Low Computation Vision-Based Navigation For a Martian Rover

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Abstract[1]

In the design and construction of mobile robots vision has always been one of the most potentially useful sensory systems. In practice however, it has also become the most difficult to successfully implement. At the MIT Mobile Robotics (Mobot) Lab we have designed a small, light, cheap, and low power Mobot Vision System that can be used to guide a mobile robot in a constrained environment. The target environment is the surface of Mars, although we believe the system should be applicable to other conditions as well. It is our belief that the constraints of the Martian environment will allow the implementation of a system that provides vision based guidance to a small mobile rover.

The purpose of this vision system is to process realtime visual input and provide as output information about the relative location of safe and unsafe areas for the robot to go. It might additionally provide some tracking of a small number of interesting features, for example the lander or large rocks (for scientific sampling). The system we have built was designed to be self contained. It has its own camera and on board processing unit. It draws a small amount of power and exchanges a very small amount of information with the host robot. The project has two parts, first the construction of a hardware platform, and second the implementation of a successful vision algorithm.

For the first part of the project, which is complete, we have built a small self contained vision system. It employs a cheap but fast general purpose microcontroller (a 68332) connected to a Charge Coupled Device (CCD). The CCD provides the CPU with a continuous series of medium resolution gray-scale images (64 by 48 pixels with 256 gray levels at 10-15 frames a second). In order to accommodate our goals of low power, light weight, and small size we are bypassing the traditional NTSC video and using a purely digital solution. As the frames are captured any desired algorithm can then be implemented on the microcontroller to extract the desired information from the images and communicate it to the host robot. Additionally, conventional optics are typically oversized for this application so we have been experimenting with aspheric lenses, pinholes lenses, and lens sets.

As to the second half of the project, it is our hypothesis that a simple vision algorithm does not require huge amounts of computation and that goals such as constructing a complete three dimensional map of the environment are difficult, wasteful, and possibly unreachable. We believe that the nature of the environment can provide enough constraints to allow us to extract the desired information with a minimum of computation. It is also our belief that biological systems reflect an advanced form of this. They also employ constant factors in the environment to extract what information is relevant to the organism.

We believe that it is possible to construct a useful real world outdoor vision system with a small computational engine. This will be made feasible by an understanding of what information it is desirable to extract from the environment for a given task, and of an analysis of the constraints imposed by the environment. In order to verify this hypothesis and to facilitate vision experiments we have build a small wheeled robot named Gopher, equipped with one of our vision systems.

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