Distributed User Tracking System for Positioning Mobile Objects

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Abstract

The continued advances in positioning technologies and wireless communication technologies provide the ability to track and record the position of objects capable of continuous movement. One of the important positioning technologies is Global Positioning System (GPS). GPS provides continuous, real-time, three dimensional positioning and navigation worldwide. It can also be used for any application that requires location coordination, since a user with a GPS receiver is able to access the system satellites. In this paper we propose to design and develop a system which employs positioning technologies to allow prevention of many deadly and violent accidents and crimes utilizing any type of vehicles. Our proposed system provides the required safety for the security personnel including police force and the ordinary innocent people through the elimination of unpredictable behaviors of the drivers.

Introduction

Positioning technologies provide location or position information and services about resources for general public by using the new location finding systems and techniques. The main positioning technology is the Global Positioning System (GPS), which is a satellite-based radio navigation system. It is equipped with atomic clocks and provides highly accurate position/time information at low cost by transmitting two specially coded carrier signals, one for civilian use and another for government and military use [1]. Most civilian uses of GPS fall into one of the following four categories: navigation, surveying, mapping and timing.

The first GPS satellite was launched by the U.S. Air Force in late 1970. There are now at least 24 satellites orbiting the earth at an altitude of about 11,000 nautical miles. The high altitude insures that the satellite orbits are stable, precise and predictable, and the motion of the satellites through the space is not affected by atmospheric drag. These 24 satellites make up the full GPS constellation. Also there are other positioning systems such as GLONASS and GALILEO. The first one is developed by Russian and the later is the European's contribution to the next generation of Global Navigation Satellite System (GNSS).

The remainder of this paper is organized as follow: In section 1, we provide a brief overview of the GPS technology. In section 2, the application of the GPS technology for vehicle tracking is explained. Section 3, presents our proposed system for creating safety through controlling the driver's behavior, and finally section 4 presents the conclusion and suggestion for the future research in order to provide the required safety on the roads for all the drivers.

1. Global Positioning System Technology

The Global Positioning System (GPS) consists of three segments: The space segment (that is the GPS satellites themselves), the control system segment, and the user segment. The space segment (GPS satellites) continuously broadcast their information using radio signals. The radio signals travel at the speed of light. It is shown that GPS signals down to -155 dBW could be acquired without any assistance data or the need for a complex FFT (Fast Fourier Transform) post-processing [10]. Any device with a GPS receiver is able to access the GPS satellites, and it can be used for any application that requires the location coordination [2]. However the performance of a receiver is very much dependent on the ability to receive signals from the satellites. The GPS satellites transmit navigational messages for the receivers. The receivers can determine the target positions by using the three dimensional coordinates (i.e. latitude, longitude, and altitude) of the target [3].

The positioning methods can be implemented in two ways: self-positioning and remote positioning [4]. In self-positioning method, the mobile user (i.e. terminal, phone) calculates its position by using signals which are transmitted by the gateways/antennas (which can be either terrestrial or satellite). More specifically, the positioning receiver makes the appropriate signal measurements from geographically distributed transmitters and uses these measurements to determine its position. Therefore a self-positioning receiver knows where it is. Also the applications which are co-located with the receiver can use this information to make positioned-based decisions, such as those required for vehicle navigation. The second method is called remote positioning. In this method the mobile user can be located by measuring the signals which are traveling to and from a set of receivers. More specifically, the receivers which can be installed at one or more locations measure a signal originating from, or reflecting off the object to be positioned. These signal measurements are used to determine the length and/or direction of the individual radio paths, and then the mobile terminal position is computed from the geometric relationships.

The GPS receivers process the signals to compute positions in three dimensions (i.e. latitude, longitude, and altitude) with high accuracy (e.g. ten meters or less) [5]. However, in order to operate properly these receivers require to have a clear view of the sky and need to receive signals from at least three or four (depending on the type of information needed) satellites [6, 5]. These requirements prevent these receivers from operation in indoor environments. Also research shows that attenuation of the GPS signal through the buildings is not typically more than 1 dB per meter of structure [10]. Therefore in these environments the Assisted-GPS method need to be used to track the GPS signals inside the high buildings and elevators. As the receiver needs to acquire signals with the power level raging from -155dBW to -200dBW. In the Assisted-GPS method the mobile network or a third party service provider can assist the navigator or self-locator either by directing it to look for specific satellites; or by collecting data from the navigator to perform location identification calculations. That is because the navigator may be unable to perform the calculation of the location identification due to the limited processing power. The Assisted-GPS method can be extremely accurate, ranging from one to ten meters [5].

1.1 GPS Receivers and Position Calculation

The GPS receivers are sophisticated receivers with digital demodulation systems which controlled by powerful microprocessors. The principle components of a GPS receiver are: receiver, antenna, processor, I/O devices. The basic operations of a GPS receiver consist of: satellite selection, signal acquisition, tracking, measurement, data recovery and corrections. The GPS receivers come in many shapes and forms. The most common receivers in the consumer market are handheld devices. These receivers provide the information about the location of any objects to around 100m, depending on the receivers' design. These receivers can be used for marine, aviation, or terrestrial navigation use. Currently they are readily available from a number of manufacturers, and they are not as costly as sophisticated counterparts. Furthermore, the demand for these devices is set to rise with the US FCC mandate for inclusion of these devices to mobile phones [11]. Also more advanced receivers are available for use in more demanding applications such as accurate navigation, surveying, tracking and the like [7].

A GPS receiver calculates its position by a technique called satellite ranging. It involves measuring the distance between the GPS receiver and the GPS satellites, which it tracks. The range or distance is measured as an elapsed transit time (the range that a receiver calculates is actually an estimate of range rather than a true range). Also the position of each satellite is known; since the satellites transmit their positions as part of the "messages" which they send via radio waves. However the GPS receiver on the ground is the unknown point, and must compute its position based on the information it receives from the satellites.

1.2 Measuring Distance to Satellites and Using the Distance Measurements to Calculate a Position

The first step in measuring the distance between a GPS receiver and a satellite is to measure the time it takes for the signal to travel from the satellite to the receiver. In order to compute a three dimensional (i.e. latitude, longitude and altitude) position it is required to measure the distances from four satellites. Once the receiver knows how much time has elapsed, it multiplies the travel time of the signal by the speed of light (as the satellite signals travel at the speed of light, approximately 186,000 miles per second) for computing the distance.

To measure the travel time of the satellite signal, the receiver needs to know when the signal left the satellite and when the signal reached the receiver. The latter is easy to compute, as the GPS receiver just needs to check its internal clock whenever the signal arrives. However, how does it know when the signal left the satellite? This can be easily answered, as all the GPS receivers are synchronized with the satellites so they will generate the same digital code at the same time. Therefore, when a GPS receiver receives a code from a satellite, it can look back in its memory bank and find out when it emitted the same code. This allows the GPS receiver to determine when the signal left the satellite. Once the receiver has done the distance measurements, the rest is solving a simple geometry problem. That is, if it knows where the four satellites are, and how far its distance is from each satellite, then it can easily compute its location.

2. The GPS Applications

There are many possible uses for GPS, in fact in any application where the location information (i.e. land, sea, air) is needed, that application is a possible candidate for GPS. There are also many additional applications, such as in agriculture, mapping and surveying, property evaluation and tax assessment, air quality studies, environmental protection, demographic analysis including marketing studies, atmospheric studies, oil and gas exploration, scientific exploration, and vehicle tracking and more.

2.1 GPS Based Automatic Vehicle Tracking System

From all of the applications of GPS, vehicle tracking and navigational systems have brought this technology to the day-to-day life of the people. Today GPS enabled cars such as ambulances, fleets and police vehicles are common sight on the roads of developed countries. These vehicles are known by many names such as Automatic Vehicle Locating System (AVLS), Vehicle Tracking System (VTS), and Mobile Asset Management System (MAMS). These systems offer an effective tool for improving the operational efficiency and utilization of vehicles [8].
In these vehicles, GPS is used for both tracking and navigation. Tracking systems enable a base station to keep track of the vehicles without the intervention of their drivers, while navigation systems help drivers to reach to their destinations. Whether navigation system or tracking system, the architecture is more or less similar. The navigation system will have convenient presentation; usually a graphical display for those drivers which do not need to use the tracking system. The Vehicle Tracking System (VTS) combines a number of well-developed technologies. It consists of three subsystems irrespective of the technologies being used: In-Vehicle Unit (IVU); Base Stations; and Communication Channels.

The IVU includes a suitable position sensor and an intelligent controller together with an appropriate interface to the communication channels. The controller interacts with the GPS receiver, collects and co-ordinates at predefined intervals, processes it and sends out to the communication channels. Optionally in certain cases, it uses a man-machine-interface similar to a display which can be combined with a keyboard for message communication between the driver and the base station. The network overlay systems use mobile (cellular) phone infrastructure for locating vehicles. The cell centers with additional hardware and software assess the time of arrival (TOA) and the angle of arrival (AOA) of radio signals from vehicles for computing the position of the vehicles. This information is sent to the tracking centre through the cell channels or conventional channels. Another technique in use for locating the vehicles is, to compute the time difference for signals to reach the vehicle from two different cell centers. This computation is made in the IVU and the position information is sent to the tracking centre through the mobile (cellular) phone link. A more common technique used is direct radio link (DRL). In this system dedicated radio infrastructure is used along with special IVU to compute vehicle location. Alternatively, embedded GPS receivers provide absolute position coordinates at any point, without any area restrictions. As, opposed to the above techniques that imposing some limitations on the operational area.

The second subsystem namely Base Stations consist of a high-speed system which receives the position data from the vehicles and displays them on a digital map. The base station has the interface to the communication channels as well as some enhanced features such as video features, trace mode, history track, vehicle database and network support. The most costly part of a VTS is the data channels. The data channels, together with a suitable communication protocol, has to be selected after a thorough study of various parameters such as the bandwidth requirement, number of vehicles to be tracked, expandability, terrain, area of coverage, etc. Sophisticated VTS are linked to different databases, which can support information about the vehicles such as the cargo, the temperature of storage of perishable goods, fuel consumption rate, etc. Naturally, such systems demand data link with higher bandwidth. The UHF links are suitable for short range without shadow region, as they require line of sight. The mobile phone based systems demand minimum infrastructure investment, but they are limited in coverage. On the contrary, Low Earth Orbit (LEO) based Satellite systems are expensive and offer the largest coverage [11]. The recently introduced Wireless Application Protocol (WAP) and General Packet Radio Service (GPRS) technologies hold great promises for VTS.

When multiple vehicles are being tracked, a suitable communication protocol needs to be established to avoid collision of radio signals. The simple technique is Time Division Multiple Access (TDMA), where each IVU communicates during predefined time slots. This synchronization is easy in a GPS based IVU as the GPS receiver provides very precise time reference signals. However, TDMA based systems have limited expandability, flexibility and are known for underutilization of bandwidth [9].

3. The Propose System

We propose a Distributed User Tracking (DUT) system which uses GPS technology and has remote access facilities which enables the security forces (specially the police force) to combat violent crimes. The proposed system consists of two components namely the Enforcer and Tracker. Each of these components basically, consists of an intelligent coordinator (processor, memory), a monitor, and an appropriate interface to the communication channels. The Enforcer component is installed in each vehicle has a unique ID (for example the vehicle plate number) in order to identify the vehicle. It is also able to perform a number of functionalities such as interpreting the signals (commands) received from the Tracker and applying them to the engine of the specified vehicle. The Tracker however, is used by the authorities or security forces only. It communicates with each Enforcer remotely to track and control the violating vehicles by issuing the appropriate signals. These signals will put the violating vehicles under the control of the authorities. As a result, these two components together allow the security forces, firstly to track the suspected/criminal drivers who are endangering the life of other innocent people, and secondly to reduce or shut down the flow of the gasoline to the engine of the offending vehicles by utilizing the remote control capability of the Tracker component. In this way, the suspected drivers are not able to speed up while the security personnel are approaching them, and they will be put out of action instantly without dragging many vehicles of the security forces behind themselves and creating a number of tragic incidents in the cities or the road ways.

Currently, there are many devices ready in the market which have the remote access control capability to access the vehicles. Such as the devices that can remotely lock or open the doors of the vehicles; or start the engines of the vehicles, etc,. Also some newer vehicles have other functionalities such as path finding system, vehicle tracking capability, etc., as explained in section 2.1. As a result of all these improvements, many initial issues such as how to track a specific vehicle or how to remotely access a vehicle had been resolved. Therefore in our proposed system the basic idea works as follow: upon the remote request from the Tracker component. The Enforcer component, which is installed in each vehicle, provides the related information about the pursued vehicle to the Tracker component. And it facilitates the Tracker to get the control of the pursued vehicle. This can be achieved by employing the Global Positioning System (GPS) and mobile wireless technologies. Each Enforcer component is unique in each vehicle and must not be tampered with. Therefore, this allows the Tracker to communicate and issues the specific signals to a particular Enforcer. These signals can range from reducing the flow of the gasoline to the engine or locking the functionalities of an appropriate vehicle. The Enforcer also can be used for many other purposes such as tracking the stolen vehicles, finding the stolen vehicles in big car yards.

Therefore, our proposed Distributed User Tracking system can prevent and reduce many deadly and violent crimes caused by utilizing any type of vehicles, for example stopping the violent criminals when they are fleeing from the scene of crimes using high speed cars, juvenile car rages, criminals that are escaping from police chase, vehicle theft, etc. As in any of these incidents the security forces have to pursue these vehicles intensely in order to arrest or stop the drivers. Unfortunately, these pursuits usually turn into a dangerous high speed car chase in the cities or highways which endanger the life of the innocent bystanders, security forces and may cause costly damages to common and private properties as well.

4. Conclusion

In this paper, we propose to design and develop a Distributed User Tracking system (DUT) which allows the authorities such as the security or police forces to have the universal access and control to all vehicles in order to stop or slow down the suspected vehicles before approaching to it. The DUT system allows the authorities to control the speed of the suspected vehicle by reducing or stopping the flow of the gasoline to the engine of the suspected vehicles. This compels the suspected vehicles to travel with a limited speed, or if it is required the offending vehicles can be completely stopped. The fuel reduction not only prevents the drivers from speeding when they realized that they have been pursued, but also it allows the offending vehicles to be directed to a safer environment for further investigation. Further extension to our system enables the highway patrols to inform or automatically control the speed of drivers in parts of the roads which have suddenly been changed due to an earthquake or other natural disasters. This allows the drivers to drive with a safer speed on those parts of the roads or highways. As a result our proposed system not only protects the security forces from the violent criminals, but also provides a safer driving environment for everybody on the roads or highways.

5. References

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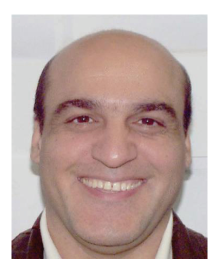
Biography



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