Visualization in Operations Research

by

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M.I.T. Operations Research Center 50th Anniversary Celebration
April 24, 2004

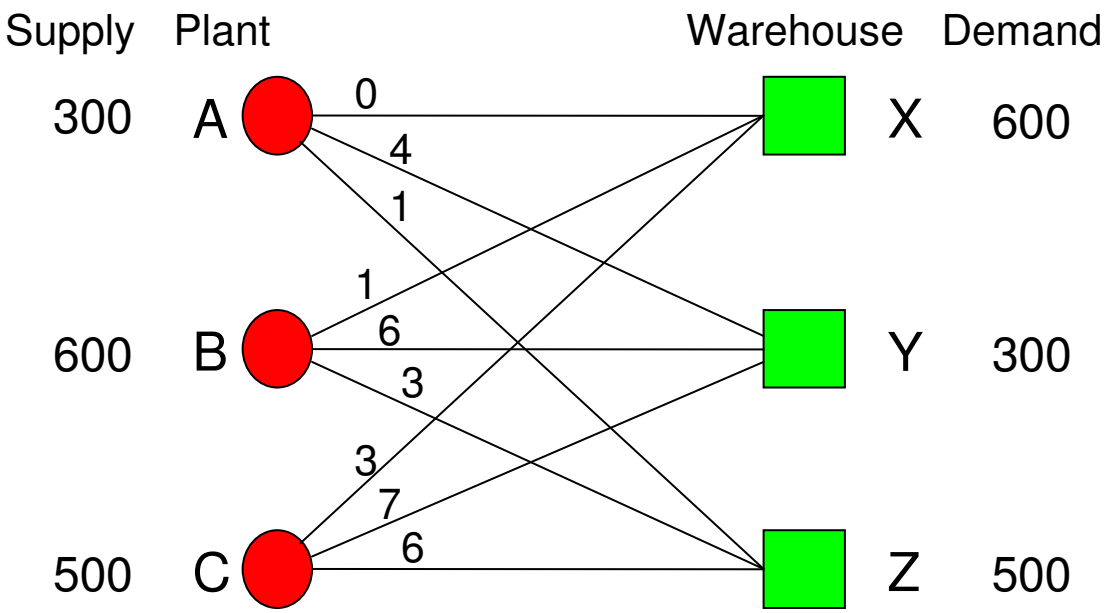
Focus

- A common thread: visualization

> Psychologists claim that more than 80% of the information we absorb is received visually (Cabena et al., 1997)

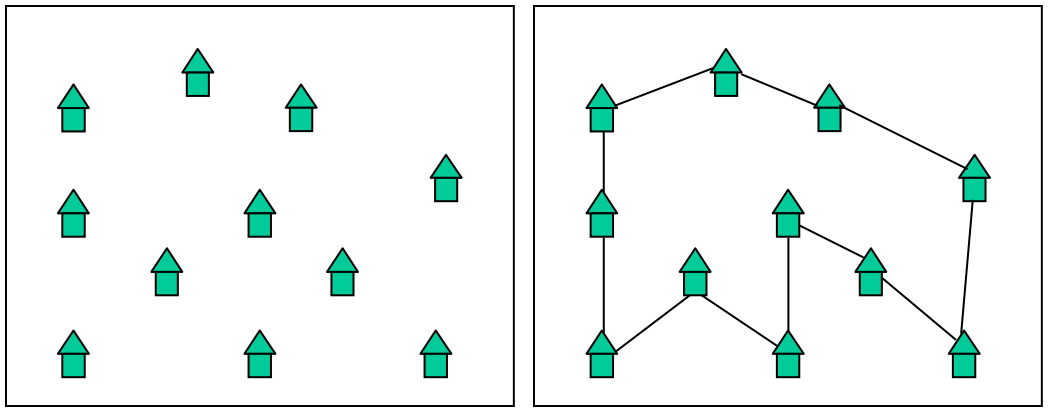
- Early contacts with visualization
- Vehicle routing
- Ranking great sports records
- College selection
- Conclusions

A Small Transportation Problem



Goal: Determine product flows from Plants to Warehouses to minimize total cost

The Traveling Salesman Problem



Original problem *Possible solution*

Goal: Sequence the buildings on a college campus for a security guard to inspect to minimize total time

My Dissertation Research

- Involved large-scale vehicle routing
- Partially supported by the American Newspaper Publishers Association (from January 1974 to June 1975)
  - Develop a computer code for specifying vehicle routes for bulk newspaper deliveries
  - Determine if these computerized approaches look promising
- We worked with the Worcester Telegram (WT)
  - Evening circulation of 92,000, approximately 600 drop points
  - We located the depot and drop points on a large map with pins
  - We used Euclidean distances and generated routes quickly

Transition from Ph.D. Student to Consultant

- Next, we compared our routes to existing WT routes
- WT re-examined their routes and altered several
- The experiment was reasonably successful and fun
- Larry Bodin and I started at the University of Maryland in 1976
- Arjang Assad and Mike Ball arrived in 1978
- In 1978 and 1979, the four of us worked for Scientific Time Sharing Corp. (STSC) on two projects involving vehicle routing
- We worked with Donald Soults at STSC
- The projects were exciting, but STSC got most of the money

Founding and Running a Consulting Company

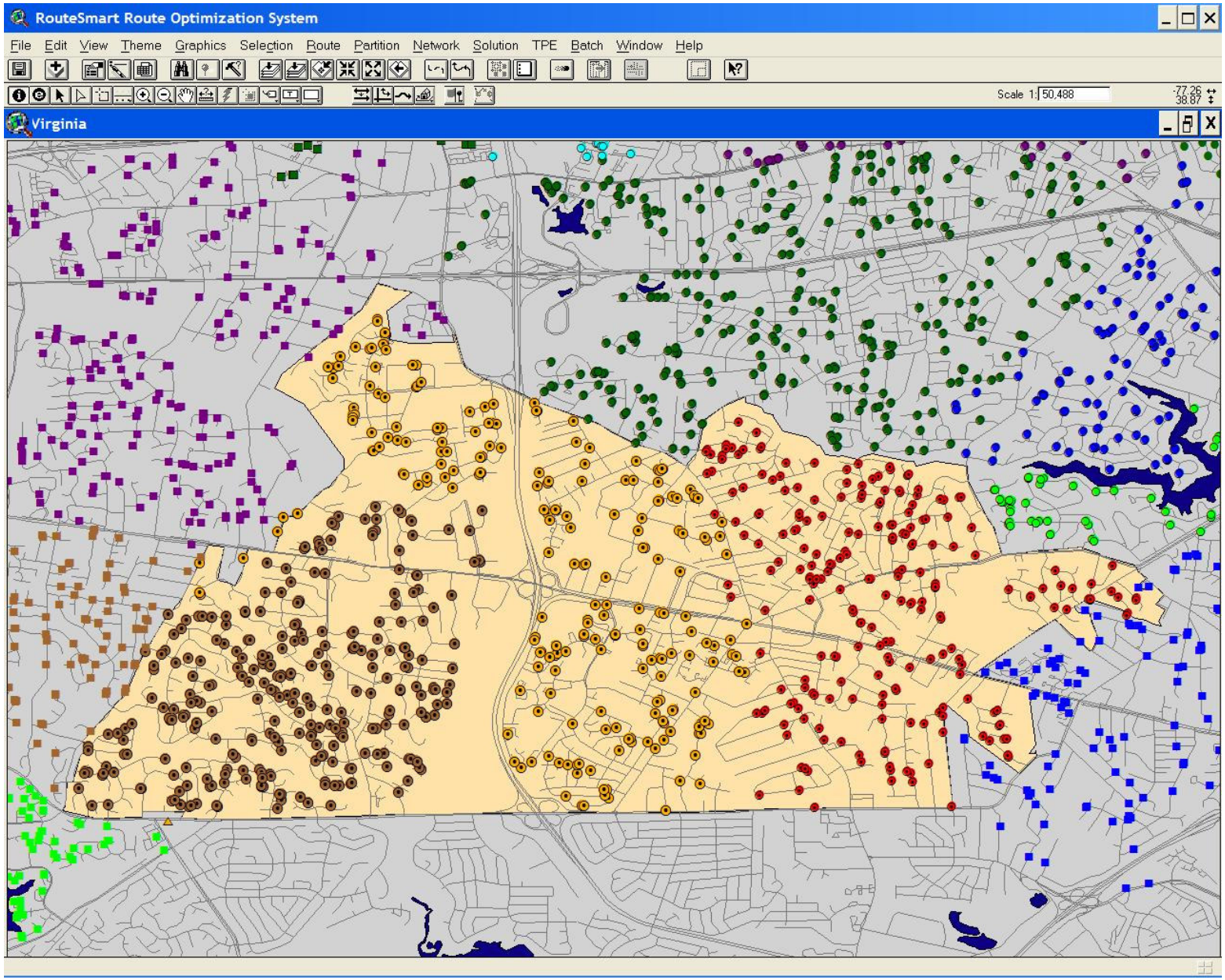
- Assad, Ball, Bodin and Golden founded RouteSmart in 1980
- In the 1980s, we consulted with large companies on vehicle routing
- Starting in 1989, we designed and sold vehicle routing software
- In 1998, we sold the business to a large NY civil engineering company
- We remained connected to RouteSmart until early 2004
- RouteSmart Technologies, Inc. is currently run by Larry Levy – my newspaper boy in 1978 & 1979
- RouteSmart has major installations in the newspaper, utility, waste/ sanitation, and postal/local delivery industries
- Let's focus on RouteSmart's work in newspaper distribution

A Partial List of RouteSmart's Newspaper Clients

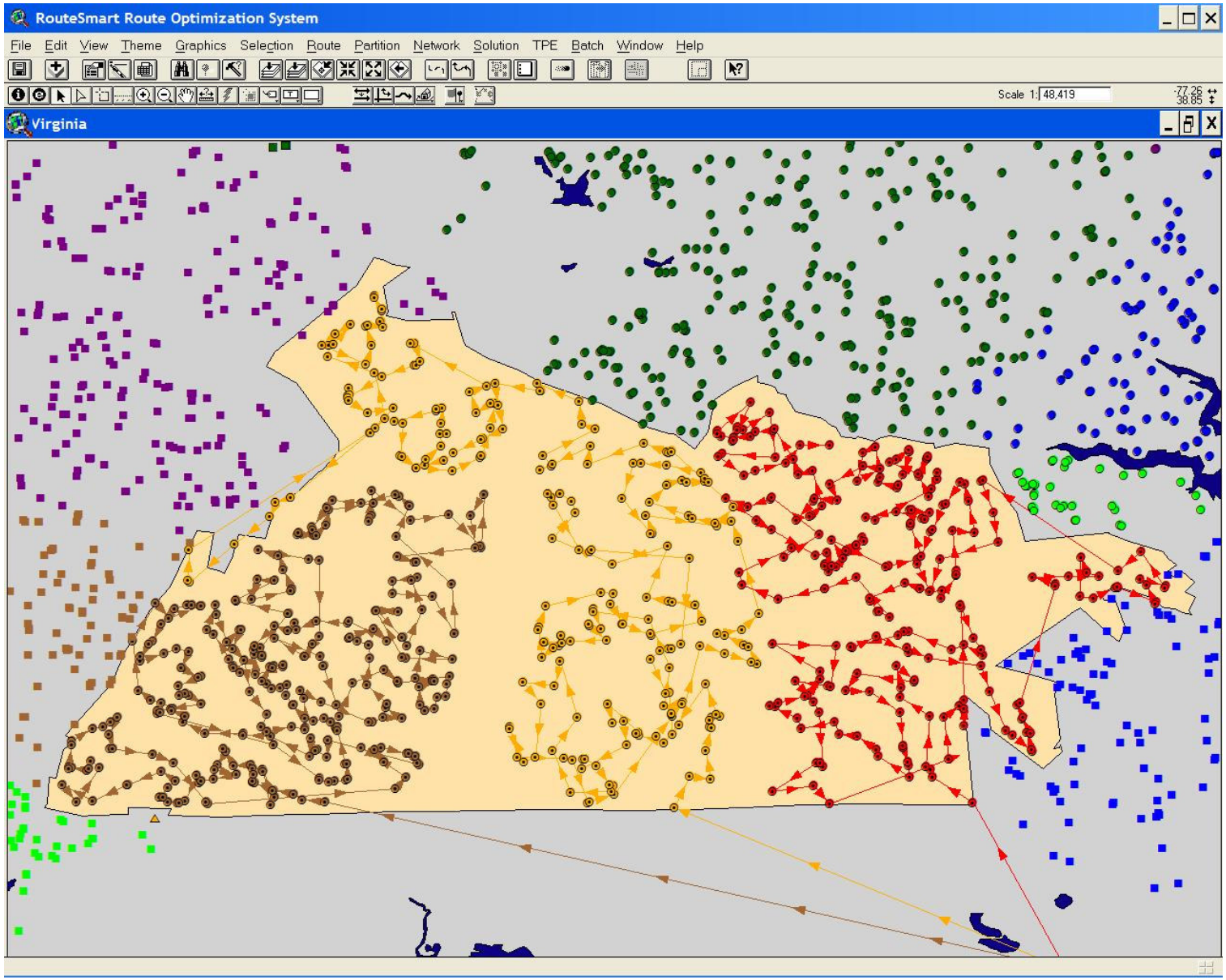
- Washington Times
- The (Toronto) Globe and Mail
- Dow Jones & Company
- Orlando Sentinel
- Pittsburgh Tribune-Review
- The Baltimore Sun
- The New York Times
- The Boston Globe
- The Seattle Times
- Chicago Tribune
- St. Louis Post-Dispatch
- The New York Post
- Detroit News
- San Diego Union Tribune
- The San Francisco Chronicle
- Orange County Register

Newspaper Route Optimization

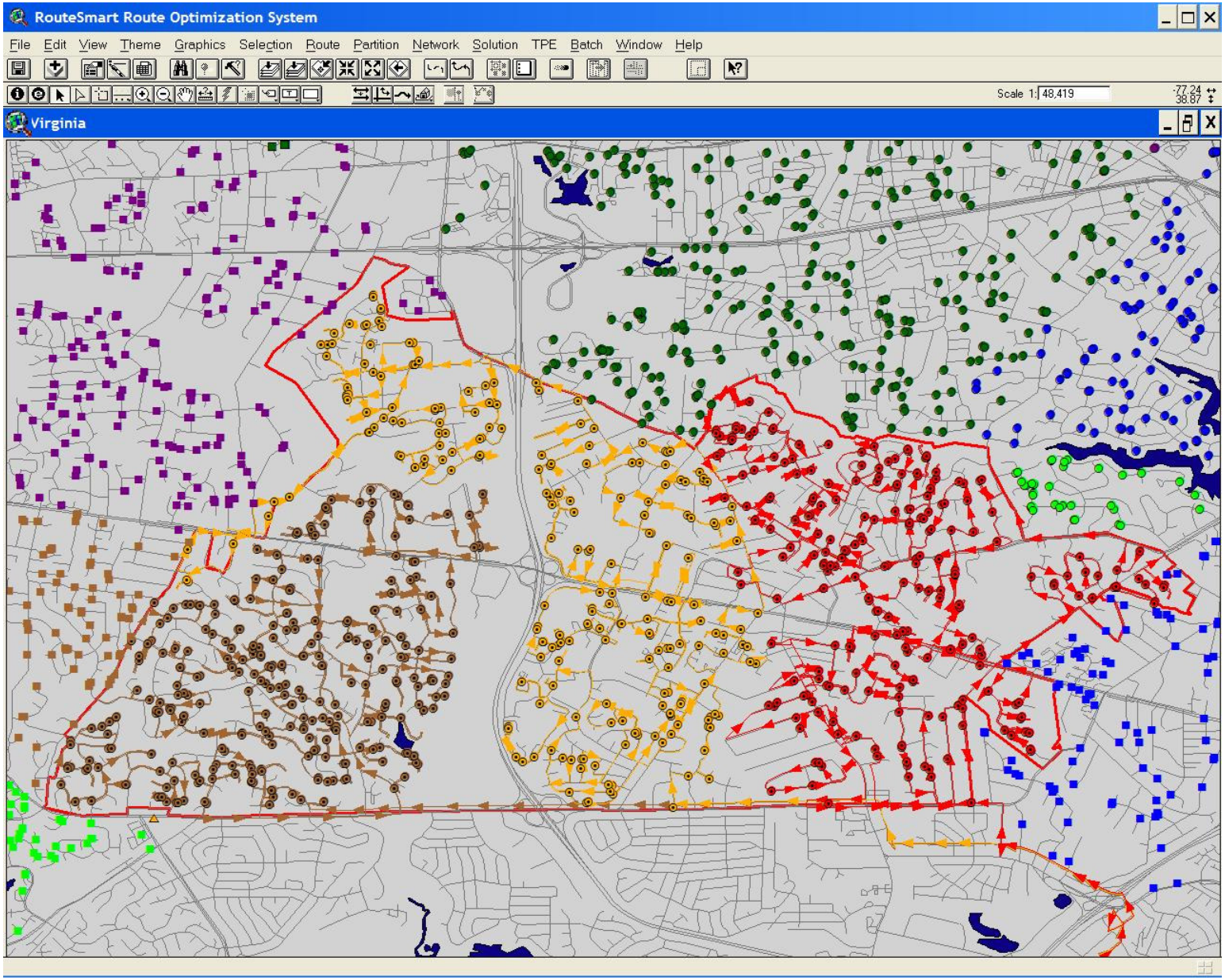
- A major success story for OR: optimization & visualization
- Two different routing problems
  - Home delivery (arc routing)
  - Single-copy routing (node routing)
- Recent Developments
  - The distribution task is being outsourced (PCF)
  - Numerous newspapers are distributed simultaneously (e.g., Orlando Sentinel, IBD, New York Times, Wall Street Journal)
  - The routing is driven by advertising



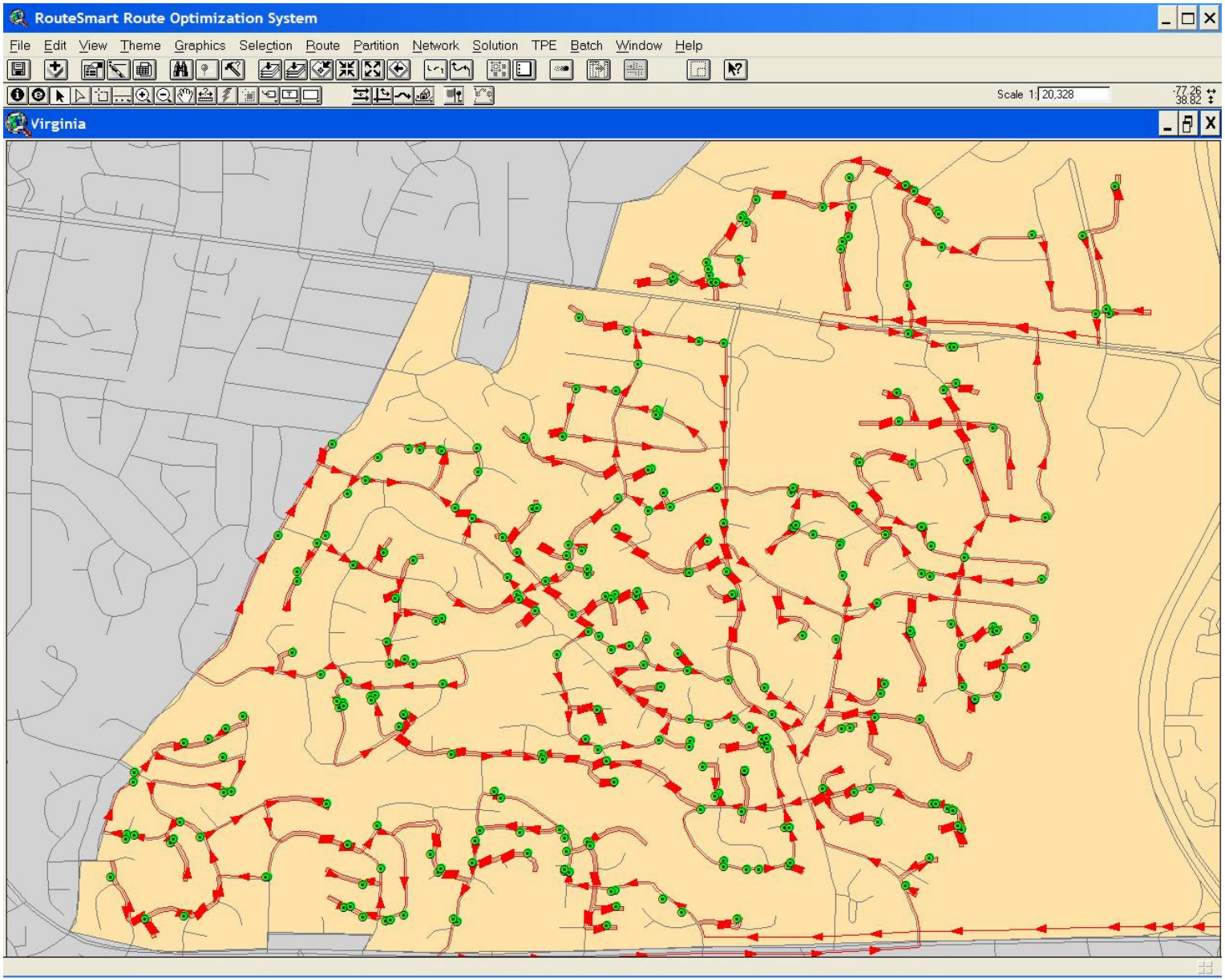
Home Delivery: Routes within a Zip Code



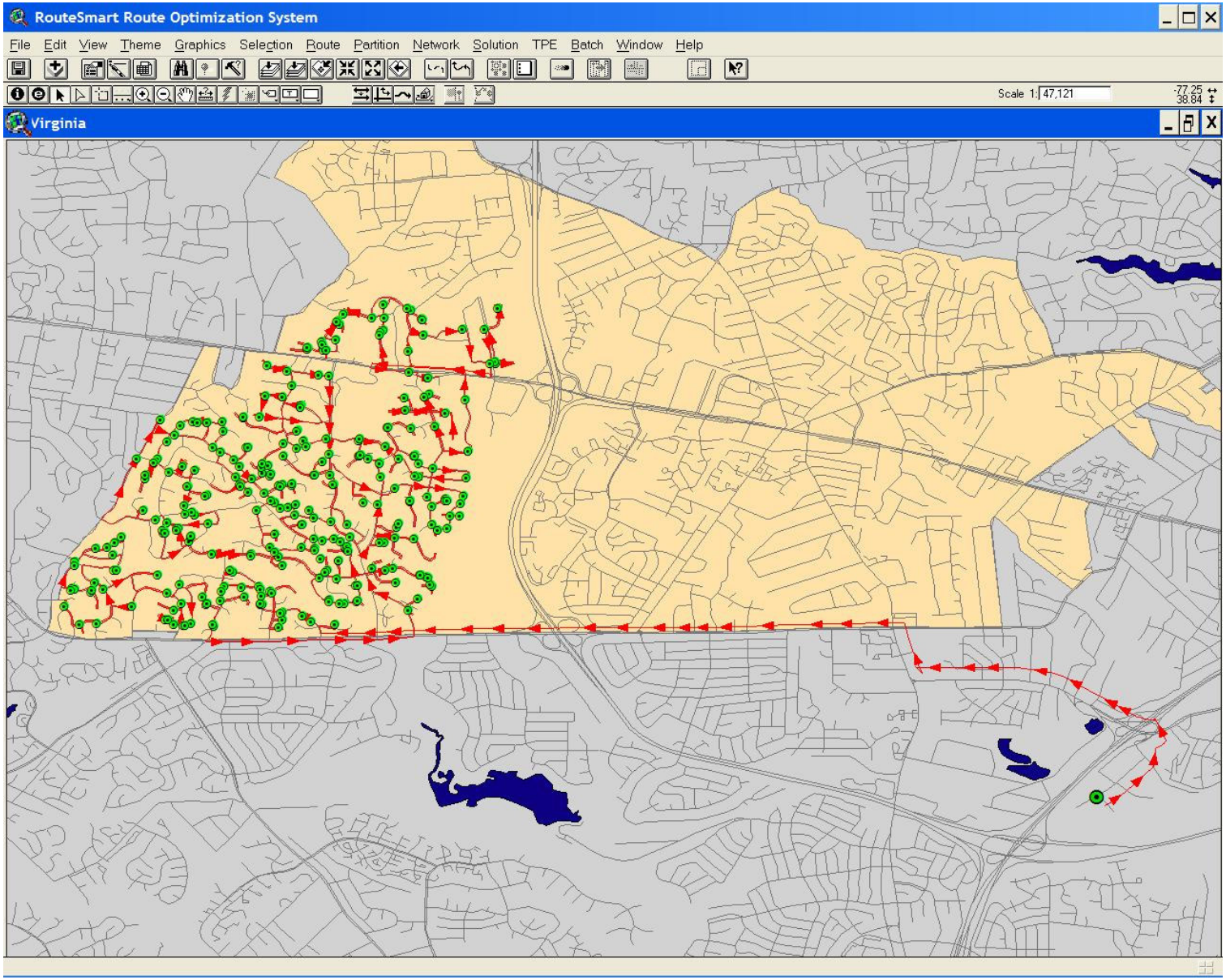
HD: Sequenced Stops as Crow Flies (Streets Suppressed)



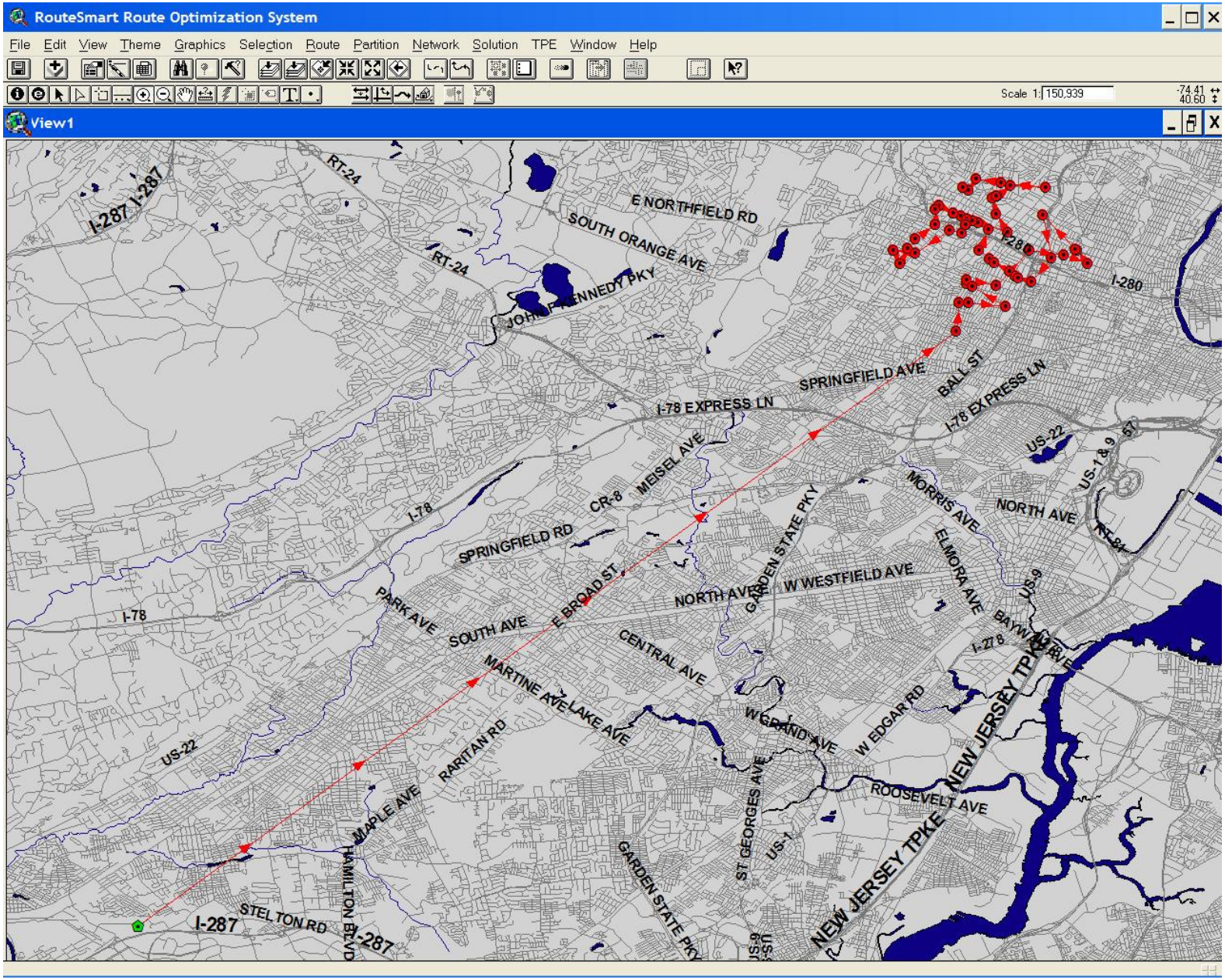
HD: Travel Paths over the Street Network



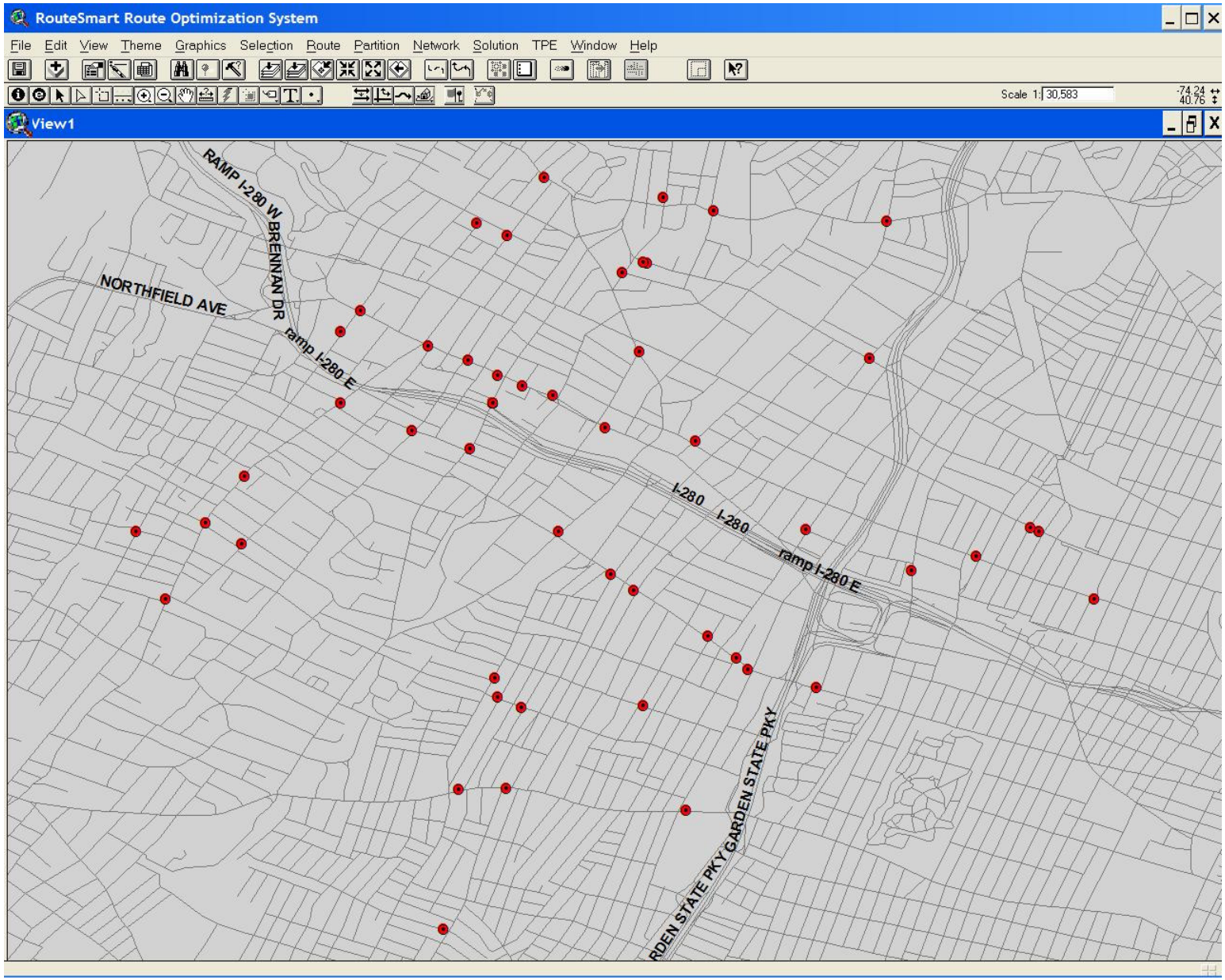
HD: Detailed Display of a Single Travel Path



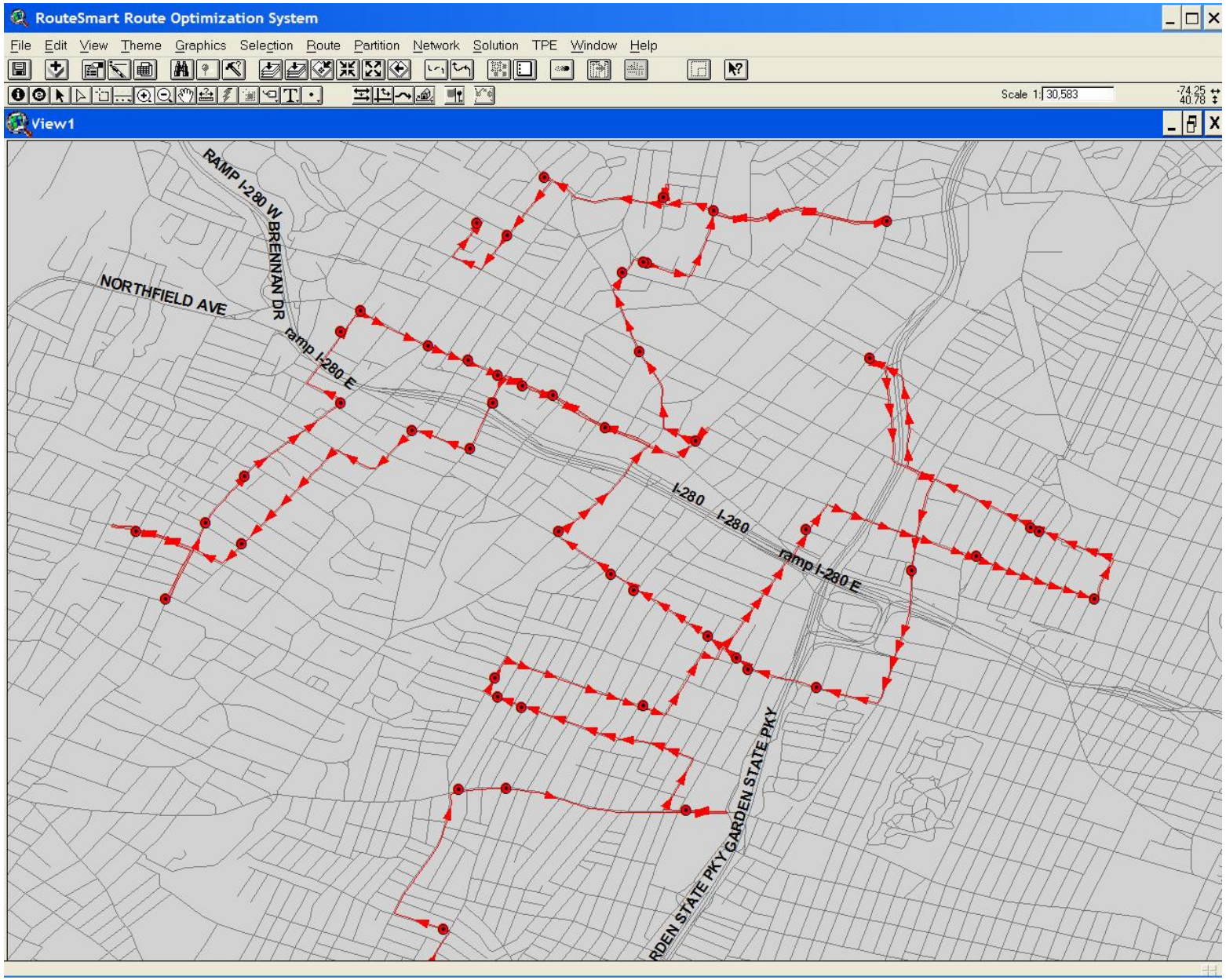
HD: Detailed Display of a Travel Path from the Depot



Single-Copy Routing: Sequence of Stops from the Depot



SCR: Stops and the Street Network



SCR: Travel Path over the Street Network

Newspaper Route Optimization: Then and Now

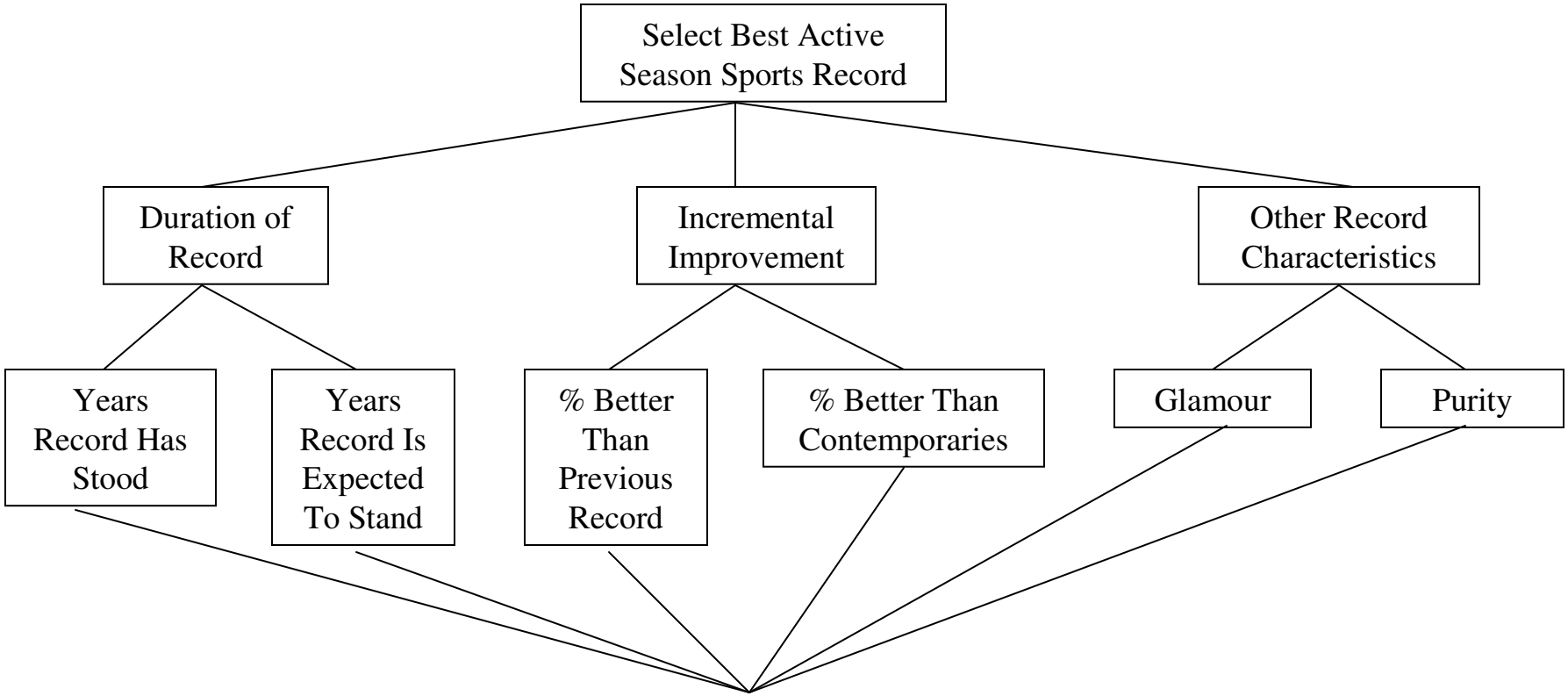
	1974	2004
mapping	wall map with pins, Euclidean distances	sophisticated GIS technology (think Mapquest)
customer locations	static: locate once	daily changes: no problem
driving directions	driver's responsibility	detailed travel path provided each day
goal	just find a feasible set of routes	take full advantage of cost-saving and advertising possibilities

Ranking Outstanding Sports Records

- Address several key questions
  - What makes a “great” sports record?
  - What factors separate “good” records from “great” records?
  - What are the “great” sports records?
- Rank the greatest active sports records
  - season records (discussed here)
  - career or multiple-year records
  - daily or single-game records
- Study conducted in 1986

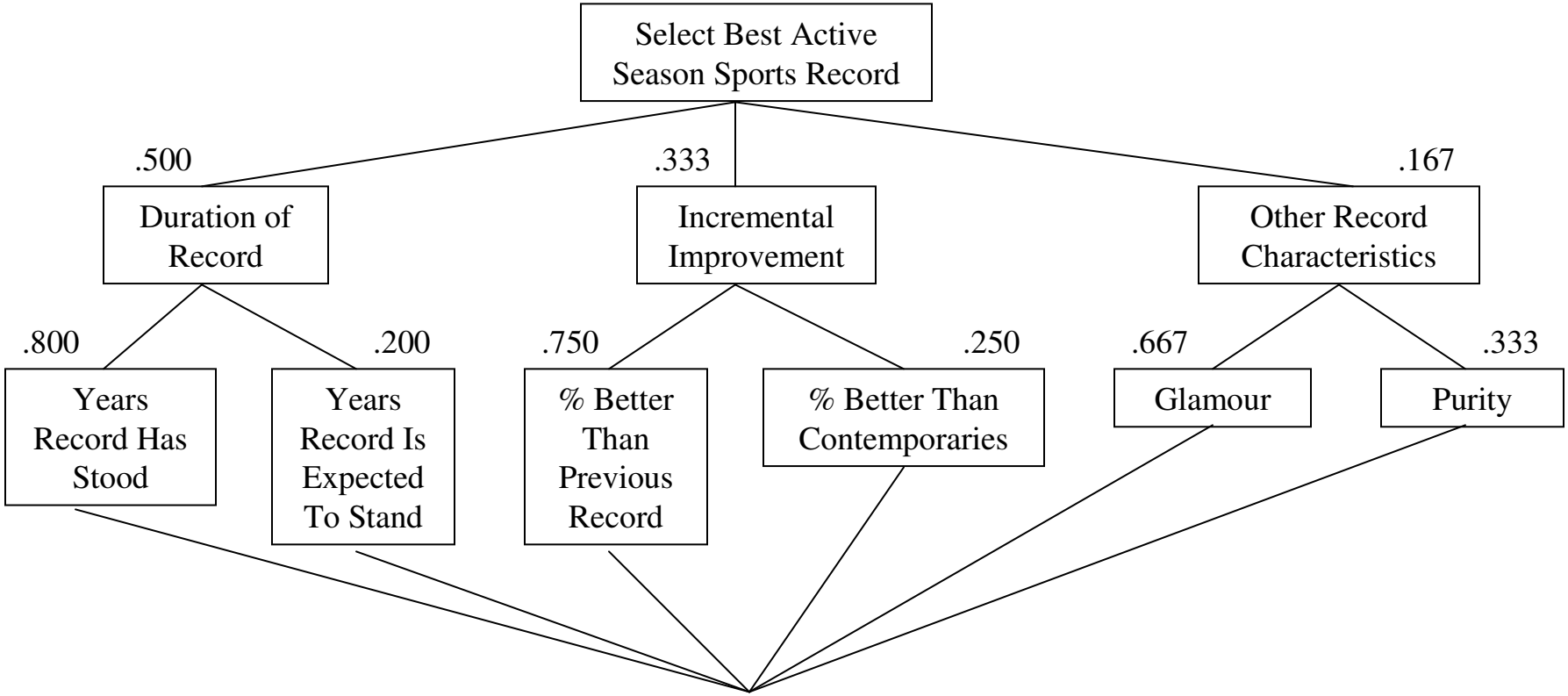
Motivation

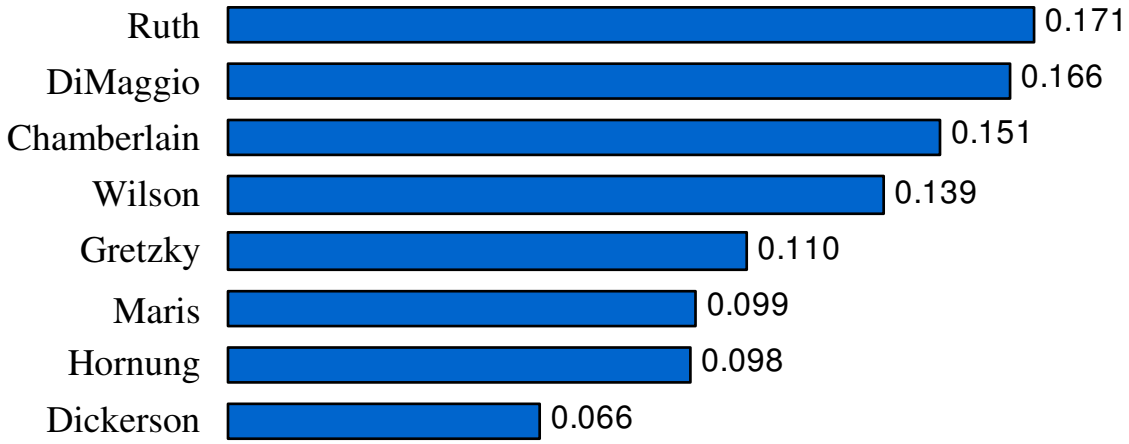
- It's fun to argue the merits of your favorite sports records
- It's a challenge to carry out the comparison in a rigorous and comprehensive manner
- It provides a nontrivial application of the analytic hierarchy (decision-aiding) process (AHP)
- The AHP is based on the concept of pairwise comparisons and a hierarchy, which is very visually informative
- We focus here on season records



DiMaggio	56 game hitting streak
Maris	61 home runs
Ruth	.847 slugging average
Wilson	190 runs batted in
Chamberlain	50.4 scoring average
Dickerson	2105 yards gained rushing
Hornung	176 points scored
Gretzky	215 points scored

Results of 1986 Comparison





Babe Ruth's record was broken by Barry Bonds in 2001

Application of Visualization to College Selection

- Data source: The Fiske Guide to Colleges, 2000 edition
  - Contains information on 300 colleges
  - Approx. 750 pages
  - Loaded with statistics and ratings
  - For each school, its biggest overlaps are listed
- Overlaps: “the colleges and universities to which its applicants are also applying in greatest numbers and which thus represent its major competitors”

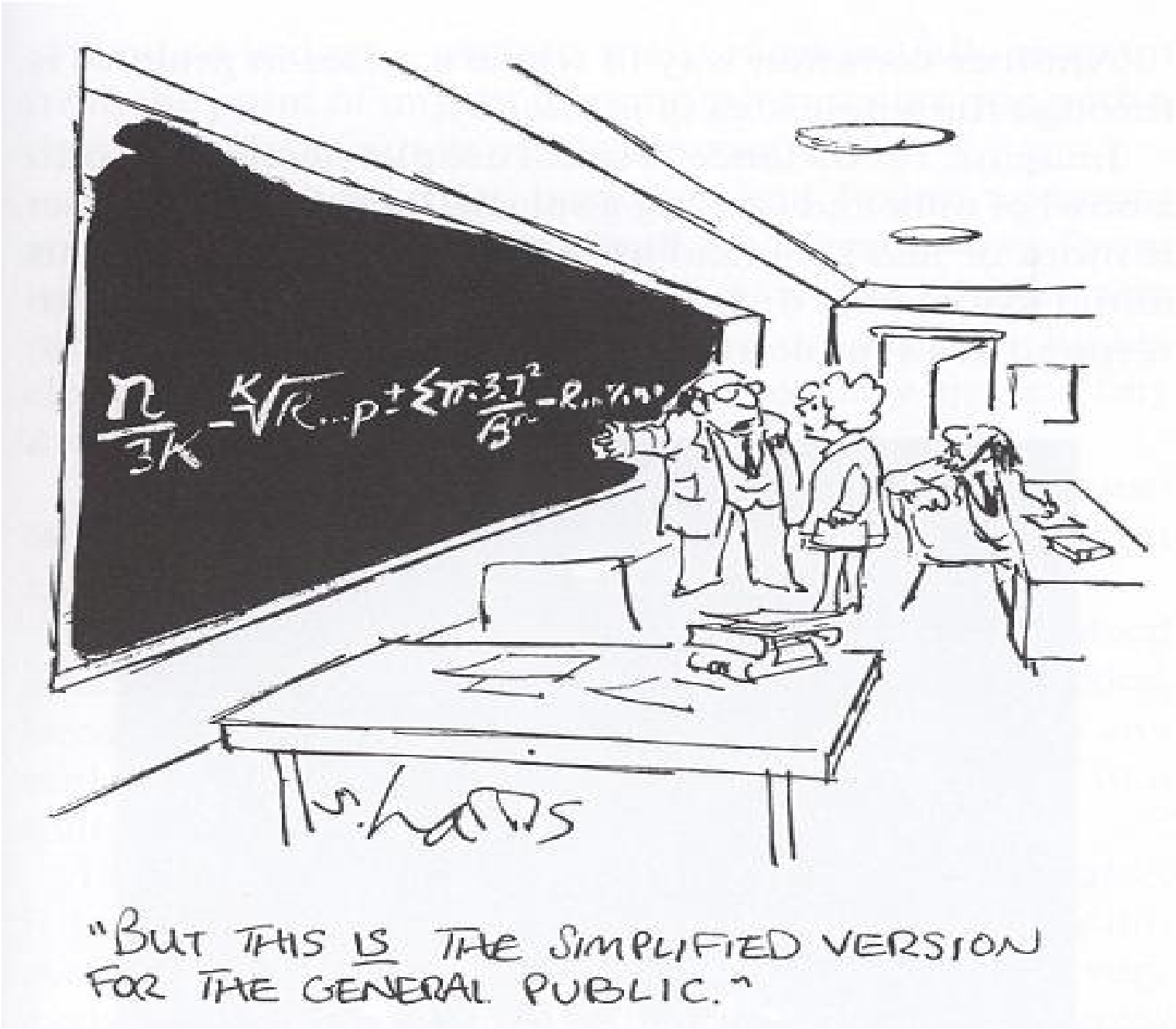
Overlaps and Adjacency

- Penn's overlaps are Harvard, Princeton, Yale, Cornell, and Brown
- Harvard's overlaps are Princeton, Yale, Stanford, M.I.T., and Brown
- If college *i* has college *j* as one of its overlap schools, we say that *j* is adjacent to *i*
- Note the lack of symmetry
  - Harvard is adjacent to Penn, but not vice versa

From Adjacency to a Two-Dimensional Map

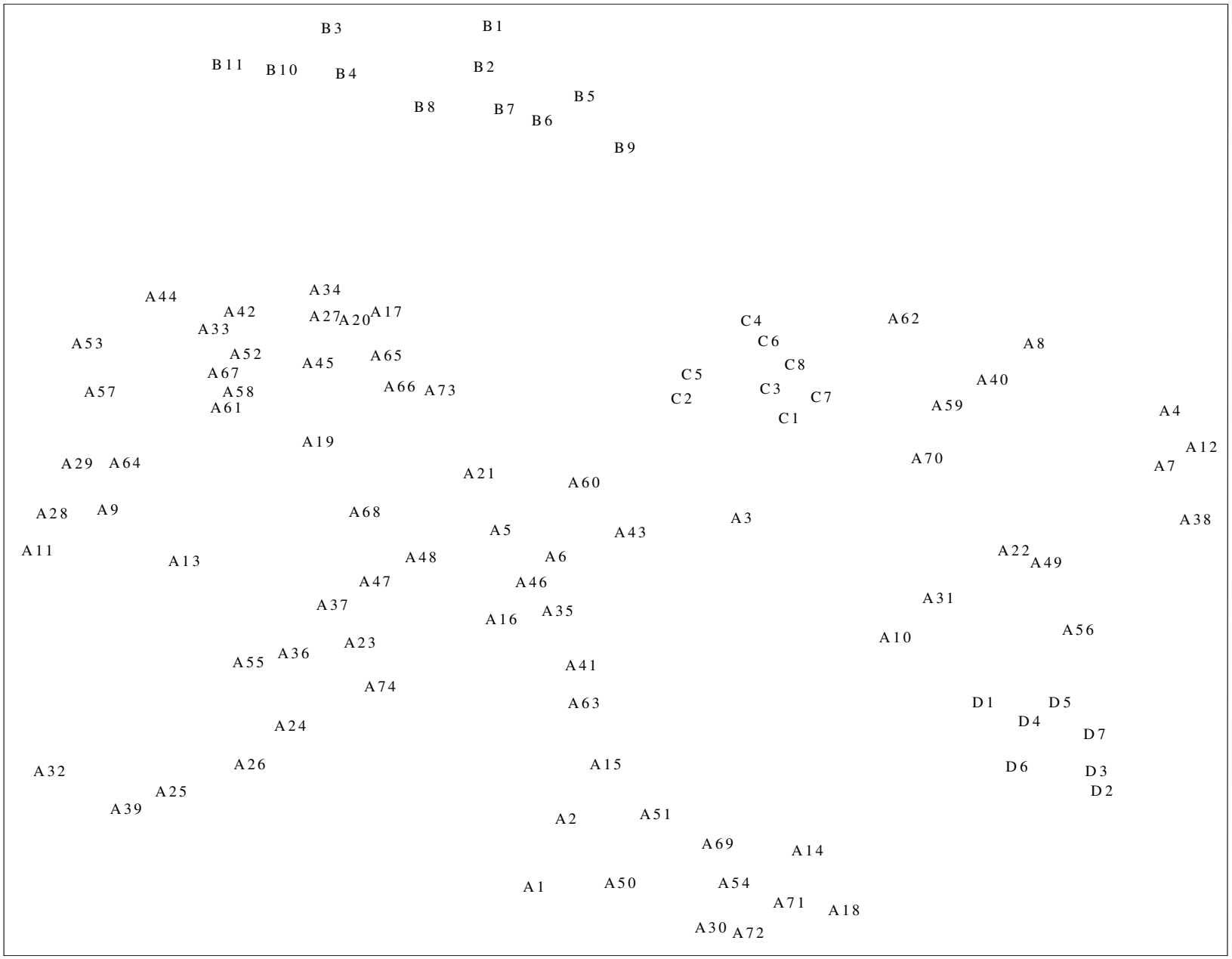
- Adjacency indicates a notion of similarity (not necessarily symmetric)
- If college *j* is adjacent to college *i,* we draw an arc from node *i* to node *j* of length one in an associated graph
- Next, compute the shortest distance between each pair of nodes
- Finally, we solve a nonlinear optimization problem to build a Sammon map

$$\text{Minimize} \quad \frac{1}{k} \sum_{\substack{i=1 \\ i \neq j}}^{n} \frac{(d_{ij} - \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}\,)^2}{d_{ij}}$$

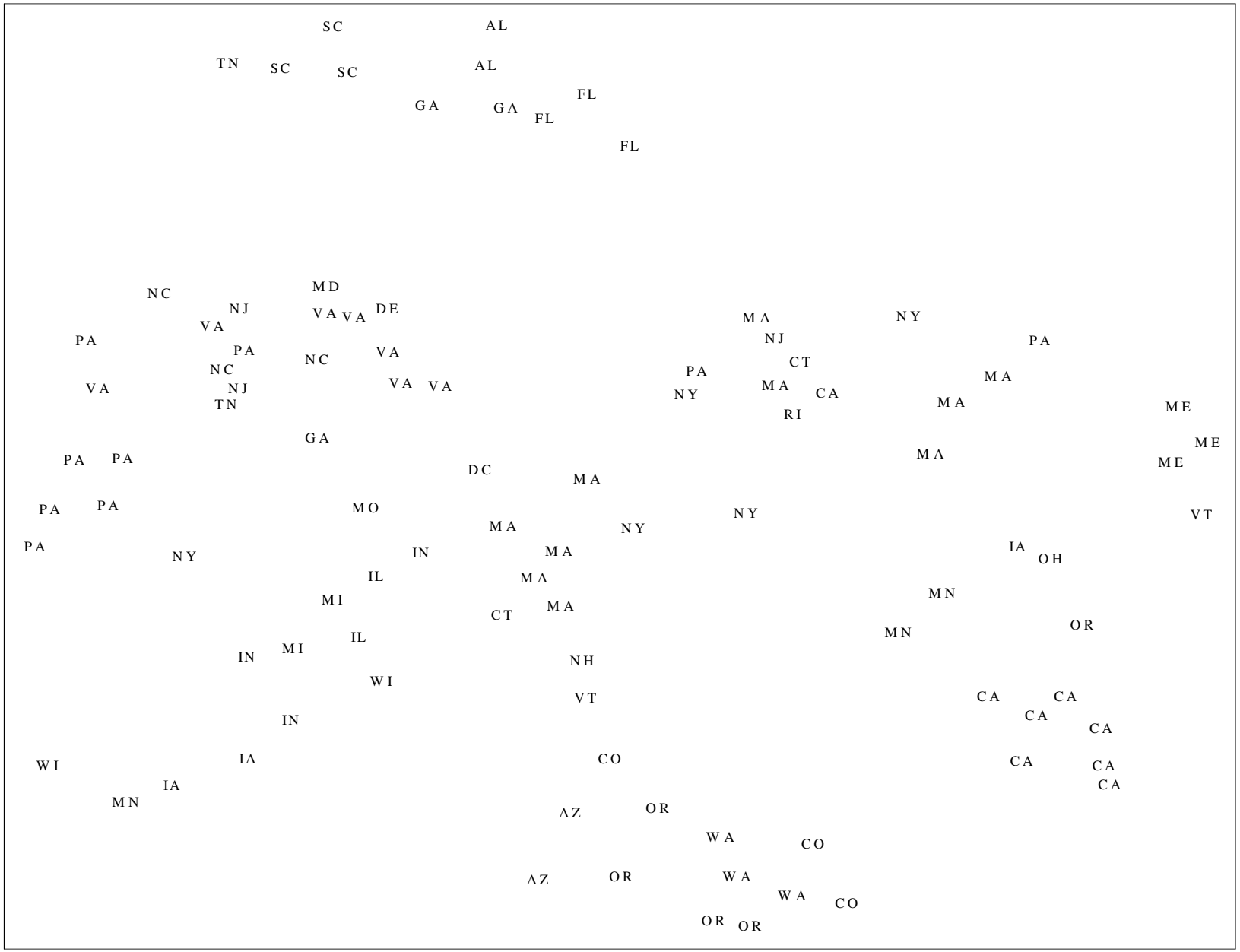

"BUT THIS IS THE SIMPLIFIED VERSION FOR THE GENERAL PUBLIC."

Proof of Concept

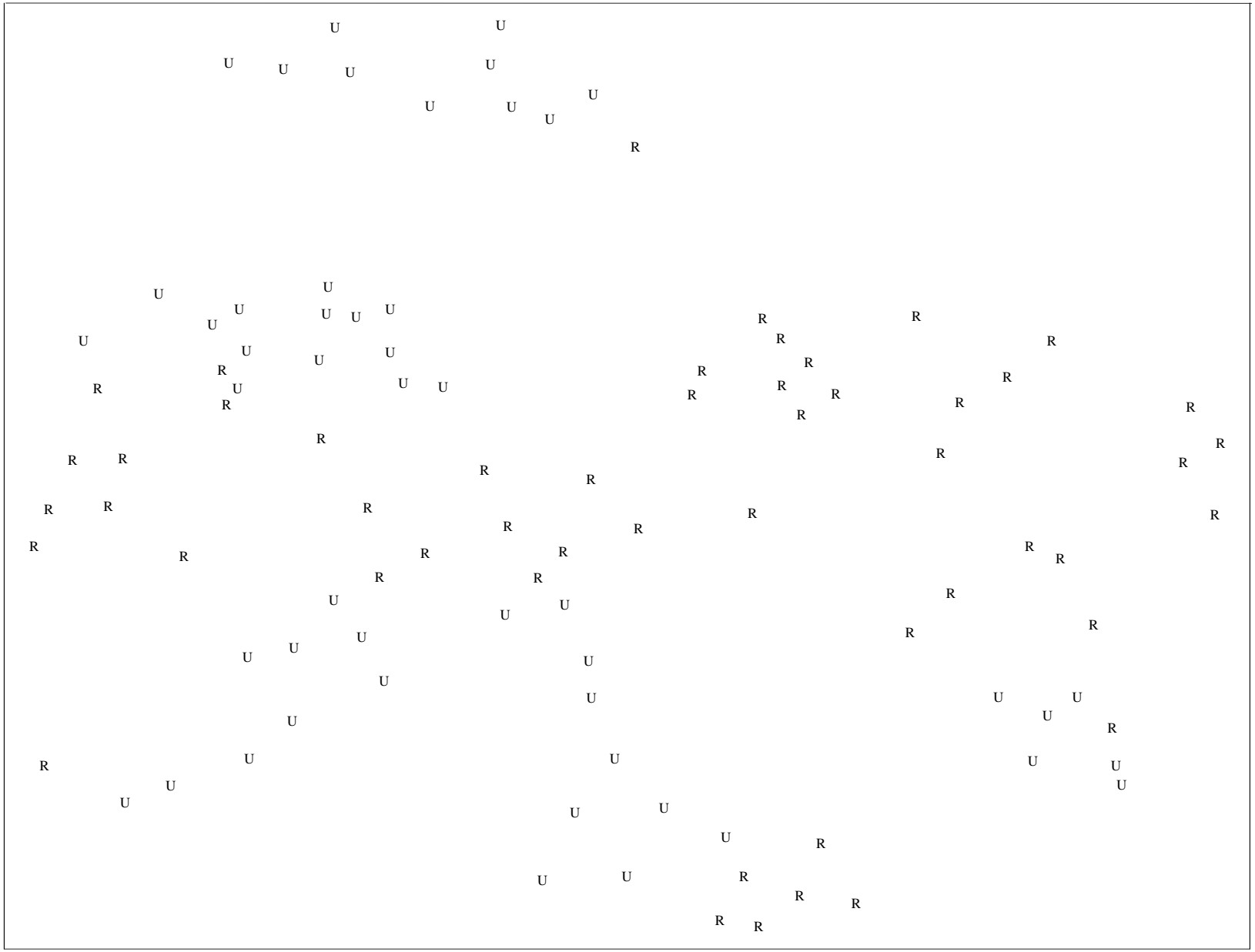
- Start with 300 colleges and the associated adjacency matrix
- There are many groups of colleges that comprise the 300
- We focus on four large groups to test the concept (100 schools)
  - Group A has 74 national schools
  - Group B has 11 southern colleges
  - Group C has 8 mainly Ivy League colleges
  - Group D has 7 California universities



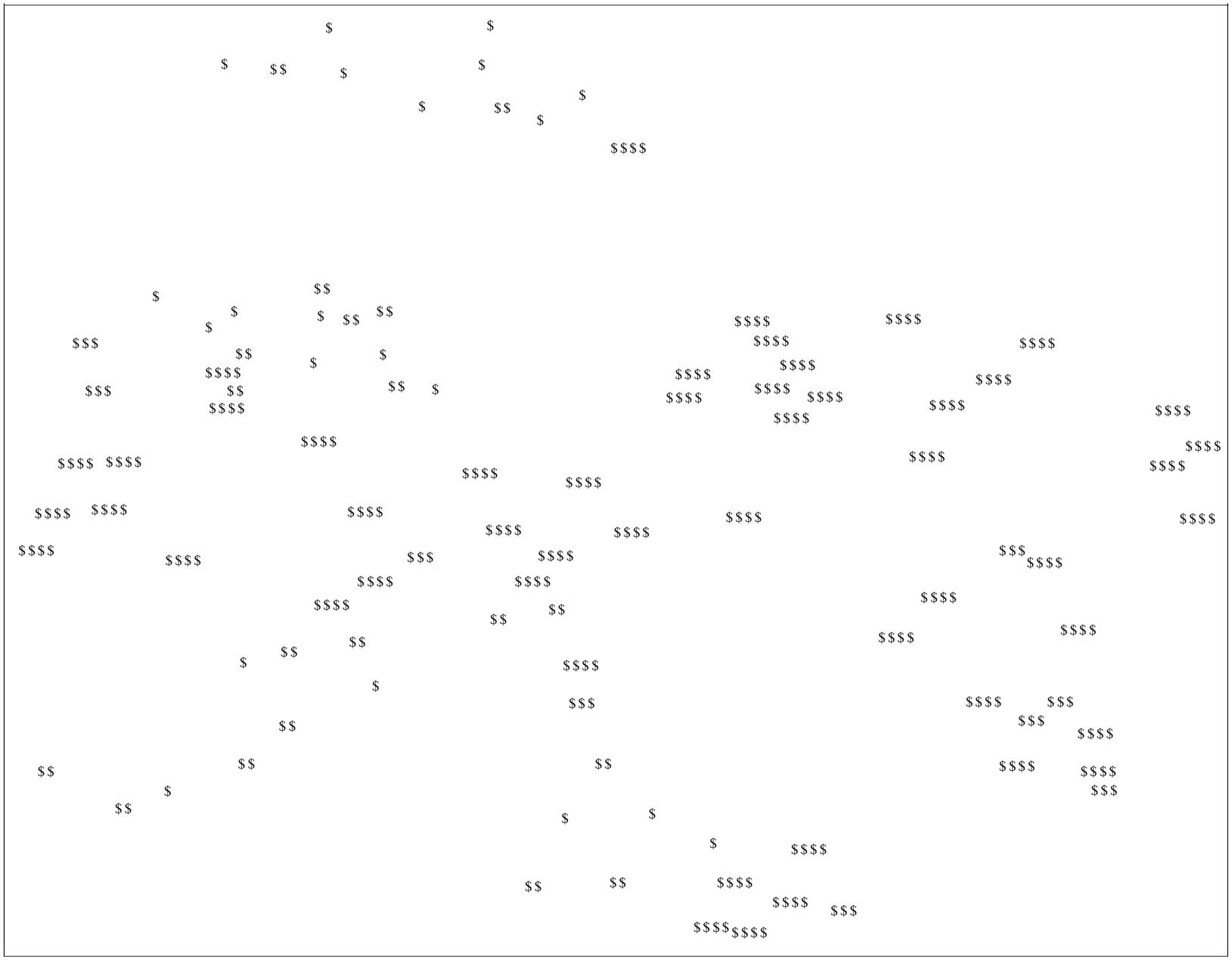
Sammon Map with Each School Labeled by its Group Identifier



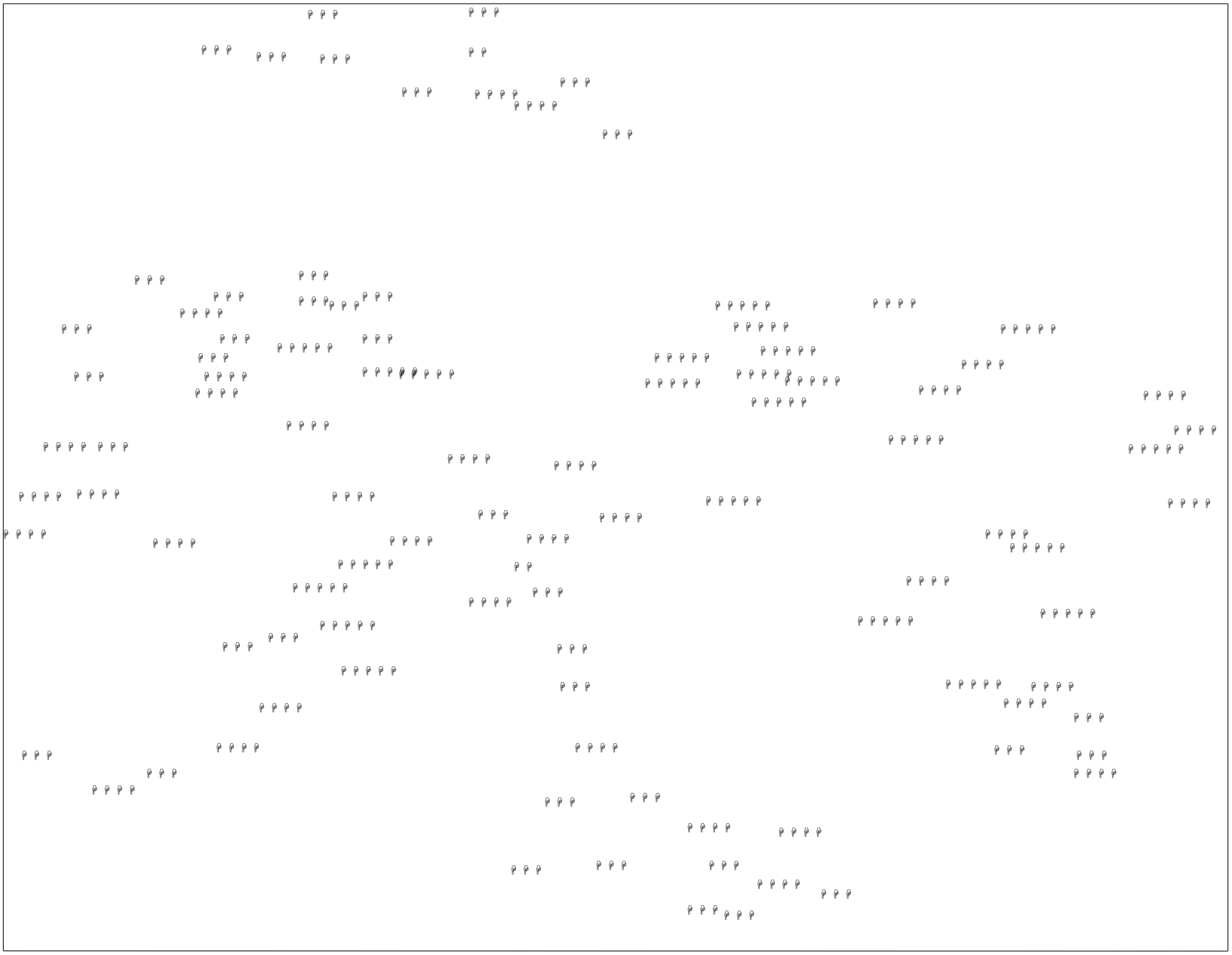
Sammon Map with Each School Labeled by its Geographical Location



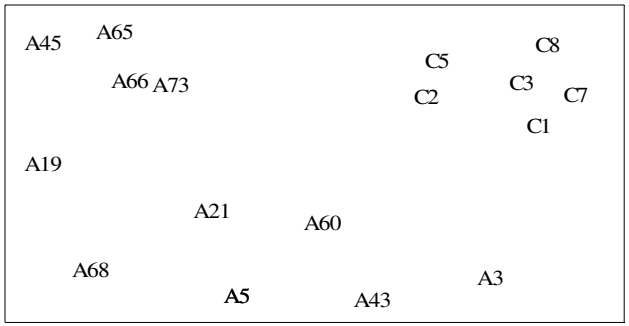
Sammon Map with Each School Labeled by its Designation
(Public (U) or Private (R))



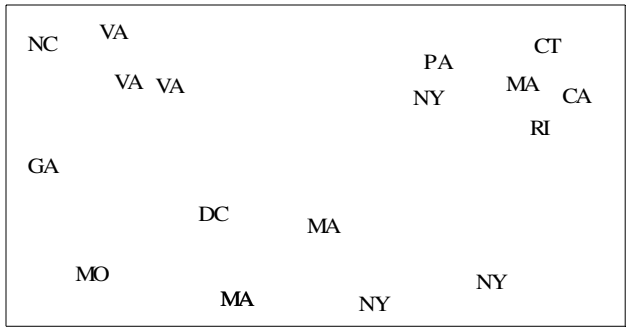
Sammon Map with Each School Labeled by its Cost



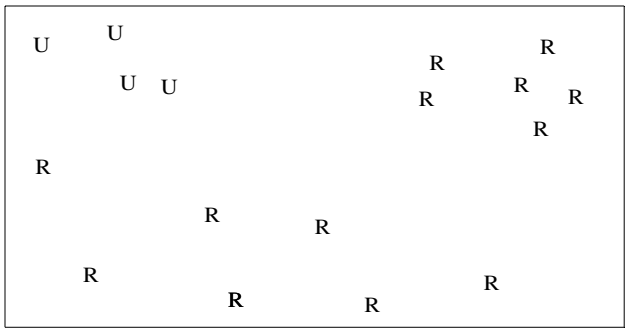
Sammon Map with Each School Labeled by its Academic Quality



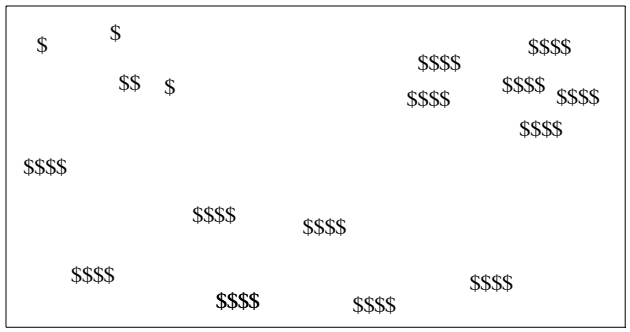
(a) Identifier



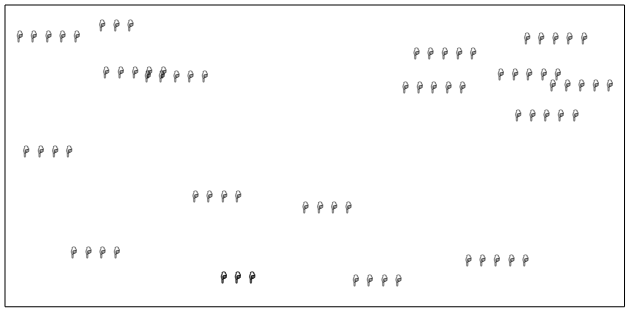
(b) State



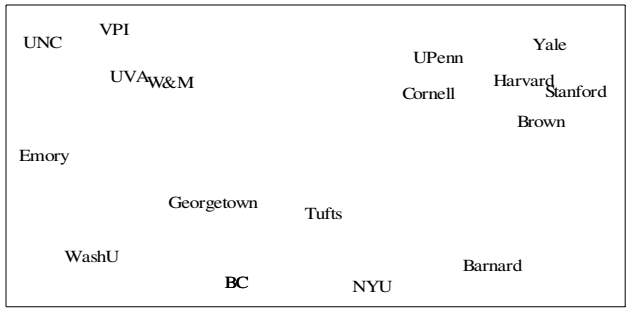
(c) Public or private



(d) Cost



(e) Academics



(f) School name

Six Panels Showing Zoomed Views of Schools that are Neighbors of Tufts University

Benefits of Visualization

- Adjacency (overlap) data provides “local” information only
  - E.g., which schools are Maryland’s overlaps ?

- With visualization, “global” information is more easily conveyed
  - E.g., which schools are similar to Maryland ?

Conclusions

- Visualization helps to sell OR techniques and tools, especially in the commercial world
- Visualization of OR solutions makes them transparent and promotes credibility
- Visualization (and animation) plays a positive role in many other OR applications (e.g., decision trees, clustering, simulation, belief networks)
- Visualization plus optimization is a powerful, winning combination