GLOBAL POSITIONING SYSTEM IN TRANSPORTATION PLANNING

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KEY WORDS:

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1. INTRODUCTION

Global Positioning System, a worldwide satellite navigational system formed by 24 satellites orbiting the earth and their corresponding receivers on the earth which provides practical and affordable means of determining position, velocity and time around the globe. The satellites orbit the earth at approximately 12,000 miles above the surface and make two complete orbits every 24 hours. The GPS satellites continuously transmit digital radio signals that contain data on the satellites location and the exact time to the earth-bound receivers. The satellites are equipped with atomic clock that is precise to within a billionth of a second. Based on this information the receivers know how long it takes for the signal to reach the receiver on earth. As each signal travels at the speed of light, the longer it takes the receiver to get the signal, the farther away the satellite is. By knowing how far away a satellite is, the receiver knows that it is located somewhere on the surface of an imaginary sphere centered at the satellite. By using three satellites, GPS can calculate the longitude and latitude of the receiver based on where the three spheres intersect. By using four satellites, GPS can also determine altitude. GPS was developed and is operated by the U.S. Department of Defense(DOD). It was originally called NAVSTAR (Navigation System with Timing and Ranging). Before its civilian applications, GPS was used to provide all-weather round-the-clock navigation capabilities for military ground, sea, and air forces. GPS has applications beyond navigation and location determination. GPS can be used for cartography, forestry, mineral exploration, wildlife habitation management, monitoring the movement of people and things and bringing precise timing to the world.

1.1. Objective of Study

The objective of the study is to explore the applications of GPS in the field of traffic engineering or more specifically in Intelligent Transport System (ITS). More emphasis has been placed on the use of GPS in dynamic route guidance.

1.2. Advantages

GPS is becoming more popular due to the following advantages:

a. The relatively high positioning accuracy, from tens of meters down to the millimeter level

b. The capability of determining the velocity and time, to an accuracy commensurate with position.

c. The signals are available to the users anywhere on the globe (in the air, on the ground or at sea).

d. It is a positioning system with no user charges that simply requires the use of relatively low cost hardware.

e. It is an all weather system with 24 hours availability.

f. The position information in the three dimensions that is vertical as well as horizontal information is provided.

2. Components of a GPS

The GPS is divided into three major components

§ The Control Segment

§ The Space Segments

§ The User Segment

2.1. The Control Segment

The Control Segment is the sole responsibility of the DOD who undertakes construction, launching, maintenance, and virtually constant performance monitoring of all GPS satellites.

Functions of control segment

· The DOD monitoring stations track all GPS signals for use in controlling the satellites and predicting their orbits.

· Meteorological data also are collected at the monitoring stations, permitting the most accurate evaluation of troposphere delays of GPS signals.

· Satellite tracking data from the monitoring stations are transmitted to the master control station for processing.

· This processing involves the computation of satellite ephemeredes and satellite clock corrections. The master station controls orbital corrections, when any satellite strays too far from its assigned position, and necessary repositioning to compensate for unhealthy (not fully functioning) satellites.

2.2. The Space Segment

The Space Segment consists of the Constellation of NAVASTAR earth orbiting satellites (21 operational and 3 in-orbit spares). The satellites are arrayed in 6 orbital planes, inclined 55 degrees to the equator.

They orbit at altitudes of about 12000miles each, with orbital periods of 12 sidereal hours. Each satellite contains four precise atomic clocks (Rubidium and Cesium standards) and has a microprocessor on board for limited self-monitoring and data processing.

The basic functions of the satellites are as follows:

· Receive and store data transmitted by the control segment stations.

· Maintain accurate time by means of several on board atomic clocks.
· Transmit information and signals to user on two L-band frequencies.
· The transmission is in passive way, i.e. the signal transmission is one way only.
· Provide a stable platform on orbit for the L-band transmitters

2.3.The User Segment

The User segment is a total user and supplier community, both civilian and military. The User Segment consists of all earth-based GPS receivers. The typical receiver is composed of an antenna and preamplifier, radio signal microprocessor, control and display device, data recording unit, and power supply.
The GPS receiver decodes the timing signals from the 'visible' satellites (four or more) and, having calculated their distances, computes its own latitude, longitude, elevation, and time.
This is a continuous process and generally the position is updated on a second-by-second basis, output to the receiver display device, if the receiver provides data capture capabilities, stored by the receiver-logging unit.

1. Antenna: Antennas used for GPS receivers have broad beam characteristics; thus they do not have to be pointed to the signal source
2. Radio Frequency Section: The R.F. Section contains the signal processing electronics. Different receiver types use somewhat different techniques to process the signal.
3. Microprocessor: The microprocessor is provided not only to carry out the
computations such as extracting the ephemeredes and determining the elevation/azimuth of satellites, and so forth, but also to control the tracking and measurement function within the modern digital circuits and in some cases to carry out digital signal processing.
4. Control and Display: The control and display units enable the operator to interact with the microprocessor.
5. Recording Device: In case of the GPS receivers, intended for specialized uses such as ITS applications, in the logging of vehicle movement, only the GPS derived coordinates and velocity may be recorded. The storage device may be a floppy, magnetic tape, or a solid state (RAM) memory with memory cards.
6. Power Supply: Transferable GPS receivers these days need low voltage DC power. Most GPS receivers operate from a number of power sources, including internal Nicad or lithium batteries such as wet cell car batteries or from main power.

3.Basic modules of GPS

3.1. Digital Map Data Base Module

A digital map database is an dispensable module for any vehicle and navigation system that involves map-related functions.
Without a map, it is very difficult for a traveler to explore an unfamiliar area and make correct decisions concerning the route. With a map as medium, complex information can be communicated very easily.
In general, computer can present a map to a traveler by digitize a paper map (or photographs) using a scanner in the form of a raster-encoded structure (raster encoding), other is to convert a paper map into a data structure or a vector encoded structure .Both the methods require the use of GIS.

3.2. Positioning Module

Positioning involves determination of the coordinates of a vehicle on the surface of the earth. Three positioning technologies are most commonly used: stand alone, satellite based, and terrestrial radio based.
Dead reckoning is a typical stand-alone technology. A common satellite-based technology involves equipping a vehicle with a global positioning system (GPS) receiver. Dead reckoning and GPS technologies have been used widely in vehicles.

3.3.Map-Matching Module

To provide drivers with proper maneuvering instructions or to correct display the vehicle on a map in an error-free fashion, the vehicle location must be precisely known. Therefore, an accurate vehicle location is considered a prerequisite for good system performance.
Dead reckoning can track the position of a vehicle relative to another position, such as an origin. Typically vehicle heading and distance traversed are used to determine incremental changes in the position of the vehicle relative to the origin.
When the dead-reckoning behavior indicates that vehicle is in a certain position on the map, the vehicle position may be adjusted to some absolute position on the map. This will eliminate the cumulative error until the next map-matching step.

3.4. Route-Planning Module

Route planning is a process that helps vehicle drivers plan a route prior to or during a journey. It is widely recognized as a fundamental issue in the field of vehicle navigation.
Route Planning can be further classified into either multi-vehicle (system-wide) route planning, which plans multi-destination routes for all vehicles on a particular road network, or single-vehicle route planning, which plans a single route for a single vehicle according to the current location and a given destination.

3.5.Route Guidance Module

Guidance, an integral part of Intelligent Transport System (ITS), is the process of guiding the driver along the route generated by the route planning module. Guidance can be given either before the trip or in real time while on route.
The pre-trip guidance could be presented to a driver as a printout. These instructions might include turns, street names, travel distances, and landmarks. On the other hand, en-route guidance would require providing turn-by-turn driving instructions to a driver in real time. It is much more useful, but requires a navigable map database, an accurate positioning module, and demanding real-time software.

3. 6.Human-Machine Interface Module

Human-machine interface is a module that provides the user with the means to interact with the location and navigation computer and devices. To develop a successful human-machine interface, a certain procedure must be followed that may include identification of requirements, determination of functions to be supported, specification of interface type(s), selection of controls and displays, and finally, designing and implementing these interfaces.

3.7.Wireless Communication Module

Wireless data applications in Intelligent Transport System (ITS) play a critical role in making the vision of mobile computing a reality. It provides a very valuable opportunity to present relevant information to the vehicle and its occupants as well as to obtain data for transportation management systems.

Many quality services can be provided to drivers using communication technology.

4.Forms Of GPS

GPS is available in two basic forms: the standard positioning service (SPS), or civilian signal, and the precise positioning service (PPS), or military signal.

Prior to 2000 the U.S. military intentionally corrupted or degraded the SPS signal for national security purposes by using a process known as Selective Availability. As a result, the SPS signal was much less accurate than PPS.

In May 2000 President Bill Clinton announced that the military would stop Selective Availability. This increased the accuracy and reliability of SPS by a factor of ten. Today, the military and civilian GPS signals are believed to be of the same accuracy. For national security reasons the Defense Department retained the ability to jam the SPS signal on a regional basis if necessary. Both the SPS and the PPS signals provide a horizontal position that is accurate to about 10 m (about 33 ft).

5. DGPS and WAAS

Several techniques have been developed to enhance the performance of GPS. One technique, known as Differential GPS (DGPS), employs two fixed stations on Earth as well as satellites.DGPS provides a horizontal position accurate to about 3 m (about 10 ft).

Another technique, known as WAAS, or Wide Area Augmentation System, was developed by the Federal Aviation Administration (FAA) to improve the safety of aircraft navigation. WAAS monitoring stations around the United States catch GPS signals, correct errors, and send out more-accurate signals.

6.GPS Applications

One of the most significant and unique features of the Global Positioning Systems is the fact that the positioning signal is available to users in any position worldwide at any time.

There are countless GPs applications, a few important ones are covered in the following passage.

6.1. Surveying and Mapping

The high precision of GPS carrier phase measurements, together with appropriate adjustment algorithms, provides an adequate tool for a variety of tasks for surveying and mapping. The GPS is used to map cut blocks, road alignments, cadastral mapping and environmental hazards such as landslides, forest fires, and oil spills. Continuous kinematic techniques can be used for topographic surveys and accurate linear mapping.

6.2.Navigation

Navigation using GPS can save countless hours in the field. GPS navigation in helicopters, in vehicles, or in a ship can provide an easy means of navigation with substantial savings.

6.3.Remote Sensing and GIS

It is also possible to integrate GPS positioning into remote-sensing methods such as photogrammetry and aerial scanning, magnetometry, and video technology. Using DGPS or kinematic techniques, depending upon the accuracy required, real time or post-processing will provide positions for the sensor which can be projected to the ground, instead of having ground control projected to an image.

GPS are becoming very effective tools for GIS data capture. The GIS user community benefits from the use of GPS for locational data capture in various GIS applications.

6.4.Geodesy

Geodetic mapping and other control surveys can be carried out effectively using high-grade GPs equipment. Especially when helicopters were used or when the line of sight is not possible, GPS can set new standards of accuracy and productivity.

6.5.Military

The GPS was primarily developed for real time military positioning. Military applications include airborne, marine, and land navigation.

7. TrafficEngineering

Intelligent Transport System (ITS) is an example of a GPS application. GPS can be applied in the following fields 3 of traffic engineering effectively due to its higher accuracy.

a. Automatic vehicle location
b. General fleet operation
c. Dynamic route guidance

The application also includes support to emergency vehicles (police search & rescue, etc) and for the monitoring of cars, taxis dangerous/hazardous or valuable cargos, trucks and railways. GPS can also be applied in the following fields, but yet not found effective compared to other positioning systems.

· Advanced Traffic Management System (ATMS)
· Advanced Traveler Information System (ATIS)
· Commercial Vehicle Operation (CVO)
· Advanced Public Transport System (APTS)

7.1. General Fleet Operation

The major benefit of positioning for fleet applications is that it makes it possible to send the closest vehicle to a dispatch point, with consequent saving of fuel and time. This can be used both for commercial vehicle operation and emergency vehicle management. The accuracy required depends on the size of fleet and total area being serviced. For fleet operation in metropolitan areas a wide area of coverage is sufficient. For interstate/inter-country fleet operations, a positioning system with global coverage satisfies the requirement. Hence positioning requirement for interstate/ inter-country fleet operation is better fulfilled by GPS.

7.2. Automatic Vehicle Location (AVL)

AVL system, shown in Fig, tracks the positions of a fleet of vehicles in a particular area and reports the information to a host via a communication infrastructure. GPS positioning system is more appropriate because the accuracy needed is of the order of centimeters. Determination of the location of each vehicle typically involves a transmission initiated by the mobile vehicle. In this system, the communication system transmits the actual location to the host server. The transmission contains a position report data packet, which includes the vehicles latitude and longitude derived using a GPS receiver installed in the mobile vehicle.

A generic distributed AVL system

In this system, the only location determination component is an on board GPS receiver. After receiving the reported position from the mobile GPS unit, the known route plus the position information will provide enough information for the host to obtain a rough estimate of location.

7.3. Dynamic Route Guidance

A dynamic navigation system uses real time traffic information to assist users traveling on the road networks. This technique is also known as dynamic route guidance. The other sensors along with GPS receiver used for route guidance in a vehicle are shown in Fig and described below:

The sensors those are used along with GPS for dynamic route guidance are as follows:

Generic GPS Aided vehicle Navigation system

a. Odometer: It is a distance sensor that may be mounted singly or in pairs on to either the wheel or the transmission of the vehicle.

b. Magnetic Compass: It measures the heading of a vehicle. The most popular electronic compass technology for land vehicle application uses the flux-gate principle.

c. Tilt Sensor: It gives information about the pitch and roll angles of the vehicle. It may include one or more inclinometers.

d. Gyroscope: It measures the rate of change of heading of the vehicle

e. Digital Maps: These are used through GIS to relate mathematical coordinates to locations on the street segments and intersections. In turn, the stored coordinates of the map features provide a means in coordinate space, and hence allow the digital map to contribute the navigation function. Enroute guidance of vehicles is done using the position data received by a GPS receiver. Once the position is known, proper signals and instructions can be prepared for the driver after comparison of the position against the planned route. This planned route consists of a sequence of road segments stored by digitizing the map through GIS.

At any point during the trip, the vehicle should be traveling on a segment contained in the planned route. The route following task closely monitors the position of the vehicle on this segment to determine when to take proper guidance action. Those actions are prescribed to the driver through the display units. The display information may be in terms of a series of voice announces to warn the driver of the approaching maneuver. Fig shows the maneuver announcement during the journey.

Manoeuver announcement during the journey

7.3.1. Centralized dynamic navigation system: This system 10 shown in Fig relies upon a multi vehicle route planning module to guide vehicles on the road based on real time traffic information. In this system a host server (i.e. traffic management centre) uses the position data from vehicles through wireless communication and then using this position data plus digital map data base, gives information or guidance to the drivers of the mobile vehicle through wireless.

Generic centralized dynamic Navigation system

8.Factors that affect GPS

There are a number of potential error sources that affect either the GPS signal directly or your ability to produce optimal results:

§ Number of satellites - minimum number required:

At least four common satellites are required- the same four satellites - at both the reference receiver and rover for either DGPS or RTK solutions. Also to achieve centimeter -level accuracy and fifth satellite for on- fly RTK initialization. This extra satellite adds a check on the internal calculation. Any additional satellites beyond five provide even more checks, which is always useful.

§ Multipath - reflection of GPS signals near the antennae:

Multipath is simply reflection of signals similar to the phenomenon of ghosting on our television screen. GPS signals may be reflected by surfaces near the antennae, causing error in the travel time and therefore error in the GPS positions.

§ Ionosphere - change in the travel time of the signal:

Before GPS signals reach antenna on the earth, they pass through a zone of charged particles called the ionosphere, which changes the speed of the signal. If reference and rover receivers are relatively close together, the effect of ionosphere tends to be minimal. And if we are working with the lower range of GPS precisions, the ionosphere is not a major consideration. However if our rover is working too far from the reference station, we may experience problems, particularly with initializing our RTK fixed solution.

§ Troposphere - change in the travel time of the signal:

Troposphere is essentially the weather zone of our atmosphere, and droplets of water vapour in it can effect the speed of the signals. The vertical component of our GPS answer (elevation) is particularly sensitive to the troposphere.

§ Satellite Geometry - general distribution of the satellites:

Satellite Geometry - or the distribution of satellites in the sky - effects the computation of our position. This is often referred to as Position Dilution of Precision (PDOP).

PDOP is expressed as a number, where lower numbers are preferable to higher numbers. The best results are obtained when PDOP is less than about 7.

When satellites are spread out, PDOP is Low (good). When satellites are closer together, PDOP is High (weak).

§ Satellite Health - Availability of Signal:

While the satellite system is robust and dependable, it is possible for the satellites to occasionally be unhealthy. A satellite broadcasts its health status, based on information from the U.S. Department of Defense. Receivers have safeguards to protect against using data from unhealthy satellites.

§ Signal Strength - Quality of Signal

The strength of the satellite signal depends on obstructions and the elevation of the satellites above the horizon. To the extent it is possible, obstructions between GPS antennae and the sky should be avoided. Also watch out for satellites which are close to the horizon, because the signals are weaker.

§ Distance from the Reference Receiver

The effective range of a rover from a reference station depends primarily on the type of accuracy trying to achieve. For the highest real time accuracy (RTK fixed), rovers should be within about 10-15 Km (about 6-9 miles) of the reference station.

Radio Frequency (RF) Interference:

RF interference may sometimes be a problem both for GPS reception and radio system. Some sources of RF interference include:

· Radio towers
· Transmitters
· Satellite dishes
· Generators

One should be particularly careful of sources which transmit either near the GPS frequencies (1227 and 1575 MHz) or near harmonics (multiples) of these frequencies. One should also be aware of the RF generated by his own machines.

§ Loss of Radio Transmission from Base:

If, for any reason, there is an interruption in the radio link between a reference receiver and a rover, then rover is left with an autonomous position. It is very important to set up a network of radios and repeaters, which can provide the uninterrupted radio link needed for the best GPS results.

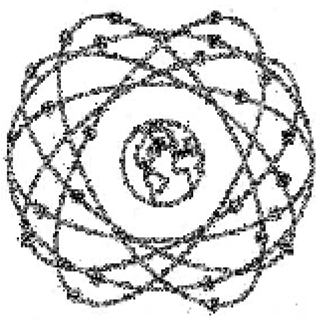
9. Conclusion

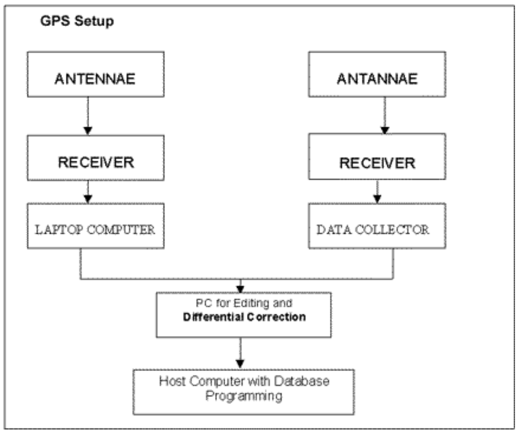
1. The GPS is one of the primarily enabling technologies for ITS. For many years GPS has addressed an ever-growing list of applications in navigation. During the last five years GPS has grabbed the imagination of public. However, there are still scope for future improvement and increased use of GPS in transportation engineering.

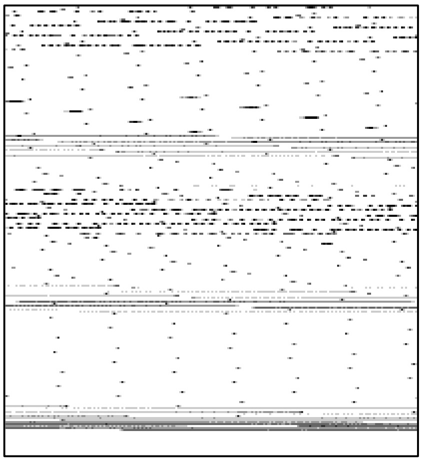
2. Basic Modules of GPS are Digital map database, Positioning, Map-matching, Route planning, Route guidance, Human-machine interface and Wireless communications.

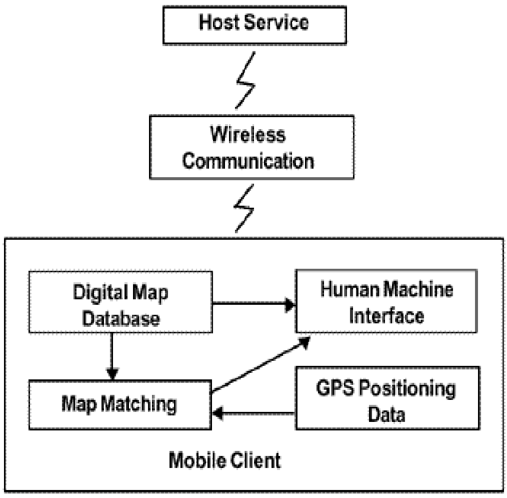
3. GPS with the use of GIS can be successfully applied in three fields of transportation engineering namely, Automatic vehicle location, General fleet operation and Dynamic route guidance.

4. It is confidently predicted that near future, GPS will play a major role to assist the Intelligent Transport System (ITS) through GIS applications.




GPS Setup
ANTENNAE
ANTANNAE
RECEIVER
RECEIVER
LAPTOP COMPUTER
DATA COLLECTOR
PC for Editing and
Differential Correction
Host Computer with Database
Programming

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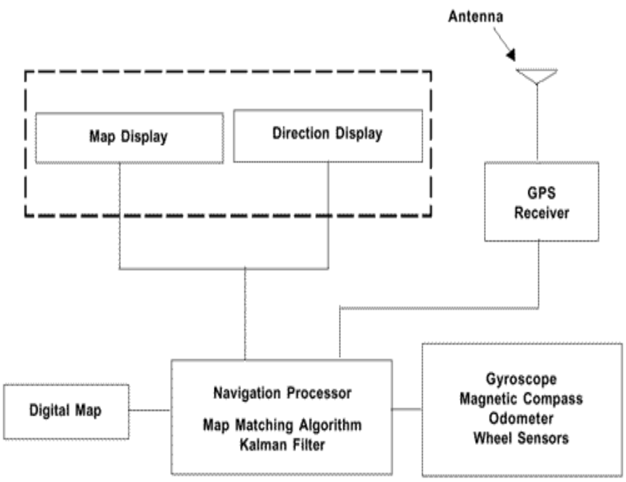
Wireless
Communication
Digital Map
Database
Human Machine
Interface
Map Matching
GPS Positioning
Data
Mobile Client


Antenna
Map Display
Direction Display
GPS
Receiver
Digital Map
Navigation Processor
Map Matching Algorithm
Kalman Filter
Gyroscope
Magnetic Compass
Odometer
Wheel Sensors