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A Decision Support System based on smartphone probes as a tool to promote public transport

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Abstract

In the last few years, the increase in mobility has coincided with an ever greater use of an individual mode of transport. The causes of this situation are imputable not only to a growth in economic wellbeing, but also to an inadequate organization of public transport services that still represent a valid alternative to the car use only in sporadic cases. Recently the research community, local public administrations, national and federal governments focused their attention on methods and techniques able to promote the use of public transport, reducing energy consumption, pollution levels, congestion levels and road traffic. However, in order to make more effective all initiatives to promote public transport, a large amount of information about service network accessible to users is essential. Based on this assumption, this paper presents a Decision Support System that relies on a logical network architecture characterized by the communication paradigm REST and powered by the use, on Client side, of smartphones that today have an enormous social relevance. Key goals of a REST-based platform include scalability of components interactions, generality of interfaces, independent deployment of components and intermediary components to enforce security and reduce latency.
Through the elaboration of a large amount of transportation systems and land use data (Server side) and an user-friendly interface on the client it is possible to simultaneously register users' behavior on each trip they made (GPS sensors on smartphones allow the storage of the origin, the destination, the temporal window, the used mode of transport, the routes of the trips on the Server) and propose to users travel strategies alternative to car use.
The Decision Support System is based on a Service Oriented Architecture (SOA) structure and it is characterized by interoperability of the entire set of data as well as support the independent Open Geospatial Consortium (OGC) web services, such as Web Feature Services (WFS) and Web Map Services (WMS), in order to provide a series of spatial analysis web services via a spatial database back end, as well provide a basis to share spatial data with different data models and from different sources without data conversion.

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1. Introduction

In order to follow the progressive increase of population density in urban centers and, consequently, the increase in mobility, public transportation sector, in recent years, has been involved in big technological changes. According a new transport planning concept targeted at orientating the demand towards sustainable forms of mobility, public transportation can be considered a possible solution to reduce networks congestion levels and atmospheric pollution in urban centers. However, to reduce the use of individual modes of transport and attract an higher rate of passengers, the quality of provided services must be improved. To accomplish this task, the public transport must be accessible, must have frequent runs, trip times at least comparable with individual vehicles and users need to know the service network for planning their trips.

The application of intelligent transportation Systems (ITS) in public transport sector allows the solution of various categories of decision problems, such as vehicle routing and scheduling, crew scheduling, service optimization, fleet and transportation infrastructure maintenance and renovation, transportation projects evaluation, and others. In particular, due to the complex data required by services planning and problem solving, there has been a growing interest in the use of decision support systems (DSS).

In literature, most of the DSS-s are combined with Geographic Information Systems (GIS) (Eibl, 1994; Lopes et al., 2008; Randall et al., 2005; TRANSCAD, 2012), that for spatial data analysis are composed of three basic modules: graphical user interface (GUI), data-base management system (DBMS) and spatial modeling tools.

In order to raise the communication to/among users an emerging feature of DSS-s is the use of Internet sources and Internet communication, with the development of web-based DSS-s applications (Prindezis & Kiranoudis, 2005; Ray, 2007; Vannieuwenhuyse et al., 2003), characterized by standardized data exchange protocols (XML and EDIFACT) in order to ensure quality, reliability and consistency of the information and, at the same time, the compatibility between different computer systems. Another important issue in transportation oriented DSS-s is the need for on-line communication and accurate data exchange in real-time (Giaglis et al., 2004). For these purpose, a series of mobile applications for transportation are developed and linked with DSS-s. Traffic data transmission is ensured by GSM (Global Systems for Mobile Communications) and GPRS (General Packet Radio Service) technologies. Recently, with the development of smartphone mobile technology, the DSS-s, are virtually able to share traffic data among several connected users, capturing behavioural choices of each user and, consequently, offering customizable collection of data. Besides a GSM/UMTS module, the smartphone can be viewed as an intelligent terminal that is now ubiquitous. It guarantees a mobile internet connection through a 3G network environment and, in addition, it is equipped with a series of sensors as high-resolution cameras, assisted GPS, accelerometers, and magnetometers. According Lane et al. (2010), the research area of mobile phone sensing will improve planning and managing aspects of many business sectors, including transportation. In recent years some researchers applied mobile smartphone technology to transportation problems. Bierlaire et al. (2010) proposed a method for estimating route choice models from smartphone GPS data achieving satisfactory results. Magliocchetti et al. (2011) presented an application for smartphones and tablets which promotes use of public transport by helping user to identify the best travel option across a multi-modal transport network. Guido et al. (2012) led a road safety study on rural highways based on vehicle speed and acceleration parameters obtained from smartphone probes.

The main objective of the research is the development of a fully working platform prototype that, using a logical network architecture characterized by a client / server communication paradigm and the smartphone mobile technology, is capable of capture users' behavior in each trip they made (storing trips origin and destination, time window of the trip, kinematic parameters related to the specific transport mode used and trip routes) and suggests, for the same trips, alternative travel strategies characterized by the use of public transport. In this way, this technological platform allows for travel strategies planning an high level of customization of services to personal preferences and encourages sustainable forms of mobility with indirect benefits for the overall community reducing external costs as pollution and congestion levels.

2. Platform architecture

Transportation Decision Support System (T-DSS) paradigm changes and evolves as more technology and knowledge become available to the transportation community.

The main objective of the T-DSS designed for this study is to support users to take decisions about trips based on a large amount of geographical data and information; a GIS can be used to manage geographical data, which are otherwise difficult to access by traditional methods. In order to achieve this objective, the system is based on a geospatial object-oriented database structure for a wide variety of data, supported by a user friendly web based application equipped with GIS capabilities.

The chart below shows an overview of the system architecture, with a specific indication of the levels of information.

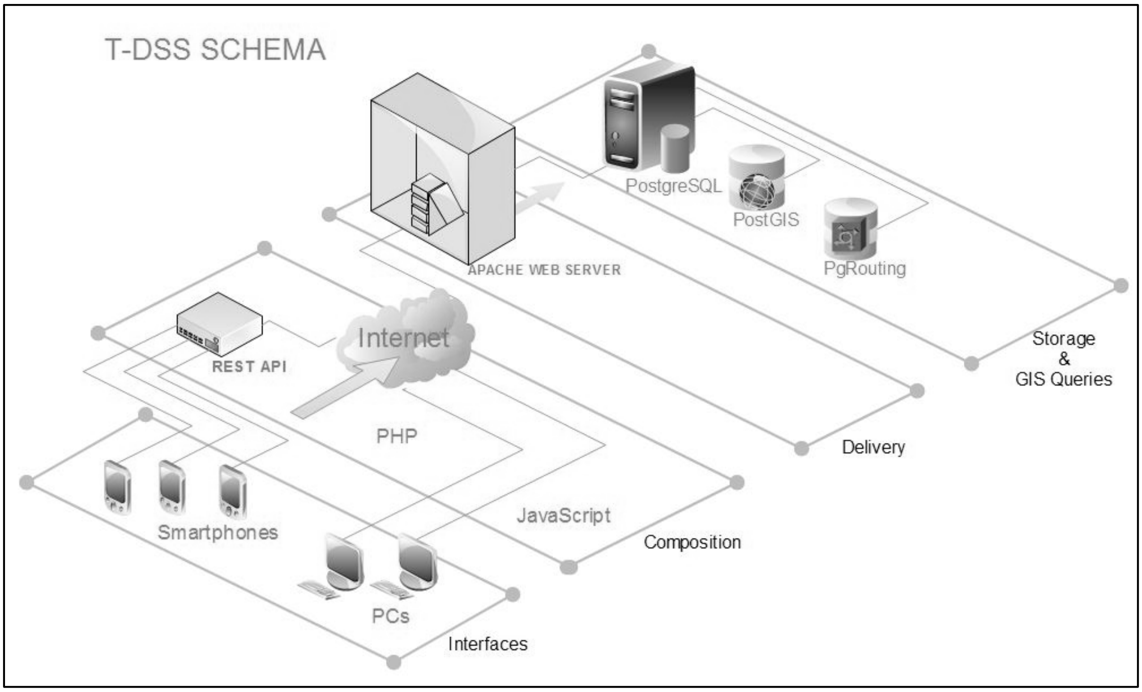

Fig. 1. Overview of system architecture

The entire platform is based on open-source technologies. Motivations for developing open source software are various, ranging from philosophical reasons to pure practical issues. Open source software is free to use, modify and distribute, in addition to the continuous analysis by a large community that produces secure and stable code.

The operating system used for development is a Linux distribution known as one of the most stable server environment: Debian Linux. The web server installed is Apache HTTP Server, which is able to ensure HTTP service delivery in according with the last protocol standards, suitable to the implementation of a Service-

Oriented Architecture (SOA). The entire dataset is processed and shared over the internet as REST service, used as a typical implementation of SOA. Using REST to publish information ensures scalability of components interaction, independent deployment of modules and generality of interfaces, according to future development of platform.

A Database Management System (PostgreSQL) supports the platform regarding storage and management of geographical data with the spatial language extension module PostGIS.

PostGIS is implemented compliant to the OGC (Open Geospatial Consortium) Simple Features Specifications for SQL standard, a set of operations and schema to insert, query, manipulate and delete spatial objects. The coordinates of the spatial objects are stored in Features Tables, which contain one type of geometry (point, line, polygon, ecc.).

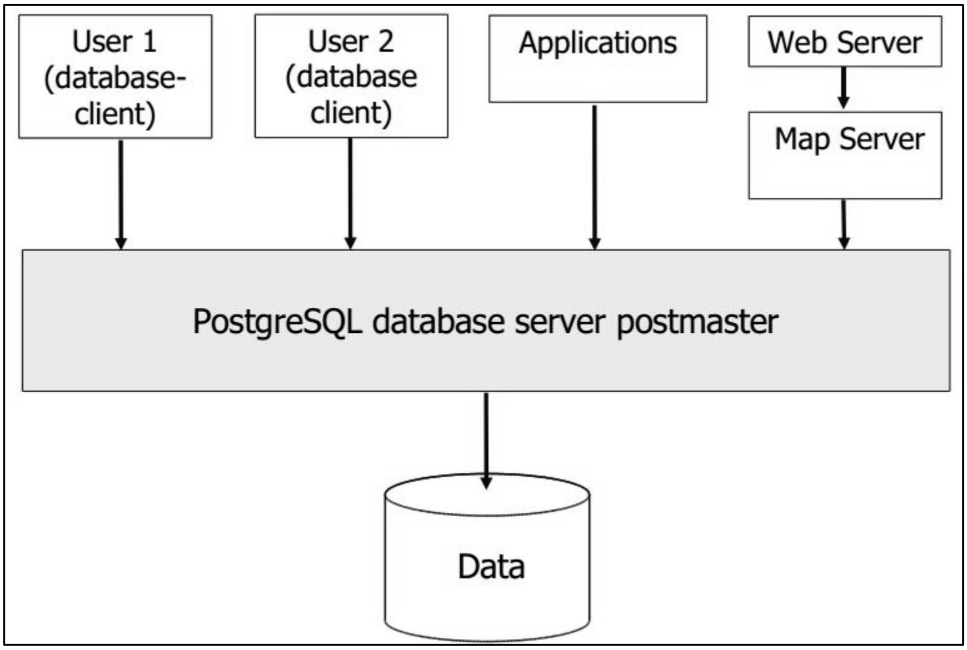

Fig. 2. Database management system

3. Routing Algorithm

Navigation system applied to road networks requires routing algorithms that support turn restrictions and even data structure compatible with the platform considered. pgRouting is an open-source library that provides a variety of functions for network routing as extension of PostgreSQL and PostGIS.

Many benefits can be observed by using database routing approach, such as accessibility by multiple clients through JDBC, ODBC or directly using SQL calls (pgSQL); the clients can either be PCs or smartphones (or any other mobile device). Using the Open Source tool QuantumGis data and attributes can be modified continuously; data changes can be reflected instantaneously through the routing engine, without precalculation need.

Through the use of this tool is easy to implement routing algorithms, or use built-in functions provided, such as “Shortest Path Dijkstra” (without euristic), “Shortest Path A-Star” (routing algorithm with turn restrictions and based on euristics), “Traveling Salesman Problem” (TSP).

Both Dijkstra and A-Star algorithms are able to compute the cost for sides the edge of the road network graph and are particularly performing in finding a route with a road network that has one-way streets.

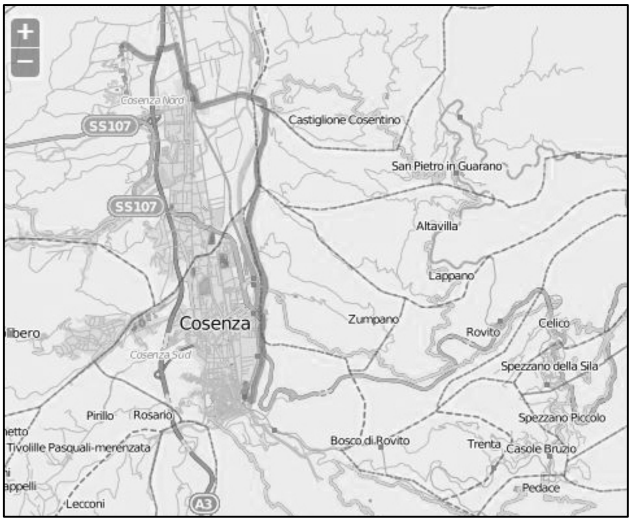

Fig. 3. Oneway routing management

However, navigation applied to the public transport service requires more algorithms that take into account the complexity of this target. In fact, the first complication in the management of public transport derives from the presence of multiple sources and destinations for routes planning. In this regard, it is necessary to implement public transport routing functions in the spatial database, as well as identify a common format for public transportation schedules and associated geographic information.

According to what mentioned above, implementation requires some preliminary steps, such as the arrangement of road network data into a new topology for storing public transit information, additional routing functions to find optimal transit route instead of shortest path (identified as a pgRouting core function). The factors that need to be optimized aiming to find the ideal routing through a public transport network are “Travel time”, “Number of Changeovers”, “Frequency of Service”, “Travel Confort” and “Travel Cost”. In order to make routing engine based on the above factors, extra information should be stored into the database. Main topology elements are “Stop”, representative of a point where changeovers can occur, “Route”, a sequential order of stops which a vehicle cross in a trip, “Trip”, representative of time information of a route, and “Way”, a Linestring (a standard format for storing geographical information into PostgreSQL) representing a road on DB.

A dataset format compatible with the platform is General Transit Feed Specification (GTFS), a common format for public transportation derived from a project that aim to make public transit data universally accessible.

With the availability of a dataset collection that meets the specifications defined according to GTFS, all information can be validated an displayed through a web browser.

In order to test platform and routing algorithms functionality the cartographic layers of the province of Cosenza (Southern Italy) road network were acquired (Fig 3).

The launched test consists in calculation of the shortest path between two determined vertices of the road network far from each other of 12 kilometers measured on the network path (the shortest in terms of link length), simulating ten simultaneous connections. PgRouting implements most of its functionality on C++, so it is quite-complex query capable, In order to use different connections, the different queries were parallelized.

The road network runs on PostgreSQL Database, and the source is OpenStreetMap; in particular the file loaded for the experiment is “Calabria.highway.osm”, free to use from claudmade.com provider. Once loaded on the database, the file is reorganized in 464’638 nodes, 16’910 ways, 70’478 edges and 27’034 vertices (Fig.5).

The shortest path function has the following declaration:

*SELECT * FROM shortest_path('SELECT gid AS id, source::int4 target::int4 FROM calabria', ‘source’, ‘target’);*

Where *id* is the identifier of the edge, *source* is the identifier of the source vertex and *target* represent the identifier of the target vertex. The test result highlights a computational time of 0.0124 seconds.

This results show that, in spite of the great number of network elements threated by routing algorithm, the computation time of the platform was very low, denoting a good responsiveness of the system.

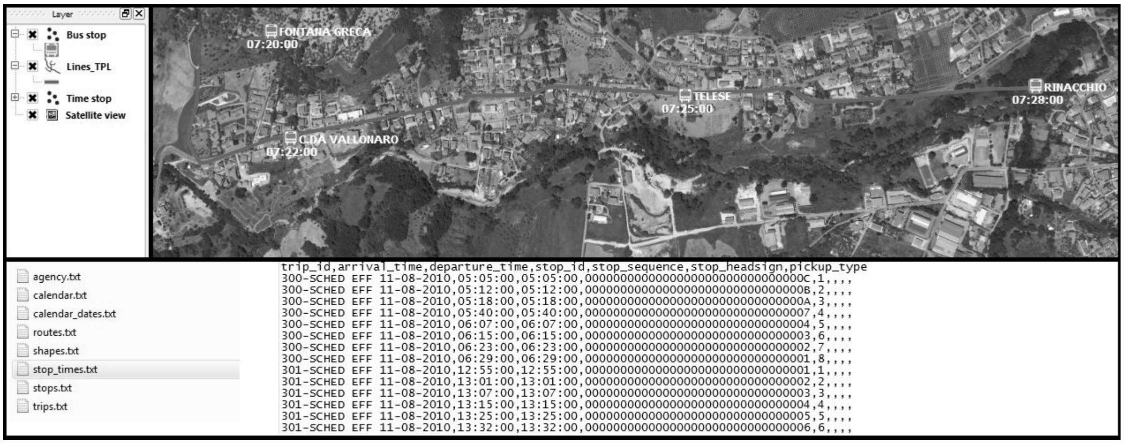

Fig. 4. Desktop front-end sample

4. Mobile Front-End

Once the entire dataset is stored on the platform, a Front-End can be implemented for consultation of data from mobile devices. For the development of the front-end jQuery mobile dynamic programming technology has been used. jQuery Mobile is a JavaScript framework designed specifically for the development of applications that must be processed on a mobile device. In fact, using jQuery Mobile the graphical interface of a web application can be standardized, without worrying about the thousands of differences between screen sizes and operating small details that can be found between an environment and each other. The programming technique is based entirely on HTML5 and JavaScript. The use of JQuery Mobile overcomes the problem of cross device, covering all aspects of compatibility between the various operating systems.

The web application implemented for mobile devices allows registration of users remotely, with the ability to view contents on personal devices (Fig. 5). Furthermore, the application allows the storage of all users’ tracks, a server-side routine extrapolates source and destination of each track in order to generate a custom profile for each user.

Based on all tracks of each user, the system generates several proposals alternatives to the use of personal vehicle offering a solution based on the traces of local public transport system resident on the platform.

Fig. 5. Mobile view sample

5. Conclusions

A T-DSS (Transportation Decision Support System) able to generate several alternatives paths based on traces of a local public transport service and from source and destination given by users has been implemented. The entire platform has been developed via Open Source, which means a rapid bug-fixes and increased reliability, with the possibility of additional future development through the modularity of the platform. The routing algorithm of the platform was tested on a real road network and the experiment results underlined a good responsiveness of the system.

Future efforts of the present research will focus on the experimentation of the platform involving a sample of users of the province of Cosenza. The provincial territory is made up of 155 municipalities. Public transport in Calabria is almost exclusively by bus. The local public transport supply by bus is in slow, but continuous, growth. The public transport services supply system presents an extensive series of critical points, which concur to create complexity and low quality of service.

For these reasons the described platform applied in this area could help to promote the use of public transport, improving user information.

Other future efforts will focus on the implementation of a module for mobile ticketing that, respect traditional ticketing systems, offers to users several advantages as queue avoidance and ubiquitous and remote access to payment. However, this module necessitates the implementation of a protocol to provide secure validation and check of e-tickets. Further development of the platform may include also the access to information gathered from smartphones accelerometers on the comfort level of each vehicle ride detecting, eventually, sharp accelerations or decelerations which could be indicators of possible accidents.

References

Bierlaire, M., Chen, J., & Newman, J. (2010). *Modeling Route Choice Behavior From Smartphone GPS data*. Report TRANSP-OR 101016. Transport and Mobility Laboratory, Ecole Polytechnique Fédérale de Lausanne, October 2010.

Eibl, P. (1994). Design and Use of Digitized Road Networks. *International Road Transport. J. Logst. Inf. Mgmt. 4*, 40–46

Giaglis, G., Minis, I., Tatarakis, A., & Zeimpekis, V. (2004). Minimizing Logistics Risk Through Real – Time Vehicle Routing and Mobile Technologies. *International Journal of Physical Distribution & Logistics Management. 34*, 749–764.

Guido, G., Vitale, A., Astarita, V., Saccomanno, F.F., Giofré, V.P., & Gallelli, V. (2012). Estimation of safety performance measures from smartphone sensors*, Procedia Social and Behavioral Science, 54*, 1095–1103.

http://www.transcad.com, visited May 2th 2012

Lane, N.D., Miluzzo, E., Hong Lu; Peebles, D., Choudhury, T.; & Campbell, A.T. (2010). A Survey of Mobile Phone Sensing. *IEEE Communications Magazine*, September 2010, 140-150.

Lopes, R., Barreto, S., Ferreira, C., & Santos, B. (2008). A Decision Support Tool for a Capacitated Location – Routing Problem. *Decision Support Systems 46*, 366–375

Magliocchetti, D., Gielow, M., De Vigili, F., Conti, G., & De Amicis, R. (2011). A Personal Mobility Assistant based on Ambient Intelligence to Promote Sustainable Travel Choices. *Procedia Social and Behavioral Science 5*, 892–899.

Prindezis, N., & Kiranoudis, C. (2005). An Internet-Based Logistics Management System for Enterprise Chains. *Journal of Food Engineering 70*, 373–381.

Randall, T., Churchill, C., & Baetz, B. (2005). Geographic Information System (GIS) Based De-cision Support for Neighborhood Traffic Calming. *Canadian Journal of Civil Engineering 32*, 86–98.

Ray, J. (2007). A Web-Based Spatial Decision Support System Optimizes Routes for Over-size/ Overweight Vehicles in Delaware. *Decision Support Systems 43*, 1171–1185.

Vannieuwenhuyse, B., Gelders, L., & Pintelon, L. (2003). An Online Decision Support System for Transportation Mode Choice. *Logistic Information Management 16*, 125–133.