Robots as Individuals in the Humanoid League

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Abstract. Having the goal of winning against the human world champions in soccer in 2050 in mind, the Humanoid League is facing the challenges of having to increase field and robot size until the sizes of regular fields and regular players are reached in the year 2040. The next major step is foreseen for the year 2020, when minimum robot size will increase by 50%, the number of robots per team will increase and the field size will fourfold. All three aspects will have a crucial impact. For the organizers, it will become increasingly hard, if not impossible at some point, to make arrangements for up to six fields at the RoboCup venue. For the participants, sustaining a team of ever increasing robots, in size and numbers will be a similar challenge. We believe that the 2050 goal can only be achieved if a new scheme of competition of individual robots, playing with others, can be found. Then, teams could focus on a single robot. To encourage this, we propose to revise the competition scheme, moving away from participating with a team of robots to participating with a single robot, that preserves the competitive element of ranking performance of individual robots and awarding trophies. This paper is intended to spark a discussion of a rule change to encourage participation of single robots in the Humanoid League and still contribute to reaching the 2050 goal.

1 Introduction

According to the Humanoid League Proposed Roadmap [6] released in 2014, by 2020 the field size should be increased significantly and duration of the matches should be doubled, the number of players increased from 4 to 6 and the minimum robot height increased from 40 cm to 60 cm. Figure 1 shows the evolution of field and robot sizes over the coming years. The increase of the number of robots would increase the necessary investment by 50%. Furthermore, often larger robots will have to be developed and built.

The larger size and number of robots will also increase the effort to participate in events, e.g. for logistics. This will also be the case for the organizers of events,

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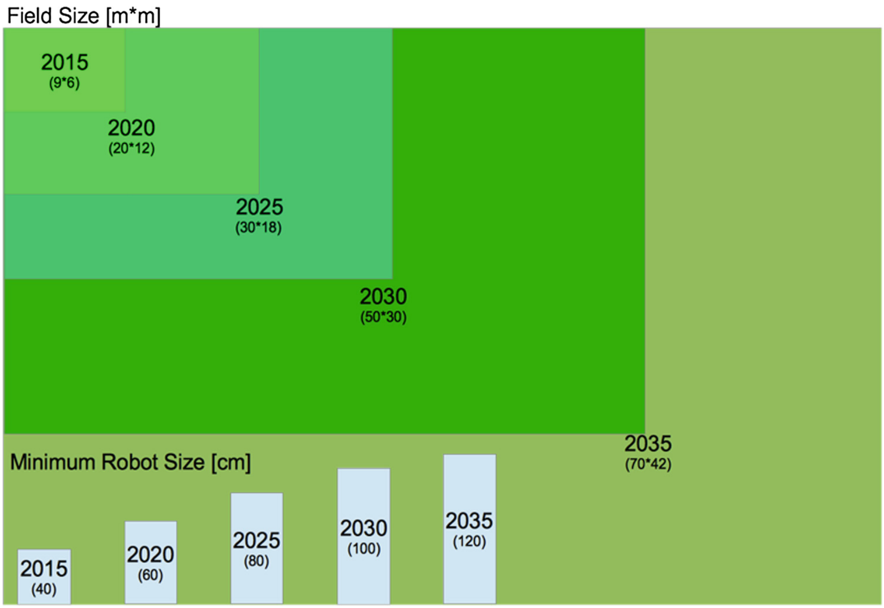

Fig. 1. HL roadmap for field and robot sizes.

which would have to fourfold the size of fields. Even though there is foreseen to be only a single class of robots, which means the division in Kid, Teen and Adult Size will be obsolete, if the number of teams still is the same, this will not reduce the number of fields required. Actively reducing the number of teams would not support reaching the goal of the 2050 game. In view of the very high challenges an increase of the number of teams would be advisable. However, with ever increasing investments and cost this may not be within reach. The league already faces stagnation of the number of teams participating in the Humanoid League. We believe that one main reason is that teams fear both the cost as well as the Hardware and Software challenges connected to larger robots.

Currently, a team is usually based in one university, so this university has to provide the whole budget and researchers working in the team. As the budget and manpower in all research institutes is limited, we believe that the key to mastering the challenges of the 2050 goal is to

(a) lower the barrier for participation, e.g. to a single robot and
(b) foster a closer cooperation and collaboration between the teams, e.g. by means of a common inter-robot communication [1].

This cooperations can be shaped very differently: Teams can jointly develop a new Hardware platform sharing costs and workload, but it is also possible that a team consists of different robots from different Universities if each University can only afford to build a very limited number of robots. In any case, a pre-requirement to building a successful joint team lays in the ability of the robots to communicate with each other. The Humanoid League does not provide a common communication protocol and attempts by teams to provide such a framework did only become accepted regional. An example for such a communication protocol the *mitecom* protocol developed by team FUmanoids [8], which is used by many teams in Europe.

In this paper we suggest a new playing scheme that allows to award individual robots based on their performance within a cooperative game as soccer. We review the state of the art of such a challenges in real sport and in other leagues of the RoboCup and based on this we sketch potential approach rule sets for the Humanoid League.

2 Performance Indicators in Human and RobotSport Disciplines

We shortly present the state of the art in human sport disciplines and in other hardware soccer leagues. In human sport disciplines we are faced with a similar challenge. Identifying the 'importance' of a player for the team play or overall is a challenging task. This task ranges from identifying the 'Most Valuable Player' of a game, over highest performers of a season to determining the 'value' of a player. Soccer coaches are faced by this challenge for a long time in order to identify suitable players for games, for specific trainings or for transfer to other teams. Typically they observe players during training and during games and rate performance in a number of categories, like 'technical ability', 'tactical awareness', 'physical fitness', and 'personal attitude'. Categories typically are further subdivided into individual aspects, e.g. dribbling, passing and heading [5]. A shortcoming of many catalogues of performance aspects is the lack of universal applicability for all players of a team. This becomes immediately obvious if strikers and goal keepers are considered and also holds for any other specialized position like midfield and defense. The individual aspects are then rated and can be aggregated to single number. However, this kind of assessment requires a considerable effort. Transferred to a competition situation, it would require to have many referees, preferably one per player, to watch and record performance with respect to the catalogue of relevant aspects.

Some human sport disciplines like Basketball count the number of activities related to offense and defense activities. Highly prominent aspects are scored points and assists, to help another player to score. These aspects are typically less subjective than those relevant for coaching. However, there still are specialized players, such that a comparison of all players of a team can not be based on indicators that are in any way related to specific aspects. A highly condensed performance indicator is the number of goals or points scored and goals suffered. Many leagues use this very objective scheme to determine the ranking of teams within leagues. Some disciplines, e.g. ice hockey, try to rank their players according to their contribution to scoring and suffering goals without necessary having to be immediately involved in it.

Another ranking scheme, observable in human sport business is auctioning players for transfer to other teams. Assuming a perfect market situation, auctions would reveal the true price of a player and thus allow a ranking of players. The underlying theory of auctions is described in numerous publications related to game theory, e.g. [4].

The Standard Platform League (SPL) [9] can be considered the closest to the Humanoid League due to the Hardware similarity. The SPL introduced a Drop-In competition in 2014. The main purpose was encouraging the development of robots which are *"good teammates and play well with a team composed of drop-in players from a variety of teams"*. All teams participating in the main tournament have to participate in the SPL Drop-In challenge. Additional teams to only compete in this challenge may be selected. This is very important as it allows teams to get started in a RoboCup competition without being able to provide a full team of robots. In the SPL Drop-In competition the same game rules as in the regular games are applied, with some exceptions like not having a coaching robot, a designated goal keeper and timeouts. The scoring is a mixture of the game score for a team and a score per robot assigned by human referees. The robots are constantly rated, based on positive and negative team play and once for the entire game based on the overall positioning and game participation. A separate award is given to the best player after a number of Drop-In games have been played.

The Middle Size league [7] has a Technical Challenge called *Cooperative Mixed-Team Play* in which teams need to demonstrate the team play of at least 90 seconds between two or more robots from different teams. The activity to demonstrate is not fixed in the rules.

3 Player-Centered Competition Approach

The core of the new approach to reduce costs for participants and organizers is a robot centered assessment, i.e. all results of a gameplay have to be broken down to and awarded to individual robots. In order to account for granularity of the scoring mechanism, a number of games with robot teams assembled from different robots for each game are required. This would result in a series of Drop-In games with possibly changing teammates for every game. The question remaining is, how many games are required and how are results allocated to individual robots.

3.1 Goal-Based Ranking

A very simplistic goal-based approach would be to have a counter for every robot to count goals scored while being member of a team with $+1$ and goals suffered with -1. A high score would thus be an indicator of a good and successful team play. The approach does not require a specific refereeing overhead and is based on objective measures. It would award a equal share of the goal to every single player, even if not immediately involved in the scoring action.

A respective statement would hold for goals suffered. The thought model would be an incapable player whilst the other one scores or prevents goals being rewarded an equal share. However, with a number of games in changing configurations of team mates, the teams with lower-performing players are expected to be less successful and thus any player insufficiently contributing will have a lower score. The number of games to reliably make the difference obvious depends on the number of team mates and the actual performance gap. Team mates could be allocated randomly or by a fixed scheme to assure as many different team configurations as possible.

3.2 Auction-Based Ranking

A very basic auctioning situation often can be observed when children assemble their teams by interchanging selection of team mates by team leaders. Team members selected first typically are considered more 'valuable' than others. Any goals scored and suffered by the team can then be weighted with the reciprocal position of selection (first selection = highest weight). This approach, however, requires the team leaders to base their choices upon objective judgement of the individual performance and is generally prone to collusions. Choices will also reflect a specific strategy of the team leader. Since the team leader needs to have an incentive for making the decision to the best of his or her abilities, he or she should be considered as the first selection. As with the previously presented approach, a number of games need to be played. In order to have equal opportunities for every participating university, every group needs to be team leader once. Therefore the number of games needs to be fixed to the number of participating groups divided by two.

3.3 Referee-Based Ranking

The SPL Drop-In Challenge can be easily adapted to the Humanoid League rules and serve as a basis for the new award scheme for individual robots. As a start, the game time should be shortened to only one 10 min half with no timeout and pushing rules applied and no dedicated goal keeper as in the SPL. Whichever defending robot reaches the goal area first is considered the current goal keeper. The illegal defense rule then applies to all robots entering afterwards. All other goal keeper specific rules do not apply during the Drop-In games, which among others means that the goal keeper does not have special protection from being touched by other players in the goal area.

The main improvement over the SPL Drop-In challenge we suggest is the introduction of a set of objective rules for judging the performance of a specific robot. We aim to have only one additional referee per team for the entire challenge to not add too much overhead for the teams to provide referees (Fig. 2). The referee for a team provides the player-specific score for all robots playing for one team. The robot specific score will be added to the average game result to determine the overall score of a robot. We acknowledge that the *referee-based ranking* might become difficult over time, when speed and intensity of game play evolves. By that time it would be desirable to have an automated referee assistant system to help judging the proposed rules.

Fig. 2. Refereeing duty during HL game.

We propose the following set of rules which shall be judged constantly during the game. For every positive game play the robot receives one point, for every negative game play one minus point.

Positive game play:

- **Successful pass of the ball to a team mate:** A pass is considered successful if the ball stops in a radius of 30 cm around a team mate or if a team mate can take the ball in move.
- **Successful receiving of a pass:** A pass is considered successfully received if a team mate passes the ball and the receiving robot touches the ball in move or within 10 s after it stopped.
- **Intercept an opponents shot:** If an opponent passes the ball and the robot either touches the ball in move or withing 10 s after it stopped and before another robot of the opponents team could touch the ball.
- **Man-marking:** A robot positions itself in between the opponent currently in possession of the ball and another opponent who is not already marked by another robot.
- **Position to receive a pass:** A robot positions itself between the opponent goal and the robot of its own team currently in possession of the ball without being marked by an opponent, or the reasonable attempted to resolve the situation of being marked by an opponent.

Negative game play:

- **Pushing team mates:** A robot touches another robot from its own team for longer than 1 s. If only one robot was actively walking towards the team mate, only this robot will receive a negative score. If both were actively walking towards each other, both will receive a negative score. A negative score is not given if the touching was caused by at least one robot falling.
- **Steeling the ball from teammates:** A robot kicks or attempt to kick the ball if it is in front of a teammate, within a range of 20 cm and the teammate focuses the ball with the camera.
- **Illegal defense:** In addition to the 30 s penalty the robot will receive a negative score for this move.
- **Illegal attack:** In addition to the 30 s penalty the robot will receive a negative score for this move.
- **Incapable player** and **Request for pickup/Request for service:** To encourage teams to build robust robots, in addition to the time penalty the robot will receive a negative score for each of the moves. This also means if a team requests a pickup and extends it to a request of service, the robot will receive -2 points for this combined move.

There is no overall game performance or positioning rated by the referees, as we believe this is already covered by the sum of the specific rules.

4 Discussion

The three approaches presented in this paper are all based on the idea of judging the play of individual robots during multiple games in different team compositions. This idea is different from regular human team sport events, where teams on the level of world championships are announced in advance and remain mostly constant throughout the tournament. The players then have the chance to practice together and develop a team game strategy beforehand, which often becomes an important factor for winning. We could potentially adapt our approaches to having fixed teams for a tournament and announcing those in advance. However, as most teams are located far away from each other, we believe that it would remain difficult for teams to train together for financial and logistical reasons and most of the training would still be performed on the tournament. In addition, developing a game strategy is still possible in our proposed approaches, as the teams compositions will be announced at least some hours in advance, which gives the teams time to adapt to the new circumstances.

All proposed approaches support specialization of team players. Teams are highly encouraged to develop different game behaviors for goal keepers, defenders and strikers as the robot's team mates might themselves have different specializations. In order to perform well in teams with all kinds of robots with different abilities, each robot must be able to switch roles accordingly.

Whichever approach for ranking is followed, having a common team communication protocol for the robots will be advantageous and thus foster its use.

It could be based on one of the existing team communication protocols shared between teams in the league. One possibility is the *mitecom* protocol from team FUmanoids, which is popular among European RoboCup teams. In the SPL, it has already been shown that teams could adapt to a common team communication protocol without causing major complications. We therefore aim to discuss the requirements for such a protocol with all teams during the next world championships and then publish a team communication protocol shortly afterwards so teams have enough time to convert their own team communication.

In general, as the teams can focus on one or two robots in terms of hardware maintenance and the joint teams will highly encourage teams to share software and ideas with others, we believe that all of our proposed approaches would lead to an increase in the overall game performance within the league.

5 Conclusions

Drop-In games address the issue of ever increasing effort and cost for contributing to the RoboCup Humanoid league. Teams can participate with a single robot only and thus the entry barrier will be lowered for new universities.

Since there are many questions yet to solve, e.g. the number of games that need to be played for a robust ranking result, Drop-In games should be introduced as a technical challenge for a start. With the gained experience, the Humanoid League may gradually adopt the Drop-In approach as a general scheme to address the challenges of the 2050 soccer game between humans and robots as a research community and still preserve the competitive element.

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