RESEARCH REGARDING THE DESIGN AND DEVELOPMENT OF A LINE FOLLOWER ROBOT IN THE MEDICAL INDUSTY

IONESCU Raluca, DUGĂEȘESCU Ileana, ULMEANU Mihaela

Faculty of Industrial Engineering and Robotics, Study program: Industrial Engineering,
Year of study: 2, e-mail: raluca.ionescu98@gmail.com

ABSTRACT: The aim of this paper is to research the possibility of designing and developing an automated method for the transportation tasks performed inside a hospital. The proposed solution is a line follower robot that can track a black line drawn on a white surface. This paper is composed of two main parts. The initial section of the paper describes the advancements achieved concerning the product's mechanical component, detailing the design process of these parts and the utilization of 3D printing technology for their production. The second part of the paper delves into the creation and evaluation of an experimental model for the electrical aspect of the circuit. It elucidates the assembly procedure for the electrical components and delineates the operational principle of the robot.

KEY WORDS: line follower robot, medical industry, transportation

1. Introduction

This paper focuses on the impact that the evolution of robotics had on the medical field because of the high importance that medicine has in our lives. Although there are complex robots that are already used by medics and surgeons, the current paper analyzes the possibility to implement a cheaper technology to help especially the nurses in the hospital: a solution for the transportation tasks performed inside a hospital (such as transporting food and medicine). Considering this as the main objective, the proposed solution entails the design and development of a line follower robot.

A line follower robot is an automated guided vehicle, a programmable mobile vehicle that can follow a line drawn on a surface. It can be a black line on a white surface or a white line on a black surface – the main idea is to be a high contrast. This type of robot can also use an invisible magnetic line [1]. The robot follows the pre-defined lane by using a feedback mechanism [2].

This type of robot is useful for transportation tasks, especially for transporting heavy weights from one certain point to another. The line follower robot has multiple applications, in areas such as industry – replacing conveyer belts, automobile – the robot can be used as an automatic car, domestic – for example floor cleaning or guidance – in public places such as museums or malls [3].

By using this type of robot for transportation tasks, the medical personnel can better focus on the urgent needs of the patients and on providing better healthcare for them. Also, due to the pandemic situation, the medical department faced a lot of changes and difficulties. By using robots, human interactions will be limited, so there will be less chance of spreading the virus from an infected patient to a member of the hospital staff.

Keeping this in mind, the next part of this paper will be centered on describing the progress that was made regarding designing and developing the solution proposed.

2. Current stage

Other studies have considered introducing line follower robots in the medical sector. For example, one research [4] analyzed the possibility of transferring the patients from the ambulance to the hospital room by using a line follower robot. This concept represents a solution for the need to limit the human interactions in the pandemic scenario and to properly manage the high number of incoming patients considering the reduced number of medical personnel. The prototype uses an Arduino board, DK Electronics, a Bluetooth chip and IR sensors and Arduino language was used to write the code. One of the problems of the prototype was that it didn't stop if there were obstacles on the path. The authors decided to program the robot in a way that allows them to stop its automatic movement and move it manually if there is any obstacle on the path.

Another study [5] states that there are a high number of patients who die because of the low number of trained medical personnel. That's why the authors suggest designing and manufacturing a line follower robot for a better health care management system. This robot has the following components: a LDR sensor for sensing the path, an IR proximity sensor to stop the robot in case any obstacles appear on the path, a comparator, a motor driver, actuator, and a microcontroller. The main advantages offered by this solution are lower medical costs for the patients, less work for the reduced number of nurses and better monitoring of the patients.

3. Development of the prototype

3.1. The mechanical component

The hardware part of the product has two main functions, first to be able to sustain and transport the supplies and second to support the electrical components of the assembly. To create the mechanical subassembly, the components presented in Table 1 were designed. These will be manufactured by using additive manufacturing technologies.

Table 1. Components of the assembly

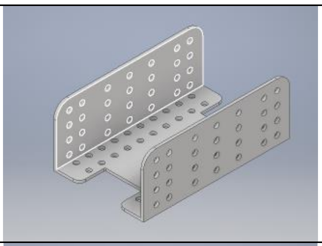
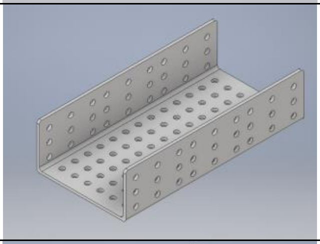
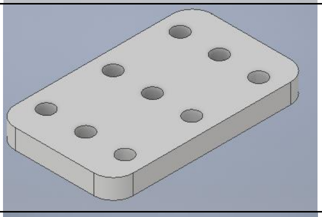
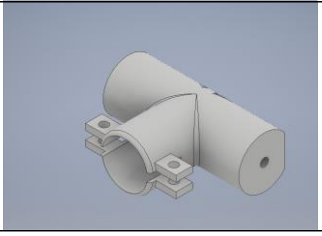
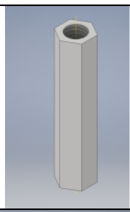
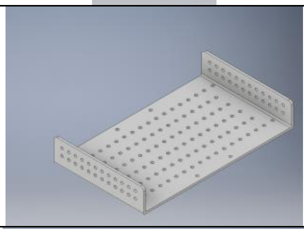
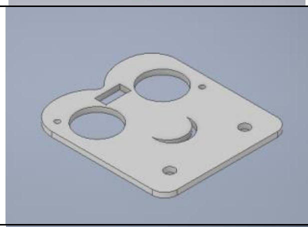
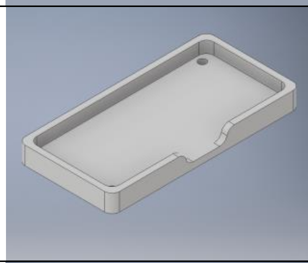
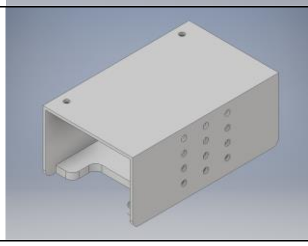
Number	Name of the component	Image of the component	Quantity in the assembly	Material
1	Case 1		1	Z-hips material
2	Case 2		1	Z-hips material
3	Spacer		2	Z-hips material
4	Motor support		2	Z-hips material

Table 1. Components of the assembly (continuation)

Number	Name of the component	Image of the component	Quantity in the assembly	Material
5	Pin		8	Z-hips material
6	Upper part		1	Z-hips material
7	Distance sensor support - front		1	Z-hips material
8	Distance sensor support – back		1	Z-hips material
9	Wheel support		1	Z-hips material

The final 3D design is presented in fig. 1.

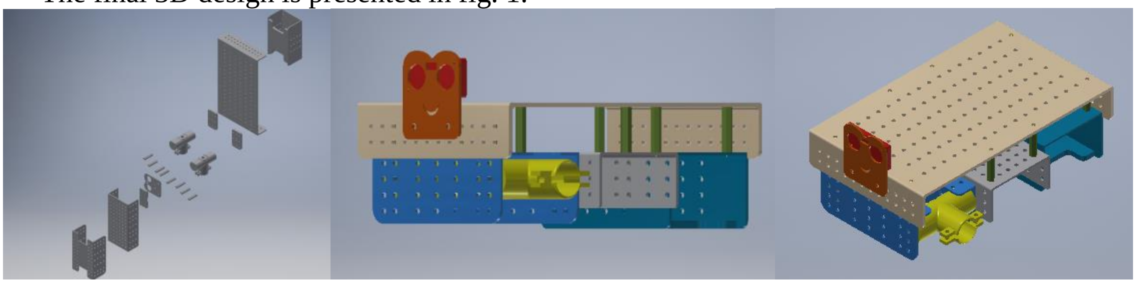


Fig. 1. Mechanical components of the robot

At this stage, the assembly contains only the parts that will be manufactured by 3D printing. To fix the parts, screws and nuts (M4) will be used. Those were not included in this stage of the 3D design.

To manufacture the parts Fused Deposition Modelling (FDM) technology was used. The machine used is Zortrax M300+ [10]. Some of the components required support structures to be printed correctly while others could be printed without those structures. Considering this, the parts were grouped into two printers and the parameters were set accordingly (fig. 2 A, fig.2 B.).

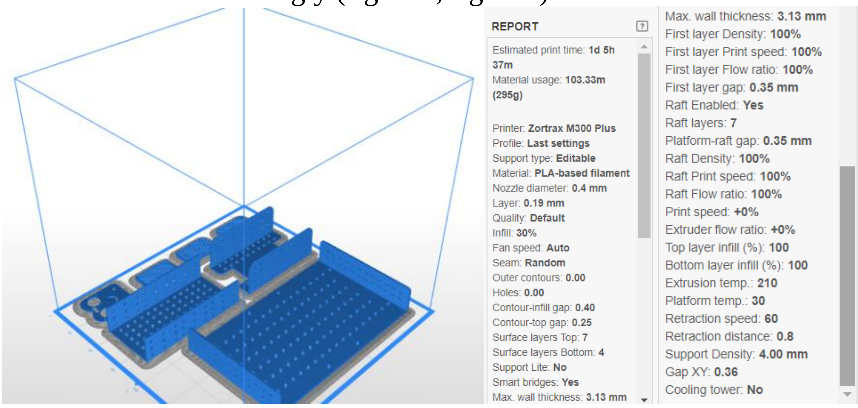


Fig. 2. A. First printer – without support structures

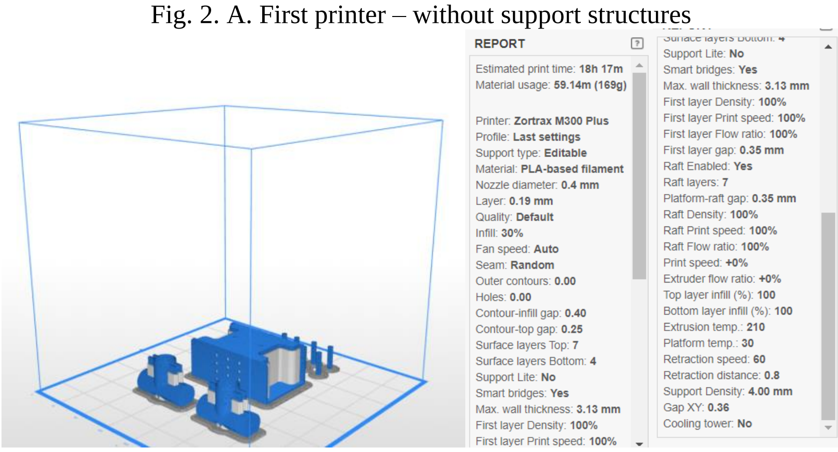


Fig. 2. B. Second printer – with support structures

The results of the printing simulation regarding the printing time, the material used, and the cost of the material are presented in Table 2.

Table 2. Results of the printing simulation

	First printer	Second printer
Estimated print time	29 hours 37 minutes	18 hours 17 minutes
Material usage	295 g / 37 m	169 g / 59.14 m
Material cost	21 euro (105 lei)	12 euro (60 lei)

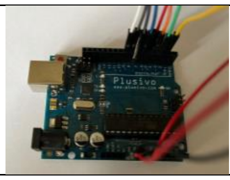
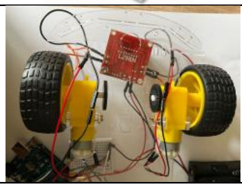
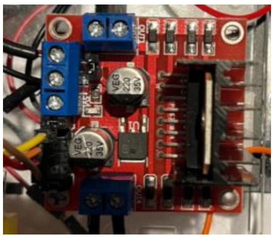
The 3D printed parts are presented in Figure 3.

Fig. 3. 3D printed components

3.2. The electrical component

The list of the components used to manufacture the experimental model described in Table 3.

Table 3. Description of the electrical components

Index	Name of the component	Image of the component	Number of components used in the circuit	Description of the components and its connections
1	Arduino board		1	This is a microcontroller board [7]. The rest of the components will be connected to its digital/ analogic pins.
2	Breadboard		1	A breadboard was used so that all the connections could be made. A mini version was chosen so that all the components can fit on the chassis.
3	DC motor		2	Each DC motor has two pins that will be connected to the motor driver's outputs [11].
4	Motor driver L298N		1	This motor driver has 4 outputs, to which the two motors will be connected. Also, it has 4 input pins that will be connected to digital pins of the Arduino board. Besides that, to control the speed of the motors, the two enable pins were connected to PMW pins of the Arduino board. Additionally, the motor driver needs to be connected to GND and to power supply [11].
5	Ultrasonic sensor HC-SR04		1	The ultrasonic sensor has four pins – one pin that must be connected to 5V, one trig pin, one echo pin and one pin that must be connected to GND. The trig and echo pins are connected to digital pins of the Arduino board [7].
6	Infra-Red (IR) sensor		2	The IR sensor has 3 pins – one is connected to GND, one is connected to 5V, and the third one is connected to a digital pin of the Arduino board [12].
7	Battery		4	Four batteries of 1.5V each were used to ensure the power supply for the two motors. The battery support is connected to the motor driver.

After establishing all the components that must be used, a connection diagram was created (Figure 4).

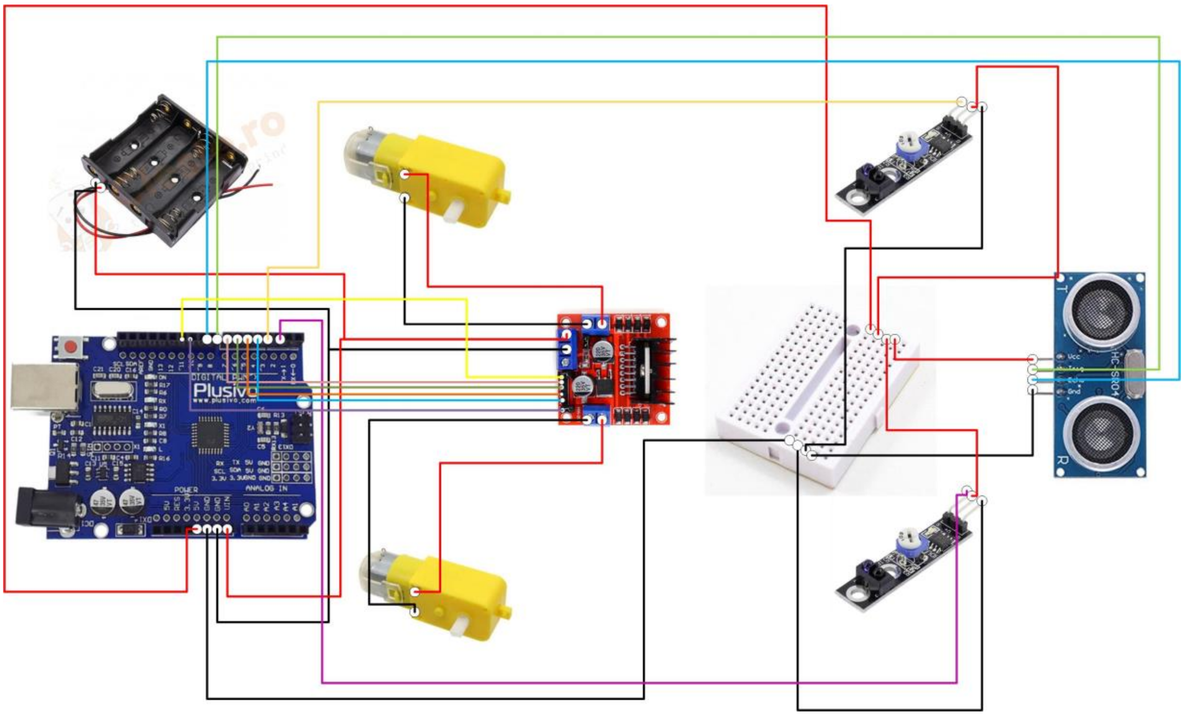


Fig. 4. Connection diagram of the electrical components

The robot will work by the following working principle: the IR sensors are assembled on the chassis so that they can detect the black line. Depending on the values received from the IR sensors, the motors rotate or stop. The ultrasonic sensor is used to detect the possible obstacles that might appear on the line. If there is any obstacle closer than 20 cm, the line follower will stop.

To test the code, the experimental model presented in figure 5 was developed.

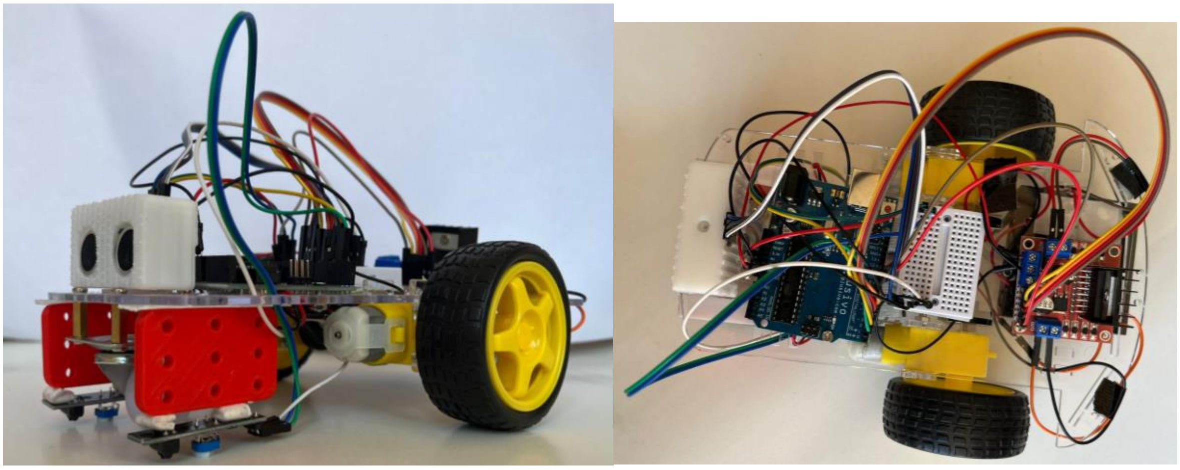


Fig. 5. Experimental model

This is an experimental model designed just for testing the prototype. This setup helped in better understanding the working mode and the correct placement of each component on the chassis. This might generate some design modifications on the mechanical component of the product.

The code used for the robot is composed of three main parts [9]:

1 – in this part of the code all the connection of all the components to the board's pins were declared. The connection diagram presented in Figure 4 was respected. The IR sensors are connected to digital pins 2 and 3. The trig pin of the ultrasonic sensor is connected to pin 8 while the echo pin is connected to pin 9. The two motors are connected to the motor driver, that is connected to the Arduino board. For the left motor, pins 4 and 5 were used and for the right motor pins 6 and 7 were used. The enablers of the motor driver are connected to pins 10 and 11. Besides that, two constants were also declared: "duration" and "distance", used to store values received from the ultrasonic sensor.

2 – in this part of the code the data type of each component was declared. The IR sensors and the echo pin of the ultrasonic sensor are inputs, while the motors and the trig pin of the ultrasonic sensor are outputs. The input components read information and send it to the controlling board. It processes it and, depending on the information received, it sends certain "instructions" to the output components.

3 – first, the ultrasonic sensor was initialized. Its echo pin is an emitter. It sends an ultrasonic pulse and if there is any obstacle it reflects to the sensor, to the receiver trig pin. The travel time must be calculated to determine the distance to the obstacle. After that, the value read by each IR sensor must be known. To do that, the "digitalRead" function was used [9]. The speed of the motors was set by using "analogWrite" function [9]. The two enable pins of the H bridge were connected to PMW (Pulse Width Modulation) pins of the Arduino board. Those type of pins allow us to adjust the average value of the voltage that is reaching the motors. In the next part of this section, the "if" function was used to control the DC motors depending on the information received from the IR and ultrasonic sensors. The working conditions are summarized in Figure 6.

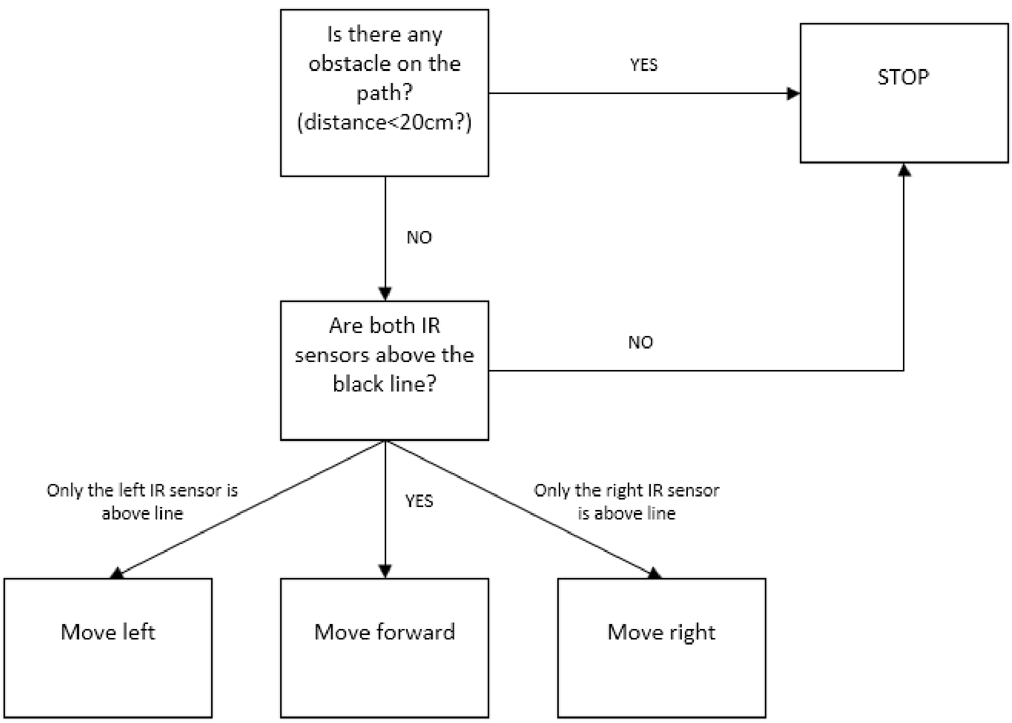


Fig. 6. The working conditions of the robot

To control the spinning directions of the motors the HIGH or LOW logic was applied, according to the information received from the IR sensors.

This logic is presented in Table 4.

Table 4. HIGH/LOW logic used to control spinning direction

Input 1	Input 2	Spinning Direction
Low	Low	Motor OFF (stop)
High	Low	Move forward
Low	High	Move backward
High	High	Motor OFF (stop)

4. Conclusion and future research directions

In conclusion, this research represents a first step in developing the solution proposed. The most notable improvements made are:

- Designing and manufacturing a first concept of the mechanical component of the product.
- Choosing the electrical components and creating a connection diagram and a working principle.
- Connecting all the components according to the connection diagram and writing the code according to the working principle of the robot.
- Testing the experimental model.

However, there are still aspects that need to be improved. Regarding this aspect, the future research directions that will be considered are:

- Adapting the code, so that the robot will be able to come back to the starting point of the path and to avoid the obstacles.
- Optimize the mechanical design of the robot so that all the components can properly fit on the chassis and create a special compartment for the medication that needs to be transported to the patient.

5. Bibliography

[1] – Anusha (2017), "How to make Arduino line follower robot", https://www.electronicshub.org/arduino-line-follower-robot/ ; Last accessed: 07.01.2022

[2] – Das, S. K. (2016). Design and methodology of line follower automated guided vehicle-a review. International Journal of Science Technology & Engineering, 2, 9-13.

[3] - "Line Follower Robots – Controlling, Working Principle and Applications" article, https://www.elprocus.com/line-follower-robot-basics-controlling/ ; Last accessed: 07.01.2022

[4] - Hadi H. A., "Line Follower Robot Arduino (using robot to control Patient bed who was infected with Covid-19 Virus)," 2020 4th International Symposium on Multidisciplinary Studies and Innovative Technologies (ISMSIT), 2020, pp. 1-3, doi: 10.1109/ISMSIT50672.2020.9254906.

[5] - Punetha, Deepak & Kumar, Neeraj & Mehta, Vartika. (2013). Development and Applications of Line Following Robot Based Health Care Management System. International Journal of Advanced Research in Computer Engineering & Technology (IJARCET_. 2. 2446-2450.

[7] – Dugaesescu Ileana, Mechatronics and robotics course

[8] – Ulmeanu Mihaela, Additive Manufacturing course

[9] – Ardunio software

[10] – Zsuite software

[11] – L298N H-bridge datasheet, http://www.handsontec.com/dataspecs/L298N%20Motor%20Driver.pdf , last accessed 18/05/2023

[12] – "IR Sensor Module | How IR Sensor Module Works", https://www.electroduino.com/what-is-ir-sensor-module-how-ir-sensor-module-works/ , last accessed 18/05/2023