Fleet Management: A GPS-GIS integrated approach

S.S.S. Prakash, Madhav N. Kulkarni
Department of Civil Engineering, IIT Bombay, Mumbai - 400076
Tel: 91-022-25767308, Fax: 91-022-25767302
sssprakash@iitb.ac.in, kulkarni@civil.iitb.ac.in

Abstract

Global Positioning System (GPS) is a satellite system that provides highly accurate location with the use of special GPS receivers and their augmentations. This accurate GPS data is of limited use by itself, unless it is coupled with a powerful visualization tool like the Geographic Information Systems (GIS). The GIS is a widely accepted visualization tool that presents data in a graphic form, which is a convenient and effective means of communicating complex information. These systems also have loads of relevant spatial and non-spatial data existing as different layers of information that can be expressed as a map. Thus, the integration of GPS and GIS brings into existence a powerful tool that has location and visualization aspects that can be put to effective use in all its applications. Fleet management deals with remote vehicle tracking and monitoring for effective utilization of resources and for building an information interface through which the consumers as well as the fleet owners can keep track of goods and vehicles. GPS-GIS integrated systems provide real-time meaningful location and status of the vehicles in the fleet, which can be used to plan trips, attend to real-time demands from consumers and monitor the traffic condition and driver behavior. These systems are an integral part of all modern fleet management systems and play a vital role in providing data for logistic planning and optimization in today's increasingly competitive scenario. This paper deals with the use of GPS-GIS systems for fleet assessment and management for commercial, public and utility fleets. It is proposed to integrate the available GPS-GIS systems to form a prototype of a system that will show the instantaneous positions and direction of motion of the environment-friendly internal vehicles (the battery driven Vikram vehicles) plying in the IIT Bombay campus. For this purpose, a pilot test was conducted inside the IIT Bombay campus to check for GPS satellite signal availability, which gets hampered due to the heavy canopy. The test gave satisfactory results of horizontal and positional accuracy for vehicle positioning purposes.

Introduction

By augmentation of the Global Positioning System (GPS) with other satellite or land-based navigation monitoring methods, we can acquire precise positioning of any point where a receiver or an antenna can be planted. This precise positioning data can be made meaningful and can be put to various uses through integration with Geographic Information Systems (GIS), which have various forms of data organized as layers of information. The GIS can integrate the various data layers and present the same from different perspectives, which are pertinent to the problem at hand in a manner that best appeals to human perception.

Fleet management addresses the problem of managing fleets of trailers, containers, boxcars, taxi-cabs, locomotives, business jets and other modes of public transport. Such operations of management of a fleet of vehicles require solutions to various problems like dynamic assignment, trip allocation, dynamic routing, responding to real-time customer demands and dispatch instructions, automatic vehicle location (AVL), trip and freight reporting and monitoring driver and vehicle characteristics to attain efficient and optimized performance with available resources. Owing to the tough competition among transportation companies, fleet management problems with their implications of logistics and optimization are vital issues to be attended to for achieving the best possible performance and maximum profits. GPS-GIS integrated systems provide vital data in a graphic form that is easily comprehendible by the drivers, customers, fleet operators and fleet owners. The data that is provided by these systems is then fed to the logistics and optimization software that various fleet operators use to manage their operations.

GPS Augmentations

Various methods have been explored as augmentations to GPS signals to derive continuous precise positioning on GIS-based maps, which is vital for fleet management applications. A few have been discussed below.

(1) *Differential GPS:* This method is used to minimize errors in positioning by mutual comparison of current data and previously known data for a base station and applying the corresponding correction to the rover station. This correction can be applied in the following 2 ways:

- The 'Block Shift Technique' uses the computed coordinates at any time and compares them with the known coordinates of the base station. The error, which is in terms of a correction in coordinates, is applied to the rover. This method requires essentially that the two positions be found using the same set of satellites.
- The 'Range Correction Technique' uses the instantaneous and known base station coordinates to compute the error in all pseudo-ranges. Since, this correction is computed for all pseudo-ranges, this method gives the flexibility to the rover receiver to use whichever satellites it wants to compute the corrected coordinates.

(2) *Beacons and Antennae:* These are used along routes where GPS signals are hard to receive or are faced with multi-path problems due to tall buildings, canopy or terrain conditions. These instruments detect the presence of the vehicle along the road and relay information to the control station to help track the vehicle even during loss of GPS signals. They can also be placed inside long tunnels where tracking becomes very difficult and loss of signals for a long time cannot be afforded.

(3) *GLONASS and Galileo Integration:* The GLONASS is a system similar to the GPS and was established by the USSR (now the Russian Federation). The Galileo is a similar system being developed by the European Union, to be functional by 2008 (*Rizos, 2000*). The integration of GPS with these systems is favourable because they complement each other and can provide good accuracy on integration. Other benefits are multiple frequency allocations, better geometry and large number of available satellites and hence greater reliability of data (*Han, 1999*).

(4) *Pseudolites:* These are ground-based pseudo-satellites that transmit GPS-like signals and can be used as substitutes for space-borne satellites when their signals are hard to track. They are normally located on high buildings or hills from where they can track vehicles just like a normal satellite would do in absence of

obstructions and are also free of ionospheric and tropospheric errors that are faced by GPS signals. The pseudolites then transmit signals to the control station to allow continuous tracking of vehicles even in difficult terrain like deep open-cut pits and mines and downtown urban canyons. Inertial Navigation Systems (INS) like gyroscopes and accelerometers have also been used in integration with GPS signals and perform to a better level of accuracy when coupled with pseudolites. A problem faced by pseudolites is the multi-path error due to their location close to the ground. To resolve this problem, High Altitude Platform Systems (HAPS) have been amongst the research projects taken up by many countries. Japan has been investigating the use of an airship system that will function as a stratospheric platform (at a height of about 20 km) above the ground for applications in communications, broadcasting and environment monitoring. The possibility of these airships being equipped with pseudolites to provide centimeter level accuracy is being explored in Japan (*Tsujii et al., 2002*).

Types of fleets and associated problems

(1) *Public transport and Utility fleets:* Public transport includes bus services, trains, trams and private fleets of hotels, airlines and educational institutions. Utility fleets cover fire brigades, police vehicles, ambulances and other fleets that are on standby in case of emergency or disasters. It is extremely necessary for fleet operators to track their vehicles in unforeseen cases of accidents, thefts or hijackings. For any public transport organization, scheduling and planning of routes and ensuring that the vehicles run as per schedule is vital. Failure in management of fleets that make large number of repetitive trips in larger cities cause the system to become unpopular among the masses and results in a shift in traffic towards personal modes of transport. In conventional systems, tracking used to be done by posting traffic controllers and time-keepers along the route. This does not provide complete coverage and also is error-prone due to human dependability. The paperwork too is very cumbersome to handle and analyze. A good example of implementation of GPS-GIS systems in India is the case of the Bangalore Metropolitan Transport Corporation (BMTC), which installed indigenous GPS units on all buses of a depot. The readings were downloaded every three days and reports were drafted with emphasis on missed trips, short trips and punctuality problems (*Kharola et al., 2002*).

GPS-GIS integrated systems provide the operators with location, speed, distance traveled in a certain time and time taken to complete trips, which can be used for automatic billing to make payments in case of hired private vehicles and for assessment of performance of the fleet to ensure public comfort. In case of utility fleets, when a customer calls the control center for service, the operator can easily see the availability of the vehicles near the customer's area on a map. The individual drivers have different colour codes showing their status of job which is used by the operator to assign the new job immediately through an electronic message via the Global System for Mobile Communication (GSM) network without the need of waiting for the driver to establish verbal contact. The GPS-GIS system also monitors idling vehicles and precise destination locations for devising shortest paths for total coverage.

(2) *Commercial Fleets:* The freight transportation industry is facing severe competition with a large number of organizations venturing into the lucrative goods transport and logistics sector with increasing economic growth. Businesses are flourishing and the supply of raw materials to the manufacturing plants and the finished goods to the consumers in limited time with minimum requirement of storage at warehouses is becoming a vital challenge. Fleet owners must have real-time information about the location and status of all

their vehicles for dynamic scheduling and planning of trips that originate as a result of dynamic consumer requests.

Logistics and supply chains

Requests from customers of commercial fleets arrive randomly over time and require service within a short interval of time. Since, it may take upto several days to move transportation equipment over long distances, it is not advisable to wait until a customer request is known before starting to move the equipment. Among the randomness of transit times and equipment failures, it is necessary to wisely move equipment to serve demands before they are known (*Powell and Topaloglu, 2002*).

Truckload motor carriers in specific have to take care of carrier requests and place dynamic orders for delivery and pick-up. The equipment and cargo to be carried must be decided and the protocol planned. If a cargo needs to be taken through a long distance, it may go thorough the hands of several drivers and may have to take breaks at warehouses on its journey to the destination. After a driver completes his segment of the trip, it is the fleet manager's duty to get him another task that will carry him back home or ask him to wait till a demand is created in that area. These complex components of commercial fleet management – supply and demand management and logistics (strategic movement, storage of materials, parts and finished goods on supply chains through stages of procurement, work-in progress and final distribution) require real-time visual positioning of all vehicles that can be very effectively done by a GPS-GIS system. The fleet operator can use data from such systems for optimizing his operations by visual monitoring and dynamic routing of his fleet.

Disaster relief and recovery operations

One of the most important applications of fleet management is in immediate dispatch of relief to disaster-struck areas. GPS-GIS systems can be used to plan evacuation routes and to design centers for emergency operations. During the relief process, these systems help rescue operations in areas where the communication networks have been destroyed. A case worth discussing is the erratic traffic condition immediately following a landslide or an earthquake. The Laboratory of Geodesy at the School of Engineering of the Aristotle University, Thessaloniki at Greece has developed a system of fleet management working with real-time DGPS. The objective after an earthquake is to make an assessment of traffic conditions for easy and quick movement of relief vehicles to the site of disaster. The constraints are loss of earlier uniform accepted data of normal traffic conditions on various routes, which go invalid after disruptions due to the earthquake or landslide. The system developed at the Aristotle University assumed utility vehicles like fire engines, ambulances and other emergency vehicles to be at different locations in the area and by monitoring their real-time positions after the disaster, a real-time database of the current traffic conditions is built and is used to guide relief vehicles through the least congested routes providing shorter access times using the GIS database (*Savvaidis et al., 2000*).

The effectiveness and success of the GPS-GIS integrated systems for fleet management is evident from the cleaning-up operation taken up at 'Ground Zero' after the World Trade Center disaster on the 11th of September 2001. After the devastation, the city of New York was faced with the overwhelming task of removing more than 1.8 million tons of debris from the site. The continuing search for human remains and processing the debris as evidence further complicated the clean-up effort. A GPS-GIS solution was sought for the management problem due to the extensive scope of the project with costs that threatened to overwhelm existing resources. Criticom International Corporation of Minneapolis, Minnesota used a broadband communications network, a camera monitoring and time-lapse recording system, a GPS-based vehicle tracking system and Internet services to access various GIS databases for achieving the task. Debris hauling was started under a paper-ticket system, which was quickly replaced by installation of GPS receivers on 235 trucks that were used to carry the debris to various locations. The tamper-proof GPS receivers were designed to send alarms to the control center in case of signal loss, trailer disconnection, tampering, deviation from pre-determined routes and ensured safety and prompt delivery and dispatch. The real-time information from the receivers was used to develop an electronic system that had features of record-keeping, tracking-data storage and billing and other details about each truck, the driver, the debris type carried and destination. The GIS-based maps on the computer screen at the control station displayed real-time positioning that made it possible to plan intervals at which trucks were ready to load, dump and return for reloading. This prevented long queuing of trucks at the site and helped prevent traffic bottlenecks there. The data of truck-time spent in queues, total travel time and loading time stored in the GIS database could be used to substantiate claims and resolve disputes and helped to improve the efficiency of the operation. The GPS-GIS system had an important feature called 'geofencing' that prevented deviations from the given dispatch routes. The system used the exact defined routes and location of tunnels in the GIS to sense the proximity of a tunnel and automatically lowered tracking levels for the period when the particular truck was near and in the tunnel to prevent loss of signal.

This was the first time GPS technology was used in a disaster recovery setting and it gave remarkable results. The integration with GIS provided enhanced security and efficient management of operations by more than tripling the number of loads per truck per shift over the initial paper-ticket system. The removal project that was estimated at $ 7 billion by city officials was achieved in just $ 750 million. The task was completed in an amazing duration of just 8 months and the audit data and other information were kept online for the trucking companies even after the system was closed (*Menard and Knieff, 2002*).

Proposed work

It is planned to install GPS receivers on the battery-driven, eco-friendly internal vehicles in the IIT Bombay campus to be able to monitor their performance and provide locational information to all users. A major problem encountered was the canopy and multi-path complication due to buildings on either side of the route on which the vehicles ply and the heavy leaf coverage. A pilot test was conducted to check on the availability of signals in the navigation mode using the simplest procedure. Trimble GeoExplorer3 hand-held receivers were used to map the campus roads by collecting data walking at a steady pace. No differential correction was applied to check for results in the worst possible case. The results obtained were surprisingly quite well suited for our purpose. The GPS data was downloaded and processed using the Trimble Pathfinder Office 2.8 software that plotted the roads and the few select points that were mapped in static mode (Figure 1).

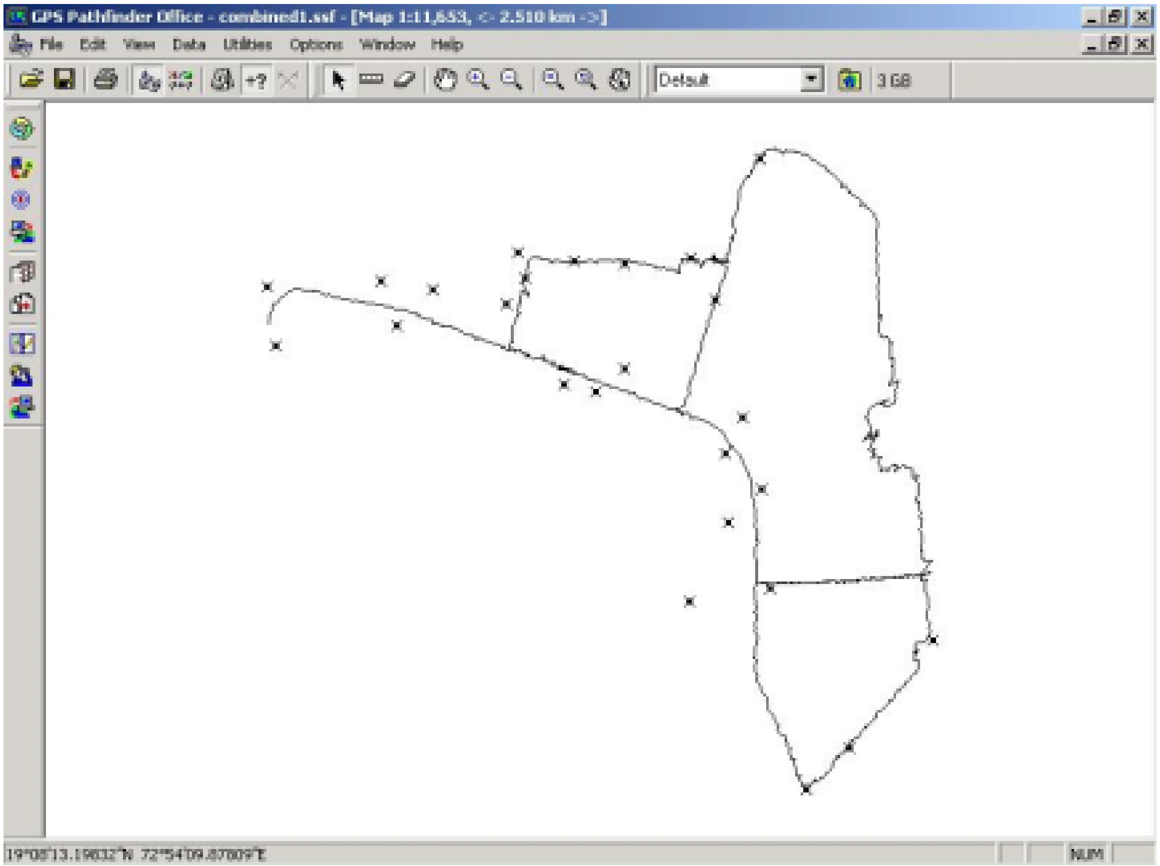

Figure 1: GPS data plotted by the Pathfinder Office 2.8 processing software.

The dilution parameters were downloaded for all the static points and a statistical analysis of the Positional (PDOP), Vertical (VDOP), Horizontal (HDOP) and Time (TDOP) dilution of precision values showed least correlation between PDOP and HDOP. Hence, the parameters of PDOP and Horizontal Accuracy (in meters) for all the points on the route of the internal vehicles were considered for monitoring. The GPS data was exported from the Pathfinder Office to ArcView GIS version 3.1 as a shape file and a database file. The vehicle-plying route was plotted as one theme and the other roads as another one. The static points with attributes have also been shown in the figures that follow. The PDOP (Figure 2) and horizontal accuracy parameters (Figure 3) were plotted for each point on the route using a colour gradation method in the ArcView GIS. As is clear from the 2 figures, the blue and pink coloured region (denoting PDOP 6.3 to 13.1 and Horizontal Accuracy 7.33 to 16.8 meters) is the critical region as confirmed by both the figures. The remaining areas have PDOP range 2 to 6.3 and Horizontal accuracy 5.7 to 7.3 m, which is acceptable for our purpose of tracking the vehicle positions.

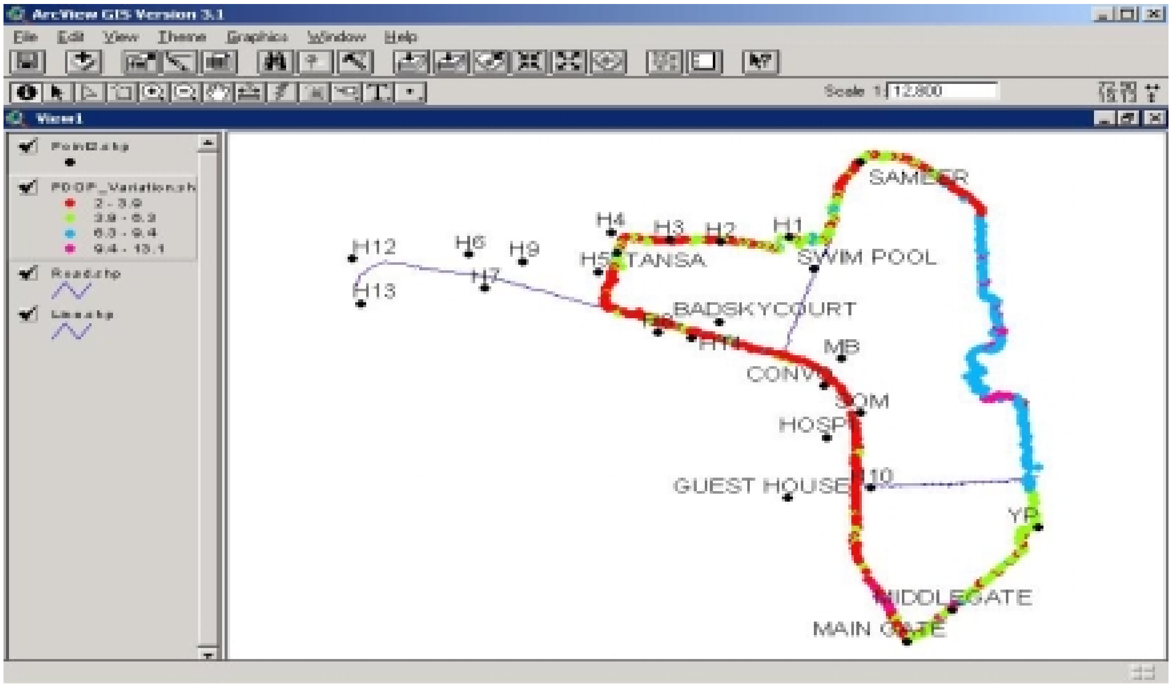

Figure 2: PDOP variation along the route.

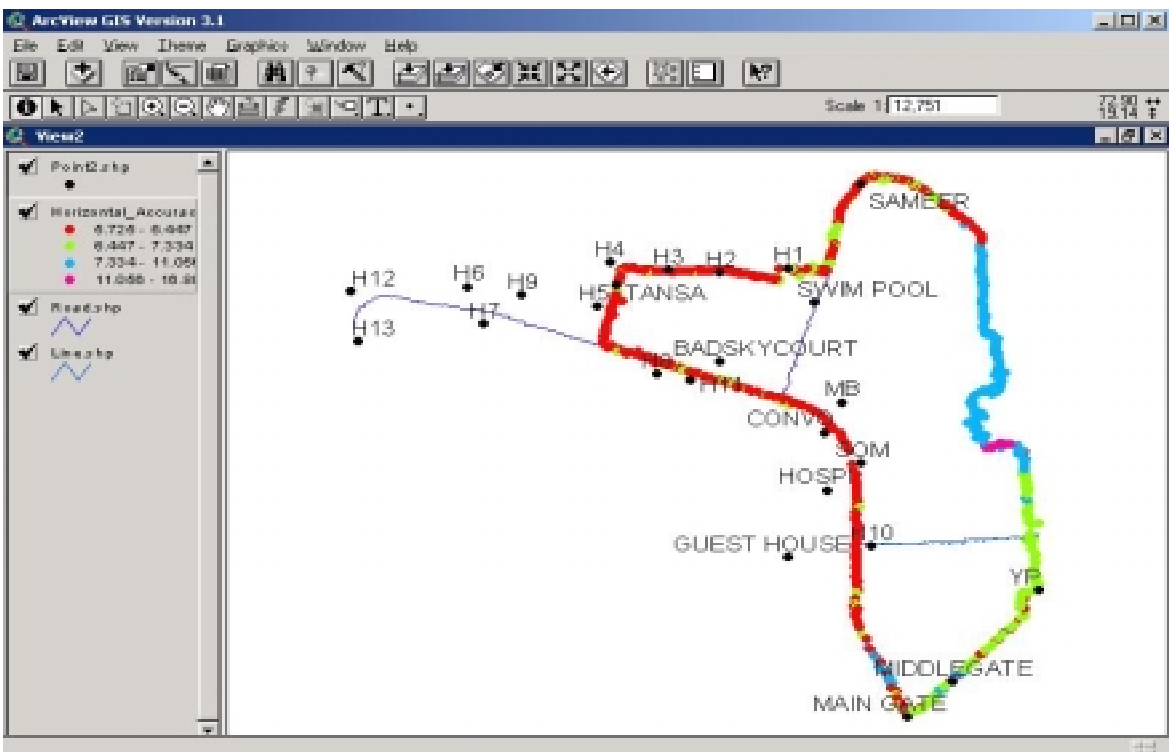

Figure 3: Horizontal Accuracy variation along the route.

The pilot experiment cleared the way for the actual experiment of monitoring the vehicle fleet performance. Experiments for the same are being conducted and results are expected by the end of January. After successful installation of the GPS receivers, it is proposed to develop an interface where the users in the IIT Bombay campus can view the position of the vehicles on a web-based GIS map through the LAN. The canopy problem will be solved by 'snapping' the instantaneous position of the vehicles shown by the GPS receivers to the accurate GIS map of the roads on which they ply.

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