Bremen Small Multi-Agent Robot Team (B-Smart) Team Description for RoboCup 2004

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Abstract. This paper describes the current state and further development of the B-Smart Small Size team since RoboCup 2003 as well as the goals of the team for the next competition. Amongst other things, it will give an overview about the new robot platform and will also introduce the techniques used for behaviour control.

1 Introduction

The B-Smart team is originated in the student project *RoboCup* at the Universität Bremen that also participates in the Sony Four-legged Robot League and the Simulation League. The overall goal is to build a robot team that can compete in RoboCup competitions. So far, B-Smart has participated in the German Open 2003 and 2004 and the RoboCup 2003. Since then, the development has gone further. At RoboCup 2003, a prototype of the new robot platform, which is capable of omni-directional motion, was already used and was improved since then. Completely new software had to be designed to fit the needs of fast omni-directional motion. This was also taken as a chance to integrate a new behaviour architecture, that is based on potential fields, to control the autonomously acting robots. This architecture was developed as a diploma thesis [1] in the affiliated faculty of the RoboCup project and has also been described in a paper which will be presented at the RoboCup Symposium 2004 [2].

2 Development of a New Robot Platform

The development of new robots was one of the main goals. The old platform had a differential drive and a rotating shooting device [3]. In the run-up to RoboCup 2003, it was already realized that this platform will not be competitive and a prototype for a more state of the art robot was designed and finished a few days before the first day of the competition. A whole set of these robots has been developed. Since the B-Smart team consists of computer science students who have only basic knowledge in mechanical engineering, the design had to be simple but effective. The chosen type of construction is very similar to the *FU-Figthers*' design of 2003 [4].

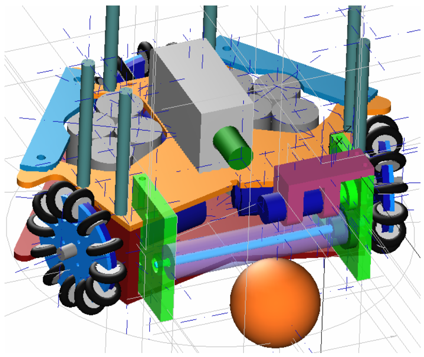

Fig. 1. 3D-CAD drawing

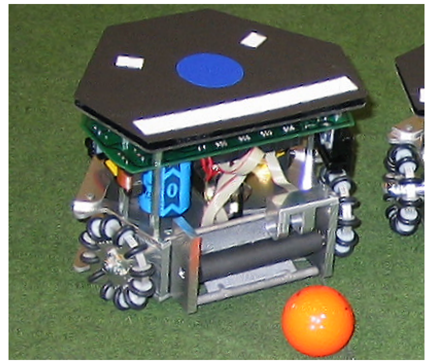

Fig. 2. Assembled B-Smart robot

2.1 Mechanical Design

There were several requirements for the new platform and it was decided to use some of the well known RoboCup teams as examples.

First of all, an omni-directional drive, which is capable of fast moving and easy control, is a necessity. Linear speed of $2.0 - 2.5$ m/sec and an accordant acceleration are common among the successful teams in RoboCup Small Size competitions. Omni-directional motion can be achieved with three or four wheels which are arranged in a triangle or a rectangle. Several variations are possible. The B-Smart robots now have three wheels in an arrangement which is optimised for straight forward motion, since the wheels are not aligned in uniform angles. Using this design, it is possible to achieve high speed in forward directions while moving sideways is a bit less precise and slower, but still reasonable in comparison to robots with a differential drive. With a wheel-diameter of ca. 54 mm, a 9.1:1 gear, an estimated motor speed of 6500 rpm and an angle of the front wheels of $150°$ a theoretical top speed of about 2.02 m/s is possible. Unlike several other teams, it was decided to build appropriate proprietary wheels, which are again similar to the FU-Fighters' approach. The advantage is a higher friction on the field. The use of Faulhaber DC-motors is a reasonable choice of most teams. They are equipped with a 9.1:1 planetary gear.

A solenoid based kicker was tested with the 2003 prototype and is also used in a modified version in the new version of the B-Smart robot. Since a kicker can only be effective when the ball is clinging to the robot, a dribbling device is also integrated to hold the ball at a defined position. But due to the new rules about dribbling, such a device is not too important anymore.

The chassis is built out of laser cut aluminium plates. They integrate pockets for the accumulator batteries and other hardware components. This design is very lightweight and easy to manufacture. See Fig. 1 and Fig. 2

2.2 Electrical Design

The electrical components are built around the 16 MHz Fujitsu MB90F594A micro-controller. A Radio-Metrix transceiver-module communicates via a one-way radio link with the PC. The micro-controller interprets and executes the commands sent by the control software on the PC. Information about the revolutions per minute of each motor is integrated with the local PID control.

3 Overall Software Architecture

The whole control software splits up in stand-alone components, which communicate over UDP network sockets. There is a component for each different task. This includes vision, building a representation of the world, agent control and radio transmission.

Due to the new field size, the usage of more than one camera is required to do appropriate observations on the field. Two Sony fire-wire cameras are used by B-Smart. They are capable of capturing 30 frames per second. The percepts from the two different points of view are combined to provide an integrative world model, which is then distributed to the agents. Because of the new lighting conditions, the markers used to track the robots were changed. They now consist of less colours. Only the team colour is either blue or yellow. The recognition of the rotation and the identification of the robots is realised via black and white patterns. In our laboratory, it is possible to track the robots at a light intensity of about 280 *lux*, which is only the standard ceiling lighting without any extra spotlights.

The software agents controlling the robots are running completely independent from each other. They all use a common description of the world (respectively the field and all the objects on it) in which they act. When an agent has made a decision e. g. based on the behaviour architecture described later, the commands are transferred to a server process which integrates all commands from all agents to send them over the radio link to the accordant robots.

4 Behaviour Control

To control the agents, a behaviour-based architecture is used that integrates existing potential field approaches concerning motion planning as well as the evaluation and selection of actions into a single architecture. This combination allows, together with the concept of competing behaviours, the specification of more complex behaviours than the usual approach which is focusing on behaviour superposition and is mostly dependent on additional external mechanisms.

4.1 General Approach

Artificial potential fields, originally developed by [5], are a quite popular approach in robot motion planning, because of their capability to act in continuous domains in real-time. By assigning repulsive force fields to obstacles and an attractive force field to the desired destination, a robot can follow a collision-free path via the computation of a motion vector from the superposed force fields. Especially in the RoboCup domain, there also exist several applications of potential functions for the purposes of situation evaluation and action selection [6–8].

The approach used by B-Smart [2] combines several existing approaches inside a behaviour-based architecture [9] by realising single competing behaviours as potential fields. Such behaviours are e. g. *Move to ball*, *Move to defence position* or *Kick to goal*. The architecture has generic interfaces allowing its application on different platforms for a variety of tasks, e. g. it has already been used by the *Bremen Byters* in the Sony Four-legged Robot League. The process of behaviour specification is realised via a generic description language based on XML.

As already mentioned, potential fields are based on the superposition of force fields. Being a quite smart technique for obstacle avoidance, this approach fails accomplishing more complex tasks including more than one possible goal position. An obvious example is the positioning of a goalkeeper: The usage of attractive force fields for its standard defence position as well as for a near ball to be cleared would lead to a partial erasement of the fields causing an unwanted behaviour. This problem could be solved using an external entity selecting the most appropriate goal, but this proceeding would affect the claim of a stand-alone architecture. Therefore, different tasks have to be split into different competing behaviours. This applies also to tasks based on action evaluation, especially since they use a different computation scheme, which will be explained in Sect. 4.3.

The approach of action selection by [10, 9] has been considered as being most suitable for this architecture. A number of independent behaviours without any fixed hierarchy as in [11] compete for execution by the respective computation of activation values representing the current appropriateness.

4.2 Motion Planning

All motion behaviours are mostly based on the standard motion planning approach by [5]. Some of the main extensions have been the integration of relative motions that allow the robot to behave in spatial relations to other objects, e. g. to organize in multi-robot formations, and the implementation of a path planner to avoid local minima. Figure 3 shows a potential field in the Small Size domain.

Assigning force fields to single objects of the environment allows the avoidance of obstacles and the approach to desired goal positions. Nevertheless, moving to more complex spatial configurations, e. g. positioning between the ball and the penalty area or lining up with several robots to build a defence line is not possible directly. Therefore, a technique, quite similar to [12], has been integrated to map complex spatial configurations to potential fields.

One inherent problem of potential fields are local minima [13]. To avoid situations in which robots get stuck because of defending or narrow positioned opponent robots, all motion behaviours are able to use a real-time path planner. Based on the current gradient of the potential field, it is possible to detect local

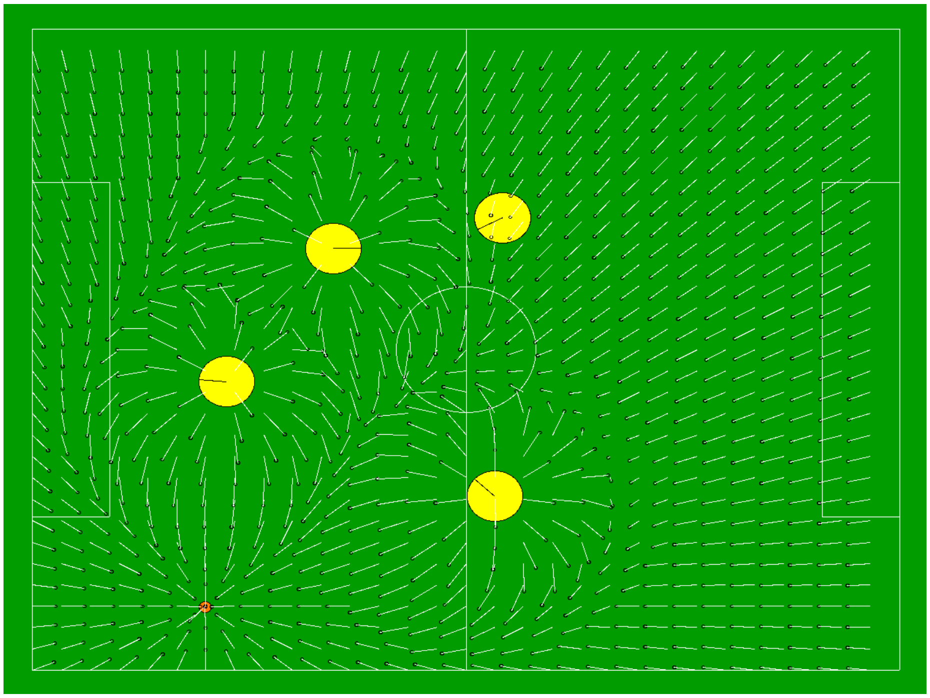

Fig. 3. A potential field for moving to the ball and avoiding the collision with other robots. This field is computed by the agent controlling the upper right robot.

minima and to use an A* algorithm [14] together with a dynamic search tree, similar to [15].

4.3 Action Evaluation

In this architecture, actions are considered to be indivisible entities which have to be executed by the robot after their selection, e. g. the activation of a kick or a predefined dribbling sequence. It is also possible that an action evaluation behaviour is combined with a motion behaviour inside the architecture, the appropriateness of which has to be determined and which has possibly to be executed.

The evaluation is based on the potential functions assigned to the objects in the environment. But instead of using a rasterisation with a large number of evaluated cells [7, 16], a variant of the *Electric Field Approach* [6] has been implemented, as it is computationally more efficient and allows a direct evaluation of positions or actions like kicks or passes to team-mates.

To use this method to evaluate a certain action changing the environment, e. g. kicking a ball to the opponent goal, this action has to be mapped to a geometric transformation describing the motion of the manipulated object. A set of different transformations, inter alia including rotation, translation, and tracing the potential field gradient, has been implemented, together with mechanisms to check for collisions and practicability of the action, external mechanisms as planners are not needed. To describe more complex actions, e. g. turning with a ball and subsequently kicking to the goal or dribbling away from an opponent, also sequences of actions may be specified.

5 Conclusion and Outlook

The new team has been tested for the first time at the RoboCup German Open 2004. Since the mechanical part of the team has performed well, we will focus on the improvement and tuning of our software until the RoboCup competition. Due to the new vision system, B-Smart will be able to handle the rule changes concerning lighting and field size. The behaviour architecture, which will also be used by the German Team in the Sony Four-legged League, allows an easy specification of a variety of fast and reactive behaviours.

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