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### Team Qualification Document for RoboCup 2022 Bangkok, Thailand

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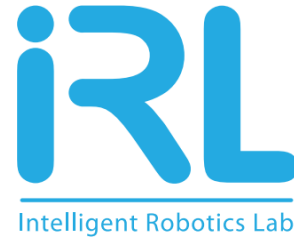
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TEAM QUALIFICATION DOCUMENT FOR ROBOCUP 2022  
BANGKOK, THAILAND

# DUTCH NAO TEAM

<http://www.dutchnaoteam.nl>



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Wike Duivenvoorden, Hidde Lekanne gezegd Deprez, Thomas Wiggers, Jakob Kaizer, Rogier van der Weerd, Pim Heeman and Arnoud Visser  
February 14, 2022

## 1 Team Information

This is the qualification document for the Dutch Nao Team with Wike Duivenvoorden as its team leader. The team consists of four master students, six bachelor students, one alumnus and one staff member from the University of Amsterdam, The Netherlands. In the last twelve years the team has bought 25 NAO robots, although not all of them are operational anymore. The team currently has six NAO V6 robots. The qualification video is available on our YouTube channel<sup>1</sup>. A research report [1] describing the technical details of the team's work for RoboCup 2021, has previously been published on our website<sup>2</sup>.

## 2 Code Usage

From April 2017 onward, the team has been using its own framework. The decision to start a new framework was made to provide the team with a codebase it fully understands and is documented in a way that is understandable for all members of the team, new and old. By creating its own framework, the team has gotten a better understanding of all components required to go from sensor values to high level actions. Ultimately, every team member should be able to largely understand its inner workings and feel comfortable with it. Our new framework is based on messages sent between modules, where each module represents one algorithm handling a task in the football playing robot.

<sup>1</sup> <https://youtu.be/SsINcoBisJg>

<sup>2</sup> [https://www.dutchnaoteam.nl/wp-content/uploads/2022/01/dnt\\_techreport.2021.pdf](https://www.dutchnaoteam.nl/wp-content/uploads/2022/01/dnt_techreport.2021.pdf)

Each message shared between modules contains a representation. The system uses a message naming convention comparable to the ROS messaging system, which makes it easy to use for developers that have some experience with ROS.

So far, the team has noticed that despite the obvious drawbacks of having to recreate basic functionality, the educational value of our new framework has increased the motivation of (newer) team members and has had a positive impact on the overall productivity.

A stripped version of the walking engine of BHuman<sup>3</sup> based on rUNSWift's walking engine<sup>4</sup> has been integrated into the framework because of its proven stability and the large impact of walking on overall performance.

BHuman's CABSL<sup>5</sup> is used in our framework as behaviour engine because of its simplicity and clear design paradigm.

### 3 Past History

The predecessor of the Dutch Nao Team was the Dutch Aibo Team [2]. The Dutch Nao Team debuted in the Standard Platform League (SPL) competition at the German Open 2010 [3]. Since their founding, the Dutch Nao Team has been qualified for the world cup competitions in Istanbul [4], Mexico City [5], Eindhoven [6], João Pessoa [7], Leipzig [8], Nagoya [9], Montreal [10], Sydney [11] and Worldwide [12]

Besides the major RoboCup events, we have attended multiple GermanOpens, IranOpens, the Humanoid Soccer School 2013, the Mediterranean Open 2011, the Colombia Robotics week, TechFest 2015<sup>6</sup>, the European Open 2016, Rodeo 2019 and every Robotic Hamburg Open Workshop between 2016 and 2021. At the Benelux Conference on Artificial Intelligence 2016 the team received the award for best demonstration [13], at the Iran Open 2017 the team received the Award in the Open Challenge with a presentation on our behaviour engine.

The results from 2018 onward in major RoboCup competitions are presented in Table 1a. In Montreal, we ended second in our first round robin pool and fourth in our second round robin pool, and in Sydney we were able to score twice in-game and promoted to the champions cup second round robin by beating Camellia Dragons in a penalty shootout. Table 1b shows the scores for the open competitions.

Although not visible in the scores, the field play has improved a lot, resulting in games with a lot of ball possession. Yet, without localisation scoring is difficult. The Dutch Nao Team will come well prepared to the competition in Bangkok: in December 2021 the Dutch Nao Team attended the RoHOW<sup>7</sup>.

### 4 Impact

During the participation in the RoboCup, the Dutch Nao Team has provided its support or resources in a number of bachelor & master theses [14,15,16,17,18] and projects that lead to publications on

<sup>3</sup> <https://github.com/bhuman/BHumanCodeRelease/tree/coderelease2017>

<sup>4</sup> <https://github.com/UNSWComputing/rUNSWift-2016-release>

<sup>5</sup> <https://github.com/bhuman/CABSL>

<sup>6</sup> TechFest is Asia's largest science and technology fair with more than 165,000 people attending: <http://techfest.org>

<sup>7</sup> See <https://rohow.de/2021/en/teams.html>

Year	Round	Opponent	Score
2018	Round Robin	Aztlan	0:0
		Naova	0:0
	Second round	NTU RoboPAL	0:2
		Naova	0:2
			<b>Year Competition Opponent Score</b>
2019	Round Robin	Starkit	2:0
		RoboEireann	0:0
		NomadZ	0:2
	Champions cup play-in round	Camellia Dragons	0:0[1:0]
	Second round	TJArk	0:6
		Nao Devils	0:9
Champions play-in	UT Austin Villa	0:7	
2021	1 vs 1	B-Human	0:16,5
		SPQR	1:0
	1 vs 1 play-in's	UT-Austin Villa	0:2

(a) Game scores for RoboCup 2018, 2019 and 2021.

(b) Game scores for open competitions since 2018.

Table 1: Game scores for the Dutch Nao Team in different competitions.

a large variety of topics [19,20]. At the Maastricht University, a PhD thesis is finished [21] based on e.g. a paper on learning a more stable gait [22], compared to the energy efficient gait from earlier work [23]. Additionally side projects were done regarding ball-detection [24,25]. The Dutch Nao Team extended the application of the Nao robot to the @Home league of the RoboCup: the Nao robot was used to help in a kitchen environment by finding a tomato and grabbing it from a table [26,19]. Finally, the Dutch Nao Team has made the penalty shootout situation into a standalone demonstration [13] which it premiered at the Benelux Conference on Artificial Intelligence 2016<sup>8</sup> and won the first prize for best demonstration.

Earlier the Dutch Nao Team has published papers in the International Conference on Advanced Robotics [27], the Performance Metrics for Intelligent Systems Workshop [28], the RoboCup IranOpen Symposium [29], the RoboCup Symposium [30] and the international conferences as International Conference on Autonomous Robot Systems and Competitions [26]. The Dutch Nao Team also proposed and supervised RoboCup related projects as part of a compulsory course in the Artificial Intelligence bachelor at the University of Amsterdam.

Over the last two years covid has hit hard on the productivity of the team. Nevertheless progress was made and there was work done on improving load balancing between threads and supporting different operating systems to allow an easier introduction into the team. More importantly, we worked on refining our localisation, rewriting the behaviour engine, enhancing our framework for desynchronized updates and end-to-end object detection.

<sup>8</sup> <http://bnaic2016.cs.vu.nl>

## 4.1 Field line detection

The existing field line detection algorithm, developed in 2019, suffers from a high false-positive rate. This is problematic since detected lines play a key role in the particle filter that is used for localisation. An analysis of the false-positive instances showed this was particularly prevalent on robots in the image. Indeed, white tones on the robot tend to be very similar to those of field lines in recorded images and are likely to yield many Canny edge detections that trigger positive line detections.

Visual inspection showed that in the vast majority of cases, false positive line detections were for lines with a vertical orientation and/or with a low projected length. Hence, a simple solution was implemented that filters detected lines that are near-vertical or below a certain threshold length. Filtering out vertical lines will also affect true-positives. This may occur when the robot looks straight down a field line. However, these instances are rare and localisation can temporarily rely on odometry alone in these cases.

## 4.2 Perception

**Object Detection** Our participation in the 2021 RoboCup SPL Obstacle Avoidance challenge<sup>9</sup> required the development and implementation of robust real-time object detection (primarily ball and other robots on the field) and the capability to navigate through a field of obstacles, while walking with a ball. In order to achieve object avoidance capability, a number of new functionalities were developed and integrated into our existing framework.

First, in order to avoid objects, they will need to be detected with high confidence and projected on a representation of the environment. The current DNT framework contains a Haar feature based cascaded classifier for ball detections[31][32]. The Haar detector is fast (30 FPS), but inaccurate. It suffers from a high false positive rate and low recall, so this needed to be improved.

Secondly, Ball and Robot models are required, calculated by applying Kalman filters on (potentially noisy) detection signals, in order to make best estimate predictions of object locations with respect to the robot.

Thirdly, a Navigation module is required to plan a feasible and optimal path to a target position. From that point on, the existing behaviour engine can be used to define a behaviour that consists of walking with the ball to the first waypoint in the queue.

**Tiny YOLO** After a review[25], Tiny Yolo-v3[33] was selected as a suitable high performing detection algorithm. It is preferred over optimised algorithms for specific classes given the ability to include additional classes in the future that can be relevant for our framework such as goal posts, penalty markers, different robot stances, etc. Although more recent versions of Yolo are available[34,35,33,36], Yolo-v3 has many well established implementation frameworks and portability options and it contains all critical improvements needed for our purposes. A clear performance improvement is observable when the Yolo detector is used. Yolo's ball detection precision is nearly perfect and recall improves from 19% (Haar classifier) to 70% (mixed detection). Recall on robot detection is 76%. Overall F1 scores improve from 0.3 (Haar classifier) to 0.8 and above when using the Yolo detector. Visual inspection of the result indeed confirms many false positive detection errors by the Haar classifier in regions of the robot (see [25] for details). Many ball detections are missed

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<sup>9</sup> <https://spl.robocup.org/rc2021/#oac>, <https://cdn.robocup.org/spl/wp/2021/01/SPL-Rules-2021.pdf>

by Haar, especially at higher distances. Yolo, on the other hand, is robust against motion blur and successfully detects at different distances (scales) as is expected given the 3-layer scale pyramid used in Tiny Yolo-v3/3L.

**Sweeper** When playing a match, looking for the ball is a critical aspect. The current technique of finding the ball consists of three stages. When the robot first loses track of the ball, the robot will go to the place it has last found it. If the robot has lost the ball for longer than 13 seconds it will start looking at its surroundings. To do this the robot rotates its whole body. This takes up a lot of time and is not very effective. If this too does not work, the last thing the robot does is go back to the ready position. To improve our current method of searching for the ball we needed to do more with head motions. As the robot never turns its head, only its whole body. The idea is that a robot will now “sweep” with its head moving it continuously from left to right, starting from a random angle and not turning past the shoulders. This function is a replacement of the full body turn in the second option when the robot has lost the ball for longer than 13 seconds.

### 4.3 Localisation

Last year we planned to extend the localisation module by adding re-localisation. This has been successfully implemented into our framework. We are now working on integrating newly detected field features, such as the middle circle and corners, into our localisation module. This would make it possible to achieve better re-localisation and more precise estimation of the robots position on the field.

**Localisation based on the middle circle** When the robot is totally lost on the field, it is useful to be able to completely reset the localisation when the robot stumbles along a distinctive landmark. The middle circle is such a landmark, and conveniently defined as a circle with a line through it. The combination of line and circle makes it possible to calculate the precise location of the robot when these two features are observed. This information is then used to improve localisation by adding this position as a function of  $P_{i+1} = P_i * \alpha + \hat{P}_i * (1 - \alpha)$  where alpha is the update constant between 0 and 1. This way the robot is able to re-localise without being wrongly localised after a false positive detection.

### 4.4 Framework with desynchronised updates

With the introduction of large models requiring multiple frames to compute their output, a way to retroactively place those observation in the correct context was needed. Therefore, the framework was expanded into keeping a queue of messages in memory ordered by timestamps. Modules are now able to access messages received in past to, for example, place a detected ball from 1 second ago on the proper global position.

## 5 Other

For the broader community, the Dutch Nao Team continues to provide many lectures about robotics and AI, and demonstrations of autonomous football at companies and schools throughout the year. This spreads knowledge about robotics and AI, and is a way for the Dutch Nao Team to fund the trip to the RoboCup. After RoboCup 2016 a foundation was started to allow for transparent financial communication, solely for the benefit of AI and robotics research.

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