

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

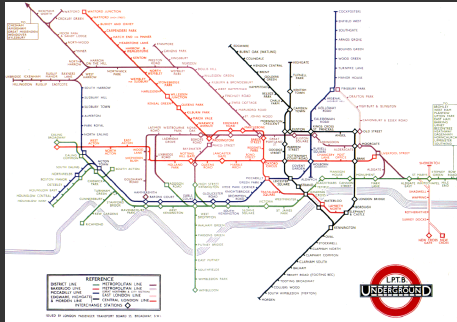
- Project proposal: 10/27
- Project presentation: 11/10, 11/12
- Final paper and presentation: TBD, likely 12/1-12/5

Grading

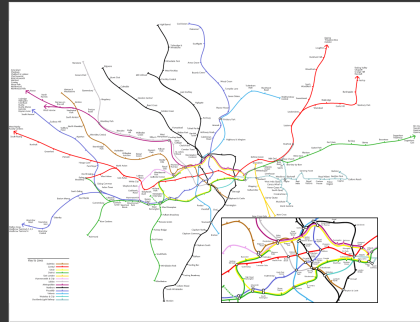
- Groups of up to 3 people, graded individually
- Clearly report responsibilities of each member

Identifying Design Principles

Good Design Improves Effectiveness

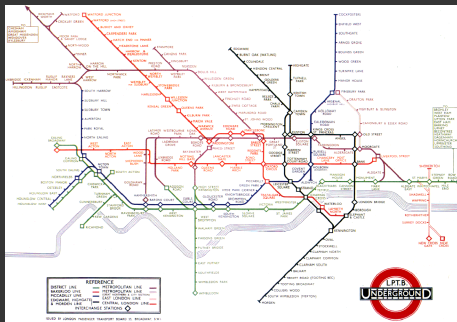


London Underground [Beck 33]

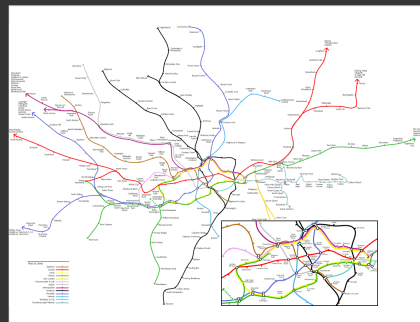


Geographic version of map

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

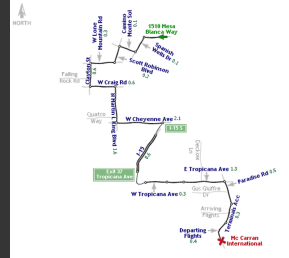
Approach

Identify design principles

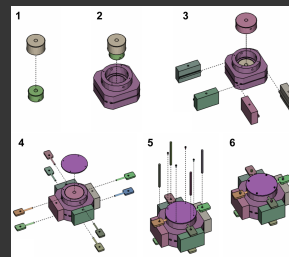
- Cognition and perception

Instantiate design principles

- Principles become constraints that guide an optimization process



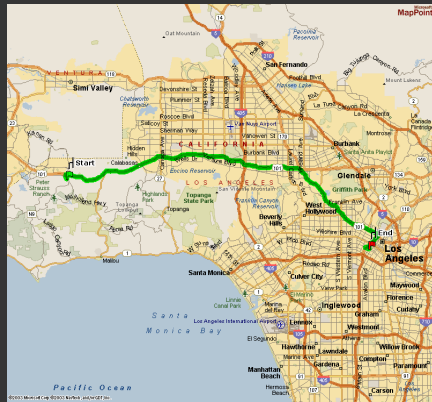
Route maps



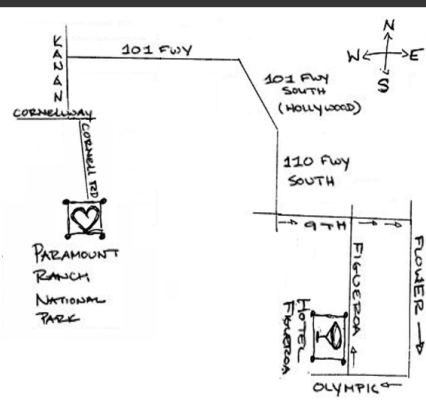
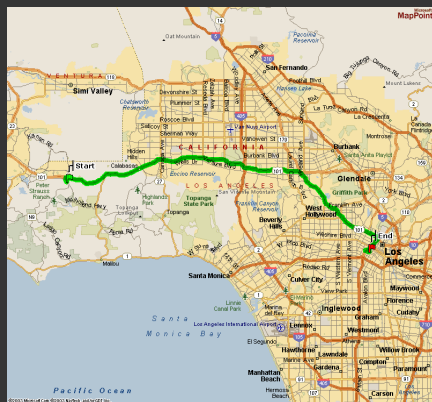
Assembly instructions

Route Maps

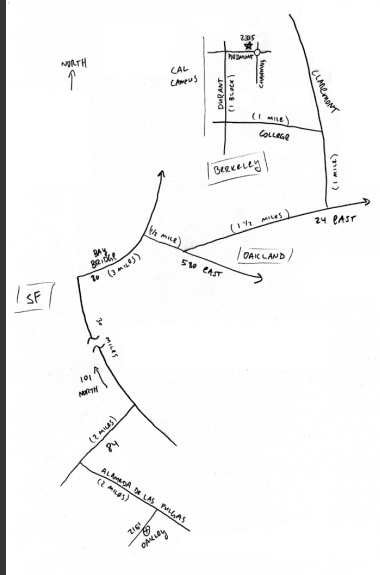
Visualizing Routes



A Better Visualization



Cognition of Route Maps



Essential information

- Turning points
- Route topology

Secondary context information

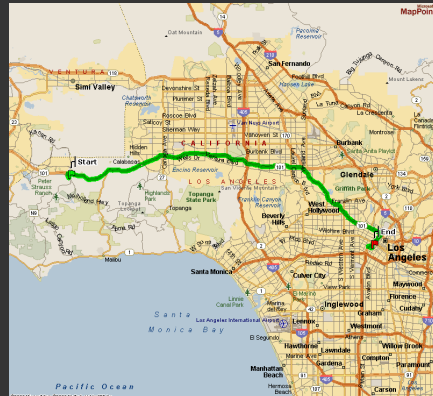
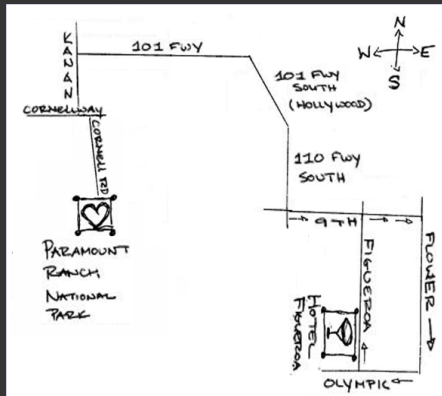
- Local landmarks, cross streets, etc.
- Overview area landmarks, global shape

Exact geometry less important

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

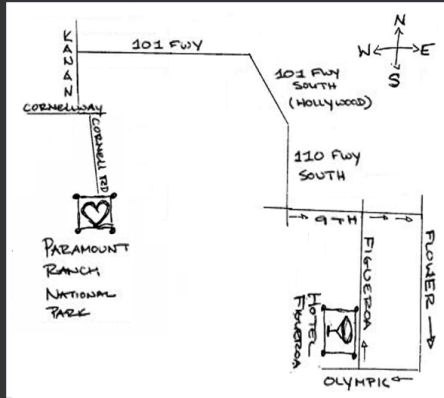
[Tversky 81] [Tufte 90] [Tversky 92]
[MacEachren 95] [Denis 97] [Tversky 99]

Design Principles

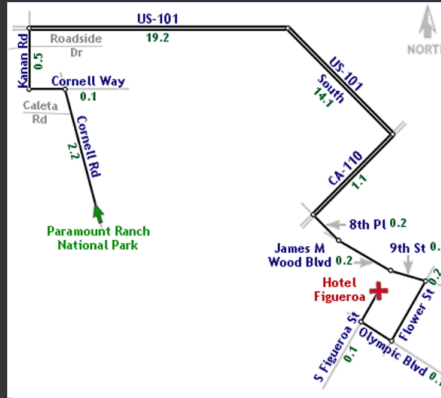


- Exaggerate road length
- Regularize turning angles
- Simplify road shape

LineDrive



Hand-drawn route map



LineDrive route map

Map Design via Optimization

Set of graphic elements

- Roads, labels, cross-streets, ...

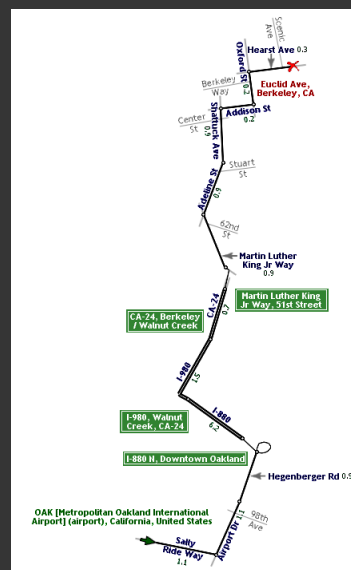
Choose visual attributes

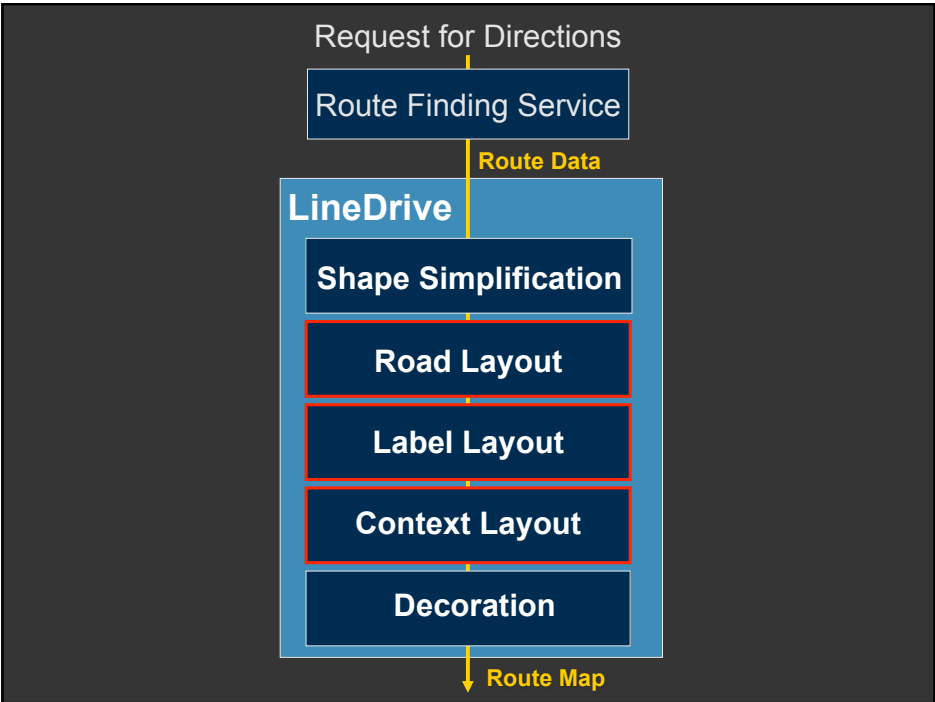
- Position, orientation, size, ...
- Distortions increase flexibility

Develop constraints based on design principles

Simulated annealing

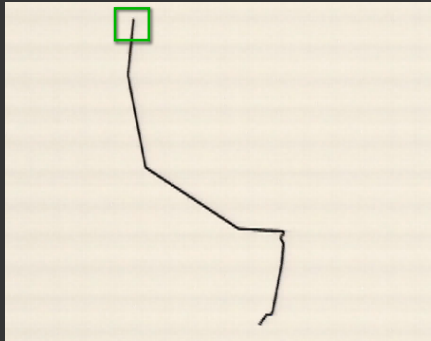
- Perturb: Form a layout
- Score: Evaluate quality
- Minimize score



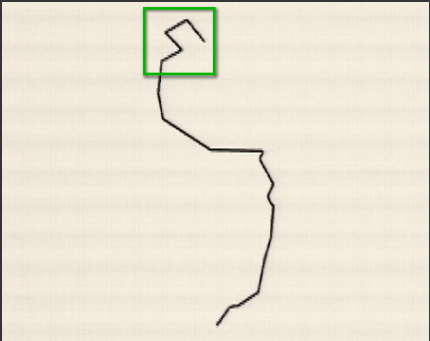


Road Layout

Choose road lengths and orientations



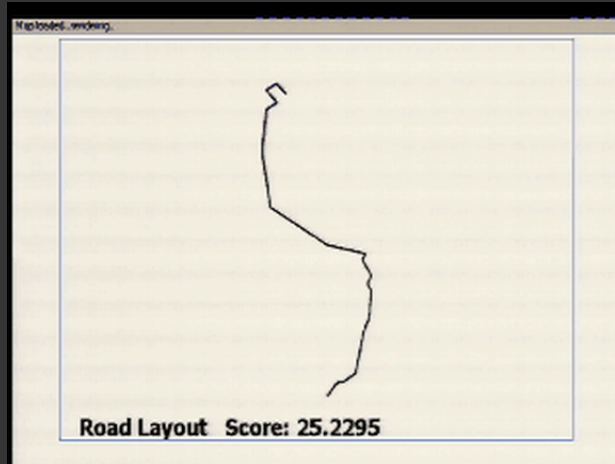
Before road layout



After road layout

Road Layout

Choose road lengths and orientations



Road Layout Constraints

Length

Ensure all roads visible

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

Maintain ordering by length

$$W_{\text{shuffle}}$$

Orientation

Maintain original orientation

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

Topological errors

Prevent false

$$\min(d_{\text{origin}}, d_{\text{dest}}) * W_{\text{false}}$$

Prevent missing

$$d * W_{\text{missing}}$$

Ensure separation

$$\min(d_{\text{ext}}, E) * W_{\text{ext}}$$

Overall route shape

Maintain endpoint direction

$$|\alpha_{\text{curr}}(v) - \alpha_{\text{orig}}(v)| * W_{\text{enddir}}$$

Maintain endpoint distance

$$|d_{\text{curr}}(v) - d_{\text{orig}}(v)| * W_{\text{enddist}}$$

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

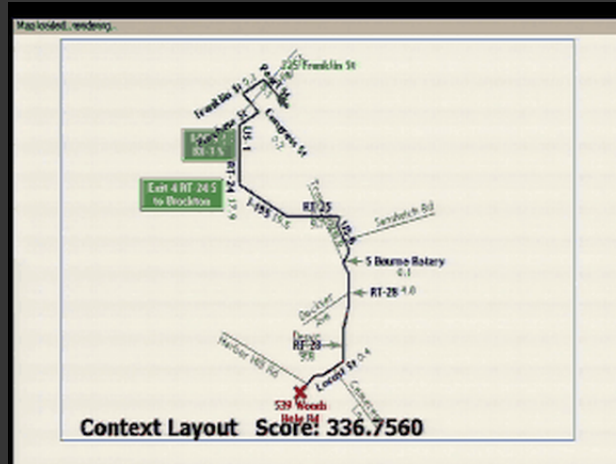
Label Layout

Find overlap-free position for each label



Context Layout

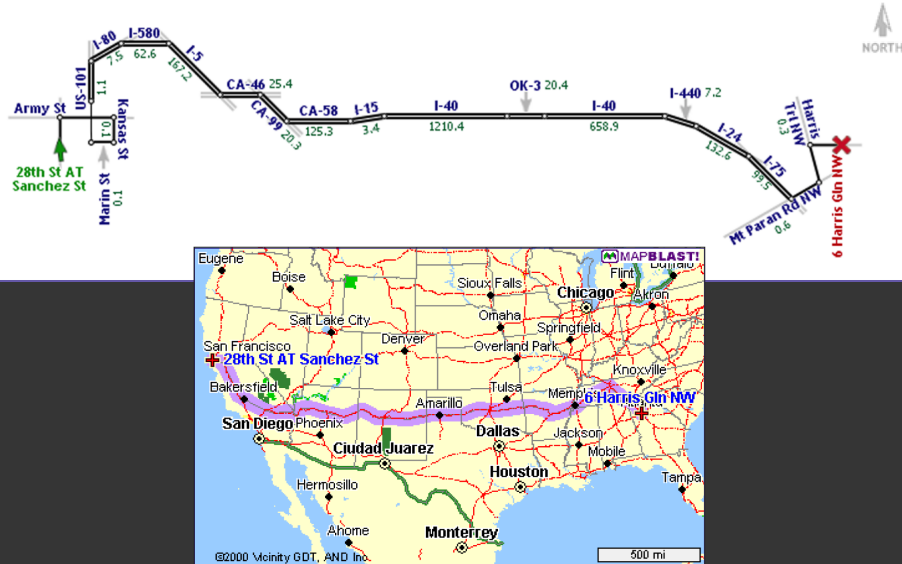
Place cross-streets and exit signs if possible



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

Start: OAK (Metropolitan Oakland International Airport) (airport), California, United States
 End: Euclid Ave, Berkeley, CA 94709
 Total Distance: 13.3 Miles
 Estimated Total Time: 24 minutes

Direction	Miles
Start: Depart OAK (Metropolitan Oakland International Airport) (airport), California, United States on Saly Ride Way (East)	1.0
1: Turn LEFT (North) onto Airport Dr	1.0
2: Turn RIGHT (North) onto Hegenberger Rd	0.8
3: Bear RIGHT (North-West) onto ramp	0.2
4: Continue (North-West) on I-880/Nimitz Fwy	6.1
5: Continue (North) on I-580	1.5
6: Continue (North) on CA-24/Grove Shafter Fwy	0.7
7: Continue (North) on ramp	0.7
8: Bear RIGHT (North) onto Martin Luther King Jr Way	0.9
9: Turn RIGHT (North) onto Addison St	0.9
10: Bear RIGHT (North) onto Shattuck Ave	0.8
11: Turn RIGHT (East) onto Addison St	0.1
12: Turn LEFT (North) onto Oxford St	0.2
13: Turn RIGHT (East) onto Hearst Ave	0.3
End: Arrive Euclid Ave, Berkeley, CA 94709	

Original Design

Layout

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

MAPBLAST! From 111 Park St San Francisco, CA 94110-5835 To: Pescadero, CA

Everyone needs a little direction in life

The estimated travel time is 1 hour, 2 minutes for 46.77 miles of travel, total of 14 steps.

Directions	Elapsed Distance
1 Begin at 111 Park St on Park St and go West for 300 feet	0.1
2 Turn left on Mission St and go Southwest for 0.3 miles	0.3
3 Turn right on Bosworth St and go West for 0.4 miles	0.7
4 Turn left on ramp and go Southwest for 0.4 miles	1.1
5 Continue on I-280 and go South for 17 miles	18.4
6 Exit I-280 via ramp at sign reading "CA 35 to Half Moon Bay / Bunker Hill Dr and CA 92 W" and go South for 600 feet	19.5
7 Turn left on Skyline Blvd, CA 35 and go Southeast for 1.1 miles	20.6
8 Turn right on CA 92 and go Southwest for 7 miles	26.8
9 Turn left on Cabillio Hwy S, CA 1 and go South for 16 miles	42.3
10 Turn left on Pescadero Creek Rd and go East for 2.6 miles	44.9
11 Turn right and go Southeast for 300 feet	44.9
12 Bear right on Cloverdale Rd and go Southeast for 0.8 miles	45.7
13 Turn left on Ranch Rd and go East for 1.0 miles	46.7
14 Turn left on Willow Spring Rd and go Northeast for 400 feet to Pescadero, CA	46.8

These driving directions are provided only as a rough guideline. Please be sure to call ahead to verify the location and directions.

NAVTECH BOARD

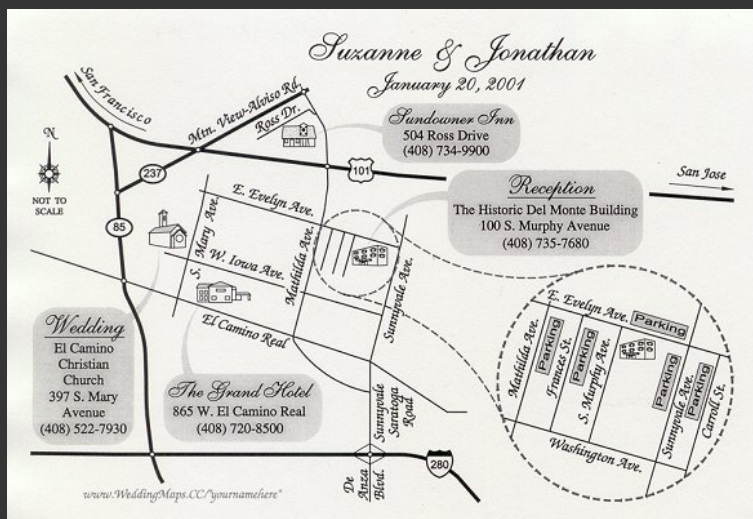
Overview Map Destination Map

©2001 Mobily Corp. 001_Nevada ©2001 Mobily Corp. 001

Limited Resolution PDA



Next Steps: Wedding Maps



Hand-designed Wedding Map www.WeddingMaps.CC

The image shows two side-by-side map panels. The left panel, titled "Input map drawn to scale", displays a street map with a network of orange lines representing roads. The right panel, titled "Our result", shows the same geographic area with a more detailed and accurate road network, including major highways like I-5, I-90, and SR-520, and local streets. A compass rose is visible in the bottom-left corner of the right panel.

Input map drawn to scale **Our result**

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

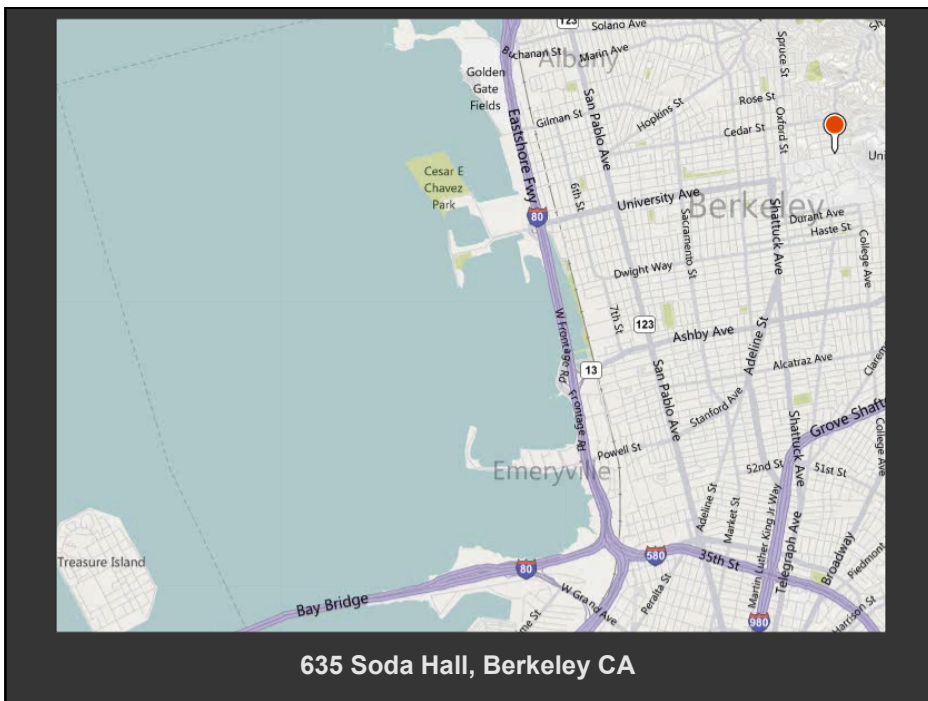
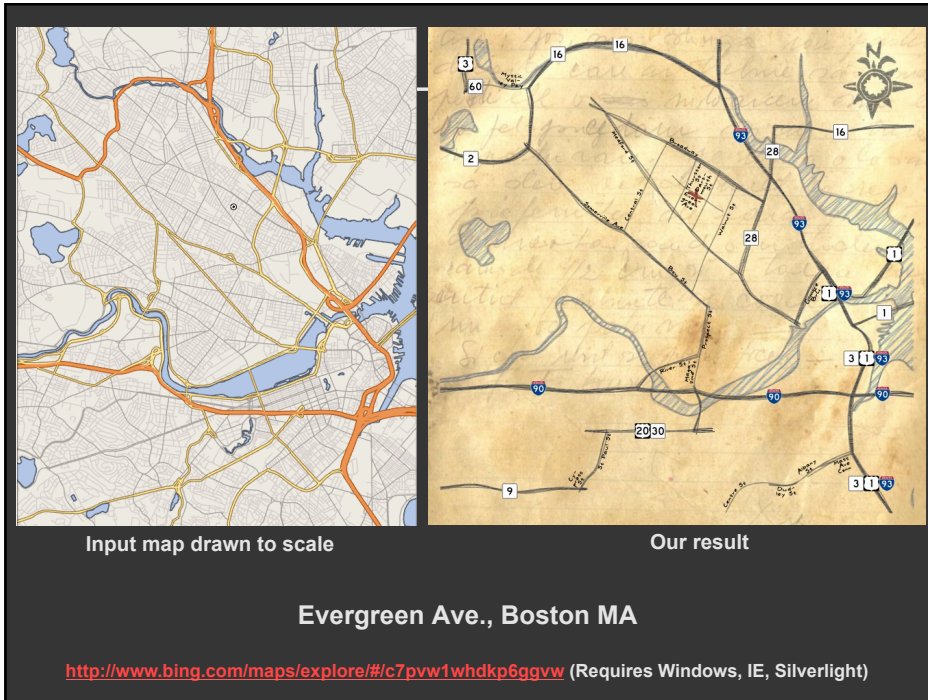
<http://www.bing.com/maps/explore/#/c7pww1whdkp6ggvw> (Requires Windows, IE, Silverlight)

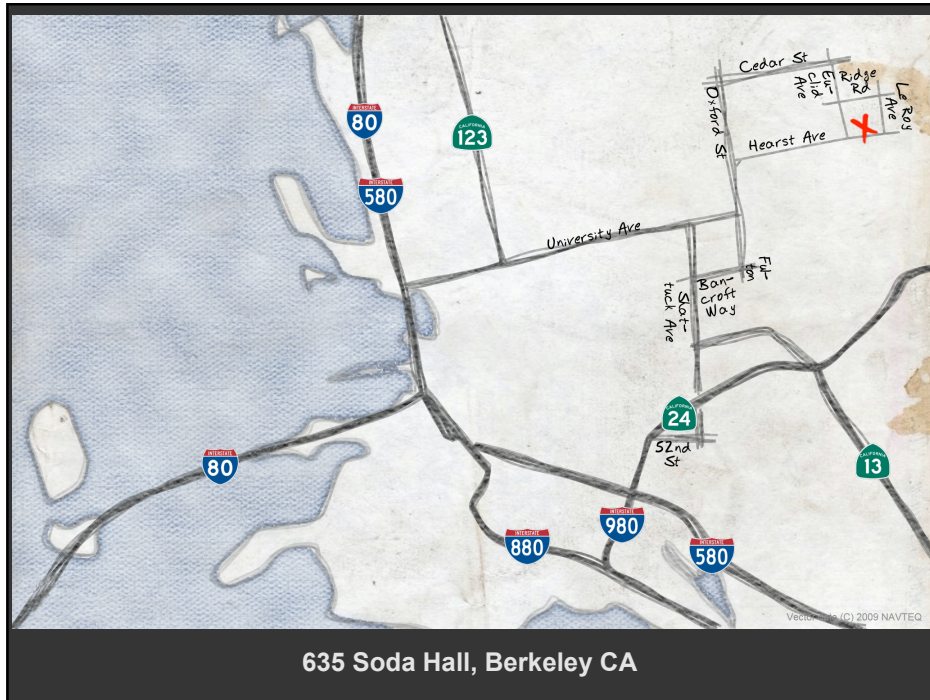
The image shows two side-by-side map panels. The left panel, titled "Roads selected from input", shows the same street map as the first image, but with several roads highlighted in red and purple. The right panel, titled "Our result", shows the same geographic area with a more detailed and accurate road network, including major highways like I-5, I-90, and SR-520, and local streets. A compass rose is visible in the bottom-left corner of the right panel.

Roads selected from input **Our result**

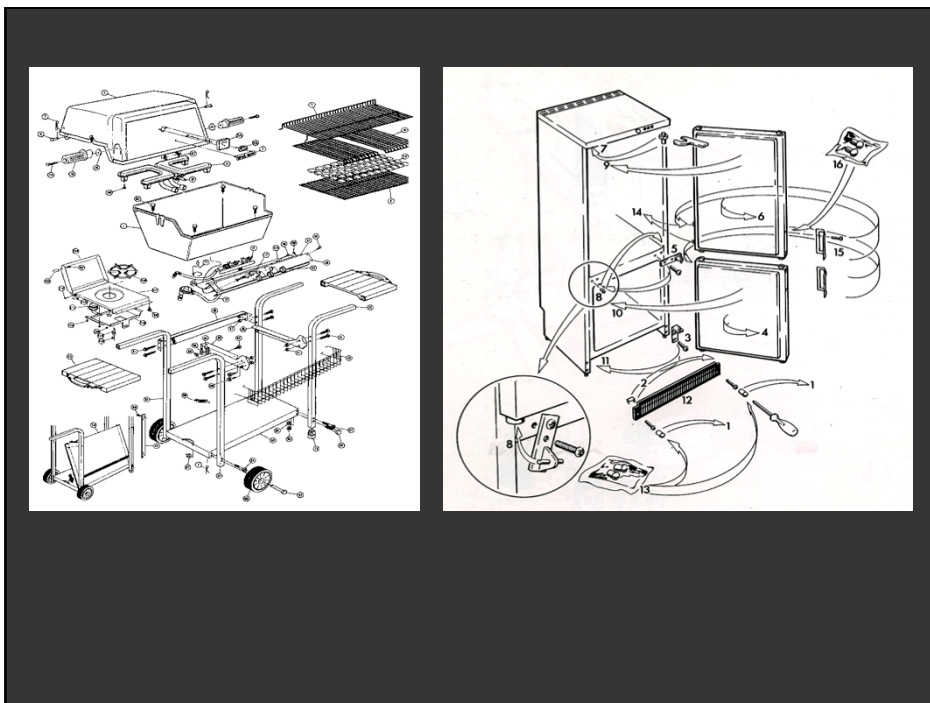
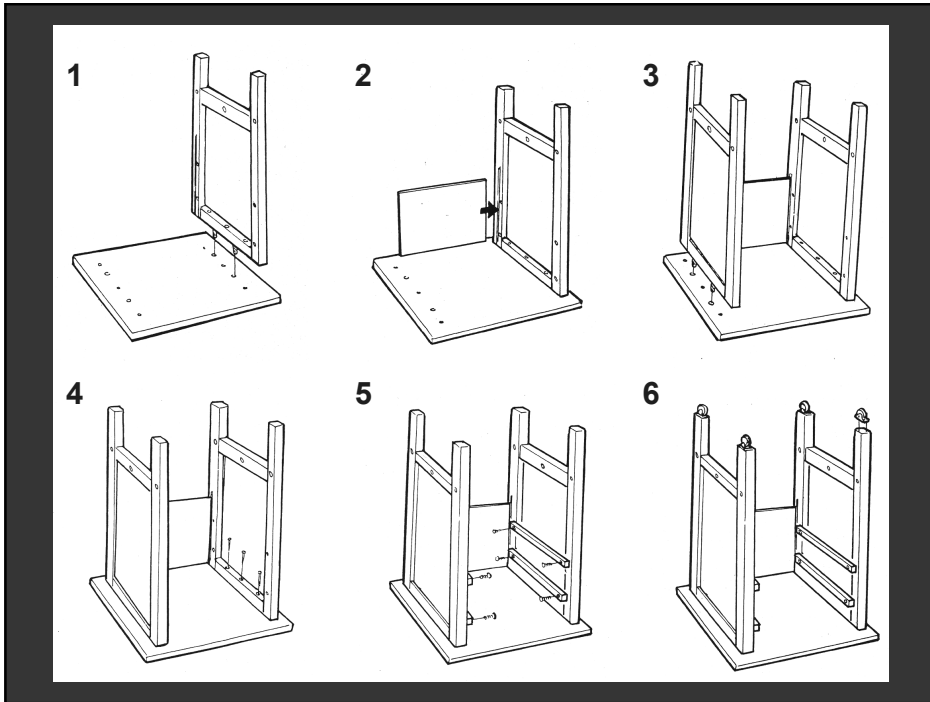
1st Ave. and 19th Ave. NW, Seattle WA

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





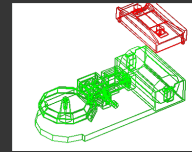
Assembly Instructions



Previous Work

Planning

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



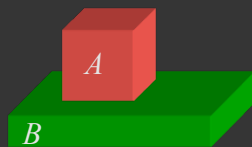
Presentation

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

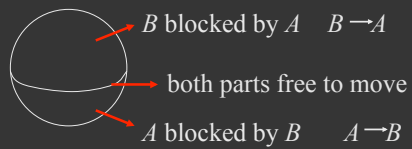


Jointly optimize plan and presentation

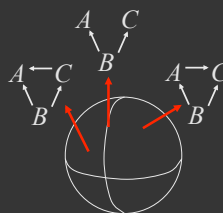
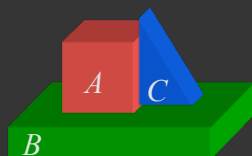
Geometric Analysis [Romney 95]



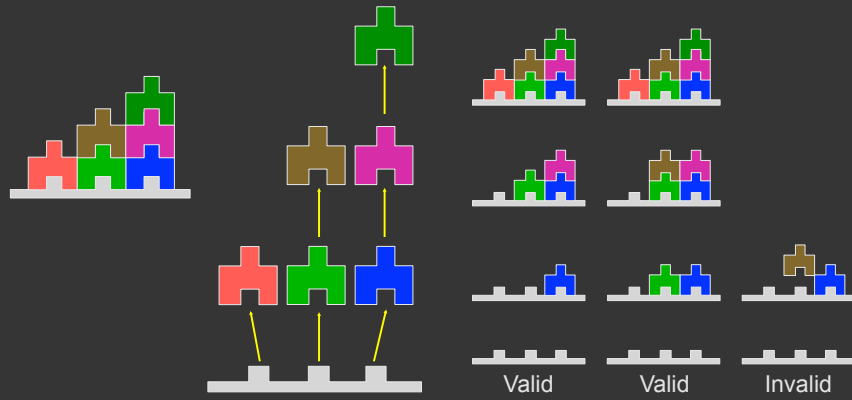
Input Parts



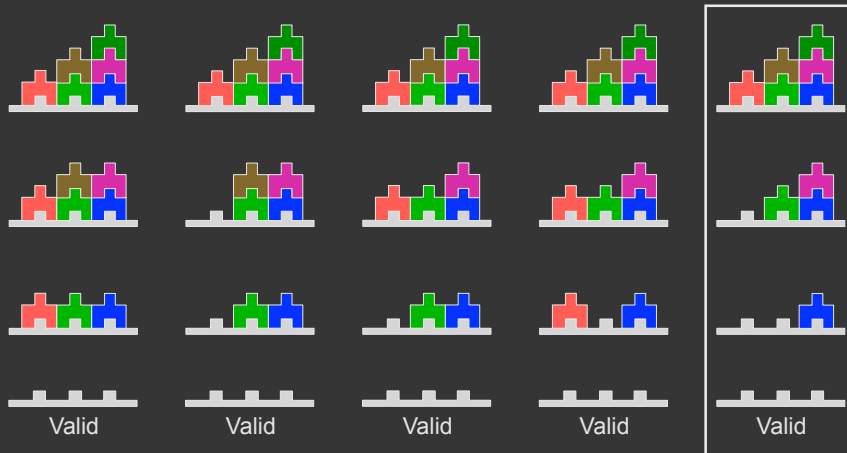
Blocking Graph



Geometric Assembly Planning



Many Geometrically Valid Sequences



How do we choose the best sequence?

Identifying Design Principles

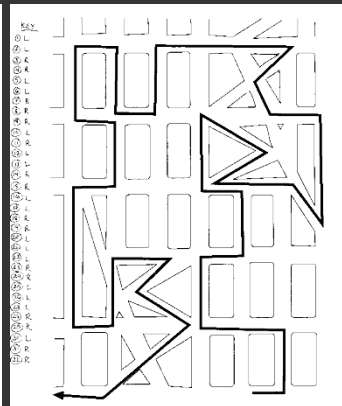


- Stage 1: Production
- Stage 2: Preference
- Stage 3: Comprehension

Spatial Ability Tests

Answers: (1) first and second drawings are correct
(2) first and third drawings are correct
(3) second and third drawings are correct

Mental Rotation [Vandenburg 78]



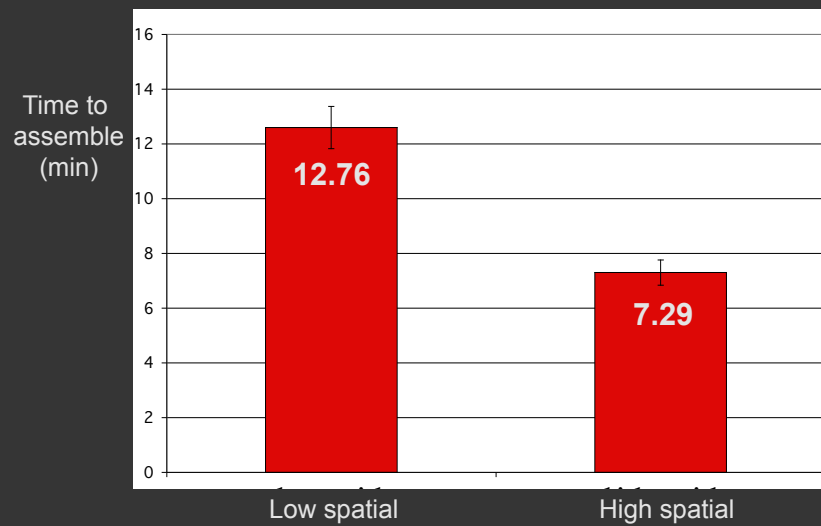
Separate high and low spatial ability

Stage 1: Production

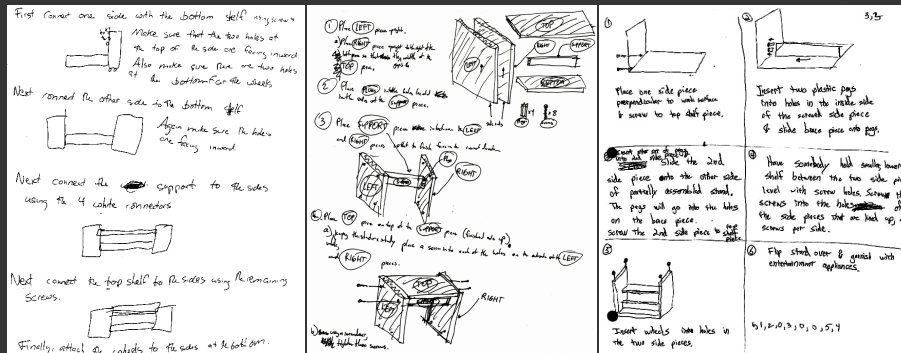


- 43 Participants
- Assemble TV Stand without instructions
- Write instructions for novice assembler

Stage 1: Mean completion time

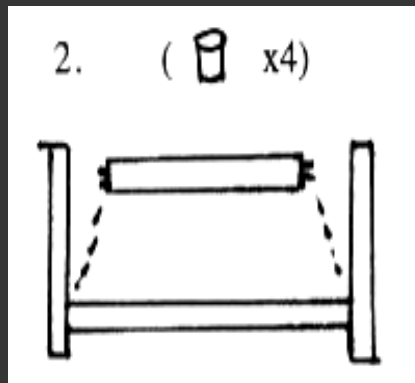


Stage 1: Instructions produced



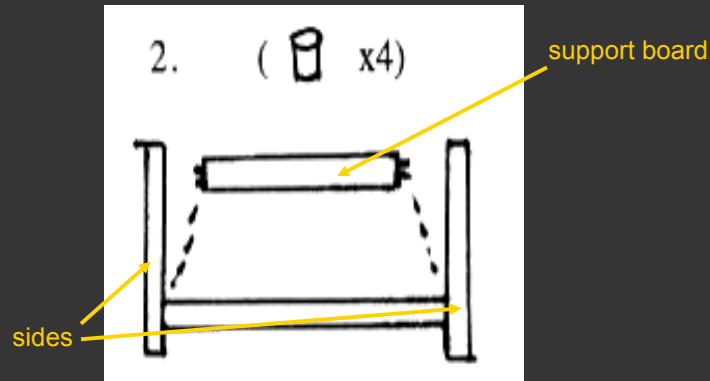
- Almost all contained diagrams 98%
- Text redundant with diagrams 62%

Stage 1: Errors in instructions



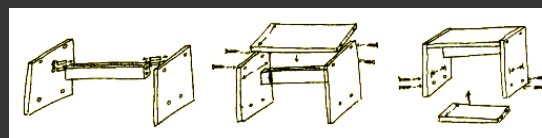
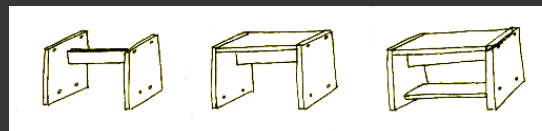
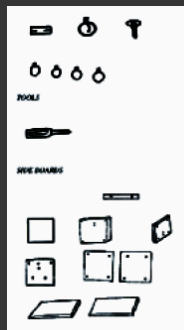
- Errors in low spatial instructions 86%
- Errors in high spatial instructions 12%

Stage 1: Errors in instructions



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

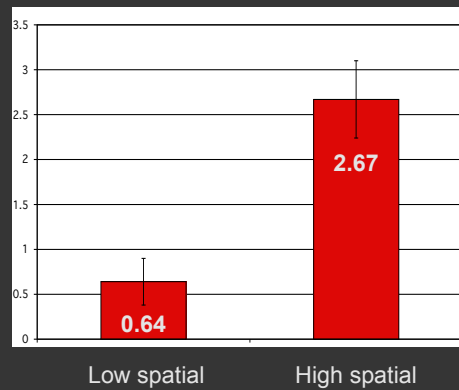
Stage 1: Classes of Diagrams



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

Stage 1: Action diagrams

Mean number per set



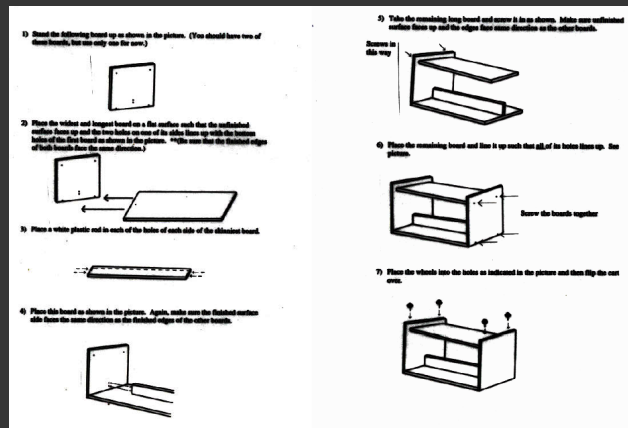
- High spatial
 - More action diagrams
 - More 3D diagrams
 - Less text

Stage 2: Preference

<p>①</p> <p>Place one side piece perpendicular to work surface & screw to top shelf piece.</p>	<p>②</p> <p>Insert two plastic pegs into holes in the inside side of the second side piece & slide brace piece onto pegs.</p>	<p>1.</p> <p>Place one side piece perpendicular to work surface & screw to top shelf piece.</p>	<p>2.</p> <p>Insert two plastic pegs into holes in the inside side of the screwed side piece and slide brace piece onto pegs.</p>
<p>③</p> <p>Insert other set of pegs. Slide the 2nd side piece onto the other side of partially assembled stand. The pegs will go into the holes on the brace piece. Screw the 2nd side piece to shelf piece.</p>	<p>④</p> <p>Have somebody hold smaller shelf between the two side pieces level with screw holes. Screw the screws into the holes of the side pieces that are held up. 2 screws per side.</p>	<p>3.</p> <p>Insert other set of pegs into second side piece and slide the second side piece onto the other side of partially assembled stand. The pegs will go into the holes on the brace piece. Screw the second side piece to top shelf piece.</p>	<p>4.</p> <p>Have somebody hold smaller, lower shelf between the two side pieces, level with screw holes. Screw the screws into the holes of the side pieces that are lined up. 2 screws per side.</p>
<p>⑤</p> <p>Insert wheels into holes in the two side pieces.</p>	<p>⑥</p> <p>Flip stand over & garnish with entertainment appliances.</p>	<p>5.</p> <p>Insert wheels into holes in the two side pieces.</p>	<p>6.</p> <p>Flip stand over and garnish with entertainment appliances.</p>

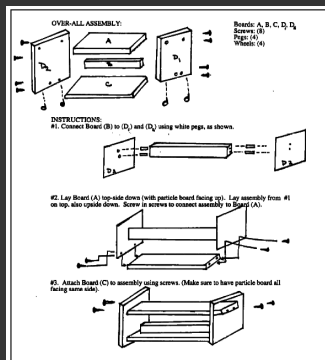
- 21 Participants
- Assemble TV Stand without instructions
- Rated 39 sets of redrawn instructions

Stage 2: Highest Rated

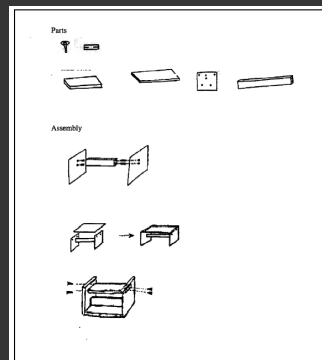


- Ratings similar across all participants
- Spatial ability does not affect preference

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

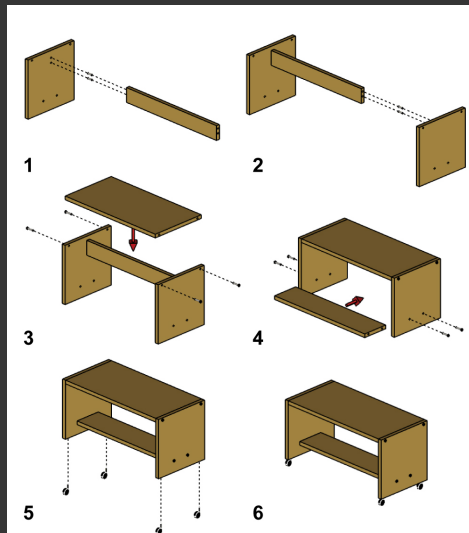
- No difference in assembly time by condition
- Instruction consultations: Low 8.9 High 7.1
- Box picture consultations: Low 9.1 High 3.4

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

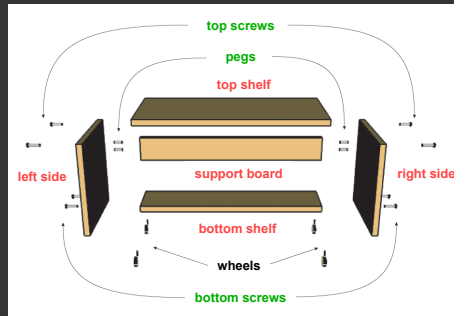
Preferred orientation for each part

Groupings: Fasteners, significant parts, similar actions, symmetry

required
optional



Assembled geometry in default orientation



Parts grouped as **fasteners** and **significant parts**

All parts

Search

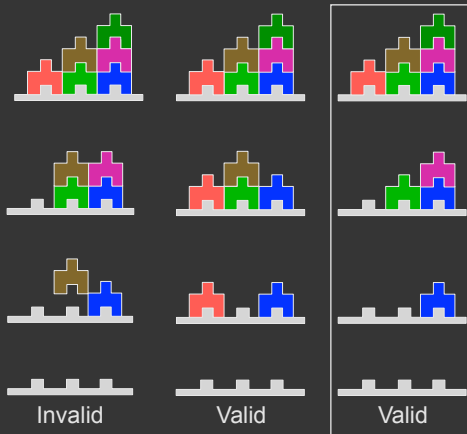
Subdivide Steps

Reorientation

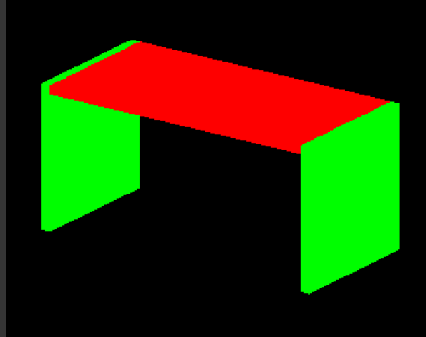
Step-by-step assembly sequence

Find best assembly sequence

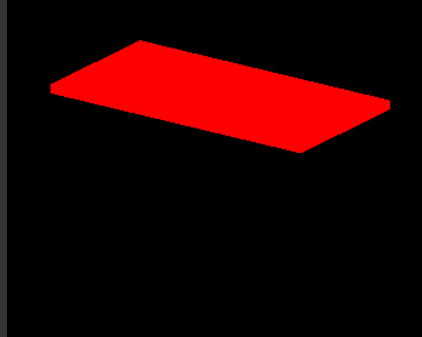
- Planning: Geometric feasibility
- Presentation: Visibility



Computing Visibility



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



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

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

% pixels that remain visible when sides are included

Visibility Constraints

1. Parts being attached R

- Check that each part is visible

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

2. Previously attached parts A

- Check that context is visible

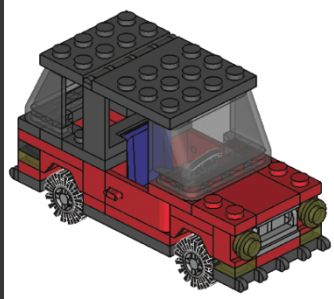
$$\text{Vis}(A, R) * W_A$$

3. Future unattached parts U

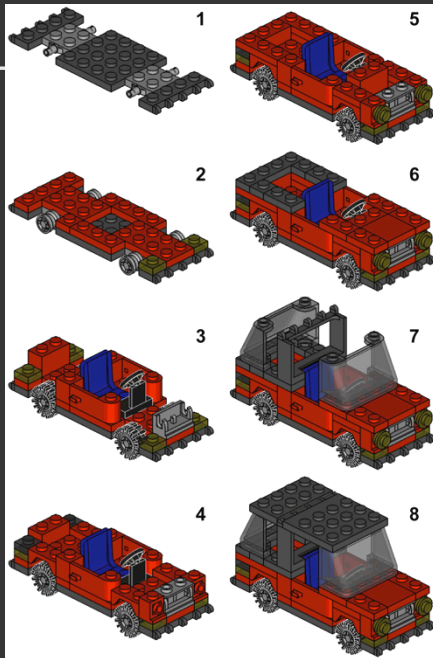
- Check that future parts will be visible

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

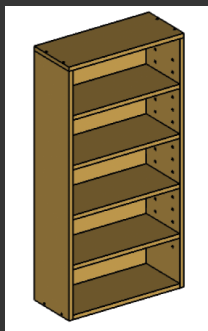
Lego Car



Input model

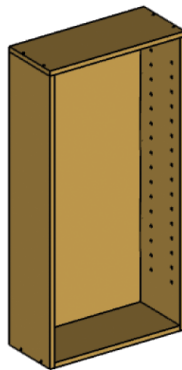


Bookcase

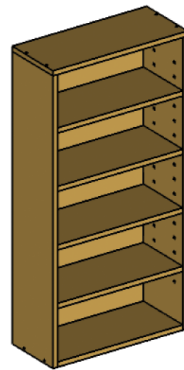


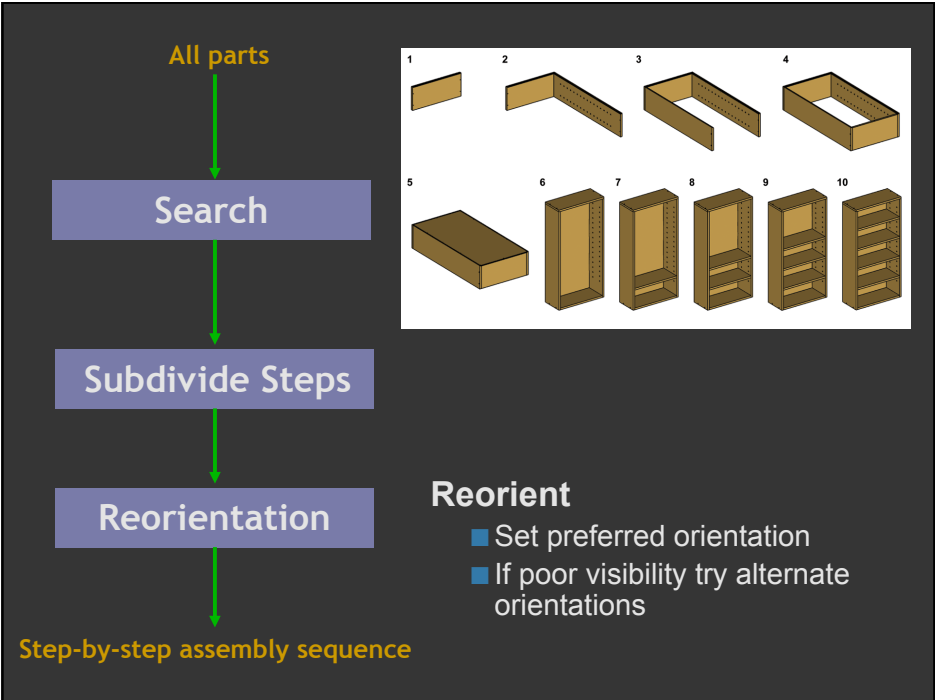
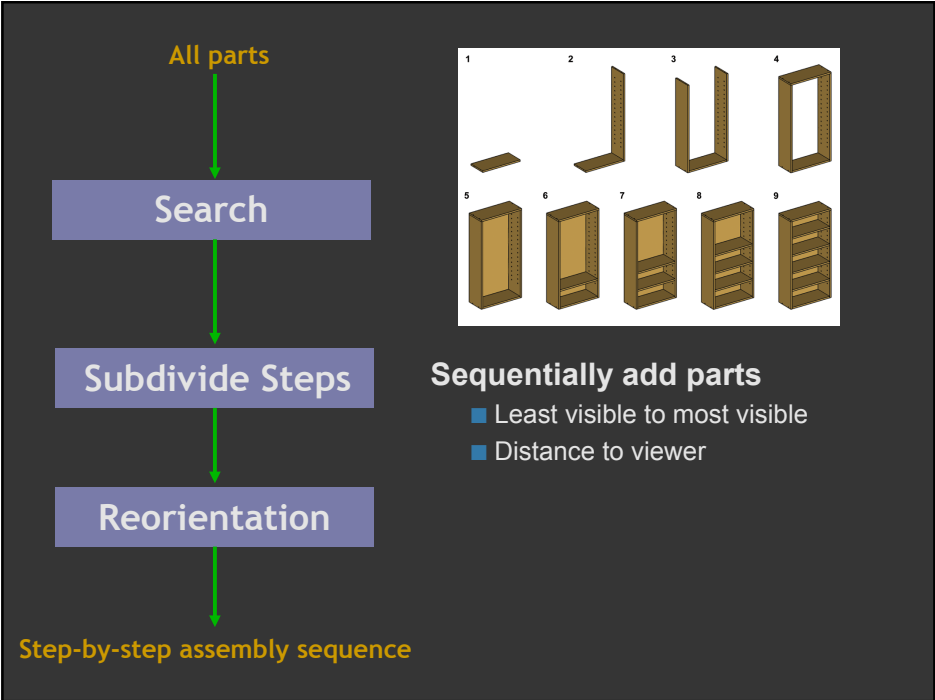
Input model

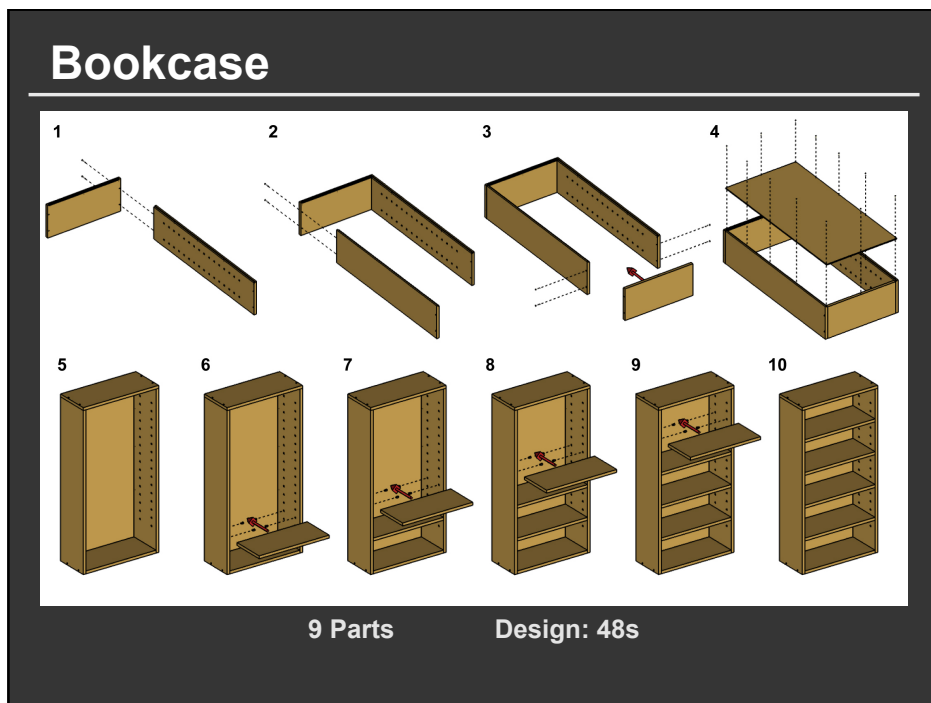
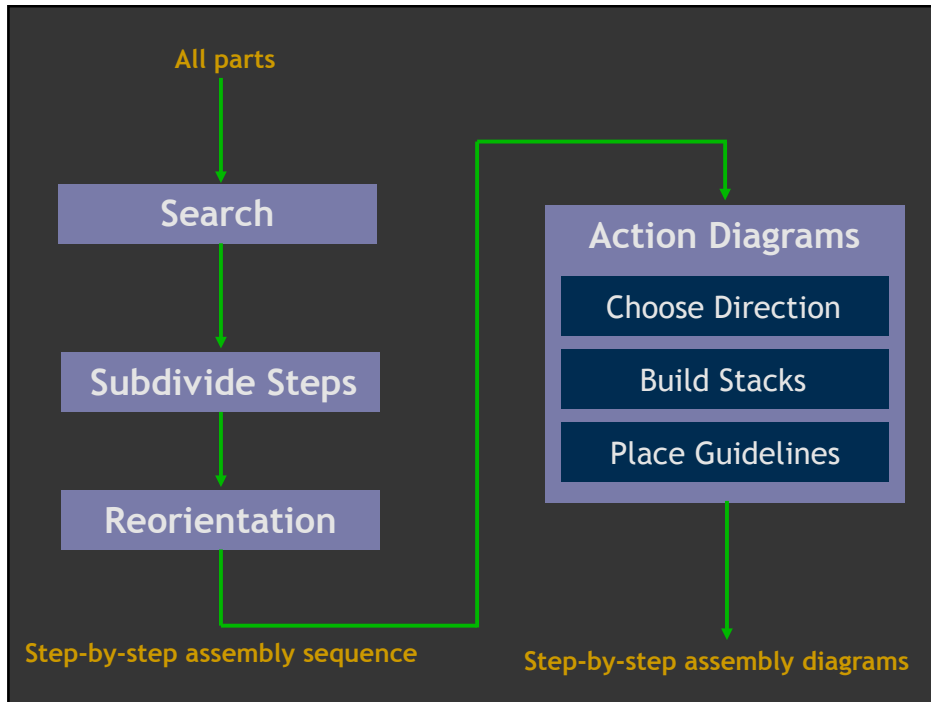
1



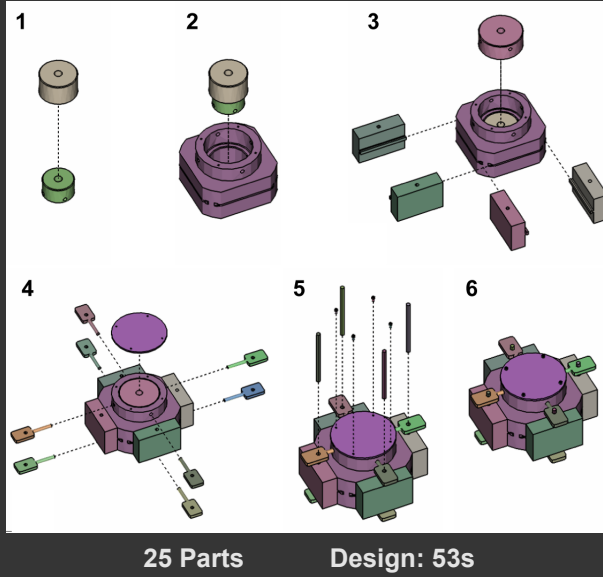
2







Test Object

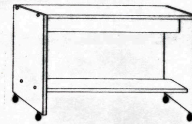


Evaluation

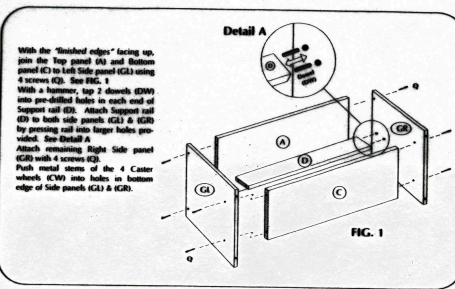
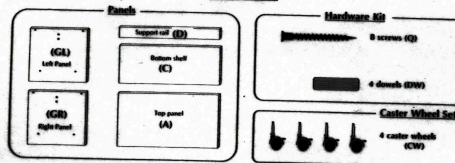


- 30 Participants
- Given 1 of 3 instruction sets: factory, hand-drawn, computer
- Assemble TV stand using instructions

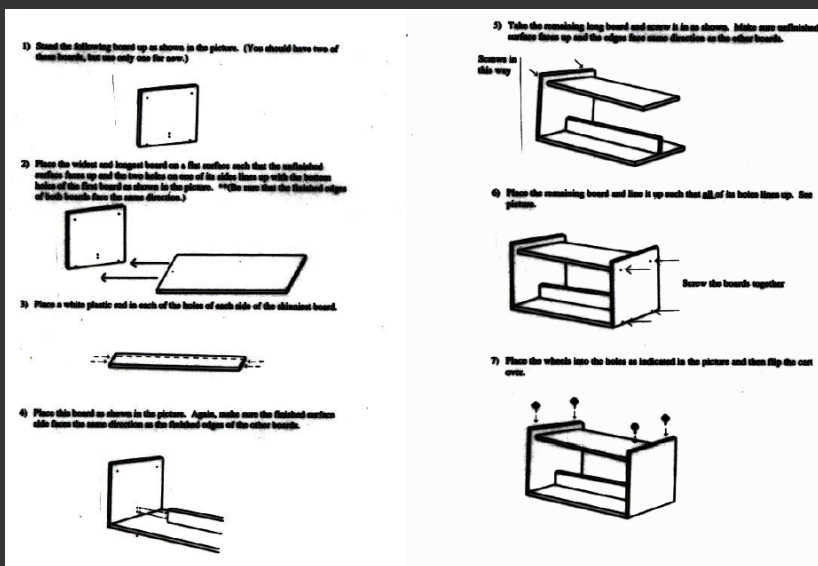
Factory



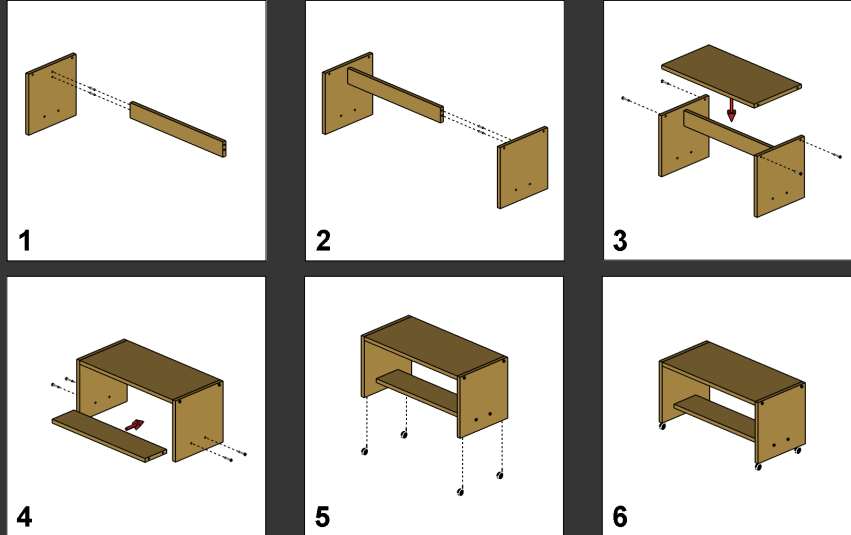
PARTS LIST



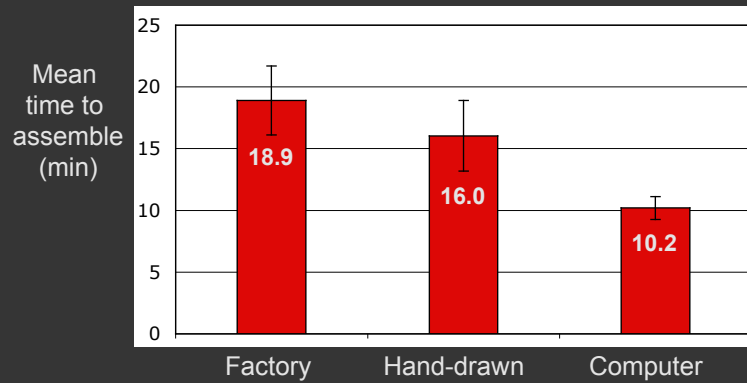
Hand-drawn



Computer Generated



Results



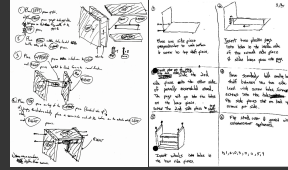
Errors: Factory 1.6 Hand-drawn 0.6 Computer 0.5

Task rated easiest in computer condition

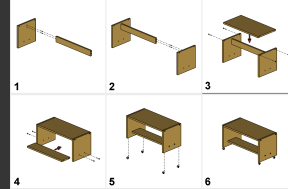
Summary

Identification of design principles

- Production
- Preference
- Comprehension



Instantiation of design principles



Validation of design principles

