Design Principles for Visual Communication

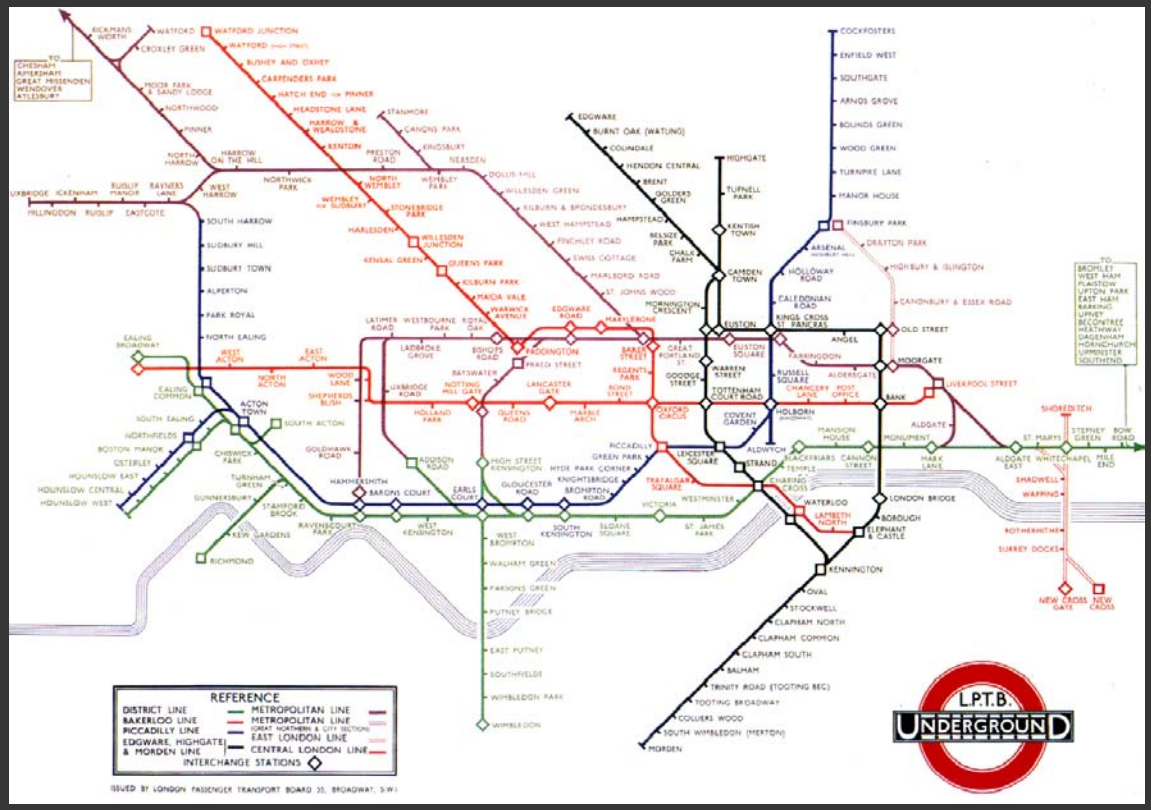
Maneesh Agrawala

March 19, 2010

Collaborators: Raanan Fattal, Floraine Grabler, Mike Houston, Greg Humphreys Wilmot, Li, Chris Niederauer, Mark Pauly, Szymon Rusinkiewwicz, David Salesin, Chris Stolte, Robert Sumner

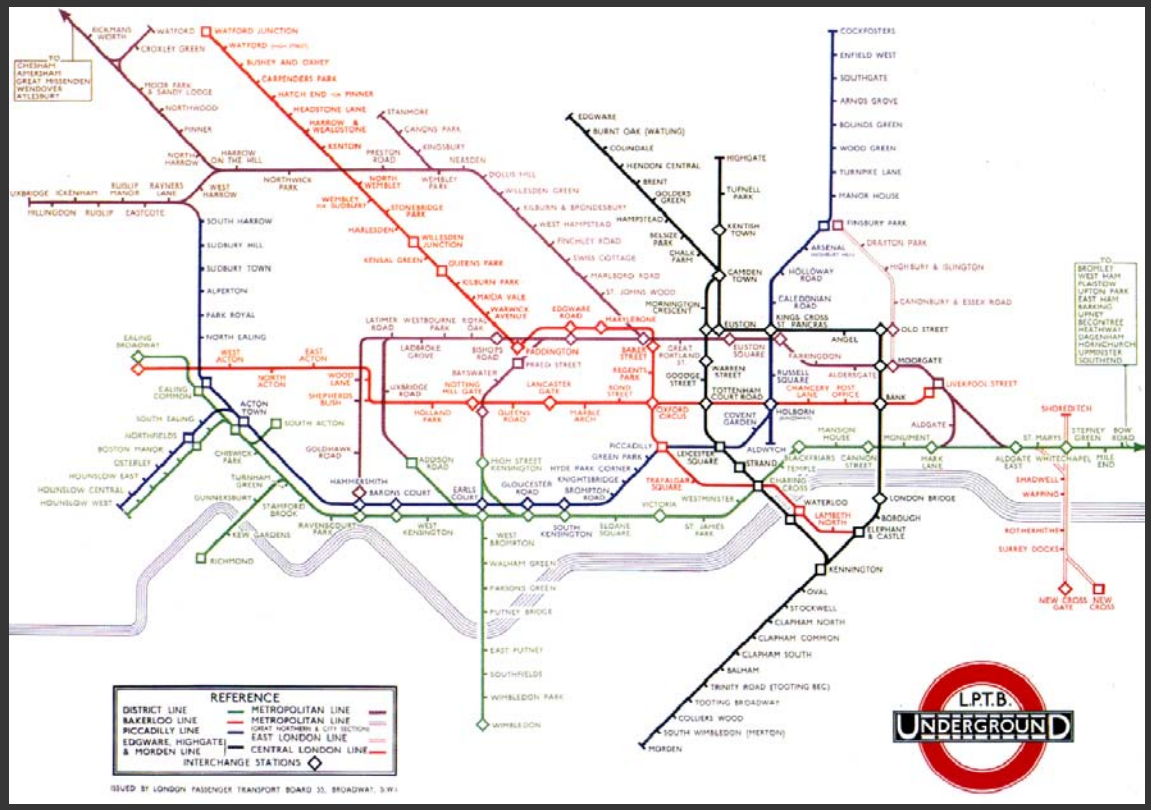
Collaborators: David Bargeron, Michael Cohen, Raanan Fattal, Floraine Grabler, Johannes Kopf,

Subway Map



London Underground [Beck 33]

Subway Map



London Underground [Beck 33]

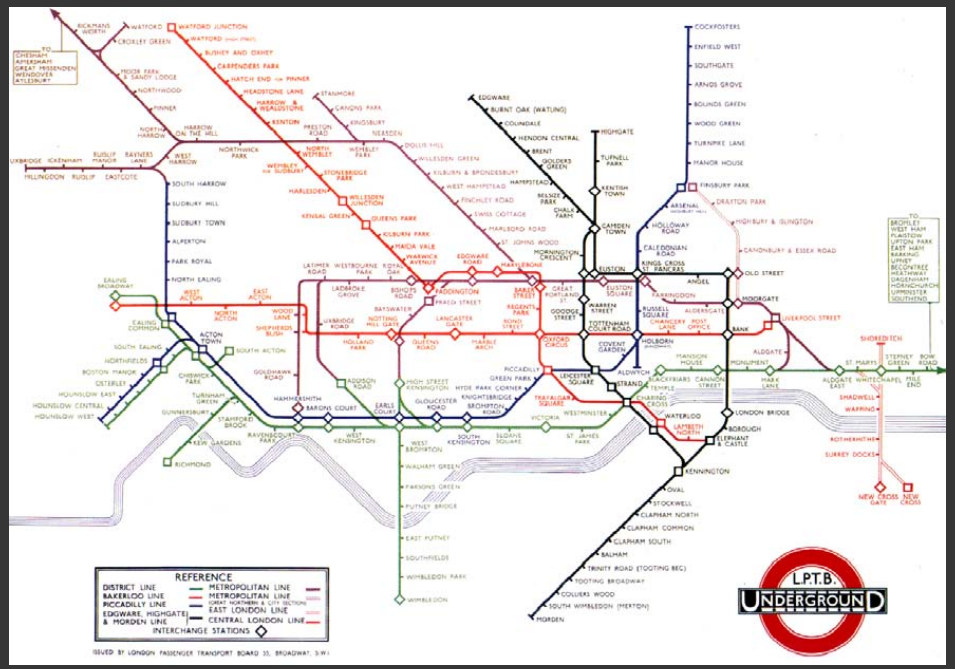
Users' task:

- Understand how to get from point A to point B

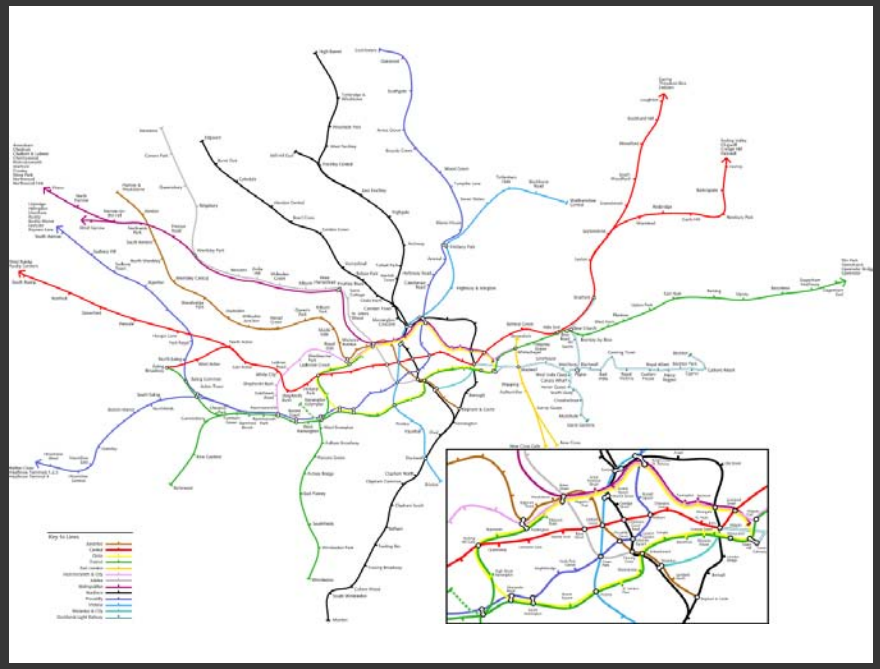
Important information:

- Sequence of stops/interchanges along each line

Design Principles



London Underground [Beck 33]



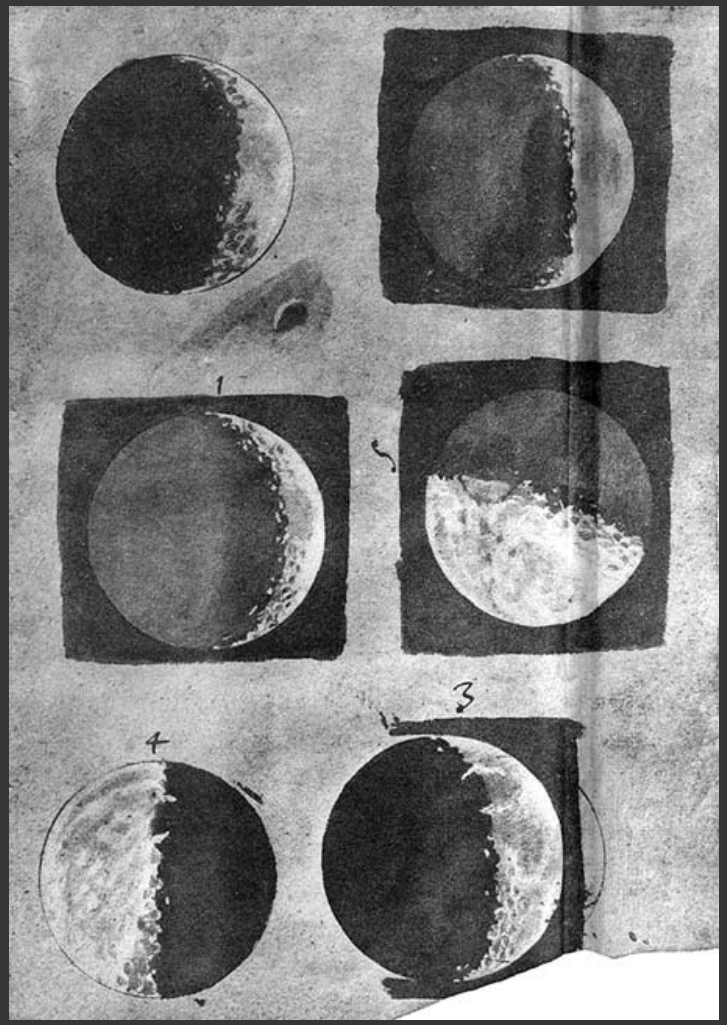
Geographic version of map

Design principles:

- Straighten lines and evenly space stops to emphasize sequence of stops
- De-emphasize geographic shape of subway lines

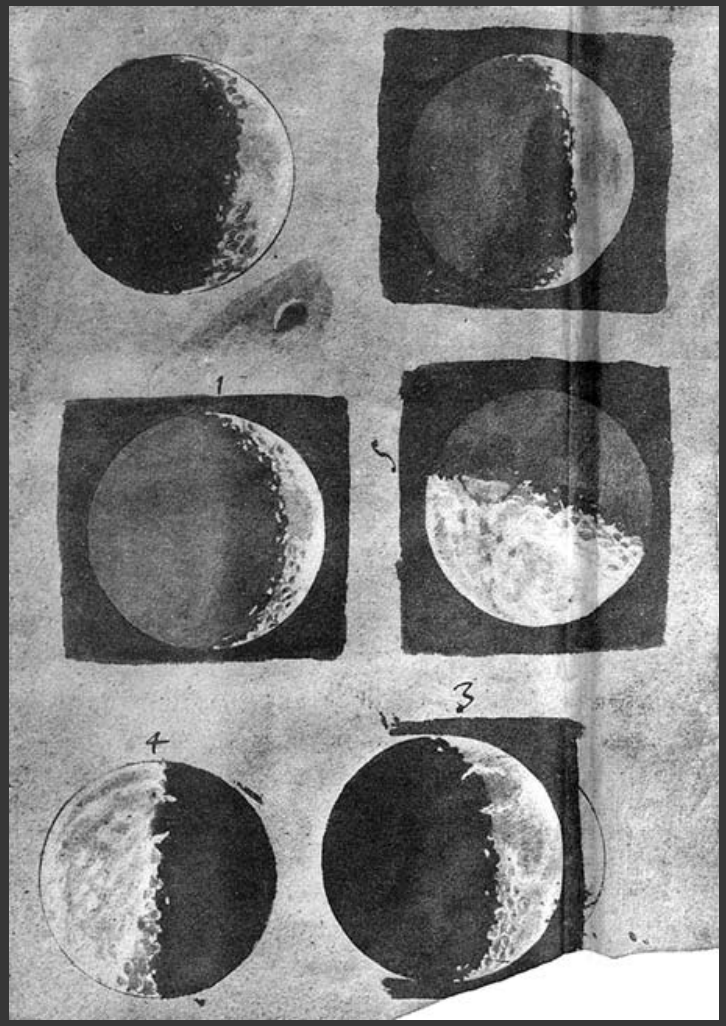
Techniques used to emphasize/de-emphasize information

Phases of the Moon



Galileo's drawings from 1616
http://galileo.rice.edu/sci/observations/moon.html

Design Principles



Galileo's drawings from 1616

Users' task:

- Understand shape of moon's surface

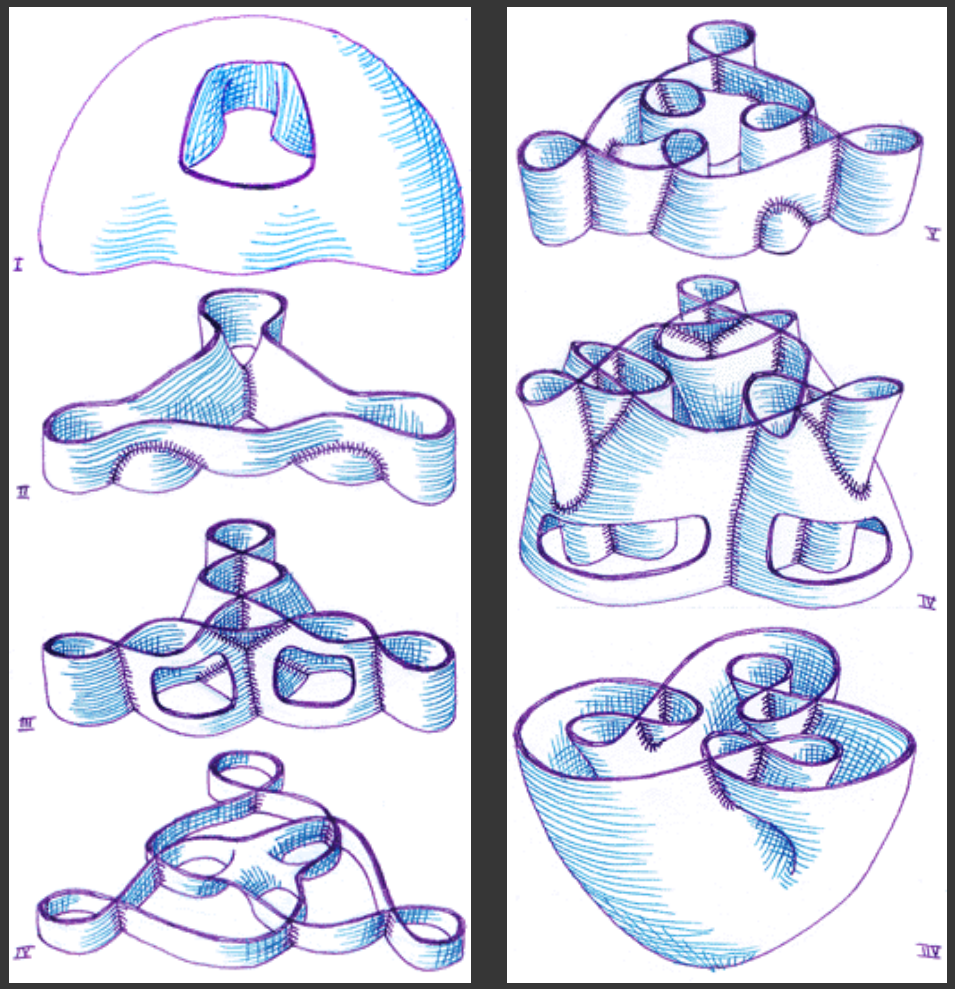
Important information:

- Variation in illumination, especially along terminator

Design principles:

- Detail light/dark variation at terminator
- Reduce detail elsewhere

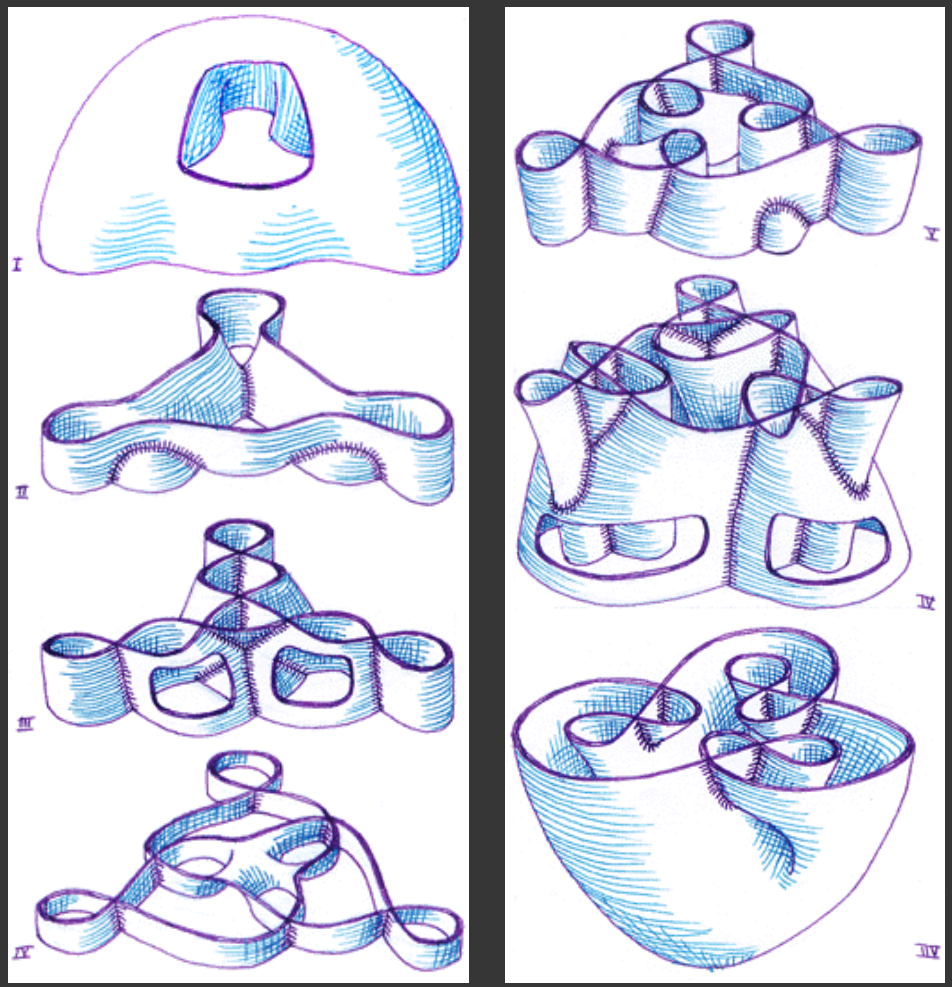
Torus Exploded View



Strange immersion of torus in 3-space

[Curtis 92]

Design Principles



Strange immersion of torus in 3-space
[Curtis 92]

Users' task:

- Understand shape of torus

Important information:

- Silhouettes, curvature and self intersection features

Design principles:

- Explode and create holes to reveal internal features
- Use hatching and contrast to emphasize features

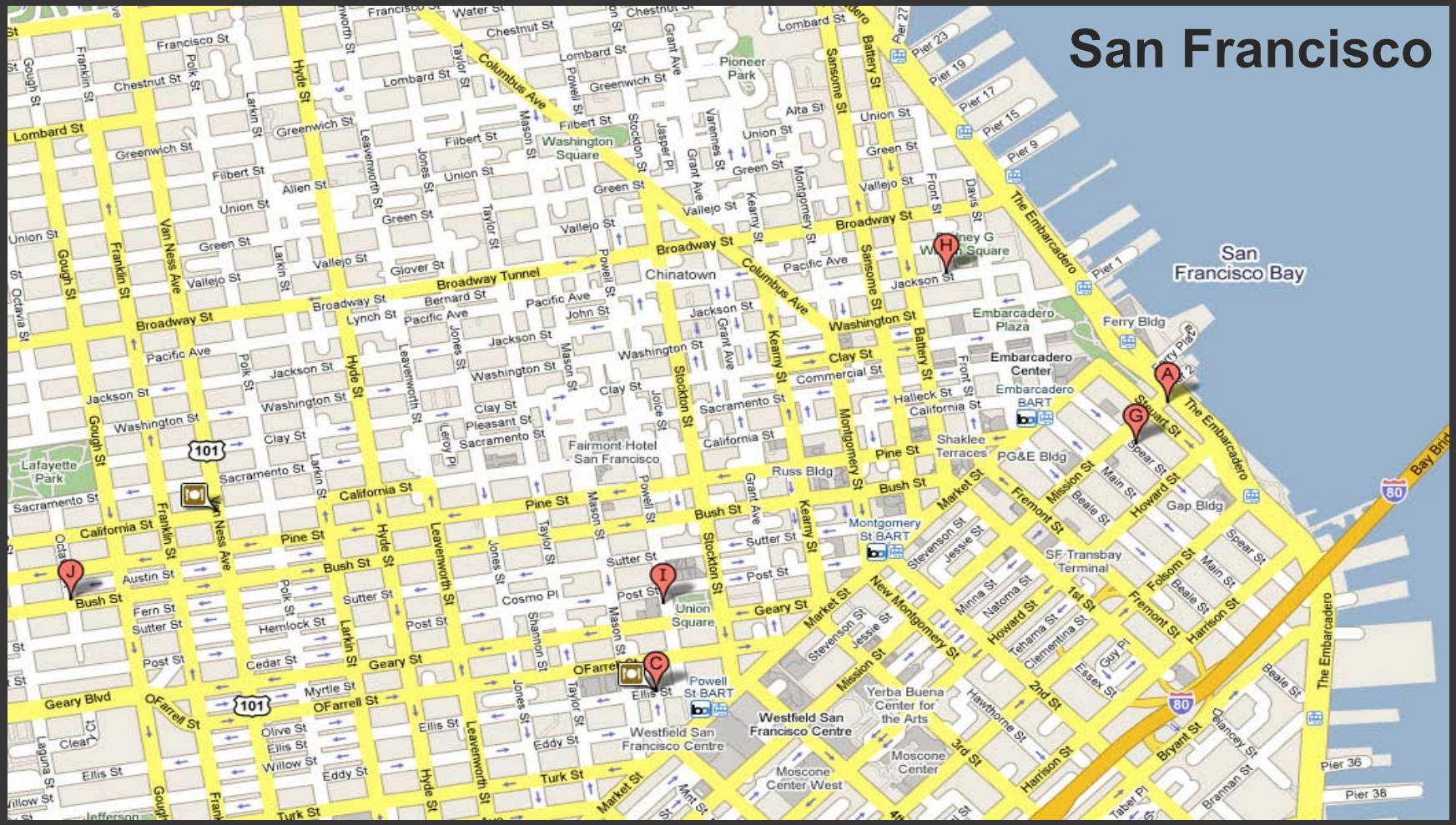
Procedure

1. Find most effective visualizations within domain

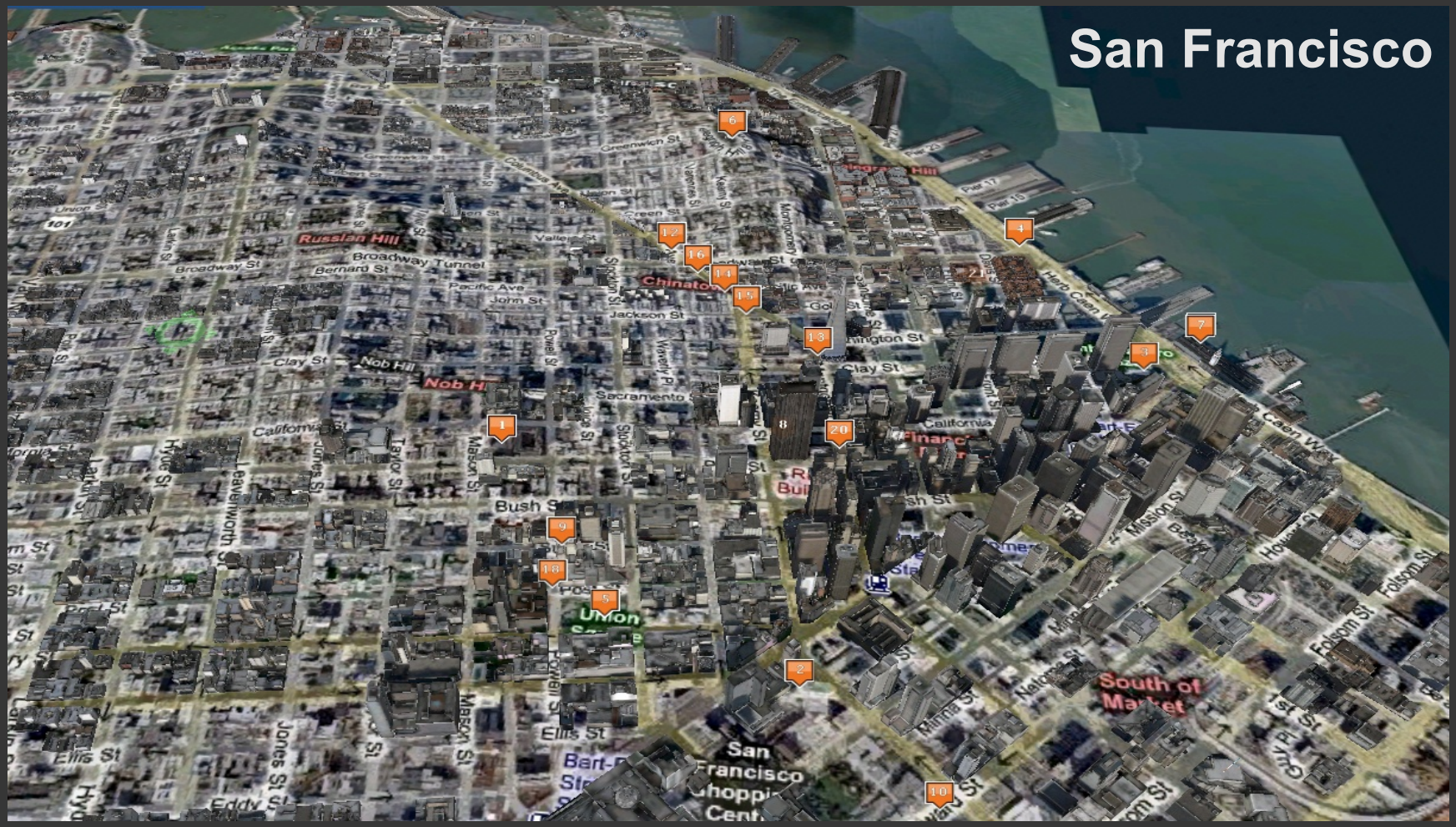
2. Analyze example visualizations to identify
   - Users' tasks
   - Important information (perception/cognition)
   - Techniques used to emphasize/de-emphasize information

3. Instantiate principles in automated design algorithms

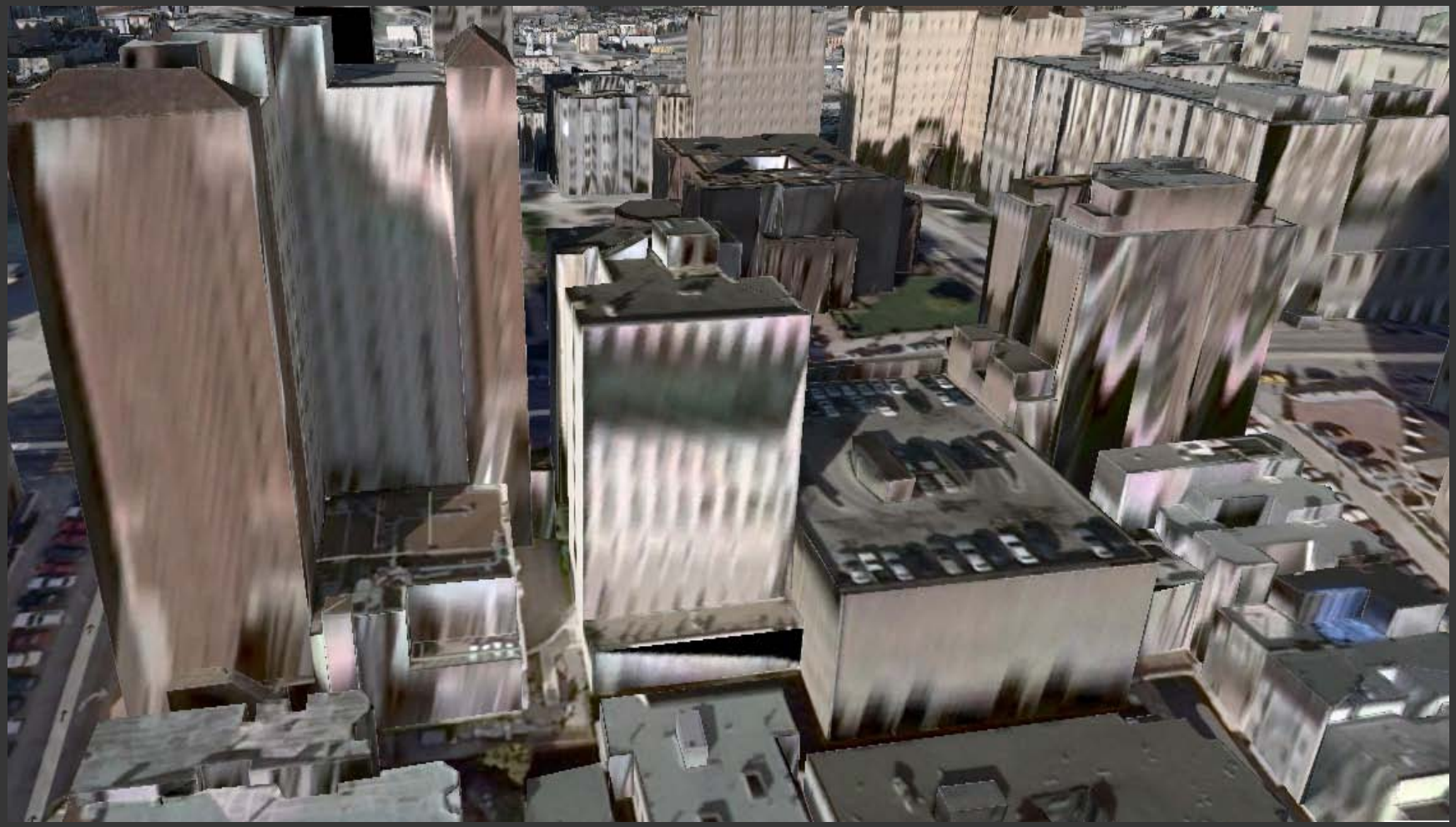
Tourist Maps


San Francisco
San Francisco Bay
Pioneer Park
Chinatown
Union Square
Westfield San Francisco Centre
Yerba Buena Center for the Arts
Moscone Center
Moscone Center West
Embarcadero Plaza
Embarcadero Center
Ferry Bldg
Fairmont Hotel - San Francisco
Lafayette Park
Shaklee Terraces
PG&E Bldg
Gap Bldg
SF Transbay Terminal
Russ Bldg
Embarcadero BART
Montgomery St BART
Powell St BART
Broadway Tunnel
The Embarcadero
Columbus Ave
Van Ness Ave
Market St
Geary St
Geary Blvd
OFarrell St
Bush St
Pine St
California St
Sacramento St
Clay St
Washington St
Jackson St
Broadway St
Lombard St
Chestnut St
Union St
Green St
Vallejo St
Filbert St
Greenwich St
Pier 1
Pier 9
Pier 15
Pier 17
Pier 19
Pier 23
Pier 27
Pier 36
Pier 38
Bay Bridge
101
80

[Google Maps]



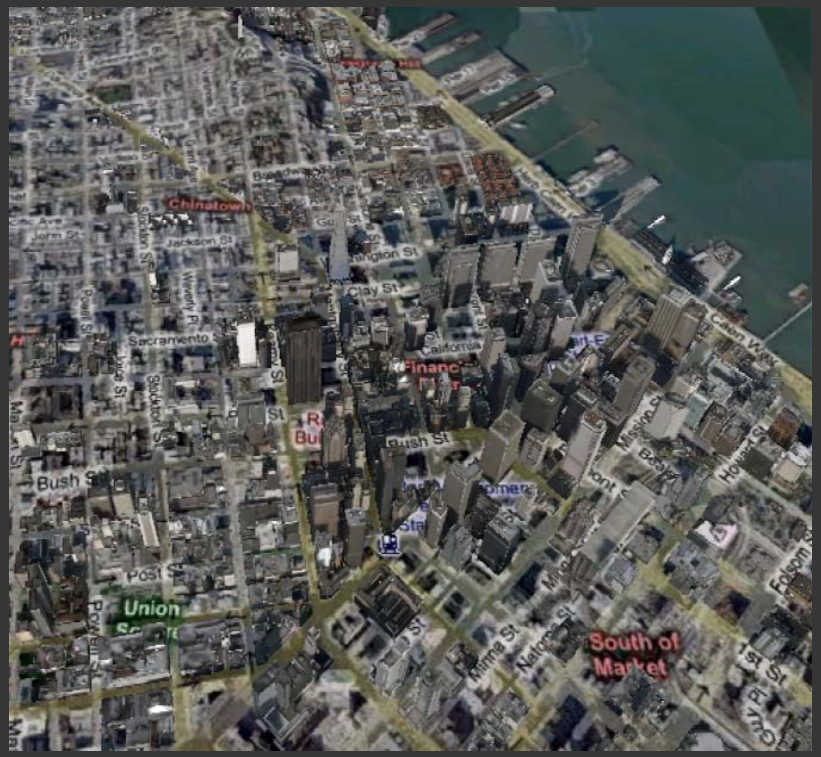
[Microsoft Virtual Earth]



[Microsoft Virtual Earth]

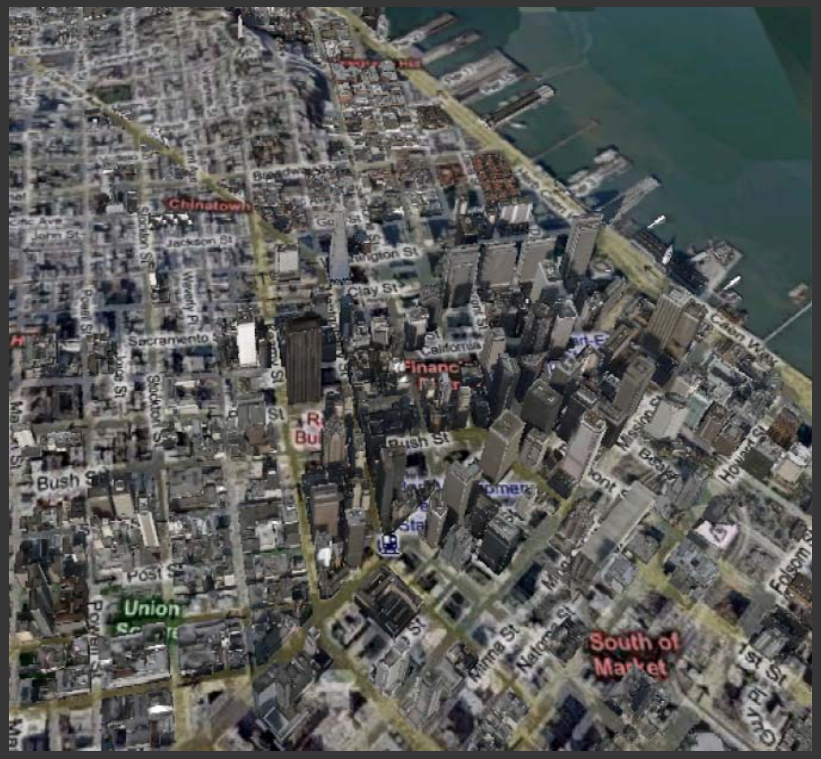
[Travel Graphics International]

Goal


Chinatown
Bush St
Union
South of Market


Hill
North Beach
Chinatown
Financial District
Jackson Square
COLUMBUS
EMBARCADERO

Goal



Input Data

Selection

Rendering

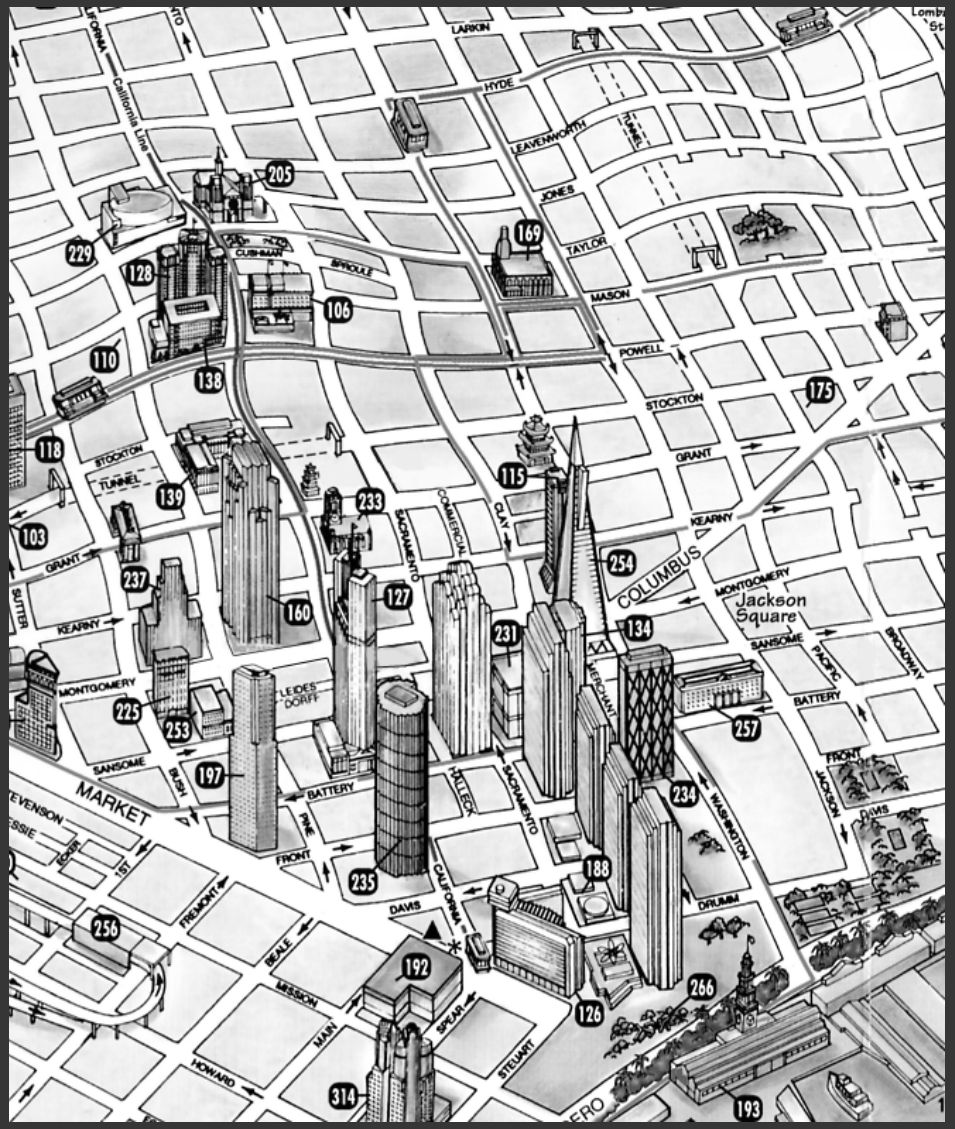
Tourist Map

Selection Principles: Map Cognition

Mental maps of cities based on 5 elements

- Landmarks
- Paths
- Edges
- Districts
- Nodes

The Image of the City [Lynch 60]

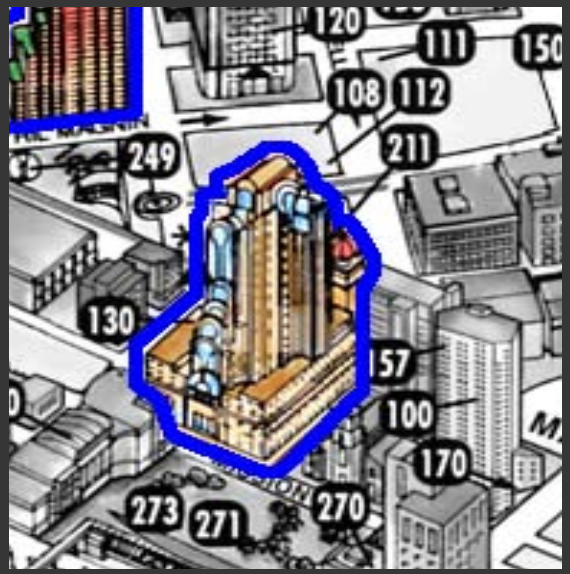


[Travel Graphics International]

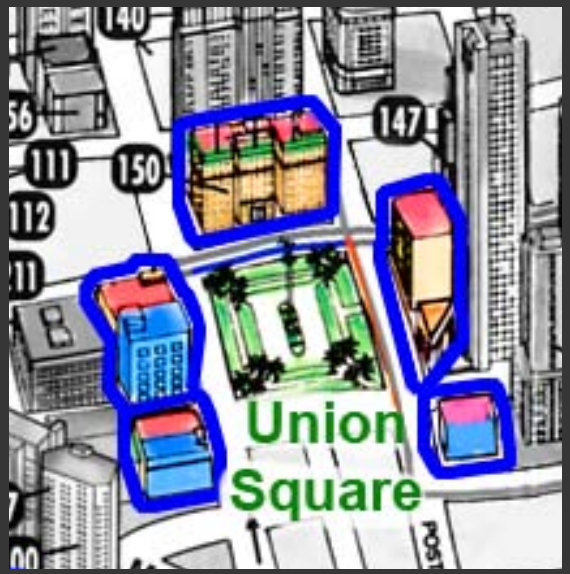
Types of Landmarks

[Sorrows 99]

Semantic



Visual

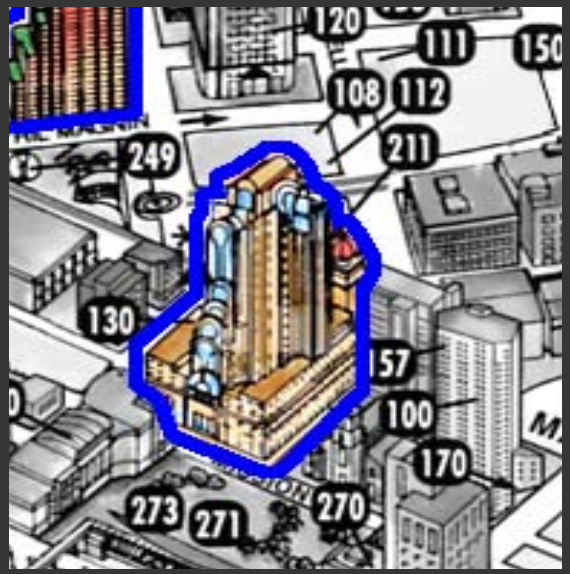


Structural

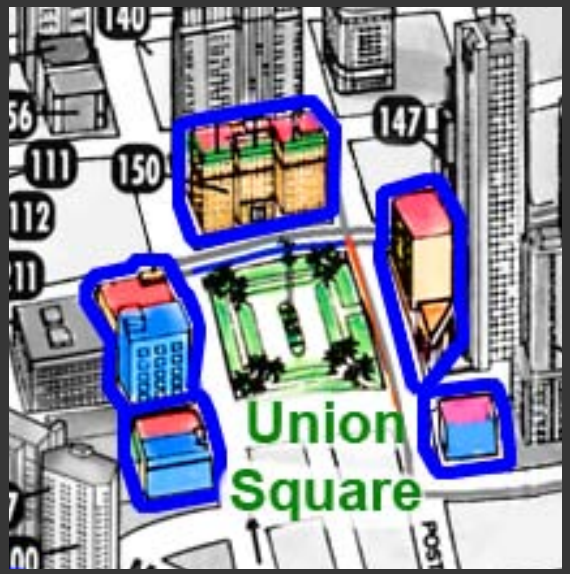
Types of Landmarks

[Sorrows 99]

Semantic



Visual

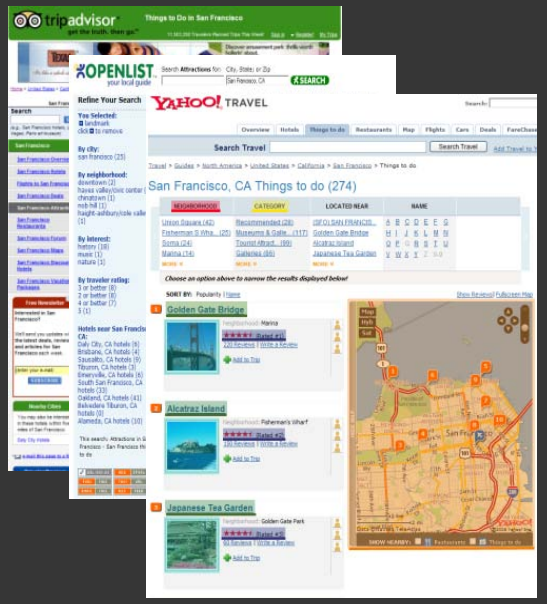


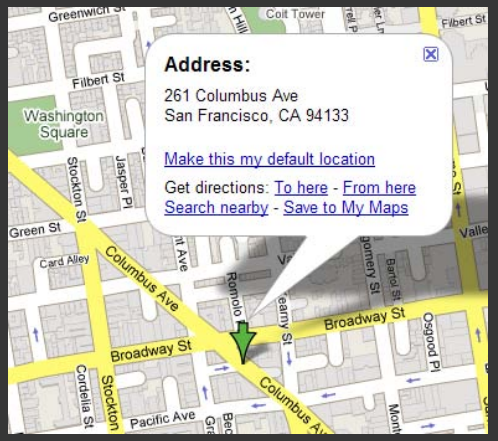
Structural

We compute quantitative scores in each category for each building

Semantic Features

INPUT WEBPAGES





GOOGLE MAP API

Name	Category	District	Rating	Address	Position
City Lights Booksellers	Business Facility	North Beach	3/5	261 Columbus	Lat: 37.7975 Lon: -122.4062
Japanese Tea Garden	Tourist Attraction	Golden Gate Park	4.5/5	7 Tea Garden Dr	Lat: 37.7692 Lon: -122.4698

Score based on user ratings

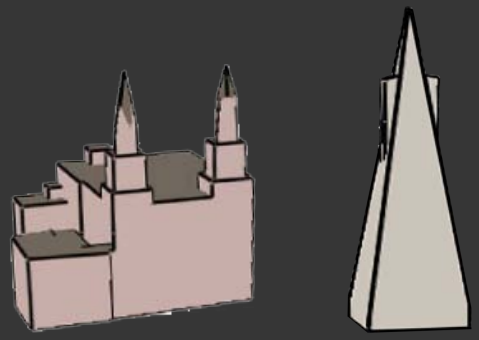
Visual Features

Color

- Choose representative color

Shape Complexity

- Non-rectangularity
- Angle variation

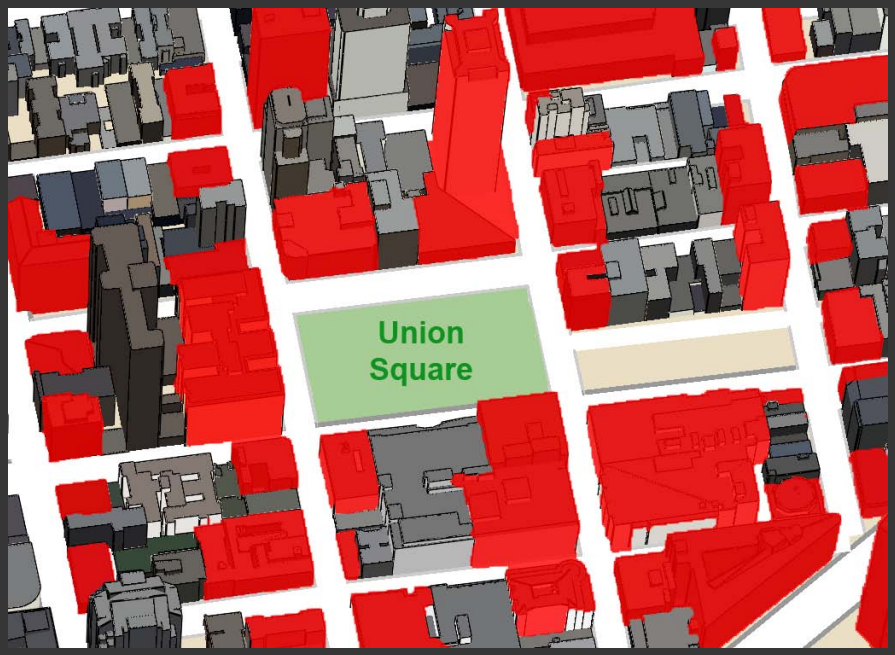


Height

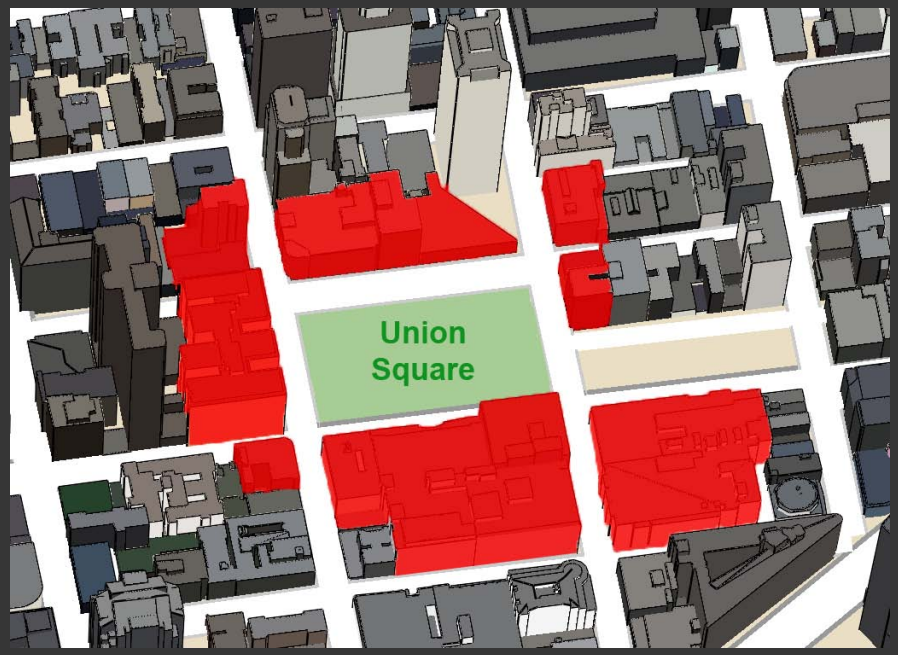
- Distance from top to ground plane

Score based on local distinctiveness of features

Structural Features



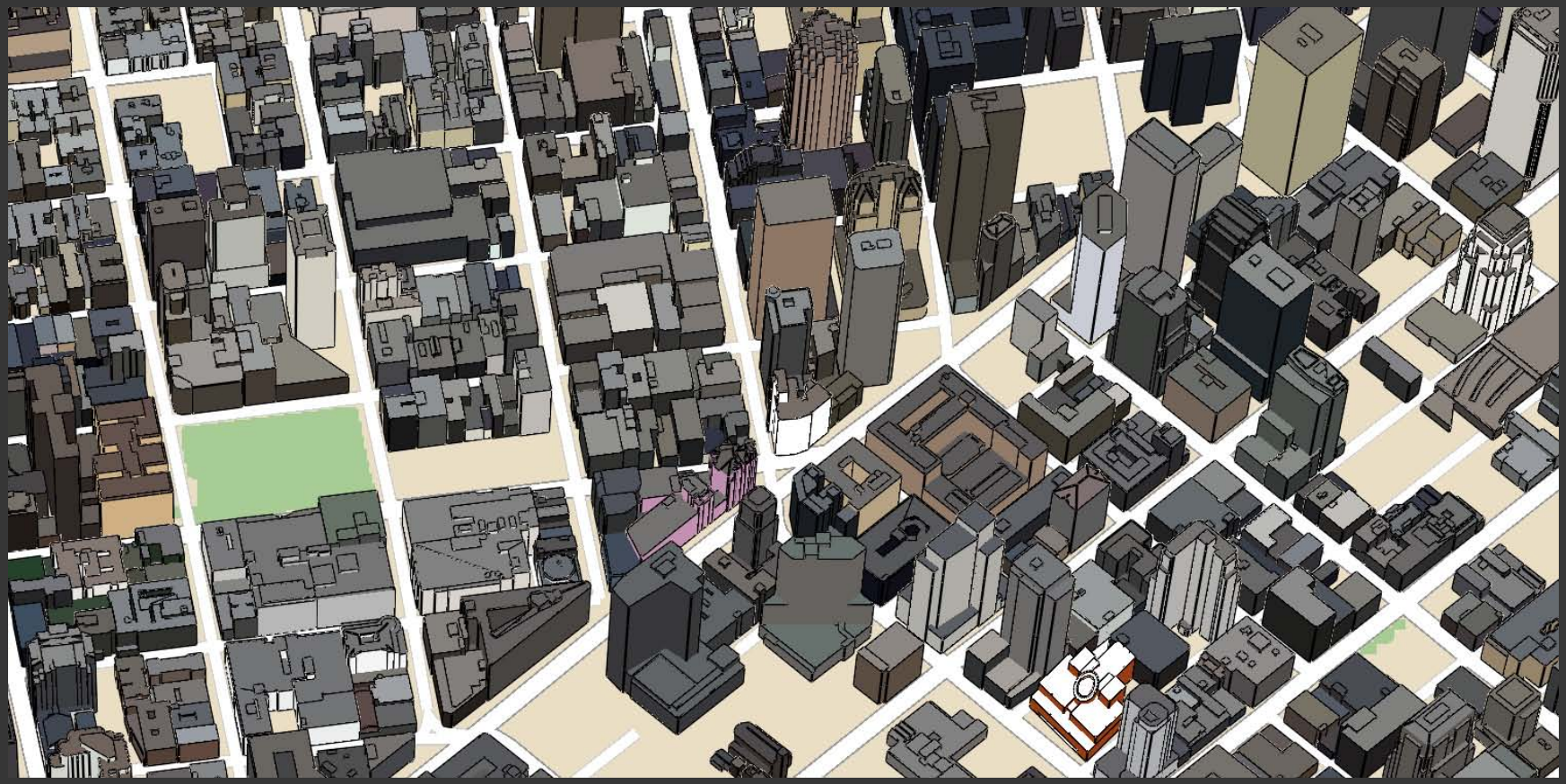
Intersections

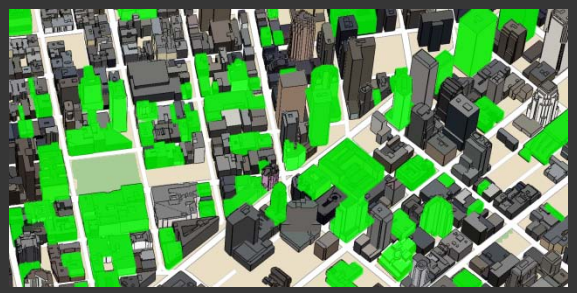


Squares

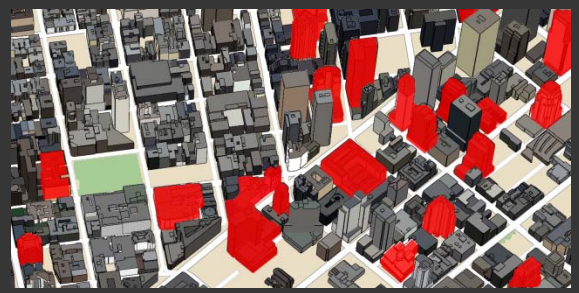
Score based on importance of intersection or square

Combining Feature Scores

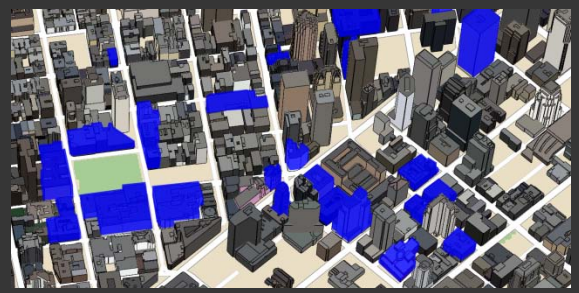




Semantic

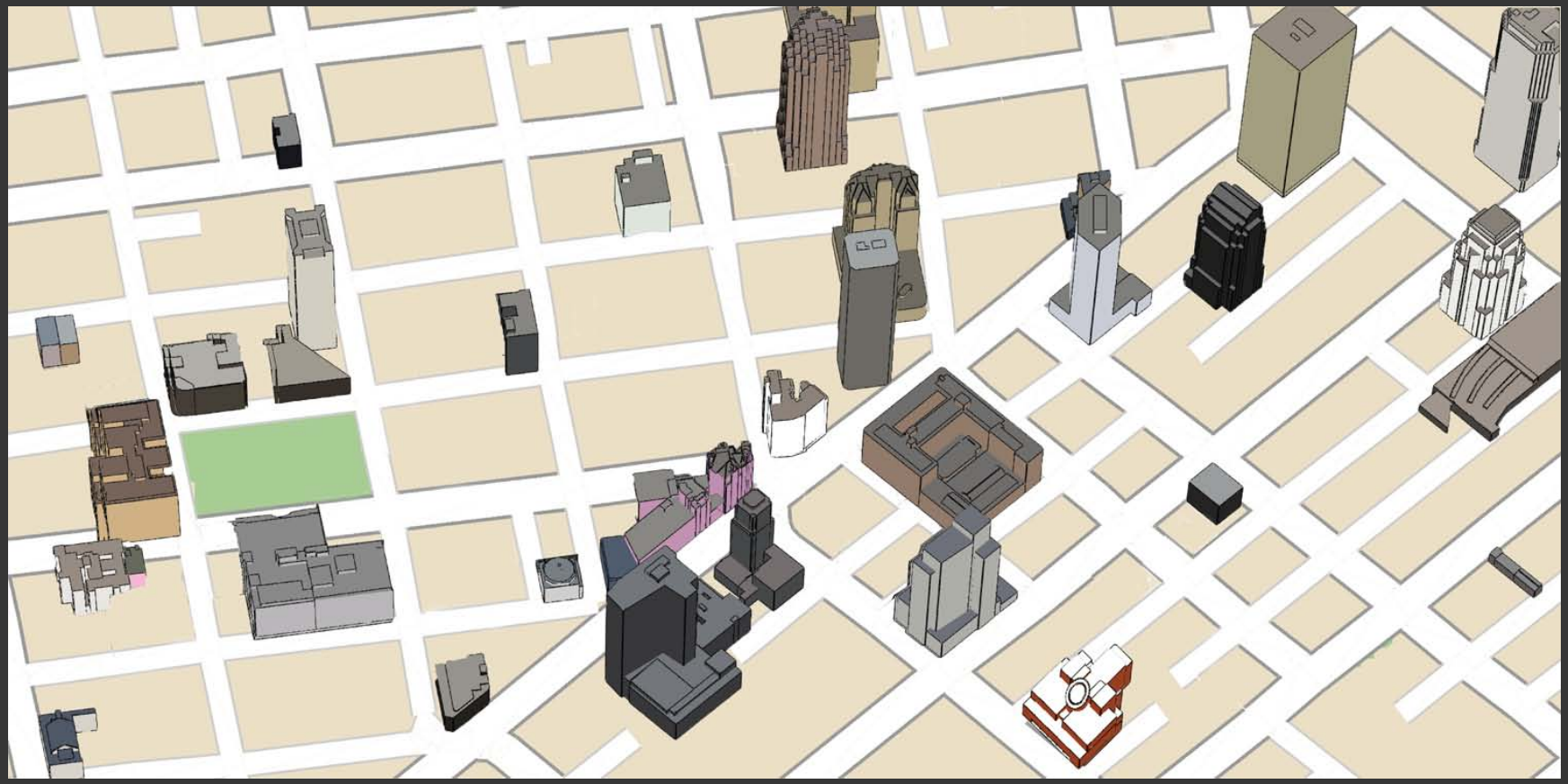


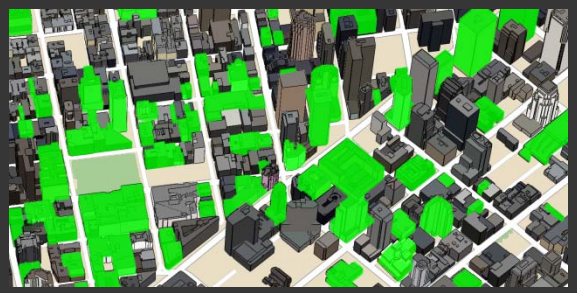
Visual



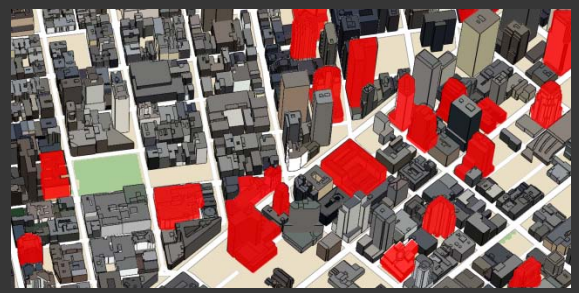
Structural

Threshold Weighted Sum of Scores

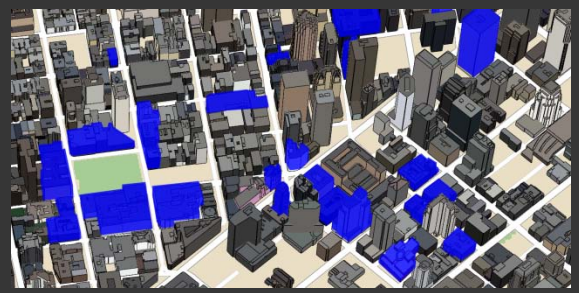




Semantic



Visual



Structural

Rendering Principle: Multiperspective

Streets

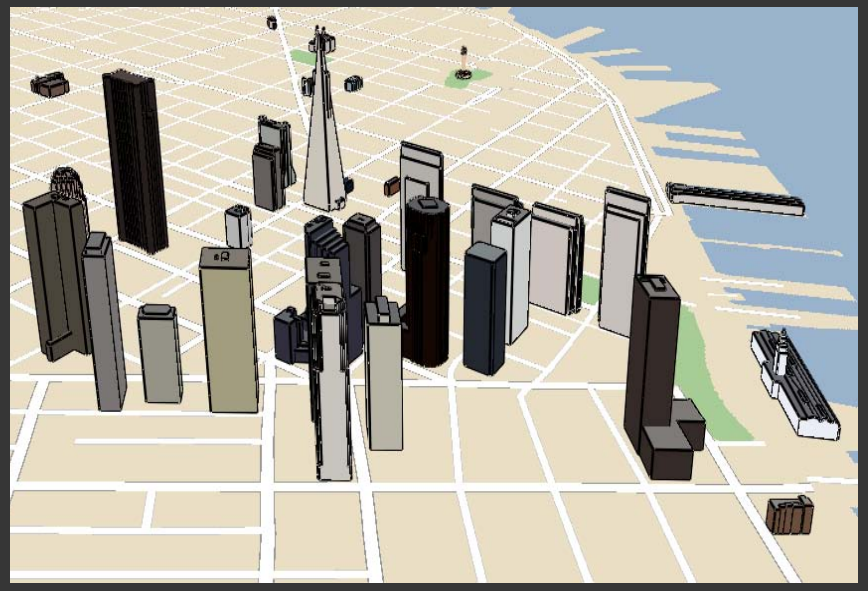
Prevent foreshortening distortion via orthographic projection

Landmarks

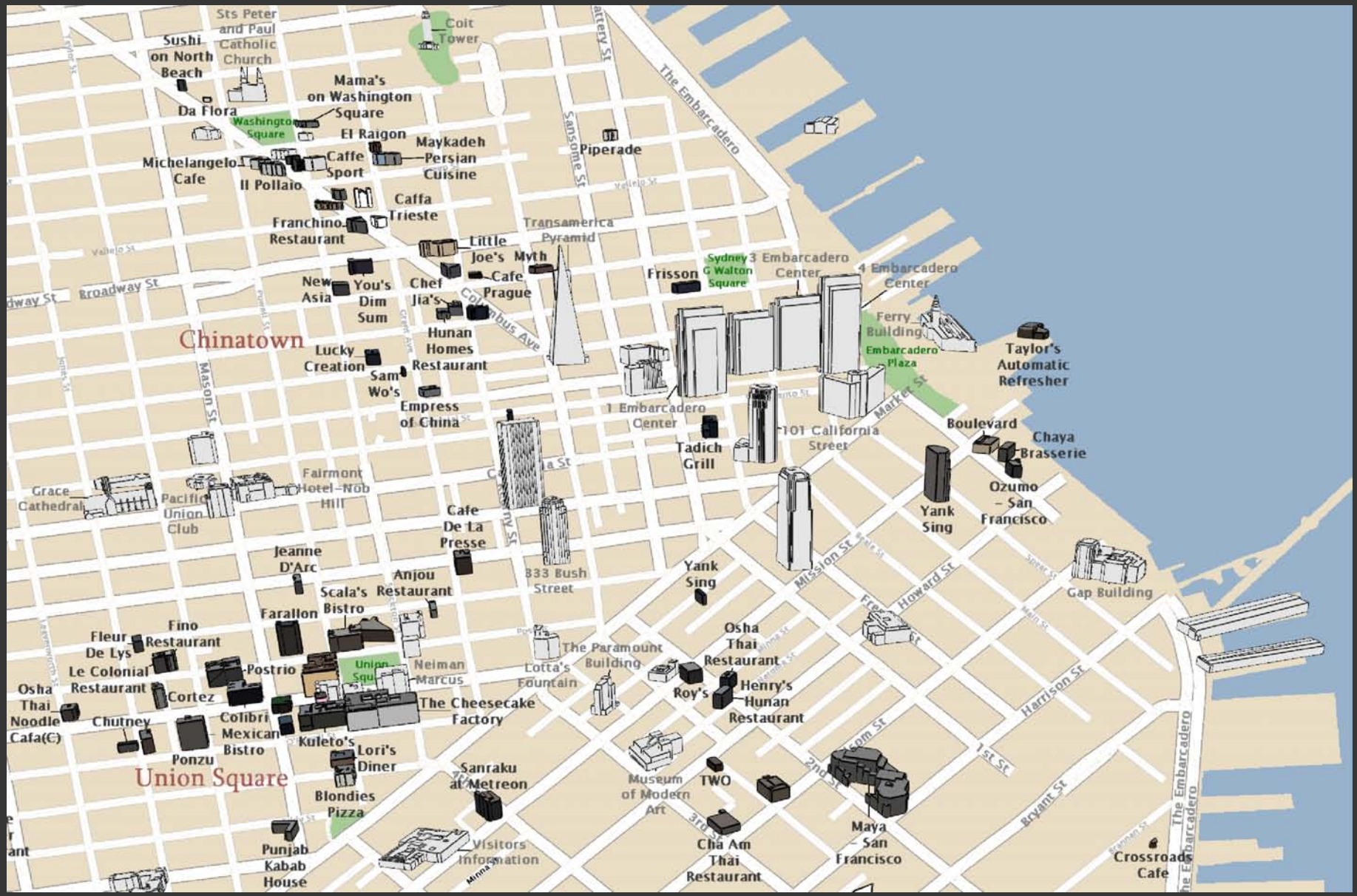
Choose projection to ensure visibility of street-side facades

Combine Multiple Views

Roads: Top-Down Orthographic



Buildings: Side Perspective



Result: Restaurants in San Francisco

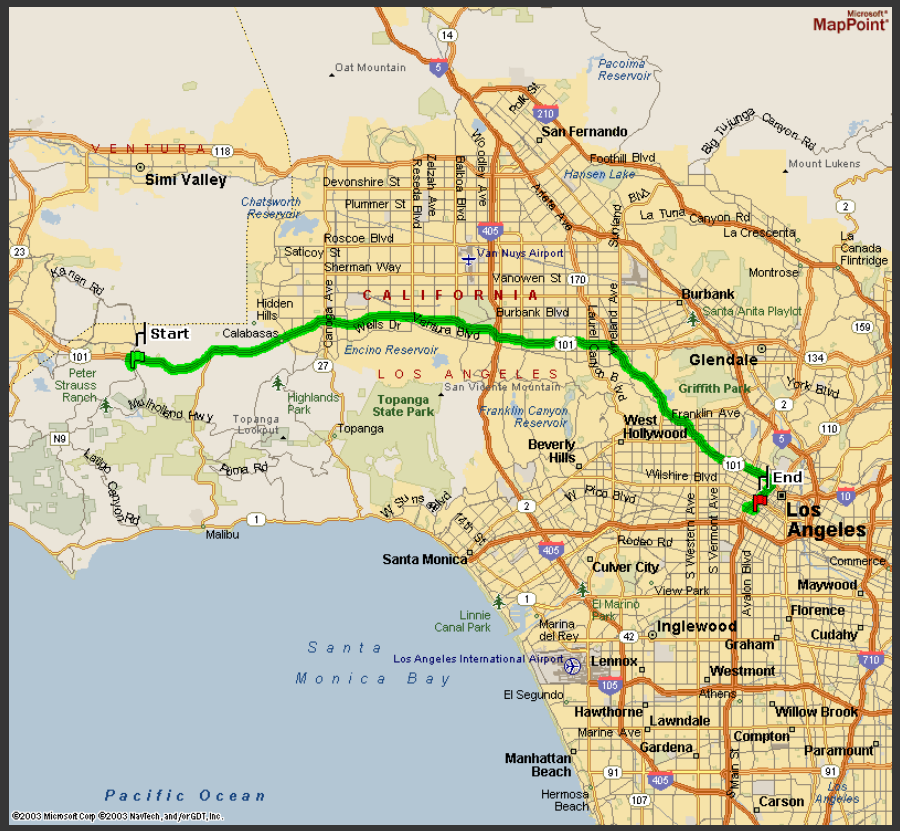
Result: Shopping in San Francisco

Single Street View

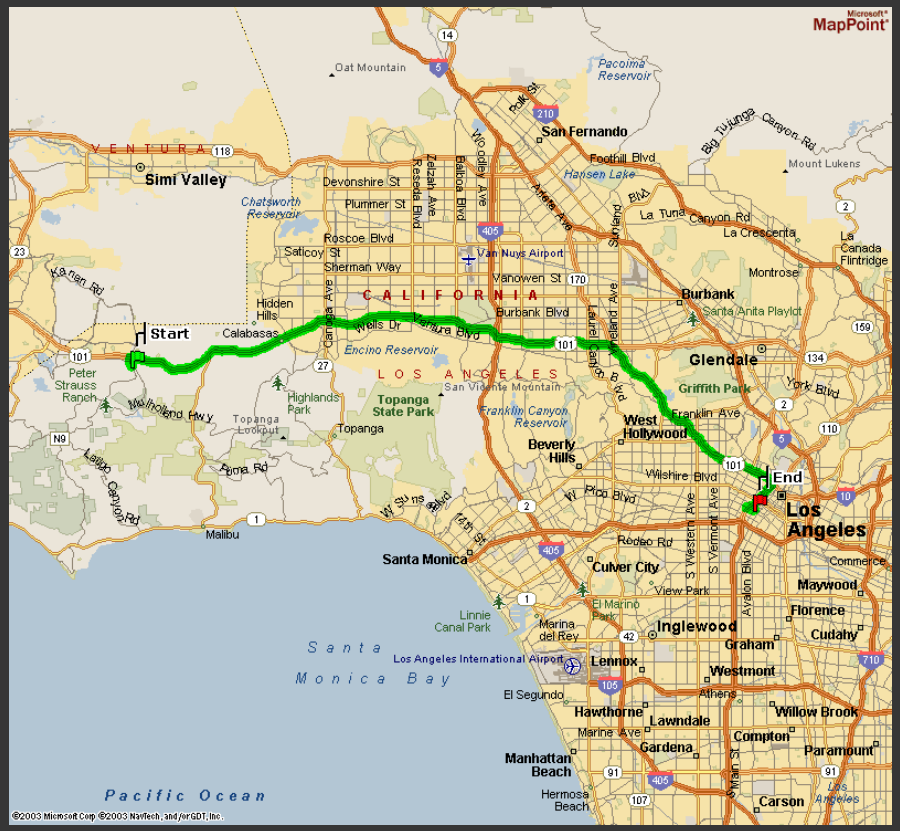
Single Street View

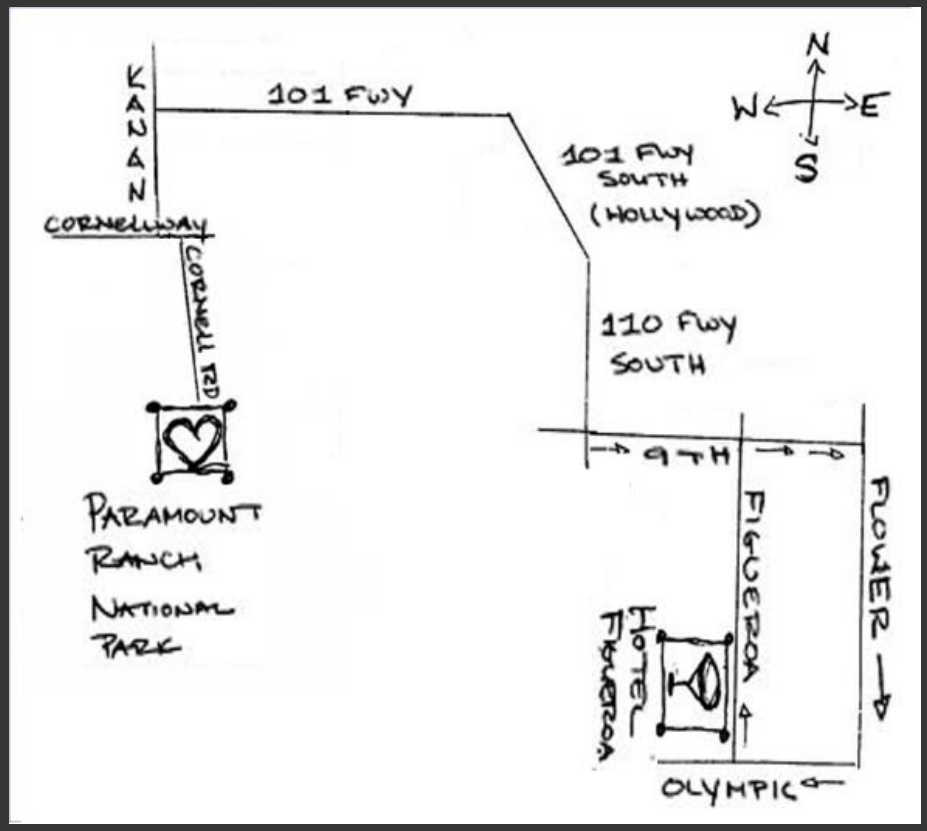
Route Maps

Visualizing Routes

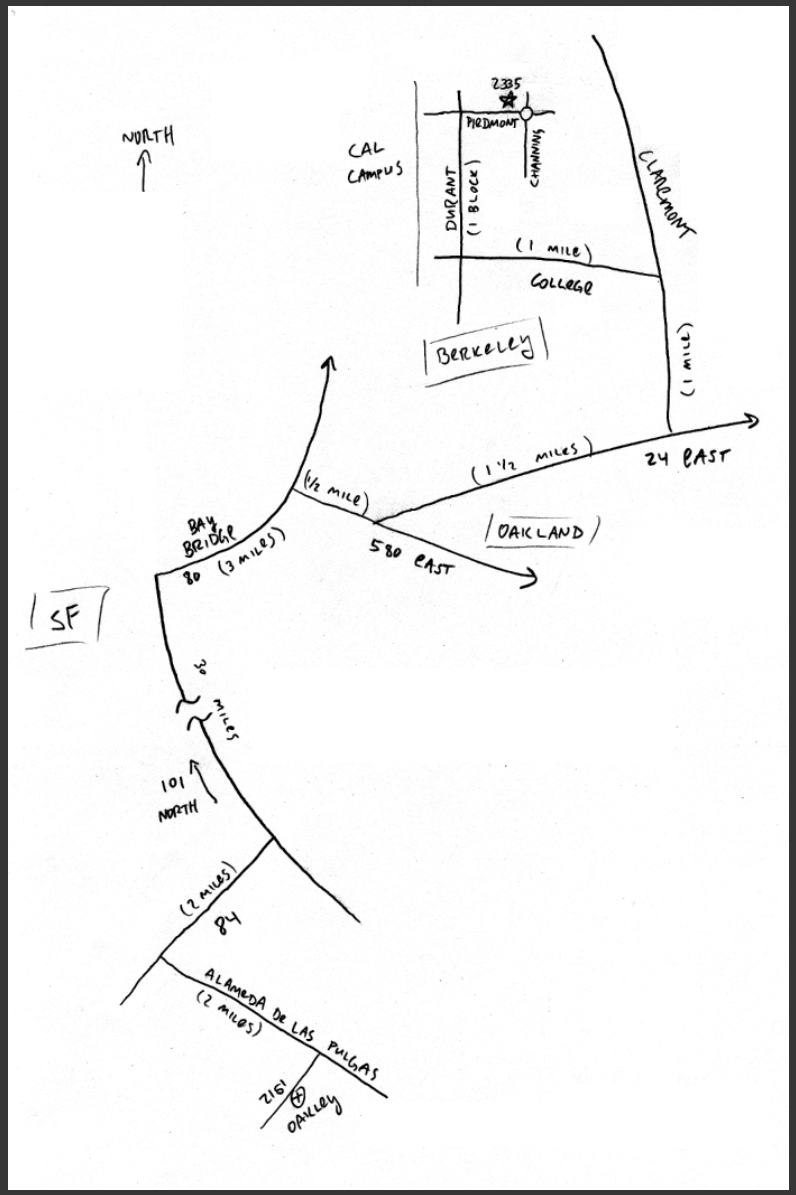


A Better Visualization





Cognition of Route Maps



Essential information

- Turning points
- Route topology

Secondary context information

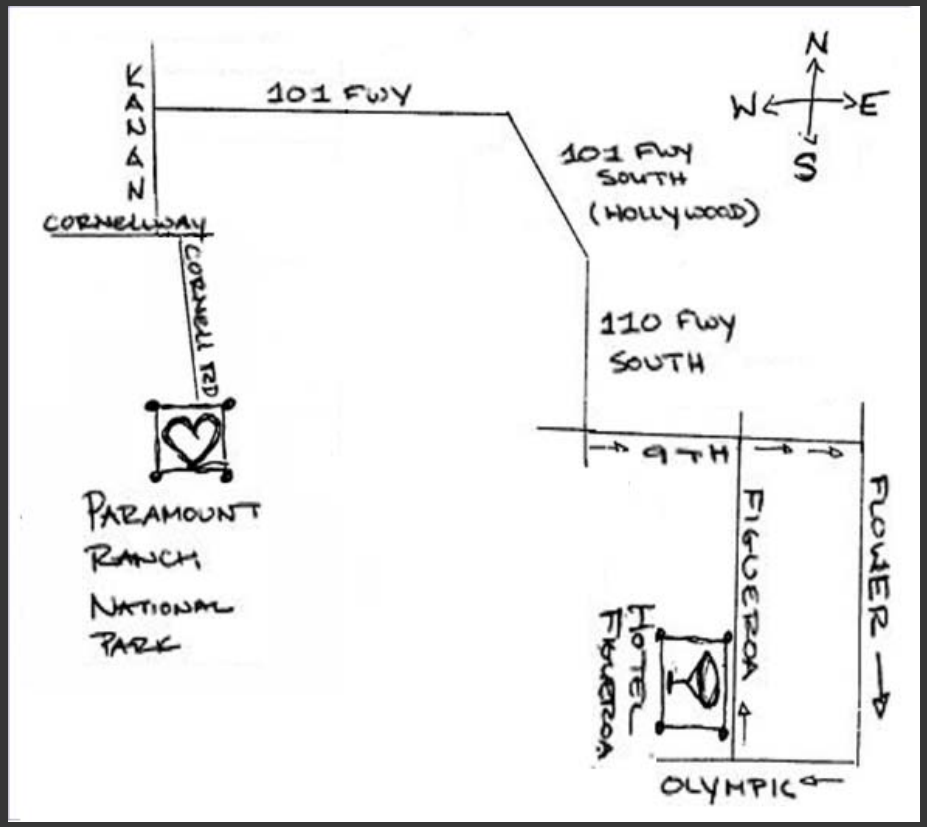
- Local landmarks, cross streets, etc.
- Overview area landmarks, global shape

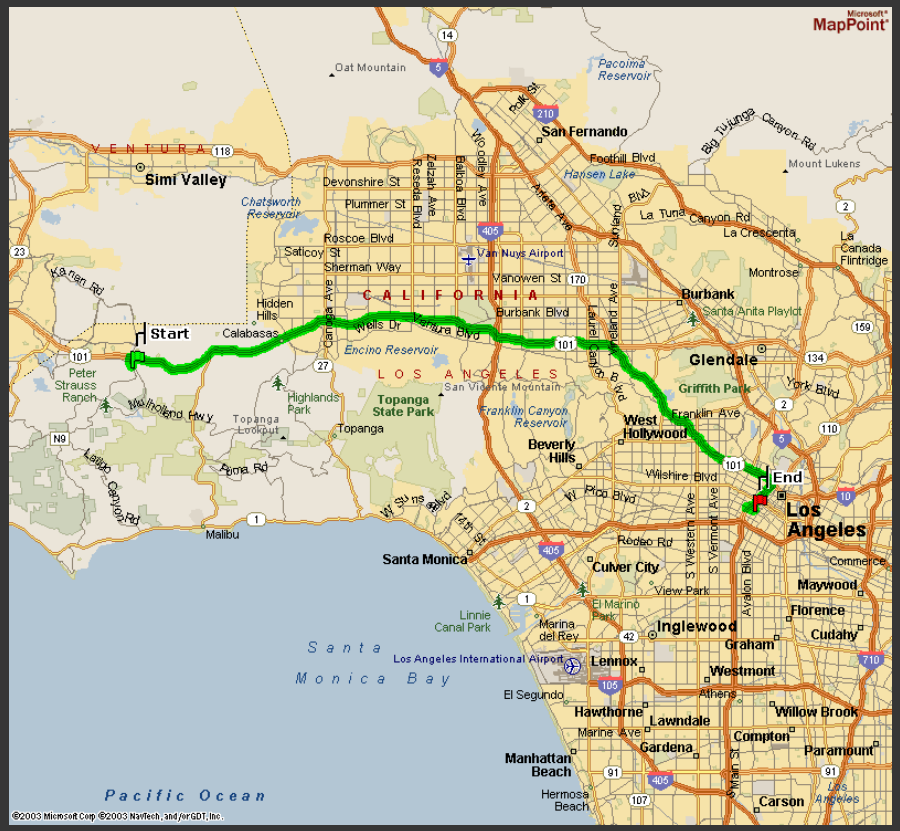
Exact geometry less important

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

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

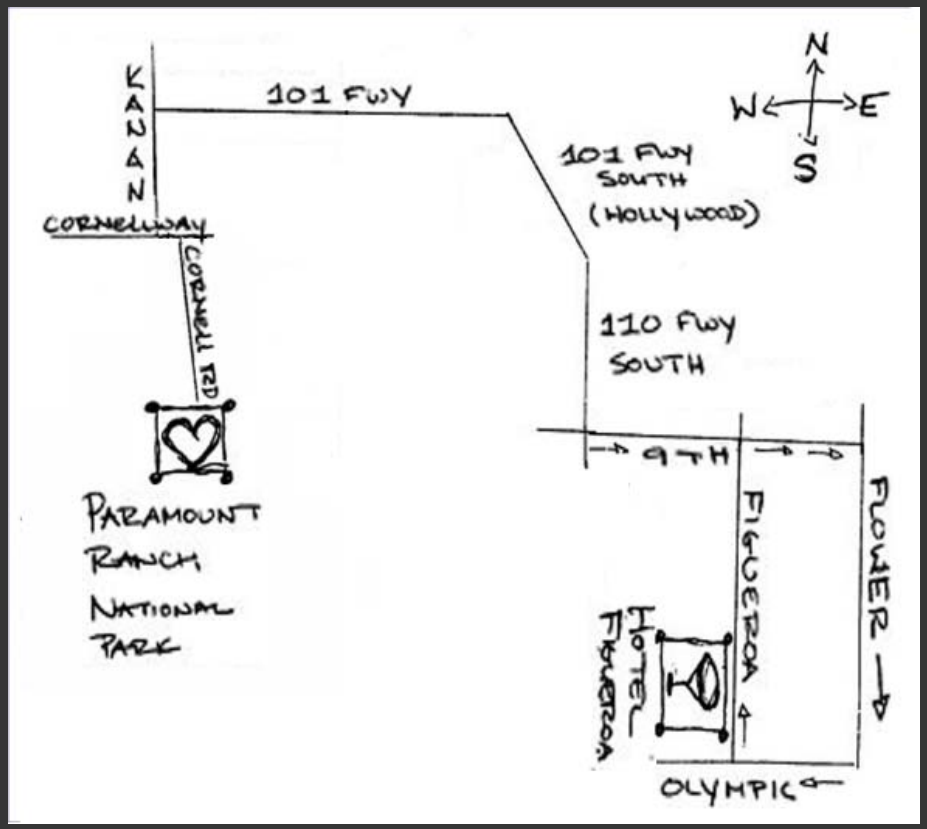
Design Principles



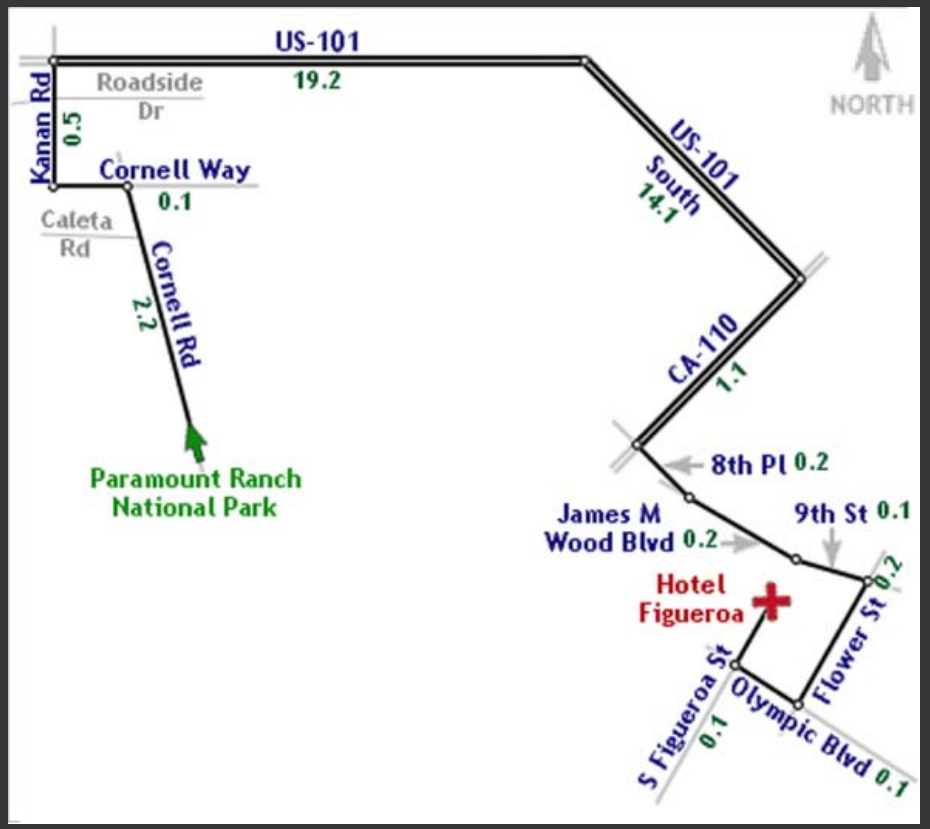


- Exaggerate road length
- Regularize turning angles
- Simplify road shape

LineDrive



Hand-drawn route map



LineDrive route map

Map Design via Optimization

Set of graphic elements

- Roads, labels, cross-streets, …

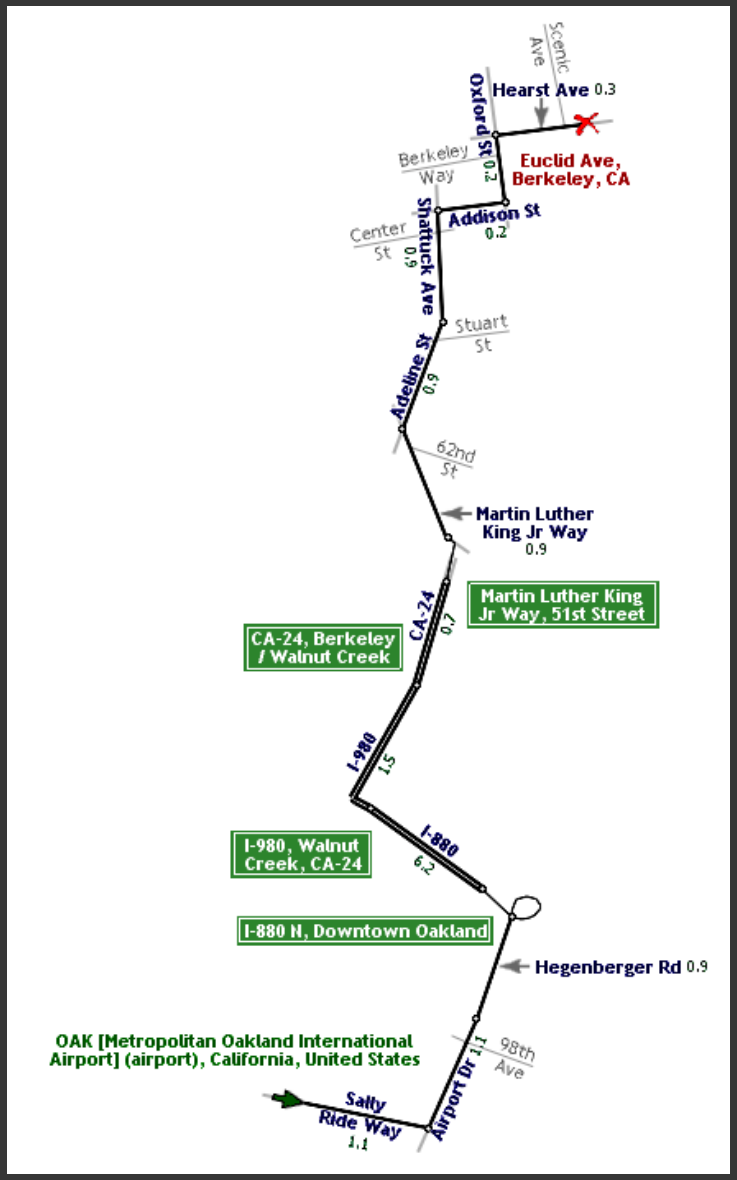
Choose visual attributes

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

Develop constraints based on design principles

Simulated annealing

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



DEMO

mappoint.com

Results

Beta version — 6 months

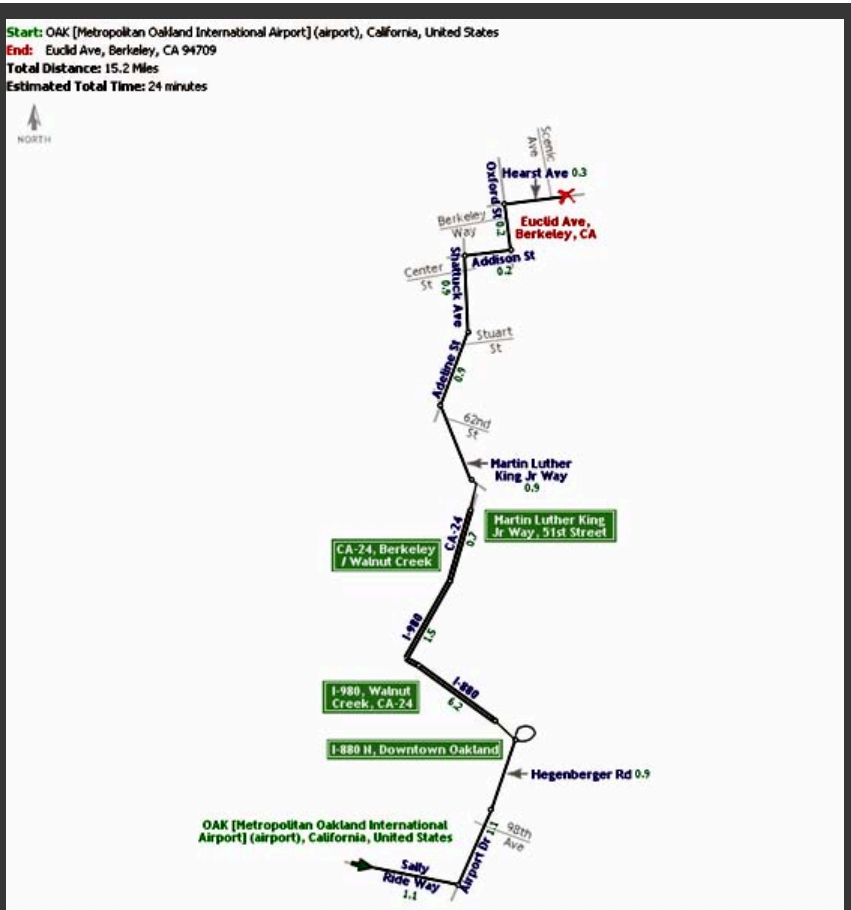
- 150,000 maps served

2242 responses

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

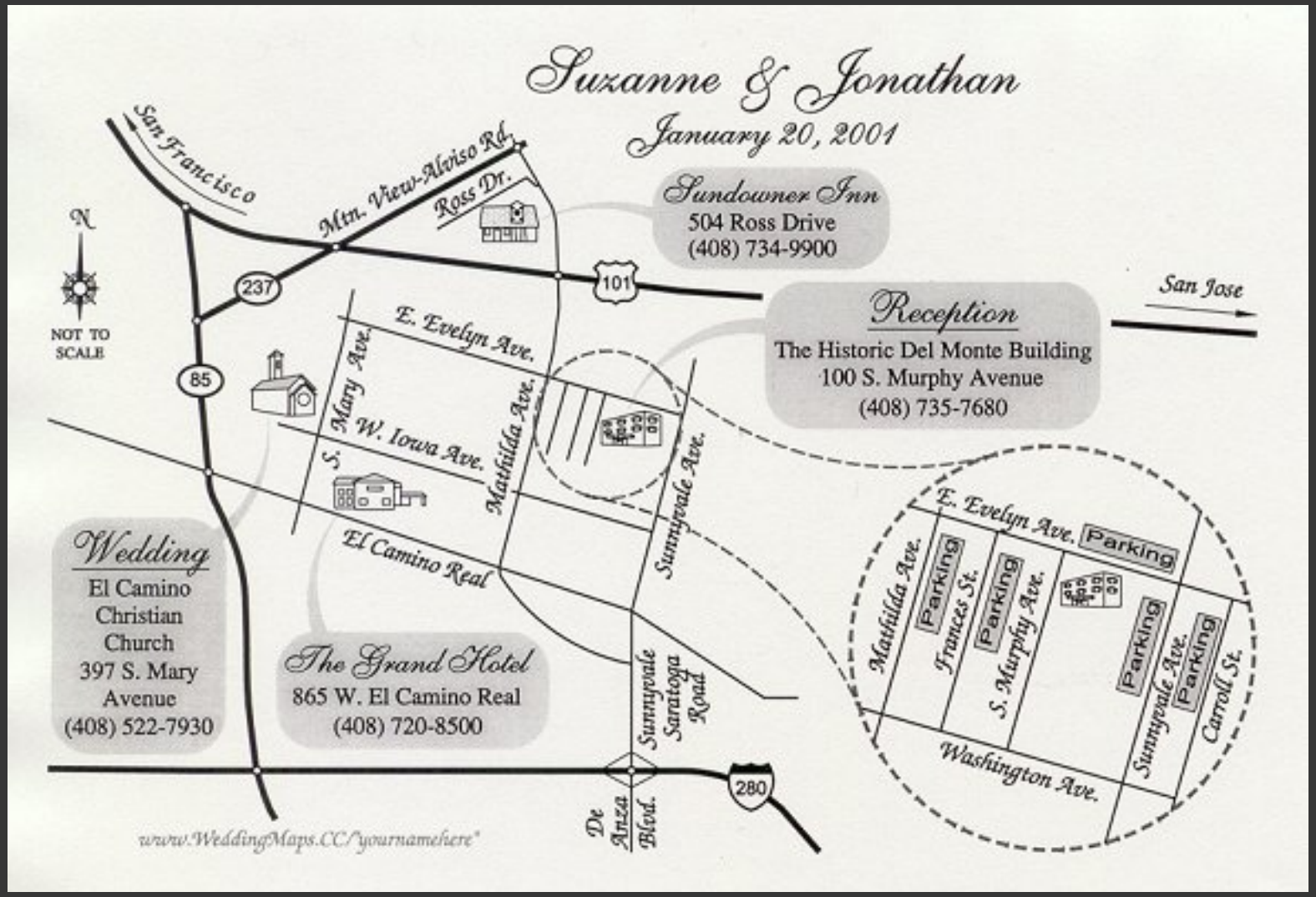
Current Status

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



Directions	Miles
Start: Depart OAK [Metropolitan Oakland International Airport] (airport), California, United States on Sally 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	

Next Steps: Wedding Maps

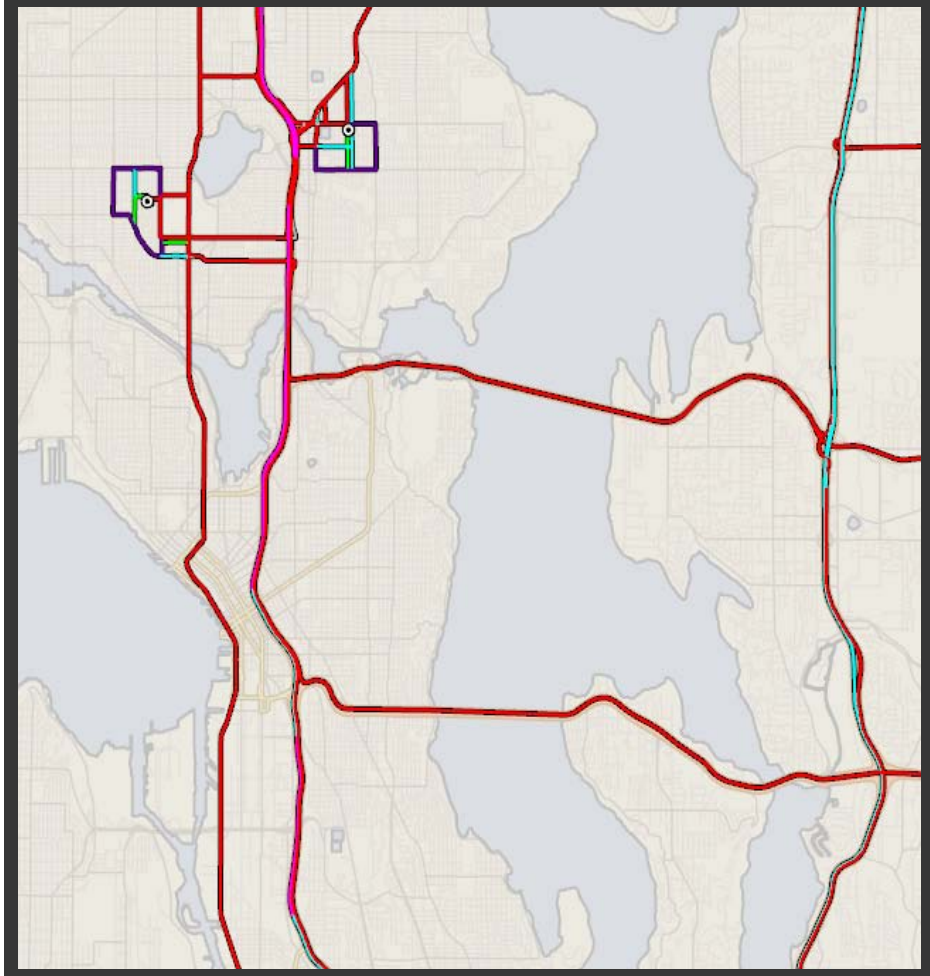


Hand-designed Wedding Map www.WeddingMaps.CC

Input map drawn to scale

Our result

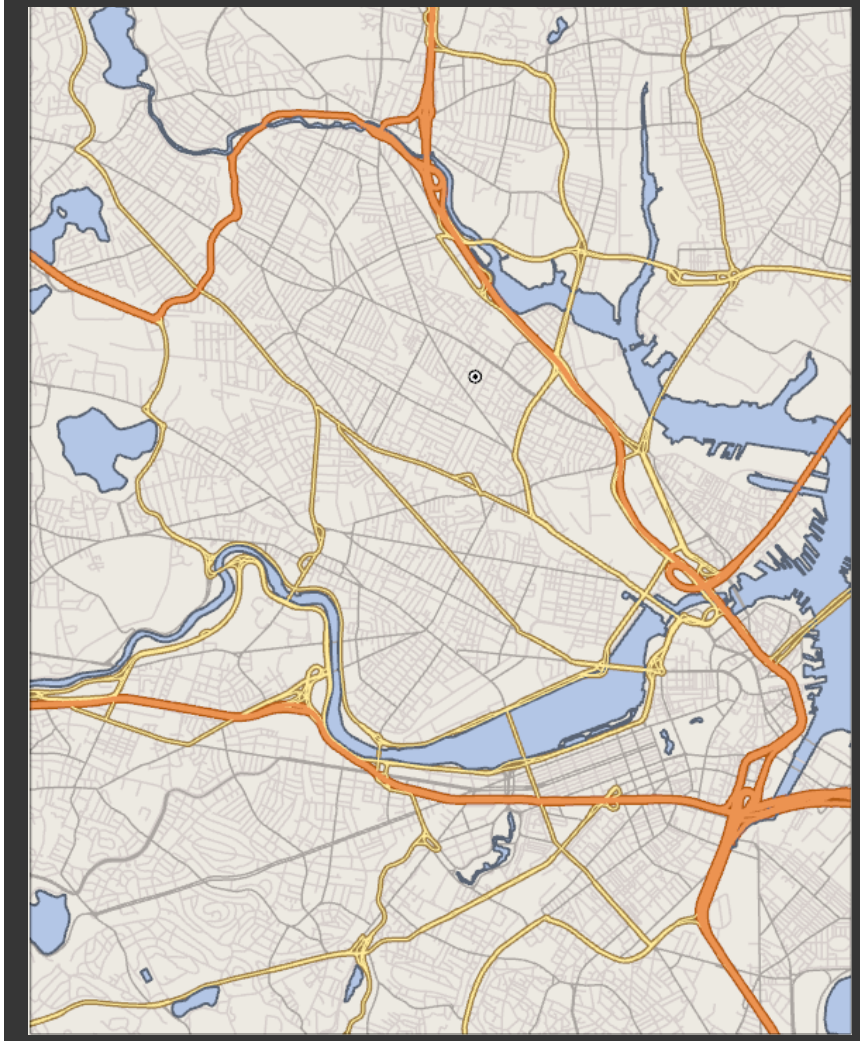
1st Ave. and 19th Ave. NW, Seattle WA



Roads selected from input

Our result

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

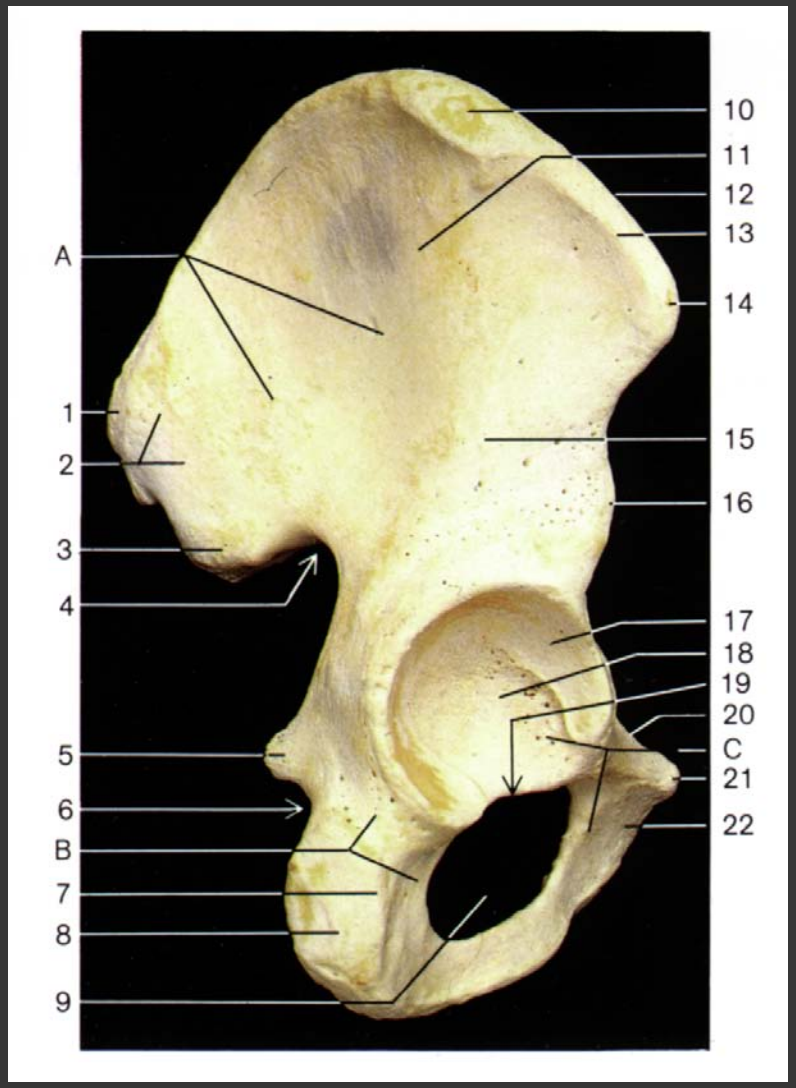


Input map drawn to scale

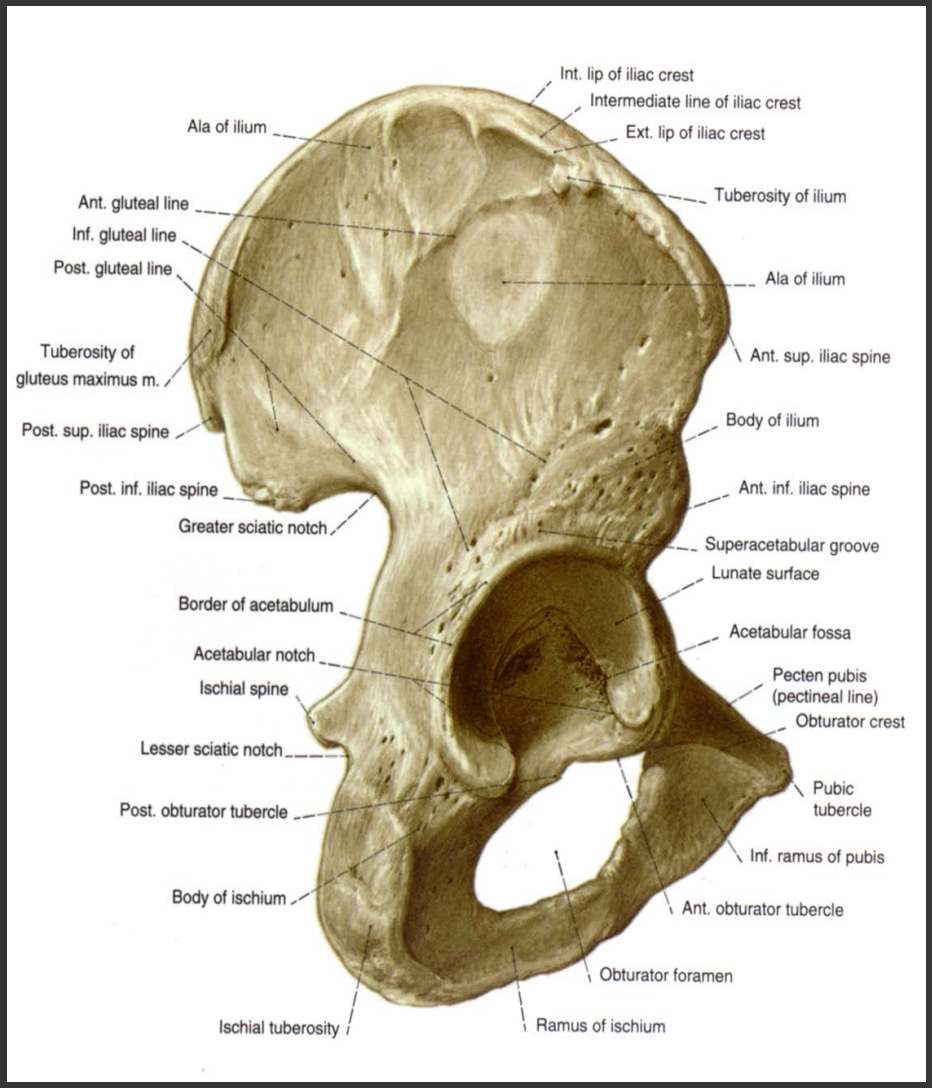
Our result

Evergreen Ave., Boston MA

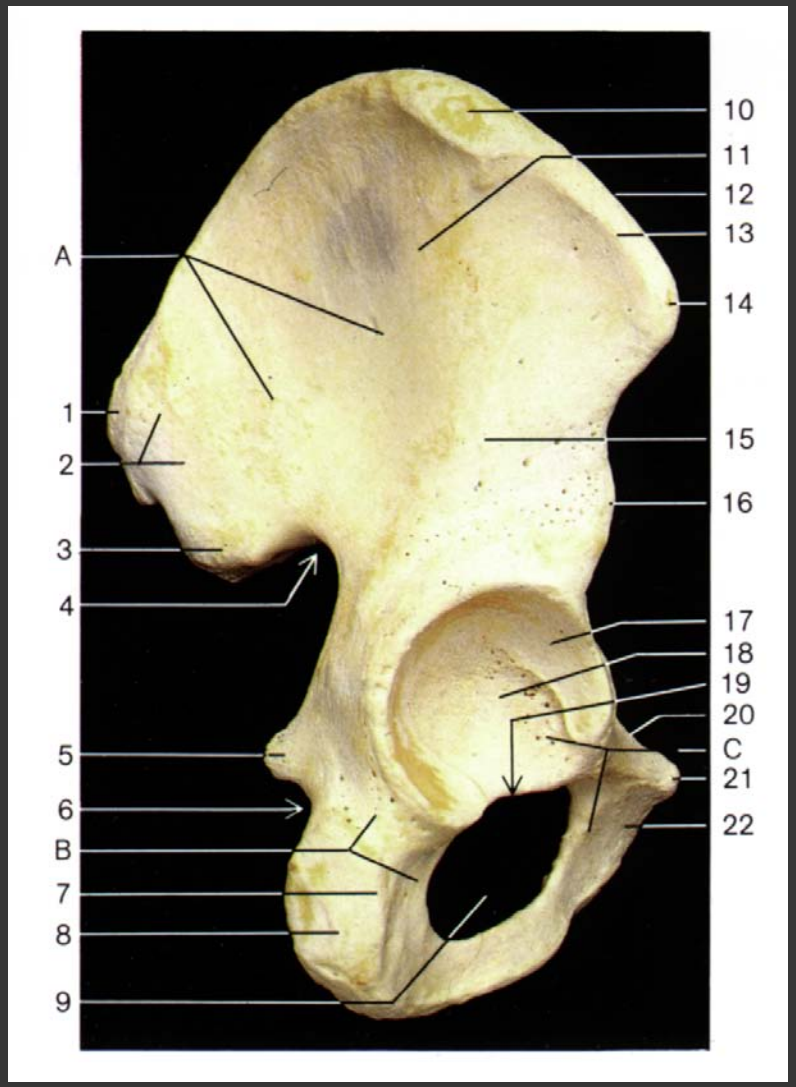
Shape & Detail Enhancement from Multi-Light Image Collections

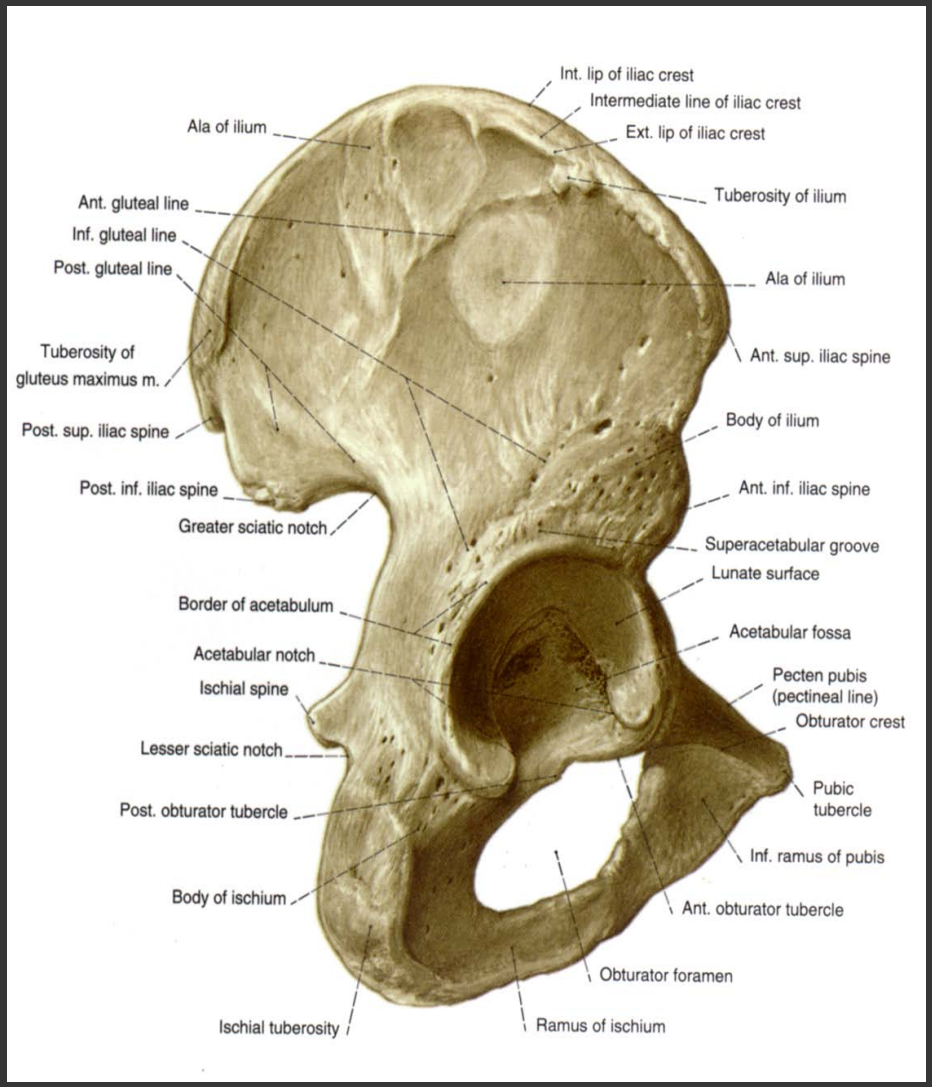


Hip Bone Photograph [Rohen 93]



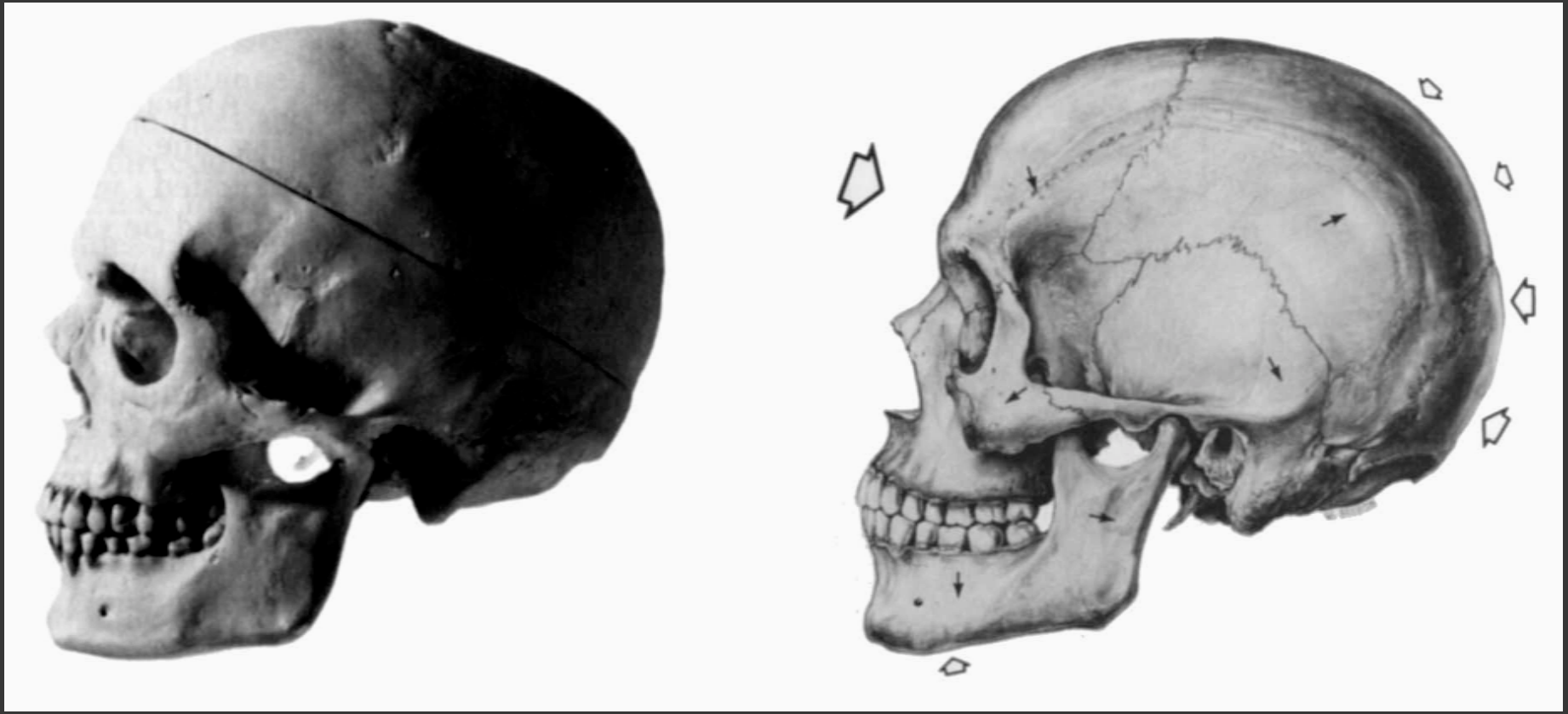
Hip Bone Illustration [Staubesand 90]





- Photograph captures appearance (color, texture) much the way we see it.
- Shading and lighting in illustration clarifies shape and structural elements

Silhouettes



[from Hodges 89]

- Constrains shape of surface → important shape cue
- Increase contrast at silhouettes to emphasize shape

Highlights and Shadows

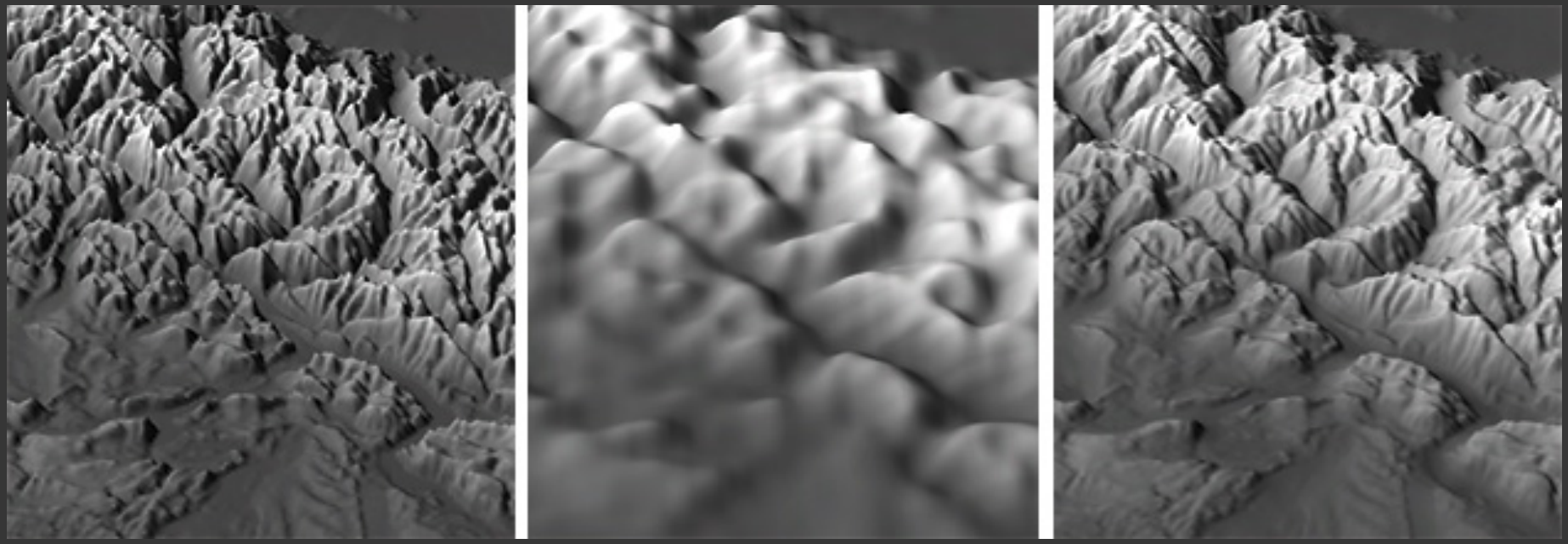
- Remove distracting highlights and shadows

Creases, Ridges and Valleys

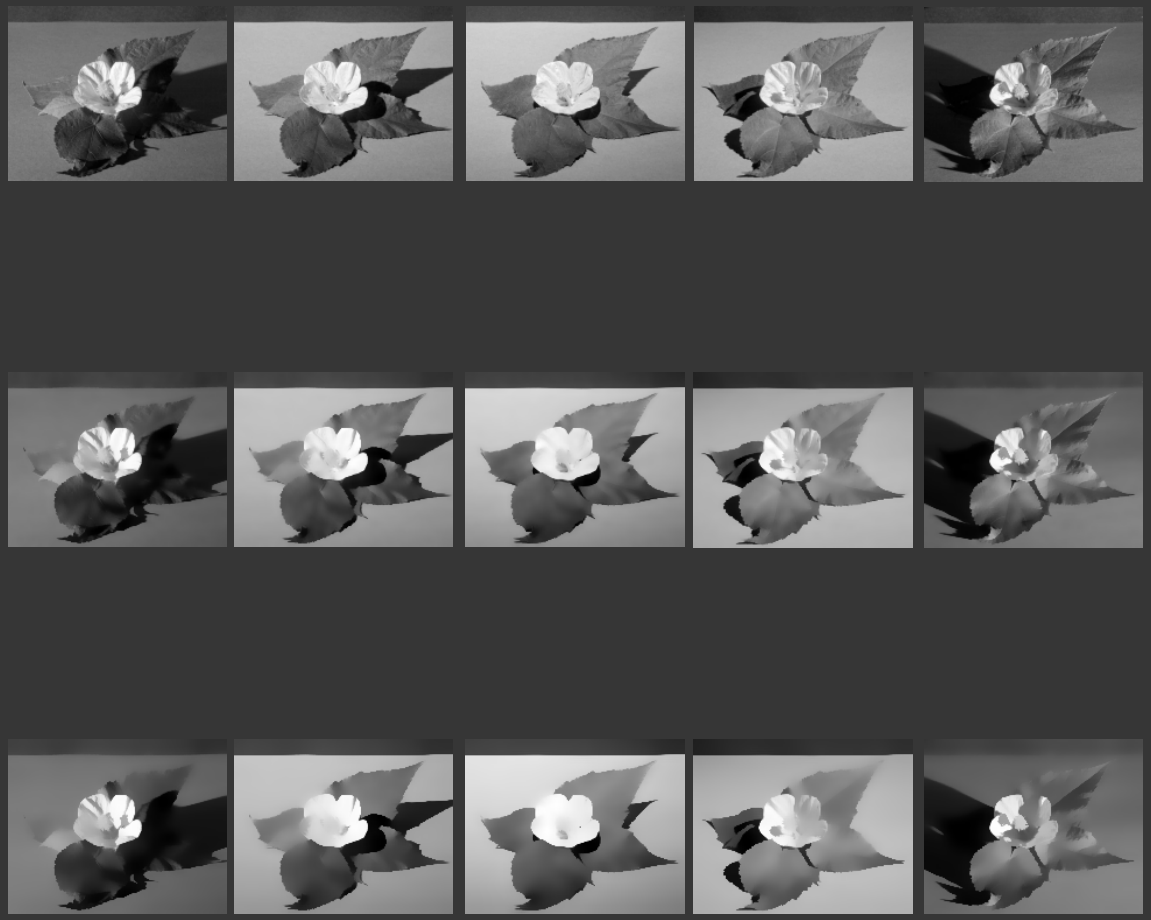
[Imhof 83]

- Sharp dark/light transitions to emphasize boundaries [www.shadedrelief.com]

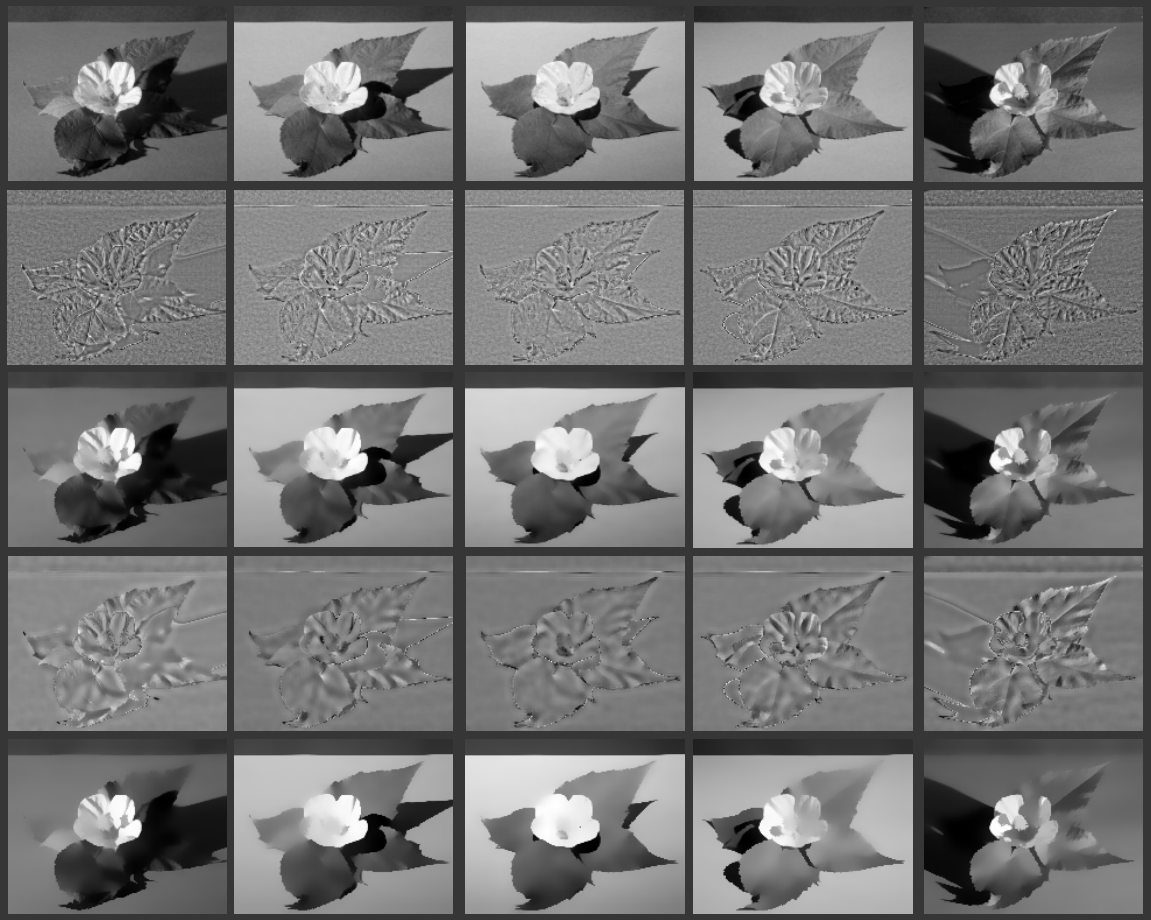
Multiple Scales



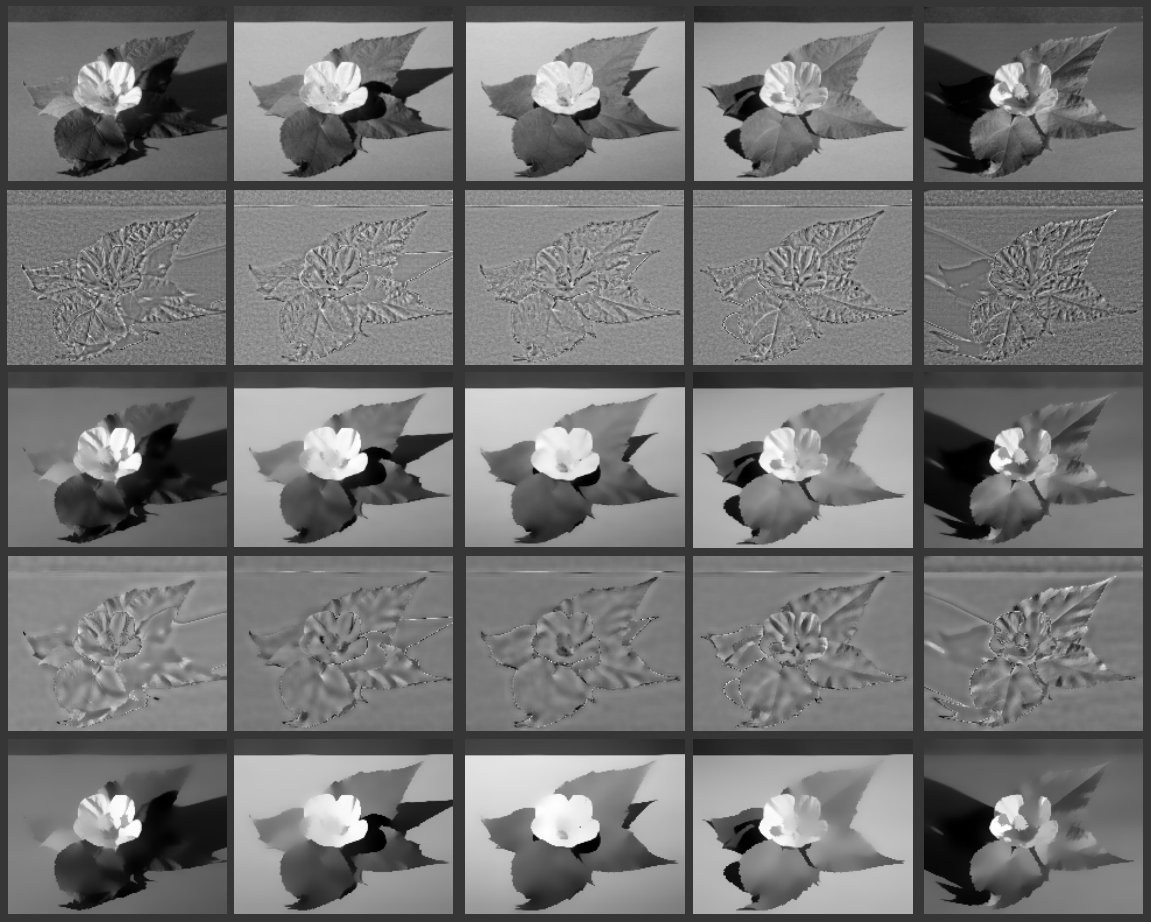
- Blend between depictions at multiple scales [www.shadedrelief.com]

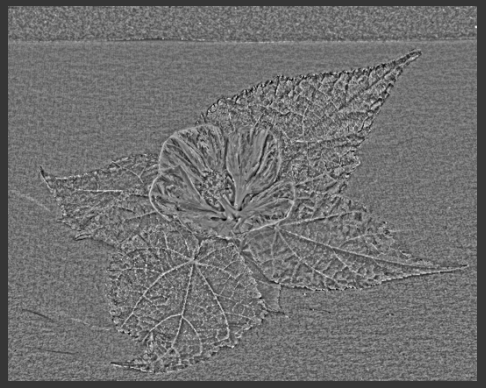


Multiscale bilateral decomposition



Differences between successive levels





+

Detail reconstruction + base image

Input Image

Automatic Result

Emphasizing coarser scales

1 of 5 Input Images

Increasing Strength of Details

►

1 of 5 Input Images

Automatic Result

1 of 3 Input Images

Automatic Result

User Combined

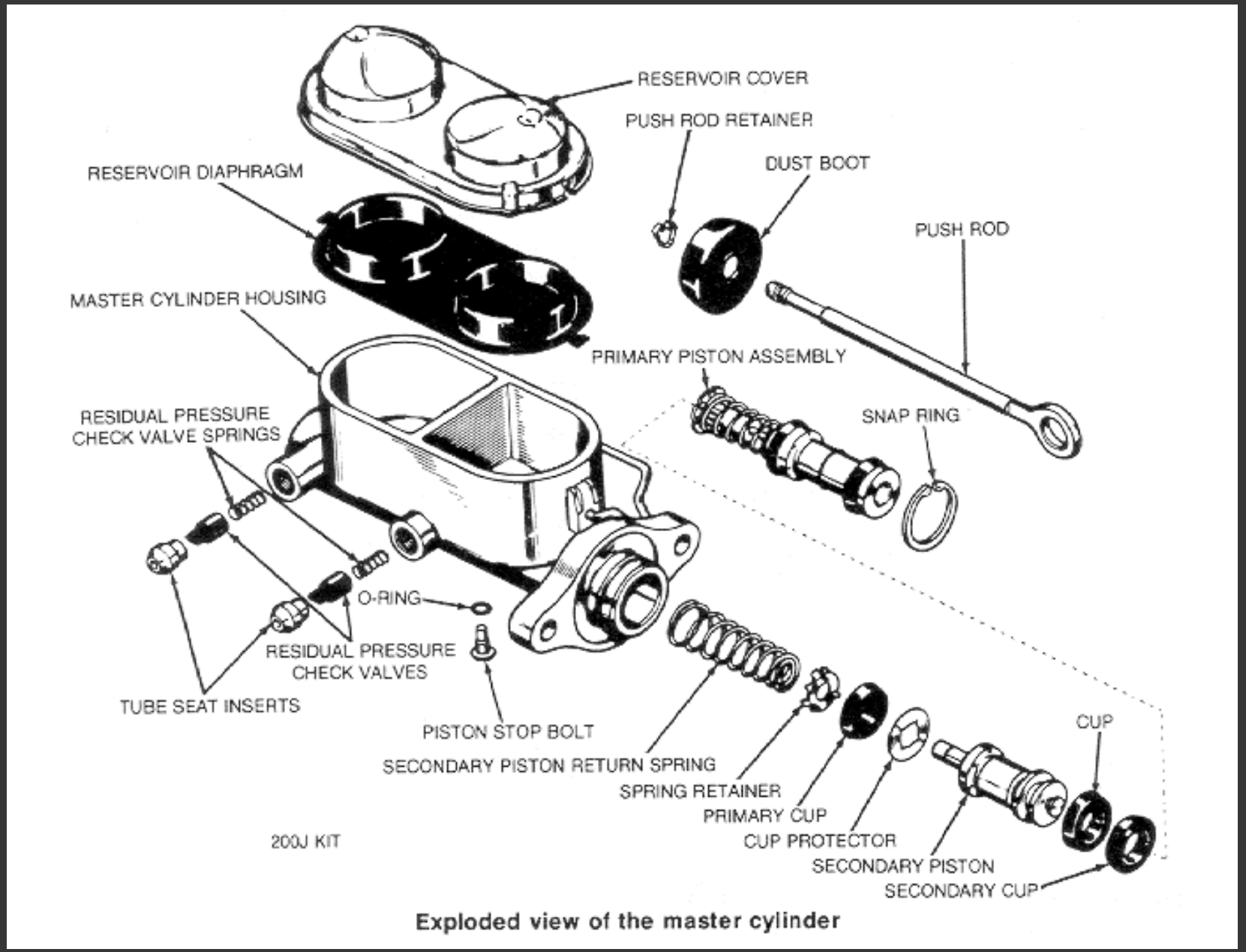
Summary

1. Find most effective visualizations within domain

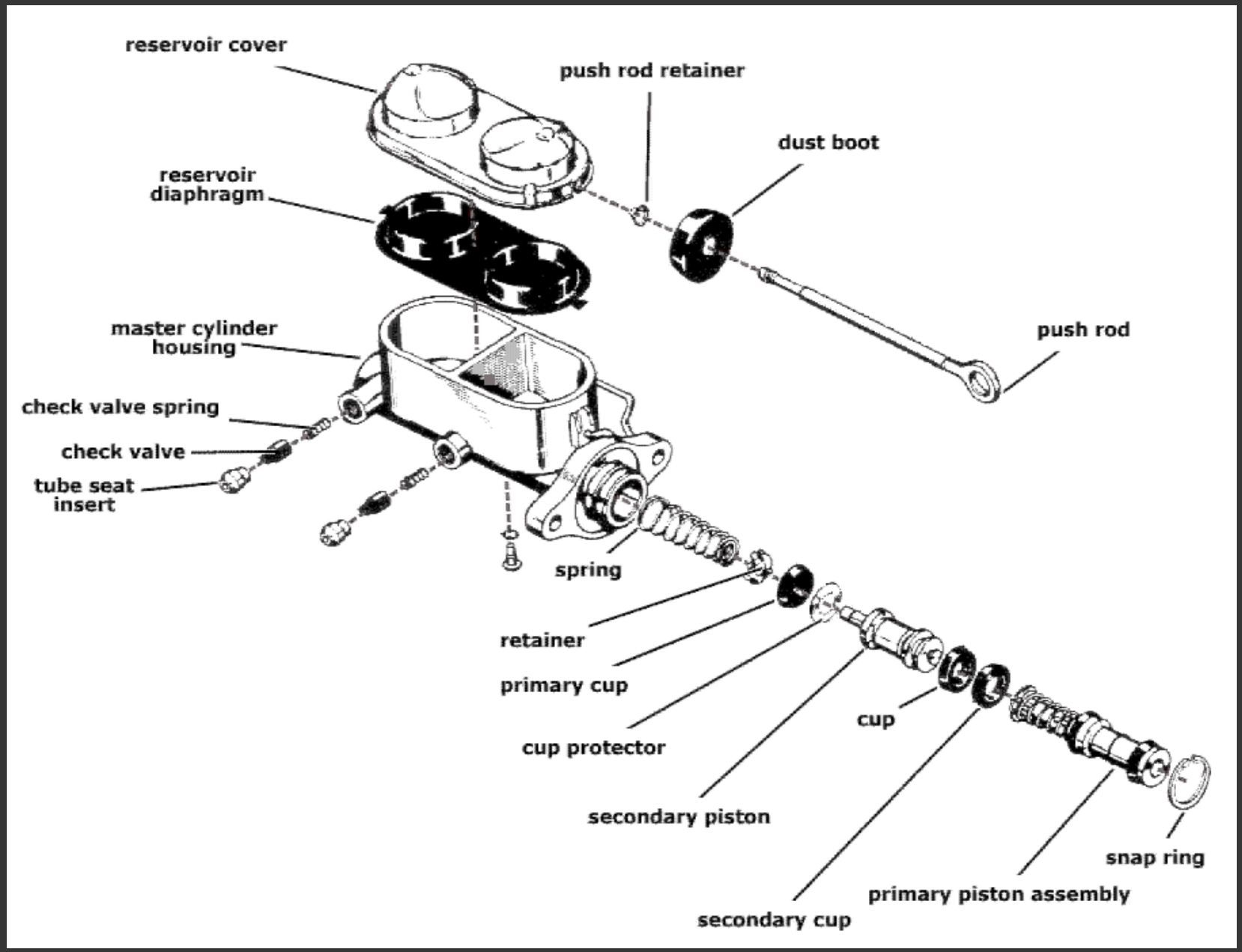
2. Analyze examples to identify
   - Users' tasks
   - Important information
   - Techniques used to emphasize/de-emphasize information

3. Instantiate principles in automated design algorithms

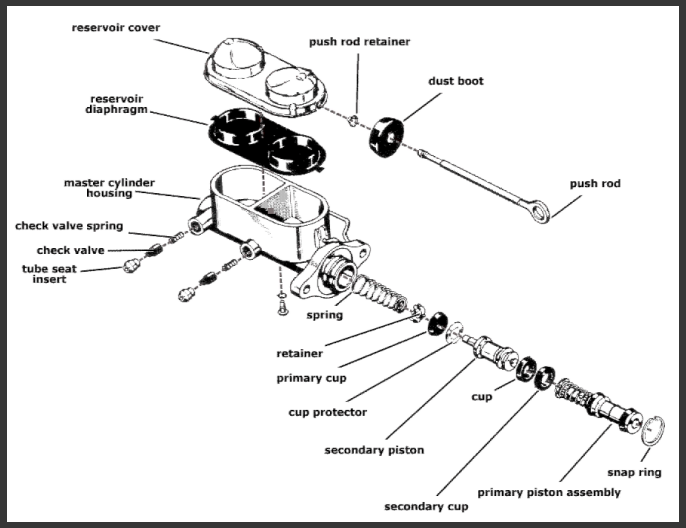
Image-Based Exploded Views



Exploded view of the master cylinder


reservoir cover
push rod retainer
dust boot
reservoir diaphragm
push rod
master cylinder housing
check valve spring
check valve
tube seat insert
spring
retainer
primary cup
cup protector
cup
secondary piston
snap ring
primary piston assembly
secondary cup

Design Principles



Clarify spatial relationships

- Direct manipulation [Schneiderman 83]
- Animated transitions [Woods 84] [Robertson 91] [Grossman 01]

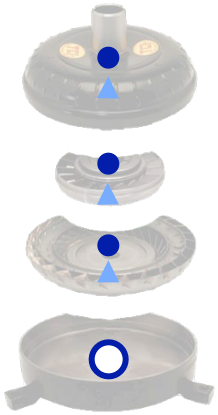
Reduce visual clutter

- Interactive filtering [Schneiderman 96] [MacEachren 97]
- Highlight most important information [Tufte 83] [MacEachren 97]

Authoring Pipeline

Input

Segment



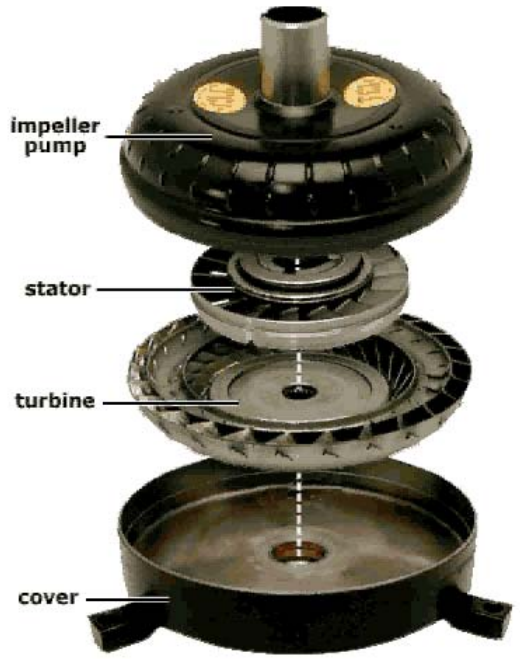
Stack

Fragment

Assign ordering

Annotate

Interactive Viewing

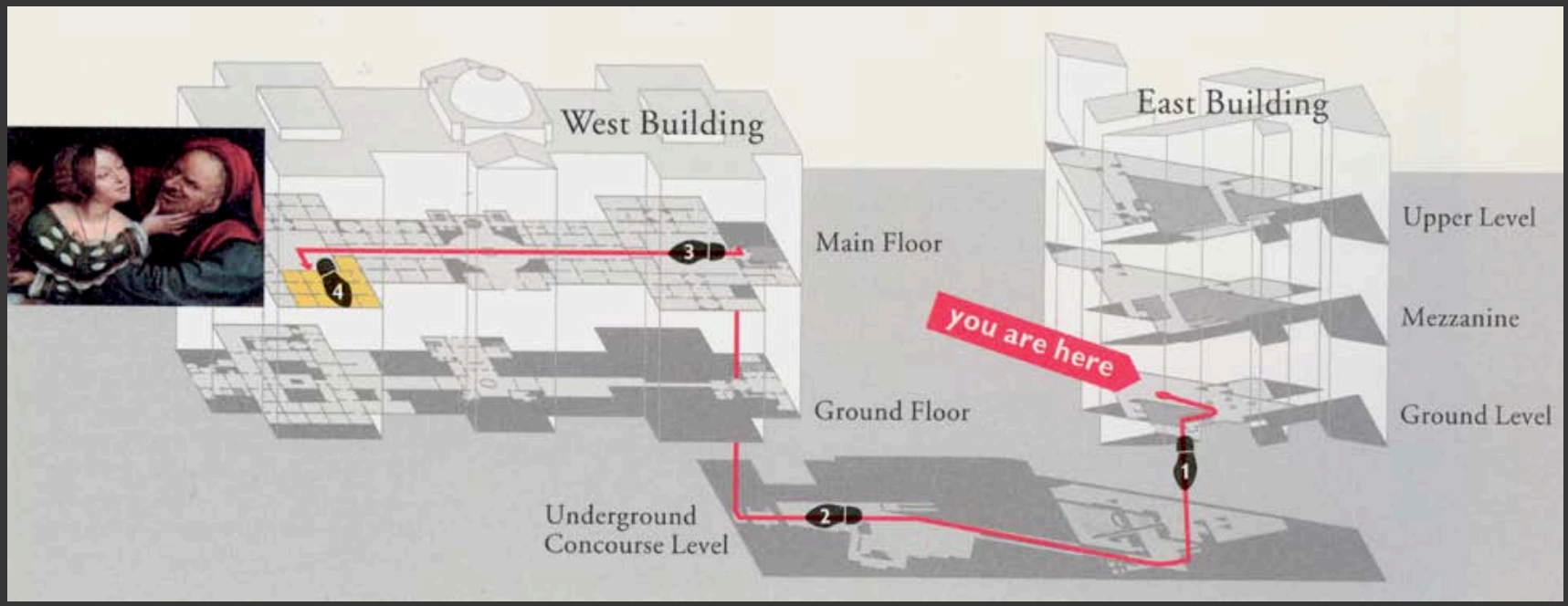


Visualizing Buildings

Non-Invasive Interactive Visualization of Dynamic Architectural Environments.
Chris Niederauer, Mike Houston, Maneesh Agrawala and Greg Humphreys. I3D 2003.

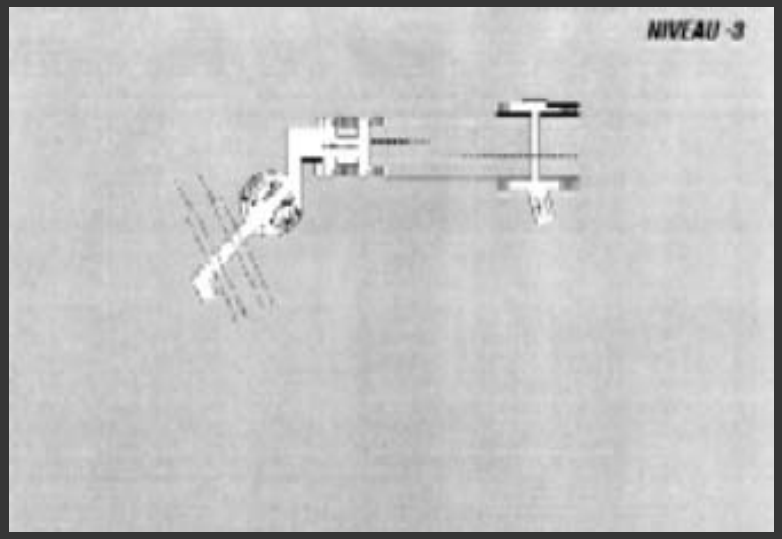

SODA HALL

Exploded View

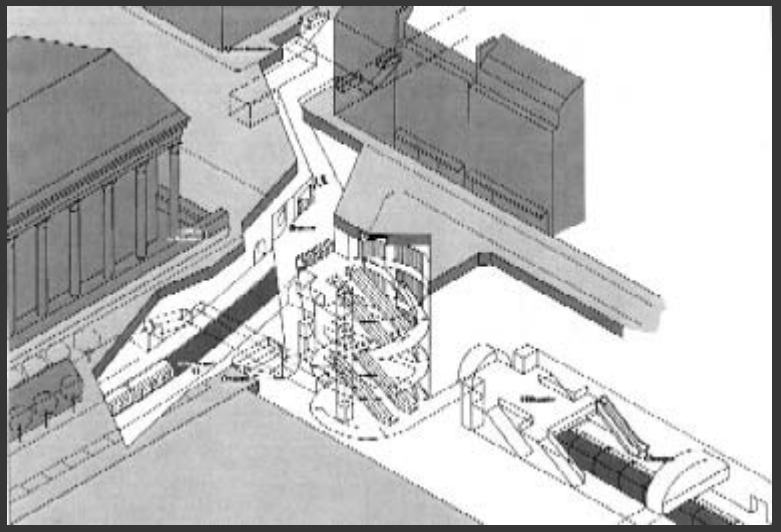


Concept design for museum guide [Tufte 97]

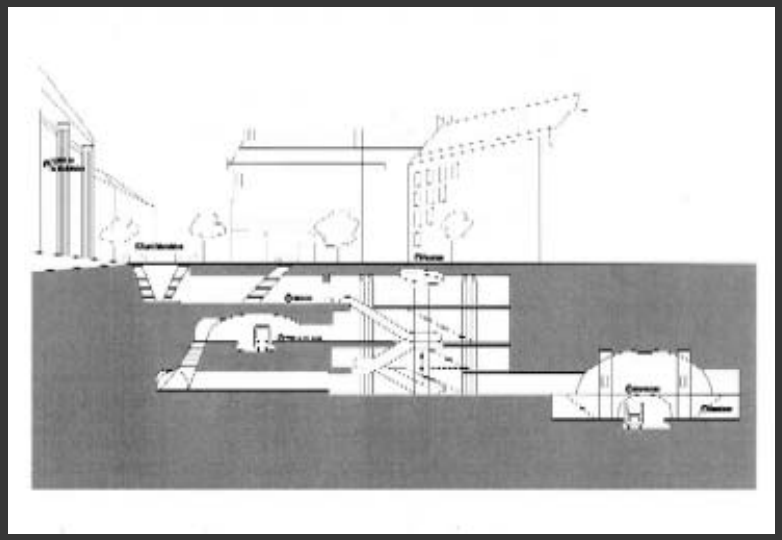
Design Principles



Floorplans



Axonometric View



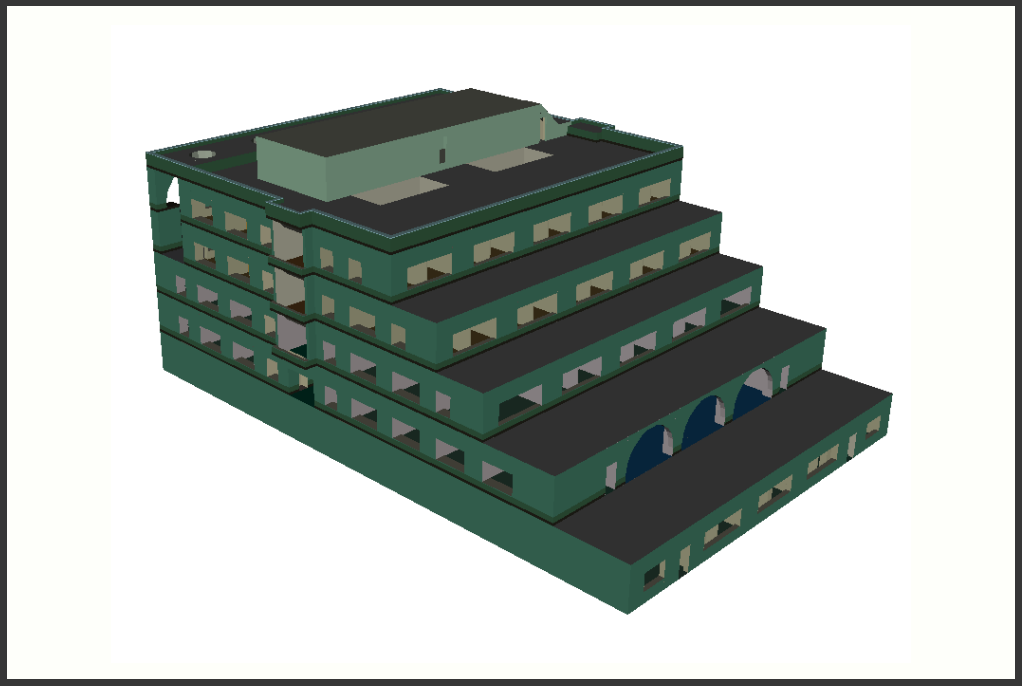
Floorplans + Front View

Use 3D exploded view [Fontaine 01]

External, axonometric perspective better than egocentric view

Single integrated 3D view better than multiple 2D floorplans

Generating an Exploded View



Soda Hall model from Funkhouser, Séquin, Teller

1. Geometric analysis - Find downward facing *ceiling* polygons
2. Place sectioning planes below ceilings
3. Multi-pass render each story separately

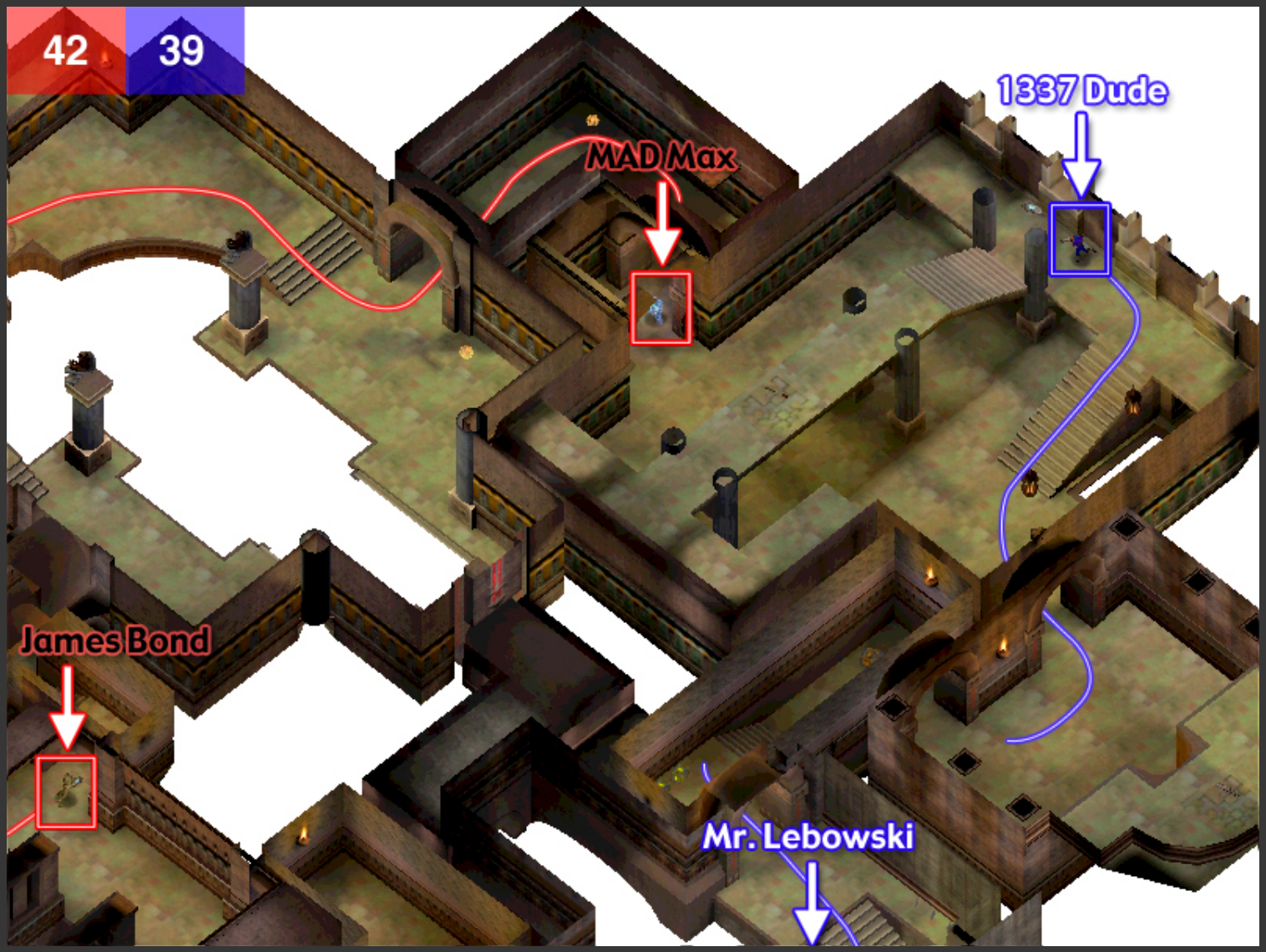
Works with Existing 3D Applications

Quake III Arena by Id Software

Intercept and modify OpenGL stream

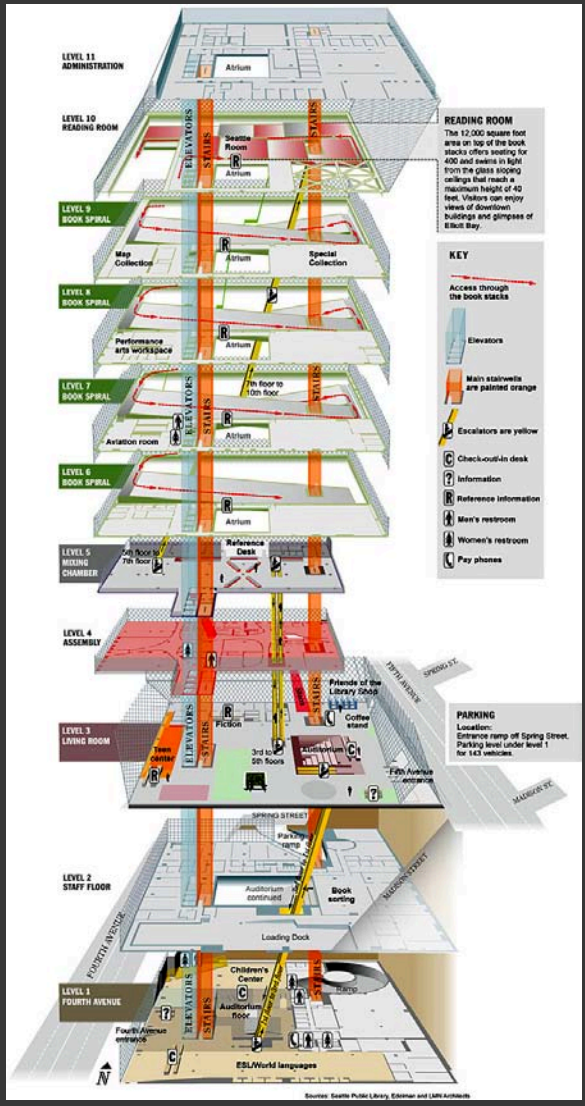
- Non-invasive [Mohr 01]
- Apply to existing OpenGL application without modification

Future: Enhanced Spectator Mode



Mock-up design

Future: Building Maps



Seattle Public Library [from Seattle Times 04]

Summary

1. Find most effective visualizations within domain

2. Analyze examples to identify
   - Users' tasks
   - Important information (perception/cognition)
   - Techniques used to emphasize/de-emphasize information

3. Instantiate principles in automated design algorithms