A WEB-BASED AUTOMATED GPS PROCESSING SYSTEM

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ABSTRACT

In the conventional scenario for GPS surveying based on the post-processed mode, users have to purchase a minimum of two sets of GPS receiver hardware, as well as the associated processing software package. This is not only a significant capital cost, but the GPS survey operation incurs additional logistical costs due to the need to operate both a Base (or Reference) receiver as well as the User receiver. In addition, in many instances the data post-processing step may be more awkward and labour-intensive (and therefore more costly) than the field data capture task, involving as it does the downloading of two data files into a PC, the operation of complex software (especially for users with minimum experience with GPS technology), and the subsequent transformation of the coordinate results into a form appropriate for the application. Use of real-time techniques is one solution to this problem, but there are many constraints to such an implementation, such as cost, distance from the Reference receiver, and the need for special communications hardware. On the other hand, a web-based GPS processing system could help users in a number of ways. A web site can be established that would accept GPS data and automatically process it. In this way the cost of GPS surveying could be reduced, as users will no longer need to buy and maintain any data processing software, or even understand the operation of such software! This web server application would allow users to send their data (in the RINEX format so that its instrument specific data files need not be used) via the Internet. The web application can be hosted by a computer anywhere in the world! Examples of such services already exist. The users will then be notified of their results by e-mail after the data processing step has been completed. In addition to such an implementation where the user submits BOTH the Reference and User receiver data files, the system can be improved so that the web application is connected to one or more Reference receivers. In this implementation, the User need only operate one GPS receiver. The complementary Reference data file is obtained from a database. In this way, data processing schemes not possible with commercial off-the-shelf GPS baseline software can be used. For example, true GPS network-based processing (where multiple Reference receiver data is used) is possible, permitting higher performance (in the form of higher accuracy, less observation time, or longer baselines) than is currently the case with single baseline modes of positioning. This paper describes how GPS carrier phase data processing via Internet could be implemented. The design and configuration of a pilot system will be discussed and some results presented.

INTRODUCTION

In high precision applications, GPS surveying technique based on carrier phase processing is widely accepted as a viable technique, since it has many advantages over traditional surveying techniques. However, in the conventional scenario for GPS surveying based on the post-processing mode, this requires the users to purchase a minimum of two sets of GPS receiver hardware as well as the associated processing software package. This is not only a significant capital cost, but the GPS survey operation incurs additional logistical costs due to the need to operate both a Base (or Reference) receiver as well as the User receiver. In addition, in many instances the data post-processing step may be more awkward and labour-intensive than the field data capture task, involving as it does the downloading of two data files into a PC, the operation of complex software, and the subsequent transformation of the coordinate results into a form appropriate for the application. For these reasons, the GPS surveying technique is still seen as being less attractive in comparison to other techniques.

At present, a tremendous amount of information is available on the Internet including GPS raw data (which is provided by International GPS Service (IGS) and many other organisations), as well as some GPS processing software packages. According to Strang & Borre (1997), a GPS data processing software package developed using Matlab code is already available on the Internet for free download. However, users still need to develop the requisite skills required to use this software. With the availability of precise GPS ephemeris and satellite clock information, the Jet Propulsion Laboratory (JPL) has initiated some work on an automated GPS data analysis service for single-point, static positioning known as the 'Auto Gipsy (ag) service' (Zumberge et al., 1997; Zumberge, 1999). This service allows users to submit data via the Internet, but users are required to have their own FTP server and only data obtained from a dual-frequency receiver can be processed. Most recently, JPL has presented a paper on an Internet-Based Global Differential GPS System which can produce single-point positioning solutions in real-time (Muellerschoen et al., 2000). However, the accuracy of results from this system is still not satisfactory for high precision surveying applications. Furthermore, the users are restricted to employing a dual-frequency receiver for field data collection.

Another alternative to the conventional scenario for GPS surveying is a Web-Based GPS Processing System. This system is able to help users in a number of ways. A web site can be established that would accept GPS data and automatically process it. In this way a reduction in the cost of GPS surveying could be achieved, as users will no longer need to buy and maintain any data processing software, or even understand the operation of such software. This web server application would allow users to submit their data via the web page. The web application can be hosted by a computer anywhere in the world. The users will then be notified of their results by e-mail after the data processing step has been completed. In addition to such an implementation where the user submits BOTH the Reference and User receiver data files, the system can be further improved allowing the web application to be connected to one or more Reference receivers. In this implementation, the User has only to operate one GPS receiver and the complementary Reference data file can be obtained from a database. In this way, data processing schemes not possible with commercial off-the-shelf GPS baseline software can be used. For example, true GPS network-based processing (where multiple Reference receiver data is used -- Rizos et al., 1999) is possible, permitting higher performance (in the form of higher accuracy, less observation time or longer baselines) than is currently the case.

In this paper, the authors first describe the design and configuration of this system as well as the implementation of the GPS data processing via the Internet. Then, two examples of GPS surveying are demonstrated. Finally, future developments and implementation issues are discussed.

SYSTEM DESIGN AND CONFIGURATION

Types of Web Server Applications

A web server application receives HyperText Transfer Protocol (HTTP) request messages from a web server. Web server applications consist of either a Common Gateway Interface (CGI) or use a web server Application Programming Interfaces

(APIs) which is usually a Dynamic Link Library (DLL). The CGI permitted the first web application programming between the user application of a web browser and applications located on the web server. CGI could be implemented in any programming language but have lacked performance. When a request for a CGI script is made it would spawn another process. In the case of the web application referred to in this paper, web server APIs were used because they result in faster execution and will not start a new process. With a server API program it shares the address space with other instances of itself. On the other hand, when a CGI program runs, the process has its own memory space, which it does not share with the HTTP server.

The web server application was developed with Borland's C++ Builder Enterprise 4.0 using Internet Server Application Programming Interface (ISAPI) -- Microsoft IIS Web server DLL extensions. The program currently works using Microsoft Personal Web Server or Microsoft Internet Information Server.

The Applications

- **Uploading reference receiver and rover receiver RINEX data files from users**

This web server application requires the user to upload both the reference receiver and rover RINEX files to the server. The only software the user requires is a web browser and the Uniform Resource Locator (URL) address to the web server. Connecting to the server returns back a HyperText Markup Language (HTML) page allowing the user to enter their e-mail address and four filenames. The files consist of the RINEX observation and navigation files of the base station and the RINEX observation and navigation files of the rover station. Figure 1 shows the HTML page of the web-based automated GPS processing system. The e-mail address is used to send the results back to the user.

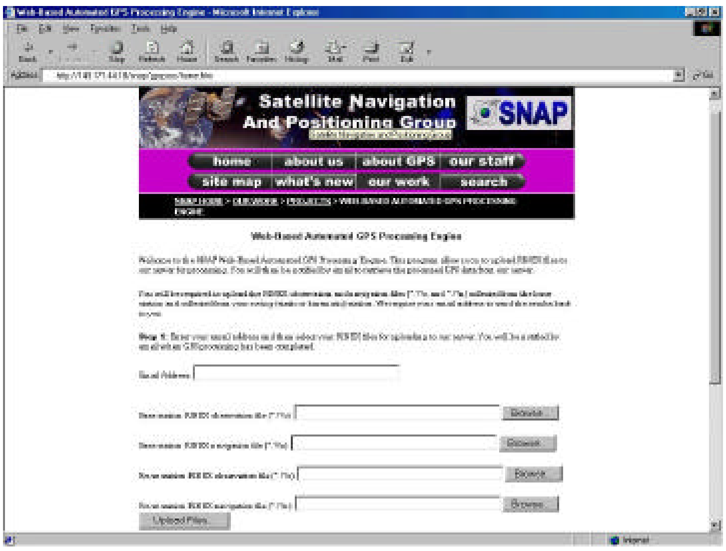

Figure 1: A HTML page of the SNAP web-based automated GPS processing system.

Once the files have been selected they can be uploaded to the server's hard disk. The uploading was implemented with Cold Fusion Markup Language (CFML) code integrated into the HTML files. This requires the Cold Fusion Server to be installed with Microsoft's Internet Information Server. This step starts the GPS processing on the server. Once it executes the baseline processing software, it then returns back a HTML page to the user before the processing has finished. This step is essential, as the user does not have to wait until the processing is finished. The user can decide to log off the Internet and wait for the results to be sent back by e-mail. The file locations of the RINEX formatted GPS data are then sent to the UNSW baseline software for processing. The results are then saved into a file, which is then sent back to user by e-mail. Various issues must also be considered, such as the automatic deletion of uploaded files to avoid the hard disk from running out of space, and the checking of RINEX files before processing. Uploaded files and files created with the GPS baseline processing program must also have unique filenames to avoid the overwriting of existing files.

- **Uploading rover receiver RINEX files from users and using complementary RINEX files from a permanent GPS base station**

In this implementation the web server application allows the user to upload only rover RINEX files to the server and a complementary data file can be obtained from a database linked to a permanent GPS base station. This is an ideal solution, as the surveyor does not need to set up a base station. The surveyor only requires one GPS receiver to be used in the field. Development started at SNAP in mid 1999 of a continuously operating GPS base station. A Leica CRS1000 GPS receiver was used as the reference receiver with the Leica Binary 2 format sent via the serial port into a server. GPS data was not stored in the flash disk of the CRS1000. The MC_CDU source code provided by Leica was used to control the CRS1000. This source code was ported to Windows NT 4.0 and compiled using Borland C++ Builder 4.0 Enterprise with the serial communications provided by the component from TurboPower's Async Professional. The ported MC_CDU source code was used to interpret the Leica Binary 2 format from the serial port. The GPS data was then inserted into an Oracle 8 database using Structured Query Language (SQL) at a one-second data rate. Currently about a week of GPS data is stored in the database. Old GPS data is constantly deleted from the database every 2 minutes. By repeatedly deleting old GPS data allows the database to reduce the number of rows to be deleted. However, by constantly adding new data the binary height of the index increases. This will increase the amount of I/O required when retrieving data from the database. Rebuilding of indexes is necessary in this application, as it reduces the binary height and the empty space caused from the constant deletion of the GPS data. For this application, GPS data is not being archived. To extract the data from a database a user can use a web browser to retrieve RINEX formatted data. The current web server application could be further improved to extract the GPS data from the Oracle database for the relevant time period and allow the survey to use only one GPS receiver in the field. The system architecture is displayed in Appendix 1.

Advantages of Processing GPS Data over the Internet

There are a few advantages of processing data on the Internet. No software installation is necessary for the user. Any software updates can be done at the one location on the server. There is no need to install client software on the machine, as only a web browser software is required. This leaves client machines 'thin'. The web browser has a common easy-to-use interface. The GPS processing software can decide automatically on what parameters are needed for a particular circumstance. There is no need to operate an anonymous FTP site, as in the case of JPL's 'Auto Gipsy' implementation. A user can upload RINEX observation and navigation files via the web browser. The program remains platform independent as far as the user is concerned, and there is no longer the need for commercial baseline processing software.

Disadvantages of Processing GPS Data over the Internet

However, there are some disadvantages with GPS data processing on the Internet. RINEX files tend to be large and the uploading time of RINEX files to the server can be long. However, this is dependent on the bandwidth of the connection to the Internet. There is less functionality available compared to commercial software. Furthermore, commercial software tends to come equipped with a full suite of options, ie, baseline processing, network adjustment, coordinate transformation, and so on.

TEST RESULTS AND DISCUSSIONS

Two examples are presented in this section. The first example demonstrates the capability of the web-based automated GPS processing system in comparison to the conventional scenario for GPS surveying. The second example demonstrates a new scenario in which users may employ only one GPS receiver.

Example 1

In this example, the GPS survey was carried out on the 10th April 2000 at the National Artillery Museum, Sydney, Australia. The aim was to establish a digital map of the museum site. The GPS surveying technique was used to establish a local base station as well as some minor control points inside the museum area. Two sets of dual-frequency GPS receivers (Leica system 300) were used in this project. Firstly, the coordinates of the local base station (G02) were determined using the traditional static positioning procedure with a 1-hour observation period, and referenced to the known coordinates of a State Survey Mark No. 35400 located in the area. Subsequently, minor control points were established using the rapid static positioning method, with a 15-minute observation span for each point. A GPS receiver on the SSM35400 station is shown in Figure 2.

Figure 2: The SSM35400 station.

The GPS RINEX data files were submitted to the web-based automated GPS processing system and the results of processing were compared with the coordinate results obtained post-processing the data using Leica's SKI software (Table 1).

Table 1: A comparison of coordinate results.

Station		Results from SKI				Results from the web-based system			
From	To	ΔX(m)	ΔY(m)	ΔZ(m)	Baseline length(m)	ΔX(m)	ΔY(m)	ΔZ(m)	Baseline length(m)
35400	G02	-117.9052	522.0017	502.7646	734.2749	-117.9106	522.0038	502.7602	734.2743
G02	205	-167.9561	-193.0743	79.2979	267.9087	-167.9552	-193.0737	79.2976	267.9077
G02	601	92.2484	-42.5359	-131.4645	166.1385	92.2506	-42.5381	-131.4695	166.1442
G02	602	100.1500	57.2221	-77.0854	138.7319	100.1532	57.2250	-77.0827	138.7339
G02	603	25.4026	29.9172	-6.3811	39.7624	25.3986	29.9225	-6.4001	39.7669
G02	604	-57.6308	-23.9934	49.9817	79.9698	-57.6339	-23.9933	49.9807	79.9714
G02	605	-69.4677	-62.0231	37.1872	100.2772	-69.4693	-62.0233	37.1818	100.2764
G02	606	-16.1528	-88.2743	-48.0557	101.7969	-16.1522	-88.2727	-48.0576	101.7964

From Table 1, it can be seen that results obtained from the web-based system agree closely with results obtained using the SKI software. (The results of more test results with the same processing algorithm can be found in Rizos et al., 1998.)

In this scenario, the web-based automated GPS processing system indeed makes the GPS survey operation easier and more effective, in a number of ways. For instance, the labour cost involved in processing the GPS data could be reduced, users will no longer need to buy any GPS processing software and do not need to understand the operation the GPS data processing software. More importantly, the accuracy of GPS results obtained from the web-based system can be expected to be at the same level as commercial software.

Example 2

This example aims to demonstrate an alternative scenario for low-cost GPS surveying in which the web application is connected to one Reference receiver. The User needs only to operate one GPS receiver, and the complementary Reference data file may be obtained from a database. In this way, data processing schemes are possible which cannot be matched by commercial, off-the-shelf GPS baseline software. An experiment was carried out on the 17th March 2000. A dual-frequency GPS receiver (a Leica CRS1000) was the User receiver, located at Bexley, in Sydney, and the complementary Reference data file was obtained from the UNSW base station. The data was collected in static mode for 1 hour and 45 minutes, at 15-second observation rate. The data was then cut into 15-min sessions and submitted to the web-based automated GPS processing system. *It is also important to note that only single-frequency data was used in the data processing step*. The results are summarised in Table 2.

Table 2: Baseline results using 15-min data sessions (UNSW base station->User station).

Time(UT)	ΔX(m)	ΔY(m)	ΔZ(m)	Baseline length(m)
23:35-23:50	-11057.8299	-1904.1804	-61.0466	11220.7501
23:50-00:05	-11057.8227	-1904.1811	-61.0524	11220.7431
00:05-00:20	-11057.8140	-1904.1795	-61.0529	11220.7343
00:20-00:35	-11057.8113	-1904.1795	-61.0409	11220.7315
00:35-00:50	-11057.8101	-1904.1837	-61.0474	11220.7311
00:50-01:05	-11057.8203	-1904.1900	-61.0519	11220.7423
01:05-01:20	-11057.8173	-1904.1820	-61.0485	11220.7379

With reference to Table 2, it is evident that the results are compatible although the baseline length is longer than 10km. From this implementation, it shows the possibility of reducing the cost of GPS surveying as well as optimising the operation of GPS receiver in the fieldwork. As a result, the cost of buying and operating a second receiver could be saved.

FUTURE DEVELOPMENTS AND IMPLEMENTATION ISSUES

The new scenario of GPS surveying described in the previous section has the ability to assist GPS users in a number of ways. For example, the cost of GPS surveying could be lowered, as users will no longer need to buy and maintain any data processing software, or even need to understand the operation of such software. Furthermore, users need only purchase one GPS receiver for their data collection, if base station data is assumed to be available and linked to the web application. The quality control issue in the new scenario, however, has not been emphasised. In the case of the implementations in the two examples discussed so far, all data processing involves only single baselines. Hence, it does not provide any check of solutions. QC and redundancy will increasingly become a serious concern for many high accuracy applications. The problem is how to establish a check of GPS solutions, or 'quality assure' the results. It is almost impossible to provide a check of GPS solutions using an implementation of only one Reference receiver. Therefore, a multi-reference receiver scenario is an alternative. The concept of a multi-reference receiver network is similar to traditional surveying techniques, as they ensure adequate levels of redundancy. The redundancies can be created by linking to nearby base stations. An example of a GPS multi-reference receiver network is one proposed for Hong Kong (Figure 3).

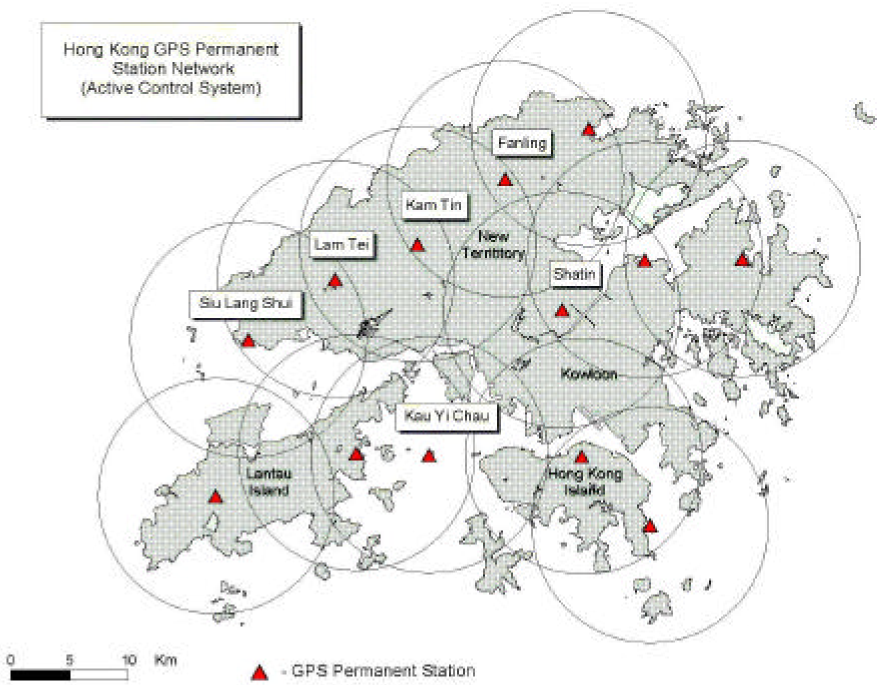

Figure 3: Proposed layout of an active control system in Hong Kong. *(Simon Kwok)*

This system provides a check by comparing a solution obtained from one Reference receiver against solutions obtained from other Reference receivers. If the discrepancy between these solutions is below a certain threshold value, the solution is then said to be acceptable (or 'quality assured'). However, the system is still restricted to operating in the single baseline processing mode, and a large number of base stations need to be established in order to maintain the inter-receiver distances below about 10km (between the nearest Reference receiver and the User receiver).

Another example is the GPS reference receiver network recently established in Singapore. This is a 'true' GPS network-based processing system, as it seeks to integrate the data from all Reference receivers (see SNAP, 1999, for details of the project). However, the web-based application is not yet incorporated into this system. Figure 4 shows the network of GPS reference receivers in Singapore. In the implementation of this GPS reference receiver network, it is possible to obtain high accuracy and reliability of GPS solutions over baselines up to several tens of kilometres, even in rapid static positioning and using single-frequency instrumentation (Rizos et al., 1999). The authors' future work will be based on the algorithm used in this project, the mathematical details of which can be found in Han (1997).

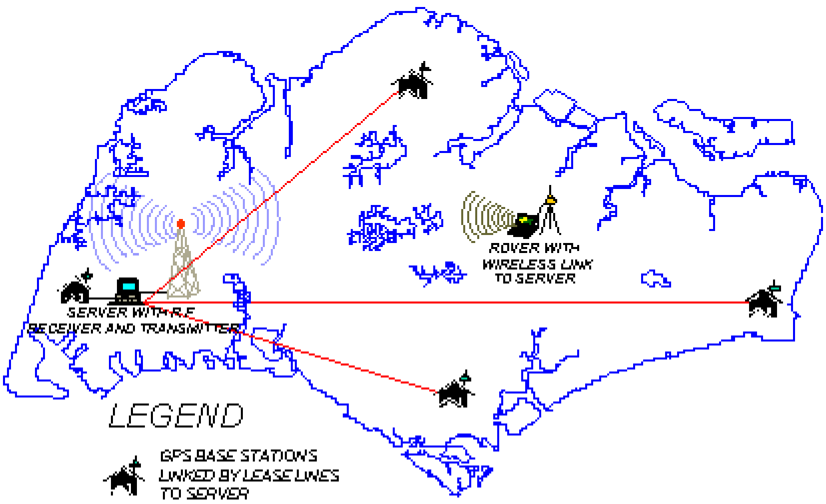

Figure 4: The Singapore GPS reference station network (Rizos, 1999).

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APPENDIX 1--THE SYSTEM ARCHITECTURE