3D2Real: Simulation League Finals in Real Robots

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Abstract. We present a road map for a joint project of the simulation league and the humanoid league that we call 3D2Real. This project is concerned with the integration of these two leagues which is becoming increasingly important as the research fields are converging. Currently, a lot of work is duplicated across the leagues, collaboration is sparse, and knowhow is not transfered effectively. This binds resources to solve the same problems over and over again. To address this, we discuss the current situation of both leagues with respect to these points and focus on open issues that have to be fixed. In addition, we describe existing open standards and contributions from the RoboCup community that we plan to use for the project. As a milestone, we propose to conduct the finals of the 3D simulation tournament on real robots by the year 2008. Finally, we propose a database of simulated parts and algorithms in which each league can benefit and contribute with their expertise. These contributions facilitate synergies to be used across individual leagues for the benefit of the RoboCup project and the year 2050 goal.

1 Introduction

Looking at the stated goal of RoboCup to present a team of humanoid robots able to win against the human soccer champion in 2050 [1, 2] it is apparent that the different leagues we see in RoboCup today will have to move closer to one another and eventually be merged. There are certain unique features in every league that make it attractive as an environment for researchers to focus on a set of specific problems on the way to the final goal. In the end, however, it will be humanoid robots taking on the challenge in 2050.

To ensure steady progress, the competitions held at RoboCup are made more complex and challenging every year. Through this evolutionary process, we already start to see some boundaries getting blurred across the leagues. The Small Size League, for instance, is expanding the field size and is coming closer to the

Middle Size League. In the humanoid league, we saw the first real games in 2005. More players will be introduced, giving rise to the need of tactics in addition to the low-level control methods which have been the traditional focus of this league. The simulation league, on the other hand, in which researchers had concentrated on those high-level strategies is starting to use more realistic models for their agents, targeting simulation of 11 vs. 11 humanoid robots within the next few years.

One problem is that a lot of work is being repeated in the different leagues while solutions for the same (or at least similar) issues exist in another league. Nearly every team uses more or less advanced simulators for their robots as part of their development tools, for instance. Designing and implementing a good robot simulator is a difficult and time consuming task, so it makes sense to reuse the existing work. It is obvious that the knowhow of the different leagues has to be integrated in order to achieve synergy effects and free resources for other challenging tasks.

First steps in direction of a league-independent soccer theory were outlined in [3]. Some documented examples of collaborations between researchers from different leagues can be found. In [4], the authors describe the revision of a software framework for behavior development for a humanoid robot according to a design which had been successfully used in simulation league before. At the same time, it was planned to integrate a model of the humanoid robot into the simulation league 3D simulator.

Keeping the pace towards the ultimate goal, both hardware and software complexity tend to grow fast. This tendency makes it difficult for the current structural division of the leagues to keep developing their independent architectures in an isolated way. Particularly, problems like this can already be observed both in humanoid and simulation league teams. Development ends up covering technical issues not directly related to the interests of a particular league.

This paper is focused on the aforementioned problems. It is very clear for the authors of this work that in the long term there would be gradually fewer platforms of very high complexity. This makes apparent that the current league-oriented division of architectures would not be a feasible endeavor for current teams. We provide a well-grounded road-map and suggest tools for helping the gradual long-term shift from the current league-based division of architectures into a new cooperative and modular labor division. It is our hope that efforts in this sense will help the coordination of the work of different leagues, complementing and completing each other towards the 2050 challenge.

2 Current State of the Leagues

The humanoid league (HL) underwent a profound development since it was introduced in the RoboCup of 2002 in Fukuoka. The rules maturated in many points and gained focus on the issues that are essential from a technical point of view. Thus, the center of mass of all robots has to be on a certain height in relation to the size of the feet. The competitions and challenges have changed in various ways. In the RoboCup 2005 regular 2-2 games have been conducted for the first time. Like in other leagues, the organizers see a maturation process also in the design of the robots. The typical robot of the current competition is a small robot that uses servo motors as actuators and a simple but robust control structure. One aim of the technical committee is to lead the development towards important research problems. Dynamic walking and stability are currently the most important issues, which are enforced by the technical challenge and the rules about the shape of the robot. As a consequence, we see a significant progress within this relatively new league. The HL also grew in the number of participants. Between 2002 and 2004 around 10 teams participated in the HL. In 2005, there were around 20 participants already. For the RoboCup 2006 we received 23 pre-registration for the KidSize League and the 12 pre-registrations for the TeenSize League.

One of the first leagues of RoboCup was the two-dimensional soccer simulation league. The actual hardware of the simulated robots, the actuators and also the perception are simulated on a relatively high level as opposed to the robots in the current hardware leagues. The motivation for the high level of abstraction was the desire to create a league where participants can concentrate mainly on coordination and cooperation of robot teams. The rationale was that in the (quite far) future, many "lower level" problems of the hardware leagues would be solved, leaving cooperation among agents in a team as main challenge. In fact, two-dimensional soccer simulation league helped to address many different open problems of creating cooperative multiagent systems.

Because of the simplified model of 2D simulation league, a three-dimensional physical simulation was created. The three-dimensional physical simulator used in Soccer Simulation League addresses additional classes of problems:

– Articulated agents create the problem of coordinating several actions of the same agent among each other, as well as with global team behavior.
– Decision making procedures have to deal with a much higher complexity of the decision space, compared to 2D Soccer Simulation League.

At least the latter of these applies already to the current 3D simulation, where agents are very much simplified. Methods to create soccer playing agents for a team have to deal with a higher complexity of the environment, and hopefully can be transferred to humanoid robotics more easily. The current development of 3D Soccer Simulation League leads to simple two-legged agents used in technical challenges already this year (see also Fig. 2).

One of the problems of making Soccer Simulation League closer to humanoid robotics is that solely researching high level coordination and cooperation becomes intractable, when lower level controllers have also to be implemented by everybody. One of the advantages of the 2D simulator however was the possibility to research cooperation in a team quite easily. In order to keep the advantages of the 2D simulator while adding new possibilities for the additional research problems listed above, two different levels of interfaces should be provided for users of a Simulation League Simulator: one high-level interface granting the possibility of researching high-level coordination only. This way, existing approaches can be

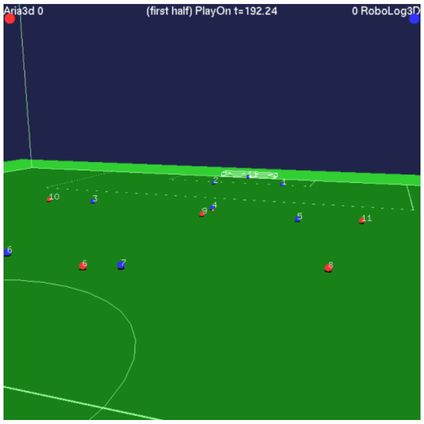

Fig. 1. The current version of the 3D simulation using spheres as agent models. Every agent has an omni-vision camera which delivers noisy data about the environment, a kick-effector to shoot the ball, and an actuator simulating omni-drive to move on the field.

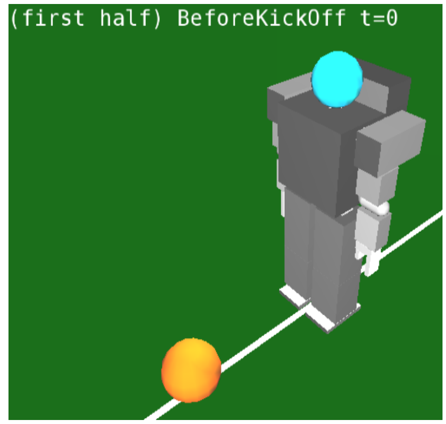

Fig. 2. An exemplary robot model of Fujitsu's HOAP-2 that could be used in the RoboCup-2007 simulation league competition.

transferred to the domain of robotic soccer easily. The lower level interface has to provide full control over all features of the simulated robots, so that developers can research and take care of dependencies between lower-level and higher level control.

Currently, the development in Soccer Simulation League leads towards humanoid robots, which already can be controlled by a lower level interface. However, controllers for these robots have to be developed in order to provide an easy-to-use interface.

As a result, humanoid and simulation league have more common qualities. This way, joint competitions of Soccer Simulation League and Humanoid League become possible, which promotes a faster progress in both leagues.

3 Road Map

In both the HL and the SL significant changes are underway. We suggest a time frame for the development of the joint events and propose for both leagues a number of synchronized steps in the following subsections.

3.1 RoboCup 2007: 3D2Real Competition: Technical challenge in Simulation League with a real robot model

We propose for 2007 an additional tournament called *3D2Real* competition in the SL. The competition consists of an obstacle run with a humanoid robot.

The layout of the competition is going to be identical to a technical challenge in the HL of the same year. It is planned to simulate a real existing humanoid robot. The type of the robot is decided within the next year by the SL technical committee in collaboration with the HL technical committee.

The SL 3D2Real competition is done in simulation first by applying the same criteria as in the corresponding HL competition. The three best participants of the simulation round qualify for a second round in which real robots are used. The programs of the virtual agents therefore have to be able to run on the real robot.

The simulation environment is going to be derived from the existing simulation environment of the SL 3D league and the RoSiML [5] modeling language. RoSiML is an XML-based modelling language successfully used for a simulator in Sony legged league.

The robot model, as well as the physical and control parameters are planned to be as close as possible to the real robot. A standardized interface for the controller commands will be provided.

The first step is intended to get an overview of the problems that arise from porting a simulated behavior into the real world. In particular we are interested in the following questions:

- What differences exist between the real world robot and the simulated environment. How similar are they?
- What kind of tools are necessary?
- How reliable are the control parameters, and what kind of noise model is appropriate to simulate real world fluctuations and randomness?

Results from the 3D2Real competition are intended to be integrated into the 3D SL simulator for the following year. It is also intended to automate the upload of a behavior program to the robot.

3.2 2008: The 3D Simulation League final is played on real robots

In this year it is intended that the 3D SL players are simulated versions of a real existing robot type. It is intended that the round robin is done in computer simulation, whereas the finals are done in real world robots. It might be appropriate, however, to reduce the number of players from 11 to five robots.

The robots and the playground are provided by the organizers of the RoboCup competition 2008.

In the HL, a description of each of the participating robots in the RoSiML language is going to become part of the qualification process. The intention is that beginning from the year 2008 the RoSiML files of all robots participating in the HL are published and integrated into a online repository that is available for research and development. More details on this repository are given in section 5.

	Simulation League	Humanoid League
until RC 2007	simlation environment simulates a real robot-type	
RC 2007	3D SL TC 2nd round in real robots	
2007-2008	Development of CPR	
RC 2008	3D finals in real robots (one type)	RoSiML models become part of the HL qualification
RC 2009	3D SL finals with several types of robots	HL team commit to CPR

Fig. 3. 3D2Real project: Overview of the roadmap towards simulation league finals in real robots.

3.3 RoboCup 2009: Games with several types of robots

Based on this repository, the organizers of the 2009 SL competition select several types of robots that can be used as models for the 2009 SL 3D competition.

4 Requirements on Humanoid Robot Systems eligible for the 3D2Real

A real existing humanoid robot type eligible for the 3D2Real competition should fulfill a set of requirements and should come with a certain software environment (see also Fig. 4). We suggest the following necessary requirements:

- The robot has to be compliant with the rules of the RoboCup humanoid league. The architecture should include a small IBM PC(386-architecture).
- The software environment should be published in source code, the programming language is C/C++, with a preference to C++. The vision processing comes with the robot.
- The robots mechanical design has to be described in the RoSiML language.
- The robot comes with a compatibility layer for ODE that consists of two parts: The first part covers the sensor processing. Generic classes for camera, touch sensors, attitude sensors, actuator states are to be provided by the SL organizers. A detailed description of these sensors and their noise levels have has to be worked in. The output of the vision processing is a list of recognized

objects, i.e. ball, posts, goals, line crossings, and their position in a list. The second part consists of compatibility layer for the actuator processing. ODE type of motors are assumed at the simulation layer. An encapsulation of the real actuators has to be provided, this may include high level motion primitives e.g. *walk*, *turn move camera*.

The aim is that a control program coming from SL participant results in the same robot behavior in the simulation as in the real robot, as far as this is possible. The organizing/technical committee chooses the first robot type for the competitions in the years 2007 and 2008 in an open and fair selection process.

5 Central Parts Repository

Traditionally, simulation league has focused on *game strategy* while the humanoid league has a major focus on *robot design and control*. Simply making more realistic simulations, or simply forcing more strategy on games of real-robots would not be effective ways of helping the future cross-development towards a common goal. This *strategy* vs.*design and control* division is not just a casual one – it is deeply rooted in the researchers of both leagues, reflecting their particular backgrounds and interests, and this should be respected. The *Central Parts Repository* (CPR) is here proposed as a common framework for allowing professionals in multidisciplinary fields to help each other within their different spheres of interest and backgrounds.

The CPR is conceptualized as a database of parts and algorithms in which each league should contribute with their expertise and at the same time enjoy out of the box solutions for the problems that are out of their sphere of interests (expertise of others). The database would cover a diversity of items ranging from single robotic parts, such as servos, to entire assembled robots, including controllers and algorithms. Special care would be needed for assuring realistic constraints, especially in regard to physical behavior of fundamental parts and their controllers.

The software architecture of the current 3D Soccer Simulator is a rather complex piece of engineering, result of years of development by experienced experts in computer-related fields. Developed with very powerful plug-in mechanism, the 3D Simulator brings great flexibility for development of independent modules in a decentralized way. Moreover, the current implementation of the 3D Soccer Simulator allows the use of a modular and convenient script language for the geometric and functional assemble of simulated entities. The strong plug-in architecture along with the support for RSG files provides already all the necessary tools for the development of a modular CPR with little interference into the current course of development.

6 Discussion

In our paper, we have argued for shared competitions between humanoid soccer league and Soccer Simulation League, and presented a joint road map for both

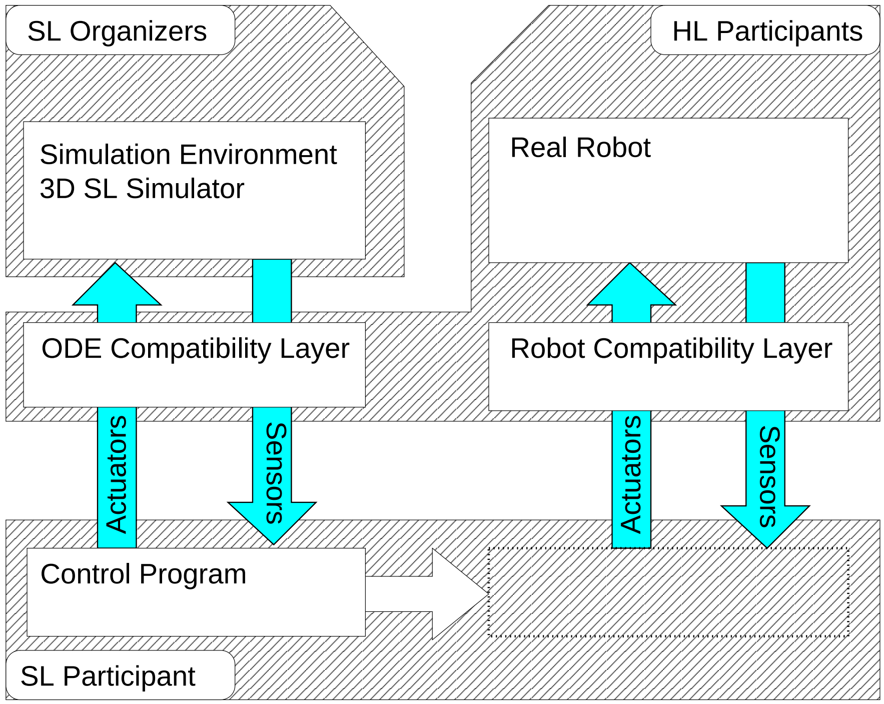

Fig. 4. 3D2Real project: Layout of the control architecture. The hatched boxes show how the different leagues contribute to the complete system architecture of the 3D2Real project. The control program for simulation system and real robot system are identical.

leagues. We suggest to establish the 3D2Real project. A part of the project is to conduct the finals of the simulation league in real robots. It is further suggested to establish a central part repository in which the parts of real existing robots are described in RoSiML. The RoboCup project can benefit in several ways from this project. In the following we outline a subset of the possible benefits:

Compare simulation and real robot The performance of a behavior program in the simulation can be compared with the performance of a behavior program in a real robot. Differences may result from unrealistic assumptions about the statistics of the sensory input.

Sensory input in real robots is very noisy, biased input. The difference between the simulated sensory input and the sensory input that comes from a real world humanoid robot system can be directly recorded and compared. In this way we can get accurate statistics and can integrate the results into the simulated sensory environment.

In this way a stepwise improvement of the 3D SL simulator is possible. In this way it is possible to establish feedback from the reality to the simulation league. In particular, it can be seen how applicable are the strategies that have been developed in the SL in real robots.

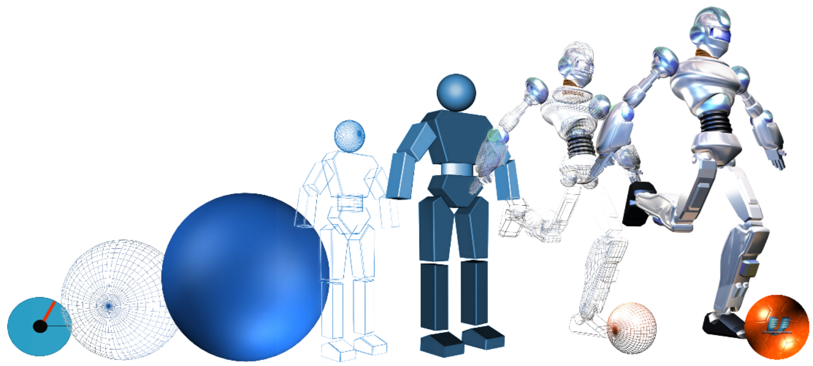

Fig. 5. Simulation league past and future: the 3D2Real project can help to program realistic robots in the SL. (Rendering by Heni Ben Amor)

Real world humanoid robots in the SL The simulation league is aiming to become a more and more realistic environment with realistic robots as players (Fig. 5). The development of humanoid robots, however is dynamic. In the HL every year different types of robots are going to appear. The 3D2Real project gives a natural link between the two leagues. It keeps the SL automatically on track with the most recent developments in humanoid robotics.

Standard simulation environment In the HL the improved 3D SL simulation environment can be standard tool to simulate their robots. Many teams participating in the RoboCup soccer competition develop at some point of their work a simulation environment in order to be able to test their behaviors. The aim of the authors is to establish the 3D SL simulator as an easy to use standard tool for the HL teams.

Central Parts Repository The proposed central repository can help in several ways to establish a fruitful interaction among the HL and between the SL and HL. It can help the HL participants to create rapidly RoSiML files describing their humanoid robot. In addition, it may be in later stages be used for SL participants to construct hypothetical, but realistic robots that might show improvements. These robots can be shown in a demonstration and give hints to the HL.

Merging of two leagues We propose an example how separate leagues can contribute to a joint project. In present day RoboCup it is a challenge to make the knowledge of one league available for the other leagues in the RoboCup project. The simulation league started around 10 years ago with the proposition to be 10 years ahead the real robots. The present work describes how the knowhow of can be made available for the current real world teams and thus, 10 years of work and development available.

Similar project in the Rescue League Finally, we would like to note that a similar project is underway in the rescue simulation league, which has recently shown remarkable progress with the introduction of their simulator

USARsim[6]. Similar as in our proposal the aim of the USARsim simulator is to give a physically correct description of the enviornment (here soccer; there a desaster area) and the robots (here biped robots; there ususally wheeled or tracked robots). Although environment and robots are different, we see on the long time scale some potential to benefit from synergies in the two simulators.

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