EFFICACY OF GPS AS MULTIDISCIPLINARY APPROACH IN FORENSIC SERVICES: A REVIEW

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ABSTRACT: The use of Satellite Navigation System (SNS) has become gradually common in current years. The extensive adoption of this technology has the potential to provide a valuable resource in forensic investigations. Global positioning System (GPS) has made major advances on ground and in space where the devices have increasingly contribute evidential importance in the forensic field. The value of collecting evidence from GPS devices has been well established where GPS evidence has played a major role in different crime cases ranging from sex monitoring, forensic archaeology, as well as vehicle tracking to crime mapping. This paper provides a review on how GPS is meticulously being used in various aspects and how the implementation of collection and acquisition of GPS evidence has enabled unsolved case dockets and also helped discover unreported cases. Recommendation for further research by implementation of GPS chip in the evidence package found at the scene of crime could be conducted in the mere future. This would make the forensic process of collection more secure and effective in timely manner. The evidence package could then be monitored about its whereabouts and also provide the integrity to the collected data, thus affecting positively in justice delivery system.

Keywords: GPS, forensic services, efficacy, multidisciplinary, review.

Introduction

The use of global positioning system (GPS) in forensic field is a new tool and a new technology approach that has become increasingly common in a variety of legal context. Its use has become common in civilian population and not only in military population due to the potential to provide location data in any weather, day or night anywhere on earth. This is done by triangulation method in which the GPS receiver gets signal from at least three satellites. The information derived by the satellites signal allows the receiver to pinpoint its position, time and velocity of movement [1].

With the importance and ubiquity of tasks relying in GPS infrastructure, it is worth considering the possible forensic implications of this technology. The GPS receiver has proved to be excellent in tracing position worldwide and provide evidentiary data. If the GPS data is examined forensically, a good deal of information will be harvested which could be used as an irrefutable evidence in a court of law. Due to the fact that today's technology is advancing rapidly and when it comes to embedded devices, which grow quicker especially in their capacities and in their use. The common digital evidence is always about desktop and laptop in a couple of years ago. Nowadays, embedded device such as GPS or satellite navigation, smart phones has a much processing power as that of normal desktop computer [2]. Devices receiving GPS information have access to precise location information as well as extremely accurate time data. The wide scale adoption of this technology has the potential to provide a valuable resource in forensic investigations based on the ability of retrieving historical location data from the device. A range of criminal investigation have been reported to potentially utilise GPS information [3]. The main objectives of this review research is to find out how well this sophisticated devices has been served in the field of forensic science. The use of GPS in various areas is highlighted, thus showing its practical usage and efficiency.

Overview of GPS

GPS is a satellite based navigation system made up of a network of 24 satellites placed into orbit by the U.S department of defense. The satellites orbit the earth at a height of about 12,000 miles and travels at a speed of about 7,000 miles per/hour. GPS satellites are powered by solar energy. They have backup batteries on board to keep them running during a solar eclipse when there is no solar power. The GPS was originally intended for military purpose but later made the system available for civilian use in the 1980's by the U.S department. GPS can work in any weather condition, anywhere in the world, 24 hours a day. GPS is one-way ranging system because it serves as an unlimited number of users as well as being used for security reasons [4].

GPS Segments

The GPS consists of three segments, namely the space segment, the control segment and the user segment [5].

Space segment
The space segment consists of 24 satellite constellations, where each satellite transmits a signal with a number of components *i.e.* two sine waves, two digital codes and navigation message. The codes and navigation message are added to carriers as binary bi-phase modulations. The navigation message contains, along with other information, the coordinates of the satellites as a function of time.

Control segment
The control segment of GPS system consists of a worldwide network of tracking stations, with a master control stations (MCS) located in the United States at Colorado spring, Colorado. The important task of the control segment is tracking the GPS satellite in order to determine and predict satellites atomic clocks, atmospheric data, the satellite almanac and the other considerations.

User segment
These include all the military and the civilian user. A user can receive the GPS signals which can be used to determine the user's position anywhere in the world when a GPS receiver is connected to a GPS antenna.

Mechanism of GPS

GPS works in a very simple way. If the distances from a point on the earth (a GPS receiver) to three GPS satellites are known along with the satellite locations, then the location of the point *i.e.* the receiver can be determined by simply applying the well-known concept of resection [2].

GPS satellite continuously transmits a microwave radio signal. When a GPS receiver is switch on, it picks up the GPS signal through the receiver antenna. Once the GPS signal is acquired by the signal, it will start to process using its in-built software. The partial outcome of the signal processing consists of the distances to GPS satellite through the digital codes which is known as pseudo-ranges and the satellites coordinate through the message. The more the satellite, the better is the accuracy.

DGPS and Its Mechanism

Differential global positioning system (DGPS) is an enhancement to global positioning system that delivers highly accurate position of information, from the 15-meter nominal GPS accuracy to about 10 cm in case of the best implementations. Comparatively, DGPS is less affected by atmospheric conditions and system errors. The error sources are mostly removed in differential GPS.

DGPS works with the help of two receivers to achieve the benefits of differential GPS to more accurately determine the location. DGPS receives the signal from satellites and compute its pseudo ranges, and simultaneously, it also receives correction signals from a reference source or base station that has already known its exact location. Thus the receiver applies these corrections to its computed pseudo-ranges to produce a much more accurate position.

Efficacy of GPS in various aspects

GPS monitoring sex offenders
GPS monitoring has tremendously increased the ability to investigate the offenders about his current whereabouts and past behaviours. Under current law, GPS tracking is defined a as system that actively monitors and identifies a person's location and timely reports or records the person's presence, near a crime scene or in an exclusion zone or the persons departure from the inclusion zone.

Sex crime is considered as one of the heinous crime that is damaging to victims and extremely unpleasant to society. Sex offenders are likely to recidivate which can bring public unsafety. Therefore, reducing sex crimes victimisation is an important goal for public safety authorities. GPS monitoring device are designed to track parolee or sex offenders in order to make sure they do not commit any crime, to investigate his/her current whereabouts and past behaviour. Parolees are fitted

with a small tamper-proof GPS tracker worn as a bracelet or anklet. The ankle device is in the shape of a right plastic ring, accompanied by a small tracking box that can fit in a pocket [6]. GPS monitoring has enabled the law enforcement department to control sex offenders and their behaviour and avoid situations that would encourage new crimes. These sex offenders know that their activities are being monitored, documented, time stamped and stored which can be used as evidence in the investigation of any new sex crime and thus also act as deterrence. The sex offenders constantly receive a reminder that they are liable for wearing the monitoring equipment at all times and for recharging the GPS tracker battery at least once every day. Parolees who fail to meet the requirements are subject to prosecution and arrest [7]. One drawback of the parolee tracking is its labour intensive nature [8].

In general, there are two main types of GPS monitoring systems, active and passive. Both the systems give the fix location of the GPS device in the same way. The only difference is how that information is transmitted to the supervising agency. Passive GPS monitors the parolee whereabouts throughout the day. The offender must plug the monitor into a unit attached to a telephone at a predetermined interval at which GPS unit transmit the log of its activity to the monitoring center for review by the parolee agent. While dynamic GPS gives almost constant data about sex offender area consistently [9]. According to the IACP resource, active GPS is the most appropriate technology for sex offenders. There are possibilities where GPS can give error readings in certain conditions such as in the dense forest, tall buildings, cloud cover and moisture which may produce inaccuracies in reading [10]. This has significantly lower the recidivism rate of high risk sex offenders. The monitoring provides an invaluable resource for investigation, by providing data that can be compared with the times and places of new sex crime [7]. GPS location and crime scene co-connection is a law enforcement investigative device that can concentrate a police on a suspect. It is an upgrade but not a substitute for convention law implementation investigative system. Therefore, the ability to track an offender every minute of every day provides new opportunities and challenges for the criminal justice system.

Crime mapping

Crime presents a major challenge for the social, economic and physical development of cities and towns all over the world. Hence, the need for more advanced way, technology and methodology to combating crime in which application of Geographic Information System (GIS) will help a great deal through crime mapping. Geography is a field that is ever-changing and ever-growing. One of its newer sub-disciplines is crime mapping which uses geographic technologies in order to aid in crime analysis. Crime mapping is an integral and an essential part of crime monitoring, control and management [11] and GIS plays an important role in crime mapping and analysis. It focuses on mapping incidents, identifying hot spots where the crime had occurred most and analysing the spatial relationships of targets and these hot spots. Crime mapping identifies not only where the actual crime took place, but also the perpetrator "lives, works, and plays" as well as where the victim "lives, works, and plays." Crime analysis has indicated that the majority of criminals tend to commit crimes within their comfort zones, and crime mapping allows police and investigators to see where that comfort zone might be. GIS software also helps co-ordinate vast amounts of location-based data from multiple sources. Crime analysis once focused purely on the perpetrator and the victim, but did not take into account the location that the crime took place, and thus successful application of crime mapping is important.

In the last fifteen years, crime mapping has become more prevalent and uncovering patterns has become pertinent as an integral part of the law enforcement agencies globally. The crime analysts, researchers, practitioners, law enforcement personnels, crime prevention and executives have relied on this data driven through crime mapping so as to strengthen in better way. It has been made clear that crime analysis can provide critical support for crime prevention and crime reduction strategies through the multi-fold scholars and practitioners in the field of the international association of crime analyst (IACA) and regional crime analysis association. In developed countries, the growth of police department has hindered tremendously due to the lack of infrastructure like GPS and GIS. A simple, useful and cost effective solution for crime mapping was proposed [12]. Google cloud resources like satellite data and GIS software have been used to develop the application. They proposed to build a block which will have daily, weekly, monthly crime maps that will help to identify crime patterns and clusters. One of the main objectives was to single out the crime prone area and also give ancillary information's like location of the police stations, hospitals, fire brigade *etc*. Using google imagery, these crime mapping processes often enhanced and elucidate the quality in preparing the case for presentation in court, detecting errors in crime dockets and enabling unsolved case dockets that can be linked to crime series and even helped the unearthed, unreported and unsolved cases [13].

Cooper *et al*. (1999) developed two innovative techniques for analysing aggregated crime data, namely crime clocks and target performance maps [14]. Crime clocks may display the distribution of crime in time and space to show the relative crime rates using scale pie chart for the selected periods. Crime clocks can be used to map the type of crime, a set of selected crime or all crimes in the area. The advantages of crime clocks are that one can see immediately when there are peak of crime incidents during the day where midnight does not provide any artificial break. Target performance maps are particularly useful for determining the specific crime prevention interventions by the police. It also provides a quick view of where concentrations of crime occur. Mapping out time in "real time" can increase the safety of the officer through real time location identification location, reduce police response time and increase the prediction capability of crime analysis. This also enables the law enforcement to conduct real time monitoring, incident tracking, risk identification and resource allocation [15]. The maps produced are used in court or before the jury to help the court understand the sequence of events when evidence is presented. Without such visual aids, there can be difficulty in understanding the crime. GIS provides a powerful easy to use tool that makes a big impact on a court case. GIS will continue to improve and evolve our understanding, sensitivity, identification and forecasting of reported map able events [16].

Use of GPS in scattered human remains

The use of GPS as a tool for scene mapping in scattered human remains has become an essential aspect in the field of forensic investigation. GPS were employed to track the disarticulation and spread of the scavenged remains, and a GIS database was created to help map and organise the data collected in the field [17]. For medico-legal purposes, the sites are often mapped and photographed to create the original view of the sites. Therefore, by applying the appropriate mapping technique, investigators could accurately document the locations of the human remain, thus maintaining a precise geospatial record of evidence. In situation where the landscape is topographically varied or where the scattered remain are dispersed widely, hand drawn maps become difficult even with total stations. Therefore, in such situations, GPS may be a useful tool.

In order for the GPS to be a useful tool in forensic investigation, whether for locating the artifacts, mapping the scattered remains or locating a single position, the accuracy must be high [18]. Traditional archaeological methods may be difficult to use in wide outdoor scenes due to the time constraints in setting up the equipment or because of the terrain. In order to see if GPS offers an accurate and reliable alternative for mapping scattered artifacts, it was presented that good accuracy can be achieved using an average price unit; hence GPS offers an excellent means of marking a location [19]. But, generally the accuracy of the GPS data can be affected by various factors, as in position of the satellite, atmospheric conditions [20] and tree cover density, terrains like building or other structures or the receiver itself. Though several factors may influence the accuracy of the GPS unit, the more advanced technology *i.e.* DGPS could provide much better accuracy (cm level accuracy) with post processing does not get hindered by these factors. A study conducted in an open environment determined with DGPS unit was found applicable for mapping skeletal dispersal [21]. In relation to forensic investigation, the GPS and GIS have been used for geographic profiling and mapping crime as well as for studying distribution of dumbed and scattered human remains. Therefore, GIS can be of valuable presentation by incorporating base maps to provide context to a scene, drawing tools to highlight important aspects of the dispersals, and to illustrate the accuracy of DGPS unit. Determining the utility when analyzing and displaying skeletal dispersals for small scale and large scale should be investigated in future research.

Use of GPS in vehicular tracking system

Law enforcement has found that many uses of GPS technology in criminal investigations [22] to provide directional assistance to any individual drivers. GPS tracking system is probably the most impressive forensic evidence where they are fitted to increasing number of trucks, tractors, delivery vans, rental cars *etc*. [23]. As this provides directional assistance to every individual, state and federal law enforcement have also incorporated such technology to obtain evidence in criminal investigations. Currently, GPS devices are most widely used in car satellite navigators. The principle purpose of vehicle tracking systems is generally to provide real-time information that enhances the efficient control of fleets and also vehicle's movement. If a GPS is installed in a vehicle, the location of the vehicle will be known at all times. If the vehicle got stolen, locating it again would be of no trouble. Therefore, vehicle tracking systems are now among the most important application of GPS for the society. Few researchers have done on this work and have shown that tracking could be analysed forensically to provide intelligence that can be of considerable value in the detection of crime. Vehicle satellite navigators contain multiple records concerning their users. The information stored in car navigators can be extracted and plotted disclosing a great deal of information. Such examination must be conducted profoundly by maintaining a very high forensics

standard of the evidence so as to survive hostile cross-examination in court.

Wisconsin police attached a GPS device to the suspect's car without obtaining a warrant that was on a tip about a former methamphetamine manufacture. Information's recorded on the device led them to a large tract of land visited by the suspect. With the consent of the landlord, they searched the property and found the paraphernalia used to manufacture methamphetamine and the suspect was subsequently arrested [24].

A couple of 17-year-old daughter had a drug problem that would disappear for hours at a time. Worried that she might overdose, they placed a GPS tracker on her car. When they saw that she was visiting the same house repeatedly, they informed the police. Another quick look at cases involving GPS systems was the case involving the murder of a pregnant 27 year old wife by her husband. The husband was charged with killing his pregnant wife and their unborn son. Their bodies washed up separately on the shore of San Francisco Bay in April 2003. Prosecutors have said they would seek the death penalty if the man is convicted. A GPS system was placed on his vehicle to track the location at all times. A prosecution witness testified that the GPS devices, despite briefly malfunctioning at least four times, accurately tracked the suspect's travel to San Francisco Bay between the time his wife was reported missing and he was arrested. The GPS location device pinpoints the suspect's location along with a witness to verify the information. The bodies washed up on shore only two miles from this location. Even though the prosecutors claimed the GPS evidence was circumstantial, the evidence has led investigators to believe that the suspect was guilty by driving to the bay for fear of someone would find the bodies washed up on shore. GPS tracking systems in investigations did help to solve and the suspect was apprehended soon [25].

Such GPS based navigation devices have the option of recording vehicle movement parameters thereafter securing these devices especially in murder or road accident cases, since the data obtained can be useful in digging out the whereabouts of the vehicle which directly helps in linking the investigation, broad accident reconstruction, determining the transportation routes of cargo and people, searching for missing person *etc*. [26]. Also, the use of GPS and global system for mobile communication (GSM) modem has served a great work in preventing the theft of a vehicle. A new system has been developed where the embedded system based on GSM was used. The designed and developed system has been installed in the vehicle. A connection is required where interfacing mobile was connected to the micro controller which is in turn connected to the engine. So, whenever any vehicle is stolen, the information is being used by the vehicle owner for further processing. Then, the information is passed to the central processing insurance system which is in the form of SMS, the micro controller than reads the SMS and sends it to GPS, thus by using the triangulation method, GPS module determines the exact location with the details of latitude and longitude. This would be used as a valuable tool for real time control [27]. But according to Janneta (2006), the cost of tracking system using GPS and GPRS of GSM network that provide real time tracking is comparatively much lower compared to SMS based tracking system [8]. Navigation professionals can narrow down the search of criminals, suspected vehicles and *etc*. Through profound knowledge and quality level of tracking records these records or evidences can be essentially preserved. They can present the data in court and defend in cross-examination. For instance, in Maryland courts, hearsay is generally not admissible into evidence. In some cases, the state sought to introduce records from the GPS device to show the location of the work vehicle at various times. The information was relevant because the state sought to show where the defendant was at various times as evidence that the suspect was participating in a theft scheme, stealing copper from his employer and selling it for scrap. Since the device is providing information that is being considered by the court and the device is not a person who can take the stand and be subject to cross examination, the information provided is hearsay. Hearsay evidence is generally not admissible at trial because it is generally unreliable. Without being able to cross examine the source of the information, there is no way to test the accuracy of the information provided. If these elements are pointed pin out carefully to a jury in simple language, tracking evidence can be compelling.

Conclusion

The outcome of this review suggests that GPS have made significant contributions in helping the courts to understand the proceedings of complex cases and also helped to improve the quality of the case being presented. GPS evidence which is found to be a valuable supplement to other forms of evidence is legally growing more important, their role more dynamic and successful in degrading the crimes. The use of GPS is not a panacea, however, it is just another helpful tool to assist in supervision, crime fighting and society protection. Ultimately for GPS to progress, the law must keep pace with technological advancement. This approach is limited to few findings of GPS usage, while further

detailed review on GPS usage in forensic field can be integrated and studied.

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