of solution
- 6-8 page paper in format of conference paper submission
- Project progress presentations

Schedule
- Project proposal: 11/7
- Project progress presentation: 11/14 in class (3-4 min) slide presentation
- Final poster presentation: 12/9 Location: TBD
- Final paper: 12/11 11:59pm

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

Announcements
Identifying Design Principles

Good Design Improves Effectiveness

London Underground [Beck 33]  Geographic version of map
Good Design Improves Effectiveness

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

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

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

Choose road lengths and orientations

Road Layout  Score: 25.2295
# Road Layout Constraints

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

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

## Orientation
- Maintain original orientation

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

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

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

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

\[
|\alpha_{\text{curr}}(v) - \alpha_{\text{orig}}(v)| \cdot W_{\text{enddir}} \\
|d_{\text{curr}}(v) - d_{\text{orig}}(v)| \cdot W_{\text{enddist}}
\]

## 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
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


Input map drawn to scale

Our result

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

[http://www.bing.com/maps/explore/#/c7pvw1whdkp6qyw](http://www.bing.com/maps/explore/#/c7pvw1whdkp6qyw) (Requires Windows, IE, Silverlight)
1st Ave. and 19th Ave. NW, Seattle WA

http://www.bing.com/maps/explore/#/c7pww1whdkp6ggvw (Requires Windows, IE, Silverlight)

Evergreen Ave., Boston MA

http://www.bing.com/maps/explore/#/c7pww1whdkp6ggvw (Requires Windows, IE, Silverlight)