N89-26373

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AUTONOMOUS EXPLORATION SYSTEM: TECHNIQUES FOR INTERPRETATION OF MULTISPECTRAL DATA

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An on board autonomous exploration system that fuses data from multiple sensors, and makes decisions based on scientific goals is being developed using a series of artificial neural networks. Emphasis is placed on classifying minerals into broad geological categories by analyzing multispectral data from an imaging spectrometer.

Artificial neural network architectures are being investigated for pattern matching and feature detection, information extraction and decision making. Neural nets offer several advantages over traditional techniques. A hardware implementation may be put on a single chip for real time data analysis. Nets are robust against noisy and incomplete data and can be designed to provide both an answer and an estimate of the correctness of that answer. Multiple nets may process data from a number of pixels in parallel, speeding computation time.

As a first step, a stereogrammetry net (developed by Niles Ritter in the Cartographic Applications group at JPL), extracts distance data from two gray scale stereo images. This net works by matching pixels of a similar intensity between the two images, and determining the horizontal offset. Near objects have the greatest offset between corresponding points, far objects the least. Resulting distance planes can be overlaid, and viewed in a compact representation where a given distance is assigned a certain color.

For each distance plane, an edge-finding net identifies edges using vertical and horizontal discrepancies in slope between pixels. Objects are outlined by an edge follower, and spectral reflectance data taken in a limited set of wavelengths to determine whether the outlined region is homogeneous. When a subregion is identified a full spectrum is sampled, then sent to a neural net classifier and a feature detection net. The output is the probable mineral composition of the region, and a list of spectral features such as peaks, valleys, or plateaus, showing the characteristics of energy absorption and reflection.

The classifier net is constructed using a "grandmother cell" architecture: 1) an input layer of spectral data (32 analog values, each for a single wavelength in the range of 2.04 to 2.5 microns), 2) an intermediate processor, and 3) an output value. The processor takes the dot product of the input layer with each of the stored memories (each memory represents a general geological class, e.g., carbonates, oxides). The memory with the highest output value is the closest match to the input spectrum, and the spectrum is assigned to that class.

The feature detector is a three-layer feed-forward network that has been developed to map input spectra to four geological classes (Amphiboles, Clays, Borates, and Carbonates), and will later be expanded to encompass more classes. The input layer receives spectral data as above. The hidden layer is an internal representation of the input consisting of 8 nodes that detect features common to a geological class (e.g., Carbonates have an absorption feature around 2.3 microns).

The feature detector net is a software simulation of a system that will later be put into hardware, where the nodes represent transistors to hold analog voltage levels, and the connections represent resistance values between nodes. There are 44 nodes and 288 connections in the current simulation. The weights of the connections are determined by training the net with preclassified minerals using a backward propagation learning algorithm. This algorithm compares the desired output of the net with the actual output for each of the training set of minerals. Weights are adjusted so as to maximize the log likelihood that the desired output occurs. After training, hidden layer performance is analyzed to determine what features are being detected. Features that are characteristic of a mineral class may be valuable for determining composition of a mineral mixture.

Results from the classifier and feature detector nets will help to determine the relative importance of the region being examined with regard to current scientific goals of the system. This information is fed into a decision-making neural net along with data from other sensors to decide on a plan of activity. A plan may be to examine the region at higher resolution, move closer, employ other sensors, or record an image and transmit it back to Earth.