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The First Segway Soccer Experience: Towards Peer-to-Peer Human-Robot Teams

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ABSTRACT

In this paper, we focus on human-robot interaction in a team task where we identify the need for peer-to-peer (P2P) teamwork, with no fixed hierarchy for decision making between robots and humans. Instead, all team members are equal participants and decision making is truly distributed. We have fully developed a P2P team within Segway Soccer, a research domain, built upon Robocup robot soccer, that we have introduced to explore the challenge of P2P coordination in human-robot teams with dynamic, adversarial tasks. We recently participated in the first Segway Soccer games between two competing teams at the 2005 RoboCup US Open. We believe these games are the first ever between two human-robot P2P teams. Based on the competition, we realized two different approaches to P2P teams. We present our robot-centric approach to P2P team coordination and contrast it to the human-centric approach of the opponent team.

Categories and Subject Descriptors: I.2.11Artificial IntelligenceDistributed Artificial Intelligence[coherence and coordination, multiagent systems]

General Terms: Performance, Experimentation.

Keywords: Segway soccer, human-robot teams.

1. INTRODUCTION

An ongoing challenge in multi-robot research is how to effectively coordinate heterogeneous teams. When these heterogeneous teams include humans and robots, often a human-leader hierarchy is established to effectively communicate commands and information. By contrast, our work is developing a scenario where teams of humans and robots would face adversarial environments as peers. One standardized domain in which to explore multi-robot teamwork in dynamic, adversarial tasks is Robocup robot soccer (*http://www.robocup.org*). Within this, we have developed Segway Soccer to explore balanced, flexible, and distributed approaches to human-robot coordination, as we introduce *Peer-to-Peer* (P2P) teams. P2P teamwork is encouraged by requiring both humans and robots to have identical motion capabilities by deriving from the Segway mobility platform developed by Segway LLC [5].

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Recently, the first ever Segway soccer games were held as part of the 2005 RoboCup US Open, hosted by the Georgia Institute of Technology. We believe these were the first human-robot P2P competition with two participants, namely CMBalance'05, our team from Carnegie Mellon University (CMU) and BrainWorks, from the Neurosciences Institute (NSI) [4], (see also *http://vesicle.nsi.edu/nomad/segway*). In this work, we present our robot-centric approach to P2P team coordination, contrast it to the human-centric approach of the opponent team, and present our thoughts on the challenges to P2P teamwork which became evident throughout 2005 Robocup US Open.

2. THE HUMAN-ROBOT TEAM

In this section we detail our development of a soccer playing Segway RMP, and each team's approach to coordination.

2.1 Developing a Soccer Playing Segway RMP

Our robot is entirely autonomous in action selection, and thus makes all on-field decisions independently of its human teammate. A control structure was implemented in which finite state machines, which we call skills, organize into a hierarchy. Skills process information from our world model and then generate action commands, either by execution of an action or by calling another skill as a sub-skill.

Our world model is constructed based upon vision, using a new technique for fast color-object recognition [1, 2] that is suitable for use in robot platforms like the Segway. Its key feature is that it is able to adapt its segmentation process to different lighting conditions. Since the objects we have interest in are not always visible, we use tracking to estimate their position and velocity consistently. To track the ball, we use a tactic-based multiple model approach to model the ball motion [3] and combine this with sensory information.

2.2 Team Coordination

Our approach to human-robot team coordination was dominated by an interest in the autonomy of the robot, and so our team strategy was a robot-controlled one. By contrast, NSI developed a human-dominated game strategy.

2.2.1 Our Approach: Robot-Driven

The initial human participation in our offensive strategy was dictated by robot decision making almost exclusively; the human player always responded to the decided action of the robot. The strategy developed, however, to encourage stronger coordination between teammates. Our initial

defensive strategy had the robot keeping goal. However, as the robot was unable to consistently position itself inside of the goal (see Section 4.2), its role was reallocated to instead mark the ball while the human player defended the goal.

Full realization of the extent of our robot-bias, and identification of individual player strengths, meant that our team strategies developed to encourage stronger teammate coordination. This not only better adhered to the spirit of P2P games, but also produced a more successful, more competitive team.

2.2.2 Opponent Approach: Human-Driven

By our observations, the majority of decision making on the field by the Brainworks team was performed by their human player. The robot was then informed, by voice (through a headset augmenting their human Segway), of the chosen action.

3. THE 2005 US OPEN EXPERIENCE

Five Segway soccer demonstrations were played at the 2005 US Open. Key rules [6] specific to Segway soccer include a 1.0m safety distance between all players and the requirement that both robot and human must interact with the ball prior to scoring a goal. The actual execution of multiple Segway soccer demonstrations made evident several issues with the game implementation.result of the

- Robot Movement: A marked lack of robot positioning, due jointly to reduced field size and the safety distance required between players, resulted in a reduction of passing between teammates.

- Ball Deflection: Passes occured that deflected the ball off of the robot, which appeared often unaware that the deflection was occuring. At times the deflected ball was then recaught by the human teammate.

- Acceptable Passing: A ball within the 1.0m safety distance of a receiving player, but yet untouched, is technically considered possessed and the pass valid.

- Robot Goal Scoring: Goal scoring was human-dominated, due in part to robot positioning difficulties, and so a rule which prohibited human player goal scoring was agreed upon during the US Open and added.

While we may have an intuition for whether a robot should be aware of any coordinated actions, such as ball deflections, and what constitutes an acceptable pass, to determine robot awareness or pass validity explicitly is a diffult task, which is heavily situation dependent. A challenge presented by this domain involves determining the appropriateness of platform-specific rules, such as the restriction on goal scoring being applicable only to humans. This ties in to the difficulty of platform-independent rule enforcement, in the cases where rule obedience is clearly platform-dependent. For example, the safety distance between players was largely respected by the robot players exclusively, and was in general unenforced by the human referee who, like the human players, was unable to determine this distance as quickly or accurately. Properly constructed, the game rules should enforce the P2P spirit on all of these issues.

4. FUTURE HUMAN-ROBOT GAMES AND CONCLUSIONS

Each team was unaware, until the first game, of the development angle chosen by the other team; that our strategies were opposite in player dominance was not intentional, but their contrast did exemplify many of the difficulties with the development of human-robot balance within the game. As the intent of this research domain is true human-robot coordination, where the players are equally autonomous yet also able to accomplish tasks, it seems a balance somewhere between the two approaches must be found.

In summary, we have introduced the concept of peer-to-peer (P2P) teamwork for human-robot teams, where a P2P team is one in which all teammates are equal and decisions are made in a distributed manner, and have presented the development of Segway soccer as a standardized research domain for exploring and validating P2P coordination techniques. After participating in the first Segway soccer games at the RoboCup US Open, which we believe to be the first of its kind, we identified a number of key confounds to the structure of the Segway soccer domain to further promote balanced human-robot interaction.

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