RoboHub Eindhoven: Robocup@Work Team Description Paper 2024

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Abstract. This paper introduces the RoboHub team submission to the RoboCup@Work World Championship 2024. This papers details the current state of our robot and the team behind the robot. We give an overview of the hardware platform, the software framework and technical challenges in navigation, object recognition and manipulation. In particular, improvements of the robot are describe. The outline present and future research interests and discuss relevance to industrial tasks.

Keywords: ROS2 · 3D Vision · lite6 · YOLO V8.

1 Introduction

RoboHub Eindhoven is a team of motivated students, teachers and professionals that are working together to discover new solutions for robotic systems. RoboHub Eindhoven is part of the Engineering department of the Fontys University of Applied Sciences. We are challenging ourselves to find creative ways to bring robotics to the next step. Together we want to share our knowledge with other motivated people, therefore we work with companies that want to support us and our technology. Within the RoboHub Eindhoven we are participating at the RoboCup@Work league with the RoboHub team that focuses on the industrial use of autonomous robots. We have a multidisciplinary team of students working on the robot, where the core team is complemented with students from our Adaptive Robotics Minor and guided by experienced RoboCup coaches. Furthermore, we created an educational outreach project around our robot. With our educational outreach project we expect to inspire non-technical students to embrace technology and start learning to create and program robots and how to work with robots. The team already started in 2017 and competed multiple times in the RoboCup German Open. At first we participated using a KUKA YouBot[1], but due to the fact that the YouBot was discontinued we started to investigate the usage of another platform. In 2018 we competed with a prototype of the Probotics Packman platform [2] equipped with a UR3 manipulator [3]. From 2019 onwards, we compete with our custom designed robot platform *Sui^2*, which is also equipped with an UR3 manipulator. In 2021 "Robohub Eindhoven" became an official non-profit foundation registered in the dutch "Kamer Van Koophandel". Which facilitates the team to grow further as an organisation. In 2022 the development of the new competition robot started named "SLICK". It was first send to the Robocup in 2023 in Bordeaux. The lessons were learned during that season and a redesign version of SLICK has been developed and will be presented at the Robocup 2024 in our hometown Eindhoven.

[1] http://youbot-store.com
[2] https://probotics-agv.eu
[3] https://www.universal-robots.com

2 Description of the hardware

SLICK is an holonomic mobile platform developed by Robohub Eindhoven, shown in Fig. 1. The drivetrain consists of 4 mechanum wheels of which two have a costum-made suspension system. The motors, encoders, gearbox and motor controllers are from Maxon motors. The robot has a 6-dof cobotic manupulator from the company Ufactory called the "Lite-6". For gripping the objects, a parallel 3d printed gripper is developed with an integrated 2d and 3d vision camera. An Asus pc is used for the high level control. The Vision system runs on separate Jetson Xavier. For navigation, two Hukuyo lidar sensors are used. The battery can be easily replaced using a battery slider. The cover of the AGV can be easily detached to quickly replace or test the hardware. The hardware diagram of the robot is shown in Fig. 2

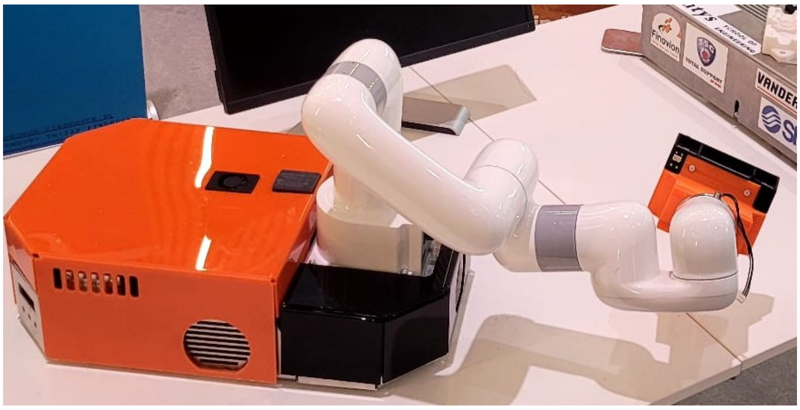

Fig. 1. SLICK, the 3^{th} costum-made robot for the robocup@work

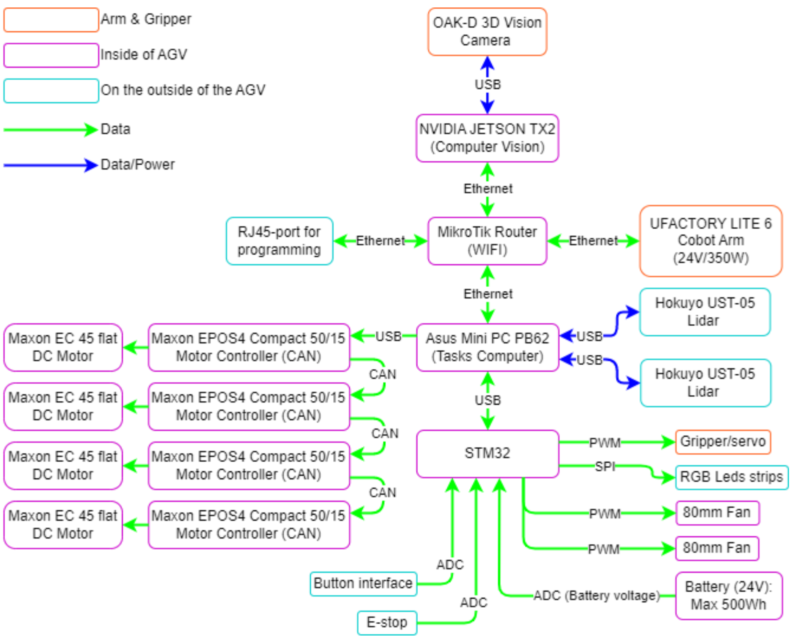

Fig. 2. The hardware diagram from SLICK.

2.1 Improvements of SLICK

The frame of SLICK has been redesigned for size reduction and accessibility. The comparison of the two frames is shown in Fig. 3. The reduced footprint improves the maneuverability of the platform in the competition arena.

Fig. 3. Left: The redesigned frame of SLICK. Right: The frame of SLICK used during the 2023 season

The frame consists of a structural frame a nonstructural cover, this cover can be removed without any screws. The hardware is placed on two different levels. The top level is attached to the frame using a hinge, this way the level can be opened which improves the hardware accessibility.

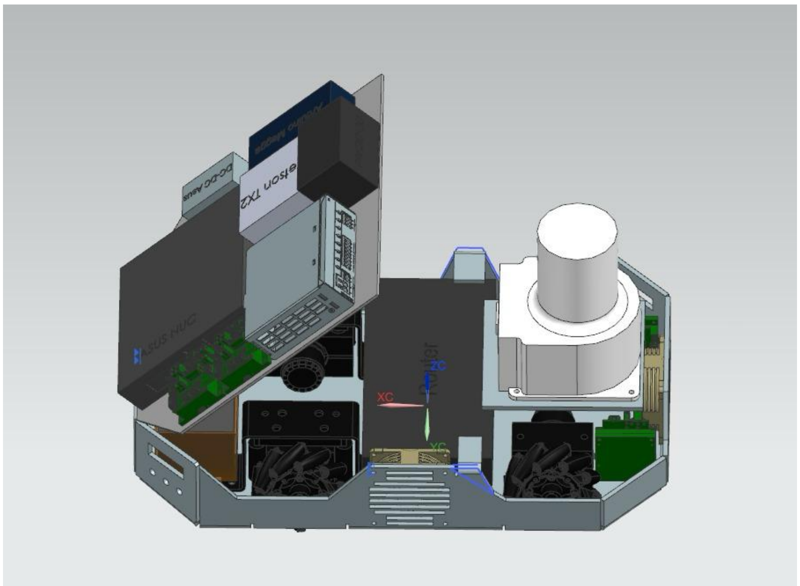

Fig. 4. The inside of SLICK, using a hinge to easily access the hardware.

3 Description of the software

Our software implementation includes the high-level and low-level controls, sensor and actuator processing and monitoring software.

High-level Control: For the High-level robot control we make use of the Robot Operating System (ROS2). ROS2 [2] provides many useful tools, hardware abstraction and a message passing system between nodes. Nodes are self contained modules that run independently and communicate which each other over so called topics using a one-to-many subscriber model and the TCP/IP protocol.

Localization and Navigation: For localization, SLICK uses two Hokuyo lidars. The raw lidar data is processed within ROS2 to perform robust localization. The Global planner is unchanged, but the local planner is replaced in our system by the Timed Elastic Band planner [4] which locally optimizes the robot's trajectory with respect to trajectory execution time [4]. Furthermore, low level smoothing of the acceleration profiles is implemented to make the robot more controllable.

YOLO V8: For object detection and recognition the robot is equipped with a realsense RGB-D camera. This camera is located on the robot-arm near the end-effector. The images are processed with YOLO V8 [5] (The robot used to use YOLO v3 but we switched to YOLO v8.), a clever neural network for doing object detection in real-time [3]. The model determines what object the camera is seeing in real-time and gives the coordinates of the object, as seen in Figure 6. When using four objects the model needs around two hours of training on our GPU, this approach is fast enough that we are able train for new object the moment we get to the competition.

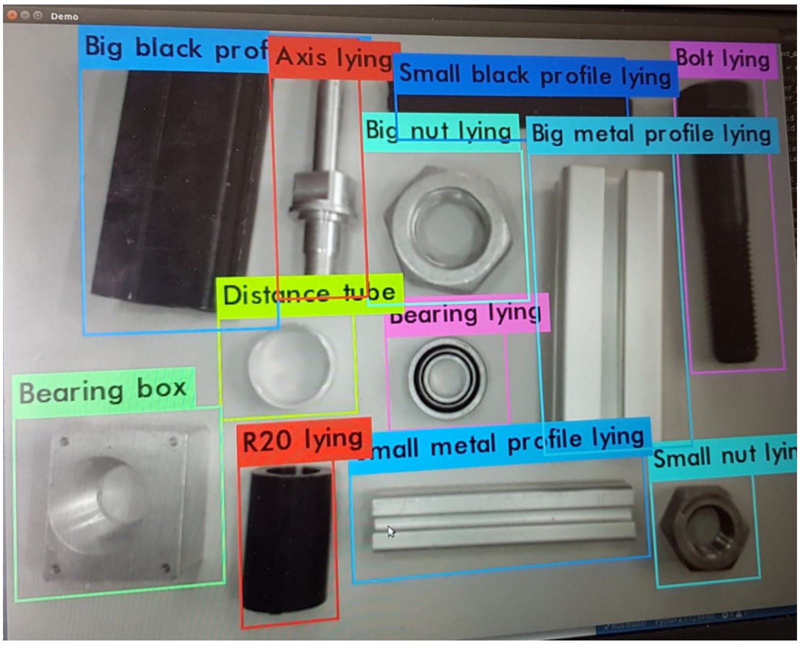

Fig. 5. 2D object detection using YOLO.

Perception using 3D vision: A new 3D vision is developed by RoboHub Eindhoven to determine the transformation of objects with respect to the robot. The code is written in C++ and python and communicates over ROS2. With the integration of YOLO V8 object recognition, the software is able to detect the competition objects in a 2D image. These objects will then be processed in a 3D point cloud using various algorithms and filters. After processing the 3D data, the

[4] https://wiki.ros.org/teb_local_planner
[5] https://pjreddie.com/darknet/yolo/

transformation of each object is published in ROS2.

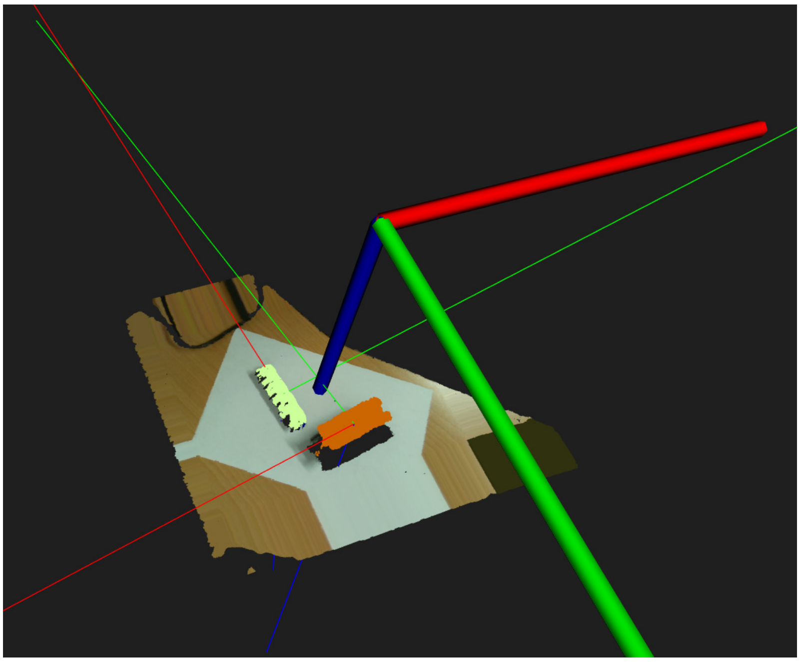

Fig. 6. 3D vision

Manipulation: A lite6 robotic manipulator is mounted on top of the AGV for the pick and place functionality. Designed with six axes, Lite 6 is perfect for simple, repetitive and monotonous tasks. It provides the speed and precision manufacturers require, meanwhile ensures quality and accuracy. The flexibility of Lite 6 allows manufacturers to optimize workflow, increase productivity, reduce floor space utilization, lower production costs.

Barrier detection: We have also developed barrier tape detection which is able to the detect the line on the ground and transfer the location into the coordinate system of the robot. This will be detected by the main camera attached to the gripper of the robot. This one will point to the ground while driving. Currently the plan is to only detect the lines in the driving direction. Our robot does also sometimes drive backwards so a camera on the back might be needed as well but for now we've constrained this development to one camera. The new development still needs to be integrated into the state machine. We are not able yet to draw the line in the map to actually drive around it.

4 Focus and Relevance

There are a wide range of industrial applications for autonomous mobile manipulation, we focus our education and research mainly on the manufacturing and logistic domains.

Industry: We contribute to the ambitions of the Dutch smart industry [6] agenda. We collaborate with several companies where we use our platform as a showcase to explain how logistic and manufacturing companies can benefit from mobile robots in their warehouses and factory floors. We are also involved in research project that are funded by the dutch government and are in close collaboration with industry partners. Such a project is the 'Fieldlab Flexible Manufacturing' where mobile manipulating robots contribute to a flexible manufacturing line by delivering parts just on time at the specific (automated) assembly stations, where all these tasks are strongly related to

[6] https://www.smartindustry.nl/english/

Industry 4.0 [5].

Research: Our current and future research aims at multiple directions, we aim to have adaptive multi-robot systems that are able to autonomously operate in these complex and diverse environments. Think of industrial tasks where multiple robots navigate in a single warehouse and collaboratively transport the required parts in an optimal way, where robots exchange products during transport. We also are focusing on smart/dynamic path-planning, based on the robots experience. Here high and low level traffic rules can not only be pre-programmed, but also should arise on given knowledge of the environment. Furthermore, we work on a set of robot-safety related issues, as on the natural interaction between humans and robots.

First step in automation:
Taking the first step in automation is a difficult and often can be a scary step to take if you don't know where to begin. We want to make this first step more accessible with small projects by advising companies and by possibly providing a pre-study, a proof of concept or by executing experiments. This can be done a lot cheaper and a lot more accessible than with a big company. The result of this will be constrained to the 'first step'. After this process we will suggest companies which we have gotten to know over the years who could execute the following steps in automation.

Education: First of all we use this competition to motivate and challenge our engineering students to achieve a higher and more professional level in their engineering education. By performing such a project the students get highly motivated, apply their knowledge and push their boundaries to acquire new knowledge to solve the given problems. In addition to the technical research challenges we as a team also focus on getting younger people involved into robotics. Our goal is to show the impact that technology can have in our daily lives. During the last year we visited several events where we give young children (and their parents) the opportunity to control our robot. Furthermore we visited several (primary) schools to give demonstrations to inspire the children.

Online Material: Video's of our platform in action is available at our YouTube Channel [7]. Additional team information can be found at our RoboHub website [8]. Furthermore, all software will be published on the teams GitHub [9] page.

5 Future work

The team is still working hard on the redesign version of SLICK. A team of students will start in April to focus on the following challenges:

- Optimize navigation with the new platform
- Improve the pick and place.
- Improve and implement the new vision software.
- Improve the state-machine
- referee communication

Additionally, a full-time Mechatronics graduation student is focusing on developing the rotating table challenge. A student-assistant from the Fontys University of Applied Sciences has joined the team to help the main team from the minor with the navigation. Lastly, the rest of the team is supporting whereever they can.

[7] https://www.youtube.com/channel/UCQkpwno0b1QEp96Wy66yLPQ
[8] http://robohub-eindhoven.nl
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