ANNUAL REPORT 2021

Photo: Bart van Overbeeke

PREFACE

This year was full of hard work, developments, and achievements. Not only did we obtain second place in the Scientific challenge, but we also won first place in the Technical Challenge, which once again makes us the World Champion of 2021! Although the pandemic had kept us from participating in an on-site World Cup, we were able to program together at our University and test the features we have been working on throughout the year. We welcomed many new members, from bachelor-end-project students to interns, to full members. Besides our developments, we were also able to give demonstrations with our robots and participate in several events, which you can read all about in this year's annual report.

MSL

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

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

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

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

World Championship, Leipzig, Germany: 1st place
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
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
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
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
German Open, Hannover Germany: 1st place

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

World Championship, Bremen, Germany

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

@Home

2020

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

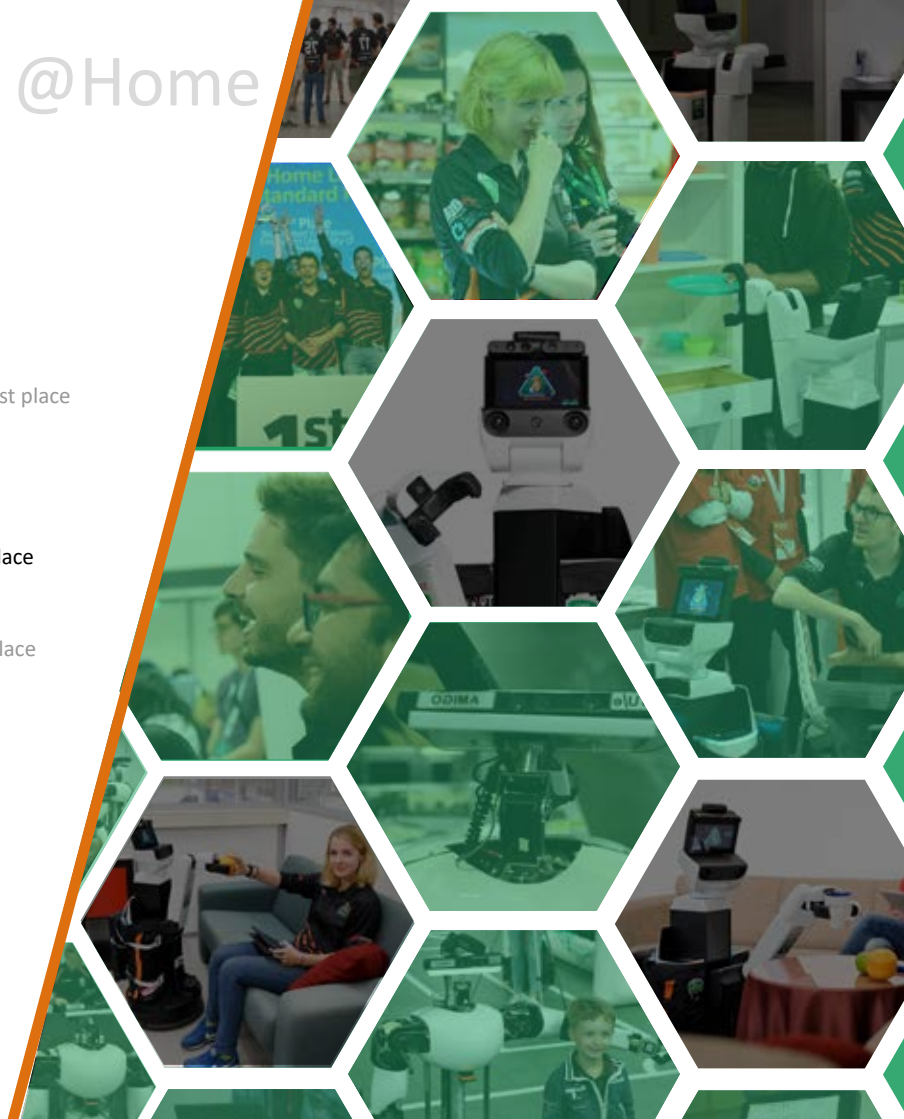
2012

World championship, Mexico City, Mexico, 7th place
RoboCup Dutch Open, Eindhoven, the Netherlands, 1st place
World Championship, Istanbul, Turkey, 14th place
German Open, Magdeburg, Germany, 6th place

2010

2008

2006



TECH UNITED EINDHOVEN

8 wheel TURTLE »

0.3 Megapixel	Omnivision Camera
2 Megapixel	Kinect V2
12 m/s	Shot speed
equal to 8 iPhone 13's	Battery Capacity
8	Motors
260 W	Power per Motor
2000 W	Total driving power
2.0 m/s²	Max Acceleration
4.0 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 13's**
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

In RoboCup MSL, teams of five fully autonomous robots play soccer with a regular FIFA soccer ball. The only interaction with humans is that with the referee, who can start or stop the play when necessary. 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

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 13's**

TECH UNITED EINDHOVEN

In June 2021 RoboCup Worldwide took place. The first online edition of the RoboCup World Championship. Our MSL team participated again this year, but the set-up of the tournament was different from other years. Instead of playing soccer matches against each other, we competed in the Technical Challenge and the Scientific Challenge. These challenges were already a part of the tournament in previous years. In these challenges the teams are asked to present their developments of the year.

Technical Challenge

We won the 1st place in the Technical Challenge! We presented our integration work of "OpenPose" in our software and demonstrated human pose recognition by our robots. With this, we can for example ask a ball from a robot with a hand signal, or let the robots predict where a human opponent will shoot. See our video with all explanation here:

SCAN ME

Scientific Challenge

Our submission for the Scientific Challenge was awarded with the 2nd place! Our goal for this challenge was to let the soccer robots shoot more unpredictable shots, by a new mechanism that can give a curve effect to the ball. By giving a spin to a ball, it will deviate from its original path and bounce in a different direction. This would particularly come in handy during penalties. We have developed and tested a mechanism that can achieve the desired effect. The next step will be to implement this mechanism in our robots.

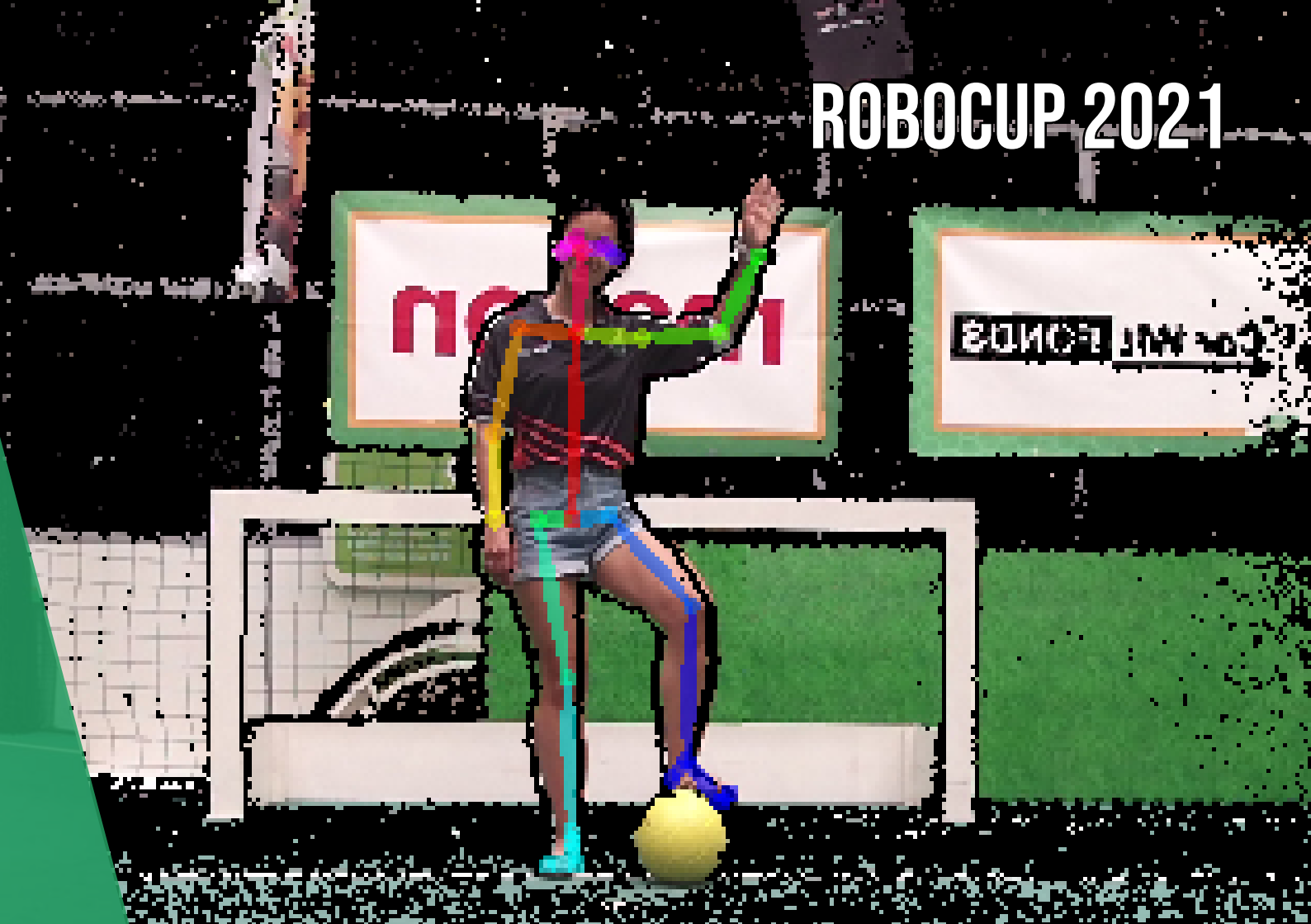

ROBOCUP 2021

Photo: Bart van Overbeeke

DEVELOPMENTS MSL

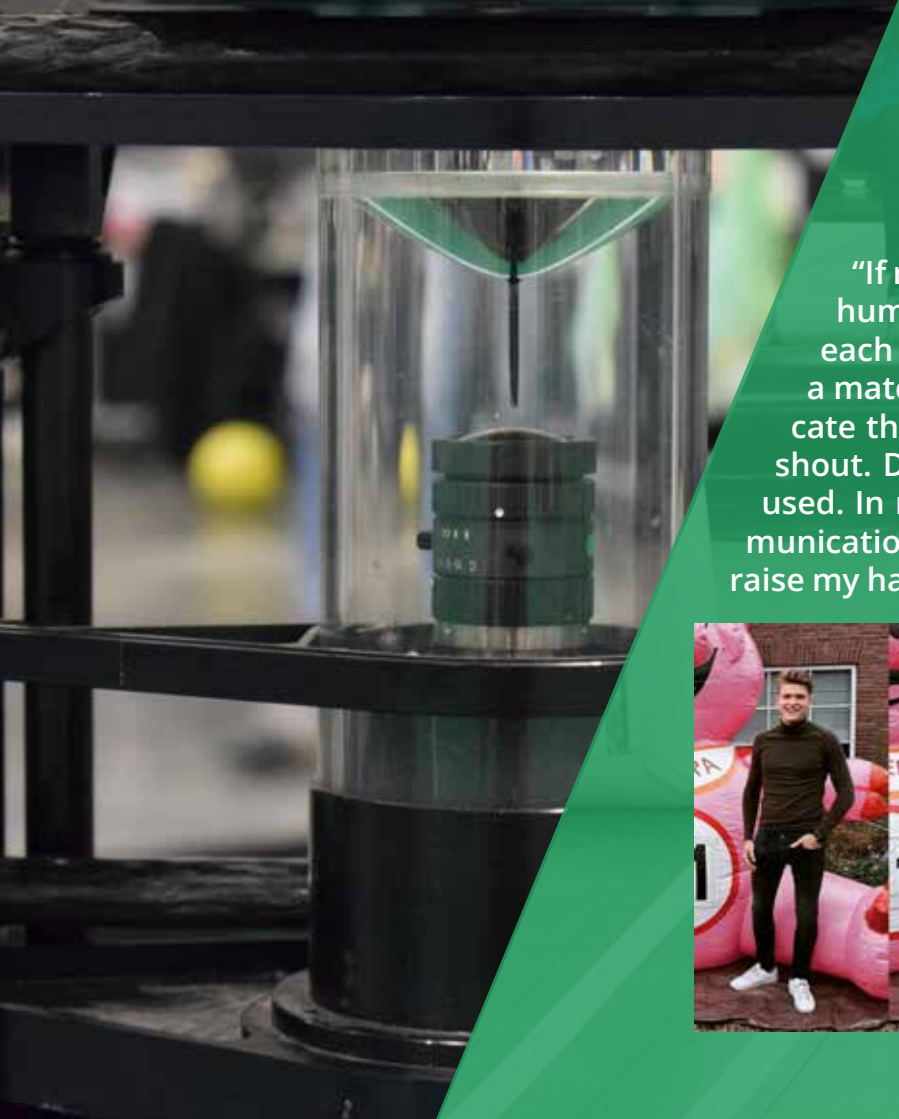
At the start of 2021 we, just as the rest of the world, had the hope that everything would soon go back to normal. Unfortunately, as we all know, this was not the case. Despite the possibility to return to the lab and finally meet again in person, we were not able to play a match to see if our developments of the past year worked in game.

During the year, Stefan started working on a detection method for bouncing balls. Currently, the detection of balls being passed around the field is done by the Omnivision camera on top of the robot. However, all information on the height of the ball is lost. Instead of seeing the ball in 3D-space, the robot projects the ball onto the 2D-field. This causes the robot to drive straight into a bouncing ball. To solve this problem, work is done on the detection of bouncing balls. The idea is to use the Kinect camera mounted on the robot to accurately determine the height of the ball. Based on the vertical velocity of the ball, the robot can detect whether a ball is bouncing or not. When a bouncing ball is detected, the Omnivision will be overruled by the Kinect camera. In this way, the height information of the ball is not lost and the robot will know the full 3D-position of the ball. This will not only avoid the robot from driving into bouncing balls, but also creates the possibility to catch bouncing balls and it can allow us to make more use of passes through the air.

We guided 7 Bachelor students with their Bachelor End Project, had one intern student and hosted a Master thesis project all contributing to improvements of our robots.

Despite not being able to play matches, RoboCup continued with an online format. We as a team worked on our robots throughout the week and showed in the Technical and Scientific Challenge what we were capable of coming first and second in the respective categories. We noticed that it was great to experience each other's company again in person and we decided to have another development week at the end of the year.

Photo: Bart van Overbeeke

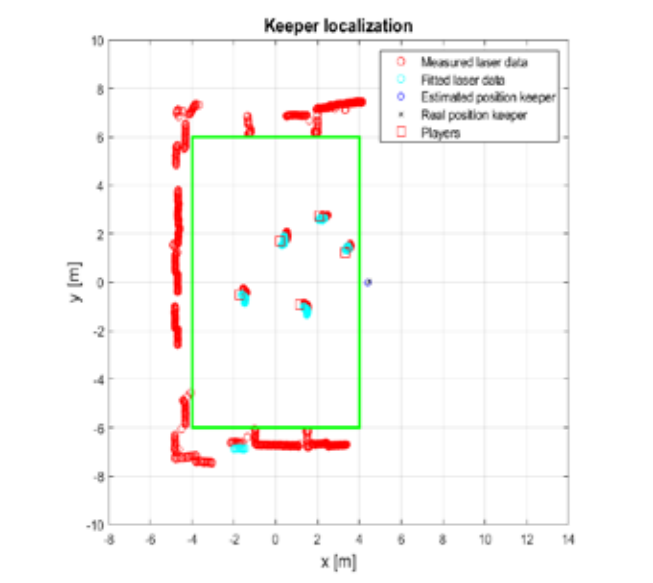


Open Pose

"If robots ever want to play with or against humans, they have to communicate with each other. When I am standing free during a match and want to get the ball, I communicate this to my peers by raising my hand and shout. During soccer a lot of body language is used. In my project I tried to improve the communication between human and robot. When I raise my hand to the robot, it should know that he has to pass the ball to me. I do that with OpenPose, a piece of software that recognizes poses and gestures of humans. With the help of machine learning I trained some poses so that the robots would recognize these."

Luuk

BACHELOR END PROJECTS (MSL)



Goalkeeper positioning

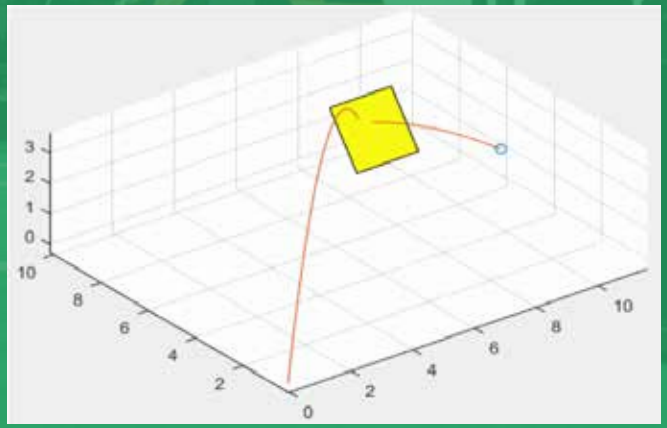
"Last year I did research on how the goalkeeper could find its position on the field in a new way. It uses his omnivision when he is outside of the penalty area. To make room for a catching mechanism, this omnivision should be removed and the goalkeeper should find his position on the field in another way. I made use of the laser range sensor and made an algorithm from which his position can be determined. By comparing the laser data with the world model, where the locations of all players are in, an estimate is made of where the goalkeeper is located. This resulted in a position estimate with a maximum error of about 0.5 m in both static and dynamic environments. With this, a base is set for the new goalkeeper localization."

Lotte

Headers

"During my internship, I looked at performing headers on the current generation TURTLEs. This was done by first dividing the header into three parts: Shot to header robot, impact on header robot and header robot to target. These were then divided in separate components. From these parts a simulation was made. To make the simulation more representative to the real situation, previous work was used to add an error distribution on each component. The resulting simulation was then run for 1000 times. With a moving header robot this resulted in a hit rate of ~4%. In order to increase this, every component was tested separately. This showed that errors introduced early in the simulation had the most effect. To solve some of these components the incoming ball to the header robot could be tracked using the Kinect and the robot could do a stationary header. This resulted in an increase in the hit rate to ~26%. The last method to increase the hit rate proposed was to increase the header surface to the full width of the Kinect. This resulted in a hit rate of ~50%."

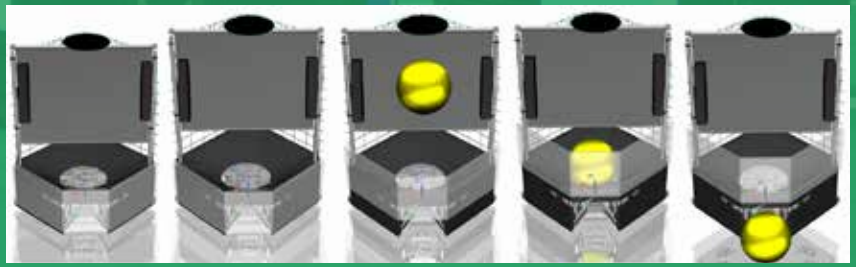
Koen



Catching balls

"During my project I worked on a design for a goalkeeper that could catch balls instead of only blocking the balls. After considering several ideas and concepts, I finally chose for a design where the ball first gets in contact with a fixated piece of cloth, which is only attached to the top and then to a net which is attached to all sides. After a few experiments it turned out that this worked quite well and with an addition of foam at the bottom, all balls from the test setup were catched. Altogether, it seems like this mechanism has potential and we could apply this to the goalkeeper, so that we will even have more ball possession in the future."

Karin

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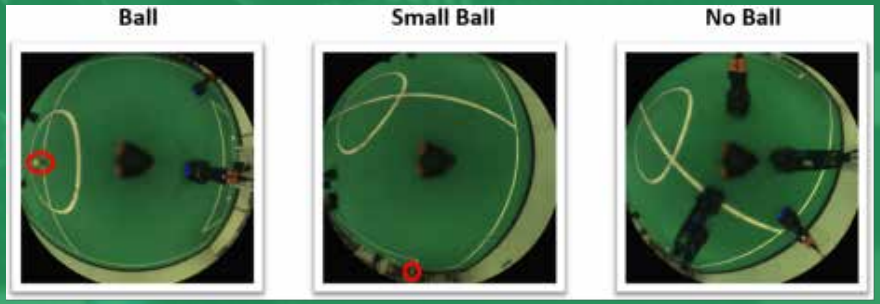
Ball recognition

"In my project I designed a neural network that learns to recognize the ball. Of course the robots were already capable to find the ball on the field, however they based this on the color of the ball. The goal is to let the robots understand what a ball looks like. For this research only pictures of yellow balls are used. The neural network got an input of images that were labeled whether there was a ball in the picture or not. No information about the location of the ball was given. The neural network has as a goal to classify the ball correctly and to locate the balls in the picture. The results can be seen in the table, from which can be concluded that the robots are capable to follow the ball. For further research, it would be interesting to see how the neural network works on different ball colors, what the influence is of the surroundings and how the network can be applied to the robots."

Dennis

Performance Neural Network	
Precision	94.1%
Recall	99.8%
Accuracy	93.9%



2021 was a year of recovery. Our team was able to return to the lab, where seeing each other for the first time in way too long was a breath of fresh air that we all needed. But conversations on catching up quickly turned to conversations about robots, as we continued development in software and started testing the software that was developed but not tested in 2020.

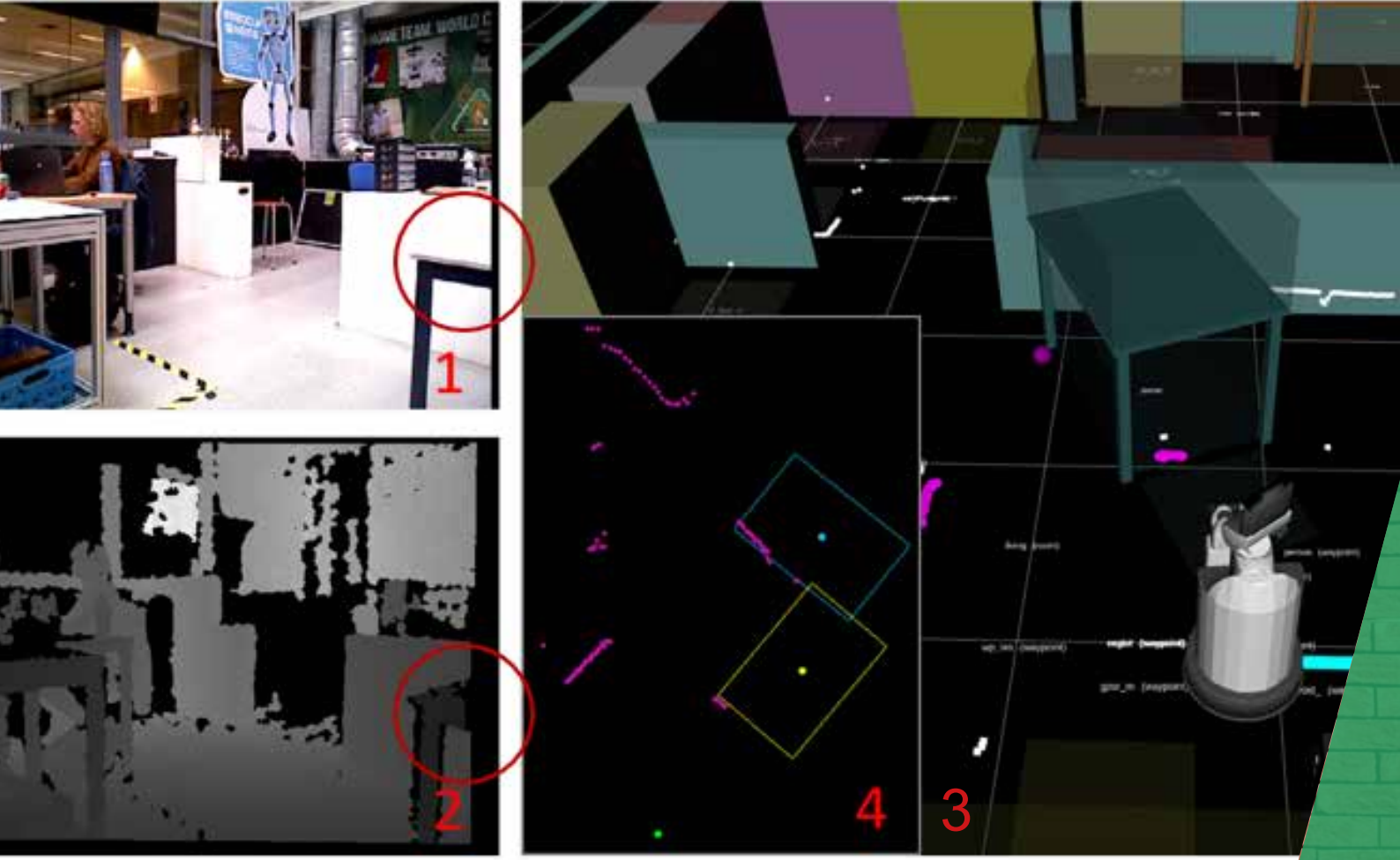
We welcomed 7 new people in our team, 2 permanent new members and 5 bachelor students, who are eager to learn all about our robot. Our new members are exploring the software and the capabilities of both themselves and the robot. Five students joined us this year for their bachelor final project. Three of whom have successfully graduated and gave HERO many new capabilities. HERO can now to estimate the position of furniture, detect when they are holding something in their gripper and carefully navigate near objects. Two students are currently hard at work to allow HERO to grasp a wide range of object shapes and to allow HERO to work with tables they have not encountered before.

Last summer the team spent a weekend in countryside of Brabant to enjoy nature and work on a fascinating topic. A household robot will often need to move furniture around and open doors to navigate to its destination, so how do we implement this knowledge so that our robot can get where it needs to go? This led to the development of a new planner and at the end of the weekend our robot opened a door and moved a coffee table to get where it needed to go. Watch HERO open a door by scanning the QR!

SCAN ME

DEVELOPMENTS @HOME

Photo: Bart van Overbeeke



(1) RGB image, (2) depth image, (3) HERO's world model,
(4) actual (yellow) and perceived (blue) position of the table

BACHELOR END PROJECTS (@HOME)

Improved furniture fitting

In short, my project was about HERO being able to percieve objects in his direct surroundings and to estimate how these objects are orientated. During the project it was found that this 'furniture fitting' goes wrong when there is an object on the edge of HERO's view area. The cause for this was in his depth camera, where the objects that are nearby were not well seen compared to the objects further away. This can be seen in Figure 4, where the yellow square shows the actual position of the table and the blue square shows where HERO thinks the table is placed. These two positions differ a lot from each other, causing the fact that HERO cannot have interaction with the table. The cause of this is found in the two red circles, where the depth camera cannot see the right part of the table. With the way the algorithm processes this depth image, HERO thinks that the wall behind the table is the most nearby object. The exact cause of this problem is not found, so a couple of hypotheses are formulated. However, a solution is added to the algorithm, that simply removes some pixels at the left and right side of the depth image. This improved the 'furniture fitting' in the same situation, but this is only a temporary solution.

Victor

Object detection in gripper

“The goal of my project was to find a smart solution for the object detection in the gripper of HERO. There is no sensor in between the two fingers of the service robot that can sense the force between these fingers, so I had to think of a creative alternative. After several measurements and experiments I came to the conclusion that the best way to detect objects, is the difference between force and torque between object or no object in the gripper. The force-torque sensor measures the forces and torque that the gripper feels. If there is an object with a minimal mass in the gripper, the moment and the force in the direction of the gravity go above a set threshold value. This is being communicated with the robot as: Object present. The force is being measured at the moment in the grasping pipeline from HERO that he should hold an object. If the value does not exceed the threshold value, it is communicated with the robot that there is no object present in the gripper.”

Jeroen

WHERE WE AS HUMANS WERE ADVISED TO NOT SHAKE ANY HANDS, HERO HAD THE OPPORTUNITY TO DO SO. DURING THE YEAR IT HAS SHAKEN HANDS WITH:

- TU/E DIRECTOR ROBERT-JAN SMITS
- EURO COMMISSIONER MARIJA GABRIEL
- SECRETARY OF STATE MONA KEIJZER
- MAYOR OF EINDHOVEN JOHN JORRITSMA
- MINISTER OF EDUCATION, CULTURE AND SCIENCE INGRID VAN ENGELSHOVEN

Photo: Bart van Overbeeke

FACTS

DURING THE ONLINE VERSION OF ROBOCUP, MSL CAME FIRST IN THE TECHNICAL CHALLENGE RECEIVING 107.66 POINTS AND SECOND IN THE SCIENTIFIC CHALLENGE WITH 300.4 POINTS (ONLY 2.6 POINTS BEHIND THE FIRST PLACE)!

@HOME MADE AN ANIMATION VIDEO OF HERO WITH HONOURED MEMBER HENK VAN ROOY AS LEAD ACTOR.

DURING THE MSL DEVELOPMENT WEEK THE TEAM ATE TOGETHER EVERY EVENING AND TO EXPERIENCE THE FEELING OF BEING ABROAD, A DIFFERENT TYPE OF CUISINE WAS ORDERED EVERY DAY.

JORRIT OLTHUIS JOINS WOUTER HOUTMAN THIS YEAR AS A MEMBER OF THE ROBOCUP TECHNICAL COMMITTEE.

IN TOTAL WE HAD 14 STUDENT PROJECTS: 1 MSC AND 13 BEP PROJECTS

01/10/2021
New TU/e Employees

09/11/2021
LIBRE visit

02/09/2021
Master Kick-Off

17/10/2021
Pitch at DDW

25/08/2021
TU/e Intro week

21/05/2021
Sint Jozef Basisschool Nootdorp

DEMONSTRATIONS & SCHOOL TOUR

In 2021 it was still difficult to give demonstrations due to the ongoing COVID-19 pandemic. Despite this, we were still able to give nine demonstrations, showed our soccer robots to the new Bachelor students during the bachelor introduction week, held a workshop for new Master students and gave a pitch at the Dutch Design Week. The demonstrations given in the second half of the year were given at our new location. Due to the TU/e renovating Gemini, the building where we were housed, we had to relocate to another building on the campus, Impuls. Until Gemini has been fully renovated this will be the new home of Tech United.

HERO IN FRONT OF MAYOR

HERO was able to shine in front of the mayor of Eindhoven at Strijp-T!

KINGSDAY

A part of the Kingsday 2021 website was dedicated to the studenteams of the TU/e, and thus to us. Watch the video we made here!

SPECIALS

PODCAST TANGIBLE COMPUTING

One of our team members gave a podcast about the value of student competitions, which elaborates on why we participate in the RoboCup tournaments. Listen to the podcast by scanning this QR-code!

DUTCH DESIGN WEEK

This year we could be visited in the Green House at the TU/e campus during the Dutch Design Week. One of our soccer robots, and our previous service robot AMIGO were representing our team. In addition, we gave a presentation during the Pitch Parade.

MEET OUR SERVICEROBOT HERO!

A video was made that explains what obstacles service robots need to concur and how our robot HERO handles daily life obstacles by making use of its sensational awareness. Watch the interesting animation by scanning the QR code.

ZORGROBOT HELPT BIJ HUISHOUDELIJKE TAKEN

MENSEN HELPEN BIJ EENVOUDIGE DAGELIJKSE TAKEN DIE ZE ZELF NIET MEER KUNNEN UITVOEREN.

WAAROM ZOU JE ROBOTS LEREN VOETBALLEN?

EEN INTERVIEW MET TEAMLEIDERS AINSE KOKKELMANS EN PETER VAN DOOREN.

TOCH NOG EEN BEETJE WINST VOOR NEDERLAND OP VOETBALVLAK

TECH UNITED MAAKTE ZONDAG VOOR DE ZOVEELSTE KEER HAAR REPUTATIE ALS INTERNATIONAAL TOPTEAM WAAR.

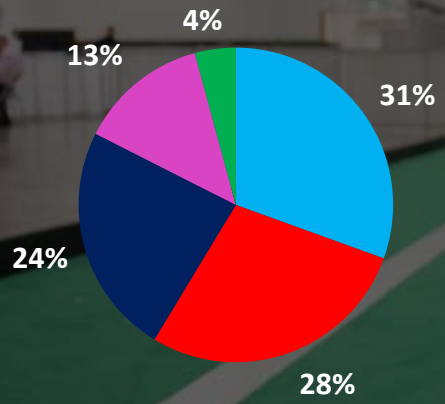
ROBOCUP 2021 IS DIFFERENT IN FORMAT, BUT TECH UNITED CAN STILL SHOWCASE ITSELF

THE SOCCER ROBOTS ARE CHALLENGED TO THINK CREATIVELY, TO PLAY TOGETHER AND TO ANTICIPATE QUICKLY ON WHAT THE OPPONENT IS DOING.

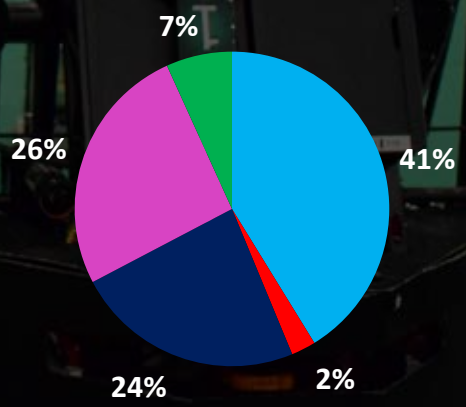
MORE THAN 6.500 FOLLOWERS AND 120.000+ PEOPLE REACHED ON SOCIAL MEDIA IN 2021!

MEDIA

FOLLOWERS (6.5K)



PEOPLE REACHED (120K)



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


TECH
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