Technology Focus: Data Acquisition

A Deep Space Network Portable Radio Science Receiver

Receiver filters and records IF analog signals.

NASA's Jet Propulsion Laboratory, Pasadena, California

The Radio Science Receiver (RSR) is an open-loop receiver installed in NASA's Deep Space Network (DSN), which digitally filters and records intermediate-frequency (IF) analog signals. The RSR is an important tool for the Cassini Project, which uses it to measure perturbations of the radio-frequency wave as it travels between the spacecraft and the ground stations, allowing highly detailed study of the composition of the rings, atmosphere, and surface of Saturn and its satellites. The RSR is also used to track and detect the signals for important events in other missions such as the Mars Exploration Rover (MER) entry descent and landing (EDL). Some of these events require extra RSRs or require them to be shipped to non-DSN stations such as the 100-meter Greenbank Telescope (GBT) in West Virginia. Sending and installing an RSR consisting of a large DSN rack to one of these sites is a daunting and expensive task. A smaller, more portable equivalent to the RSR was needed both for these special events and to enhance the existing capability of the DSN.

A prototype Portable Radio Science Receiver (PRSR) has been developed that can fit in a standard-size suitcase and uses a laptop PC as its controlling computer. The PRSR chassis is a 2-U steel box with 19-in. (48-cm) rack-mount capability and external connections for power, Ethernet, RS-232 control, 100 MHz reference signal, 1-pulse-per-second reference, and one input port for an IF signal in the range of 0–640 MHz. Inside the PRSR, there is a steel plate that separates the IF digitizer unit from the digital signal-processing board to reduce spurs that may affect the sensitive analog components.

This innovation contains firmware that runs on a Xilinx field-programmable gate array (FPGA), and consists of code that down-converts the DSN's 640-MHz IF spectrum into two channels: a wide bandwidth channel and a narrow bandwidth channel. The wide bandwidth channel can be configured from 160 MHz down to 1.25 MHz with 16 bits of resolution. The narrow channel can be configured from 1.25 MHz down to 10 kHz with 32 bits of resolution.

The present PRSR software consists of a driver, a command processor, and a graphical user interface (GUI) for viewing monitor data and plots. While limited in scope, this software is able to demonstrate on the prototype hardware the key features of a fully operational PRSR. For example, data can be recorded onto a disk from the PRSR's narrowband channel, but recordings only occur in discontinuous snapshots of 4,096 samples each.

The PRSR was shipped to GBT along with an existing DSN RSR rack and recorded signals in parallel with the RSR coming from the Phoenix lander during the May 25, 2008 EDL. This test demonstrated the potential of the PRSR prototype and the value for developing it into a fully operational DSN receiver.

This work was done by Andre P. Jongeling, Elliott H. Sigman, Kumar Chandra, Joseph T. Trinh, Robert Navarro, Stephen P. Rogstad, Charles E. Goodhart, Robert C. Proctor, Susan G. Finley, and Leslie A. White of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-46289

Detecting Phase Boundaries in Hard-Sphere Suspensions

Liquid and solid phases are distinguished through differences in motions of spheres.

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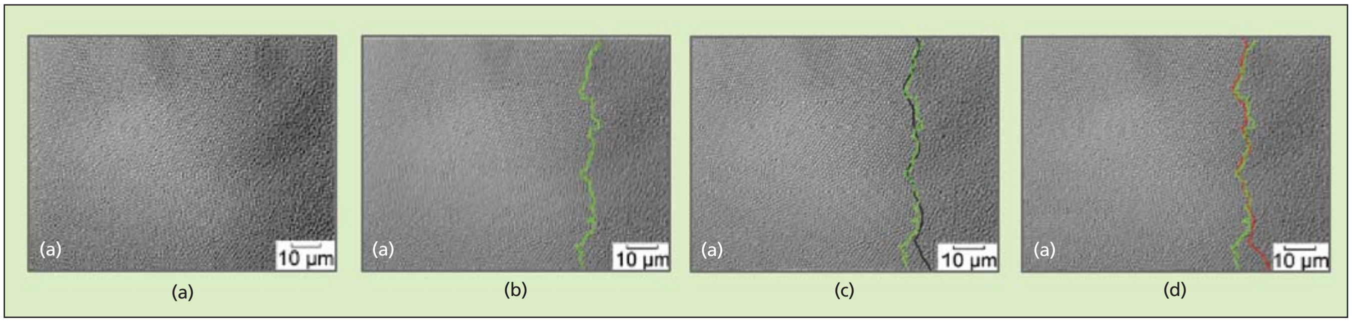
A special image-data-processing technique has been developed for use in experiments that involve observation, via optical microscopes equipped with electronic cameras, of moving boundaries between the colloidal-solid and colloidal-liquid phases of colloidal suspensions of monodisperse hard spheres. Such suspensions are used as physical models of thermodynamic phase transitions and of precursors to photonic-band-gap materials. During an experiment, it is necessary to adjust the position of a microscope to keep the phase boundary within view. A boundary typically moves at a speed of the order of microns per hour. Because an experiment can last days or even weeks, it is impractical to require human intervention to keep the phase boundary in view. The present image-data-processing technique yields results within a computation time short enough to enable generation of automated-microscope-positioning commands to track the moving phase boundary.

The experiments that prompted the development of the present technique include a colloidal equivalent of directional solidification. The interactions between the spheres in these suspensions closely approximate an ideal hard-sphere potential, so that the phase behavior becomes, to a close approximation, solely a function of volume fraction (φ) of spheres. When φ of a given suspension sample is less than a threshold value (φ_f = 0.494) denoted the freezing volume fraction, the suspension is in the colloidal-liquid phase, in which the spheres are disordered and free to diffuse throughout the entire volume of the sample. When φ exceeds another threshold value (φ_m = 0.545) denoted the melting volume fraction, the suspension is in the colloidal-solid phase, in which the sample is crystalline in the



This **Image Sequence** illustrates the technique: (a) 1st image in the experiment sequence, (b) 1st automated interface technique (*n*=10) result superimposed on original image, (c) 1st automated interface technique (*n*=10) and authors' results superimposed on original image, and (d) 1st automated interface technique (*n*=10) and independent experts' results superimposed on original image.

sense that each sphere is "caged" by its neighbors and thus restricted to small movement about a lattice point. Between φ_f and φ_m is a regime of coexisting colloidal liquid and colloidal solid.

At the beginning of an experiment, a suspension is prepared at φ well below φ_f and placed in a cell. Then through slow evaporation or gravitational sedimentation, the spheres become concentrated toward one end of the cell, where crystallization starts when φ_f is reached. When the sphere size falls within a range accessible to optical microscopy, the disordered (liquid) phase and the ordered (solid) phase (and, hence, the boundary between them) are visible to, and clearly distinguishable by, a human observer. However, prior image-data-processing techniques do not enable automated distinction between regions of order and disorder in images of closely packed spheres.

In the present technique, automated distinction (see figure) is made possible by differences between the motions of the spheres in the liquid and solid regions. In particular, the technique exploits the fact that in the solid phase, the spheres are restricted to their small "cages," whereas in the liquid phase, the spheres are free to move. Consequently, when images are averaged over successive frame periods, the liquid region tends to become blurred or gray while the solid region retains a higher degree of contrast, showing the spheres as individual particles. Each frame-averaged image is subjected to a brightness-slicing, a cleaning (noise-suppression), and a particle-finding operation. These operations utilize the brightness and contrast differences between the solid and liquid regions. Then the image region showing particles is deemed to be the solid region and the phase boundary is located accordingly.

This work was done by Mark McDowell and Richard B. Rogers of Glenn Research Center and Elizabeth Gray of Scientific Consulting, Inc. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18157-1.

Low-Complexity Lossless and Near-Lossless Data Compression Technique for Multispectral Imagery

The technique allows substantially smaller compressed file sizes when a small amount of distortion can be tolerated.

NASA's Jet Propulsion Laboratory, Pasadena, California

This work extends the lossless data compression technique described in "Fast Lossless Compression of Multispectral-Image Data," (NPO-42517) *NASA Tech Briefs*, Vol. 30, No. 8 (August 2006), page 26. The original technique was extended to include a near-lossless compression option, allowing substantially smaller compressed file sizes when a small amount of distortion can be tolerated. Near-lossless compression is obtained by including a quantization step prior to encoding of prediction residuals.

The original technique uses lossless predictive compression and is designed for use on multispectral imagery. A lossless predictive data compression algorithm compresses a digitized signal one sample at a time as follows: First, a sample value is predicted from previously encoded samples. The difference between the actual sample value and the prediction is called the prediction residual. The prediction residual is encoded into the compressed file. The decompressor can form the same predicted sample and can decode the prediction residual from the compressed file, and so can reconstruct the original sample.

A lossless predictive compression algorithm can generally be converted to a near-lossless compression algorithm by quantizing the prediction residuals prior to encoding them. In this case, since the reconstructed sample values will not be identical to the original sample values, the encoder must determine the values that will be reconstructed and use these values for predicting later sample values. The technique described here uses this method, starting with the original technique, to allow near-lossless compression.

The extension to allow near-lossless compression adds the ability to achieve much more compression when small amounts of distortion are tolerable, while retaining the low complexity and good overall compression effectiveness of the original algorithm.

This work was done by Hua Xie and Matthew A. Klimesh of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-46625