Spatial Layout

Maneesh Agrawala

CS 294-10: Visualization
Spring 2010

Announcements: Ben Shneiderman

Speaking: March 3, 2010

Noon – 1pm
Banatao Auditorium, Dai Hall

Please attend lecture instead of class

Assignment 4: Visualization Software

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

1. **Describe data and storyboard interface** **due March 1 (before class)**
2. **Implement interface and produce final writeup** **due March 8 (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 Mar 8, 2010

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: 3/29
- Initial problem presentation: 3/31
- Midpoint design discussion: TBD
- Final paper and presentation: TBD

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

Example: Timeline label layout

Problem

Input: Set of graphic elements (scene description)

Goal: Select visual attributes for elements

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

Topics

Direct rule-based methods

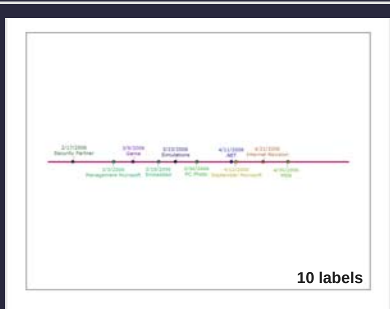
Constraint satisfaction

Optimization

Example-based methods

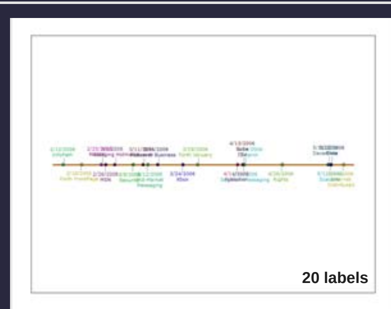
Direct Rule-Based Methods

Rule-based timeline labeling



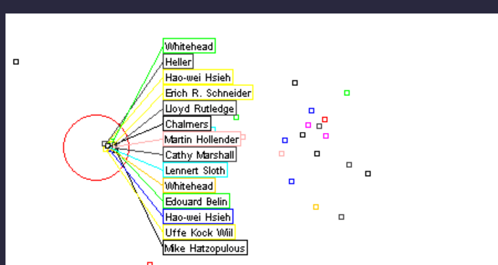
- Alternate above/below line
- Center labels with respect to point on line

Rule-based timeline labeling



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

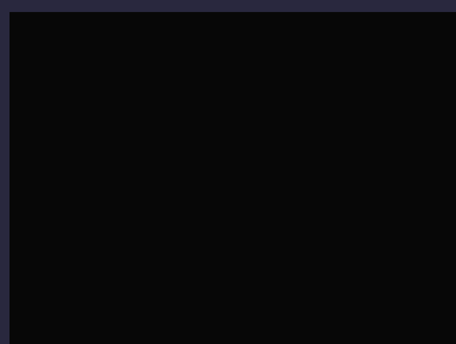
Excentric labeling [Fekete & Plaisant 99]



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

Dynamic space management [Bell 00]

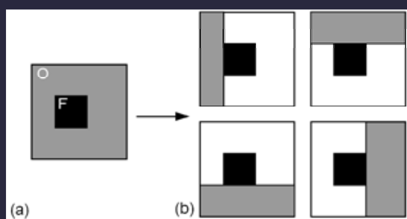
Manage *free space* on desktop to prevent window overlap



Dynamic space management [Bell 00]

Goal: Place new elements to avoid overlap

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



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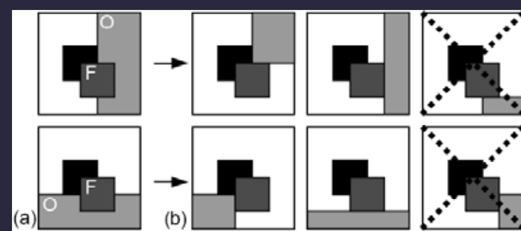


Pros and cons

Pros

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

Cons

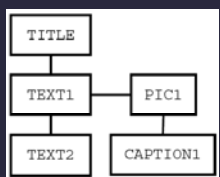
- **Complex layouts require large rule bases with lots of special cases**

Linear Constraint Satisfaction

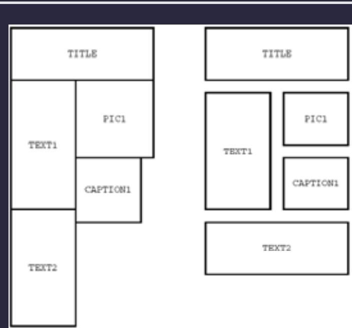
Network of layout constraints

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

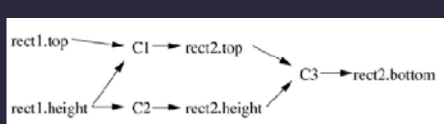
- Each constraint has 1 output variable
- Update output when any input changes

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

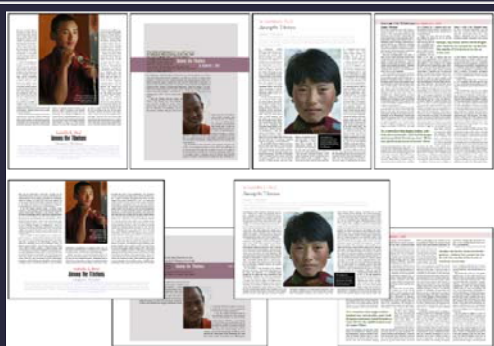


One-way constraints form a directed acyclic graph (DAG). Given the value for any variable we propagate it's value locally through the graph updating the other variable.

Page layout example [Weitzman and Wittenburg 94]

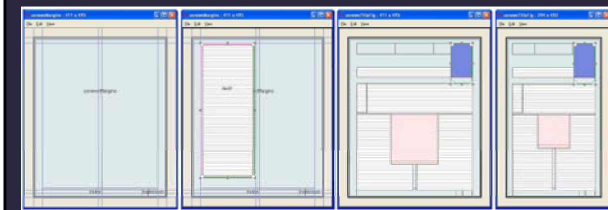
```
(Defrule (Make-Article The-Grammar)
  Article -> Text Text Text Number Image
     0        1    2    3     4      5
   (Author-Of 2 1)
   (Description-Of 4 1)
   (Page-Of 4 1)
   (Image-Of 5 1)
   (article-name 0) = r
   (article-image 0) = 5
  ;OUT
   (right-of 1 5)
   (top-aligned 1 5)
   (top-aligned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

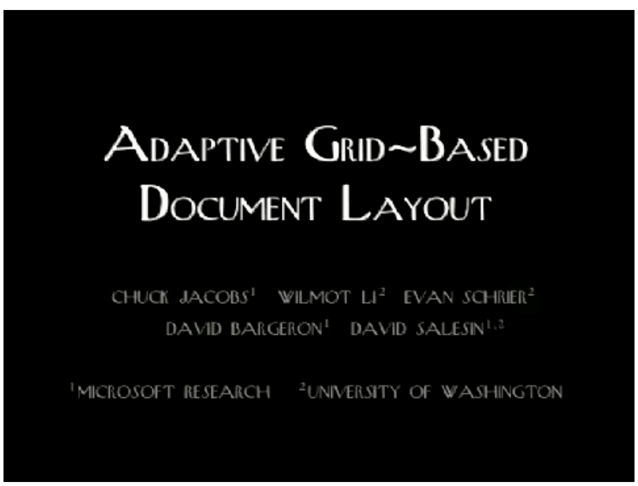
Adaptive document layout [Jacobs 03]



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

ADL template authoring [Jacobs 03]





Pros and cons

Pros

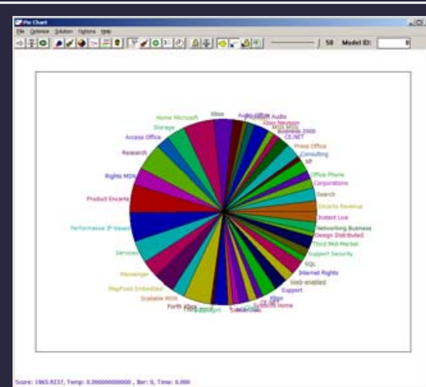
- Often run fast (at least one-way constraints)
- Constraint solving systems are available online
- Can be easier to specify relative layout constraints than to code direct layout algorithm

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



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

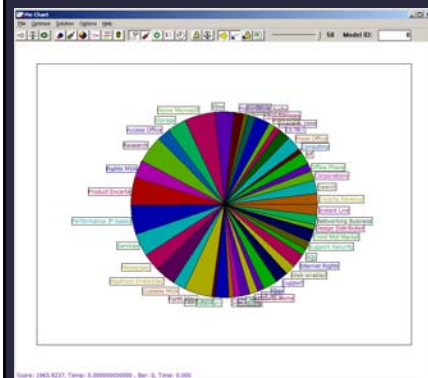
```
currL ← Initialize()
while(! termination condition)
  newL ← Perturb(currL)
  currE ← Penalty(currL)
  newE ← Penalty(newL)
  if((newE < currE) or
    (rand[0,1) < e^(-ΔE/T)))
    then currL ← newL
  Decrease(T)
```

- Form initial layout
- Perturb to form new layout
- Evaluate quality of layouts
- Always accept lower penalty
- Small probability of accepting higher penalty

Perturb: Efficiently cover layout design space

Penalty: Describes desirable/undesirable layout features

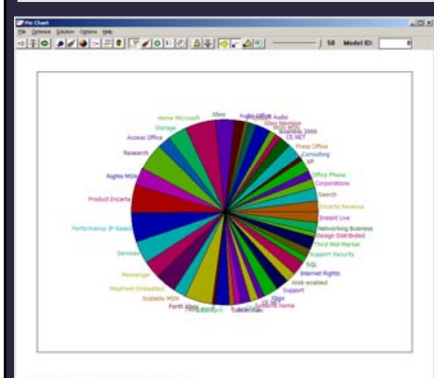
Scene description



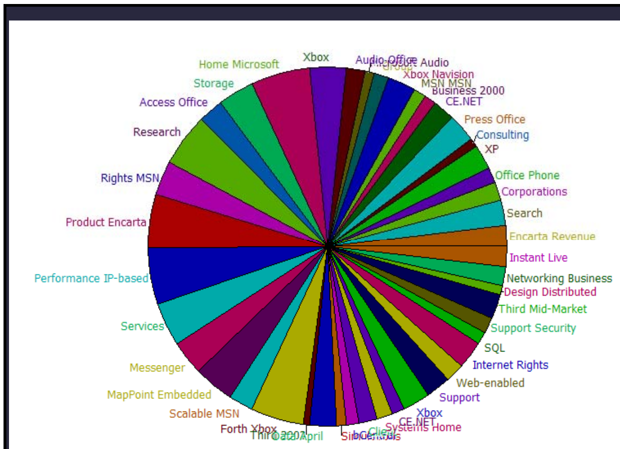
Geometry

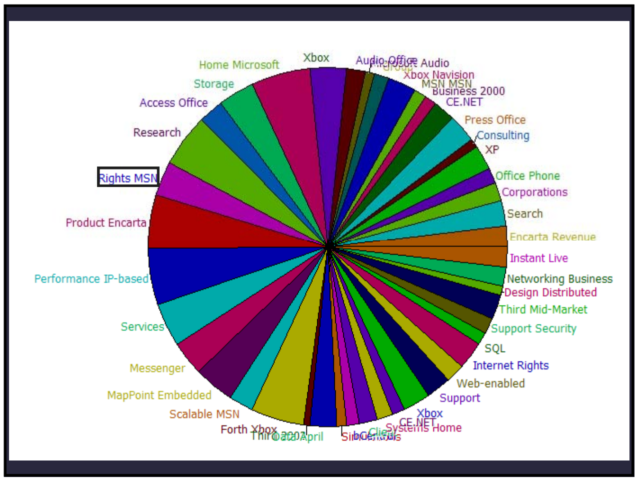
- **Pie slices**
  anchors for labels
- **Labels**
  bounding boxes

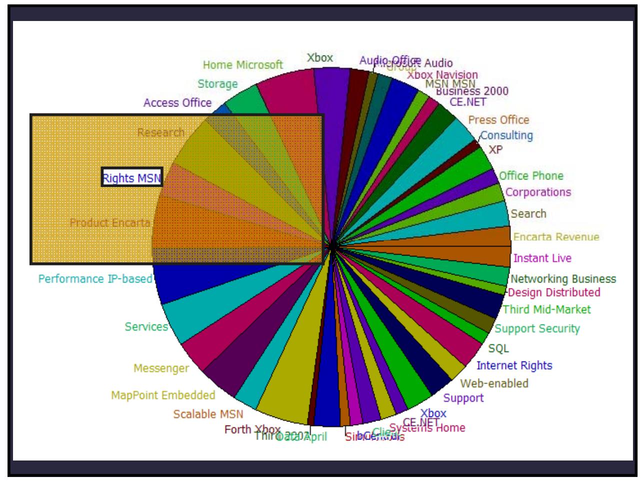
Layout parameters

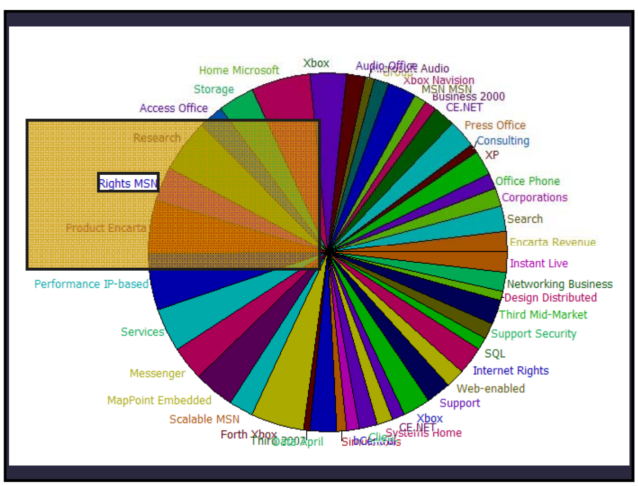


- **Position *(x, y)***
- **Leader line**
- **Word wrap**
- Color
- Alignment
- Orientation
- Scale

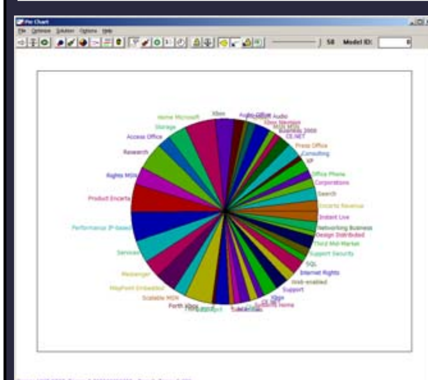








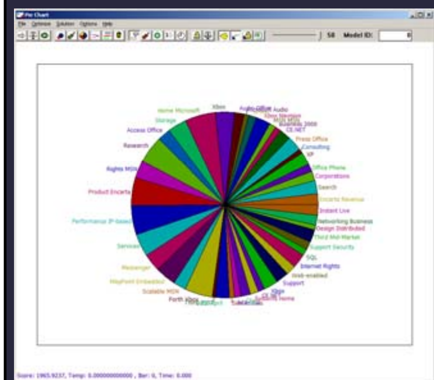
Many dimensions → large space



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

2D x 50 labels → 100D space

Penalties



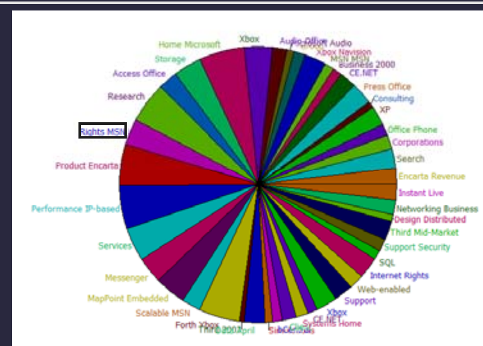
Overlap & Distance
- Label – anchor slice
- Label – other slices
- Label – label

Leader lines
- Length
- Intersections

Word Wrap

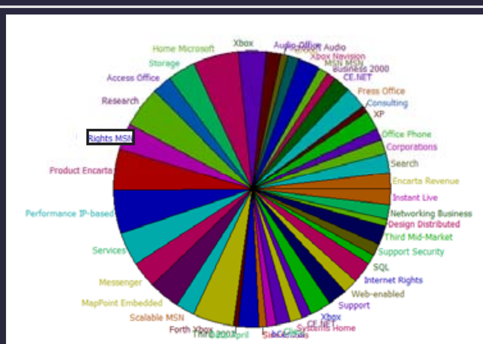
Annealing minimizes sum of all penalties

Overlap: Label – Anchor Slice



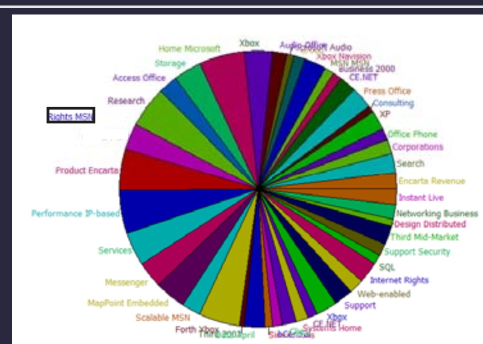
Avoid partial overlap: No penalty if fully inside /outside

Overlap: Label – Anchor Slice



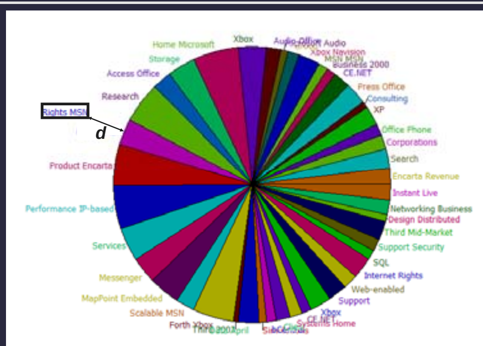
Penalize partial overlap by overlap amount

Distance: Label – Anchor Slice



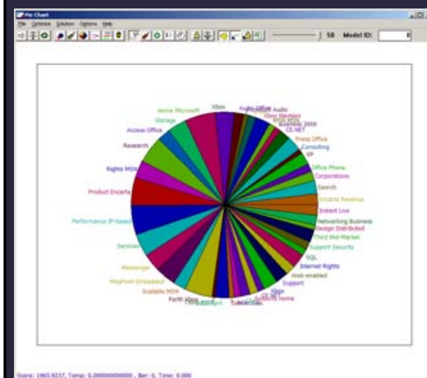
Ensure label near center of edge of anchor slice

Distance: Label – Anchor Slice



Minimize distance *d*

Penalties



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Leader lines
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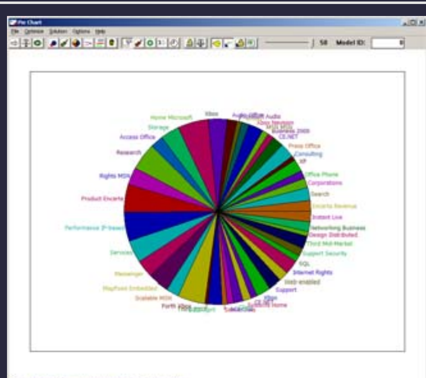
Word Wrap

Annealing minimizes sum of all penalties

Demo



Pros and cons

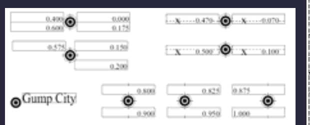
Pros
- **Much more flexible than linear constraint solving systems**

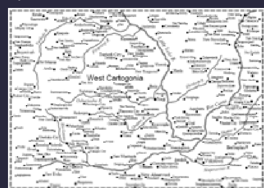
Cons
- **Can be relatively slow to converge**
- **Need to set penalty function parameters (weights)**
- **Difficult to encode desired layout in terms of mathematical penalty functions**

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

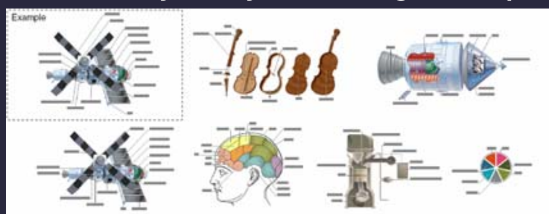
Nonlinear Inverse Opt. [Vollick et al. 07]

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

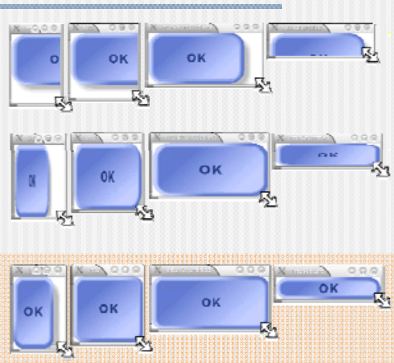
Pierre Dragicevic
Stéphane Chatty
David Thevenin
Jean-Luc Vinot

intuilab

Direction Générale de l'Aviation Civile
dgac

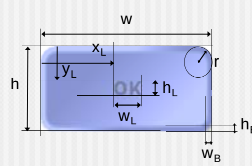
The Resizing Problem

- Fixed size
- Naive scaling
- Artistic resizing



Expressing Artistic Resizing

- Commonly described using formulae

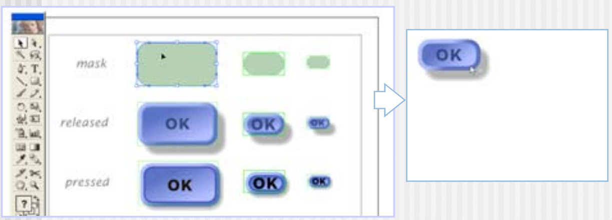


- $x_L = (w - w_L) / 2$
- $y_L = (h - h_L) / 2$
- $w_L = 20$
- $h_L = 10$
- $w_B = 5$
- $h_B = 5$
- $r = 20$

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

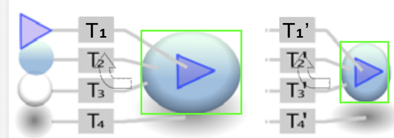
Example-Based Approach

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



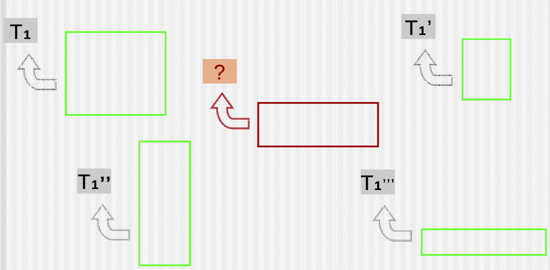
Artistic Resizing
How does it work?

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



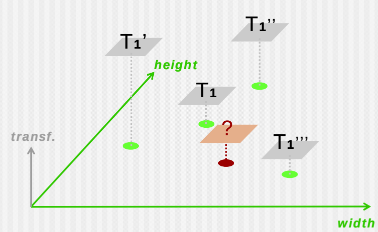
Artistic Resizing
How does it work?

- 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