ANNUAL REPORT 2024


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UNIVERSITY OF
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PREFACE

2024 was a succesful year for both our team and our robots.
We dedicated ourselves to tournament preparations, innovative developments, and engaging demonstrations.
We're thrilled to share that our soccer robots once again claimed victory at the world championship, held in Eindhoven, Netherlands, this summer. Not only did they deliver an exceptional performance, securing their eighth world championship title, but we're also incredibly proud of the progress made towards our quadrupedal robot: the Cheetah, achieving great advancements this year!
Additionally, HERO, our care robot, received some good updates and improvements, enhancing its existing features to reach new levels of performance and functionality.
Our team also welcomed several new members, including students working on their final projects, interns, and full-time contributors. The diverse expertise and enthusiasm they bring have enriched our team spirit!
As you continue reading, we invite you to discover the exciting innovations and milestones that shaped our year.

World Championship, Eindhoven, The Netherlands: 1st place 2024

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

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

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

2020

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

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

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

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

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

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

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

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

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

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

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

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

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

World Championship, Bremen, Germany 2006

Roboludens Dutch Open, Eindhoven, the Netherlands 2005

2024 **World Championship, Eindhoven, The Netherlands: 5th place**

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

TECH UNITED EINDHOVEN

Swerve drive TURTLE

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

Omni-drive TURTLE

Omnivision Camera	0.3 Megapixel
Zed 2	2,1 Megapixel
Shot speed	12 m/s
Battery Energy Capacity	180 Wh
Motors	3
Power per Motor	150 W
Total driving power	200 W
Max Acceleration	1.7 m/s^2
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 play 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.

TECH UNITED EINDHOVEN

« 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

ROBOCUP 2024

This year, RoboCup took place in our very own city, Eindhoven. The @Home team aimed for their third world championship, while the Tech United MSL team successfully defended their title.

MSL

The Tech United MSL team competed against six teams this year. Alongside Eindhoven's other teams—Falcons powered by ASML and Robotsports powered by VDL—the competition included two familiar names, Robot Club Toulon and Portugal's LAR@MSL, as well as two other teams: the Japanese Hibikino-Musashi and the Chinese Big HeroX. The final match was against Big HeroX, and after an exhilarating game, Tech United won with a 6-1 victory, securing their eighth world title. In addition to the main competition, Tech United participated in the Technical and Scientific Challenges, earning 1st and 2nd place respectively. The Technical Challenge showcased a new set-point generator, improving route planning by factoring in moving opponents. In the Scientific Challenge, the team demonstrated their dribbling mini-cheetah robot. With their eighth title, Tech United has once again demonstrated their strength and commitment to teamwork and continuous improvement in robotics!

@Home

The DSPL @Home league featured nine teams this year. Despite having a small team of only four members, Tech United @Home started strong in the first stage, tackling challenges like "Carry My Luggage" and "Receptionist," and advanced in 3rd place. The second stage proved more challenging, and the team finished in 5th place—just missing the finals but achieving an impressive result nonetheless!

Watch one of the matches here!


RoboCup
Middle Size League

FRIENDLY MATCHES | DE LOCHT

Friendly matches this year have been both exciting and essential for testing software and hardware in realistic scenarios rather than simulations. Highlights include implementing Setpoint Generation (SPG), led by Aneesh, which improved motion control significantly, and developing strategies against tactics like Oppball ASML.

We also introduced the Sweeper Keeper role for dynamic play and tested faster, more agile designs like swerve drive turtles.

DEVELOPMENT @HOME

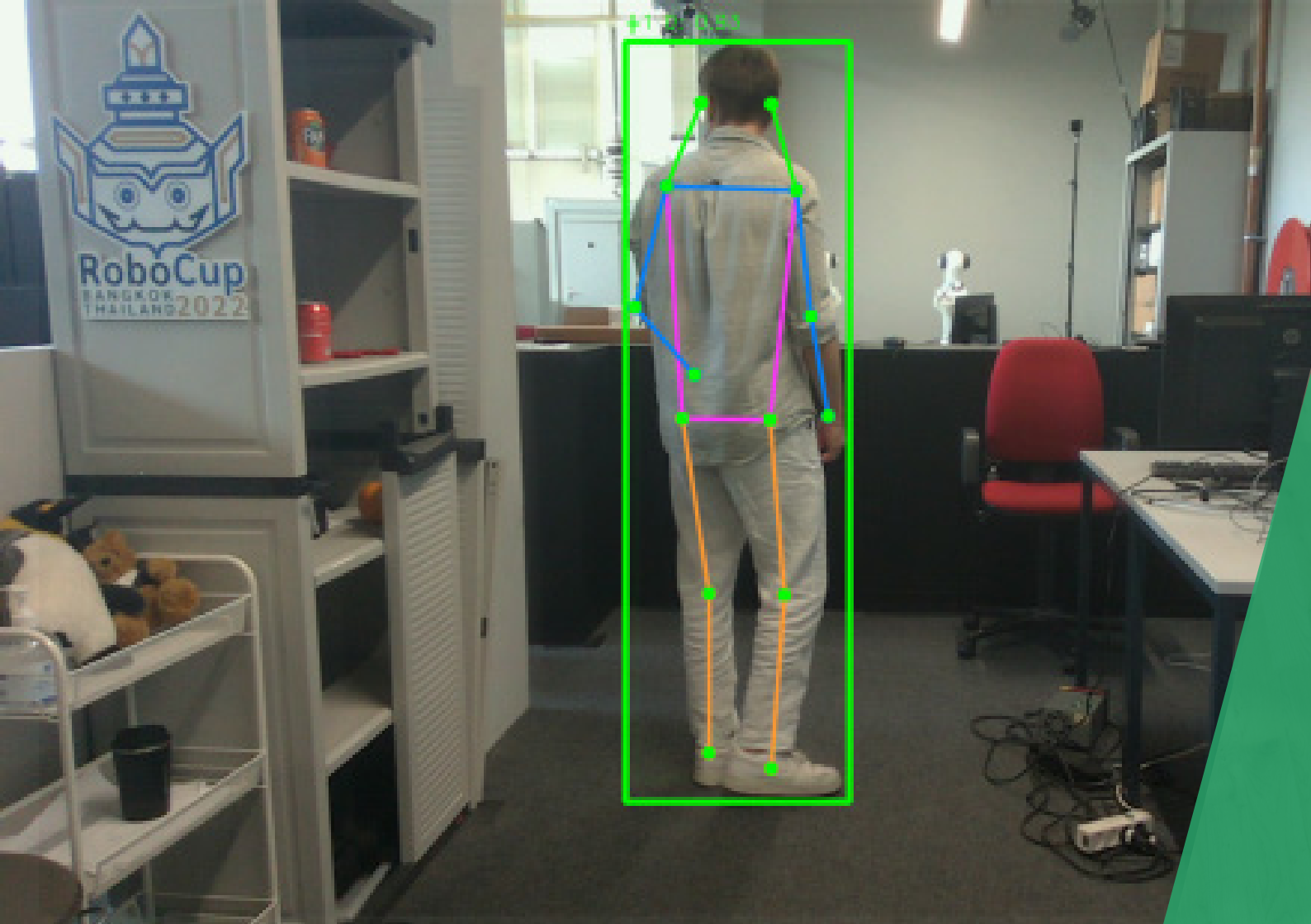
At the start of this year, one of our primary objectives was to enhance the robot's perception capabilities. This included improving its ability to detect individuals, recognize and remember faces, classify and detect objects, and perform object segmentation, among other tasks critical to perception.

Updates were made to some of our core components, such as object pose estimation and face detection. Additionally, foundational work was made to facilitate further upgrades to other perception-related tasks in the upcoming year. Beyond these updates, we introduced new perception capabilities, such as enabling the robot to organize objects based on similarity—a feature that was successfully demonstrated in the "Storing Groceries" challenge during the Robocup tournament.

Our progress was showcased during the Eindhoven Robocup, where the robot exhibited significant improvements in perception. These advancements brought it closer to achieving the long-term goal of providing practical assistance in household scenarios.

The experience at Robocup provided valuable insights and underscored areas requiring further development. With the addition of our new team members and a focused effort to modernize perception tasks, we are confident in our ability be competitive in next year's competition.


JUMBO


RoboCup
BANGKOK THAILAND 2022

PROJECTS @HOME

Development of a grasp strategy for a robot to pick up cutlery

Lucette Alewijns

This project focuses on improving the ability of the HSR Hero robot from Tech United to detect and manipulate cutlery with high accuracy. The goal is for the robot to identify, locate, and grasp cutlery placed on a surface. Three different grasping methods were tested: a top grasp at the center of the object, a top grasp at the outer end, and a side grasp at the handle. The side grasp method proved to be the most effective, providing a firm and consistent hold on the cutlery, and was adaptable to different shapes.

The robot uses an RGB camera for object detection, with a pre-trained YOLOv8 model to identify and segment objects. The robot's arm plans a trajectory to reach the object's center and adjusts for the object's orientation. The robot's gripper is aligned, and once contact is made, the robot closes the gripper and checks if the grasp is successful. If the grasp fails, the robot returns to the detection stage.

The strategy showed a 90% success rate in experiments. It is also adaptable to other objects with similar shapes and can be used for tasks beyond just transportation. Future improvements include better direction computation and faster, more accurate actions through visual feedback and sensory inputs.

An Adaptive People Tracking Approach for Service Robots

Miguel Cólera Borrás

This project aims to improve the ability of domestic robots to track a user in crowded environments, even when the user is temporarily obscured. It proposes a two-stage tracking solution that combines sensory information for more accurate operator identification. The first stage uses position-based tracking, while the second stage applies feature-based tracking, which includes color processing and height measurement.

In this approach, the robot first detects a person's position, then processes the color distribution of their image and extracts height data using pose estimation. The position of each detected person is compared with the predicted position of the operator. If a match is found, that person is identified as the operator. If not, the robot compares the color and height features with previously stored data of the known operator. If these features match sufficiently, the person is identified as the operator.

The two-stage method, tested using an RGB-D camera in various real-life scenarios, proved effective in tracking the operator in real-time within a multi-person environment, even when temporary occlusions occurred. The integration of adaptive feature selection ensures that the robot can maintain a robust and accurate tracking system.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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 2024.

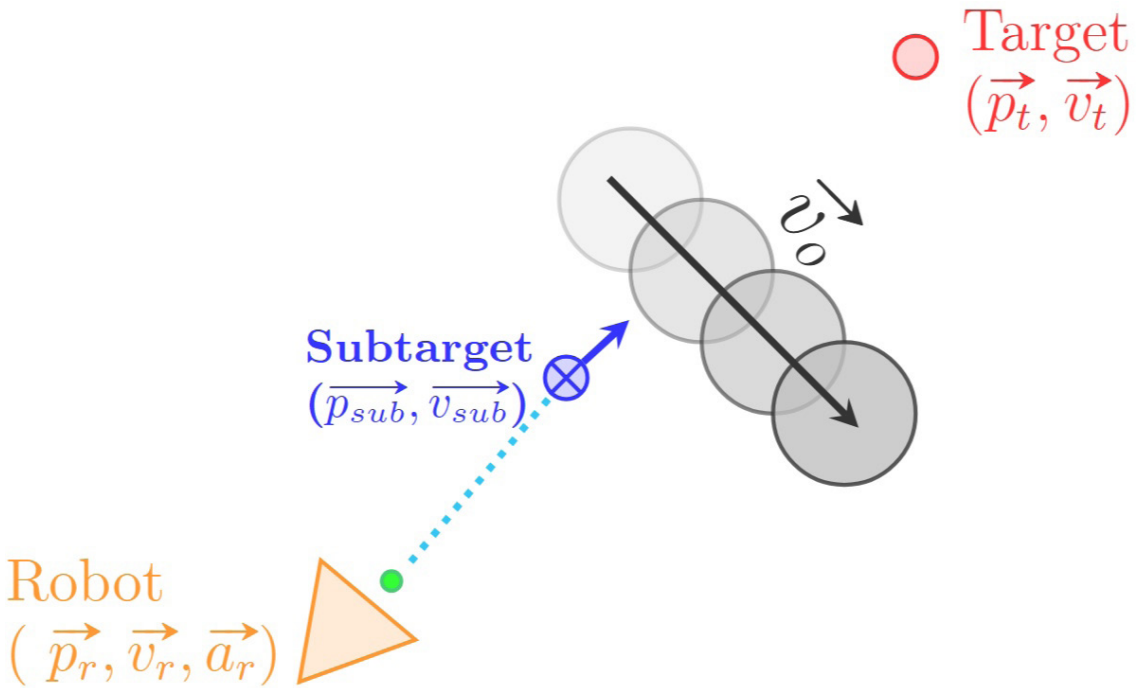
Overhaul of the trajectory planner | Aneesh, Dennis, Wouter A., Sander

In a dynamic environment, such as a soccer match, the optimal path can vary a lot based on the current positions of obstacles. We have therefore developed a new method of finding an optimal path between two locations. This setpoint generator (SPG) creates more stable trajectories in a much shorter time.

Currently, our robots use a trajectory planner that calculates the optimal path from point A to point B. Whenever an obstacle interrupts this path, the trajectory planner recalculates all possible paths to find the new optimal route to the target. This process is time-consuming and inefficient, as the robot has to slow down and accelerate every time the optimal path is readjusted.

With the new SPG, this problem is solved by integrating the subtarget planning with the trajectory planning and taking the robot constraints into account. The concept of the subtarget is as follows: if the direct path to the desired destination is blocked by an obstacle, another pre-target (so called subtarget) is calculated which is always collision free that the robot will move towards, before heading to the final target.

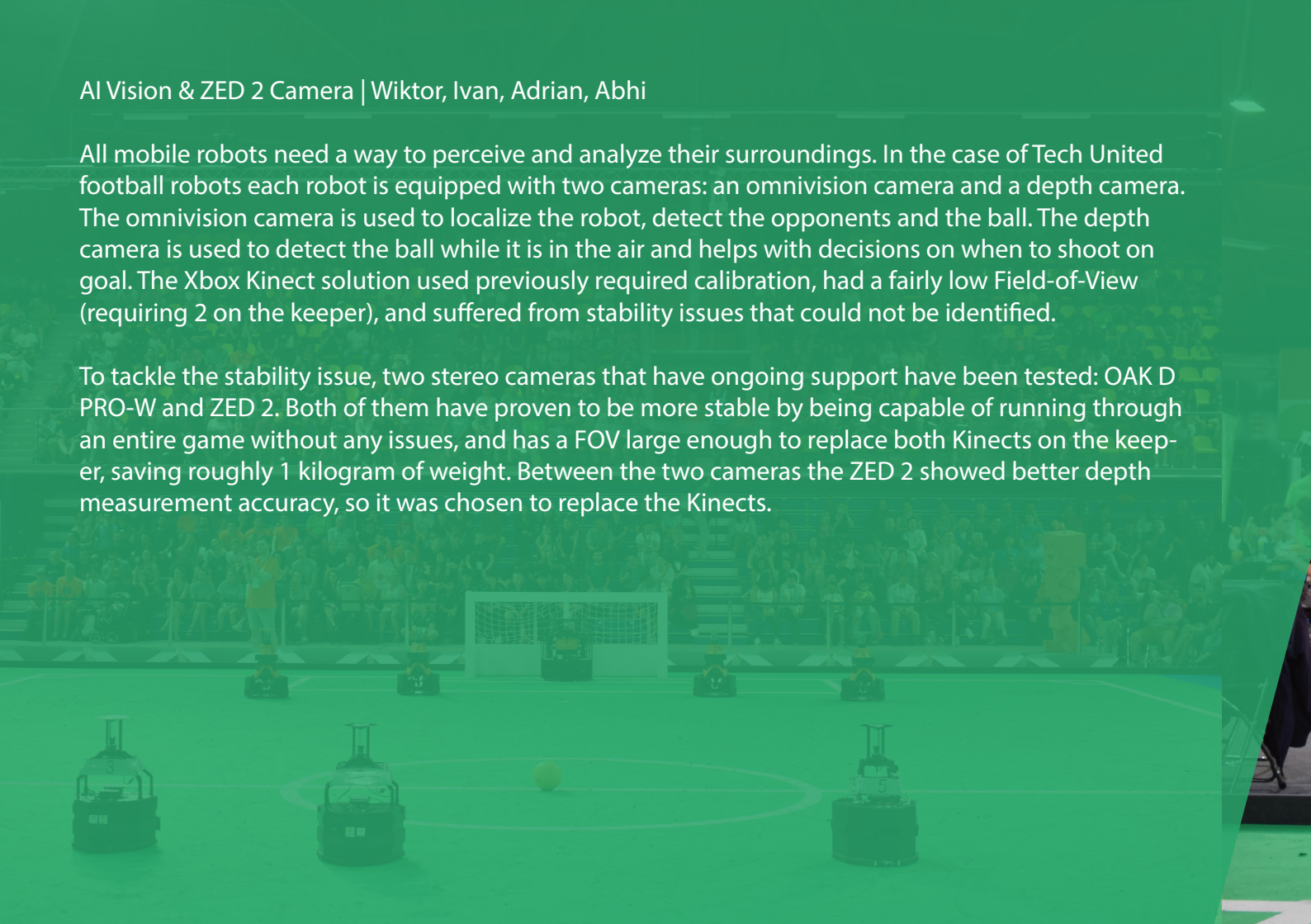
An example of a scenario where a moving obstacle is blocking the direct path from the robot to the target. The large green dot in front of the robot is the current motion setpoint and the smaller blue dotted line represents the predicted setpoints.


Target
$(\overrightarrow{p_t}, \overrightarrow{v_t})$
$\overrightarrow{v_o}$
Subtarget
$(\overrightarrow{p_{sub}}, \overrightarrow{v_{sub}})$
Robot
$(\overrightarrow{p_r}, \overrightarrow{v_r}, \overrightarrow{a_r})$

AI Vision & ZED 2 Camera | Wiktor, Ivan, Adrian, Abhi

All mobile robots need a way to perceive and analyze their surroundings. In the case of Tech United football robots each robot is equipped with two cameras: an omnivision camera and a depth camera. The omnivision camera is used to localize the robot, detect the opponents and the ball. The depth camera is used to detect the ball while it is in the air and helps with decisions on when to shoot on goal. The Xbox Kinect solution used previously required calibration, had a fairly low Field-of-View (requiring 2 on the keeper), and suffered from stability issues that could not be identified.

To tackle the stability issue, two stereo cameras that have ongoing support have been tested: OAK D PRO-W and ZED 2. Both of them have proven to be more stable by being capable of running through an entire game without any issues, and has a FOV large enough to replace both Kinects on the keeper, saving roughly 1 kilogram of weight. Between the two cameras the ZED 2 showed better depth measurement accuracy, so it was chosen to replace the Kinects.




RoboCup
RESCUE
RoboCup
INDUSTRIAL
RoboCup
SOCCER
RoboCup
RoboCup
SCIENCE FESTIVAL
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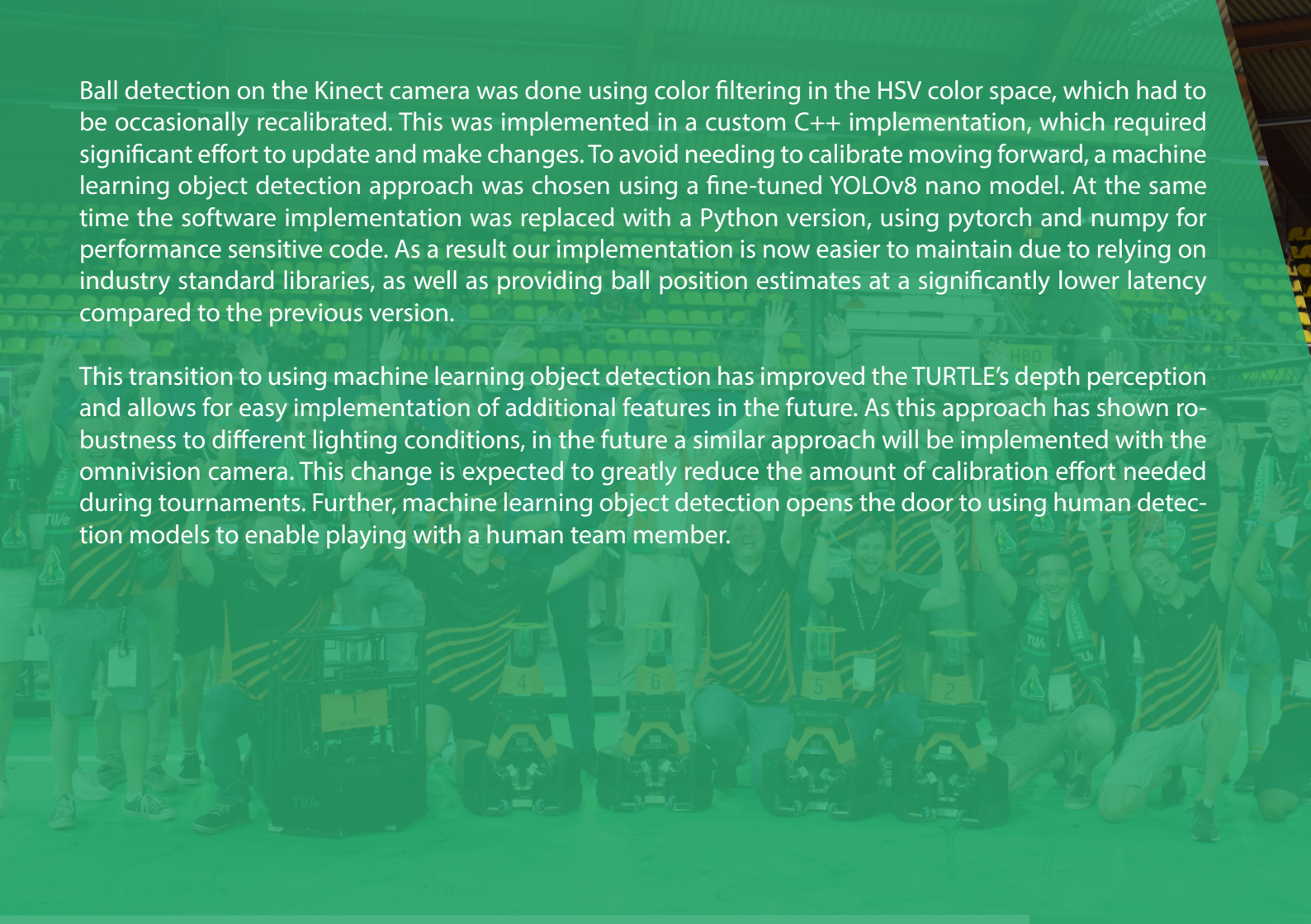
VAN SLEUTELEN

Ball detection on the Kinect camera was done using color filtering in the HSV color space, which had to be occasionally recalibrated. This was implemented in a custom C++ implementation, which required significant effort to update and make changes. To avoid needing to calibrate moving forward, a machine learning object detection approach was chosen using a fine-tuned YOLOv8 nano model. At the same time the software implementation was replaced with a Python version, using pytorch and numpy for performance sensitive code. As a result our implementation is now easier to maintain due to relying on industry standard libraries, as well as providing ball position estimates at a significantly lower latency compared to the previous version.

This transition to using machine learning object detection has improved the TURTLE's depth perception and allows for easy implementation of additional features in the future. As this approach has shown robustness to different lighting conditions, in the future a similar approach will be implemented with the omnivision camera. This change is expected to greatly reduce the amount of calibration effort needed during tournaments. Further, machine learning object detection opens the door to using human detection models to enable playing with a human team member.

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PROJECTS MSL

Quadruped | Danny, Luuk van Bree, Luuk Verstegen, Lars Blommers

Current MSL robots like Tech United's wheeled TURTLEs do not align with RoboCup's goal of using humanoid robots to win against humans. To bridge this gap, new research has focused on legged robots, using a quadruped, as an intermediate step toward (bipedal) humanoid soccer players. Quadrupeds provide more stability than bipeds when performing loco-manipulation skills, for example when the legs are also used to handle ball manipulation.

This research explores how imitation learning (IL) combined with reinforcement learning (RL) can enable a quadruped robot, the Mini Cheetah, to perform complex ball-handling tasks, such as dribbling and shooting. By leveraging adversarial motion priors (AMP), the study utilizes limited motion capture data from a German Shepherd to build foundational locomotion and ball manipulation skills, essential for the Mini Cheetah's soccer capabilities.

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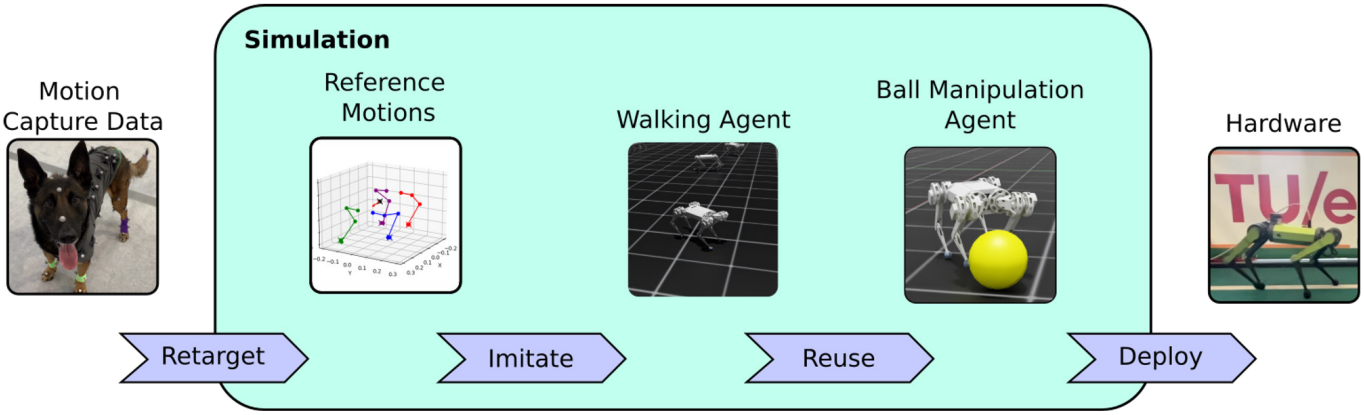
Our approach can be divided into four steps. The first step is re-targeting dog motion data to the Mini Cheetah. Then, we train the quadruped to mimic basic walking. In the third step, the agent is reused to manage ball handling. The final step is to deploy and test the model in different environments, including simulations and real-world settings.

The task formulation involves reward functions tailored to each activity: for locomotion, rewards encourage the robot to follow commanded velocities, while for dribbling and shooting, rewards emphasize control over the ball's speed and direction. Specifically, the rewards for dribbling include precise ball orientation and movement, whereas the rewards for shooting prioritize speed and accuracy in directed shots. The project demonstrates that combining IL and RL through AMP is effective for enabling a quadruped robot to perform soccer-related tasks, establishing locomotion as a foundation for more complex manipulation skills. CL allowed safe exploration of new movements without destabilizing the policy, and domain randomization proved essential for real-world application. Future improvements should address sensor limitations, ball dynamics, and control consistency to enhance real-life performance.


Simulation
Motion Capture Data
Reference Motions
Walking Agent
Ball Manipulation Agent
Hardware
TU/e
Retarget
Imitate
Reuse
Deploy

FACTS

THE MSL TEAM BECAME WORLD CHAMPIONS FOR THE 3RD YEAR IN A ROW, MAKING IT OUR 8TH WORLD TITLE IN THIS DIVISION. @HOME CAME OVERALL 5TH IN THEIR COMPETITION!

DURING ROBOCUP 2024, THE TURTLES SCORED A TOTAL OF 71 TIMES OUT OF 101 ATTEMPTS AT GOAL, RESULTING IN A CONVERSION RATE OF 70%. THIS IS AN INCREASE OF 8% COMPARED TO LAST YEAR! THE CUMULATIVE DISTANCE TRAVELLED BY THE TURTLES DURING THE TOURNAMENT WAS 35.1 KM.

SPOT WAS A REAL EYE CATCHER THIS YEAR! THE ROBOT ATTENDED MANY EVENTS WITH THE FOLLOWING HIGHLIGHTS: NERDLAND FESTIVAL, NEXTM, AN APPEARANCE IN DE MOL BELGIUM AND A CAMPAIGN WITH FILMORE.

IN 2024 WE FACILITATED AND GUIDED 4 GRADUATION PROJECTS, 7 BEPS (BACHELOR END PROJECTS), 1 INTERNSHIP AND A GROUP OF ENGD STUDENTS. THIS RESULTS IN A TOTAL OF 300 ECTS.

DEMONSTRATIONS

This year, we had the opportunity to present 40 demonstrations featuring our football robots and SPOT at various events focused on the future of technology. Through these demonstrations, we inspired and engaged audiences of all ages and backgrounds. With this, we encouraged people to watch our world champions live in action at the Robocup 2024 in Eindhoven, an extra advantage of playing a home game!

De Zonnebloem | Liempde
12/11/2024

OBS Ter Bosch | Eerderwolde
25-26/04/2024

Rocksolid | Cuijk
20-21/09/2024

Nerdland Festival | Wachtebeke
25/05/2024

Open day Differ | Eindhoven
05/10/2024

Kennisknetters | Utrecht
26/05/2024

TIKI TAKA TOUZANI

OUR SOCCER ROBOTS SHOWED THEIR SKILLS TO THE PSV FOOTBAL PLAYER SAIBARI AND THE HOST TOUZANI.

DE MOL BELGIUM

SPOT MADE AN APPEARANCE IN THE FINAL EPISODE OF DE MOL BELGIUM. HE GUARDED AN ABANDONED CASTLE KEEPING PARTICIPANTS OUT.

TECHUNITED ON TELEVISION

MOMENTUM TU/E
TOGETHER WITH THE RECTOR MAGNIFICUS OF THE UNIVERSITY, SPOT, NAO AND HERO REVEALED THE WINNER OF THE AUDIENCE AWARD 2024.

SERBIAN NATIONAL TV
A FILM CREW FROM SERBIA CAME TO THE UNIVERSITY TO MAKE A DOCUMENTARY ABOUT AI AND HOW WE USE IT IN THE SOCCER ROBOTS.

NOS NIEUWS

"EINDHOVENS TEAM VOOR ACHTSTE KEER WERELDKAMPIOEN ROBOTVOETBAL"

DE VOLKSKRANT

"NA PASS VAN 'WIELEMA' MAAKT 'ROBODINHO' NEDERLAND ZONDAG WERELDKAMPIOEN"

CURSOR

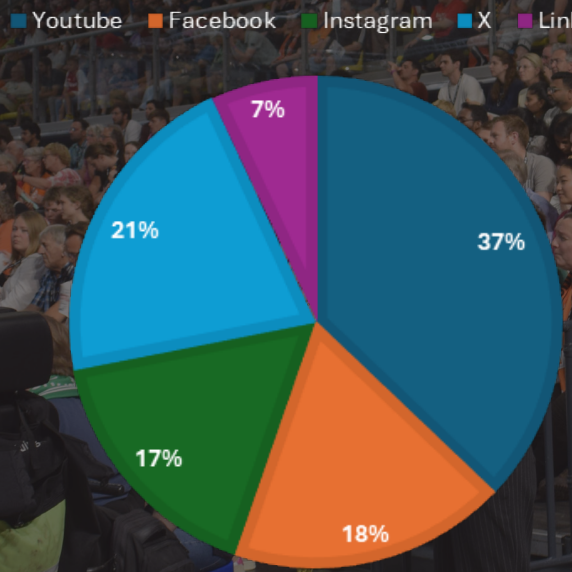
"TECH UNITED WANTS TO WIN ROBOCUP MSL WITH NEW WHEEL SYSTEM"

RECAP ROBOCUP 2024

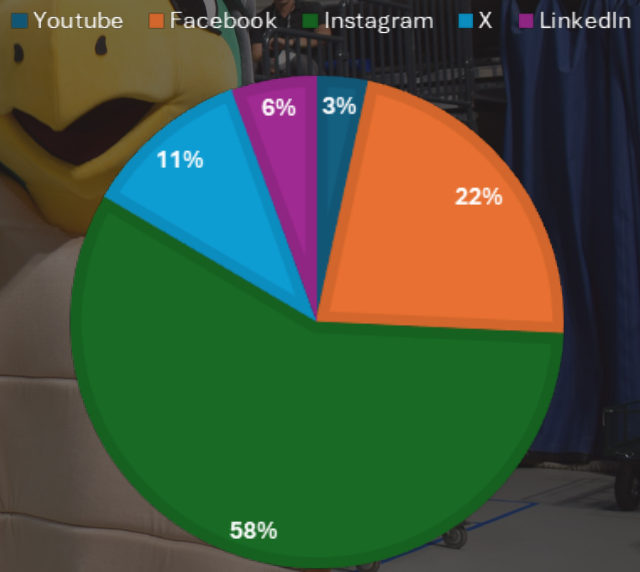
MORE THAN 9.000 LOYAL FOLLOWERS AND 100.000+ PEOPLE REACHED ON SOCIAL MEDIA IN 2024!

SOCIAL MEDIA

FOLLOWERS



INTERACTIONS



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

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BECKHOFF

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SANDERS MACHINEBOUW BV

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WÜRTH ELEKTRONIK MORE THAN YOU EXPECT


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