A Mobile Terrestrial Surveillance Robot Using the Wall-Following Technique and a Derivative Integrative Proportional Controller

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Abstract. This research aims to develop a land mobile robot of surveillance, whose primary task is to collect real-time videos and images, in closed environments, using the Wall-Following technique and a derivative integrative proportional controller to navigate the environment. We use ultrasonic sensors, infrared, IP camera and encoders for speed control in a closed loop. The development of the robot happened in three stages: definition, acquisition of the model and used components (mechanical structure, microcontroller, sensors, and actuators). Then, the user-robot interaction software will be defined, and the creation of the robot, of the control software and integration tests will be done. The integration test has the job of improving the programming routines of the robot and the interaction with it. Finally, the supervisory module will be described, whose interface will use the visualization and capture of real-time videos and images.

Keywords: Development, Robot. Software, Camera.

1 Introduction

The resurgence of violence in the daily life of contemporary life and, at the same time, the considerable advances in science and technology have become a subject in the constant debate by civil society and governmental bodies in search of social protection, institutions and public and private assets. Given this problem, the following research question is proposed: How to develop the activity of monitoring and surveillance in internal environments with the aid of robotic technology?

Thus, this study is the development of a terrestrial mobile robot, with application directed to the monitoring of internal environments, that can be used in public, residential or private companies and institutions, to provide visualization and image capture and videos, performing mapping of the area to be covered in real time, through

adfa, p. 1, 2011.

a supervisory system. For this, the robot will navigate autonomously and manually in internal environments, having as components: ultrasonic sensors, infrared, IP camera and encoders to perform the position and speed control of the motors.

The rest of the paper is organized as follows: Section 2 deals with issues theoretical foundation. Moreover, in the section 3 provides a brief development, in which it is divided into two sections one describes the project as a whole, in summary, form and the other describes the robot, with its main characteristics in the development and the form that was developed being divided into three parts, are the mechanics with the structure and motors, electronics with microcontroller, sensors and camera, and programming with control and communication thereof. On the other hand, Section 4 describes the results the results of the mobile robot application, presents an overview of the procedures and tests adopted and their answers. Finally, in Section 6, the conclusions and suggestions for further work are provided. [3].

2 Theoretical Foundation

2.1 Mobile robots

Robots have different skills and competencies specific to each type of application. Given this particularity, they present themselves in a variety of ways, according to the complexity of the actions to be performed. [11]

Autonomous mobile robots interact with the environment using a sensing system that allows them to pick up information and then process them, to choose the corresponding action to be performed through the middle of the drive of their actuators. They can be operated with complete autonomy or semi-autonomous, depending on the greater or lesser capacity of perception and performance in the environment, that is, the quality of the sensor system, actuators and motors, as well as the robustness of the intelligence, as it will be responsible (10). In this paper, we present the results of the study.

2.2 Wall-Following

The Wall-Following navigation technique, which bases its orientation on wall tracking. Through this technique, it is possible for the robot to refer to the trajectory to be followed through the use of walls or the accomplishment of the contour of objects in the working environment. We can then navigate intuitively, planning the path he/she should follow indoors or indoors [5].

Navigation based on this technique allows the robot to traverse all the environment in which it is acting and to be able to return to the starting point. Another advantage that it offers in robotics applications is computational cost, well below the values of other techniques that are more complex, especially those that use "image processing through cameras, laser sensors and Global Positioning System (GPS) to map the trajectory [5].

2.3 Controlador PID

A control system is one or more devices with the ability to control a particular system and is therefore specific to each of the functions it must control. According to [7], almost all electronic equipment of the modern era uses this type of control.

Proportional, Integral and Derivative control, or PID is one of the control methods that are frequently used, especially in industry. The PID control comes from the sum of three necessary control actions, each with a specific function: Proportional Action, Integral Action, and Derivative Action. [4]

3 The Proposed Robot

3.1 Description of the project

This research consists of the development of a mobile robot that uses the Arduino Mega 2560 platform based on the ATmega2560 microcontroller. For the complete development of the project, Eclipse software, a Java-based extensible free software development platform, was selected for programming the AVR in C, the software was chosen for having greater flexibility and control in the implementation of the libraries for peripheral use necessary for development. [12]

The robot also has a printed circuit board in which both the Arduino board and all other sensors are connected to reduce the number of connection wires and to power the IP camera in a mobile way. As shown in fig. 1

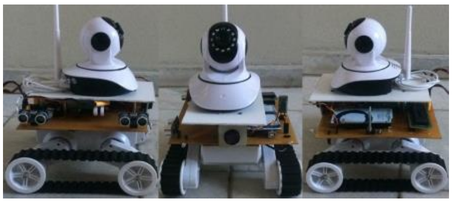

Fig. 1. Sentinel Robot (Prepared by the author)

3.2 Description do Robot Mobile

The robot uses two ultrasonic sensors HC-SR04 to its right, named as S1 and S2, which serve to guide the distance from the wall or obstacle to be circumvented. We determine the distance between the sensor and the obstacle given in centimetres using Equation 1, where ΔT is the duration in µs of the pulse generated by the echo pin and Dist is the distance of the obstacle in centimetre (cm).

$$Dist = \frac{\Delta T}{58} \tag{1}$$

On the other hand, to avoid what is called busy waiting, in which the processor gets stuck in a loop waiting for some event to happen, the operation of the two ultrasonic sensors used in the design is entirely based on interrupts. The echo pins are connected to the external interrupt inputs of the ATmega 2560, and a timer is used to timing the events, as shown in fig 2.

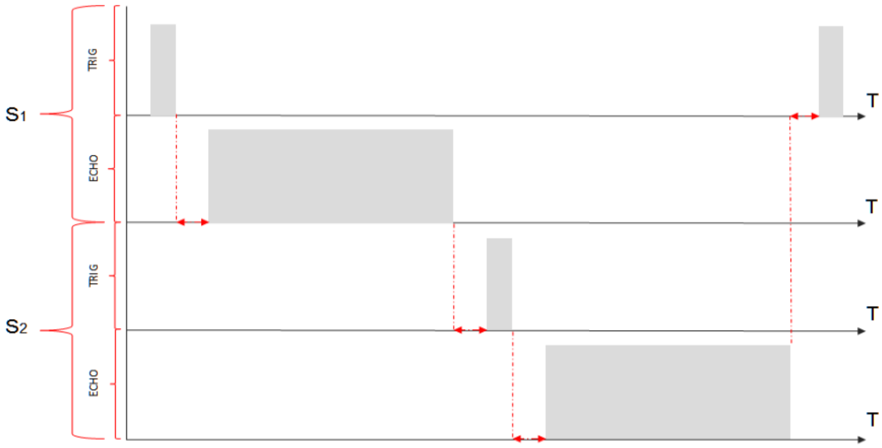

Fig. 2. Operation of the ultrasonic sensors in the robot (Prepared by the author).

Initially, the trigger pin of sensor one (S1) is set to high level, and the timer is set to generate an interrupt after a time of 10μs. When this interrupt occurs, the trigger pin is set low, and the timer is set to generate an interrupt in 2 milliseconds (ms). If a rising edge is detected in the echo pin before this time, the timer is prepared to generate an interrupt in 40ms, and the current count of this timer is saved in a variable. When a falling edge is detected on the echo pin, the current value of the timer is saved again in another variable. Subtracting this variable from the one above has the duration of the pulse generated in the echo pin that is directly related to the distance of the obstacle through equation 1. If the rising edge is not detected, a reading cycle of sensor two (S2).

If the process of reading sensor one (S1) occurred as expected, after detecting the descent edge on the echo pin, the timer is set to generate an interrupt in 2ms. This procedure has the purpose of generating an interval between the end of the reading of a sensor and the beginning of the reading of the next one because it was realized that if the readings are executed immediately consecutive one sensor would interfere in the operation of the other. After 2ms has elapsed and the timer interrupt is triggered, the trigger pin of sensor two (S2) is set to high level, and everything is processed as explained for sensor one (S1). The Wall-Following algorithm uses data from the sensors to navigate autonomously and with the developed logic it makes possible changes in the environment without the function of following walls is affected.

Figure 3 shows, from a flowchart, the reactive logic used in the mobile robot, for navigation in the operating environment, positioned at a parameterizable distance of 10cm from the wall.

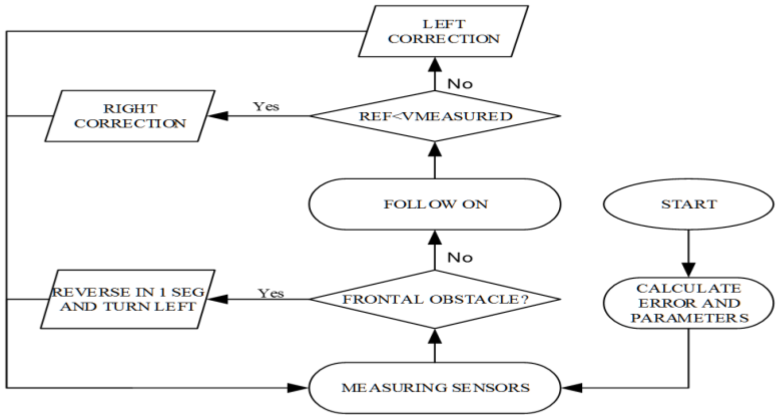

Fig. 3. Wall-Following Flowchart (Prepared by the author)

The derivative integrative proportional controller (PID) for navigation in the closed-loop speed control is carried out on-board. Thus, when receiving the data of the ultrasonic sensors, the algorithm will take the necessary actions sending proportional signals via Pulse Width Modulation (PWM) to the motors, correcting or maintaining its position. Figure 4 shows the control diagram of the mobile robot as a whole.

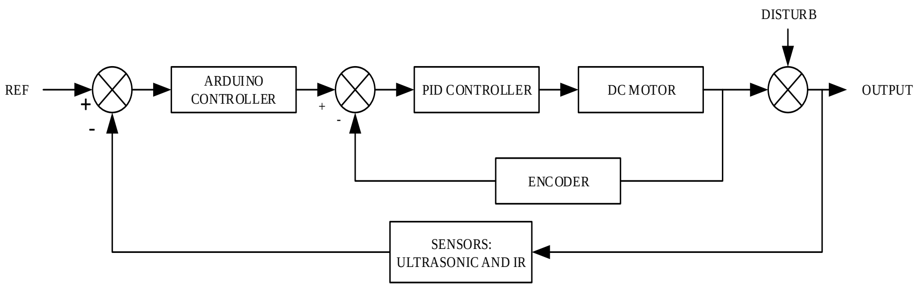

Fig. 4. Control diagram of the mobile robot (Prepared by the author)

For the implementation of the PID controller in the Atmega2560 microcontroller this be discretised. The starting point for deriving the discrete time controller is the continuous controller shown in equation 2.

$$U(t) = K_P e(t) + K_i \int_0^t e(t)\,dt + K_d \frac{d}{dt} e(t) \qquad (2)$$

In equation 3, e(t) is the controller error and is defined as indicated in Equation 3, where r (t) is the reference, or desired value, y (t) is the current output of the system being controlled.

$$e(t) = r(t) - y(t) \qquad (3)$$

The derivative and integral present in Equation 3 can be approximated with the expressions in Equations five and six respectively, where T is the sampling period of the system.

$$\frac{de(t_k)}{dt} \cong \frac{e(k)-e(k-1)}{T} \tag{4}$$

$$\int_0^{t_k} e(t)dt \cong \sum_{i=1}^{k} e(t_i)T \tag{5}$$

Substituting Equations 4 and 5 in Equation 2 and after performing some algebraic manipulations, we arrive at Equation 6 which represents the digital implementation of the PID controller. In this format, it can be implemented in the microcontroller.

$$u[k] = u[k-1] + \left(K_p + K_i\frac{T}{2} + \frac{K_d}{T}\right)e[k] + \left(-K_p + K_i\frac{T}{2} - \frac{2K_d}{T}\right)e[k-1] + \frac{K_d}{T}e[k-2] \tag{6}$$

The camera makes the video stream using the H263 codec. Provides better quality for high-resolution images and better quality in transferring audio and video over the TCP network [9]. The communication can be done with Wi-Fi 2.4ghz or ethernet. Used for the robot will be independent of the connection of commands. The network being managed by the Wi-Fi router [8]. Fig 5 shows the layout and communication flowchart in the software developed for video monitoring.

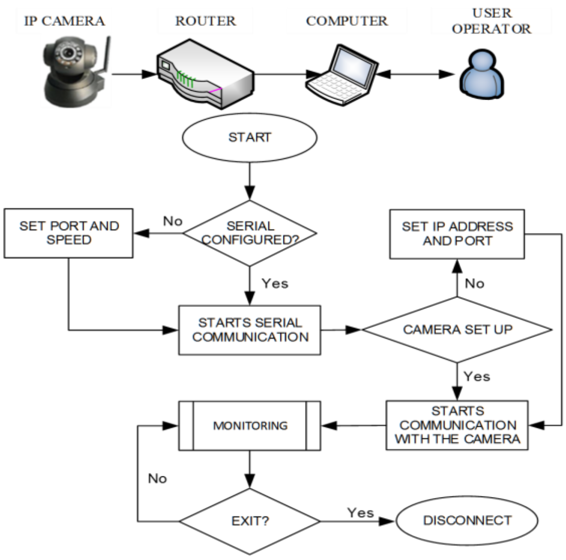

Fig. 5. Flowchart and Communication Layout of the software. (Prepared by the author).

The supervisory system used to access the camera was developed in C ++ using the QT Creator platform. The developed form consists of four tabs: in the first one, there is the boot menu; in the second, the configuration menu of the camera, with the serial port used, in which the IP to be placed in that of the camera itself. The third one is the ActiveX add-in for capturing images and videos in real time. The fourth is a graphical analysis of the sensor reading [2].

Moreover, in the fig. 6 shows the program configuration tab developed in the QT software, in which confirmation of the connected serial port can be visualized.

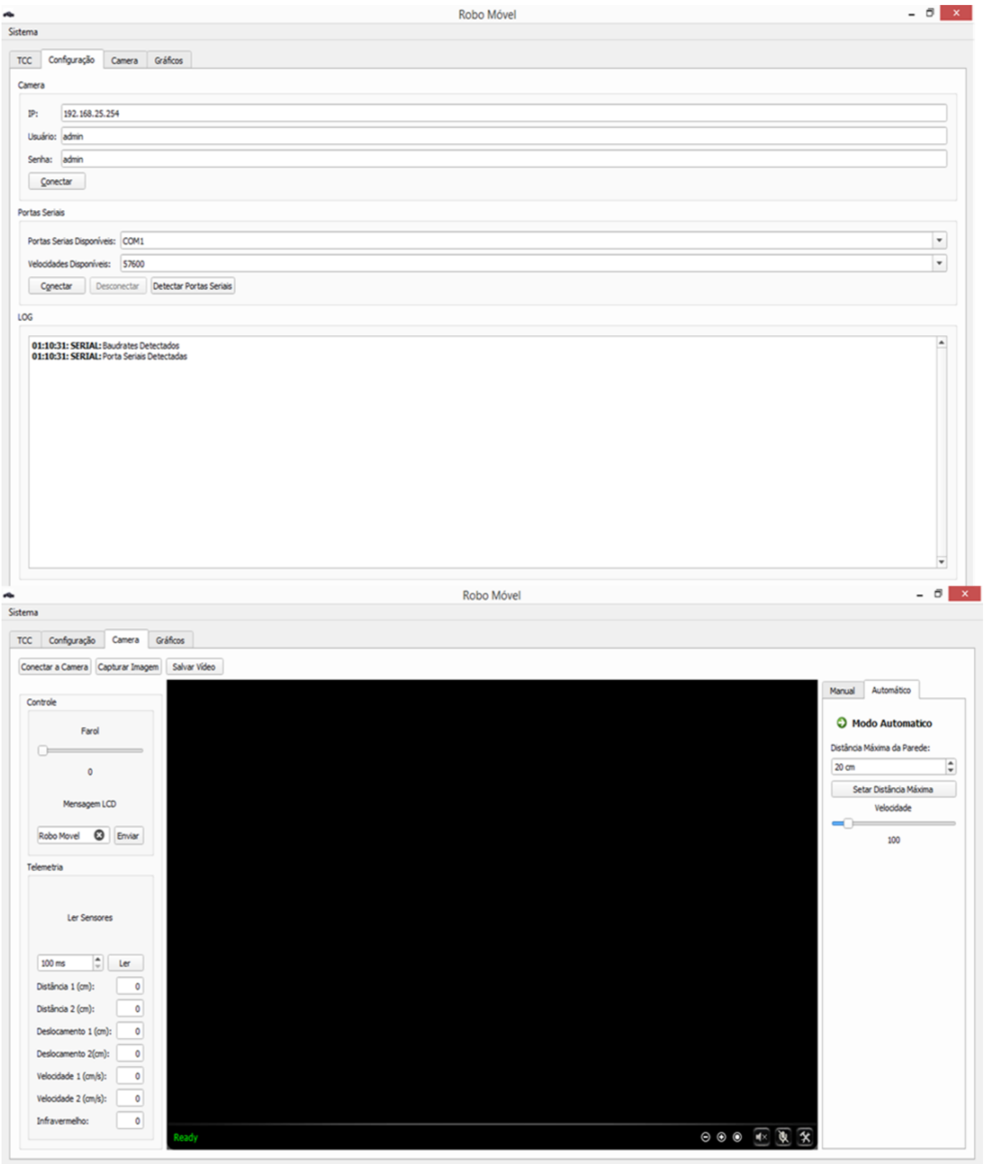

Fig. 6. The layout of the supervisory software (Prepared by the author).

4. Applications of the Prototype

4.1 Computational Results

The results were obtained initially from tests performed with the sensors, in stages in which the function of each sensor was performed in isolation. After checking the functioning of the sensors in the robot, a new library was implemented in C so that they functioned properly, according to the need of navigation in an internal environment.

Furthermore, the ultrasonic sensors HC-SR04 could be read successfully, so that they worked side-by-side without interference. During the tests, it was realized that the ultrasonic sensors in parallel must have a gap of at least 2 ms between the end of the reading of one and the beginning of the reading of the other. If there is no such interval between readings, some interference occurs between them, generating inconsistent readings. Moreover, Fig 7 shows the graph of the robot performing the correction about the reference defined in the tests as 20cm and 30cm demonstrating the effectiveness of the controller.

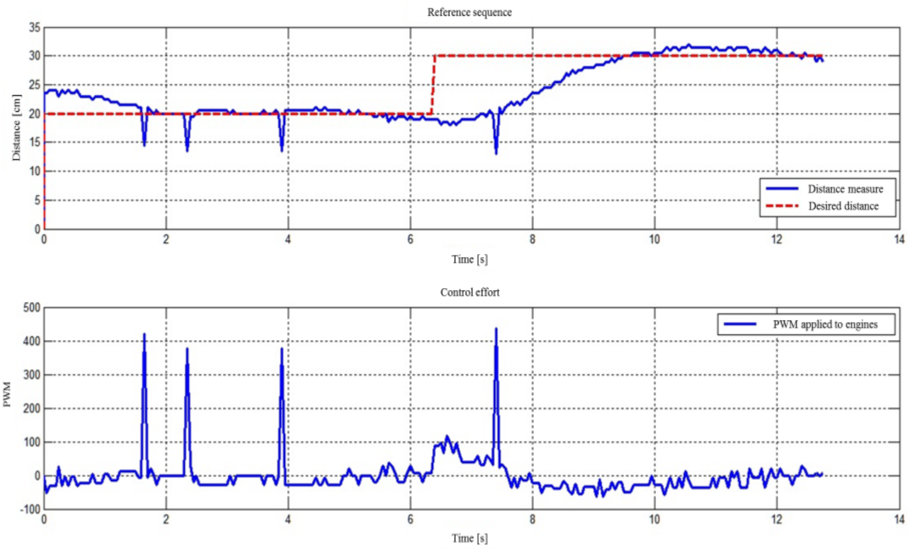

Fig. 7. Graph performed control test (Prepared by the author).

By applying the encoders coupled to the driven engines of the rover platform 5, it was possible to carry out the readings successfully. With them, it was possible to measure both the displacement and the speed of the vehicle. Using the Bluetooth module, it was possible to establish a connection between the robot and software in the computer, through which it was possible to send commands and receive measurements of the sensors.

The developed software worked expectedly, being able to view the images and videos online, provided by the camera and control the robot manually, and thus help in the surveillance and monitoring of internal environments.

The IP camera works satisfactorily by being able to transmit and capture images online through software created exclusively for this project [6]. Fig 8 shows the operation of the camera.

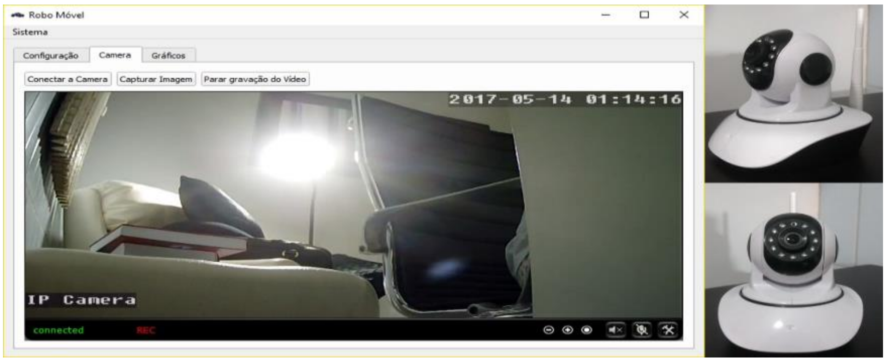

Fig. 8. Functioning of the camera (Prepared by the author).

After all the tests it was possible to develop the printed circuit board to improve the structure and organize the positioning of the components, to improve the structure of the robot and adjust the positioning of the camera.

4 Conclusion and Future Works

The mobile robot development project has brought results that can corroborate with the effectiveness of its operation in applications with a robust and straightforward platform, where it can be modified for a future need, easily navigates indoors with a programming accessible by allowing an adaptation in its implementation, such as the exchange of sensors by other desired ones [1].

The derivative integrative proportional controller in the internal environment was able to maintain the robot at the desired distance of 10cm, by following the wall to the right, effectively responding to abrupt changes in the trajectory as curves that allow traversing the entire perimeter the environment.

For future work, it is believed that it is possible to perfect the controller by making the data processing remotely and include other sensors, increasing the accuracy of the robot. Real-time mapping can also be implemented to obtain two-dimensional maps and location with the printing of navigation data as coordinates and can use the robot even in outdoor environments.

Infrared sensors positioned below the robot can be implemented with the objective of detecting possible steps, avoiding falls and, consequently, damage to the robot. It is also possible to have logic for using a rechargeable base where the robot is detecting a certain percentage of the battery seeing the need to recharge it would return to its initial position.

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1 References

1. A. Aouf, L. Boussaid and A. Sakly, “A PSO algorithm applied to a PID controller for motion mobile robot in a complex dynamic environment," International Conference on Engineering & MIS (ICEMIS), Monastir, 2017, pp. 1-7.
2. Arshad, S. Badshah and P. K. Soori, "Design and fabrication of smart robots," 5th International Conference on Electronic Devices, Systems and Applications (ICEDSA), Ras Al Khaimah, 2016, pp. 1-4.
3. Goel, J. Bhattacharya and Anika, "Robot relay: An optimal path planning for multiple client services," International Conference on Inventive Computation Technologies (ICICT), Coimbatore, 2016, pp. 1-6.
4. ÂSTRÖM, Karl Johan; HAGGLUND, Tore. PID Controllers: Theory, Design, and Tuning. 2. ed. United States of America: Copyright, 1995. 343 p.
5.] K. Al-Mutib, F. Abdessemed, M. Faisal, H. Ramdane, M. Alsulaiman and M. Bencherif, "Obstacle avoidance using wall-following strategy for indoor mobile robots," 2nd IEEE International Symposium on Robotics and Manufacturing Automation (ROMA), Ipoh, 2016, pp. 1-6.
6. K. Loukil, M. Khalfa, M. Wassim Jmal, T. Frikha and M. Abid, "Design and test of smart IP-camera within the reconfigurable platform,” 2nd International Conference on Anti-Cyber Crimes (ICACC), Abha, 2017, pp. 25-29.
7. Ogata, K. Modern Control Engineering, 5. ed., Pearson/ Prentice Hall, 2010.
8. Pinheiro, Plácido Rogerio; Neto, Álvaro Meneses Sobreira; Aguiar, Alexei Barbosa; Pinheiro, Pedro Gabriel Caliope Dantas. A Novel Hybrid Methodology Applied Optimization Energy Consumption in Homogeneous Wireless Sensor Networks. Wireless Sensor Networks - Insights and Innovations. 1ed.: IntechOpen, 2017.
9. S. Purbaya, E. Ariyanto, D. W. Sudiharto and C. W. Wijiutomo, "Improved image quality on surveillance embedded IP camera by reducing noises," 3rd International Conference on Science in Information Technology (ICSITech), Bandung, 2017, pp. 156-159.
10. SIEGWART, Roland; NOURBAKHSH, Illah R. Introduction to autonomous mobile robots. Massachusetts: Massachusetts Institute of Technology, 2004. 336 p. Available in: <http://home.deib.polimi.it/gini/robot/docs/siegwart.pdf>. Acesso em: 05 mar. 2017.
11. SK, Lakshmanaprabu; k, Shankar; Khanna, Ashish; Gupta, Deepak; Rodrigues, Joel J. P. C.; Pinheiro, Placido R.; de Albuquerque, Victor Hugo C. Effective Features to Classify Big Data using Social Internet of Things. IEEE Access, v. 1, p. 1-1, 2018.
12. T. Bin Mohamed et al., "Development of mobile robot drive system using mecanum wheels," International Conference on Advances in Electrical, Electronic and Systems Engineering (ICAEES), Putrajaya, 2016, pp. 582-585.