An Investigation of Global Positioning System (GPS) Technology for Disabled People

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Abstract. There has been a good deal of both interest and confusion regarding the capabilities and use of the Global Positioning System (GPS) to assist people with disabilities. The confusion has resulted mainly from the uncertainty regarding the resolution of the system in determining the position of a user. The Technology for Disabled People Unit (UMIST) has examined this problem in two ways: by purchasing a GPS development system for field trials; and by undertaking a search of relevant information in an attempt to clarify the situation. This paper reports on the results of these investigations and also highlights potential applications, problems, and, where known, possible solutions.

1 Introduction

The Global Positioning System (GPS) is a radio navigation system with world-wide coverage, originally implemented by the United States military. The specifications of the system were released in 1978, and subsequently a number of commercial systems have been produced. Basically the system gathers information from satellites and delivers an accurate fix of the position of the receiver. As well as its military applications, GPS has proved to be particularly valuable for marine navigation systems where a number of systems are now commercially available [7]. Research interests are also very strong in the area of navigation systems for automated vehicles [8].

The Technology for Disabled People Unit (TDPU) is a research unit in the Computation Department at UMIST that is interested in the use of microelectronic systems to assist people with disabilities. It was thought that GPS could prove to be a valuable 'assistant' to blind people [2][4], providing information on a user's position, and also may prove to be useful for automating systems such as 'intelligent' wheelchairs. During discussions with professionals in the field it became clear that there was a great deal of confusion regarding just how GPS could be used by disabled people especially with regard to the level of positional accuracy. To gain some experience with GPS the TDPU purchased a Rockwell NavCore V [6] and has been undertaking some field trials. At the same time the TDPU has been undertaking a search of relevant literature to determine the current state and future direction of commercially available systems, particularly with respect to their positional accuracy.

2 How does GPS work?

As stated above, the Global Positioning System was originally intended for military use, it consists of 24 satellites (including 3 spares) orbiting in circular 20,200km orbits with a 12 hour period. Each satellite transmits unique location information in the same frequency band (1575MHz) using a spread spectrum technique. To calculate a position on the ground information is required from 4 satellites (or 3 if the altitude of the user is known). Users have a receiver (with aerial) that receives and decodes the signal from each satellite and uses this information to calculate the user's position from a matrix of four simultaneous equations. This requires considerable processing. The derivation of a user's position using 3 satellites is shown in Fig.1. The position of the user is determined where the three wavefronts propagating from each of the satellites intersect.

Fig.1. Position of user relative to 3 GPS satellites

Two services are currently provided by GPS: the Standard Positioning Service (SPS) and the Precise Positioning Service (PPS). The PPS is only available to US Department of Defence authorised user. The SPS was made available to all users on a continuous, world-wide basis with no direct charge in a 1983 Presidential Proclamation. The accuracy of SPS is stated by the US Department of Defence as being 100 m for 95% of the time and 300 m for 99% of the time. This level of accuracy is useful for many applications, notably marine navigation. However the PPS is very much more accurate, around 18m. The SPS accuracy is downgraded by adding small, random perturbations to the navigation orbit data and the satellite clock frequency. This added 'noise' reduces the precision with which an SPS

derived location can be calculated. The methods by which the noise is applied is highly secret, of course. This is known as Selective Availability and by this technique SPS has lower accuracy than DPS. However, during the Gulf war the lack of sufficient DPS receiving sets caused the removal of Selective Availability. This meant that SPS receivers obtained the higher level of accuracy for a period of time. This is responsible for some of the confusion that surrounds the accuracy of these systems.

There are several factors which can affect the accuracy of a GPS system, namely signal obscuration (i.e. the blocking of the signal from the satellite to the receiver by, for example buildings or natural features), spurious reflections and the fact that the satellites may be decommissioned at will by the US. Within a city, buildings may either obscure and reflect transmission, and, although reflections can be minimised by suitable choice of more directional aerials, in the general case signal obscuration is potentially much more serious.

3 How can the accuracy be improved?

A relatively simple way to remove the effects of Selective Availability is to use a fixed receiver at a known position. From a known position the perturbations added to the satellite data can be determined and transmitted to the mobile receivers which can then apply the corrections to their own GPS calculations (see Fig.2). This system is known as Differential GPS and the accuracy is reported to be 5 to 10 m although some claim better encoding of the difference information might increase this to 2.6 m [3]. Note that the user requires two receivers, one for the GPS signals, and the second for the differential information from the fixed receiver.

Fig. 2. The Configuration for Differential GPS

The US Coast Guard has a programme, due for completion in 1996, implementing a Differential GPS by adding the difference signal to its existing marine radio beacons operating on the Longwave band. These marine transmitters have various ranges - typically 125 Nautical Miles (approximately 230 Km), and are intended to aid

shipping in the Great Lakes area and the coastal areas of the USA., however, they can be received inland. The US. Coast Guard has liaised with the International Association of Lighthouse Authorities (IALA) to provide a uniform system world-wide and some implementation has taken place in Europe [1]. If this system is further implemented 5 to 10 m accuracy positioning may be achieved by land based users in coastal districts.

A further improvement in accuracy has been claimed by determining the phases of the carrier signal [5]. The carrier frequency of the satellites is about 1.5 GHz, a wavelength of about 200 mm. It is possible to determine the phase of this carrier wave and hence ascertain position to this resolution; accuracy of 1 cm + 1 mm for each kilometre of separation between the two receivers can be obtained. However, this requires considerable processing power and, using current technology, takes 10 minutes to compute the result.

During periods of signal loss from whatever cause, dead-reckoning may be used by using only the last received data from the GPS system, since both course and speed can be determined from two consecutive readings. Information for dead reckoning can be augmented by a compass to provide directional information, although magnetic compasses can be affected by geological magnetic anomalies or man-made anomalies such as large buildings or buses. These disadvantages could possibly be overcome by using gyroscopic compasses, but these are not absolute devices and thus require frequent calibration. Similarly, the use of accelerometers can provide data for dead-reckoning, but since their outputs must be integrated to obtain the new position, errors are also integrated. The use of such techniques is application dependent, subject to safety and accuracy requirements.

4 Potential of GPS technology for people with disabilities

There are two groups of disabled people for whom it is thought that GPS technology can be of assistance, namely blind people and wheelchair users. In the case of blind people it should be made clear that the use of GPS is to be considered very much as an assistant to the current methods of navigation using a combination of cane, guide dog and tactile maps. The detailed requirements of such systems for blind have been discussed elsewhere [4], however, in short there are requirements for the blind person: to find out their current position; to be given routing information and advice; and to have the information presented in a suitable manner, whether this be tactile, or acoustic, whilst they are moving around.

The use of the system for wheelchair users would be to enhance existing 'intelligent wheelchairs' so that they could be told where to take a user, and then be left to get on with it. In this case there are clearly issues to do with the safety critical aspects of the system, particularly with respect to obstacles. In addition it is clear that the resolution of the positioning is critical, even though it can be aided by dead-reckoning of the wheelchair's movement.

In both cases the GPS system needs to be complemented by an electronic encoding of a map from which suitable position and routing information can be

determined, and, of course, the system needs to be small enough to be wheelchair mounted, or carried by a blind person.

It should be noted that the accuracy of the GPS system plays a major role in determining the potential usefulness for disabled people. If we consider such a system for blind people, it is clear that a resolution of 100m would permit a user to know the area of the country and town where they are located, and in which direction they are heading. However such a level of accuracy is insufficient to determine which street or road they are travelling along. A resolution of 10m would, in many cases, permit a user to know the street or road name but not the side of the road they were on. It is considered vital that GPS systems for disabled people clearly identify which mobility needs they are attempting to address, and how they deal with the issues relating to accuracy.

5 GPS accuracy on the UMIST campus

An experiment has been undertaken to investigate the accuracy of a GPS system in a built up area, particularly with respect to see if the position deterioration (due to Selective Availability) could be reduced. The experiment was undertaken on the UMIST campus which has a number of multi-storey buildings as can be seen in Fig.3.

On a number separate occasions during a six hour period, sets of sixty readings were taken at each of three sites on the UMIST campus: on the benches to the front of the main building, from the corner of a roof on top of a multi-storey car park at the side of the campus, and on the lawn between the Ferranti Building and the Maths and Social Sciences Building.

The results support the accuracy level predicted in the GPS specification. Whilst the sixty readings in each set were clustered closely together indicating in the short term (around 2 minutes) a stable signal, the sets of readings taken at different times differed by up to 100m. This limited testing on the campus also showed that despite the large numbers of multi-storey buildings satellite visibility was generally good and signal loss due to signal obscuration was rare.

6 Concluding remarks

The Global Positioning System offers great potential to assist disabled people in the area of orientation and mobility. Although there is considerable interest in GPS perhaps the greatest obstacle to it becoming available to disabled users will be the cost. However, the hope is that with the considerable interest in GPS for automated vehicles and cars that the GPS hardware will become a commodity device and hence low cost.

Fig. 3.. The UMIST campus

7 Acknowledgements

The authors would like to acknowledge the work of Sartaaaj Rihal who has developed a prototype evaluation system as part of his undergraduate degree in Software Engineering from the Department of Computation at UMIST. He has contributed greatly to the practical evaluation of GPS.

This project has been carried out within the Technology for Disabled People Unit at UMIST. The authors would like to acknowledge the grant funding for this unit by both The Guide Dogs for the Blind Association and the UMIST Millennium Fund.

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