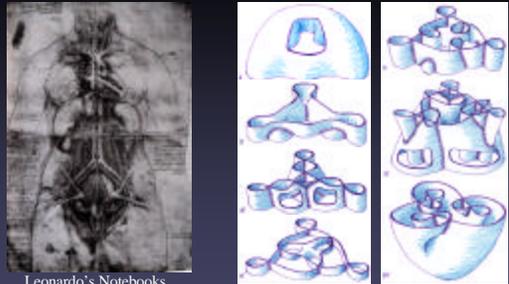


# Rendering Effective Route Maps: Improving Usability Through Generalization

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Chris Stolte

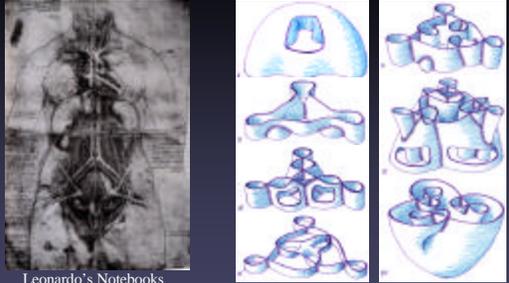
Stanford University

## Visualization: Explore & Present Data



Leonardo's Notebooks [Da Vinci ca. 1490]      Strange Immersion of Torus in 3-Space [Curtis 92]

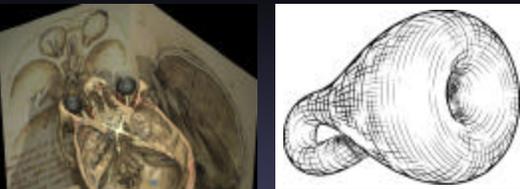
## Most Visualizations Hand-Designed



Leonardo's Notebooks [Da Vinci ca. 1490]      Strange Immersion of Torus in 3-Space [Curtis 92]

- Can we automate visualization design?

## Emulating Artistic Rendering Styles



Anatomy [Hoehne 95]      Mathematical Illustration [Hertzmann 00]

- High-level design specified manually

## Fully Automated Visualization Design

- **Step 1: Identify design principles**
  - Perception, cognition, communicative intent



Guide for Visitors to Ise Shrine [from Tufte 90]

- **Step 2: Encode principles algorithmically**

## Visualizing Routes

Stripmap



Britannia road atlas [Ogilby 1675]

Subway Map

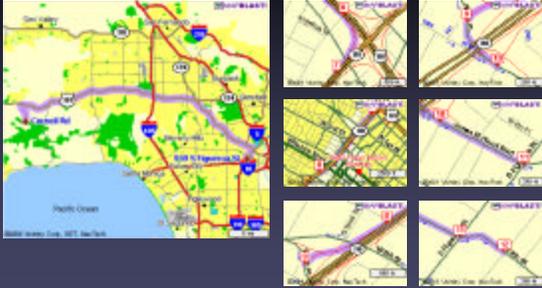


London Underground [Beck 1933]

- Abstraction, distortion help emphasize routes

## Motivation

- Standard online route maps difficult to use



## Motivation

- Standard online route maps difficult to use



- Can't see turns
  - Short roads vanish
  - No complete map
- Cluttered
  - Detail far from route
  - Unnecessary features
- Inconvenient
  - Multiple pages

## A Better Visualization

- Handdrawn map much easier to use



- All turns visible
- Clutter-free
- Compact size

- Goal: Fully automated, real-time system for creating such effective route maps

## Communicative Intent of Route Maps

- Route = sequence of turns [Tversky 92] [MacEachren 95]

1. Start at 100 Serra
2. Turn Right on University
3. Turn Left on El Camino
4. Turn Right on San Antonio

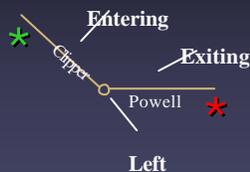
...

- Verbal directions emphasize turns [Denis 97]
- Handdrawn maps exaggerate turns [Tversky & Lee 99]

- Maps - must communicate turning points

## Turning Point Information

- **Pair of roads (entering / exiting the turn)**
  - Connect map to physical world
- **Turn direction (left / right)**
  - Specifies action to take at turn



- Turns essential for understanding route

## Context can Facilitate Navigation

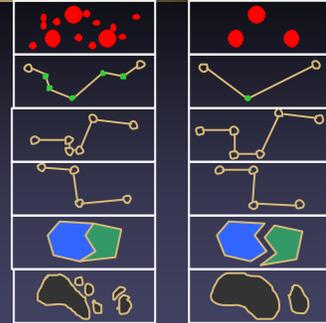
- Local context – consistency checks
  - Cross-streets
  - Landmarks along route
  - Distance along each road
- Overview context – orient route to geography
  - Large scale landmarks (oceans, city names)
  - Overall shape and heading of route
- Context is secondary to turning points

## Geometric Properties Often Distorted

- Far less useful for navigation
  - Exact road lengths
  - Precise turning angles
  - Detailed road shape
- Mental representation distorted [Tversky 81]
- Handdrawn maps also distorted [Tversky & Lee 99]
  - Geometry altered: length, angle, shape
  - Topology intact: turning point information

## Cartographic Generalization

- Selection
- Simplification
- Exaggeration
- Regularization
- Displacement
- Aggregation



[Monmonier 96], [MacEachren 94], [DiBiase 91]

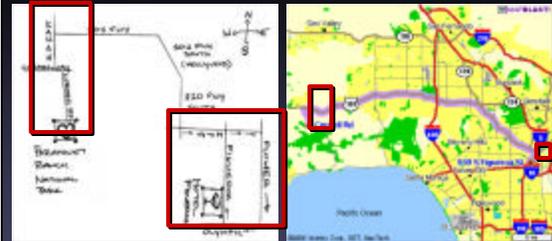
## Three Generalizations for Route Maps



- Our observations from handdrawn examples:
  - Distortion
    - Road length
    - Turning angle
  - Simplification
    - Road shape

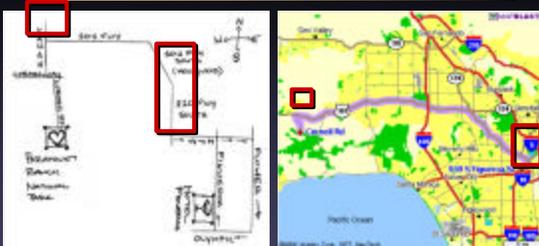
- Generalizations emphasize turning points!

## Distortion: Length Generalization



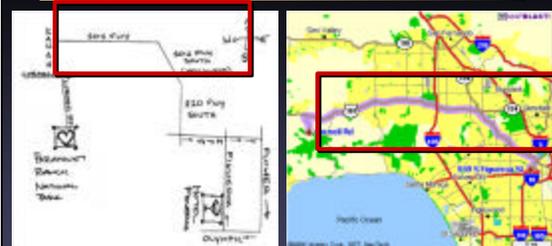
- Grow short roads, shrink long roads
  - Ensures all roads visible
  - Maintain relative ordering by length

## Distortion: Angle Generalization



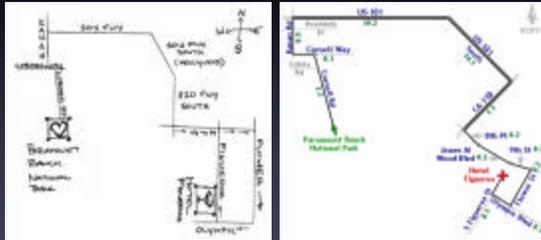
- Regularize turning angles
  - Reduces visual complexity
  - Maintain consistent turn direction

## Simplification: Shape Generalization



- Simplify roads to straight lines
  - Differentiates roads and turning points
  - Maintain overall shape of route

## LineDrive: Route Map Design System



Handdrawn route map

LineDrive route map

## Automating Route Map Design

- Layout problem
  - Set of map elements
    - Roads
    - Labels
    - Cross-streets
  - Choose visual attributes
    - Position
    - Orientation
    - Size
- Generalizations increase choices
- Large space of possible layouts

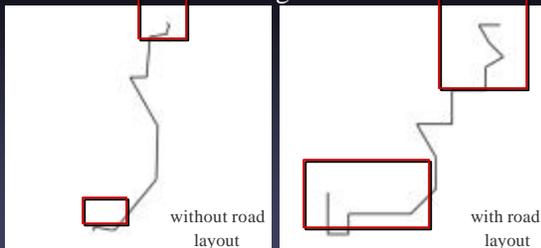
## Layout as Search-Based Optimization

- Hard constraints
  - Required characteristics
- Soft constraints
  - Desired characteristics
- **Challenge: choose relevant constraints**
- Simulated annealing
  - *Perturb:* Form a layout
  - *Score:* Evaluate quality
  - Minimize score



## Stage 2: Road Layout

- Goal: Choose road lengths & orientations



- All roads visible
- Map fits within given viewport

## Road Layout Search

- Initialize
  - Uniformly scale route to fit given viewport
- Perturb
  - Pick random road
  - Either
    - Rescale by random factor
    - Reorient by random angle
  - Rescale entire route to fit viewport
- Hard Constraints
  - Must fit in viewport
  - Must maintain consistent turn direction

## Designing Soft Constraints

- **Challenges**
  - Choose desirable characteristics
  - Express as numerical score function
  - Balance constraints, deal with conflicts
- **Desired characteristics for road layout**
  - All roads visible
  - Prevent excessive distortion

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

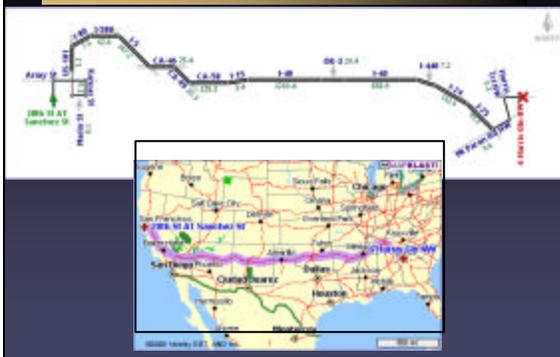
## Balancing Soft Constraints

- **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
- **Informal usability engineering**
  - Consider maps containing errors
  - Rate which errors most confusing

## Results: Bellevue to Seattle



## Results: Cross-Country Route



## Limited Resolution: Palm



## User Response

- Beta publicly accessible Oct 00 – Mar 01
- 150,000 Maps served
- 2242 Voluntary responses
  - Should replace standard maps 55.6 %
  - Use along with standard maps 43.5 %
  - Standard maps preferable 0.9 %
- Feedback
  - Choose better routes
  - More context in unfamiliar areas

## Sketch-Style Rendering



## Future Work

- In-depth user study
  - Watch users following LineDrive maps
- Map enhancements
  - Cross-street after turning point
  - Large area landmarks (oceans, lakes)
- Point location maps
  - Show routes from major highways to point location



## Acknowledgements

- Christian Chabot
- Vicinity Corporation
- Pat Hanrahan

Try LineDrive at: [www.mapblast.com](http://www.mapblast.com)