Connected Commute

Hyperpersonalised cost efficient travel

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TATA CONSULTANCY SERVICES

IN BRIEF

Two seemingly different problems are discussed here: multimodal urban commute and airline routing. Today, urban commuters face multiple challenges in the form of congestion, unpredictable travel times, and unoptimized transportation networks. City planners are under tremendous pressure to improve cost efficiency while responding to events near real time. Similarly, in air travel, service providers operate on very thin margins while the travelers are compelled to optimize their journeys through tedious manual planning. In response to such challenges, stakeholders are leveraging the computing power of smartphones, pervasive network of sensors, and machine learning algorithms to make commute easier.

This article describes our research on development of commodity sensor-based traffic prediction and multimodel navigation systems and their extensions to the airline route optimization problem.

Traditional travel industry business models are being undercut by technology-based services

Rapid urbanization and population growth are exerting enormous pressure on transportation resources, be it urban commute or long-distance travel. Traditional travel industry business models are being undercut by technology-based services such as cab aggregators, and online travel portals. To enable better traffic management and ease of commute planning, our research team has looked at four problem areas: instrumentation, analytics, real-time navigation, and journey planning.

Instrumentation

Extensive instrumentation in developing countries is a necessity for city administrators to efficiently manage congestion. Unfortunately, most developing cities aren't sufficiently instrumented.

Developed countries, on the other hand, now face the complications of too much instrumentation. Cities such as London and New York have expert teams like Transport for London (TfL) and Department of Transport (DOT), respectively, to plan, monitor, and optimize their transportation resources. The

Fact File

TCS Research: Data and Decision Sciences (DDS) / Intelligent Transport Systems (ITS)

Outcomes: TCS Multi-modal Trip Planner Application, Pilot Instrumentation, Prediction Module, Smart Journey Planner, Live Navigation, and Routing Platform

Principal Investigator: Arvind Ramanujam

Academic Partners: Indian Institute of Technology, Madras

Techniques used: Machine Learning, Open Source Routing Machine, Computer Vision, Geographic Information System (GIS), Sensor Fusion

Industries benefited: Travel, Transportation

Patents: 5 filed

Papers: 4 in Tier-1 Journals and Conferences

accuracy of predictive analysis is high, thanks to the large amounts of instrumentation data collected over time. Now, many of these hardware devices have become redundant and thus expensive to maintain. These cities are migrating toward predictive analysis tools while reducing their instrumentation footprint.

Most of the instrumentation devices such as induction loop counters, cameras, and lasers are tailored for western traffic conditions. They may not work well in developing countries where lane separations are nonexistent and vehicle types are highly heterogeneous. Thus, there is a need for a cheap, scalable instrumentation architecture that adapts well to the traffic conditions in these countries.

Prediction and Analytics

Prediction and analytics services based on instrumentation require clean and reliable data for good results. This is often not possible in developing countries. The data is noisy and unreliable. Data quality issues also arise due to ad hoc planning and changes by transportation authorities. Unplanned events increase the fragility of the transport system and pose additional challenges.

Real-time Routing and Navigation

Today, navigation app users rely on static schedules to plan their journey. These apps often provide inaccurate start and arrival times. Real-time scheduling can help users obtain accurate and latest information on temporary transport inconsistencies and delays. Real-time navigation view across all modes of transport can help the user enjoy a seamless journey experience. Therefore, data from historic trends and current traffic conditions must be fused to provide correct navigation cues.

The accuracy of predictive analysis is high, thanks to the large amounts of instrumentation data collected over time

"Someplace where the food is terrible, the weather stinks and the rooms are filthy. My wife loves to criticize!"

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High-performance Long-haul Journey Planning

For an airline, multimodal long-haul journey planning with the help of search engines had its share of challenges:

- With the addition of every new mode and every connection/ break in journey, the search options explode by many orders of magnitude.
- The network throughput required to service millions of queries per second, when search options explore was very high.

Therefore, it was decided making incremental changes to the airline's existing platform was untenable.

Solution Approaches

For each of these problem areas, we initiated research with our academic partners. Our anchor customers allowed us to work on validated datasets and test solution approaches.

Instrumentation

To monitor the traffic, we worked on an approach that uses:

- Wi-Fi-enabled MAC scanners deployed at specific points of interest (POIs) between which we can track data (MAC address and time) anonymously from the various mobile devices that cross these points.
- GPS devices on public transport to capture geospatial information along with time, which can be used in predicting the arrival and travel times.
- Traffic cameras, to capture the live feed information of city traffic flow patterns.
- Social media platforms like Twitter to extract sentiments regarding the city traffic.

Commercial-grade sensors and cameras were chosen for their simplicity, ruggedness, and ability to work in difficult conditions including unreliable power supply, dust, and irregular maintenance schedules. Their limitations in data accuracy, consistency, and quality were managed in the data processing pipeline.

Prediction and Analytics

The sensor and camera data were processed using a combination of domain-based techniques and machine learning techniques. Domain-based techniques include a flow-based model (spatial and temporal). Data-driven techniques include:

- Artificial Neural Networks (ANN), K-NN (k-nearest neighbors), SVM (Support Vector Machine)
- Image processing with deep learning and custom training sets
- Time series analysis

Data noise was reduced with domain-based preprocessing techniques. Custom image

Real-time scheduling can help users obtain accurate and latest information on temporary transport inconsistencies and delays processing techniques were developed to deal with heterogenous vehicle types, lane splitting, and non-uniform lighting. The state of the traffic network and public transportation system were tracked in real time along with future projections.

Real-time Routing and Navigation

With an accurate tracking of the present and future state of the network, a custom routing algorithm was engineered fusing schedule-based (RAPTOR algorithm) and topology-based (contraction hierarchy) routing techniques. This provided multimodal capabilities to the end user. The state and the validity of a route under navigation were constantly evaluated against the evolving network state. Based on a custom scoring mechanism, alternate routes were computed and provided to the user.

High-performance Journey Planning

While in principle the routing problem is the same for the city-scale public transport system and global airline network, the underlying engineering challenges are different. The major differences are the dependency on unreliable third-party systems to get availability of seats and the inherent volatility of fares. In addition, the throughput requirements and the nature of the airline network warranted a different engineering of the routing algorithm. In addition to this, an extensible query mechanism was put in place to generate complex

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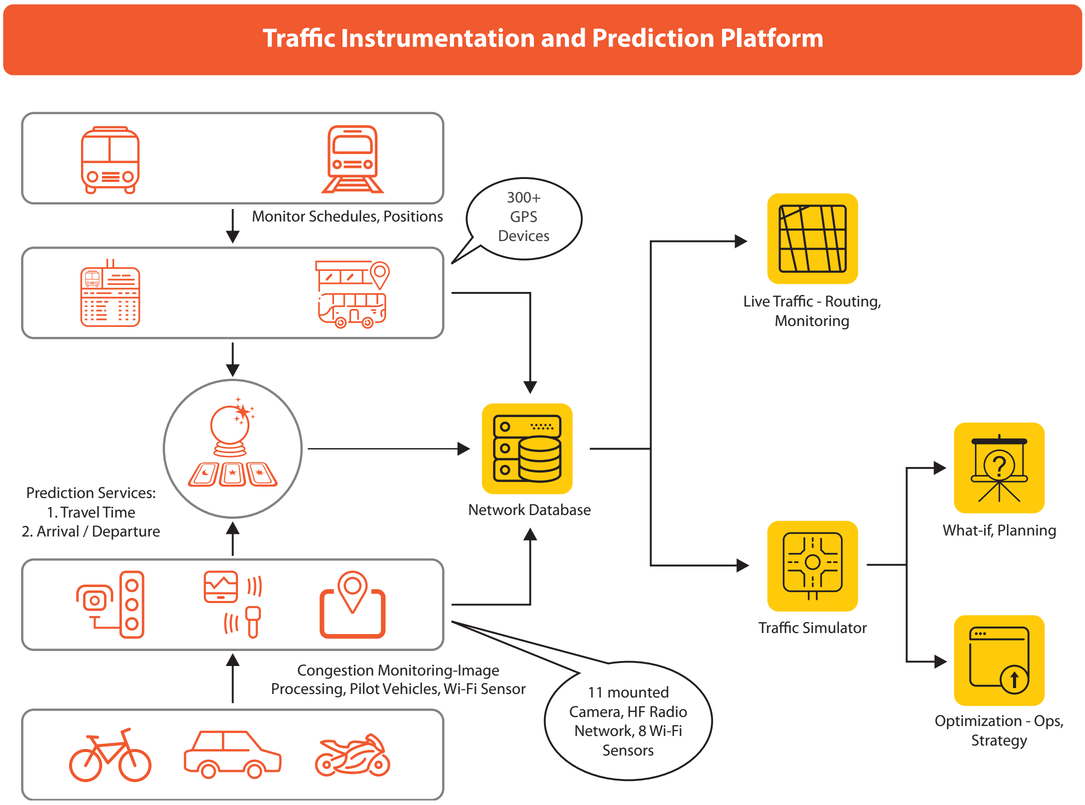

Figure 1: *Instrumentation, Prediction, Routing, and Analysis*

journey planning requirements across space, time, and user preferences.

Field Trials

Trip Planning Research Concept

About 300 GPS sensors were installed in Chennai's Metropolitan Public transportation buses, 8 Wi-Fi MAC scanners were installed in arterial roads. Initial experiments were done with data generated from 1,231 trips over a period of 45 days for GPS and 1.3 km distance of road stretch for about two weeks for the Wi-Fi sensors.

For the purposes of field trial we created an app that was tested for buses plying within the IIT campus.

City-scale field testing was done with buses, the metro rail, overland rail, and walking. Other navigation systems simply failed due to their inability to track the actual schedules.

(View also "Multimodal Travel Options, Meaningful Search Results.")

Future Work

Given the effectiveness of our pilot program at IIT Madras, the next step will be to establish an optimal network of low-cost devices throughout the city. This will help us enhance traffic analysis and prediction.

Multimodal Travel Options, Meaningful Search Results

Travel meant moving from point A to point B with few variations in route or mode of transport. No longer so. Not just adventurers, even the mainstream traveler often wants to go down paths less taken. Today it is common for travelers to make two or three hops, stay in a hotel en route, the choice of these driven by various personal preferences. For such journeys, travelers are unable to get quick and optimal options from online portals of airlines, or travel aggregators. At the same time, travelers view the travel agent model of travel planning, where the agent orchestrates the journey, to be outdated.

Today, most travel information is received, and transactions are made, online. Web-based over-the-air (OTA) aggregators are projected to grow into a trillion-dollar business by 2022 at nearly 11% growth year over year (YoY). Every transportation major wants to get into the travel planning space and offer as seamless journeys as possible, thereby gaining market share for their core services.

Global Distribution Systems (GDS) and airline companies now work together with other service providers like cabs and hotels to plan multimodal journey options along with virtual interlining. Some OTAs provide virtual interlining along with travel insurance to cover the risk of missed flights. However, travelers often tend to find better deals by planning travel themselves. Currently available multimodal multi-hop travel plan aggregators are not suited to users' needs as they provide suboptimal results based on static schedules. Third-party information aggregators like Google provide journey planning options based on static schedules but cannot book tickets for the traveler. Search engines also throw up thousands of suboptimal search results which are difficult to sift through.

While in principle, the routing problem is the same for the city-scale public transport system and global airline network, the underlying engineering challenges are different. The major differences are the dependency on unreliable third-party systems to know the availability of seats and the inherent volatility of fares. In addition, the number of origin–destination pair combinations and the number of searches per second along with the nature of airline network which currently do not provide interlining of mainstream and low-cost carriers. This warranted a different sort of engineering of the routing algorithm.

A focused design thinking workshop was held with the customer (a GDS platform provider) team. Through the workshop the problem statements were crystallized. The MVP was built in a time boxed schedule with continual interactions with the customer in an agile way.

As part of the MVP, an extensive query mechanism was put in place to generate complex journey planning requirements across space, time, and user preferences for the customer.

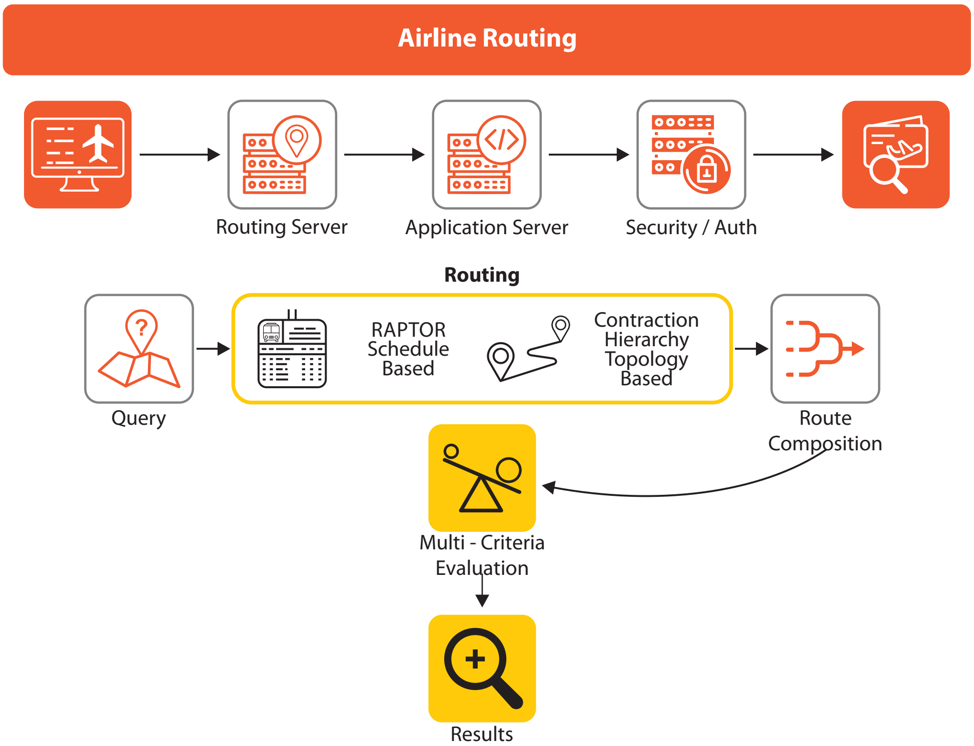

Figure 2: *Airline Routing System*

The task of optimizing the user's time, cost, and choice in getting from point A to B was undertaken. The MVP provided the following advantages to the traveler:

- Search: Relevant but limited options to help the traveler make a choice easily were provided.
- Modes: Three modes of travel air, bus, and rail were offered; all combinations of these could be tried.
- Choices: Cheapest, shortest, or earliest arrival options were highlighted; cities that could be excluded en route were all provided as searchable options.
- Hotels: Layover options could be included.
- The Golden Ticket: The best option at every minute of booking was displayed.

From an engineering perspective, the MVP was built for extensibility with:

- A normalized data model and objects with low ingestion barriers to the data
- An abstracted algorithm that can run over new sources of data without the need of modifying the internal system of the routing engine

The airline routing engine MVP was built on a variant of TCS multi-modal trip planner routing engine and it provides features that the current GDS providers are yet to build into their core systems such as virtual interlining, multimodal transportation, journey planning with complex requirements and last-mile connectivity. The MVP worked well with the valid datasets provided by the airline customer alongside open data available for rail and bus. The engine was tuned for matching the throughput of the existing platform while consuming a fraction of its resources.

Arvind Ramanujam

Arvind Ramanujam is a Scientist at TCS Research and Innovation and is a member of the Data and Decision Sciences Research group. Arvind's area of interest includes large-scale traffic simulation, Electric Vehicle modeling and cross-domain simulation. Arvind's team has been working with IIT-Madras's Center for Excellence in Urban transportation to monitor and predict traffic parameters using frugal instrumentation. He has designed and delivered network planning and management products for customers across the world.

Arvind holds a bachelor's degree in electrical engineering from Pondicherry University.
He is also a telecom network architect.

Sowmya Arasu

Sowmya is an Architect from the Travel, Transportation and Hospitality (TTH) unit. She was part of the innovation team that created a Journey Planner for the customer. She has over 12 years of experience and has worked with customers in Telecommunications and Travel Commerce domains. Her interests are in Data Science, Database design and Query Optimization. She is a TCS Contextual Master and has participated in & won hackathons in TCS. Sowmya is a University Rank Holder from Anna University for Bachelors of Engineering in Computer Science.

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