Multiple Agents from the Bottom Up: The Interaction Lab's Robot Competition Effort

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Overview

Our goal is to exploit the benefits of multi-agent systems so as to gain a super-linear increase in performance relative to that of a single robot. By this we mean that a team of n robots either performs a task more than n times "better" (depending on the task, faster, more thoroughly, more reliably) than a single robot could perform the task, or performs a task that a single robot simply cannot. We strive to build these systems from the bottom up using behavior-based principles of system organization such as subsumption and activation (Brooks 85). We are preparing entries for three events - Find Life on Mars, Vacuuming, and Hors-d'oeuvres serving - where the responsiveness and flexibility of this approach will enable our robots to organize themselves into efficient, effective, and entertaining teams.

Our Approach

Our programs are built "upwards", starting with simple sensor- and actuator-control behaviors over which higher level task-oriented behaviors are layered. The behaviors all run in parallel and may activate or inhibit each other and subsume each other's messages. There is no explicit attempt to model the world or the behavior of other agents, and we avoid any central control of team activities. Communication between agents is only through physical or visual interaction. Work in our lab has shown how simple behaviors of distributed agents can be combined to form complex behaviors (Matarić, M. 95), how such systems can achieve tasks that require global knowledge (Werger and Matarić 96), how robot teams and tasks can be organized for efficient operation (Fontan and Matarić 96),(Goldberg and Matarić 97), and how robots can learn behavior selection (Matarić 97) and learn through observation of their history of behavior activation (Michaud and Matarić 97).

Figure 1: The Interaction Lab Robots. In front are the Pioneers, surrounded by the four R2Es and twenty R1s.

Our Robots

The Interaction Lab has twenty-six robots, including RWI Pioneers and ISR R1s and R2Es. We are sure that the Pioneers will participate in all three events, and are investigating feasible means of incorporating some of the other robots. We'd like to field the largest teams we can.

The three Pioneers - Ben, Mae, and Ullanta[1] - are manufactured by Real World Interface, Inc., and are differentially steered bases with seven sonar sensors along the front and sides. They are additionally outfitted with grippers for object manipulation and the Fast Track vision system from Newton Laboratories, which is an on-board system that supplies information about blobs of three trainable colors at a rate suitable for real-time control. The main processor is a 68332

[1] Ullanta is on loan from robot theater company Ullanta Performance Robotics.

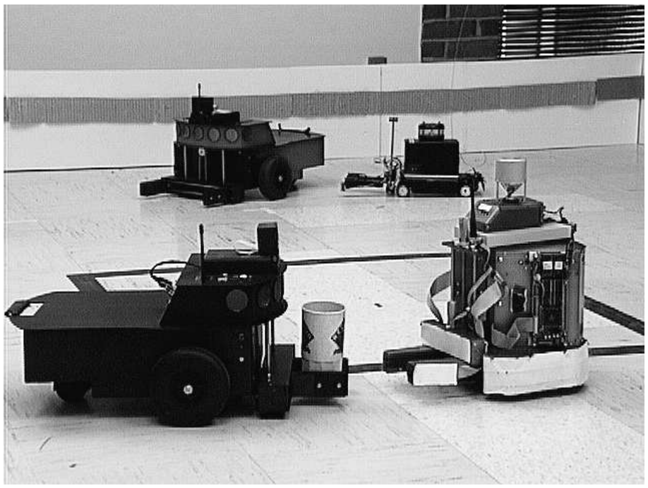

Figure 2: Cooperative Interaction. In this mock-up, a Pioneer places an object into an R2E's pickup area, from which the R2E will place it in the proper final location, while in the background another Pioneer leads an R1 to a good search location.

running the MARS/L system from IS Robotics, which provides a fast on-board Common LISP with multi-tasking and message-passing extensions designed for behavior-based control.

The four R2E robots, manufactured by IS Robotics, are differentially steered and feature infrared and contact sensing as well as grippers which can determine the color of objects held. We have additionally outfitted these with compasses. The main processor is a 68332 which runs the Behavior Language, the predecessor of the MARS/L system which provides multi-tasking and message passing but not the full power of LISP.

The twenty R1 robots, also by IS Robotics, are Ackerman steered, and have minimal IR and contact sensing and forks that can lift objects of specific size and shape. They are 68HC11-based and are also programmed in the Behavior Language.

Event Specifics

For the Find Life on Mars event, we will need to make extensive use of cooperation to overcome the color- and shape-sensing deficits of our robots. The Pioneers' vision systems cannot perceive shape in any way useful to the contest (that is, that would distinguish, say, a sphere from a cube), and can each distinguish only three narrowly-defined colors. The R2Es have no vision capability, but can get generalized color readings of objects already within their grippers. We are testing various types of two-stage collection/sorting strategies.

For the Vacuuming event, we will to adapt and combine some of our task-division (Goldberg and Matarić 97) (Fontan and Matarić 96) and physical communication (Werger and Matarić 96) strategies to allow efficient coverage of the areas to be cleaned without any global-positioning information, and to allow all the robots to take advantage of the information gained by the robots with vision.

In the Hors-d'oeuvres event, we will take advantage of the life-like appearance of behavior based systems and the engaging interactivity of our multi-robot techniques to help the guests-judges to appreciate the charming hospitality and *camaraderie* of our robots.

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