N89-26344

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METHODS AND DECISION MAKING ON A MARS ROVER FOR IDENTIFICATION OF FOSSILS

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We are developing a system for automated fusion and interpretation of image data from multiple sensors, including multispectral data from an imaging spectrometer. Classical artificial intelligence techniques and artificial neural networks are employed to make real time decisions based on current inputs and known scientific goals. Emphasis is placed on identifying minerals which could indicate past life activity or an environment supportive of life.

Multispectral data can be used for geological analysis because different minerals have characteristic spectral reflectance in the visible and near infrared range. Absolute identification of minerals is probably not possible using only multispectral data; mixtures of minerals in one rock, albedo levels, and mineral crystal size alter real spectra from the laboratory results. However, classification of each spectrum into a broad class, based on overall spectral shape and locations of absorption bands is possible in real time using artificial neural networks.

The goal of this system is twofold:

First, multisensor and mutispectral data must be interpreted in real time so that potentially interesting sites can be flagged and investigated in more detail while the rover is near those sites. In particular, we are trying to identify the spectral features that will identify potential life indicators: Carbonates often derive from fossilization of carbon based life forms. Clays may derive from past water activity, thus indicating a good starting point when looking for fossils.

Second, the sensed data must be reduced to the most compact form possible without loss of crucial information. Multispectral data can be very large 200 or more bytes for a single image pixel. Complete data sets are too large to be transmitted to Earth. We are developing methods for real time clustering of spectrally similar pixels using hierarchical neural networks for edge-finding and classification. The multispectral information in an image can represented as a set of compact region descriptors and representative spectra for each region. This description may then be transmitted to Earth for further interpretation by human operators. Currently we expect to realize a 500 fold data reduction.

Autonomous decision making will allow a rover to achieve maximum scientific benefit from a mission. We are considering both a classical rule based approach and a decision neural network for making real time choices. For example, if a potentially interesting region is discovered while the rover is taking a panoramic survey of its surroundings, higher resolution images should be taken and transmitted automatically without awaiting instructions from human analysts.

Decision making is based on incoming data and current scientific goal. Any system must be flexible enough to allow for dynamically changing goals. If the current goal changes from "search for carbonates" to "differentiating between classes of silicates," this will change the wavelengths to be examined most closely and the spectral features considered important.

Neural nets may work well for such adaptive decision making. A rule based decision system might require extensive search through numerous rules covering all possible input states. A neural net can be trained to work in two steps. First, the actual input state (consisting of sensor inputs, outputs of classification and feature detector nets, resolution, distance and scientific goal information) is mapped to the closest of a number of memorized states. The mapping algorithm takes into account that some input parameters (e.g., scientific goal) are more important than others (e.g., a single spectral feature). Then the net produces an output decision based on the matched memory state.

A decision network will allow decision making in real time for any type of situation that can be anticipated in advanced. Rule based methods may be added for handling exceptions, with a facility for requesting guidance from Earth for unusual situations.

Real time, autonomous image data analysis and decision making capabilities are required for achieving maximum scientific benefit from a rover mission. The system under development will enhance the chances of identifying fossils or environments capable of supporting life on Mars.