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Understandable teams of Pepper robots^{*}

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Abstract. The term *understandable robots* refers to robots making their actions and intentions understandable (or explainable) to humans. To support understandability of a team of collaborating robots we use natural language to let the robots verbalize what they do and plan to do. Our solution is based on Cooperating Distributed Grammar Systems for plan derivation and a Multi-agent algorithm for coordination of robot actions. We implemented and evaluated our solution on a team of three Pepper robots that work collaboratively to move an object on a table, thereby coordinating their capabilities and actions and verbalizing their actions and intentions. In a series of experiments, our solution not only successfully demonstrated collaboration and task fulfilment, but also considerable variation, both regarding actions and generated natural language utterances.

1 Introduction

Detection and recognition of human actions and behaviors has for a long time received attention within the Human-Robot Interaction (HRI) community. Robots often are supposed to be able to correctly infer what the humans are currently doing and what they plan to do, in order to support them in service robot scenarios. Robots are becoming increasingly autonomous and capable and it is not evident for an interacting human what the robot does or what it is planning to do and why. The area of understandable or explainable robotics specifically addresses this problem [3]. Failure to take understandability into consideration may affect safety, efficiency, user-experience, and interaction quality in general [1].

We investigate understandability for teams of robots collaborating to solve a common task. While such a robot team will rarely need to communicate verbally with each other for successful coordination, human bystanders might benefit from overhearing verbal dialogues between the robots, describing what they currently do and plan to do. A robot may ask another robot for help, suggest to other robots to perform actions, or inform the other robots about what it intends to do. Moreover, in a scenario where a team of robots works together with a team of humans, using natural language is a very efficient way to coordinate actions and plans.

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We introduce models for collaborative planning, task execution, and the generation of actions and utterances [4]. Our solution is demonstrated on a team of three Pepper robots solving a pick-and-place task by coordinating the work with each other, thereby verbally informing human bystanders.

To the best of our knowledge, architectures supporting verbal understandability for teams of collaborating robots have not been previously investigated. As far as we are aware, there has not been a demonstration of a team of Pepper robots moving objects in a pick-and-place task while speaking.

2 Main purpose

To support understandability of a team of collaborating and speaking robots we present an approach that is divided into parts: plan derivation and plan execution. The robots first cooperatively derive a plan thereby considering their individual capabilities to perform actions. The derived plan is then executed, also in cooperation between the robots. During plan execution, the robots verbalize what they intend to do or what they request other robots to do. Plan derivation is modelled using the grammar formalism known as Cooperating Distributed Grammar System (CDGS) [2], which is a formal model of blackboard architectures for collaborating multi-agent systems. During plan execution, the robots communicate to decide who should do what and when. The robots generate verbal utterances to explain what is going on to human bystanders. Plan execution and generation of verbal utterances is modelled with an agent-based architecture synchronizing actions and utterances. For more details on our approach we refer the reader to [4].

Our approach is illustrated in Figure 1, where the autonomous robots silently interact using a virtual blackboard during cooperative plan derivation and execution. The execution comprises interaction with the physical world, and is accompanied by verbal utterances to make the robots behavior understandable for human bystanders.

3 Demonstration

A derived plan is used as input for plan execution. Our solution comprises a main coordinating component and identical control systems running in parallel on each robot. The coordinating component is given a plan, places it on the blackboard, and starts all robot’s control systems.

The robots communicate through the blackboard to execute the plan. In addition to the current plan, a string denoting the action currently scheduled for execution resides on the blackboard.

To demonstrate the developed models and algorithms, plan execution was implemented on a team of three Pepper robots. Although the Pepper robots are not designed to manipulate objects, we managed to grip and move lightweight objects made with a base of polystyrene foam, and a tip of softer rubber foam that allows for safe gripping. Fig. 2 shows the experimental setup.

Fig. 1. Illustration of the interaction model in which three robots collaborate to solve a pick-and-place task. See text for details.

Fig. 2. Experimental setup showing one of the collaborating robots gripping an object.

The concurrent execution of our plan execution in all three robots results in several randomized operations. The behavior and verbalization for a given plan varied from one execution to another, and several experiments were therefore conducted for evaluation. Some results are presented in a video demonstration at <https://people.cs.umu.se/thomash/understandablerobotteams.mp4> in which the robots have the task to move the red object on cell 7. The video demonstration shows the variability in behaviour and verbalization as well as how obstacle removal is handled.

4 Conclusions

We proposed and evaluated a novel solution for understandable, collaborating robot teams, based on CDGS and a multi-agent algorithm for coordination of actions, and generation of verbal explanations. In our conducted experiments, the robot team successfully collaborated to solve given tasks. The individual robots verbally commented on their own planned actions, and also on actions requested to be performed by other robots. The randomized agent-based approach, together with the under-specified plans, demonstrated considerable variation, both regarding actions and generated utterances. The underlying motivation for the work presented in this paper is understandability for improved safety, efficiency, and user-experience in HRI.

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