# Problem Definition :

This work is about the extension of the mobile robot on wheel basis, which is equipped with different sensors and cameras(((name and paper))). This robot is used to repair metal plates of dimension (((size in meter))). These metal plates can have defects in the surface after production. At present, these defects are repaired by hand. Since this process is very labour intensive and physically demanding, this work is to be done by an autonomous robot. To avoid long-term damage to workers' health. The areas to be repaired are a small part of the whole plate. These partial areas are marked with a high intensity marker. The robot recognizes these marked areas automatically and should then repair them independently. After repairing this area, the result is to be checked by a high precision laser camera to determine the quality of the repair.

This work is about inspect these partial surfaces for that the rover has to expand with a high precision laser camera. To achieve this, an attachment for this camera must be designed and constructed. This includes the mechanical part of the master thesis.

To perform these movements actors are needed. For this purpose, suitable actors with controll electronic should be developed.

In order to accurately scan the processed areas, a coverage path planning algorithm must be developed and implemented. For this, certain restrictions must be included. This is explained in more detail in section 1.2. This Software will be implemented with Ros and in the end incorporated into the main software.

Finally, the implemented points will be evaluated and suggestions for improvement will be made. In addition, a detailed documentation in the form of a master's thesis will be prepared.

## Camara

The laser camera (((NAME and source) is used. It has a resolution of XXX. Works in a distance range around 200mm. This camera has the advantage that it can inspect the surface of the metal plate to XXX mm. To be able to connect this camera with our robot, the following further tasks have to be done.

### 1.1.2 Mechanic

To connect the camera to the frame, a construction must be designed. In addition, the camera should be adjustable in height, as well as be able to rotate around an axis. The height adjustment is used to move the camera into a safe position during the repair work. The axial movement is needed to align the camera parallel to the ground. There are no specifications on the material and no restrictions on the design. However, to meet today's industry standards, metal fabrication must be considered. For first prototypes a production from a 3D printer would also be conceivable.

### 1.1.2 Electronic

In order to implement the mechanical linear as well as rotational movement, suitable actor must be found. For this purpose, the loads of the motors must be calculated in order to select them accordingly. For the selected actuators then also a appropriate electronics and Controll unit must be selected. In addition, the electronics should be designed so that it can be controlled by a Raspberry.

## 1.2 Informatic – Robotic

The computer science/ robotics part contains the largest part. Here, the areas must be approached and scanned with an intelligent coverage path planning algorithm. There are 3 restrictions for this process:

1. the robot cannot scan the partial areas completely from all directions.

2. in order for the camera to deliver reasonable results, it must travel at a constant speed.

3. the robot must never leave the base plate.

In addition, the computer science part is to be implemented with Ros, since all previous functions were implemented with it. The programming language can be C++ or Python. The operating system is Linux. Different versions of Linux and Ross will be used, so that a functioning downward compatibility must be ensured.

# State of the Art

This chapter describes the current state of the robot and the other subtasks such as mechanism, electronic and coverage path planning. It will describe what the current technical status is and if there is any preliminary work already done for this project.

## 2.1 Project

The project was also started in 2019 as a master thesis. It is a collaboration of the UNI Oviedo with the company Daorje S.L.U. This produces large metal plates. However, during the manufacturing process, there are surface imperfections which are laboriously reworked by hand by the workers. Therefore, a robot was developed in this project which should repair these impurities autonomously and independently. For this purpose, the robot can find its way around the room, recognizes. The areas to be repaired are marked with a high intensity marker, the areas are automatically detected and repaired by the robot.

The SUMMIT XL STEEL robot from Robotnik was selected as the basis. This can not only move like a normal vehicle but can also move sideways due to its special tires. This gives a higher flexibility in the movements. There for the robot can turn on a small surface and change the orientation easier. Subsequently, the robot was extended with the repair tool. This includes the repair tool (grinder itself) as well as the corresponding electronics. Furthermore, various camera modules were added. It has 4 intel RealSens with deep information. With the help of these RGBD cameras the base plate is recognized on which he can move. In addition, 8 individual cameras were mounted in a ring to have a 360 degree view. These cameras are used to calculate the positioning in space. For the coverage path planning for the repair there is also a master thesis. This will be discussed in more detail in section 2.4 - computer science part - robotics.

## 2.2 Camera - Mechanical part

There are several ways to attach the camera to the robot and to realize the movements at the same time. For this purpose, this chapter has been divided into two parts. In the first part, the height adjustability is discussed first. In the second part, the axial mobility will be discussed.

### 2.2.1 Vertical Movement

Various systems are available for vertical movement. A lifting cylinder would be the simplest and most widespread variant. These are available in pneumatic and hydraulic versions. However, they have the disadvantage of requiring a pneumatic or hydraulic system just to make a movement. In addition, they also have the disadvantage that they can usually only determine their position with the help of end position sensors.

A further variant are electronic systems these do not need larger supply system. These systems are also called linear systems. Not to be confused with a linear motor this would fulfil the function but are mostly used for horizontal movements.

There are also electronic lifting cylinders which have no information about their exact position. They are controlled like normal lifting cylinders with end position sensors.

A linear system always consists of a mechanical guide system and a mechanical carriage. With the combination of stepper motor and spindle high accuracies can be achieved. By using the stepper motor, no further sensors have to be used for positioning and the system knows the exact position at any time. Stepper Motors are discussed in more detail in section 2.3.1.

The spindle and slide connection is usually implemented with a ball screw transmission. Here, instead of sliding friction, rolling friction is obtained, which improves the accuracy and smoothness of movement. These systems have been used for years in milling machines and are well developed. These systems are very complex and consist of many individual components. This makes development and production very complex and expensive. Therefore, one is dependent on buying these from a third-party supplier. There are many different manufacturers such as Festo or Bosch which have specialized in linear systems and a wide range for different applications.

Also in the previous work [[[Link of the previous project]]] such a linear system was used. This [[[name of the linear system]]] was bought by the company [[[company name and link]]] and yields good results since then.

[[[Bosch Rexroth handbook linear systems]]]

### 2.2.2 Axial movement

To implement the axial rotating movement for cameras, the end consumer area is the gimbal. This is there to stabilize the camera or if desired to implement a movement. These are available as a purely mechanical variant or in professional camera systems with built-in motors. [[[Example search with image and source]]] Such gimbal systems are also used in the industry mostly they are used in surveillance area. This means moving surveillance cameras or highly complex surveillance cameras in drones and helicopters.

Simple models of such gimbals are available ready to download and can be directly 3D printed. [[[Search Image and source]]]. In this example, the electronics plans are also provided.

However, it is important to note that the accuracy of 3D printed parts is much lower than the accuracy of traditional manufacturing. Therefore, 3D printed parts can always have inaccuracies that affect the positioning accuracy. It should be noted that the more parts are used, the more the production inaccuracy will be propagated.

## 2.3 Camera - Electronical part

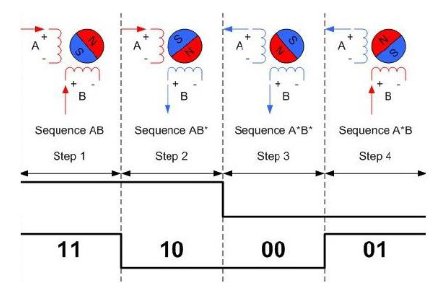
The electronics consists of a motor for linear systems, the corresponding motor driver.

### 2.3.1 Linear Systeme - Motors

Basically, a linear system always consists of two components. The mechanical and a drive. Depending on the application different motors are used for the drive of the linear system.

For linear systems used in conveying technology, acceleration and speed are important. That is why the Brushless motors are mainly used there. Because these motors have a very good efficiency, as well as a low wear. Moreover, they can run at high speeds. However, they have no information about the position of the rotor, so their exact position is not possible without additional electronics. This can be implemented via hall sensors or encoders.

Nevertheless, for linear systems for positioning as used in barrel machines or 3D printers, Stepper motors are standard. Due to their structure of a permanent magnet in the rotor and coils on the stator. Depending on the number of these coils, different numbers of pole pairs can be created. With the correct control, only individual partial steps can now be implemented. In figure XXX you can see a stepper motor with 2 phases and therefore 2 pole pairs. With these 4 steps can be converted for a total rotation.



The standard for stepper motors is 200 steps, which means one step is 1.8 degrees. Stepper motors are generally characterized by a high torque even at a low number of revolutions. The torque is in a range from 1 micoNewtonMeter up to 40 Nm. The speed is usually up to 1000 1/min, but higher speeds can also be achieved. For these stepper motors, a suitable driver is necessary, but more about this in section 2.3.2 Driver. The disadvantage of stepper motors is that they have a lower torque at higher speeds. And that they always consume a high current which leads to a high heat development.

[[[Buch Electric Motors and Drivers /// Bosh Rexroth Handbook Linearsystems]]]

[[[ Stepping Motors Fundamentals paper ]]]

[[[wie funktioniert ein schritt Motor - <https://www.achstron.de/fileadmin/Resources/Public/Documents/HowTo/Schrittmotor_closed-loop.pdf> ]]]

### 2.3.2 Stepper Motor Driver

There is a wide range of Driver for Stepper motors to choose from. The drivers must be selected depending on the motor. It depends on how much voltage and current the motor consumes. The latest generation is characterized by the possibility of micro stepping. This means that a step of the motor can be divided into smaller parts, which means that the motor has an even higher resolution and angles of less than 1.8 degrees can be driven. There are these micro steps in the range of 1/32, 1/128, 1/256. means in the example of 1/128 steps, that a single step can be divided into 128 micro steps. With 200 steps this would be 25600 micro steps for a full rotation of 360 degrees. This means that an angle of 0.014 degrees per step can be achieved. This micro stepping also improves the energy efficiency as well as the noise load. However, it should be noted that the use of such micro stepping also increases heat losses. Therefore, the motor should be cooled accordingly or be dimensioned accordingly larger.

[[[ Quelle <https://www.zikodrive.com/de/ufaqs/microstepping-can-gebraucht-verbessern-stepper-motor-performance/>]]]