Road selection.
Overview: a little bit of ...
modelling, ...
interpretation, ...
algorithms, ...
evaluation, ...
Road selection
Road selection • Depends on user task

route map
destination map Kopf et al.
you-are-here map Schmid et al.
Motivating example

• Pedestrian with a smartphone
• Current location available
• Wayfinding to a destination

• Interest in surroundings
• Freedom of movement
• Contrast: in-car sat nav
Road selection

- Edge selection in a graph

:focus-and-context map

route map
Example road network
Example scores

*Betweenness centrality*
From scoring to selection

• Pick a threshold
Betweenness centrality

Consider all shortest paths between all pairs of nodes; count how often each edge is used

Folklore interpretation:

• People are likely to travel shortest paths
• Heavily traveled edges are important
Betweenness centrality

Consider all shortest paths between all pairs of nodes; count how often each edge is used

Probabilistic interpretation:

• Pick a uniformly random shortest path
• Probability that you visit a certain edge
PageRank primer

• Origin in web page ranking
  - (Page, Brinn, Motwani, Winograd... Google)

• Has been applied for predicting human movement (Jiang)

• Usually stated as eigenvector calculation
• Also: interpretation in terms of random walks
Traveler

Random Surfer model

• Hypothetical user is at a web page

• Transitions along a uniformly random link

• All transitions take equal time

• Sometimes jumps to a uniformly random page
Non-uniform transition probability

• Walking along a road segment...
• Coming up to a crossing...
• Where to go...?

• Shortest path? Straight on? Anywhere?

• What’s the network anyway?
  – Web pages, hyperlinks?
Bidirected line graph
Bidirected line graph
Bidirected line graph
Bidirected line graph
Bidirected line graph
Non-uniform transition probability

• At a node of the line graph...
• Follow an arc...
• Where to go...?

• Straight on?
  – Constant given road network
Bidirected line graph
Bidirected line graph
Non-uniform transition probability

- At a node of the line graph...
- Follow an arc...
- Where to go...?

- Straight on?
  - Constant given road network
- Shortest path?
  - Constant given road network and destination
Bidirected line graph
Bidirected line graph
Non-uniform damping

• PageRank jumps to uniformly random node
• Instead, jump to the current user location

Probabilistic interpretation:

• Consider random walk starting at user location
• Constant probability to terminate walk
• Exponential distribution of walk length
• Score of node = probability of going to node
Data set

• OpenStreetMap

• City of Würzburg and surroundings
  – Lower Franconia, Germany
  – Approx $10^5$ nodes

• Examples here: crop to the city itself
  – 3786 nodes, 4987 road segments
Demo
Shortest-path bonus

(a) $\beta_{SP} = 0$

(b) $\beta_{SP} = 1$

(c) $\beta_{SP} = 5$
Non-turning bonus

(a) $\beta_\parallel = 0$
(b) $\beta_\parallel = 5$
(c) $\beta_\parallel = 15$
Runtime of simple implementation

- Calculate PageRank
  - Loop over nodes
  - Distribute score to neighbours
  - Repeat
- Select nodes with high score

- Runtime: ~100 ms
‘Direct’ selection

• Select all nodes with high rank
• Select no nodes with tiny rank

• $O(\log n)$ time
  – Correctness holds almost surely
  – Almost immediately from Borgs et al.’s algorithm for Significant PageRanks.
Really big maps?

1. Just calculate, then select

2. Approximation algorithm:
   - Runtime $O(\log(n) \log(\varepsilon^{-1}) \varepsilon^{-1} \rho^{-2})$

<table>
<thead>
<tr>
<th># nodes</th>
<th>Calculate + Select</th>
<th>Direct selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>3786</td>
<td>~100ms</td>
<td>~200ms</td>
</tr>
<tr>
<td>$10^5$</td>
<td>~10,000 ms</td>
<td>~300ms</td>
</tr>
</tbody>
</table>
Overview

Road network

Scoring

Input

Previous step

Polynomial time

Strokes + Stability

YOU WERE HERE
Road netwerk
Scoring

Betweenness centrality
Overview

Road network

Scoring

Strokes

Stability

You are here

Input

Not our business

Polynomial time

Strokes + Stability

NP-hard
Score cutoff: disconnected
Gaps

• Selection is not necessarily connected
• Simplified example with PageRank weights:
Road selection as optimization

- Edge-weighted graph. Select edges:
  - Maximize weight
    - Fixed number of edges
  - Fixed weight
    - Minimize number of edges

- Connectivity constraint:
  selection must be connected

- **NP-hard** (known as Maximum-Weight Cardinality-k Connected Subgraph)
Score cutoff: interrupted strokes
Road selection as optimization

- Edge-weighted graph. Select edges:
  - **Maximize** weight
  - **Fixed** number of edges
  - **Fixed** weight
  - **Minimize** number of edges

- Stroke **constraint**: on every stroke, selection must be connected
- **Polynomial time** using dynamic programming
Overview

Road network

Scoring

Strokes

Stability

Strokes + Stability

Input

Not our business

Polynomial time

NP-hard
Animated selection

- Road network is constant
- Input: time $\times$ edge $\rightarrow$ score
- Output: time $\rightarrow$ selection

- Discrete time frames
- All scores known in advance
  - E.g. navigation system: route is known
- Compute entire animation
Animated selection
Stability

• Unpleasant: flickering edges
• Solve by optimization

• Possible constraint: single “active range”

• Instead: minimize “switching costs”
Select $k$ edges in every frame
Min-cost flow
Min-cost flow
Min-cost flow
Min-cost flow
Min-cost flow
Overview

Road network → Scoring

Strokes → Stability

Input
Not our business
Polynomial time
NP-hard

YOU ARE HERE
Switching + Stability = \ldots

- Different strokes at each time: NP-hard
- Non-uniform switching costs: NP-hard
- Reduction from Independent Set

- Uniform switching + constant strokes = ???