Identifying Design Principles II

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CS 294-10: Visualization
Fall 2014

Announcements

Final project

Design new visualization method
- Pose problem, Implement creative solution

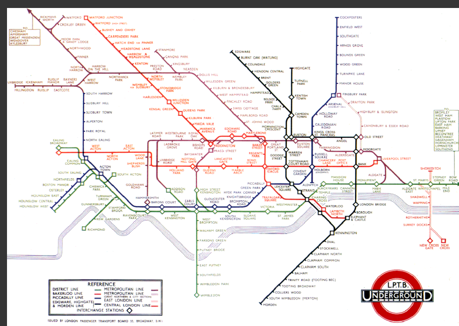
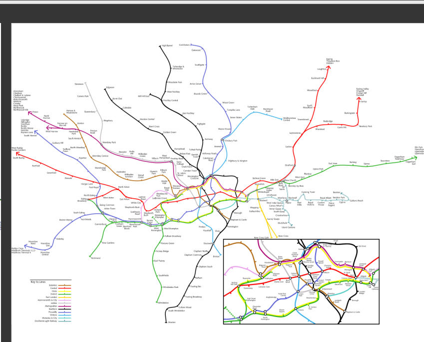
Deliverables
- Implementation of solution
- 8-12 page paper in format of conference paper submission
- 1 or 2 design discussion presentations

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

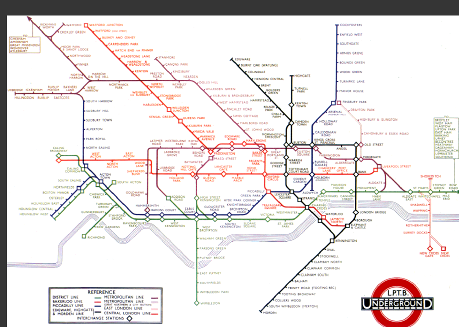
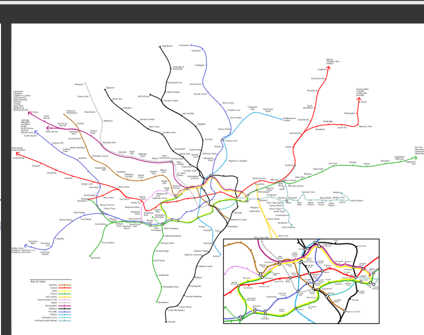
Good Design Improves Effectiveness

London Underground [Beck 33]

Geographic version of map

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

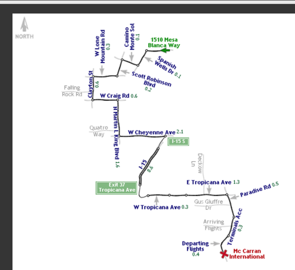
Approach

Identify design principles

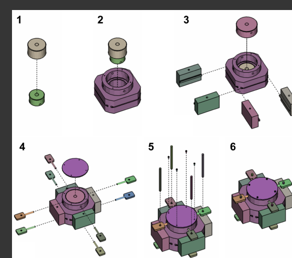
- Cognition and perception

Instantiate design principles

- Principles become constraints that guide an optimization process



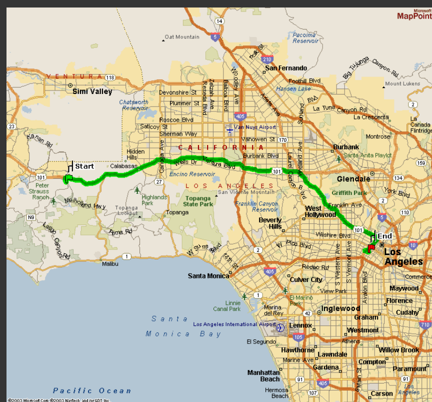
Route maps



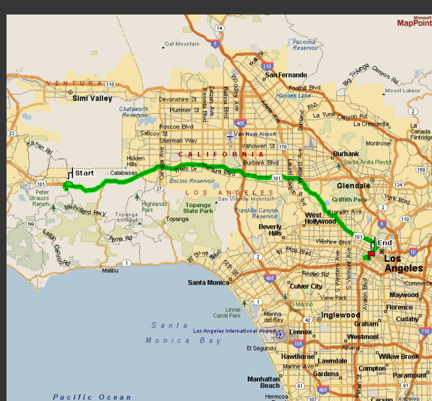
Assembly instructions

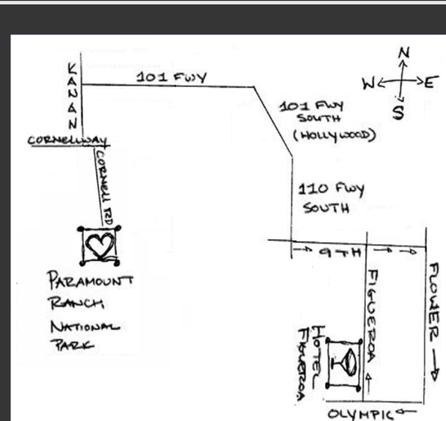
Route Maps

Visualizing Routes

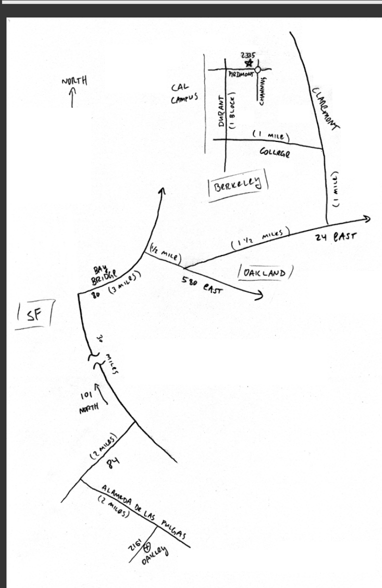


A Better Visualization





Cognition of Route Maps



Essential information

- Turning points
- Route topology

Secondary context information

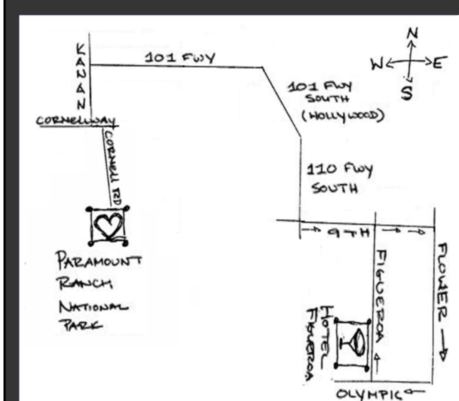
- Local landmarks, cross streets, etc.
- Overview area landmarks, global shape

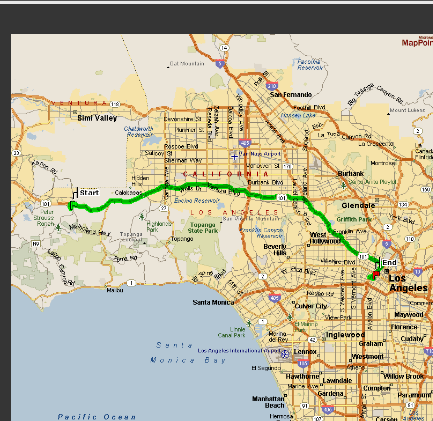
Exact geometry less important

- *Not* apprehended accurately
- *Not* drawn accurately

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

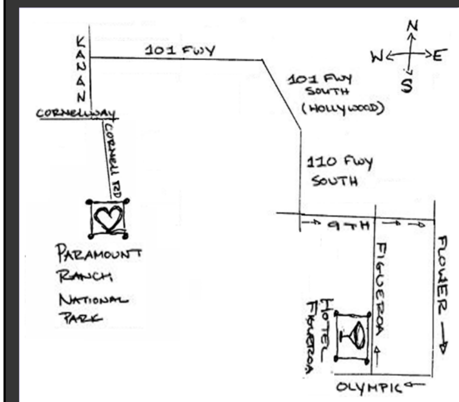
Design Principles



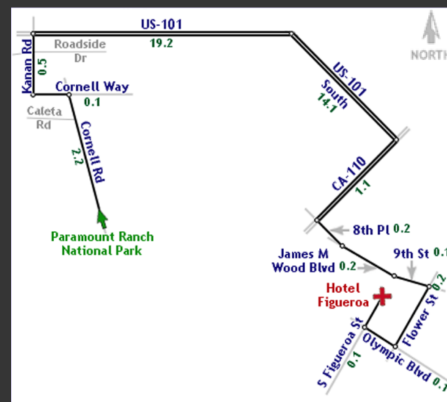


- **Exaggerate road length**
- **Regularize turning angles**
- **Simplify road shape**

LineDrive



Hand-drawn route map



LineDrive route map

Map Design via Optimization

Set of graphic elements

- Roads, labels, cross-streets, …

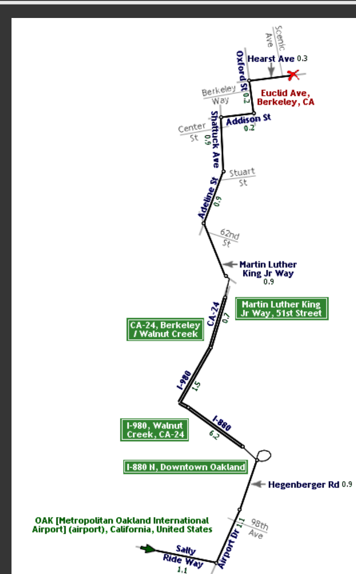
Choose visual attributes

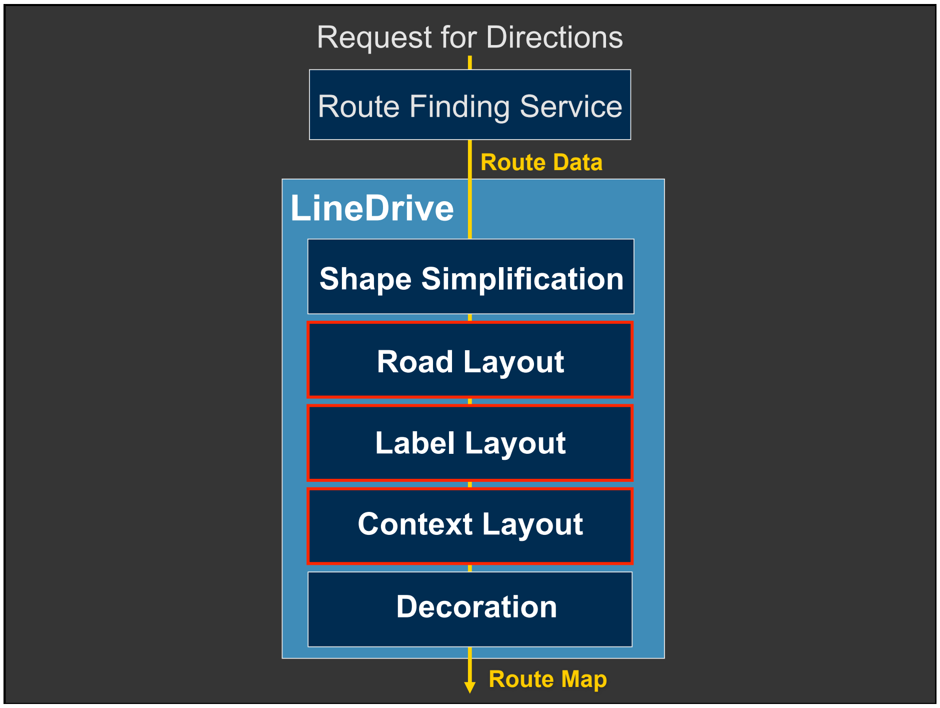
- Position, orientation, size, …
- Distortions increase flexibility

Develop constraints based on design principles

Simulated annealing

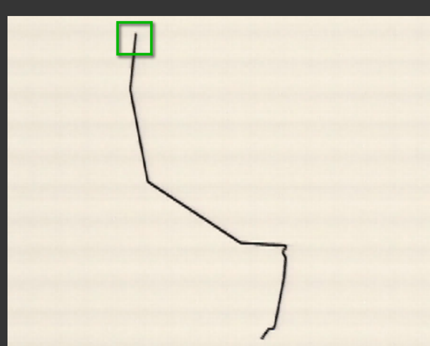
- Perturb: Form a layout
- Score: Evaluate quality
- Minimize score



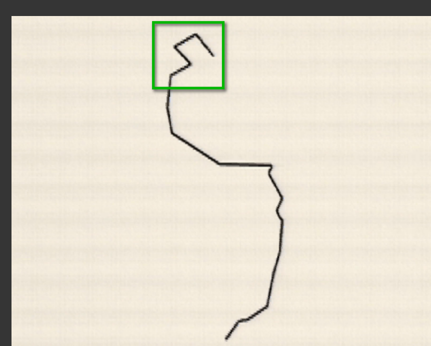


Road Layout

Choose road lengths and orientations



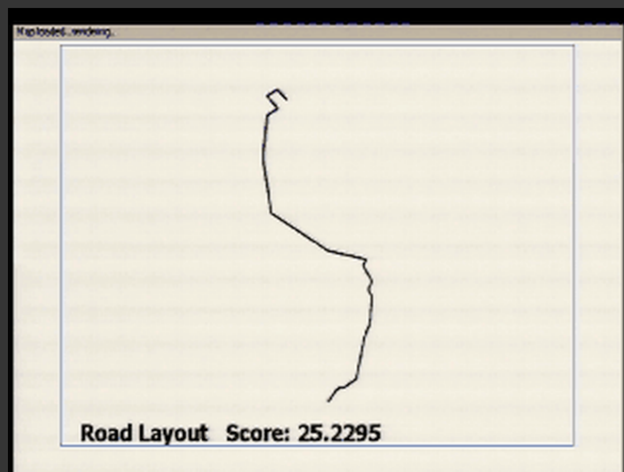
Before road layout



After road layout

Road Layout

Choose road lengths and orientations



Road Layout Constraints

Length

- Ensure all roads visible — $((L_{min} - l(r_i)) / L_{min})^2 * W_{small}$
- Maintain ordering by length — $W_{shuffle}$

Orientation

- Maintain original orientation — $|\alpha_{curr}(r_i) - \alpha_{orig}(r_i)| * W_{orient}$

Topological errors

- Prevent false — $\min(d_{origin}, d_{dest}) * W_{false}$
- Prevent missing — $d * W_{missing}$
- Ensure separation — $\min(d_{ext}, E) * W_{ext}$

Overall route shape

- Maintain endpoint direction — $|\alpha_{curr}(v) - \alpha_{orig}(v)| * W_{enddir}$
- Maintain endpoint distance — $|d_{curr}(v) - d_{orig}(v)| * W_{enddist}$

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

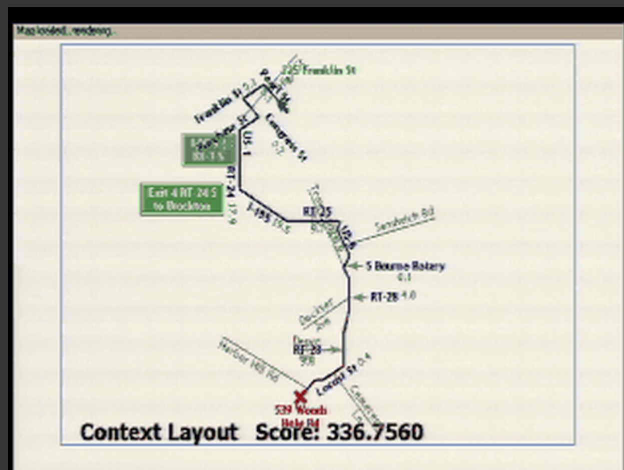
- Users given maps containing errors
- Rated which errors most confusing

Label Layout

Find overlap-free position for each label

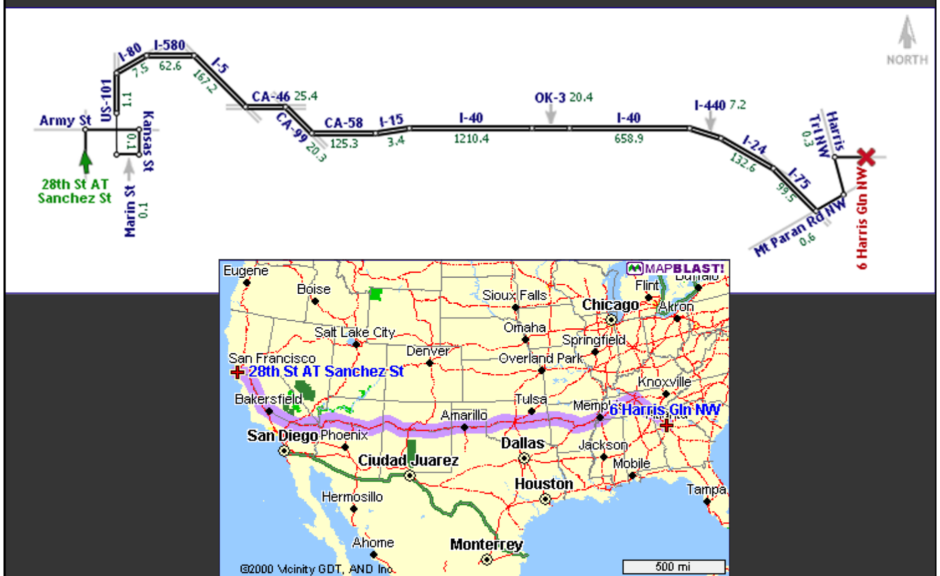
Context Layout

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

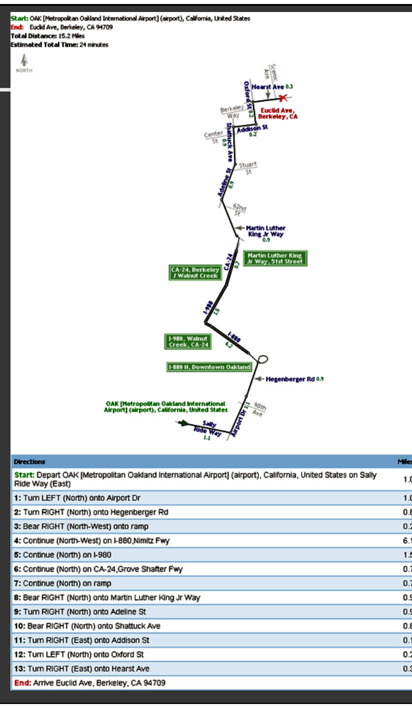
- 150,000 maps served

2242 responses

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

At peak

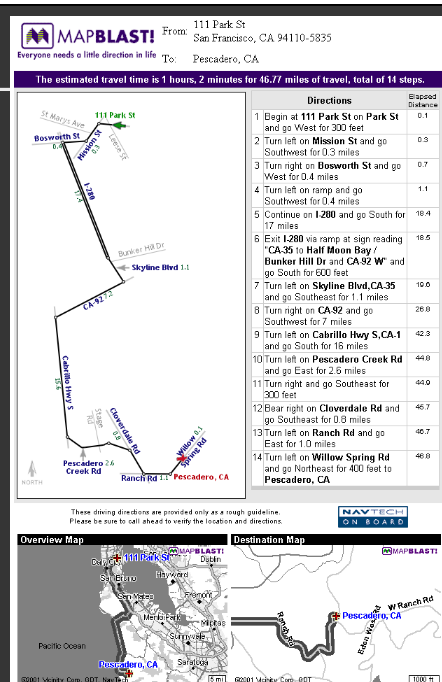
- Deployed at: mappoint.com
- Served 750,000 maps/day
- Taken offline in fall 2011



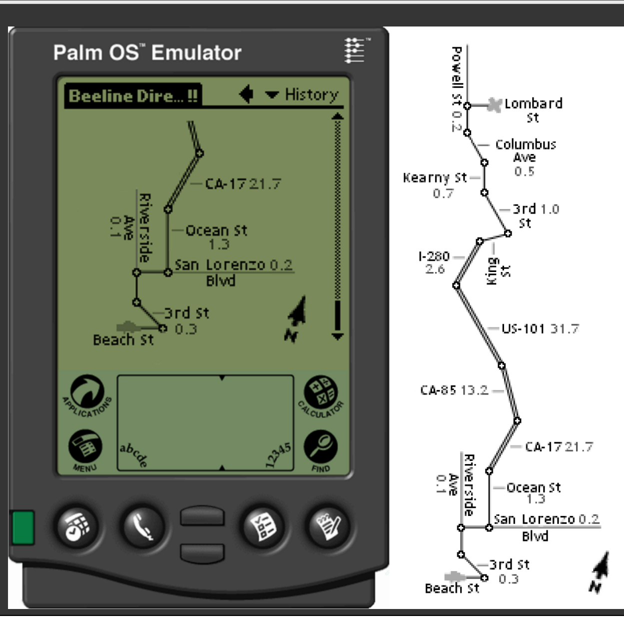
Original Design

Layout

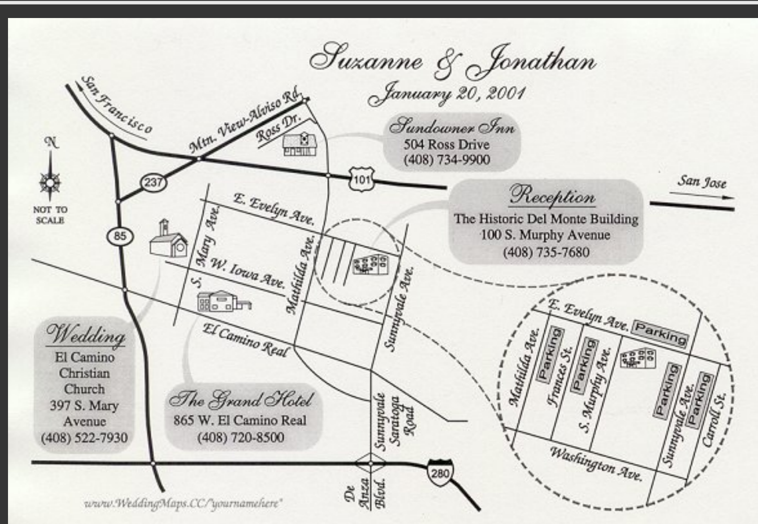
- Map and text close together
- Overview and destination maps for more content



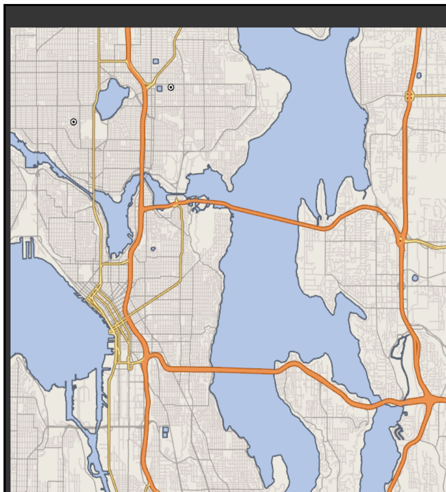
Limited Resolution PDA



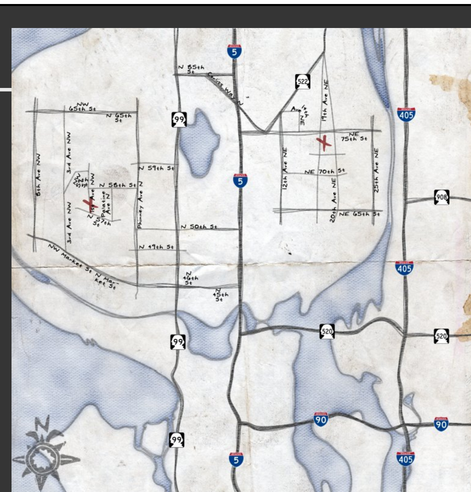
Next Steps: Wedding Maps



Hand-designed Wedding Map www.WeddingMaps.CC



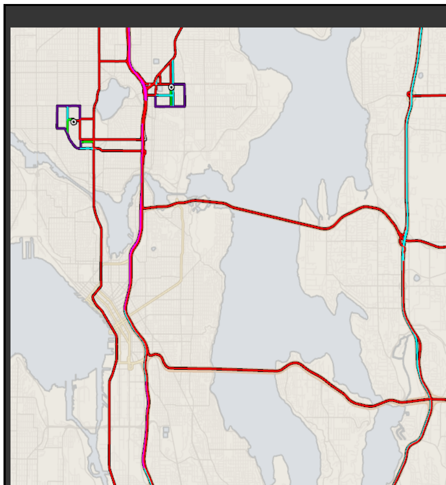
Input map drawn to scale



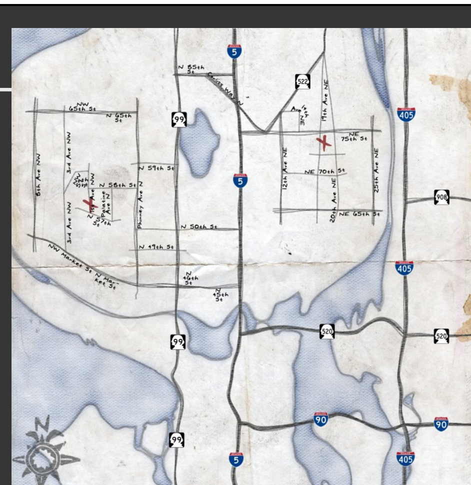
Our result

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

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



Roads selected from input



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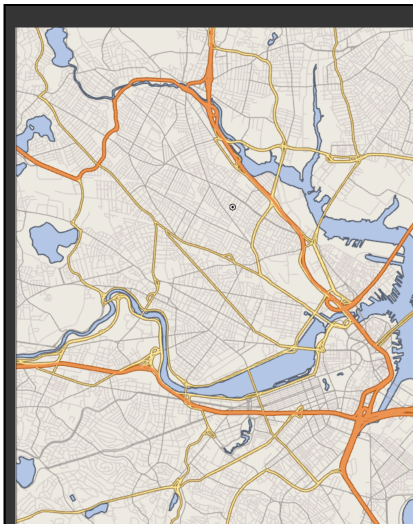
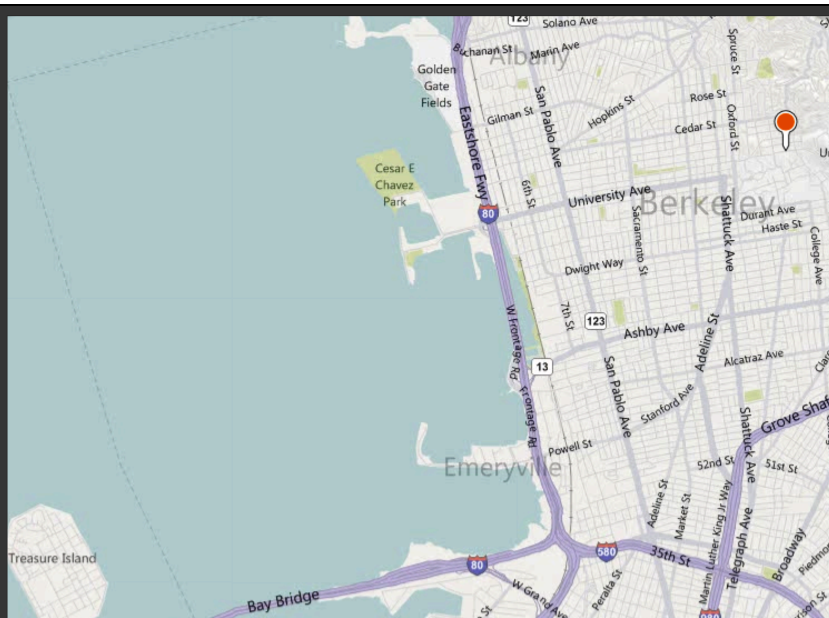


Input map drawn to scale

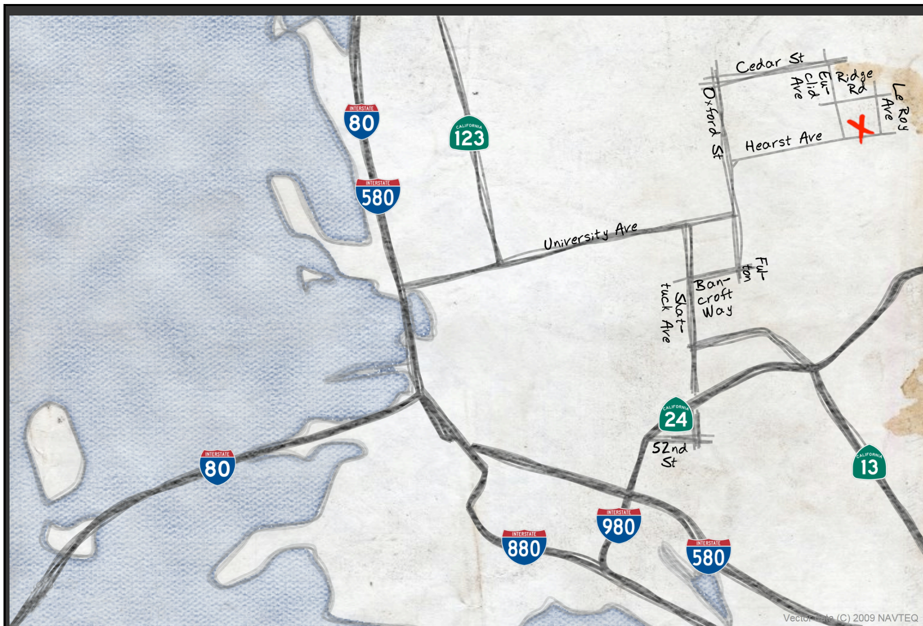
Our result

Evergreen Ave., Boston MA

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

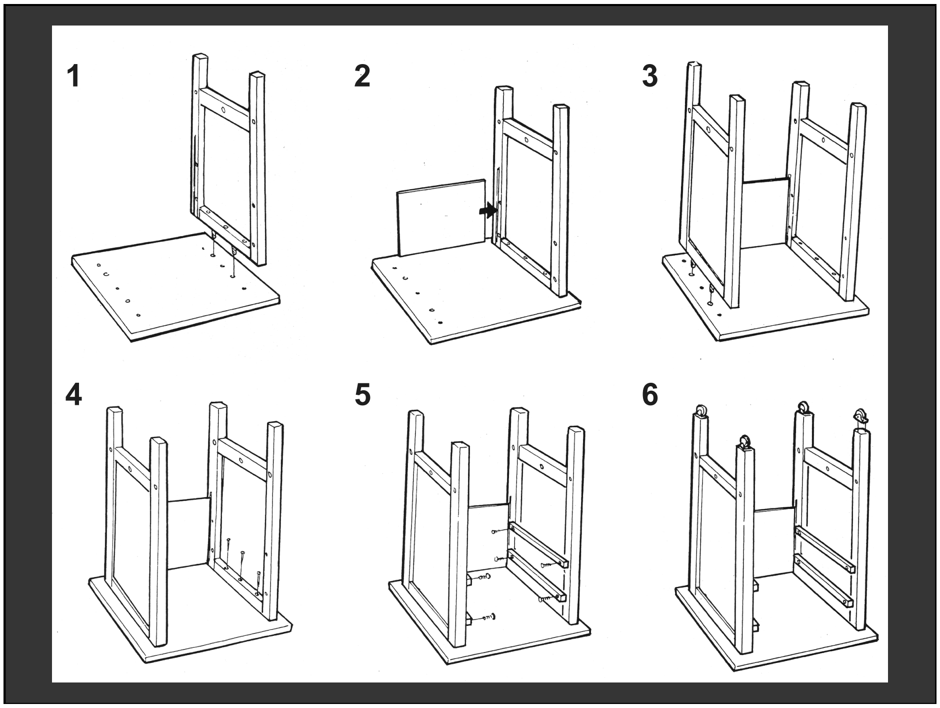


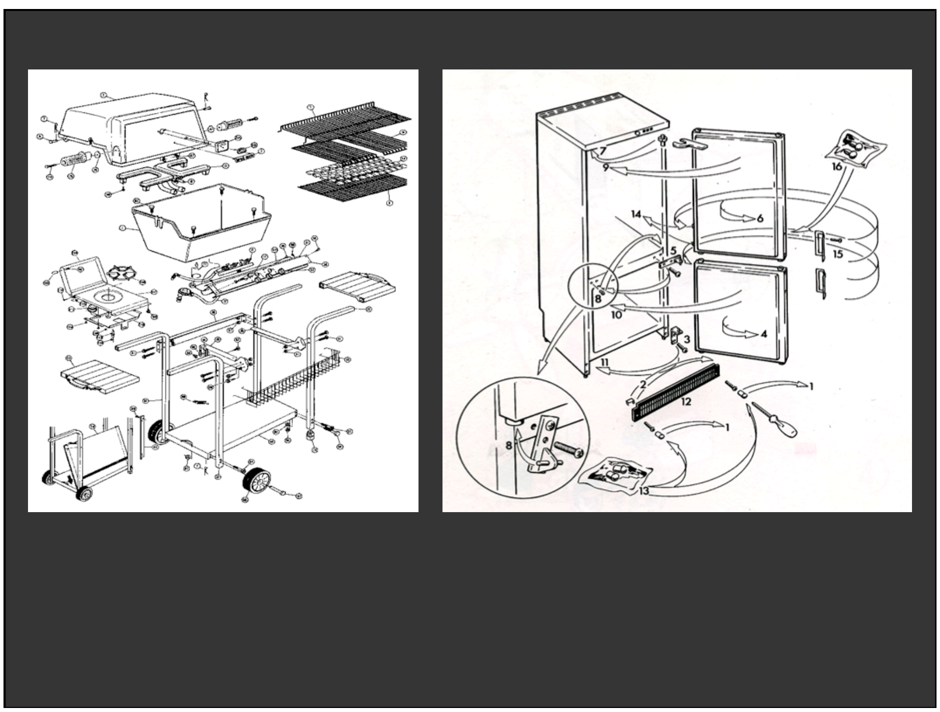
635 Soda Hall, Berkeley CA



635 Soda Hall, Berkeley CA

Assembly Instructions


1
2
3
4
5
6

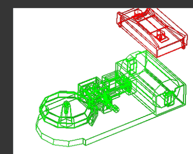


Previous Work

Planning

- Choose sequence of assembly operations
- Robotics / AI / Mechanical Engineering

[Wolter 89], [de Mello 91], [Wilson 92], [Romney 95]



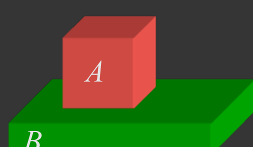
Presentation

- Visually convey assembly operations
- Visualization / Computer Graphics

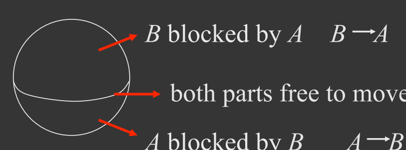
[Seligmann 91], [Rist 94], [Butz 97], [Strothotte 98]

Jointly optimize plan and presentation

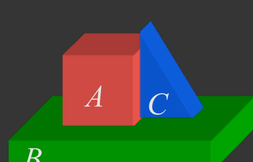
Geometric Analysis [Romney 95]

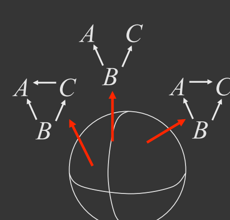


Input Parts

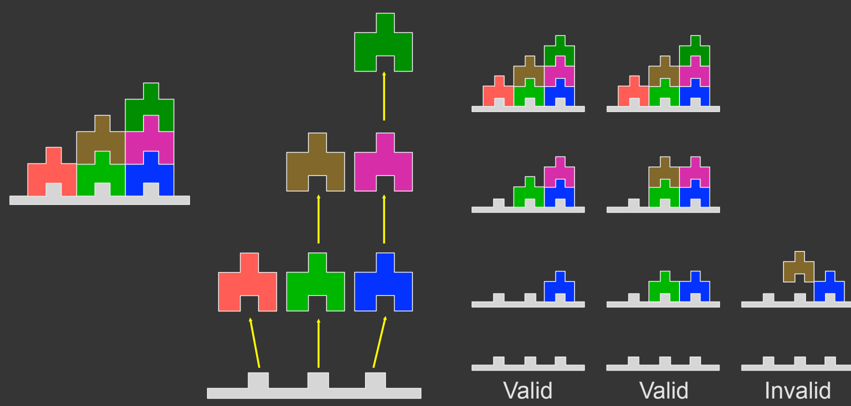


Blocking Graph

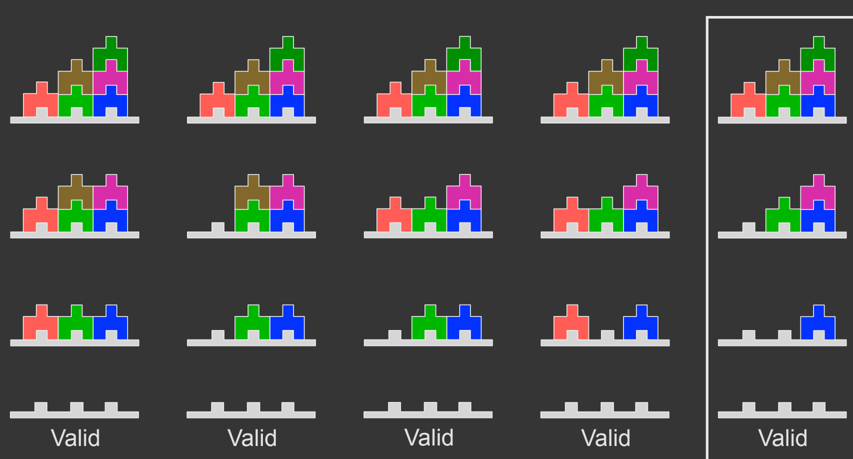




Geometric Assembly Planning



Many Geometrically Valid Sequences

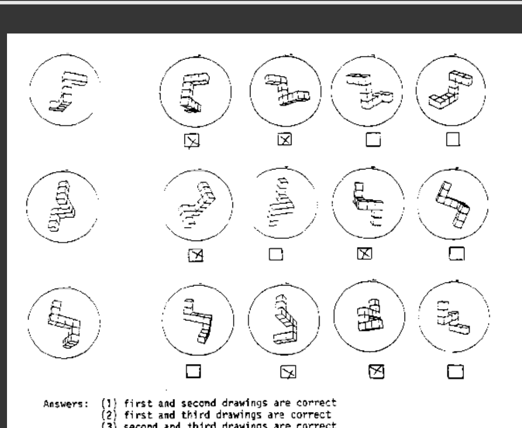


How do we choose the best sequence?

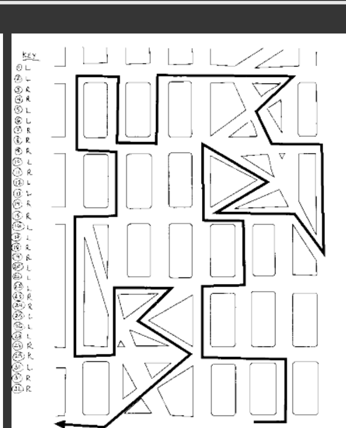
Identifying Design Principles

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

Spatial Ability Tests



Mental Rotation [Vandenburg 78]



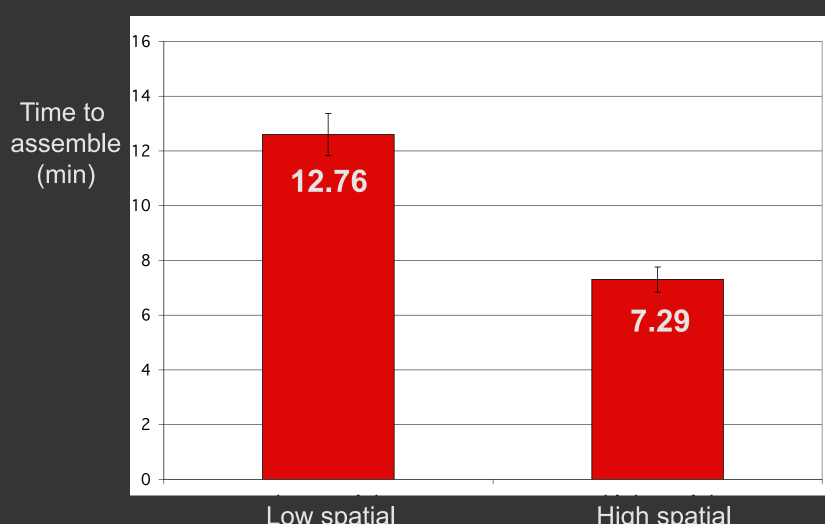
Navigation [Money 78]

Separate high and low spatial ability

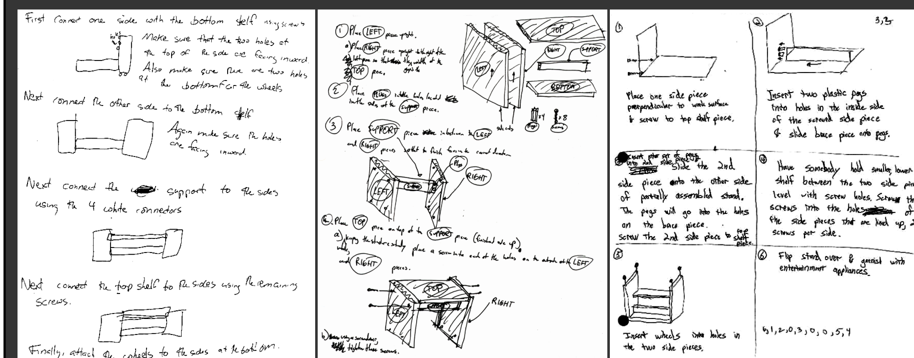
Stage 1: Production

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

Stage 1: Mean completion time

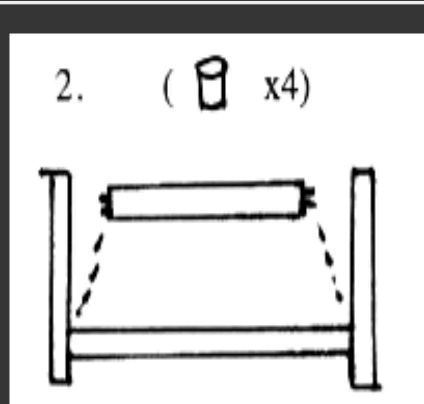


Stage 1: Instructions produced



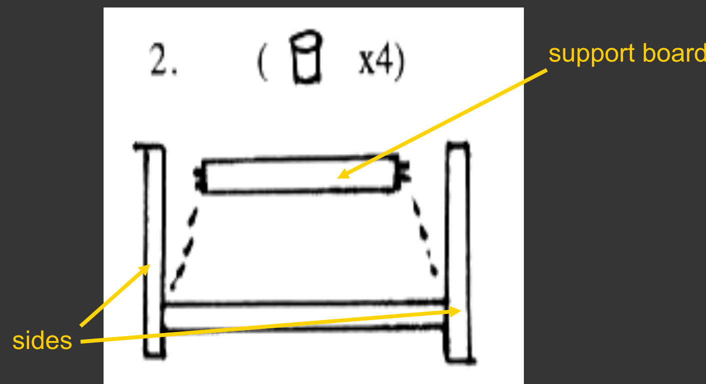
- Almost all contained diagrams 98%
- Text redundant with diagrams 62%

Stage 1: Errors in instructions



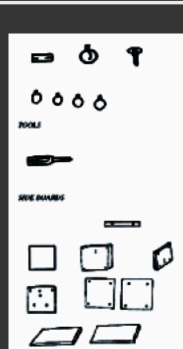
- Errors in low spatial instructions 86%
- Errors in high spatial instructions 12%

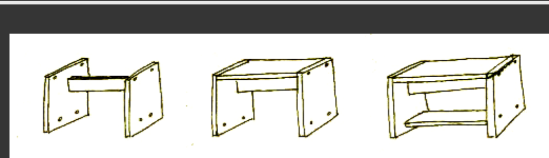
Stage 1: Errors in instructions

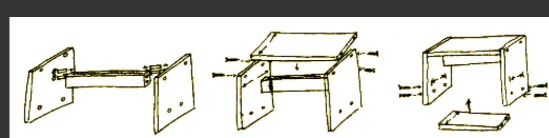


- Errors in low spatial instructions 86%
- Errors in high spatial instructions 12%

Stage 1: Classes of Diagrams

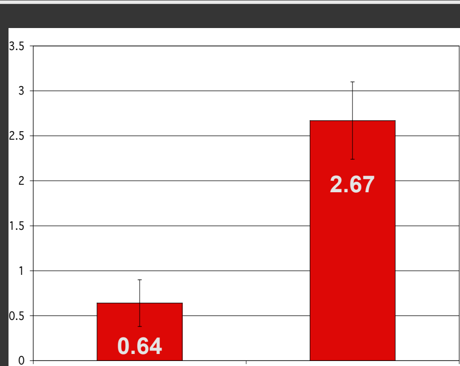

Parts menu


Structural diagrams


Action diagrams

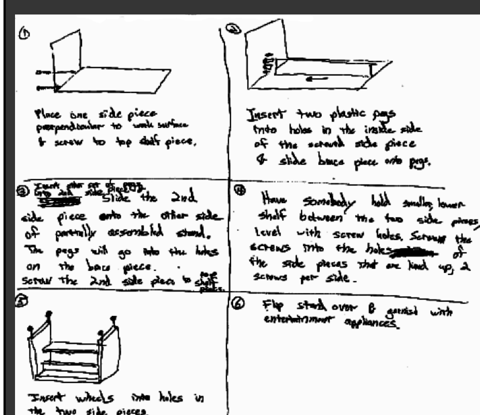
- Parts menu to differentiate parts
- Structural diagrams depict completed step
- Action diagrams show assembly action/operation

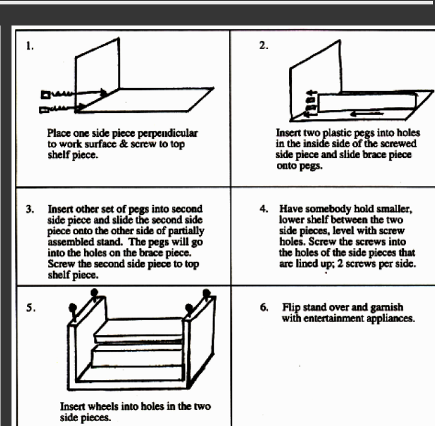
Stage 1: Action diagrams



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

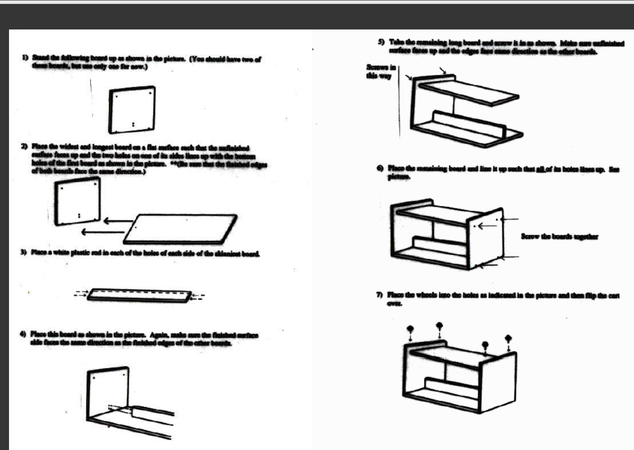
Stage 2: Preference





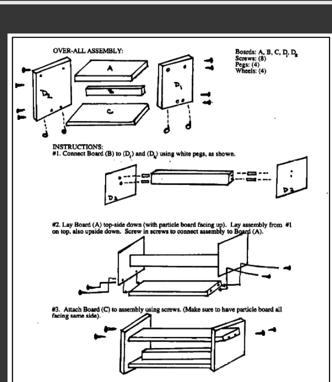
- 21 Participants
- Assemble TV Stand without instructions
- Rated 39 sets of redrawn instructions

Stage 2: Highest Rated

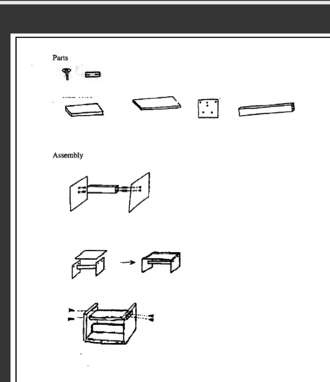


- Ratings similar across all participants
- Spatial ability does not affect preference

Stage 3: Comprehension



Set 1: Text + Action



Set 3: Parts menu + Structural + Action

- 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

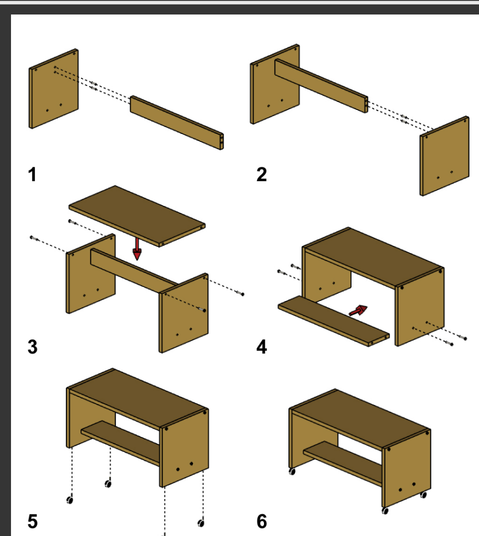
- Should show relevant parts and attachments
- Structural diagrams and exploded view hard to use
- Text not very useful

Design Principles

Step-by-Step

Action diagrams

Good visibility



TV stand instructions generated by our system

Input

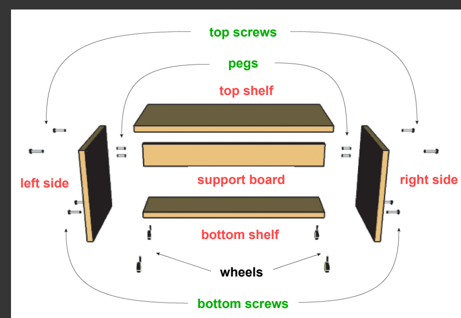
Geometry: Parts in assembled configuration

Orientations: Default viewpoint / orientation
Preferred orientation for each part

Groupings: Fasteners, significant parts, similar actions, symmetry

required
optional

Assembled geometry in default orientation



Parts grouped as fasteners and significant parts

All parts

Search

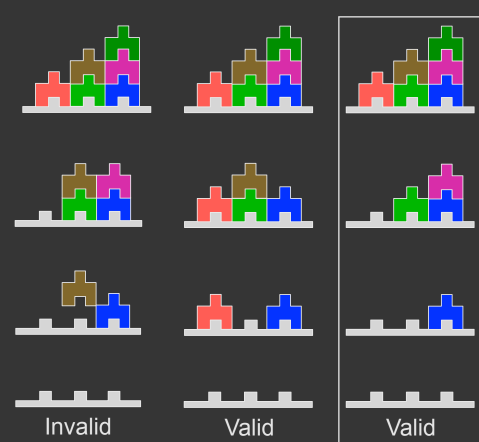
Subdivide Steps

Reorientation

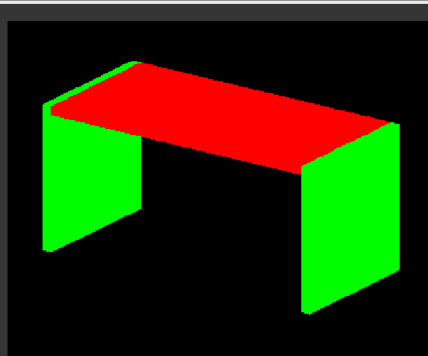
Step-by-step assembly sequence

Find best assembly sequence

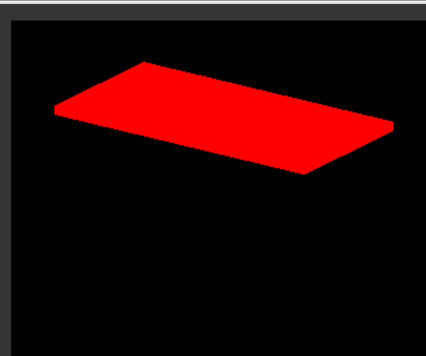
- Planning: Geometric feasibility
- Presentation: Visibility



Computing Visibility



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



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

Vis(P,Q) = Area(P,Q) / Area(P)
% pixels that remain visible when sides are included

Visibility Constraints

1. Parts being attached R

- Check that each part is visible

$\min_{r \in R} (Vis(r, R-r)) * W_R$

2. Previously attached parts A

- Check that context is visible

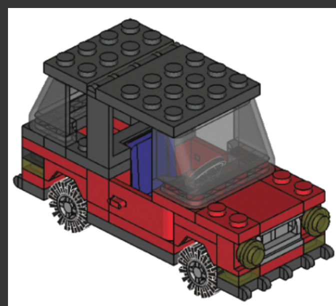
$Vis(A, R) * W_A$

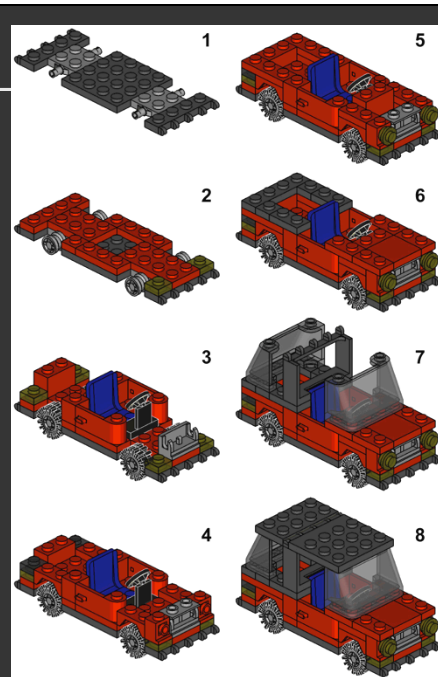
3. Future unattached parts U

- Check that future parts will be visible

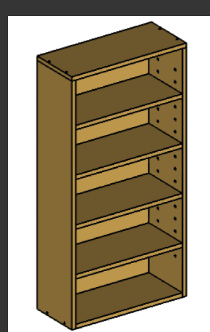
$\min_{u \in U} (Vis(u,R)) * W_U$

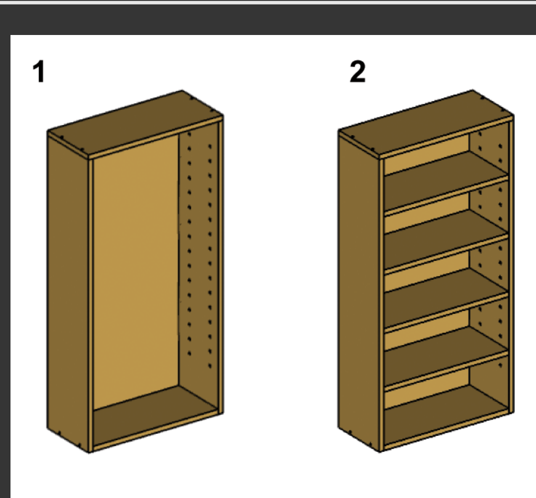
Lego Car


Input model



Bookcase


Input model



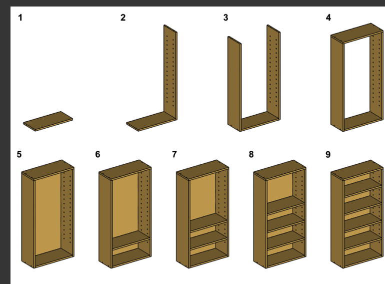
All parts

Search

Subdivide Steps

Reorientation

Step-by-step assembly sequence



Sequentially add parts

- Least visible to most visible
- Distance to viewer

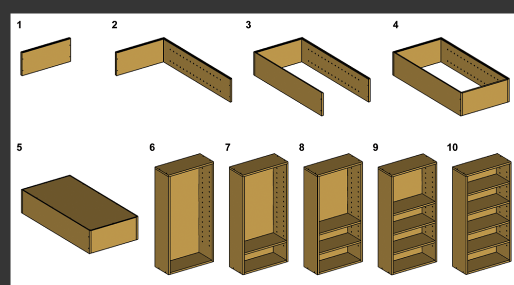
All parts

Search

Subdivide Steps

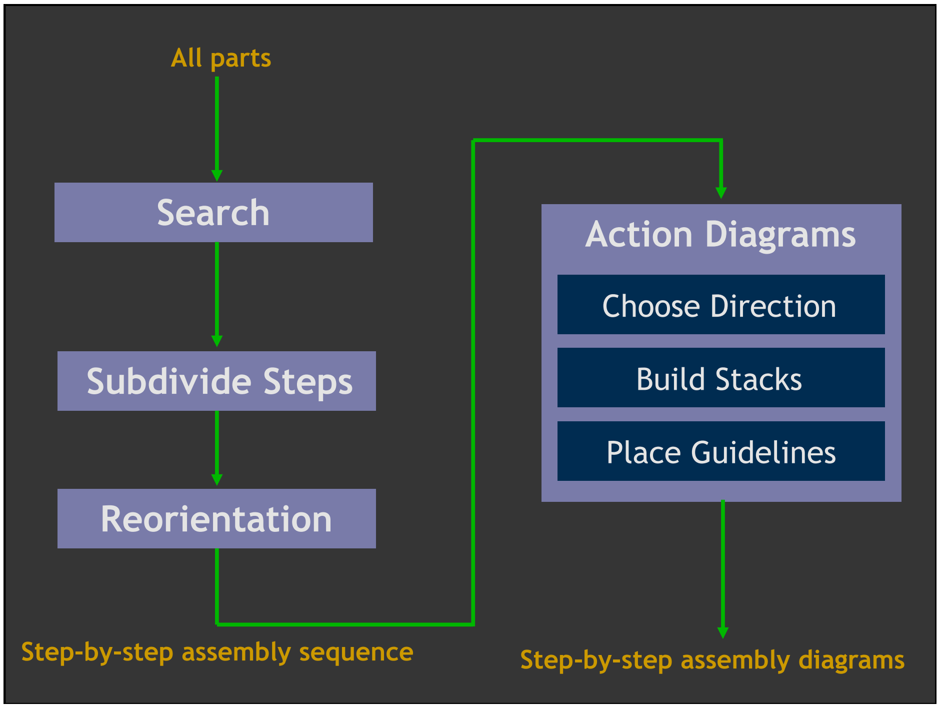
Reorientation

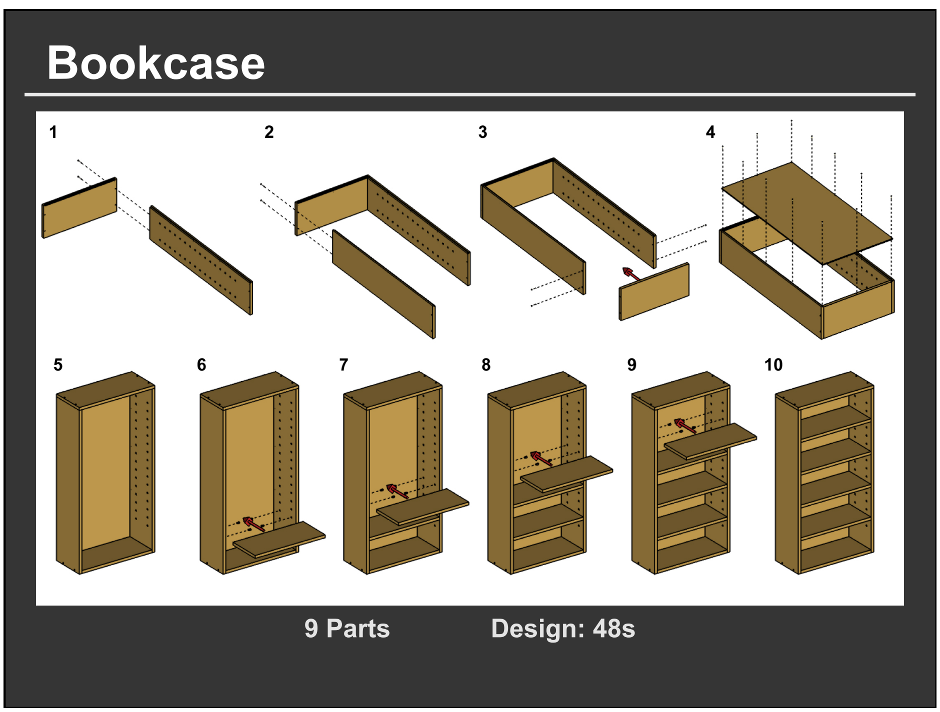
Step-by-step assembly sequence



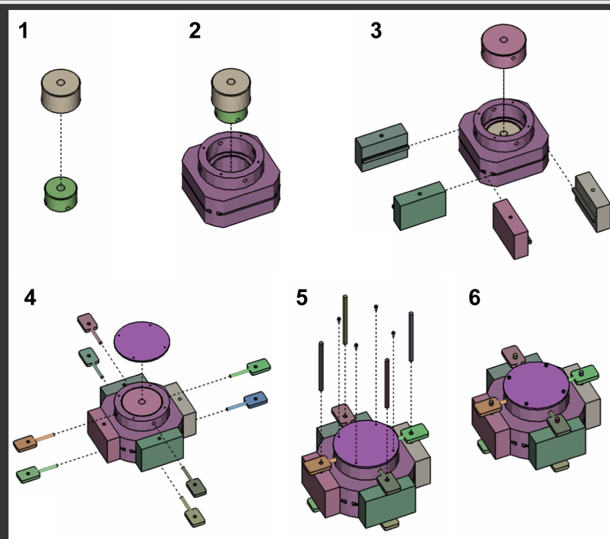
Reorient

- Set preferred orientation
- If poor visibility try alternate orientations


All parts
Search
Subdivide Steps
Reorientation
Step-by-step assembly sequence
Action Diagrams
Choose Direction
Build Stacks
Place Guidelines
Step-by-step assembly diagrams


Bookcase
1
2
3
4
5
6
7
8
9
10
9 Parts
Design: 48s

Test Object

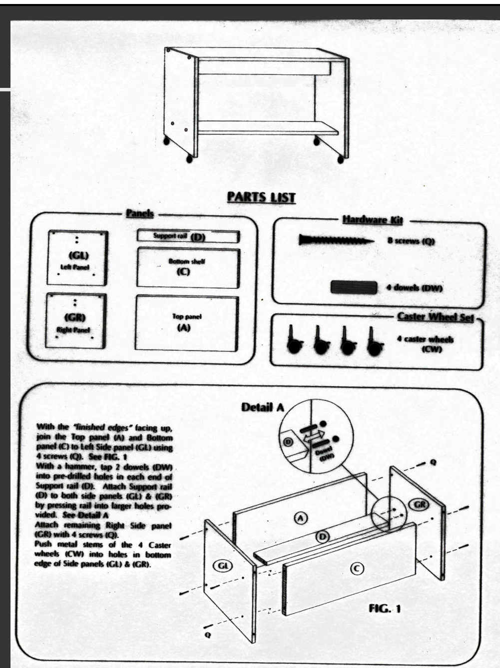


25 Parts Design: 53s

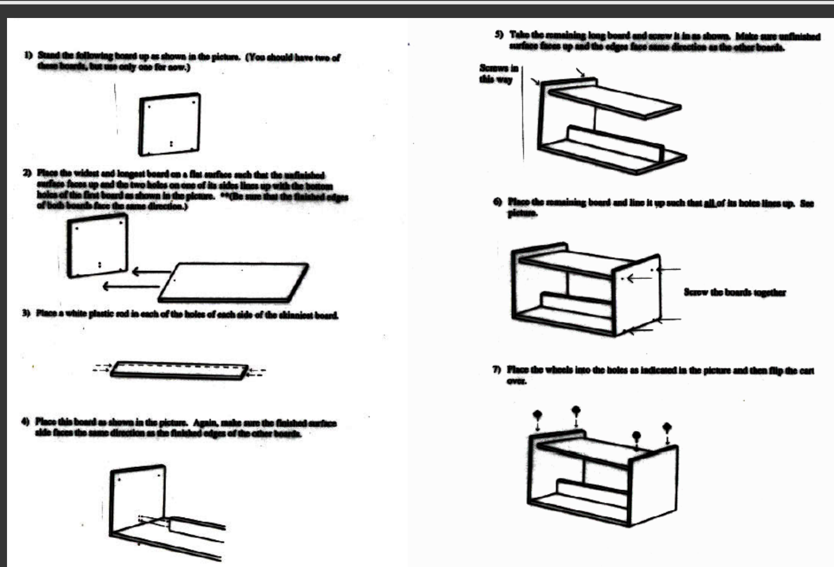
Evaluation

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

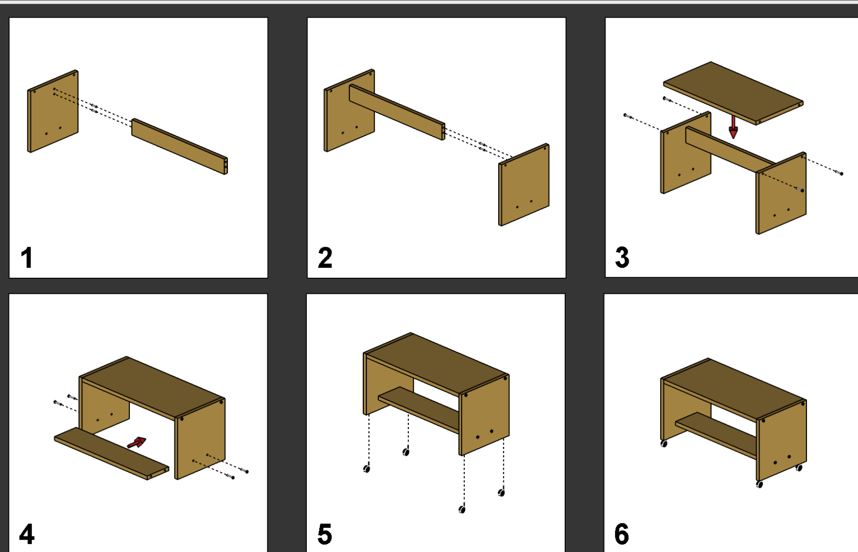
Factory



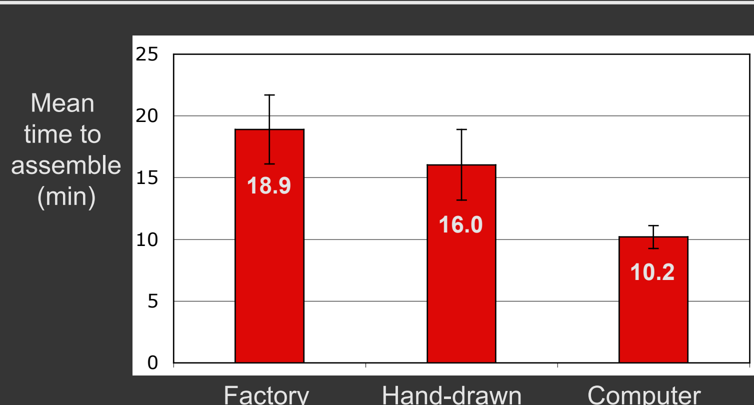
Hand-drawn



Computer Generated



Results



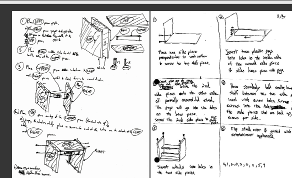
Errors: Factory **1.6** Hand-drawn **0.6** Computer **0.5**

Task rated easiest in computer condition

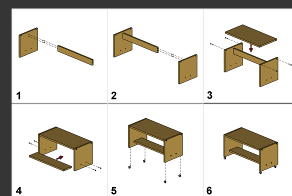
Summary

Identification of design principles

- Production
- Preference
- Comprehension



Instantiation of design principles



Validation of design principles