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Real time monitoring system used in route planning for the electric vehicle

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Abstract. The electric vehicle is a new consumer of electricity that is becoming more and more widespread. Under these circumstances, new strategies for optimizing power consumption and increasing vehicle autonomy must be designed. These must include route planning along with consumption, fuelling points and points of interest. The hardware and software solution proposed by us allows: non-invasive monitoring of power consumption, energy autonomy - it does not add any extra consumption, data transmission to a server and data fusion with the route, the points of interest of the route and the power supply points. As a result: an optimal route planning service will be provided to the driver, considering the route, the requirements of the electric vehicle and the consumer profile. The solution can be easily installed on any type of electric car - it does not involve any intervention on the equipment.

1. Introduction

There are several hardware technologies that will be involved in the solution presented in this paper. First, we will use clamp-meter current sensors. These allow for the determination of the current consumption by measuring the electric field around the isolated conductor. The measure range of sensors is between 2 – 600 A (dc), thus they cover a wide capacity area of motor sizes. The clamps can be placed on the main branch to monitor overall consumption (engine and equipment in the car) or on the engine branch. As shown, the sensors are placed on isolated conductors without any intervention on the power supply infrastructure. Secondly, the data acquired by the sensors is transmitted wirelessly to a local collector. This does not require the installation of any cable between the collector and the sensors. The communication is in the free band 2.4GHz and is resistant to disturbances. Finally, the sensors, wireless transmitters as well as the local collector are energetically autonomous. The sensors and wireless transmitters use batteries which can be charged. The local collector also uses a battery pack that loads from a small photovoltaic panel - L 20 cm, l 10 cm. In full darkness, the autonomy is 40 hours for 12 operations per hours which consist in: take data from sensors, pack with location information (from GPS receiver) and send to server via GSM network using secured SSL HTTP protocol. There are also several software technologies and planning methods implemented. To reduce consumption at the local collector, a resource planning method is used: first the gateway for data collection from the sensors is activated and in the next step the gateway is disabled and the GSM modem / GPS receiver for location and data transmission to the server is activated. At the server level, vehicle data are acquired, correlated with GIS (Geographic Information System) information about route and power points and then navigation services are provided to the driver. The application is developed using WSO2 DAS server (for complex event processing module), NodeJs and Angular2 technologies with GoogleMaterials framework for web interface. GIS services will use GoogleMaps – free for 10000 request / day (cover our request of update on 5 min).Paper will present the results with a full functional system solution. Measurements will be made for different consumers. In this sense, a different dynamic load generator will be used. Different routes will be made and will be transmitted to the server. Supply points are also entered the server application. As a result, the server will return the recalculated route considering consumption and power points. We'll have snapshots from the routes proposed by the server.The solution proposed in this paper introduces the concept of on-line monitoring for cars. The novelty is given by: real-time monitoring, using sensors that can be easily attached to power points, autonomous energy solutions for sensors, transmitters and the local collector, as well as special navigation services provided to electric car drivers.

2. State of the art

Research on route planning for electric vehicles was carried out in several papers. For example, the solution presented in the paper [1] or in the patent [2] shown are such solutions. Starting from data on navigation, traffic, etc. they can estimate an optimal route for the electric vehicle. Besides, this is not difficult: given the current navigation services - such as Google Maps - as well as APIs (application programming interface) made available to developers, it is easy to introduce supply stations into an application as intermediate points and then determine the route by estimating the consumption and considering the passage at the supply points. There are several projects and research papers (some have also materialized in commercial applications) dealing with this topic.

However, to increase accuracy in estimation, we need a parameter to be acquired and transmitted from the vehicle: instantaneous power consumption. This is because even for the same route there are many reasons for it to have different values: congestion in traffic, driving style, the presence of additional consumers in the vehicle, etc. Achieving a system that acquire power consumption from the vehicle and to be easy to install on the vehicle raises several challenges:

- Finding a power acquisition solution that does not involve any intervention on the structure of the vehicle (for example: stopping the power supply, removing terminals, etc);
- Finding a solution allowing the transmission of data acquired without intervention on the vehicle (use of data transmission wires, drilling of surfaces for wires etc.);
- The solution must transmit the data remotely for later analysis and transfer to a navigation application;
- The solution must be as energetically autonomous - it does not have to introduce additional significant consumption in the vehicle!

Each of the four points mentioned is a distinct subject of research. First, along with the classical method, whereby an amperemeter must be serial connected with the consumer and the current supply source to measure the power consumption, there are several studies that have resulted in solutions for determining the consumption of current without introducing into the circuit of a measurement device (with all that it means: disconnecting the terminals, soldering yarns). A study presented in paper [3], among others, shows that it is possible to determine the consumption by analysing the electric field loads - whether we are talking about AC or DC. The electric field can be captured by using a capacitive effect as well as an inductive effect by using a Hall sensor as shown in work paper [4]. Here it shows that it is possible to capture this field and accurately measure the current consumption even around the isolated conductor for a continuous current of values ranging from 2 to 600A. At present, there are current measuring equipment around the conductor: clamp meters.

In our case, it is necessary to measure current consumption and transmit it to a local collector (concentrator). At present, there are standards in communications from smart meters: wireless communications. They are used to transmit data in electromagnetic "noisy" environments, as shown in reference [5]. A method of communication that covers these standards is also XBee communication, which is based on the Ad-Hoc ZigBee radio protocol. This radio communication is used to deploy local radio communications networks (area of up to 2 km) using the 2.4 GHz free band. The emission power is low on some of the reasons for the use of the free band and on the other hand also because of the reduction of energy consumption in communication - one of the important elements in Smart Greed communication as shown in paper [6]. Another foreseen element is the protection of data transmitted on radio channels, especially those in the free band. We are talking about ensuring the integrity of data in disturbances, as well as protecting data from unauthorized readings. From this point of view, we apply a series of algorithms that increase the security of communication - algorithms that fit especially in the "lightweight" solutions such as the one presented in reference [7].

Finally, another aspect, involving many studies at present, is about the degree of autonomy of the solution. Any hardware solution proposed for an electric vehicle must involve very low consumption -

from this point of view, applications for the electric vehicle can be regarded as mobile applications for environments where there are no electricity sources. So, the orientation is towards other alternative energy sources that can be converted into electricity. Of these, the most feasible way in our case is to use light energy to convert to electricity, a solution that applies to wireless grids, as shown in reference study [8]. The system that acquiring electricity from unconventional sources must also be a portable one, which requires an acceptable implementation cost. Technological evolution has reduced the size of the photovoltaic panels and the required controller. Such a "energy harvesting" solution that lends itself to portable smart meter solutions is outlined in paper [9].
All the elements presented in this section have been used to implement our system as described below.

3. System architecture

Figure 1 shows the architecture of the proposed system. The system consists of a mobile component installed on the vehicle and from a server running an application that provides customer navigation services. The mobile component to be installed on the vehicle consists of: current acquisition units and local radio data transmission that are installed on the batteries or other consumers in the vehicle and a "concentrator" unit that takes the packets from the local radio network and transmits them to the server in the form of HTTP packages (HTTP POST requests). The server runs an application that contains several modules - as can be seen in the figure 1: http receiver - responsible for downloading http packages from the concentrators (vehicles), event stream that extracts the data needed for further processing, analytics core responsible for data processing - here is an assessment of current consumption to determine when it will fall below a certain threshold, UI publish that deals with the transmission of prediction results, Geo Dashboard which receives the results provided by UI publish and together with the GIS module translates them into the map, and finally the client responsible UI that displays the results map in a format that the client (the driver) can read.

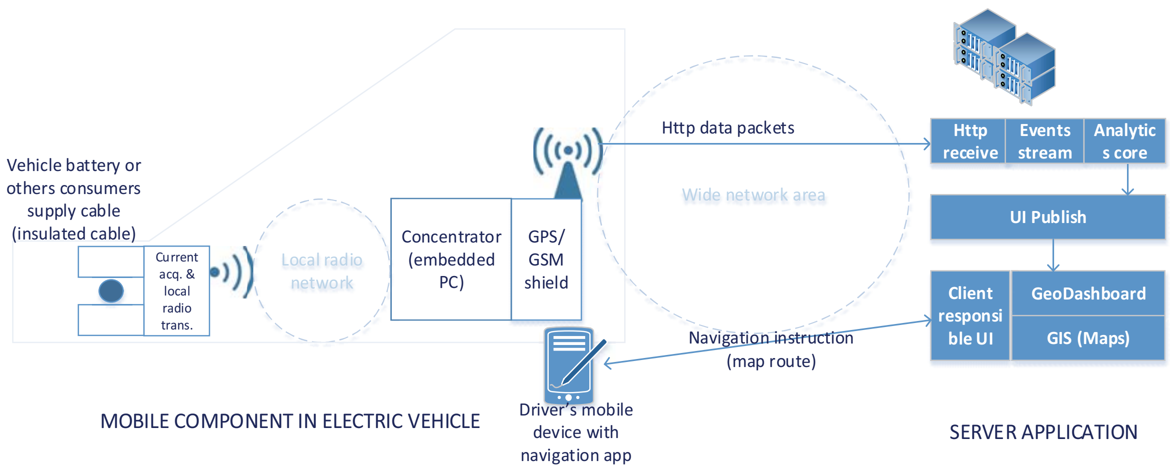

Figure 1. System architecture – block diagram.

The client application running on a mobile device (smartphone, tablet) allows you to enter data related to the desired route and provides, based on the data provided by the current sensor, the planned route. In the following sections, each of the modules involved will be presented.

3.1. Mobile equipment on the vehicle

a) The acquisition unit and local radio transmission unit

It consists of a current sensor (clamp meter) and the wireless data transmission circuit. The circuit allows:

- the acquisition of the current using a clamp sensor, which allows to determine the current consumption by capturing the electric field around the insulated conductor;
- data transmission on a local radio network in the 2.4GHz band (free band);

- the circuit is powered using batteries. The degree of autonomy of the system is one month in operation with the acquisition and transmission of information at 3 minutes. The degree of autonomy can be expanded by increasing the data transmission period.

The format in which the data is transmitted renders communications resistant to electromagnetic disturbances that may also occur in the automotive environment. The circuit can operate in automotive environment between -20 ° C - 55 ° C and 85% humidity.

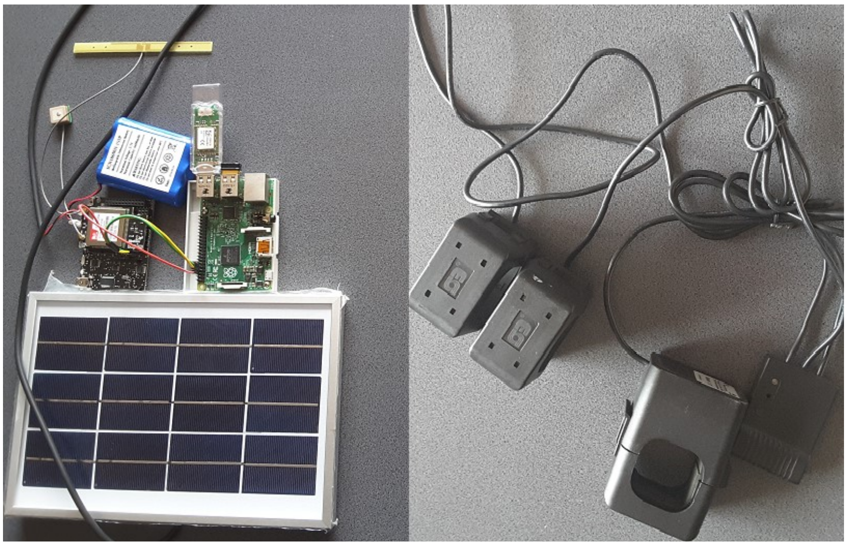

Figure 2. A capture with experimental mobile system: current consumption sensor (clamp meter) and local radio transceiver – left, concentrator: embedded PC with local radio transceiver gateway, GPS GSM shield and batteries pack with photovoltaic panel – left.

b) The concentrator unit

It consists of a gateway that manages the network and takes over the data from the local radio network, an embedded PC and a GPS / GSM shield that allows data to be transmitted over the GSM network. The embedded PC acts as a data translator - takes the data from the gateway, encapsulates the GPS data of the coordinates and transmits them via the GPS / GSM shield to the server. The unit has the following features:

- Gateway that allows up to 15 units (monitoring points) to acquire and transmit power consumption from the vehicle. Modifying the network configuration is very simple: only a power-on acquisition unit is introduced and the synchronization of the communication with the other units is automatically done. The communication protocol is XBee is based on the use of a unique address of the transmission device. The concentrator has set the interrogation rate of each unit. The transmission envisages using a CSMA / CA protocol to avoid collusion. The experiment and solution presented here uses only one acquisition unit.
- The GSM data transmission rate (and, implicitly, the acquisition rate of the data from the units) is set by the user - the data communication protocol is EDGE GPRS;
- Receiving coordinates, speed and time by using a GPS module. In fact, we used an integrated GPS / GSM module;
- Power supply using batteries charged from a photovoltaic panel (mounted on the vehicle). For the transmission rate set to 3 minutes, the battery's autonomy when it is not charged (the car is in the dark) is 48 hours. The charging time for the batteries is about 5 hours at the average illumination of the panel. Basically, if the panel is cleaned, the concentrator unit has total energy autonomy, including in the cold season for a region at the latitude of Romania (at least).

The concentrator sends the data (current values, coordinates, speed, time, and concentrator ID) as HTTP POST packages, with data attached to the body of the packets. These packages are sent to the server.

3.2. Server
Receives HTTP packets, extracts data from them (creates an event stream), analyses them and estimates the battery discharge rate using instantaneous consumption, speed, current coordinates, time - all taken from the mobile unit - and the information about the route you want and the type of electric vehicle battery - information provided by the driver. The discharge rate of the vehicle battery is associated with the desired route, with the power supply points and map data provided by the GIS module. By using the Geo-DashBoard module and the client interface, is given to the driver important data about the route to be followed. The central element of the server is the Complex Event Processing module of the DAS (Data Analytics Server) WSO2 analytics server. A concept scheme is shown in the figure below:

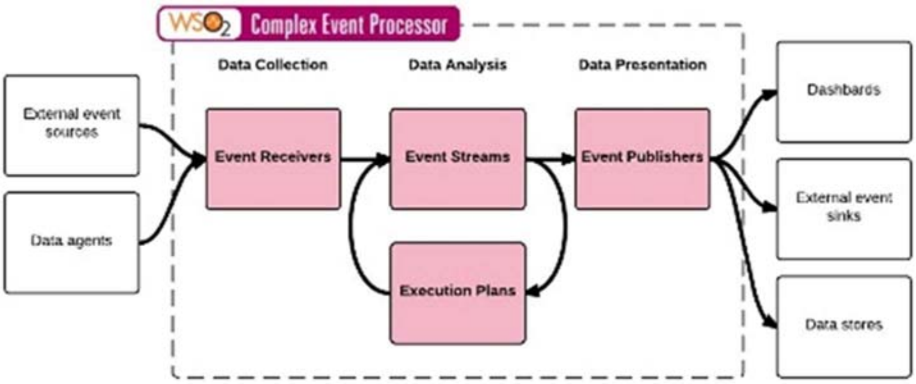

Figure 3. WSO2 CEP module block diagram.

The main components are: event receiver, event flow, execution plan, and publisher. In very short terms:
- the receiver is the one that handles data retrieval - here the HTTP packages sent from mobile units (concentrators) via GSM;
- event stream is the one that allow the data extraction and structuring. Also at this level is data analysis. This is done by using flow plans of execution;
- event publisher is responsible for publishing event results. In our case, the results are sent in the form of coordinates of the route to the Geo Dashboard where they are also displayed. A capture with Geo-DashBoard interface is presented in figure 4.

The result will be a route shown on the driver's device with the intermediate power points. The route will include information about power points, battery status at any of the points on the route (estimated status) and information on the directions that the driver should to follow.
The technologies used at the server application level are follows:
- WSO2 DAS is used to implement the responsible event handler, from the HTTP packets delivered by the concentrator to the GeoDashBoard data delivery. WSO2 DAS contains CEP (Complex Event Processing) component in our system. The data is made available through a data interface called Geo-DashBoard integrated into the DAS. WSO2 DAS is provided free of charge and can be used free of charge in development, testing and production with all the features;
- Google Maps services for all GIS and navigation. Entering intermediate points representing power stations, entering the starting point and destination point, route information, and navigation itself (including voice guidance) are services provided by Google Maps. Access to these services is at the client application level - we are talking about integrating these services into the client application that we have achieved. Google provides the necessary APIs to integrate GMaps into its own applications. For a maximum of 10000 requests per day, services are free of charge;
- Google Materials is a framework of CSS classes that provides formats for all the controls required for the client application: forms, frames where the map, buttons, the application page. Controls are "responsive": portable on both desktop and mobile systems (smaller screens) - without any additional change. The framework is free;

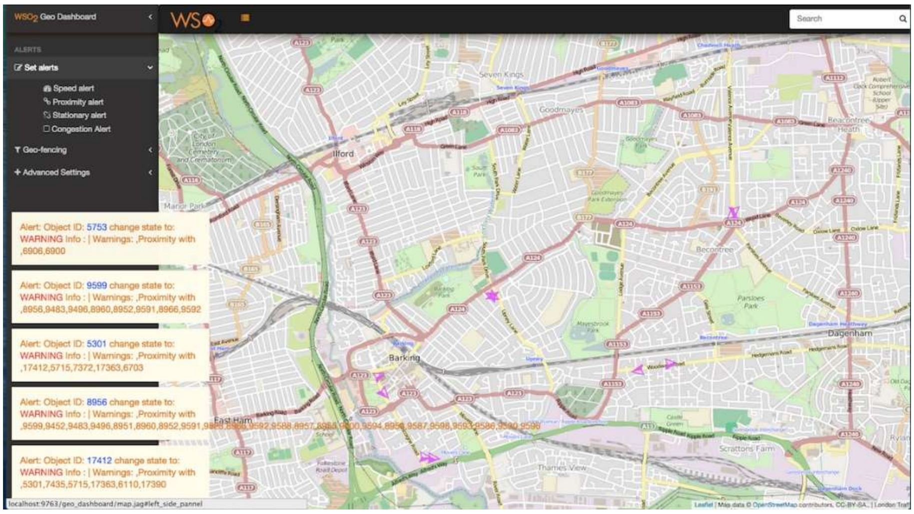

Figure 4. WSO2 Geo-Dashboard interface.

- Angular 2 and Typescript are the technologies by which the custom client application is built. G Materials, Google Maps services, GeoDashboard results are implemented by these two technologies: the first is the concept and framework through which the controls are placed on the client application, and two are the proper language for writing.

Figure 5. List of technologies used for our server application (from left to right): WSO2 DAS, Google Maps, Google Materials, Angular 2 and TypeScript.

4. Implementation

The system presented in this article has been implemented at experimental level with the following equipment:

- A Hall continuous current (CC) sensor connected to a Libelium Waspmote board with the XBee communications shield - this is the local radio acquisition and transmission unit. In our project there have been developed: the shield for data acquisition from the current sensor and the program (firmware) at the Waspmote system for reading data from the sensor and transmitting it to the concentrator. The system is powered by batteries;
- A system consisting of an embedded PC Raspberry PI to which it is connected to the XBee USB gateway and has a Waspmote (serial asynchronous) card connected to a GPS / GSM shield. Developed in our project: the Raspberry PI software for retrieving data from gateway and transmitting it to Waspmote board in NodeJs and the Waspmote firmware for retrieving data from Raspberry and transmitting them to GSM in HTTP Post packages. Here, more optimizations can be made to reduce the number of circuits. This system is the concentrator. The concentrator is powered by batteries that are charged from a photovoltaic panel (batteries 8000 mA / h, and the Waspmote photovoltaic kit – photovoltaic panel and controller).
- A server with the following features running on a VBox virtual machine: i7 2 core processor allocated, 16GB RAM, OS LUbuntu. The WSO2 DAS is installed and started on the server. Here we developed for our solution: implementing the full event stream using the WSO2 DAS interface, implementing the client application in the typescript / angular 2 using the Google Materials framework and the Google Maps API.

In the figures below are presented results displayed for several experiments.

12AB	19b3b4b	0	1c	1c	2017-5-22 12:37:17
12AB	19abda8	2	2	2	2017-5-22 12:34:6
12AB	19b3b4b	0	1c	1d	2017-5-22 12:34:5
12AB	19abda8	2	2	2	2017-5-22 12:34:38
12AB	19b3b4b	0	1c	1d	2017-5-22 12:34:37
12AB	19abda8	2	2	2	2017-5-22 12:33:34
12AB	19b3b4b	0	1c	1c	2017-5-22 12:33:33
12AB	19abda8	2	2	2	2017-5-22 12:33:2
12AB	19b3b4b	0	1d	1d	2017-5-22 12:33:1
12AB	19abda8	2	2	2	2017-5-22 12:31:27
12AB	19b3b4b	0	1c	1c	2017-5-22 12:31:26
12AB	19abda8	2	2	2	2017-5-22 12:30:55

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Figure 6. Capture from application: list with current values and a map point with values displayed in real time.

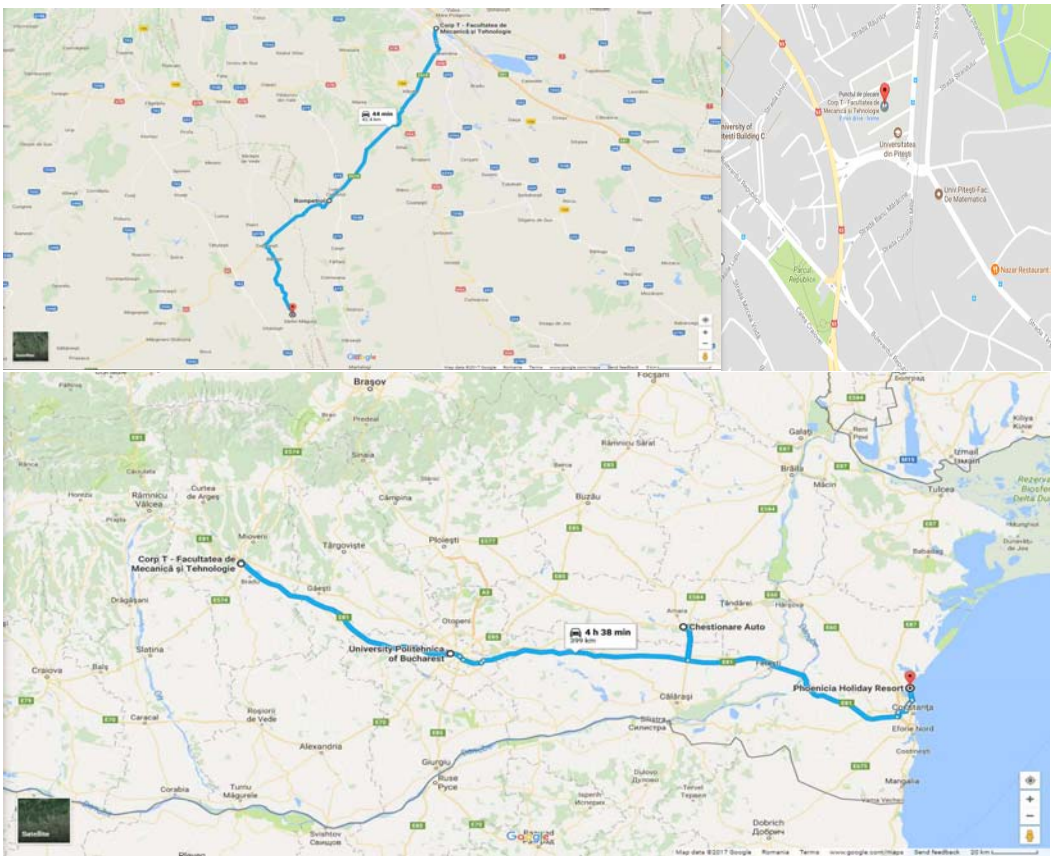

Figure 7. Capture from application: up – setting start point as is usually done in google maps (left), a route between "Corp T Facultatea de Mecanica" start point and "Sarbi Magura" destination point with intermediate point for recharge "Rompetrol" (right); down – another route between "Corp T" and Phoenicia Holiday Resort using 2 intermediate recharge stations: "University Politechnica" and "Chestionare Auto".

5. Conclusions

The system implements a dedicated navigator for electric car owners. Unlike normal navigators, here is the need to ensure the vehicle's power supply - given the lower degree of autonomy that electric vehicles do (yet) have. A system for monitoring the current consumption and transmitting it as an input for the navigation application has been designed for this purpose.

The driver will be provided complete navigation services, which also considers the degree of autonomy of the vehicle. The services are provided depending on the type of battery and its charging status - data that is first entered with the navigation data.

Two key components are identified in this project: the side of monitoring and transmission of instantaneous power consumption - it is a specialized hardware equipment developed here - and the part of the processing and fusion of current consumer related data with those related to navigation and of route planning. The system is currently functioning as an experimental model. As future development directions, we are considering creating a prototype in which to optimize the equipment on the vehicle to obtain a long-lasting energy autonomy.

6. References

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