Web-tool for optimizing locations of health centers

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This collection shows heart patients/hospitals in whole Finland, and time to travel to nearest location for each patient.
STEMI case study

- 22 Health centers (HC)
- 17346 patients (ICD10 codes I21.0-I21.3)
- Patient locations (postal code precision)
- Red patients do not reach HC in time.
- Fast travel-time estimation (almost ready)
Infarctions are serious and **life threatening**. A patient not within **90** minutes of a hospital is considered at Risk.
Infarctions are serious and **life threatening**.
A patient not within **45** minutes of a hospital is considered at Risk.
Web-tool for optimizing
Control parameters

Parameter choices in the tool:

- HeatMap Tools
  - All Heat Maps
  - Risk Threshold Time

- Distance Estimation
  - Distance Estimation
  - Graph Node Size

Distance functions:
- Estimated
- Bird
- Estimated
- True RN

Graph size:
- 512
- 16
- 32
- 64
- 128
- 256
- 512
- 1024

Optimization goal:
- Optimized Risk 90 min
- Health Centers
- Original locations
- Remove two
- University hospitals
- Optimized Locations
- Optimized Distance (Bird)
- Optimized Distance (Road)
- Optimized Time
- Optimized Risk 30 min
- Optimized Risk 45 min
- Optimized Risk 60 min
- Optimized Risk 75 min
- Optimized Risk 90 min
Critical time: 30 minutes
Critical time: 45 minutes
Effect when removing HC
University hospital clusters

- Safe
- At Risk

Road infrastructure supports furthest reach

Travel-Time Clusters

Patients nearest is not always the best choice

Lakes (detours)
Optimization Procedure

Random Swap Algorithm

Fast Travel-Time Estimation

Objective function

\[ \sigma_{Risk}(x) = \frac{1}{1 + e^{-x+90}} \]

P. Fränti
Efficiency of random swap clustering

R. Mariescu-Istodor and P. Fränti
Estimating travel-cost using an Overhead Graph
K-Means

K-Means \((\mathbf{P}, K) \rightarrow (\mathbf{C}, \mathbf{L})\)

Input: points \(\mathbf{P} = \{p_1, \ldots, p_N\}\)
the number of clusters \(K\)

Output: cluster centers \(\mathbf{C} = \{c_1, \ldots, c_K\}\)
cluster labels \(\mathbf{L} = \{\text{label}(i), \ i=1, \ldots, N\}\)

Randomly choose \(K\) initial centers \(\mathbf{C} = \{c_1, \ldots, c_K\}\)

REPEAT
\(\mathbf{C}_{\text{previous}} \leftarrow \mathbf{C}\)
FOR all \(i \in [1, N]\) DO \ // Partitioning
\(\text{label}(i) \leftarrow \text{arg min} \ d(p_i, c_j)\)
FOR all \(j \in [1, k]\) DO \ // Centroid update
\(c_j \leftarrow \text{Average of } p_i, \ \text{whose } \text{label}(i) = j\)
UNTIL \(\mathbf{C} = \mathbf{C}_{\text{previous}}\)
K-Means: Partitioning

K-Means \((P, K) \rightarrow (C, L)\)

Input: points \(P = \{p_1, \ldots, p_N\}\)
the number of clusters \(K\)

Output: cluster centers \(C = \{c_1, \ldots, c_K\}\)
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Estimating travel using Overhead Graphs

North Karelia
Overhead Graph: Node density

512 nodes

Helsinki

Joensuu

Jyväskylä
Two cost functions

**Optimizing Travel-Time**

\[ f(x) = x \]

**Optimizing Risk**

\[ f(x) = \frac{1}{1 + e^{-x+90}} \]

![Graph showing travel-time and risk optimization](image)
Experiments
Euclidean distance
Travel time

Facility Optimizer

Stemi

Travel-time

Map Satellite

5132 (30 %)

5401 (31 %)

23 Health centers

23 Optimized locations

Collections

Distance Estimation

Distance Estimation

Graph Node Size

512

HeatMap Tools

Patient allocation

All Heat Maps

Critical Time

45 Minutes

Statistics table
Optimization results

Current Locations

45 min
At Risk: 5389
90 min
At Risk: 832

Optimized Locations

45 min
At Risk: 3973
29%
90 min
At Risk: 135
1%
## Summary of results

<table>
<thead>
<tr>
<th>Optimization Function</th>
<th>Bird Distance</th>
<th>Travel Distance</th>
<th>Travel Time</th>
<th>At Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original HC Locations</td>
<td>29.0 km</td>
<td>36.6 km</td>
<td>35.3 min</td>
<td>832 (5 %)</td>
</tr>
<tr>
<td><strong>Bird Distance or time (fixed speed)</strong></td>
<td><strong>27.9 km</strong></td>
<td>36.1 km</td>
<td>36.2 min</td>
<td>792 (5 %)</td>
</tr>
<tr>
<td>Travel Distance</td>
<td>28.4 km</td>
<td><strong>34.7 km</strong></td>
<td>34.1 min</td>
<td>519 (3 %)</td>
</tr>
<tr>
<td>Travel Time</td>
<td>29.8 km</td>
<td>36.8 km</td>
<td><strong>34.0 min</strong></td>
<td>488 (3 %)</td>
</tr>
<tr>
<td>Sigmoid (Travel Time)</td>
<td>44.3 km</td>
<td>54.9 km</td>
<td>48.6 min</td>
<td><strong>135 (1 %)</strong></td>
</tr>
</tbody>
</table>

- Travel times and distances are estimates using the overhead graph
Total patients: 17,346

<table>
<thead>
<tr>
<th>Test-case</th>
<th>At Risk*</th>
<th>Time</th>
<th>Distance</th>
<th>Hospitals in Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>All Hospitals</td>
<td>5,401</td>
<td>73 min</td>
<td>79 km</td>
<td>51 %</td>
</tr>
<tr>
<td>Two Removed**</td>
<td>5,775</td>
<td>75 min</td>
<td>82 km</td>
<td>49 %</td>
</tr>
<tr>
<td>University hospitals</td>
<td>11,570</td>
<td>121 min</td>
<td>142 km</td>
<td>33 %</td>
</tr>
</tbody>
</table>

* Round trip to nearest hospital > 90 minutes
** All Hospitals except Savonlinna and Länsipohja
Changes in detail
Jyväskylä moved to logistically better location at Tikkakoski.
Kontiolahti better location to catch Lieksa and Nurmes
South Finland reconstruction

- Åland will have own
- Turku moved to Salo
- Lappeenranta moved to Taavetti
- One is enough for Helsinki
- ... but in Mäntsälä
Optimized using Euclidean distance

Optimized using travel time
Optimized for travel time
Conclusions

• Web-tool for optimizing health center locations
• Support: Euclidean, travel distance, travel time, patients at risk
• Optimizing for patients at risk increases average time.