Die Enten

Willibald-Gluck-Gymnasium (Germany)

Team description

RoboCup Eindhoven 2024

1. About us

2. System

3. Application

4. Conclusion

5. Appendix

1. About us

1.1 Logistical information

Team name: Die Enten

Name of robot: N10

School: Willibald-Gluck Gymnasium

Country: Germany

Contact Person: Tobias Wagner

Email: t.wagner@wgg-neumarkt.de

1.2 Team

Mr. Tobias Wagner
He is the team mentor, and he helps with delivering or ordering the needed parts for our robot. He also gives good advice and tips on how to assemble the robot. Additionally, our mentor also gives us directions when needed.

Antonello
He isn't a member of our MINTex group but will support our team in Eindhoven as a mentor since he has a profound knowledge about programming and the hardware.

Jonas Nicklas
Jonas is our main programmer and does most of the software work. Moreover, he helps the other team members with explaining and teaching them how to program.

Florian Schäff
He focuses on making the 3D design of the chassis of our robot, but he helps Florian Hierl and Luca with building the robot too.

Florian Hierl
Mostly, he works on the mechanical aspect of our robot. Currently he is focusing on building the robot arm.

Dalea Badri
Dalea focused on taking care of the logistics and organizes the TDP. She also helped designing our T-shirts with Fiona and another friend. Furthermore, she helps with the hardware when needed.

Fiona Schäff
Fiona's emphasis is on the logistics as well and she handles the TDP together with Dalea too. Additionally, she aided with designing the T-shirts. If help is needed with the hardware, she lends a helping hand.

Friedrich Worch
Friedrich is also one of our programmers, so he helps the others with the software and spend his time on developing the code for our robot.

Luca Zylla
Luca is mostly working on the hardware, but he always lends a helping hand where it is needed. Recently, he has also been learning how to program.

Simon Sturm
Simon's job is to work on the hardware with Florian Hierl and constructing the robot arm.

Christopher Zech
Since he is quite talented and interested in math and programming, he focused on all informatics and mathematical aspects as well as programming and the software. He works closely together with Friedrich and Jonas.

Ilian Odenbach
Ilian is one of our program specialists who already finished school but still supports our team a lot for example by developing and improving our software.

Felix Schreiber
Felix finished school as well, but is still extremely helpful, like Ilian, with our software and programming.

Our official Team for the RoboCup in Eindhoven will be the first eight, but the others will be there as daily visitors and support.

1.3 Introduction

Our team, "die Enten", is made up of the students who are in the "Mintex"-course, of the Willibald Gluck gymnasium in Neumarkt, Germany. Our name "Enten" is the German word for "ducks" and sounds very similar like N10. Since we have chosen a Lego-duck as mascot, we decided to name our robot N10 – a mix between international, technical, and traditional German.
We haven't been able to compete on an international level before, therefore we are very motivated to take part in this competition. We meet up weekly in order to improve our robot, brainstorm about new ideas and solutions or fix problems. To name some examples, we had some delivery problems, which caused time problems and created extra pressure. Though we quickly solved this, by meeting on the weekend and in our holidays.
The aspects we want to focus on are manoeuvrability and stability. We realised both these things were important when we were at the RoboCup German Open RMRC 2023 in Nurnberg. Since one of the problems, we faced was that our robot was not stable enough, because it was a little

too tall. But also, our 3D-printed tires did not have any grip. So, we want to avoid having that problem again, but also, we realised how important it is to be able to change positions and go back and forth quickly. Which is exactly why we want to focus on those aspects.
We also want to focus on making the robot arm better, because we believe that it will help us a lot during the competition. It was also something that we thought would a nice experience to make and it would evolve our skills.

Our school: Willibald-Gluck-Gymnasium Neumarkt

1.4 Experience

Numerous events at which we have taken part with our robot have enabled spectators to see them in action and to recognise the necessary aspects of building and control of such a robot. These events allowed us to exchange ideas with the other groups on site and receive helpful information and suggestions for improving our robot, but also to pass our ideas on to the other groups.

One of the events took place at the Christoph-Jakob-Treu school in Lauf. From the 17th to the 18th of March 2023, during our stay, several courses were offered to us so we can deepen our understanding in programming and building the parkour. During the project, the team had ample time to collaborate on the robot's development. Both software and hardware experts were able to freely exchange ideas and design new concepts with the guidance of teachers and experts.

Towards the end of the 2022/23 school year, the final of the "Robots unite!" project took place at our school. The project was supervised and organised by Professor Stefan May from the Georg Simon Ohm University of Applied Sciences and was designed to encourage the participating teams of students to get their robots to work together to complete a large course to which all teams had contributed. The course itself was strongly modelled on the well-known video game "Portal" and included challenging course passages as well as entertaining mini games. Despite minor technical problems, the day was a remarkable success overall and the local press also reported on it. This test also drew our attention to some of our robot's faults, which we were subsequently able to rectify.

Our visit to the 'Langen Nacht der Wissenschaft' (November 2023) enabled us the access to different tools but also the professional knowledge of the organiser. Also, we get the chance to test our robot with different parcourse elements. Even if they were incredibly challenging for N10, we gained valuable information which aspects we had to improve. On this event we profit by the helpful and inspiring exchange with other schools and our teamwork skills were strengthened.

In Autumn 2023, we took part in the German Opens on the Consumenta, in Nuremburg. As an achievement we reached the third place and won the Team-competition. There we experienced the weak points of N10 and get an impression how the competition in Eindhoven will work.

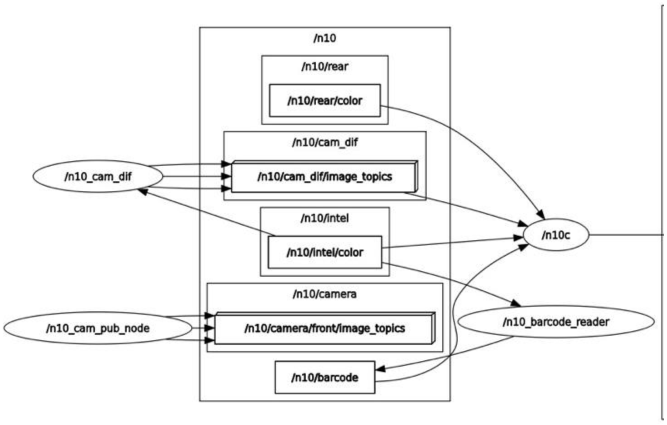
The final meeting of the participating schools in our region before the RoboCup on 18th June took place at the technical Ohm university of Nuremburg. Unfortunately, we had to go through some hardware as well as software problems there but on the other hand we not only had the chance to experience the RoboCup relevant obstacles once more but also to exchange some new ideas and discuss problems with professionals and get help.

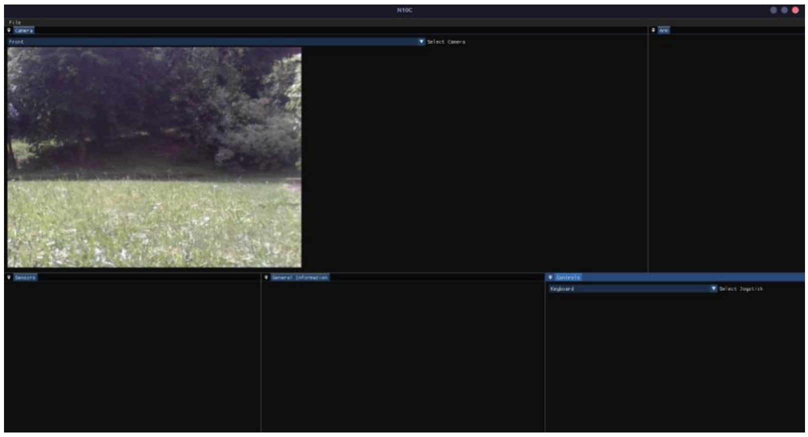
2. System

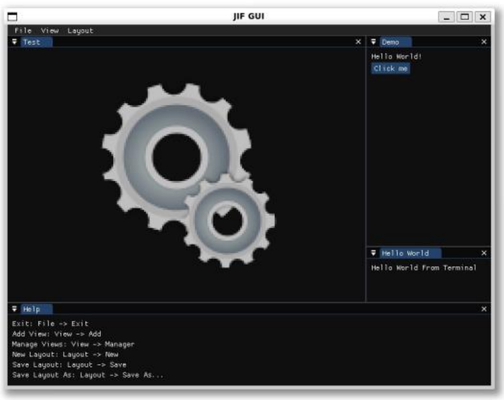
2.1 Software

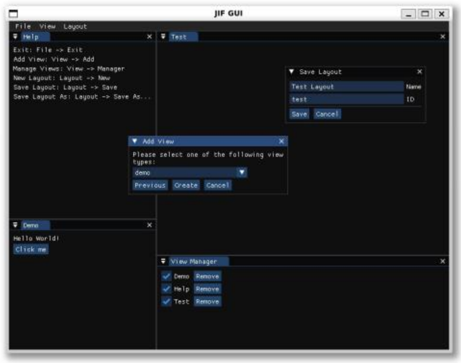
The software of our robot N10 is written in C++ and Python and is based on the ROS 2 framework. Therefore, the software is divided into several nodes that communicate with each other via ROS 2 topics. To control the robot, we use a self-developed GUI written with the GUItar library by Felix Schreiber (a former team member). This GUI is called "N10C". It can also be found on Github under the following link: https://github.com/wggRobotic/N10C this GUI receives the camera images from our rear camera as well as from our Intel Realsense and in the future also a thermal image as well as a motion capture version of the image of the Intel Realsense to make movements visible from N10-CAM-DIF. The GUI also receives recognised barcodes from BarcodeReader.

Our 6 motors and 6 servos are controlled via our self-written nodes N10-Translator and Servo-Controller to maneuver the robot. Our nodes also communicate with Professor Mai's Eduart Node to control the tires, because the N10 translator only acts as a communicator.



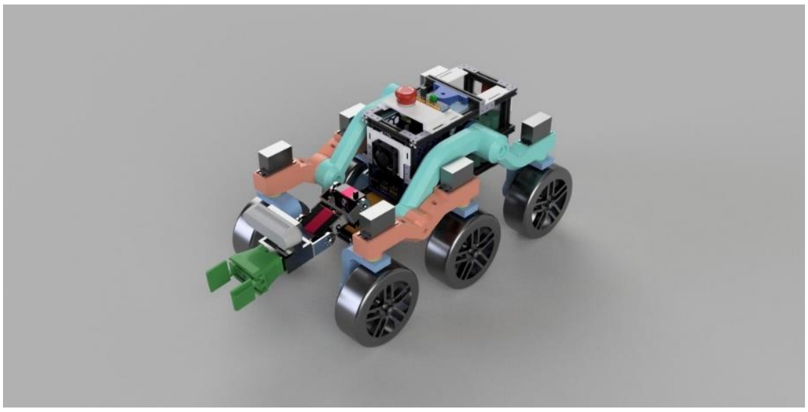


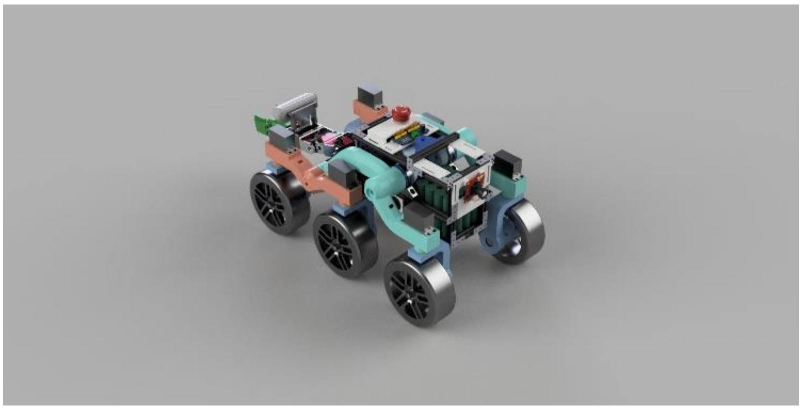




2.2 Hardware

Our robot is a rover featuring a Rocker-Bogie suspension system, inspired by the Mars rovers and the open-source project Stair Climbing Rover by WildWilly. The components have been modified, supplemented, and completely redesigned to suit our specific needs.





Main Body Structure

The main body of the rover is assembled using aluminium extrusions from Makerbeam. This design choice ensures a stable, robust, yet lightweight framework for the robot.

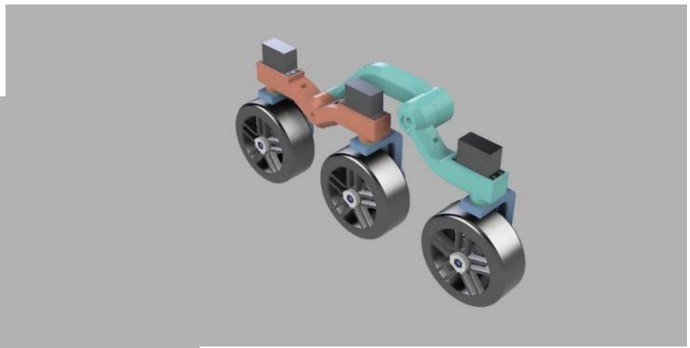
Most of the other components are designed for 3D printing and can be assembled using M3, M2.5, or M2 machine screws. For additional stability and support, the servomotors, motor mounts, and wheel hubs are anchored in the plastic using M3 heat-set inserts. The materials used to print the parts are PETG, due to its elasticity, which makes the parts less likely to scatter under large impacts, and PLA for the rather decorative elements, due to its lower cost.

Wheel control and alignment

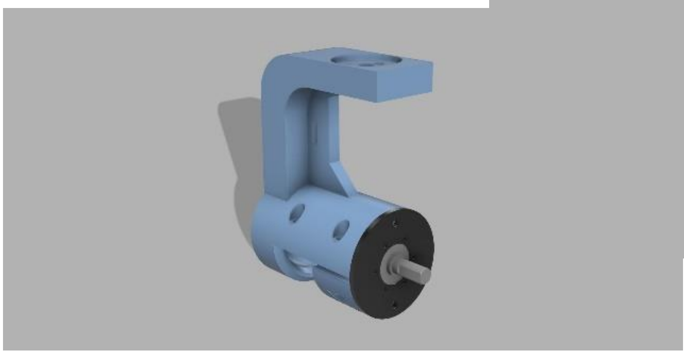
The control and alignment of each wheel are managed by Hobby servomotors of the type MG996. These servomotors are addressed via I2C through an Adafruit PCA9685 servo board.

The wheel and motor mounts, as well as the wheel hubs, are specially designed for our purposes and printed from PETG. Due to space constraints, the motor mounts needed to be fabricated from steel to prevent rotation, as a printed part with a thickness of 2mm would not provide the necessary strength. All 3D-printed parts and CAD-files can be found in our Github.

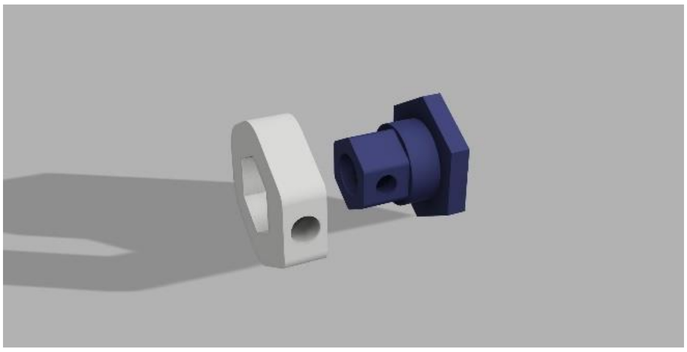
Rocker-Bogie-System with servomotors and motor-mounts:



Motor-mounts:



Wheel-mounting



Motors and motor control

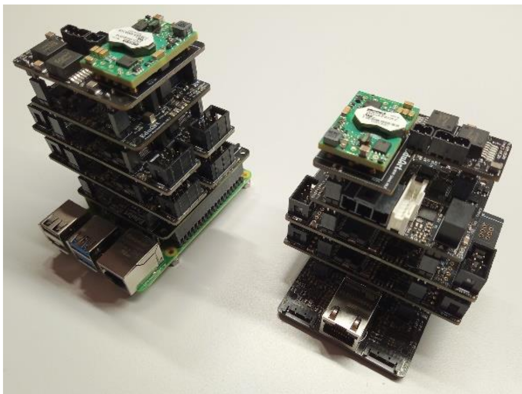
Our six wheels are powered by Faulhaber DC motors with planetary gearboxes 2224U018S R IEH2-512 22GPT 44:1, generously provided by Faulhaber for this project. Motor control and regulation, as well as the power supply for other components, are handled by a Kinematics Kit, kindly provided by EduArt . This kit is designed to be mounted on a Raspberry Pi 4 or 5 and can be expanded modularly. The basic components of the kit include:

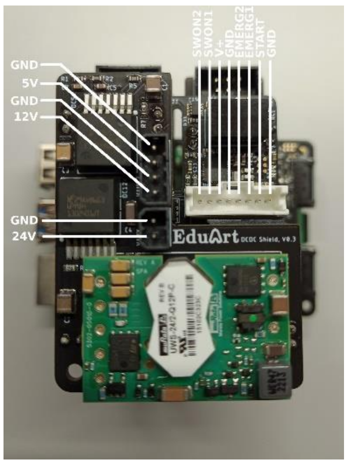
- Adapter Board either directly pluggable onto a Raspberry Pi 4/5 or as a standalone EduArt Ethernet controller board, with which you can connect any computer with an Ethernet interface. This gives you the freedom to build the computing power into your robot that you need for your desired application. This board is supplied via the socket strips, i.e. a circuit board with the appropriate sockets for a power supply unit or a battery should be used. The possible input voltage Vin is 12V to 55V. Depending on how many motors are connected, the power supply must be able to supply higher currents. High-current batteries are recommended for operating a robot (min. 8A).

- Motor controllers can be plugged in directly. This allows you to control the speed of 1 to 8 motors. The motor controllers are available in two versions, single-channel or dual-channel. Up to four motor controllers can be used, i.e., it is possible to use 1 to 4 larger motors (IRMS up to 5A) or 1 to 8 smaller motors (IRMS up to 2.5A). The dielectric strength of the single-channel motor controllers is 55V. The dielectric strength of the dual-channel motor controllers is 35V.

- The Power Management Module takes over the charge control of a 19.2V NiMH battery pack and also offers an on/off logic. Temperature monitoring of the battery uses an integrated 6.8 kOhm NTC. Never connect a battery other than the one supplied by EduArt.

- The Auxiliary Power Supply Module provides additional voltage levels with which you can supply additional devices. The permissible operating voltage is between 15V and 36V.





Power Supply

The power and voltage supply is provided by a NiMH, 19.2V, 4.5 Ah battery pack. Although Nickel-metal-hydride batteries are significantly heavier than comparable Li-ion batteries, they have much lower risks of fire and explosion. Additionally, these batteries are more maintenance-friendly, which outweighs the disadvantages for us. For powering the Raspberry Pi 5 and the servomotors, the voltage is stepped down using DC-DC converters, as described in the Motor Control section. Specifically, for powering the servomotors, we use an additional DC-DC converter UWS-5/10-Q12P-C on our board that supplies the servos on the PCA9685 board with 5V at 10A as an external power source.

Cameras and Camera Feed

The robot is equipped with three cameras:

- Front Cameras: Mounted on the robot arm are an Intel RealSense D435 and a Waveshare MLX90640 thermal imaging camera, both facing forward.
- Rear Camera: A USB camera module OV2710 is used as a rearview camera.

All cameras have been recycled from older projects. In our GUI, users can switch between the different camera feeds with the press of a button.

Simple Robot Arm Assembly

The main components include two powerful servomotors with aluminium brackets, these form the basic structure of the arm, a camera module equipped with an Intel-RealSense D435 camera and a thermal imaging camera module (Waveshare MLX90640). The last part of the arm is our Gripper, a simple gripper-design controlled by a 9g servomotor.

The arm is controlled via I2C using an Adafruit PCA9685 servo board.

2.3 Communication

Our robot, N10, communicates with a laptop via an Ethernet cable, ensuring a stable and reliable data exchange. The camera date is captured and processed using OpenCV.

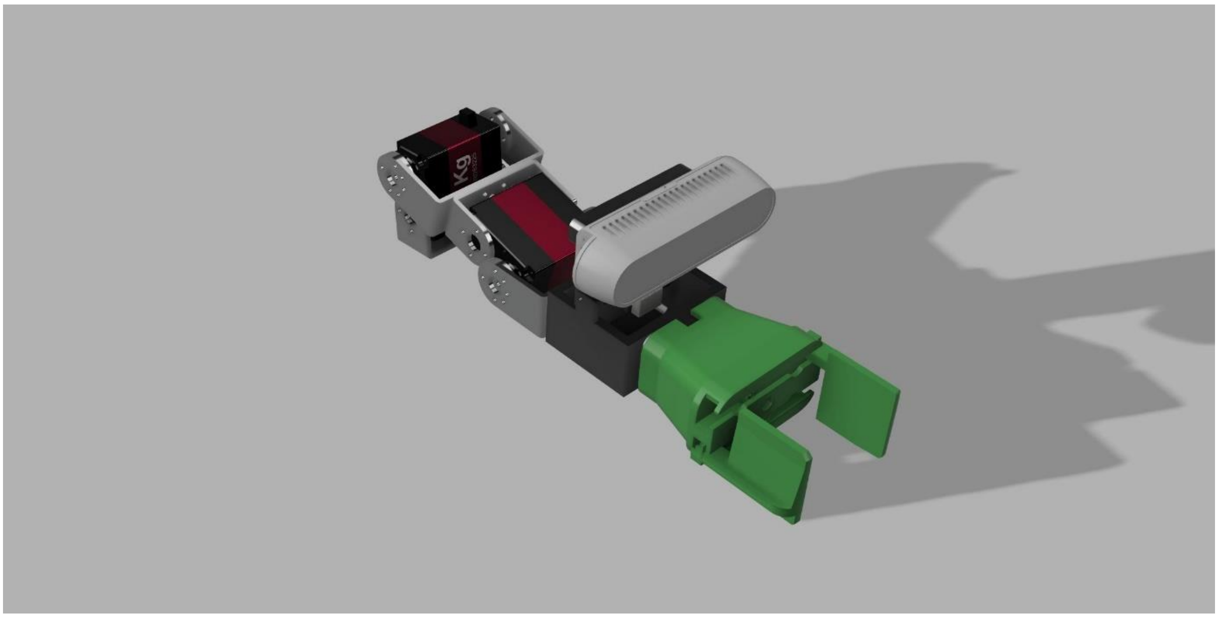
We use ROS 2 (Robot Operating System 2) as the foundation of our software architecture, with nodes programmed in C++ and Python. These nodes interact through ROS 2 topics, allowing for efficient and scalable communication between different components of the robot.

The core of our communication system is our self-developed GUI, "N10C," created with the GUItar library by Felix Schreiber, a former team member. This GUI, available on GitHub at [N10C](https://github.com/wggRobotic/N10C), serves as the control center for the robot, receiving and processing data from various sensors and cameras. The GUI handles camera images from our rear camera and Intel Realsense camera, with plans to incorporate thermal imaging and motion capture capabilities in the future.

To further enhance communication, our nodes integrate with the BarcodeReader node for barcode recognition, utilizing the zbar_ros node. The motors and servos of our robot are controlled via self-written nodes, such as N10-Translator and N10-PCA9685-Servo-Controller, ensuring precise and responsive movements.

Overall, our communication setup is designed to be robust and efficient, leveraging advanced software frameworks and custom tools to ensure seamless operation and control of our robot.

2.4 Human-Robot interface



We use a Logitech X3D controller as well as an XBOX-Controller to drive the motors and servos. The joystick moves the robot in the desired direction.

3. Application

3.1 Set up, pack up and operator station.

As for our operator station, our programmers use their own laptops for controlling the robot with the help of ROS2. The robot uses a Raspberry Pi 5 on board.

3.2 Strategy

Our strategy for the international RoboCup 2024 in Eindhoven revolves around using a combination of agility and an adaptable robot arm, ensuring superior performance in diverse competition scenarios.
At the core of our approach is the remarkable manoeuvrability of our robot. Its ability to effortlessly navigate obstacles, accurately position itself, and swiftly adapt to dynamic conditions on the competition field sets it apart. One of the standout features is its capability to drive sideways, which enhances its agility and grants us a significant competitive advantage. This lateral movement allows our robot to efficiently change directions without the need for complex turning maneuvers, enabling it to navigate through tight spaces and respond rapidly to evolving challenges. This exceptional agility translates to efficient and effective movement, ensuring our robot can keep optimal positioning and capitalise on opportunities in real time.
Complementing our robot's manoeuvrability is the precision, versatility, and independent functioning of its robot arm. The arm is designed to tackle a wide array of tasks with accuracy and reliability. Whether it's picking and placing objects, manipulating tools, or interacting with various elements on the field, the robot arm operates with a high degree of precision.
Moreover, the adaptability of our robot arm is a significant asset. It can be programmed and adjusted to handle different types of challenges that may arise during the competition, making it a versatile tool in our arsenal. This adaptability ensures that we can swiftly reconfigure our strategy to address unexpected obstacles or changes in the competition environment.
Our strategy is rooted in the constructive interaction between our robot's manoeuvrability and the autonomous capabilities of its arm. This combination enables us to seamlessly integrate navigation and task execution, providing us with a robust and flexible approach to the competition. By focusing on both movement and functionality, we aim to achieve a well-rounded and dynamic performance.
We believe that the combination of these strengths will not only enhance our performance but also significantly increase our chances of success in Eindhoven.

3.3 Testing and experiments

To make sure our robot can handle different situations, we tested it on various terrains during the "Lange Nacht der Wissenschaft" event. This was a great chance to see how well it performs on different surfaces and obstacles. However, we did not have enough time to test as much as we wanted. To get ready for RoboCup 2024, we plan to do more tests on different terrains in the coming weeks. We will have our robot drive on uneven surfaces, slippery areas, and through obstacles to see how well it adapts.

To help with this, we are building some course elements at our school. These will mimic the competition field, giving our robot a chance to practice in similar conditions. By doing this, we hope to find and fix any problems with our robot's design and performance. We will also use advanced monitoring systems to track the robot's responses in real-time. This will help us make precise adjustments and improve our control algorithms. Additionally, we will conduct stress tests to ensure our robot's components are durable and can withstand the competition's demands. Through these tests, we aim to improve our robot's agility, precision, and overall performance. Our commitment to thorough testing will ensure that our robot is well-prepared and excels under the challenging conditions of RoboCup 2024.

3.4 Strengths

Our team excels not only because each of us has our own roles but because we help each other out whenever needed. We understand each other well, which allows us to communicate effectively and solve problems quickly. This strong teamwork is one of our biggest strengths, enabling us to tackle challenges more efficiently. Additionally, our elevated level of motivation and genuine interest in the project drive us to meet even during our free time, including holidays, to ensure we finish our work.

One of the best aspects of our team dynamic is the way we share responsibilities. Every task is handled by at least two or more people, allowing us to collaborate and support each other. This not only makes the work more enjoyable but also ensures that we can cover for one another if someone encounters a problem or is unavailable. It fosters a sense of camaraderie and makes the full process much more productive and fun.

From a technical standpoint, we believe we have a significant advantage with our Mars-rover concept. Our robot is designed with maximum ground clearance, enabling it to overcome high obstacles like steps. This design feature is crucial for navigating the varied and challenging terrains we expect to meet at RoboCup 2024. The ability to handle such obstacles gives us a competitive edge.

Additionally, our use of high-quality servos allows our robot to drive sideways, adding to its manoeuvrability. This capability ensures that our robot can make quick and precise movements, enhancing its performance in dynamic and unpredictable environments. The combination of high ground clearance and lateral movement capability makes our robot versatile and well-equipped for the competition.

In summary, our team's strengths lie in our strong teamwork, effective communication, and shared motivation. We support each other in every aspect, from technical challenges to time management, making us a cohesive and resilient unit. Coupled with our innovative robot design, we are confident that these strengths will lead us to success at RoboCup 2024.

4. Conclusion

4.1 What we learned

Through various events (see 1.4 for more information) we did not only gain a lot of new experience, but also improved our ability to work under time pressure, to communicate effectively and identify problems to enhance and adapt our robot. For example, our wheels had truly little grip, so we had to temporarily drill nails into them to create something like spikes. Furthermore, we struggled with the wireless connection between the robot and computer because the router was too weak. To solve this problem, we switched to a connection with cable. Another difficulty that occurred, were problematic software issues. In this case, we were not able to find a solution ourselves, so we asked for professional support in a forum. Furthermore, we developed into a team, full of team spirit, joy and profession.

4.2 What we plan to do

Since our last vision of the TDP, we realised a lot of our plans, like improving the robot arm or the image recognition. But that is not enough, so we plan to test and improve our robot more until the competition. Also, we want to go through the concept of our robot once more in order to check for possible problems or new ideas to upgrade it as well as gain some more useful experiences which could be very important and necessary considering the competition.

Of course, our main goal is to achieve a good place at the robocop, to be satisfied with our results and are able to work as a unit together.

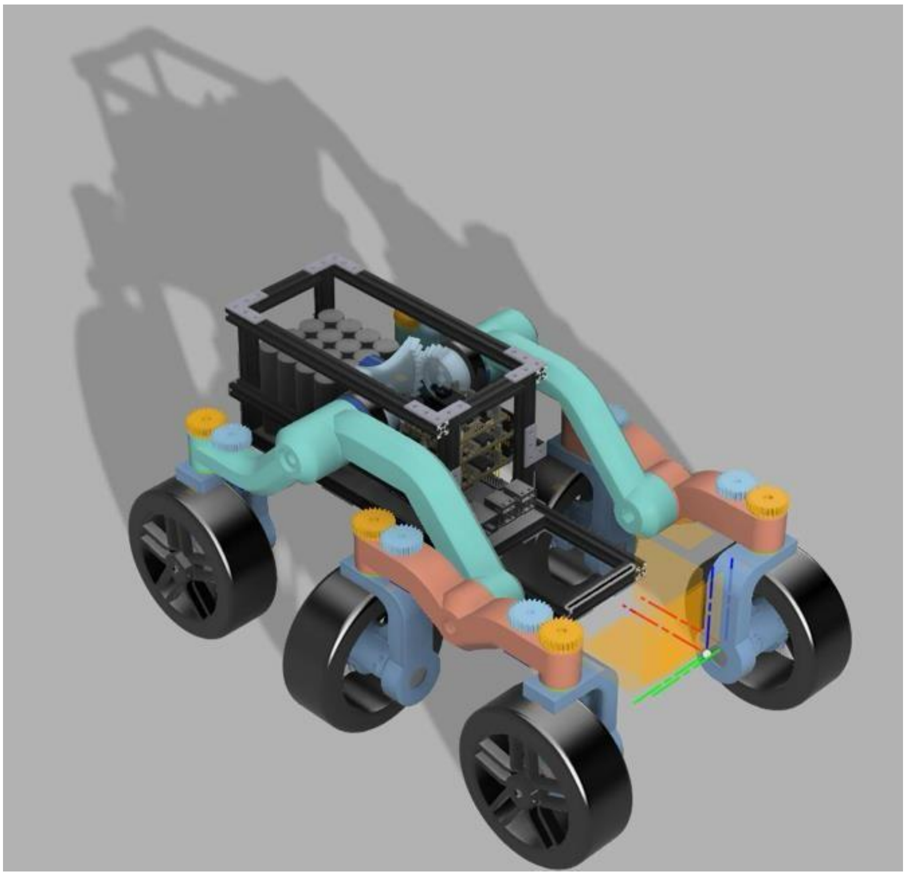
5. Appendix

5.1 Components

Item	Quantity	Total price in €	Link
Mg996 - Servomotor	6	36.00	Amazon
ANNIMOS 25kg Servomotor	2	59.96	Amazon
9g Micro Servomotor	1	2.00	Amazon
EduArt Kinematics Kit	1	786.75	Eduart Robotic
Faulhaber DC motors with planetary gearboxes	6	1255.20	Faulhaber
Raspberry Pi 5 8Gb	1	86.50	Berrybase
Intel RealSense D435	1	343.92	Amazon
Waveshare MLX90640	1	71.99	Amazon
USB camera module OV2710	1	33.40	Berrybase
PCA9685 Servomotor Drive Module	1	6.50	Amazon
Black Starter Kit Regular MakerBeam	1	117.95	Makerbeam
Maschine screws (M2, M2.5 M3)	1	24.65	Amazon
Heat-Set Inserts	1	8.99	Amazon
TOTAL:		2833.81 €	

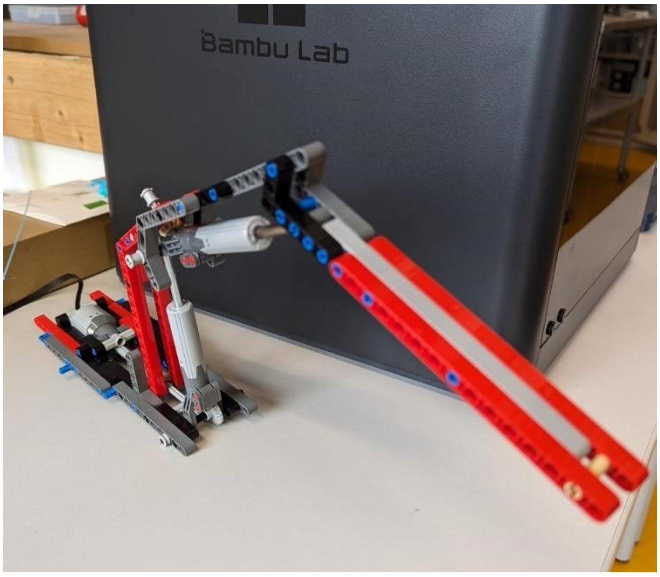
5.2 3D Rendering

All 3D designed parts will be available in our Github as Step-files after we finished redesigning and testing.

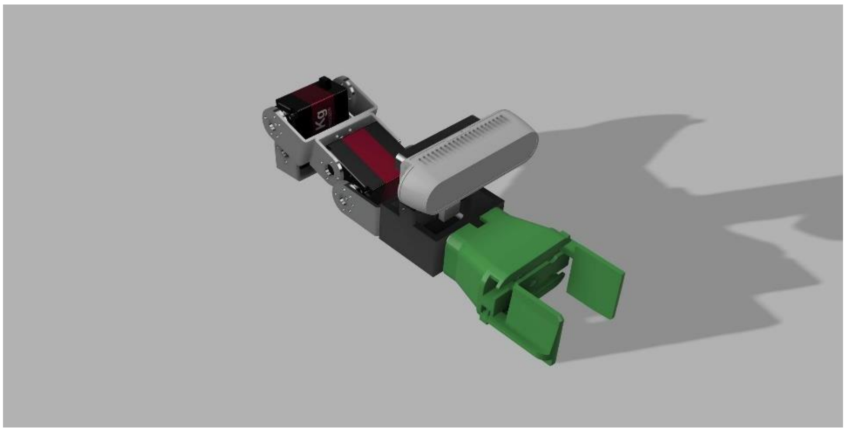


5.3 Robot arm prototype in LEGO

We started our project 'robot arm' with a prototype, which was built from Lego parts. Nowadays, two powerful servomotors, which are also serve as counterweights, with aluminium brackets form the basic structure of the arm. Since we decided to use a top-down perspective, we equipped our arm with Intel-RealSense D435 camera and a thermal imaging camera module, called Waveshare MLX90640. The gripper is simply constructed and is a 3D-printing, which is controlled by a 9g servomotor. The whole arm in turn is controlled via 12C using an Adafruit PCA9685 servo board.

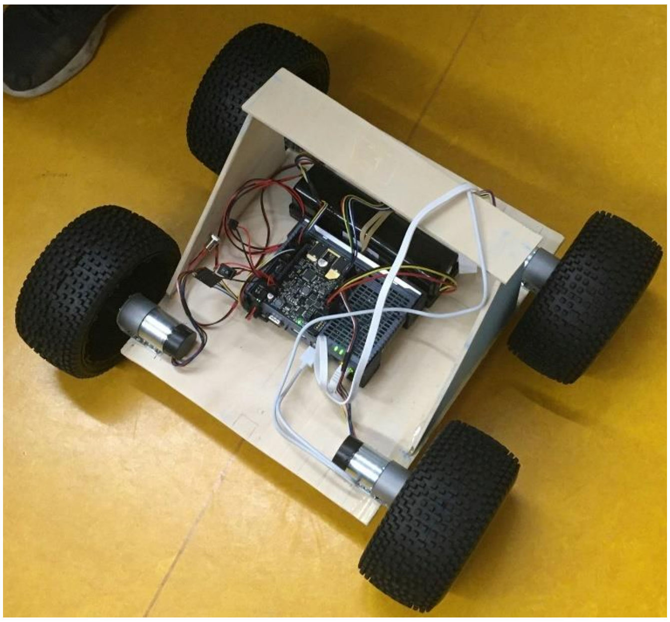


Our new Arm:

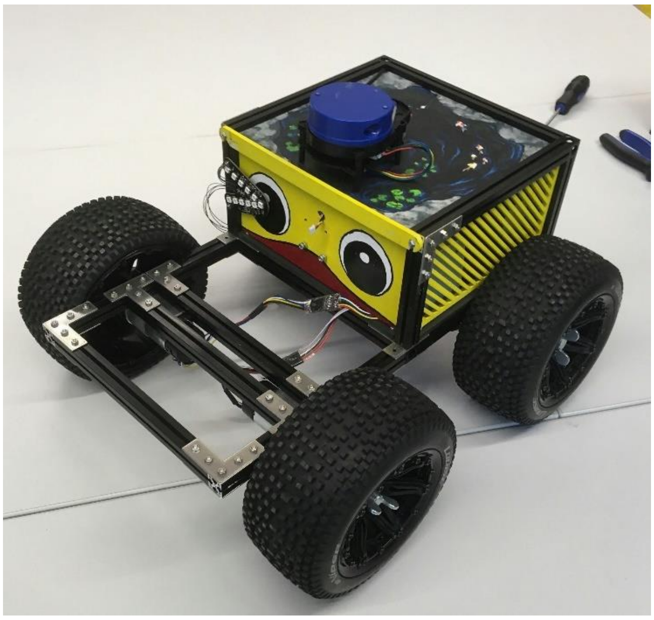


5.4 N10 pictures (building process)

At the beginning of the 2021/22 school year, the elective course "MintEX", which was supervised by Ms Ulrike Englert and Mr Tobias Wagner, decided to take part in Siemens' "Mission to Mars" project, which provided us with several new components. Professor May introduced us to robotics and shortly afterwards we were able to start building the "Fischdings 1.0". The chassis of this prototype was made of wood, and the name "Fischdings" came from a sketch of this very model. With this version, we took part in a meeting of the various teams organised by Siemens, which was held at the main branch in Nuremberg. To further improve our robot, we decided to replace our prototype with the new "Fischdings 2.0" model, which already used an aluminium frame. This new version was used for the rest of the school year 2021/22 and for the school year 2022/23 and was continuously developed further. Some of the changes that were developed during this time include a centre bar that made it possible to rotate both halves against each other and several gripper arms, which we were then unable to use due to shortcomings in the IoT. With the "Fischdings 2.0", we also successfully took part in the final of "Mission to Mars" in summer 2022 and the final of "Robots Unite" in summer 2023. As we wanted to improve the robot even further following these events, this version was broken down into its individual parts, which we then used to build version 3.0 and a first version of n-10. The "Fischdings 3.0" was developed during the 2022/23 school year and used a rocker bogie suspension. During the following school year 2023/24 we disassemble "Fischdings 3.0" in order to focus on one single robot and to reuse to material. Nevertheless, after the german open, we determined some serious weak points, like stability or our high centre of gravity, so we decided to rebuild N10 as well. In the following photos our building process is documented.

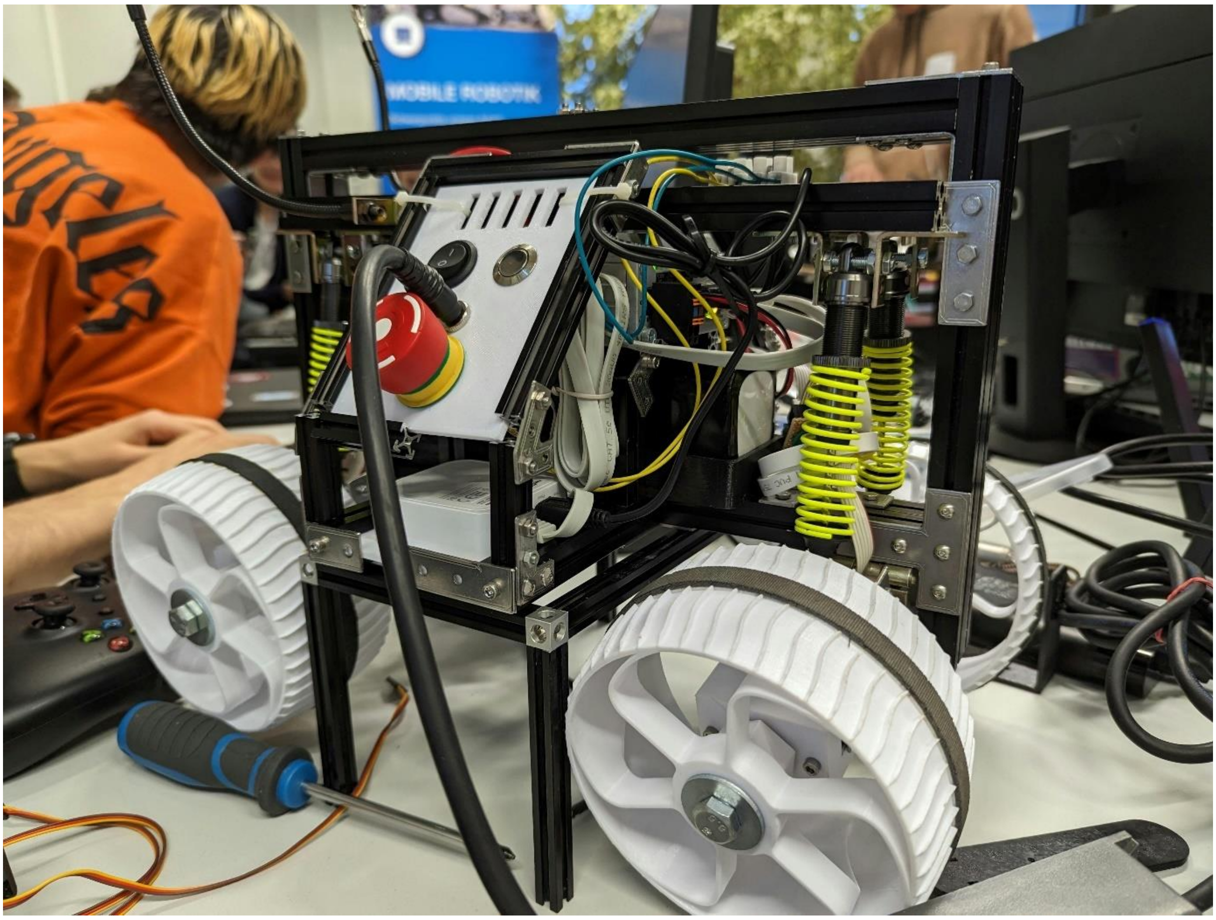


Fischdings prototype



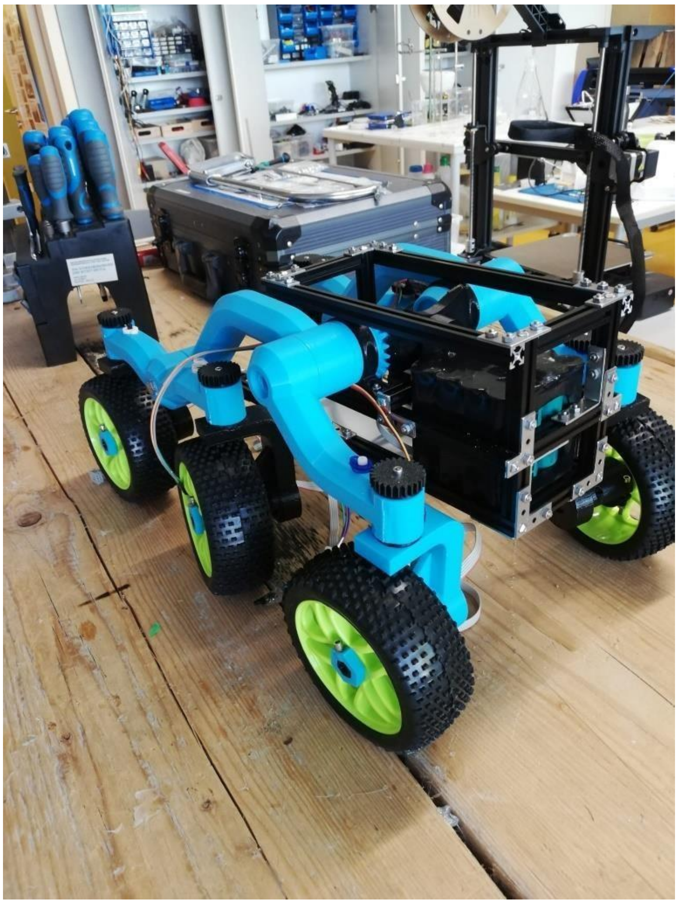
Fischdings 2.0 [2022-2023]

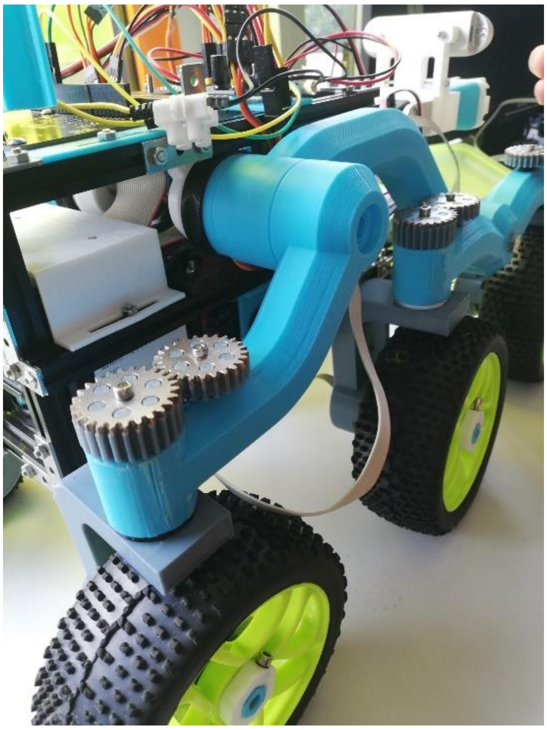
Fischdings 3.0 [June 2023]



N10 (first version) [October

First Version of the Rocker-Bogie-System [March 2024]:





Camera-Modul and Gripper Test [June 2024]