Teaming Up: Georgia Tech's Multi-robot Competition Teams

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Introduction

In past AAAI competition entries (1992-94), Georgia Tech has fielded robots developed by experienced graduate students. This year, we will take a different approach, with two separate teams: a group of experienced graduate students will enter the *Find Life on Mars* event with research-quality equipment, and a less-experienced group will enter the *Home Vacuum* event with entry-level robots.

Find Life on Mars entry

Georgia Tech expects to compete in *Find Life on Mars* with at least two (and potentially four) robots operating as a cooperating group. Research at Georgia Tech and elsewhere has demonstrated the speed and robustness afforded by multiple robot cooperation (Balch et al. 1995a, Balch and Arkin 1995b). The robots, Nomad 150s from Nomadics Technologies, are pictured in Figure 1.

The Nomad 150 is a holonomic three-wheeled mobile robot about half a meter in diameter. The steerable upper turret supports sensors and a control computer. Standard sensors include 16 ultrasonic range sensors and bump sensors. Color vision is provided by a separate hardware system capable of tracking multiple color objects at real-time rates. Additionally, each robot is equipped with a passive gripper for collecting Martian "life."

The control software runs on laptop computers under the Linux operating system. The laptops direct robot movement by issuing commands through a serial connection to the robot hardware The computers are networked using wireless modems supporting full TCP/IP services.

The motor schema paradigm is the central method of robot control in use at the Georgia Tech Mobile Robot Laboratory, and is utilized for these robots. Motor schemas are the reactive component of Arkin's AuRA, or Autonomous Robot Architecture (Arkin and Balch 1997). AuRA's design integrates deliberative planning at a top level with behavior-based motor control at the bottom.

The lower levels, concerned with executing the reactive behaviors, are incorporated in these robots. Individual motor schemas, or primitive behaviors, express separate goals or constraints for a task. As an example, important schemas for a navigational task would include **avoid_obstacles** and **move_to_goal**. Since schemas are independent, they can run concurrently, providing parallelism and speed. Sensor input is processed by perceptual schemas embedded in the motor behaviors. Perceptual processing is minimal and provides just the information pertinent to the motor schema. For instance, a **find_obstacles** perceptual schema which provides a list of sensed obstacles is embedded in the **avoid_obstacles** motor schema.

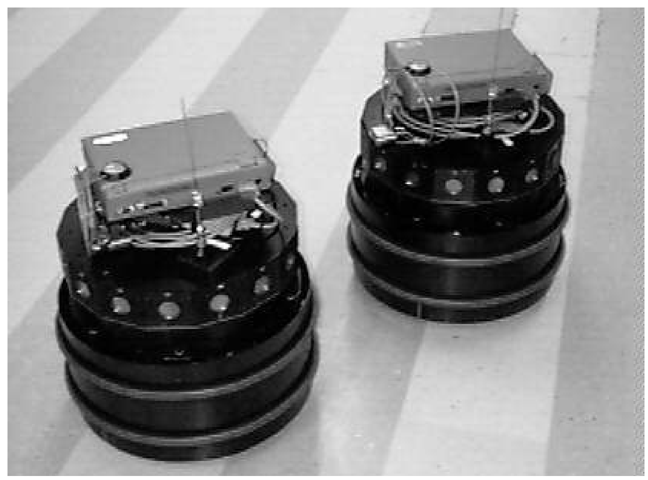

Figure 1. Sally and Shannon, two of the four Nomad 150 robots used for the *Find Life on Mars* event.

The concurrently running motor schemas are integrated as follows: First, each produces a vector indicating the direction the robot should move to satisfy that schema's goal or constraint. The magnitude of the vector indicates the importance of achieving it. It is not so critical, for instance, to avoid an obstacle if it is distant, but crucial if close by. The importance of motor schemas relative to each other is indicated by a gain value for each one.

Motor schemas may be grouped to form more complex, emergent behaviors. These groups are referred to as *behavioral assemblages*. One way behavioral assemblages may be used in solving complex tasks is to develop an assemblage for each sub-task and to execute the assemblages in an appropriate sequence. A resulting task solving strategy can be represented as a Finite State Acceptor (FSA). This technique is referred to as *temporal sequencing* (Arkin and MacKenzie 1994).

Find Life on Mars is a foraging task, in which a robot is to wander about the environment looking for items of interest (Martian life). Upon encountering a life form, the robot moves towards it, finally attaching itself. After attachment, the robot returns the object to a specified home base. In our approach to solving the forage task, individual simple behaviors are developed for these steps in the task, e.g. search-for-life-form, acquire-life-form, deliver-life-form. The behaviors are selected in an appropriate sequence based on the robot's situation.

Home Vacuum entry

The Georgia Tech entry in the *Home Vacuum* event will be a direct follow-on to a new special topics course, *Sensor-Based Intelligent Machines*. In this undergraduate course, newly-developed *LoCoRoBo* (Low-Cost Robust Bot) robots are being used as platforms for experiments with a variety of sensors. Toward the end of the course this spring, a project assignment will address part of the *Home Vacuum* event, and volunteers will continue to refine the effort.

A LoCoRoBo is similar to other entry-level robots, possessing two-wheel differential drive, passive casters, and a *Handy Board* Motorola 68HC11 controller (*http://lcs.www.media.mit.edu/groups/el/projects/handy-board/*). The unique characteristic of this platform is that it was designed to be exceptionally reliable, robust, and expandable while still remaining inexpensive enough to replicate in large quantities. To this end, stock hardware and hobby parts have been used extensively, with 1/8" aluminum plate and 1/4" wall-thickness acrylic tubing for structural integrity.

To allow for expandability, the LoCoRoBos support a stacking bus structure consisting of two 64-pin connectors. The current systems include a locomotion level and a controller level, but future plug-ins may include levels for vision and other sensors, as well as alternative locomotion levels. As the capabilities of the Handy Board are exceeded, PC/104 modules can be plugged directly into a reserved connector.

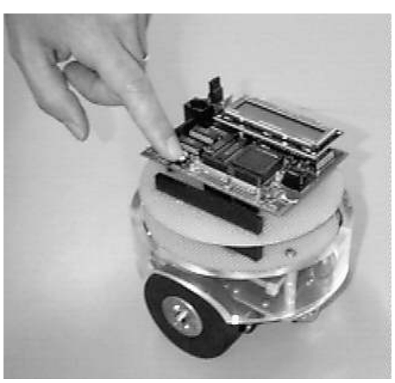

Figure 2. One of the six LoCoRoBos available for the *Home Vacuum* event.

Once before, in the 1994 *Clean Up the Office* task, Georgia Tech has taken a minimalist approach to a AAAI competition event with good results (Balch et al. 1995a). For this year's competition, the *Home Vacuum* event was chosen as the most suitable for the small LoCoRoBos, since there is no requirement to manipulate large objects or to examine surfaces that are out of reach. The vacuuming task also presents an excellent opportunity for cooperation.

A primitive implementation of AuRA will be adequate for this event. Since the charging/disposal station is a key location for the event, a dominant **move_to_goal** schema, attracted to the station, will be required as part of the temporal sequencing. Sensing or remembering the location of the station is a problem to be solved by the students in the *Sensor-Based Intelligent Machines* course, who may consider the advantages and disadvantages of explicit marking of both humans and room features.

Systematic cleaning of the rooms can be accomplished by careful odometry, perhaps aided by periodic landmark detection. This, too, can be accomplished with sequential **move_to_goal** schemas, although it may also prove effective to wander, using an **avoid_past** schema to improve the coverage of each robot. Throughout the process, an **avoid_obstacles** schema will be active to minimize points lost due to collisions.

Acknowledgments

The Georgia Tech Mobile Robot Competition Team thanks Ronald C. Arkin, Director of the Mobile Robot Laboratory, for allowing us to use the lab's Nomad robots and facilities in this effort. We would also like to thank the AT&T CIMS Intelligent Mechatronics Laboratory, the Georgia Tech Office of Interdisciplinary Programs, the Georgia Tech Research Institute, Maxon Precision Motors, and Motorola for their support in the construction of the LoCoRoBos.

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