Geostatistical approach for controlling bus movements in Greater Lisbon using GPS

Marco Painho, Thomas Bartoschek, Roberto Henriques
ISEGI - Universidade Nova de Lisboa
Campus de Campolide, 1070-312 Lisboa, Portugal
Telephone: +351 21 387 04 13 Fax: +351 21 387 21 40
{painho, tbarto, roberto}@isegi.unl.pt

SUMMARY

This paper describes the running development of a Location Based Application as part of an Integrated Geographic Information System ("SIIG"), made for the Lisbon Transport Delegation (DTL). The stand-alone application "busGPS", has basic GIS Viewer functionality as zooming, mapping and measuring. It allows tracking of a moving object, in this case a public bus, with a GPS receiver, saving the geographical data with the needed attributes (speed, time error, heading…) in different formats (shape and ASCII). It is connected to a database containing data on bus-routes, bus-stops and timetables. Out of the collected GPS-data the application recognizes the driven route or the most approximate one. It recognizes the bus-stops, where passengers entered or got out the bus and the time-delay at each station. The collected data can be saved for efficiency-control and statistics can be done to support operational performance. For this issue "busGPS" offers data analysis tools providing several statistical indicators on geographical deviations of bus routes/bus stops, time deviations of the timetables.

KEYWORDS: LBS, GPS, Transport

INTRODUCTION

The Lisbon Transport Delegation (DTL) is one of the components of the DGTT (General Directorate for Land Transportation) structure, operating in the Region of Lisbon. DTL has two main purposes: strategic planning and operational performance. The first of these concerns is own ability to perform more effectively in transport planning, especially public passenger transport. For this reason DTL is using a geographic information system (GIS) to facilitate the mapping, storage and integration of data for transport analysis. The second main purpose involves licensing and inspection processes. For controlling issues a location based application is a needed solution. The use of this technology could supply new instruments (like location based statistics) increasing the efficiency of the operators service.

An Integrated Geographic Information System (SIIG) has been set up and is in use both on DTL as on operator side to automate work processes and routines, to be more efficient in the inspection and licensing process and to establish a database on the public road-transport passenger service.

SIIG consists of 5 distinct but complementary applications that are related to each other through a general database (*Figure 1*):

SICO (Information System for Operators' Routes) loads a general database with information on routes, stops, timetables and other relevant topics, on the part of the operators. SIPI (Information System for the Production of Indicators) produces a series of indicators and statistics related to traffic, production or other matters that are essential for planning and producing reports based on the database. SIAP (Information System for Planning Support) allows incorporating new information into the database. SAICO (Information System for Graphical Output Reports) supports spatial queries on the database. Technical staff is able to assess licence applications in accordance with the current legislation and/or other aspects that the DTL sees fit to include. SIACC (Information System for Route Licensing Support) supports Licence requests via the internet.

This existing GIS is missing a module, which treats live tracking position data for different issues. The module has to be above the other applications to supply them with this new additional information. Examples could be on DTL-side: controlling of operators on offering the certain licensed bus route, controlling of timetable certainty and delay statistics. On Operator-side: possibility of implementing a Passenger Information System or Fleet Management and Tracking System. The use of the Global Positioning System (GPS) for this kind of location based application is inescapable. Finding the position of a moving object, in this case a bus, needs a certain accuracy, which has increased in the GPS since new systems like WAAS/EGNOS are included.

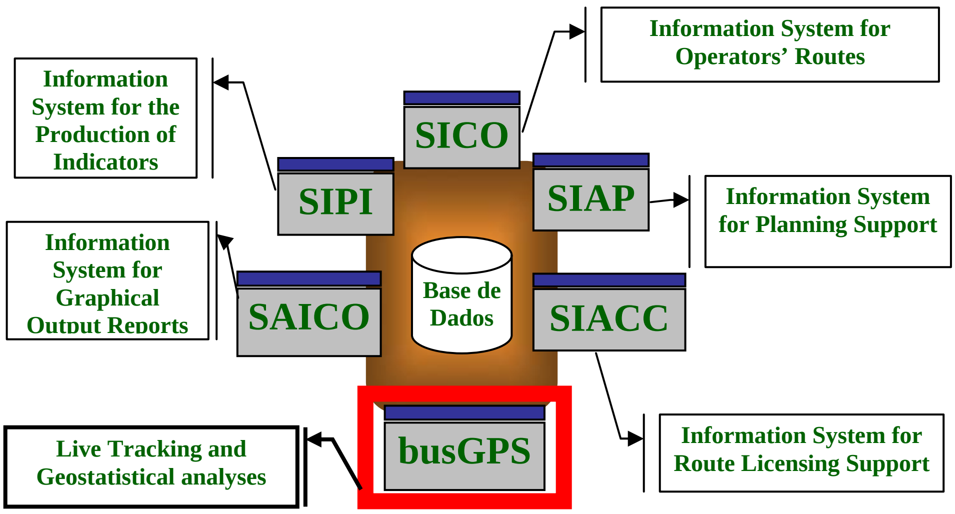

Figure 1: SIIG Architecture

DEVELOPMENT

busGPS is a stand-alone application. It is thought as a module for SIIG, but can be used on its own, too. The application has basic GIS-viewer abilities. Different kinds of layers (Shapes, Images, Coverages or GRIDs) can be added, zooming, panning and measuring is possible. An identification-button is included for attribute analyses of map objects. It is possible to change symbology and consult a map legend.

Besides that busGPS allows connecting to a GPS-receiver through the serial port or a simulated serial port (like used by the Bluetooth technology) and receive data from the GPS-device. The data transferred has to be in the common NMEA 0183-format (*Figure 2*), which is supported by all common GPS Receivers. The data is parsed and passed to the different components of busGPS: The actual position is shown on a map; attributes like speed, error or time can be displayed. For controlling matters the user can see the passing NMEA-sentences, satellite positions and signal strength are shown too, if wished so. The received data can be saved on runtime into an ASCII-format file containing the NMEA-sentences. It is possible to load this kind of file and review the complete tracking process saved. The second possibility to log the tracking object is the shape-file format. The tracking process is saved into a shape-file together with its current attributes.

```
$GPGGA,145118.56,3843.9718,N,00909.5928,W,0,04,3.6,115.3,M,50.1,M,,*7A
$GPGLL,3843.9718,N,00909.5928,W,145118.56,V*07
$GPVTG,249.3,T,255.4,M,2.1,N,3.9,K*4D
$GPRMC,145118.56,V,3843.9718,N,00909.5928,W,02.1,249.3,110305,06.,W*76
$GPGSA,M,*0F
$GPGSV,3,1,08,20,76,259,44,11,69,063,49,01,38,069,,24,29,293,*79
$GPGSV,3,2,08,07,28,312,,28,26,263,,23,24,172,,19,23,146,*7D
$GPGSV,3,3,08,,,,,,,,,,,,,,,,*71
$GPGGA,145118.56,3843.9718,N,00909.5928,W,0,04,3.6,115.3,M,50.1,M,,*7A
$GPGLL,3843.9718,N,00909.5928,W,145118.56,V*07
$GPVTG,249.3,T,255.4,M,2.1,N,3.9,K*4D
$GPRMC,145118.56,V,3843.9718,N,00909.5928,W,02.1,249.3,110305,06.,W*76
```

Figure 2: NMEA-Sentence example

Use Case DTL

The application can be used by DTL for controlling, if a bus is on its licensed route: Based on the given bus position (received through GPS), the route database, which contains data of all operators, is searched for passing routes in this point. Several routes can pass in one point, so the next received points by the GPS are added to a collection and then compared again to the database. To exclude more routes from the probable route collection the time-constant can be included to the query. Not every bus route is provided at every time of the day and day of the week. After a short time the certain route is found. Or it is not found, if the bus is on a not licensed route, which would lead to a fine for the operator. The applications statistics-tool performs spatial analysis operations like calculating distances from the measured GPS-Points to the bus route and provides minimums, maximums, averages and other statistical indicators to see in which terms the bus has left its original route. The results can be shown in a report and/or spatial on the map. An analysis of the bus stops, where the bus has stopped on can be done too. The received GPS-Points with the attribute of speed equal to 0 (where the bus stopped) are compared to the bus stops in the bus-stop database (of all operators). Not every time the bus has a speed of 0 it has to be on a bus stop, a traffic light or a simple traffic jam can provide this information too. Only GPS-points are chosen to represent a bus stop where speed is equal to 0 and a proximity of less then 10 Meters (the approximate length of a small bus vehicle) to a bus stop from the database is given (*Figure 3*). The information about time delays on each bus stop is calculated from the time difference between the values in the timetable database and the time values delivered by the GPS in the points, which represent the respective bus stop. Statistics on this data are supplied by the statistics-tool, too.

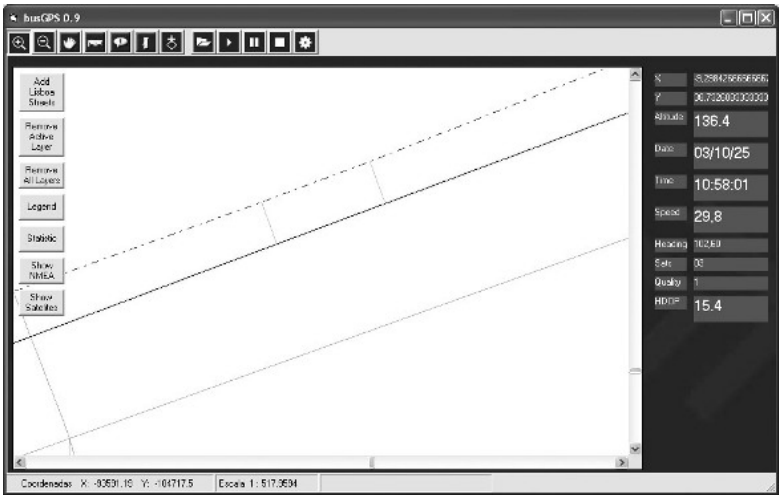

Figure 3: Spatial output on distance analysis of GPS-points to bus route. Vertical lines are the differences, the dotted line is the course of the bus (connection of GPS points), the bold line is the bus for statistics selected bus route

Use Case Operator

Operators can use busGPS during the route planning phase to collect GPS data on existing bus stops or time analysis. Other uses could be calculating statistics on the own efficiency on time delays, to improve the timetable management. Further possibilities are the extension of the application to a Passenger Information System or Fleet Management System. The basic data for these kinds of applications is given with the parsed GPS-data and the connection to the database on routes, bus stops and timetables.

Design

An application's interface is of extreme importance. It is inextricably related to the usefulness of a geographic information system. An interface should be easy to learn, appear natural, and be independent of implementation complexities such as data structures and algorithms *(Egenhofer and Frank, 1988)*.

The User Interface Design of busGPS is adapted to the design of SIIG, especially SICO, to maintain the link between these applications. It is kept easy with the map in its centre and a toolbar with common buttons for GIS applications. On the right side of the map are shown the interesting numerical GPS attributes (Coordinates, Altitude, Date, Time, Speed, Heading, Error…). Additional components like legend, satellite display and other are available in extra windows on click, not to confuse the user with to many objects on the main window. A Beta-version of a conceptual design (*Figure 4*) with a map as the core of the User Interface and half-transparent graphical buttons, toolbars and components above it is in its development phase. It is planned to let the user choose between one of the interfaces, the classical or conceptual view.

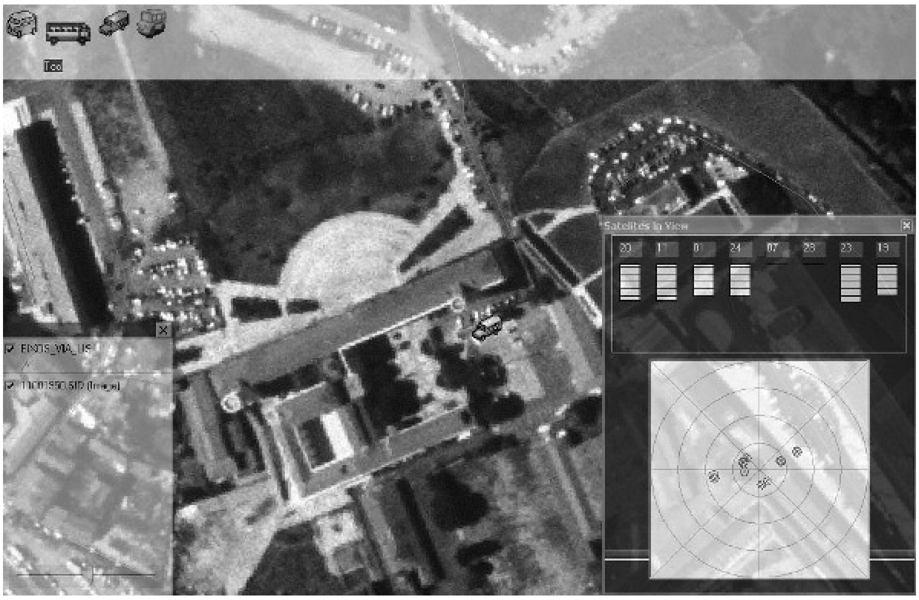

Figure 4: Conceptual design beta version

Implementation

busGPS, like all other SIIG Applications, is implemented in Visual Basic 6 due to its capacities in database connection and progress effectiveness, using the component software technology Map Objects® 2.2. from ESRI.

Testing

The application was tested with different GPS-Receivers to ensure its equipment-independent functionality. Tests have been run on GPS-Receivers of the following brands: Magellan, ANYCOM and Garmin. The geostatistical functionality was tested with data from the operator Vimeca, serving the western Lisbon area, who also facilitated live tests on its busses.

Future Work

Main objective on the future work is the implementation of busGPS for a mobile device, like a PDA to provide better mobility. Other relevant possibilities of the development are the implementation of a Passenger Information System, offering the time delay or vehicle position data collected with busGPS to the customers. The time delay could be displayed in a numeric form on a panel at the bus stop or graphical on a web-interface offering platform-dependent information.

RESULTS

The result is an application with some general and some very specific functionality. It is adapted to the particular needs of DTL. The state of the art covers GIS/GPS-viewer abilities, live tracking, location based analysis and statistical operations. The User Interface (*Figure 5*) is simple and clear.
The application is still in its development process and not yet in use for DTL or operators, additional features and enhancements (i.e. conceptual user interface) will be implemented and tested to reach a more user friendly but still powerful level.

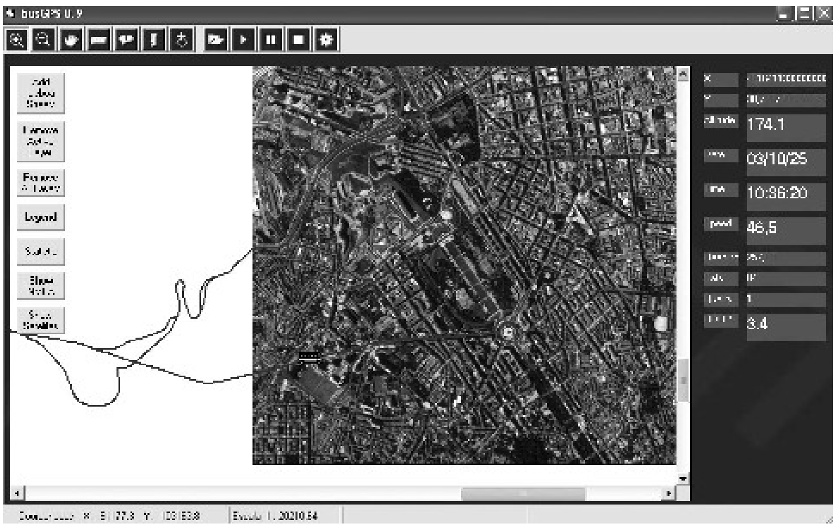

Figure 5: View on classical design on application in use

DISCUSSION

In the transportation area, geographic analysis is the key to making better decisions. Geographic Information Systems and Location Based Applications are, in this way, very efficient tools for managing and analysing information with spatial qualities.

The use of the Global Positioning System as source of location data is increasing and new technologies (WAAS/EGNOS) improve its accuracy on runtime. This makes the system even more mobile, because no post precessing is needed for a high accuracy like in DGPS.

Recent developments in geographic information technologies, mainly component software, allow better adjusted applications, and also promote the insertion of geographic information technologies in institutional information systems (*Painho et al, 2000*).

BIBLIOGRAPHY

ESRI, 1997 Building Applications with MapObjects

Egenhofer, M. and Frank, A., 1988: Designing Object-Oriented Query Languages for GIS: Human Interface Aspects, Proceedings of the Third International Symposium on Spatial Data Handling, International Geographical Union Commission and Mapping; Falls Church, VA

Painho M., Peixoto M., Sena R. and Cabral P. (2000): Integração de Sistemas de Informação Geográfica: O Sistema de Apoio à Avaliação de Estudos de Impacte Ambiental, - Proceedings of the 1st Conference of the Portuguese Information Systems Association, October 25th – 27th

Painho, Marco and Henriques, Roberto and Laginha, Christina, 2002: A Geo-based information system for transportation planning, 23rd UDMS

Henriques, R., Sousa, P., Freitas, M.J.,Seabra,I., Painho, M., 2004: SIGGESC – Sistema de Informação Geográfica de Gestão de Carreiras, ESIG 2004