Mecanum Wheel Robotic Platform for Educational Purposes: A Cost-Effective Approach

Emanuel Viana
ISEP & SYSTEC - DIGI2
Polytechnic Institute of Porto
Research Center for Systems and Technologies
Digital and Intelligent Industry Lab
4200-465 Porto, Portugal
e.t.viana2000@gmail.com

Vítor H. Pinto
FEUP & SYSTEC - DIGI2
University of Porto
Research Center for Systems and Technologies
Digital and Intelligent Industry Lab
4200-465 Porto, Portugal
vitorpinto@fe.up.pt

José Lima
CeDRI & IPB
Research Centre in Digitalization and Intelligent Robotics
Instituto Politécnico de Bragança
5300-253 Bragança, Portugal
jllima@ipb.pt

Gil Gonçalves
FEUP & SYSTEC - DIGI2
University of Porto
Research Center for Systems and Technologies
Digital and Intelligent Industry Lab
4200-465 Porto, Portugal
gil@fe.up.pt

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***Abstract*—This paper presents a cost-effective approach of a mecanum wheel robotic platform for educational propose on the development of an autonomous or remote controlled mobile robot with a four-wheel mecanum drive train. The main structure of the mobile robot was developed in Solidworks and it was built using additive manufacturing to validate in a real scenario. The main objective of developing this type of mobile platform was the ability to transport different types of cargo or robotic arm on industrial spaces or on rough terrain, since the implemented suspension mechanism allows the wheels contact to the floor. Another important objective is the maneuverability and the capacity to be guided in various environments, a great advantage in this type of mobile platform. An additional advantage of the developed mobile robot is the easy way to reconfigure the structure for new acquired parts.**

***Index Terms*—mecanum wheel robot, AWD robot, education, STEM, mechatronics**

I. Introduction

Nowadays, technology is more associated with education. In a world where everyone has technology in their daily life, it's impossible to think about living without technology and also robots. On the one hand, there is a lot of robots that can be purchased on market with the simple goal of automate more and more the daily tasks and, on another hand its possible to associate a robot to the educational field and deepen the knowledge about this area.

Using robotics to learn more about electrical and computer components is one of the most interactive methods to teach a great group of students of all ages, making the encounter with robots a means of education about specific components and all the associated mechanics. Therefore, it is possible to take the world of robotics closer to the community, creating new ideas such as locomotion systems for autonomously guided robots, data acquisition through sensors or cameras, localization and sending/receiving information, among others. The main goal of this paper is to present the development of a Mecanum Wheel Robotic Platform (MWRP) for academic use and cost-effective integration in other projects of the same scope, as example robotics competitions.

This article is structured as follows: After a brief introduction, section 2 starts by addressing the existent literature of this type of applications and describes the theoretical concepts adopted in the application, detailing about orientation representations of mecanum wheel and robotics. Section 3 presents the prototype design, explaining how the theoretical concepts were implemented and adapted. In Section 4, the visualization is conceptualized to interpret the glove data. The paper ends with the conclusions and proposes improvements to future work.

II. Literature Review

Robotic competitions are an excellent way to promote an innovative and entrepreneurial spirit through active teaching methods. They also allow the acquisition of transversal skills, promoting this area to the public. The Robot at Factory proposal simulates an Industry warehouse scenario, applying education through STEM (Science, technology, engineering, and mathematics) methodology. STEM education is a popular pedagogical approach for enhancing the creativity of the students, problem-solving skills increasing the interest in these areas [1]. Since robotics address multidisciplinary areas, it plays an important role in the STEM concept and it can be used from Schools to Universities to teach several areas [2]. The participants have to work on a solution to overcome its challenges and competitions, such as Robot at Factory Lite, are a starting point for school or university students to start to awaken their interest in robotics and take the first steps towards the job market [3], [4].

Simulation also plays an important topic for robotics teaching [5]. There are several robotic simulation environments that can be used by students to develop and test their skills [6]. The Robot at Factory competition also have previous publications that addresses the rules, its description and simulation environment with hardware-in-the-loop, such as [7], [8] and [9].

On the education point of view, several authors uses robotics as a teaching aid for the most different topics such as Electronics, Control Systems, mechatronics, sensors and actuators, prototyping, among the others [10], [11], [4]. Robotics can also be used as an inspiration in engineering Curriculum Design and Educational Assessment [12] and impact [13].

Competition promotes an evolutionary factor and is used in the nature and humanity, on the most different areas, as examples: Biology, Education, Economics, Politics and Sports [14]. On the robotics area, competition brings to students and researchers a way to evolution, as it can be stated in [15]. There are a large number of robotic competitions around the world. One of the most well-known in the competition is the RoboCup, where the ultimate goal is, by the mid 21st century, a team of fully autonomous humanoid robot soccer players shall win a soccer game, comply with the official rule of the FIFA, against the winner of the most recent World Cup [16]. Robotics on education and on competitions are acting, side-by-side, to accomplish this goal [3], [17] and [18] .

III. Prototype

The development of the project was subdivided into several stages, such as:

1) Development of the mechanical parts(Computer Aided Design (CAD));
2) Printing of the elaborated parts on the 3D printer;
3) Choice of hardware;
4) Assembly test.

One of the main goals of this project is to obtain an Omnidirectional robot, also known as omni wheels on MWRP with an operational suspension. A vehicle with the power of the mechanum omni wheel alone is already an excellent technology, which allows a huge freedom of movement and an incredible adaptation to the environment that surrounds it. Adding a suspension to this technology allows reaching a new level in the field locomotion requirement. The mechanical structure of the MWRP was developed from the scratch, taking into account the established goals. For the locomotion of the robot it was necessary to evaluate the weight and its structural strength because any of these variables physically affects its locomotion power and transport capacity or hardware.

It is important to take the measurements of the mechanical components and traction power that have been acquired and adapt to the base of the chassis with these measurements. To implement this task, it is possible to make a first attempt of tuning the set of all components in the prototype. The creation of the prototype is a help during the development of the project to understand if it is necessary to convert the developed parts in CAD to real scenario. So, it is necessary to use a 3D printer, after adjusting these parts, to implement the next phase of the robot's development. In the third phase we have the choice of hardware. This must be chosen in order to meet the minimum requirements of the chosen motor driver, after making the choices and assembling everything on the developed platform it is possible to move on to the testing phase.

Before moving on into the testing phase, it is necessary to evaluate all the different functions that the robot will handle, create a prototype, and adapt each part appropriately for its purpose. All structural components of robot was develop in Solidworks. The main base is quite important, therefore it is responsible for supporting all the electro-technical aspects, suspension and motor parts. The base dimension/scale was obtained by evaluating the size of the main components that are required to enable the robot to drive. On the other hand it is easy printing on a 3D printer.

The structure of the base was adapted throughout the project, in order to obtain the maximum performance possible for the characteristics of the chosen hardware. The used version went through some field tests to validate. These tests allowed to make the necessary changes to obtain a good suspension performance and to realize that it is possible to have a specific control on each wheel, using 4 motors instead of 2 motors with transmission shafts.

From the tests carried out, the decision was made to have a direct connection between the motor and the wheel. By this way, it is possible to avoid losses and obtain a better efficiency and effectiveness of the motor. The use of a motor with direct connection to each wheel, makes the use of a common suspension impractical, being necessary to make adaptations for the support of the motor in the suspension arm. There are many variables to analyze after this decision. One of them with high importance is the size of the motor for the design of the whole robot axle.

A. Prototype Design

There are already several types of suspension developed in the mechanical researching, always keeping the basic principle: to obtain a set of components able to act in real time allowing the free movement of the wheel on the Z axis that is aggregated to the main chassis and always maintain wheel contact with the ground. Using the suspension structures of cars, a suspension arm was created with four components: an engine mount, a lower suspension arm, and two upper suspension arms. This method is the most capable of supporting the direct connection of the engine to the wheel without affecting the performance of the engine.

In the first design of the suspension arm for the robot is shown, initially it seemed to be the quite capable model, but with some test it is possible to realize the limitation of the shock absorber stroke and some structure fragility at the level of the motor support.

Each motor has a pair of shock absorbers, as shown in Figure 1. Each suspension arm work independently and have the ability to take more load than with just a shock absorber and the robot to always maintain wheel contact with the ground. Each suspension arm is designed to achieve greater spring force and a more stable travel. The entire suspension system is composed of several parts that can have adjustable presets. This makes it easier to adapt parts for a new component, such as shock absorbers with longer travel and to handle a heavier load.

To obtain the presets of the current suspension system it was necessary to go through several tests and calculations. To find out the shock absorber's stroke, we must take into account that the shock absorbers should always work at their sub-maximum to obtain a greater response capacity. With this method it is possible to have an acceptable performance with any type of engine.

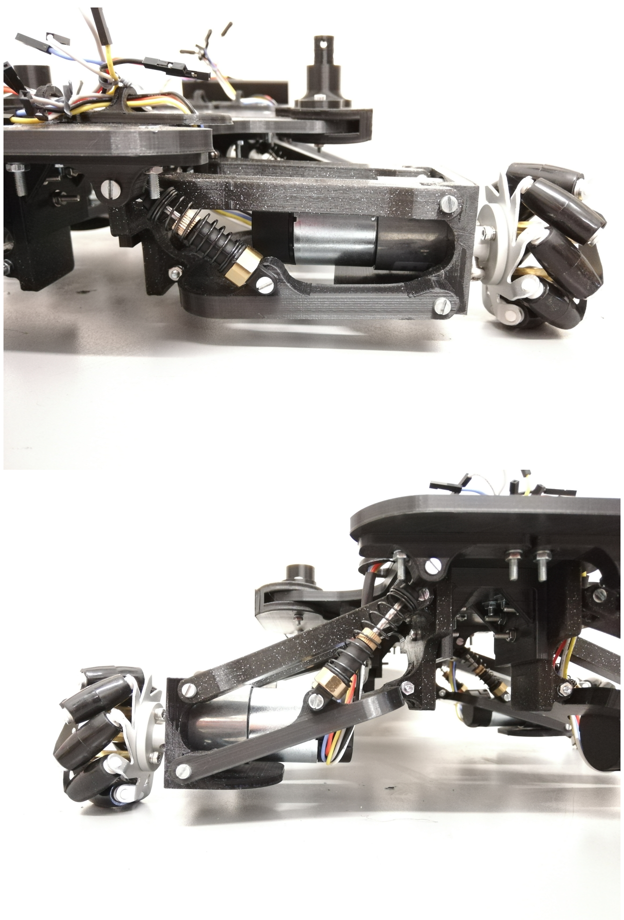

Fig. 1. Final prototype of the suspension arm and its stroke.

Regarding the transmission system, in the initial phase of the project several hypotheses were placed on how it would be possible to make the power transmission to the wheels work. The first major question was the use of a driveshaft/differential or direct application. The use of a differential or transmission system makes a big difference in the robot's behavior. The existence of such a system allows controlling the traction of the vehicle on 2 wheels at the same time making the variation between 4x2 or 4x4. By this way it is not possible to control the robot with total freedom of movement and we would have another associated problem as loss of efficiency through the transmission.

Considering all the advantages and disadvantages of each model, the direct application of the motor power to the wheel was the one that fits perfectly in this project, Figure 1. With this type of ”transmission” it is possible to obtain independent control at each wheel, better performance and a higher cost benefit.

The mecanum wheels are another essential part of the robot, as we have fixed axles it is necessary to have another method for the vehicle to move in various directions without having a standard steering system. The system used in the project is the omnidirectional mecanum system, like the one presented by Crenganis *et al.* [19]. The first version of the base, was developed thinking in the resistance and in the assembly of all the essential components for the locomotion of the robot. The base was left with enough area and some bending points, creating a set of reinforcement pieces on the sides. It no longer presented bending points, however the suspension lost performance. To correct this problem it was necessary to make some small adjustments to the base and reduce its area. With these changes we obtained the second version of the base and reach a reasonable performance since it was considered a reasonable performance when the shock absorber has no resistance moving before a great force. As mentioned before, the resistance that the material offers up to the breaking point is very important and became more important at the moment of 3D printing. For the structure to have some resistance it was necessary to tune the filling of the base and its reinforcement parts, as well as the thickness of the base. This same process was done for all the parts that were developed for the robot.

IV. Implementation and Results

In this robot we used an ESP 32 with 32 GPIO and Pololu MAX14870 motor drivers. These associated components, the two batteries and the four motors are the main responsible for the Bluetooth control of the robot. The choice of the ESP 32 was very important, being possible to get a very high degree of channel configuration and already have the Bluetooth or Wi-Fi communication component. When it comes to choosing the motor drivers must be taken into consideration the type of motor which will be used. The proper choice of a driver is very important because this is the bridge between the communication from the ESP 32 to the power transmitted to the wheels. For this prototype it was chosen the DC 6/12V motor with built-in 210:1 gearbox, from DC Gearmotor SKU: CQR37D and also contains a 64 counts per revolution (CPR) encoder when using both encoders for readout.

Making use of the traction system idea of the All Wheel Drive (AWD) system, this system uses two differentials to have the desired power at the wheels. At MWRP we do not make use of a power transmission system through differentials to keep the efficiency as high as possible. It was necessary to find other means to have traction on all wheels, so motors connected directly to each wheel were positioned. By this way we were able to imitate an AWD system with the advantage of not introducing losses in the performance of each motor.

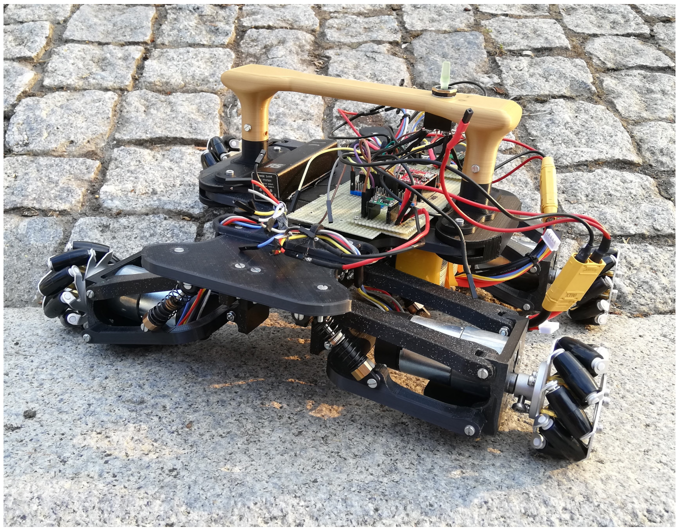

Fig. 2. First prototype of Mecanum Wheel Robotic Platform

As a result, the robot's traction system with suspension, as presented in Figure 2, has obtained a reasonable performance in outdoor environments, considering uneven terrains with bricks and steps with heights up to 3 cm. The suspension have substantially upgraded on always keeping the wheels in contact with the ground. However, there is still room for improvement in terms of locomotion since the use of wheels with a larger diameter allows the robot to have more locomotion power in terrain with higher relief and unevenness.

After obtaining the printed suspension part, there were several stages of adjustments and improvements. These improvements were in terms of structural strength and adjustments with other parts of the suspension structure. These adjustments are very important for the overall performance of the robot, as well as the suspension. The adjustments must be tuned for each type of structure and components chosen, in this case it was necessary to make the adjustments of the suspension for the stroke that the chosen shock absorber has, the adjustments in this steal can be made with the modification of the lower structure of the suspension arm or in the attachment part of the shock absorber with the base, which is presented in Figure 3.

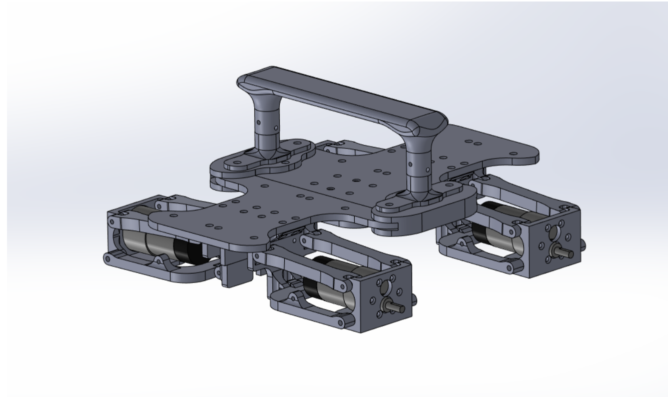

Fig. 3. Solidworks structure of Mecanum Wheel Robotic Platform

The Table I presents the list of essential materials for the development of the project, with the respective acquisition values.

TABLE I
PROJECT MATERIAL

Material List		
Name	**Qtd**	**Unit Price**
Mecanum Wheels 65mm	4	8,90 €
ESP-WROOM-32-Breakout - ESP32 WiFi+Bluetooth	1	19,50 €
ZIPPY Compact 4500mAh 4S 35C Lipo Pack	2	44,65 €
210:1 Metal DC Geared-Down Motor 37Dx65L mm 6V or 12V, with 64 CPR Encoder	4	22,49 €
MAX14870 Single Brushed DC Motor Driver Carrier	4	15,27 €
PLA Basic (color black)	1	17,35 €
Shock Absorbers	8	22,95€
Other's (Bolt's, nut's, cable, welding wire,etc)	-	30,00 €
Total	434,59€	

V. Conclusion and Future Work

This paper presented the developments and assembly of a Mecanum Wheel Robotic Platform with suspension that can be used for educational purposes. The developed prototype was validated in a real environment with rough floor and the mechanical structure with the suspension system showed that the robot keep traction and didn't slippage. The cost-effective approach allows that this prototype can be replicated and used by students educational purposes, with the base of this robot it is possible to introduce in the educational area in different ways and for all educational levels from elementary school to university education. As future work, it will be implemented a speed controller for the motors and the include a localization system. Then, an integration of a robotic arm will allow to have a mobile manipulator to perform tasks such as pick and place.

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