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MOBILE GEOGRAPHIC RANGE PREDICTION FOR ELECTRIC VEHICLES

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Abstract: Electric Vehicle (EV) requires new driver information systems because drivers need more information. The spread of mobile devices and communications cost reductions gives new business opportunities. Our work proposal is taking into account the range anxiety problem of drivers of EV and using GIS systems, we represent in a map the charging state range based on a predicting driving distance based on driving style, temperature, and charge level. All this information transferred and represented in a mobile device with a information integration of EV and public transportation.

1 INTRODUCTION

Since 1990, the automobile has made the transformation from mechanical and hydraulic control systems to a digital car with a rapidly growing volume of computer-based control systems. This transition is increased with the introduction of EV and the need of more control on charging process, guidance to charging stations, information for energy market and others. The addition of sensor-based intelligent vehicle functions will further advance digital technologies in future automobiles. Intelligent Transportation Systems (ITS) will also require increasingly capable in-vehicle digital systems. The resulting digital car will create a long-term market push and pull for telematics technologies where the introduction of EV will play an important role. Technological progress on communication and mobile devices was a real fact. The number of mobile devices has leapt from a few million to over 5 billion mobile subscriptions globally in 2010 [1]. The number of Internet users worldwide was only two million in 1990 and surpassed 2 billion in 2010 [2]. The result is that a large portion of the population is dependent on communications and content and wants to extend this capability to their vehicles. This creates a long-term market pull for telematics technologies and the resulting telematics content and services. Telematics has three basic capabilities: (1) two-way communications capabilities (wireless); (2) location technology (geographic position); and (3) computing platform for system control and interface to automotive electronics system(s).

The present work is divided in seven sections: (1) introduction, where is present context of this work and the motivations; (2) mobile application, where we show the main modules of the proposed application; (3) tracking system, to acquire automatic drivers' driving profiles; (4) range prediction, with the used process to predict the EV range based on several external factors, like weather, traffic conditions, speed, driver behaviour among others; (5) charging station, where we give driver's guidance and the possibility of reservation of charging slots; (6) public transportation interface, to show how it is possible to interact with public transportation information; and (7) the conclusions.

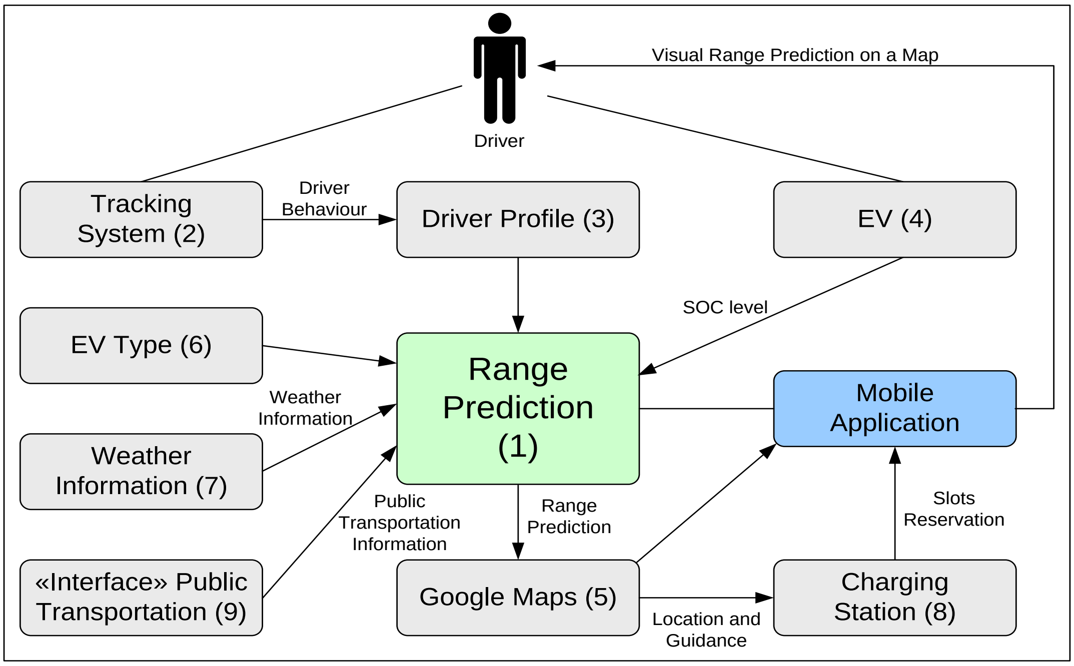

Figure 1: Main Application Modules.

Thus, focusing in EV thematic and their use, in the present work is proposed a novel approach to take the EV information's to mobile devices and explore the range prediction based on GIS approaches.

2 MOBILE APPLICATION

This work is part a Mobi_System [3] and EV_Cockpit [4] projects where this range prediction and representation systems work is integrated. Main issue is to deal with the problem of the driver range anxiety by creating a visual tool where the driver can see on a map the current location and where we can reach with the present charging level of EV. Main application modules are illustrated on Figure 1: (1) Range prediction, see section 4; (2) tracking application, see section 3; (3) drivers profile, is one of the most important parameter in the use of the EV. Mainly, in the profiles should be included: the traveled distances; the time available to charge the EV taking into account the use of the EV, and the power available to charge the EV according with the contracted power for each case (4) SOC level through Controller–Area Network (CAN-bus). This information is obtained through the Battery Management System (BMS), equipment that allows analyze the performances of the batteries. There are several topologies of BMS with different characteristics and functions; however, the main function provided by the BMS is the State of Charge (SOC) of the batteries bank, normally in percentage. This parameter is useful to obtain the range prediction of the EV. The communication with the BMS, to provide the SOC information, is done through the CAN-bus communication protocol; (5) Google Maps, for information visualizations; (6) EV type, a data base with EV descriptions, weight, battery type; (7) weather information (e.g. temperature, wind, weather conditions) pick from a web site (www.meteo.pt); (8) the charging station, for location and guidance and also to handle reservation charging slots, see section 5; and (9) Public Transportation Interface, see section 6.

3 TRACKING SYSTEM

To study drivers' habits and profile update we have developed a tracking application to run in an off-line mode (to avoid communication costs) in a mobile device with GPS device. This project was developed in an academic final year project at ISEL, described at [5], and its high level vision is showed in Figure 2. This tracking application mainly stores times, GPS coordinates and user identifications. From the GPS coordinates it is easy to calculate travel distances. Using Google Maps API we can represent the drive route and obtain the travel distance. From the travelled distance and the EV efficiency we can estimate the remaining energy stored in the batteries of each EV (SOC level), as well as the community SOC level (sum of all individual community SOC levels). The studied population (from the city of Lisbon area), with 50 cases, contains a mixture of university students and their parents, and takes into account the first EV introduced in Portugal: the Nissan Leaf (with a 24 kWh lithium ion battery pack, a 3.3 kW on-board charger, with a CHAdeMO fast charger that can charge 80 % of the batteries capacity in about 30 minutes, and with an autonomy of 160 km obtained with a careful driving, avoiding, among others parameters, high speeds and accelerations and a careful use of air conditioning.). The application designated as GPS Tracker was developed to be used in mobile devices, like PDA, on top of Android. The purpose of this application is to create GPX files with the recording of the GPS data (namely: latitude, longitude and instantaneous speed) related to the travels of the user. The user has yet the possibility of observing, in real time, the collected data.

The system allows seeing statistics on the route taken, including: travel duration time; total distance traveled; average speed; and others that can be obtaining by data manipulation (e.g., trip cost). The system can also provide all the above parameters for all the paths of the user, thus obtaining the total average values. The presentation of statistical results for one route or for all the paths of the user is done via GPS ReportView. The purpose of this application is to allow viewing all the statistical data corresponding to journeys made by the user (and owner). This application provides a list of all journeys made to the user menus and two more with statistics and a course with the average values of all paths. The GPS Tracking System allows the user to see the GPS data on its position, direction, and speed, as showed in Figure 2.

4 RANGE PREDICTION

Range prediction is based on three main dependency type (Figure 3):

1. The EV with their main variables: the model of the vehicle (mainly their performance under different scenarios, speed, and acceleration), the

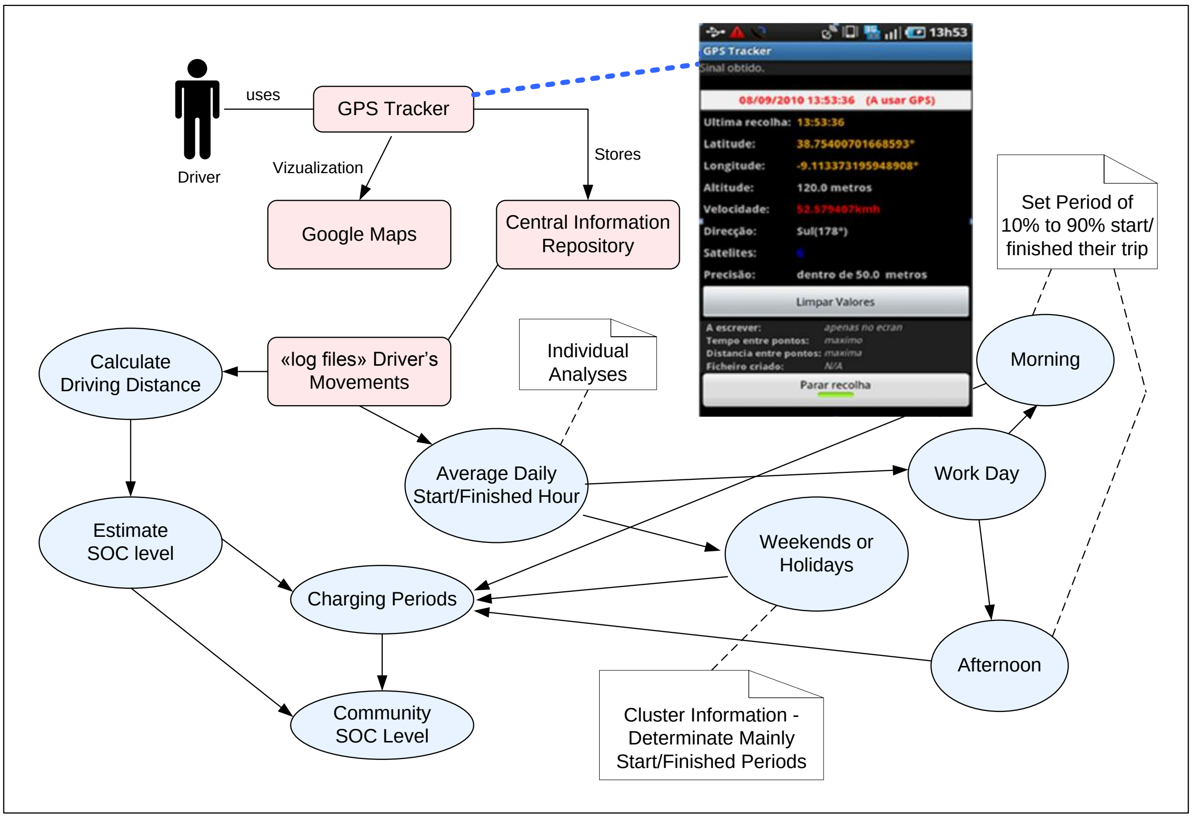

Figure 2: GPS Tracking Application and main functionalities.

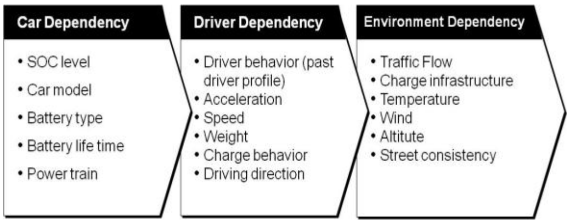

Figure 3: Main parameters for range prediction.

chemical technology of the batteries (as lithium-iron-phosphate, lithium-titanate, or nickel-metal-hidride) the batteries characteristics (mainly variation of SOC, lifespan, performance, specific power, specific energy, and safety), and the EV powertrain (electric motor and their power converter as well as the other electric parts as batteries charger, controllers, and power cables).

All of these parts will influence the SOC and consequently the range prediction. The batteries SOC, and others relevant parameters, are provided to the main control system through CAN-bus communication, and then these informations are stored in a data base (DB) in order to predict the range available.

2. The driver behavior: speed and acceleration is taken from EV through the CAN-bus communication, the driver past behavior (e.g. SOC level versus distance achieved) is stored in a DB, weight is a manual input and driving direction is acquired based on the GPS information.
3. Environment: current location, traffic conditions (taken from a web service), road information (in a distance graph), weather information (wind and temperature, taken from a web service), altitude taken from GPS.

The prediction procedure is based on: First step is based on SOC level and using driving behavior (decrease versus distance achieved). This distance is tuned based on weather information, if it is hot a percentage of energy is taken for air condition, if it is raining a percentage of energy is taken for the window cleaning process. Night drive also a percentage of energy is taken for light services. Also a web service brings traffic information and based on past experience (e.g. information about driving's times and traffic information) a driving range is predicted. Current driving behavior (e.g. driving speed and accelerations) are taking into account in this process. Once we have an estimation of EV range we start calculation based on current position.

The topographical search start with current driver position and the prediction range. Main road nodes are used to check distances from current position and a polygon representation is achieved (see Figures 4, 5 and 6). An uncertain zone can you be marked based on the uncertainty parameters used to estimate the drive range, see Figure 7.

If SOC level is below 25 % (range should be around 50-30 km) only main road are taking into account to avoid big computation process. Taking into account Figure 4, we have Lisbon as a start point. Since the range is around 160 km, we look for main destinations in a radius of 130 km to 180 km. In this case we have the follow places: Pombal, Leiria, Marinha Grande, Ourem, Tomar, Avis, Évora, Grandola, Santiago Cacém e Sines. Then distances are calculated based on Google Maps query and we find that Pombal and Avis are out the EV range. The others locations we calculate remain distance. For example the distance Lisbon to Évora is 134 km, so we have more 26 km, that we increase range representation in Évora with a radius of 20 km (see Figure 3. In this process we look to motorways (in this case, A1, A12, A2, A6, A8, A9, A13) and represent maximum point possible to reach. This simple interaction process gives us a visual range represented on Figure 4. Every 5 km of EV movement this map is again calculated and represented. When SOC is under 25 %, we start looking for all places. Web range estimator represents range by the connection of main distances and putting the polygon together. To do so, our application uses Google maps API and shows the polygon on mobile device display as showed in Figure 4, 5, and 6.

Figure 4: Range estimation of a Lisbon trip to north. Four different cases are showed.

Figure 5: Representing charging ranging for different SOC levels at a charging process.

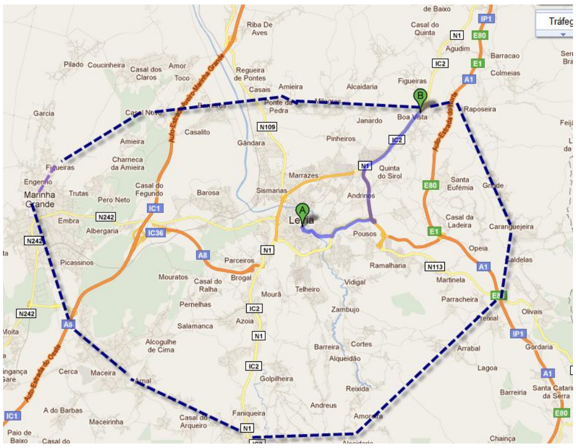

Figure 6. Range estimation of a low SOC level.

For charging process the range prediction and representation is performed in the same way. Based on the charging level (SOC information) the application predicts the range based on previous driving parameters (past relations of SOC levels and distances achieved stored in driver profile) and based on this information represents using Google Maps the regions that is possible to reach with that charging level. System is prepared to generate alerts about charging levels needed to reach a charging station (we assume charging process is always performed in charging station, driver's home and work place). The range prediction process has several uncertainty factors that reflect driving behavior and external condition (e.g. traffic, road topology and weather). These factors showed in Figure 3 can be used to estimate a safe range (green shadow in Figure 7) and a maximum range. The red shadow in Figure 7 is a range that is possible to achieve but the driver needs to perform driving optimization (air condition off and avoid big accelerations). This could be helpful information because driver can customize his behavior function of the range we needs to achieve in their trip. This process is can be continue updated and when SOC level is low this uncertain gets low.

5 CHARGING STATION

There are several issues related with Public Charging Station. Infrastructure creation, standardization, energy network distribution (high power) and the time that charging will take. Charging process will take more time than a usual gasoline deposit fill up (consequently more vehicles will implies more congestion to charge the batteries), and a regulated pre-reservation system should help on this process. The batteries charging process can be realized in two different shapes: coordinated or uncoordinated. With a coordinated charging profile the batteries of the EVs are charged according the capabilities of the electrical power grid in real time and the needs of the vehicle driver. In this context different parameters are taken into account, mainly the price of energy to sell or buy and the remaining energy stored in the batteries, their SOC. On the other hand, with uncoordinated charging profile the charging process can starts immediately or a fixed time delay from the moment which the vehicle is plugged into the electrical power grid. With uncoordinated charging profile the power consumption (due to the large number of EV to charge) will be great and will bring problems to the electrical power grid. Nowadays, this is the most common charging profile. So our proposal is a System Management Reserves (SGR) that driver's mobile devices will communicate and performs reservations. To communicate with the SGR should be used a technology that allows synchronous communication. The Mobi system is prepared to communicate with the SGR with a WebService. The SGR responds to mobile device communication response with reserve confirmation or with the unavailability of slots. One of the issues that arise when proposing an SGR is the possibility of missing drivers to reserve a place, a situation that can happen either contingency that preclude compliance or situations of neglect or misuse.

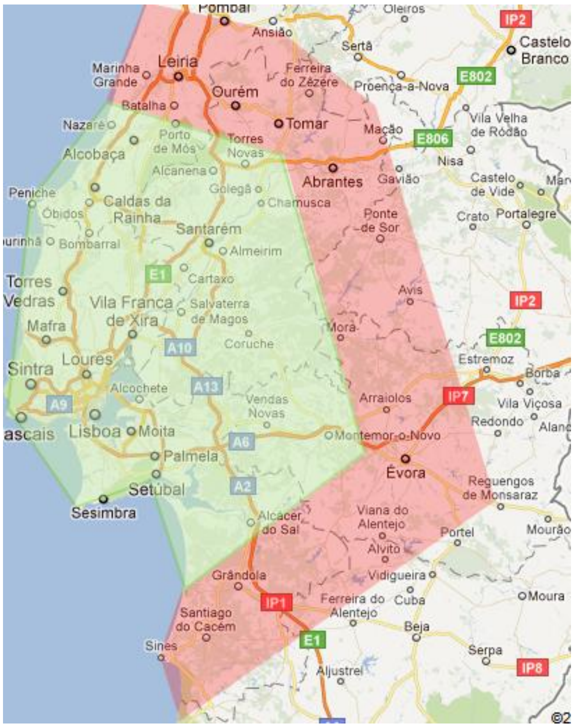

Figure 7: Range estimation based on the uncertainty factors showed at Figure 3.

Whatever the situation, the SGR must implement mechanisms to minimize the impact of slots are being reserved, and then run out by failure of the driver. One possible solution is to implement a point system that penalizes drivers when they fail to reserve a sum equivalent to the failure of a point in the driver's record. When the driver reaches three points, equivalent to three failures will have to go to an operator and try to reactivate your access to the SGR. The following diagram on Figure 8 illustrates how it can be implemented by the system of penalty points. There will be only one system that centralizes information SGR communicating with all operators, which also allows the exchange of information on penalty points, making the engine more efficient.

The SGR is prepared to follow a business model which we implemented with a slot reversion, failures penalties and a waiting of reservation of 5 minutes (administrator configurable time).

The android platform defines user specific interfaces called activities. This application has the follow functionalities, for a complete description see [6]:

- Information Services: the batteries SOC level, the range available, the electricity price, and public transportation information and points of interests.
- Public Charging Station: Find & Guidance (see Figure 9) and charging slots reservation.
- Home Charging: start and stop charging, program charging, discharging, transactions account.

6 PUBLIC TRANSPORTATION INTERFACE

Public Transportation information integration and availability on mobile devices could create conditions/incentives for drivers use less their own car, by giving guidance and suggestions for others transportation systems, like public transportation, bike sharing, car sharing or even car pooling [7].

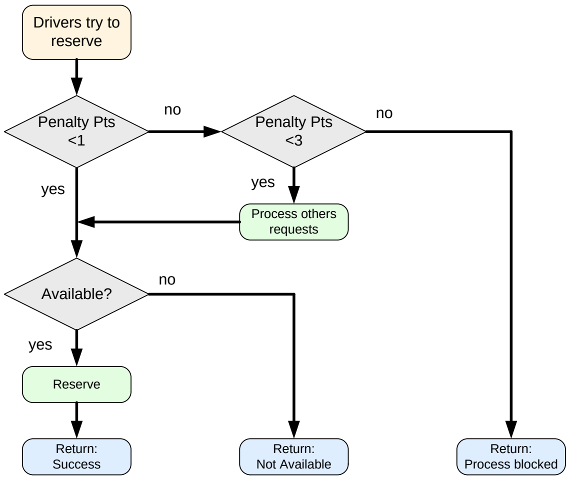

Figure 8: SGR penalty points to avoid user reservation failures.

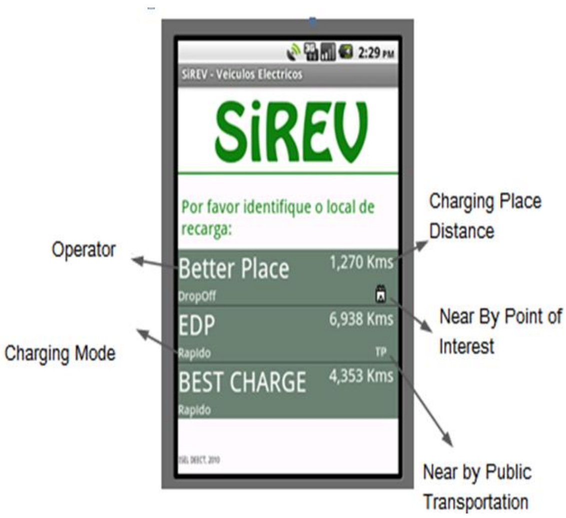

Figure 9: Screens of the Application developed for Android operating system.

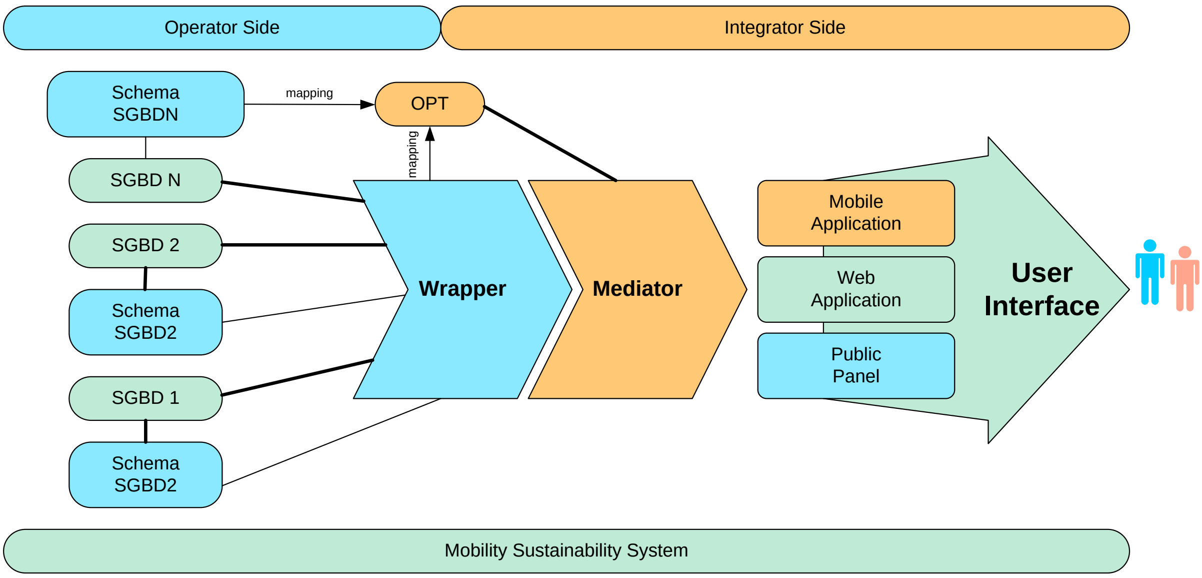

Figure 10. Public Transportation Data Integration.

There is difficulty in obtaining integrated information about public transportation in the same city due to the diversity of transportation operators. Most of these operators have their own system and plan the routes and schedules independent of nearby operators. Still, public transport systems differ from region to region. Also transportation planning requires substantial amounts of data and cooperation among transportation planning agencies. This data integration with increasing availability of Geographic Information Systems (GIS) is giving transportation planners the ability to develop and use data with a much higher degree of efficiency.
We developed a project [8] that allows the interrogation of multiple sources of information through a single interface. The questions and answers to them should reflect a single data model. The existence of a common data model takes the software applications with the difficult task of dealing with various technologies and their different relational schemas. Different public transportation system can be added with total transparency to the end user. As suggested in Figure 10, this integration task is performed, through a domain ontology definition for public transportation, where local public transportation operator data base are mapped. This allowing the citizens to obtain information (eg timetables, routes and prices) on the various modes of transport (e.g. bus, tram, metro, train, ferry, ...) available in a particular region (e.g. Lisbon, Porto, among others) focusing on the integrated use of soft transport (e.g., electric vehicle, bicycle,...) and occupation of waiting time (e.g. visiting points of interest). We believe that this information available in mobile device in real time will contribute a lot for drivers stop their car in parking places and take public transportation specially when the traffic is heavy and public transportation time is less than our car driving.

7 CONCLUSION

Mobile devices and real time information will play an important role in this century, and associated with the new bet in Electric Vehicles (EV) will contribute to the expansion of the Electric Mobility, improving the life quality of the citizens and the cities. The results obtained in this paper are a contribute to these expansion, allowing integrate the EV and theirs drivers with the charging slots available in the nationwide (with possibility to reserve charging slots and avoiding failures), reducing the range anxiety of the drivers, and maximizing the advantages of the use of the EV. Thus, the use of the EV is constantly monitored (through centralized information about EV and Public Transportation aiming Electric Mobility) and the driver accompanies the evolution of the most important parameters involved in the use of the EV. This visualization tool for EV range could help to deal with the driver range anxiety problem, providing a much more reliable journey planning.

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