GPS/GIS and Space Time Data

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BIOGRAPHIES

Ewan Masters is a *senior* lecturer in the School of Geomatic Engineering at The University of New South Wales. He is also director of the Centre for Remote Sensing and Geographic Information Systems. He worked for five years in the early 1980's in the area of Geodynamics resear h. In 1987 he moved into the Remote Sensing and GIS field where he is now interested in the integration of the these technologies.

Bernd Hirsch has been a computer Systems Officer in the School of Geomatic Engineering for 20 years. He has extensive experience in software development and systems integration and has been mainly responsible for the software and hardware developments described in this paper.

Ken Wong is a PhD research student in the School of Geomatic Engineering. He received his Bachelor of Surveying Degree in 1993 and is now working in thearea of GPS applications and has been extensively involved in testing GPS receivers for transport applications

ABSTRACT

Abstract - The Global Positioning System (GPS) has been with us now for over a decade, providing positioning information across a broad range of applications. In the geographical information systems area the potential of GPS technology is really only just starting to be realized The major areas of use have been for mapping the locations of features particularly for asset management This papa describes the technology integration projects being undertaken Geomatic Engineering. that explores the potential of integrated technologies for space-time monitoring of any phenomena. A prototype DGPSIGIS system was developed using light-weight inexpensive, off-the shelf parts. The development of this type of technology promises to revolutionise the way we can acquire space-time data, providing us with an expanded vision of how to monitor the environment and manage all types of assets This paper also describes a few of the issues that arise when using the Global Positioning System to acquire data for Geographic Information Systems (GIS).

INTRODUCTION

GIS provides facilities to acquire, store, manage, manipulate and report on spatial data in order to assist decision making processes [I]. It is now well recognised that GPS can play an important role in the areas of data acquisition and quality *control in the GIS area.*

Data acquisition is usually regarded as the most expensive part of setting up a GIS. Figures of 80-90 percent of the cost **of** a GIS project are often ataibuted to the data capture phase. GPS technology, in many applications. therefore provides a means of reducing some of these data capture costs, especially where data is not already available in analog map form, or where field survey is still *required* to collect information in the first place Many decision-making processes will also require *results* of GIS analyses to be verified in the field In these cases, **GPS provides** a simple solution to "ground truthing GIS and remote sensing analyses or in the case of asset management **re-locating** and evaluating assets in the field.

The features of GPS that make it especially applicable to the GIS area are that it is cost effective, easy-to-use, globally available, can be as **accurate as needed, and** provides three dimensional position as well as time and velocity. GPS also enables dynamic phenomena to be tracked which means a wide field of applications have **opened** up to integrated GPS and GIS technology.

With the price of GPS receivers now below the $1000 **mark** people are taking about tracking everything from cars trains native animals to sheep and sheep dogs (for example see [2]). GPS provides an excellent tool for

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locating all types of features and themes, and mapping them. However, the usefulness of GPS in any application will be determined by three aspects of GPS: accuracy of the GPS position mode, coordinate system transformations and the data collection process. These issues must all be carefully considered when GPS technology is being **used to acquire** positional data for GIS

It is possible to purchase Real-time Differential GPS (DGPS) "off the shelf from many of the vendors that will satisfy the positioning requirements for all but the mosr accurate or unusual GIS applications. However, for many of the unique applications that are now arising that could be considered to be under the GIS banner, such technology does not provide the flexible alternatives for interfacing with other sensors and providing the desired links with other software and display systems [2;3]. This paper describes the development of a set of GPS tools for monitoring dynamic phenomena, using inexpensive GPS hardware and basic components that can be acquired "off the shelf".

A LOW-COST DIFFERENTIAL GPS SYSTEM

A GPS data acquisition system has been developed with the following requirements being kept in mind:

* the system shouId be as compact and tight as possible.
* the system should only use off-the shelf components where possible.
* the cost of the system should be as low as possible.
* it should enable real time or post processing modes.
* the system should be able to operate in a tracking mode or navigation mode.
* independent DGPS calculations should be possible.
* other electronic sensors should be capable of being logged as weII as GPS data
* automatic logging and integration into any map display system or GIS system should be Possible.
* the system should be have the flexibility to eventually log GPS data from any type of receiver.
* **the system** should have the capability to output data for any GIS data type.

Along with these requirements, the development of this System was expected to provide many side benefits in terms of expertise, that can be used in GPS **surveys and** other data collection experiments For **example the** development of the base station facilities, as described below, was required for other project work anyway.

With these requirements in mind, a GPS data acquisition system was developed as indicated by the conceptual diagram in Figure 1. The system comprises a roving receiver unit built around a Trimble SV6 GPS receiver and a pocket computer. A simple heart -rate monitor was integrated into the system as an external sensor, through the parallel port of the pocket computer. Software was developed so that the GPS and heart rate data could be logged automatically and be read by other programs if required-

The base station was developed ***around*** a Novatel GPS Card and a 486 PC. Much of the software used to log data in the roving receiver had already been developed to operate with the GPS card. Software was also developed to calculate DGPS positions on the Base Station Computer. In principle, this procedure gives the system the flexibility to calculate DGPS for any GPS receiver, that outputs the appropriate pseudo-range, time and satellite data

Custom display facilities for the GPS and sensor data were also developed rather than trying to run a standard GIS package over the top of all the other software under DOS. These facilities can display the tracked sensor data in real-time over a background map. The background maps are stored as images to enable fast redraw times whenever the position moves from one image to another. The images can be set up fairly easily from ARC/INFO coverages or by directly scanning a paper map.

DGPS surveys can be undertaken under a few scenarios. In the first alternative data can be logged independently at both the base station and roving receiver. After the survey, data is combined at the base station and DGPS calculations undertaken. The data is then reformatted for the appropriate display system. This alternative gives the "post-processed tracking option". This scenario could be used for mapping roads and tracking animals.

The second alternative uses the same configuration as the first scenario, with additional communications hardware and software to permit data to be transferred from the rover receiver to the base station. Differential corrections are calculated in real time at the base station. This alternative is the "real-time tracking" option (see Figure 2): **This** alternative could be used when real-time feedback on some phenomenon is required. For example, the performance of a person or a vehicle could be viewed in a spatial context in real rime.

Alternative scenarios can be developed around the RTCMlO4 DGPS capabilities of the GPS receiver [4]. Here the base station would broadcast the RTCM corrections and the DGPS positions would be automatically updated in the roving receiver (see Figure 3). DGPS data could then be logged or displayed in the field if required. This alternative is suitable for navigation applications, or the post-processed tracking of any phenomenon if data is stored. Car navigation systems would typically be expected to work under this scenario. This option would be difficult to implement as a real-time tracking option because two communication systems would need to he operating simultaneously from the roving receiver and base station.

To enable real-time DGPS tracking to be undertaken a suitable communications system is required to transfer data between the roving receiver and the base station. The system here was implemented with a standard cellular telephone using pocket modems and a relatively low data rate of 2400 baud.' In principle any radio or telephone system should be suitable for the communications link. However, issues that need to be considered usually include how robust the transfer of digital data over the link is and how far the base station can be from the roving receiver. At the time of implementation mobile telephones with adequate facilities for data transmission had relatively high power consumption and were also too heavy for our intended requirements of low weight and low power. However, we were interested in determining whether the telephone system was robust enough to cope with the data transmission for this application and therefore proceeded with the implementation.

The system was built as a proof-of-concept as shown in Figure 1. In principle, any of the scenarios for data coIlection could be easily catered for. The first operational real-time system fitted in a small backpack. weighing 5 Kg, with most of the weight being derived from the portable cellular phone system and the battery packs, that were required to power the mobile computer. The GPS receiver, pocket computer and health monitor weighed less than 1 Kg. The hardware for the rover system cost about US$2500 to put together at the time. All the software components were written using standard C and implemented under DOS. The computing hardware components can therefore be easily interchanged with more conventional components. The pocket computer has often been replaced with a laptop when the weight of the system is not so much of an issue

The hardwware for the base station that was already in place at UNSW cost about US$9000 to put together. The software required to drive the communications links, calculate differential corrections for the mobile GPS receiver, log the GPS data and health monitor data and display the data required 05 man years to develop.

After putting the system together and trying to operate it, the limitations of the technology soon became evident. Two computers were required at the base station; one to drive the communications link and the other to process and map the GPS data These type of problems will occur as long as DOS is used for the operating system. Also. the weight of the communications and power supply preclude the prototype system from being suitable for a person carry easily. However. these problems could be overcome by replacing various components in the system.

TESTING THE SYSTEM

The intended initial test of the “real-time” system was to track a person’s health functions while running in Sydney’s popular City-to-Surf fun run, that covers a distance of about 14Km between the Sydney CBD and Bondi Beach. The base station was located on the UNSW campus that is about 14 Km from the fun run route. On small tests around the University campus the system successfully transferred data and tracked the roving receiver. Unfortunately, the communication links were not robust enough to maintain continuity of data transmission to enable a runner to be tracked in the city-to-surf race.

As most of the problems were caused by the ambitious requirements of “real-time” tracking, a second test was attempted using the same system in the “post-processed” mode, thus eliminating the complications of the communications system. In this experiment the same equipment, minus the communications componenr. was carried by a cyclist in the annual Sydney to Wollongong bike ride. This event is run in November each year with thousands of cyclists taking the scenic ride down the coast road from Sydney to Wollongong, a distance of about 90Km. In this case the logged data was GPS tagged heart monitor data that was successfully collected for about 2 hours before the roughness of the trip disrupted the power supply to the system.

The logged data was later transferred to the map display system. where the rider's progress and heart beat could be tracked down the fun-ride route. The heart beat data was easily transferred to a spreadsheet or other numerical analysis package to cross analyse the spatial data. A portion of the data is shown in Figure 4 and Figure 5. These graphs show the cyclist’s heart beat plotted with the height and height velocity along a small section of the route. There is no particular correlations between these data sets that can be observed at this stage.

THE OTHER ISSUES

Matching GPS and GIS Accuracy

For many GIS applications, where GPS is being used to locate database features in the field_ update an existing database or simply display GPS positions on existing maps , the accuracy of GPS will need to be matched to the GIS database accuracy [7;8]. Table 1, shows which *mode* of GPS processing can be used to match GIS data that has been derived from a specific scale of source mapping. For this exercise, the positional error in the GIS database was assumed to be at the 0.5mm level at the scale of the source map. This error value is only approximate but is based on the standard mapping accuracy statement that "90% of well-defined points will be within 0.8mm of their true position on the map" and the fact that the dominant error in GIS databases is due to the basic accuracy and scale of the source mapping.

The values in Table 1 are only a guide. For any specific application, the accuracy of the GIS database would need to be more carefully assessed before deciding on the type of GPS processing that would be required. Also this table assumes that GPS data can be transformed to local geodetic datums with no error. It is evident that single receiver navigation will only be suitable for the lowest accuracy GIS applications. Generally, for nost GIS applications DGPS will be required. with a smaller subset such as asset management requiring DGPS at the sub-meue level.

Scale of Mapping	Map Accuracy	GPS Processing Mode
100 000	50 m	navigation
20 000	10 m	DGPS
10 000	5m	DGPS
5000	2.5 m	Phase Smoothed DGPS
1 000	1.0 m	Phase Smoothed DGPS
500	0.5 m	Kinematic, Rapid Static

DGPS..Differential GPS

Table 1
Matching GPS Position to GIS Databases

Coordinate Systems

Real world coordinate systems evolve and change in accuracy, though fortunately only over long time frames. Any base mapping that has been used to develop a GIS database is therefore likely to inherit the evolutionary changes of real world coordinate systems. Also, GPS operates in a fundamentally different coordinate system to that used in most current GIS databases. The transformation between aJI these coordinate systems can be caried out at varying levels of accuracy depending on the time constraints for processing and fieldwork.`

The most accurate conversion between coordinate systems requires the location of at least four points in the GIS database to be observed in the field with GPS and the transformation formulae to be empirically determined. This procedure would be required if the GIS was on a coordinate system with no known transformation values. On the other hand, published transformation formulae will transform between the common map reference systems, like those in Australia; to accuracies varying from one to 20 metres [6]The validity of the transformation process would need to be carefully assessed for any particular GIS application. In the Sydney region, published transformation values can be used to convert GPS data to the existing mapping and GIS systems with an accuracy of about lm. These formulae were used for the map display system to plot GPS position data over existing maps. The results so far indicate that the transformation is more accurate than the small scale mapping that was used in the trials.

GPS Data Collection Process

The GPS data collection process will impinge on GIS in two ways. Firstly GPS data is basically point oriented. Most of the GPS literature seems to view GIS data capture as finding a feature determining its position and assigning an attribute to it, whereas GIS data is more complex comprising points, lines and polygons and images and Relational Databases [5]. GPS dataloggers have been developed to improve the data acquisition process. However, existing datalogging systems may not have adequate flexibility and capabilities to service all GIS requirements.

The second aspect of the data collection process is how quickly the GIS database data is available after field survey. The standard post-processed DGPS scenario provides very slow feedback on the GIS data acquisition phase. In asset management applications if something is wrong, the field officer has to return to the field to recollect the data. For some operational asset management applications there would seem to be significant cost savings to be gained by providing real-time access to the GIS database using GPS as rhe database "cursor". The expense of maintaining the quality of a GIS database should also be improved if more feedback on the data acquisition process is available to the field datalogger/GIS. The feedback mechanism could be improved by providing a communication link to the base GIS system or by carrying a subset of the main database on the system in the field.

COMMENTS and the FUTURE

The results from the proof of concept system showed that the system could be further developed to track any spatially dynamic phenomena using any of the desired scenarios. The system has since been set up to navigate in vehicles using the RTCM option of the receiver to provide DGPS positions displayed on a local map. Other applications that are being explored include tracking the aerodynamic effects on a person using a parachute and tracking the spatial components of the biological functions of animals.

In Australia the future for the use of GPS for GIS looks bright with many GPS vendors setting up their own transmitting base stations. Also the Australian Surveying and Land Information Group (AUSLIG) has plans to install the AUSNAV service that will provide **base** *station data* via bulletin boards and also will transmit RTCM corrections over a standard FM broadcast. The AUSNAV base stations will be **developed** around the permanent GPS receivers that wiIl be located on the stations of the zero order geodetic network plus other stations where required. In principle, **it will be** possible for a GPS user to undertake DGPS surveys anywhere in the country without the need to provide independent base station facilities.

ACKNOWLEDGMENTS

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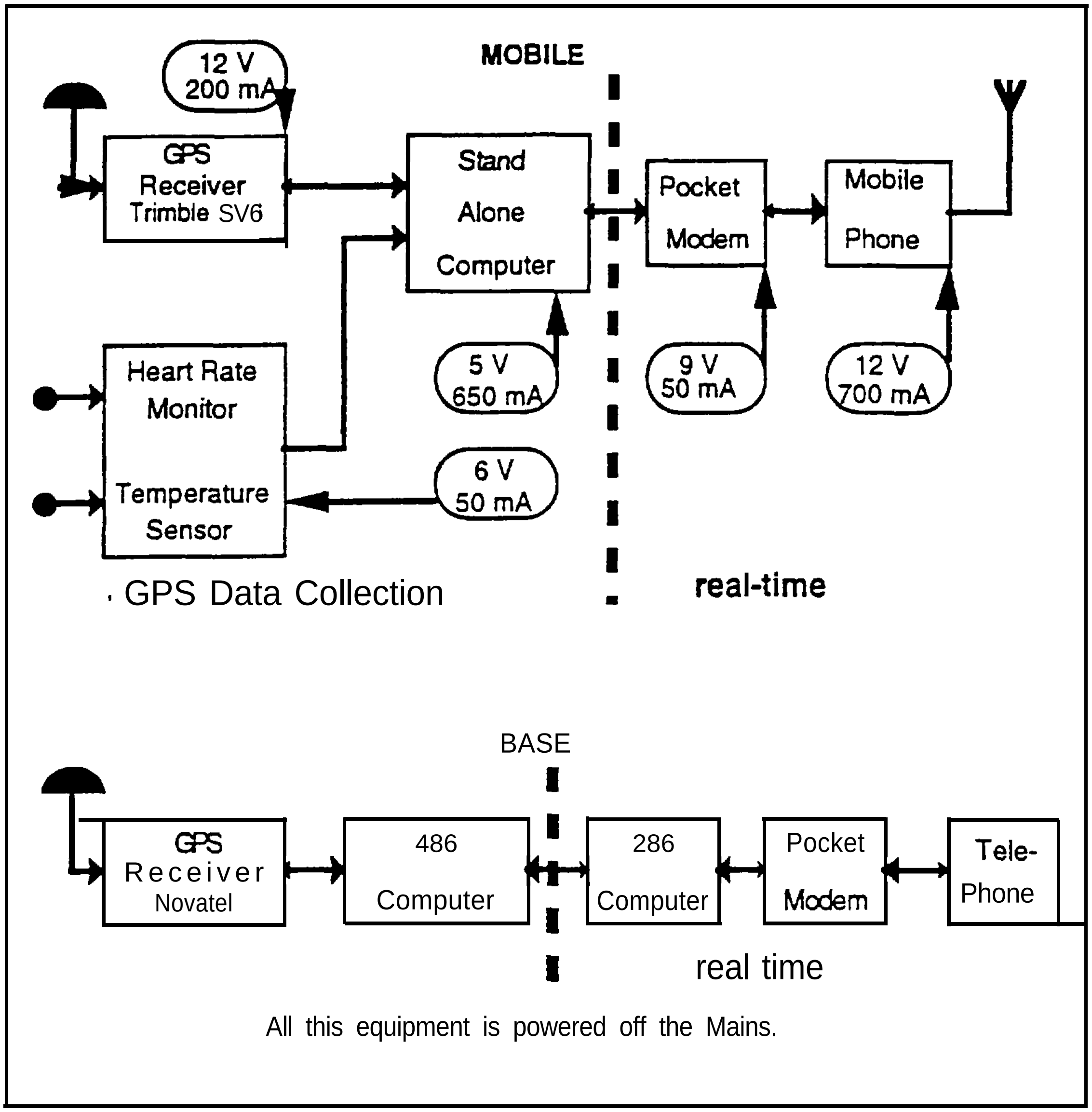

figure 1

conceptual Structure of Real-Tile, Low Cost DGPS Data Acquisition System

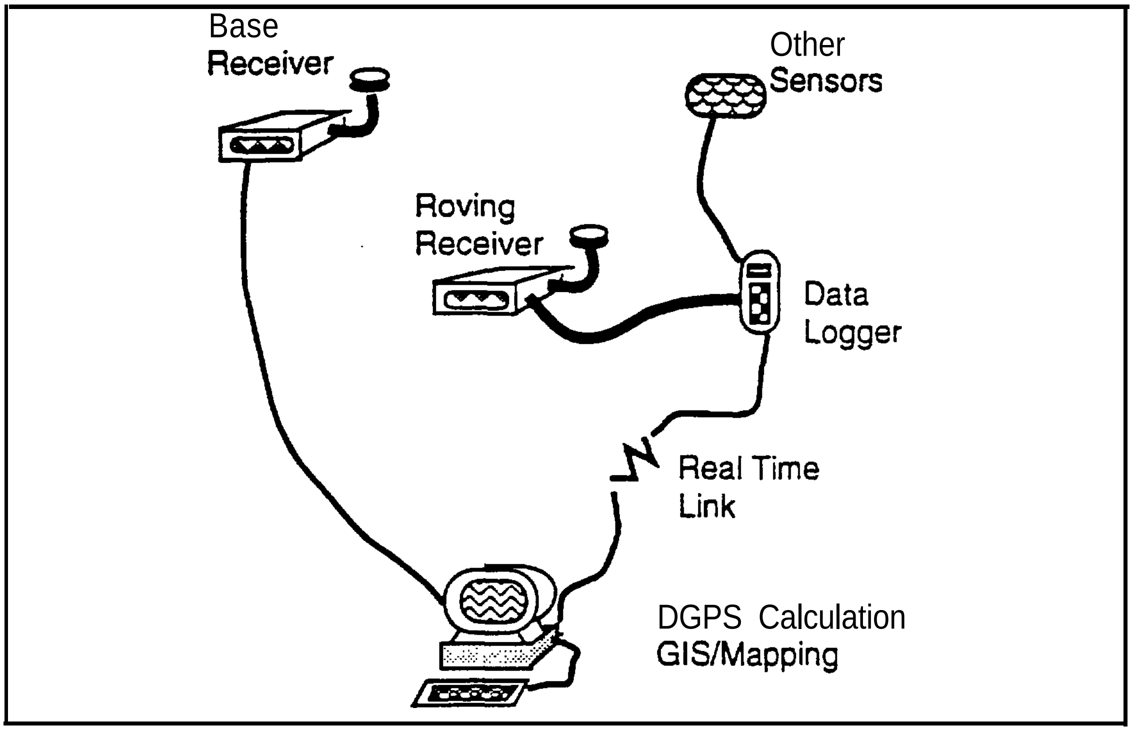

Figure 2
DGPS Configuration for Real Time Tracking **with Centralised** Processing

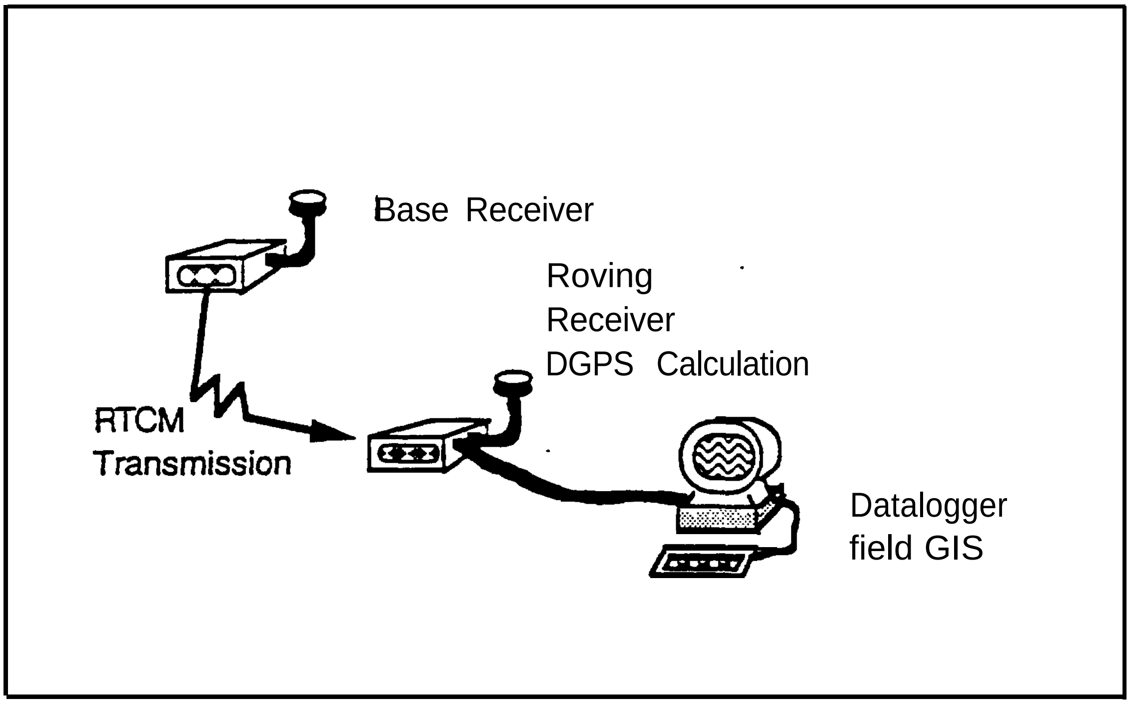

Figure 3
DGPS Configuration using Broadcast RTCM corrections

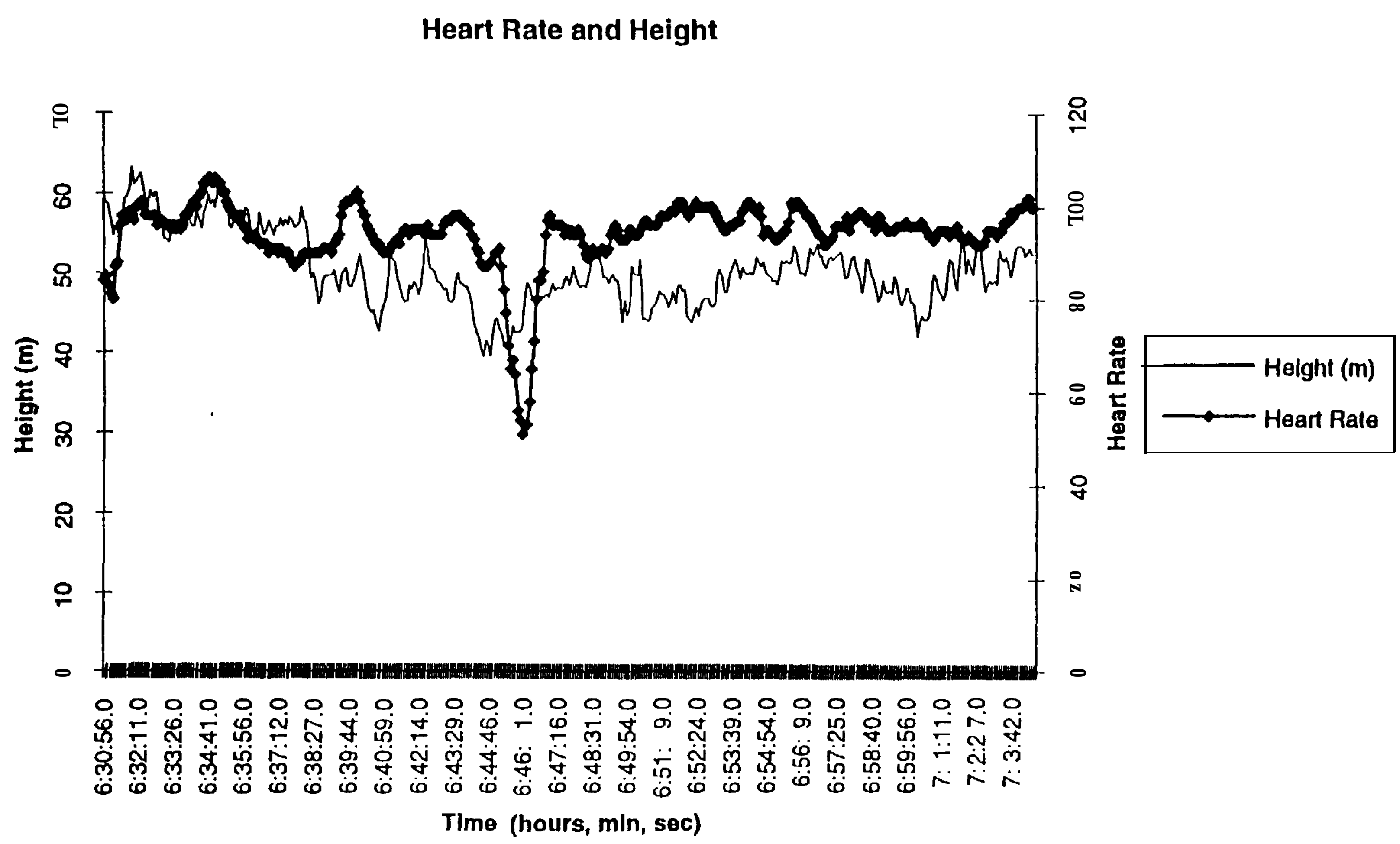

Figure 4

Plot of DGPS Height and Heart Rate for a Section of Sydney to Wollongong Fun Ride

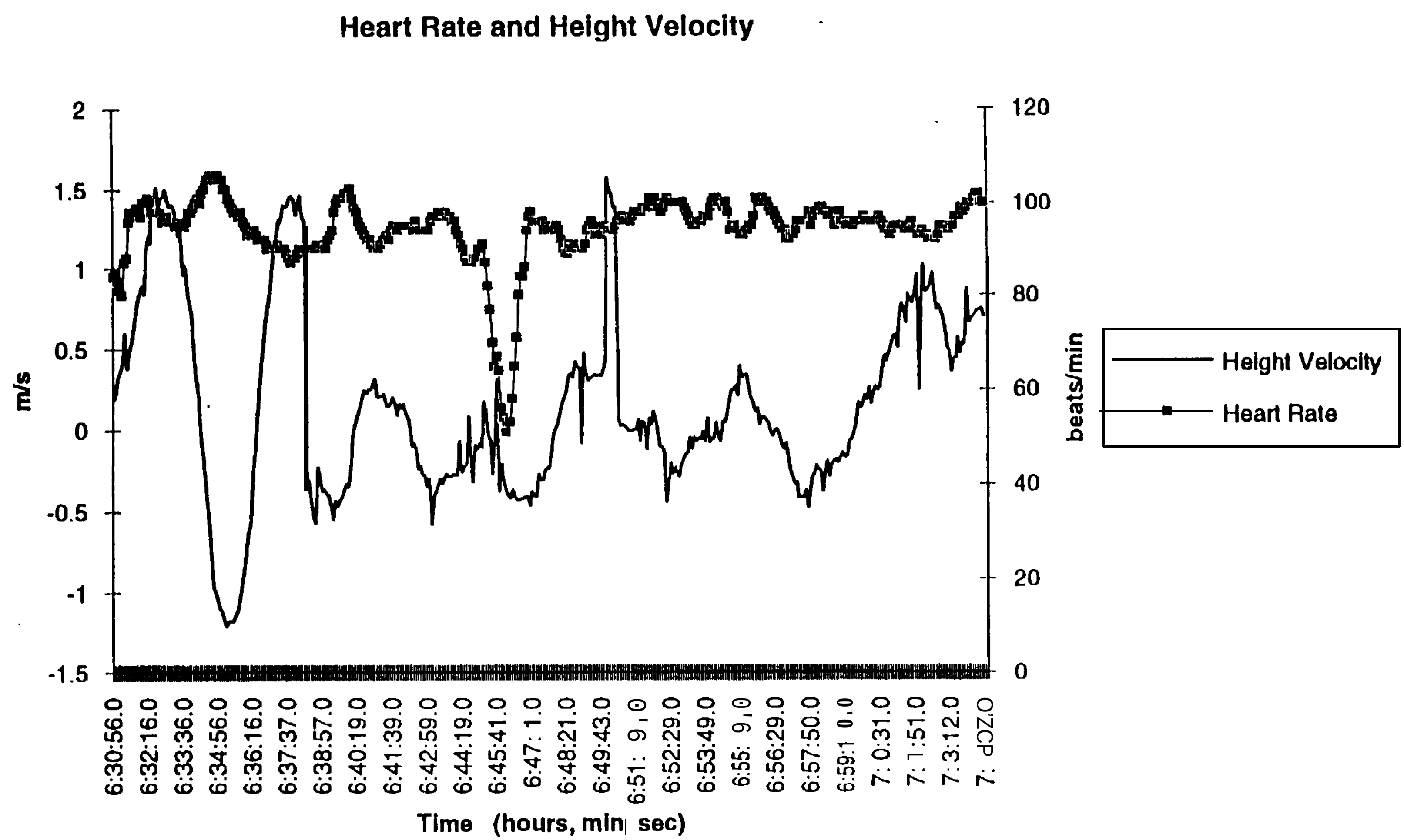

Figure 5

Plot of DGPS Height Velocity and Heart Rate for a Section of the Sydney to Wollongong Fun Ride