Information Sciences

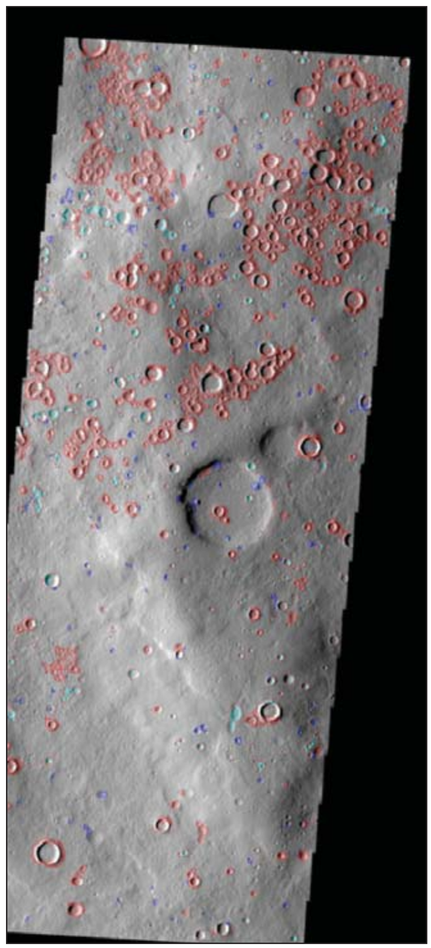
Landmark Detection in Orbital Images Using Salience Histograms

This technique enables automated identification of objects and regions in airborne or orbital images.

NASA's Jet Propulsion Laboratory, Pasadena, California

NASA's planetary missions have collected, and continue to collect, massive volumes of orbital imagery. The volume is such that it is difficult to manually review all of the data and determine its significance. As a result, images are indexed and searchable by location and date but generally not by their content. A new automated method analyzes images and identifies "landmarks," or visually salient features such as gullies, craters, dust devil tracks, and the like. This technique uses a statistical measure of salience derived from information theory, so it is not associated with any specific landmark type. It identifies regions that are unusual or that stand out from their surroundings, so the resulting landmarks are context-sensitive areas that can be used to recognize the same area when it is encountered again.

A machine learning classifier is used to identify the type of each discovered landmark. This classifier can also indicate when a previously unknown type of landmark is encountered, enabling the discovery of new and unusual physical phenomena. Using a specified window size, an intensity histogram is computed for each such window within the larger image (sliding the window across the image). Next, a salience map is computed that specifies, for each pixel, the salience of the window centered at that pixel. The salience map is thresholded to identify landmark contours (polygons) using the upper quartile of salience values. Descriptive attributes are extracted for each landmark polygon: size, perimeter, mean intensity, standard deviation of intensity, and shape features derived from an ellipse fit. Each landmark is classified as one of a set of known types, or marked as "unknown" using a classifier previously trained on hundreds of manually annotated landmarks. Each image is annotated with its contents (list of landmarks with their locations, types, and attributes).



Landmarks Are Automatically Identified in THEMIS image V19619013 of Terra Sabaea (Mars). Craters are marked in red, streaks in blue, and unrecognized landmarks in cyan.

This method enables fast, automated identification of landmarks to augment or replace manual analysis; fast, automated classification of landmarks to provide semantic annotations; and content-based searches over image archives.

Automated landmark detection in images permits the creation of a summary catalog of all such features in an image database, such as the Planetary Data System (PDS). It could enable entirely new searches for PDS images, based on the desired content (landmark types). In the near future, landmark identification methods using Gabor filters (texture) or covariance descriptors will also be investigated for this application.

This work was done by Kiri L. Wagstaff and Julian Panetta of Caltech; Norbert Schorghofer of the University of Hawaii; and Ronald Greeley, Mary Pendleton Hoffer, and Melissa Bunte of Arizona State University for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-46674

Efficient Bit-to-Symbol Likelihood Mappings

A new algorithm that increases decoder speed contributes to the development of high-speed optical communications links.

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This innovation is an efficient algorithm designed to perform bit-to-symbol and symbol-to-bit likelihood mappings that represent a significant portion of the complexity of an error-correction code decoder for high-order constellations. Recent implementation of the algorithm in hardware has yielded an 8-percent reduction in overall area relative to the prior design. This gain resulted from changing just two operations in a complex decoder. Larger gains are possible for larger constellations that are of interest for deep-space optical communications. The algorithm structures the bit-to-symbol/symbol-to-bit operations like a tree that forms a portion of a Fast-Fourier-Transform (FFT). Much like an FFT, the parallel computation may be structured in order to reduce repeated computations. Symmetry in the values was noted and allowed for the reduction of the bit-to-symbol mapping by a factor of 2.

This method computes bit-to-symbol likelihood mappings for a soft-in/soft-out decoder that operates over M-ary symbols, but receives and transmits bit-log likelihoods. There are two bit-to-symbol mappings. The first requires $M - 2$ operations and $\log_2 M - 1$ clock cycles. The second requires $O(M \log_2 M)$ operations and $\log_2\log_2 M$ clock cycles. The symbol-to-bit mapping requires $\log_2 M$ clock cycles and $3M - \log_2 M - 4$ operations. In a pipelined architecture, the reduced operation counts also translate into reduced memory requirement.

This technology can apply to communications channels that use high-order constellations and decode over symbols from that constellation. This would potentially include a large number of communications channels, such as cable modems, disk drives, etc., as well as being a direct improvement to the Optical Communications End-to-End Testbed, which is currently in use to demonstrate, test, and develop deep-space optical communications technology.

This work was done by Bruce E. Moision of Caltech and Michael A. Nakashima of Skillstorm, Incorporated for NASA's Jet Propulsion Laboratory.

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Capacity Maximizing Constellations

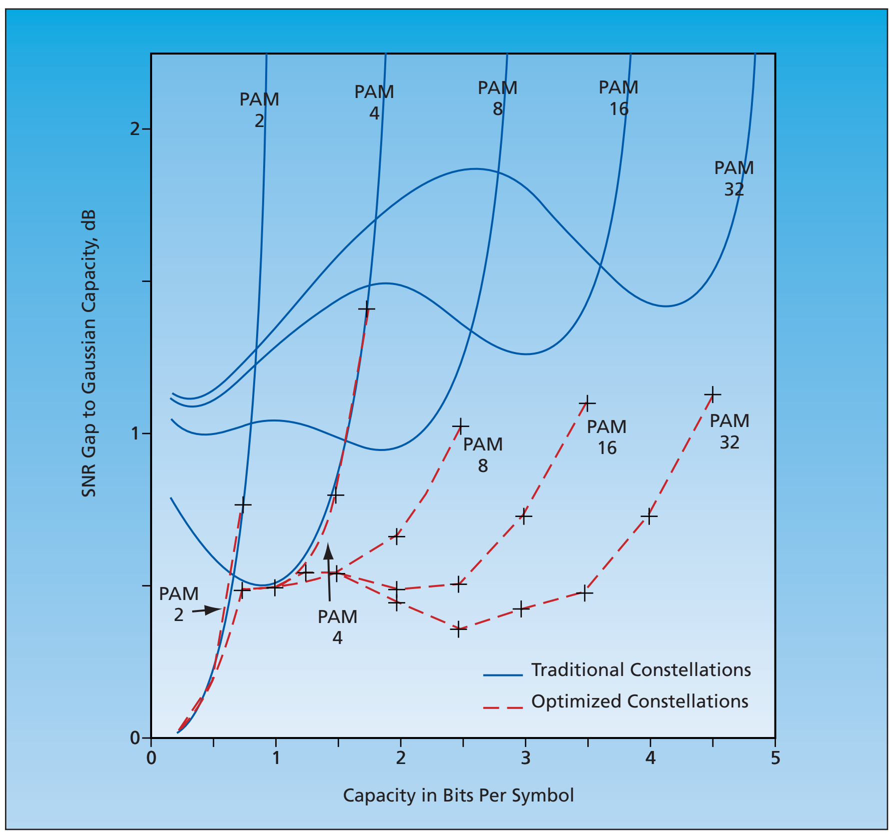
Locations and bit labels of constellation points are optimized jointly.

NASA's Jet Propulsion Laboratory, Pasadena, California

Some non-traditional signal constellations have been proposed for transmission of data over the Additive White Gaussian Noise (AWGN) channel using such channel-capacity-approaching codes as low-density parity-check (LDPC) or turbo codes. (As used here, "constellation" signifies, with respect to a signal-modulation scheme, discrete amplitude and/or phase points corresponding to symbols to be transmitted.) Theoretically, in comparison with traditional constellations, these constellations enable the communication systems in which they are used to more closely approach Shannon limits on channel capacities. Computational simulations have shown performance gains of more than 1 dB over traditional constellations. These gains could be translated to bandwidth-efficient communications, variously, over longer distances, using less power, or using smaller antennas.

The opportunity to effect improvements through use of the proposed constellations arises as follows: The introduction of turbo and LDPC codes during the 1990s made it possible to formulate coding schemes that afford near-Shannon-capacity performance for binary and quaternary phase-shift-keying modulation schemes. However, in these and other channel-capacity-approaching coding schemes, when traditional signal constellations are used, the gap between the achievable performance and the Shannon or the Gaussian capacity increases with bandwidth efficiency (in effect, as more bits are packed into each transmitted symbol). While the channel-capacity-approaching codes are highly optimized, the traditional signal constellations are not optimized.

The amplitude and/or phase intervals between points in a constellation accord-



Gaps Between Parallel Decoding Capacity and Gaussian Capacity [quantified as equivalent signal-to-noise-ratio (SNR) gaps] were computed for optimized and traditional PAM 2-, 4-, 8-, 16-, and 32-point constellations.