USE OF GROUND PENETRATING RADAR AND GLOBAL POSITIONING SYSTEMS FOR ROAD INSPECTION

Fernando I. Rial, Manuel Pereira, Henrique Lorenzo, Pedro Arias, Alexandre Novo

Natural Resources & Environmental Engineering, EUET Forestal. University of Vigo Campus A Xunqueira s/n. 36005 Pontevedra (Spain) – firv@uvigo.es

KEY WORDS: Ground penetrating radar (GPR), global positioning system (GPS), data acquisition, synchronism.

ABSTRACT:

At the moment of carry out a study with ground penetrating radar (GPR) it is interesting to count with the support provided by other information sources. All the available information relative to the study area will be valuable in the subsequent phases of processing and interpretation of the obtained GPR records. Nowadays there is a logical trend to the integration of GPS devices. The decrease in size of these equipment, the increase of their accuracy and new wireless communication technologies (802.11, Bluetooth,…) encourage this incorporation. GPR/GPS integration allows an accuracy positioning of the radar data under favourable conditions. Furthermore it brings the possibility to import this data into a geographic information system (GIS). This study deepens the process of integration of both technologies applied to road evaluation. To the accomplishment of this study, a dual frequency (L1+L2) RTK GPS, two Bluetooth GPS receivers (with SiRF chip), admitting both real time differential corrections (SBAS) and a GPS receiver with postprocessed sub-meter accuracy were used. As regards GPR equipment, shielded 500, 800 and 1000 MHz antennas were used in different configurations.

1. INTRODUCTION

When preparing a study using a GPR system, it is of great interest the support provided by various information sources such as corers, odometers, thermographic cameras, laser levellers, falling weight deflectometers, profilometers or photographic cameras. All the available information related to the area studied, will be very useful for processing and interpretation of GPR data later obtained[1,2].

The characteristics of the area where the study is carried out and its use, are indicative of additional techniques that could be used more appropriately in particular cases. However its use would depend on the operator's availability and preferences. The main issue of its application would be to correctly coordinate and synchronize the information given by these devices of different nature.

Currently there is a logical tendency to integrate GPS devices, the equipment's smaller sizes, improved precision and new wireless communication technologies (802.11, Bluetooth...) help their incorporation. The integration of GPR + GPS allows to correctly position, under favourable conditions, the data obtained by radar, and incorporate all that information to a Geographical Information System (GIS).

This work examines in depth the integration process of both technologies applied to road evaluation. The interconnection viability of these devices is studied, establishing imposed limitations by both referring to: transfer speed, communications port, coordinates systems, protocol utilised and database format.

A modus operandi analysis of the GPS equipment (RTK, XT (SiRF Xtrac), SBAS...) has also been studied, which allows evaluating precision and limitations results of each system. This will help to later establish suitable configurations that will better match the requirements of a specific study.

Once the above is achieved, efforts will be directed to integrate and synchronize GPR/GPS technology with complementary information given by other devices and applications such as video cameras, or the positioning of data collected on cartographic maps of the area.

2. INSTRUMENTATION

In order to carry out tests, a Ground Penetrating Radar (GPR) model *RAMAC* from Mala Geoscience was employed. *Ground-coupled* shielded antennas of 500, 800 MHz and 1 GHz (Fig. 1) were used, as well as a group of odometer wheels of different sizes adapted and gauging to the equipment. The GPR also allows gathering simultaneous data with different antennas.

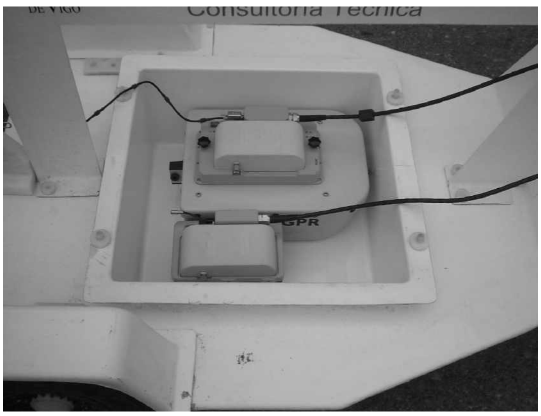

Fig.1. 500 MHz and 1 GHz antennas.

Regarding GPS systems, we used a double frequency and RTK work option *Z-Surveyor* from Ashtech, and two models of Bluetooth GPS: the *Fortuna clip-on Bluetooth GPS receiver* and the *Pretec GPSBluetooth*, allowing both of them differential corrections based on SBAS. During this study a GPS Mobile Mapper from Thales Navigation was also acquired, which offers the possibility of applying post-process differential corrections.

Although other IT support equipment was utilised, for most of the tests two laptops were used: a *Panasonic Toughbook CF-28* (PIII) with PCMCIA card *Bluetooth* (class I) and an *Acer* (Centrino) of 1.5 GHz with *FireWire* (IEEE 1394) port.

2.1 Software

Regarding software, two commercial programs were utilised.

2.1.1 GroundVision (v1.4.1)

This program allows gathering GPR and GPS data via a computer connected to a radar control unit through a parallel cable and a GPS terminal on a serial port. The software interface shows on real time both GPS coordinates and GPR data that are being registered. Regarding communications with GPS, baud rate of *NMEA* and *TSIP (Trimble)* data allowed by the program, must be set between 110 and 19200 bps. Serial ports that can be managed by the program go from *Com1* to *Com4*.

Apart from GPR database (*.rad* (heading), *.rd3* (raw data)), the program generates an *Ascii* file, in which the GPS coordinates received are associated with a trace number. By doing this, we can establish coordination between GPR and GPS data. The file's extension will depend on the selected coordinates system: *.cor* (WGS84), *.utm* (UTM), *.fri* (WSKTRANS). In any case, data is stored considering the following scheme:

Trace Number, Date, Latitude, Longitude, Altitude, HDOP

When running simultaneous measurements through several channels (multi-antenna configuration), the program generates independent files for each channel.

2.1.2 RoadCam

Road Cam is part of the applications pack Road Doctor of Roadscanners Oy. It allows simultaneous data gathering from different devices in order to study road surfaces, making possible the synchronization of radar data from a SIR unit (Geophysical Survey Systems), multimedia information supplied by video camera, GPS positioning and additional information supplied through a serial port.

The dialogue with GPR is done through a parallel port, even though this system is apparently only compatible with the radar model *SIR* of *GSSI*. Baud rate of *NMEA* data allowed by the program must be set between 1200 and 38400 bps. Serial ports that can be managed by the program go from *Com1* to *Com8*. It allows the possibility of synchronization between the database and the *frames* of a camera connected to the computer through a *FireWire* port (IEEE 1394). In this case the program takes care of creating an additional *.avi* file in which images sequences captured by the camera are stored.

An *Ascii* file is generated from this data, with *.sync* extension, where the synchronized information is stored. All the *NMEA* reports sent by GPS are collected on this file, although Road Doctor program will only take into account *$GPGGA* reports when it comes to synchronizing information. Road Cam requires a security key in order to function.

Once all the synchronized data through Road Cam is available, Road Doctor allows, amongst many processing and interpreting options, visualizing and organizing the results.

3. METHODOLOGY

In order to gather data, the above mentioned programs: Groundvision and Road Cam were used to obtain synchronized GPR, GPS and video data. As mentioned before, Road Cam synchronizes all this information in the case of the radar GSSI, but in the case of RAMAC units it is different, as it is not compatible with data obtained by GPR offered by this program. The idea a priori was to use both programs during the data gathering process, and during post-process look for a way to synchronize, in a precise manner, the traces with the remaining information already synchronized by Road Cam.

Taking into account this idea, the first solution was to use only one computer in which both programs could run simultaneously. In order to synchronize the data gathered by each program, it was established as a common nexus the GPS coordinates, so the data received through a communications port would be multiplexed using suitable software based on two virtual ports which would be connected to these programs. The main issue to this solution was the security system of the Road Cam program which made almost unviable the normal use of any other program running at the same time and on the same operative system, even using two processors working in parallel on the same motherboard.

The delay of the system required to utilise two computers. The idea to establish a common nexus between the GPS coordinates was kept. GPS data transfer was physically multiplexed by using an adapted cable, so the same *NMEA* sentences were transferred to both computers. Firstly, one computer uses Ground Vision to synchronize the radar traces, the information provided by an odometer wheel and the GPS coordinates. Secondly, the other computer using Road Cam synchronizes these same coordinates with the frames captured by a video camera.

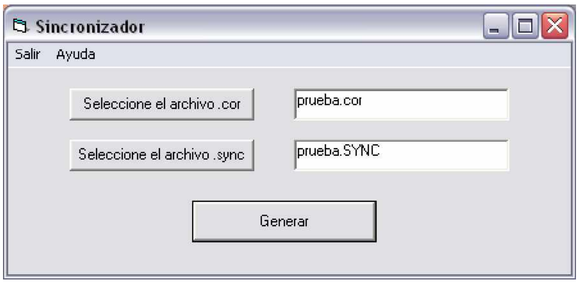

Fig.2. Synchronizer User Interface.

Once the above is achieved, during post-process, the *.sync* coordination files are modified using the information registered in the *.cor* file, so Road Doctor can present all the information simultaneously. In order to do this, a Visual Basic program was created. This program (Figure 2) reads the file traces generated by Groundvision and adjust them to the corresponding coordinates of the file generated by Road Cam.

In order to run this project, different tests under different conditions were performed, directing this study towards its application at evaluating in real time the state of the road.

4. RESULTS

When gathering GPR data, there are certain limitations that must be taken into account. The electromagnetic nature of the signal causes the proximity of metallic elements, of little interest to study, to introduce unwanted interference. This interference makes difficult the visualization and later interpretation of the obtained data.

Because of this and taking into account its specific application to road surface evaluation, it has been necessary to design a special trolley adapted to this type of study. The absence of metallic elements, in the chassis as well as rolling elements, has made difficult its design, due to the dynamic charge that it must carry. This trolley allows transporting up to two antennas simultaneously; their orientation and height with respect to the ground can be changed in order to use different antenna configurations[3,4]. As is shown in Figure 3, the rest of the equipment controlled by operators is placed inside the vehicle.

Fig.3. Equipment used during data acquisition.

4.1 GPS Precision

From available equipment and taking into account its future applications in the study of road surfaces, different circuits in different places were performed in order to evaluate and compare its precision and behaviour (Figure 4). At different stages we looked for simulating different conditions that a study like this could face, taking into account the parameters such as characteristics of the circuit, orography or data gathering speed, looking at the limitations imposed by the radar.

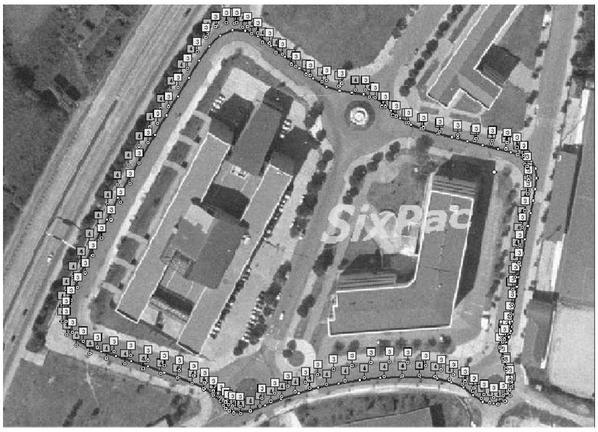

Fig.4. Example of evaluation tests: precision and coordination of available GPS equipment and GPR.

4.2 GPR and GPS Synchronization.

The following types of transmission NMEA were used:

v1.5 APA: Autopilot sentence “A”. (*GPGLL / GPVTG).*
v1.5 XTE: Crosstrack error according to NMEA0183 v1.5. (*GPGLL / GPVTG).*
v2.1 GSA: NMEA0183 v2.1 (*GPGLL / GPGGA / GPRMC / GPGSA / GPGSV / GPGSV / GPGSV/ PMGMST).*

In the trace-coordinate files generated by Ground Vision, the traces are the dominant parameter, so each of the registered traces are assigned in any case, a GPS coordinate. The information of time and date allocated to each trace-coordinate in these files, it is determined by the time and date of the system (*NMEA0183 v1.5*), or by the GPS time and date (*NMEA0183 v2.1).* In the first case, the *Height* and *PDOP* always appear with a null value due to the fact that the sentences in this version do not provide this information.

In the frame-coordinate files generated by Road Cam, the *NMEA* sentences and therefore GPS coordinates are the dominant parameter. So all *NMEA* messages that arrive to the program remain registered in the archive and each of them is assigned a frame and the corresponding milliseconds (as well as other parameters, optional or not, as seen before).

After performing several tests, some irregularities were observed in the files generated by Ground Vision. Something to be highlighted is the appearance of different traces in the same second with different GPS coordinates, as well as different traces in different seconds with the same GPS coordinates. It is also interesting to mention that in specific traces, randomly and without an apparent reason, the GPS date was substituted for the date in the system.

These small alterations have been taken into account when developing the application to obtain the suitable file *.sync,* which allows the program Road Doctor to synchronize all the information (GPR, GPS, Video…). On one hand, for the case of several traces in the same second, new *$GPGGA* instructions are generated with the same time but interpolating frames *(n2)* and starting milliseconds *(n1)* in relation to the next command. In another case, when traces present the same

GPS coordinates, these are interpolated with the next command following the route taken.

4.3 GIS Integration

We have collaborated with the technical consultancy Enmacosa in the GPR data integration process obtained in GIS of their property, oriented to the inventory of the national road network.

5. CONCLUSIONS

In order to synchronize all data and being able to visualize it simultaneously with Road Doctor, two computers were used. One computer is connected to a GPR through a parallel port and a GPS through a serial port. Ground Vision is executed, generating three files. The first one contains the 16-bit binary data (*.rd3*), the second one saves the header information (*.rad*) and in the last one the trace number and GPS data are logged (*.cor*, *.utm*, *.wks*).

The other computer is connected to a video camera through a *FireWire* port (IEEE-1394) and a GPS through a serial port. This GPS is the same one that is connected to the first computer. For this, an adapted serial cable with two exits was used. RoadCam is executed, generating the two files. One that contains the video file (*.avi*) and another one in which frame number and GPS data are logged (*.sync*).

This *.sync* file is modified from the information trace-coordinate provided by Groundvision so, it can be interpreted later by Road Doctor. By doing this, all synchronized data can be presented simultaneously.

The way to interconnect data could be through an odometer wheel (it is being developed) or through GPS coordinates. In this last case, it has been observed that, despite some difficulties, it can be a quite precise method, and it will also depend on the available equipment's features.

Following results, the Mobile Mapper is the equipment offering the best features, therefore it will be utilised to run the rest of the tests. In any case, due to the fact that Road Doctor only reads *$GPGGA* reports, the selected *NMEA* transmission must contain commands of this type. Groundvision is the least restrictive in this case as it can interpret without problems *$GPGLL* reports.

We continue to work on the programs clean up, as well as the behavioural study in each case of lost satellite coverage. We continue to work on the study of the gap between samples and GPS coordinates, in order to obtain the best possible adjustment, also using map-matched correction techniques[5].

ACKNOWLEDGMENTS

This project is the result of a collaborative effort between the Environmental Engineering & Natural Resources Department of the University of Vigo and the companies Panatec S.L. (Spain) and Roadscanners Oy. (Finland). Authors are also grateful to Maria and Adam Vietri for review of the text.

REFERENCES

1. Saarenketo, T., Scullion, T., 2000. "*Road evaluation with ground penetrating radar*" Journal of Applied Geophysics, Vol. 43, pp. 119-138.

2. Nedad Gucunski, Parisa Shokouhi, March 2004. "*Demonstration of Ground Penetrating Radar (GPR)*" NJDOT Statewide GPR Pilot Project" Final Report. Center for Advanced Infrastructure & Transportation (CAIT). GPR-RU4474. 29 pages. NJ (US).

3. Richard Bloemenkamp, Evert Slob, 2003. "The effect of the elevation of GPR antennas on data quality. Proceedings of the second International Workshop on Advanced Ground Penetrating Radar (IWAGPR), May 14-16, Delft, The Netherlands".

4. J. van der Kruk, J.H. Zeeman and J. Groenenboom, 2002. "Multicomponent imaging of different objects with different strike orientations" Proceedings of the ninth International Conference on GPR, pp 150-155.

5. Geoffrey Blewitt and George Taylor, 2002. "Mapping Dilution of Precision (MDOP) and map-matched GPS" Int. J. Geographical Information Science. Vol. 16, no. 1, pp 55-67.