ANNUAL REPORT 2023


TU/e Technische Universiteit Eindhoven

PREFACE

This year marked a period of intense performance for both our team and our robots. We engaged in thorough preparations for tournaments, focused on innovative developments, and conducted informative demonstrations.

We are pleased to announce our victory in the world championship with our soccer robots once again, held in Bordeaux, France, this summer. Our soccer robots not only performed exceptionally well, securing their seventh world championship title, but we are also extremely proud of the significant advancements made by our team on our service robot HERO this year.

We welcomed several new members this year, including students contributing to their end-projects, internships, and full members. Our team is thrilled about the diverse expertise and enthusiasm these individuals bring, enriching our collaborative efforts.

As you continue reading, we invite you to explore the exciting developments and adventures that unfolded throughout the year.

World Championship, Bordeaux, France: 1st place **2023**
Portuguese Open, Tomar, Portugal: 1st place

World Championship, Bangkok, Thailand: 1st place **2022**
Portuguese Open, Guimarães, Portugal: 1st place

World Championship, Online: Technical Challenge 1st place **2021**
Scientific Challenge 2nd place

2020

World Championship, Sydney, Australia: 1st place **2019**
Portuguese Open, Porto, Portugal: 2nd place

World Championship, Montreal, Canada: 1st place **2018**
Portuguese Open, Torres Vedras: 1st place

World Championship, Nagoya, Japan: 2nd place **2017**
Portuguese Open, Coimbra: 1st place

World Championship, Leipzig, Germany: 1st place **2016**
RoboCup European Open, Eindhoven, the Netherlands: 1st place

World Championship, Hefei, China: 2nd place **2015**
Portuguese Open, Vila Real: 1st place

World Championship, João Pessoa, Brazil: 1st place **2014**
Portuguese Open, Porto, Portugal: 1st place

World Championship, Eindhoven, the Netherlands: 2nd place **2013**
Portugese Open, Lisbon, Portugal: 1st place

World Championship, Mexico city, Mexico: 1st place **2012**
RoboCup Dutch Open, Eindhoven, the Netherlands: 1st place

World Championship, Istanbul, Turkey : 2nd place **2011**
German Open, Magdeburg, Germany: 1st place

World Championship, Singapore: 2nd place **2010**
German Open, Magdeburg, Germany: 1st place

World Championship, Graz, Germany : 2nd place **2009**
German Open, Hannover, Germany: 3rd place

World Championship, Suzhou, China: 2nd place **2008**
German Open, Hannover Germany: 1st place

World Championship, Atlanta, USA: 5th place **2007**
German Open, Hannover, Germany: 3rd place

World Championship, Bremen, Germany **2006**

Roboludens Dutch Open, Eindhoven, the Netherlands **2005**

2023 **World Championship, Bordeaux, France: 4th place**
Portuguese Open, Tomar, Portugal: 1st place

2022 World Championship, Bangkok, Thailand: 1st place

2021

2020

2019 World Championship, Sydney, Australia: 1st place
German Open, Magdeburg, Germany: 2nd place

2018 World Championship, Montreal, Canada: 3rd place
German Open, Magdeburg, Germany, 2nd place

2017 World Championship, Nagoya, Japan, 2nd place
German Open, Magdeburg, Germany, 2nd place

2016 World Championship, Leipzig, Germany: 2nd place
RoboCup European Open, Eindhoven, the Netherlands, 1st place

2015 World Championship, Hefei, China, 4th place
German Open, Magdeburg, Germany, 1st place

2014 World Championship, João Pessoa, Brazil, 2nd place
German Open, Magdeburg, Germany, 2nd place

2013 World Championship, Eindhoven, the Netherlands, 3rd place
German Open, Magdeburg, Germany, 7th place

2012 World championship, Mexico City, Mexico, 7th place
RoboCup Dutch Open, Eindhoven, the Netherlands, 1st place

2011 World Championship, Istanbul, Turkey, 14th place
German Open, Magdeburg, Germany, 6th place

2010

2009

2008

2007

2006

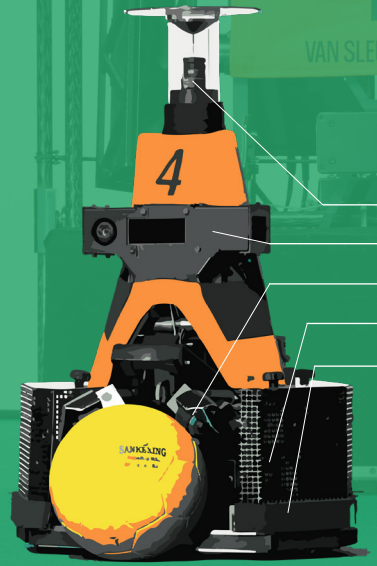
2005

@Home

TECH UNITED EINDHOVEN

Swerve drive »

3	Driving (hub) motors
3	Steering motors
600 W	Power per motor
1800 W	Total driving power
3.5 m/s²	Max Acceleration
5.5 m/s	Max Velocity



« 3 wheel TURTLE

Omnivision Camera	**0.3 Megapixel**
Kinect V2	**2 Megapixel**
Shot speed	**12 m/s**
Battery Capacity	**Equal to 8 iPhones of the 1st generation**
Motors	**3**
Power per Motor	**150 W**
Total driving power	**200 W**
Max Acceleration	**1.7 m/s²**
Max Velocity	**3.5 m/s**

Middle Size League (MSL):
In the RoboCup Middle Size League, a soccer game is played by teams consisting of five fully autonomous robots using a standard FIFA soccer ball. Starting from 2023, one human is permitted to participate alongside the robots during matches. The primary areas of research emphasis include mechatronic design, robotic skills, control systems, and collaborative multi-agent team play.

@Home:
The RoboCup@Home league focuses on advancing service and assistive robot technology tailored for future personal domestic applications. As the most extensive international competition for autonomous service robots held annually, it employs a series of benchmark tests to assess the abilities and performance of robots within a realistic home environment.

« HERO, Toyota Service Robot

Camera's (3D, stereo, wide-angle)	**1 of each**
Head Display	**7 inch**
Gripper	**4-DOF with suction cup**
Max payload	**1.2 kg**
Robotic Arm	**5-DOF**
Arm reach	**600 mm**
Weight	**37 kg**
Wheels (driven and passive)	**2 of each**
Max Velocity	**1 m/s**
Battery Capacity	**Equal to 19 iPhone 14's**

TECH UNITED EINDHOVEN

In July 2023 the team went to Bordeaux to defend both of their World Cup titles. This year an extensive media team also joined us to capture this exciting competition and to make sure every game can be viewed live.

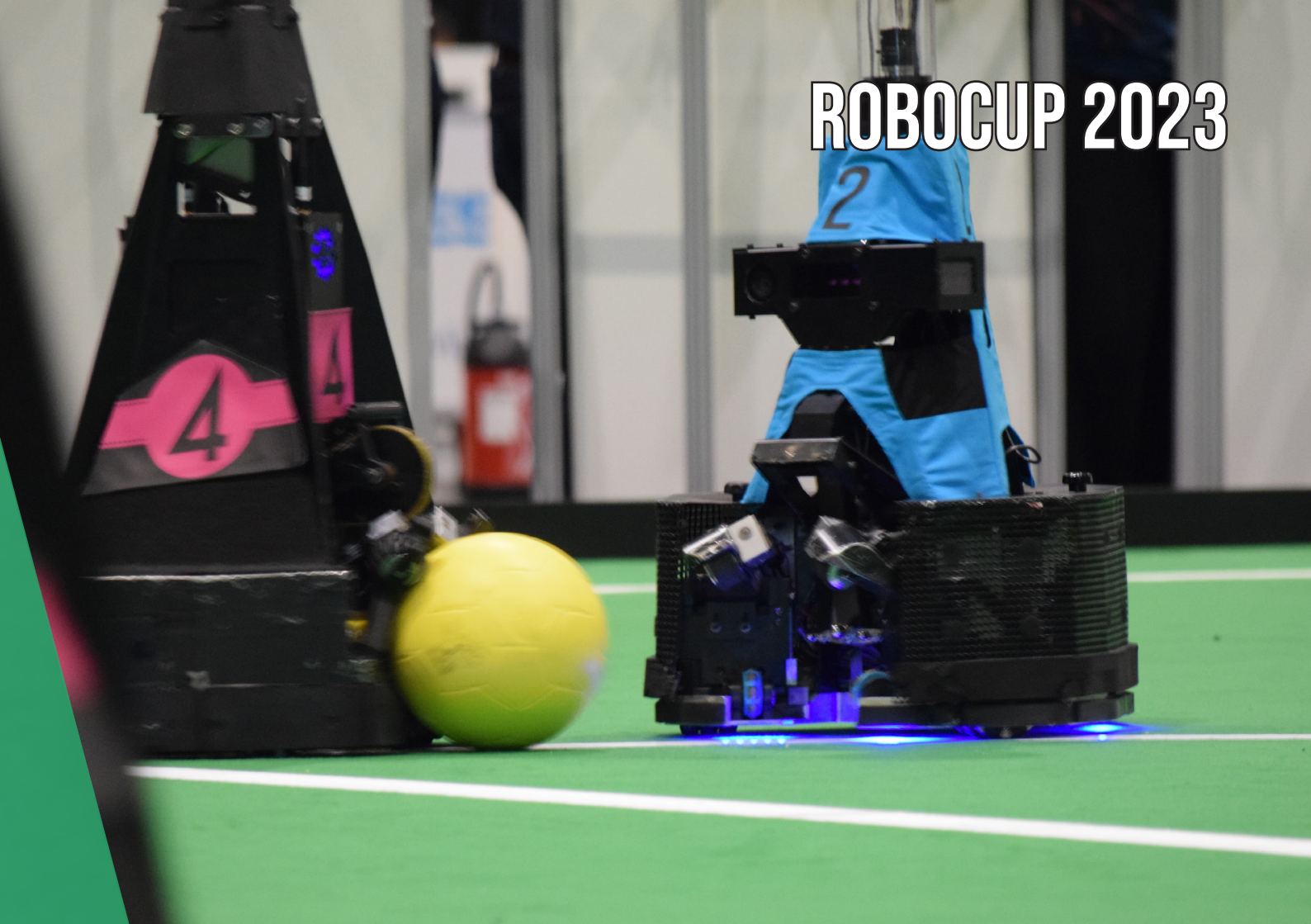
MSL

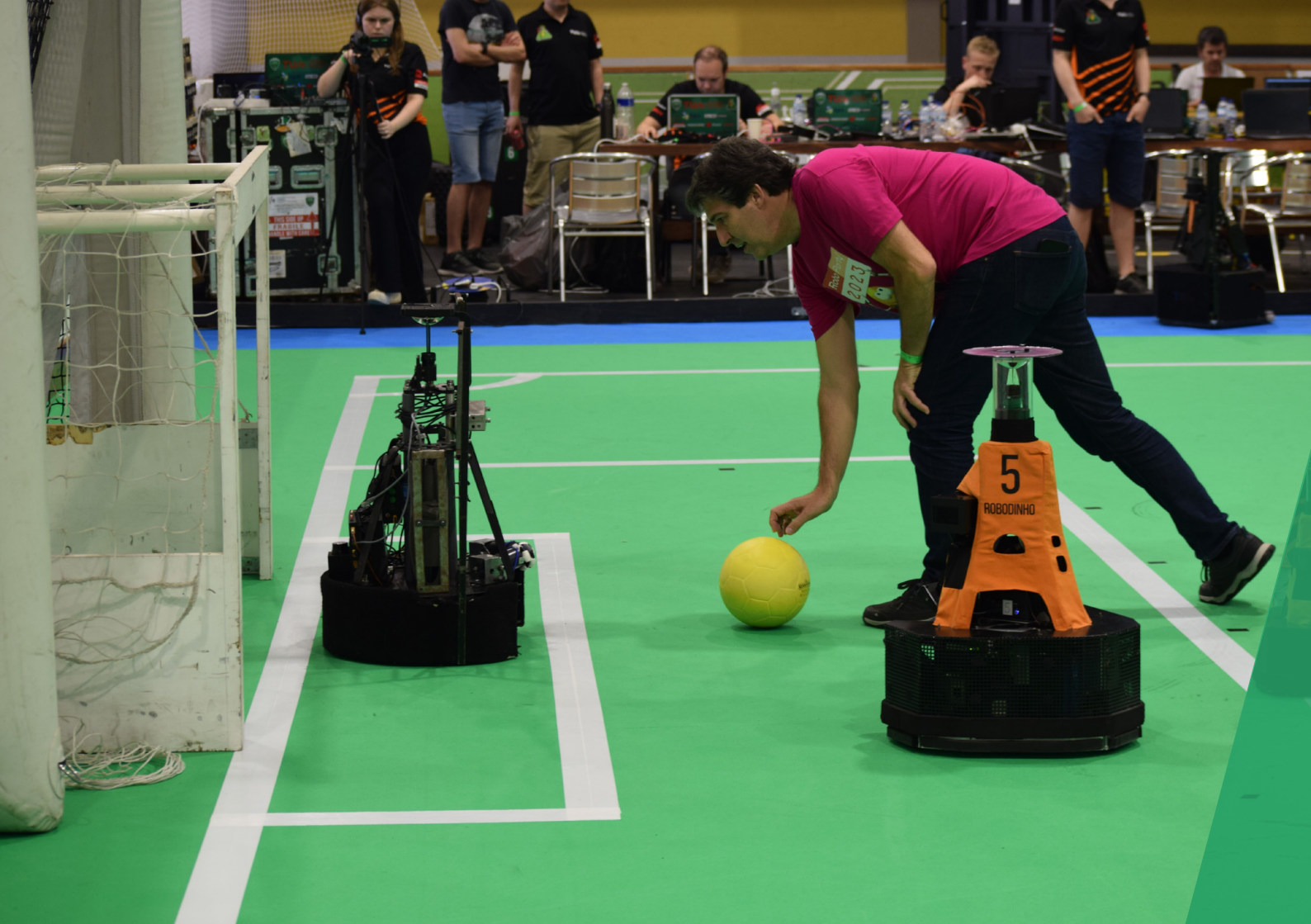
This year there were 3 new teams in the MSL competition. The Portuguese LAR team, which is a relaunch of Minho had their first world cup. Robot Team Toulon from France also plays their first matches and then there was a Croation team that did the scientific challenge. The MSL team had quite a few big wins in the first matches so they decided to try out some of the newest innovations of the team, namely the swerve drive, the sweeper keeper and the human dribble! Unfortunately the first try of the sweeper keeper led the team to a goal against in the match with the Falcons, but luckily after this little mistake the robots improved and the game was still won. Through the semifinals against LAR the team landed in an exciting finale against the Falcons that ended in score of 6-2! And thus Tech United retains its name as a world champion.

@Home

The @Home competition in Bordeaux consists of 11 teams, so the competition was quite tough. HERO faced 9 challenges in 3 days and especially shined in the restaurant challenge where he won! Unfortunately despite several successful challenges, HERO did not make it into the finals and achieved a 4th place.

Watch the MSL final here:


ROBOCUP 2023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ROBODINHO

PORTUGUESE OPEN 2023

In April the team went to Tomar, Portugal, for the Portugese Robotics festival. This year, for the first time the @Home team also joined with HERO.

MSL

This year, the main opponent in MSL was LAR, which is the relaunch of Minho. The LAR team made impressive progression. The first day they did not have a working robot yet, whereas the last day they had a full team working. Our team also played against humans; they shot penalty's against Tomar's mayor and the IPT president, they played against the team members of LAR and lastly against a talented girls team from Tomar. The final game against LAR was won with 10-0.

@Home

In the @Home competition Tech United competed with LAR and Socrob, the last two being from Portugal. HERO acted as a bag-carrying assistant, a house cleaner, and a restaurant waiter and thereby collected the most points.

Watch the match between Tech United and LAR here:

DEVELOPMENTS @HOME

At the start of this year we set out with one goal: to improve our manipulation. That includes the robot's ability to pick up and place various objects. One of the biggest challenges we still faced was the robot bumping into the table or shelf when picking something from it. Our world model has all the information the robot needs to plan a collision-free path. We had to implement a path planner which could find a collision-free path even when there are many obstacles near the robot and then we had to export our worldmodel into a format this planner could understand.

We got to see this system working in action in Portugal, where our robot could successfully place 4 objects in a cupboard without bumping into the wooden doors. Now our robot is one step closer to helping people around their house.

We went to Robocup with a rather small team consisting of 5 members. We still managed to achieve 4th place in the competition with the best performances in the restaurant and receptionist challenges. We learned a lot and are eagerly preparing to seize the title next year on our home turf during Robocup 2024 in Eindhoven!


SUGAR
MAXWELL HOUSE
Ice Tea

PROJECTS @HOME

Ken Haagh
Bachelor End Project - People Tracking and Following

A fundamental aspect of HERO's service as a robot is its human interaction capabilities. One significant aspect of this interaction involves HERO's ability to accurately follow a human who is leading it to a destination. For HERO to achieve this, a solution for detecting and tracking a target is needed. Developing such a solution for HERO is the focus of my bachelor's end project.

The solution implemented uses HERO's camera to detect all individuals within its field of view. This is achieved through the use of YOLO, a real-time object detection system. To track the target a combination of data association, a model and target re-identification is used. Using data association with both position and pose information a Kalman filter is updated. This filter is used to predict the target's location in real time. Which then can be used by HERO to follow the target.

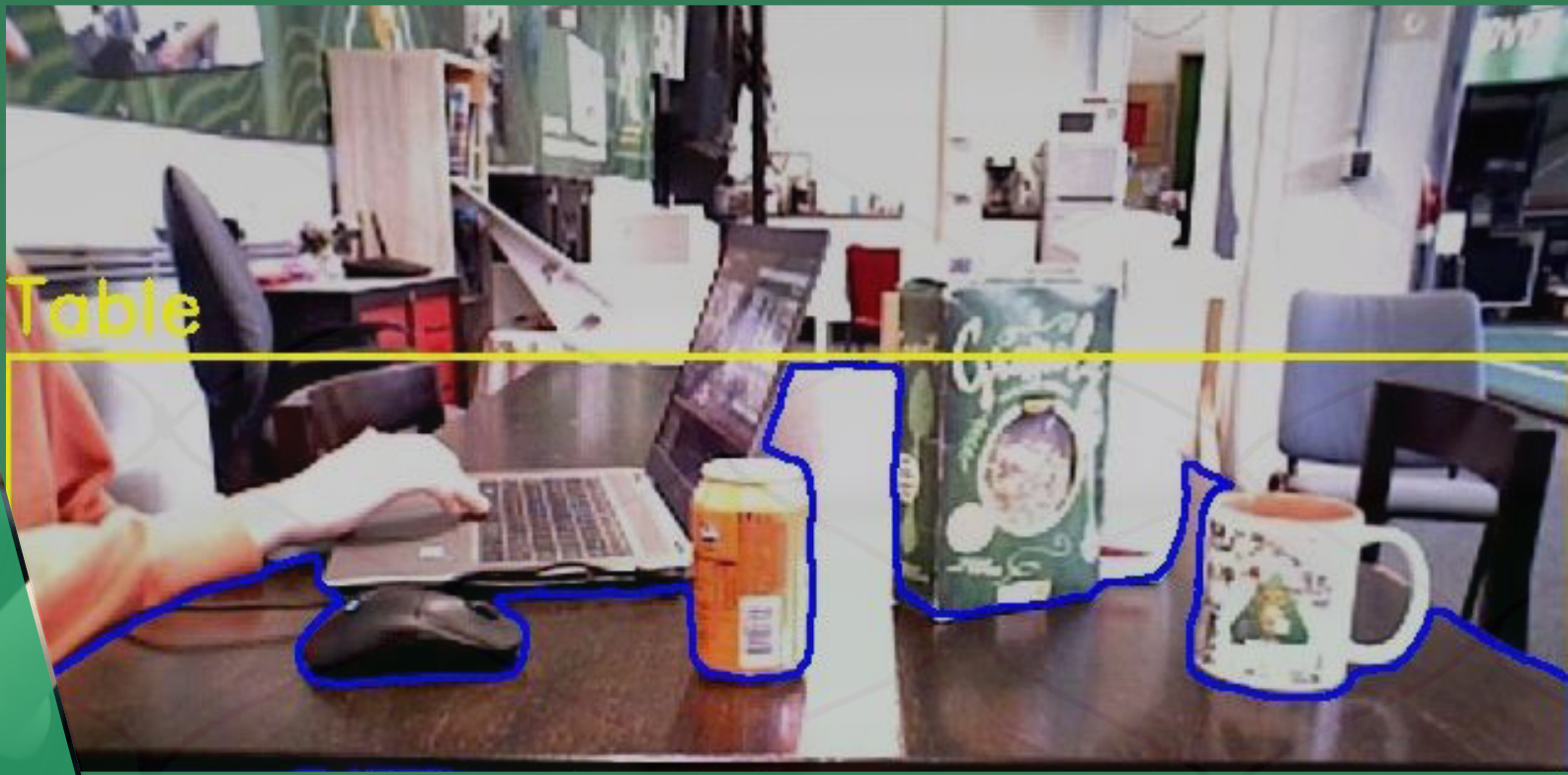
To make sure that HERO keeps tracking the correct target reidentification, using colour histograms is done. This process creates distinct colour profiles for each detected individual. These profiles can then be matched to the target, making sure the correct person is still being followed. This re-identification will also help keep track of the target when it briefly disappears from HERO's view.

Dónal Ryan
Bachelor End Project - Modelling of an unknown table for object placement

My project revolves around the modelling of a table surface in a room such that HERO, the companion robot at Tech United, can successfully place objects onto a table when requested by the user.

Currently, I seek to achieve this by using a neural network (YOLOv8) with RGB image data from HERO's camera to identify if a table exists in the image, then create a segment of the table within the image and lastly take a localized depth measurement based on the segment using hero's depth sensor to model the surface.

A lot of challenges arise in this project due to the abstract nature of the problem but I hope to create a robust solution that can allow HERO to successfully place an object on a table in an unknown environment.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DEVELOPMENTS MSL

As every year, the MSL team works hard to improve the software and hardware on the robots in order to win RoboCup tournaments. To do this, each year we come up with new possible developments that will improve our TURTLEs. This wishlist of developments will be turned into a multitude of projects, ranging from projects team members do together to guiding Bachelor End Projects (BEPs) and Master theses. Read here what projects we worked on in 2023.

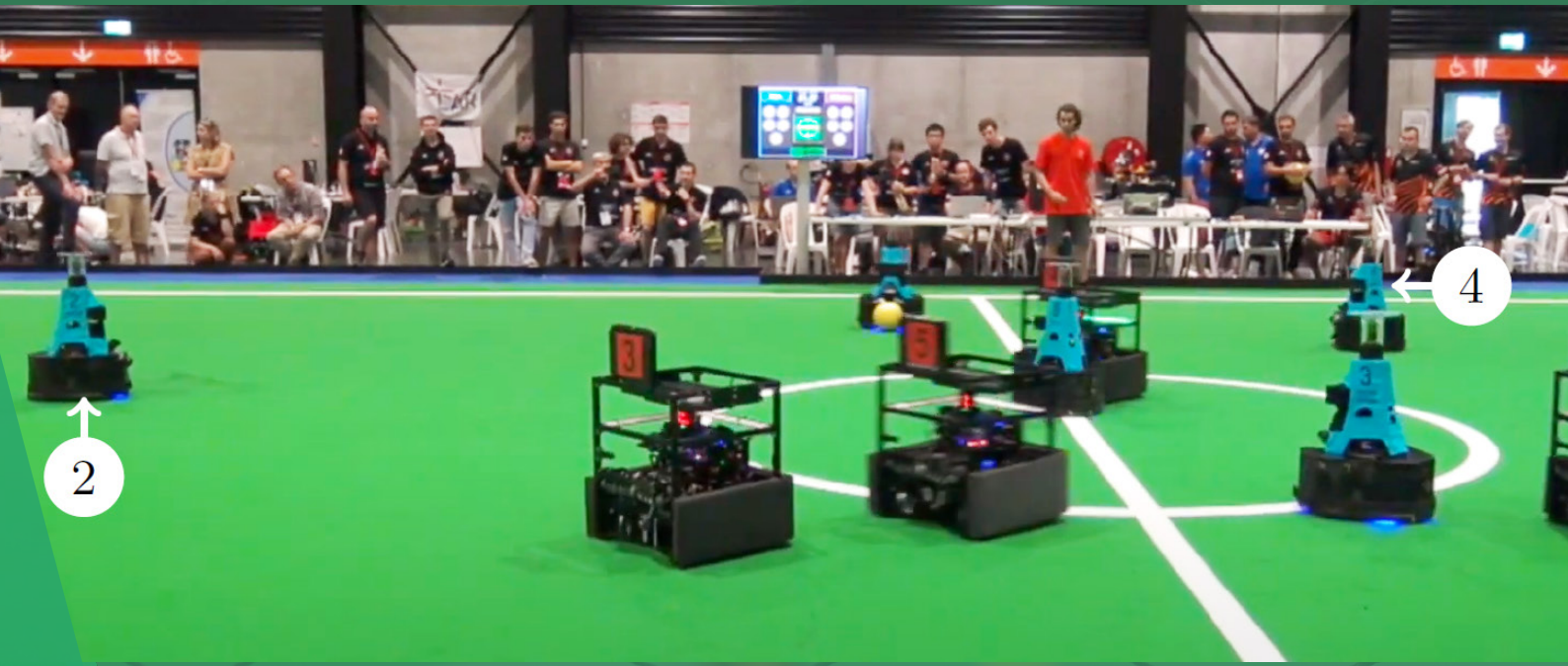
Sweeper Keeper

In the RoboCup MSL, one of the five robots per team can be a goalkeeper, being the only robot allowed to be in the goal area and to use extendable frames. Until this year, goalkeepers in the MSL have always remained within their goal area and have only been used to prevent balls from entering the goal. Goalkeepers in human soccer and futsal, however, sometimes leave their goal area to intercept balls from the opponents that are behind their own defensive players, and serve as an additional (defensive) field player when their team has the ball. They are often called sweeper keepers.

This year, Tech United applied this idea for the first time in a RoboCup MSL match. To enable it, the robot with goalkeeper hardware (extendable frames, but no ball handling and shooting mechanism) was substituted by a 'normal' robot. Every time we possessed the ball, the sweeper keeper left its goal area, either still staying in between the ball and the center of its goal or even joining the attack in the same way as the other robots. As soon as possession of the ball was lost, it quickly returned to its goal area.

An example from a match is shown in the figure, where the sweeper keeper (robot 2) serves as a fifth field player for Tech United (black with blue robots, playing towards the right side), making it impossible for the four opponent field players (black robots with red number plates) to defend every robot. As a result, robot 4 could receive a pass and score a goal.

In the future, we aim to develop a robot with the same ball handling and kicking mechanism as the field player robots, and additionally the goalkeeper's extendable frames with adapted dimensions.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VAN DER LANDWIEL
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VAN PERSLUCHT
5
ROBODINHO
6

PROJECTS MSL

Hao Liang Chen

PhD Project - Incorporating strategies to allow less-reactive soccer robots

Current soccer robots perform actions in a reactive principle, where passing and shooting is done based on the current "state" of the world, i.e., the robots positions and velocities. This allows the robot to seize chances when the opposition makes positional errors, e.g., too big gaps between their robots. This practice has resulted in many victories in the robocop middle size league, but we foresee difficulties when competing against humans in the future. As humans will less likely make those positional errors and can better predict what our robots may want to do. It is therefore that we do not want to solely rely on the current state of the world, but also want to include some prior discussed strategies, e.g., passing routines that may not bring the ball closer to the goal but may confuse the opponents prediction of your future actions.

Currently we have incorporated a simple passing routine in the STP framework, which shows the feasibility of introducing such strategies into our robot program. Next steps are to include more routines and test it out (in simulation) against robots that are solely reactive.

Wiktor Bocian

A low-cost alternative for the vision system for a middle-sized football robots

Currently, many parts of low-cost middle-size football platform are being developed. One of those is a low-cost vision system that can be used for localisation of the robot on the field. Because of low cost and good video quality mono-camera with a Sony IMX477 sensor was tested in combination with different lenses with a field of view of 125, 150 and 180 degrees. To get data for localisation from images the relation between the pixel and real-world coordinates needs to be known. This is done by undistorting images using the intrinsic parameters of the camera and then by changing perspective to the top-down view of the field as shown in Figures 1 and 2.

The image with the new perspective is used for line detection using color filtering. This data is matched to a previously created field map using a particle filter to compute the position on the field as shown in Figure 3.

Initial testing with static images shows that images can reliably detect the lines on the field and match them to the map and the increase in field of view has no downsides. However further testing still needs to be conducted, especially with the camera being in motion and filtering methods for line detections should be implemented since sometimes extra points are being detected as lines.

Fig 1: Undistorted camera image.

Fig 2: Image transformed to top-down view.

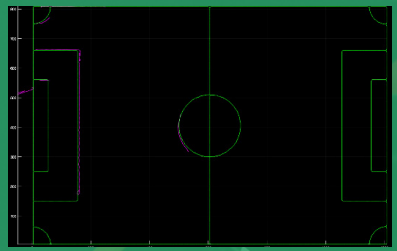

Fig 3: Example of matching lines to the map.


IARoMSL
02:07
STOP
2
3
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ROBODINHO

FACTS

THE MSL TEAM BECAME WORLD CHAMPIONS ONCE AGAIN THIS YEAR, MAKING IT OUR 7TH WORLD TITLE IN THIS LEAGUE. @HOME CAME OVERALL 4TH IN THEIR COMPETITION, BUT STILL WON THE PRICE FOR BEST WAITRESS CAPTAIN!

DURING ROBOCUP 2023, THE TURTLES SCORED A TOTAL OF 107 TIMES OF THE 172 ATTEMPTS AT GOAL, RESULTING IN A CONVERSION RATE OF 62%. THE CUMULATIVE DISTANCE TRAVELLED BY THE TURTLES DURING THE TOURNAMENT WAS 50.7 KM.

ALTHOUGH BEING RELATIVELY NEW TO THE TEAM, ROBOT DOG SPOT HAS ALREADY BEEN PART OF THE YEARLY GRADUATION EVENT MOMENTUM AT THE TU/E AND THE OPENING OF THE DUTCH

ININ 2023 WE GUIDED 9 STUDENT PROJECTS: 1 GRADUATION PROJECT, 6 BEPS (BACHELOR END PROJECTS) AND 3 INTERNSHIPS, FOR A TOTAL OF 195 ECTS.

DEMONSTRATIONS

As always, giving demonstrations and promoting technology to a broad range of audiences is one of the key points of the team. In 2023 we have given more than 30 demonstration at the TU/e for all kinds of occasions. This includes being part of the parting of the previous rector magnificus Frank Baaijens and the welcome of the new rector magnificus Silvia Lenaerts. We also received a visit from Habbekrats who support children and young people whose life situation is characterized by structural disadvantage or poverty. We also visited dutch schools as part of our School Tour in Breukelen, Boxtel and Ysselsteyn to name a few. We also added a new robot to our demo team: SPOT. This robot ,designed by Boston Dynamics, has already attended seven different expo's and always catches the attention of all visitors.

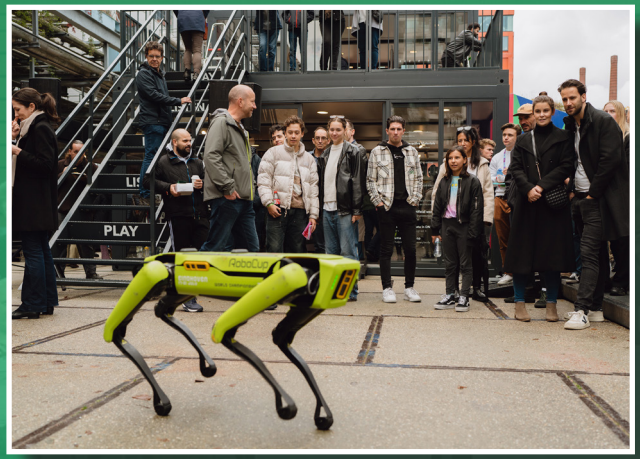
Angelaschool Boxtel
09/03/2023

Opening Neuron TU/e
28/03/2023

Comenius leergangen
11/01/2023

Vision, Robotics & Motion

Brabantse Ondernemers Maatschappij



DUTCH DESIGN WEEK

Joining the TU/e Drivers of Change we were present at the Dutch Design week. Not only did we promote the RoboCup 2024, but a TURTLE and HERO were also present the whole week!

SPECIALS

MOMENTUM

SPOT was present at momentum this year, to make sure the presenter had his cards!

FRANK BAAIJENS FAREWELL

Frank Baaijens said farewell to being the TU/e rector this year. Because he has always been a big support of TU/e student teams, we were invited to attend his farewell ceremony.

SWERVE DRIVE

This year we improved the driving speed of our robots. The robots are so fast now that they can almost lose control! Do you want to see our robot in action? Scan the QR code.

WAT GEBEURDE ER IN DE ZOMER?

TECHUNITED IS DEZE ZOMER WEER WERELDKAMPIOEN ROBOTVOETBAL.

EINDHOVEN SOCCER ROBOTS WORLD CHAMPION AGAIN, AFTER WINNING FINALS AGAINST ASML FALCONS

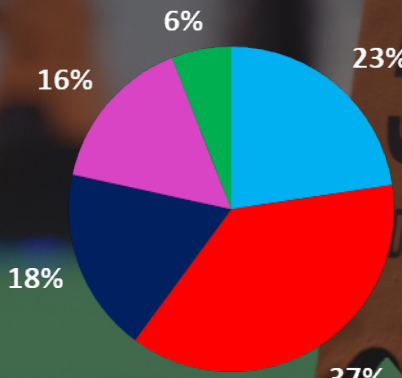
VIER WERELDKAMPIOENEN VAN 2023 AAN WIE HET SPORTGALA VOLLEDIG VOORBIJ IS GEGAAN: 'IK VERDIEN ER NIKS MEE, IK DOE HET ALLEMAAL UIT PASSIE EN LIEFDE

ANNOUNCEMENT: ROBOCUP 2024 WILL BE HELD IN EINDHOVEN!

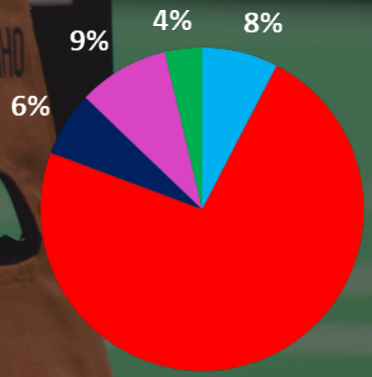
MORE THAN 8.700 FOLLOWERS AND 360.000+ PEOPLE REACHED ON SOCIAL MEDIA IN 2023!

MEDIA

FOLLOWERS (8.7K)



PEOPLE REACHED (360K)



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SANDERS MACHINEBOUW BV

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT


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