Finding Life on Mars, and Other Tasks for NCSU's Mobile Robots

Jason A. Janét, Bruce R. Linnell, Sean M. Scoggins, et. al.
Center for Robotics and Intelligent Machines
North Carolina State University
Raleigh, NC 27695-7911
jajanet, brlinnel, smscoggi [@eos.ncsu.edu]

Introduction

The North Carolina State University (NCSU) team intends to participate in the 1997 Mobile Robot Competition and Exhibition[1]. This year marks our fourth entry in this competition. While there are many events in which we intend to compete, our primary focus is on the one entitled "Find Life on Mars". We decided to concentrate most of our efforts on this event because it requires environment learning, intelligent navigation, localization of objects in the environment and deliberate interaction with (or avoidance of) these objects.

Robot Description

The Center for Robotics and Intelligent Machines (CRIM) has several mobile platforms that could be used for this competition. At this writing (April 1997, five months before the actual competition), we are weighing our options. However, we can provide a general description of the base and on-board sensors.

Main Processor and Network Link

The main on-board processor runs Linux (UNIX). The main processor will be equipped with wireless ethernet, making it accessible from any workstation on the network (including the Internet).

Tactile and Ranging Sensors

Our platforms are equipped with sonars in a full- or partial-ring configuration. Sonars and tactile bumper sensors mounted low on the platform are used to detect low profile objects.

Vision Systems

Our color vision hardware consists of an on-board image processor and a single RGB camera mounted on a pan/tilt unit. The image processor was purchased from Traquair Data Systems and contains two 'C40 DSP's running in parallel. Performing all computation on-board the robot has several advantages: the video data is not corrupted by radio transmission noise, commands are not lost, and there is no communication lag that may result in crashing into things. These findings are consistent with those of previous competitors. On the downside, the on-board image processor contributes significantly to the battery drain, which is partly due to its intended desktop use. Still, we are able to get about 2 hours of operation per charge. This vision system is used for computation-intensive image processing as well as tracking objects that might contain color.

Our black-and-white vision system uses the parallel port as an image bus. The camera has a 670nm bandpass filter to isolate the grid projected by the laser-grid pattern generator. Preliminary experiments indicate that we can quickly detect the 4×4 grid even in daylight. This vision system enables us to recognize environment topology as indicated by the warping of the projected grid.

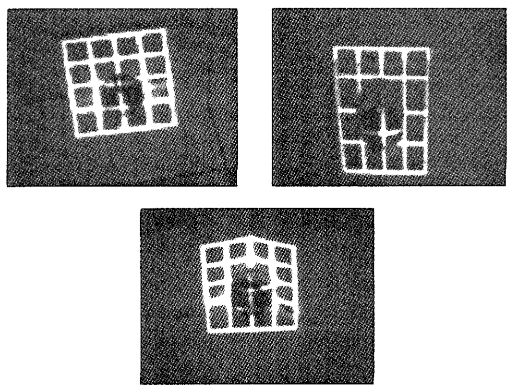

Figure 1: Clockwise from top left, grid projections on: 1) intersection of floor and wall; 2) flat floor; and 3) intersection of floor and two walls.

Laser Grid-Pattern Generator

To recognize the physical topology of the environment, our platform is suited with a laser grid-pattern generator. The 670 nm, 10 mW diode laser was donated by LaserMax (LaserMax 1997). A diffractive optical element at the output of the laser, generates a 4×4 grid at a 16 deg full-angle spread. Fast visual isolation of the grid is achieved with the black-and-white vision system mentioned above. The projected grid is a regular geometric grid with known size. By determining the amount of warpage in the reflected grid pattern, shape information can be extracted about the surface on which the grid is projected.

4-DOF Arm

To deliberately move objects in the environment, our platform is equipped with a 4 degree-of-freedom (DOF) arm. Due to the rapid prototyping capabilities of the CRIM, this arm was quickly designed and built in preparation for the 1996 AAAI robotics competition. Since that time, some refinements have been made to enable faster movement of the end-effector, reduce the arm's physical size, strengthen certain gear-trains and reduce the amount of real estate consumed by the electronics. The arm can reach approximately 60 cm,

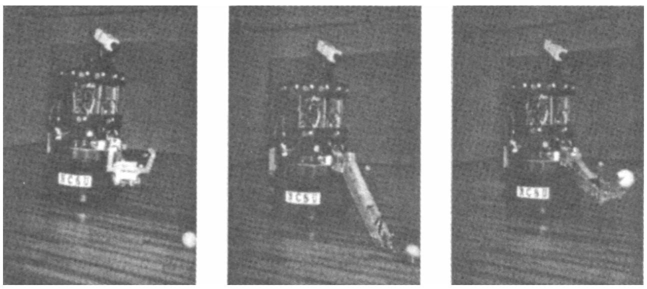

Figure 2: Sequence of robot approaching, grasping and lifting a tennis ball with 4-DOF arm.

Methodology

We intend to build on the hardware and software we used in the 1995 and 1996 Mobile Robot Competition. The basic approaches under consideration are summarized in the following sections.

Navigation Architecture

The navigation architecture consists of the following:

- **High-level planning:** Global motion planning can be done using the Essential Visibility Graph which is based on traversability vectors (Janét 1997a). We can also plan motion using a topological map built with a hyper-ellipsoid clustering (HEC) neural network (Janét 1997c, Janét 1997d).
- **Place recognition:** We can use the HEC neural network (Janét 1997c, Janét 1997d) or the Region-Feature Neural Network (Janét 1997b) to estimate the location of the robot in the topological map from dead-reckoning, sonars and vision.

Perception/Manipulation

To detect, track, avoid and/or manipulate objects in the environment we can employ the following:

- **Perception:** The color vision system on the robot and a color-histogramming technique can be used to recognize and track colored objects (LeGrand 1996). Another alternative would be to use the HEC neural network for for adaptively tracking multi-colored objects In addition, the laser grid pattern projected in front of the robot will be analyzed by the black-and-white vision system to extract local topological information about the environment within the arm's work envelope.
- **Manipulation:** With our 4-DOF arm we can retrieve objects up to 18 cm wide. The laser grid-based vision system will provide information with respect to the layout of objects immediately in front of the robot. This information can be used to construct safe and effective gripper trajectories for grasping. In addition, local shape information from the vision system can be used to optimally grasp objects of various shapes.

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