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A THESIS

Diagnostic The Pipelines By Crawler Robot

FOR

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Mohamed & firas

Dedication

This work is the culmination of hard work and a lot of sacrifice, our thanks go first to the Creator of the universe who endowed us with intelligence, and kept us healthy to complete this year of study. I also want to express my thanks to my family, and more specifically to my mother and my fiancée whom has always supported and pushed me to continue my studies. This present work was made possible thanks to their support.

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Dedication

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information regarding this research & also for their support in completing this endeavour.

Feras ebied

ملخص

مجال الروبوتات هي واحدة من أسرع المجالات الهندسية نموًا. حيث يتم استخدام هذا المجال في معظم الأعمال وخصوصا مجالات الصناعة والامن، على سبيل المثال اللحام الموضعي، تحميل وتفريغ السلع والادوات، والطلاء ... الخ.

المهمة الرئيسية لكل روبوت بشكل أساسي هي القليل من التدخل البشري من بيئات العمل الخطرة الصناعات الثقيلة، في بعض الأحيان يتم استخدامه أيضًا لاكتشاف مكان العمل الذي يتعذر الوصول إليه او الذي يستحيل بشكل عام الوصول إليه من قبل الإنسان.

فحص الأنابيب من الداخل للتأكد من درجة تحمله لتفادي بعض الحوادث الصناعية الخطيرة التي تلوث البيئة او حتى تؤدي خسائر في الأرواح أيضًا هو ضرورة قصوى حيث يتم هذا دوريا. لفحص هذه الأنابيب بشكل جيد يجب أن تكون مزايا الروبوت خاصة للتحقق من مستوى من الانبوب، والهدف من هذا العمل هو دراسة وانجاز روبوت فحص الانابيب من الداخل والبحث على حلول تقنية وتكنولوجية من اجل اختيار أجزاء النظام بموجب المعايير ومحاكاتها على برنامج SolidWorks لضمان دقة وموثوقية المكونات، ثم ننتقل الى مرحلة الإنجاز وتجربة النظام كاملا.

الكلمات المفتاحية:

روبوت, فحص الانابيب, SolidWorks,المجالات الهندسية

Abstract

Robotics is one of the fastest-growing engineering fields. It is currently used for a variety of businesses specifically in manufacturing industries, for example, spot welding, loading, and unloading of tool and workpiece, painting, etc. Primarily robots are designed in such a way that they reduce human intervention from heavy industries and hazardous work environments, sometimes it is also used to discover inaccessible workplace which is generally impossible to access by humans. Inspection of the pipe becomes so more necessary that, bear it may lead to some serious industrial accidents which pollute the environment and loss of human lives also. For inspection of such pipes, robot requirement is a must especially in order to check the corrosion level of pipe, recovery of usable parts from the pipe interior, for a sampling of sludge and scale formation on the pipe internal surface.

Keywords :

Robotics, pipe inspection, SolidWorks, engineering fields

Résumé

La robotique est l'un des domaines de l'ingénierie à la croissance la plus rapide. Il est actuellement utilisé pour une variété d'entreprises spécifiquement dans les industries manufacturières, par exemple, le soudage par points, le chargement et le déchargement d'outils et de pièces, la peinture, etc. Principalement les robots sont conçus de manière à réduire l'intervention humaine des industries lourdes et environnements de travail dangereux, il est parfois également utilisé pour découvrir des lieux de travail inaccessibles auxquels les humains ne peuvent généralement pas accéder. L'inspection du tuyau devient tellement plus nécessaire que cela peut entraîner des accidents industriels graves qui polluent l'environnement et la perte de vies humaines. Pour l'inspection de telles conduites, il est impératif de disposer d'un robot, notamment pour vérifier le niveau de corrosion de la conduite, la récupération des pièces utilisables à l'intérieur de la conduite, pour un prélèvement de boues et la formation de tartre sur la surface interne de la conduite.

Mots clés:

Robotique, inspection de canalisations, SolidWorks, domaines de l'ingénierie

Abbreviations list

PIG Pipe Inspection Gauge

X-Y x and y axis

LCD liquid-crystal display

LED light-emitting diode

USB Universal Serial Bus

SRAM Static random-access memory

KB Kilobyte

RAM Random-access memory

CPU central processing unit

EEPROM electrically erasable programmable read-only memory

TTL Time to live

UART universal asynchronous receiver-transmitter

TCP Transmission Control Protocol

DNS domain name system

SOC system on a chip

ABS Acrylonitrile butadiene styrene

GPIO general-purpose input/output

PCB printed circuit board

APSD Automatic Power Save Delivery

VOIP Voice over Internet Protocol

RF radio frequency

DC direct current

AC alternating current

API application programming interface

HTTP Hyper Text Transfer Protocol

GPS Global Positioning System

RDM résistance des matériaux

3D tree-dimensional

DOF degrees OF LIBERTY

CAD computer-aided design

CAE computer-aided engineering

CNC Computer numerical control

PWM pulse width modulation

BITS basic unit of information in computing and digital communications

OS operating system

SD Secure Digital

HDMI High-Definition Multimedia Interface

IDE Integrated development environment

AVR is a family of microcontrollers developed since 1996 by Atmel

STM is a Swiss-domiciled multinational electronics and semiconductor manufacturer headquartered in Geneva, Switzerland.

C/C++ general-purpose programming language

FTDI Future Technology Devices International

SPI Serial Peripheral Interface

symbols list

ρ Volume mass [kg/m^3]

ν Poisson's ratio

K Bulk modulus [GP_a]

m Mass [KG]

I moment of inertia [mm^4]

$\mathbf{R_a}$,$\mathbf{R_b}$ The reactions [N]

E Young's modulus [GP_a]

$\mathbf{M_a}$ Moment [N.mm]

x, y, z Cartesian coordinate system **[**mm]

$\vec{Y}$ $\vec{Z}$

Y, Z The axes

$\vec{P}$

P Weight [N]

C Couple [N.m]

F Strength [N]

R Ray [m]

P puissance [W]

ω Angular velocity [s^{-1}]

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1. Project Statement

Mobile robotics is a rapidly developing branch of robotic science. Mobile robots are used to perform tasks as support or substitution of human actions and consequently fill the gap between functionality of stationary robots and the need of mobile solutions. Application of mobile robots for supervision, penetration and identification of hazardous, inaccessible or unknown environments is constantly becoming a common practice and an indispensable part of industrial automation. Modern inspection techniques are utilized to substitute human in dangerous tasks and to introduce monitoring of unreachable places. Due to the fact that for each environment requiring inspection, it is recommended to use a dedicated mobile platform, there exist numerous designs of motion unit, sensors, power supplies and control systems, dedicated for mobile robots.

1.1. Defining the problem

The diagnostic of pipelines is an operation for testing and checking the pipelines from any damages, flaws and oxidation that will be located inside the pipelines. This operation is done through a robot called a crawling robot. These robots help us to reach places that humans can't reach to, and also it can work's in a very difficult environments that include high temperatures, wet and dark conditions as well. This project was developed for redesign the electronics control systems one of these **pipeline crawler robots,** utilizing flexible mechanical platform. In this project we use a flexible robot that equipped with crawling motion units that make us moving freely deep inside the pipelines. Although in this one there are electronic boards with mechanical components and provides video feedback to show up what we want.

In user controllable mode, user sends the signal to robot body using WIFI and controls it automatically with android application installed with your phone. User could watch the surroundings through wire camera built in the robot.

1.2. Title of the project

The project entitled as diagnostic the pipelines by crawler robot, and as we can see at (Figure I-1, Figure I-2, and Figure I-3) is the final prototype of our robots for several angles showing the approximate shape of the robot

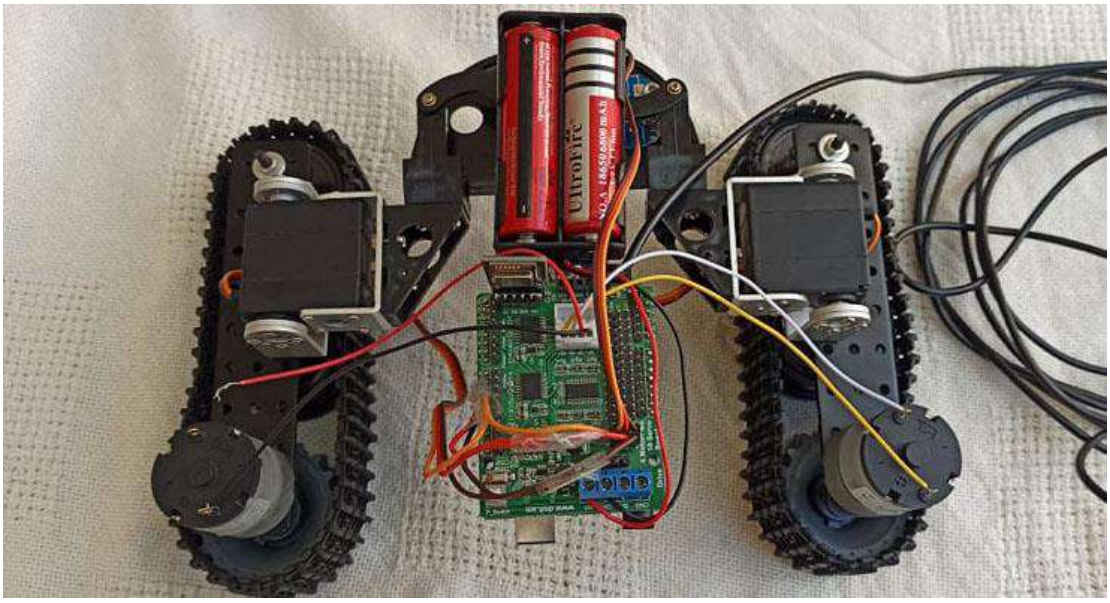


Figure I-1 : top picture of the robot

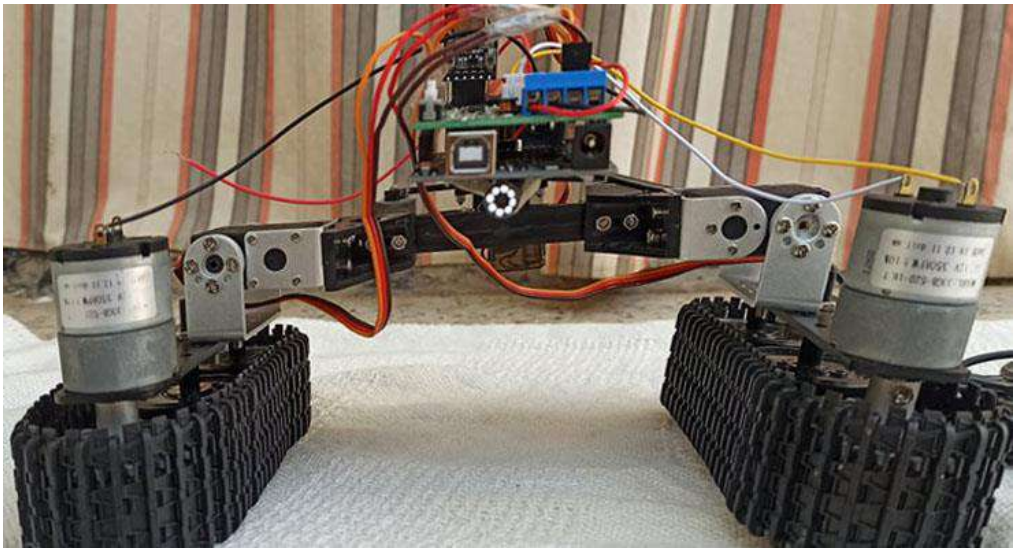


Figure I-2 : picture of the robot with open legs

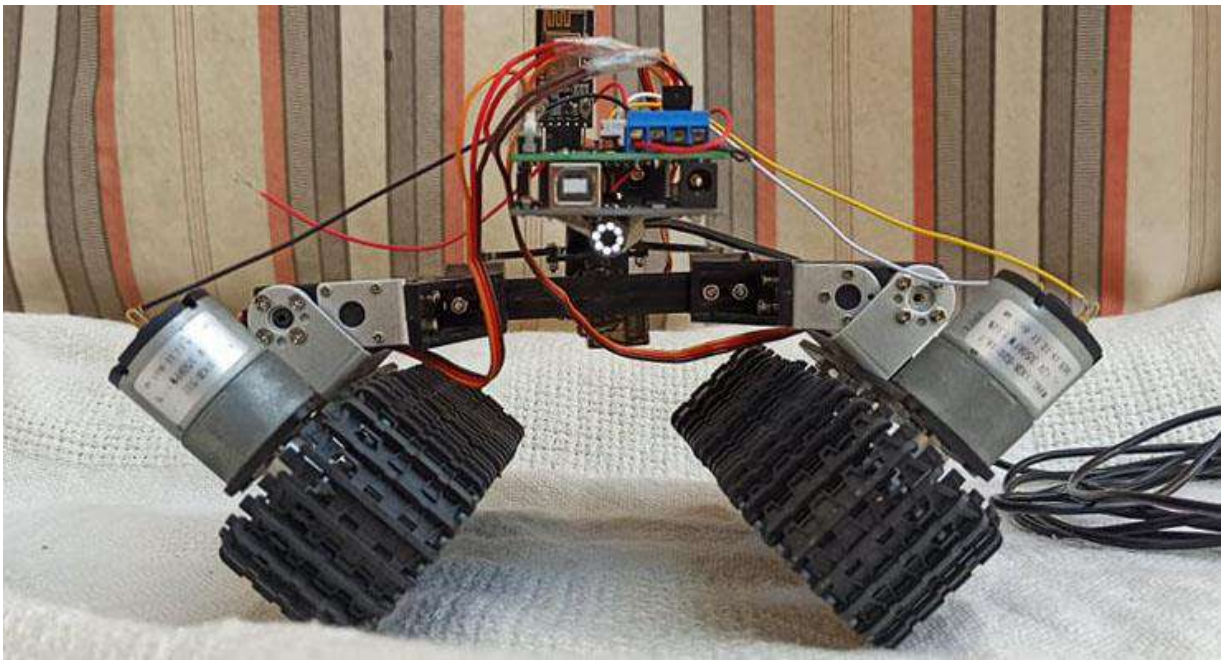


Figure I-3 : picture of the robot with close legs

1.3. Objective of the situation

- Check for any damage or obstruction inside the pipelines
- Reduce the human intervention in dangerous work and inaccessible environments*
- Improve security and efficiency in industrial facilities such as cleaning and maintenance
- The ability to move flexibly, either horizontally or vertically inside the pipelines to facilitate diagnosis

1.4. Pipe defects

Depending on pipe material, different defects can be found in pipelines. defects that are likely to develop in pipes are presented. Depicts coating defect that appeared after long exploitation time, shows corrosion of a steel pipe in a preliminary phase, whereas presents radial deformation of pipe wall caused by excessive ground pressure.



Figure I-4 : Example of Pipe defects[2]

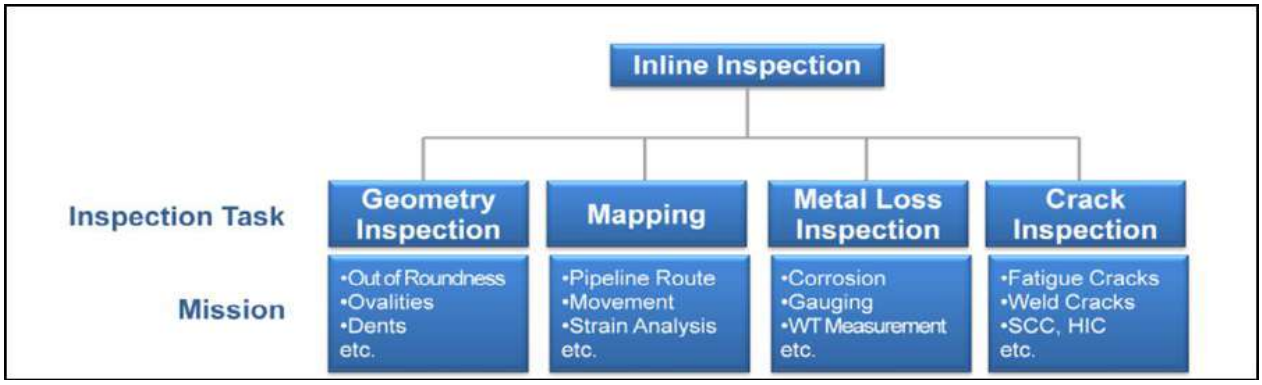
Defects that appear in pipes may be much more drastic and lead to malfunction or blockage of fluid flow .Depicts blockage by corrosion that reduces cross section of pipe, formation of sediments that solidify on the bottom of pipe and penetration of pipe wall by roots that may lead to leaks and breakdowns of pipe walls.

To prevent leaks and excessive damage of pipelines, inspection methods are used to avoid deterioration of pipe structure and plan maintenance procedures. The majority of inspection methods require long distance operation in hardly accessible environments; thus, mobile inspection robots are utilized for these tasks[1].

Table I-1 :milestones in live of a pipeline

Milestone	Possible Flaws
Steel Production	Impurities, cavities, segregation etc.
Plate Production in Steel Mill	Laminations, blisters, scabs, cracks and other rolling defects such as slivers etc.
(Line)Pipe Production in Pipe Mill	Out of roundness, roofing, any flaws/cracks related to the welding technique (ERW or SAW) etc.
Pipeline Construction and Commissioning	Dents, plastic deformation, flaws/cracks related to the girth weld etc.
Pipeline Operations	Geometric Flaws, Metal Loss and Cracks, Pipeline Movement etc.
Pipeline Rehab and Repair	Flaws introduced during a rehab or repair operation

Figure I-5 : Inline inspection tasks[3]



1.5. General challenges faced by the pipe-crawlers

- The unstable movement of the robot due to the slippery inner pipe walls
- Constant monitoring of the robot's location to determine its location
- bends in the pipeline and moving with difficulty
- Irregular gas flow and turbulence
- Wear and tear due to long distance travel inside the pipelines
- The presence of factors that cause robot wear

1.6. Tangible benefits

1. Very useful for cleaning the pipelines
2. Flexible, it allows the robot to move smoothly into different types of pipes
3. The robot can travel horizontally through the pipes
4. The robot can travel vertically through the pipes

1.7. –Intangible benefits

1. Reducing human effort
2. The operating cost is low compared to other methods
3. Reducing the risk of failure
4. These types of robots provide high accuracy

1.8. Field application of our project

1.8.1. Oil Refineries

The mineral oil industry can benefit from the transportation, distribution and treatment of mineral oils, and it also helps to protect the environment. Our robot does exactly this.

1.8.2. Nuclear Power Factories

This type of facility must be at the highest level of security and protection before considering any other interests such as commercial utility. Regular and continuous inspections of pipe systems must be performed and this type of robots is widely used.

1.8.3. Gas Pipelines

Robots that inspect and check natural gas pipeline systems of this type are deployed for inspection and maintenance purpose; these robots are very suitable this purpose.
Especially that has many bends, pipe branches and vertical sections where we can move flexibly within the pipes, whether the movement is horizontal or vertical.

1.8.4. City Sewer Pipe Systems

Underground sewer systems are responsible for collecting waste and transporting it from cities to their dump sites -the sea most of the time-, these sewer systems are owned by cities or communities. The systematic inspection of these large networks is an expensive and complex process at the same time.

1.8.5. Conventional power plants

By taking advantage of the NDT inspection methods that our robots offer, defects and faults can be avoided increasing the 'up and running' operational time of all kinds of pipe systems. Worldwide, many power plants already use our robots to do just this.

1.8.6. Chemical and petrochemical plant

It is of course vital to continually reduce the risks brought about by the manufacture, transport and storage of chemicals. This means that the possible dangers need to be examined and the necessary testing and inspections carried out in order to avoid or at least lessen and contain them. The use of our robots has become obligatory in many well-known companie [4].

1.9. Limitation of pipe inspection robot

Pipe inspection robots have such limitations as their ability to turn in a T-shaped pipe or move in a plug valve

- The robot does not work in water.
- The robot works only in empty pipe.
- The robot can work on horizontal pipes that has minimum diameter of **190mm**
- The robot can work on vertical pipes that has minimum diameter of **280mm** and maximum diameter of **329mm**

1.10. Features of pipe line inspection robot

1.10.1. Feasibility

We take feasibility study plays the major role in the success of the project. Feasibility study is an analysis of how a project can be completed successfully, accounting for factors that affect it such as technical, operational, economical, and schedule factors. The project manager uses this feasibility study to determine the favourable and non-favourable outcomes of the project before investing a considerable amount of time and money into the project

1.10.2. Technical Feasibility

The different system used in the pipeline inspection robot can be designed. There is complexity in designing the all system. The components and the hardware for this project are not easily available. The all systems can be easily implemented in the pipeline inspection robot .

1.10.3. Operational Feasibility

The operational feasibility mainly focusses on the evaluation which will analyse the system that how well the system is working. And how to deal with the changes occurs in the system during the development period. The operational feasibility includes the following design-parameters

1.10.4. Reliability

We check how much the system is reliable in terms of hardware that can perform consistently according to its specification.

1.10.5. Maintainability

We try to know how a product can be maintained in order to correct the defects or their cause, how to replace the faulty components without replacing the working components.

1.10.6. Supportability

We also ensure that the project can support multi platforms without any problem .

1.10.7. Usability

We ensure that how the system is learnable to the user. It must be easy to learn and use for the success of the project .

1.10.8. Sustainability

We ensure that the product is sustainable enough, so that it meets the need of present generation without compromising the need of the future generation.

1.10.9. Affordability

We ensure that the project is affordable to almost all the target users.

1.10.10. Information

System provides the service to the end user with timely, relevant, accurate and usefully formatted information. Since the user provides the input in the form to get the generated code. The information handling in the current system is done manually.

1.10.11. Control

It associated with the control and system security for the data control and the transaction of data. The system that has to be developed has enough control to resist the system to be hacked, or people who are fraud and it provide enough security for the information available on the system.

1.10.12. Service

This determines whether the reliable services are provided to the users and whether the system is acceptable or not. This will also check whether there is a scope of expansion or improvement in the system or not. [4]

1.11. Methodology

The theoretical part of this project collects information and notes on similar projects that have already been implemented. The basic concepts of the model are gathered and an alternative solution is proposed. Then a project is conceptualized which is effective and inexpensive during implementation. The necessary equipment and components are chosen according to the required standards. Finally, the system was simulated, the results were obtained for subsequent accounts,

and they were improved accordingly. The following algorithm diagram shows the steps used to solve the pipe inspection problem robot

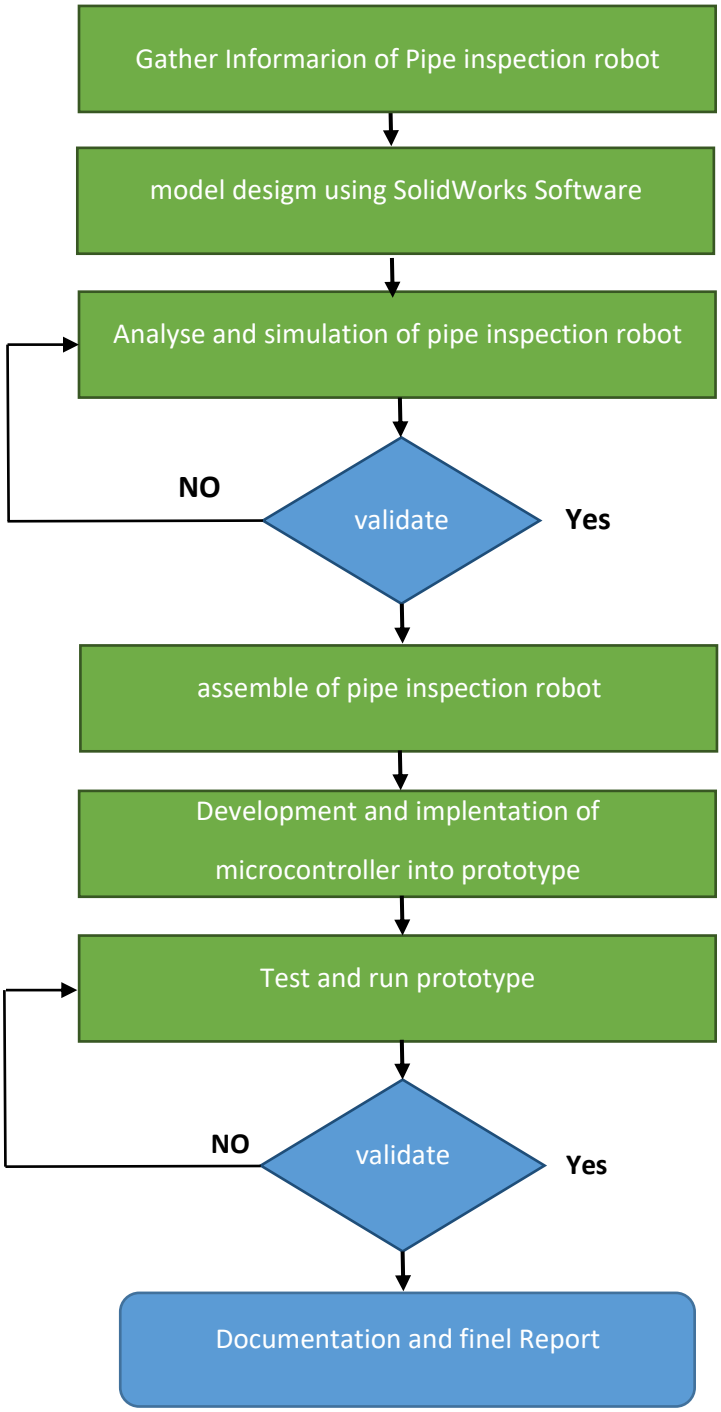


Figure I-6 : Methodology of the project

1.12 CONCLUSION

In this chapter we got to know the process **diagnostic of pipelines**, the aim of this process and the problems facing these pipelines. And also discussed the defects that pipelines suffered from. Then we are exposed the multiple challenges facing our crawling robot, and we touched up the fields in which it uses the multiple processes of the robot, and the benefits obtained from the project implementation.

Finally, the methodology that we worked on in terms of collecting the information that related to the project, its relatively low cost and the steps that address the problem of diagnosis pipelines.

2. Literature Review

2.1. Introduction

In this chapter, we will mention the different types of different pipeline inspection robots that have been developed, and we will look at their structure and mechanism of action. We will also talk about the different classifications of inspection robots, depending on the type of tubes used and the environment in which it can operate and the ability to adapt them to the surrounding conditions. Information that we could collect from previous work and projects can be important for conceptual development, comparative analysis, and model / prototype development of data analysis and computation.

2.2. Different types of robots

2.2.1. PIG [Pipe Inspection Gauge]

These robots PIG is mainly used for removal of deposited wax and slug into the pipeline, they are powered by propellants such as gas or water. These pipe inspection gauge robots are used to accomplish a variety of tasks such as thickness measurement of pipelines, detection of corrosion & erosion, opens choking of pipelines [5].



Figure II-1 : PIG inspection robot

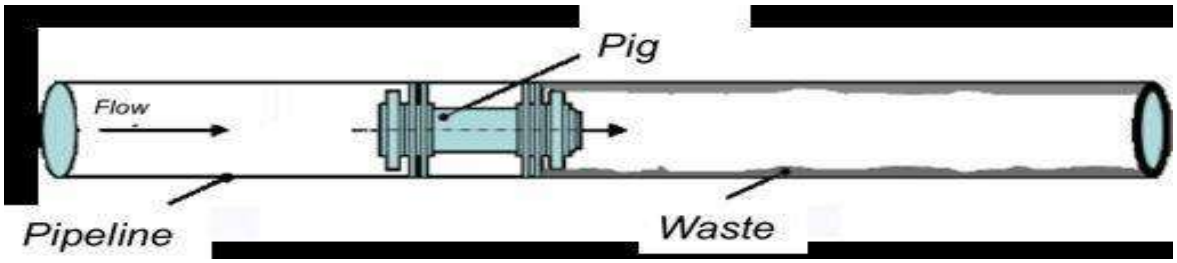


Figure II-2 : how PIG robot works [6]

2.2.2. The Inchworm Robot

These robots have a very flexible movement as they can pass the folded pipeline. This robot has small feet that help it connect to the inner surface of the pipe and provides the necessary stabilization force for movement. It is especially used in pipes with small diameters as it adapts to the diameter of the pipes during diagnosis, and is often used to detect gas leaks [7]-[8].

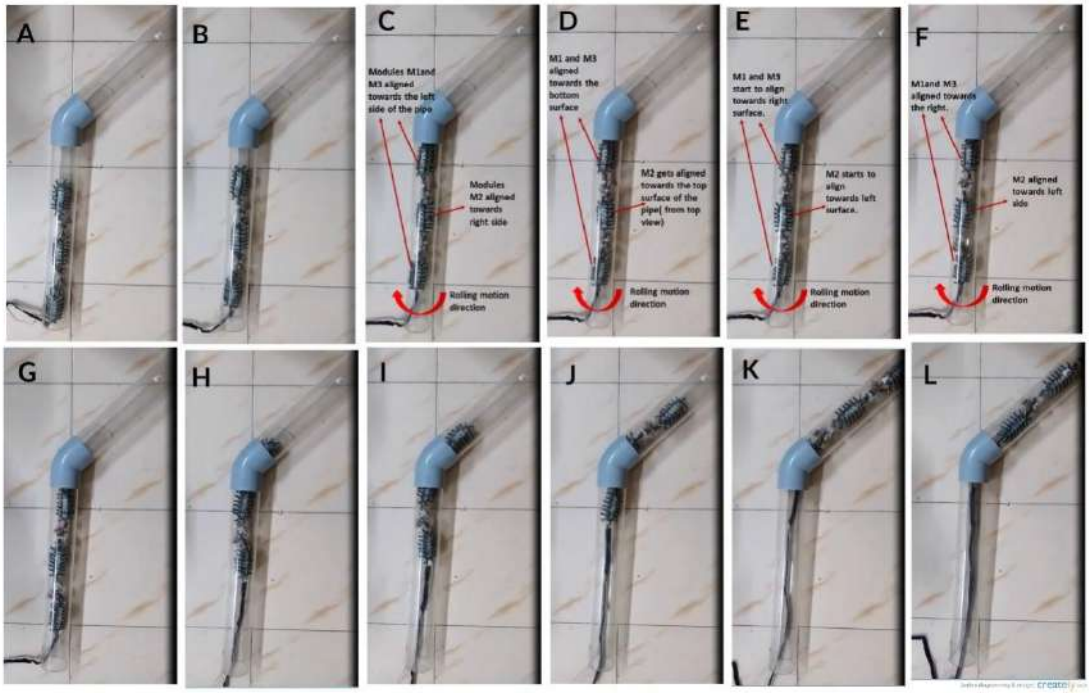


Figure II-3 : The Inchworm Robot

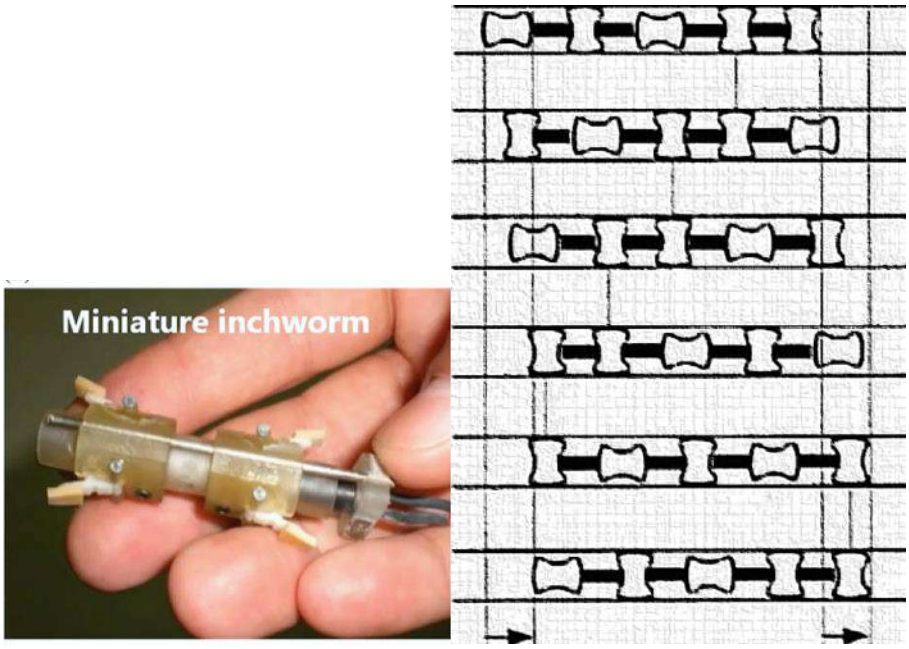


Figure II-4 : How the Inchworm Robot works [9]

2.2.3. Serpent Type Robot

This type of robots known as a micro robot can work inside tubes that range in diameter from 40 mm to 90 mm, and is able to move at the T-junction. Where it can adapt to tubes of different diameters. And this kind of robot may be susceptible to accidental falls[10].

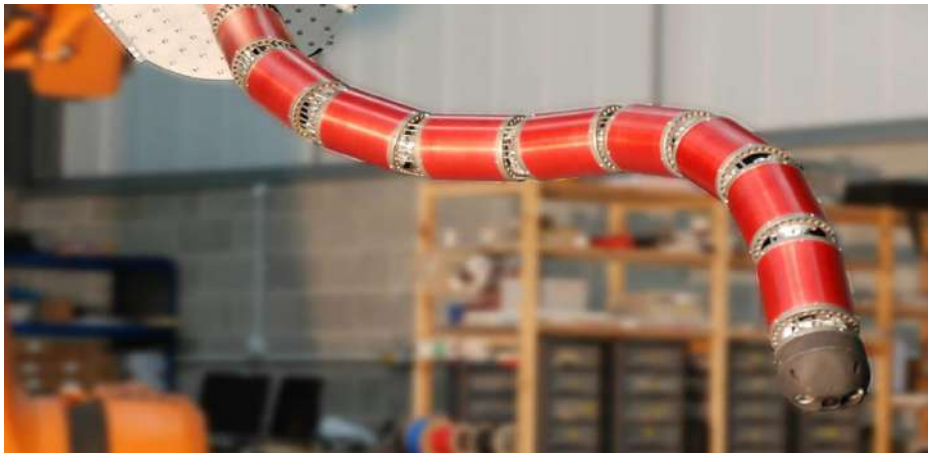


Figure II-5 : Serpent Type Robot

2.2.4. –Simple Wheeled Robot

This robot moves inside the tube using wheels without any force on the wall of the tube, unlike the crawler type robots as we will look at next. There are different types of these robots as: RESPONDER, HAWK, KATE, etc. Wheel robots are one of the most commonly used techniques for driving pipe-robots. These robots are generally used for large diameter pipes such as drainage pipes. They are also good for variable pipe diameters and high-speed driving. Maximum speed of such robots recorded in open literature is around 163 mm/s (approximately about 0.6 km/h). In fact, for medium-sized pipes, the speed is even low about 30–80 mm/s[11].

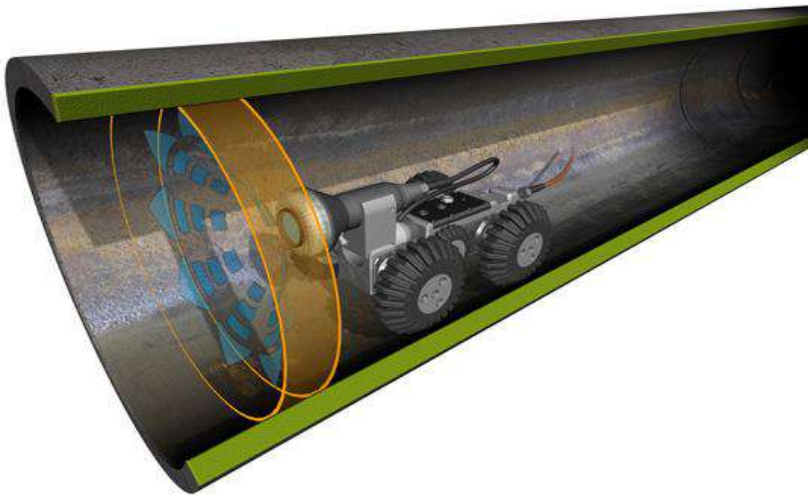


Figure II-6 : Simple Wheeled inspection Robot

2.2.5. Crawler Robots

In this model, three similar kinds of wheel assemblies, circumferentially 120° apart from each other are used in the robot. The height of the wheel set can be varied by adjusting individual springs for each wheel. The springs are used to maintain traction force on the wheels and also to self-adjust the wheels to pass through the varying diameters of the pipelines.

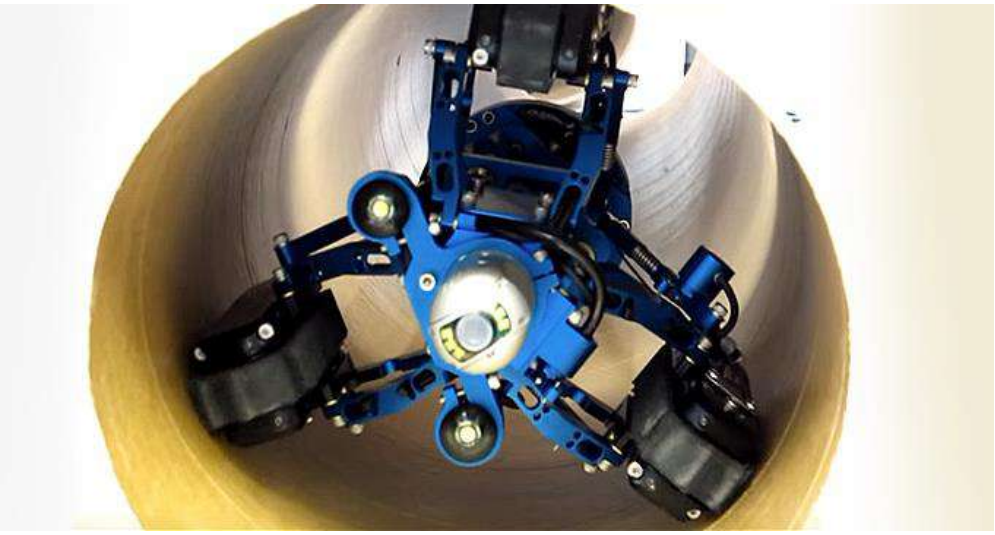


Figure II-7 : 3 Crawlers inspection Robots

There is another model of crawling robot similar to the one we mentioned previously, but in this one we have two kinds of wheel assemblies where this robot adapts according to the diameter and type of the pipeline. This type that we talk about in this project in detail [1].



Figure II-8 : 2 Crawlers inspection Robots

2.3. Mechanism of the crawler

The crawler mechanism has a body that is fixed to a spaced track apart by axles that extend through the body. Track assemblies are moved in two different directions relative to each other, to enable the width of the crawler mechanism to be changed. Spacers are provided for use in locating the track assemblies in predetermined positions on the axles. The track assemblies are driven by servo motors that can move relative to the body with a connected track assembly, the servo motors are drivingly connected to the associated track assemblies by transmissions located between upper and lower drags and within lateral frontier of the correlating track assemblies [12] [13].

2.3.1. Tracks

Is always believed that tracks have a better ability to move than wheels. Anyone who designs a high-mobility vehicle must use the tracks, as the robot with tracks can be moved through the situations easily where the wheeled robots face many obstacles.

The tracks are characterized by having a continuous surface contacting the ground, and this is what produces the benefits of the tracks. One of the advantages of the truck that it has a long surface with a width that is approximately larger than the wheels, which creates a great pressure on the ground. This reduces the internal impact on the surface of the pipes in terms of scratching or causing damage to them, and provides more space for the tread in terms of increasing the number of teeth contact with the ground.

Different geometry track systems use more flexible track than others, allowing them to bend around the sprocket and idler wheels and bend in both directions [14].



Figure II-9 : the Tracks

2.3.2. Sprockets

The simplest way to increase negotiable obstacle height is to make the front wheel of the system larger. This method does not complicate the system; in fact, it simplifies this system by eliminating the need for support rollers along the path of the track.
When the sprocket position is in the forward position of the robot, reduce the chance of damaging the sprocket and other parts.

The sprocket is attached to the track through internal holes in the track, so that they overlap symmetrically so the sprocket moves the track to properly move [14]-[15].



Figure II-10 : The sprockets

2.3.3. The Bearing Wheel:

The utility model discloses a suspension-type bearing wheel system for a crawler unit of a small-sized combined harvester, and the suspension-type bearing wheel system comprises a bearing wheel shaft, wherein the inner side end of the bearing wheel shaft is fixedly arranged on a longitudinal beam of a harvester frame, and a bearing wheel is hung on the outer side end of the bearing wheel shaft. The suspension-type bearing wheel system is firstly adopted in the crower unit of the combined harvester; and suppleness in structure and reliability in running can be realized. The bearing wheel only has one sealing surface, so that the muddy water entering a bearing can be effectively reduced, the rust of the bearing can be reduced, and the service life of the crawler unit can be improved [16].



Figure II-11 : The Baring Wheel

2.4. Guide ways bearing slider

A linear-motion bearing or linear slide is a bearing designed to provide free motion in one direction. There are many different types of linear motion bearings.

Motorized linear slides such as machine slides, X-Y tables, roller tables and some dovetail slides are bearings moved by drive mechanisms. Not all linear slides are motorized, and non-motorized dovetail slides, ball bearing slides and roller slides provide low-friction linear movement for equipment powered by inertia or by hand. All linear slides provide linear motion based on bearings, whether they are ball bearings, dovetail bearings, linear roller bearings, magnetic or fluid bearings. X-Y tables, linear stages, machine slides and other advanced slides use linear motion bearings to provide movement along both X and Y multiple axis.

Rolling-element bearings are manufactured in two forms: ball bearing slides and roller slides and we can mention from them [16].

2.4.1. Ball Baring slides :

Also called "ball slides," ball bearing slides are the most common type of linear slide. Ball bearing slides offer smooth precision motion along a single-axis linear design, aided by ball bearings housed in the linear base, with self-lubrication properties that increase reliability. Ball bearing slide applications include delicate instrumentation, robotic assembly, cabinetry, high-end appliances and clean room environments, which

primarily serve the manufacturing industry but also the furniture, electronics and construction industries. For example, a widely used ball bearing slide in the furniture industry is a ball bearing drawer slide.



Figure II-12 : Ball Baring slides

2.4.2. Roller slides

Also known as crossed roller slides, roller slides are non-motorized linear slides that provide low-friction linear movement for equipment powered by inertia or by hand. Roller slides are based on linear roller bearings, which are frequently criss-crossed to provide heavier load capabilities and better movement control. Serving industries such as manufacturing, photonics, medical and telecommunications, roller slides are versatile and can be adjusted to meet numerous applications which typically include clean rooms, vacuum environments, material handling and automation machinery.



Figure II-13 : Roller slides

2.4.3. Dovetail slides:

Dovetail slides, or dovetail way slides are typically constructed from cast iron, but can also be constructed from hard-coat aluminium, or stainless steel. Like any bearing, a dovetail slide is composed of a stationary linear base and a moving carriage. a Dovetail carriage has a v-shaped, or dovetail-shaped protruding channel which locks into the linear base's correspondingly shaped groove. Once the dovetail carriage is fitted into its base's channel, the carriage is locked into the channel's linear axis and allows free linear movement. When a platform is attached to the carriage of a dovetail slide, a dovetail table is created, offering extended load carrying capabilities [17].



Figure II-14 : Dovetail slides

2.5. The basic mechanical structure of our robot

When the mechanical structure of the robot was designed, several criteria and measurements were taken into account: adaptive driving mechanism, possibility of operation in pipelines of different diameters, movement in vertical pipelines, movement on flat surfaces, remote operation, and integration with a cable video camera. And also, to reduce the size of the robot and enhance its ability to man oeuvre on rough terrain or flat surfaces, the robot is designed as a single piece and is characterized by a solid external structure.

We used servo motors to make our robot open with specific angel and diameter to make traveling and crawling the pipe lines easier

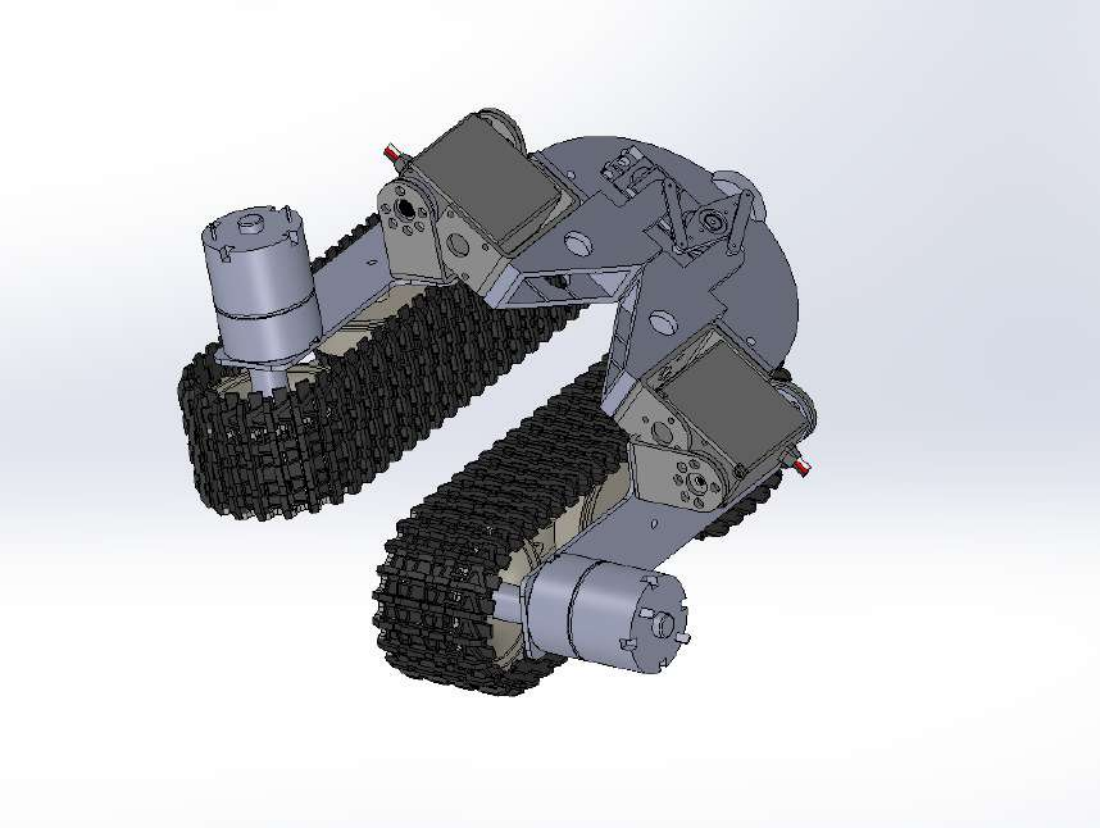


Figure II-15 : basic mechanical structure of our robot

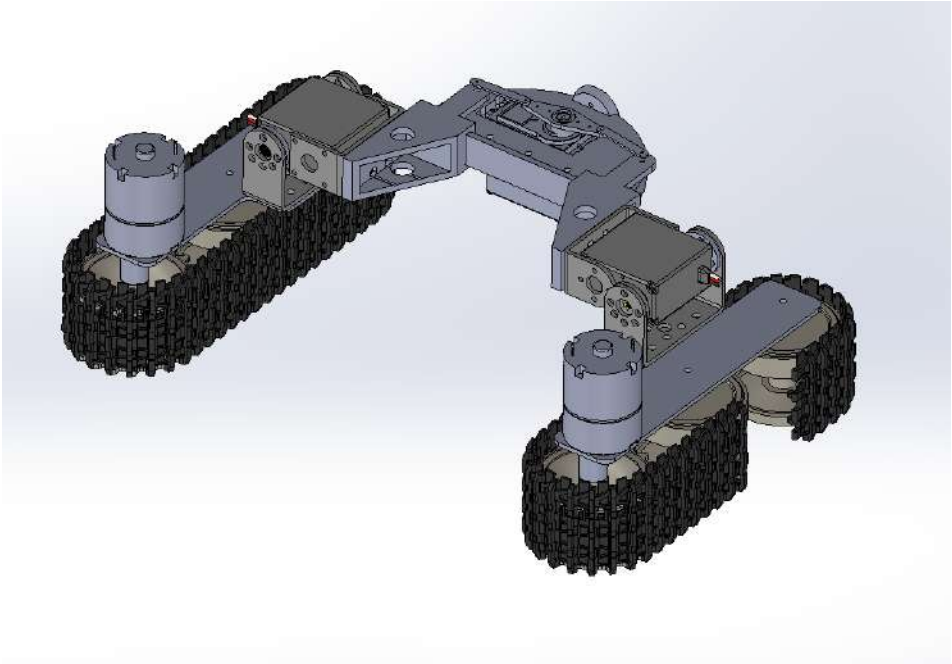


Figure II-16 : basic mechanical structure of our robot open

Our slider can travel from 56 to 105 mm like we can see in the next figure, that can make Our robot move in vertical pipelines

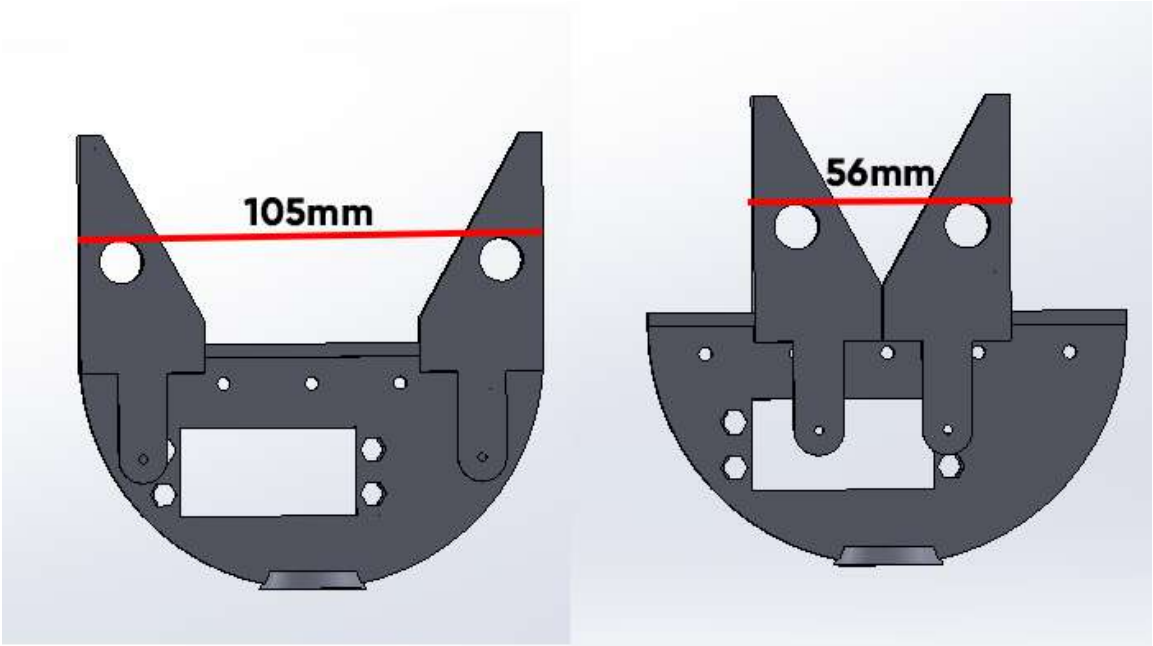


Figure II-17 : the robot support slider

And with adding the crawler and rotation parts for each side of the support we can tell that the robot can travel from 190mm to 329mm and 0 to 180 Degrees

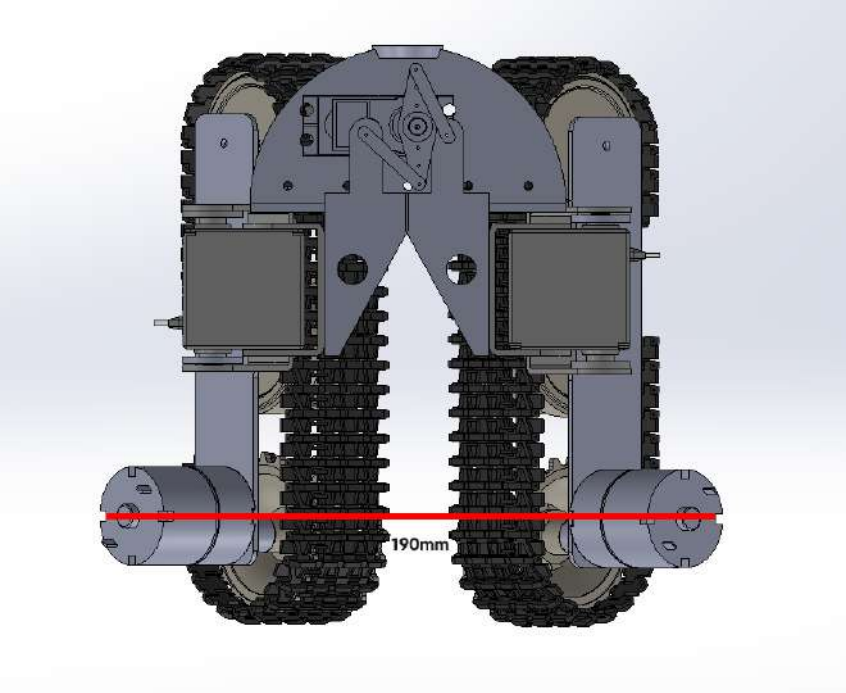


Figure II-18 : the robot arm

2.6. Conclusion

Pipe inspection has been used in many pipe inspection applications over the past few decades to meet different operating standards. Robots are made in different shapes to satisfy the purposes for which they are made. There are many types of robots such as the Inchworm robot that can pass through the narrow tubes. There are also robots that take a simpler form, such as wheeled robots.

Robots play an important role in the maintenance and repair of pipelines, some of which are designed to achieve specific tasks for pipes with fixed diameters, while others adjust their structure to fit the pipes are being tested. These robots are implemented using the best available technologies.

A modular design was considered for easily adapted to new environments with small changes. Presence of obstacles within the pipelines is a difficult issue. In the proposed mechanism the problem is solved by increasing the flexibility of the mechanism.

Comparative analysis

3. Introduction

A microcontroller is a self-contained system with peripherals, memory and a processor that can be used as an embedded system. Most programmable microcontrollers that are used today are embedded in other consumer products or machinery including phones, peripherals, automobiles and household appliances for computer systems. Due to that, another name for a microcontroller is "embedded controller." Some embedded systems are more sophisticated, while others have minimal requirements for memory and programming length and a low software complexity. Input and output devices include solenoids, LCD displays, relays, switches and sensors for data like humidity, temperature or light level, amongst others.

3.1. Types of microcontrollers

There are several different kinds of programmable microcontrollers at Future Electronics. We stock many of the most common types categorized by several parameters including Bits, Flash size, RAM size, number of input/output lines, packaging type, supply voltage and speed.

Programmable microcontrollers contain general purpose input/output pins. The number of these pins varies depending on the microcontroller. They can be configured to an input or an output state by software. When configured to an input state, these pins can be used to read external signals or sensors. When they are configured to the output state, they can drive external devices like LED displays and motors.

Future Electronics has a wide range of programmable microcontrollers, including pic, low power, and LCD, USB and wireless microcontrollers from several manufacturers. Once you decide if you need 8-bit, 16-bit general purpose, 16-bit digital signal controllers or 32-bit microcontrollers, you will be able to choose from their technical attributes and your search results will be narrowed to match your specific microcontroller application needs.

Programmable microcontrollers are designed to be used for embedded applications, unlike microprocessors that can be found in PCs. Microcontrollers are used in automatically controlled

devices including power tools, toys, implantable medical devices, office machines, engine control systems, appliances, remote controls and other types of embedded systems [18]-[19].

3.1.1. Raspberry Pi

One of the smallest computers with Linux OS on board. The architecture of Raspberry Pi is based on an ARM processor. This tiny PC includes a lot of modern technologies built together to provide another level in hardware and software developing. The board has a high performance, in comparison to its' small size. One of the best things in Raspberry Pi is a great community support – hundreds and thousands of people all around the Globe. In the bookstores and libraries, we can already find a special literature based on this board and over the Internet a huge number of tutorials, FAQs and forum topics available. The very low price comes as another great advantage of this system (approx. 40 Euros for a board and 90 Euros for a development kit). To use a Raspberry Pi, we would need some additional components: SD Card, HDMI Cable, Wi-Fi modem, Power Supply and more. This powerful board would be even more than enough for our project, but into it the board would not use all of its features and power. This board could be good for a project which is much bigger than ours. And it would also be better for a people programming in Python. During our studies here we learnt Android and Windows Phone systems, meaning that it would be better for us to use Java and C programming languages. We can apply the knowledge straight to the real project [20]-[21].



Figure III-1 : Raspberry Pi board

3.1.2. ARM

High performance microcontrollers. Used in Raspberry PI, phones and professional projects. Deficient tutorials and documentation compared to AVR microcontrollers. Most of IDEs are paid. Need special programmer. Not suitable for our project because of high additional costs and low support for beginners [22].



Figure III-2 : ARM board

3.1.3. AVR

Small, cheap and very popular version of microcontrollers. May be programmed in Assembler or C language. The AVR family may cause some inadmissible problems for us: Internet connection, communication by sockets, etc [23].

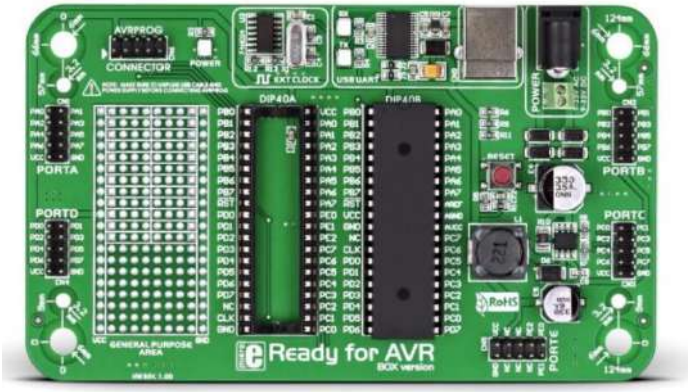


Figure III-3 : AVR board

3.1.4. Netduino

Rather new and growing community but still hard to find different tutorials on the connection between different components.

Also, it requires additional Wi-Fi shield to establish connection between the board and the phone (we decided on the wireless connection). Based on STMicro 32-bit microcontroller. The platform uses NET Micro Framework [24].



Figure III-4 : Netdiono board

3.1.5. Arduino

Arduino has been placed on the list of the biggest invention in electronics of 21st century. Friendly IDE based on C/C++ programming language. Big community, thousands of tutorials, dozens of board choices and one of the most important – it is OPEN SOURCE.

We chose the newest one – Arduino UNO. The board has ATmega32u4 microcontroller and AR9331 processor. Microcontroller controls Arduino board and processor to have access to Wi-Fi and USB host. Devices communicate by bridge. It provides ability to run shell scripts, communicate with network interface and receive information from AR9331[25].



Figure III-5 : Arduino uno board

3.2. Choosing the Right Microcontroller

When we search for the right microcontroller for our project, we start to filter the results by the number of Bits required. We carry the following size microcontrollers:

- 8-bit Microcontrollers
- 16-bit Digital Signal Controllers
- 16-bit General Purpose Microcontrollers
- 32-bit Microcontrollers

Once we choose the microcontroller size, we can narrow them down by various attributes: by RAM size, Flash size, number of input lines, speed and supply voltage to name a few. And we will be able to find the right power supplies, shields ...etc using these filters.

3.2.1. Arduino

Arduino is an open-source prototyping platform based on easy-to-use hardware and software. Arduino board are able to read inputs - light on a sensor, a finger on a button - and turn it into an output - activating a motor, turning on an LED.

You can tell your board what to do by sending a set of instructions to the microcontroller on the board. To do so you use the Arduino programming language (based on Wiring), and the Arduino Software (IDE), based on Processing.

Over the years Arduino has been the brain of thousands of projects, from everyday objects to complex scientific instruments. A worldwide community of makers - students, hobbyists, artists, programmers, and professionals - has gathered around this open-source platform, their contributions have added up to an incredible amount of accessible knowledge that can be of great help to novices and experts alike.

Arduino contains on-board power supply, USB port to communicate with PC, and a microcontroller chip. It simplifies the process of creating any control system by providing the

standard board that can be programmed and connected to the system without the need to any sophisticated PCB design and implementation. It is open source hard ware, anyone can get the details of its design and modify it or make his own one himself [25].

3.2.2 Micro-Controller

It is a micro-computer. As any computer it has internal CPU, RAM, and IOs interface. It is used for control purposes, and for data analysis. Famous microcontroller manufacturers are Microchip, Atmel, Intel, Analog devices, and more [26].



Figure III-6 : Micro controller

3.2.3. Power

The Arduino UNO can be powered via the Mini-B USB connection, 6-20V unregulated external power supply (pin 30), or 5V regulated external power supply (pin 27). The power source is automatically selected to the highest voltage source.

3.2.4. Memory

The ATmega168 has 16 KB of flash memory for storing code (of which 2 KB is used for the boot loader); the ATmega328 has 32 KB, (also with 2 KB used for the boot loader). The ATmega168 has 1 KB of SRAM and 512 bytes of EEPROM (which can be read and written with the EEPROM Library); the ATmega328 has 2 KB of SRAM and 1 KB of EEPROM.

3.3. Communication

The Arduino UNO has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega168 and ATmega328 provide UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). An FTDI FT232RL on the board channels this serial communication over USB and the FTDI driver (included with the Arduino software) provide a virtual com port to software on the computer. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board. The RX and TX LEDs on the board will flash when data is being transmitted via the FTDI chip and USB connection to the computer (but not for serial communication on pins 0 and 1). A Software Serial library allows for serial communication on any of the Nano's digital pins. The ATmega168 and ATmega328 also support I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus; see the documentation for details. To use the SPI communication, please see the ATmega168 or ATmega328 datasheet.

3.4. Programming

Arduino programs are written in the Arduino Integrated Development Environment (IDE). Arduino IDE is a special software running on the system that allows to write sketches (synonym for program in Arduino language) for different Arduino boards.

The Arduino programming language is based on a very simple hardware programming language called processing, which is similar to the C language. After the sketch is written in the Arduino IDE, it should be uploaded on the Arduino board for execution [25].

3.5. Why ARDUINO?

Thanks to its simple and accessible user experience, Arduino has been used in thousands of different projects and applications. The Arduino software is easy-to-use for beginners, yet flexible enough for advanced users. It runs on Mac, Windows, and Linux. Teachers and students use it to build low cost scientific instruments, to prove chemistry and physics principles, or to get started with programming and robotics. Designers and architects build interactive prototypes, musicians and artists use it for installations and to experiment with new musical instruments. Makers, of course, use it to build many of the projects exhibited at the Maker Faire, for example. Arduino is a key tool to learn new things. Anyone - children, hobbyists, artists, programmers - can start tinkering just following the step by step instructions of a kit, or sharing ideas online with other members of the Arduino community.

There are many other microcontrollers and microcontroller platforms available for physical computing. Parallax Basic Stamp, Net media's BX-24 and many others offer similar functionality. All of these tools take the messy details of microcontroller programming and wrap it up in an easy-to-use package. Arduino also simplifies the process of working with microcontrollers, but it offers some advantage for teachers, students, and interested amateurs over other systems:

- **Inexpensive**

  Arduino boards are relatively inexpensive compared to other microcontroller platforms. The least expensive version of the Arduino module can be assembled by hand
- **Cross-platform**

  The Arduino Software (IDE) runs on Windows, Macintosh OSX, and Linux operating systems. Most microcontroller systems are limited to Windows.
- **Simple, clear programming environment**

  The Arduino Software (IDE) is easy-to-use for beginners, yet flexible enough for advanced users to take advantage of as well. For teachers, it's conveniently based on the Processing programming environment, so students learning to program in that environment will be familiar with how the Arduino IDE works.

- **Open source and extensible software**

  The Arduino software is published as open source tools, available for extension by experienced programmers. The language can be expanded through C++ libraries, and people wanting to understand the technical details can make the leap from Arduino to the AVR C programming language on which it's based. Similarly, you can add AVR-C code directly into your Arduino programs if you want to.

- **Open source and extensible hardware**

  The plans of the Arduino boards are published under a Creative Commons license, so experienced circuit designers can make their own version of the module, extending it and improving it. Even relatively inexperienced users can build the breadboard version of the module in order to understand how it works and save money.

3.6. Wi-Fi MODULE (ESP8266)

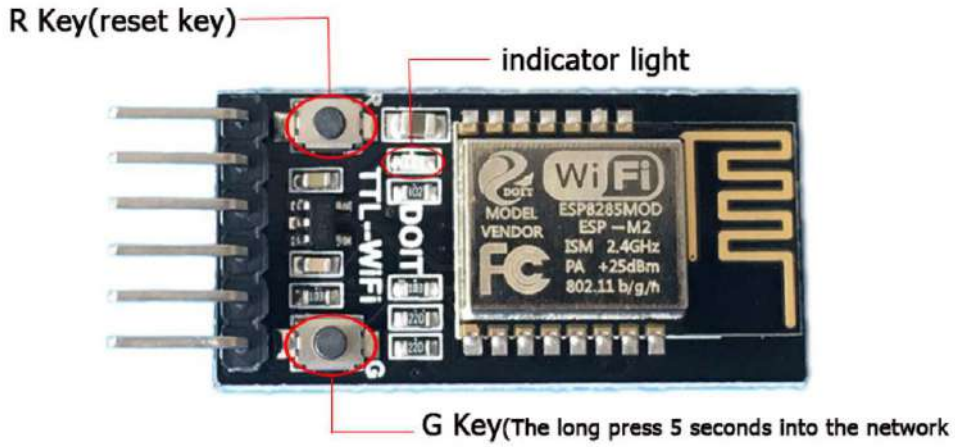


Figure III-7 : ESP8266 module

3.6.1. Description of ESP8266 module

ESP8266 (TTL-Wi-Fi module) is designed and developed based on ESP-M2 Wi-Fi module from our company Shenzhen Doctors of Intelligence & Technology Co., Ltd., which is extracted the TTL and other pins. Importantly, the TTL-Wi-Fi is already built-in the serial transparent transmission firmware, which can realize the transparent transmit the data to the cloud on the

real-time, together with low-power control, status indictor. This board can replace the old wiring serial Wi-Fi device to realize the data collection and control. It has the following features [27].

3.6.1.1. Features of ESP8266 module

- Fully compatible with the original electrical interface and physical interface for the serial transparent Bluetooth;
- Built-in the industrial transparent transmission firmware V3.0 with stability and reliability by using the Web Configuration;
- Built-in the high-performance Wi-Fi module ESP-M2 with size: 34mm*17mm*4mm;
- Working voltage: 4.5V~6.0V, TTL working voltage: 3.3V (compatible with 5.0V);
- Average current: 80mA; when data sent, it is 170mA; but it is 20μA at deep sleep mode;
- Seamless transparent transmission between serial and Wi-Fi;
- Built-in HTTP Web Server, support configure parameters by web page;
- Support re-connect automatically at TCP Client;
- Support set baud rate, data bit, parity check, stop bits, and/or subcontracting time;
- Support DNS resolution automatically for the remote sever address;
- Working temperature: -40℃-125℃;
- Applications: smart home, wireless data connection and transparent transmission, smart car control, wireless serial printer, LED light industrial control etc [28].

3.6.1.3. How ESP8266 module works

The ESP8266 Wi-Fi Module is a self-contained SOC with integrated TCP protocol stack that can give any microcontroller access to the Wi-Fi network. The ESP8266 is capable of either hosting an application or offloading all Wi-Fi networking functions from another application processor.

This module has a powerful enough on-board processing and storage capability that allows it to be integrated with the sensors and other application specific devices through its GPIOs with minimal development up-front and minimal loading during runtime. Its high degree of on-chip integration allows for minimal external circuitry, including the front-end module, is designed to

occupy minimal PCB area. The ESP8266 supports APSD for VOIP applications and Bluetooth co-existence interfaces, it contains a self-calibrated RF allowing it to work under all operating conditions, and requires no external RF parts [29].

3.7. 4ch DC motor and 16ch servo shield

This shield allows to us to control 2 pcs or 4 pcs DC motors at the same time, and then is also able to control 16 pcs servo. So, it is the best choice to use in our robot

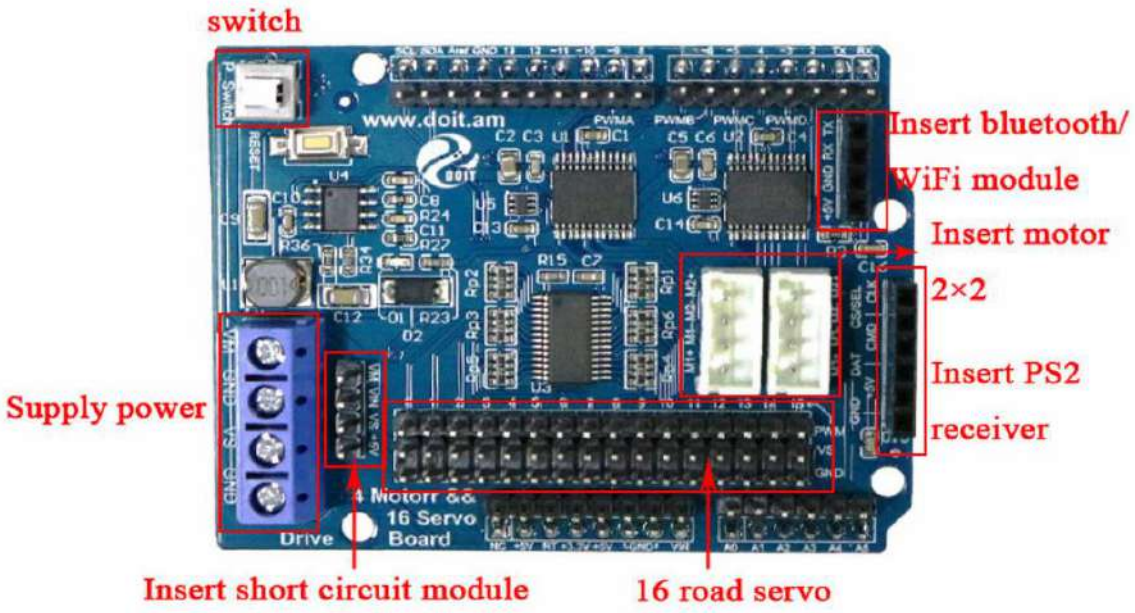


Figure III-8 : 4ch DC motor and 16ch servo shield

3.7.1. Features of the shield:

- Control 2pcs or 4pcs DC motors, and 16pcs servo at the same time;
- Fully compatible with Arduino board;
- Fully support Wi-Fi DT-06, Bluetooth HC-05, or HC-06.

3.7.3. Specifications:

- 16ch servos and 4ch DC motor driver board, which use TB6612 to drive 4ch DC motor, and PCA9685 is used to control 16ch servo.
- Having Arduino UNO, I/O pins;
- Max power 15V/DC;
- 4 DC motor driver, and the single max current is 1.2A(mean)/3.2A(peak);
- 16ch servo, and the jumper to change the servo and motor working voltage [30].

3.8. Servo Motor

A **servomotor** is a rotary actuator or linear actuator that allows for precise control of angular or linear position, velocity and acceleration. It consists of a suitable motor coupled to a sensor for position feedback. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotors.

Servomotors are not a specific class of motor although the term servomotor is often used to refer to a motor suitable for use in a closed-loop control system.

Servomotors are used in applications such as robotics, CNC machinery or automated manufacturing.

To fully understand how the servo works, you need to take a look under the hood. Inside there is a pretty simple set-up: a small DC motor, potentiometer, and a control circuit. The motor is attached by gears to the control wheel. As the motor rotates, the potentiometer's resistance changes, so the control circuit can precisely regulate how much movement there is and in which direction.

When the shaft of the motor is at the desired position, power supplied to the motor is stopped. If not, the motor is turned in the appropriate direction. The desired position is sent via electrical pulses through the signal wire. The motor's speed is proportional to the difference between its actual position and desired position. So, if the motor is near the desired position, it will turn

slowly, otherwise it will turn fast. This is called **proportional control.** This means the motor will only run as hard as necessary to accomplish the task at hand, a very efficient.

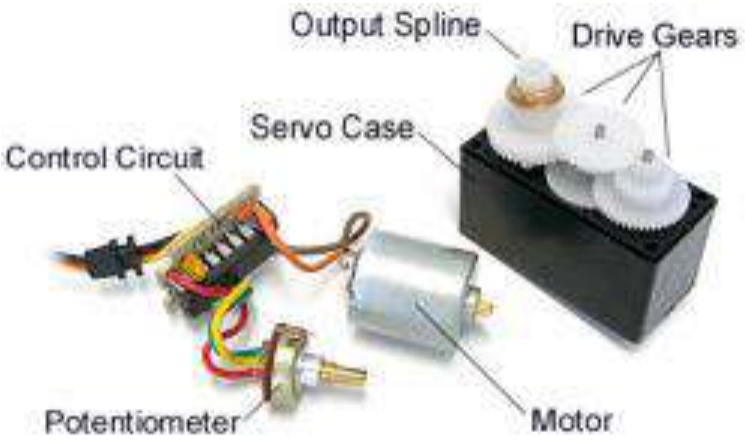


Figure III-9 : Servo motor components

Servos are controlled by sending an electrical pulse of variable width, or **pulse width modulation** (PWM), through the control wire. There is a minimum pulse, a maximum pulse, and a repetition rate. A servo motor can usually only turn 90 degrees in either direction for a total of 180-degree movement. The motor's neutral position is defined as the position where the servo has the same amount of potential rotation in the both the clockwise or counter-clockwise direction. The PWM sent to the motor determines position of the shaft, and based on the duration of the pulse sent via the control wire; the rotor will turn to the desired position. The servo motor expects to see a pulse every 20 milliseconds (Ms) and the length of the pulse will determine how far the motor turns. For example, a 1.5ms pulse will make the motor turn to the 90-degree position. Shorter than 1.5ms moves it to 0 degrees, and any longer than 1.5ms will turn the servo to 180 degrees.

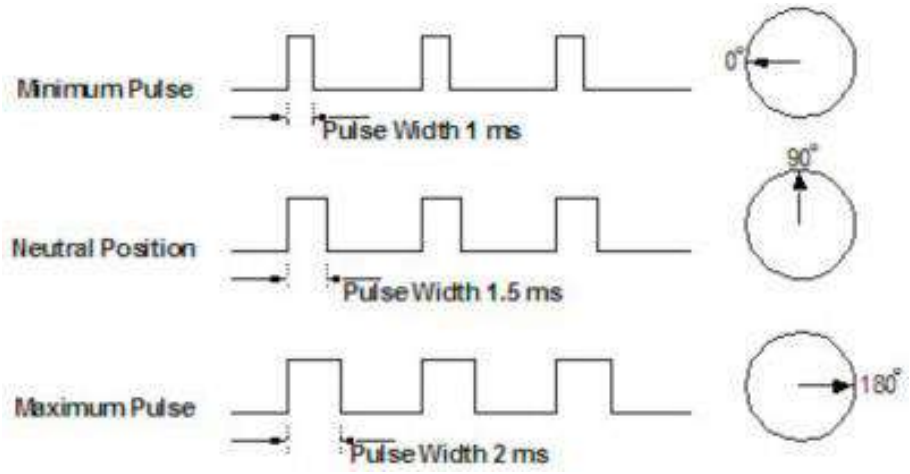


Figure III-10 : Servo motor pulses

When these servos are commanded to move, they will move to the position and hold that position. If an external force pushes against the servo while the servo is holding a position, the servo will resist from moving out of that position. The maximum amount of force the servo can exert is called the **torque rating** of the servo. Servos will not hold their position forever though; the position pulse must be repeated to instruct the servo to stay in position.

3.8.1. Types of servo motors

There are two types of servo motors - AC and DC. AC servo can handle higher current surges and tend to be used in industrial machinery. DC servos are not designed for high current surges and are usually better suited for smaller applications. Generally speaking, DC motors are less expensive than their AC counterparts. These are also servo motors that have been built specifically for continuous rotation, making it an easy way to get your robot moving. They feature two ball bearings on the output shaft for reduced friction and easy access to the rest-point adjustment potentiometer.

3.8.2. Servo Motors Applications

Servos are used in radio-controlled airplanes to position control surfaces like elevators, rudders, walking a robot, or operating grippers. Servo motors are small, have built-in control circuitry and have good power for their size.

In food services and pharmaceuticals, the tools are designed to be used in harsher environments, where the potential for corrosion is high due to being washed at high pressures and temperatures repeatedly to maintain strict hygiene standards. Servos are also used in **in-line manufacturing**, where high repetition yet precise work is necessary [31]-[32].

3.9. Power supply

There is an additional power supply source present in Arduino microcontroller. Power supply port is present at the corner of the Arduino microcontroller. Either we can use this power supply port by connecting with external power supply. (i.e., ac power supply), or by connecting an dc power supply through input pins. These power supplies produce an active form to the Arduino microcontroller. These Arduino microcontrollers can accept a range of power supply. When the power supply voltage range Exceeds, the microcontroller gets damaged. Hence, only the particular range of power supply should be given to the Arduino microcontroller and we have these options of power supply to use:

3.9.1. Alkaline

The most popular, energy efficient and have almost this same voltage all the time when it works. But they cannot be recharged.

The motors and an Arduino board with motor shield consume a lot of energy – using non-rechargeable alkaline batteries would be too expensive and non-productive.

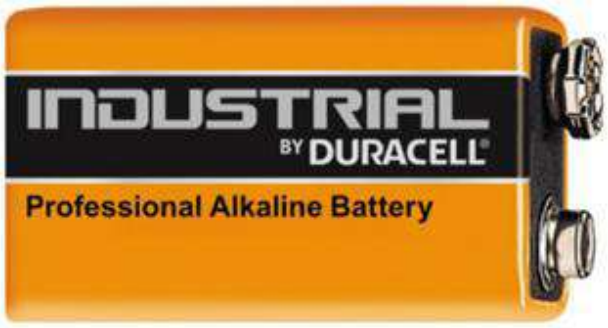


Figure III-11 : Alkaline battery

3.9.2. Ni-MH (nickel metal hydride)

Rechargeable batteries. They have less capability than a simple battery used in remote controls, watches etc. They lose some energy even If not in use. This battery has only one great disadvantage: when it is fully charged – it has a higher voltage. Full 9V battery can have even 11,2V. Because battery life is not very important for our project,



Figure III-12 : Ni-MH battery

3.9.3. Li-Po (lithium polymer)

Rechargeable batteries. They are lightweight, powerful and save capability. Disadvantage is high price and the need in special charger [33].



Figure III-13 : Li-Po battery

After our researches we decided to use Ni-MH type of batteries because they provide the functionality we need for the board.

4. SYSTEM Communication

We need for our robot a communication system for command our robot moves and for getting the video streaming live to our device (**mobile phone or laptop**) for doing that we have a few options to mention

4.1. **Wired**

4.1.1. Wires

Wires are commonly used to establish a static connection. They provide a high-speed data transfer and reliable connection between the recipient and sender. In this project our main object is moving, so this type of connection would not fit all the needs. As well as movement restrictions, the robot would rely on the length of the cable too much when it need mobility.

4.2. Wireless

4.2.1. Bluetooth

Bluetooth connection is an old technology but still popular nowadays. Its' popularity is as high as the Bluetooth module can be found on almost every modern device (mobile phones, smart phones devices, etc.). It doesn't allow so high speed for transfer of data like wires but it would be enough to send commands to our robot. The worst drawback in this type of wireless connection is its' short range. Bluetooth usually operates at frequency rates lower than **2.4 MHz** We could use it, but we want stronger signal (Bluetooth concedes Wi-Fi technology in data transfer range) to let the robot moving further while connected to the phone.

4.2.2. Radio:

Most wireless controlled toy cars are controlled by the radio remote controls. Those remote controls have a frequency range from **25 up to 75 MHz** this is why they can cover a long range and the user may control the device on a long distance. They can have a variety of antennas (depending on the budget), different designs and functions. One of the advantages of using the remote control is a variety of choice and a huge range to control. But it has disadvantages – the remote control may be an expensive choice and it could be really hard to organize. The time frame for the project is not enough to create the remote control from scratch or use any existing one.

4.2.3. Wi-Fi

Our final decision was made for a Wi-Fi technology. This type of technology is very popular and every modern Smartphone has a built-in Wireless module. It can be accessed from our board and we can easily send commands from the phone to our robot. The only drawback is a range, which is quite small compared to the Radio remote controls. But this is the price to build a working system using our knowledge [34].

4.3. Our decision

Our final decision on connection technology was made for Wi-Fi. We decided to use it because it's very popular and every modern Smartphone has it. Wi-Fi does not provide a huge cover range like Radio technology described, but it has a range which is enough to move the robot for appropriate distances from user. Wi-Fi technology is easy to use and easy to implement in our project.

4.4. Technologies

- **Android**

  We used the Android Framework to develop the application. The application can be installed from Smartphone that support the API 11 and upper.

  Android uses widespread java language, Java.

- **Sockets**

  We use sockets to communicate between the Android application and the Arduino application, it's the best way to communicate because it's really efficient, almost real time and really better than HTTP requests, we started by using simple HTTP requests but the response time was too important so we decided to change and use sockets instead.

4.5. Communication system description:

Our robot is to be designed to be easy and user friendly to use with some extra functionality like live video stream, pictures and more.

The system will consist of two different parts, the robot first, which we described earlier, the second part is about a phone application, actually we will only use Android for the moment. But it could be done for Windows or Apple phones. This application will display a video stream from the camera on board of the car and some buttons for control the car. (Turn, go forward, etc.)

The robot will have its own battery for all the components on board (motors, servo motors, shield, etc).



Figure IV-1 : Communication system

The Wi-Fi network is generated by the Arduino UNO, he is able to acts as a hotspot and the Android phone has to connect to this hotspot to be able to communicate with the Arduino.

The user can use also a computer, instead of a Smartphone, but we didn't develop any software on a computer and it's better to use a Smartphone, because the user can move with the robot, the application is designed to control everything on the robot and user will not have to use any other devices for this.

- **System Functionalities**

  After our researches we decided to use specification functionalities to our robot that will allow for user to control each part of our robot

  It also shows our user interfaces and some non-requirement specifications.

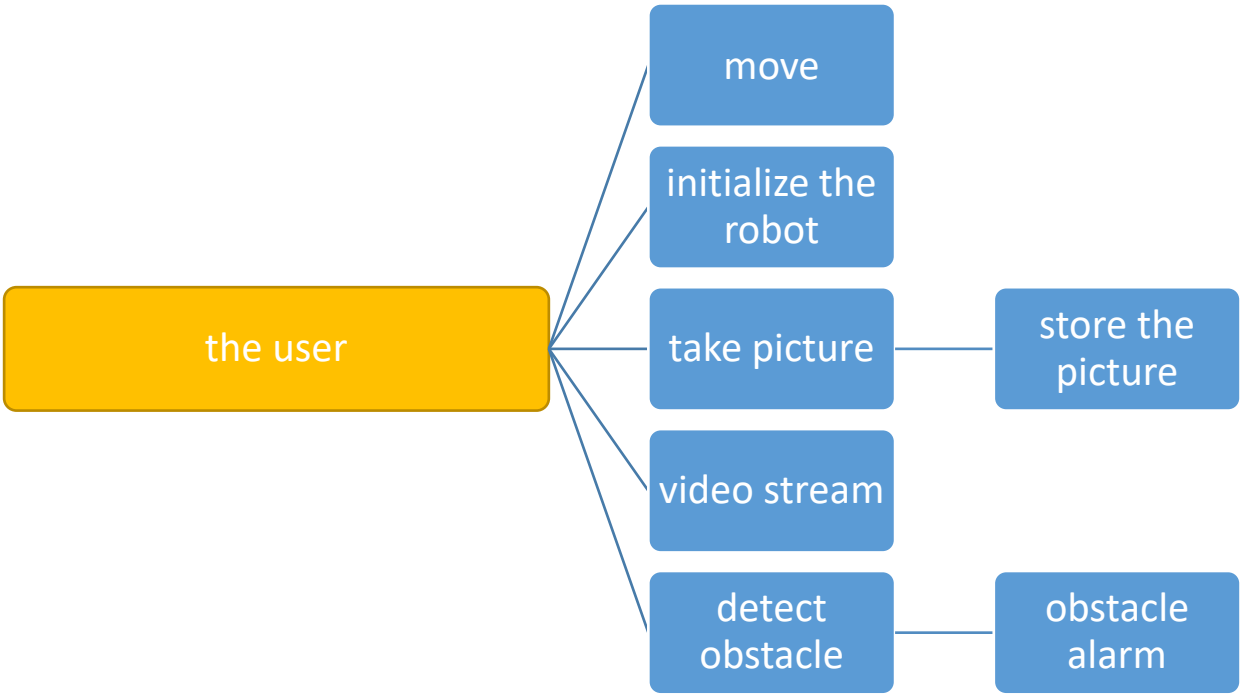
1. Move (including turn)

2. Adjust the robot arms (angle and width)
3. Take pictures and store them
4. Get a video stream from the camera
5. Detect obstacles and play a sound on the phone.

But we decided later to abandon the last one because we had not the component either the time to implement it.

4.6. Communication system design:

We will present our design using a top-down approach, starting by the overviews of the system and explaining details only at the end, using detailed sequence diagram



.

Figure IV-2 : Communication system diagram

We didn't reach completely this diagram, we didn't use a proximity sensor, so the use cases "Detect obstacle" and "Alarm obstacle" are not done. This diagram is what we planned to do. Other use cases are done and work properly.

4.7. Development/Implementation view:

4.7.1. Component diagram:

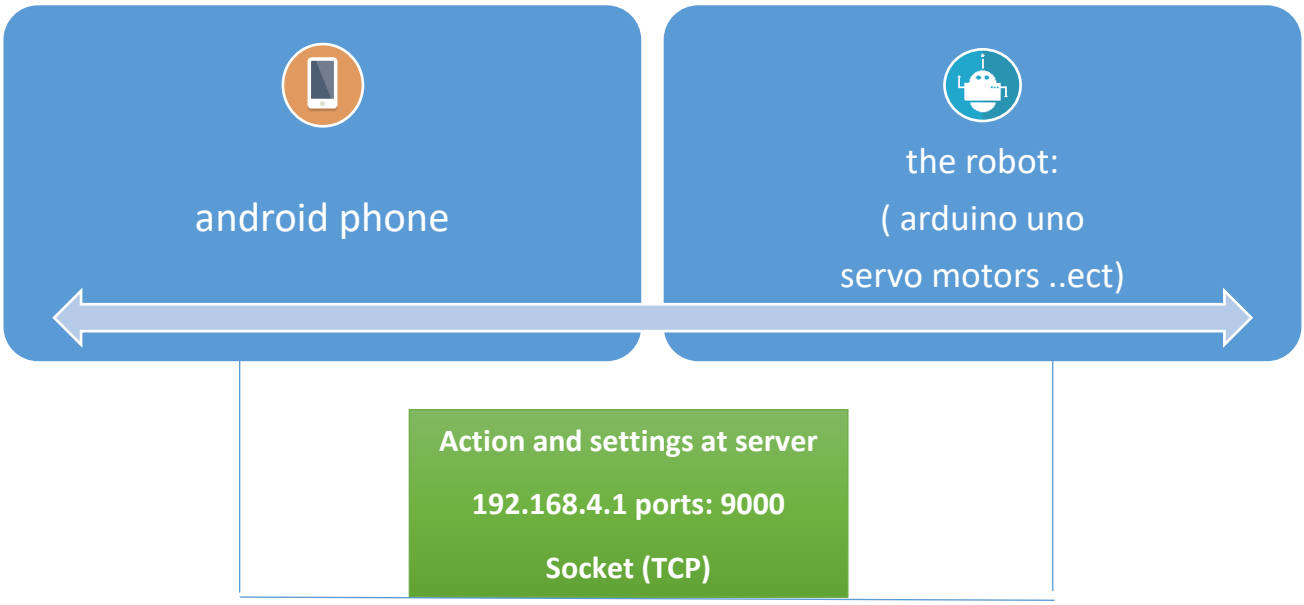


Figure IV-3 : communication method

4.7.2. Protocol

The android application send commends to the robot application using sockets via the Arduino WIFI hotspot. The protocol used is TCP

These commends are strings, they are split using a slash separator in several part in robot application:

- Action
- Setting

The action is typically the action to realize in the robot, sash as forward backward, left right…etc

4.7.3. Camera and video streaming

We use wired USB camera with 10m long to stream the video to our device, we decide to do that because the Arduino chip bandwidth is to small and can't transfer live video



Figure IV-4 : Weird USB camera

4.8. Limitations of the system

The system has some limitations, for instance there is the radio communication because of the wireless limitation. We suppose be able to control the robot in about 10 meters range before the Wi-Fi signal shutdown.

We designed the application to use video stream but we could do that because the Arduino UNO is not powerful enough for live stream, or the Wi-Fi, which could be not fast enough for transmit the live stream.

The robot embedded a battery 9V. The user will need to charge or change it from time to time.

The size of the program stored in the Arduino flash memory is limited, about 32Ko, it's too small and will maybe not be enough to do everything we want to do.

4.9. Future of the system

The system could be extended with new embedded hardware like buzzer, GPS tracker and control centre box that will make the robot go deeper with weirs connected to robot is self

4.9.1. user interface of the android application:

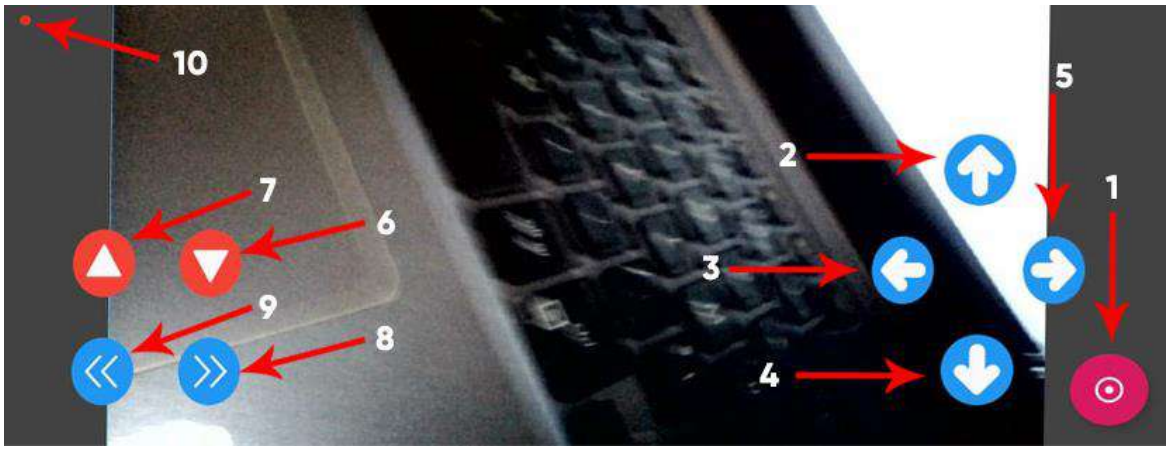


Figure IV-5 : The Android application interface

This interface is the only interface in the application, where the user can see the picture from the embedded camera and choose direction, and see if the Arduino chip is connected in the left top corner

And this is the full buttons documentations:

1. stop all of the robot from moving
2. move the robot forward
3. move the robot to the left
4. move the robot backward
5. move the robot to the right
6. rotate the robot arm for down
7. rotate the robot arm for up
8. open the robot arm
9. close the robot arm
10. for check if Arduino is connected with the application

5. Mechanical studies

5.1. Introduction

In this chapter we will have dimensionally different elements that constitute this robot. But before we start, we should illustrate the mechanisms .

This chapter will therefore be divided into three parts :

- Kinematic study of links and sizing .
- RDM study using the SolidWorks program .
- Servo motors choice .

5.2. Cinematic Study

5.2.1 Cinematic Scheme 2D

The 2D cinematic scheme of the rod, we study main links between the design elements of the robot to better understand how it works :

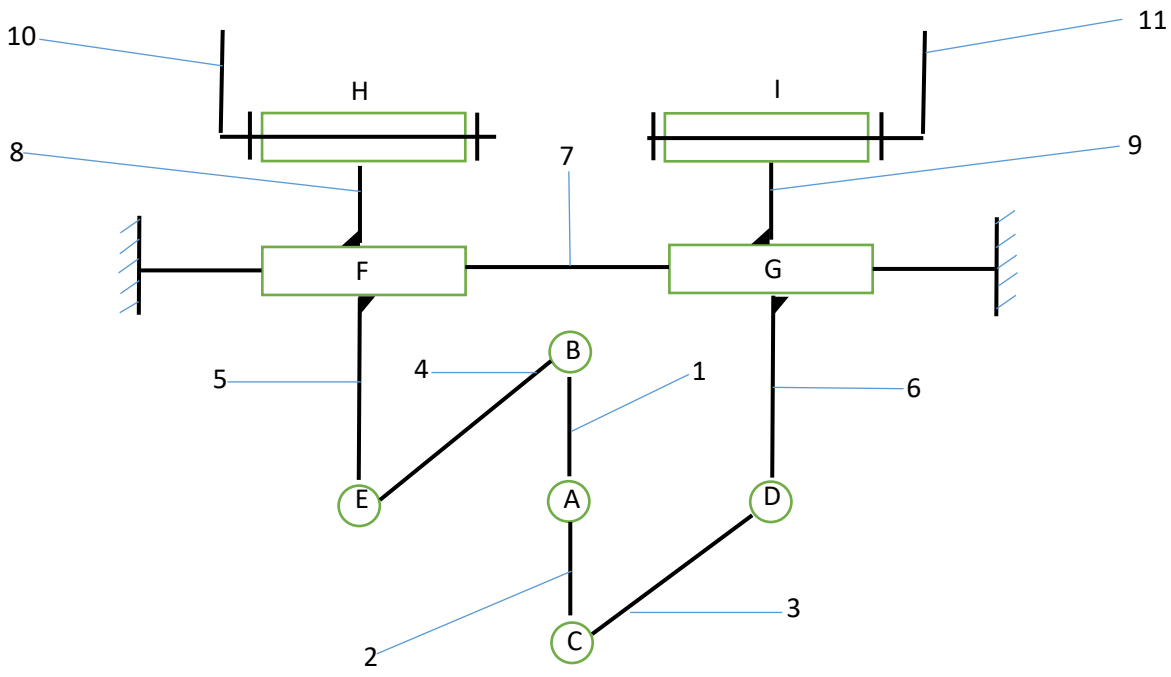


Figure V-1 : Cinematic Scheme of the robot

5.2.2. Table of the liaisons:

Table V-1 : table of Cinematic liaisons

Pair (joint)	type	DOF	AXIS	Representative orientations
$L_{0/1}$	revolute	1	Z	Direction of the rotation axis
$L_{0/2}$	revolute	1	Z	Direction of the rotation axis
$L_{2/3}$	revolute	1	Z	Direction of the rotation axis
$L_{3/6}$	revolute	1	Z	Direction of the rotation axis
$L_{6/7}$	**Prismatic**	1	Y	Direction of the translation motion
$L_{7/9}$	**Prismatic**	1	Y	Direction of the translation motion
$L_{9/11}$	revolute	1	Y	Direction of the rotation axis
$L_{1/4}$	revolute	1	Z	Direction of the rotation axis
$L_{4/5}$	revolute	1	Z	Direction of the rotation axis
$L_{5/7}$	**Prismatic**	1	Y	Direction of the translation motion
$L_{7/8}$	**Prismatic**	1	Y	Direction of the translation motion
$L_{8/10}$	revolute	1	Y	Direction of the rotation axis

5.3. Objective of the Cinematic Study

The kinematic study of mechanisms in general allows us to better understand their operations and constituent systems. this study will lead us to :

- Determine the mechanical links between the components of the machine
- Define the parts that are required for manufacturing .
- Determine the efforts to which these elements are subjected .
- Better understanding how the elements work .

5.4. The mechanical components of the robot

- **The support:**

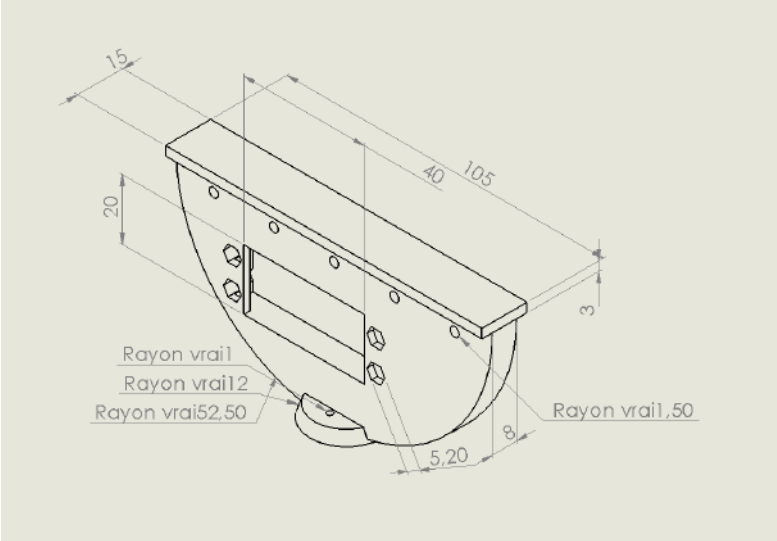


Figure V-2 : dimensions of the support

- **the prismatic part**

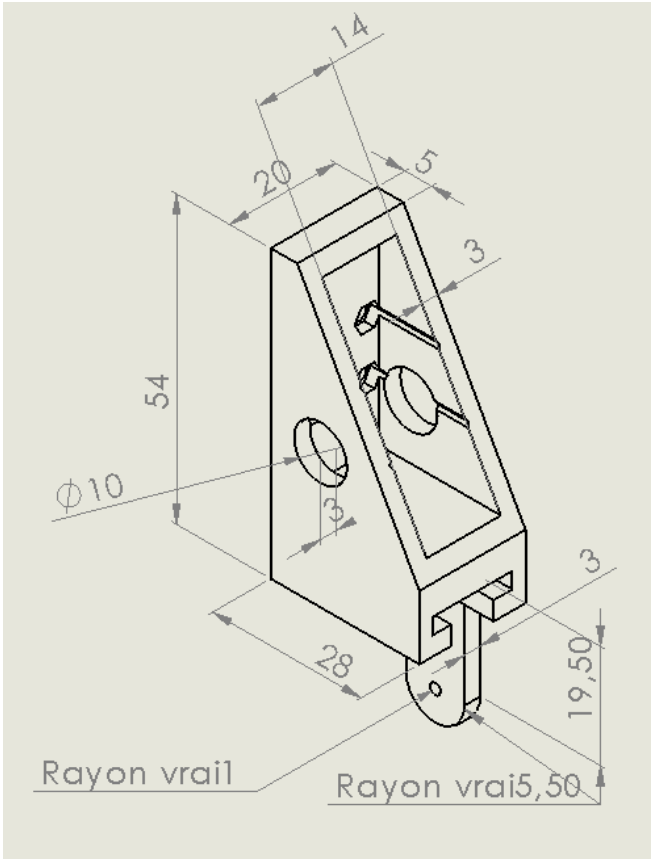


Figure V-3 : dimension of the the prismatic part

- **support of the crawler**

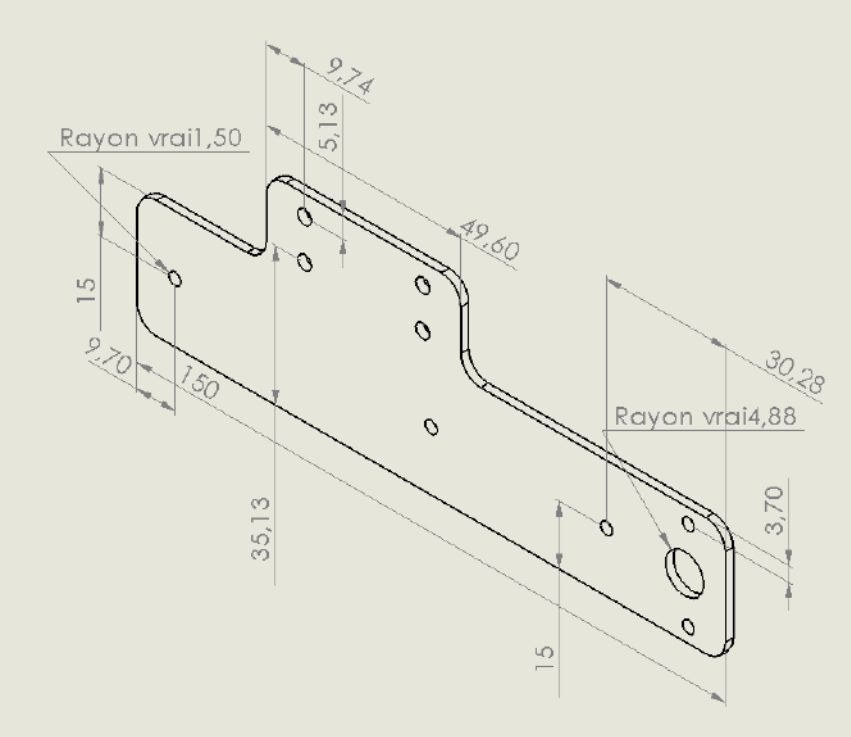


Figure V-4 : dimension of the support of the crawler

- **large bracket**

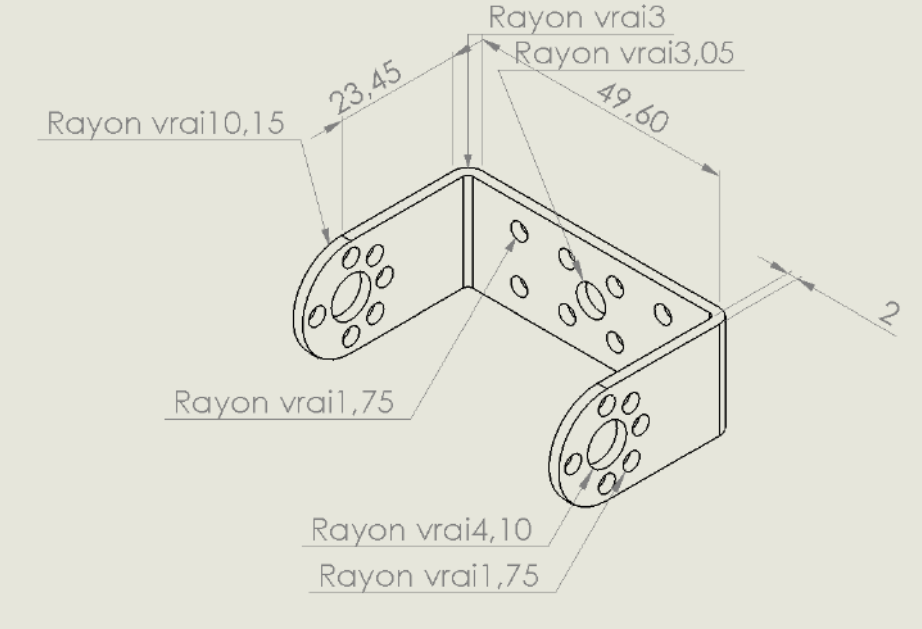


Figure V-5 : dimension of the large bracket

- **Small bracket**

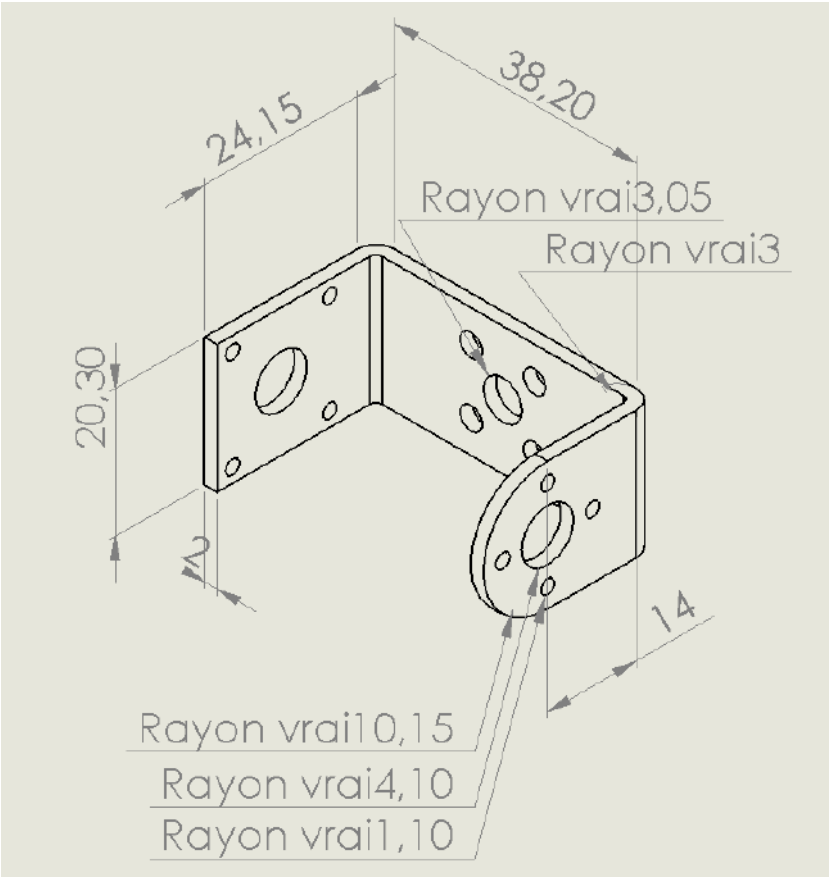


Figure V-6 : dimension of the small bracket

5.5. Presentation of drawings and simulation with solid Works

Safety when using the system will need to be studied. Changes have been made follow-up to this study .

Support elements deemed vulnerable will need to be studied using the finished elements. This will allow the planning to be carried out .

This last Part presents a part in which we will describe, analyse the results of previously conducted research and sizing. It will be divided into three parts :

- Definition of the program (Solid Works) .
- Static analysis and simulation of machine elements with program (**Solidworks**).

5.5.1. Program Definition (SolidWorks)

SolidWorks is a solid modelling computer-aided design (CAD) and computer-aided engineering (CAE) that runs primarily on Microsoft Windows. While it is possible to run SolidWorks on MacOS, it is not supported by SolidWorks wish is published by **Dassault Systems**.

It uses the principle of parametric design and generates three types of files that Related: **part, assembly, and layout.**

So, any changes on one of these three files will be passed on to the other two .

SolidWorks Corporation was founded in December 1993 by Jon Hirsch tick accompanied by a team of developers to make CAD more accessible .

Released his first SolidWorks 95 product in November 1995 .In 1997, Dassault Systems became a major shareholder .

SolidWorks was directed by John Mc Eleney from 2001 to July 2007 and Jeff Ray from 2007January 2011. The current managing director is Gian Paolo Bassi from January 2015 .

SolidWorks is a 3D modeller using parametric design. It generates 3 types' files relating to three basic concepts: part, assembly and layout. These files are related. Any changes at any level are passed on

To all the files involved .

A complete file containing all the relating to the same system constitutes a digital model. Many software programs complement the SolidWorks publisher .

Business-oriented utilities (metalwork, wood, construction, etc.), but also applications of simulator mechanical or synthetic picture work from the elements of the virtual model .

SolidWorks software allows :

- Design objects in 3D in a very precise way .
- Check the conception of your file .
- Set up 2D layouts .
- Create pictures and animations of your 3D objects [35].

5.6. Static Analytics

5.6.1. Calculate Support Reactions

5.6.1. 1. Model information's

Table V-1 : information about the support

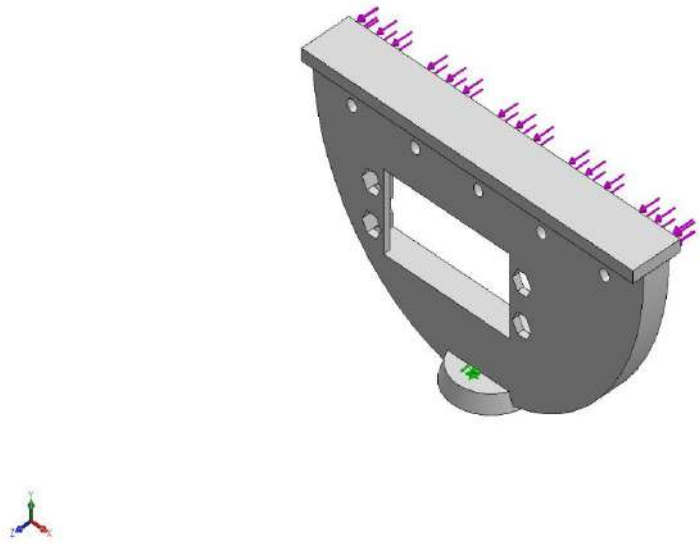


Figure V-7 : forces applied on the support

Treated as	Volumetric properties
Volumetric bodies	Bulk:0.0327987 kg Volume:3.21555e-005 m^3 Bulk volumetric:1020 kg/m^3 Weight:0.321427 N

5.6.1.2. properties of the material:

- **Name : ABS plastic**
- **Model type : Linear elastic isotropic**
- **Traction limit : 3e+007 N/m^2**
- **Elasticity module : 2e+009 N/m^2**
- **Poisson Coefficient : 0.394**
- **Bulk volumetric : 1020 kg/m^3**
- **Module of shear : 3.189e+008 N/m^2**

5.6.1. 3. External actions

Table V-2: The Support fixation

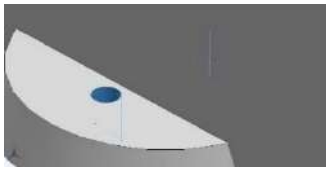
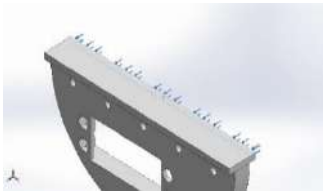
Name of shifting imposed	The fixation	Details of shifting imposed
Fixe-1		**Entitles:** **2 side (s)** **Type:** **Fixed geometries**

Table V-3 : The support loading

Name of loading	Picture of loading	Details of loading
Force-1		**Entities:** **1 face(s)** **Type:** **Force normal** **Value:** **9.21 N**

5.6.1. 4. Results of static etude of the support

Table V-4 : Constraints of von Mises to the support

Name	Type	Min	Max
Constraints1	Von Mises constraint	917.355 N / m ^ 2 Knot: 1318	8.09959e + 006 N / m ^ 2 Node: 17572

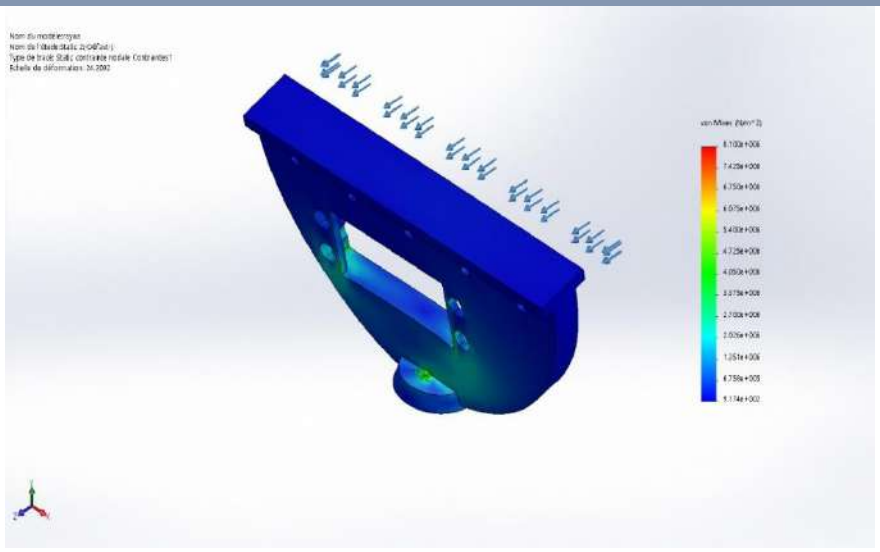


Figure V-8 : Constraint of von Mises to the support

Table V-5 : Displacement results of the support

Name	Type	Min	Max
Displacement1	Resulting displacement	0 mm Knot: 1	0.44082 mm Knot: 1359

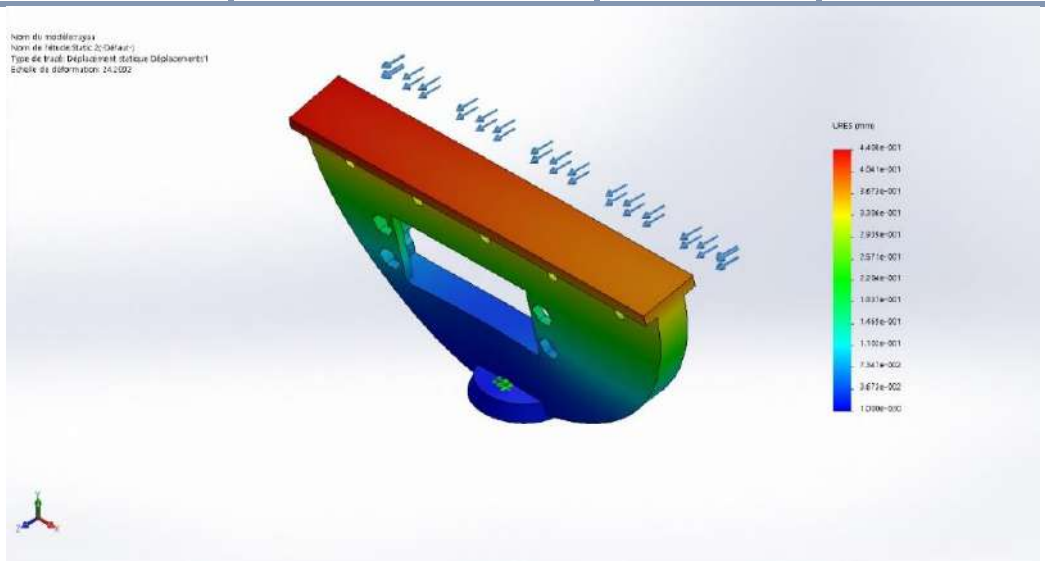


Figure V-9 : Displacement results of the support

5.6.2. Calculate of the prismatic part Reactions

5.6.2.1. model information's

Table V-6 : information about the prismatic part

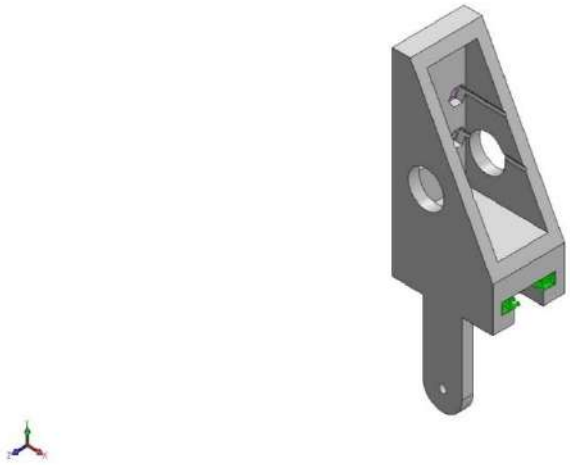


Figure V-10 : forces applied on the prismatic part

Treated as	Volumetric properties
Volumetric bodies	Bulk:0.0123074 kg Volume:1.2066e-005 m^3 Bulk volumetric:1020 kg/m^3 Weight:0.120612 N

5.6.2.2. Properties of the material

- **Name: ABS plastic**
- **Model type: Linear elastic isotropic**
- **Traction limit: 3e + 007 N / m ^ 2**
- **Elasticity modulus: 2e + 009 N / m ^ 2**
- **Poisson Coefficient: 0.394**
- **Bulk volumetric: 1020 kg / m ^ 3**
- **Module of shear: 3.189e + 008 N / m ^ 2**

5.6.2.3. External actions

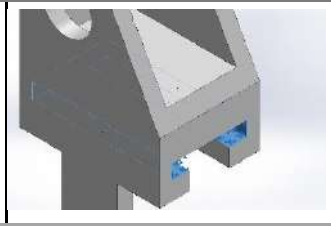
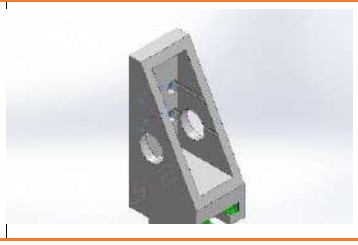
Name of shifting imposed	Picture of shifting impose	Details of shifting impose
Fixe-2		**Entities:** **5 side (s)** **Type:** **Fixed geometries**

Table V-7: the prismatic part fixation

Table V-8: the prismatic part loading

Name of loading	Picture of loading	Details of loading
Force-2		**Entities:** **4 face(s)** **Type:** **Force** **Value:** **-4.41 N**

5.6.2.4. Results of static etude of the prismatic part

Table V-9 : constraint of von Mises to prismatic part

Name	Type	Min	Max
Constraints2	Von Mises constraint	0.568376 N / m ^ 2 Node: 13102	397,017 N / m ^ 2 Knot: 120

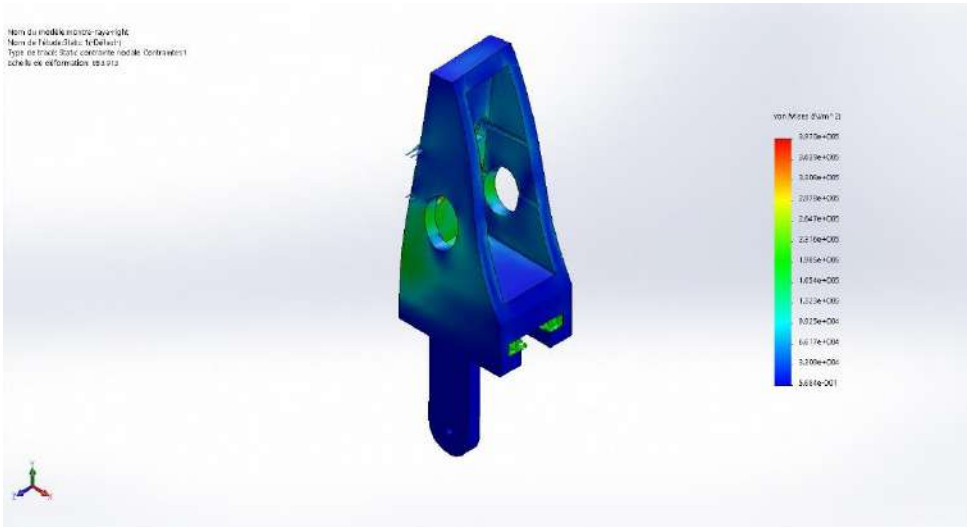


Figure V-11 : constraint of von Mises to prismatic part

Table V-10 : Displacement results of the prismatic part

Name	Type	Min	Max
Displacement2	Resulting displacement	0 mm Knot: 304	0.00959206 mm Knot: 686

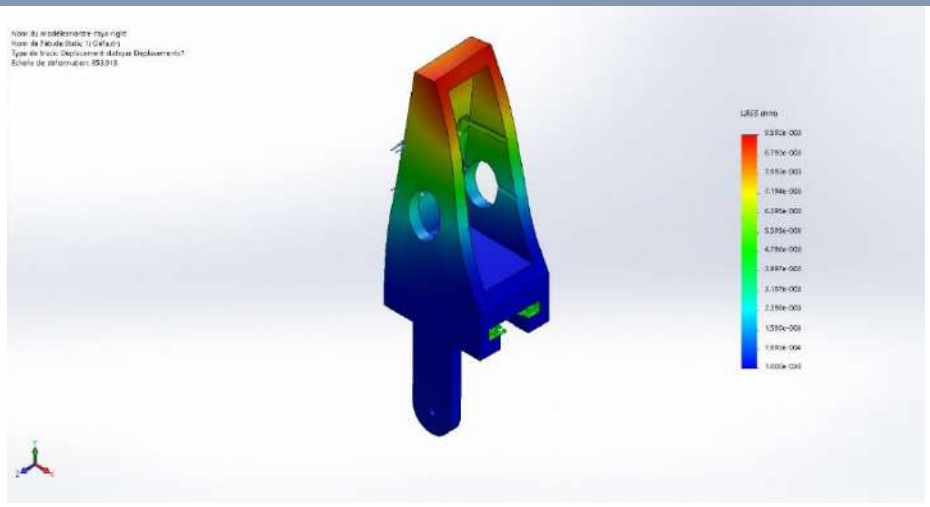


Figure V-12 : Displacement results of the prismatic part

5.6.3. Calculate of the support of the crawler

5.6.3.1. model information's

Table V-11 : information about support of the crawler

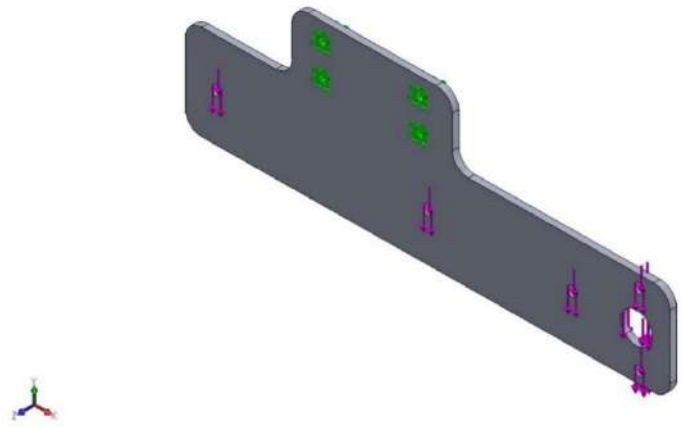


Figure V-13 : support of the crawler

Treated as	Volumetric properties
Volumetric bodies	Bulk:0.0288194 kg Volume:1.06739e-005 m^3 Bulk volumetric:2700 kg/m^3 Weight:0.28243 N

5.6.3.2. properties of the material:

- **Name: aluminum 6061-T4**
- **Model type: Linear elastic isotropic**
- **Elasticity limit: 2.27527e + 008 N / m ^ 2**
- **Traction limit: 2.4e + 008 N / m ^ 2**
- **Elasticity modulus: 6.9e + 010 N / m ^ 2**
- **Poisson's ratio: 0.33**
- **Bulk volumetric: 2700 kg / m ^ 3**
- **Modulus of shear: 2.6e + 010 N / m ^ 2**

5.6.3.3. External actions

Table V-11: support of the crawler fixation

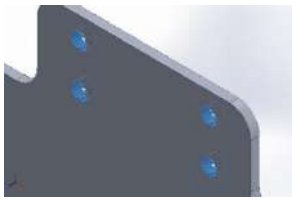
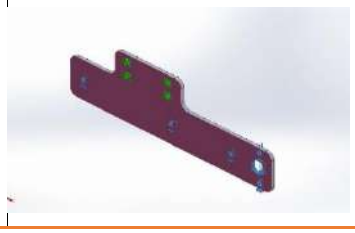
Name of shifting imposed	Picture of shifting imposed	Details of shifting imposed
Fixe-3		**Entities:** **4 side (s)** **Type:** **Fixed geometries**

Table V-12: support of the crawler chargement

Name of chargement	Picture of chargement	Details of chargement
Force-3		**Entities:** **6 face(s)** **Type:** **Force** **Value:** **1.17N**

5.6.3.4. Results of static etude of support of the crawler

Table V-13 : constraint of von Mises to support of the crawler

Name	Type	Min	Max
Constraints3	Von Mises constraint	83.9863 N / m ^ 2 Node: 13770	327098 N / m ^ 2 Node: 15366

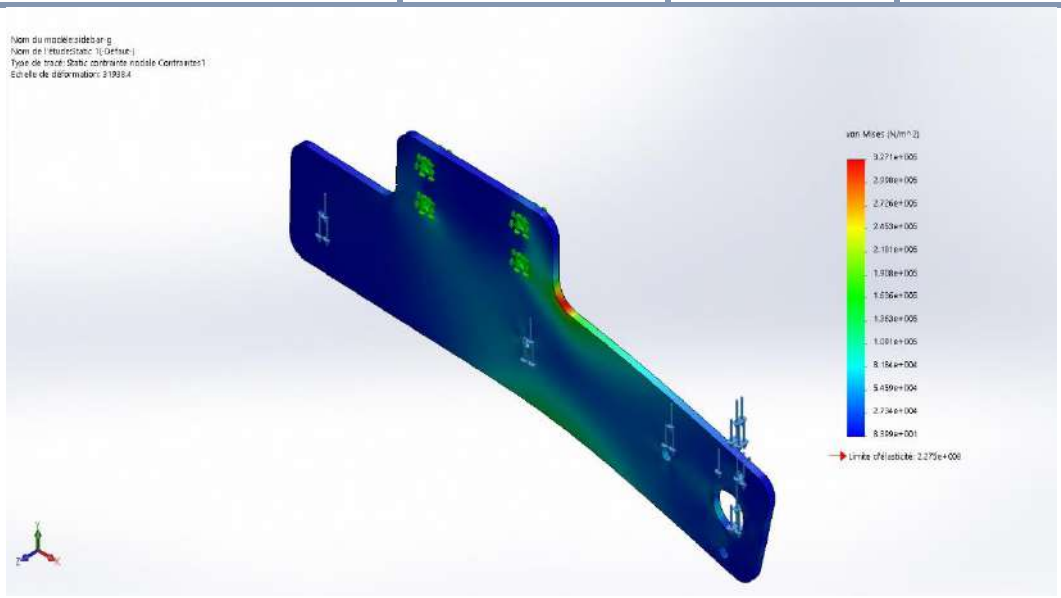


Figure V-14 : constraint of von Mises to support of the crawler

Table V-14 : Deplacement results of support of the crawler

Name	Type	Min	Max
Displacement 3	Resulting displacement	0 mm Knot: 29	0.000482114 mm Node: 14859

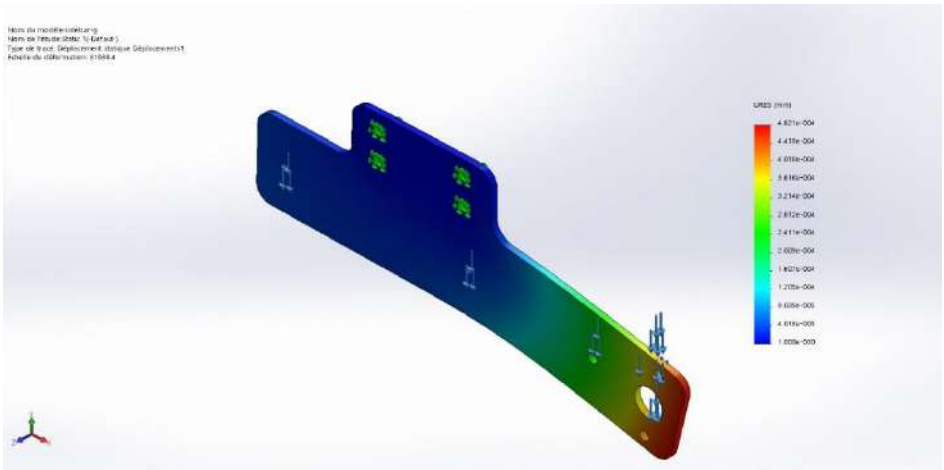


Figure V-15 : Deplacement results of support of the crawler

5.6.4. Calculate of the support of the large bracket

5.6.4.1. model information's

Table V-15 : information about the large bracket

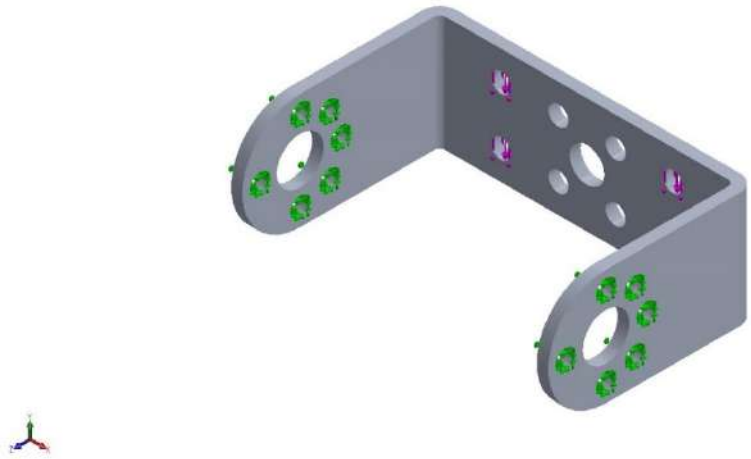


Figure V-16 : the large bracket

Treated as	Volumetric properties
Volumetric bodies	Bulk:0.0112476 kg Volume:4.16577e-006 m^3 Bulk volumetric:2700 kg/m^3 Weight:0.110226 N

5.6.4.2. properties of the material:

- **Name: aluminum 6061-T4**
- **Model type: Linear elastic isotropic**
- **Elasticity limit: 2.27527e + 008 N / m ^ 2**
- **Traction limit: 2.4e + 008 N / m ^ 2**
- **Elasticity modulus: 6.9e + 010 N / m ^ 2**
- **Poisson's ratio: 0.33**
- **Bulk volumetric: 2700 kg / m ^ 3**
- **Modulus of shear: 2.6e + 010 N / m ^ 2**

5.6.4.3. External actions:

Table V-16: the large bracket fixation

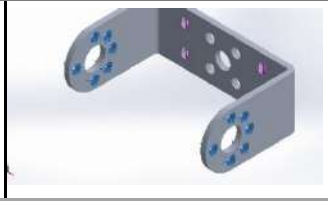
Name of shifting imposed	Picture of shifting imposed	Details of shifting imposed
Fixe-4		**Entities:** **12 face(s)** **Type:** **Geometries fixe**

Table V-17: the large bracket loading

Name of loadin	Picture of loading	Details of loading
Force-4		**Entities:** **4 face(s)** **Type:** **Force** **Value:** **-2.05 N**

5.6.4. 4. Results of static etude of large bracket

Table V-17 : constraint of von Mises to large bracket

Name	Type	Min	Max
Constraints4	Von Mises constraint	33.8926 N / m ^ 2 Node: 15274	199,429 N / m ^ 2 Knot: 298

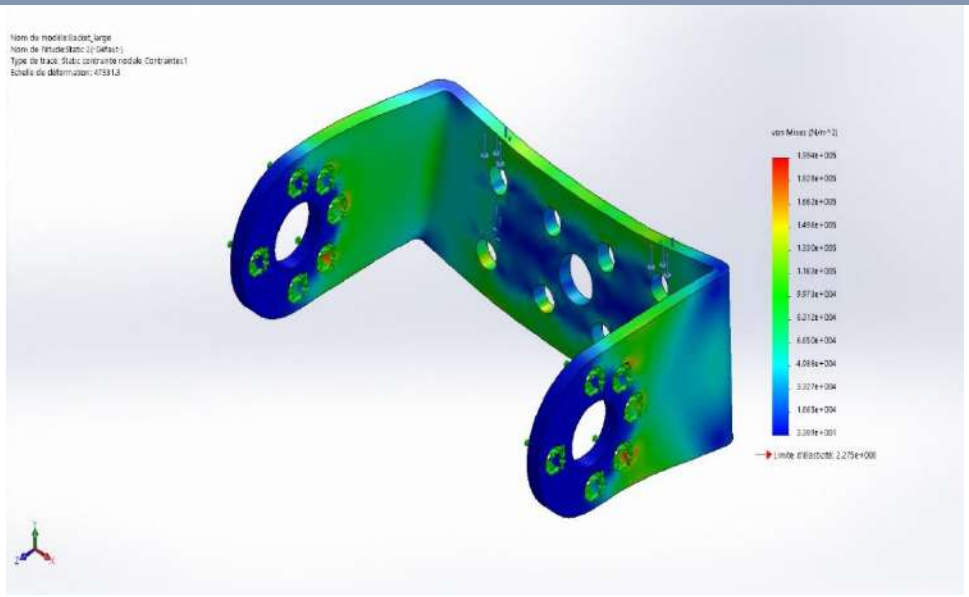


Figure V-17 : constraint of von Mises to large bracket

Table V-18 : Displacement results of large bracket

Name	Type	Min	Max
Displacement4	Resulting displacement	0 mm Knot: 206	0.000118027 mm Node: 8229

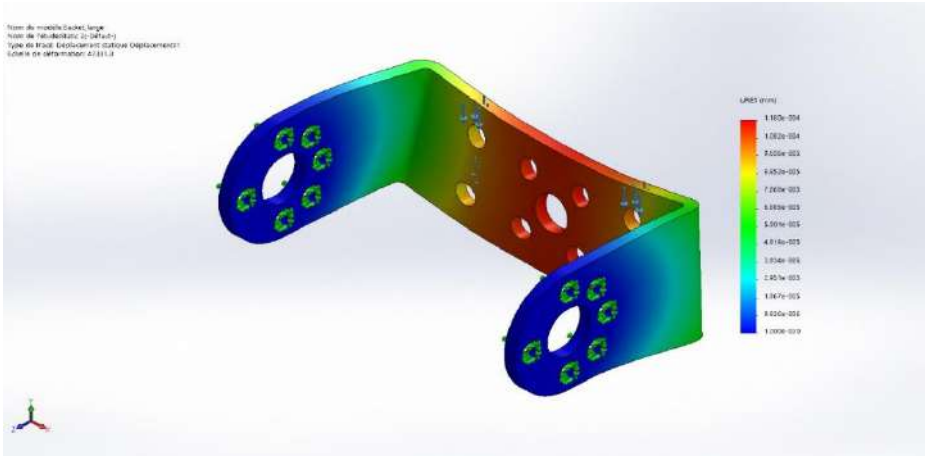


Figure V-18 : Displacement results of large bracket

5.6.5. Calculate of the support of the small bracket

5.6.5.1. Model information's

Table V-19 : information about the small bracket

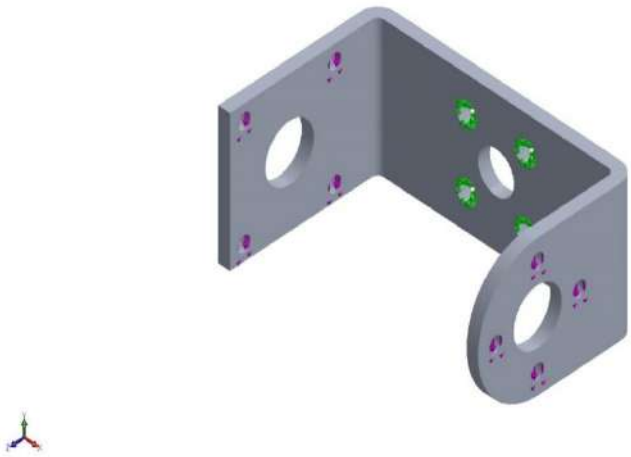


Figure V-19 : the small bracket

Treated as	Volumetric properties
Volumetric bodies	Bulk:0.00883192 kg Volume:3.27108e-006 m^3 Bulk volumetric:2700 kg/m^3 Weight:0.0865528 N

5.6.5.2. properties of the material:

- **Name: aluminum 6061-T4**
- **Model type: Linear elastic isotropic**
- **Elasticity limit: 2.27527e + 008 N / m ^ 2**
- **Traction limit: 2.4e + 008 N / m ^ 2**
- **Elasticity modulus: 6.9e + 010 N / m ^ 2**
- **Poisson's ratio: 0.33**
- **Bulk volumetric: 2700 kg / m ^ 3**
- **Modulus of shear: 2.6e + 010 N / m ^ 2**

5.6.5.3. External actions:

Table V-20: the large bracket fixation

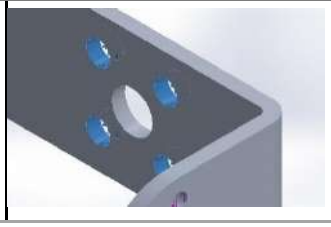
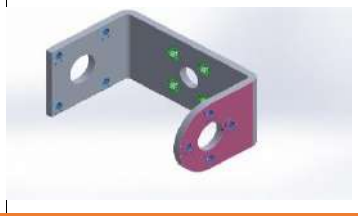
Name of shifting imposed	Picture of shifting imposed	Details of shifting imposed
Fixe-5		**Entities:** **4 face(s)** **Type:** **Fixed geometries**

Table V-21: the small bracket loading

Name of loading	Picture of loading	Details of loading
Force-5		**Entities:** **8 face(s)** **Type:** **Force** **Value:** **-2.15N**

5.6.5.4. Results of static etude of small bracket

Table V-22 : constraint of von Mises to small bracket

Name	Type	Min	Max
Constraints5	Von Mises constraint	8417.36 N / m ^ 2 Node: 15138	1.41521e + 007 N / m ^ 2 Node: 15379

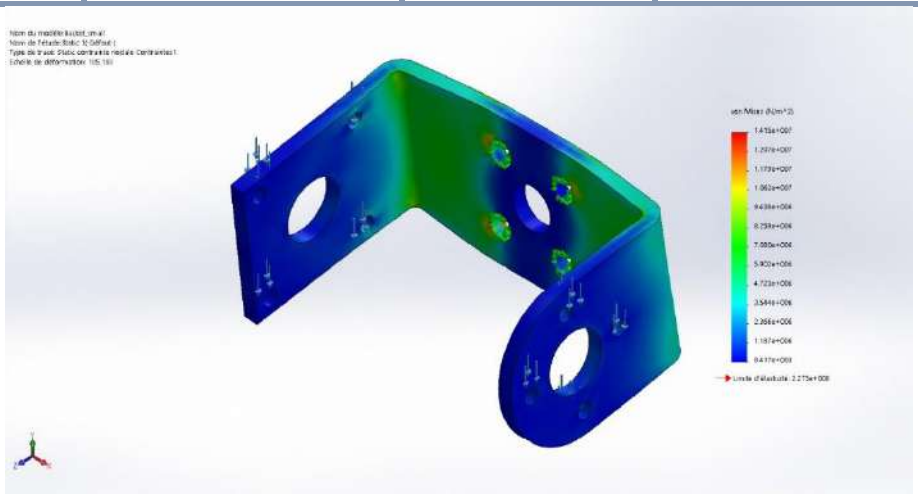


Figure V-20 : constraint of von Mises to small bracket

Table V-23 : Displacement results of small bracket

Name	Type	Min	Max
Displacement 5	Resulting displacement	0 mm Knot: 1	0.025681 mm Knot: 636

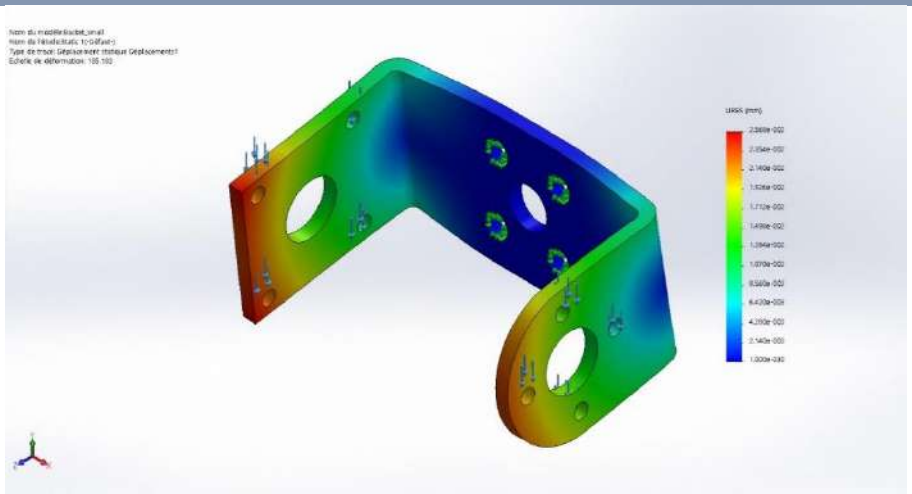


Figure V-21 : Displacement results of small bracket

5.6.5.5. conclusion

After reviewing the results that we got from SolidWorks, we make sure that our system can withstand all external forces, and from that we conclude That our system can work without any mechanical problems.

5.7. Motors Choice:

To do this performs the work operation it takes the motor with sufficient torque to thwart the force because it an average friction between the plate and the coding plate .

To define the motor torque, one must first measure the necessary force ,for this we used an experimental method using newton meter **Figure V-22**



Figure V-22 : newton meter.

1. The force measured by the dynamometer for the part that move the support of the crawler **(Figure V-23)** is equal **1.17N**. and the arm is equal to 24.15mm like we can

see at the reference bibliography part, so the minimum torque to pull the support of the crawler is C=F×R and that equal 0.028N.m.

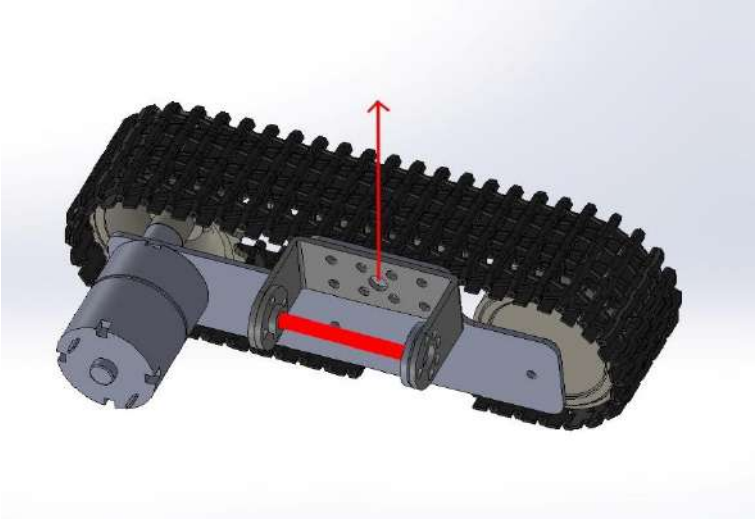


Figure V-23 : Robot arm fixation servo 1

2. The force measured by the dynamometer for the part that move the support of the crawler **(Figure V-24)** is equal **9.21N**. and the arm is equal to 35mm like we can see at reference bibliography part , so the minimum torque to pull the support is C=F×R and that equal 0.32N.m.

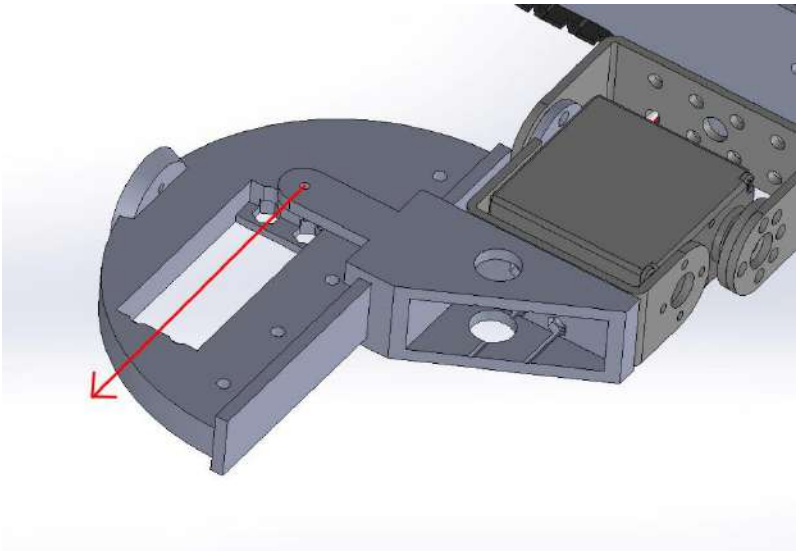


Figure V-24 : Robot arm fixation prismatic part

3. Lastly we have to calculate the minimal torque of the DC motors The force measured by the dynamometer for the part that move the robot **(Figure V-25)** is equal **10.98N**. and the Driver Wheel diameter equal ٢٧,٢٩mm like we can see at reference bibliography part (**Driver Wheel design**) , so the minimum torque to pull the robot is C=F×R and that equal 0.29N.m.

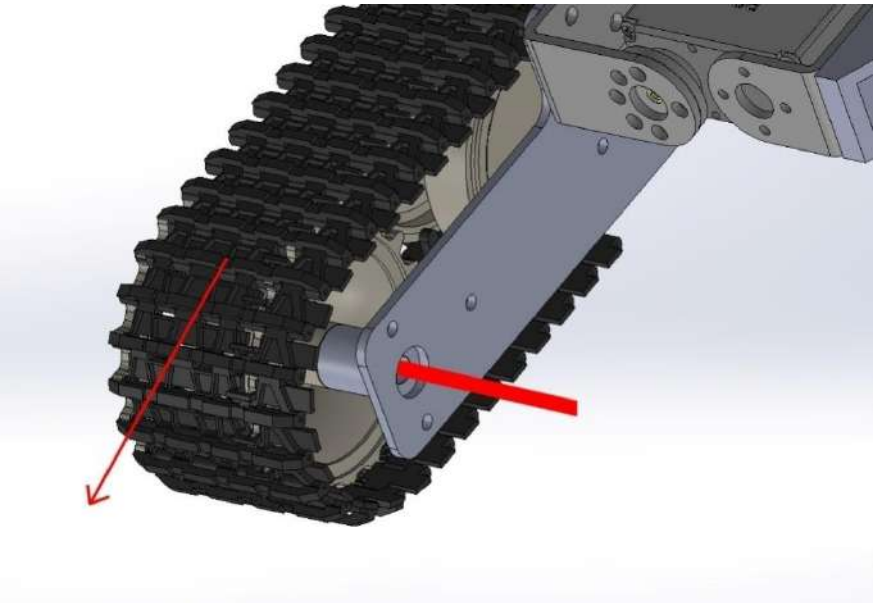


Figure V-25 : Robot arm fixation DC motor

5.8 Conclusion:

In this chapter, we have made a cinematic study on robot links and its explanation by kinematic study

Then we studied the RDM various parts of the robot with the help of the Solid Works program, and this study enabled us to confirm that the design and materials used in it can successfully withstand all external forces.

Finally, we did a laboratory experiment with newton meter to find out the minimum torque that enables us to move the robot parts and based on this information we chose the motors that will move the robot and its parts

Conclusion general

Robots have an important role in repairing and maintaining pipelines faults. Some of them are designed to fulfil specific roles and tasks for pipes with fixed diameters, and others have the ability to adapt to the size of the pipes that passes through to perform its function.

Robot has been designed that offers major improvements compared to similar robots. This robot has a wide industrial use in terms of checking pipelines under various shaped conditions, which include passing through vertical pipes, elbows, and long horizontal pipelines. The presence of obstacles is one of the most difficult issues related to passage within pipelines.

Using a camera installed on the outside, we enable this robot to photograph the inspection inside the pipes or other devices necessary to detect faults that appear inside the pipes (sensors, laser measurement systems, etc).

In the proposed mechanism, the pipe diameter problem is solved by using a specific mechanism. We have developed a pipeline inspection robot that can pass through a pipeline with 190 mm280 mm diameter and reached to maximum 329mm.

Obstacles within pipelines are difficult. In the applied mechanism, the problem is solved by two pairs of flexible crawlers who walk on the inner walls of the pipes by applying pressure on them to enable us to move inside the horizontal and vertical pipelines smoothly. Several robots are designed to check pipelines. Many of the goals of these robots have been completely fulfilled.

Perspectives

We have challenged ourselves to complete the work within the specified period with the presence of the Covid-19 virus, the curfew, the unavailability of work materials and many other factors that were many obstacles.

And after completing this work, we noted that there are some improvements in the system, most of them are from Arduino code.

For those who want to improve this project, you will find the open source codes for Arduino and android app in GitHub website: https://github.com/oualaeddine/Nedjai_car_with_camera_lib feel free to use the codes in any way you want

This design is a prototype design only, the basic design for this project is using an external control unit that is connected to an application installed on the phone using Wi-Fi.

The control unit contains all the hardware, which are connected to the robot using wires, and this system enables us to use the robot deep underground without the need for a Wi-Fi device connected to the robot.

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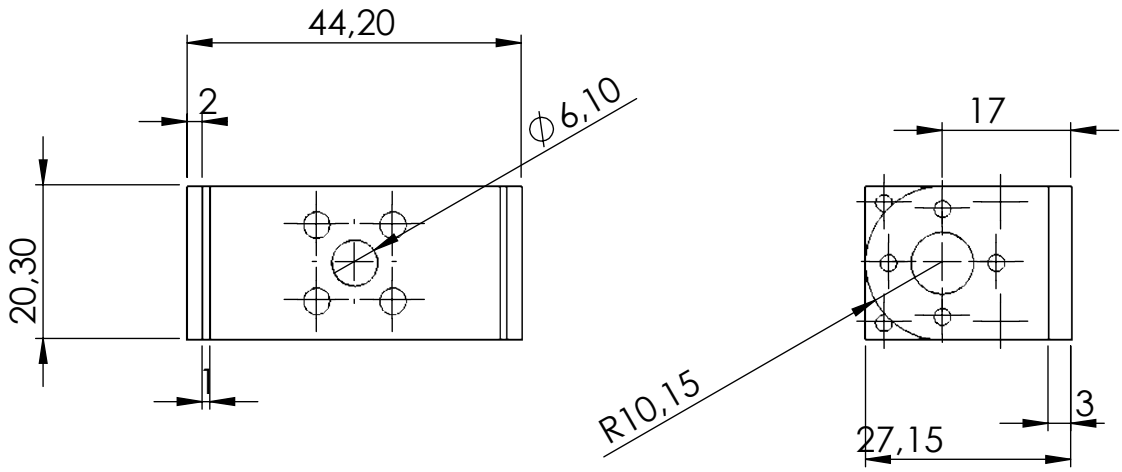
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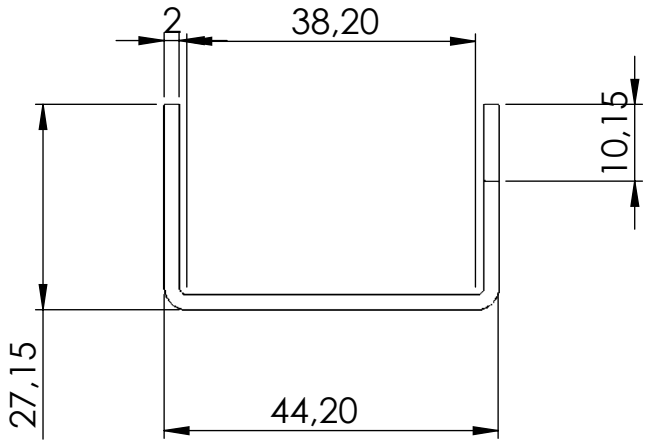
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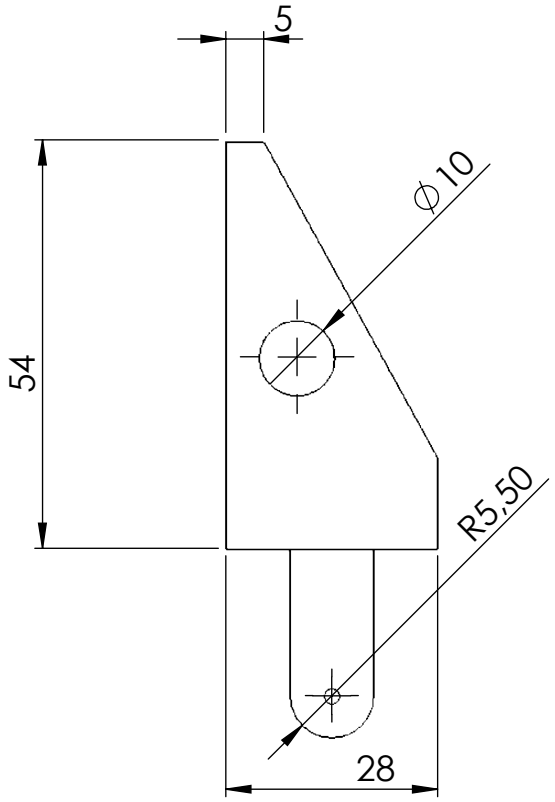
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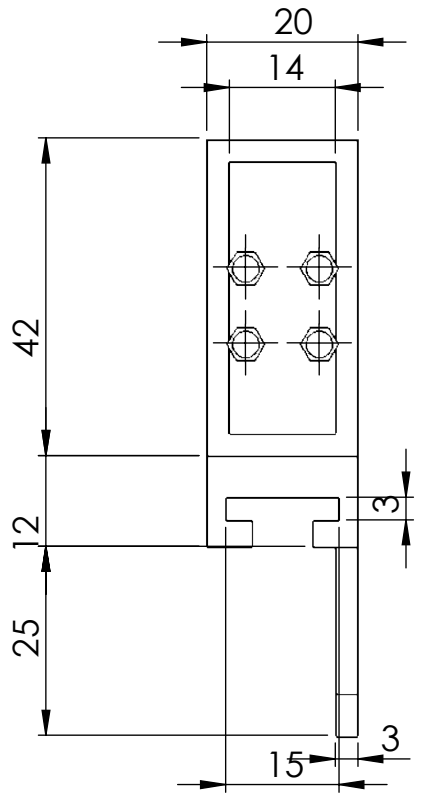
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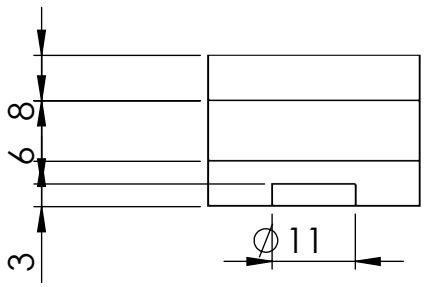




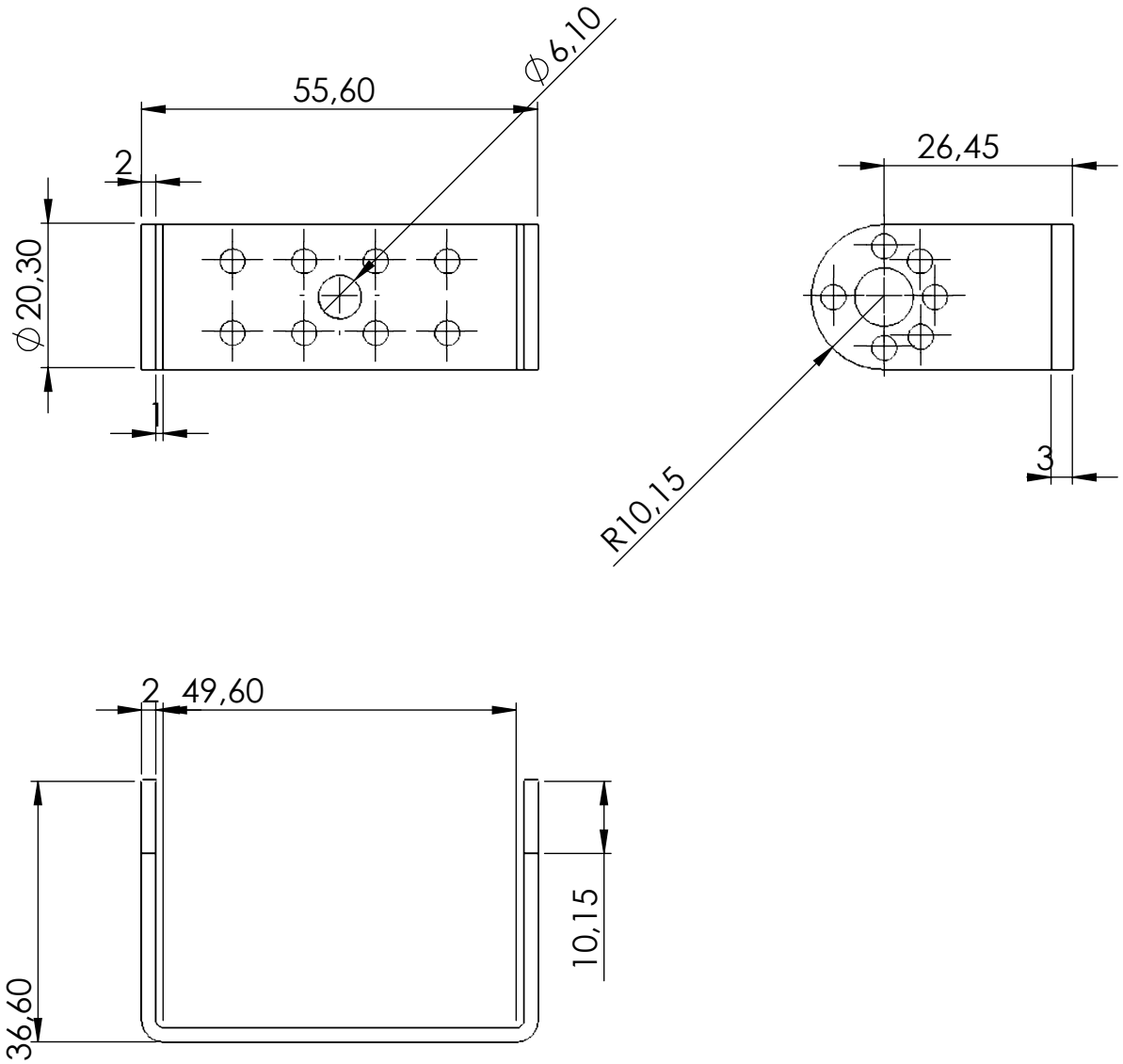
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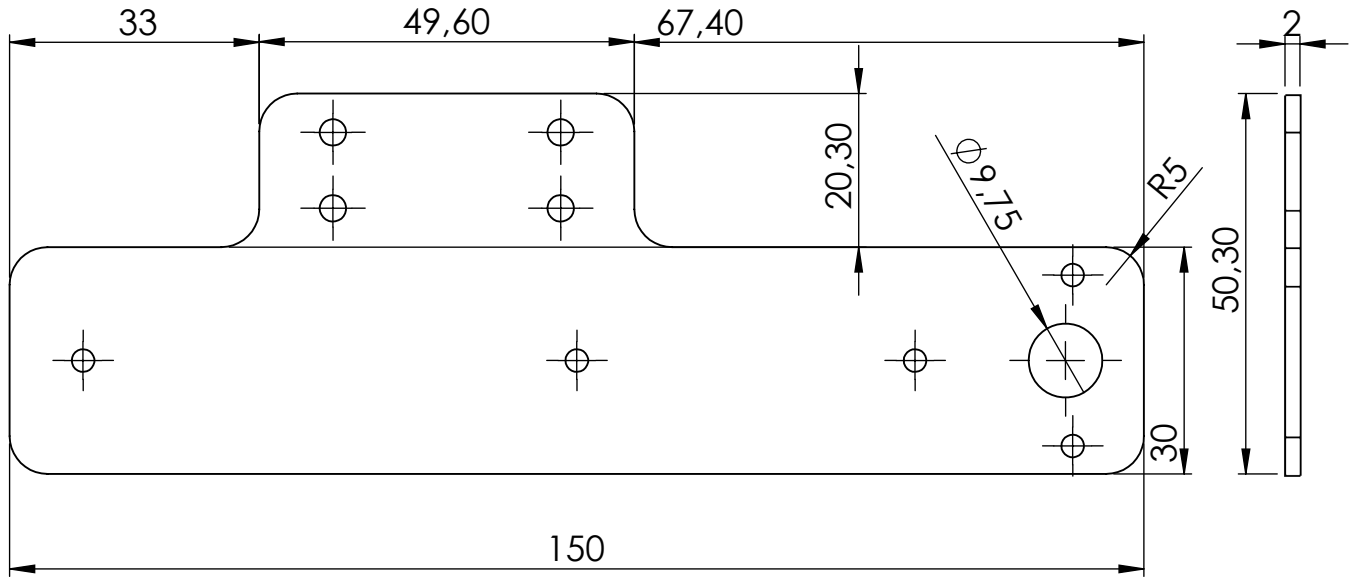


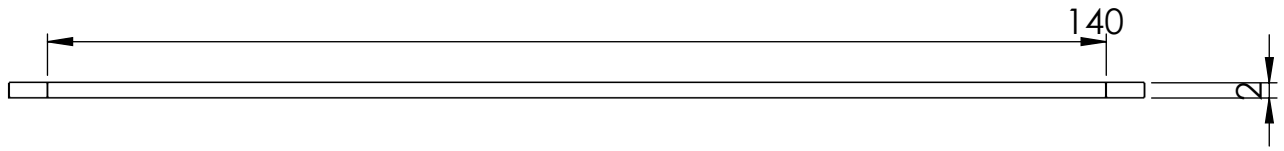


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2eme année MASTER		Dessin
2019/2020	Nedjai Mohamed / Obied Firas	

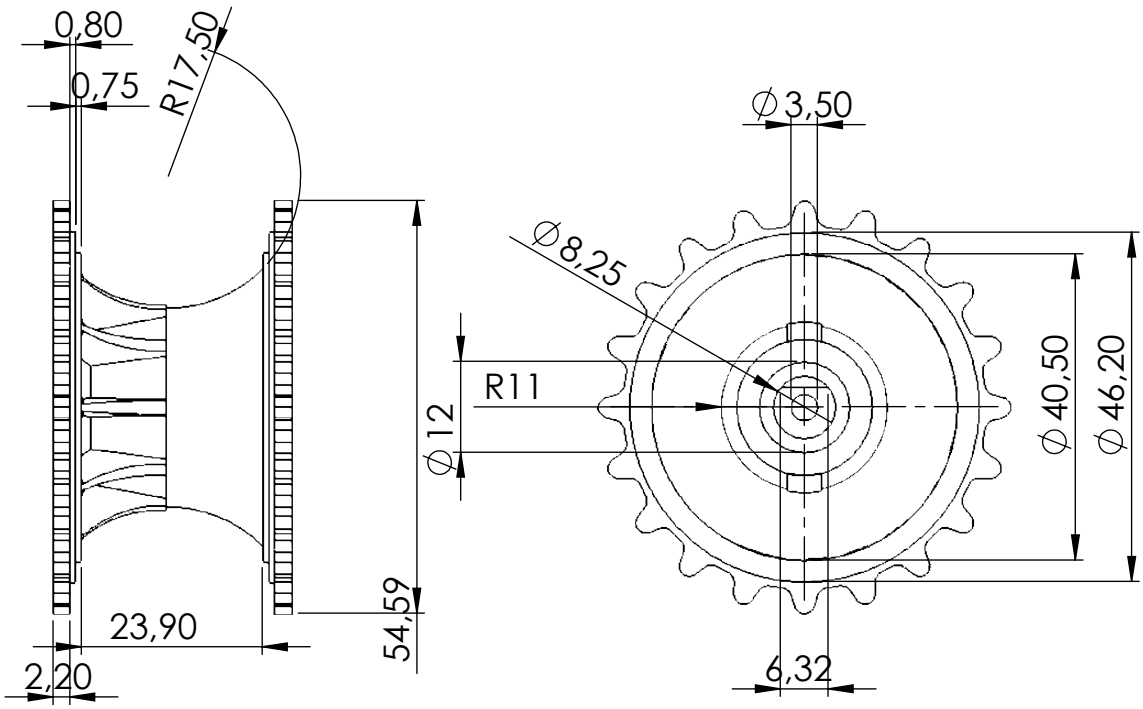


University: Yahia Fares De Medea		
dessin technique	large bracket	ECH: 1:1
2eme année MASTER		Dessin
2019/2020	Nedjai Mohamed / Obied Firas	

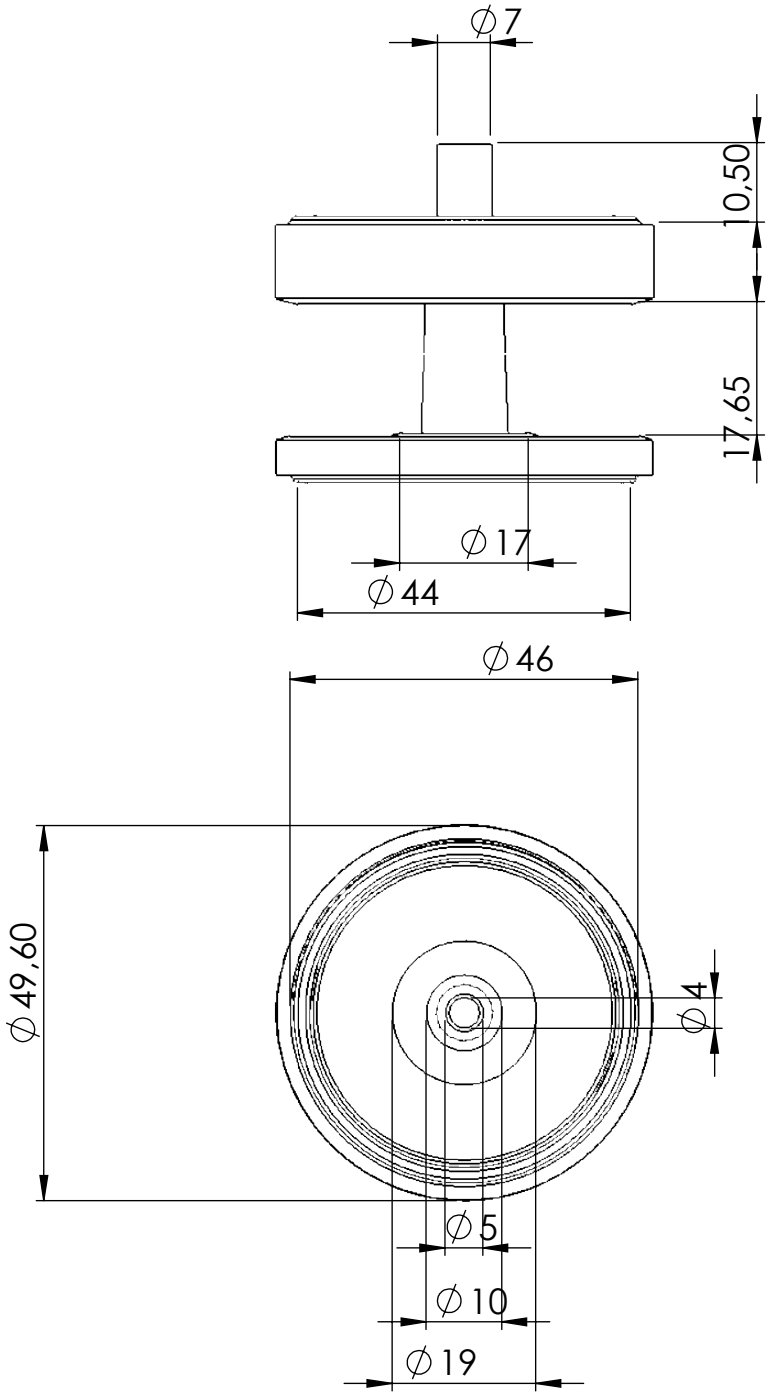




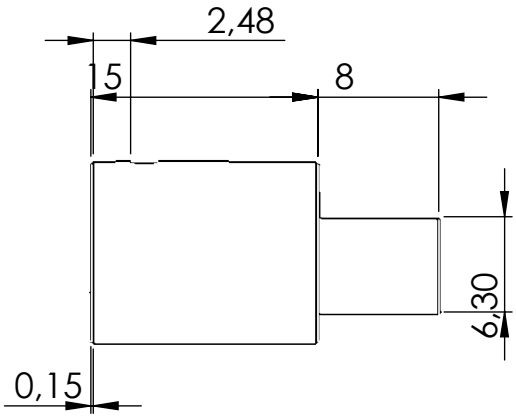
University: Yahia Fares De Medea		
dessin technique	support of the crawler	ECH: 1:1
2eme année MASTER		Dessin
2019/2020	Nedjai Mohamed / Obied Firas	

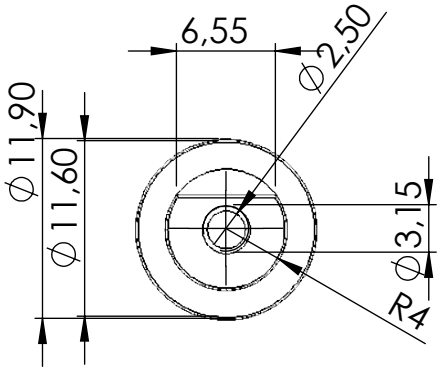


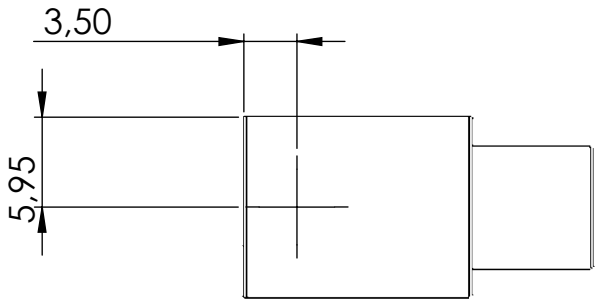
University: Yahia Fares De Medea		
dessin technique	driver wheel	ECH: 1:1
2eme année MASTER		Dessin
2019/2020	Nedjai Mohamed / Obied Firas	



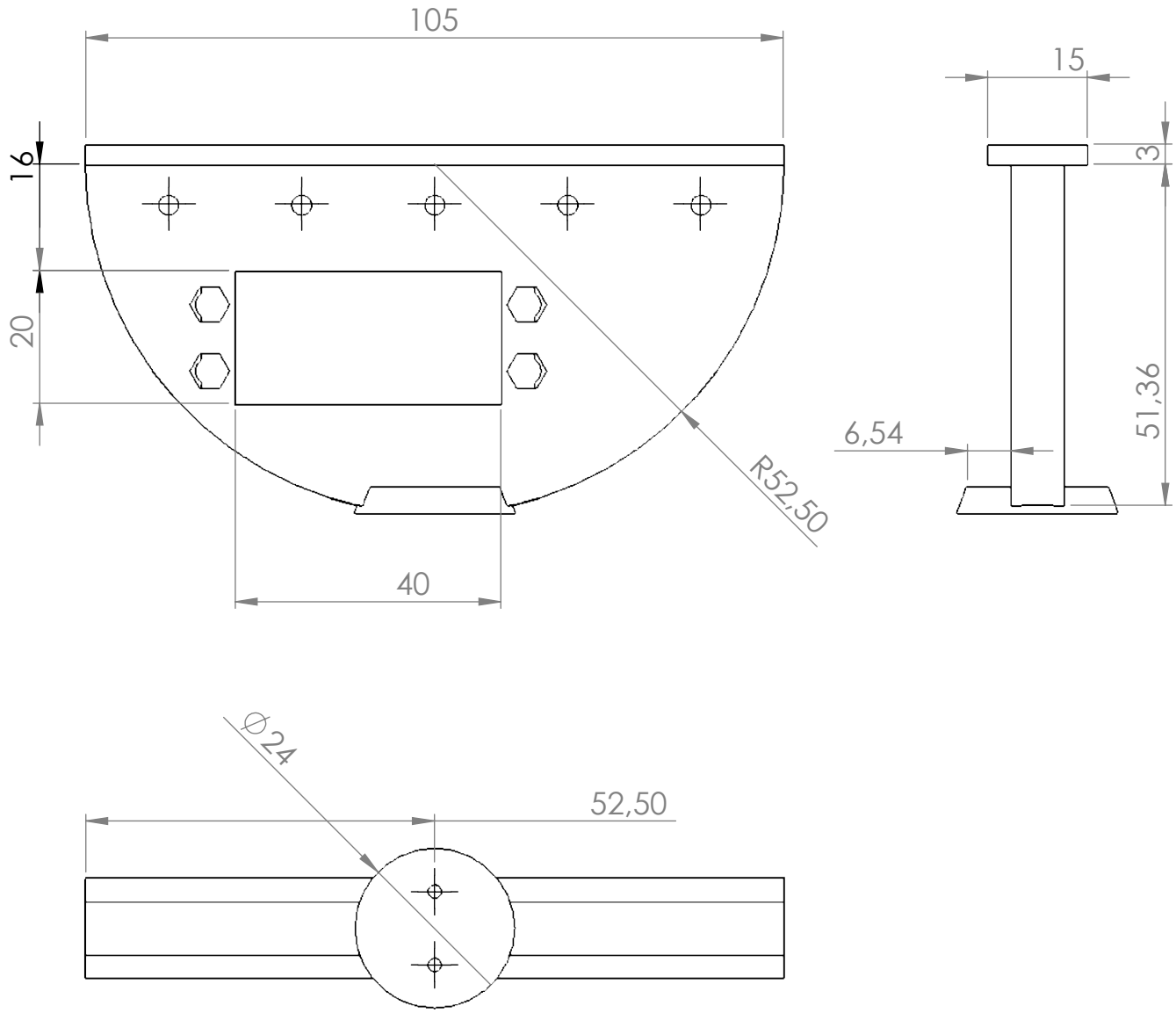
University: Yahia Fares De Medea		
dessin technique	free wheel	ECH: 1:1
2eme année MASTER		Dessin
2019/2020	Nedjai Mohamed / Obied Firas	



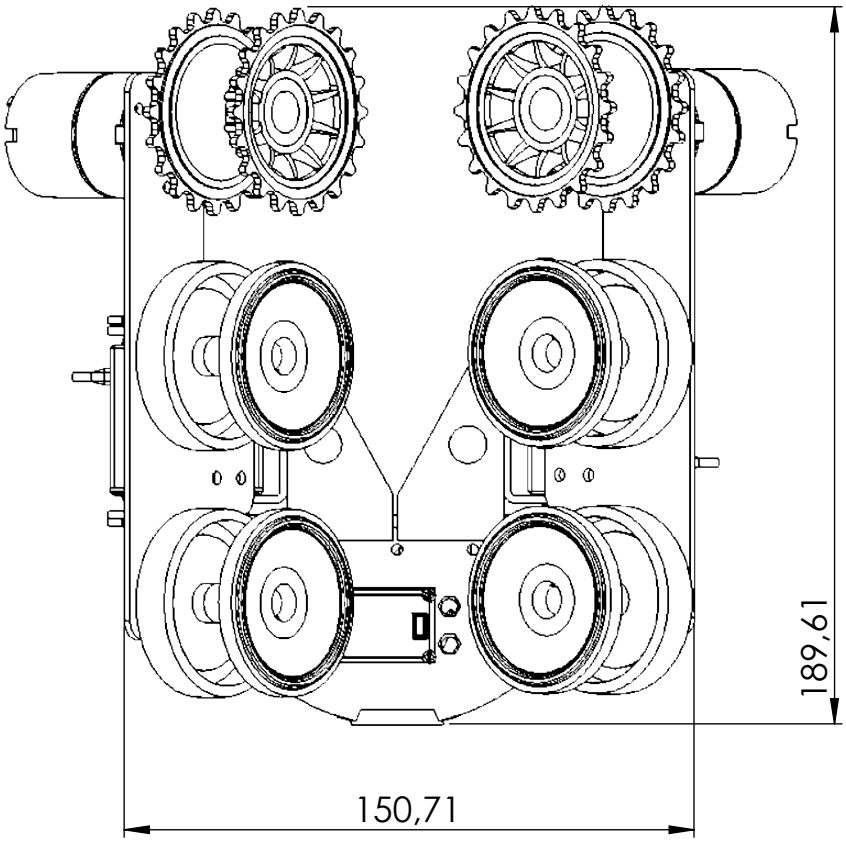


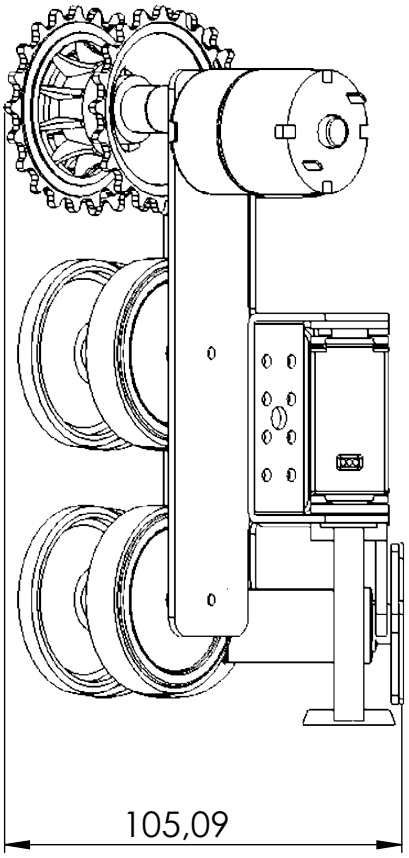


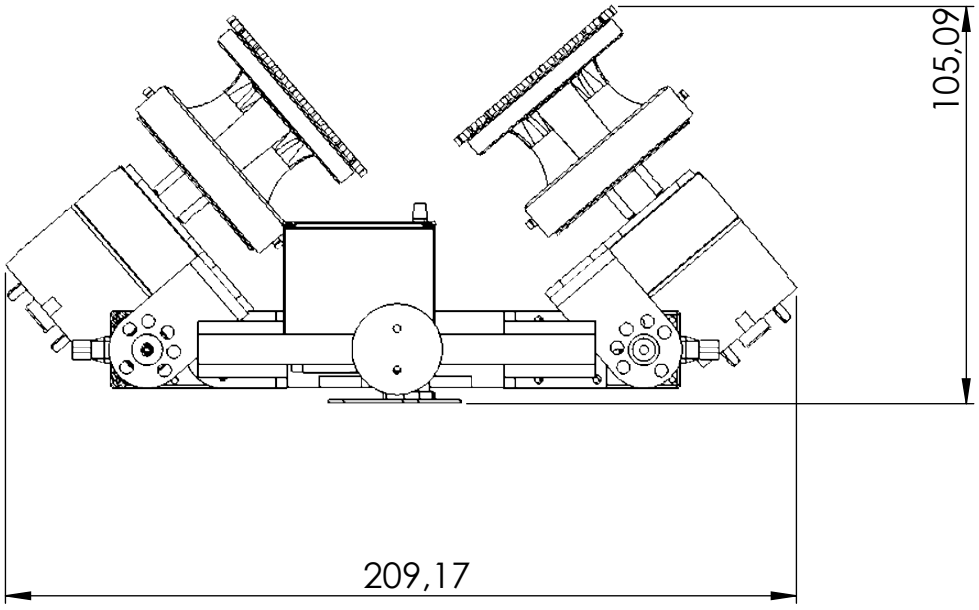
University: Yahia Fares De Medea		
dessin technique	motor horn	ECH: 2:1
2eme année MASTER		Dessin
2019/2020	Nedjai Mohamed / Obied Firas	



University: Yahia Fares De Medea		
dessin technique	SUPPORT	ECH: 1:1
2eme année MASTER		Dessin
2019/2020	Nedjai Mohamed / Obied Firas	







University: Yahia Fares De Medea

dessin technique	robot final	ECH: 1:2
2eme année MASTER		Dessin
2019/2020	Nedjai Mohamed / Obied Firas	