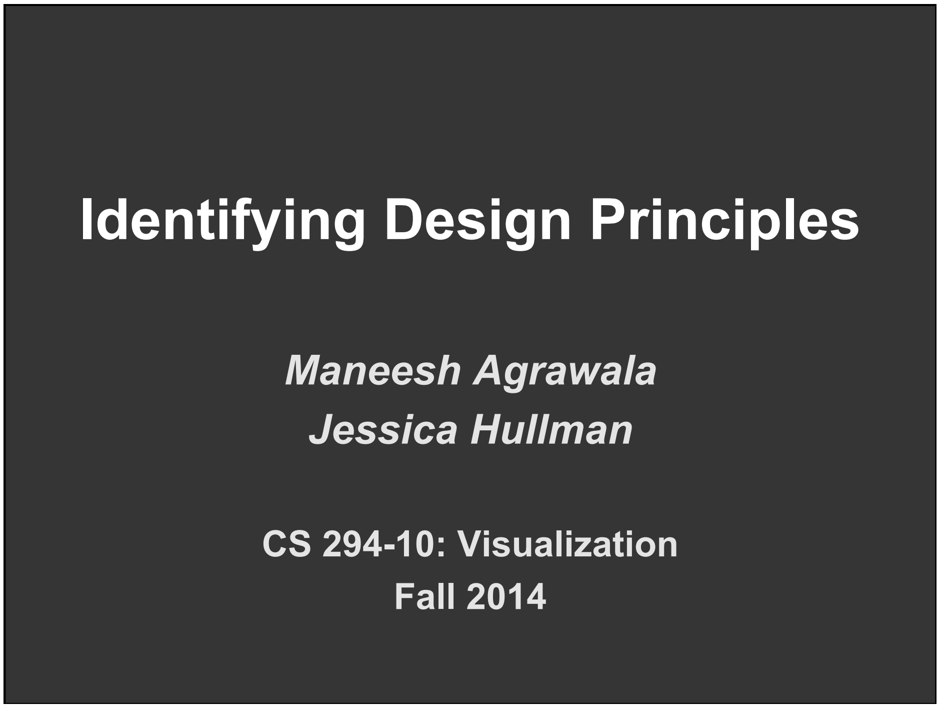
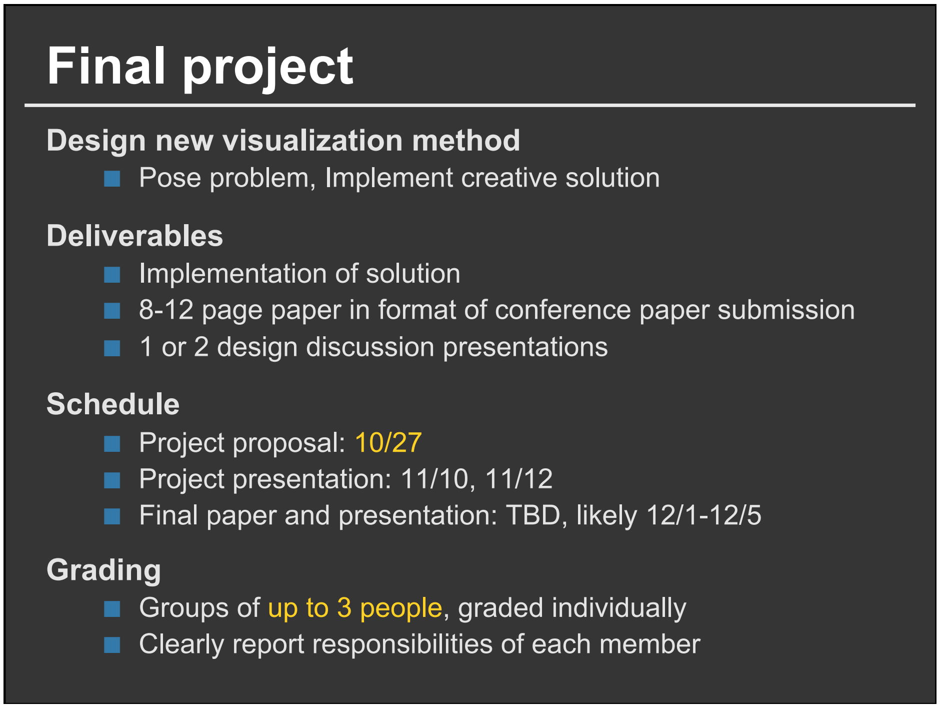


Identifying Design Principles

Maneesh Agrawala
Jessica Hullman

CS 294-10: Visualization
Fall 2014

Announcements



Final project

Design new visualization method

- Pose problem, Implement creative solution

Deliverables

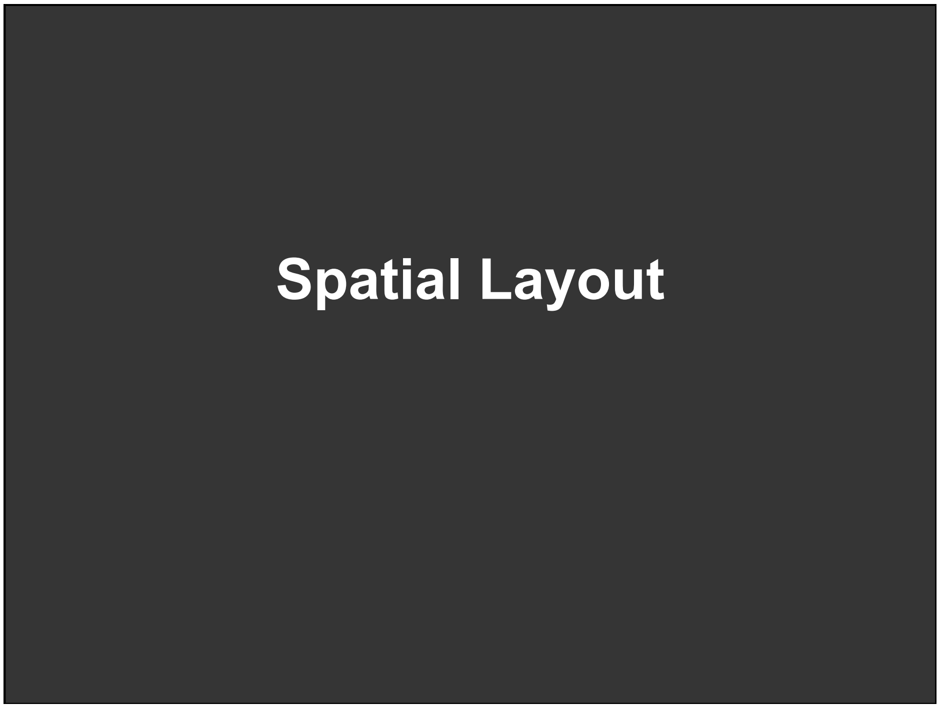
- Implementation of solution
- 8-12 page paper in format of conference paper submission
- 1 or 2 design discussion presentations

Schedule

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

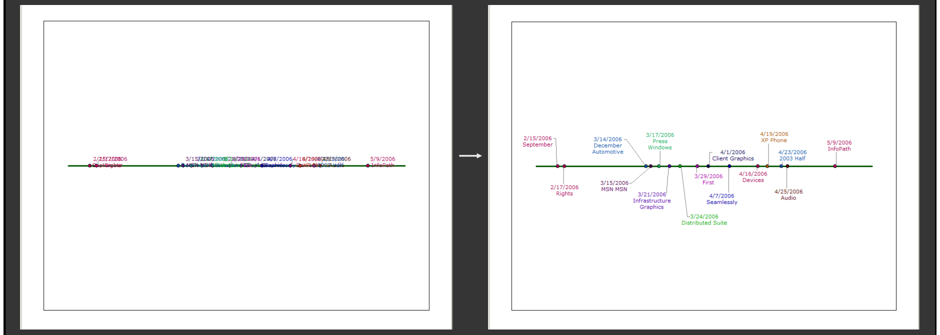
Grading

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



Spatial Layout

Example: Timeline label layout

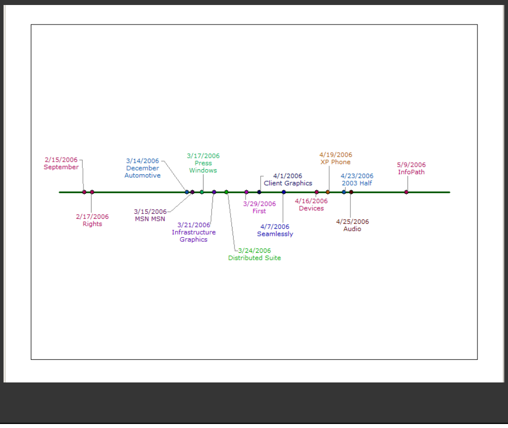


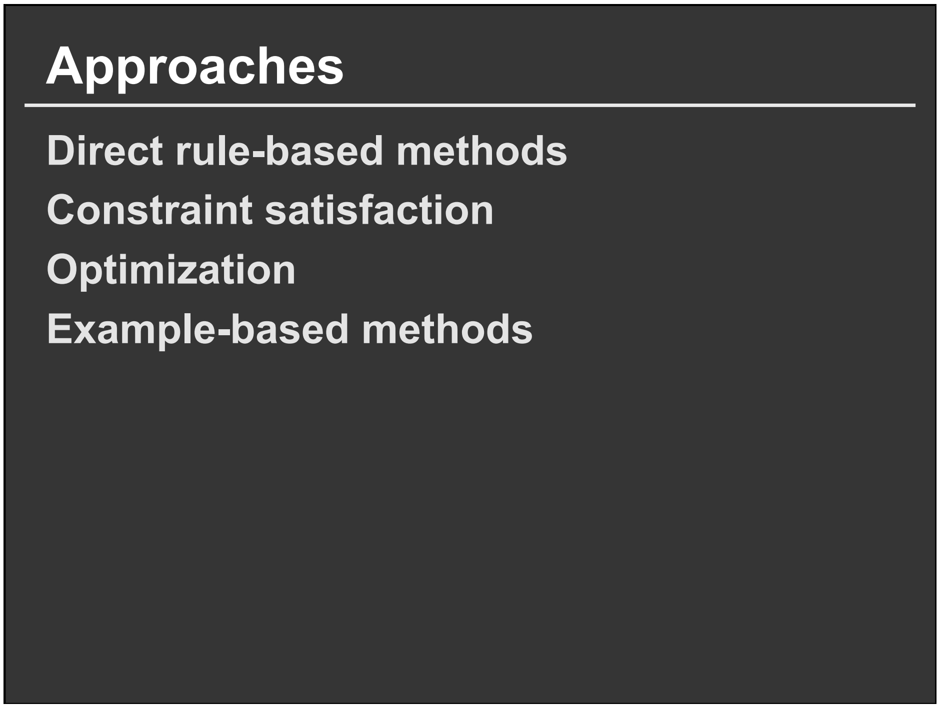
Problem

Input: Set of graphic elements (scene description)

Goal: Select visual attributes for elements

- **Position**
- Orientation
- Size
- Color
- …



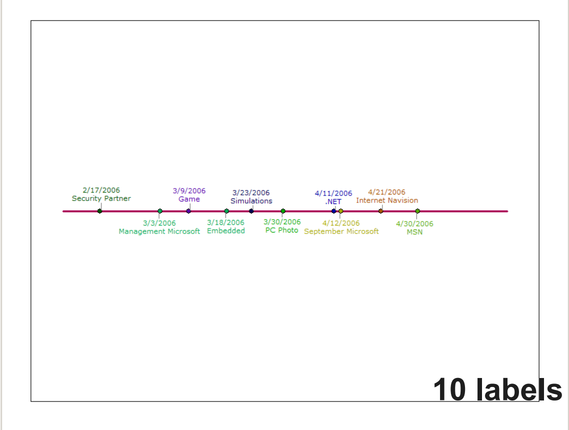


Approaches

Direct rule-based methods
Constraint satisfaction
Optimization
Example-based methods

Direct Rule-Based Methods

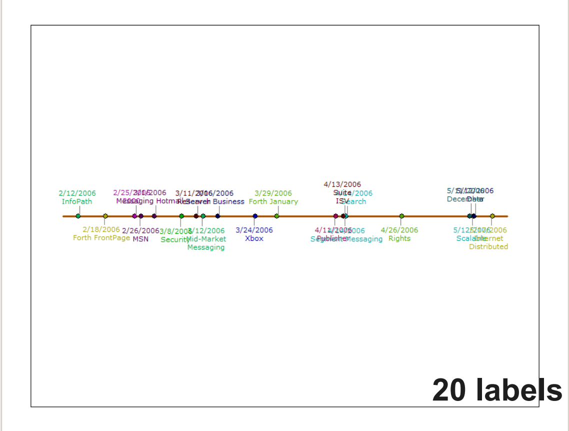
Rule-based timeline labeling



10 labels

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

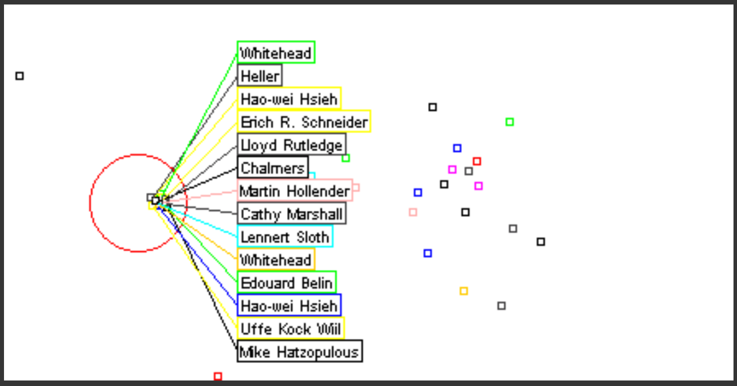
Rule-based timeline labeling



20 labels

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

Excentric labeling [Fekete & Plaisant 99]



http://www.cs.umd.edu/hcil/excentric/

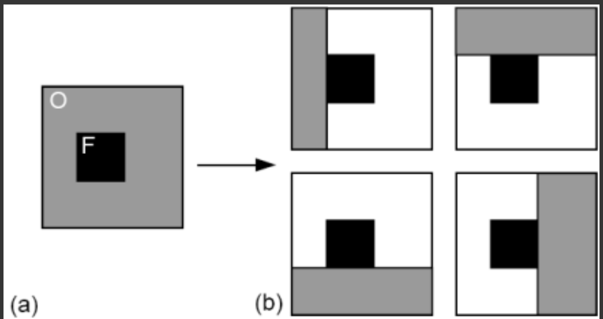
Dynamic space management [Bell 00]

Manage *free space* on desktop to prevent window overlap

Dynamic space management [Bell 00]

Goal: Place new elements to avoid overlap

- Elements are axis-aligned rectangles
- Keep track of largest empty space rectangles



Dynamic space management [Bell 00]

Goal: Place new elements to avoid overlap

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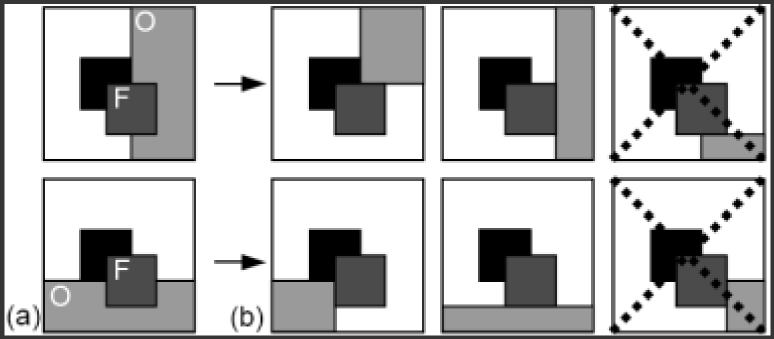
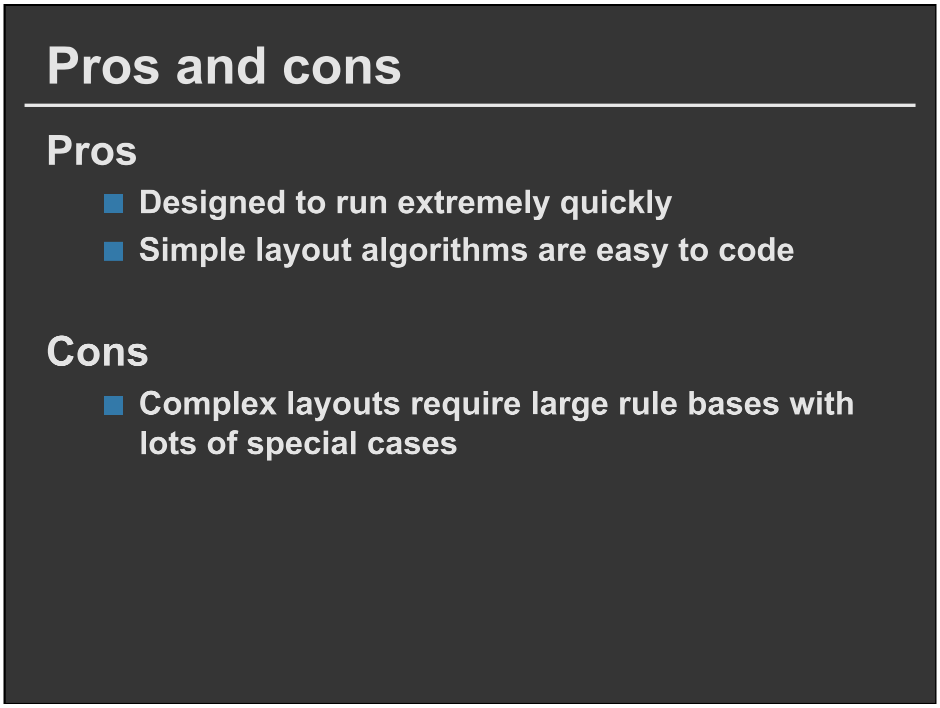




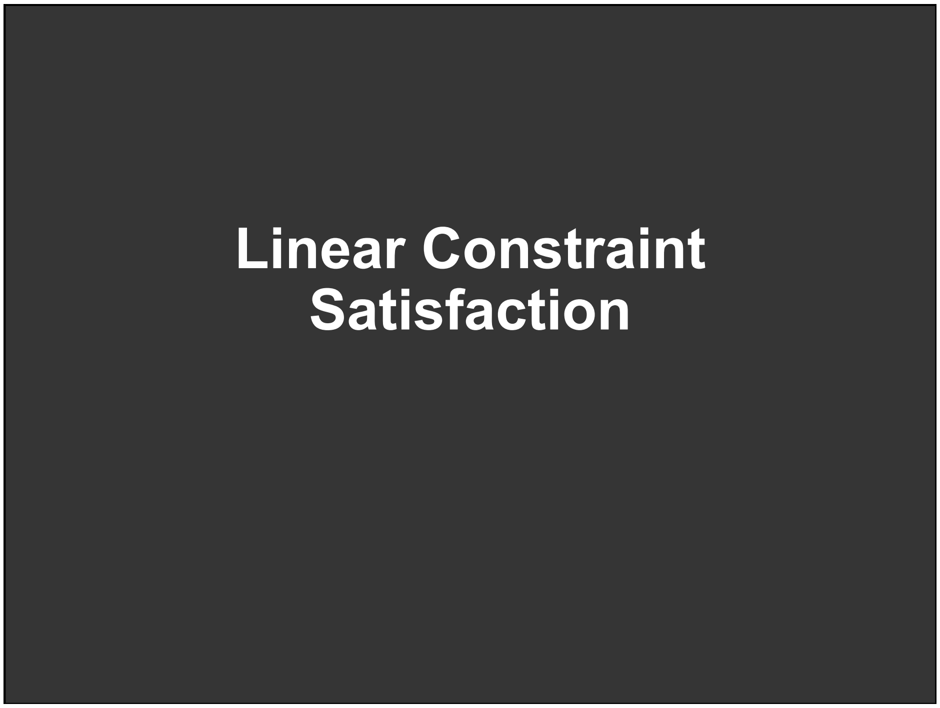
Pros and cons

Pros

- Designed to run extremely quickly
- Simple layout algorithms are easy to code

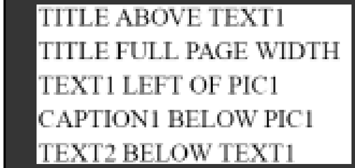
Cons

- Complex layouts require large rule bases with lots of special cases



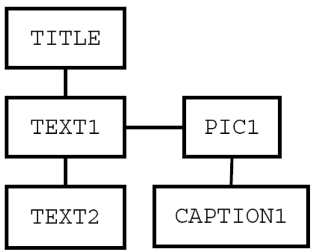
Linear Constraint Satisfaction

Network of layout constraints

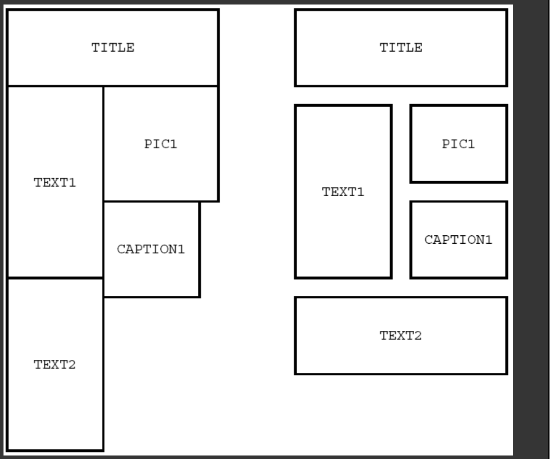


TITLE ABOVE TEXT1
TITLE FULL PAGE WIDTH
TEXT1 LEFT OF PIC1
CAPTION1 BELOW PIC1
TEXT2 BELOW TEXT1

Constraints



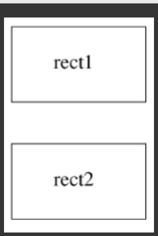
Network

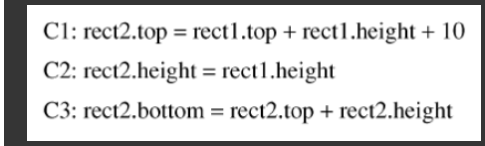


Two possible layouts

[from Lok and Feiner 01]

Constraints as linear equations





C1: rect2.top = rect1.top + rect1.height + 10
C2: rect2.height = rect1.height
C3: rect2.bottom = rect2.top + rect2.height

Local propagation

- Set any variable
- Update other variables to maintain constraints

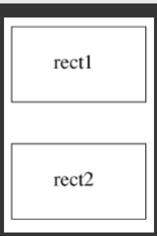
One-way

- Each constraint has 1 output variable
- Update output when any input changes

Multi-way

- Each constraint can be written so that any variable is output
- More complicated to maintain

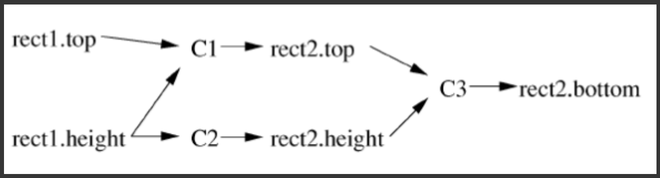
One-way constraints



C1: rect2.top = rect1.top + rect1.height + 10

C2: rect2.height = rect1.height

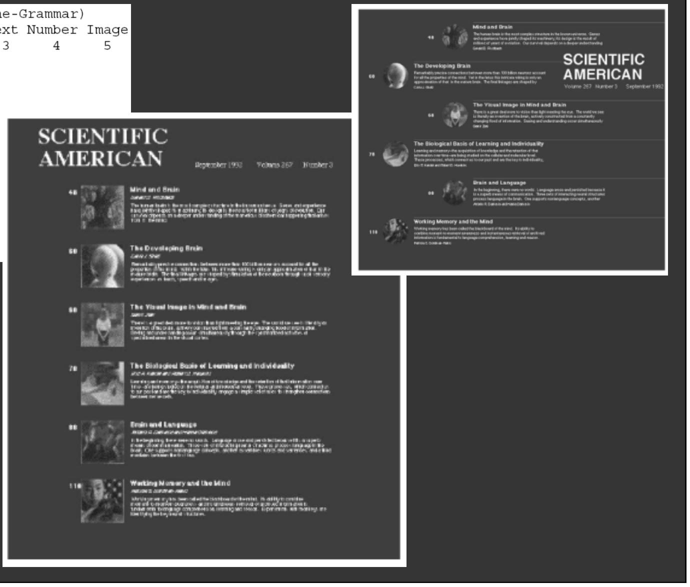
C3: rect2.bottom = rect2.top + rect2.height



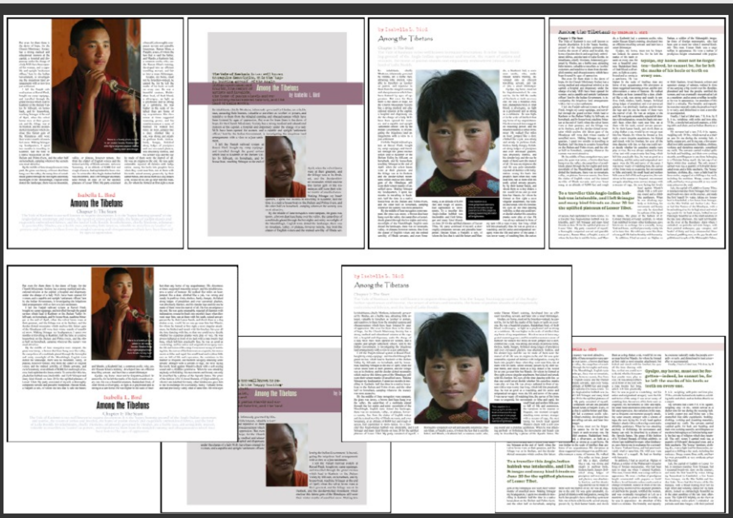
One-way constraints form a directed acyclic graph (DAG). Given the value for any variable we propagate it's value locally through the graph updating the other variable.

Page layout example [Weitzman and Wittenburg 94]

```
(Defrule (Make-Article The-Grammar)
  Article -> Text Text Text Number Image
     0          1    2    3     4      5
  (Author-Of 2 1)
  (Description-Of 4 1)
  (Page-Of 4 1)
  (Image-Of 5 1)
  (article-name 0) = r
  (article-image 0) = 5
  :OUT
  (right-of 1 5)
  (top-aligned 1 5)
  (top-aligned 5 4)
  (spaced-below 2 1)
  (spaced-below 3 2)
)
```

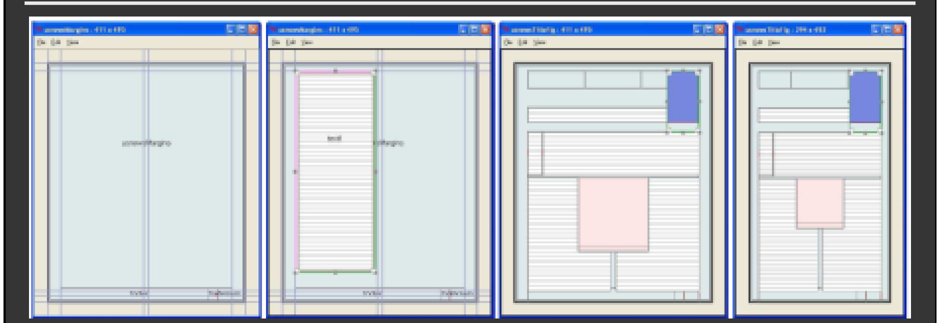

SCIENTIFIC AMERICAN
Mind and Brain
The Developing Brain
The Visual Image in Mind and Brain
The Biological Basis of Learning and Individuality
Brain and Language
Working Memory and the Mind

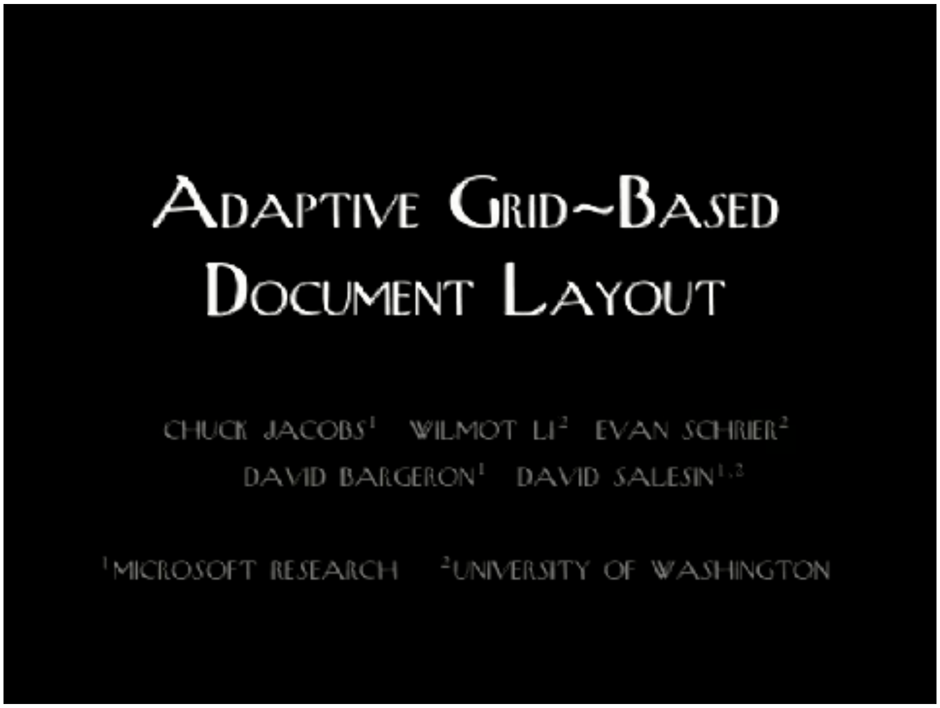
Adaptive document layout [Jacobs 03]



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

ADL template authoring [Jacobs 03]





Adaptive Grid~Based Document Layout

Chuck Jacobs[1] Wilmot Li[2] Evan Schrier[2]
David Bargeron[1] David Salesin[1,2]

[1] Microsoft Research [2] University of Washington

Pros and cons

Pros

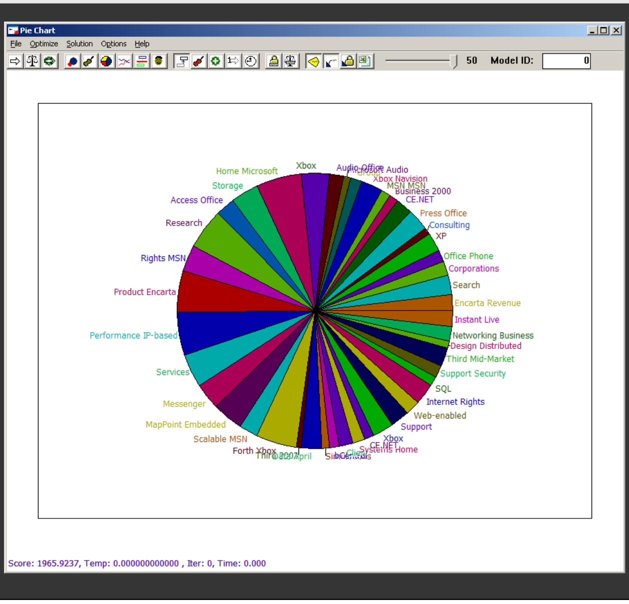
- Often run fast (at least one-way constraints)
- Constraint solving systems are available online
- Can be easier to specify relative layout constraints than to code direct layout algorithm

Cons

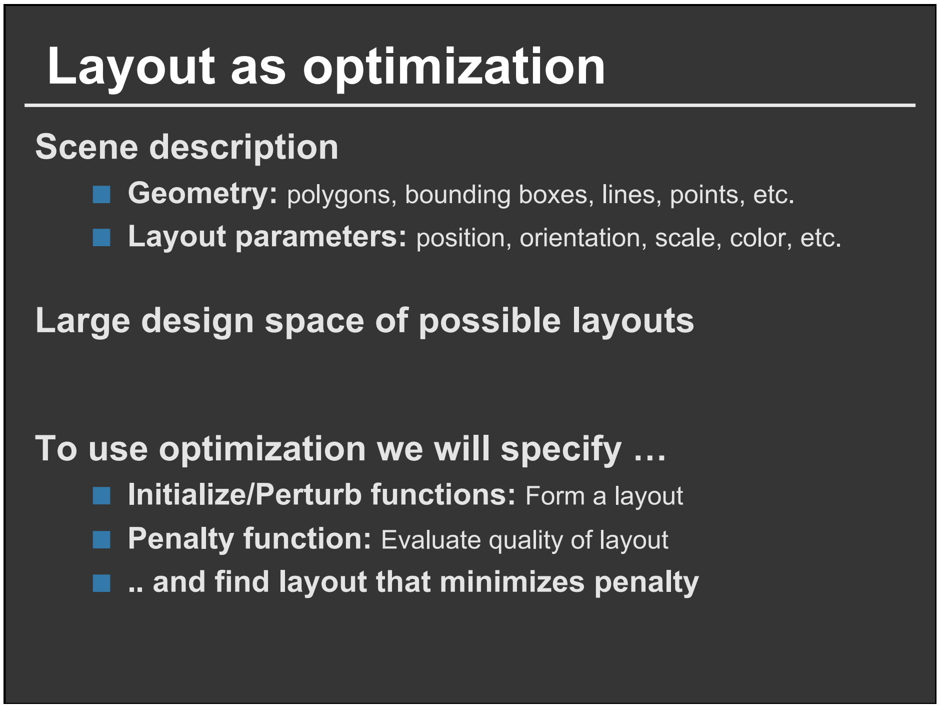
- Easy to over-constrain the problem
- Constraint solving systems can only solve some types of layout problems
- Difficult to encode desired layout in terms of mathematical constraints

Optimization

Demo



Score: 1965.9237, Temp: 0.000000000000 , Iter: 0, Time: 0.000



Layout as optimization

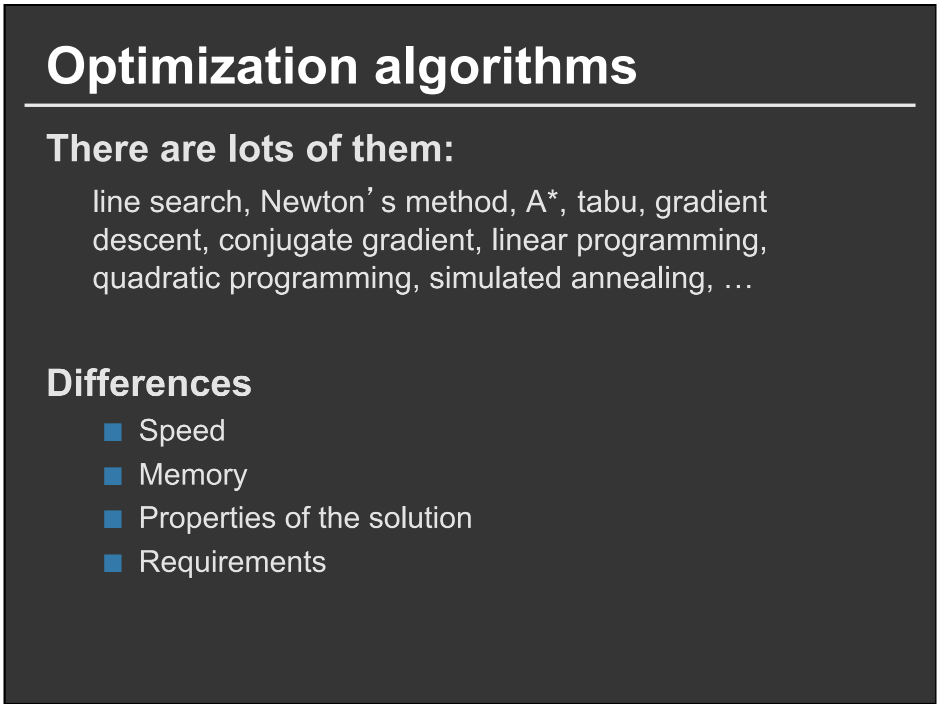
Scene description

- **Geometry:** polygons, bounding boxes, lines, points, etc.
- **Layout parameters:** position, orientation, scale, color, etc.

Large design space of possible layouts

To use optimization we will specify …

- **Initialize/Perturb functions:** Form a layout
- **Penalty function:** Evaluate quality of layout
- **.. and find layout that minimizes penalty**



Optimization algorithms

There are lots of them:

line search, Newton's method, A*, tabu, gradient descent, conjugate gradient, linear programming, quadratic programming, simulated annealing, …

Differences

- Speed
- Memory
- Properties of the solution
- Requirements

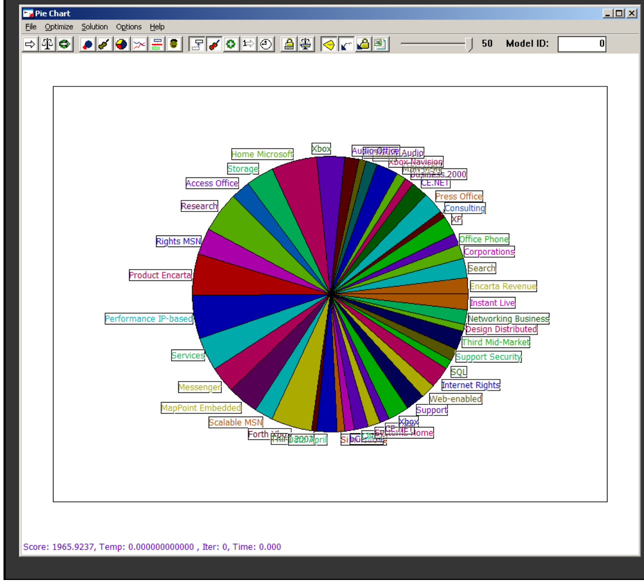
Simulated annealing

```
currL ← Initialize()                          → Form initial layout
while(! termination condition)
  newL ← Perturb(currL)                       → Perturb to form new layout
  currE ← Penalty(currL)                      → Evaluate quality of layouts
  newE ← Penalty(newL)
  if((newE < currE) or                        → Always accept lower penalty
    (rand[0,1) < $e^{-\Delta E/T}$))          → Small probability of accepting higher penalty
    then currL ← newL
  Decrease(T)
```

Perturb: Efficiently cover layout design space

Penalty: Describes desirable/undesirable layout features

Scene description

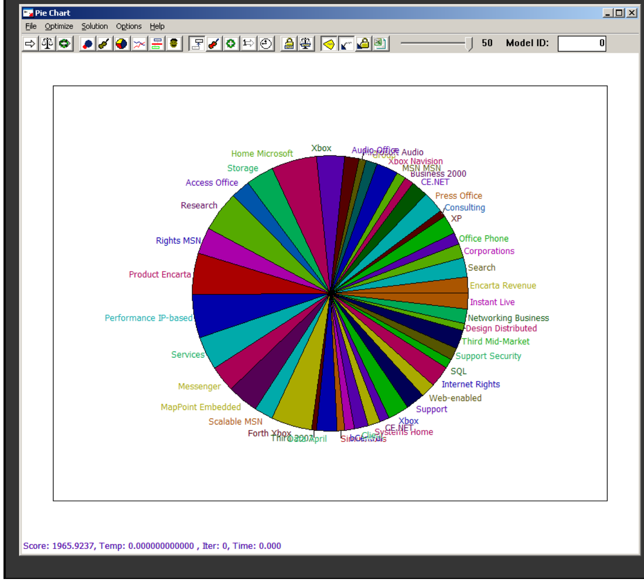


Score: 1965.9237, Temp: 0.000000000000 , Iter: 0, Time: 0.000

Geometry

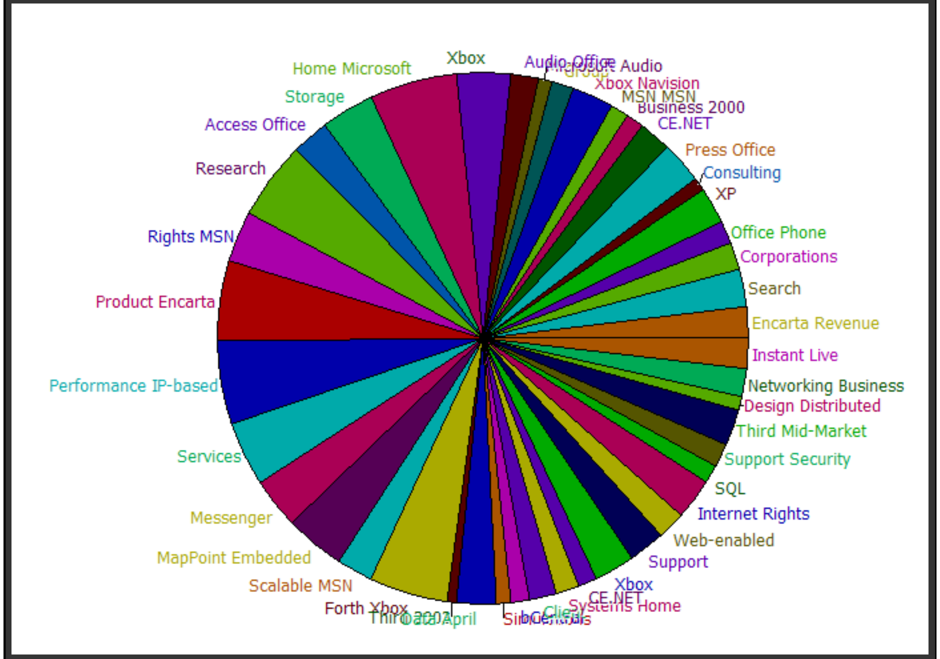
- **Pie slices**
  anchors for labels
- **Labels**
  bounding boxes

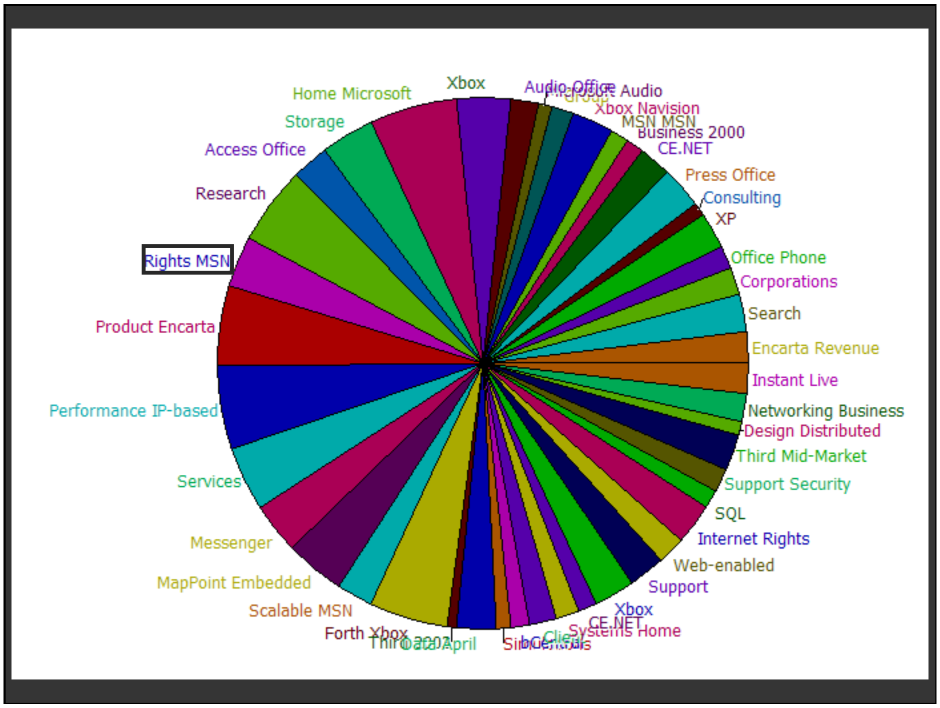
Layout parameters

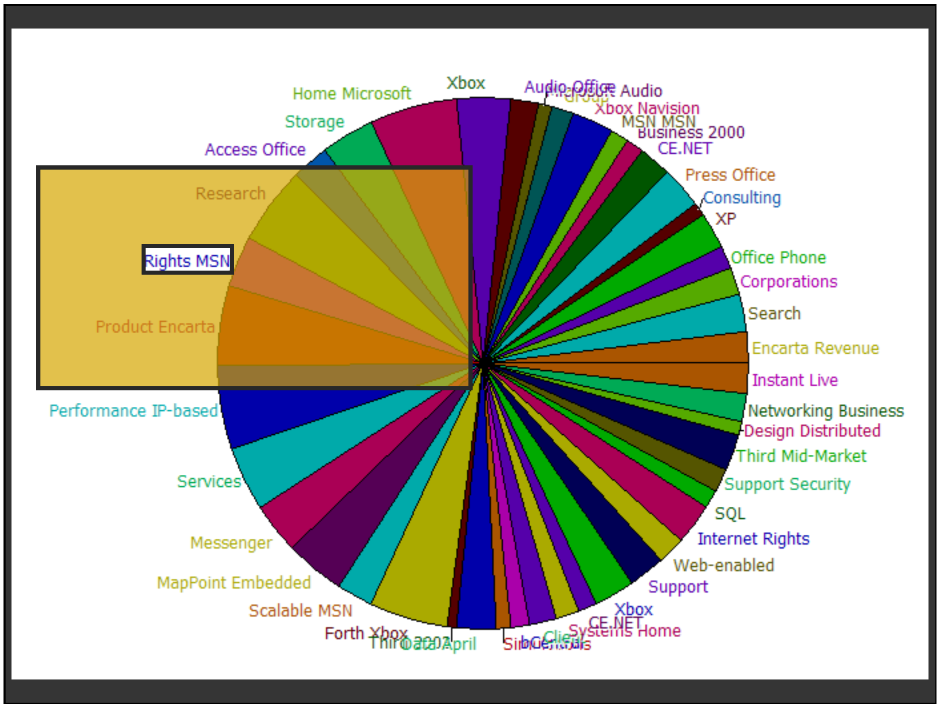


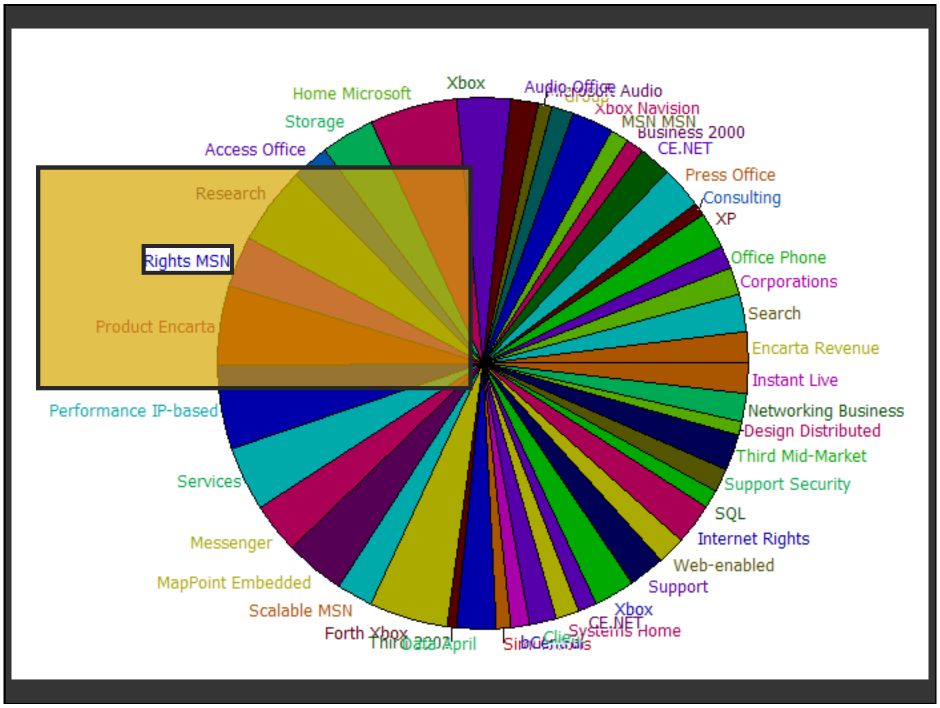
Score: 1965.9237, Temp: 0.000000000000 , Iter: 0, Time: 0.000

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

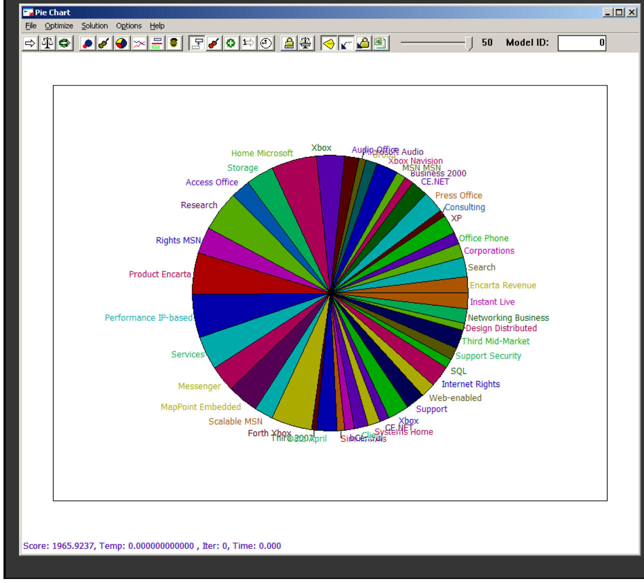



Home Microsoft
Xbox
Audio Office
Product Audio
Group
Xbox Navision
MSN MSN
Business 2000
CE.NET
Storage
Access Office
Research
Press Office
Consulting
XP
Rights MSN
Office Phone
Corporations
Product Encarta
Search
Encarta Revenue
Instant Live
Performance IP-based
Networking Business
Design Distributed
Third Mid-Market
Services
Support Security
SQL
Messenger
Internet Rights
Web-enabled
MapPoint Embedded
Support
Scalable MSN
Xbox
CE.NET
Forth Xbox
Systems Home
Third 2002
Data April
Client


Home Microsoft
Xbox
Audio Office
Product Audio
Group
Xbox Navision
MSN MSN
Business 2000
CE.NET
Storage
Access Office
Research
Press Office
Consulting
XP
Rights MSN
Office Phone
Corporations
Product Encarta
Search
Encarta Revenue
Instant Live
Performance IP-based
Networking Business
Design Distributed
Third Mid-Market
Services
Support Security
SQL
Messenger
Internet Rights
Web-enabled
MapPoint Embedded
Support
Scalable MSN
Xbox
CE.NET
Forth Xbox
Systems Home
Third 2002
Data April
Client



Many dimensions → large space

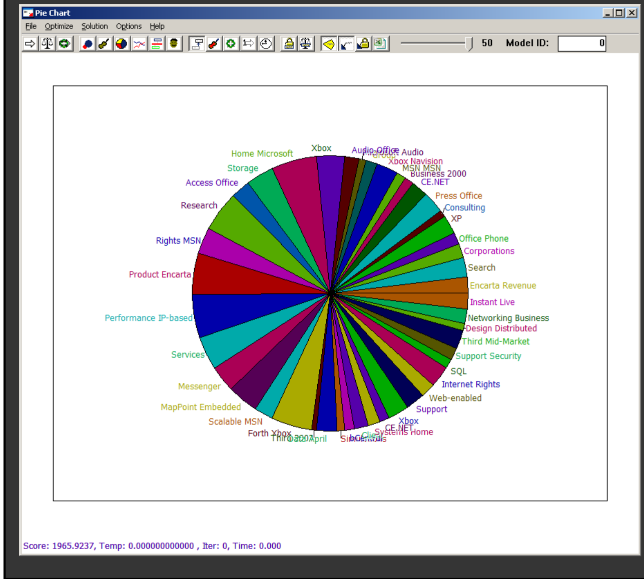


Score: 1965.9237, Temp: 0.000000000000 , Iter: 0, Time: 0.000

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

2D x 50 labels → 100D space

Penalties



Score: 1965.9237, Temp: 0.000000000000 , Iter: 0, Time: 0.000

Overlap & Distance

- Label – anchor slice
- Label – other slices
- Label – label

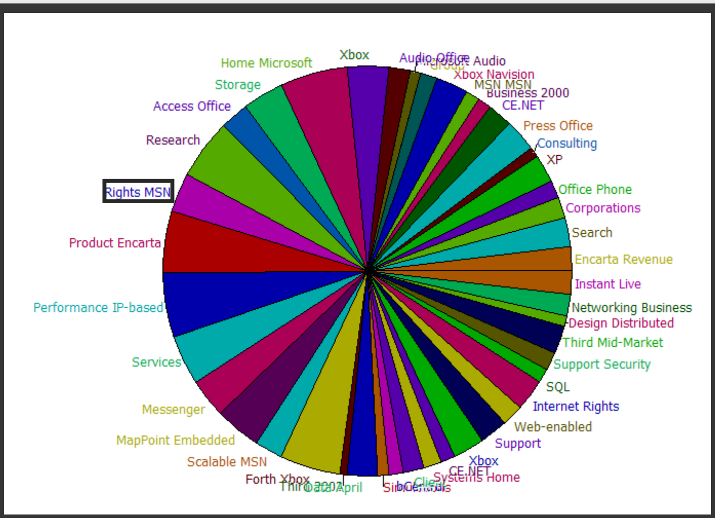
Leader lines

- Length
- Intersections

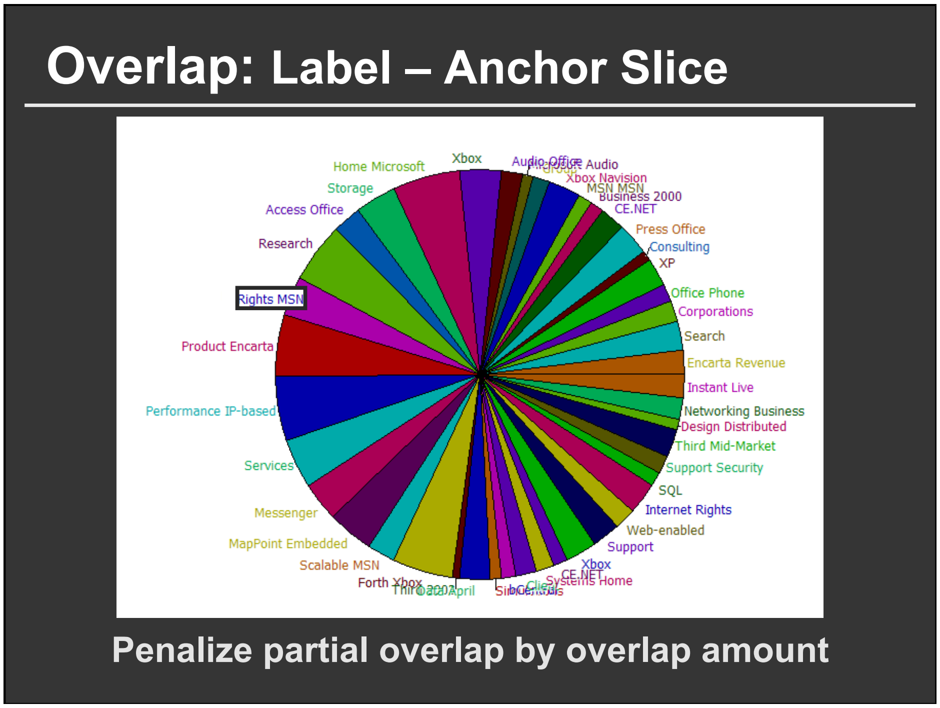
Word Wrap

Annealing minimizes sum of all penalties

Overlap: Label – Anchor Slice

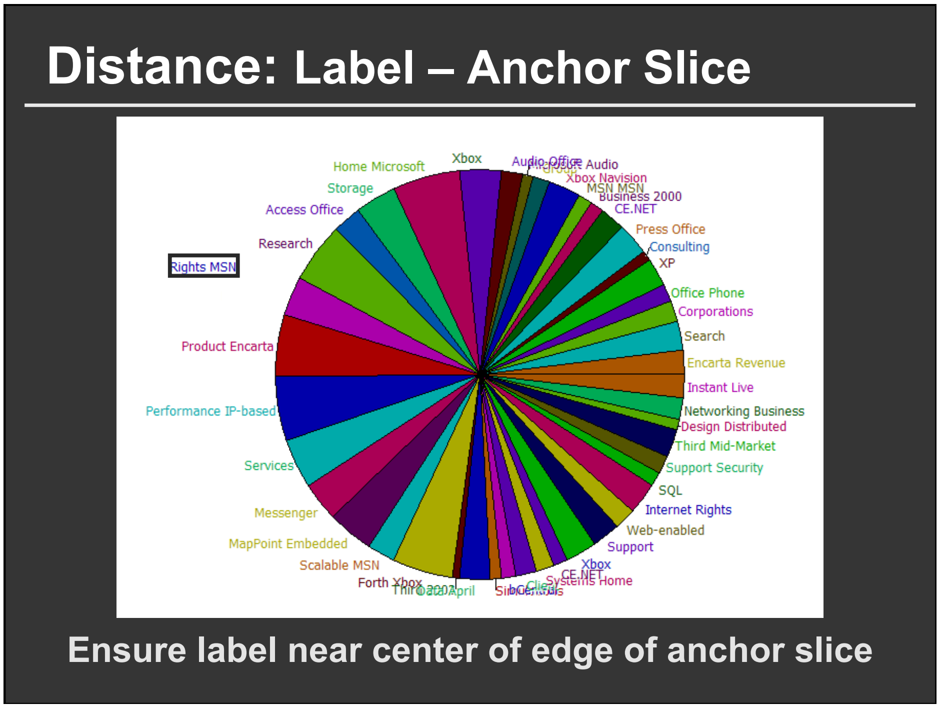


Avoid partial overlap: No penalty if fully inside /outside



Overlap: Label – Anchor Slice

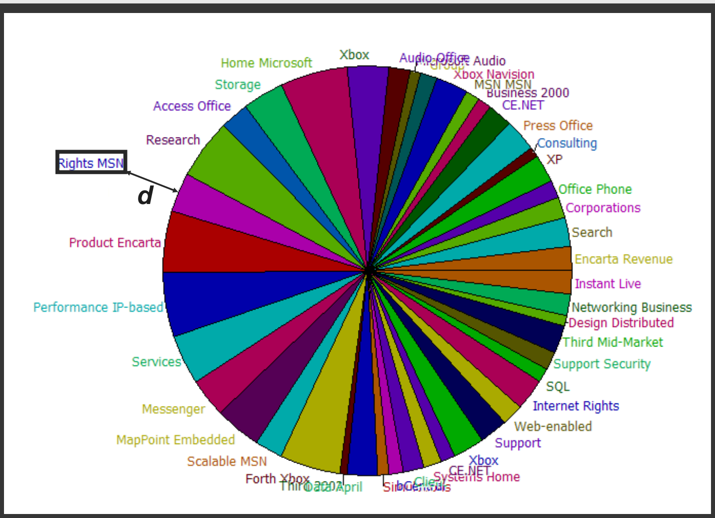
Penalize partial overlap by overlap amount



Distance: Label – Anchor Slice

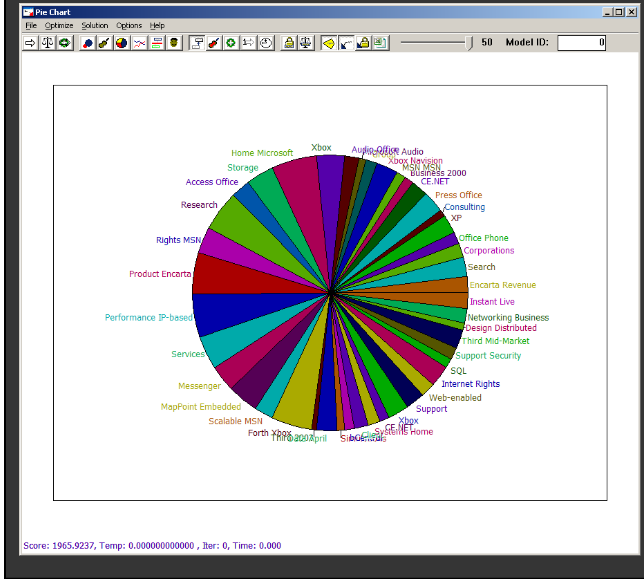
Ensure label near center of edge of anchor slice

Distance: Label – Anchor Slice



Minimize distance *d*

Penalties



Score: 1965.9237, Temp: 0.000000000000 , Iter: 0, Time: 0.000

Overlap & Distance

- Label – anchor slice
- Label – other slices
- Label – label

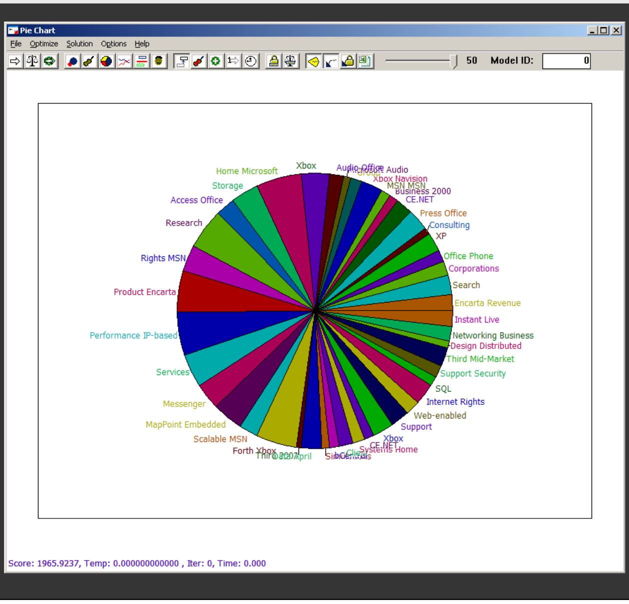
Leader lines

- Length
- Intersections

Word Wrap

Annealing minimizes sum of all penalties

Demo



Score: 1965.9237, Temp: 0.000000000000 , Iter: 0, Time: 0.000

Pros and cons

Pros

- Much more flexible than linear constraint solving systems

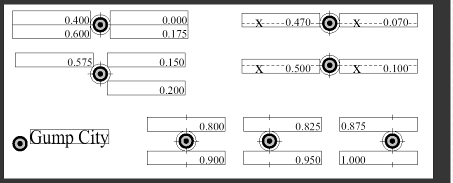
Cons

- 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



West Cartogonia

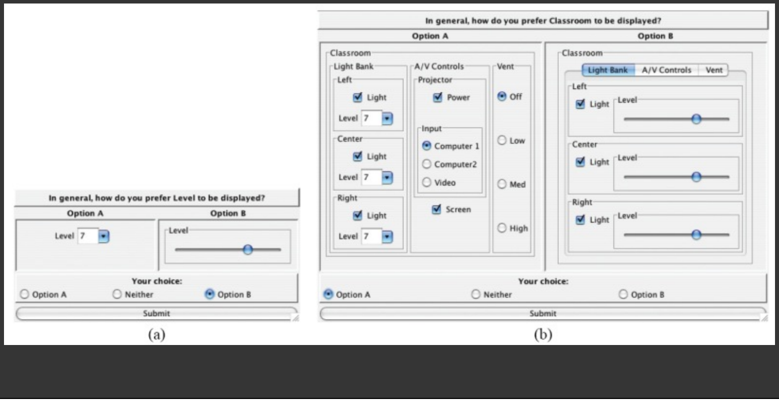
Cartographer Eduard Imhof's labeling heurists transformed into penalty functions for an optimization based point labeling system [Edmondson 97]

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



In general, how do you prefer Level to be displayed?

Option A: Level 7

Option B: Level

Your choice: ○ Option A ○ Neither ● Option B

Submit

(a)

In general, how do you prefer Classroom to be displayed?

Option A: Classroom — Light Bank: Left ☑ Light, Level 7; Center ☑ Light, Level 7; Right ☑ Light, Level 7. A/V Controls: Projector ☑ Power; Input ● Computer 1 ○ Computer2 ○ Video; ☑ Screen. Vent: ● Off ○ Low ○ Med ○ High

Option B: Classroom — Light Bank | A/V Controls | Vent; Left ☑ Light, Level; Center ☑ Light, Level; Right ☑ Light, Level

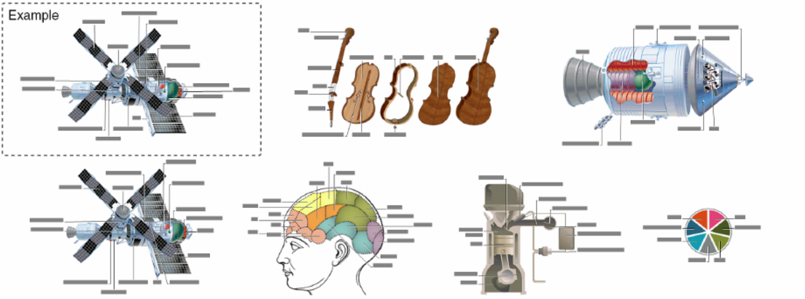
Your choice: ● Option A ○ Neither ○ Option B

Submit

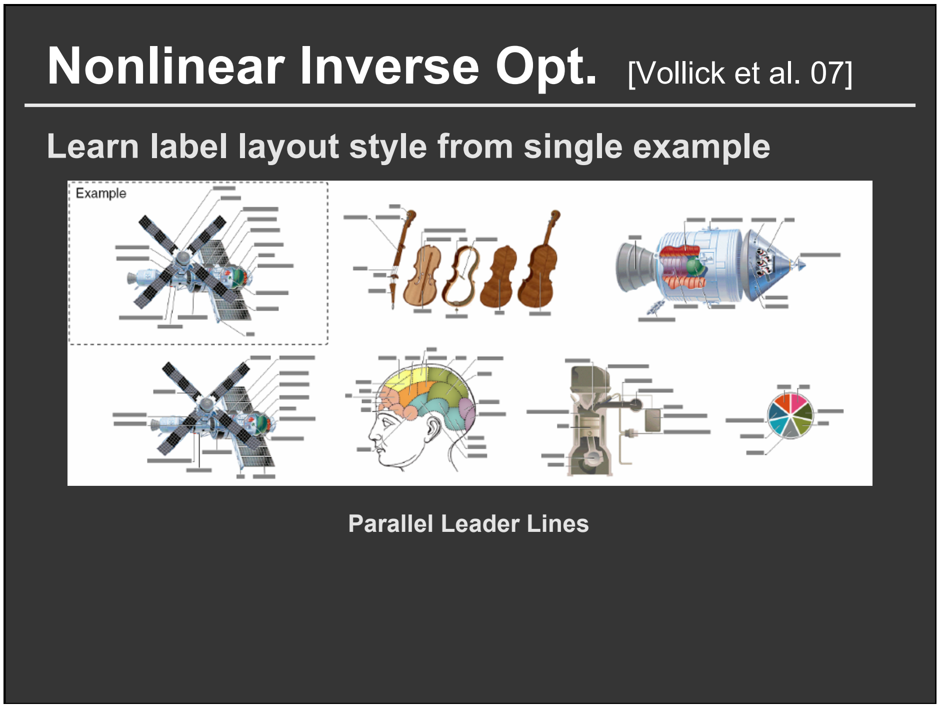
(b)

Nonlinear Inverse Opt. [Vollick et al. 07]

Learn label layout style from single example



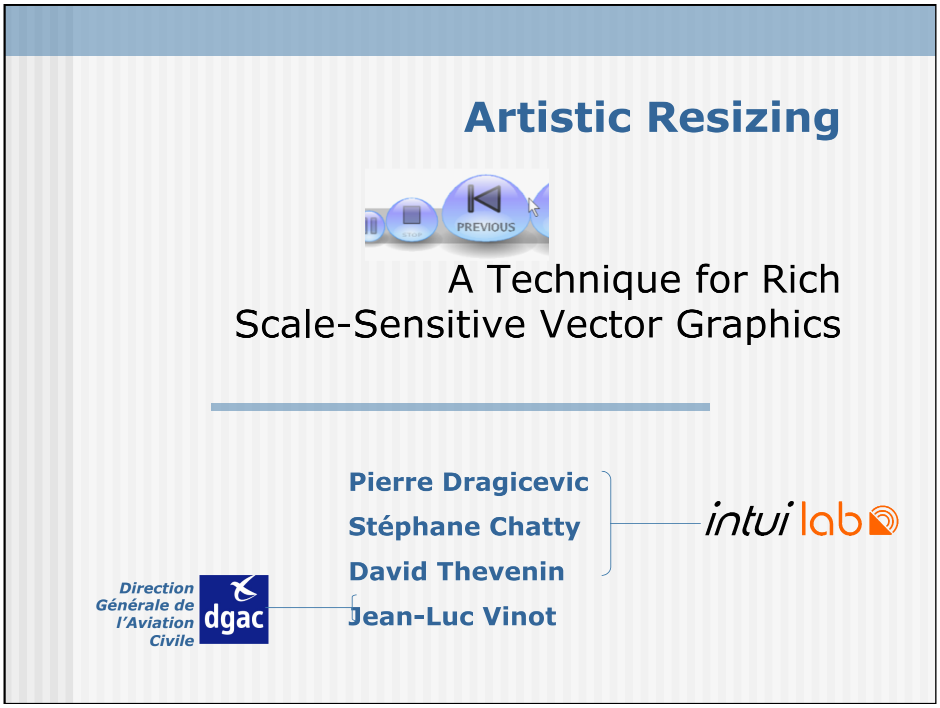
Horizontal/Vertical



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

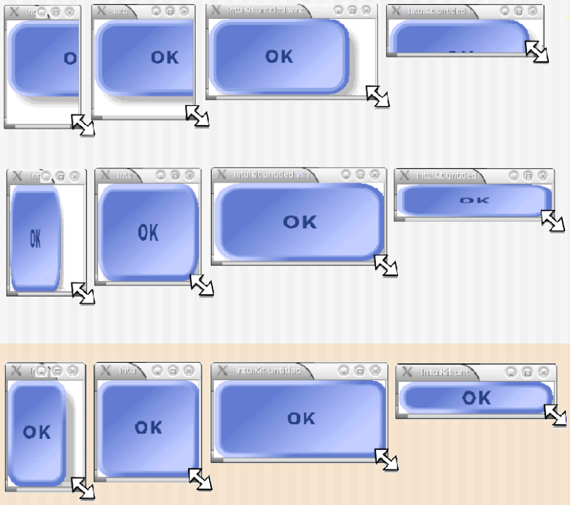
Pierre Dragicevic
Stéphane Chatty
David Thevenin
Jean-Luc Vinot

intuilab

Direction Générale de l'Aviation Civile
dgac

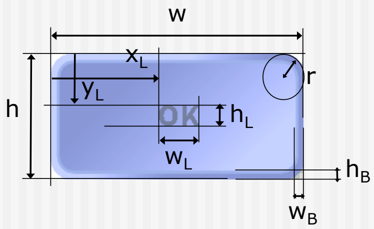
The Resizing Problem

- Fixed size
- Naive scaling
- Artistic resizing



Expressing Artistic Resizing

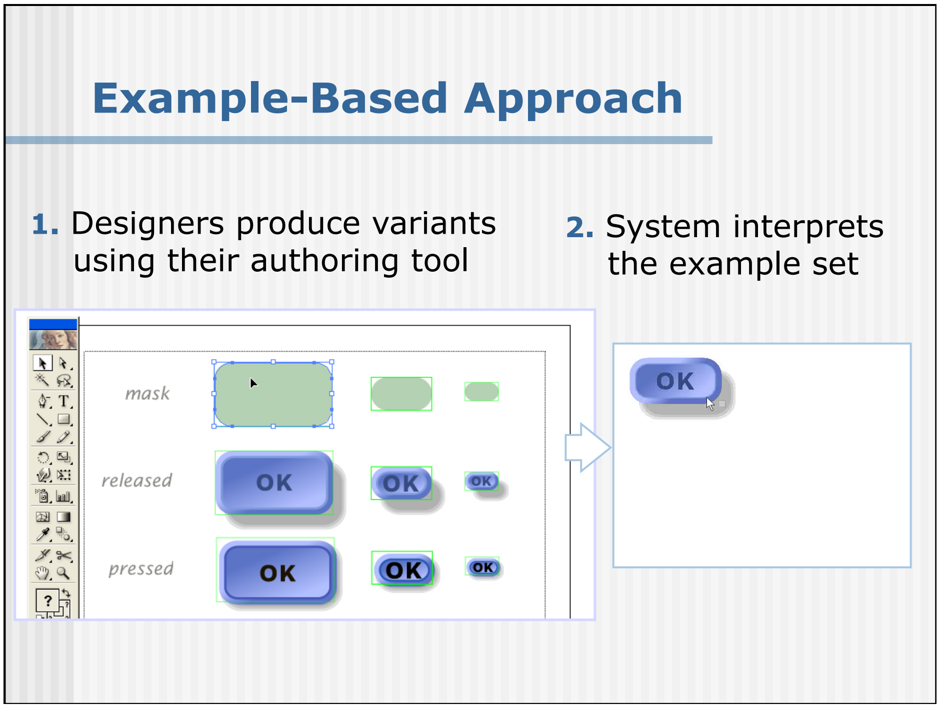
- Commonly described using formulae



- $x_L = (w-w_L) / 2$
- $y_L = (h-h_L) / 2$
- $w_L = 20$
- $h_L = 10$

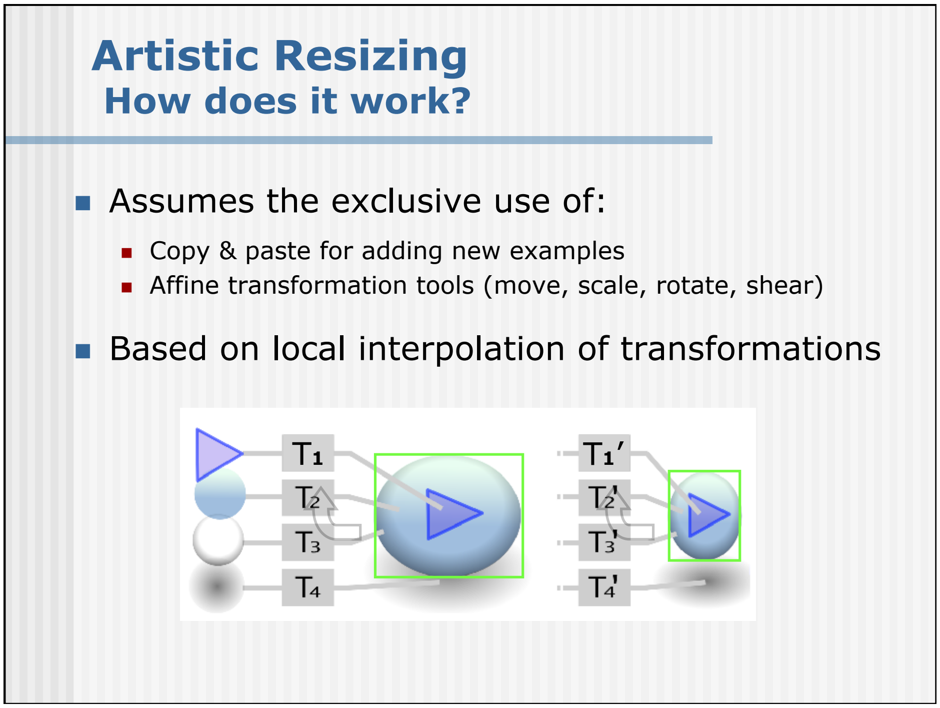
- $w_B = 5$
- $h_B = 5$
- $r = 20$

- 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



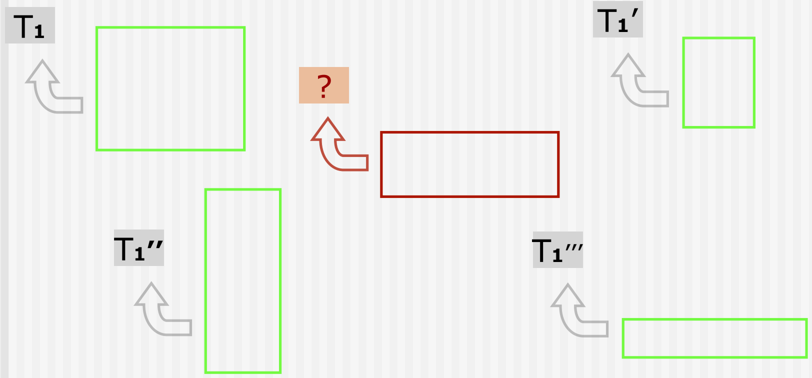
Artistic Resizing
How does it work?

- 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?

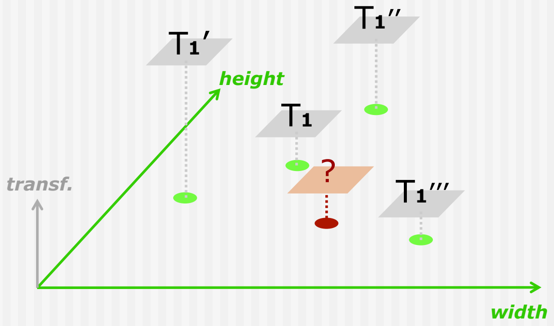
- Each variant of T1 is associated with the example’s bounding box



Artistic Resizing

How does it work?

- Problem of multivariate interpolation



Pros and cons

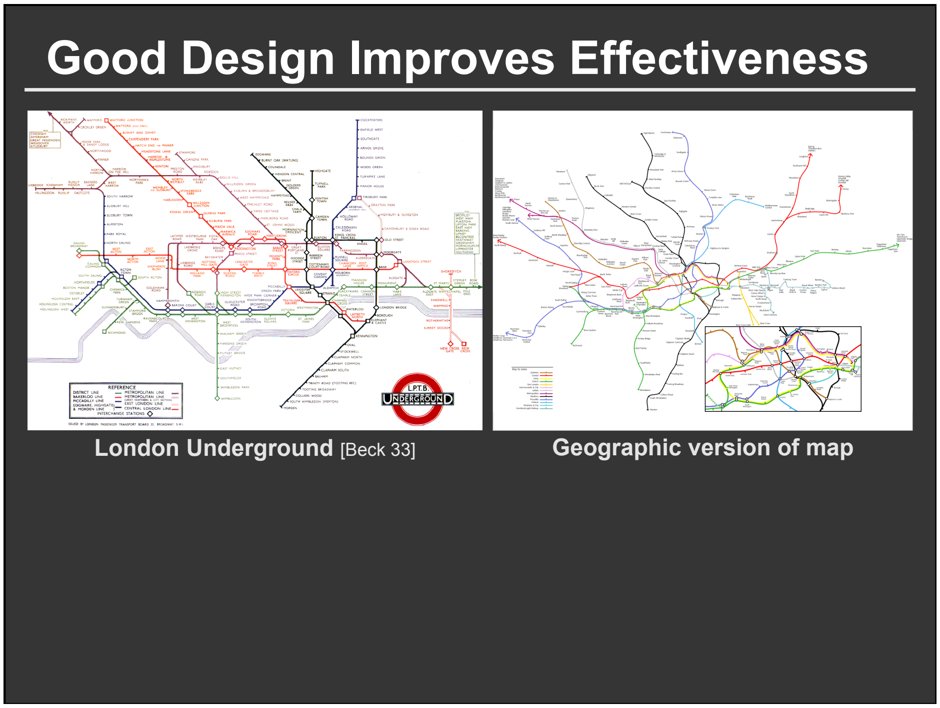
Pros

- Often much easier to specify desired layout via examples

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

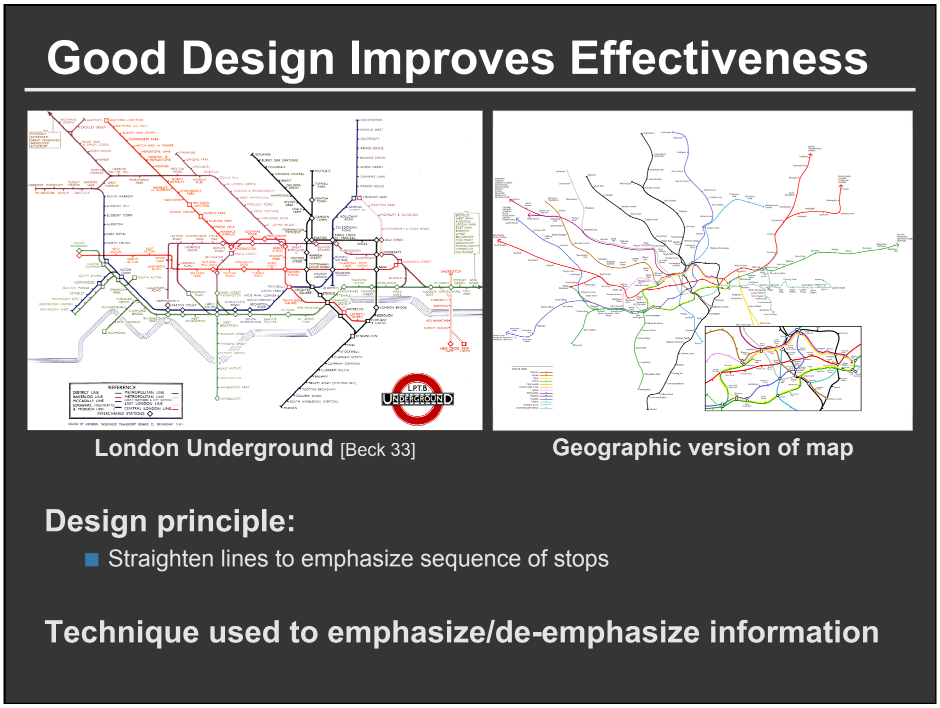
Identifying Design Principles



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

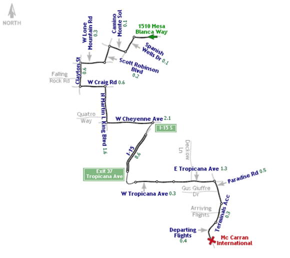
Approach

Identify design principles

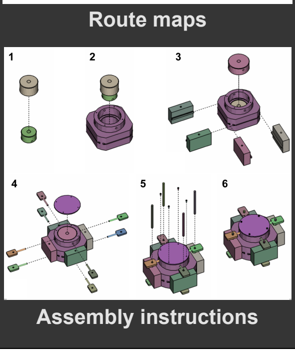
- Cognition and perception

Instantiate design principles

- Principles become constraints that guide an optimization process



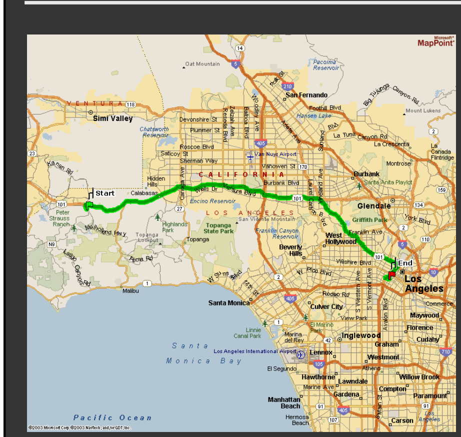
Route maps

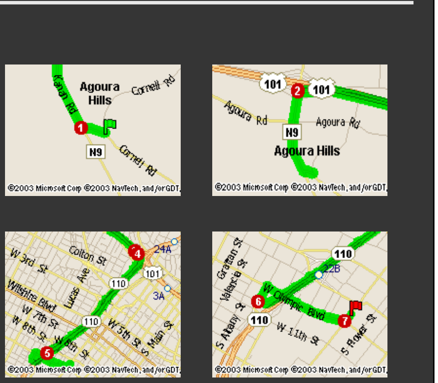


Assembly instructions

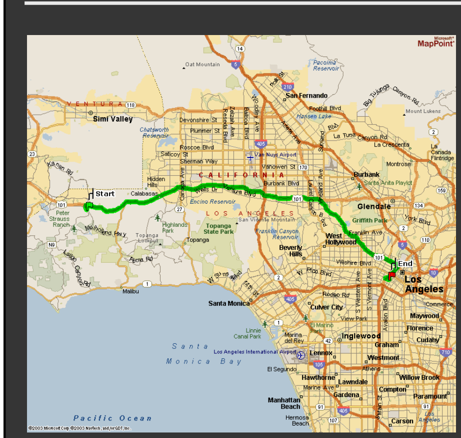
Route Maps

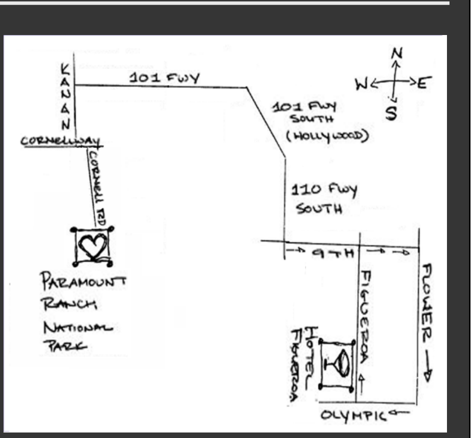
Visualizing Routes



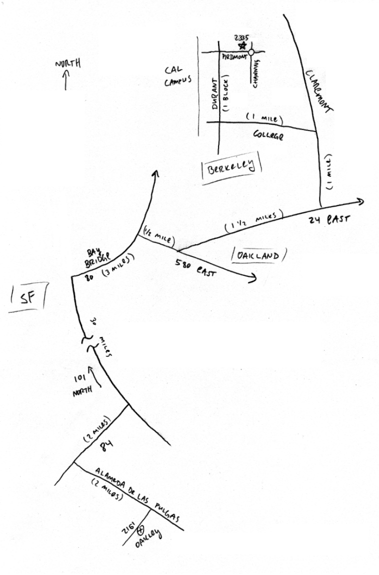


A Better Visualization





Cognition of Route Maps



Essential information

- Turning points
- Route topology

Secondary context information

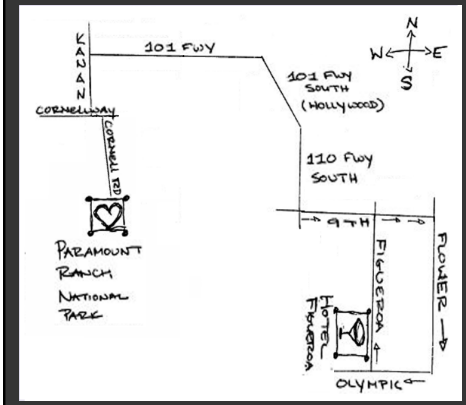
- Local landmarks, cross streets, etc.
- Overview area landmarks, global shape

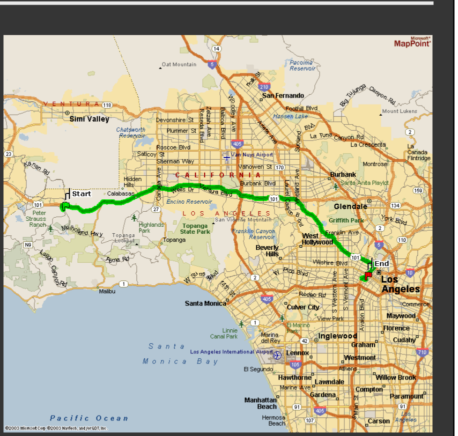
Exact geometry less important

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

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

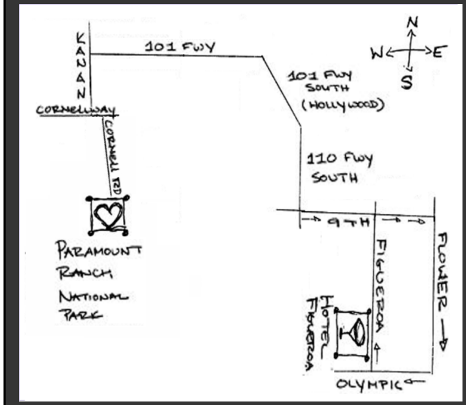
Design Principles



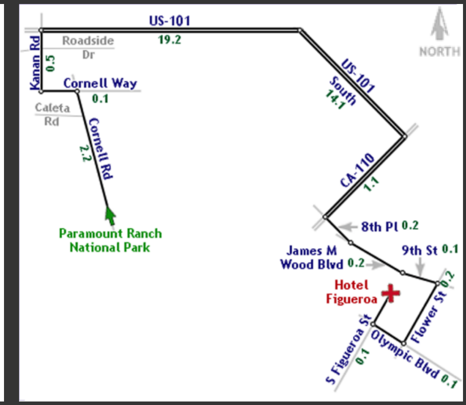


- Exaggerate road length
- Regularize turning angles
- Simplify road shape

LineDrive



Hand-drawn route map



LineDrive route map

Map Design via Optimization

Set of graphic elements

- Roads, labels, cross-streets, …

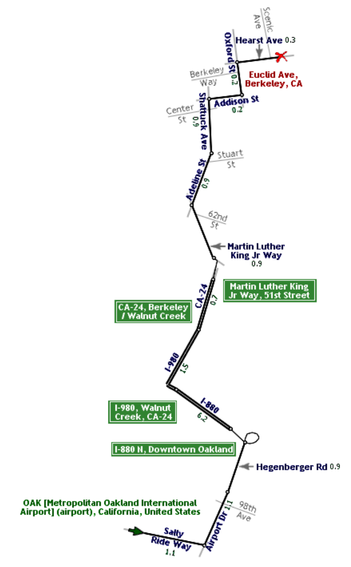
Choose visual attributes

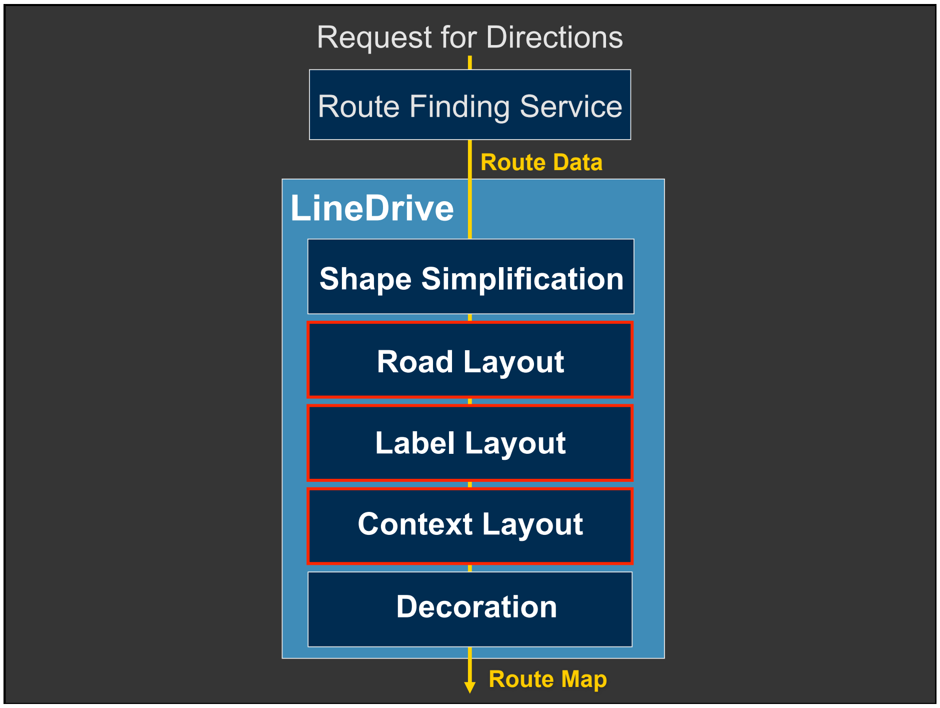
- Position, orientation, size, …
- Distortions increase flexibility

Develop constraints based on design principles

Simulated annealing

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


Scenic Ave
Oxford St 0.2
Hearst Ave 0.3
Berkeley Way
Euclid Ave, Berkeley, CA
Addison St 0.2
Center St
Shattuck Ave 0.9
Stuart St
Adeline St 0.9
62nd St
Martin Luther King Jr Way 0.9
Martin Luther King Jr Way, 51st Street
CA-24 0.7
CA-24, Berkeley / Walnut Creek
I-980 1.5
I-880 6.2
I-980, Walnut Creek, CA-24
I-880 N, Downtown Oakland
Hegenberger Rd 0.9
98th Ave
Airport Dr 1.1
OAK [Metropolitan Oakland International Airport] (airport), California, United States
Sally Ride Way 1.1



Request for Directions

Route Finding Service

Route Data

LineDrive

Shape Simplification

Road Layout

Label Layout

Context Layout

Decoration

Route Map