AutoRef — Autonomous Referee System

Module 2 — MSD PDEng, TU/e (draft version)
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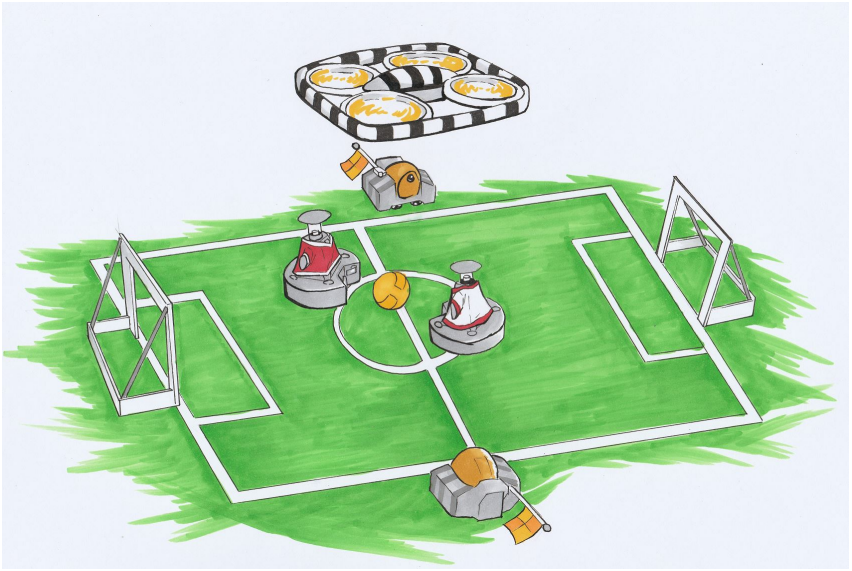

1 Introduction

Football is a long-standing cross-generational passion and represents a growing industry with a market size of several billions of euros.[1] As a result, technology is being increasingly used in football, ranging from automatic goal detection [2] and use of trackers to monitor players' performance [3] to soccer robots where the players are robots themselves [4]. In a 2014 interview [5], Franz Beckenbauer, honorary Bayern Munich president and former famous player, predicted that in the future drones will replace human referees.

A drone referee[2] may provide several advantages with respect to a human referee or a camera based system covering the entire field. First, human referees, naturally prone to human errors, are one the main sources of controversy in the game; they have their own interpretation of the rules, introducing a non-predictable factor often leading to unfair situations in a game where both financial and emotional stakes are high. An autonomous system would mitigate this, and in particular remove the unfairness factor — every game would be refereed according to the same algorithm. In turn, while a camera based autonomous systems covering virtually any possible game situation can provide a solution for professional games at major leagues and stadiums, it is rather expensive in many other contexts such as regional games; for example in the World Cup 2014, the production plan used a high-end system with 34 cameras [6]. A moving camera provided by the drone can therefore replace the need for such an expensive solution, and therefore appeal to a large market.

While the technology to *automatically* enforce the rules of the game based on video is not available, a camera system capturing important game situations can assist a remote auxiliary referee, to which it provides video and repetitions in real-time. In turn, the remote auxiliary

[1] According to [1] the European football market size in 2012/2013, 2014/2015, was 20 billion euros and 22 billion euros, respectively, and in 2016/2017 it was expected to be 24 billion euros.

[2] Drawing by Peter van Dooren, BSc students at Mechanical Engineer, Nov 2016.

referee informs the main referee of his/her decision. This has been introduced recently in several major european (e.g. in The Netherlands) and United States' leagues.

The use of an autonomous referee also makes sense in a robot soccer match, where, although the players are robots, the referee is still human. In particular, some rules are rather difficult to check and enforce by a human referee. For example, according to [9, pag. 50], when a free kick is given to one of the teams, "*all other players of the free-kick awarded team can stay anywhere on the field except in a circle with a radius of 2m around the ball until the ball is in play*" and "*all players of the defending team can stay anywhere on the field except in a circle with a radius of 3m around the ball until the ball is in play. One robot may stay anywhere inside the penaly area (except goal area) of its own team, even if the distance to the ball is shorter than 3m*". Checking if these rules are exactly met by the robots is typically hard for a human, but rather easy for an autonomous robot referee with for instance a vision system.

From a broad perspective the goal of the present project is to contribute to this vision and create an autonomous robot referee system using drones. The drone can be used to provide images to a remote referee, who decides based on images and repetitions. The remote referee can then inform the drone or another onsite referee system about decisions (which in turn are communicated to the teams). In the (perhaps distant) future, the drone will automatically and autonomously make decisions.

From 2016 through 2020 AutoRef's development was based on camera-equipped quadcopter drones in autonomously refereeing RoboCup Middle Size League (MSL) robot soccer matches. Most of the 2016–2020 projects introduced their own systems engineering and implementation approaches. This repetitive work combined with the relatively short two-month duration available to these teams prevented the entire V-model from being realized for AutoRef and therefore causing relatively poor overall project progress across different teams.

Repetitions of the project definition (i.e., the left-hand side of the V-model) are specifically evident across the 2016–2020 team documentation. Earlier MSD cohorts emphasized a fully autonomous referee, while later years scoped the project towards an assisting, supplementary system for human referees. All teams from 2016–2020 specify the requirement that the AutoRef system be based on quadcopter drones. The majority of teams each used a different type of drone model in their implementation. This discontinuity in drone hardware between teams (among other hardware differences) further contributed to the slow progress AutoRef's development.

In 2021, to prevent further repetitive efforts and slowed progress in the development of AutoRef, the MSD 2020 team was tasked with ensuring continuity in their contribution to the project. AutoRef's technical specification resumed that of an autonomous refereeing system as to fully replace human refereeing in MSL. The drone-based specification for AutoRef featured in previous team systems — that is, the requirement that AutoRef use drones — was also eliminated by MSD 2020.

As of MSD 2020, AutoRef's wiki pages [9] (including the main, system architecture, and implementation pages) describe the current state of the project as a collective of team contributions. Whereas pre-MSD 2020 team contribution pages provide standalone descriptions of their respective architecture and implemention, pages for MSD 2020 onwards only summarize their contributions, keeping the detailed documentation on AutoRef's pages. An archive was also initiated by MSD 2020 to satisfy their stakeholder requirement for an overview of all team contributions, which is downloadable with access to AutoRef's TU/e SharePoint folder [7].

2 Problem setting

The goal of this project is to deliver an autonomous refereeing system for the RoboCup Middle Size League. The MSD 2020 team has made some first steps, by archiving the work by MSD teams of previous years, as well as determining functions of the autonomous referee derived from the MSL rulebook [8] as part of the AutoRef system architecture. This functional specification is a breakdown of MSL rulebook *laws* into robot *skills* through robot *tasks*.

2.1 Goal

The final goal is to have a 5 minute long 2 against 2 robot soccer game, using the Tech United turtles, refereed by the system described above, which receives a positive recommendation by an experienced human referee. By positive recommendation we mean that the human referee acknowledges that the provided refereeing system, for that 5 minute long game, refereed the match well.

3 Input

When starting the project you will be given access to the hardware mentioned above (the drone crazy flie, ultra-sound positioning system, top camera in the soccer field, etc). Additional hardware in agreement with the coaches can be ordered if required. Besides this hardware, the following software is provided:

1. Software for simulating a robot soccer game, to control and a moving viewpoint and the motion planner "following the bubble of active play" [10]
2. Software to autonomously control the drone. [12]

4 Output (Final deliverables)

1. Translation of skills and tasks into system components.
2. Software of the proposed solutions.
3. Mid term presentation by the end of week 5 (assuming the duration of the project is 10 weeks)
4. Demo to be scheduled by the end of week 10.
5. A Wikipage documenting the project and providing a repository for the software developed [13].
6. One minute long video illustrating the work.
7. 5 minute long video with the actual game, the remote referee visualizations and the audience screen visualizations.

References

[1] Deloitte Anual Review of Football Finance, 2016. Available at `https://www2.deloitte.com/uk/en/pages/sports-business-group/articles/annual-review-of-football-finance.html`

[2] FIFA.com (April 1, 2014): "Goal-line technology set up ahead of FIFA World Cup", archived on `https://web.archive.org/web/20140511001351/http://www.fifa.com/worldcup/news/y=2014/m=4/news=goal-line-technology-set-ahead-fifa-world-cup-2311481.html`

[3] Carling, C., Bloomfield, J., Nelsen, L. and Reilly, T. (2008). The role of motion analysis in elite soccer: Contemporary performance measurement techniques and work rate data. Sports Med. 38 (10) pp. 839–862.

[4] Tech United, see `https://www.techunited.nl/nl/en`

[5] Franz Beckenbauer: "Drones will replace referees and we need to stop them" David Gilbert, December 8, 2014, https://www.ibtimes.co.uk/franz-beckenbauer-drones-will-replace-referees-we-need-stop-them-1478612

[6] Live Production TV (October 21, 2014): "The 2014 FIFA World Cup in Grazil — The Case Study". Available at https://www.live-production.tv/news/sports/2014-fifa-world-cup-brazil-case-study.html

[7] https://tuenl.sharepoint.com/sites/MCS_Drone_Referee_project_Team/_layouts/15/Doc.aspx?OR=teams&action=edit&sourcedoc={EA8BF37F-3469-4424-9010-BEADD8E96EE9}

[8] Robocup Middle Size League: "Rules and regulations". Available at https://msl.robocup.org/rules

[9] http://cstwiki.wtb.tue.nl/index.php?title=AutoRef_-_Autonomous_Referee_System

[10] Tech United wiki: Simulator https://redmine.wtb.tue.nl/projects/tech-united-msl/wiki/Simulator

[11] https://redmine.wtb.tue.nl/projects/tech-united-msl/wiki/DevPC_with_Ubuntu_1604

[12] https://www.bitcraze.io/crazyflie-2/

[13] https://gitlab.tue.nl/autoref/autoref_system