ROBOTICS PROJECT – ROBO3

School year 2023-2024

„GRABBY - the Warehouse Robot “

Final Project Report

Students:

Hendrikse Jérémy

Ortstadt Julius

Ecole Polytechnique Universitaire de Nice Sophia-Antipolis, Département robotique et systèmes autonomes
1645 route des Lucioles, Parc de Sophia Antipolis, 06410 BIOT

Introduction

Logistics demand is at an all-time high especially with the soar of e-commerce and the massive number of parcels sent and received every day. Being aware of this demand, we took it upon ourselves to develop an autonomous warehouse robot. Out of this idea came Grabby. A robot whose goal is to navigate through the warehouse to retrieve a parcel and deliver it to the user. This increases efficiency, allows for more flexibility in work flows and reduces the risks of accidents and errors.

All this will be achieved by utilizing a combination of autonomous navigation and computer vision. This technology will allow Grabby to create an entire map of the warehouse, use pathfinding algorithms to determine which way is the fastest to get to the parcel and update the map if new changes and/or obstacles are detected in the environment.

The objectives for this first development year were to get a fully built prototype on which we could experiment, perform basic tasks and movements, and build the code architecture.

Wiring schematic

The project uses a lot of different components, boards, and sensors. If we want the project to work, we need to wire everything accordingly. Below you can find the wiring diagram for both the mobile base and the grabbing system.

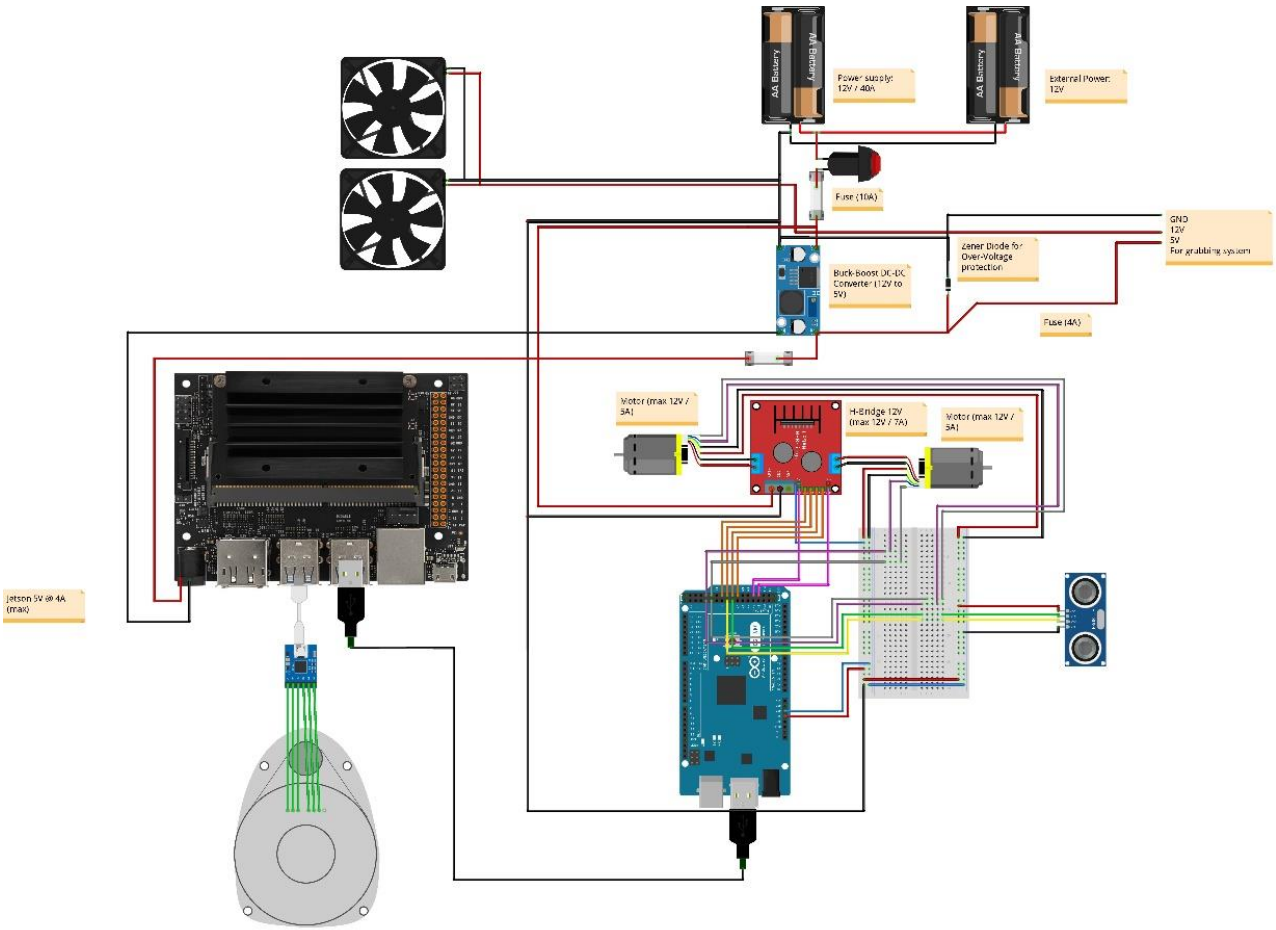

Figure 1 - Mobile Base Wiring

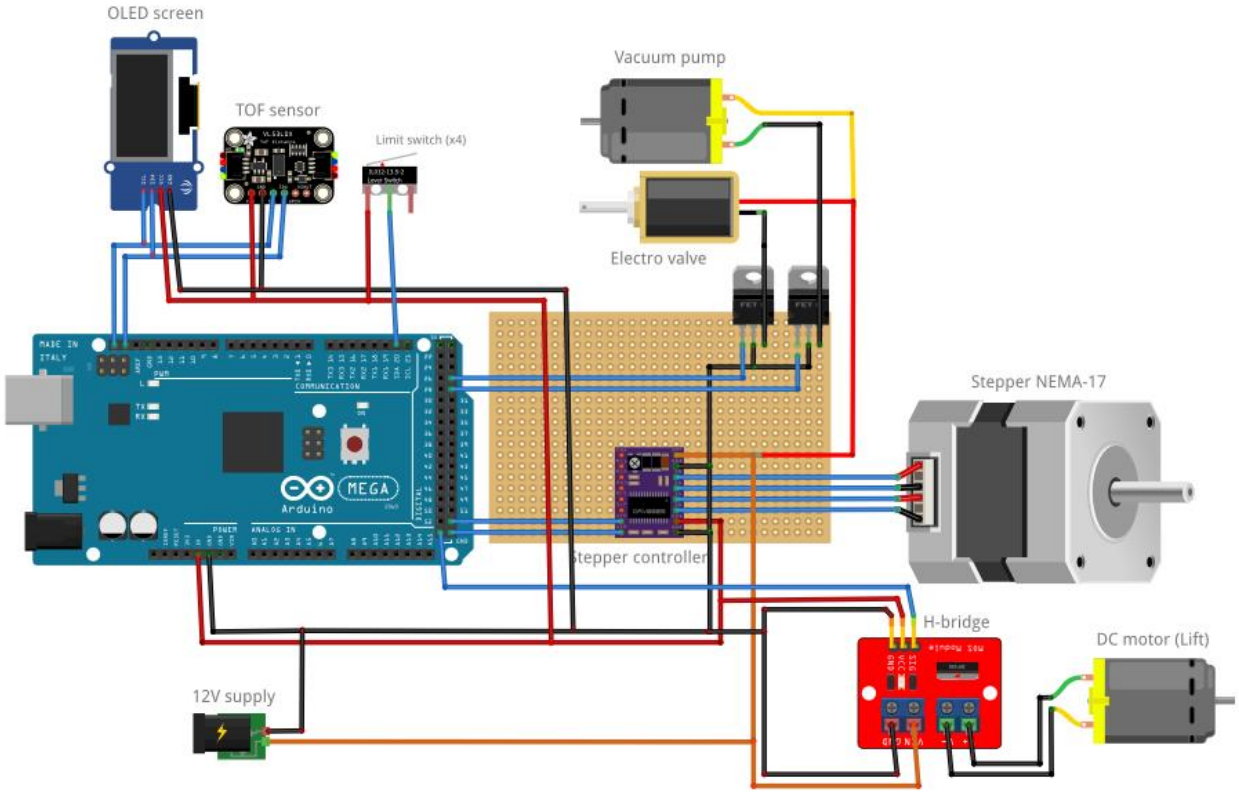

Figure 2 – Grabbing System Wiring

Flowchart

All these sensors and boards will work together through an algorithm. The way in which this algorithm is supposed to work is represented in the flowchart below. It describes the different tasks that will happen depending on what the robot is doing.

The first part of the algorithm will be all about the navigation of the robot. First, it'll have to check if an order has been received and if the box is in the warehouse. Then it'll need to navigate to the box using the stored map and the sensors present on it, like the LiDAR, the motor encoders, the ultrasonic sensor and later the IMU sensor (Inertial Measurement Unit).

The second part is about positioning the robot correctly in front of the shelf and to retrieve the box. For this task we will mainly rely on the stereo camera which will be mounted on the grabbing system of the robot.

When this is done, meaning when the package is secured on the top of the robot, Grabby will navigate to the drop of zone where the user can then get his package.

Grabby will then go back to a stand-by mode, awaiting new orders.

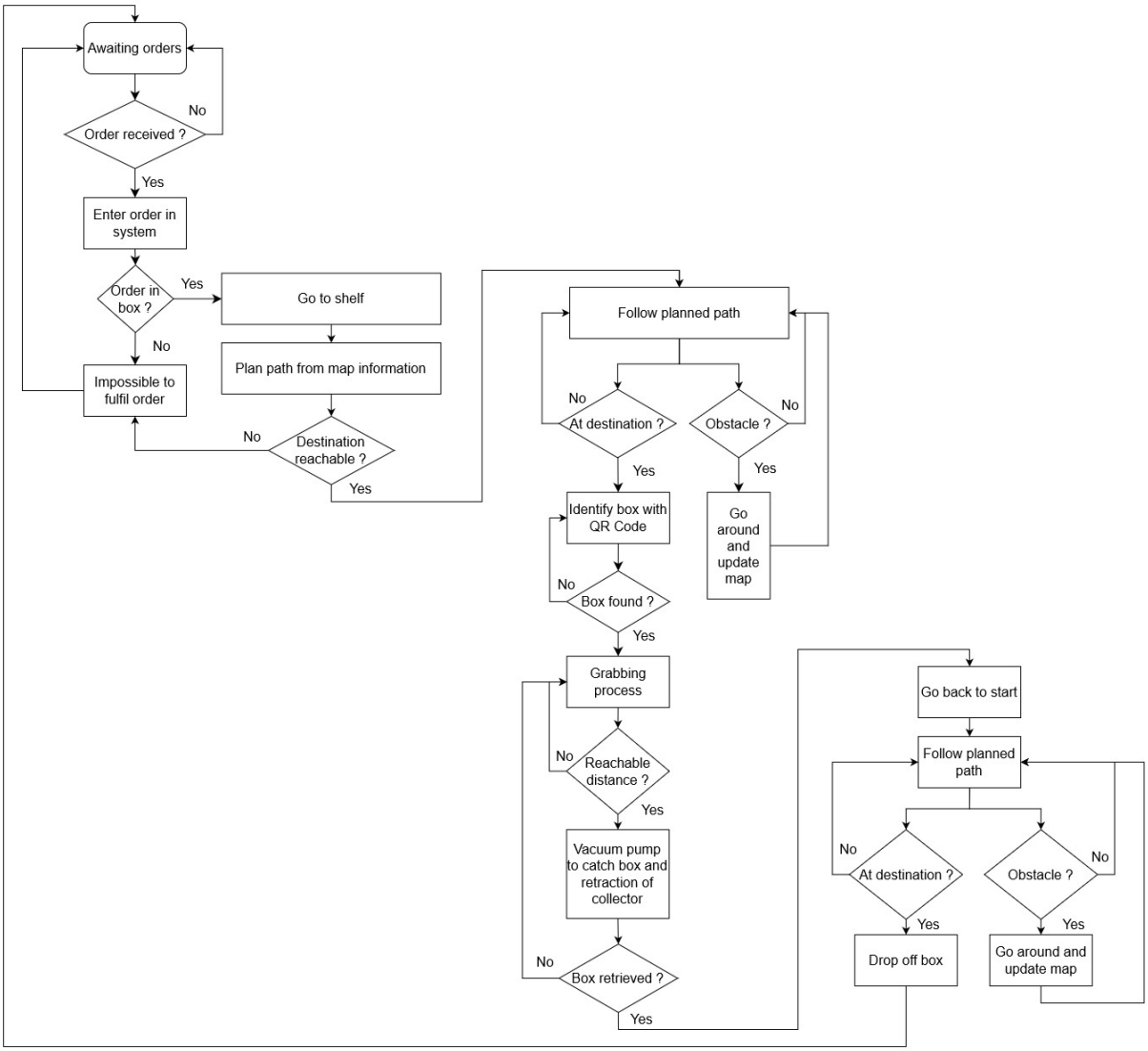

Figure 3 - Flowchart

Project Cost

We put a lot of time and effort into this project, and we are dedicated to continuing it next year. As a result of this we tracked the overall cost of the project by combining the material cost as well as the work cost. Below you can find a detailed list of the cost summary.

➔ For the materials:

Description	Qty	Total price	Description	Qty	Total price
Screws and bolts		82,18 €	Stereo camera	1	80,00 €
Bearing and shaft support		38,77 €	Ultrasonic sensor	1	0,49 €
Connectors and cables		32,91 €	Motors 99:1 and support	2	130,00 €
Linear guide	1	13,82 €	Motor Driver	1	24,80 €
Vacuum system kit	1	12,44 €	DC-DC Converter	1	3,00 €
Stepper NEMA-17	1	3,97 €	Nvidia Jetson Nano	1	224,00 €

Endless screw and rod	1	1,00 €	Arduino Mega	3	50,34 €
OLED screen 0,91inch	1	2,45 €	Cooling fan	4	6,00 €
DC motor 148:1	1	31,50 €	12V Power Supply	1	20,00 €
Led strip 144Led/m	1	5,84 €	Wood (€/panel)	5	25,00 €
VL53LOX TOF sensor	1	1,00 €	PETG (€/kg)	4,5	135,00 €
Iron rod	1	3,69 €	Plexi (€/panel)	0,5	15,00 €
Limit switch	1	1,00 €	Electric components		1,83 €
CITRUS motor controller	1	13,90 €	Scooter Wheel	2	7,40 €
Stepper controller	3	3,00 €	Wheel Hub	2	13,60 €
Belt	1	1,36 €	Ball caster wheel	2	5,70 €
Total			**990,99 €**		

➔ For the work:

The average salary on which we are supposing our work cost is 38k euros for 1600h of work. We worked a total of 545 hours on the project. This includes work time in class as well as outside of university. This comes in at a total of 12.943,75 € (using the average hourly salary of a French engineer described above).

The overall cost of the project including materials and salary is 13.934,74 €.

Bibliographic project report

Regarding the bibliographic project report, we made at the start of the project. There are a few things we should have done differently and some more research on others.

We should have done more research on autonomous navigation and mapping. These two methods are challenging to put in place and more research on the subject would have prepared us better. The part with which we had the more problems was the combination of odometry and LiDAR data.

We could have also made more research on ROS and other systems, in order to better choose what is better suited for our application.

Problems and Solutions

We encountered numerous problems during this project. We managed to solve some of them but other will take more time to get out of the way. Below, we listed some of the main problems we encountered and the solution we implemented to resolve the issue if we could find one.

First, concerning the hardware. Since we made everything from scratch and in two main parts there were problems regarding stability and weight. The weight would be a concern for later, but the stability needed to be addressed and resolved. The frame on which the robot is built is the 4th prototype. The advantage of this is that the frame and the wood are working together to create a solid base in contrary to the previous version where the PETG would hold all the

weight and therefore curve the base plate of the robot. This led to the motorized wheels losing ground contact rendering the robot immobile.

Second, another issue was the power system. We wanted everything to be powered by either an external 12V power supply or a battery. But some of our components have a different operating voltage. We had to use a converter and implement multiple safety measures to avoid damaging precious components like the Nvidia Jetson Nano.

Lastly, on the software side. It is not yet operational. The robot uses ROS as an operating system, and we needed to make a few tweaks to adapt it to our architecture. In the end, we managed to connect all the sensors and boards individually and use the data provided, but the problem of using all the sensors together to achieve the robots main goal is still persistent.

Conclusion and Evolution

To date, the hardware for the robot is mostly complete with a few optional things left to do, but the robot is ready receive the software and be tested.

The things that don't work yet are the autonomous navigation. For this, we need more time to implement functions and services for the sensors to work together and for the SLAM algorithm to reliably navigate the map. Additionally, although the QR code detection works, we still have some issues with the depth perception of the stereo camera. This is crucial since the grabbing system will rely on this data to determine how much it still needs to move forward in order to grab the box.

The things that have been done to this point are mostly what we expected we could do in the time we had. We created a prototype which will be capable of achieving everything it needs to, we learned a lot about ROS, CAD conception and a lot more.

We will continue working on this project next year, and our goal is to have an autonomous robot at the end of it. As said previously, we need to make some small improvements to the hardware, and we also need to figure out how to make all the sensors work together.

Working on this project was a lot of fun and we gained a lot of insight into the world of robotics. We learned about the things we shouldn't do and how we can do the ones we should.

The reason why we chose this project is because we were always fascinated by how logistics networks and warehouses function. All this to deliver parcels to the customer. So we chose this project to learn more about how all this is done and how we can bring something to the table and learn while doing so.

Bibliography

Below you can find a list of the main websites which helped us in developing this project:

- ROS Wiki
- OpenCV documentation