RoboHub Eindhoven: Robocup@Work Team Description Paper 2022

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Abstract. This paper introduces the RoboHub team submission to the RoboCup@Work World Championship 2022. 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. We outline present and future research interests and discuss relevance to industrial tasks.

Keywords: ROS2 · 3D Vision · UR3 · YOLO V5.

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. Since 2021 we started the development of the new generation of the Robohub Eindhoven competition robot which will be used in 2023. In the last year we have made "Robohub Eindhoven" an official non-profit foundation registered in the dutch "Kamer Van Koophandel". This will make us able to grow further as an organisation.

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

2 Description of the hardware

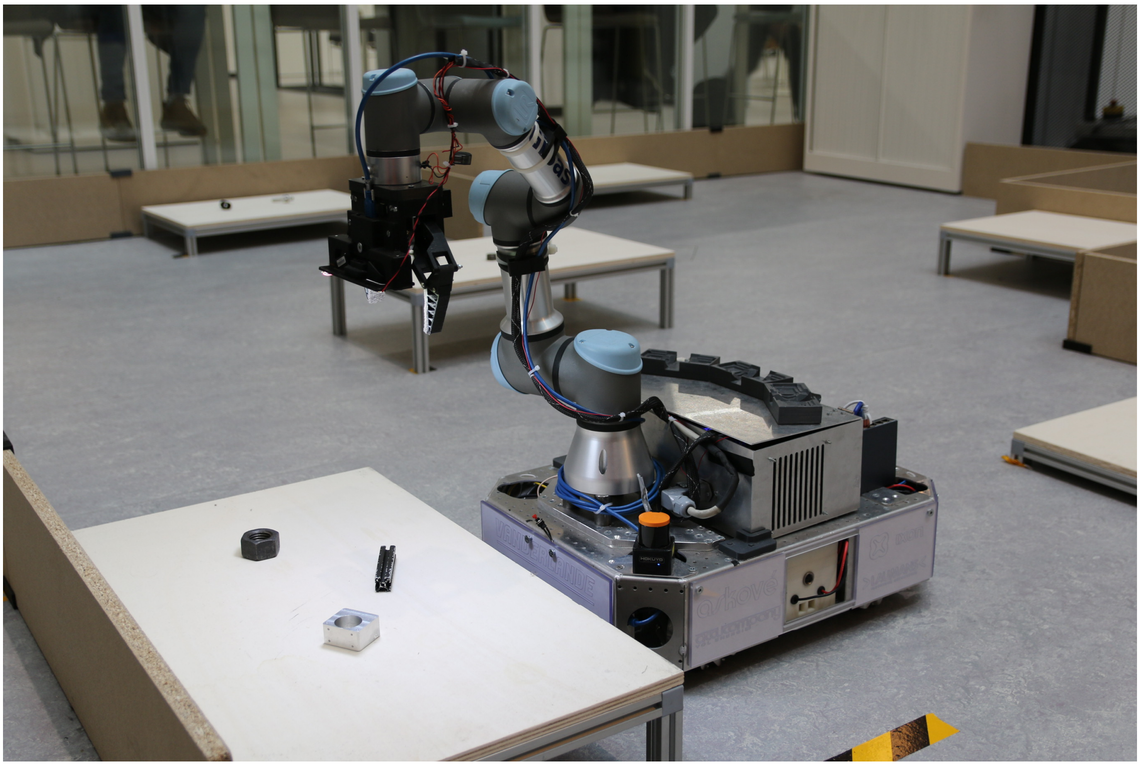

Fig. 1. the Suii robot in action.

Our custom designed robot is named *Sui²*, the name is derived from 'sui iuris', which is Latin for autonomy. The frame of *Sui²* is a sheet-metal design made of 3mm aluminum that has been bent and welded to form a rigid body. The frame has everywhere rounded corners, which gives the robot a softer appearance. Large holes in the frame will save a lot of weight while maintaining strength, where the small holes reduce the weight further and can be used for attaching electronics or mechanical parts. The corners are opened on the top to allow lidars to be placed there, in addition the platform is equipped with 2D and 3D camera's. A battery pack can easily be exchanged through an opening at the side of the robot. The bottom plate offers room for the motors and a suspension system. A suspension is needed to ensure that all four wheels stay on the ground at all times, and that the platform does not tilt when the center of gravity changes. The drive-train of the robot has four 180-watt brushless DC motors with PID control on the velocity, and the robot can reach speeds up to 1.7m/s. The motors are equipped with encoders and attached to mecanum wheels to ensure an omni-directional drive. On top of the robot platform an UR3 robot arm is mounted to perform the manipulation tasks. The hardware in the control box of the UR3 was taking apart and reinstalled to reduce the dimensions of the control box to fit it on the AGV. The final design of *Sui²* is shown in Figure 1.

The robot is controlled from an Intel NUC with an i7 processor for the high-level control, and an ARM Cortex M7 for the low-level control. To connect to the refbox, an industrial graded IXrouter [4] is added which includes a cloverleaf antenna for good connectivity. Additional low-level controls are being performed to make the robot more reliable, reduce internal communication and ensure faster computationally.

[4] https://www.ixon.cloud

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.

ROS2: Last season we have mainly been busy rewriting our software. The reason for this is that we have decided to switch from ROS1 to ROS2. Several parts have been realised. A start has been made on the state machine. This is able to communicate with the current referee box. For this, communication between ROS1 and ROS2 was necessary and we have managed to realise this. In addition to integrating the statemachine, a basis has been made for the navigation. This is not yet fully functional but we will have this sorted out in upcomming season.

Field Oriented Control: Field oriented control (FOC) is a method to control three-phase motors such as the brushless DC motors used in *Sui²*. Unlike regular brushless DC motor drivers, FOC drivers control the motor windings with sinusoidal currents witch will get rid of unwanted torque ripples. By keeping track of the rotor position, the torque applied on the rotor will always be maximal as the magnetic field is adjusted to the position of the rotor. By tracking the position of the rotor, the currents in the motor windings can be reduced to the absolute minimum and higher currents are only applied when needed [**?**]. This results in a stable and coordinated behavior while keeping the current consumption and heat development in the motors at a minimum. The FOC algorithm used in our platform provides a closed loop PID-controller including a third order position profile while accelerating and decelerating. All these properties are ideal for being used within an Autonomous Guided Vehicles as they lead to a precise position control and energy saving behavior of the robot.

Localization and Navigation: For localization, *Sui²* uses two Hokuyo lidars. The raw lidar data is processed within ROS to perform robust localization. The Global planner is unchanged, but the local planner is replaced in our system by the Timed Elastic Band planner [5] 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 V5: 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 V5 [6] (The robot used to use YOLO v3 but we switched to YOLO v5.), 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 3. 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.

5 https://wiki.ros.org/teb_local_planner
6 https://pjreddie.com/darknet/yolo/

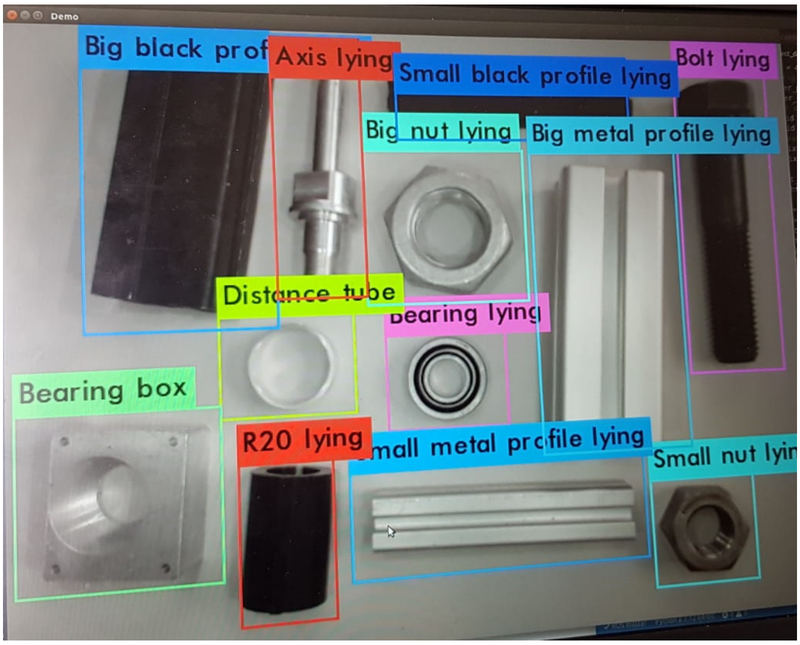

Fig. 2. 2D object detection using YOLO.

Perception using 3D vision: A new 3D vision is developed by RoboHub Eindhoven to determine the transformation of objects in respective to the robot. The code is written in C++ and python and communicates over ROS2. With the integration of YOLO V5 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 transformation of each object is published in ROS2.

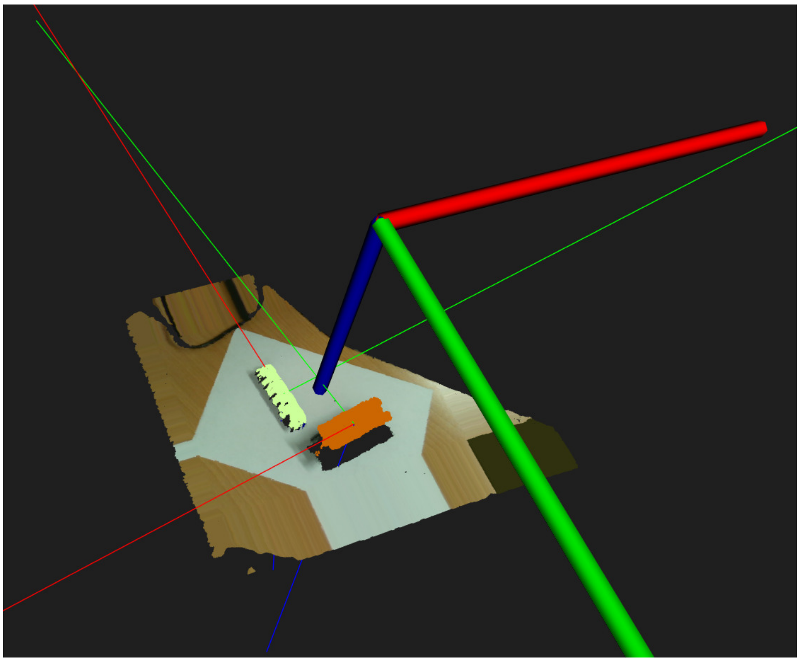

Fig. 3. 3D vision

Manipulation: A UR3 robotic manipulator is mounted on top of the AGV. To communicate with the UR3 manipulator, the Universal Robots RTDE C++ Interface is used. The RTDE (Real-Time Data Exchange) interface provides a way to synchronize the C++ ROS2 application with the UR3 controller over a standard TCP/IP connection, without breaking ant real-time properties of the UR3 controller. [7] This RTDE interface is used to read the robot's joint positions, to construct the robot model in ROS2. Next to that the RTDE interface is used to control the tool and joint positions of the robot, and to control digital and analog outputs of the robot.

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 [8] 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 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

[7] universal-robots.com/articles/ur/interface-communication/real-time-data-exchange-rtde-guide/
[8] https://www.smartindustry.nl/english/

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.

5 Future work

For this years competition we will still have the focus on making the switch from ROS to ROS2 [9]. In addition to switching to ROS2, we will also be working on implementing some newly created modules into the robot.

- The newly developed 3D vision.
- The newly developed barrier tape collision avoidance.
- The newly developed end-effector capable of sensing failed picks.

Besides these points focused on current competition robot "SUII" we are also working on a new robot which will be used in 2023. Some of the most important improvements we are working on are:

- New robotic arm
- New gripper
- ROS2
- 3D vision
- New low level and high level control
- New AGV frame design
- New suspension system

We are planning to publish details on this robot in the summer period and we are happy to answer all question regarding this project. Also if teams need help with the development of their own platform, we are happy to help!

[9] http://ros2.org

Online Material: Video's of our platform in action is available at our YouTube Channel [10]. Additional team information can be found at our RoboHub website [11]. Furthermore, all software will be published on the teams GitHub [12] page.

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[10] https://www.youtube.com/channel/UCQkpwno0b1QEp96Wy66yLPQ
[11] http://robohub-eindhoven.nl
[12] https://github.com/robohubeindhoven