Virtual Werder 3D
RoboCup 2007 Team Description Paper

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Abstract This paper describes the current status of the *Virtual Werder 3D* team. The recent changes in the 3D simulation league from the spheres-based simulation to the humanoid simulation forces the teams to work on basic skills first as it is not sensible to work on elaborated behavior if the agent does not yet feature a sufficient set of basic skills. Although the agent framework from the previous year remained intact, we had to develop a completely new skill level including a walking engine to allow the agent to move on the field, and a set of special actions, such as kicks and stand-up moves. The development of this basic skills is based on experiences and results of the Bremen humanoid team *B-Human*. Further, the plan recognition and other issues are addressed as mid-term-goals of our team beyond RoboCup 2007.

1 Introduction

In the tradition of the *Virtual Werder 2D* team since the year 2000, the *Virtual Werder 3D* has participated in RoboCup competitions since 2004. The recent changes in the 3D simulation league from the spheres-based simulation to the humanoid simulation forces the teams to work on basic skills first as it does not make sense to work on elaborated behavior if the agent can not rely on a fundamental set of basic soccer skills. In this year's *Virtual Werder 3D* agent the soccer skills are developed in cooperation with the humanoid league team *B-Human* from Universität Bremen, Germany [10] (a follow-up of the *BreDo-Brothers* [11]).

The intended research activities of *Virtual Werder 3D* [6] can be divided into two parts: The short-term activities to be addressed before the RoboCup 2007 and the mid-term activities beyond this competition. Thus, the short-term goals address the development of basic skills as presented in section 3 up to 6. Previously a short look was taken on the agent architecture in section 2. The mid-term goal of our team is to apply plan recognition methods in order to bring in valuable knowledge into the behavior decision process. These efforts are presented in section 7.1. Followed by an outlook on a set of further future efforts of our team in section 7.2, which concludes the paper.

2 Architecture

The main structure of the agent framework is for the most part the same as of last years agent [6]. The main changes in the framework can be found primary in the sensorics input layer and in the layer which provides the basic skills of the agent. The structure of the *knowledge base*, which is the agent world model, also needed to be adjusted in order to handle the extended sensor input compared to the spheres-based agent. The basic skills of the agent are separated into walk motions which are provided by the *walking engine* and so called *special actions*, which model static motions over short-time periods.

3 Walking Engine

The *B-Human walking engine* [9], which serves also in our team and was originally developed for an slightly modified Kondo KHR-1 robot.

The *walking engine* transfers parameterized walk requests from the behavior layer into fast and stable walking movement for all translation directions and rotation up to a certain level. A walk request includes three values. There are two values for the translation values in forward and side direction relative to the body direction (in cm per second). The third value makes up for the walk rotation and is stated as rad per second. The different walk motions, like walking forward, backward, sideways, walking curves or turning in place, can be transfer from one to the other by changing the target walk request by the *walking engine* smoothly according to the actual walk values. The *walking engine* therefore controls the walking motion and provides a simple interface for the behavior layer.

The *walking engine* has three classes of parameters, which describes their characteristics. The behavior parameters contain the odometry correction values, the maximum walk speeds and the maximum walk speed changes. The control parameters include the control values for the pid-controllers that stabilize the walking in forward and side-ward directions. The most important values for the optimization of the gait are described in the walk step parameters. In total 16 parameters describe the shape of the four one-dimensional trajectories of the walking gait.

Of the four trajectories (see figure 1) are two that control the shape of the foot movement into the walk direction(*stepX*) and the lift of the foot during a double step period(*stepHeight*). The other two trajectories are responsible for the motion of the agents upper body. The *bodyShift* shifts the center from of mass of the upper body sidewards to allow lifting the unloaded foot of the ground. The *bodyTilt* models the movement in body direction, and is therefore useful to keep the center of mass over the center of the loaded foot to achieve a more stable gait. Additionally, the motion of the arms is also described by two parameters.

The positions of the feet relative to the center of the hip are given by this four trajectories. Inverse kinematics is applied to calculate the corresponding target joint angles of both legs. In order to use the *walking engine* within our team, mainly only the dimensions and physical properties of the simulated agent have

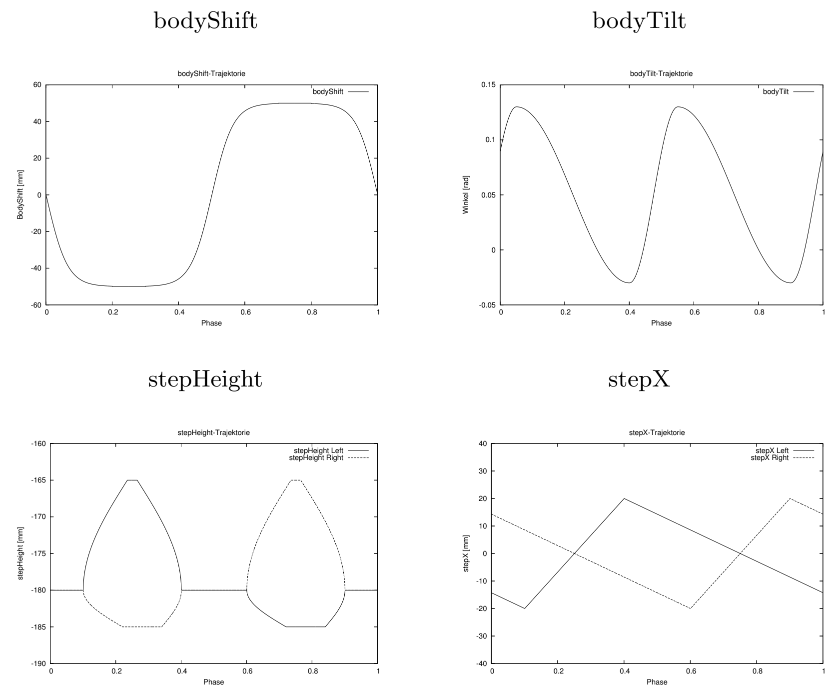

Figure 1. The walk step trajectories are in total described by 16 parameters, which are responsible for their shapes and proportions. The shown values are taken from the *B-Human walking engine*, which serves also in our team and was originally developed for an slightly modified Kondo KHR-1 robot.

to be provided. The extra hip joints are used to obtain walk turning movements while walking into any direction or even if walking in place.

On the lowest effector level, the agent framework provides a pd-controller to reach the desired target joint angles fast and accurate. The error between the actual and target joint angle and the error change from the last time stamp is used to calculate the necessary speeds for the robot motors.

4 Gait Optimization

After the successful integration of the *walking engine*, the walk parameters had to be adjust to the simulated robot. First a slow but stable walk gait was compiled by hand tuning the walk parameters. Afterwards our team again used the experience of the *B-Humam* team and selected *particle swarm optimization (PSO)*[5] [2] as a suitable tool to optimize the walk gait parameters.

In a master thesis[9] within the *B-Human* team, PSO in combination with an acceleration walk scenario [4], was used to optimize the walk gait and achieve good performance for the complete spectrum of walk speeds, from walk in place up to a maximum speed level.

So far straight forward walking is optizimized and used for the other walk directions as well. In the test scenario the agent starts to walk in place and accelerates its walk speed during short time intervals by increasing the step size up to a maximum compatible step size. A walk test terminates if one of the following terminating condition is reached:

- the time limit of 30 seconds for a test is up,
- the current body angle in comparison to starting body angle grows too large
- the agents has fallen.

The fitness value is calculated by the distance that is covered by the agent in walk direction, therefore the last distance measurement in upright position before the test ended.

The results upon the RoboCup 2007 shows that, in an automated overnight optimization process, after just 50 iterations with a swarm of 24 particles, a stable top-speed of up to 4 m/sec in straight forward walking is reachable. Surprisingly the best walk gait shows a negative value for the *double support phase* parameter, which means that it has a phase were both feet are in air simultaneously, thus the agent actually performs a *running* motion.

5 Special Actions

The cooperating *B-Human* team has developed a number of so called *special actions*, to model short-time static motion patterns. On the basis of their concept, our team uses a generic loader for arbitrary special actions, which are modeled in a way of stop motion state sequences. Each stop motion state contains a given time period in milliseconds and a set of target joint angles. During the time period the joint angles are calculated upon an interpolation between the target joint angles of the previous and the current state.

In order to have a strong link to the real humanoid league our effort is to create humanoid robot like motions, that can also be seen within real humanoid league competitions. We consider it important to let the agent move in this realistic way and therefore using only certain joint ranges which are nearly similar to humanoid movement ranges.

The modeled special actions so far are a powerful *kick forward* for the left and the right foot(see figure 2) and *stand-up motions* for standing up from the back and the front. For example the *kick forward* motion contains of only 12 stop motion states.

6 Behavior

Due to the focus of development in the area of fundamental soccer skills, our team chooses a fairly straightforward kind of behavior for this year competition.

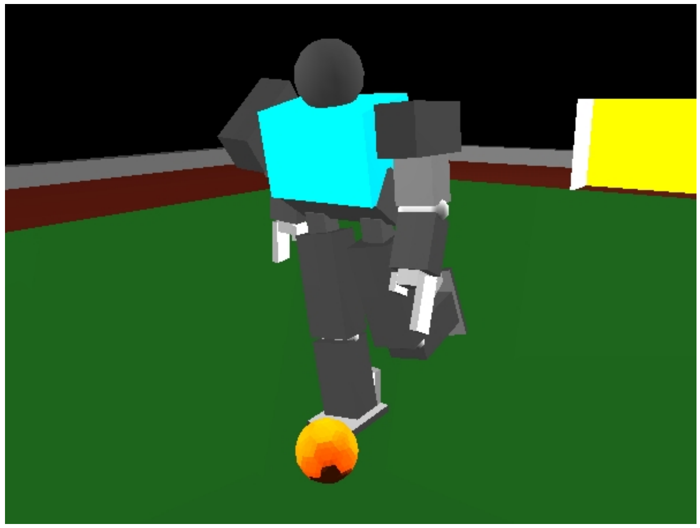

Figure 2. A snapshot of the special action *kick forward*

The distinct behaviors for individual player roles, which were used in previous competitions, where reduced to the keeper and midfielder. As the number of players will rise again in the next years to come, play roles like defender or forward can easily be reactivated. The adaptable formations were used for start-up positioning only, due to the reduced number of players. The behavior for the closest player to the ball, while the other players reposition themselves, can be described as follows, in order of achievement:

- turn towards the ball
- walk towards the ball
- walk around the ball while facing it
- align the kicking foot with the ball
- shoot towards the opponent goal

This straightforward behavior seems like the best way to develop and optimize the fundamental soccer skills, that are absolutely essential for any more complex behaviors.

In addition to this behavior, our team developed different *stand-up motions* to react even at an early stage upon situations where the agent topples. Our solution is to early start a motion which avoids the complete fall of the agent and let him get up fast, by absorbing the fall through reaching out his hands. Still, on this case there is much room for improvement to detect the current agent status and react from a wider set of *stand-up motions*.

7 Future Efforts

A persistent research direction of our working group addresses the recognition of intentions and plans of agents. Of course, such high-level functions cannot be used before a coordinated control of the agent is possible. Nevertheless, we also address this research topic as a mid-term goal. Beside this research direction our team points on a number of other interesting topics for future developments, mainly to achieve well-founded soccer skills.

7.1 Plan Recognition

Our approach to plan recognition is based on a qualitative description of dynamic scenes (cf. [14, 3, 8]). 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 [7], have been formalized [1]. 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 [13, 1].

The intended research is to apply 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*) to the new 3D server. It is necessary to identify 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) supports our research line since 2001 and invited us to submit ideas for further long-term research ideas in that area. This clearly indicates the significance of our research efforts.

7.2 Further Future Efforts

As of the first year with a totally new kind of agent the skill level will surely see large room for improvement in the years to come. The following should demonstrate the high number possible efforts and directions, that our team discusses.

In order to approach a resting ball better, we have began to develop a skill that firstly avoids objects, like other players or goal posts on the way and secondly moves in the fastest way around the ball to reach a possible shooting position. The PSO can also be used in this case, as seen in the gait optimization. The parameters of the skill, like the avoidance distance, can be optimized using PSO to achieve a fast and secure ball approach skill.

Also on the skill level the current special actions need to be improved to make them more stable and faster. Beside the improvement of existing motions more complex behaviors require the development of new motions, like goalie catch moves or ball stopping actions for the field player.

The implicit cooperation between the players can be improved by calculating the *closest* player to the ball more accurately by taking into account the time to get up in the case an agent is fallen and the time an agent needs to position himself around the ball into a suitable shoot position.

Beside the player that approaches the ball, the players which support the player with the ball have to be improved. For players that not directly approach the ball, useful positions on the field can be found to support the approaching player. This supporter role is often used by teams in the *Four-Legged League*, for example by the *German Team* [12].

Another current weakness is the kick skill. A *kicking engine* would allow kicks with different height and strength comparable with the kick skill of our sphere-like agent. This would allow the agent to play passes and cover distance up the field by not kicking directly towards the opponent goal. This would be a suitable behavior in close duel situations, where the opponent blocks the direct way to the goal and it is needful to kick the ball to keep it out of reach for the opponent.

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