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Mobile Cockpit System for Electric Bikes

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Abstract

In this work is proposed the design of a mobile system for smart phones to assist bicyclist in a smart city environment, oriented to the reality of electric mobility. Taking into account the new reality of smart cities with introduction of electric bikes (EBs), we propose a mobile application to handle the battery charging process, and to predict the utilization range taking into account the desirable path and the usual cycling effort performed by the bicyclist. We introduced also the concept of bicyclist profile, based on historical data analyses performed from previous data stored in a data base. This mobile application has the mission to recommend useful information to the bicyclist related with the EB usage, as for example, information about the existing capacity, range autonomy, information of route to reach the desirable destination, and also information about public transportation.

Keywords: Electric Bike, Range Prediction, Mobile Application.

1 Introduction

The interest in electric mobility has been increased in the last years, mainly supported by Electric Vehicles [1], Hybrid Vehicles [1] and Electric Bikes (EBs) [2]. Mobile Cockpit System (MCS) is an integration project, which gathers the developments achieved in several technical areas into a unique system. The main technological areas to be considered are navigation support, public transport information integration, and EBs energy consumption and management.

The 21st century has emerged in an era of heightened connectivity. Most people use cell phones at all the time and most of those cell phones operate as web enabled devices and search engines. The in-car infotainment industry has been developed more quickly in the past five years. Thus, as consumers become more and more interested in making their cars as connected, this industry is used to integrate their phones and laptops in the vehicles.

The navigation support to the driver is based mainly on the Global Positioning System (GPS). This system provides the position of a receiver, which is used by upgraded systems to provide additional information such as speed and further integration with maps and geo-referenced information to provide the driver with information concerning time to destination. However the integration of these systems with the traffic information is one of the main issues of current R&D in this field. In fact the potential of the integration of real time traffic information with the navigation system brings significant benefits to the final user, both in terms of route planning and driving safety. In this field, several projects have been developed integrating the navigation system, bike sensor and infra-structure information to create systems that can supply the bicyclist with information for route planning and driving awareness. Additionally, the EU ITS Directive 2010 [3] requires member states to deliver a number of systems as per the ITS Action Plan. These include provision of Multi Modal Traveler

Information Systems by 2015. For the Mobile Cockpit system project the value of this information is explored in the context of EB trips.

2 Mobile Cockpit System Project

The Mobile Cockpit System (MCS) project develops a solution that supports the bicyclist with the appropriate and relevant information to decide and plan his journey using an EB. Therefore, are reduced the constraints related with the EB autonomy and the bicyclist can perform his journey with reduced anxiety about EB range, taking into account an important parameter, the altimetry of desirable route. Also we propose the integration of data from the public transportation and the data from the EB battery charging infrastructure. This information is used to interact with the EB bicyclist a mobile device that can be carried by the bicyclist in or out of the EB.

This project is located in the intersection of the EB integration problems (e.g., new charging infrastructures are being prepared and several problems have been raised due to limited range autonomy and the long-time of the battery charging process), with the new paradigm of smart cities where a cooperative approach is established among different transportation sources. Information and Communication Technologies (ICT), with mobile communications and mobile information systems, plays an important role in this process, mainly to the integration and real time information access. The results bring a rise in bicyclists' information needs, because information forms a key part of the driver decision process.

Also this information can be complemented with appropriated sensors on bicyclist that take information and transmitted through Bluetooth to mobile application. These sensors permit to measure: heart rate (bpm), cadence (rotation per minute - rpm) and power (Watt).

3 MCS Main Modules

MCS main modules are: (1) bike interface system to exchange data with bicyclist, EB and central server; (2) bicyclist profile to store past behaviour that will provide range predictions; (3) range prediction process; (4) altimetry range effect; (5) charging process, described in section 4; and (6) interface for Public transportation, described in section 5 as a cooperative transportation, because the integration of usage of different transportation modes is key issue in smart cities.

3.1 Bike Interface System

Taking into account all the necessary data transfer between the EB, bicyclist and the mobile device application and from this to a central server due to limit store capacity of mobile devices. At this moment we have an On-Board Unit (OBU), that provides locally (in the EB) and remotely (to mobile devices applications) relevant data communications. The OBU device is based on a microcontroller that integrates, Bluetooth, GSM/GPRS (Global System for Mobile communications / General Packet Radio Service) and GPS (Global Positioning System). With the available OBU wireless communication interface, it is possible to report both locally and remotely the data through Bluetooth and/or GSM/GPRS technologies, respectively. Moreover, Bluetooth allows the OBU integration with mobile equipment, such as mobile/smart phones.

The OBU interacts through the Battery Management System (BMS), which is an equipment that allows to analyse 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 battery SoC level. This parameter is useful to determine the range prediction of the EB.

3.2 Bicyclist Profile

The bicyclist profile plays an important role in the range prediction process, and is based in three main components: (1) Bicyclist route and its altimetry information; (2) Bicyclist effort measured by a cadence sensor (rpm) and power (Watt); (3) Weather data. All this information is stored for later check average bicyclist power applied in their trip and the relation among these variables are taking into account in the range prediction process. The weather is also an important variable. In the rain days or too hot days the bicyclists traditional avoid the ride and the wind speed and direction are also important parameters for range prediction.

The weather can be found among the various existing APIs. The API takes as input the name of the city, it returns XML with the current weather and the forecast for the current day and the next three days. Figure 1 illustrates the output of this service in a XML file format.

There are other APIs, e.g., the Wunderground, which allows the access of atmospheric conditions from the coordinates of a site and thus not need to get the name of a city purposely to consult the weather information. For details see [4].

```

01 <current_conditions>
02   <condition data=" partly_cloudy "/>
03   <temp_f data="70"/>
04   <temp_c data="21"/>
05   <humidity data="Humidity: 73%"/>
06   <icon data="/ig/images/weather/partly_c
07     cloudy.gif"/>
07   <wind_condition data="wind: NO a 23
08     km/h"/>
08 </current_conditions>

```

Figure 1: Weather information extracted in XML format.

3.3 Range Prediction

Range prediction of EB is more complex than electric vehicle because the parameters involved such as the topography (steepness of the hills), and the power delivered by the bicyclist. This effort is taken from bicyclist profile, where we take the weight, EB type and combined with SOC level, route topology and weather conditions in a data mining (DM) approach based on the Microsoft Decision Trees. Figure 2 shows the flow of information, where are correlated the several input variables. In Figure 3 is shown the data flow model of the data mining process used with two main variables: the DISTANCE_PREDICTION and the CHARGE_PREDICTION. In Figure 4 is shown the distance prediction based on the proposed approach (more details are presented in [5]).

3.4 Route Topology

The study of the slope is particularly relevant for cyclists. So our application provides a service based on Google API to know altimetry for desirable path. This process allows you to get the altitudes in several ways, namely: (1) Stray Points - Gets the altitude of a particular point; (2) Two points - Gets the altitude of n points on a straight path, where n is the number of samples requested; and (3) Set Points - the altitude is obtained from a set of points.

Figure 5 illustrates a web service invocation for calculating the profile of a set of points.

In response to a request for altitude is returned as a result set (line 3 - "results") that contain a location (line 4 - "location") and an altitude (line 8 - "elevation"), see Figure 6.

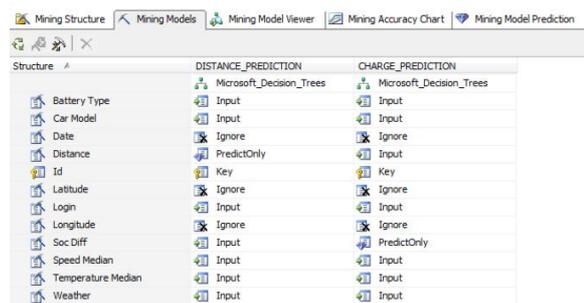


Figure 2: Flow of information of prediction models.

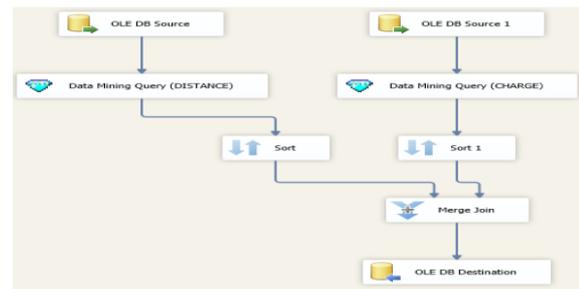


Figure 3: Data flow of data mining process used.

DISTANCE_PREDICTION	id	distance	soc_diff	speed_median	temperature_median	weather	battery_type	car_model
10	1	10	10	103	23	Partly Cloudy	Lead	PRUIS
9	2	8	15	109	25	Clear	Lead	PRUIS
10	3	10	11	111	26	Cloudy	Lead	PRUIS
10	4	10	12	93	22	Clear	Lead	PRUIS
10	5	10	14	90	23	Cloudy	Lead	PRUIS
10	6	5	20	92	27	Clear	Lead	PRUIS
12	7	11	8	99	24	Partly Cloudy	Lead	PRUIS
13	8	13	8	91	26	Clear	Lead	PRUIS
10	9	10	9	104	23	Cloudy	Lead	PRUIS
9	10	9	10	105	27	Clear	Lead	PRUIS

Figure 4: Distance prediction based on the proposed approach.



Figure 5: Determination of the path altimetry.

```

01 {
02   "status": "OK",
03   "results": [ {
04     "location": {
05       "lat": 39.7391536,
06       "lng": -104.9847034
07     },
08     "elevation": 1608.8402100 } ] }

```

Figure 6: Example of an answer of an altitude request.

In Figure 7 is presented the output of a route suggestion with the associated topology.

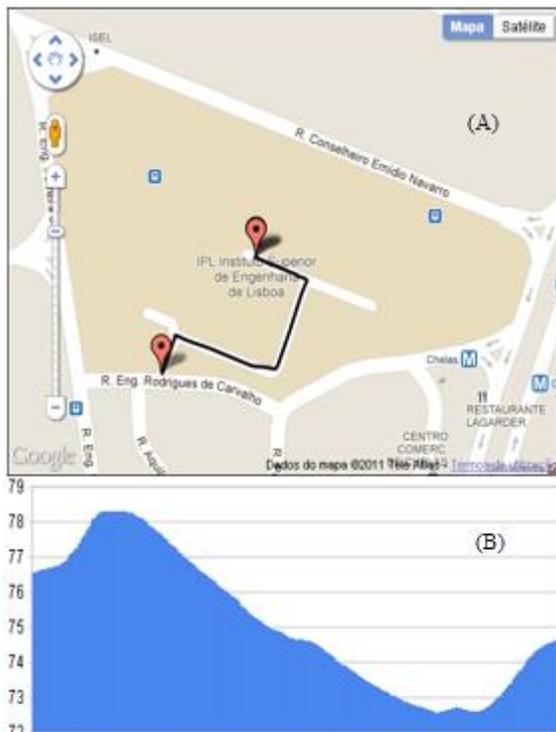


Figure 7: Path from start point A to end point B (A) and the altimetry of that path (B).

4 Charging Process

The MCS platform defines user specific interfaces, which are defined as activities. The application has the following functionalities (a complete description is presented in [6]): (1) Information Services: Battery SoC; Range; Energy price; (2) Public transportation information; and (3) Points-of-Interest (POI).

Regarding the charging process it is divided in:

1. Public Charging Station: Find and Guidance; and battery charging slots reservation.
2. Home Charging: Start and stop charging; Program charging; Discharging process; and transactions account.
3. Charging Process: The power to perform the EB battery charging process is provided from the power grid and is adjusted to the battery levels through an ac-dc converter. In order to optimize the battery lifetime, the charging process is divided in two stages: constant current followed by constant voltage.

There are several issues related with the public charging Station (CS), mainly: infrastructure creation; standardization; and the time required to perform the battery charging process. Charging process will take more time than a usual gasoline deposit fill up, and a pre-reservation system

should help on this process. In this scenario, it is proposed a System Management Reserves (SMR) that allows the communication with the CS, through the mobile device of the driver, in order to perform reservations.

To communicate with the SMR should be used a technology that allows the synchronous communication. The MCS system is prepared to communicate with the SMR with a Webservice.

The SMR communicates to the mobile device with the reserve confirmation or with the unavailability of slots. One of the issues that arises when is proposed an SMR 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.

Whatever the situation, the SMR must implement mechanisms to minimize the impact of slots that 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 bicyclist reaches three points, equivalent to three failures will have to go to an operator and try to reactivate your access to the SMR.

There will be only one system that centralizes the SMR information. This system communicates with all the operators, and also allows the exchange of information on penalty points, making the engine more efficient. The SMR is prepared to follow a business model that was implemented with a slot reversion, failures penalties and a waiting of reservation of 5 minutes (time configurable by the administrator).

5 Cooperative Transportation

The integration of a cooperative transportation infrastructure provides to the bicyclist a holistic approach of different public transportation infrastructure sources. The integration of data from the public transportation and their availability on mobile devices could create conditions/incentives for bicyclists. Due to bad weather conditions or a route with considerable accumulated altimetry the bicyclist could use the public transportation as a complementary process.

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. Even more, the public transport systems differ from region to region.

Also the transportation planning requires substantial amounts of data and cooperation among transportation planning agencies. This data integration, with the increasing availability of Geographic Information Systems (GIS), is giving to the transportation planners the ability to develop and use data with a much higher degree of efficiency.

In a previously project was developed a system [7] 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 schemes. Different public transportation system can be added with total transparency to the end user. As suggested in Figure 8, this integration task is performed, through a domain ontology definition for public transportation, where local public transportation operator data base are mapped. This allows obtain information to the citizens (e.g., 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 POI).

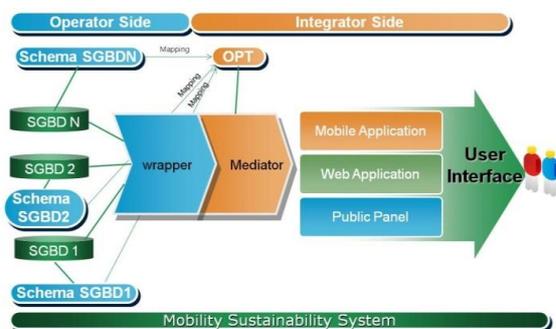


Figure 8: Public transportation data integration.

6 Results

In this section we show some of results achieve wit current project. Taking into account the public information integration we are able to integrate several sources in Lisbon area, and show on a map the various public transport stops, as well as the waiting time for each of the services, in real-time (see Figure 9).

Figure 10 shows a path with the associated altimetry. Green line shows that EB have range autonomy. The application handles also the

charging process, giving guidance and control to the charging process.

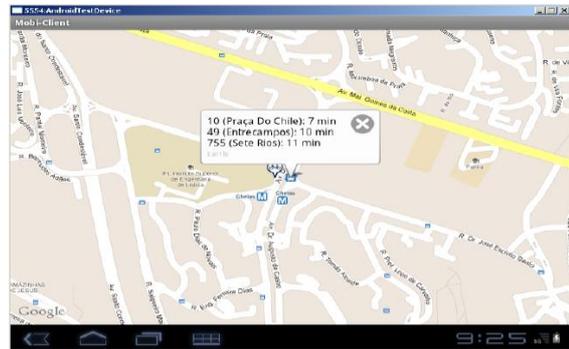


Figure 9: MCS application screen with information of nearby public transportation stops and with the indication of waiting time.

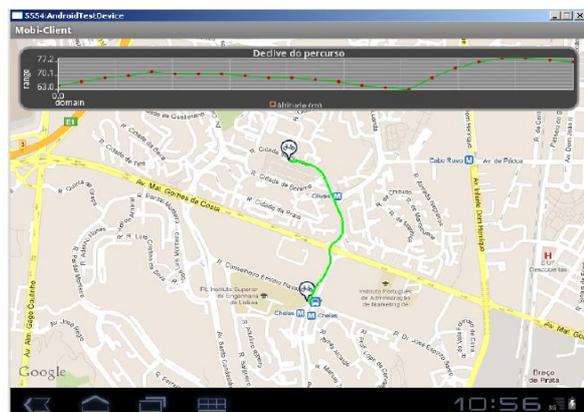


Figure 10: MCS application screen with information of route path and associated topology.

7 Conclusions

Mobile devices and real time information will play an important role in this century, and associated with the bet in electric bikes (EBs), will contribute to the expansion of the electric mobility. Consequently, these technologies will allow improving the life quality of the citizens and of the cities.

The results obtained in this paper are a contribution to the expansion of electric mobility, helping the integration of EBs and their bicyclists with the route, charging process, range autonomy and the charging slots available nationwide.

In order to provide a much more reliable journey planning, the application presented in this paper, in collaboration with Geographic Information Systems, can help to deal with the driver range anxiety problem. This application provides to the bicyclist a range prediction, aiming to check if a desired destination can be achieved without the requirement of a stop to perform the battery

charging process, or even if it is necessary to increase the bicyclist effort to reach the desired destination.

Bicyclist profile is also an important concept that can be used to understand better the bike riding process, and to study differences among the bicyclists. Due to lack of data we are not able to explore the full potential of this concept, yet. MCS (Mobile Cockpit System) project is prepared to recommend routes based on SOC level available, with the estimation of bicyclist effort needed to reach the desirable destination. This effort is measured in percentage of average effort used by this bicyclist, which is available in his profile.

Also, with sensors in the bicyclist, it is possible to check heart rate, and to generate alerts, if certain pre-defined limits are achieved.

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References

- [1] C.C.Chan, “The State of the Art of Electric, Hybrid, and Fuel Cell Vehicles,” Proc. IEEE, vol.95, no.4, pp.704-718, Apr. 2007.
- [2] P. Spagnol, G. Alli, P. Lisanti, F. Todeschini, S. M. Savaresi, A. Morelli, “A full hybrid electric bike: how to increase human efficiency,” IEEE American Control Conference, pp.2761-2766, June 2012.
- [3] Official Journal of the European Union <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:207:0001:0013:EN:PDF>, accessed on 2013-10-15
- [4] João C. Ferreira, Paulo Trigo, Alberto Silva, Helder Coelho, João L. Afonso. Simulation of Electrical Distributed Energy Resources for Electrical Vehicles Charging Process Strategy, IEEE computer magazine dedicated to the Second Brazilian Workshop on Social Simulation (BWSS 2010), 24-25 Oct. 2010, São Bernardo do Campo, São Paulo, Brazil, pp. 82-89, IEEEExplore Digital Object Identifier: 10.1109/BWSS.2010.15, ISBN: 978-1-4577-0895-4.
- [5] Joao C. Ferreira, Vítor Monteiro, João L. Afonso “Data Mining Approach for Range Prediction of Electric Vehicle,” in International Conference on

Future Automotive Technology Focus Electromobility, Munich Germany, pp.1-8, Mar. 2012.

- [6] João C. Ferreira, Vítor Monteiro, João L. Afonso, A. Silva, “Smart Electric Vehicle Charging System,” in IEEE IVS 4th International IEEE Intelligent Vehicles Symposium, Baden-Baden Germany, pp.758 763, June 2011.
- [7] João C. Ferreira, Vítor Monteiro, João L. Afonso, “Cooperative Transportation System for Electric Vehicles,” SAAEI’12 Annual Seminar on Automation, Industrial Electronics and Instrumentation, in SAAEI 19th Annual Seminar on Automation, Industrial Electronics and Instrumentation, Guimarães Portugal, pp.488 493, July 2012

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