Information Sciences

Single-Point Access to Data Distributed on Many Processors

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A description of the functions and data structures is defined that would be necessary to implement the Chapel concept of distributions, domains, allocation, access, and interfaces to the compiler for transformations from Chapel source to their run-time implementation for these concepts. A complete set of object-oriented operators is defined that enables one to access elements of a distributed array through regular arithmetic index sets, giving the programmer the illusion that all the elements are collocated on a single processor. This means that arbitrary regions of the arrays can be fragmented and distributed across multiple processors with a single point of access. This is important because it can significantly improve programmer productivity by allowing the programmers to concentrate on the high-level details of the algorithm without worrying about the efficiency and communication details of the underlying representation.

This work was done by Mark James of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

The software used in this innovation is available for commercial licensing. Please contact Karina Edmonds of the California Institute of Technology at (626) 395-2322. Refer to NPO-42505.

Estimating Dust and Water Ice Content of the Martian Atmosphere From THEMIS Data

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Researchers at JPL and Arizona State University conducted a comparative study of three candidate algorithms for estimating components of the Martian atmosphere, using raw (uncalibrated) data collected by the Thermal Emission Imaging System (THEMIS). THEMIS is an instrument onboard the Mars Odyssey spacecraft that acquires image data in five visible and nine infrared (IR) wavelength bands. The algorithms under study used data collected from eight of the nine IR bands to estimate the dust and water ice content of the atmosphere. Such an algorithm could be used in onboard data processing to trigger other algorithms that search for features of scientific interest and to reduce the volume of data transmitted to Earth.

The algorithms studied were based on regression models. In the study, the optical depths estimated by these algorithms were compared with optical depths estimated in ground-based processing using fully calibrated data from both THEMIS and the Thermal Emission Spectrometer (TES). TES is an instrument onboard the Mars Global Surveyor spacecraft that also observes the planet at infrared wavelengths, but at a lower spatial resolution than THEMIS does. Of the algorithms studied, the one that performed best was based on a Gaussian Support Vector Machine regression model. The test results indicated that this algorithm, operating on the raw data, had error rates that were within the uncertainty associated with the estimates obtained by the ground-based analysis of the fully calibrated data. This level of fidelity demonstrates that these algorithms are sufficiently accurate for use in an onboard setting.

This work was done by Kiri Wagstaff, Rebecca Castaño, and Steve Chien of Caltech for NASA's Jet Propulsion Laboratory and Joshua Bandfield of the Arizona State University. Further information is contained in a TSP (see page 1).

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Computing a Stability Spectrum by Use of the HHT

Unlike in the predecessor method, the mathematical sign of the damping is retained.

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The Hilbert-Huang transform (HHT) is part of the mathematical basis of a method of calculating a stability spectrum. This method can be regarded as an extended and improved version of a prior HHT-based method of calculating a damping spectrum. In the prior method, information on positive damping (which leads to stability) and negative damping (which leads to instability) becomes mixed into a single squared damping loss factor. Hence, there is no way to distinguish between stability and instability by examining a damping spectrum. In contrast, in the present stability-spectrum method, information on the mathematical sign of the damping is retained, making it possible to identify regions of instability in a spectrum. This method is expected to be especially useful for analyzing vibration-test data for the purpose of predicting vibrational instabilities in structures (e.g., flutter in airplane wings).

A brief summary of the HHT is prerequisite to a meaningful brief summary of the present method. The HHT has been a topic of several prior *NASA Tech Briefs'* articles, the first and most detailed being "Analyzing Time Series Using EMD and Hilbert Spectra" (GSC-13817), *NASA Tech Briefs*, Vol. 24, No. 10 (October 2000), page 63. To recapitulate: The HHT method is especially suitable for analyzing time-series data that represent nonstationary and nonlinear physical phenomena. The method involves the empirical mode decomposition (EMD), in which a complicated signal is decomposed into a finite number of functions, called "intrinsic mode functions" (IMFs), that admit well-behaved Hilbert transforms. The HHT consists of the combination of EMD and Hilbert spectral analysis.

An unavoidably lengthy description of the mathematical basis of the prior damping-spectrum method is also prerequisite to a meaningful brief summary of the present method. The instantaneous amplitude of a vibration signal at time t is given by

$$x(t) = \sum_{j=1}^{n} c_j(t) + r_n$$

where n is an integer, $c_j(t)$ is an IMF, and r_n is a residue signal.

For each IMF (for example, the kth one), a Hilbert transform is performed to obtain a complex time-dependent function: $z_k(t) = c_k(t) + id_k(t)$.

The time-dependent amplitude $[a_k(t)]$, phase $[\theta_k(t)]$, and frequency $[\omega_k(t)]$ of the kth IMF are then given by

$$a_k(t) = \left[c_k^2(t) + d_k^2(t)\right]^{1/2};$$

$$\theta_k(t) = \tan^{-1}\frac{d_k(t)}{c_k(t)}, \text{ and}$$

$$\omega_k(t) = -\frac{d\theta_k(t)}{dt}.$$

The damping of the kth IMF is given by

$$\gamma_k(t) = -\frac{2}{a_k(t)}\frac{da_k(t)}{dt}.$$

The damping loss factor of the kth IMF is then given by

$$\eta_k(t) = -\frac{2}{a_k(t)}\frac{da_k(t)}{dt}\frac{1}{\omega_{0k}},$$

where

$$\omega_{0k} = \left[\omega_k^2(t) + \left(\frac{\gamma_k(t)}{2}\right)^2\right]^{1/2}.$$

Then summing all the squared damping loss factors as functions of time and frequency and letting frequency become a continuous variable ω, one obtains the damping spectrum $\eta^2(\omega,t)$, which is related to an amplitude spectrum $a(\omega,t)$ via the equation

$$\eta^2(\omega,t) = \frac{\left[\frac{-2}{a(\omega,t)}\frac{da(\omega,t)}{dt}\right]^2}{\omega^2 + \left[\frac{1}{a(\omega,t)}\frac{da(\omega,t)}{dt}\right]^2}$$

This concludes the description of the prior method.

In the present method, one computes a damping loss factor $\eta_k(t)$ or $\eta(\omega,t)$ by use of equations similar to those shown above, but with the following notable differences:

- Instead of using the Hilbert transform to compute a complex function and then using the complex function to compute the amplitude function, one uses a cubic spline to compute the amplitude function. The reason for this change is that in a practical implementation, a Hilbert transform can introduce spurious oscillations that can mask true damping or anti-damping, whereas any spurious oscillations introduced by a cubic spline are much smaller.
- The instantaneous frequency $\omega_k(t)$ or $\omega(t)$ is not calculated as indicated above. Instead, it is calculated by use of the normalized HHT. This change is necessitated by a limitation of the Hilbert transform — too complex to discuss here — that has been a topic of prior publications.
- One retains the sign of the damping by simply refraining from squaring the damping loss factor: in other words, $\eta(\omega,t)$ becomes the stability spectrum. Areas of positive and negative damping can be readily distinguished on a plot of the spectrum. To make areas of negative damping even more readily apparent, it could be desirable, in some cases, to place areas of positive damping and areas of negative damping on separate plots.

This work was done by Norden E. Huang of Goddard Space Flight Center. Further information is contained in a TSP (see page 1).
GSC-14833-1