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Mars Rover Imaging Systems And Directional Filtering

Research Activities Summary

Submitted By Professor Paul P. Wang
Department of Electrical Engineering
Duke University
Durham, N.C. 27706

On July 20, 1989 as suggested by my NASA research colleague Mr. Friedrich O. Huck, I attended a three day conference on Visual Information Processing for Television and Telerobotics (May 10-12, 1989) sponsored by NASA. Professor Surendra N. Tiwari's suggestion of an earlier contact certainly yields a good return in this case. My research task got a quick start. Computer literature searches were carried out both at Duke University and NASA Langley Research Center. The purpose is to enhance my personal knowledge based on the technical problems of pattern recognition and image understanding which must be solved for the Mars Rover and Sample Return Mission. My intensive study effort of a large collection of relevant literature resulted in a compilation of all important documents in one place. Futhermore, they are being classified into (i) Mars Rover (ii) Computer Vision - Theory (iii) Imaging Systems (iv) Pattern Recognition Methodologies (v) Other smart Techniques (AI, Neural Network, Fuzzy Logic, etc.). Our graduate student Perry Cornelius working for Dr. John Cleland of RTI on NASA's project dealing with technology transfer has been able to utilize this collections during this summer.

A decision was made jointly by Mr. Huck and myself that I should put my major effort to identify meaningful research problems of pattern recognition and image understanding relevant to the proposal entitled "Rover Imaging Systems for the Mars Rover/sample Return Mission". This proposal with Mr. Friedrich O. Huck as principal investigator, in my opinion, is one of the very best I have ever read. Clarity in presentation, precision in technical and high information contains in text body. So far as I was able to observe, many papers concerning various issues have been written about the Viking Lander project already. However, much progress in technology has taken place since the Viking Lander landed. This is particularly true for the computer vision field. So far as computer vision aspect of the Viking Lander project is concerned, the only scenes that could be dealt with were static and essentially two-dimensional in most instances. Azriel Rosenfeld recognizes three viewpoints for computer vision:

(i) Computational Vision: modeling biological visual systems

(ii) Machine Vision: solving practical problems

(iii) Image Understanding: deriving descriptions of the scene

My experience and interest although are primarily within the scope of (iii), However, the relevancy of (i) and (ii) are very crucial if we want to do a good job in (iii) as we shall explain later. If computer vision is regarded as a science in its own right, its central goal, as pointed out by Azriel Rosenfeld, is to obtain a description of the scene that is as complete and correct as possible. This includes both "recovery" of scene geometry and recognition of objects that may be present in the scene. For Mars Rover project, these problems are hard because they involve "object" classes that are difficult to define. To include the researcher such as Steven W. Squyres, Center for Radiophysics and Space Research of Cornell University is an excellent idea because without his expertise, I don't believe the image understanding problem is meaningful.

Looking back, the analysis of Viking Lander data either relies heavily on statistical methodologies or as in many cases studies heuristic in nature. It is important to point out that scenes containing natural objects such as crater, rocks or even lava flows are much harder to handle, because such object classes are hard to define. Recognizing the advances in pattern recognition, AI, neural network, fuzzy logic and other techniques, we can expect to do much better for the Mars Rover project. In addition, methods of handling three-dimensional scenes and time-varying scenes may prove to be very important to the Mars Rover project. I am currently looking for some potential applications as I study Mr. Huck's proposal.

NASA sponsored a workshop in 1988 entitled "Neural Networks and Fuzzy Logic" at Johnson Space Center. It is worthwhile to mention in passing that my student has completed his Ph.D degree dissertation at Duke University in the reseach area of fuzzy logic and another student is in the process of writing dissertation in the area of neural network jointly directed by Professor Jack Rebman and myself. I believe both technologies are very much relevant to Mars Rover project in other application areas if not in computer vision.

During early July of 1989, A conference between Mr. Huck and myself convinced both of us that the problem of high compression image coding via directional filtering perhaps is worthy of our research effort. This problem has become my number one priority on the list ever since. The combination of transform domain coding of the low frequency component and spatial domain coding of the directional components led to the compression ratios higher than 30 to 1. As has been claimed by some researchers, this is quite remarkable because the conventional techniques offer the compression ratios of 5 to 8 for non adaptive schemes and can go up to 16 at best for adaptive schemes.

Progress in computer vision, including picture transmission has depended on the steady increase in available computer power and speed. Still largely lacking is a theoretical framework for designing solutions to computer vision problems. The compression image coding problem just mentioned is a case in point. After an enormous amount of work in this topic, some researchers decided to take a drastic change of direction which ultimately lead to a drastic improvement in performance. This novel approach has two distinguished lines of thinking: (1) Making the use of a better understanding of the human visual which has just happened recently. (2) Spatial domain interpretation: the property of some transforms (such as 2 dimensional Fourier transformation, to distribute the energy of an image in a way that it is more adequate for coding than the spatial distribution.

My research effort since early July focus on the fundamental issue of designing such a filter. However, the further study of the extension of information theory into two dimensions is needed because one can not design a filter without a thorough understanding of the natural phenonmena. I have begun some mathematical derivations which hopefully, will lead to a better understanding and the design of the "directional filters". Two aspects have been quite clear to me that these analytical works are going to be useful: (i) Mathematical results would help to explain some statements made by various researchers which are but intuitive and heuristic in nature. (ii) New interpretation and insight are possible after these mathematical results are graphically displayed via digital computers. I sincerely hope it is possible for NASA to provide some funds for me to continue my work, which has just begun.