From Cross-Country Autonomous Navigation to Intelligent Deep Space Communications: Visual Sensor Processing at JPL

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Abstract: *We describe ongoing work at JPL in two fields: autonomous navigation for terrestrial vehicles, and prioritized progressive transmission for deep space communications. While such applications may seem rather disparate, they have in common the need for autonomous reasoning about visual information. We first review a number of techniques currently under development that make use of data from color and infrared cameras, multispectral sensors, and laser rangefinder for estimating properties of the terrain cover in outdoor vegetated terrain. We then discuss how onboard visual analysis mechanisms for Mars rovers can be used for prioritizing the data to be transmitted to Earth, in order to maximize the science return of a mission.*

1 Introduction

The Jet Propulsion Laboratory (JPL) is involved in a number projects sponsored either by NASA (exploration of solar system bodies and remote sensing of Earth) or by other government agencies, most notably the US Army. The Machine Vision group at JPL provides support to a number of such projects involving the processing of visual information. In this paper, we give a broad overview of some recent work in the Machine Vision group in two main areas: autonomous navigation in cross-country terrain, and image prioritization for "intelligent" deep space communications. While such applications may seem rather disparate, they have in common the need for *autonomous reasoning about visual information.*

Autonomous navigation uses visual sensors to infer information about the geometry of the scene (for example, to determine whether there are obstacles along a certain candidate path). A purely geometric description, however, is suitable only for urban or semi-arid territory but not for vegetated terrain, where the notion of "obstacle" must be revisited. For example, a small bush or a patch of tall grass, both traversable without risk of damage for the vehicle, would probably be deemed an obstacle based solely on their geometry. For the navigation system to realize that such instances are not, in fact, "obstacles", information about the composition of the terrain cover and related physical properties must be inferred from the visual sensor data [Bellutta et al., 2000].

There are many other situations where it would be desirable to estimate the terrain cover composition. For example, distinguishing between paved and unpaved surfaces is helpful for road following. Determining the expected slippage and roughness of a terrain before actually driving over it would help determining the correct velocity for traversal. Detecting the presence of bodies of water or of muddy patches is important for the safety of the vehicle. And distinguishing between natural and man-made obstacles has a major tactical value. In Section 2 we review a number of techniques currently under development in our group, that make use of data from color and infrared cameras, multispectral sensors, and laser rangefinder for estimating properties of the terrain cover in outdoor vegetated terrain.

The visual analysis of scenes is critical also in a completely different domain – on Mars. Future NASA missions, such as the Mars Exploration Rover mission planned for 2003, will enable rovers to explore the geology of the red planet, looking for indicators of water-rock interaction, and for any evidence of pre-biotic and biotic compounds. The remote control of Mars rovers, however, is a very challenging problem due to (1) the limited bandwidth available for communication with Earth, (2) the high transmission latency, and (3) the scarce opportunity for uplinking commands from Earth. Thus, it is important that the rover does not rely continuously on human control, but that it has a large degree of autonomy.

A good deal of research is ongoing at JPL toward the development of "autonomous geology" techniques [Gilmore et al., 2000] that make use of visual, multispectral and other sensors to identify interesting science targets, and therefore to enable the rover to take autonomous planning decisions. Yet, humans will always be part of the control loop. It is therefore important to devise strategies for best exploiting the little bandwidth available and the scarce resources of the rover (such as the limited buffer size), ensuring that the data most relevant to the human operator is downlinked to Earth. In particular, the same onboard mechanisms for visual analysis could be used for *prioritizing* the data to be transmitted. In cooperation with the Information Processing group at JPL, we have developed a methodology for prioritizing images based on information from an onboard science processing