UNIVERSIDAD DISTRITAL
FRANCISCO JOSÉ DE CALDAS

**Visión Electrónica**
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https://doi.org/10.14483/issn.2248-4728

VISIÓN ELECTRÓNICA

A CASE-STUDY VISION

# Evaluation of a teleoperated vehicle for educational purposes

## *Evaluación de un vehículo teleoperado con fines educativos*

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INFORMACIÓN DEL ARTÍCULO

**Historia del artículo:**
Enviado: 01/11/2020
Recibido: 08/11/2020
Aceptado: 22/12/2020

**Keywords:**
Arduino
Educational robotics
Teleoperated vehicle



**Palabras clave:**
Arduino
Robótica educativa
Vehículo teleoperado

ABSTRACT

The use of robotics vehicles in the education of children and teenagers constitutes a modern tendency of great interest in Cuba, due to the quantity of knowledge that provides and the variety of disciplines that it integrates. The present work has as objective to evaluate the use of a teleoperated and robotic vehicle based on Arduino, in the education of children and adolescents from Cuba. It includes the study of the state of the art about educational robotics in the world and in Cuba, who allows to define the main educational activities permitted by robots and the parameters to evaluate in the vehicle of analysis. Afterwards, it carries out a description of the technical specifications of the device, which influences in the benefits obtained by the use of the vehicle. Finally, it carries out the evaluation taking into account the defined parameters in the study of the state of the art. It obtains as conclusions that the use of the vehicle with educational purposes would be very fruitful, in spite of minimum limitations that do not put directly in risk the quality of educational activities.

RESUMEN

La utilización de vehículos robóticos en la educación de niños y adolescentes constituye una tendencia moderna de gran interés en Cuba, debido a la cantidad de conocimientos que provee y la variedad de disciplinas que integra. El presente trabajo tiene como objetivo evaluar el empleo de un vehículo robótico teleoperado basado en Arduino, en la educación de niños y adolescentes cubanos. Contempla el estudio del estado del arte de la robótica educativa en el mundo y en Cuba, lo cual posibilitó definir las principales actividades educativas que permiten los robots y los parámetros a evaluar en el vehículo de análisis. Posteriormente, se realiza una descripción de las características técnica del dispositivo, las cuales influyen en los beneficios que se obtienen del empleo del vehículo. Para finalizar, se realiza la evaluación teniendo en cuenta los parámetros definidos en el estudio del estado del arte. Se obtienen como conclusiones que sería muy provechoso el empleo del vehículo con fines instructivos, a pesar de limitaciones mínimas que no ponen directamente en riesgo la calidad de las actividades educativas.

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Cite this article as: A. Hernández-Eskenazi, J. D. Herrera-Martínez, R. García-Mesa, "Evaluation of a teleoperated vehicle for educational purposes", *Visión Electrónica*, vol. 15, no. 1, pp. 50-58, 2021. https://doi.org/10.14483/22484728.17419

## 1. Introduction

Educational robotics is a didactic approach that can be easily integrated in different educational environments, in which through the use of programmable robotic devices, and the application of project-based learning methodologies, it is possible to improve the process of knowledge acquisition of students, allowing them in turn to become familiar with information and communication technologies and use them to define a plan, organize and find a solution to a specific problem through research and experimentation [1], [4], [5] .

In Cuba, robotics has begun to be present in the education of children and young people, based on the work developed by the Robotics and Mechatronics Group (GRM in Spanish) of the Technological University of Havana "Cujae", which has carried out activities such as those developed in the project Educational Robotics Learn by Playing with EZ-Robots, where children and young people are stimulated in subjects associated with robotics [4]. In spite of this, the number of projects related to educational robotics in Cuba is insufficient to satisfy the increasing demand of the use of these methodologies in the teaching of children and adolescents. For this reason, this work has as an objective to carry out an evaluation of the use of a teleoperated robotic vehicle based on Arduino (Figure 1), built by students from the Faculty of Engineering in Telecommunications of the Technological University of Havana "Cujae", in the education of Cuban children and adolescents.

**Figure 1.** Teleoperated vehicle based on Arduino

Source: own.

The teleoperated vehicle to be evaluated is composed of different functional blocks:

- Locomotion system: Integration of mechanical components in charge of the movement (the wheels).
- Processor: Programmable hardware component that executes the instructions given to the vehicle.
- Communication system: Component that allows the communication between the operator and the vehicle.
- Power supply: Provides the energy of the system.
- Sensor: Component that captures physical quantities from the environment.
- Electromechanical system: Integration of components responsible for converting electrical energy into mechanical energy (motors and H-bridge).
- Manual control: Interface that allows sending instructions to the vehicle.
- Image capture: Made up of a camera and a circuit for lighting in areas of poor visibility.

## 2. State of the art

In this section, there will be a review of the current state of the art of educational or pedagogic robotics, where prototypes used in the world and in Cuba are presented.

### 2.1. *KIBO Robot*

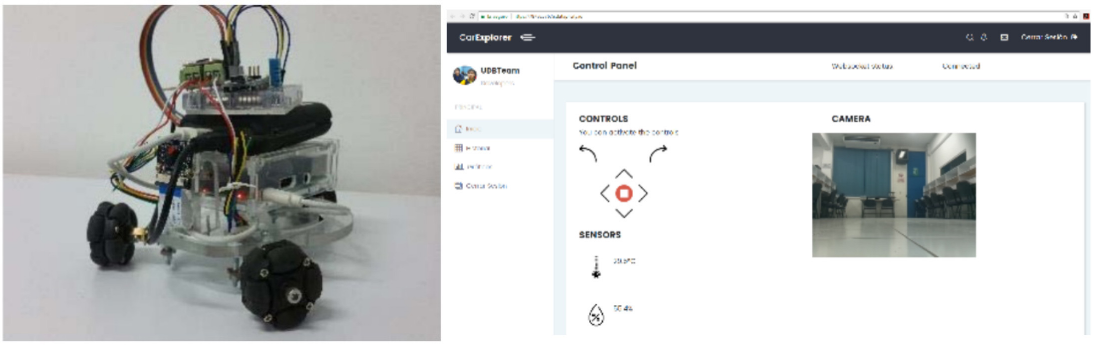
KIBO (Figure 2) has been developed by Kinderlabs Robotics at Tufts University and is an educational robot for children equipped with sound, light and distance sensors, and a bar code reader that is the means by which all programming instructions are entered. It has an appearance that looks as if its physical design has not been completed, which invites children to complete it by using materials that allow for decoration and personalization, involving and inspiring them in the creation of projects with their own meaning in which they can develop creative and artistic skills [5].

**Figure 2.** KIBO Robot [5]

### *2.2. Mobile robot explorer from the University of Don Bosco*

Another prototype developed for academic and educational purposes is the mobile robot explorer from the University of Don Bosco (Figure 3), El Salvador, which has an omnidirectional locomotion system with 3 wheels [6]. Among the tools added to the system are a camera, a sensor of air temperature and humidity so that it can have more information about its environment. Although this prototype is used for academic purposes in higher education, it can be introduced in high school, adolescents and young people, to study the locomotion in mobile robots and IoT technologies (Internet of Things) [6].

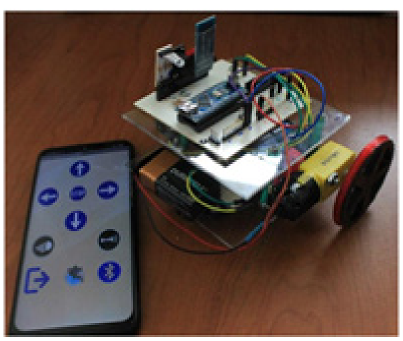
**Figure 3.** Mobile robot explorer from the University of Don Bosco and its web application for control and monitoring [6].




### *2.3. EcateBot*

EcateBot (Figure 4) is a mobile robot developed by the Autonomous University of the State of Mexico that exploits the desire of students to interact in a very easy and simple way with a robot. The project is accompanied by assembly instructions so that students can elaborate EcateBot, and at the same time apply concepts from the areas of physics, mathematics and programming, thus promoting their skills and competencies. The robot is remotely controlled from an Android device via Bluetooth, which communicates with an Arduino to execute the instructions sent by the operator. It also has lighting and sound elements, as well as materials that support heavy use [9].

**Figure 4.** EcateBot and Android control application [9].



### *2.4. Adventure Bot*

EZ-Robot is a course given by the Robotics and Mechatronics Group of the Technological University of Havana “Cujae”. Among the robotic prototypes used is the Adventure Bot (Figure 5), which has an electronic board based on an ARM microcontroller, two continuous rotation servomotors responsible for locomotion through wheels, a camera, and audio handling devices such as a microphone and a speaker [4]. With the development of these courses it was proved that the Adventure Bot is an excellent material to be considered by those interested in studying topics related to science and technology [4].

**Figure 5.** Adventure Bot [4].

### *2.5. Conclusions of the study of the state of the art*

From the study of the presented prototypes it can be concluded that certain activities exist that allow the use of a robot with an educational purpose:

- Interaction for commands: It consists in the execution of a determined task for part of the robot from a command sent by the operator.

- Construction of the robot: Implies the design and the construction of the robot. It allows the student to link to design criteria according to the different requirements of the device.

- Study of the environment from sensors: It consists of the obtaining of information of the environment from sensors installed in the vehicle.

- Programming of the robot: It consists of that the students participate directly in the elaboration of the algorithm that controls to the robot.

- Study of the parts that integrate the robot: It is about the study of the blocks that make to work to the robot as a system.

From the study carried out, the authors also defined the parameters to be evaluated in the tele-operated vehicle to determine if its use with educational purposes in Cuba is possible:

- Educational activities and areas of knowledge that allow developing

- Energy Autonomy

- Ages of interest

- Materials and size

## 3. Technical description

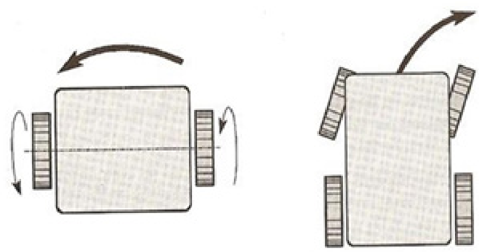
The technical specifications of the vehicle to be evaluated will be addressed below.

### *3.1. Locomotion system*

The locomotion system is based on the reuse of the mechanical structure of a disused remote-controlled toy car. From a mechanical point of view, the use of this motor distribution allows independent control over the direction of movement of each wheel, which in turn allows greater maneuverability. This represents an advantage over the use of other systems such as front or rear-wheel drive, which do not allow such independent control due to the distribution of two motors only on the rear or front wheels [11]. On the other hand, one disadvantage of the system used with respect to the others mentioned is the energy consumption caused by the use of a greater number of motors; however, this does not represent significant problems for the energy autonomy of the vehicle.

To make the turns the vehicle has a differential mechanism, represented in Figure 6 (left). This mechanism is to perform turns of up to 360 degrees without having to advance or vary the relative position of the vehicle from the change of direction of rotation of the wheels on one side over the other [11]. This configuration requires a smaller turning radius compared to other configurations such as the Ackerman, represented in Figure 6 (right), which consists of turning while moving from the control of a vertical axis on the front wheels [11]. After experimental tests during the construction of the vehicle, it was shown that the differential configuration is optimal for transit through spaces with several obstacles.

**Figure 6.** Rotation in differential configuration (left) and Ackerman configurations (right) [11].



### *3.2. Electronic board*

The electronic board installed as a processor is an Arduino UNO (Figure 7), whose technical specifications are shown in Table 1 [7]. This board is a free hardware and software platform based on an Atmega328 microcontroller and a development environment with high-level programming language; it has enough memory space for the program that controls the vehicle operations and also has a number of input and output pins left over for future connections that can be used to improve the prototype. The Arduino UNO is a low cost board but with enough technical potential for a wide variety of projects [7]. This is one of the advantages that it presents against the use of other open source boards such as Raspberry Pi, which is much more powerful and expensive [7], [12].

**Figure 7.** Arduino UNO [7].

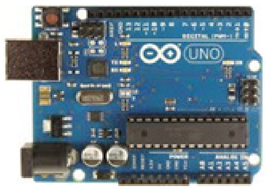


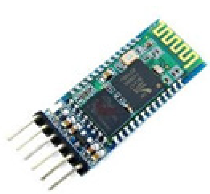

**Table 1.** Technical specifications of the Arduino UNO [7].

| | |
|---|---|
| Microcontroller | Atmega328 |
| Operating voltage | 5V |
| Input voltage (Recommended) | 7 – 12V |
| Direct current per IO pin | 40 mA |
| Direct current on pin 3.3V | 50 mA |
| Flash Memory | 32kB |
| SRAM | 2kB |
| EEPROM | 1kB |
| Clock frequency | 16 MHz |

### *3.3. Communication system*

The communication system is based on the Bluetooth module HC-05 (Figure 8). This module has the Bluetooth 2.0 + EDR (Enhanced Data Rate) standard, which is compatible with most smart phones. Its working frequency is 2.4 GHz, the maximum transmission speed is 2.1Mbps (sufficient for loseless data exchange between the vehicle and the operator) and its power supply can vary between 3.6 and 6V with a current consumption of 50 mA [8]. Its programming in Arduino is very simple and does not require external libraries. The maximum communication distance that can be achieved with this technology is 10 m [8], which is sufficient for indoor work in classrooms and rooms. The compatibility with smartphones, the low consumption and its easy programming make the use of the HC-05 an advantage of the prototype evaluated for the instruction of children and teenagers.

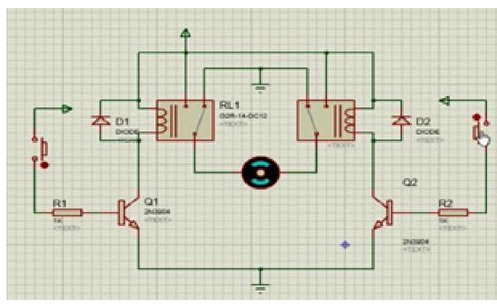
**Figure 8.** Bluetooth Module HC-05 [8].



### *3.4. Motors, H-bridge module and battery*

The electromechanical system of the vehicle is made up of four 12V DC motors with 300 mA consumption, also recycled from the toy by remote control, and a module containing four H-bridges distributed one for each motor. An H-jumper is a circuit that allows the control of the motors with the power they require using lower power stimuli. The H-bridge module implemented in the vehicle is a printed circuit at the Center for Research in Microelectronics (CIME) based essentially on the use of two transistors and two relays for each motor to control (Figure 9) [16]. This design has as a disadvantage over very popular commercial models, such as the L298N driver [2], [3], [8], the impossibility of controlling the speed of rotation; on the other hand, it has as advantages the control of four motors from the same circuit (the L298N allows the control of two DC motors from the same circuit) and a better use of the voltage provided by the battery (the L298N has internal voltage drops of more than 1V due to switching transistors that are not present in the module implemented in the project [8]). The motors are powered from the battery that energizes the vehicle and the stimuli are made with the digital pins of the Arduino UNO.

**Figure 9.** Diagram of the H-bridge that controls a motor [16].



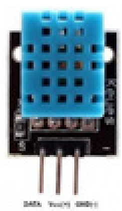

A total of 9 lithium-ion cells were used for battery the vehicle: 3 blocks in series, each consisting of 3 cells in parallel. In this way the battery provides a power supply of 11.1V and 6.6 Ah, comparable to the admissible values for the Arduino UNO in Table 1 and sufficient to supply the DC motors. In practice, the capacity of the battery used is lower than the theoretical value because most of the cells are recycled, which prevents the performance of the vehicle from being as efficient as it could be with new cells. The current battery gives the vehicle an autonomy of between 40 and 45 minutes of movement, which may be sufficient for its use in a classroom; however, if a new battery with the theoretical capacity is used, an autonomy greater than 2 hours would be achieved.

### *3.5. Sensor and lighting*

The vehicle is equipped with the DHT11 digital temperature and relative humidity sensor (Figure 10), with which real-time measurements can be taken from the area where the vehicle is located. The DHT11 sensor works in a measurement range between 0 and 50 °C of temperature and between 20 and 90 % of relative humidity; its accuracy is ± 2 °C of temperature and ± 5 % of relative humidity [13], enough values to carry out experimental work by students on the behavior of these environmental variables under different conditions.

For the illumination, the focus of a disused flashlight was used, which is composed of six white LEDs in parallel that provide sufficient illumination for working with a camera in areas of darkness.

**Figure 10.** DHT11 sensor [13].

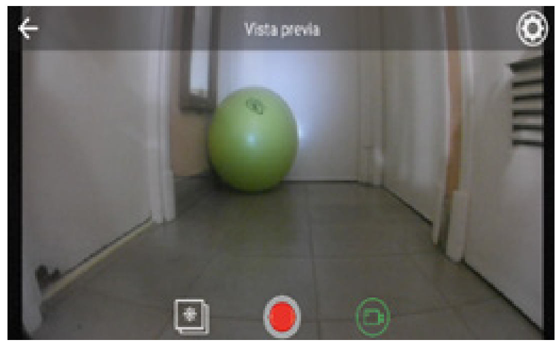


### *3.6. Camera and image viewing application*

The vehicle has a functional image capture block, which consists of a camera and the lighting circuit for areas of darkness. The camera model used is GoPro H9 (Figure 11), which is previously programmed to capture images, process them and transmit them to a terminal [17]. It can capture images in Ultra High Definition (UHD) format resolutions, but wirelessly transmits in High Definition (HD) up to 1080p (1920 x 1080 pixels) [17]. Wireless transmission is via a Wi-Fi connection in the 2.4 GHz band and has its own battery that can be recharged with a USB cable [17]. To receive and view images in real time, the Ez iCam application is used (Figure 12), recommended by the camera manufacturers [17]. This application runs on another smartphone that connects via Wi-Fi with the camera, from which it is possible to take pictures, videos and download images. Ez iCam is an application that can be downloaded for free from the Internet for any smartphone or tablet operating system [17].

**Figure 11.** GoPro H9 Camera [17].


**Figure 12.** Ez iCam Application.

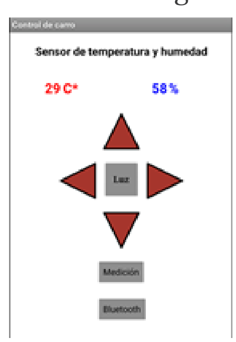



Source: own

### *3.7. Application for vehicle control and monitoring*

For the vehicle-operator interface, an application is used (Figure 13) that allows the control of the vehicle and the monitoring of the sensor measurements at the same time. It was developed using the online platform for programming applications for Android devices App Inventor. It is a platform that presents a very intuitive language, based on visual and block programming. It also has several very interesting and useful pre-defined classes for Android projects [10], [15].

**Figure 13.** Application for control and monitoring.

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## 4. Evaluation of the use of the vehicle for educational purposes

Based on the technical characteristics and taking into account the parameters established with the study of the state of the art, an evaluation will be made in this section on the advantages and limitations of the use of the analyzed vehicle for educational purposes.

### *4.1. Educational activities and areas of knowledge that allow to develop*

As for the activities with educational purposes in which a robot can be employed, the vehicle evaluated can, in different ways, be involved in all of them.

It allows interaction by commands through the application of control and monitoring, with which in a very intuitive way and with a friendly interface allows students to operate the movement, perform competitions to avoid obstacles against the clock under different levels of complexity, as well as make the measurements and monitor them. With this activity, the vehicle makes it possible to involve students in a playful way in the teleoperation of robots and in the manipulation of new technologies.

The construction of the robot can be carried out with the improvement of the current prototype by the students. The philosophy of using recycled materials can be maintained to encourage the reuse of resources. In this way students can use their creativity to add new parts to the vehicle such as a robotic arm, new sensors, or any other element of interest.

The study of the environment is carried out using the DHT11 sensor and the camera. Students can learn about the behavior of the temperature and relative humidity of the environment and maintain a real-time monitoring of the values through the application of control and monitoring. This allows the use of the vehicle in activities such as physics laboratories and solving mathematical problems from experimental data obtained. The camera allows the capture of images from the sites where the vehicle travels, allowing its observation in real time and after the operation of the vehicle.

The programming of the robot is possible due to the use of the Arduino UNO as processor, free software platform and high-level language that can be learned by students from relatively early ages [14]. The use of the Arduino technology is an advantage in the programming with educational purposes, because it has a community of programmers very active in the world, that has brought as result the presence in Internet of a lot of bibliography to initiate people in its employment, although they don't have a basic notion of the programming [14]. Students can work on improvements to the current prototype, such as the incorporation of an automatic obstacle avoidance mode. Similarly, students can learn to program Android applications with the use of App Inventor and use the knowledge gained to modify the control and monitoring application with more complex tasks to perform. These activities stimulate the logical thinking of students, ability to solve problems and practice challenges, as well as encouraging vocational training in programming related careers.

The study of the parts of the robot can be carried out from the analysis of the functional blocks that conform the system. Introductory classes to robotics can be given where the parts of the mobile robot are exemplified through the teleoperated vehicle and the blocks that integrate it. In this way students can also learn how to apply knowledge of mechanics, electronics and wireless communications in the implementation of robotic systems.

### *4.2. Energy Autonomy*

As discussed in the technical description section, the battery that powers the system provides a range that varies between 40 and 45 minutes of vehicle movement. This time may be sufficient for the use of the system in Elementary and High School classes, levels where classes last 45 min. However, it would prevent prolonged use in events such as technology fairs lasting hours. For this last use it would be convenient to renew the battery.

### *4.3. Ages of interest*

The use of the teleoperated vehicle could be oriented to different ages, depending on the activities that the students would perform with it.

It could start its use in Primary School children, from 5th and 6th grade (between 10 and 11 years old), who can learn about the vehicle from its teleoperation in a playful way, as well as from the monitoring of the measured variables, to introduce them to knowledge of physics.

Its use in students of High School who are between 12 and 14 years old, could also include the introduction to programming and robotics, from the Arduino platform and the study of the functional blocks that compose the vehicle.

In students of High School who are between 15 and 17 years old, its use can also include the programming of more complex tasks, in which students can link different disciplines that contribute to their preparation to enter university; the improvement of the current prototype from the construction of new parts and functional blocks; as well as the realization of measurements for experimental practices in physics laboratories that include mechanics, electronics or the study of temperature and relative humidity.

### *4.4. Materials and size*

The materials used in the construction of the vehicle are mainly recycled, which gives a fundamental value to the prototype: the reuse of the available resources, a very important principle to inculcate in the Cuban society, which demands technological solutions from reuse, creativity and innovation.

As for the dimensions, the evaluated prototype measures 29.5 cm high, 39.0 cm wide and 54.5 cm long. These measures compared to the state of the art designs represent a large prototype, which although it is an eye-catching vehicle, especially for children, it causes that its transportation is not so easy and its storage takes up considerable space.

## 5. Conclusions

The use of the teleoperated vehicle analyzed for educational purposes in Cuban children and adolescents turns out to be very fruitful because it allows carrying out a great number of activities that provide students with knowledge in the STEAM disciplines (Science, Technology, Engineering, Art and Mathematics) from early ages, which have gained importance in the formation of new professionals in Cuba. On the other hand, the prototype presents limitations subject to improvements regarding energetic autonomy, which prevents its movement for more than 45 minutes, and its size, which makes difficult its transportation and storage.

It was demonstrated how useful is the use of this prototype with educational purposes, during the Robotics Course for children in the Technological Park La Finca de Los Monos, in Havana, Cuba, between July and August 2020, where it was used as a teaching means to exemplify the use of the Arduino platform, motors and sensors in robotics.

## Acknowledgments

The authors would like to thank the workers of the repair shop Electrónica Viva, in Havana, Cuba, for their support, for giving space and resources to carry out the necessary tests and measurements for the obtained results.

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