Identifying Design Principles

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CS 294-10: Visualization
Fall 2008

Assignment 3: Visualization Software

Create an interactive visualization application – you choose data domain and visualization technique.

1. Describe data and storyboard interface
   due Oct 1 (before class)
2. Implement interface and produce final writeup
   due Oct 13 (before class)
3. Submit the application and a final writeup on the wiki

Can work alone or in pairs

Final write up due before class on Oct 13, 2008

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

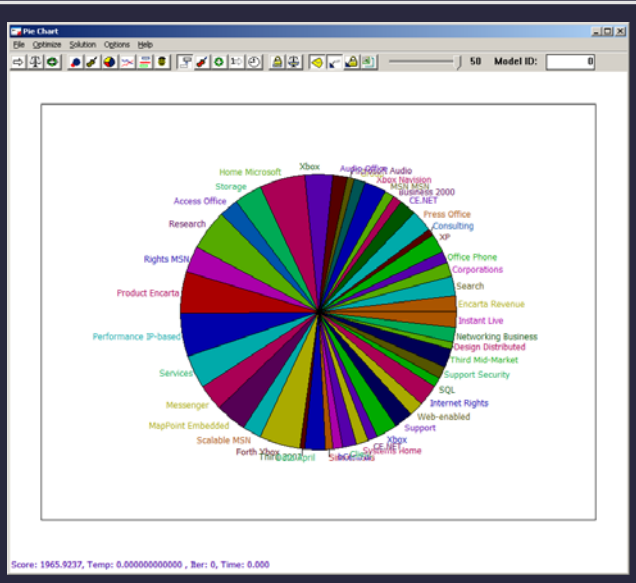
- Project proposal: 10/27
- Initial problem presentation: 10/27, 10/29 or 11/3
- Midpoint design discussion: 11/19, 11/24 or 11/26
- Final paper and presentation: 12/10

Grading

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

Spatial Layout

Demo



Pros and cons

Pros

- Much more flexible than linear constraint solving systems

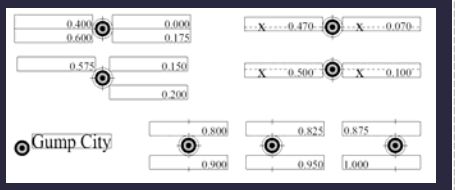
Cons

- 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



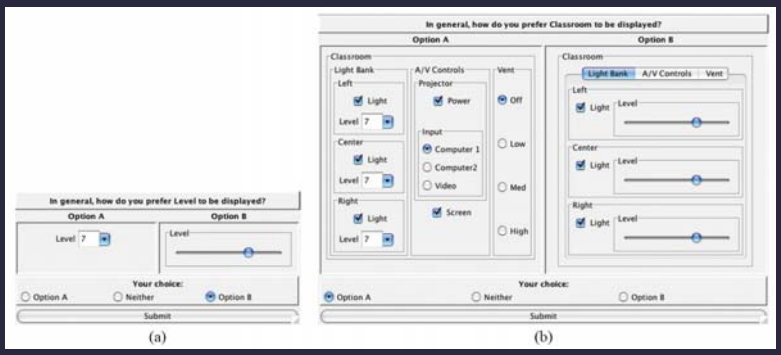
Cartographer Eduard Imhof's labeling heurists transformed into penalty functions for an optimization based point labeling system [Edmondson 97]

Example-Based Methods

Preference elicitation [Gajos and Weld 05]

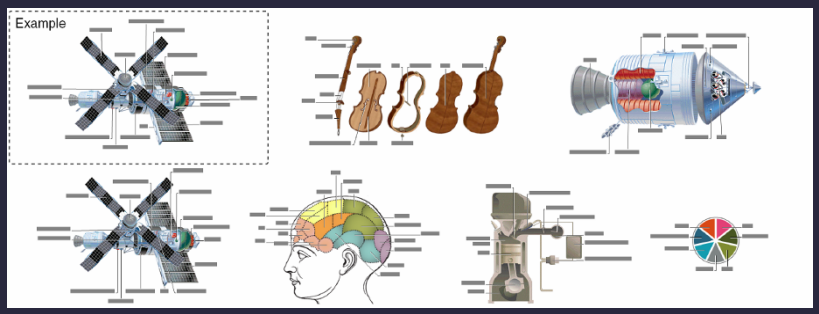
Learn characteristics of good designs

- 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]

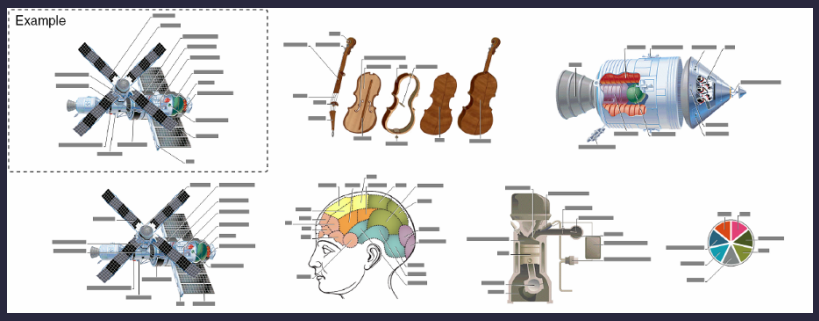
Learn label layout style from single example



Horizontal/Vertical

Nonlinear Inverse Opt. [Vollick et al. 07]

Learn label layout style from single example



Parallel Leader Lines

Artistic Resizing

A Technique for Rich Scale-Sensitive Vector Graphics

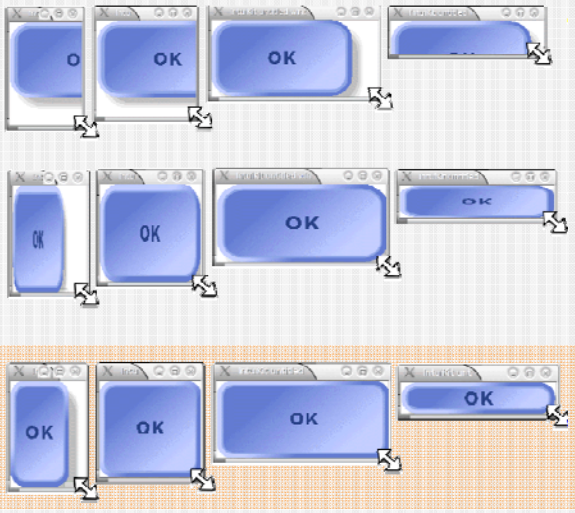
Pierre Dragicevic
Stéphane Chatty
David Thevenin
Jean-Luc Vinot

intuilab

Direction Générale de l'Aviation Civile
dgac

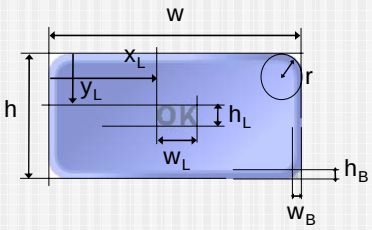
The Resizing Problem

- Fixed size
- Naive scaling
- Artistic resizing



Expressing Artistic Resizing

- Commonly described using formulae

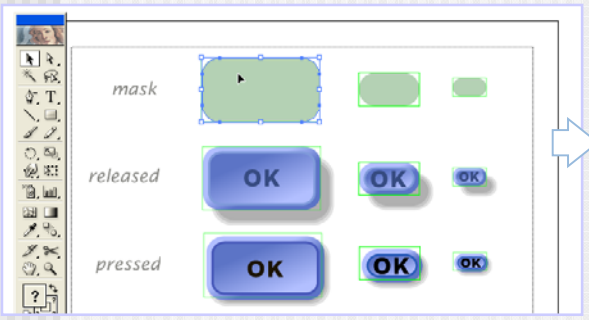


- $x_L = (w-w_L) / 2$
- $y_L = (h-h_L) / 2$
- $w_L = 20$
- $h_L = 10$
- $w_B = 5$
- $h_B = 5$
- $r = 20$

- These formulae are:
  - Translated into code by the programmer
  - Or used as an input to constraint-solving systems

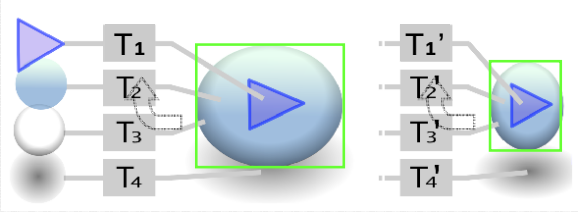
Example-Based Approach

1. Designers produce variants using their authoring tool
2. System interprets the example set



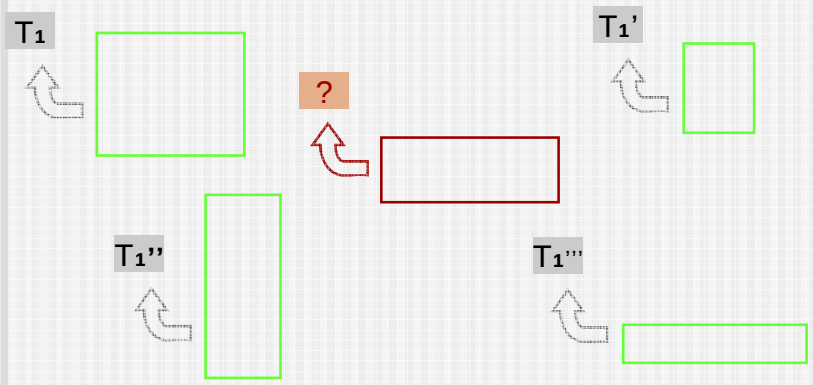
Artistic Resizing
How does it work?

- Assumes the exclusive use of:
  - Copy & paste for adding new examples
  - Affine transformation tools (move, scale, rotate, shear)
- Based on local interpolation of transformations



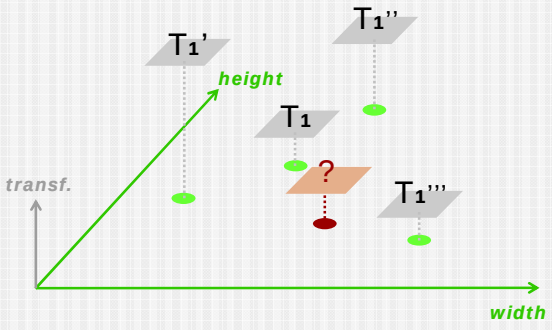
Artistic Resizing
How does it work?

- Each variant of T1 is associated with the example's bounding box



Artistic Resizing
How does it work?

- Problem of multivariate interpolation



Pros and cons

Pros

- Often much easier to specify desired layout via example

Cons

- Usually requires underlying model
- Model will constrain types of layouts possible
- Large design spaces likely to require lots of examples to learn parameters well

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

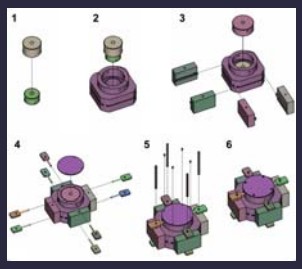
Identify design principles

- Cognition and perception

Instantiate design principles

- Principles become constraints that guide an optimization process

Route maps

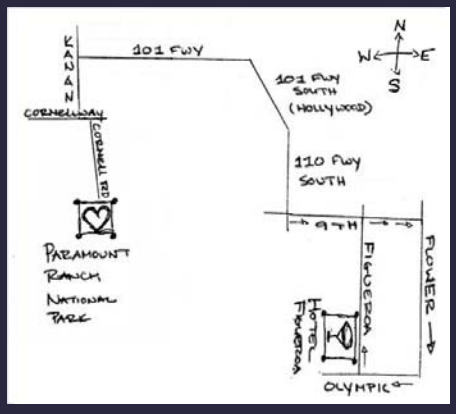


Assembly instructions

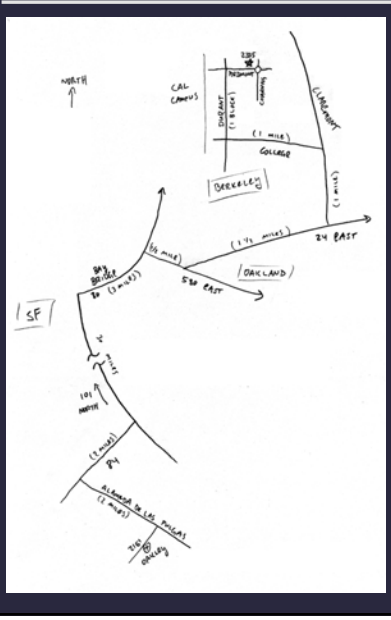
Route Maps

Visualizing Routes

A Better Visualization



Cognition of Route Maps



Essential information

- Turning points
- Route topology

Secondary context information

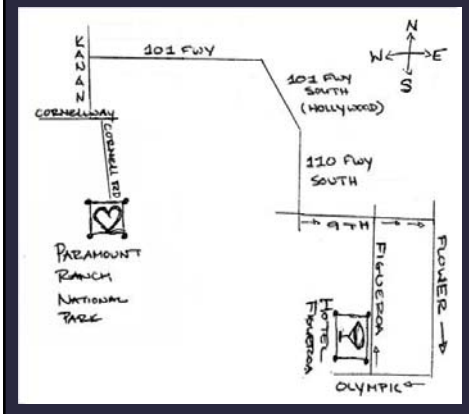
- Local landmarks, cross streets, etc.
- Overview area landmarks, global shape

Exact geometry less important

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

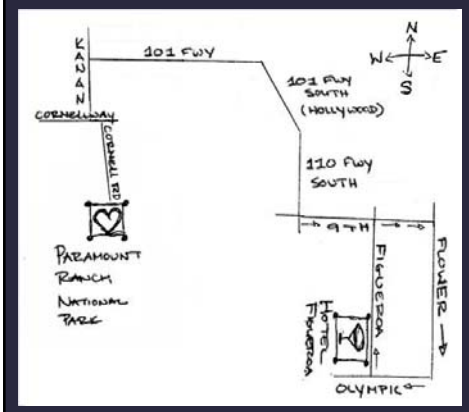
[Tversky 81] [Tufte 90] [Tversky 92]
[MacEachren 95] [Denis 97] [Tversky 99]

Design Principles

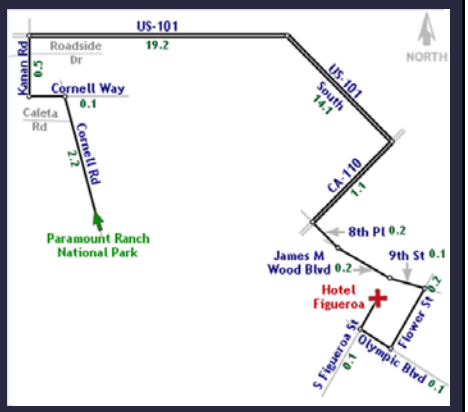


- **Exaggerate road length**
- **Regularize turning angles**
- **Simplify road shape**

LineDrive



Hand-drawn route map



LineDrive route map

Map Design via Optimization

Set of graphic elements

- Roads, labels, cross-streets, …

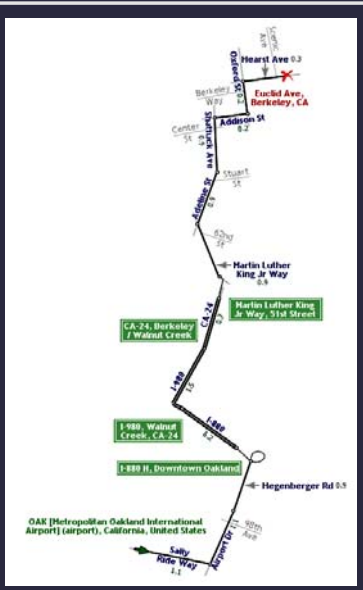
Choose visual attributes

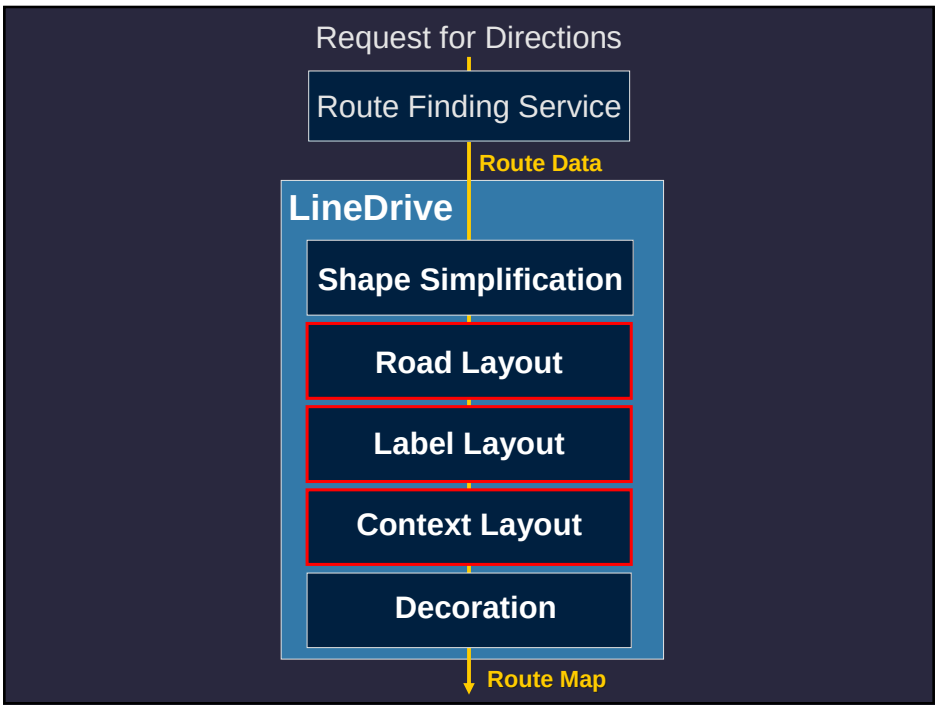
- Position, orientation, size, …
- Distortions increase flexibility

Develop constraints based on design principles

Simulated annealing

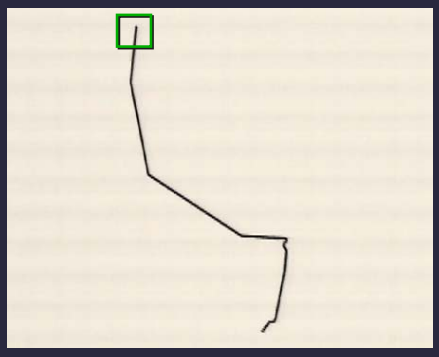
- Perturb: Form a layout
- Score: Evaluate quality
- Minimize score



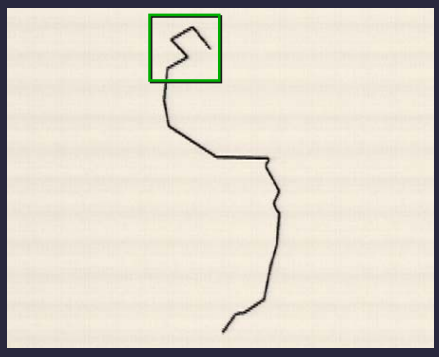


Road Layout

Choose road lengths and orientations



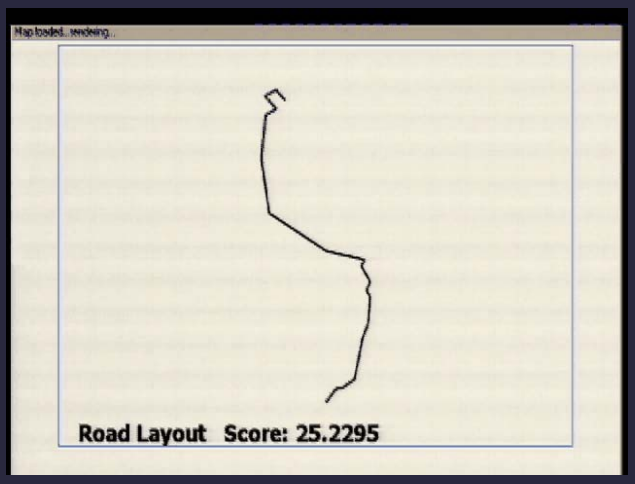
Before road layout



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

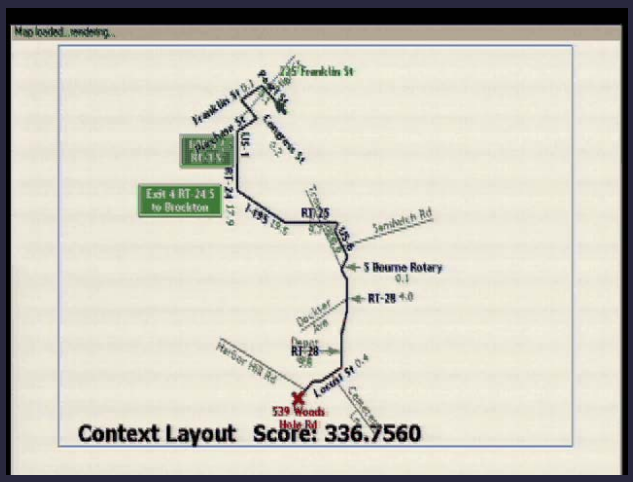
- Users given maps containing errors
- Rated which errors most confusing

Label Layout

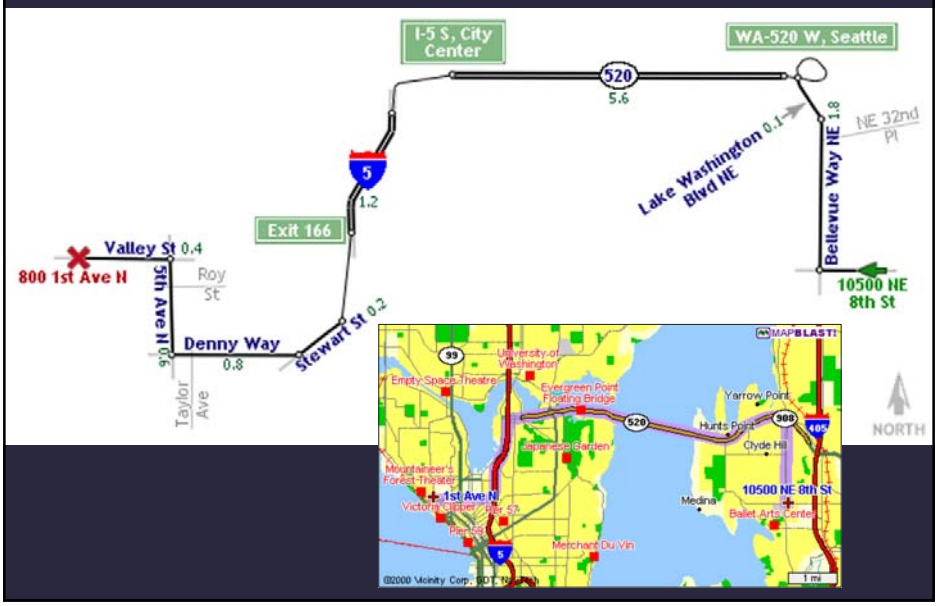
Find overlap-free position for each label

Context Layout

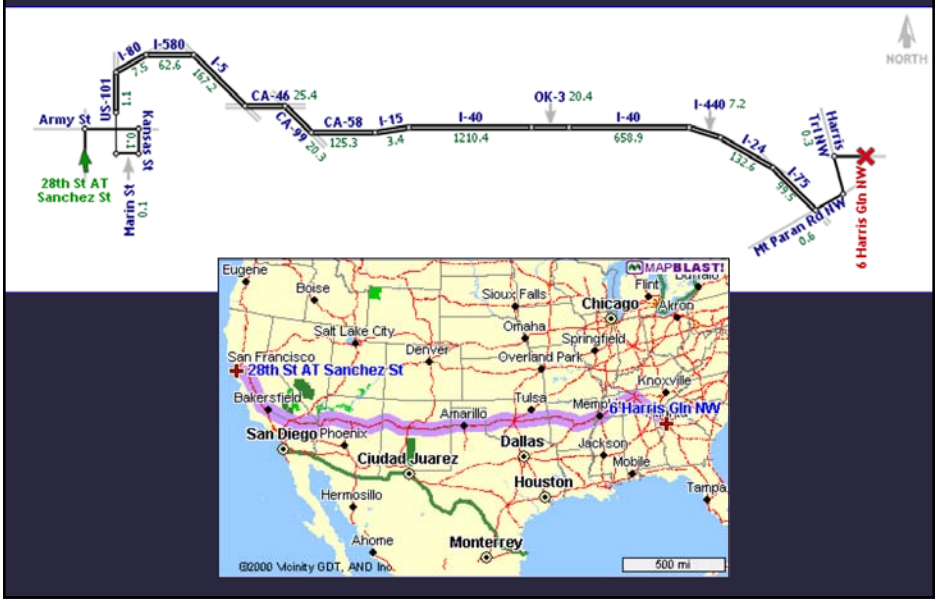
Place cross-streets and exit signs if possible



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

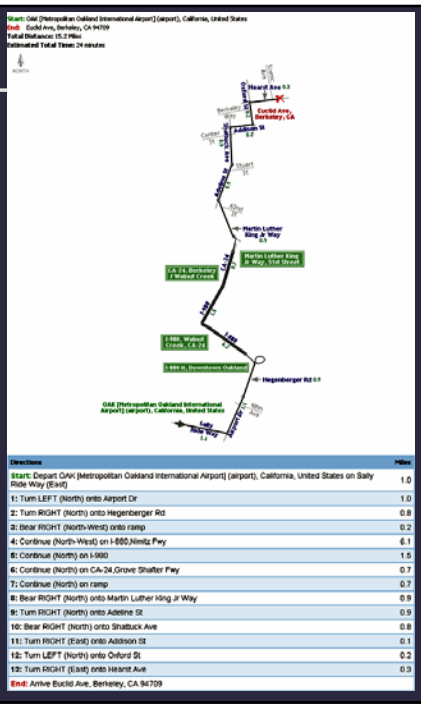
- 150,000 maps served

2242 responses

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

Current Status

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

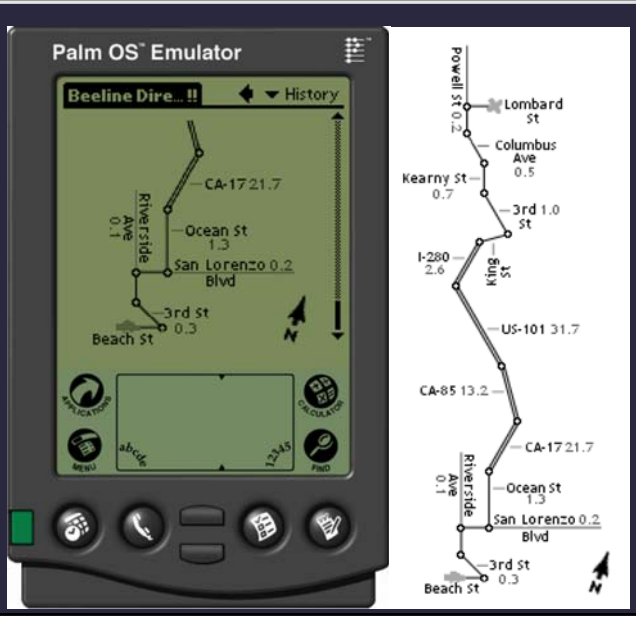


Directions	Miles
Start: Depart OAK [Metropolitan Oakland International Airport] (airport), California, United States on Bally Ride Way (East)	1.0
1: Turn LEFT (North) onto Airport Dr	1.0
2: Turn RIGHT (North) onto Hegenberger Rd	0.8
3: Bear RIGHT (North-West) onto ramp	0.2
4: Continue (North-West) on I-880,Nimitz Fwy	6.1
5: Continue (North) on I-980	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 Adeline 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	

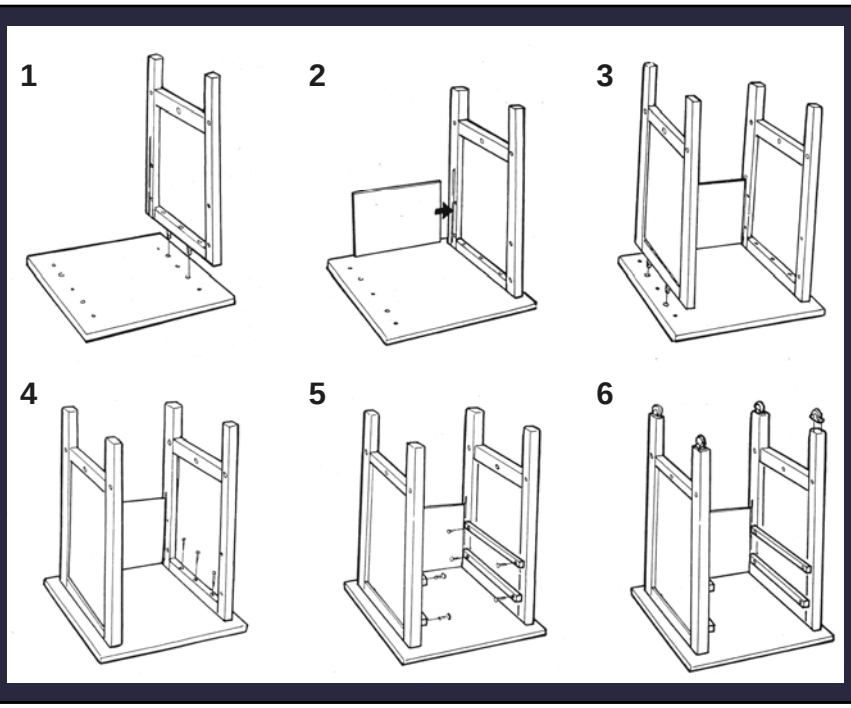
DEMO

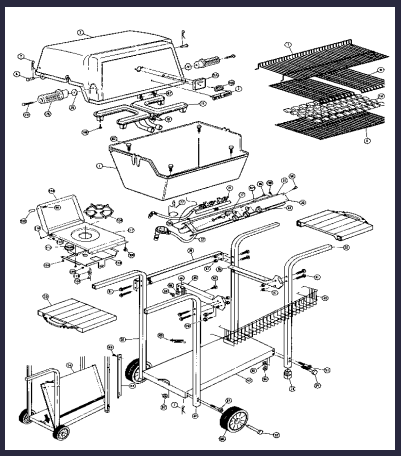
mappoint.com

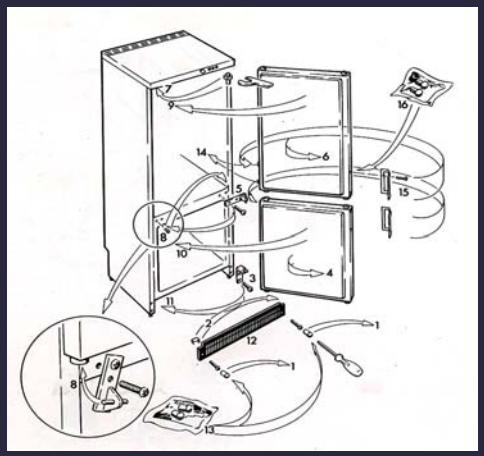
Limited Resolution PDA



Assembly Instructions


1
2
3
4
5
6



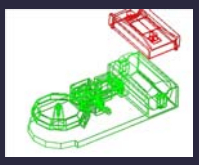


Previous Work

Planning

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

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



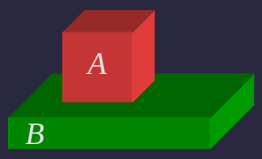
Presentation

- Visually convey assembly operations
- Visualization / Computer Graphics

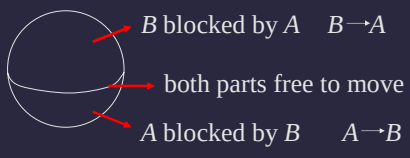
[Seligmann 91], [Rist 94], [Butz 97], [Strothotte 98]

Jointly optimize plan and presentation

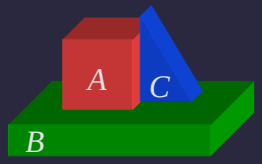
Geometric Analysis [Romney 95]

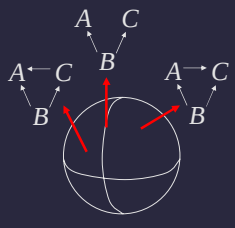


Input Parts

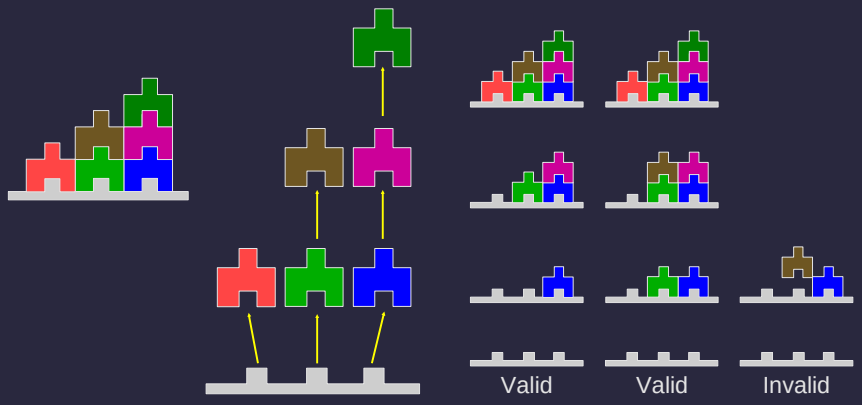


Blocking Graph





Geometric Assembly Planning



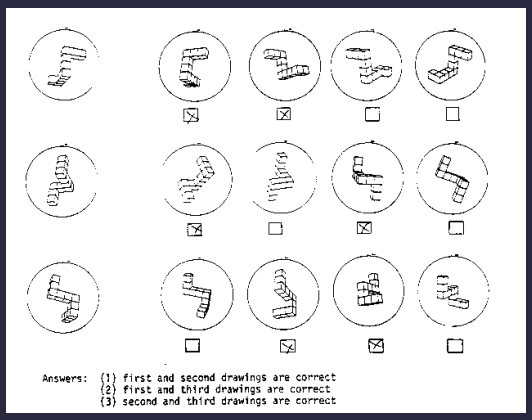
Many Geometrically Valid Sequences

How do we choose the best sequence?

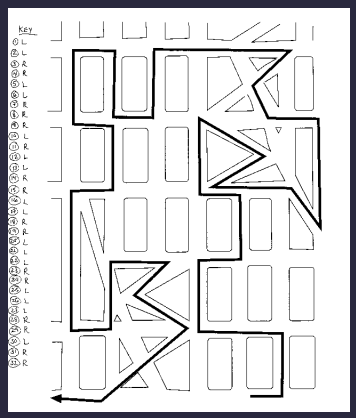
Identifying Design Principles

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

Spatial Ability Tests



Mental Rotation [Vandenburg 78]



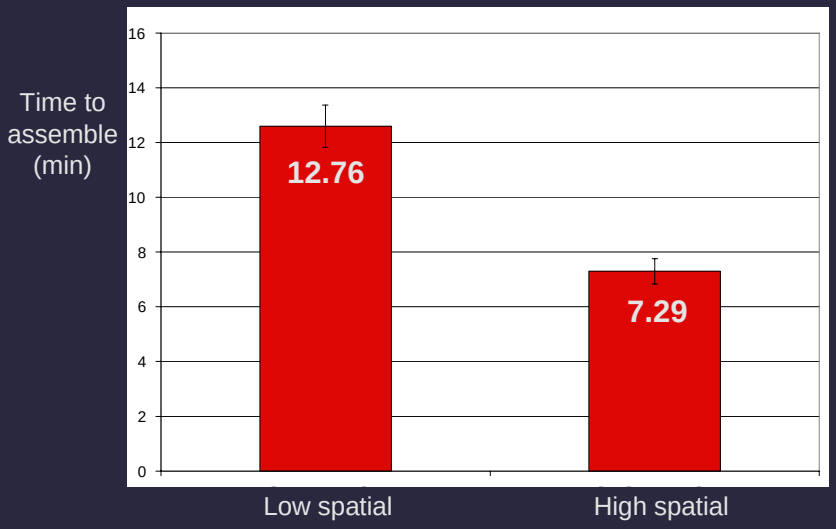
Navigation [Money 78]

Separate high and low spatial ability

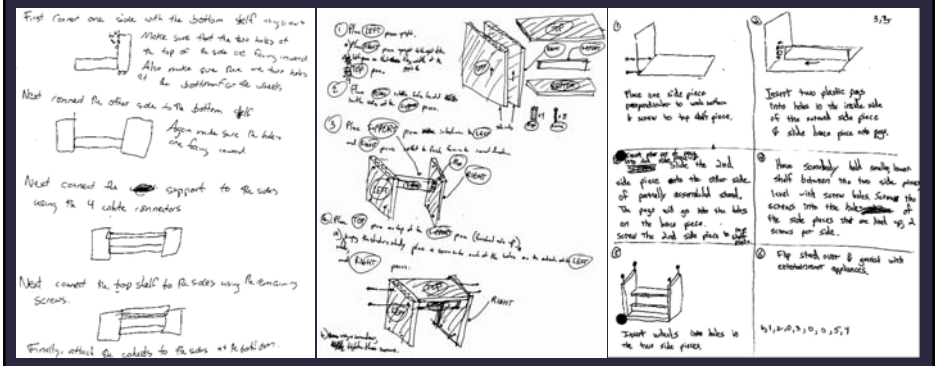
Stage 1: Production

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

Stage 1: Mean completion time

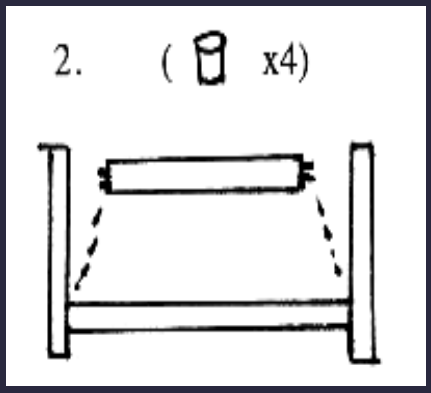


Stage 1: Instructions produced



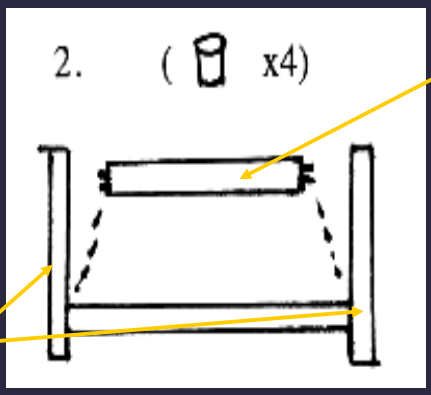
- Almost all contained diagrams 98%
- Text redundant with diagrams 62%

Stage 1: Errors in instructions



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

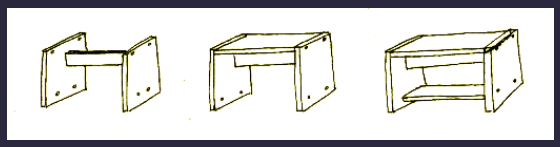
Stage 1: Errors in instructions



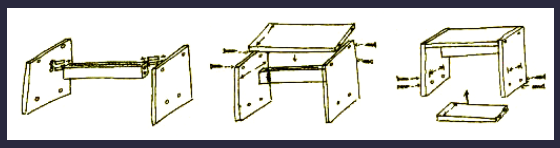
- Errors in low spatial instructions 86%
- Errors in high spatial instructions 12%

Stage 1: Classes of Diagrams

Parts menu



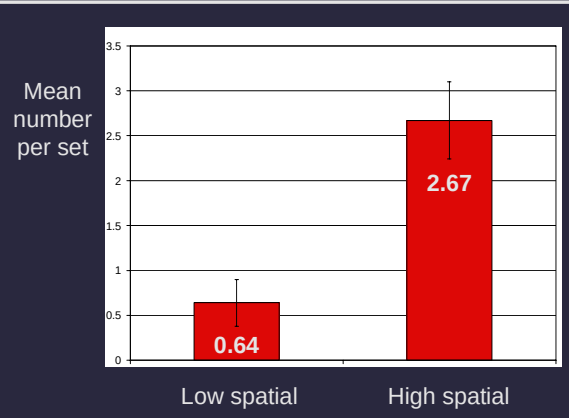
Structural diagrams



Action diagrams

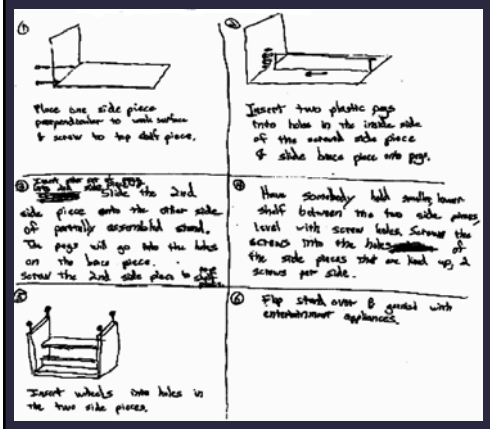
- Parts menu to differentiate parts
- Structural diagrams depict completed step
- Action diagrams show assembly action/operation

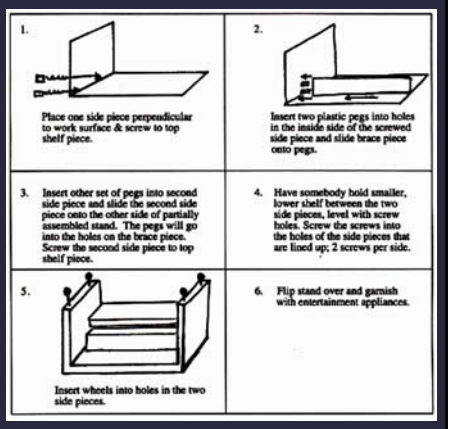
Stage 1: Action diagrams



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

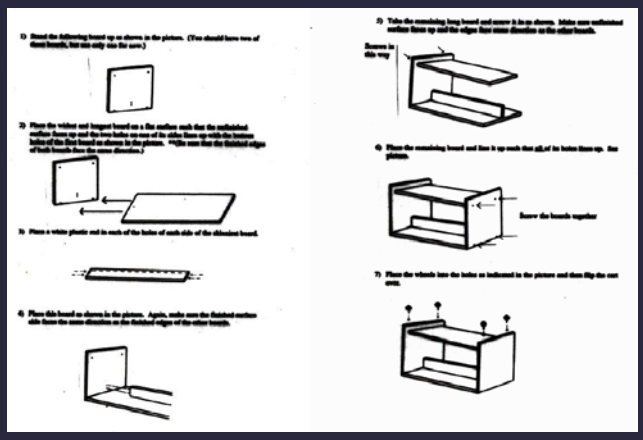
Stage 2: Preference





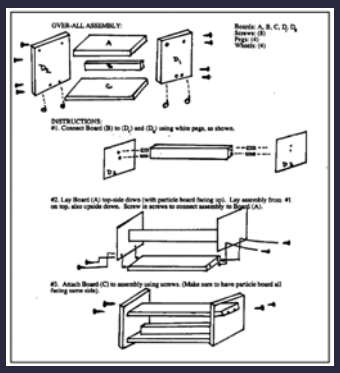
- 21 Participants
- Assemble TV Stand without instructions
- Rated 39 sets of redrawn instructions

Stage 2: Highest Rated

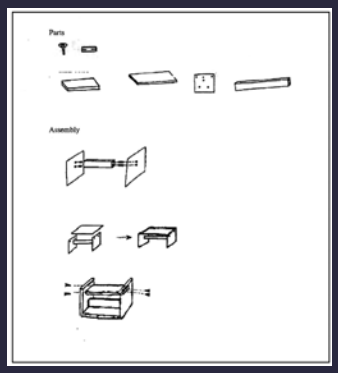


- Ratings similar across all participants
- Spatial ability does not affect preference

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

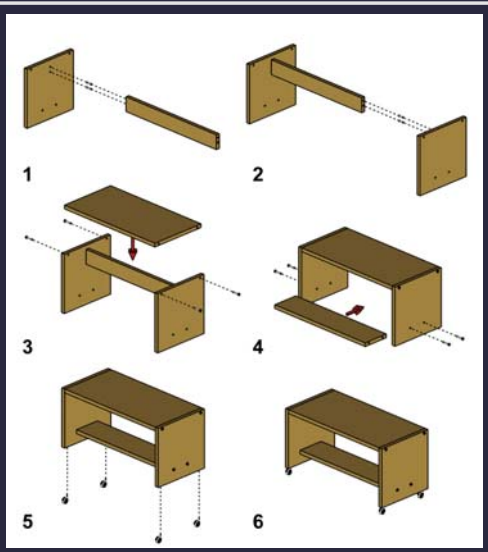
- No difference in assembly time by condition
- Instruction consultations: Low 8.9 High 7.1
- Box picture consultations: Low 9.1 High 3.4

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

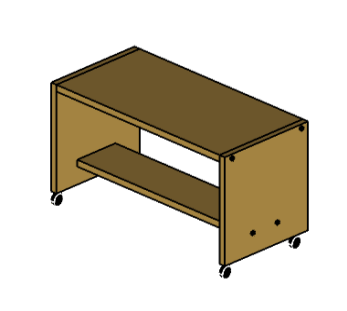
Input

Geometry: Parts in assembled configuration

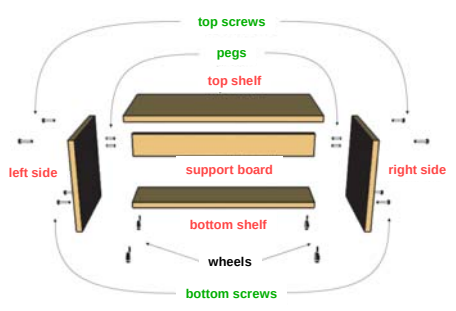
Orientations: Default viewpoint / orientation
Preferred orientation for each part

Groupings: Fasteners, significant parts, similar actions, symmetry

required
optional



Assembled geometry in default orientation



Parts grouped as fasteners and significant parts

All parts

Search

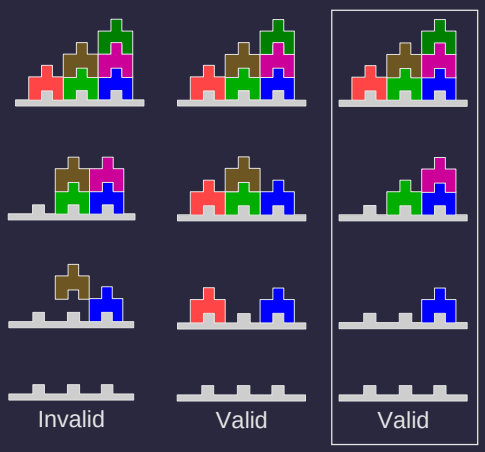
Subdivide Steps

Reorientation

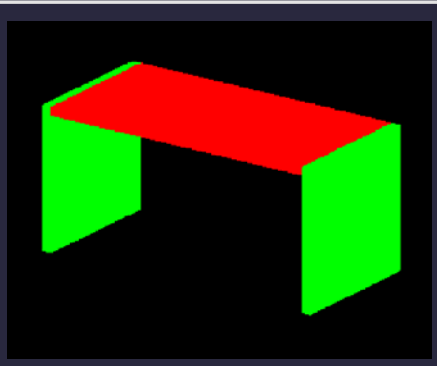
Step-by-step assembly sequence

Find best assembly sequence

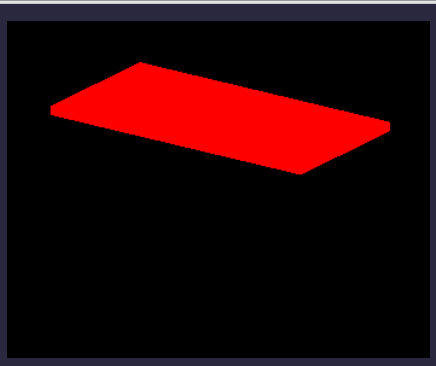
- Planning: Geometric feasibility
- Presentation: Visibility



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

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

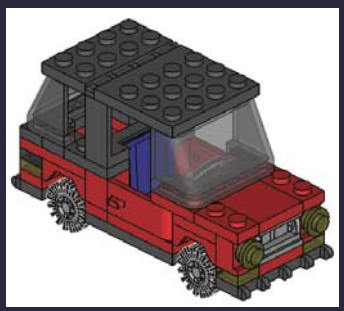
2. Previously attached parts A
- Check that context is visible

$$Vis(A, R) * W_A$$

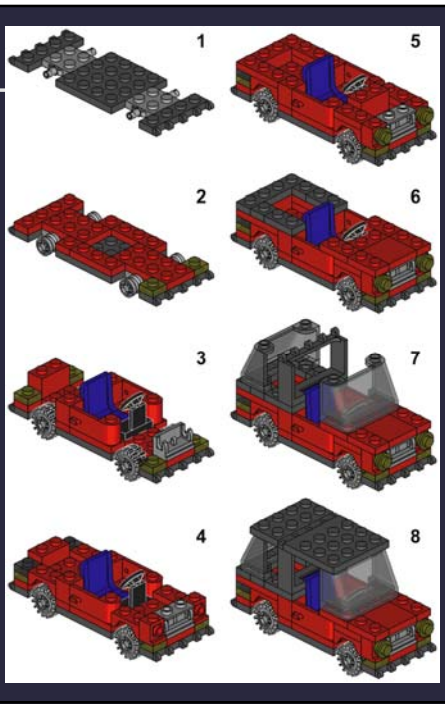
3. Future unattached parts U
- Check that future parts will be visible

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

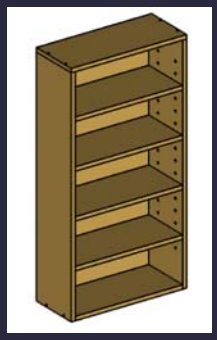
Lego Car



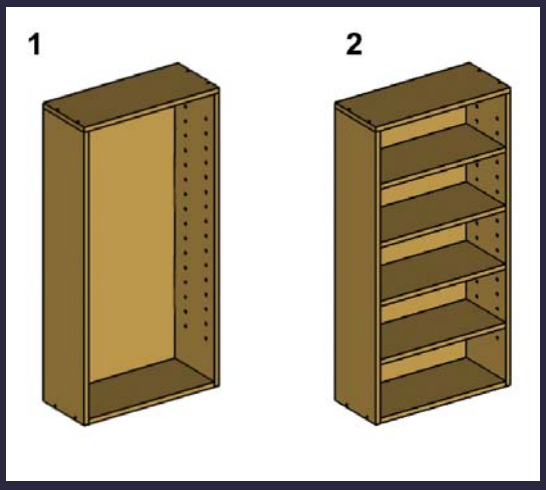
Input model



Bookcase



Input model



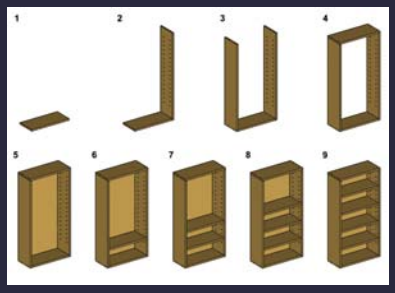
All parts

Search

Subdivide Steps

Reorientation

Step-by-step assembly sequence



Sequentially add parts

- Least visible to most visible
- Distance to viewer

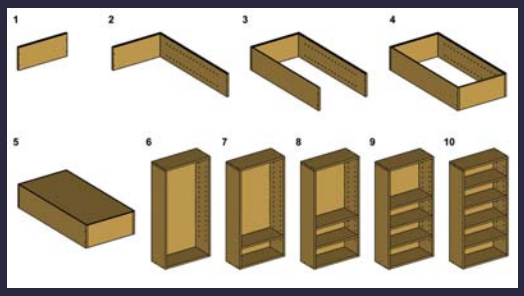
All parts

Search

Subdivide Steps

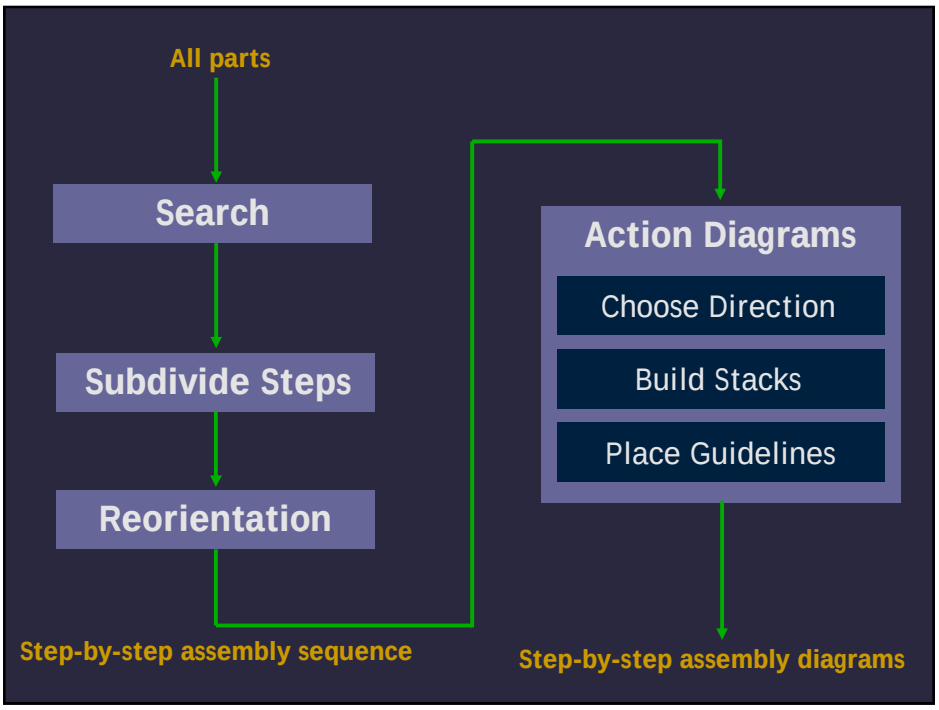
Reorientation

Step-by-step assembly sequence

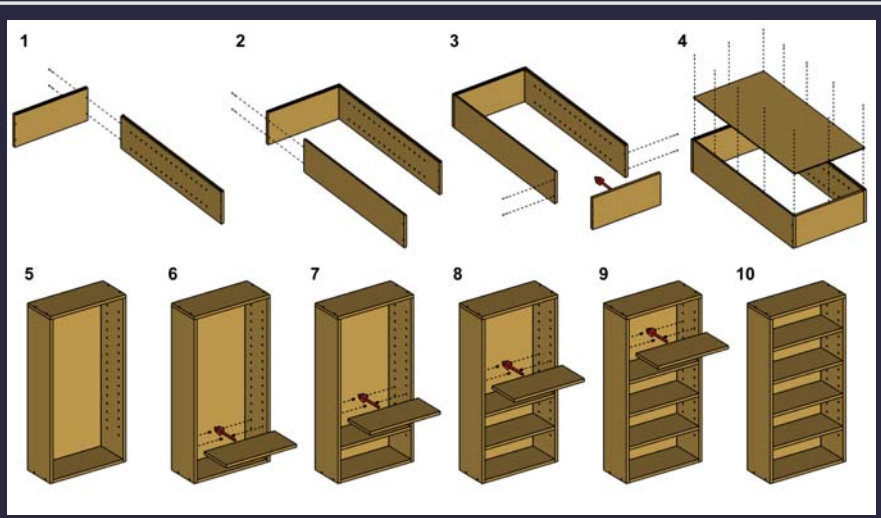


Reorient

- Set preferred orientation
- If poor visibility try alternate orientations

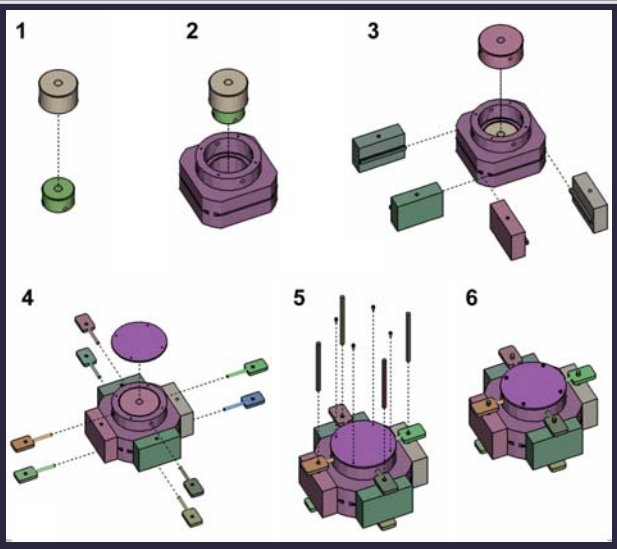


Bookcase



9 Parts Design: 48s

Test Object

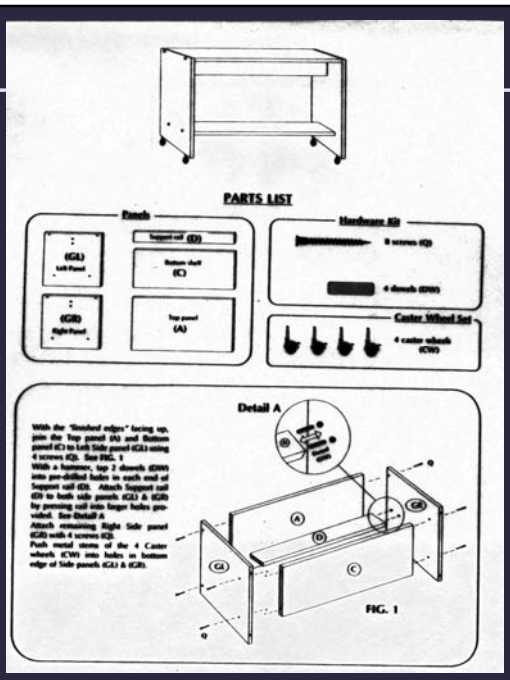


25 Parts **Design: 53s**

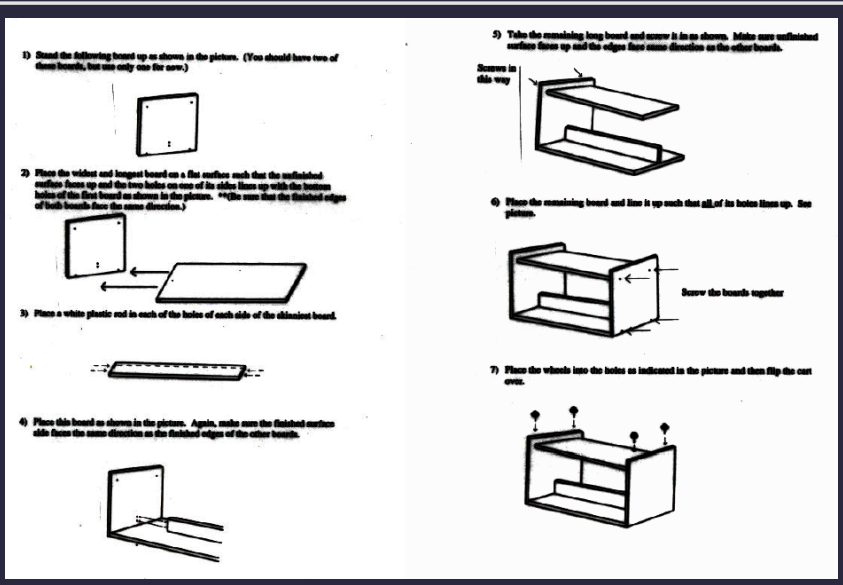
Evaluation

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

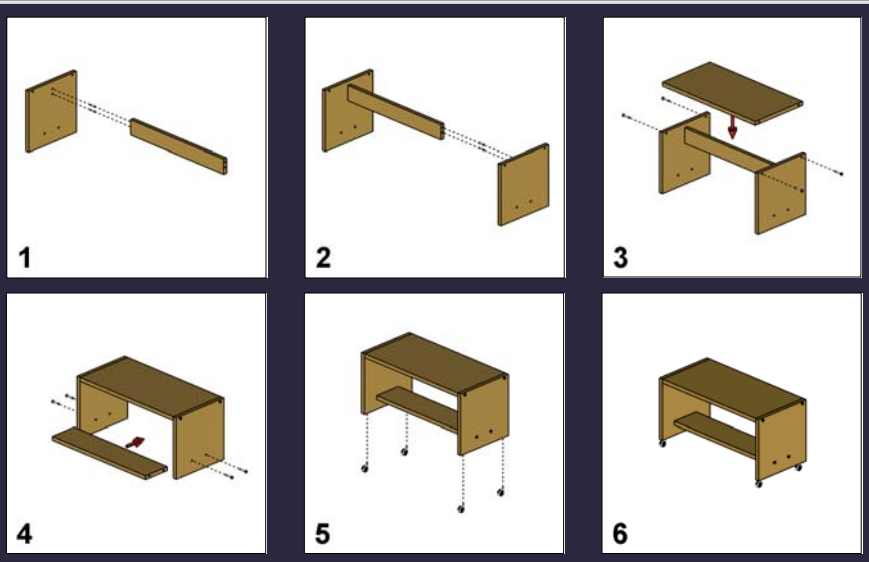
Factory



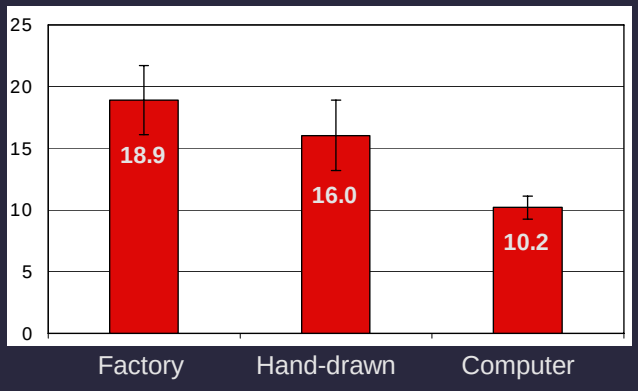
Hand-drawn



Computer Generated



Results



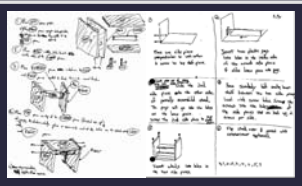
Errors: Factory **1.6** Hand-drawn **0.6** Computer **0.5**

Task rated easiest in computer condition

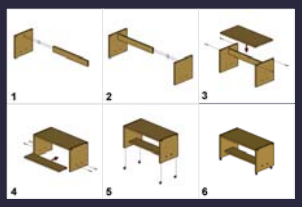
Summary

Identification of design principles

- Production
- Preference
- Comprehension



Instantiation of design principles



Validation of design principles