INSTITUTO POLITÉCNICO DE BRAGANÇA
Escola Superior de Tecnologia e Gestão

MECHANICAL DESIGN OF A FOUR WHEEL OMNI DIRECTIONAL MOBILE ROBOT

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Dedication

It is with great pleasure that I dedicate this modest work to my dearest parents and sisters,

Your love, the values transmitted, your support in the most difficult moments and your constant attention for your children. I boast, every day since the beginning of my life, even without words, of the pride I take in being your child. No matter what happens, making you proud is also one of my goals.

To the whole Industrial engineering family,

Our paths crossed for the first time when we entered the IPB , keeping the friendship and international relation that unites us and the memories of all the moments we spent together, nothing to say, I treasure each and every one of the moments we spent with you.

To everyone who has contributed in any way to the smooth running of my work.

Acknowledgements

I am pleased to express my sincere thanks to all the IPB team for their welcome and the trust they have placed in me.

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Our thanks also go to all the IPB staff who contributed to the smooth running of my final project. I have the honour to express my special thanks to the members of the jury for giving me the honour of judging this modest work. Finally, I would like to thank the

entire teaching team of the IPB for having ensured a good training during one year of research master in the electrical engineering department.

Abstract

Omni directional mobile robots have been popularly employed in several applications, especially in soccer player robots considered in Robocup competitions. Actually, the popular optimized robots are using three wheels in the mechanical structure. This situation brings the idea of omnidirectional robot at manufacturing. To design the omnidirectional wheels mobile robot respecting the requirement specifications of the factory lite competition, it's recommended to design and optimize the proposed solution using Solidworks tool. To design a mobile robot using four omni wheels, it's important to implement suspension system for each wheel. The suspension system will help the programmer when implementing the PID parameters and test the robot. Such a robot can respond more quickly and it would be capable of more sophisticated behaviors such as to transport materials and placed on processing machine and outgoing warehouses. This thesis has tried to focus the description of four wheel omnidirectional mobile robot to be applied to the Factory Lite competition.

Keywords:

Autonomous Guided Vehicle, Omni Robot, Encoders ,Omni wheels ,Suspension system

Resumo

Robôs móveis omnidirecionais têm sido popularmente utilizados em várias aplicações, especialmente em competições de futebol robótico, como a RoboCup.

Atualmente, os robôs otimizados mais populares utilizam três rodas na sua estrutura mecânica, o que leva à ideia de robôs omnidirecionais, aquando do fabrico. Para a conceção de robôs dotados de rodas omnidirecionais que respeitem as especificações requeridas pela competição, é recomendada a conceção e otimização da solução proposta com recurso à aplicação Solidworks. Para conceber de um robô móvel com quatro rodas omnidirecionais, é importante implementar um sistema de suspensão para cada roda. O sistema de suspensão ajudará o programador a implementar o parâmetro PID e a testar o robô. Um robô deste tipo consegue responder mais rapidamente, e seria mais apto para comportamentos sofisticados, como o transporte de materiais em máquinas de processamento e em armazéns de saída . Esta tese pretendeu focalizar-se na descrição de um robô de quatro rodas omnidirecionais, tendo em vista a competição Factory lite.

Após o fabrico e montagem do robô móvel, o nosso robô apresenta um bom nível de estabilidade e bom funcionamento e adaptabilidade ao programa.

Palavras-chave:

Veículo guiado autónomo, Encoders, Rodas Omni, Sistema de suspensão

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Acronyms

AGM Absorbed Glass Mat. 46

AGV Autonomous Guided Vehicle. 9

AI Intelligence Artificial. 5

FC functions constrained. 20

FMS Flexible Manufacturing System. 9

FP function principal. 20

GA genetic algorithm. 9

IOT Internet of Things. 4

IPB Instituto Politécnico de Bragança. 2

PSO Particle Swarm Optimization. 9

PWM pulse width modulation. 33

RaF Robot Factory Lite. 2

SADT Structured Analysis and Design Technique. 20

Chapter 1

Introduction

Many constraints are pointed out that need to be solved to achieve correct navigation in unstructured spaces, especially indoors, one of them being the need for localization knowledge, a necessary aspect for the most simplest of the mobile robots to provide indoor navigation, it represents a topic of study in its own right and the basis for studying more complex mobile systems.

There are many applications where human presence may be awkward, impossible or even dangerous, and these are now increasingly being replaced by unmanned vehicles. Unmanned vehicles are able to move in an unknown environment while performing specific tasks, such as exploration, surveillance, assistance, logistic services and environmental monitoring. In order for these vehicles to move in unknown environments, they are equipped with a set of sensors to observe the environment. With the information gathered, they are able to make autonomous decisions about their behaviour or transmit this information to a remote human operator who will teleoperate the vehicle. It stands to reason that sensor accuracy is crucial for robots operating in such environments. However, In indoor applications, there is a certain limitation of usable sensors. The choice of structure is often made from a range of known solutions [1] [2].

In this work, the study on the development of an autonomous mobile robot in order to participate in the robot factory competition will be predefined. This work will start with a general study on robotics, will follow after the study and mechanical design phase and will end with the choice of the hardware and data-processing part. The work will be developed within one of the laboratories of the Instituto Politécnico de Bragança (IPB). At the end of this work, a prototype of an autonomous omni-mobile robot will be made with the aim of participating in the Robot Factory Lite (RaF) lite. This document is structured as follow: There are many applications where the human presence may be inconvenient, dangerous or impossible, being nowadays increasingly substituted by unmanned vehicles. Unmanned vehicles are capable of moving in an unknown environment while executing specific tasks, such as exploration, surveillance, assistance, logistic services and environmental monitoring. For these vehicles to move in unknown environments they are equipped with a set of sensors to observe the environment. With this information, they are able to autonomously make decisions about their behavior or to give this information to a remote human operator who will teleoperate the vehicle. Sensors accuracy is crucial for robots that operate in highly unpredictable environments. In indoor applications, there is some limitation about the usable sensors. The choice of structure is often made from a panel of known solutions and for which the problems of modelling.

- The first chapter describes the general presentation of robotics and the problematic.
- The second chapter describes the functional and structure robotics studying
- The third chapter describes the equipment selection
- The fourth chapter describes the design and simulation

In this work, we will study, design, and manufactured an autonomous mobile robot in order to participate in the robot factory competition. This work will start with a general study on robotics, after the phase of the mechanical study and design and conclude with the equipment selection and data-processing part. The work will be elaborated within the LCAR laboratory of the IPB. At the end of this work we will make an autonomous omni mobile robot that will can be participate on the RaF lite.

The main constraints of this proposal are to develop a wheeled mobile platform with a metal structure supporting all mechanical and electrical parts. It must be able to be controlled autonomously during the competition. The platform must be able to support further developments.

Chapter 2

Theoretical Foundation

This chapter gives a general overview of the history of robotics in the world.Then, it presents the new techniques used and identifies the tasks to be performed in the functional analysis part. Finally, it explains the issues that led to the elaboration of this project as well as the specifications.

2.1 History of Robotics

The term robotics appeared in 1942 in the universally known cycle written by Isaac Asimov and entitled Robots.The first digitally operated and programmable robot was invented by George Devol in 1954 and was ultimately called the Unimate. Devol sold the first Unimate to General Motors in 1960, and it was installed in 1961 in a plant in Trenton, New Jersey to lift hot pieces of metal from a die casting machine and stack them [3].

2.1.1 Mobile robotics

Mobile robotics, an extremely fast-developing industrial sector that aims to find solutions, brings together engineering and computer science, but also cognitive sciences, artificial intelligence and many other disciplines such as Internet of Things (IOT).

Figure 2.1: mobile industrial robot MiR 100 [4]

The complexity of mobile robots can only be tackled through the cooperation of all these disciplines. They are able to move, interact and perform actions autonomously. At the Mobility Instar, autonomy, i.e. the independence of robots from human intervention, is also one of the major aspects of mobile robotics. A distinction is often made here between semi-autonomous and fully autonomous devices, but autonomy is mainly defined by the power supply of the robot. If an external power supply, such as a charging base, is required, autonomy is considered limited. Although mobile robotics is still in its early stages of development, prototypes and first series products have been in use for several years in a wide variety of sectors. With fully autonomous vacuum cleaners and delivery robots for Amazon customers, mobile robotics has already made its way into everyday life. Thanks to innovations in the field of Intelligence Artificial (AI) and its variations, the importance of autonomous and mobile robots and their use is set to increase enormously, the figure below show an example of mobile industrial robot.

The main feature of mobile robots is the presence of a mobile base which allows the robot to move freely in the environment. Unlike manipulators, such robots are mostly used in service applications, where extensive, autonomous motion capabilities are required. From a mechanical viewpoint, a mobile robot consists of one or more rigid bodies equipped with a locomotion system. This description includes the following two main classes of mobile robots:

Wheeled mobile robots typically consist of rigid body (base or chassis) and a system of wheels which provide motion with respect to the ground.

1. Legged mobile robots are made of multiple rigid bodies, interconnected by prismatic joints or, more often, by revolute joints. Some of these bodies form lower limbs, whose extremities (feet) periodically come in contact with the ground to realize locomotion.

2. The fixed wheel can rotate about an axis that goes through the center of the wheel and is orthogonal to the wheel plane. The wheel is rigidly attached to the chassis, whose oriented with respect to the wheel is therefore constant. The steerable wheel has two axes of rotation. The first is the same as a fixed wheel, while the second is vertical and goes through the center of the wheel. This allows the wheel to change its orientation with respect to the chassis.

3. The caster wheel has two axes of rotation, but the vertical axis does not pass through the center of the wheel, from which it is displaced by a constant offset. Such an arrangement causes the wheel to swivel automatically, rapidly aligning with the direction of motion of the chassis. This type of wheel is therefore introduced to provide a supporting point for static balance without affecting the mobility of the base, for instance, caster wheels are commonly used in shopping carts as well as in chairs with wheels [5].

2.1.2 The Evolution of robotics

While for years, aspects such as productivity, repeat accuracy and speed were at the heart of robotics, other criteria based on industrial change have long since taken on equally significant importance. In almost industries, especially in the production sector, modern robots have to meet criteria such as flexibility, adaptability, precision and autonomy of action in particular. These properties make one thing clear: The development and progress of industry relies to a large extent on mobile robotics and related automation technology.

However, it is not only the industrial sector that benefits from these developments [3], the figure below show the world wide supply progress of industrial robots.

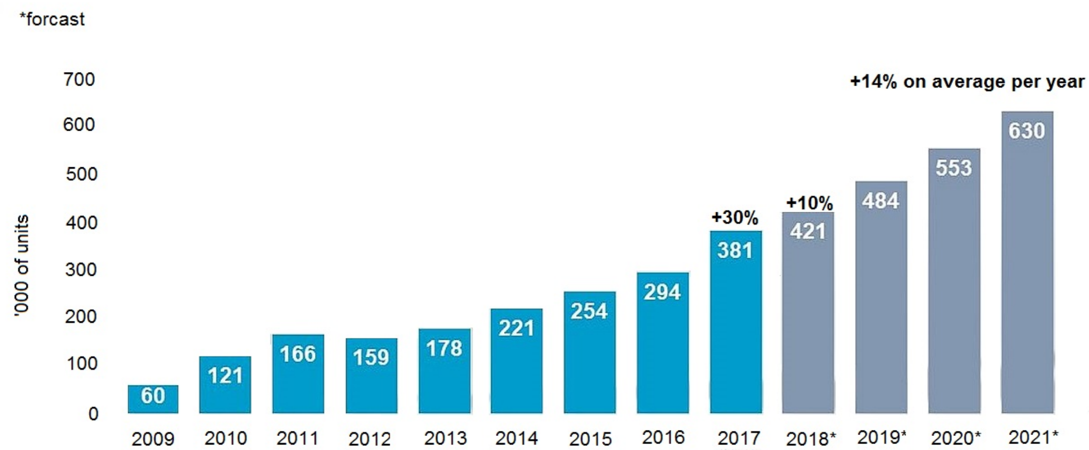

Figure 2.2: Total annual worldwide supply of industrial robots [6]

2.1.3 Mobile robotics in relation to classic robot technology

In addition to their fundamental similarities, mobile robotics, a kind of evolution of existing systems, differs from conventional robots in many respects. The example of industrial robots provides a good understanding of the decisive orientations and differences between the two. Above all, it is the importance and very diverse uses of sensors that are undergoing a huge transformation. Conventional robots are based almost exclusively on a predefined model, which does not give them any autonomy. Sensors therefore offer no particular advantages, as there is little uncertainty with regard to their operation. Mobile robotics, on the other hand, relies heavily on a variety of sensors - using cameras, laser scanners, ultrasound and other technologies. Only in this way are mobile robot systems able to react autonomously to events that occur spontaneously.

There is also a basic difference in terms of programming. Mobile robotics is rule-based and can be regarded as task-oriented, whereas conventional industrial robots have explicit software - consisting of a fixed sequence of commands. Together with a complex set of sensors, free programming in comparison forms the basis for enabling mobile devices to plan and execute their movements autonomously. The sequence of movements of mobile robots therefore depends on changes in their environment. Conventional robots usually repeat a single work process.

Since traditional industrial robots remain stationary, they always work in a known space that changes very little. Mobile robotics is designed to be more flexible, allowing autonomous devices to explore their environment with their own perception and experience. The information gathered is then processed and used as the basis for subsequent movements in the environment in question. The programmed intelligence of mobile robotics enables the devices to react to unplanned events or errors and to find alternative solutions if necessary. Faced with the same problem, conventional industrial robots usually interrupt their work and issue an error message [3].

2.1.4 The Characteristics of mobile robotics

- Perception of the environment thanks to sensors
- A capacity to adapt in the event of changes in the environment
- Autonomous navigation, planning and action
- Task-based software/task-based programming

2.2 Autonomous Guided Vehicle

AGVs are driver less mobile vehicles that are computer-controlled (usually battery operated) and equipped with different guidance systems (optical, magnetic, laser) for automated functionality. They are categorized into two groups of load towing and load carrying (forked, mandrel, unit load deck). AGVs are well-suited for long-distance horizontal movement of materials from/to multiple destinations.

They are also apt for repetitive/predictable material transportations and/or dangerous tasks. AGVs control system can be incorporated into the computer control of the production and storage equipment, thus, all the shop floor operations would be controlled using a computer system.

Flexible Manufacturing System (FMS) performance increases by better coordination and scheduling of its components like AGV. The term ‘scheduling’ refers to the process of allocating AGVs to tasks, taking into account the cost and required time for the operations to be done. Efficient scheduling therefore would increase the productivity and reduce the delivery cost whilst the entire fleet is optimally utilized. Although the AGV scheduling context has been studied before, given the diversity in objectives, limitations and considerations in scheduling problems, it is still an open area of research to improve it for real environment results. Improvement in the performance of an FMS can be expected by efficiently utilizing its resources and properly integrating and synchronizing their scheduling.

In the majority of the earlier works, make span minimization was the main objective in scheduling practices as it keeps the resources utilization rate at a balanced level and ensures proper utilization of expensive FMSs. However, those studies have discounted the importance of equal utilization of all the resources. Allocating a large number of AGVs may lead to a shorter makespan but it escalates the idle time of AGVs and costs. AGVs are such expensive devices that determining the type and the appropriate number of them in an FMS can positively influence the profitability of the business. Another issue in AGV scheduling is the charge of an AGV’s battery, where many studies do not consider the AGV’s battery charge and that leads to unrealistic scheduling models. Battery management in an AGV System (AGVS) is crucial as it can reduce the costs and increase the efficiency of the system. To address the above concerns, this research aims to schedule AGVs in an FMS environment by developing a multi-objective mathematical model that minimizes the makespan and number of Autonomous Guided Vehicle (AGV)s while considering the AGV’s battery charge. The model will be optimized using three evolutionary algorithms (genetic algorithm (GA) Particle Swarm Optimization (PSO), and hybrid GA-PSO) and validated through simulation in Flexsim software [7].

2.3 Collaborative Robots

While robots have not yet made inroads into homes or the world at large, collaborative robots work alongside humans in factories with increasing frequency. These industrial robots are common in medium and large manufacturers, but are often underutilized by small manufacturers due to the high cost of retooling and reprogramming these robots to perform a wide variety of tasks. There are two main problems with existing systems for programming these robots: clumsy user interfaces and their inability to perceive the world in ways that are meaningful to humans. Other barriers to deployment include setup time, managing configuration details, and lack of robustness to changes in the environment.

These needs have been recognized by private enterprise. KUKA Roboter GmbH posed the 2016 KUKA Innovation Award competition as the Flexible Manufacturing Challenge; indicating that "vision, manipulation and grasping, safe and intuitive human-robot collaboration, machine learning and cloud-based operations are considered most important" [1] to the future of the industry. Our entry, CoSTAR: the Collaborative System for Task Automation and Recognition, placed first among 6 finalists selected from 25 total applicants by a jury of robotics experts from industry and academia. In this work, we describe COSTAR and how it is designed to address the demand for effective collaborative robots.

We have identified three characteristics key to a system for authoring robot task plans: capability, usability, and robustness. First, a system should be capable of performing a wide variety of tasks. Second, end users should be able to understand the system's capabilities and efficiently create new task plans that meet their needs.

Finally, task plans should be robust to variation, and repeated executions should produce the expected result. We designed COSTAR to take these characteristics into consideration [8], the figure below present a collaborative robot of ABB factory.

Figure 2.3: ABB collaborative robots [9]

2.4 Industrial Robots

Industrial robotics is the discipline concerning robot design, control and applications in industry, and its products have by now reached the level of mature technology. The connotation of a robot for industrial applications is that of operating in a structured environment whose geometrical or physical characteristics are mostly know a priority. Hence, limited autonomy is required. The early industrial robots were developed in the 1960s, at the confluence of two technologies, numerical control machines for precise manufacturing, and tele-operators for remote radioactive material handling. Compared to its precusors, the first robot manipulators were characterized by:

- Versatility, in view of the employment of different end-effectors at the tip of the manipulator
- Adaptability to a priori unknown situations, in view of the use of sensors
- Positionning accuracy, in view of the adoption of feedback control techniques
- Execution repeatability, in view of the programmability of various operations

During the subsequent decades, industrial robots have gained a wide popularity as essential components for the realization of automated manufacturing [5].

2.5 Manipulator Robots

The mechanical structure of robot manipulator consists of a sequence of rigid bodies (links) interconnected by means of articulations (joints); a manipulator is characterized by an arm that ensures mobility, a wrist that confers dexterity, and an end-effector that performs the task required of the robot. The fundamental structure of a manipulator is the serial or open kinematic chain. Form a topoligical viewpoint, a kinematic chain is termed open when there is only one sequence of links connecting the two ends of the chain. Alternatively, a manipulator contains a closed kinematic chain when a sequence of links forms a loop. A manipulator's mobility is ensured by the presence of joints. The articulation between two consecutive links can be realized by means of either a prismatic or revolute joint. In an open kinematic chain, each prismatic or revolute joint provides the structure with a single degree of freedom (DOF). A prismatic joint creates a relative translational motion between the two links. Revolute joints are usually preferred to prismatic joints in view of their compactness and relability. On the other hand, in a closed kinematic chain, the number of DOFs is less than the number of joints in view of the constraints imposed by the loop. The degree of freedom should be properly distributed along the mechanical structure in order to have a sufficient number to execute a given task. In the most general case of a task consisting of arbitrarly positionning and orienting an object in three-dimensional (3D) space, six DOFs are required, three for positionning a point on the object and three for orienting the object with request to a reference coordinate frame. If more DOFs than task variables are available, the manipulator is said to be redundant from a kinematic viewpoint. The workspace represents that portion of the envirenment the manipulator's end-effector can access. Its shape and volume depend on the manipulator structure as well as on the presence of mechanical joint limits. The task required of the arm is to position the wrist wich then is required to orient the

Figure 2.4: cartesian-robot [10]

end-effector. The type and sequence of the arm's DOFs, starting from the base joint, allows a classification of manipulators as Cartesian, cylindrical, spherical, SCARA and anthropomorphic, as we present in the figure 2.4 an example of Cartesian robot [5].

2.6 Sensors and Actuators

In addition to software and control electronics, sensors and actuators are essential components of mobile robots. Sensors are used to measure and collect various information and data required for locating and planning movements. The sensors at the heart of the robot, such as voltmeters, thermometers and radio receivers, provide information on the current status of the system. External sensors in mobile robotics such as probes, bar code scanners, torque and acceleration sensors provide the system with the data needed to perform movements.

Internal actuators change the state of the system; for example, the fan or heater controls the indoor temperature. External actuators such as motors and pumps, on the other hand, are used to move the robot or to execute actions by manipulators such as robot arms [3].

2.7 Fields of Application

The spectrum of applications for mobile robotics knows virtually no limits, as the intelligent technology and working autonomy of these devices allow them to be used in a wide variety of ways. Their use extends beyond the production shop floor. Robotics also finds its place in everyday life, semi-autonomous vacuum cleaners are a perfect example of this. Like their predecessors, they clean the floor of the house with a blower that produces a vacuum and sucks up the dust particles. Unlike human-operated models, autonomous vacuum cleaners do not require human intervention, but follow a programmed pattern of movement and are able to react actively to obstacles such as steps, thanks to sensors on the floor. These models are usually only limited by their power supply.

In industrial manufacturing, mobile robotics is becoming widely available in the field of transportation. If in production, necessary materials have to be transported to particular machines for processing or if machined parts have to be sent to the warehouse, special robots take care of this. The modernisation of logistics structures and operations increases efficiency, reduces costs in the long term and, in particular, contributes to increased safety at work. As a link between the individual process steps, mobile robotics is already today an important component of the so-called intelligent factory, prevention against terrorism, civil protection and the military are some of the areas of application of mobile robotics. Whether they are used on the seabed, to defuse and dismantle an explosive device or as a drone in the air - semi-autonomous robots perform tasks that can pose a risk to humans. Other areas of application for mobile robotics include agriculture, but also road transport and autonomous vehicles. During the Covid-19 outbreak, the wheeled mobile platform makes a valuable support for the medical world [3].

2.8 Mobile robot programming language

Intelligent robots must be capable of action in reasonably complicated domains with some degree of autonomy. This requires adaptivity to a dynamic environment, ability to plan and also speed of execution. In the case of helper robots, or domestic robots, the ability to adapt to the special needs of their users is crucial. The problem addressed here is one of how a user could instruct the robot to perform tasks which manufacturers cannot completely program in advance. In such case the system would not work at all if it cannot learn [11].

1. C: is a imperative programming language designed for system programming. Invented in the early 1970s with UNIX, C has become one of the most widely used languages. Many modern read-only languages such as C++, Java and PHP take up aspects of C.

   However, professionals place C language at the top of the list for several reasons: He's supple and powerful.

2. C++: in the 80's B. Stroustrup proposed to call C++ a new language, designed not as a replacement but as an improvement of the C language.

   Like C, C++ takes a very machine-like view. It was primarily intended for writing operating systems but its characteristics have opened up other perspectives.

   It consists of very explicit, short instructions, whose execution time can be predicted in advance, when the program is written.

3. Java: Java is a high-level computer programming language. High-level languages, such as Java, allow programmers to write instructions using commands in English. Each instruction in a high-level language corresponds to many instructions in the language of the machine.

4. The assembler: The assembler language is very close to the machine language (i.e. the language used by the computer: information in binary, i.e. 0s and 1s). It therefore depends strongly on the type of processor. Thus there is not one assembler language, but one assembler language per type of processor [3].

2.9 Problematic

Robotics makes it possible to help people in difficult, repetitive or strenuous tasks. Moreover, it is the dream of replacing operator with machine in these tasks. The perception and reasoning faculties of robots are progressing every day now and even more so in the future, they are called upon to play an increasingly important role in our lives. Within the framework of our project it is a question of realizing an autonomous mobile robot, and to be able to carry out the tasks required within the faculty (delivery of the objects, monitoring ...). Considering the difficulty of the ground which is full of laying we will study well and determine the good mechanical components.

2.10 Requirements Specification

- Functional and structural analysis of the mobile robot
- Selection of materials
- Mechanical design and dynamic simulation
- Study and design of the electrical part
- Manufacture and assembly of the robot

2.11 Conclusion

After the presentation of the history of robotics in the world, we presented the evolution of robotics and the techniques used. In the following chapter we will present the functional and structural analysis of the existing system.

Chapter 3

Funcional and Structure Robotics Studying

Functional analysis is applied in the early stages of the project to analyse the need and the requirements in order to create or improve a system. It identifies the functions of the services to be provided by the system and the constraints to which it will be subjected and it characterises these functions and constraints. It details the modeling that has been based on analysis methods that are adapted to the needs of the project. Particularly in the functional specification phase.

3.1 Analysis of Needs

The need is to develop a omnidirectional mobile robot. We are trying to express the goal of this project without forget the limits of realisation in order to avoid the interaction between the present means and the future need.

It is standard to begin the needs assessment by proposing the three questions using the horn beast modeling tool :

Who does it help?

Who is it acting on?

What is the goal?

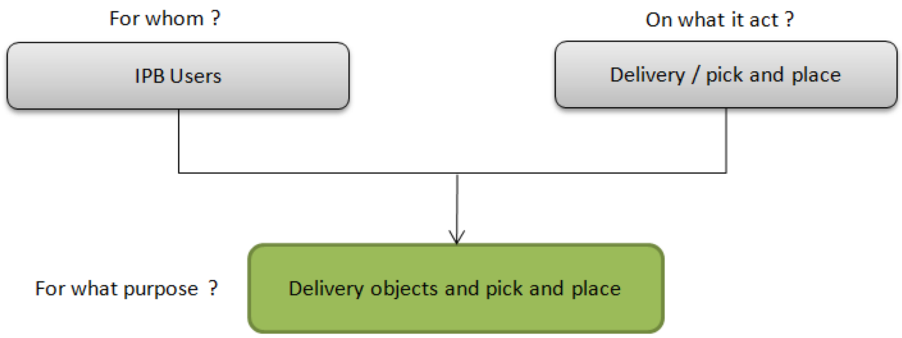

Figure 3.1: Need analyse

Following the knowledge of our need, it is necessary to evaluate it over time. This validation check consists of asking the following questions:

Why does this need exist?

- To transport materials between warehouses or machines that process those materials

What could make the product disappear?

- Appearance of a new robot that is more efficient than the old one.

3.2 Feasibility Study

During the life cycle of our product it is subject to conditions imposed by the physical, human and technical environments. All these environments are called the product environment. The figure 3.2 describe briefly feasibility studying.

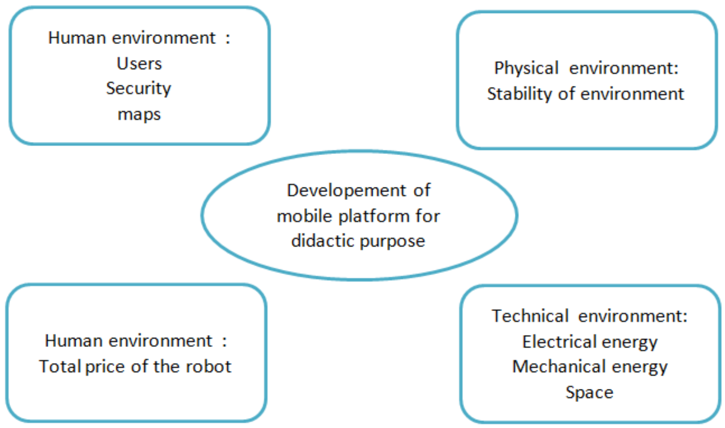

Figure 3.2: feasibility studying

For example the physical environment, the robot is in relation to a stable movements condition in the competition area.

3.3 Octopus Diagram

The octopus diagram tool in the figure 3.3 is applied to analyse the requirements and identify the service functions of our robot.

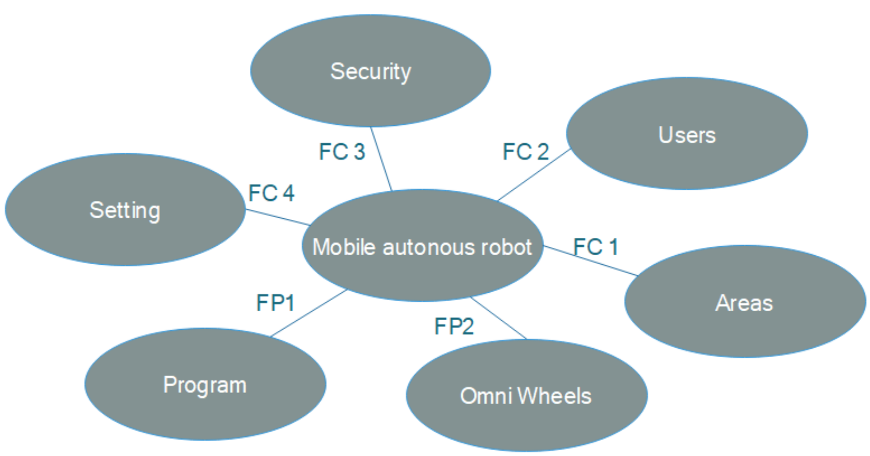

Figure 3.3: Octopus diagram

The octopus diagram highlights the relationships between the different elements of the external environment and the product. These different relationships are called the service functions that lead to the satisfaction of the need. The main function of our product is to transport materials between warehouses or machines that process those materials. The functions constrained (FC) and function principal (FP) are illustrated in the table 3.1 below to explain with details each function.

- FP1: The robot must work autonomously during the competition
- FP2: The robot should move to all the direction easily
- FC1: Navigate safely in the competition area

Table 3.1: Main and secondary functions of the robot

Service Function	**Details**
FP1	working autonomously with the programme
FP2	ensure easy movement
FC1	be easy for the wheel area contact
FC2	be easy to manipulate
FC3	work safely
FC4	be easy to set up

3.4 System Modeling

3.4.1 SADT method modelling

The Structured Analysis and Design Technique (SADT) method is a graphical method that starts from the general to the particular. It is particularly adapted to the functional specification phase of products and integrated systems or software. This method has enabled us to model a variety of complex systems. The structural and behavioural modelling of systems is carried out in the form of a hierarchical, top-down decomposition.

This method is based on the relation of these different flows with the functions that a given system performs.

3.4.2 SADT model construction

The construction of a SADT model begins with the most general and abstract description of the system. This description, contained in a single module, can be broken down into sub-modules, each representing a component of the initial box. This process can then be repeated until the desired level of detail is achieved. Each of the sub-modules or child modules must not add or subtract anything to the context of the parent module.

3.5 A-0 level Diagram

As with any automated technical system it is necessary to identify the main function of the system. The figure 3.4 shows the main function of the robotic system.

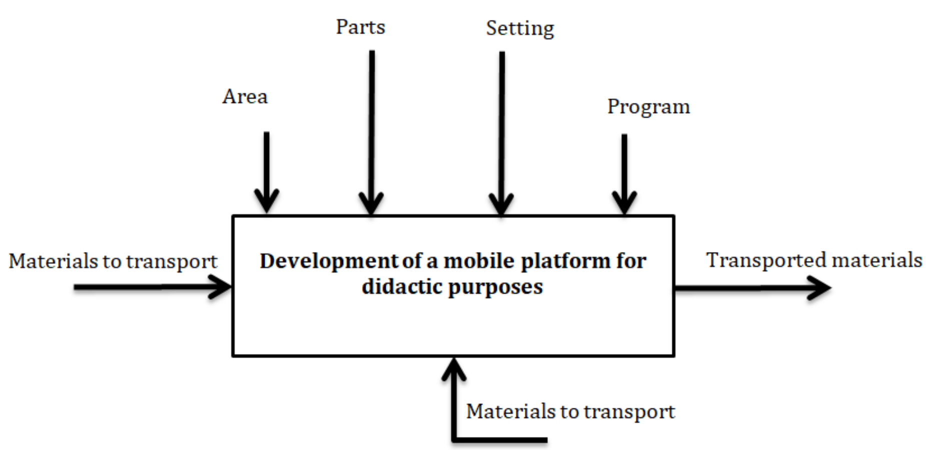

Figure 3.4: A-0 Level diagram

The operating principle of the mobile robot is based on initial conditions which are :

- Existence of the parts to be transported
- Correct programme selection for the work area

- Full battery charge
- Well-organised game plan
- Functional test of the motors
- Correct dimension of the parts to be transported

After all initial conditions have been checked the robot can start safely.

3.5.1 System level diagram

The transition from the technical modelling of the system to the development of the control part of the system, requires the determination of the energy path and the powering up of the system represented by the diagram in the figure 3.5.

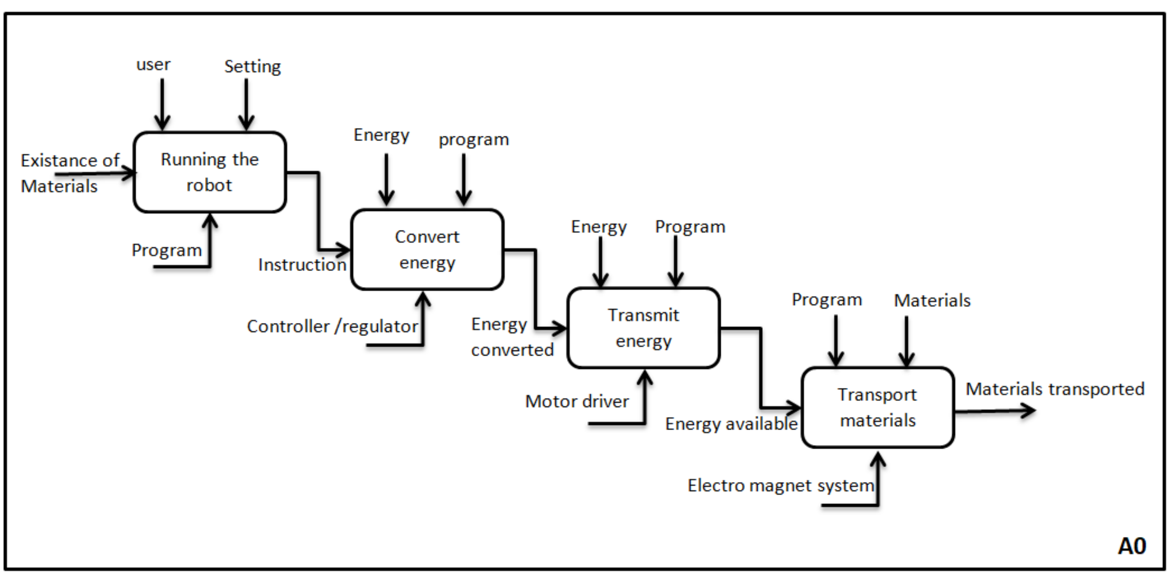

Figure 3.5: A0 Level Diagram

3.6 Technical Analysis

3.6.1 Competition Area

The competition is divided into three rounds, preferably held on consecutive days. The figure 3.6 shows the starting area for the robot and the machines types with the input and output places. For each run the robot must start inside the green area, after that the robot should go as fast as possible to the incoming warehouses to collect the materials and placed in the outgoing warehouses.

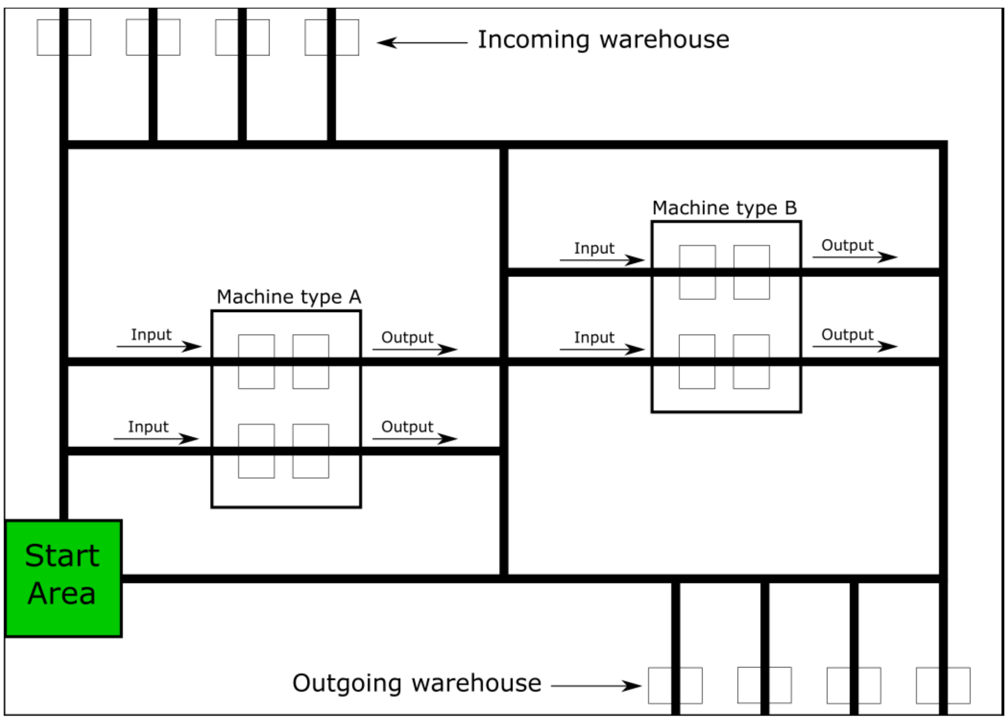

Figure 3.6: Area of the competition [12]

3.6.2 The First part of the competition

As an example the first round the objective is just to collect the four parts from the incoming warehouse and transport them to the outgoing warehouse as fast as possible. The four parts will be already placed on the incoming warehouse, ready to be moved, in the figure 3.7 we details the sequence of the first sequence in the competition.

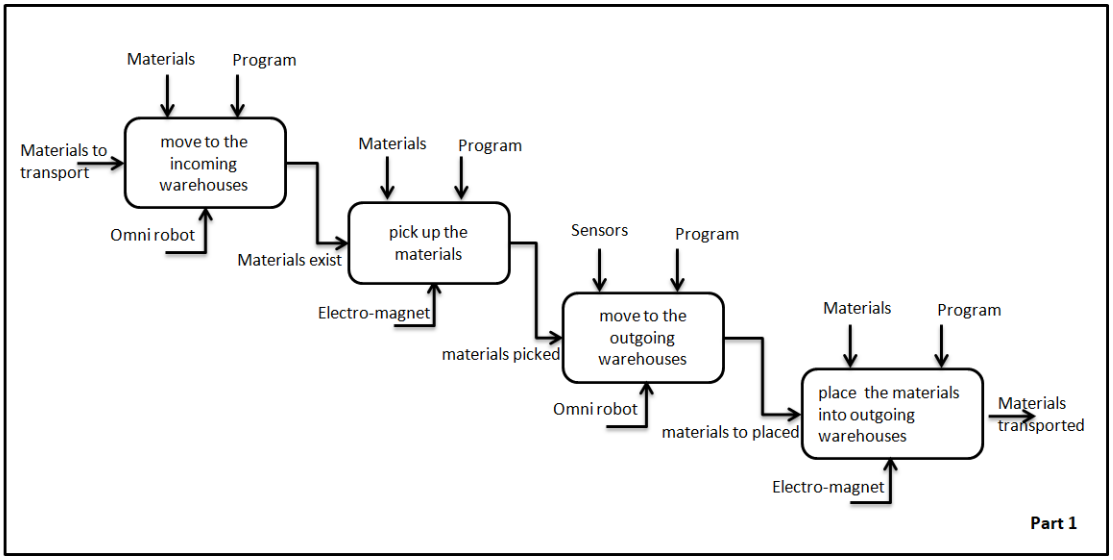

Figure 3.7: Technical description of the 1st round

3.7 Mathematical Modeling

The design proposed is to make a four omnidirectional mobile robot in X configuration. The next studying will determine all the mathematical parameters in order to use odometry in the programing process.

3.7.1 Mechanical Configuration

(X,Y,θ), robot's position , (X,Y) and θ angle to be defined front of robot .

The figure below presents the four omnidirectional mobile robots in X configuration.

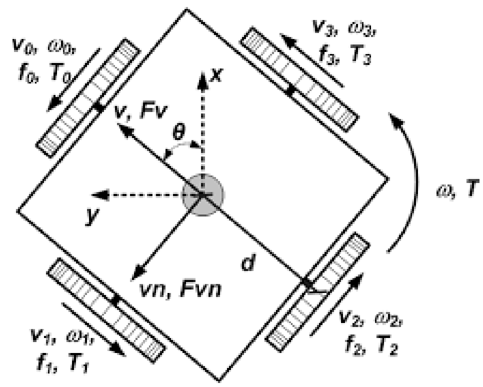

Figure 3.8: Omni directional mobile robot X configuration [13]

In the 'X' configuration, the angle of each motor axis from the robot coordinate frame 'x' axis is:

$$\theta 1 = 45^\circ \; \theta 2 = 135^\circ \; \theta 3 = 225^\circ \; \theta 4 = 315^\circ$$

We add $\pi/2$ to get the drive direction of each wheel:

$$w1 = \theta 1 + \pi/2 = 135^\circ$$

$$w2 = \theta 3 + \pi/2 = 225^\circ$$

$$w3 = \theta 3 + \pi/2 = 315^\circ$$

$$w4 = \theta 3 + \pi/2 = 45^\circ$$

We use trig to express the direction of each wheel as components in x and y relative to the robot coordinate frame:

For wheel 1,

$$x1 = cos(\theta 1 + \pi/2) \cdot s1$$

and,

$$y1 = sin(\theta 1 + \pi/2) \cdot s1$$

and the same for the other three wheels. Then gather up all the individual motor contributions to the robot motion in x, in y and in w:

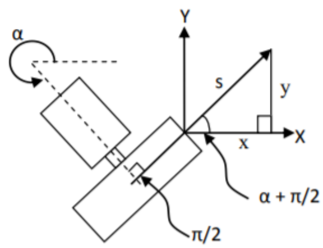

Figure 3.9: Wheel coordination

$$x = x1 + x2 + x3 + x4;$$

$$y = y1 + y2 + y3 + y4;$$

$$w = s1 + s2 + s3 + s4$$

To use the summed x and y contributions we need to substitute in the trig expressions we worked out that express the x and y contributions of each motor in terms of $'\alpha'$ and 's' to get:

$$x = cos(\theta 1 + {}^{\pi}/_{2}) \cdot s1 + cos(\theta 2 + {}^{\pi}/_{2}) \cdot s2 + cos(\theta 3 + {}^{\pi}/_{2}) \cdot s3 + cos(\theta 4 + {}^{\pi}/_{2}) \cdot s4 \quad (3.1)$$

$$y = sin(\theta 1 + {}^{\pi}/_{2}) \cdot s1 + sin(\theta 2 + {}^{\pi}/_{2}) \cdot s2 + sin(\theta 3 + {}^{\pi}/_{2}) \cdot s3 + sin(\theta 4 + {}^{\pi}/_{2}) \cdot s4 \quad (3.2)$$

V0, V1, V2, V3 [$^{m}/_{s}$] wheels linear velocity's

d[m] distance between wheels and the center robot .

w0, w1, w2 , w3 [$^{rad}/_{s}$] wheels angular velocity.

f0, f1, f2, f3 [N] wheels traction force .

T0, T1, T2, T3 [$^{N}/_{m}$] wheels traction torque

v, vn [$^{m}/_{s}$] robot linear velocity

w [$^{rad}/_{s}$] robot angular velocity

Fv, Fvn [N] robot traction force along v and vn

T [N/m] robot torque

The v direction follows the front of the robot and the vn direction is orthogonal.

3.7.2 kinematic Model

In order to find motion models for a surface vehicle, the pose of the vehicle must be identified as (x, y, θ) and associated velocities are

$$v_x(t) = \frac{dx_t}{d(t)} \ ; \ v_y(t) = \frac{dy_t}{dt} \ ; \ w(t) = \frac{d\theta_t}{dt} \tag{3.3}$$

$$\begin{bmatrix} v(t) \\ vn(t) \\ w(t) \end{bmatrix} = \begin{bmatrix} cos(t) & sin(\theta(t)) & 0 \\ -sin(\theta(t)) & cos(t) & 0 \\ 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} v(t) \\ vn(t) \\ w(t) \end{bmatrix} \tag{3.4}$$

3.7.3 Relationship between wheel velocity

The relationship between the wheels velocities v0, v1, v2 and v3, with the robot velocities v, vn and w is described by the following equation:

$$\begin{bmatrix} v_0(t) \\ v_1(t) \\ v_2(t) \\ v_3(t) \end{bmatrix} = \begin{bmatrix} 0 & 1 & d \\ -1 & 0 & d \\ 0 & -1 & d \\ 1 & 0 & d \end{bmatrix} \times \begin{bmatrix} v(t) \\ vn(t) \\ w(t) \end{bmatrix} \tag{3.5}$$

It is possible to obtain the equations that determine the robot velocities related with wheels velocity but the matrix associated with equation (2.3) is not square. This is because the system is redundant [13]. It can be found that:

$$\begin{aligned} v(t) &= (\tfrac{1}{2}) \cdot (v_3(t) - v_1(t)) \\ vn(t) &= (\tfrac{1}{2}) \cdot (v_0(t) - v_2(t)) \\ w(t) &= (\tfrac{1}{2 \cdot d}) \cdot (v_0(t) + v_1(t) + v_2(t) + v_3(t)) \end{aligned} \tag{3.6}$$

3.8 Conclusion

In this chapter, we present our needs to design and build our four Omnidirectional wheel mobile robot for the robot factory competition.We show technically all the steps and operation during the competition .The mathematical studying includes the kinematics analysis

Chapter 4

Mechanical Design

In this chapter we will presente our final design of the omni wheel robot. Simulate the robot in the area of the competition:

- show with details the components of the robot
- simulate the robot in the area of the competition
- conclude the final project

4.1 Robot Platform

The particularity of implementation of omni wheel in our design selection is to focus on the freedom of liberty of the robot in the area of the competition. The objective with omni wheels is to save time, time of moving from one store to another one. By picking up the materials with one electro-magnet and move diagonal to the second store and just turn with 90 degree, pick up second materials. After picking the materials the robot will placed all the materials in the right warehouses that was defined in the program. In the **appendix A**we show with details all the components of the mobile platform.

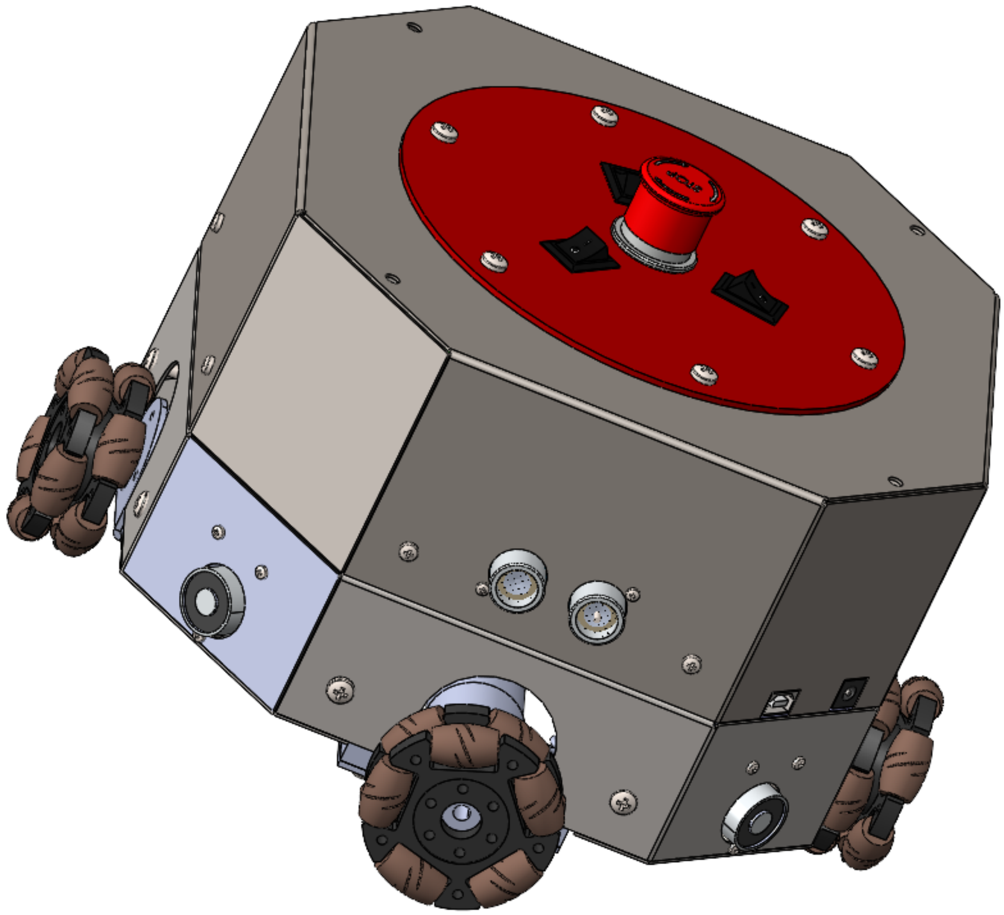

Figure 4.1: Omni wheel robot

4.1.1 Suspension system

The use of the suspension is imposed by the irregularities of the surface on which a mobile robot moves. It reduces the impact on the machine, avoiding breakages and excessive wear, improving transport comfort and mobility, and maintaining contact between the wheels and the ground despite its irregularities: an essential condition for ground handling. In addition, the fact that a mobile robot has a mass requires the use of a return mechanism to prevent the system from sagging indefinitely as the terrain becomes uneven.

Thus, the suspension consists of a connecting device between the "unsprung masses" and the "suspended masses", a spring and possibly a mechanical shock absorber.

A distinction is also made between "independent wheel" suspensions in which the left and right parts are separated on the same axle, and "rigid axle" suspensions in which the left and right parts are linked

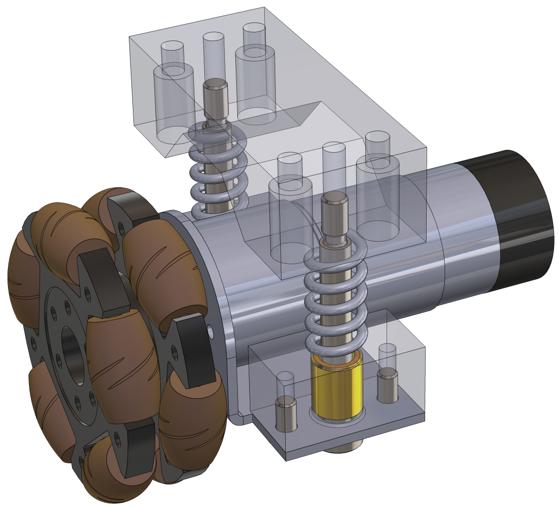

Figure 4.2: suspension system designed

For our application, we implement the suspension system in the figure 4.2 to obtain more stability of the omni wheel robot. The four suspension systems fixed with the motors maintain and avoiding breakages. The designed suspension mechanism consists of two interconnected aluminium brackets with two shoulder screws and two springs for each wheel to absorb the loads encountered on the area competition .

4.2 The Springs in relation to the structure

The purpose of using a suspension system in our omnidirectional mobile robot is to reduce the vibration due to the PID control system. The PID control system generates a certain level of vibration in the electric motors which transmits this vibration directly to the entire structure of the robot. The case of our mobile robot requires a suspension system include the springs to balance the structure and the ground.

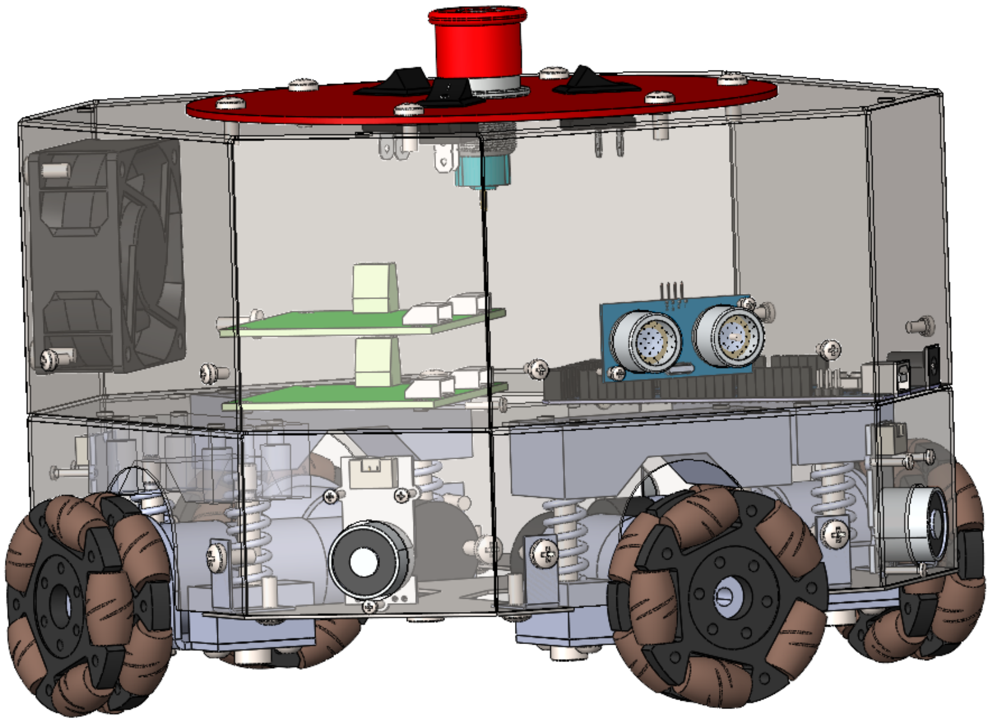

Figure 4.3: Spring Structure

4.3 The selection parameters of spring

This may seem obvious, but each spring is designed to perform a specific action or function, so there are differences between springs. Spiral torsion springs used in our robot seem to be the most suitable, as their capabilities are more interesting than traditional helical springs. They allow for a range of smooth movements and uniform, consistent loading. A constant force spring would be suitable for any application requiring more power.

4.3.1 Length in relation to the load

The load of our robot is about 4 Kg, the most load is about 1.35Kg of the battery, the load is spread over the whole surface on top of the base.The longer the spring, the greater the loading force. To save space, light and intermediate load springs should be chosen, but if the load is heavy, the spring should have a free length equivalent to six times the length of the run. Following the datasheet of the EMG30 motor, the four motors can support 6 kg with maximum speed of the robot. The springs used are selected with sampling and real test related to the stability of the omnidirectional robot.

4.4 Coupling wheeled motor

Couplings are used to transmit speed and torque, or power, between two drive shafts that are an extension of each other and may be misaligned. In the case of our robot and existing materials (Aluminium extruded exist in the mechanical laboratory), a rigid coupling is required to prevent the wheels and robots from slipping. The coupling was modified and manufactured to improve certain parameters such as the physical stability of the moving robot, the figure 4.4 shows the new and old coupling.

Figure 4.4: Coupling system

4.5 Electronic and Electric Platform

4.5.1 Electronic design

Four channel bi-directional motor driver been design to drive all four wheels.

The specifications developed for the necessary driver board were: The circuit should be compatible with a single logic-level pulse width modulation (PWM) input signal for speed control of each wheel and a single logic-level input line for the direction of motor rotation for each wheel. The circuit should be able to operate with a high PWM carrier frequency from the microcontroller (20 MHz) to provide inaudible operation. The circuit would require four independent H Bridge drivers for bi- directional motion, in this case we used the L298N motor driver. Each H-Bridge driver circuit must be capable of providing suitable continuous current at 12V DC. The EMG30 motors used in this platform are provide 200 rpm in maximum is 12V DC motor. The optical encoders provided velocity information on each wheel to the micro-controller. A four channel high power H-bridge driver board was interfaced to the arduino. The overall system hardware architecture of the connections between hardware components of the mobile robot platforms. To control the robot direction of the omni wheels, IR sensor was implemented to carry out of the system movement. In the end of each movement we set on the electro-magnet to pick up the materials exist in the incoming warehouses.

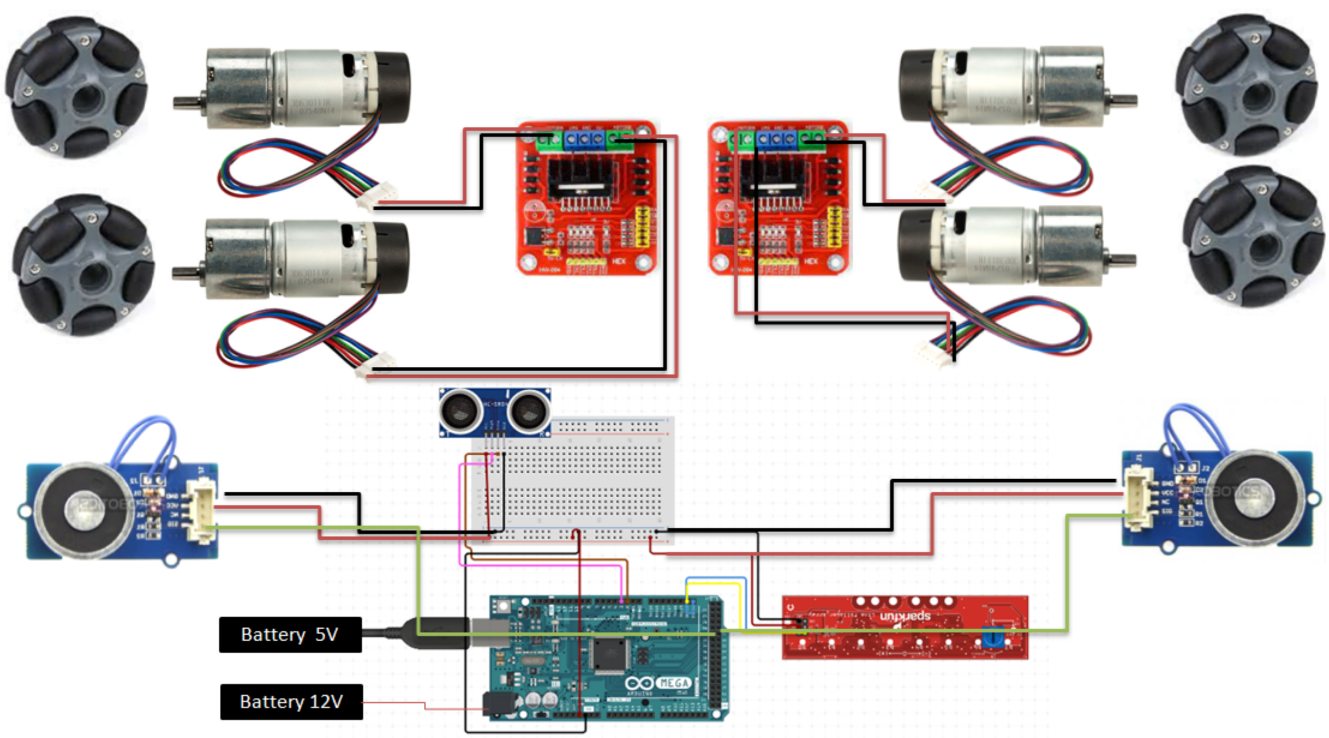

Figure 4.5: Electrical wiring

4.6 Conclusion

In this chapter, we were presented the final mechanical platform. The electronics plan of wiring all the components.

Chapter 5

Materials and Methods

In this chapter, we will expose the materials selection which is based on sensors and actuators. To implement a control process, sensors, actuators, and the microcontrollers that applied to collect, transmit and process the information, respectively. The function of each component is:

- The sensors measure the process variables
- The microcontroller receives the information read from the sensors and computes the action to be taken by the actuators
- The actuators control the system behavior

The following sections describe in detail the corresponding components applied in this work

5.1 Electronic Parts

5.1.1 Actuators

The actuators are responsible for converting the control action signal computed by the microprocessor into a physical action applied to the system. The actuation used in this control loop it is composed of two components: Two L298N board, making the interface between the micro controller and the motors. the four EMG30 motors are responsible for the motion of the robot , the figure 5.1 present the link between the motors and driver motors.

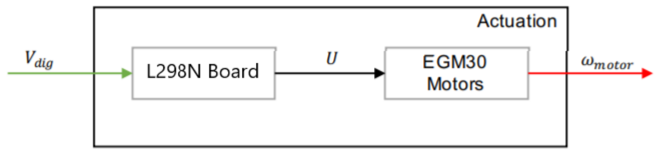

Figure 5.1: Control Loop - Actuation [14]

5.1.2 EMG30 motor

The EMG30 assembles a 12 V motor with an encoders with 30:1 reduction gearbox. It is excellent for small or medium robotic application, providing cost-effective drive and feedback for the user. It also has a conventional noise suppression capacitor across the motor windings. The EMG30 is supplied with a six-way JST connector, the connections are given in figure 5.3, and the EGM30 specifications are shown in figure 5.2.

Figure 5.2: EMG30-Motor

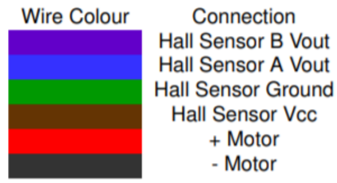

Figure 5.3: EMG30-color-connection

Rated Voltage	12 V
Rated Torque	1.5 Kg/cm
Rated Speed	170 rpm
Rated Current	530 mA
No load Speed	216 rpm
No load Current	150 mA
Stall Current	2.5 A
Rated Output	4.22 W
Encoder Resolution	360 counts/ shaft turn

Figure 5.4: EMG30-Specifications

These motors provide a wheel revolution from 1.5 rpm to 200 rpm offload when supplied 12 V power supply. About input and output of motors, the input, is voltage given by the L298N motor driver and the output is shaft angular velocity of motor. A DC motor converts direct electrical power into mechanical power, to do this it has a mechanical part, the rotor, and an electrical part, the armature.

Encoders

Encoders are one of the most used components in industrial automation and mechatronics to measure motions. This electro-mechanical device converts linear or angular motions of a shaft to an analog or digital code. They are applied in different components, for example, CNC machines, velocity and position control of electrical motors, the position of a satellite dish, telescopes and radars. There are two models of encoders: Absolute and incremental. The absolute encoder provides an numerical value for each angular position even over several revolutions, making angle transducers. On the other hand, incremental encoders generate a precise defined number of pulses per revolution, which is usually processed into information such as speed, distance, and position. The encoders applied in this work are optical incremental encoders. The optical incremental encoders are the most popular type of encoders and are constituted with a rotating disk, a light source and a photosensor. Firstly, the light source emits the light beam which passes through a transparent disk patterned with blurred lines. When the photosensor receives the light beam, it produces a sinusoidal waveform which is converted into a square wave or pulse train, and this pulse signal is then sent to the counter or controller,as shows in the Figure 5.5.

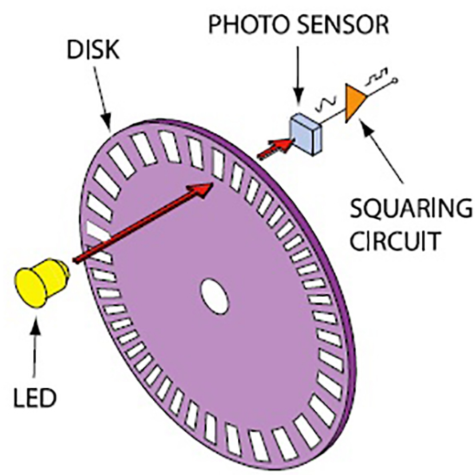

Figure 5.5: Analog rotary encoder

To use an encoder is necessary to understand how it works and define what its input and output are. In this case, it receives the angular velocity of motor W motor and it gives as output a digital value, P, that correspond to the pulse signal.

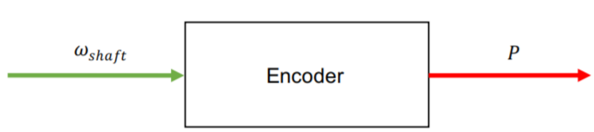

Figure 5.6: encoder-input-output[14]

The digital value P(t) given by an incremental encoder at time t, correspond the sum of pulse values read since the beginning of the movement. To know what is the distance traveled between two measurements it is necessary to subtract the last value read to the current value.

5.1.3 Motor driver L298N

A motor driver module is a simple circuit used for controlling a DC motor. It is commonly used in autonomous robots and RC cars (L2938N and L293D are the most regularly utilized motor driver chips). A motor driver module takes the low voltage input from a controller like Arduino. This input logic controls the direction of DC motors connected to the driver. To put it in simple words, you can control the direction of DC motors by giving appropriate logic to the motor driver module.

The motor driver module presented in the figure 5.7 consists of a motor driver IC, which is the heart of the module. The IC alone can control the DC motor but using the module makes the interfacing with Arduino easy. All microcontrollers operate on low-level voltage/current signals, unlike motors. For instance, the Arduino or PIC microcontroller can output a maximum voltage of 5V or 3.3V. But a decent DC motor needs at least 5V or 12V. Also, the output current limit of Arduino is relatively very low.

Hence the output of Arduino is not enough to power up the motors. To solve this problem the use of a motor driver is essential. We bridge the gap between the Arduino and motor by introducing a motor driver between them.And to supply the voltage/current required to operate the motor, an external supply is connected to the motor driver module.

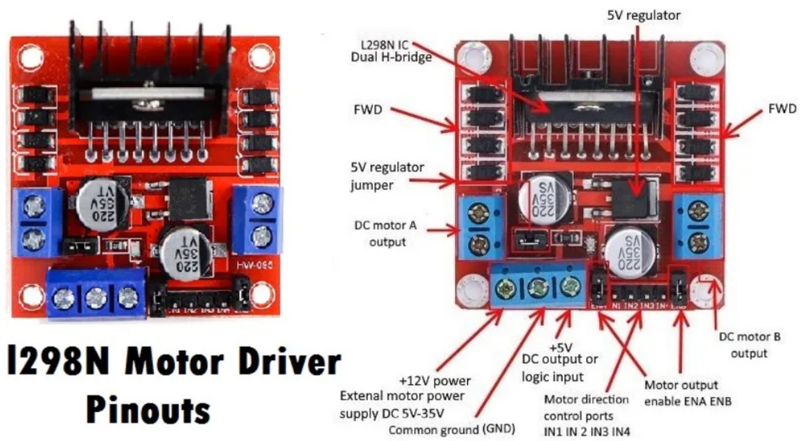

Figure 5.7: L298N

The L298N motor driver is based on the H-bridge configuration (an H-bridge is a simple circuit that lets us control a DC motor to go backward or forward.), which is useful in controlling the direction of rotation of a DC motor.

It is a high current dual full H-bridge driver that is constructed to receive standard TTL logic levels [15].

L298N Module Pin Configuration

Pin name	Description
IN1 IN2	Motor A input pins Used to control the spinning direction of Motor A
IN3 IN4	Motor B input pins. Used to control the spinning direction of Motor B
ENA	Enables PWM signal for Motor A
ENB	Enables PWM signal for Motor B
OUT1 OUT2	Output pins of Motor A
OUT3 OUT4	Output pins of Motor B
12V	12V input from DC power Source
5V	Supplies power for the switching logic circuitry inside L298N IC
GND	Ground pin

Table 5.1: Electro-magnet specifications

5.1.4 The controller

Arduino board in the figure 5.8 is an open-source micro-controller board which is based on Atmega 2560 microcontroller. The growth environment of this board executes the processing or wiring language. These boards have recharged the automation industry with their simple to utilize platform wherever everybody with small otherwise no technical backdrop can start by discovering some necessary skills to program as well as run the Arduino board.

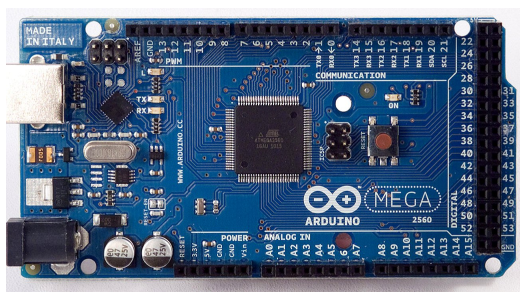

Figure 5.8: Arduino mega 2560

Microcontroller	Atmega2560
Operating Voltage	5V
Input Voltage	7V – 12V
USB Port	Yes
DC Power Jack	Yes
Current Rating Per I/O Pin	20mA
Current Drawn from Chip	50mA
Digital I/O Pins	54
PWM	15
Analog Pins (Can be used as Digital Pins)	16 (Out of Digital I/O Pins)
Flash Memory	256KB
SRAM	8KB
EEPROM	4KB
Crystal Oscillator	16 MHz
LED	Yes/Attached with Digital Pin 13
Wi-Fi	No
Shield Compatibility	Yes

Figure 5.9: Arduino mega 2560 Specification

5.1.5 The Electro-magnet

An electromagnet is a type of magnet in which the magnetic field is produced by electric current. An electric current flowing in a wire creates a magnetic field around the wire, due to Ampere's law. To concentrate the magnetic field, in an electromagnet the wire is wound into a coil with many turns of wire lying side by side. The magnetic field of all the turns of wire passes through the center of the coil, creating a strong magnetic field there. Grove - Electromagnet in the figure below can shuck 1Kg weight and hold on. it easy to use, to learn electromagnet principle.

Figure 5.10: Electro-magnet

The specifications of this electro-magnet are :

working voltage	5V
working current	400mA
standby current	200uA
load weight	1Kg

Table 5.2: Electro-magnet specifications

The materials exist in the area of the competition will be taken by this electro-magnet.

5.1.6 IR sensor

The QTR-8RC reflecting sensor array in the figure 5.11 is intended as a line sensor, but it can be used as a general-purpose proximity or reflecting sensor. The module is a convenient carrier for eight IR emitter and receiver (photo-transistor) pairs evenly spaced at intervals of (9.525 mm). Each photo-transistor uses a capacitor discharge circuit that allows a digital I/O line on a micro-controller to take an analog reading of reflected IR by measuring the discharge time of the capacitor. Shorter capacitor discharge time is an indication of greater reflection.

The outputs are all independent, but the LEDs are arranged in pairs to halve current consumption. The LEDs are controlled by a MOSFET with a gate normally pulled high, allowing the LEDs to be turned off by setting the MOSFET gate to a low voltage. Turning the LEDs off might be advantageous for limiting power consumption when the sensors are not in use or for varying the effective brightness of the LEDs through PWM control.

The LED current-limiting resistors for 5 V operation are arranged in two stages; this allows a simple bypass of one stage to enable operation at 3.3 V. The LED current is approximately 20-25 mA, making the total board consumption just under 100 mA.

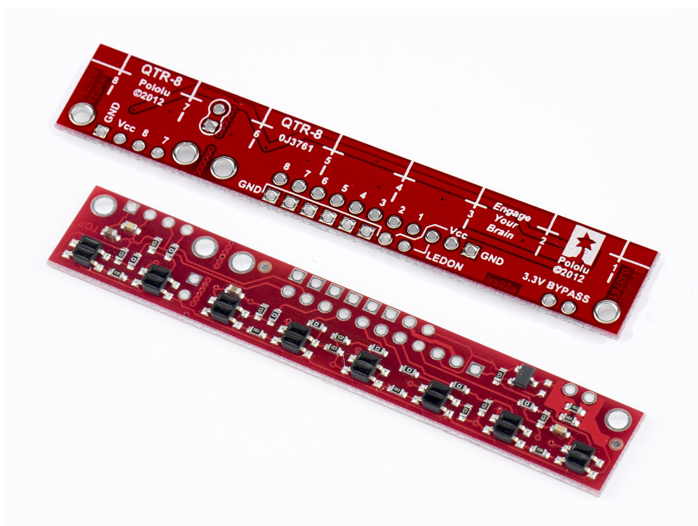

Figure 5.11: QTR sensor

In our case, the robot will follow the black line to go from the start area to the incoming warehouses. In the whole area, the robot will follow the black line and will go back and forth between the incoming warehouses and the outgoing warehouses. At the end of the competition, the robot will move between the processing machines type A and B.

5.1.7 Ultrasonic sensor HC-SR04

The HC-SR04 Ultrasonic Distance Sensor is a sensor used for detecting the distance to an object using sonar. The HC-SR04 uses non-contact ultrasound sonar to measure the distance to an object, and consists of two ultrasonic transmitters (basically speakers), a receiver, and a control circuit. The ultrasonic sensor in the figure below is used to detect the arrival of the robot in the storage area .

Figure 5.12: HC-SR04 ultrasonic

The main characteristics:

Power	3.3v-5V (DC)
Operating current	Less than 2mA
Output signal	high - 5V, low - 0V
detection distance	2cm-450cm

Table 5.3: HC-SR04 specifications

5.1.8 Power supply

Robotics are becoming more and more omnipresent in our daily lives. Robots and AGVs bring different advantages and need to have maximum autonomy to accomplish their mission. Durability and reliability are two key elements for robots and AGVs to be available 24/7. Fast or partial recharging, bottle charging or trickle charging, many options are possible with Lithium-Ion to make systems operational at any time.

Limitations of lead batteries

Useful capacity and lifetime of an Absorbed Glass Mat (AGM) lead acid battery AGM lead-acid batteries are not designed to be deeply discharged. The useful capacity of a lead battery is considered to be between 30 and 50 percent of its actual capacity. If the cycles are deeper, the result is rapid degradation of the battery and a severely limited service life. If the battery is maintained correctly, without deep discharges in excess of 50 percent, the life of a lead acid battery will be approximately 500 cycles (300 cycles for 70 percent discharges).

This means that for certain uses, such as a solar installation or the traction of regularly used vehicles, it will be necessary to replace the batteries after 1 to 2 years.The figure 5.13 present the battery used in our mobile robot.

Figure 5.13: Battery Pb 12V

Basic characteristics

Type Battery	PB Battery
Capacity	3.2 Ah
Nominal voltage	12 V
Internal resistance	45m
Max Charge Voltage	13.5 to 13.8 V
Standard Charge Current	0.96 A
Weight	1.35 Kg
Operating Temperature	40 degree

Table 5.4: Basic characteristics of the PB battery

Load and energy loss

A lead-acid battery can be charged regularly to 100% percent without prematurely shortening its life. The main problem is that charging a lead-acid battery must be done slowly at the end of the cycle (the last 20 percent) so that the battery "absorbs" the last few amps without heating up the internal chemicals.

$I_{battery} = 3\ A$

This is not a problem if the battery is connected overnight to a charger. But for some applications, a full charge can be tricky to achieve: for example, a stand-alone battery powered by solar panels may not be fully charged if there is not enough solar activity during the day. Or using a vehicle without "waiting" for charging to be completed will result in incomplete cycles.

The result of these incomplete charging cycles is a premature reduction in battery life of around 30 to 40 percent. On the other hand, lead-acid batteries suffer from another technical limitation: between 15 and 20 percent of the charging energy is lost during the charging process. If the charger supplies 100 amps, the battery will only absorb 80A in one hour. This characteristic is particularly disadvantageous in solar applications, where the aim is to optimise the installation in order to capture the maximum amount of energy during the sunny period.

Finally, a third limitation concerns losses linked to rapid discharge. The more the battery is used, the less energy it will supply. This phenomenon is linked to Peukert's law, which in practice means that high discharge currents (vehicle traction, power supply to an air conditioner, oven, etc.) cause a loss of capacity of the lead-acid battery. In this case, the battery will only be able to deliver about 60 percent of its useful capacity.

Weight and energy density of Lithium Iron Phosphate vs Lead

Final choice

If the robot will work 24 hours , we should use battery lithium because that is usally used for this type of automatic system.

Type Battery	Pb Battery	Lithium Battery
Advantages	Capable of high discharge rates Low self-discharge	Longest Life Constant Power Fast charge
Disadvantages	relatively lower volumetric energy density primarily used for power applications	Too expensive Protection circuit needed

Table 5.5: Difference between Pb batteries and Lithium Batteries.

5.2 Mechanical Parts

5.2.1 Omni wheels

Many robots use omni wheels to have the ability to move in all directions. Omni wheels are also sometimes employed as powered casters for differential drive robots to make turning faster. However, this design is not commonly used as it leads to fishtailing. Omni-wheels are designed on the concept of a normal wheel that has the ability to roll or 'slip' sideways. So although no drive can be applied in the lateral direction, the wheel is still able to be moved in that direction. This is accomplished be placing many smaller wheels or cylinders on the edges of the main wheel. The angle of the smaller wheels relative to the main wheel also gives the wheels the name Swedish 90° Wheel. To prevent awkward situations where a roller may not be in the desired place and to minimize friction in lateral movement, two wheels are often combined to form a wheel which has a more complete surface [16]. Omni-directional wheels are extraordinary, as they are able to roll freely in two directions. They can either roll like normal wheels or roll sideways, depending on the circumstances. Omni-directional wheels make it possible to convert a non-holonomic robot into a holonomic robot.

A non-holonomic robot using normal wheels has only 2 of the 3 controllable degrees of freedom: forward/backward movement and rotation. Not being able to move laterally makes a robot slower and less efficient in achieving a given goal. Holonomic omni-directional wheels overcome this problem, as they are very easy to manoeuvre. Unlike the normal non-holonomic robot, the holonomic omnidirectional robot can move in an arbitrary direction continuously, without changing the direction of the wheels. It can move forward and backward, sideways, and turn on the spot.

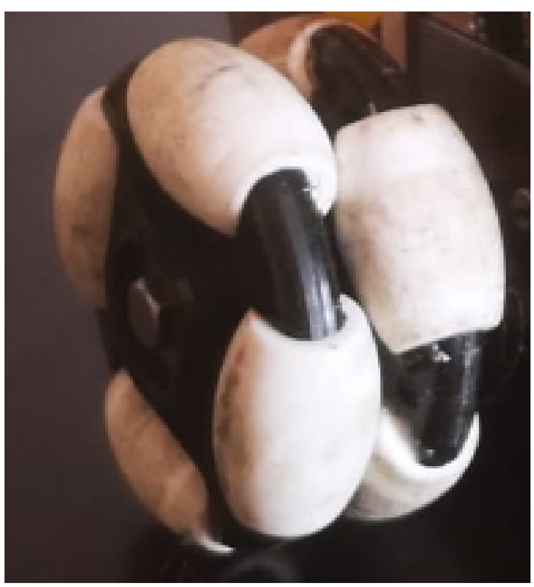

Figure 5.14: Omni wheel

Specifications :

Specifications	**Details**
Diameter of the wheel	58 mm
Diameter of a bearing	13 mm
Load capacity	3 Kg
Material (body)	nylon

Table 5.6: Specifications of omni wheels

The omni-directional wheel is defined as a standard wheel provided by a rollers array, whose axis turn perpendicularly to the normal wheel direction.

Omni wheels materials

PVC and Nylon raw material used for omni wheel drive and base of the robot were made by steel sheet which have dimension of 16 guage. As this was a complete Mechatronic project incorporating mechanical, electronic and software development, the different areas were developed synergistically thus allowing interactions between the disciplines to be viewed and managed. It also meant that all core disciplines needed to be developed to a certain stage before any one area could be further worked on. Although it was physically possible to use other means to develop the core areas independently, a synergistic approach tends to be more efficient [16].

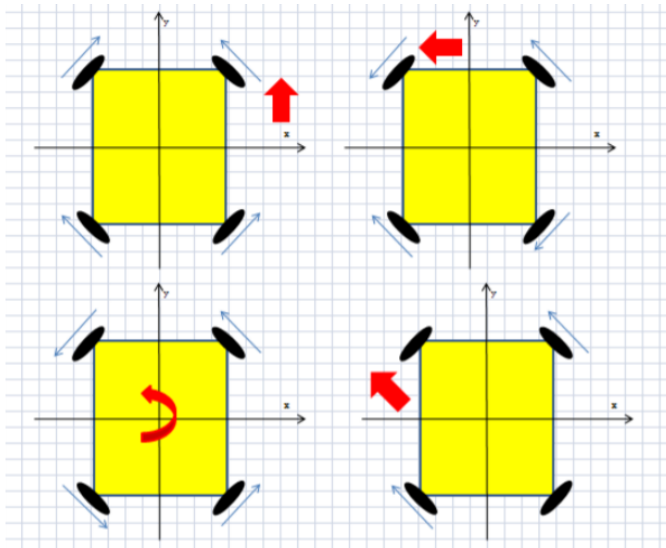

Figure 5.15: Omni wheel motion

5.3 Conclusion

In this chapter, we were selected and designed the hardware parts for our robot. We have detailed the electrical and mechanical parts as sensors and actuators.

General Conclusion and Future Work

General Conclusion

In this project we set a goal to complete the theoretical study and realisation of the mobile platform project for the factory lite robotic competition, to model and simulate the operation of the mobile robot. This missive was completed, the benefits of the final project appear during the evaluation of this work and to become aware of the constraints related to the global health situation. The choice of the IPB is to seek a practical experience and a discovery and manipulation of new technologies and values related to the field of mechatronics and robotics systems. Robot factory lite is a practical model for industry and trade like Amazon, the passage within the IPB allowed us to carry out professional study tasks, to acquire a better knowledge of the research, design and manufacture of mobile robots. The theoretical and practical experience of this end-of-studies project was particularly interested and enriching and met the objectives set in the beginning, namely the discovery of robotic life, to discover and understand the role of an industrial engineer, and above all to face the constraints of working in the field.

Future Work

The next work will be to attach the Braccio manipulator arm in the figure below to our omni wheel robot, the aim is to highlight more and more for the mobility and activities of the mobile robot. On the surface of the robot structure, a place is prepared to install this arm above the robot.

Our futur design and assembling robot is intended for research and education, it is similar to the KUKA Youbot mobile robot in the figure 5.16. KUKA well known as one of the world's leading industrial robots manufacturer has designed a rich platform, affordable and open. With a small KUKA arm with 5 degrees of freedom.

Figure 5.16: Exemple of similar robot

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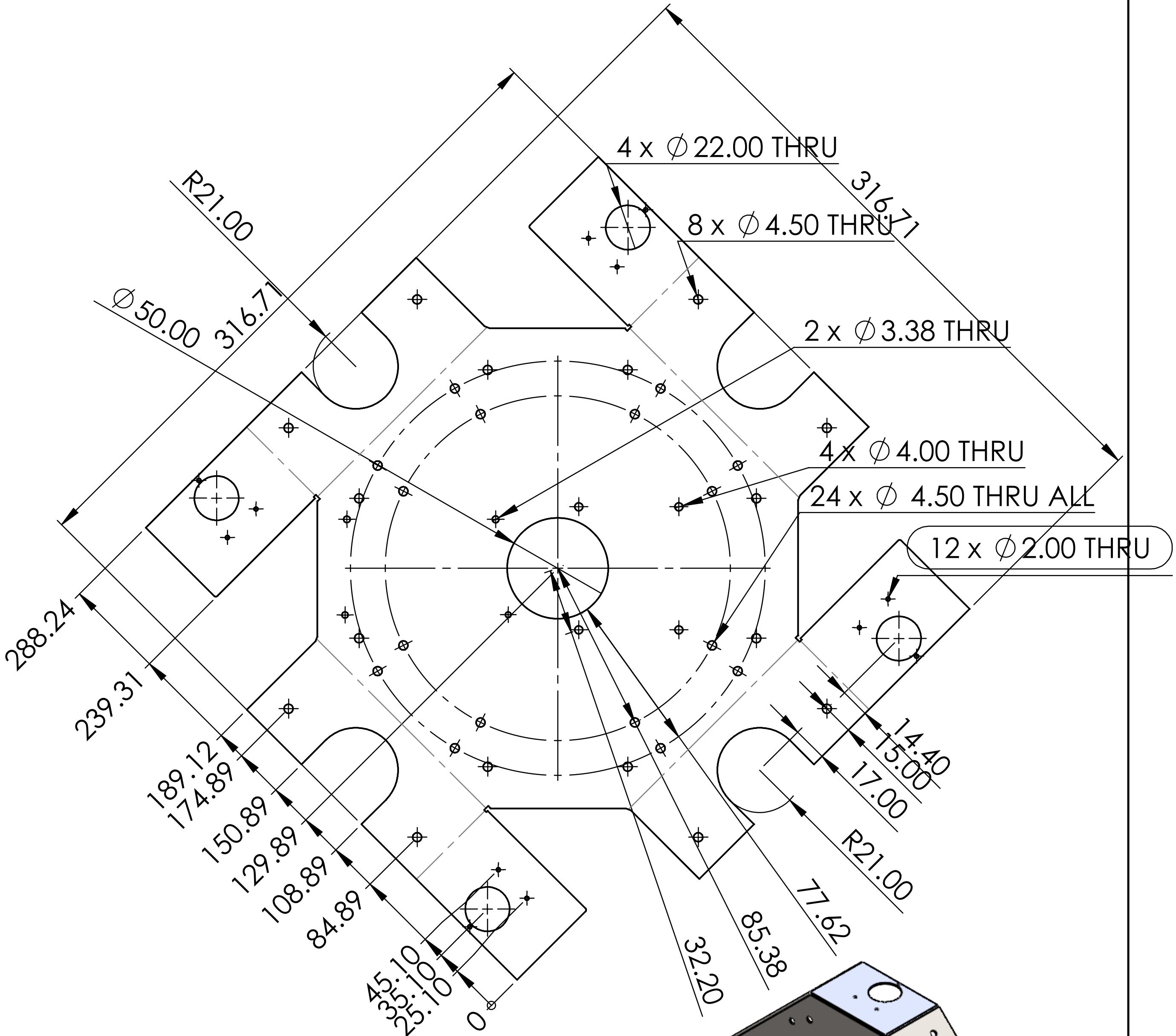
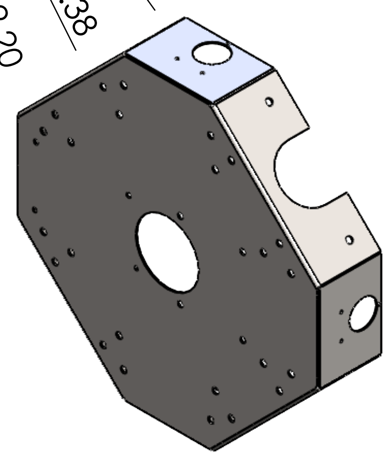
Appendix A

$2D$ Drawing





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Treatment : 2	Parts : Middle part / Project : Omni robot	Verified and approved by :
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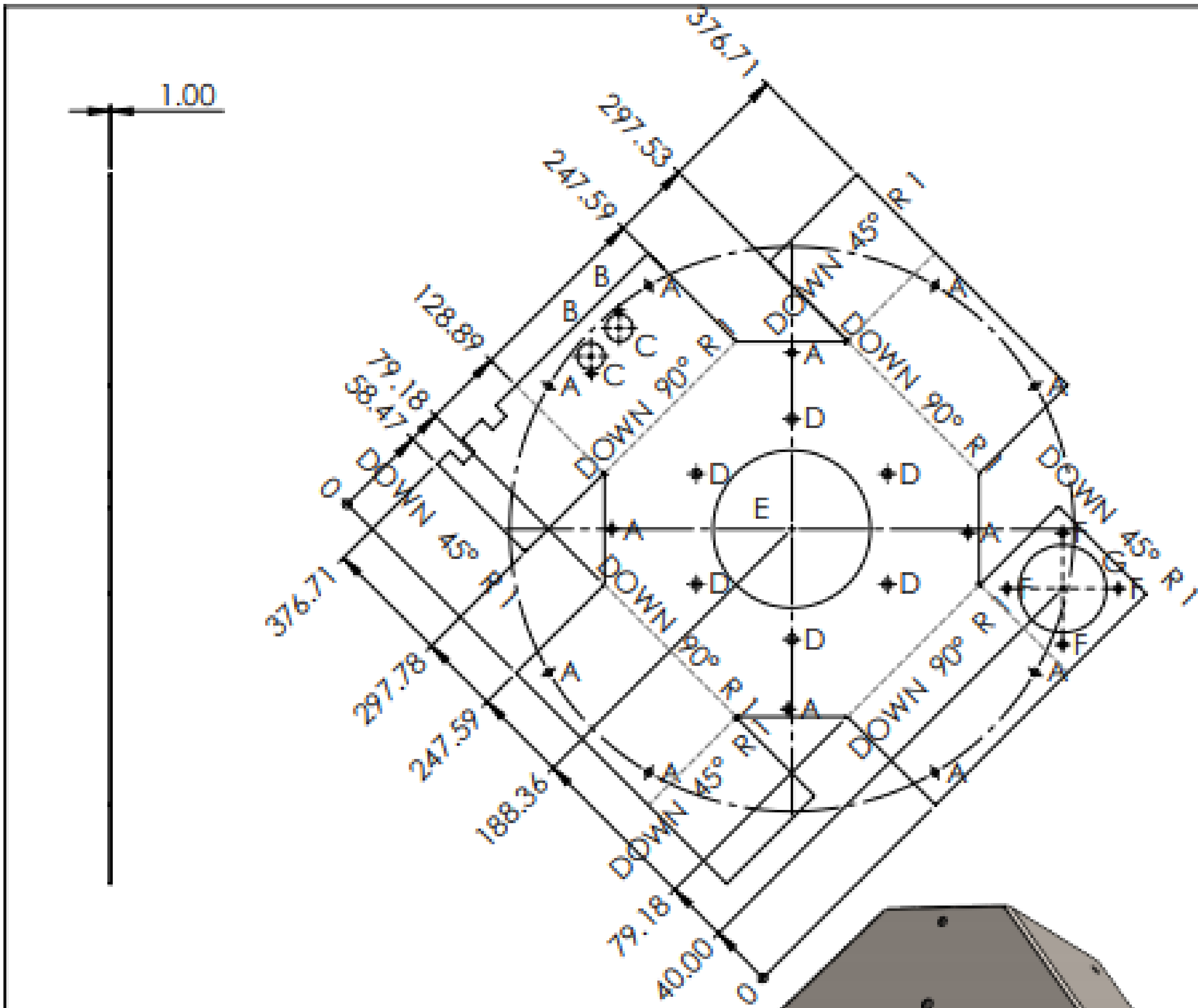
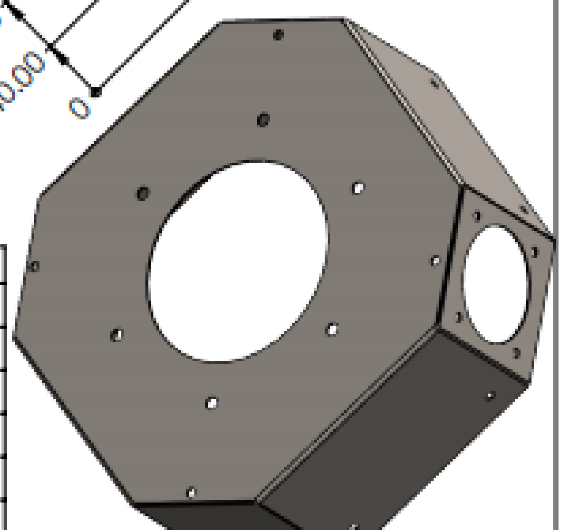


TAG	SIZE	QUANTITY
A	Ø4.50 THRU	12
B	Ø17.20 THRU	2
C	Ø3.10 THRU	2
D	Ø6.00 THRU	6
E	Ø100.00 THRU	1
F	Ø4.20 THRU	4
G	Ø55.50 THRU	1



ISO View

Material : S235 STEEL

Treatment :

Qty : 1

Weight :

Scale : 1:3

COVER PLATFORME

Parts : Support

Project : Omni robot

General linear tolerance: 0.1 mm

General angular tolerance: 1°

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Designed by : Amine Tbini

Verified and approved by :

Date: 3/8/2021

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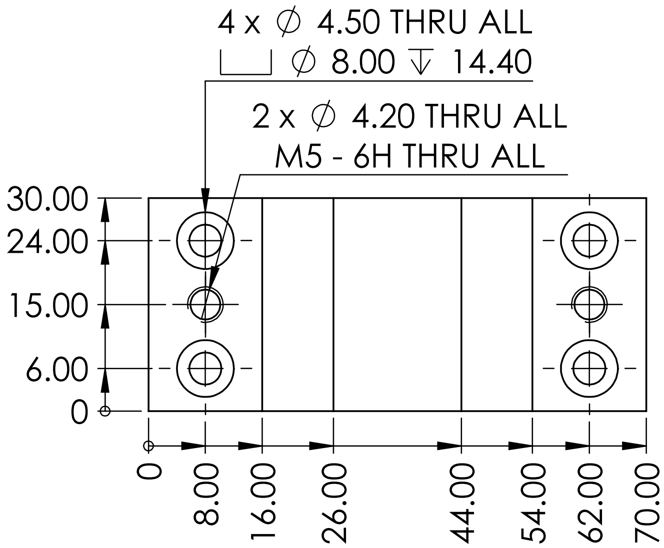
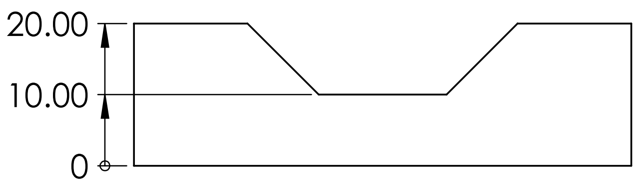
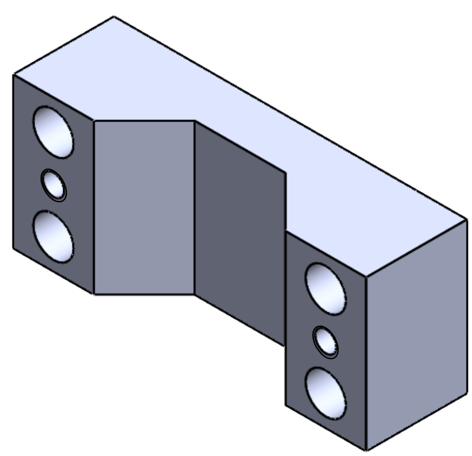




ISO View



Material : Aluminium Alloy	Support Suspension		Designed by : Amine Tbini
Treatment : 2	Parts : Support	Project : Omni robot	Verified and approved by :
Qty : 4 / Weight :	General linear tolerance: 0.1 mm	General angular tolerance: 1°	Date: 7/11/2021
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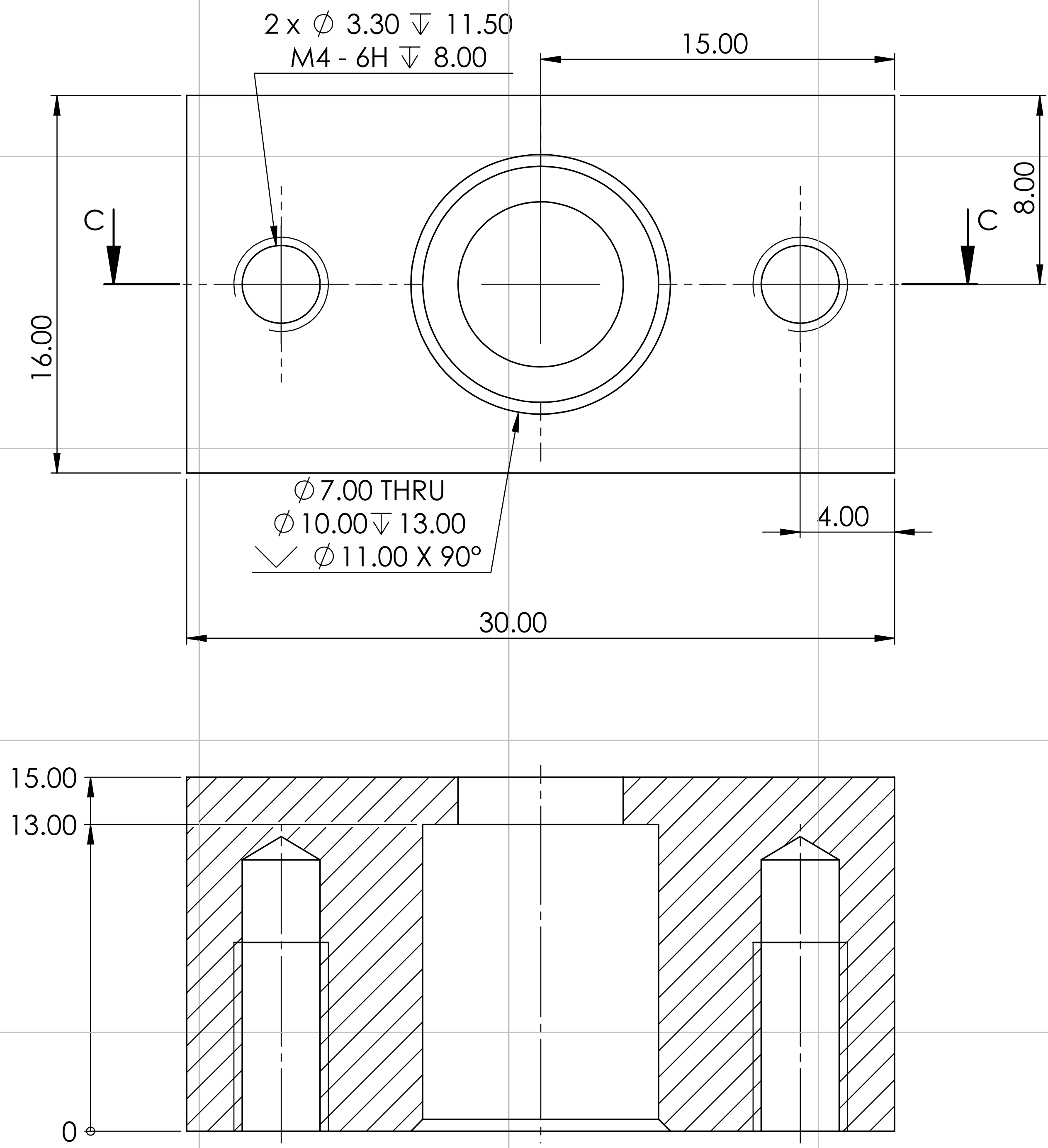

SECTION C-C

Material : Aluminium Alloy	DOWN PART SUSPENSION		Designed by : Amine Tbini
Treatment : 2	Parts : Support	Project : Omni robot	Verified and approved by :
Qty : 4 / Weight :	General linear tolerance: 0.1 mm	General angular tolerance: 1°	Date: 7/11/2021
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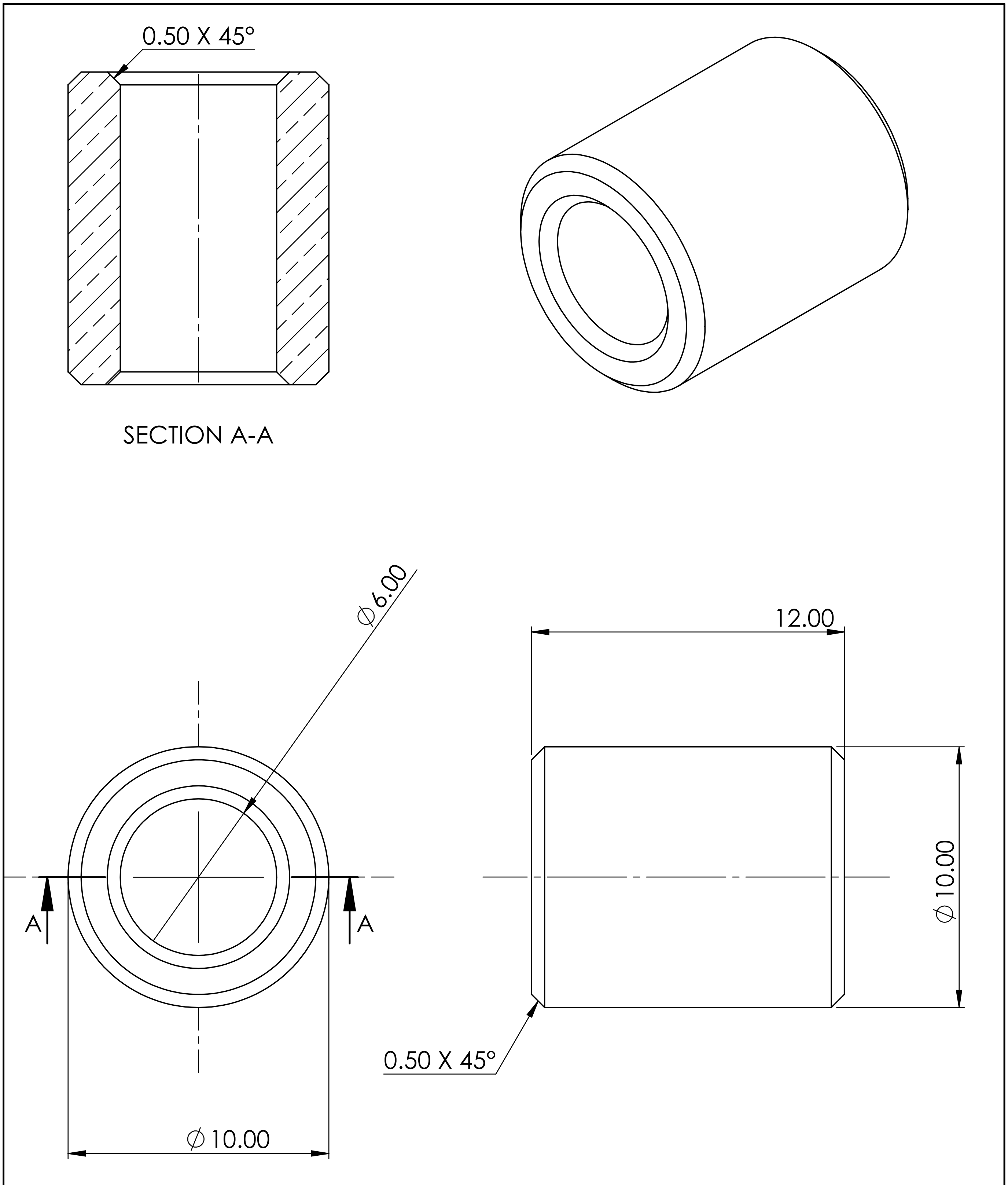

Material : Brass/Copper		Guide ring		Designed by : Amine Tbini
Traitement : 2		Parts Guide ring	Project : Omni robot	Verified and approved by :
Qty : 8	Weight :	General linear tolerance: 0.1 mm	General angular tolerance: 1°.	Date: 7/11/2021
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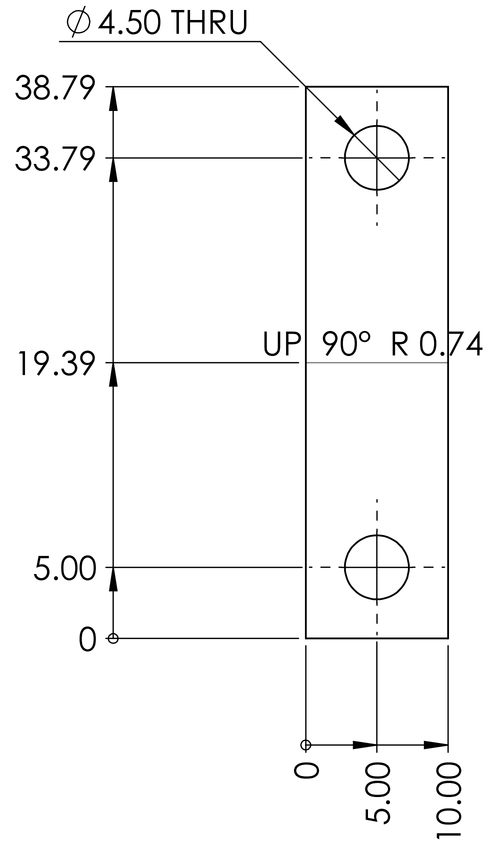
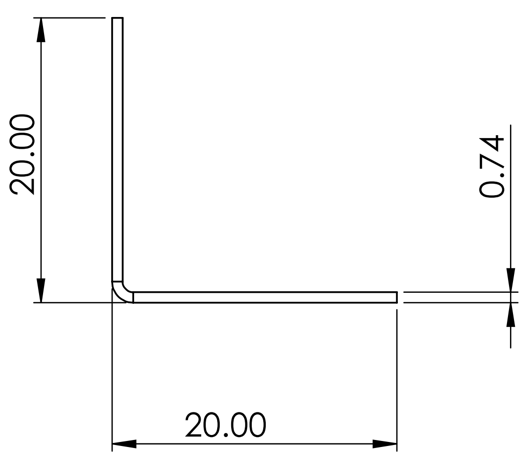
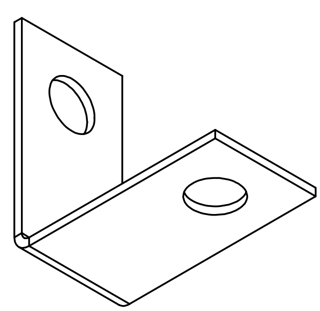
Cartouche Version 01

Flat Pattern





ISO View



Material : S235 Steel

Corner Bracket

Designed by : Amine Tbini

Treatment : 2

Parts : Corner bracket

Project : Omni robot

Verified and approved by :

Qty : 16

Weight :

General linear tolerance: 0.1 mm

General angular tolerance: 1°

Date: 7/11/2021

Scale : 2:1

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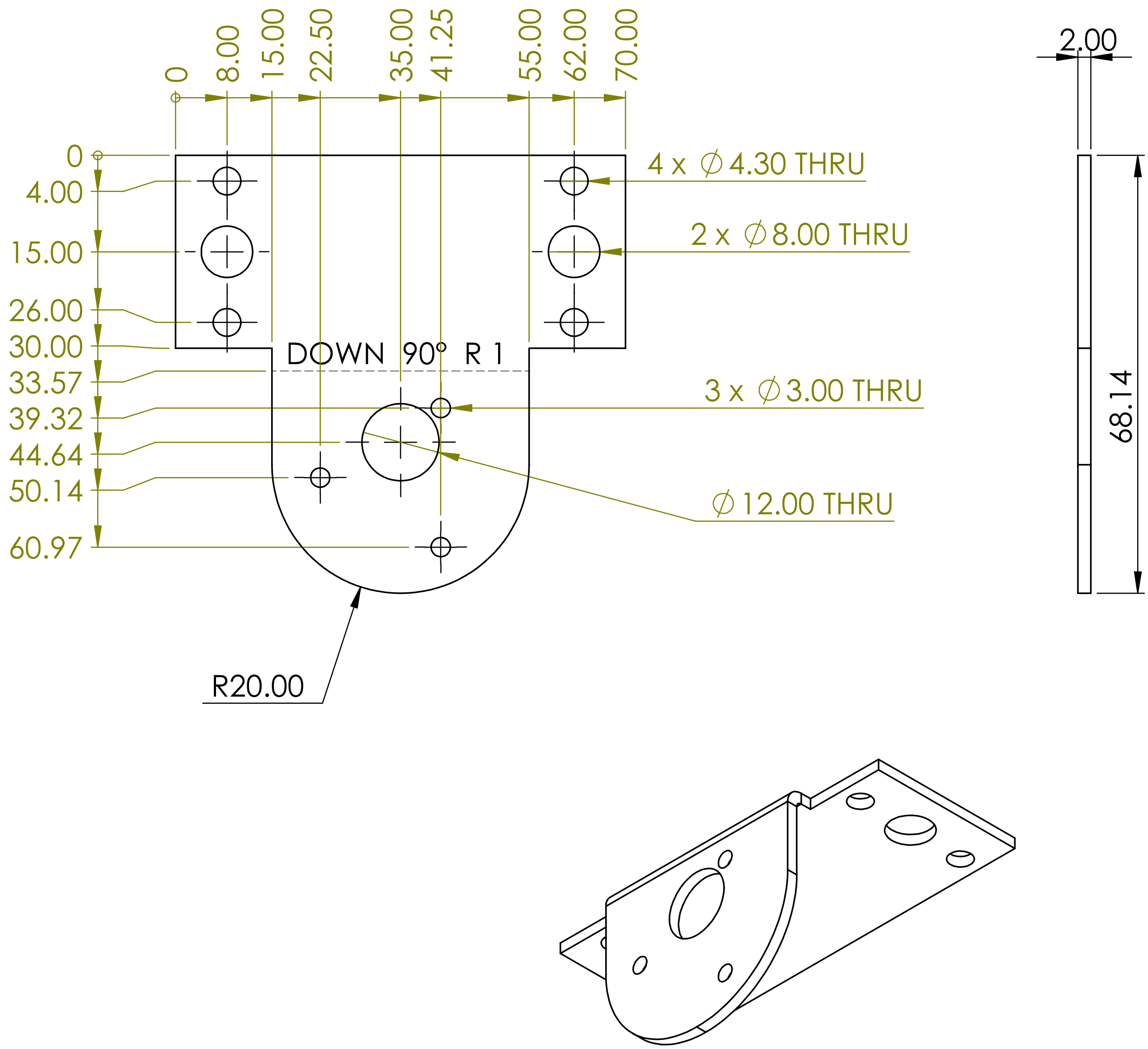

Material : S235 STEEL	Support MOTOR			Designed by : Amine Tbini
Treatment : 2	Parts : Support	Project : Omni robot		Verified and approved by :
Qty : 4	Weight :	General linear tolerance: 0.1 mm	General angular tolerance: 1°	Date: 7/12/2021
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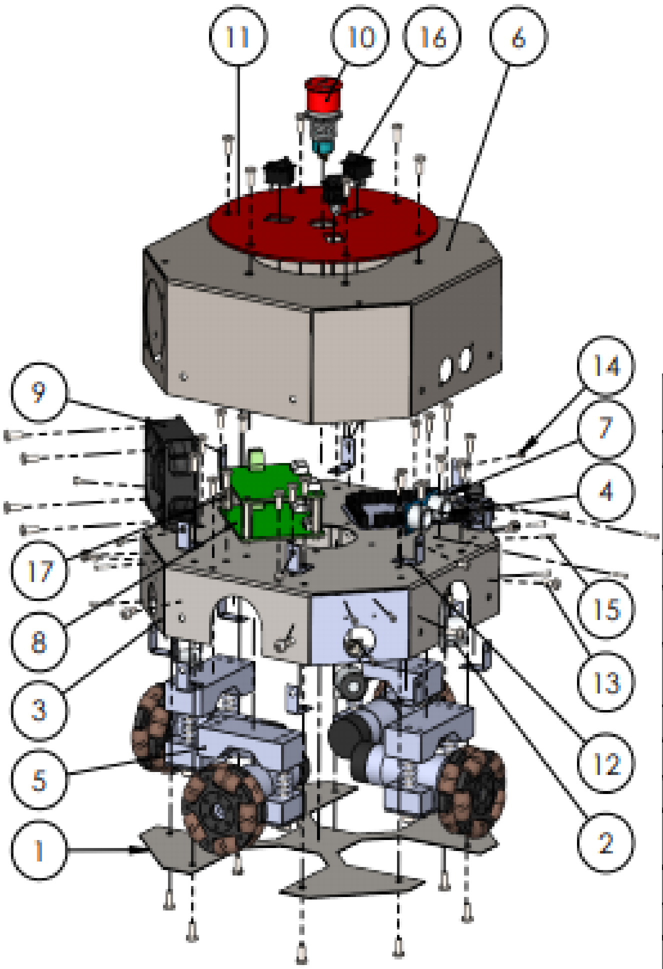


ITEM NO.	PART NUMBER	QTY.
1	Part1	1
2	Grove Electromagnet(2)^Grove Electromagnet	4
3	Part 2	1
4	HC-SR04 Ultrasonic sensor	1
5	omni wheel motor assembly	4
6	cover robot	1
7	ArduinoMega2560	1
8	MD25	2
9	60x60x25 24vDC exhaust fan	1
10	Force stop button	1
11	Part14	1
12	Bracket corner	16
13	ISO 7045 - M4 x 10 - Z - 10N	51
14	ISO 7045 - M3 x 5 - Z - 5N	8
15	ISO 7045 - M2 x 10 - Z - 10N	14
16	RockerSwitch	3
17	M3 x 6mm A-F x 25mm Hexagon Male-Female Threaded Pillar	4

Material :

Treatment :

Qty :

Weight :

Scale : 1:4

Omni Wheel Robot

Parts : Omni wheel Robot

Project : Omni wheel robot

General linear tolerance: 0.1 mm

General angular tolerance: 1°

INSTITUTO POLITÉCNICO DE BRAGANÇA

Designed by : Amine Tbini

Verified and approved by :

Date: 3/15/2021

Page: 1

Format: A4

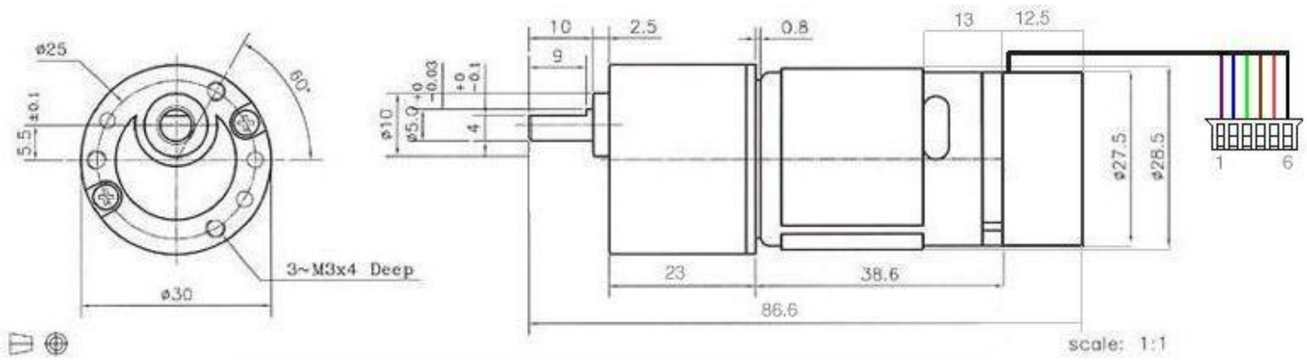
Appendix B

Electronics Components

EMG30, mounting bracket and wheel specification

The EMG30 (encoder, motor, gearbox 30:1) is a 12v motor fully equipped with encoders and a 30:1 reduction gearbox. It is ideal for small or medium robotic applications, providing cost effective drive and feedback for the user. It also includes a standard noise suppression capacitor across the motor windings.

Measurements



Connector

The EMG30 is supplied with a 6 way JST connector (part no PHR-6) at the end of approx 90mm of cable as standard.

The connections are:

Wire colour	**Connection**
Purple (1)	Hall Sensor B Vout
Blue (2)	Hall sensor A Vout
Green (3)	Hall sensor ground
Brown (4)	Hall sensor Vcc
Red (5)	+ Motor
Black (6)	- Motor

Wire colours are from the actual cable.
The hall sensors accept voltages between 3.5v and 20v.
The outputs are open collector and require pull-ups to whatever signal level is required.
On the MD25 they are powered from 12v and pulled up to 5v for the signals.