UNIVERSIDAD DISTRITAL
FRANCISCO JOSÉ DE CALDAS

Visión Electrónica
Más que un estado sólido
https://doi.org/10.14483/issn.2248-4728

VISIÓN ELECTRONICA
A CASE-STUDY VISION

Geolocation system and vehicular analysis for motorcyclists

Sistema de geolocalización y análisis vehicular para motociclistas

David Steven Garzón Ramírez[1], Michael Steve Sanabria-Guio[2], José David Cely-Fajardo[3]

INFORMACIÓN DEL ARTICULO

Historia del articulo
Envíado: 23/09/2018
Recibido: 24/09/2018
Aceptado: 12/11/2018

Palabras clave:
Coordenadas Geográficas,
Android,
Sensores,
Motocicleta, Servidor,
GPS.

Keywords:
Geographical coordinates,
Android,
Sensors,
Motorcycle, Server,
GPS.

RESUMEN

Actualmente existen aplicaciones dedicadas a la orientación de motociclistas que funcionan soportadas en una conexión a internet, pero cuando se carece de ella la mayoría no funcionan y otras permiten el funcionamiento solo si anteriormente se descargaron los mapas de los trayectos a realizar. Por lo anterior, este artículo propone un sistema de análisis vehicular en donde los motociclistas tienen acceso a una aplicación desarrollada para dispositivos con sistema operativo Android que les mostrará una metodología de orientación sin depender exclusivamente de una conexión a internet; esta orientación –en cambio- se realiza con base en los datos de recorridos almacenados en el dispositivo móvil, o en los datos alojados en un servidor mediante la implementación de un servicio web cuando hay conexión. Adicionalmente, se realiza seguimiento y graficación de las variables: posición geográfica instantánea, porcentaje de nivel de gasolina, y velocidad, obtenidas mediante el diseño e implementación de un circuito electrónico encargado de capturar las señales de los sensores de la motocicleta y enviar dicha información vía Bluetooth al dispositivo móvil. De las pruebas realizadas se observa que el sistema funciona eficientemente con un error absoluto menor a 2 metros hasta el punto de destino; sin embargo, para el recorrido desde el punto actual del usuario hasta uno intermedio la precisión es del orden de centímetros.

ABSTRACT:

Currently there are a number of applications functioning through internet connections aimed at assisting motorcyclists. However, most of these applications wither do not function or require the route maps to be downloaded prior to the trip. This paper proposes a vehicular analysis system where the motorcyclists have access to an application developed for Android devices, without relying on an internet connection. This will done either through data of the routes stored on the mobile device or through data hosted on a server through the implementation of a web service when there is a connection. Additional, variables are tracked and plotted, such as instant geographical position, percentage of necessary fuel, and speed, obtained through the design and implementation of an electronic circuit that acquires the signals of the motorcycle sensors and submit such information via Bluetooth to the mobile device. From the tests carried out it is observed that the system works efficiently with an absolute error up to 2 meters from the destination point. However, the routes from actual location of the motorcyclist to the intermediate position, the precision is even better with an error possibility of only centimeters. In general, for some distance, the system presents a standard deviation of 15,19 meters. The storage of the data and the user orientation are in real time, and the system can be implemented on any kind of vehicle.

1 Tecnólogo en electrónica e Ing. En Telecomunicaciones (UDFJ de C). Coinvestigador grupo Teletecno (UDFJ de C). Correo electrónico e-mail: dsgarzonr@gmail.com ORCID: https://orcid.org/0000-0002-4772-2583
2 Tecnólogo en electrónica e Ing. En Telecomunicaciones (UDFJ de C). Coinvestigador grupo Teletecno (UDFJ de C). Correo electrónico e-mail: mssguio@gmail.com ORCID: https://orcid.org/0000-0002-1863-3629
3 Ingeniero Electrónico. Lugar de trabajo: Universidad Distrital Francisco José de Caldas - Facultad Tecnológica, Correo electrónico e-mail: jdcely@udistrital.edu.co ORCID: https://orcid.org/0000-0001-8969-5301
Cite this article as: D. S. Garzón-Ramírez, M. S. Sanabria-Guio, J.D. Cely-Fajardo, "Geolocation system and vehicular analysis for motorcyclists", Visión electrónica, vol. 2, no. 1, Special edition, january-june 2019 https://doi.org/10.14483/issn.2248-4728

1. Introduction

Currently most mobile devices that work on an Android operative system can connect with the global positioning system (GPS). This system uses a constellation of 24 satellites -available 24 hours a day. This system gives information of any geographic position without any monetary cost [1-4]. In order to get the signal, one does not require any kind of antenna, although there are some devices which can be used in order to improve the signal reception. However, this is only possible if one the device has a line of sight with at least 4 satellites, which means that it is important stay in places where the pass of there is no limited electromagnetic microwave frequency waves. This is the reason why the system doesn´t function inside buildings, caves, forest, among other obstacles [5-7]. Thanks to this system one can get the geographical coordinates of the exact place where the motorcyclist is without the need to use an internet connection.

Existing applications that are available in the current market such as Google Maps [8] can locate the user without internet connection, but with the need to download maps of the specific areas. These downloads can occupy more than 500 MB of storage on the device. [9-14].

In the case study, proposals are being required in order to assist motorcyclists to explore new routes without having to go into zones where there is network coverage.

For the above reasons, this article describes the research which led to establish a system which can have all the data of all routes stored on it and where the motorcyclist can rely on it. The proposed system doesn't depend of connectivity for the location positioning and gives to the motorcyclist the possibility to analyze all his routes, estimating the exact levels of fuel and speed just by implementing an electronic circuit that captures the data directly from the motorcycle. This data is then sent to the application developed for Android -mobile carrier-. Once the mobile detects an internet connection the application automatically sends all information to one database configured in a server with a Windows operating system, optimizing empty storage on the device and where the user can have a record of all routes covered.
The sequence of this paper is structured in the following manner: First it displays the selected methodology for development where it explains how the acquisition of data from the motorcycle is done, the sensors that it uses and the implementation circuit. The application performance is then explained and shows how the network data works and how the reception and transmission of the information are transferred between the mobile device and the main server. Finally, the results obtained from a test about user orientation and consumption data are analyzed in a small route in the Bogota city.

2. MATERIALS AND METHODS

To carry out the proposed data storage system and orientation of motorcyclists, a block diagram about the general structure and development is being presented in figure 1 shows the diagram that constitutes the system in general.

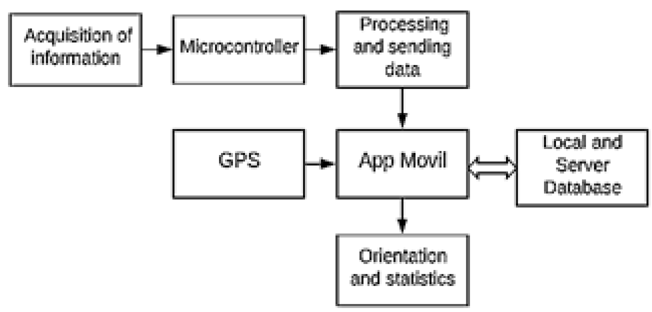

Figure 1. Blocks Diagram. Source: own.

The system is based on the acquisition and manipulation of data obtained from a motorcycle Apache (TVS) - 180 cc and an android device with GPS; with the objective of searching and visualizing information about the route performed by the motorcyclist on a mobile application.

A circuit to receive data from the motorcycle sensors was designed. Here the sensors inside are linked to electronic circuits that process the information and convert it into an electronic signal before being sent to some device for monitoring and control. Most of these motorcycles use electronic frequency or digitals sensors to calculate the speed [15]. The motorcycle used for the prototype development had a magnetic sensor in order to measure speed. The signal is then received through a coupling system able to read, handle and send the data using the best possible resolution at the appropriate size that is required to be incorporated in the motorcycle. To achieve the above an Arduino nano was used. This had the appropriate dimensions and features to take handle the information and which was also located close to the motorcycle dashboard. It has a size of 4.5 x 1.8 cm, It has 14 I/O digital pins and 8 ADC (each one providing 10 bits of resolution giving accuracy to the fuel level reading), an ATMEga328 microcontroller that works with 16 MHz of frequency and 2 external interruptions which are used and configured to be activated by falling Edge and detect speedometer pulses.

In the coupling system a Bluetooth HC-06 module is used. This ensures the connection to the mobile device and supplies a channel which is used to send motorcycle information that is being acquired and being processed by the microcontroller, which contains an algorithm to receive the variables and sending them to the Android application.

IDE of Android Studio was used as a platform for the mobile application development of the packets, where the components and the sturdiest libraries for the design and algorithm programmation. The application receives microcontroller and GPS information to combine them into an algorithm able to guide the motorcyclist in case of being lost or simply wants to view and analyze statistics on his routes [16-18].
The application is developed to store the data on the mobile device in case there is no internet connection and guide the motorcyclist accordingly. When he has connection, the application will transfer all information to an SQL Server, a database server with Windows operative system, which allows storage of large volumes of information, where finally there is a trace of the routes made.

The storage and reading of data from the main server are done through a web service developed in the IDE of Visual Studio .NET, which is responsible to receive the request from the application to store and / or obtain information in the database according to the requirement.

3. Implementation

3.1 Acquisition of information

Figure 2 shows the generated signal by the motorcycle speed sensor, a square signal with a peak voltage of 2.92 V where the frequency is proportional to the speed that the front wheel turns.

The fuel meter is a simple rheostat, that is to say a variable resistor that varies by the magnetic field generated between a magnet and a copper filament that moves away and/or about it due of the float depending of the height of float, this height changes depending on the fuel level on the fuel tank. In this way the voltage for the vehicle computer [19] is obtained. These signals can be acquired and treated properly with an analog and a digital input through a microcontroller.

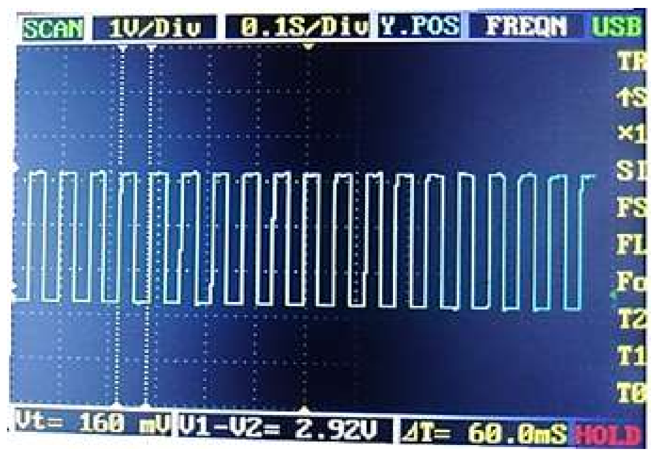

Figure 2. Speed Sensor Signal. Source: own.

3.1.1 Coupling the circuit to the motorcycle.

When the speedometer generates a signal, it is routed directly to the Arduino and it causes a tension fall from 2.9v to 1.8v insufficient for a correct reading of the sensor generated pulses. In order to solve this problem, a circuit that has a NPN transmitter and an operational circuit is implemented [20-22]; the first one is configured as an emitter follower due to its high input impedance and a low output, causing an optimal coupling to be achieved where the output voltage level is lower than the input [23]; the second one is responsible to invert and amplify the level voltage signal that leaves the transistor so that it can be read by the microcontroller [24], see Figure 3.

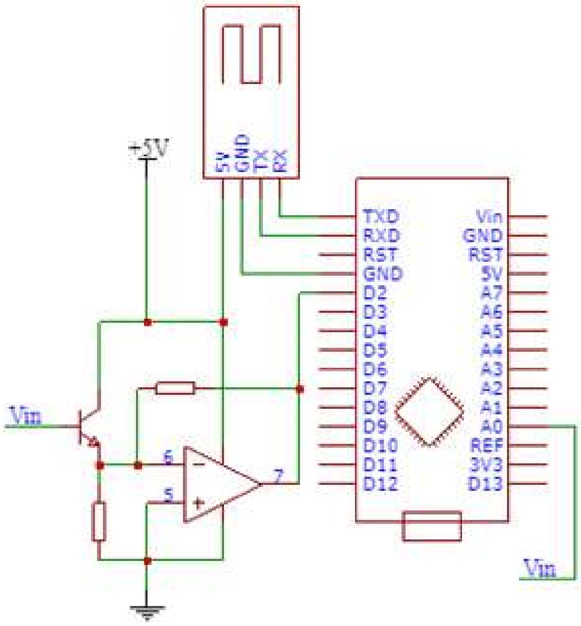

Figure 3. Implementation Circuit. Source: own.

3.2 Microcontroller

At this stage, an algorithm able to calculate the vehicle speed and fuel level obtained with the couple system is developed, where the input pulses (8 pulses by turn in Apache Motorcycle of 180CC) and the RPM are calculated and with the wheel radius the corresponds with the speed is calculated [25-28].

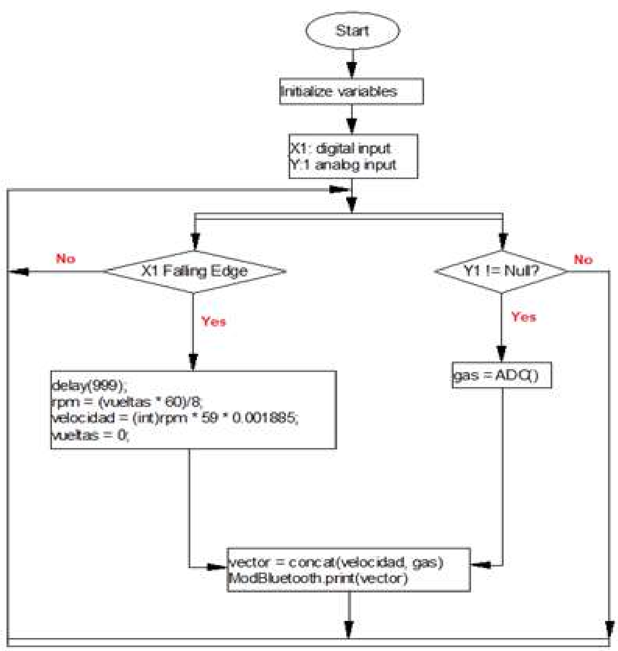

Figure 4. Flowchart of the microcontroller algorithm. Source: own.

Arduino Nano is constantly receiving data from the motorcycle and using the information to calculate as may be seen in the flowchart of the figure 4. The data obtained by each input are replaced as a function time and are sent through an HC-06 Bluetooth module that is connected with the Arduino main UART as the figure 3 shows. This communication module behave likes a slave waiting for connection requests, when the user mobile device is paired up and connected to the HC-06 transmitting the information that connects the Arduino to the device and vice versa with a speed of 9600 bauds. This communication protocol is especially designed for low consumption devices and one that require a short emission range [29,30].

3.3 Mobile application and information processing

The mobile application developed in Android Studio requests user permissions to access and activate the Bluetooth and GPS of the mobile device. With the mobile device and the HC-06 module linked, the microcontroller begins to obtain information from the motorcycle and the application will only receive it every time a change in the geographical position of the mobile device is present, with the location manager class of Android Studio providing access to the system's location services, the application is developed to detect the said movement and request from the microcontroller the information at that moment in time with the purpose of assigning the data for each geographical point of the user and omitting redundant information [31-35]. The information is stored in the mobile device and subject to an internet connection, sends to a main server without temporarily removing the latest data acquired from the routes to ensure that information is always available in case of loss of the user. For this reason, the user must only enter ranks from the date and initial time until the date and end time of the query. In order to be updated the application connects to a web service through a tool that creates a secure access tunnel called NGROK [36], and without the need to open ports in the router or edit the configuration of the server, it assigns a domain from where one can access the database of the main server, the previous data in case there is internet, otherwise, the application searches the information in the local database of the mobile device incorporated with SQLite. [Figure 5].

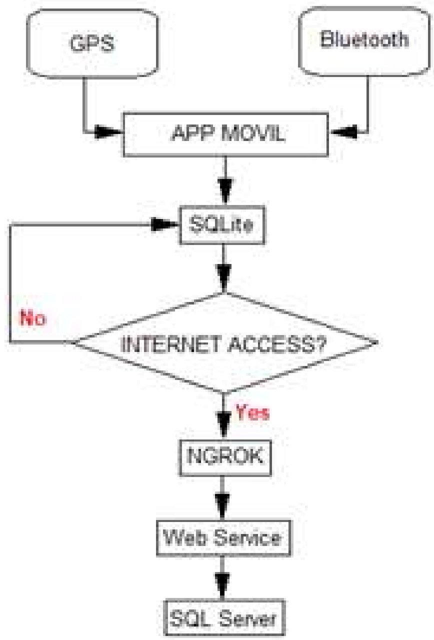

Figure 5. Flowchart of information processing. Source: own.

The application obtains the data within the range of dates that the user selects and performs the graph of the path taken on a Cartesian plane whose axes correspond to the latitude and longitude of the route. The destination point is visualized, as is the current position of the motorcyclist regarding the route and the indications in real time [37-40]. For orientation, the stored information is taken into account, thus determining the pair of coordinates closest to the current position point of the motorcyclist and indicating the cardinal point and the distance in meters that must be covered at every moment. The application is constantly being updated and performing this process for each coordinate point where there is a change of direction towards the destination; Once the end point has been reached, the user is notified and the system gives him the option to check parameters such as his fuel level consumption on the route and the different speed values [41-46].

3.4 Web Service

The implemented web service is SOAP kind because Android Studio manages a popular library whose framework allows us to implement relatively easily and comfortably the web services that use this type of standard [47]. To access from the mobile application, an object was created to perform HTTP communication with the server (type HttpTransportSE) to which the connection URL is assigned. This URL contains the domain assigned by the NGROK program next to the name of the source of the web service, therefore, since there is access to the network, the web service will always be responding to the requests of the motorcyclist to consult or store all the desired information.

3.5 Server and Database

Storing all the information of each moment of the trip covered by the motorcyclist is a job that occupies a large chunk of internal memory in the device. Thus, the storage of information is done by implementing a SQL Server database server. This server can be implemented in any machine that contains a processor with a speed greater than 1.5 GHz, RAM memory equal to or greater than 3GB and a hard disk with at least 1TB capacity, the data regarding speed, fuel, latitude, longitude and time is stored there, where any change in position in the vehicle generates data and adds to the information of the journeys made by the motorcyclist [48,49,50]

The server contains a backup of the information on all the journeys of the motorcyclist and the different applications necessary to access it as the application of the web service and ngrok.

6. Tests and Results

Figure 6 represents the behavior of the frequency values obtained for a speed range between 6 Km/h and 20 km/h

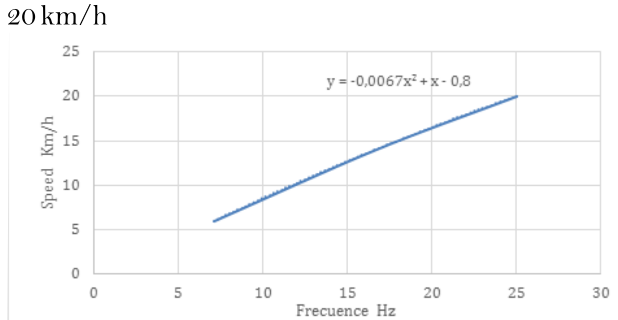

Figure 6. Speed vs Frecuency from 6 Km/h to 20 Km/h. Source: own.

Based on the acquired data a polynomial equation that represents the speed behavior against the pulses frequency by the sensors is obtained.

Sampling was done in the city of Bogotá, in figure 7 and 8 we can see the interface of the mobile application that will help the user in his orientation. This route is made between the range of dates selected in Figure 6, based on the information obtained, the geographical points that are unnecessary for the orientation of the motorcyclist are filtered by plotting those where a change of orientation in the route is evidenced

Figure 7. Mobile Interface – Route Selection. Source: own..

Figure 8. Mobile Interface – Orientation System. Source: own.

The application makes a graph of the selected path and although there is a more approximate route to reach the destination, the application will indicate to the user the steps that must be taken to get through the routes where red is indicating the cardinal point and the distance in meters that the motorist must travel from his current position to the point where he must make a turn. This is done continuously until you reach the destination; in figure 7 the mobile interface with the said orientation system is observed, where the data is user coordinates, distance to its destination, distance to the next turning point and the points of [4]the path plotted in the graph are constantly updated.

The application implements the Haversine formula which calculates the distance between two points contemplating the curvature of the earth, this formula is more accurate in the numerical calculation even at small distances unlike the calculations based on the law of spherical cosines [51], based on the path example, the application calculates a distance of 311.254 m and with the Google Earth tool a distance of 311.39 m is calculated, that is, an accurate result with an error margin of a few centimeters is achieved. [Figure 9].

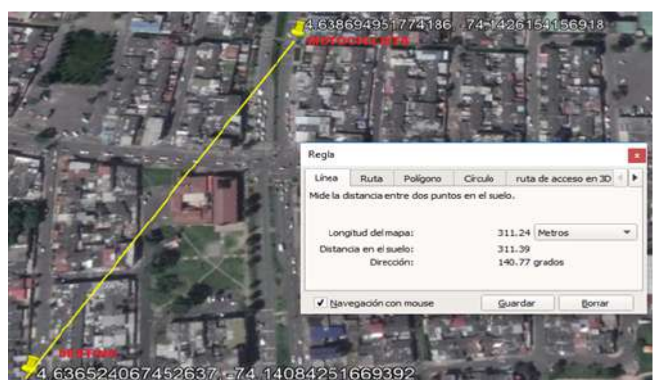

Figure 9. Distance between motorcyclist and Destination on Google Earth. Source: own.

4 Haversine's formula: Calculate the distance between two geographical coordinates: Where r = Earth's radius, λ = Latitude, Φ = Longitude

$$d = 2r\arcsin\left(\sqrt{\sin^2\left(\frac{\phi_2-\phi_1}{2}\right)+\cos(\phi_1)\cos(\phi_2)\sin^2\left(\frac{\lambda_2-\lambda_1}{2}\right)}\right)$$

To know the efficiency and reliability of the application the distance in meters over different geographical points was calculated. These were implemented as destinations directly in the coding of the program and with Android Studio DEBUG we can know the value of the parameter assigned to the distance calculated between the point of origin and each of these destinations. [Table 1]

DESTINATION	ORIGIN COORDINATES	DESTINATION COORDINATES	IDEAL DISTANCE (m)	APP DISTANCE (m)	ABSOLUTE ERROR (m)	RELATIVE ERROR (%)
Unicentro de Occidente (Bogotá)	4,638694951774186; -74,1426154156918	4,722897; -74,113490	9879,7100	9881,53456206867	1,8245620686703	0,018467769
Duitama (Boyacá)	4,638694951774186; -74,1426154156918	5,809486; -73,020909	179514,550	179532,1732455640	17,6232455639984	0,009817168
Villa Alsacia (Bogotá)	4,638694951774186; -74,1426154156918	4,644454; -74,131618	1376,8300	1376,83300473206	0,0030047320602	0,000218236
Ibagué (Tolima)	4,638694951774186; -74,1426154156918	4,435597; -75,233395	123034,510	122999,987185890	34,5228141099942	0,028059456
Castilla (Bogotá)	4.638694951774186, -74.1426154156918	4.636524067452637, -74.14084251669392	311,2400	311,25368637341	0,0136863734080	0,00439737

Table 1. Ideal Distance – App distance Source: own.

The ideal values are calculations made in the Google Earth software. This program allows you to calculate distances anywhere on earth and display them in meters, but with few decimal digits. Table 1 shows that at short distances a low margin of error is obtained; when calculations with considerably long distances are analyzed, the margin increases proportionally; however, the relative error for any distance is less than 0.1%.

The system has greater accuracy in areas smaller than $10km^2$ On the other hand, the orientation system has an arithmetic mean equal to:

$$X = \frac{\sum Error\ ABS}{5} = 10{,}79746257$$

You also get a mean for the relative error equal to:

$$Y = \frac{\sum Relative\ Error}{5} = 0{,}012192\%$$

And a standard deviation equal to:

$$\sigma = \sqrt{\frac{\sum(10{,}79746257 - (Error\ ABS)_i)^2}{5-1}} = 15{,}18886691$$

Based on the above, the motorcyclist can analyze his journeys with gasoline consumption data and speeds reached throughout the route. The application makes graphs on each parameter with respect to time independently. Figure 10 shows all the speed variations presented in the test.

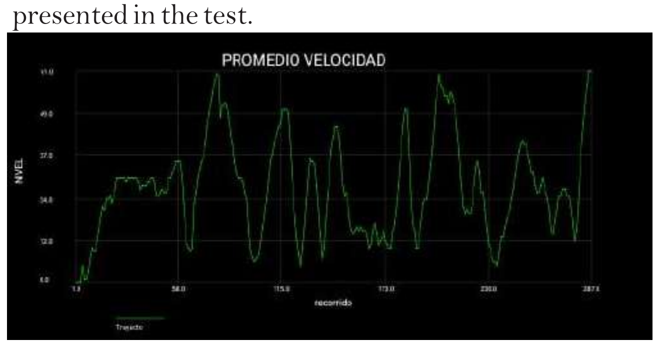

Figure 10. Average speed during the course Source: own.

Some coefficients were adjusted in the calculation of the RPM and the conversion at speed in Km / H to obtain the most accurate value of the speed level in real time by comparing the value displayed on the motorcycle and the values obtained in the database.

Nergiza (A 100% independent website on energy-related issues), in one of its blogs makes a graph that unifies the gasoline consumption of different cars and different models to verify whether a car consumes more fuel when traveling long distances, in which they conclude that: *"The consumption of a car does not increase with the kilometers against what might seem, in fact, in many cases suffers a slight decrease"*. [52]

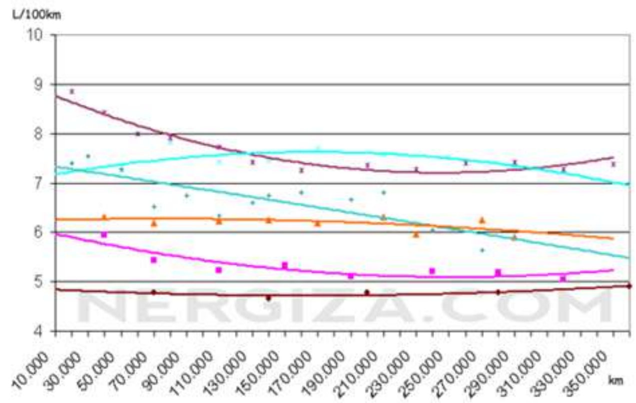

Figure 11. Gasoline consumption vs. kilometers for different cars. [52]

As can be seen in the figure above, a significant change in gasoline consumption is not noticeable at short distances. The fuel consumption of the motorcycle is inversely proportional to the resistance value, with a full tank a value of 35 ohm was obtained. And with the tank almost empty a value equal to 213 ohm; therefore, 35 ohm represents a value of 100% and 213 ohm as 0% respectively, the value of this resistance is captured with a resolution of 10 bits and the rider will visualize only a square signal that represents these percentages over the level of gasoline at the end of its journey, in the test ride begins the journey with a 40% fuel level and proceeds to fill the tank during the same and thus note a significant change in the graph presented by the application [Figure 12].

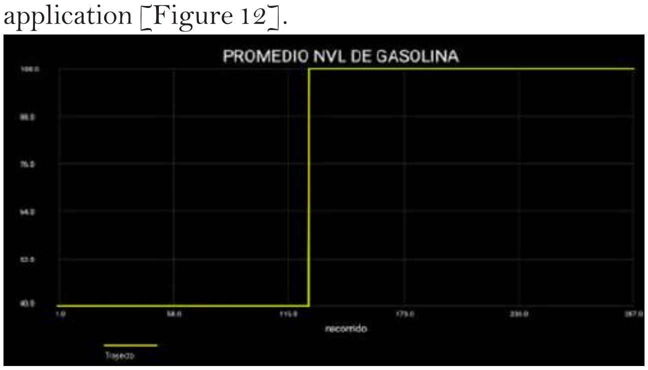

Figure 12. Fuel level during the journey Source: own

7. Conclusions

- The coupling system mitigates the voltage drop that occurs when sensors are connected to the prototype.
- In general, the system has a standard deviation of 15.19 meters and a relative error of less than 0.1%.
- The speed of the wheel is directly proportional to the frequency of the pulses generated by the speed sensor.
- The system guarantees a high efficiency in the rider's orientation since it presents an absolute error of less than 2 meters to the destination point; however, for the route from the user's current point to an intermediate one the precision is of the order of centimeters, in addition this system helps to save costs since external devices can be dispensed with.
- The Arduino nano is a microcontroller that thanks to its size and functionality is optimal for the development of the motorcycle data acquisition circuit, was found to be efficient for capturing signals from sensors and is properly coupled to the HC-06 module for Bluetooth communication, providing a quick response to requests from the mobile device.
- The system can be applied to any motorcycle, although it may be necessary to make small changes in the data acquisition circuits if the motorcycle sensors do not match those of the prototype.
- The system presented is an aid for motorcyclists who like to explore new roads because they have the information of their routes without accessing the mobile network, the data acquisition circuit is simple and easy to install, all this added to a low cost and battery consumption of the motorcycle.

Acknowledgements

To the research group TELECTECNO for its contribution in the spaces for the development of the project.

References

[1] C. A. Díaz Celis, C. A. Romero Molano, "Robot aplicado a la medición de áreas usando gps". *Visión Electrónica*, vol. 9, no. 2, 2016, pp. 206-214. https://doi.org/10.14483/22484728.11029

[2] J. D. Nieto, L. F. Santos, L. J. Vargas, S. A. Salinas. "Geolocalización para pacientes con alzhéimer: una propuesta". *Visión Electrónica*, vol. 11, no. 1, 2017, pp. 40-44, https://doi.org/10.14483/22484728.12791

[3] A. Escobar Díaz, J. Calderón Acero, I. Parra Garzón, "Prototipo Teleoperado: Una alternativa en sistemas de búsqueda de

personas". *Visión Electrónica*, vol. 2, no. 2, 2011, pp. 78-85.

[4] U. Iqbal, T. B. Karamat, A. F. Okou, A. Noureldin, (2009). "Experimental Results on an Integrated GPS and Multisensor Systemfor Land Vehicle Positioning". International *Journal of Navigation & Observation*, 2009, pp. 1-18. https://doi.org/10.1155/2009/765010

[5] Aristasur, "Cómo funciona el sistema de posicionamiento GPS", https://www.aristasur.com/contenido/como-funciona-el-sistema-de-posicionamiento-gps

[6] J. Peñafiel, J. Zayas, "Colegio oficial de ingenieros técnicos en topografía delegación territorial de madrid-castilla-la mancha, "fundamentos del sistema gps y aplicaciones en la topografía". http://www.rutasnavarra.com/gps/Teoria/GPSavanzado.pdf

[7] E. Huerta, A. Mangiaterra, G. Noguera, "GPS: posicionamiento satelital"; - 1a. ed. - Rosario: UNR Editora - Universidad Nacional de Rosario, PDF https://www.fceia.unr.edu.ar/gps/GGSR/libro_gps.pdf

[8] A. Shukla, A. Jain, (2018). "GPS-Based Tracking System for Vehicles Using Google Maps". *IUP Journal of Electrical & Electronics Engineering*, vol. 11, no. 4, 2018, pp. 57-64.

[9] M. Ramírez, "Google Maps vs Waze, comparativa a fondo: ¿qué app tiene las mejores opciones de navegación?", https://www.xatakandroid.com/aplicaciones-android/google-maps-vs-waze-comparativa-a-fondo-que-app-tiene-las-mejores-opciones-de-navegacion

[10] R. Paszniuk, "Acceso a Web Service SOAP en Android" https://www.programacion.com.py/mobiles/android/acceso-a-web-service-soap-en-android

[11] J. Wang, X. Rui, X. Song, X. Tan, C. Wang, V. Raghavan, "A novel approach for generating routable road maps from vehicle GPS traces". *International Journal of Geographical Information Science*, vol. 29, no. 1, 2015, pp. 69-91. https://doi.org/10.1080/13658816.2014.944527

[12] S. Xianfeng, V. Raghavan, D. Yoshida, "Matching of vehicle GPS traces with urban road networks. Current Science (00113891)", vol. 98, no. 12, 2010, pp. 1592-1598.

[13] H. Songlai, W. Jinling "Land Vehicle Navigation with the Integration of GPS and Reduced INS: Performance Improvement with Velocity Aiding". *Journal of Navigation*, vol. 63, no. 1, 2010, pp. 153-166. https://doi.org/10.1017/S0373463309990282

[14] J. Xie and J. Zhong, "Design and Implementation of GPS Vehicle Monitoring Information System," 2009 International Conference on Information Engineering and Computer Science, Wuhan, 2009, pp. 1-4. https://doi.org/10.1109/ICIECS.2009.5363796

[15] K. Berntorp, "Joint Wheel-Slip and Vehicle-Motion Estimation Based on Inertial, GPS, and Wheel-Speed Sensors". IEEE Transactions on Control Systems Technology, vol. 24, no. 3, 2016, pp. 1020-1027. https://doi.org/10.1109/TCST.2015.2470636

[16] H. Tan, (2010). "Design and Implementation of Vehicle Monitoring System Based on GSM/GIS/GPS," 2010 Second International Conference on Information Technology and Computer Science, Kiev, 2010, pp. 413-416. https://doi.org/10.1109/ITCS.2010.107

[17] X. L. Wei Chen, S. Xiang, Bin Li, Xianghui Song, X. Qimin. (2015). "A novel fusion methodology to bridge GPS outages for land vehicle positioning". Measurement Science & Technology, vol. 26, no. 7, 2015. https://doi.org/10.1088/0957-0233/26/7/075001

[18] Y. Zein, M. Darwiche, O. Mokhiamar, "GPS tracking system for autonomous vehicles". *Alexandria Engineering Journal*, vol. 57, no. 4, 2018, pp. 3127-3137. https://doi.org/10.1016/j.aej.2017.12.002

[19] AutoDaewooSpark, "Medidor de gasolina", https://www.autodaewoospark.com/medidor-de-gasolina.php

[20] A. Islam, U. Iqbal, J. M. P. Langlois, A. Noureldin, "Implementation methodology of embedded land vehicle positioning using an integrated GPS and multi sensor system". *Integrated Computer-Aided Engineering*, vol. 17, no. 1, 2010, pp. 69-83. https://doi.org/10.3233/ICA-2010-0330

[21] K. Jo, K. Chu, J. Kim, M. Sunwoo, "Distributed vehicle state estimation system using information fusion of GPS and in-vehicle sensors for vehicle localization," 2011 14th International IEEE Conference on Intelligent Transportation Systems (ITSC), Washington, DC, 2011, pp. 2009-2014. https://doi.org/10.1109/ITSC.2011.6083010

[22] P. Turmero; "Dispositivos electrónicos Caterpillar" https://www.monografias.com/trabajos104/dispositivos-electronicos-caterpillar/dispositivos-electronicos-caterpillar.shtml

[23] M. Olmo; R. Nave, "Estudio del Seguidor Emisor", http://hyperphysics.phy-astr.gsu.edu/hbasees/Electronic/npncc.html

[24] T. Tran, T. Nguyen, Hien, Vo Thanh Vinh, "Measuring Similarity between Vehicle Speed Records Using Dynamic Time Warping", Knowledge and Systems Engineering (KSE) 2015 Seventh International Conference on, 2015, pp. 168-173.

[25] M. B. Vukajlovi , S. Tadi , D. M. Drami anin, "The practical design of in-vehicle telematics device with GPS and MEMS accelerometers," 2011 19thTelecommunications Forum (TELFOR) Proceedings of Papers, Belgrade, 2011, pp. 908-911. https://doi.org/10.1109/TELFOR.2011.6143692

[26] L. Baghli, K. Benmansour, M. Djemai, "Development of a data acquisition and tracking system for vehicles," 3rd International Symposium on Environmental Friendly Energies and Applications (EFEA), St. Ouen, 2014, pp. 1-6. https://doi.org/10.1109/EFEA.2014.7059936

[27] T. Jeyaprakash, R. Mukesh, "A Tactical Information Management System for Unmanned Vehicles Using Vehicular Adhoc Networks," 2013 4th International Conference on Intelligent Systems, Modelling and Simulation, Bangkok, pp. 472-474. https://doi.org/10.1109/ISMS.2013.69

[28] K. T. Leung, J. F. Whidborne, D. Purdy, P. Barber, (2011). "Road vehicle state estimation using low-cost GPS/INS". *Mechanical Systems & Signal Processing*, vol. 25, no. 6, 2011, pp. 1988-2004. https://doi.org/10.1016/j.ymssp.2010.08.003

[29] J. I. Hernandez, K. Chen-Yuan. "Steering Control of Automated Vehicles Using Absolute Positioning GPS and Magnetic Markers". *IEEE Transactions on Vehicular Technology*, vol. 52, no. 1, 2003. https://doi.org/10.1109/TVT.2002.807224

[30] J. Fan, C. Fu, K. Stewart, L. Zhang, "Using big GPS trajectory data analytics for vehicle miles traveled estimation". *Transportation Research: Part C*, 2019, pp. 298-307. https://doi.org/10.1016/j.trc.2019.04.019

[31] T. Chao, X. Jufang, Z. Yiyi, H. Dong, L. Jiao, "A Smart Exhibition System of Power Measurement Vehicle based on the GIS and GPS Techniques". *International Journal of Online Engineering*, vol. 10, no. 1, 2014, pp. 41-45. https://doi.org/10.3991/ijoe.v10i1.3364

[32] E. uni , H. Hindija, A. Beširevi , K. Hod i , S. Delali , "Improving Performance of Vehicle Routing Algorithms using GPS Data," 2018, 14th Symposium on Neural Networks and Applications

(NEUREL), Belgrade, pp. 1-4. https://doi.org/10.1109/NEUREL.2018.8586982

[33] Z. Sun, X. Ban, "Vehicle classification using GPS data. Transportation" Research: Part C, 37, 2013, pp. 102-117. https://doi.org/10.1016/j.trc.2013.09.015

[34] M. Rothblatt, "The first GPS satellite radio optimized for automatic vehicle location," IEEE PLANS 92 Position Location and Navigation Symposium Record, Monterey, CA, USA, 1992, pp. 524-527.

[35] H. Hu, L. Fang, "Design and Implementation of Vehicle Monitoring System Based on GPS/GSM/GIS," 2009 Third International Symposium on Intelligent Information Technology Application, Shanghai, pp. 278-281. https://doi.org/10.1109/IITA.2009.411

[36] Zeokat, "Ngrok, crea túneles seguros a tu servidor local", https://www.vozidea.com/ngrok-crea-tuneles-seguros-a-tu-servidor-local

[37] S. Ma, F. Wen, Z. Wang, "An Efficient GPS-Free Vehicle Localization Algorithm Using Single Roadside Unit and Receiver," 2018 International Conference on Networking and Network Applications (NaNA), Xi'an, China, pp. 310-313. https://doi.org/10.1109/NANA.2018.8648764

[38] T. Hunter, W. Kosmalski, P. Truong, "Vehicle navigation using differential GPS," IEEE Symposium on Position Location and Navigation. A Decade of Excellence in the Navigation Sciences, Las Vegas, NV, USA, 1990, pp. 392-398.

[39] H. Baomin, Q. Guoqing, "A New Algorithm for GPS-Based Vehicle Navigation System," 2006 6th International Conference on ITS Telecommunications, Chengdu, pp. 1208-1211. https://doi.org/10.1109/ITST.2006.288843

[40] E. Pop, A. Botu, "Programmable GPS Receiver for Automatic Vehicle Location," 2006 IEEE International Conference on Automation, Quality and Testing, Robotics, Cluj-Napoca, pp. 387-390. https://doi.org/10.1109/AQTR.2006.254566

[41] W. Pieni ek, S. Wolak, P. Nogowczyk, "Measurement of selected parameters of special vehicle longitudinal and lateral dynamics with GPS systems," 2018 XI International Science-Technical Conference Automotive Safety, Casta, pp. 1-6. https://doi.org/10.1109/AUTOSAFE.2018.8373335

[42] M. Bandyopadhyay, V. Singh, "GIS based processing of GPS trajectories for Link Speed Determination: Applied to Link Speed profiling of Fire Emergency Vehicles," Proceedings of 3rd International Conference on Reliability, Infocom Technologies and Optimization, Noida, 2014, pp. 1-5. https://doi.org/10.1109/ICRITO.2014.7014693

[43] V. Kukshya, H. Krishnan, C. Kellum, "Performance Evaluation of a System for Estimating Relative Positions of Vehicles During GPS Outages," 2006 IEEE Intelligent Vehicles Symposium, Tokyo, pp. 394-399.

[44] D. Walsh, S. Capaccio, D. Lowe, P. Daly, P. Shardlow, G. Johnston, "Real time differential GPS and GLONASS vehicle positioning in urban areas". *Space Communications*, vol. 14, no. 4, 1997.

[45] D. Banasiak, "GPS vehicle location system". *Roads & Bridges*, vol. 35, no. 4, 1997.

[46] J. Wang et al., "A weighted clustering algorithm for clarifying vehicle GPS traces," 2011 IEEE International Geoscience and Remote Sensing Symposium, Vancouver, BC, pp. 2949-2952. https://doi.org/10.1109/IGARSS.2011.6049834

[47] R. Paszniuk, "Acceso a Web Service SOAP en Android", https://www.programacion.com.py/mobiles/an

droid/acceso-a-web-service-soap-en-android

[48] A. Bohlooli, K. Jamshidi, "A GPS-free method for vehicle future movement directions prediction using SOM for VANET". *Applied Intelligence*, vol. 36, no. 3, 2012, pp. 685-697. https://doi.org/10.1007/s10489-011-0289-9

[49] I. Sanaullah, M. Quddus, M. Enoch, (2016). "Developing travel time estimation methods using sparse GPS data". *Journal of Intelligent Transportation Systems*, vol. 20, no. 6, 2016, pp. 532-544. https://doi.org/10.1080/15472450.2016.1154764

[50] R. J. Abelleyro, "Integrated voice/telemetry/GPS location mobile radio system for public transit; Dallas Area Rapid Transit, DART, Texas," 1992 IEEE International Conference on Selected Topics in Wireless Communications, Vancouver, BC, Canada, pp. 151-153.

[51] O. Camino Costa; D. Jesus Tomas Girones, (2012). "Desarrollo de una aplicación de realidad aumentada sobre android para el apuntamiento de los nodos en el telescopio de neutrinos antares", Universidad Politécnica de Valencia, Gandia. https://riunet.upv.es/bitstream/handle/10251/18444/memoria.pdf?sequence=1

[52] Nergiza, "¿Aumenta el consume de un coche con el tiempo?", https://nergiza.com/aumenta-el-consumo-de-un-coche-con-el-tiempo/