RoboCanes
RoboCup Standard Platform League
Team Description Paper 2013

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1 Introduction

Our team, *RoboCanes*, has entered the SPL with five new Nao H21 V4 robots in 2012. We also participate in the 3D Soccer Simulation League where we are competing since it has started. We have built our SPL software from scratch using our 3D Soccer Simulation code as a basis. In 2012, we only had a few weeks programming prior to RoboCup since the robots were delivered late. Hence, we did not make it past the first round. Nevertheless, we have made significant improvements in walking, skills, localization, and behaviors since then, and we are looking forward to participate in SPL 2013 competition with great enthusiasm.

Among our team members are Saminda Abeyruwan, Alexander Härtl, Piyali Nath, Andreas Seekircher, and Justin Stoecker, all PhD students at the Computer Science Department of the University of Miami. Saminda focuses on localization (robot, ball, opponents) and role formations and has a good experience with filter techniques and reinforcement learning techniques. Alexander is a new team member (coming from B-Human SPL) and brings in a lot of expertise in the area of real-time vision. His work is focused on the physical NAO. Piyali is a new member of the RoboCanes team and is interested in parallel/distributed learning. Andreas comes from the team B-Smart and has done studies for his MSc Thesis on the physical NAO. He is interested in motions and motion learning on both the physical and the simulated NAO. Justin's specialties are in graphics/visualization. His skills lead to the new 3D monitor *RoboViz* that is used for regional opens and the World Championships for the 3D soccer simulation league since 2011.

2 Research interests and planned activities

Our research activities are in the areas of **behavior/situation recognition, vision, prediction, and control**. Our current activities can be divided into two parts: short-term activities to be addressed before RoboCup 2013 and the mid-term activities beyond this competition.

Besides getting familiar with the physical robots and thus dealing with a lot of low-level skills that are described in section 2.1 we plan to apply plan recognition methods in order to bring valuable knowledge into the behavior decision process. These efforts are presented in section 2.2. The application of learning methods for learning low-level skills as well as higher-level behaviors is another research direction addressed by our team presented in section 2.3.

2.1 Humanoid Walking Engine and Special Actions

The development of the robot's basic skills in the *RoboCanes* agent is based on the experiences and results of the 3D Soccer Simulation League and partly from the team *B-Human* [RBF+07] (a follow-up from the *BreDoBrothers*, which was a joint team from the Universität Bremen and the Universität Dortmund [RFH+06]). This is an important step towards merging research efforts of two separate RoboCup leagues. The 3D soccer simulation league with the new server version can benefit from the experiences of the real robot humanoid league. A sufficiently realistic simulation can be used to ease certain aspects during the development of real robots by (pre-) learning some skills or testing different settings in the simulation that might be disadvantageous (and costly) for real robots.

Last year, we said that we were planning to apply automated optimization methods like genetic algorithms [Mit98,PLM08,Gol89] or reinforcement learning [Wil92,SB98] in order to identify good settings for the different actions.We implemented this plan and published a paper entitled *Motion capture and contemporary optimization algorithms for robust and stable motions on simulated biped robots* [SSAV13]. We produced four complex and inherently unstable motions and then applied three contemporary optimization algorithms (CMA-ES, xNES, PSO) to make the motions robust; we performed 900 experiments with these motions on a 3D simulated Nao robot with full physics. We showed that there is a straightforward process to achieve complex and stable motions in a short period of time. We currently study the same on one of our physical Nao's. The experiences gained from the integration, adaption, and optimization of the actions in the simulation should then flow back to the real robot team in the next step, which hopefully can be helpful to improve the performance of the real robots.

The walking engine and the movement patten generation are the primary building blocks needed for succeed in SPL. In the first step, we have used existing technologies of the *B-Human* team and integrated them into the *RoboCanes* agent. The first skill that has been implemented is the walking engine; for more information about the walking engine see [NRL07,LR06,RFH+06]. In order to use the walking engine, the dimensions and physical properties of the NAO has to be provided. Furthermore, the agent's status of the different joints must be passed to the walking engine and the resulting effector command have to be mapped to the corresponding effectors in the simulation. We have improved the RoboCanes walking engine with regard to stability using the upright vector (vector between hip joint and neck joint) as an error measure.

The *B-Human* team has developed a number of further so called “special actions” like: 'getting up', 'walking backwards', 'walking left / right', 'kicking the ball' (with the left or right leg). These special actions have also been tested on the simulated robot and adapted. Our idea is to benefit from the existing code in two different leagues. These special actions did not work out of the box. After some major parameter adaption in order to create a first version of the intended behavior, fine tuning of the parameters has to be done in a second phase. We applied automated optimization methods like genetic algorithms [Mit98,PLM08,Gol89] or reinforcement learning [Wil92,SB98] in order to identify good settings for the different actions.

2.2 Behavior/Situation Recognition

A persistent research direction of our working group addresses the recognition of intentions and plans of agents. Such high-level functions cannot be used before a coordinated control of the agent is possible. Substantial advances have been made in past few years experimenting and developing various techniques such as logic-based approaches [WV11], approaches based on probabilistic theories [Rac08], and artificial neural networks [Sta08]. The results have been partly implemented in the current code. For a big portion of last year, the 3D server settings and performance (especially for a larger number of robots) lowered the probability of a fully functional behavior recognition and prediction method for a team of agents. The latest implementation of SimSpark however has changed this situation significantly so that we can follow this research approach as a short-term goal.

Our approach to plan recognition is based on a qualitative description of dynamic scenes (cf. [WSV03,WVH05,DFL$^+$04,MVH04]). The basic idea is to map the quantitative information perceived by the agent to qualitative facts that can be used for symbolic processing. Given a symbolic representation it is possible to define possible actions with their preconditions and consequences. In previous work real soccer tactical moves as, for instance, presented in Lucchesi [Luc01], have been formalized [Bog07]. As planning algorithms themselves are costly and thus hard to use in a demanding online scenario as robotic soccer, previously generated generic plans are provided to the agent who then can select the best plan w.r.t. some performance measure out of the set of plans that can be applied to a situation. As the pre-defined plans take into account multi-agent settings it is possible to select a tactical move for a group of agents where different roles are assigned to various agents. In the 2D simulation league and the previous server of the 3D simulation league this approach has already been applied as behavior decision component in some test matches [WBE08,Bog07].

We developed a set of tools for spatio-temporal real-time analysis of dynamic scenes that can be used in the 3D Simulation League. It is designed to improve the grounding situation of autonomous agents in (simulated) physical domains. We introduced a knowledge processing pipeline ranging from relevance-driven compilation of a qualitative scene description to a knowledge-based detection of complex event and action sequences, conceived as a spatio-temporal pattern matching problem. A methodology for the formalization of motion patterns and their inner composition is defined and applied to capture human expertise about domain-specific motion situations. It is important to note that the approach is not limited to robot soccer. Instead, it can also be applied in other fields such as experimental biology and logistics processes [WV11].

Our research is partly an application of the concepts developed in the parallel project *Automatic Recognition of Plans and Intentions of Other Mobile Robots in Competitive, Dynamic Environments* (research project in the German Research Councils priority program *Cooperating Teams of Mobile Robots in Dynamic Environments*). It is necessary to identify a set of relevant strategic moves that can be either applied by the own team (if the probability for a successful move is high) or recognized from observing the behavior of the opponent team. The German Research Council (DFG) supported our research line since 2001 (ended with move to US) and invited us to submit ideas for further long-term research ideas in that area. This clearly indicates the significance of our research efforts. Currently, several research proposals have been submitted or are in preparation (e.g. NSF, NIH, and internal UM proposals).

2.3 Prediction and Control through Reinforcement Learning

Reinforcement learning is a popular method in the context of agents and learning where a reward is given to an agent in order to evaluate its performance and thus, (hopefully) learning an optimal policy for action selection [Wil92,SB98]. Reinforcement learning has been applied successfully in robotic soccer before by other teams (e.g., [MR02,RGH$^+$06,KS04]). We have integrated a framework for reinforcement learning into our agent where different variants like Q-Learning and SARSA have been used (cf. [Wat89,WD92,SB98]). We have published our current work at the Humanoid Soccer Workshops at the Humanoids 2011 and 2012 conferences on soccer playing humanoids [SSVar,ASV12] and also for the AAMAS workshop ALA [ASV13].

It is planned to apply reinforcement learning at two different levels: First of all, we want to investigate how certain skills can be optimized by reinforcement learning, e.g., in order to walk faster or to stand up in shorter time. The second level where learning should be applied is located in the behavior decision process. If it is known which strategic moves are possible the selection of the preferable move should be learned by reinforcement learning methods. The set of possible actions is determined by the applicable plans. The reward is given w.r.t. to the result of plan execution, e.g., if it failed or if it could be finished successfully. The desired result would be an automatically optimized high-level behavior based on a set of pre-defined plans. Different experiments have to show how the performance of the team can be improved in matches with identical or varying opponent teams.

The recent learning tasks that have been carried out in the RL framework is based on linear function approximation, specially the penalty goal keep behavior. The reinforcement learning framework is extended with GQ(λ) and Greedy-GQ algorithms [MSBS10,BBSE10]. These algorithms have been proven to converge with linear function approximators and it is shown superior results in prediction and control problems.

3 Past relevant work

3.1 Monitor and Debugging Tool

Justin Stoecker from our team RoboCanes has invented a new 3D soccer server monitor (RoboViz) that runs platform independent. RoboViz is a software program designed to assess and develop agent behaviors in a multi-agent system, the RoboCup 3D simulated soccer league. It is an interactive monitor that renders agent and world state information in a three-dimensional scene. In addition, RoboViz provides programmable drawing and debug functionality to agents that can communicate over a network. The tool facilitates the real-time visualization of agents running concurrently on the SimSpark simulator, and provides higher-level analysis and visualization of agent behaviors not currently possible with existing tools (figure 1).

Fig. 1. RoboViz interface with debugging information and 2D bird view

Features include *visualization and debugging* (e.g. real-time debugging; direct communication with agents; selecting shapes to be rendered), *interactivity and control* (e.g. reposition of objects; switching game-play modes), *enhanced graphics* (e.g. stereoscopic 3D graphics on systems with support for quad-buffered OpenGL; effects such as soft shadows and bloom post-processing provide a visually enticing experience), *easy use* (e.g. simple controls, automatic connection to the server, platform independency), and other features (e.g. various scene perspectives, logfile viewing, playback with different speeds). A detailed description of RoboViz has been published as a paper for the RoboCup Symposium [SVar].

RoboViz has been adopted as a monitor for the RoboCup Soccer Simulation 3D sub-league since it was announced: the source code was released in February 2011, and its first public use in competition was at the 2011 RoboCup German Open held in Magdeburg, Germany. This was followed by official use at RoboCup 2011 in Istanbul, Turkey and RoboCup 2012 in Mexico City, Mexico. The visualization feature of RoboViz has been popular with many teams in the 3D simulation sub-league. In particular, we would like to note that all four of the themes in the RoboCup 2012 semi-finals (UT Austin Villa, RoboCanes, Boldhearts, and magmaOffenburg) used RoboViz during development. We have also seen agent frameworks released that explicitly provide support for RoboViz. Outside of RoboCup, we have seen RoboViz incorporated into courses in multi-agent systems at the University of Miami and the University of Texas at Austin. RoboViz has also been used at the University of Miami as a demonstration tool to promote awareness of the RoboCup events and attract students to computer science. While the primary release of RoboViz is still focused on the Simulation 3D sub-league, a branch[1] is under development that makes the tool usable for many other environments; our team, RoboCanes, is using this for use with our NAO robots. We expect this branch to become the primary version as it is polished for use in RoboCup 2013.

3.2 Reinforcement Learning Library for Robotic Platforms

Reinforcement Learning on robotics platforms need efficient implementation of the state-of-the-art algorithms. The RLLib[2] is an implementation of incremental standard and gradient temporal-difference learning (GTDL) algorithms for robotics applications using C^{++} programing language. The implementation of this highly optimized and lightweight library is inspired by the API of RLPark, which is a library of temporal-difference learning algorithms implemented in Java. The library is tested on the Robocup 3D simulator and on the NAO V4 (cognition thread)) with different configurations.

3.3 SimSpark and ODE improvements in 3D Simulation League

Sander van Dijk (Team Boldhearts) and our team RoboCanes have developed a new SimSpark and ODE version. This work is supported by a RoboCup Federation Grant and is focussed on the following goals:

1. Improve stability: fix bugs and increase robustness of simulator.
2. Enable starting multiple instances on a single machine or over a network: make it possible to easily run multiple simulations in parallel. The result has

[1] `https://github.com/jstoecker/roboviz`
[2] `http://web.cs.miami.edu/home/saminda/rllib.html`

been at the Regional Opens in Germany and Iran in 2011 as well as used during the World Cup 2011 in Istanbul.
3. Enhance run-time control: give the possibility to alter any simulation detail at run-time, alleviating need to constantly restart the system.
4. Develop graphical utility tools: facilitate setting up a batch of experiments.

4 Achievements/Publications

We have contributed with more than 40 publications since 2000. Articles have been published in journals, as books (edited), book chapters, magazine articles, refereed conference papers and refereed workshop papers.

5 Video

Please watch the video here: `http://www.cs.miami.edu/~visser/spl-quali`

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