In *Proceedings of the 5th International Symposium on Distributed Autonomous Robotic Systems (DARS)*
pages 477-478, Knoxville, TN, Oct 4-6, 2000

Learning cooperation from human-robot interaction

Monica N. Nicolescu and Maja J. Matarić

Computer Science Department, University of Southern California
941 West 37th Place, Mailcode 0781, Los Angeles, CA 90089-0781

Abstract. We present an approach to human-robot interaction that facilitates the robot's interaction with humans, permitting the robots to benefit from the humans and learn about cooperation. The approach is based on an abstract behavior representation that allows humans to freely interact with the robots without the use of a predefined vocabulary of words, gestures or signs, and also enables the robots to get useful information from this interaction.

1 Motivation

Human-robot interaction has been addressed mostly from the perspective of using predefined, common *vocabularies* between a robot and a human. In this sense, the interaction has been limited to the robot *understanding* those *symbols* and executing some predetermined behavior for each case. Due to this, the human is forced to interact with the robot at a very low level of representation which is far from the robot's high-level goals. Furthermore, the interaction becomes difficult because the human and the robot need to share the same vocabulary in order to be able to help and understand the other. We are interested in allowing the robot to learn from the interaction at the human 's high level of abstraction up to the point at which the robot is able to request appropriate help or it can help other robots in turn.

2 Approach

Our approach uses behavior-based control (BBC)[1,2], which we extend in order to make possible the goals we have proposed. We introduce an abstract behavior representation that is derived from behaviors developed for any one or more specific tasks. We constitute the pairing of a behavior's activation conditions and its effects, without the specification of its inner workings, into an *abstract behavior*. The behaviors that do the work that achieves those effects under the given conditions are called *primitive behaviors*, and may involve one or an entire collection of sequential or concurrently executing behaviors. This representation allows behavior-based systems (BBS) to be used at a high-level, like operators in a plan, for complex problems that contain temporal sequences. Also, the introduction of abstract behaviors provides

the ability of manipulating and changing the behavior's activation conditions such that solutions for new tasks can be dynamically generated without behavior re-compilation and re-design. We represent tasks in the form of abstract behavior networks in which the links represent postcondition-precondition dependencies. The generality of the network's components allows for behavior reuse both off-line (for system specification) and on-line (for system adaptation to a new task or directive).
Our approach to human-robot interaction is to allow the human to help the robot at his level of understanding and have the robot extract information from this interaction. By helping the robot, the human changes the environment, fulfilling thus some of the robot's (sub)goals, i.e. the behavior postconditions. The robot learns through continuous monitoring of the activation status of its behaviors and the state of the environment. If a goal of one of its currently not active behaviors is achieved, the robot infers that the human helped it with that. Thus, due to the abstract representation of behaviors, which defines the goals that each behavior achieves, the robot is able to relate the human 's helpful actions to its own behaviors that achieve the same (sub)goals. The interaction occurs through the environment, to which both the human and the robot have access.
After the demonstrated cooperation experience, the robot, faced with the same task, or even with a different task but involving some of the behaviors that have been categorized as suitable for cooperation, can ask another robot for help to achieve the goals of those behaviors. Help is requested for the most necessary behavior at that time, based on the behavior's activation level which is continuously monitored by the robot.
We have validated the proposed concepts on two Pioneer 2-DX mobile robots given an object delivery task, in which one robot has to move a box, through a closed door, from one side to the other of a two section, enclosed environment. First, one robot learns from a helpful human that it can get help with getting the box and opening the door. Second, it requests and gets assistance for those subtasks from a helper robot (having the same set of behaviors) that mappes those requests into corresponding behavior networks that were dynamically activated and then executed.
This describes work in progress. We intend to generalize it to other tasks, to automate the process of on-line behavior-network construction and to incorporate it with the rest of the robots behaviors. Also, we plan to use the abstract behavior representation to enable multiple robots to share their acquired knowledge and experience of cooperation.

References

1. Ronald C. Arkin (1998). Behavior-Based Robotics. MIT Press
2. Maja J. Matarić (1997). Behavior-Based Control: Examples from Navigation, Learning, and Group Behavior. Journal of Experimental and Theoretical Artificial Intelligence. H. Hexmoor and I. Horswill and D. Kortenkamp, **2-3**, 323–336