# Problem Definition :

Robots can be used in almost all areas of work due to their high flexibility. Moreover, they feel no pain and no fatigue, which makes them perfect for extreme working conditions. In which a human worker would reach its limits. Or if they are used for a long time with this work it can come to health damages. Thus, human lives can be spared and this hard work can be done by machines. Which is why more and more robots are being used in many areas in the 21st century.

This master thesis is about the extension of the mobile robot, 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.

Furthermore, 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 actuators are needed. For this purpose, suitable actuators with control electronic should be developed.

In order to accurately scan the processed areas, a coverage path planning (CCP) algorithm must be developed and implemented. Which this coverage path planning algorithm then the trajectory for the movement of the Robot can be Calculated. This will be the main part of the Master Thesis. For this, certain restrictions must be included. This is explained in more detail in section 1.2. This Software will be implemented with the ROS Framework 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

To inspect the steel plate, the robot incorporates a laser triangulation profilometer. This equipment should be protected when it is not used to protect it from collisions, dust, and other hazards that are usually present in an industrial environment.

### 1.1.2 Mechanic

To Protect and 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 also an appropriate electronics. The Camera Subsystem will be Controlled by a Raspberry Pi. It will connect the subsystem with the robot central control unit.

### 1.2 Informatic – Robotic

A suitable coverage path planning is to be developed and integrated into the ROS framework. That the Robot can get to all the marked areas and then scan them accurately. But there for these 3 restrictions must be observed.

1. the robot must never leave the base plate. Because of safety Reasons.
2. for the camera to deliver reasonable results, it must travel at a constant speed.
3. the robot cannot scan the partial areas completely from all directions.

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. There are different subsystem inside the Robot but they have different Versions of Linux and different distributions of the ROS Framework are used. The developing program must work with the different Standards and a full 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. Inspect large metal plates and if needed also repair them. These plates can have some 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. There for the Robot first detects the Plate which acts as his working space what he cant leave. This he will do with 4 Build in Real Sens cameras. Which also record Depth information. In addition, 8 individual cameras were mounted in a ring to have a 360 degree view. Those help to improve the positioning accuracy. When the robot knows his working space. He then starts to build a map of this Plate. From this map, the important areas are recognized, which were previously marked with a high intensity marker. These parts are then repaired according to the operator's selection.

The SUMMIT XL STEEL robot from Robotnik was selected as the basis. The Robot is equipped with Omni-wheels which gives him a higher flexibility in Movement. The Robot can rotate with respect to their own center of gravity. That mean he can change the Orientation without changing his Position. The big Advantage of these holonomic robots are that you can control the movement and the orientations with two independent Variables. Subsequently, the robot was extended with the repair tool. This includes the repair tool (grinder itself) as well as the corresponding electronics. For the coverage path planning for the repair there is 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

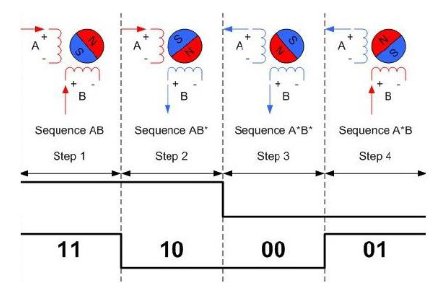
The electronics consists of a motor for linear systems, the corresponding motor driver.

### 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> time and Date last used ]]]

### 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/>]]]