

Engineering Location Based Pathfinding on Indian Road Networks Over Low End Mobile Phones ¹

Siddharth Jain R. K. Ghosh & R K Shyamasundar

IIT-Kanpur/TIFR

January 9, 2010



¹Microsoft, DST-ITPAR & Research I Foundation

Problem statement

- No single position sensing technology can meet requirements of Location-Aware Services.
- Many Value added services (VAS) can operate with tolerable approximations.
- Our focus is personalized, location based navigation on Indian roads as a path cost optimization problem over semi-structured graphs.
- Aim is to create a framework for navigation and other similar location based services available on low-end mobile phones.



The technique



We need to solve two basic problems:

- Finding source location (destination provided by user).
 - We combine existing location finding approaches to define a technique that can take advantages of signals from various networks such as GSM, WiFi, terrestrial GPS, and GPS.
- Getting a route map from source to destination.
 - We used google map APIs, and
 - Created our own route database.



Creating road network database



Centralized creation of database will be difficult for unorganized countries like India.

- A semi-automatic browser-based tool was built for collaborative community assisted database creation (similar to wikimapia).
- Our experiments involved real road networks for 4 cities in North India (Delhi, Agra, Meerut and Kanpur).
- It produced more accurate navigational directions than existing map services



Creating road network database

Arcs Insertion & Deletion Page



Source location



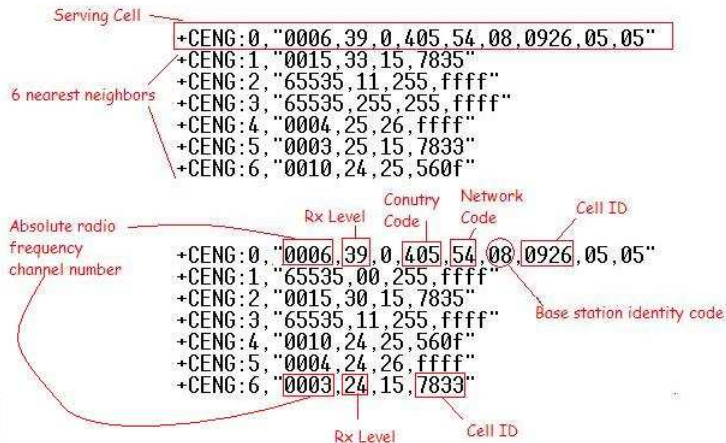
GSM infrastructure leveraged for estimating location of the phone user.

- A GSM module (a basic circuit connecting to GSM Network) is used for the same.
- An application was written for controlling this module.



Source location

The output includes measurement of signal strength in serving cell and other 6 neighboring cells.



Source location

- Theoretical range of GSM BS is 35Km.
- But micro-cellular structure is employed in urban settings, where cell range is just about 100 meters.
- In most cases, for low-end mobile phone users the location estimation is ok.



Fingerprinting

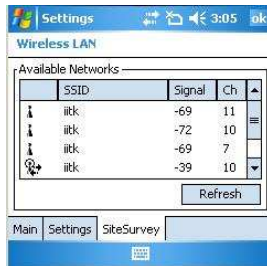
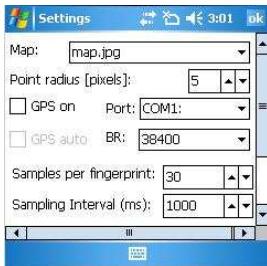


If more accurate estimation of location required, signals from WiFi n/w can be used.

- Fingerprinting with WiFi AP was employed.
- A Windows Mobile 5.0 PocketPC was used to collect signal strength data for fingerprinting experiment.
- Initially a geo-referenced image of testing area is fed as input.
- A surveyor takes PocketPC to different points, and collects fingerprint looking at the geo-referenced image.
- S/w collects signal strengths of corresponding fingerprint.



Fingerprinting





Three main components of this prototype are:

- Localization: network assisted localization of mobile device.
- CBH (Cluster based hierarchical) shortest path: a shortest path algorithm which scales up easily and take advantage of system wide caching.
- Services: a framework for rendering service over conventional ERP system architecture with modifications for rendering final result to client using mobile device.





Hierarchical structure in road n/w

- An implicit hierarchy imposed when viewing large n/w
- Details abstracted out, complexity of information increase from highest to lowest level.
- Problem is partitioned into different hierarchical levels and path finding is done in smaller subnetwork.
- Paths thus computed are close to shortest possible paths.



Cognitive clustering

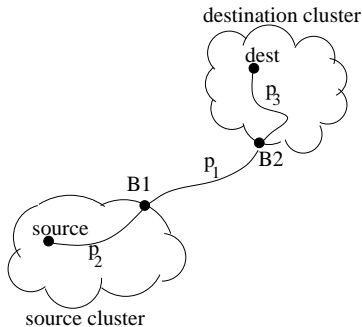


Proximity structure

- While examining a map nodes on a road n/w arranged on the basis of spatial information. Nodes closed to region "Delhi" belong to spatial cluster "Delhi"
 - Density of points of interest: cities will have more nodes
 - Density of interconnections between nodes: nodes inside a city will have more number of interconnections



Path finding



The algorithm

- Find shortest path between boundary points $B1$ and $B2$
- Then find shortest path between source and $B1$
- Finally find shortest path between destination and $B2$
- Assemble the three paths found as above



Client component

To make pathfinder service available on mobile phones we built a generic SMS based content delivery system.

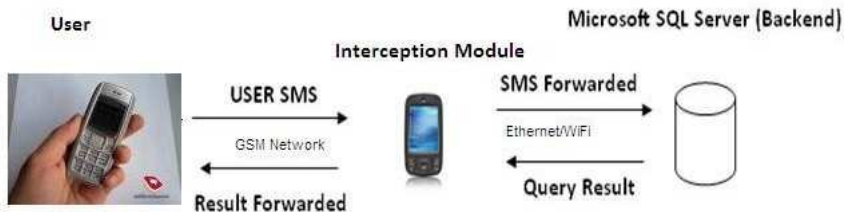
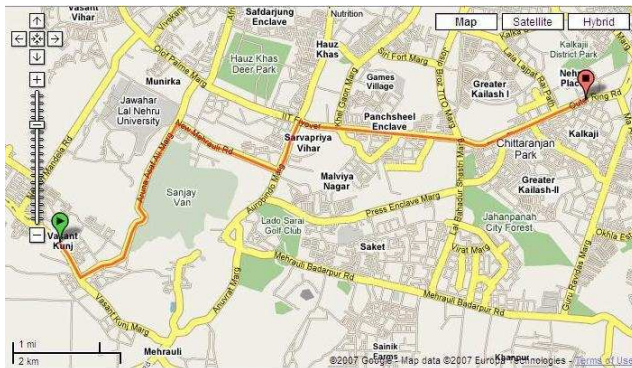


Figure 1: Basic Framework



Driving instructions from our algo



- 1) Vasant Kunj - 0.747 km on Abdul Gaffar Khan Marg - Fortis Hospital
- 2) Fortis Hospital - 1.418 km on Aruna Asaf Ali Marg - Inter University Accelerator Centre
- 3) Inter University Accelerator Centre - 1.647 km on Aruna Asaf Ali Marg - Indian Institute of Mass Communication
- 4) Indian Institute of Mass Communication - 0.678 km on Aruna Asaf Ali Marg - National Institute of Immunology
- 5) National Institute of Immunology - 2.096 km on New Mehrauli Road - NCERT
- 6) NCERT - 1.009 km on Aurobindo Marg - IIT Flyover
- 7) IIT Flyover - 0.731 km on Gamal Abdel Nasser Marg - Panchsheel Flyover
- 8) Panchsheel Flyover - 1.086 km on Gamal Abdel Nasser Marg - Panchsheel Enclave
- 9) Panchsheel Enclave - 1.179 km on Gamal Abdel Nasser Marg - Chirag Delhi
- 10) Chirag Delhi - 1.462 km on Outer Ring Road - Chittaranjan Park
- 11) Chittaranjan Park - 0.474 km on Outer Ring Road - Kalkaji
- 12) Kalkaji - 0.596 km on Outer Ring Road - Nehru Place



Snapshot of algo execution

The screenshot displays a web-based application interface for finding shortest paths on real maps. The application is titled "Shortest Paths on Real Maps" and includes a menu bar with "File" and "Help".

On the left side, there are input fields for:

- Source Cluster: Delhi (selected), Faridabad (available)
- Dest Cluster: Delhi (selected), Faridabad (available)
- Source Node: Lodhi Hotel:207 (selected), AIIMS Flyover:208 (available)
- Dest Node: Munirka:75 (selected), Munirka II:77 (available)

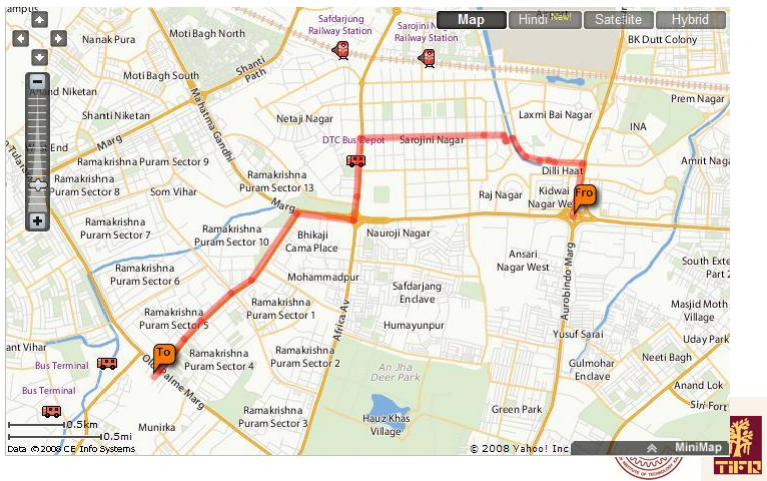
Below the input fields are several buttons:

- Generate Shortest Path (A*)
- Generate Shortest Path (ECA)
- Add Path to Cache
- Read from Cache

The main area shows a map of Delhi with a highlighted shortest path in green. The path starts at a red pin near Lodhi Hotel and ends at a green pin near AIIMS. The path follows the following route: Lodhi Hotel → Vashokan Marg → Rama Krishna Puram → Mahatma Gandhi Marg → Safdarjung Enclave → AIIMS.

The map includes a scale bar (0 to 2000 meters), a north arrow, and a "View Map" button in the top right corner. The map data is attributed to Google, NFGIS, and EuroData Technologies.

Snapshot of Yahoo execution



Additional work

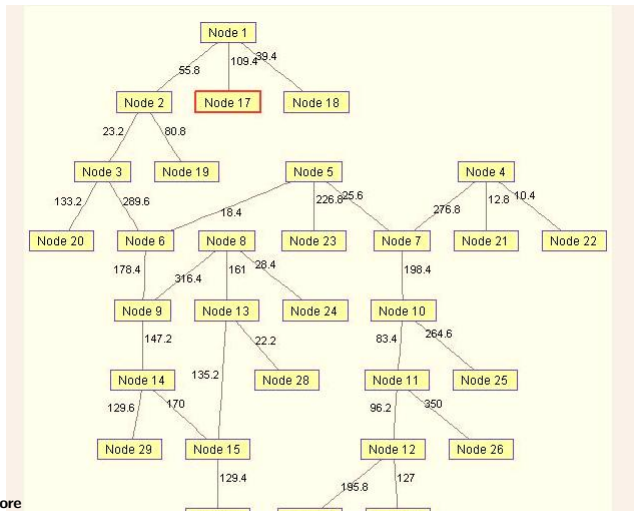
Straight From Images: Initial Map



Thinned map



Node Labelling



Deriving the Node Labelling

- The image is turned into a graph whose nodes are labeled by distinguishing between the points which represent crossing of two curve/lines and boundary points.
- The crossings has been referred to as intersection points and boundary points as end points.



Deriving the Node Labelling

- The image is scanned from top to bottom row-wise and Intersection points are labeled starting with 1 from in the order they are encountered during the scanning.
- The labeling of Intersection points are done after intersection points have been labeled. If there are m intersection points, then labeling of endpoints starts from $m+1$ onwards.
- Labeling of end points adjacent to intersection point i_1 is done before labeling those adjacent to intersection point i_2 , if $i_1 < i_2$.
- End points attached with first node will be labeled before labeling end point of any intersection points. End points attached to 2nd intersection point will be labeled after this and so on.
- Labeling order of the end point of a single intersection point (i,j) is carried out according to a feasible order (If end point is attached to intersection point at no. 1 as in above fig. has been labeled first and then 2, 3, 4, 5,6,7,8.)



Summary

- A shortest path finding algorithm for road n/w that captures human cognition.
- CBH with caching outperforms all and generates shortest path in most cases.
- A web-based tool built for collaborative community assisted creation of road database
- A prototype for pathfinding service also built
- Currently it displays route maps/driving instruction between source destination pairs for few cities in north India.
- Deriving maps directly from images

