



# ANNUAL REPORT 2022



RoboCup  
BANGKOK  
THAILAND 2022



# PREFACE

This year not only our, but also the robot's engines were running at full speed again. We had a good time preparing for the tournaments, working on new developments, and giving demonstrations.

We feel honored that, once again, we won the world championship this summer in Bangkok, Thailand. Not only did our soccer robots do an excellent job and are now the six-fold world champion, also our robot HERO brings victory back home with its second gold medal.

We welcomed many new members, from bachelor-end-project students to interns, to full members. Some of our new members even got the opportunity to join RoboCup for the first time right away! Go ahead and read what we have been up to this year, as we have a lot to tell you.

# MSL



- 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**
- Portuguese 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**

# @Home

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

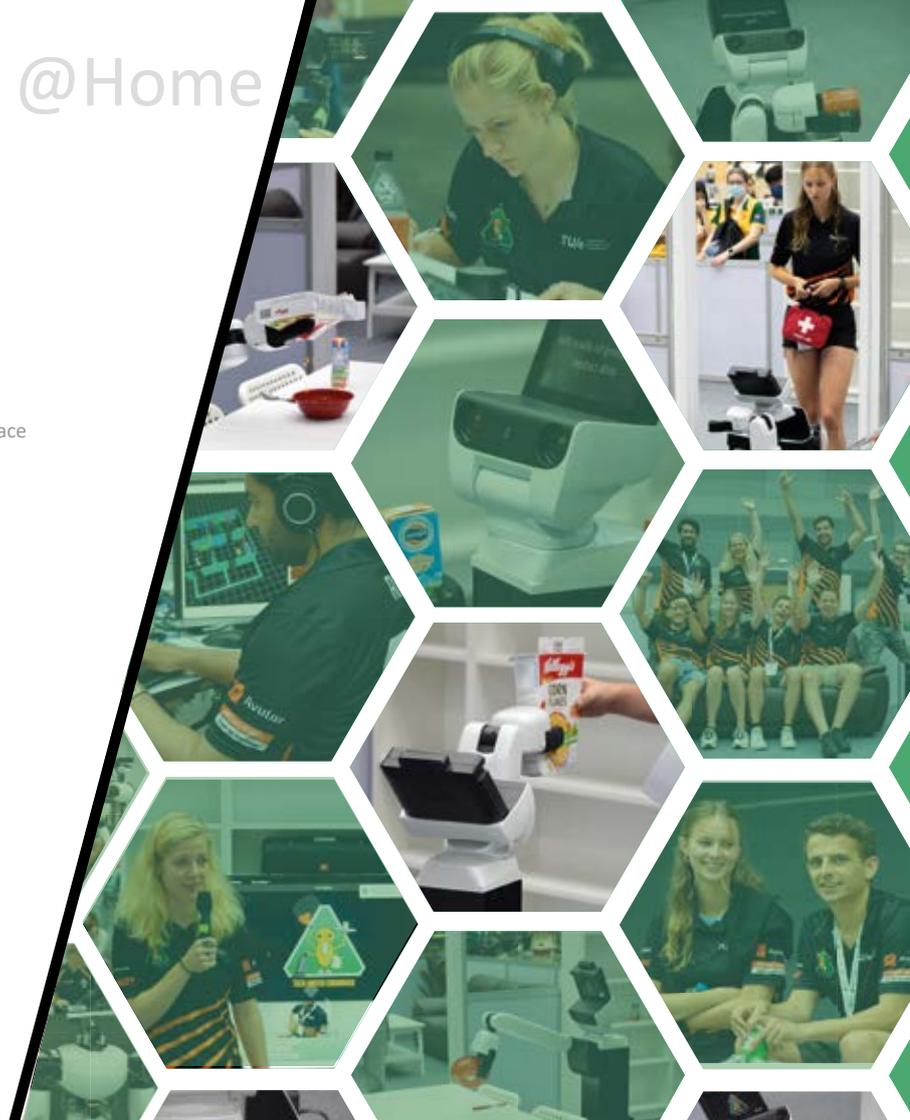
2009

2008

2007

2006

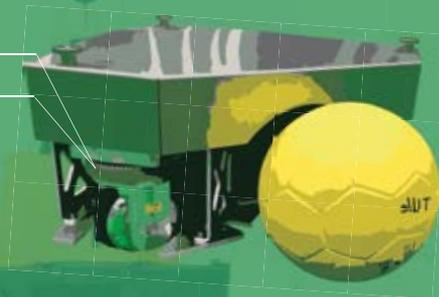
2005





## Swerve drive »

- 3** Driving (hub) motors
- 3** Steering motors
- 600 W** Power per motor
- 1800 W** Total driving power
- 3.5 m/s<sup>2</sup>** Max Acceleration
- 5.5 m/s** Max Velocity



## « 3 wheel TURTLE

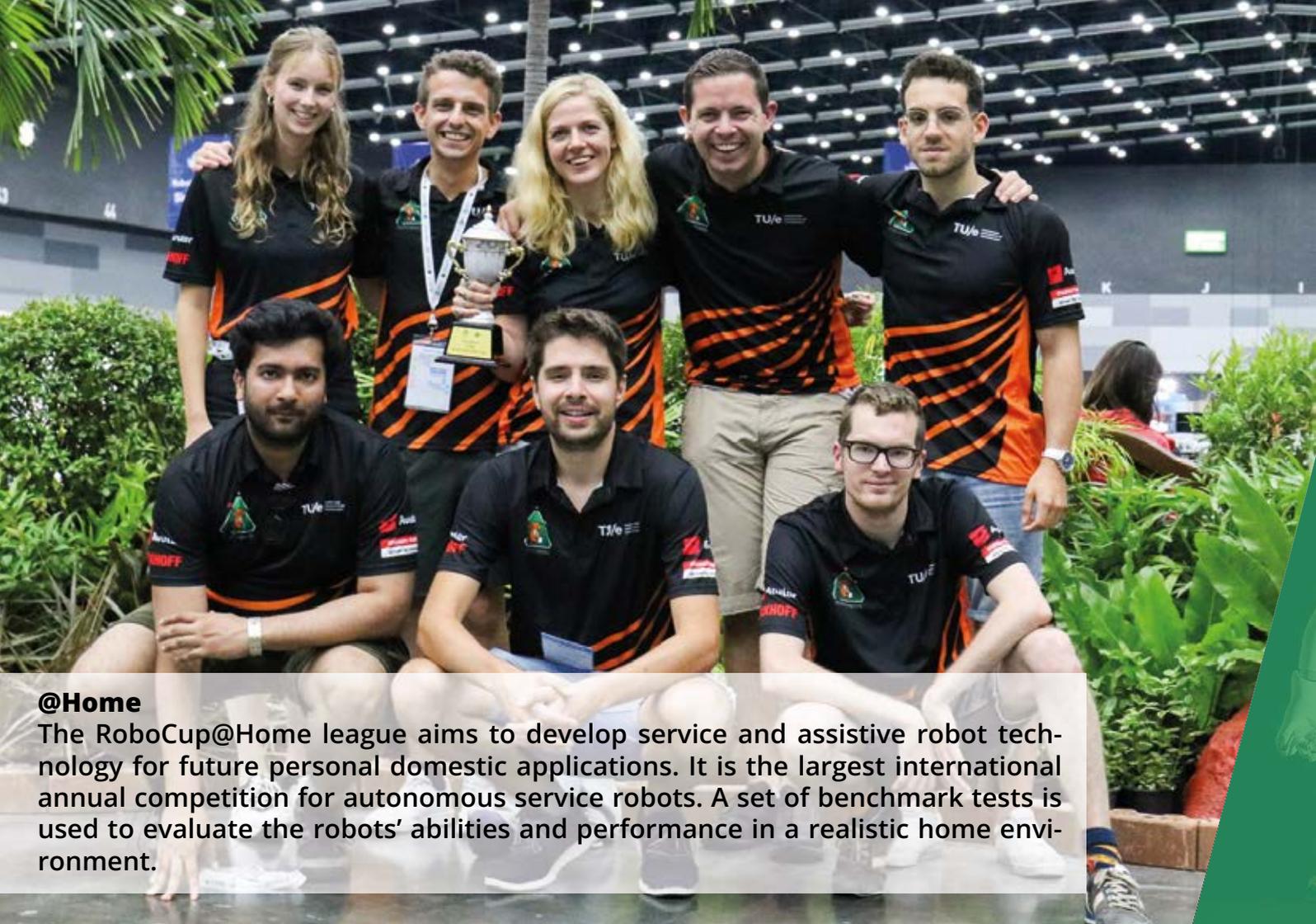
- Omnivision Camera 0.3 Megapixel**
- Kinect V2 2 Megapixel**
- Shot speed 12 m/s**
- Battery Capacity equal to 8 iPhone 1's**
- Motors 3**
- Power per Motor 150 W**
- Total driving power 200 W**
- Max Acceleration 1.7 m/s<sup>2</sup>**
- Max Velocity 3.5 m/s**



## Middle Size League

In RoboCup MSL, teams of five fully autonomous robots play soccer with a regular FIFA soccer ball. From 2023 onwards also one human is allowed to play together with the robots during matches. The focus of the research is on mechatronic design, robotic skills, control and multi-agent team play.





## @Home

The RoboCup@Home league aims to develop service and assistive robot technology for future personal domestic applications. It is the largest international annual competition for autonomous service robots. A set of benchmark tests is used to evaluate the robots' abilities and performance in 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



In July 2022 RoboCup took place in Bangkok, Thailand. After three years Tech United could finally defend their two World Cup titles from 2019. It was exciting to be at RoboCup again, because we did not know what all the other teams had been up to in the past years and what developments they made. Also, there were a few new teams that we never encountered before. We had to make sure that our software and hardware worked flawlessly and we had to give it our best. Read below how it went.

### **MSL**

Our MSL team started the tournament with some fairly big wins. We started to experiment with new developments in the software, such as the human dribble and various tactics. However, on day three we encountered software problems, which caused the robots to illegally take the ball from the opponent during a set piece. We lost a match against our toughest opponent: the Falcons. We had to step up our game and fix all bugs before the finals. Luckily we managed to do this and prolonged our World Cup title once again after a 15-0 win!

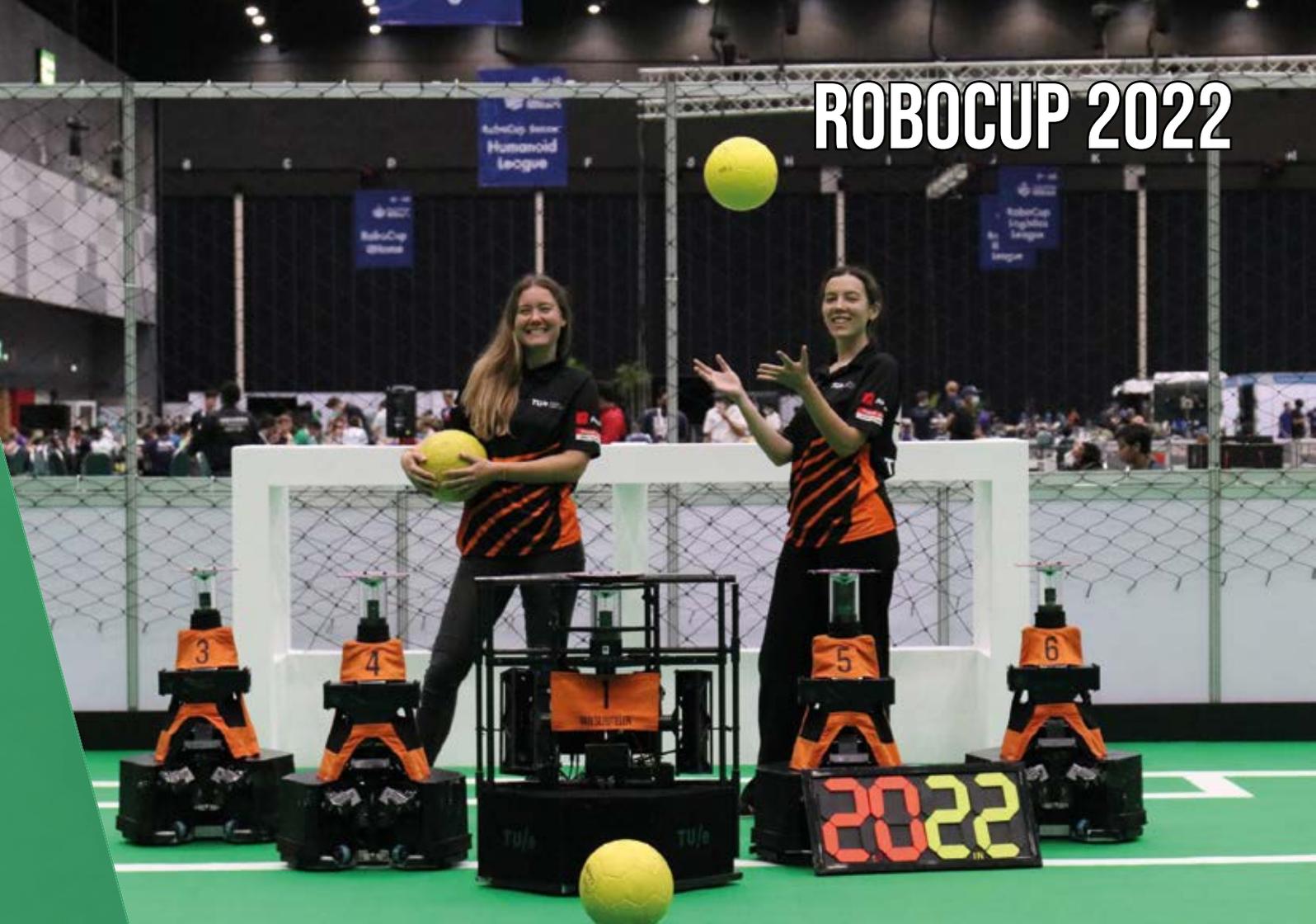
### **@Home**

Our @Home team had quite some new members this year, so we did not know exactly what to expect. However, we managed to successfully complete some of the most difficult challenges of the tournament, such as the Restaurant challenge where we served guests in an unknown environment. We were in the finals again! Here, we showed how HERO could help a person in need, which got us the second @Home World Title.

**Watch both finals here**



# ROBOCUP 2022





# EUROPEAN CHAMPIONSHIP

It was amazing to finally participate in a tournament again at the European Open in Guimarães. In the past few years covid obstructed any matches, which meant this was the first time in two years that we were able to play. On the last day we won the finals against team VDL Robotsports, claiming our sixth European Championship.

As winners of the finals we got the honor to play against the professional first women team of Guimarães, Vitória SC. At the start of the match we conceded three early goals, showing that we were still not up to speed with this level of play. Luckily the players of Vitória SC gave away some more space later on during the match, which meant that we were able to score four goals ending the match with a 4-4 draw. After an intense penalty shoot-out we came up victorious, defeating the team with 5-4.

It was a nice tournament to participate in and a good moment to test our robots two months before going to Bangkok to participate in Robocup and defend our world title!

# DEVELOPMENTS @HOME

2022 was a year full of activity. We were able to test our new developments during RoboCup and managed to show that hard work indeed pays off by defeating our long time opponent TidyBoy in the World Cup finals.

This year, we welcomed 6 bachelor students who did to do their thesis with us. Four of them have already successfully defended their thesis and gave HERO many new capabilities. HERO is now a step closer to navigating among movable objects and modeling tables in a better way. He also has an improved world model (how HERO 'sees' the world). One student is still working on relative localization, helping HERO focus his attention to the task at hand. The other student is helping HERO find an empty spot on a cluttered table to place an object on. Besides the bachelor students, we took in 3 new permanent members. Two of them had their pledging right away and joined us in Thailand on RoboCup, where they did a spectacular job.

What do you think lead us to the finals in Thailand? Spoiler alert: it was the restaurant challenge. This challenge is always a difficult one since HERO must navigate in a completely new environment and has to talk to people in the restaurant. Since the start of the team 10 years ago it never went completely successful, until this day. We nailed it! Do you want to see how HERO did it? Scan the QR!







Photo: Bart van Overbeek

## Grasp detection

Our Toyota service robot HERO currently has no method of determining whether it is holding something. In some situations this might be an issue. For instance, if the robot tries to bring something to you and is unable to grasp it, it will think it successfully grabbed the object and return empty-handed.

Team member Rodrigo is currently addressing this problem. Right now, to determine if the robot is holding something, HERO measures the distance between its two fingers, squeezes them lightly, and measures the position a second time to compare it to the starting position. We call this method “active grasp detection”. The technique works flawlessly for fairly rigid objects like a can of soda, or an apple, but it can’t be used for soft objects like a sponge.

HERO needs knowledge of the object that needs to be grasped, which is what makes this problem so challenging. Hopefully in the future HERO can know if he has something in his hands in every situation.





## YOLO (Object Recognition)

Currently we are looking into YOLOv7 to improve object detection. YOLOv7 is an object detection algorithm, which makes use of a neural network. This neural network is first trained where it learns features of the classes. For now, we have trained the network on a dataset with 4 classes: coke, sprite, pringles and orange. Which means that the robot can recognize these objects. The network predicts whether there are objects in the image by extracting features from the image. When objects are detected, a bounding box is placed around it.

This algorithm is used when the robot has to pick up an object, for example when it needs to store the groceries or serve a drink. An example can be seen in the image, where the robot is asked to serve a coke. The coke is detected and classified with high confidence.

I am going to place the  
milk carton





# PROJECTS @HOME

## **World model (Bachelor End Project)**

“During my BEP I worked on the worldmodelling of HERO. HERO has a world-model full of objects, however, because objects can move the positions of these objects in the real world are not necessarily the same as in the worldmodel. HERO is able to adjust its worldmodel based on sensor data but when objects have moved too far from their original position this method does not work anymore and some problems arise. My task was to work on a new way to use sensor data to place objects in the worldmodel. My method works by using the laser scanner. Straight lines are extracted from the laser scanner data. This information is then put into my program based on multiple hypothesis tracking. It takes the length of the lines and uses this to associate measurement data to objects in the worldmodel.

This new program was tested in both simulation and on the actual robot. In both cases the program is able to quickly associate rectangular objects to the worldmodel no matter where they are with respect to the robot. Even with partially occluded objects the program was able to correctly associate measurements to objects.”

**Twan**

## Where can I put this? (Bachelor End Project)

“The goal of my project is to find an empty spot on a cluttered table to place an object. Currently, HERO can detect the top of the table and project a 2D image of that table sheet, as seen in Figure 1. However, it does not know where on the table it can place an object. To reach my goal I have to give HERO more information that it can work with to determine a safe placement point. Firstly, HERO can find the height of the table on which it wants to place an object, therefore everything that HERO sees that is above the table sheet is defined as clutter. Secondly, the sections of the table that HERO cannot see due to the clutter on the table, occluded space, can be computed as well. This is done by using vectors between HERO’s depth camera and the clutter. These vectors can be extended until it crosses the table sheet. Thirdly, the same vector methodology can be used to determine the edge of the table. Finally, to place an object we have to take into account the dimensions of the object that we want to place. To do this the user can input the radius of the object, HERO will automatically calculate the appropriate margin to safely place an object on the table. All this information is then added to the 2D image from which HERO can choose a green point as a placement option, as seen in Figure 2.”

**Max**



Fig 1. RGB image of the situation with the resulting 2D image of the table sheet. Where yellow is an unsafe placement option, red is not a table, blue is unknown occluded space, green is a safe placement option, and grey is outside the HERO's field of view or cannot be seen.



Fig 2. Green is the table sheet and grey is unknown



0  
42  
15  
16  
1  
5  
WOUTER 10

# 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 2022.

## **The MSL kickoff platform**

Currently we are working on developing an MSL kickoff platform. This will be a lower budget platform that still has the specifications to potentially be able to compete with the best in the MSL league. This design will be shared with the world and therefore make it easier for new teams to build a robot and enter the MSL. The robot is a complete new design from the ground up and incorporates all the gathered knowledge from the past years.

This project builds on our Turtle5K project in 2012, but back then it was very difficult to create a platform for less than 5000 Euro's because most parts that are critical for the robot's performance were still relatively expensive. Because in the past few years the price of electric drive-trains, vision and computing has become more affordable it now has become a lot more feasible.

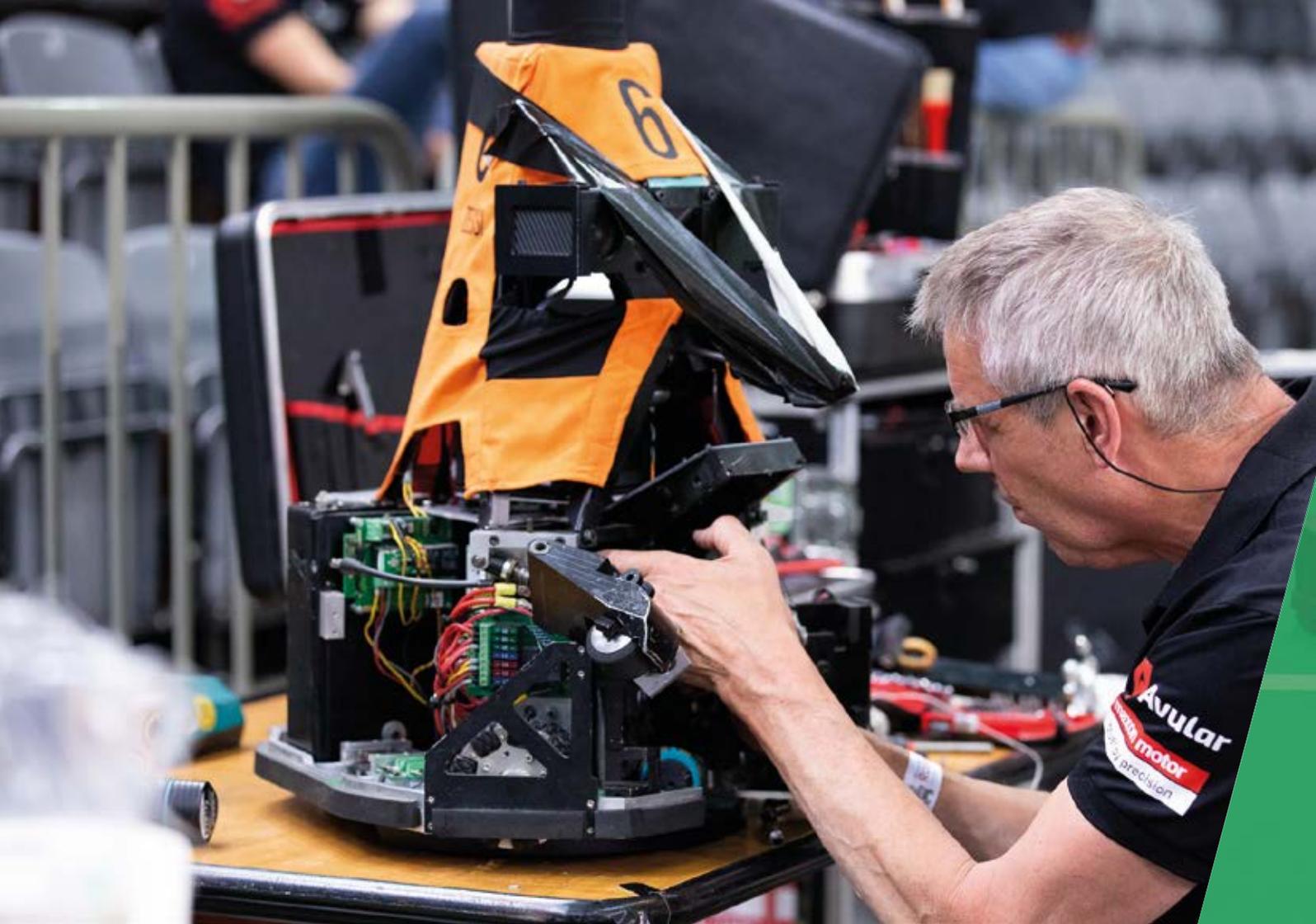
## **Swerve drive**

Next to the well-known TURTLE robots, the team started earlier this year with the development of the Swerve Drive platform. This platform has three wheel sets, where each set consists of a steering and driving motor that can be controlled independently.

The main benefit of this system compared to the old omni-wheel system is that we can use standard tires, which could give us the opportunity to reach a higher acceleration, without losing agility.

The first tests look promising and we even won the RoboCup Technical Challenge with it. In the next tournaments the new platform will really have the chance to prove itself. The platform also gives us the possibility in the future to drive outdoors or on (artificial) grass.



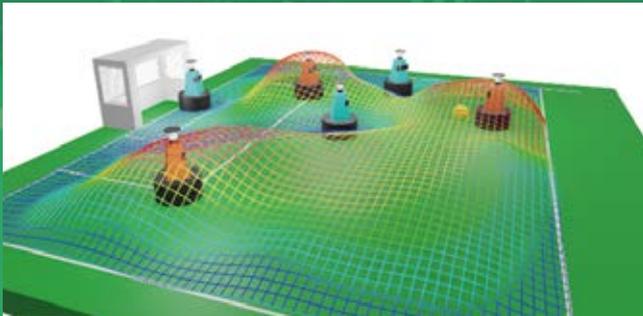


# PROJECTS MSL

## Decision making based on a semantic map (Master Thesis)

“My master thesis involves including semantic knowledge about the game of soccer we humans developed over the years to be able to better configure the tactics of the robots. The Tech United team uses Skills, Tactics and Plays (STP) as the overall strategy framework. Within STP ad-hoc decisions about which skill to deploy still have to be made to react properly to the dynamics of the game, which is currently solved by the use of potential fields. It computes numerous calculations for every point in the gridded field whether a certain action is possible and what the quality of the position is. In this work 2D regions are constructed that represent the affordance of a certain skill. This prior knowledge of the possible combination of skills and targets allows for explainable decision making, improving configurability.”

Jaap



Visualization of potential field

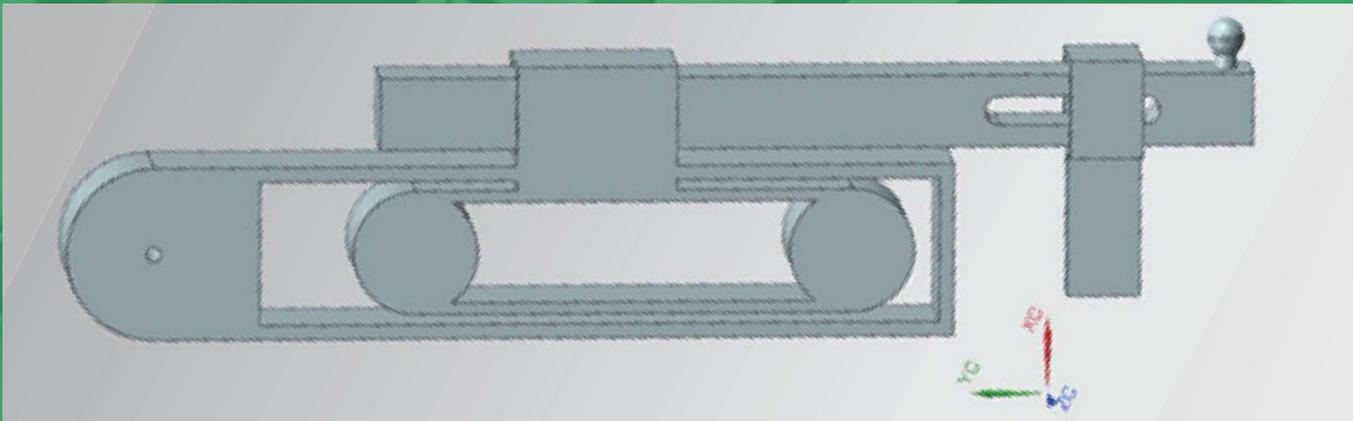


Visualization of semantic regions

## Lob mechanism (Bachelor End Project)

“To make it easier for future new teams to enter the world of soccer robots and thus increase competition, Tech United has started to develop an open source soccer robot. This football robot, called the MSL Kickoff Platform, must work as optimally as possible with the smallest possible budget, so that it becomes easier for new teams to join in. For this BEP project I am making a new design for how this can be applied to the soccer robot’s lob mechanism. A new design is being made with the aim of performing the action just as well as Tech United’s current football robot, but making it much cheaper. At the time of writing, this design phase is still ongoing. In the attached image you can schematically see one of the options that are currently available for the lob mechanism, where the height of the lob mechanism is adjustable using a belt drive that is connected to a motor.”

**Thijs**





3

VAN DER  
ZANDWIEL

4

VAN  
PERSLUCHT

5

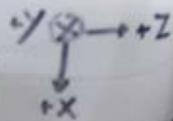
ROBOCOP

6

ROBOCOP



I am going to place the  
mug



# FACTS

BOTH MSL AND @HOME BECAME WORLD CHAMPIONS ONCE AGAIN THIS YEAR! OUR @HOME TEAM NOW HAS **2** TITLES IN THEIR NAME. OUR MSL TEAM HAS **6** (!) AND IS CURRENTLY THE TEAM WITH THE MOST TITLES IN THEIR NAME.

STUDENTS FOLLOWING THE COURSE '**MOBILE ROBOT CONTROL**' GOT TO WORK WITH OUR SERVICE ROBOT HERO. THIS WAS THE FIRST TIME THAT STUDENTS THAT WERE NOT A MEMBER OF TECH UNITED GOT TO WORK WITH HERO.

HERO, TOGETHER WITH SOME TEAM MEMBERS, PAID A **VISIT TO A CARE HOME** TO SHOW THE RESIDENTS HOW THEY CAN BE HELPED IN THE FUTURE.

IN 2022 WE GUIDED **10** STUDENT PROJECTS IN TOTAL: **1** GRADUATION PROJECT AND **9** BEPS (BACHELOR END PROJECTS), FOR A TOTAL OF **130** ECTS.

## European Open Guimarães

01/06/2022



## Visit Indonesian school

13/10/2022



## Fleet EXPO 2022

23/11/2022



## Visit Irish Companies

24/11/2022



## Visit New Employees TU/e

13/05/2022



## Basisschool de Vlinder Baarle-Hertog

22/04/2022



# DEMONSTRATIONS & SCHOOL TOUR



In 2022 we were finally able to give demonstrations more frequently. We have given more than 30 demonstrations on our own field in Impuls to all kind of visitors, ranging from an Indonesian prince to a voluntary project “Move je buurt” where TU/e students showed the campus to a primary school class. Next to groups visiting us on the campus, we also went to congresses in Franeker, Haarlemmermeer and the Klokgebouw in Eindhoven. Demonstrating and explain our robots to many children and adults. We also visited a primary school in Baarle-Hertog where we made a lot of young (potential) engineers enthusiastic for robotics! Some special demonstrations we were able to give this year were during the opening of the academic year of the TU/e and during the European Open in Guimarães.





## MSL WORKSHOP

In December, the 11th MSL workshop was a fact. This time it was at our home base in Eindhoven again. After RoboCup, we come together with the other teams to discuss about the future, new developments, and what direction we would like to head in with the league. Teams from France, Croatia, Portugal and the Netherlands were present.

# SPECIALS



## NERDLAND

In November we were present at Nerdland, the biggest science festival in Belgium. For a huge crowd full of enthusiastic children, we showed our skills and shot some balls through holes in front of our goal.



## TRICK SHOTS

We are always working on improving our shot accuracy. Team member Danny was so certain of the robot's skill that he dared to take on a challenge. Curious what he did? Scan the QR code!



## EINDHOVEN AIRPORT

Our human colleagues did an excellent job in the World Cup this year, but not as good as we did! We had a small delegation present at Eindhoven Airport showing off our victory.



## HOW WILL HUMANS FARE AGAINST ROBO-FOOTBALLERS?

THE SKILLS THE ROBOTS LEARN ON THE PITCH COULD ALSO HELP LAY THE FOUNDATIONS FOR OTHER COLLABORATIONS WITH HUMANS

## WAT ALS ROBOTS SLIMMER WORDEN DAN WIJ?

AI EXPERT CARLO VAN DE WEIJER LEGT HET UIT IN DIT COLLEGE VAN UNIVERSITEIT VAN NEDERLAND



## VOETBALROBOTS TU EINDHOVEN SLEPEN EUROPESE TITEL IN DE WACHT

EINDHOVEN IS EEN EUROPEES KAMPIOEN RIJKER. HET STUDENTENTEAM TECH UNITED HEEFT IN PORTUGAL HET EK ROBOTVOETBAL GEWONNEN

## EUROPEAN ROBOCUP 2022

PORTUGALS NATIONAL TELEVISION NEWS CHANNEL COVERS ROBOCUP EUROPEAN CHAMPIONSHIP



## TECH UNITED DEFENDING TWO WORLD TITLES AT THE ROBOT WORLD CUP 2022

THE AUTONOMOUS SOCCER AND SERVICE ROBOTS OF TECH UNITED WILL BE COMPETING FOR THE WIN AT ROBOCUP 2022 IN THAILAND

## EINDHOVENSE ROBOTS WINNEN TWEE KEER GOUD OP ROBOCUP

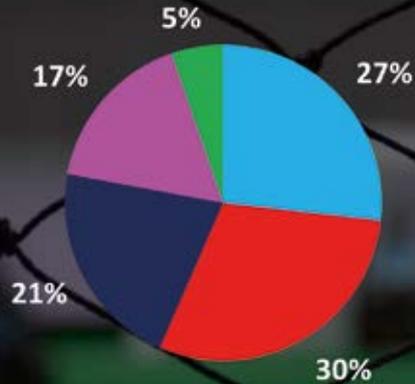
DE VOETBALROBOTS VAN TECH UNITED HEBBEN HUN ZESDE WERELDTITEL VEROVERD, OOK DE EINDHOVENSE ZORGRBOT PAKTE GOUD



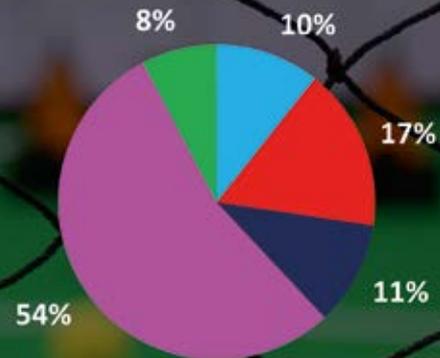
**MORE THAN 7.400 FOLLOWERS AND 326.000+ PEOPLE REACHED ON SOCIAL MEDIA IN 2022!**

# MEDIA

## FOLLOWERS (7.4K)



## PEOPLE REACHED (326K)



■ Twitter ■ Youtube ■ Facebook ■ Instagram ■ LinkedIn

WE WOULD LIKE TO THANK ALL OUR SPONSOR FOR SUPPORTING US ONCE AGAIN!

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**BECKHOFF**





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UNITED**  
**EINDHOVEN**



