Information Sciences

Ascent Heating Thermal Analysis on Spacecraft Adaptor Fairings

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When the Crew Exploration Vehicle (CEV) is launched, the spacecraft adaptor (SA) fairings that cover the CEV service module (SM) are exposed to aero heating. Thermal analysis is performed to compute the fairing temperatures and to investigate whether the temperatures are within the material limits for nominal ascent aero-heating case. The ascent heating is analyzed by using computational fluid dynamics (CFD) and engineering codes at Marshall Space Flight Center. The aero-heating environment data used for this work is known as Thermal Environment 3 (TE3) heating data. One of the major concerns is with the SA fairings covering the CEV SM and the SM/crew launch vehicle (CLV) flange interface. The TE3 heating

rate is a function of time, wall temperature, and the spatial locations. The implementation of the TE3 heating rate as boundary conditions in the thermal analysis becomes challenging.

The ascent heating thermal analysis on SA fairings and SM/CLV flange interface are performed using two commercial software packages: Cullimore & Ring (C&R) Thermal Desktop (TD) 5.1 and MSC Patran 2007r1 b. TD is the pre- and post-processor for SINDA, which is a finite-difference-based solver. In TD, the geometry is built and meshed, the boundary conditions are defined, and then SINDA is used to compute temperatures. MSC Pthermal is a finite-element-based thermal solver. MSC Patran

is the pre- and post-processor for Pthermal. Regarding the boundary conditions, the convection, contact resistance, and heat load can be imposed in different ways in both programs. These two software packages are used to build the thermal model for the same analysis to validate each other and show the differences in the modeling details.

This work was done by Xiao Yen Wang, James Yuko, and Brian Motil of Glenn Research Center.

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-18471-1.

Entanglement in Self-Supervised Dynamics

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A new type of correlation has been developed similar to quantum entanglement in self-supervised dynamics (SSD). SSDs have been introduced as a quantum-classical hybrid based upon the Madelung equation in which the quantum potential is replaced by an information potential. As a result, SSD

preserves the quantum topology along with superposition, entanglement, and wave-particle duality. At the same time, it can be implemented in any scale including the Newtonian scale. The main properties of SSD associated with simulating intelligence have been formulated. The attention with this innova-

tion is focused on intelligent agents' interaction based upon the new fundamental non-Newtonian effect; namely, entanglement.

This work was done by Michail Zak of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-47493

Prioritized LT Codes

These forward erasure correcting codes apply proper matching of data priority and data redundancy to protect against packet drops in image, voice, and video transmissions where not all bits are created equal.

NASA's Jet Propulsion Laboratory, Pasadena, California

The original Luby Transform (LT) coding scheme is extended to account for data transmissions where some information symbols in a message block are more important than others. Prioritized LT codes provide unequal error protection (UEP) of data on an erasure channel by modifying the original LT encoder. The prioritized algorithm improves high-priority data protection

without penalizing low-priority data recovery. Moreover, low-latency decoding is also obtained for high-priority data due to fast encoding. Prioritized LT codes only require a slight change in the original encoding algorithm, and no changes at all at the decoder. Hence, with a small complexity increase in the LT encoder, an improved UEP and low-decoding latency performance for high-

priority data can be achieved.

LT encoding partitions a data stream into fixed-sized message blocks each with a constant number of information symbols. To generate a code symbol from the information symbols in a message, the Robust-Soliton probability distribution is first applied in order to determine the number of information symbols to be used to compute the code symbol. Then,

the specific information symbols are chosen uniform randomly from the message block. Finally, the selected information symbols are XORed to form the code symbol. The Prioritized LT code construction includes an additional restriction that code symbols formed by a relatively small number of XORed information symbols select some of these information symbols from the pool of high-priority data. Once high-priority data are fully covered, encoding continues with the conventional LT approach where code symbols are generated by selecting information symbols from the entire message block including all different priorities. Therefore, if code symbols derived from high-priority data experience an unusual high number of erasures, Prioritized LT codes can still reliably recover both high- and low-priority data. This hybrid approach decides not only "how to encode" but also "what to encode" to achieve UEP. Another advantage of the priority encoding process is that the majority of high-priority data can be decoded sooner since only a small number of code symbols are required to reconstruct high-priority data. This approach increases the likelihood that high-priority data is decoded first over low-priority data.

The Prioritized LT code scheme achieves an improvement in high-priority data decoding performance as well as overall information recovery without penalizing the decoding of low-priority data, assuming high-priority data is no more than half of a message block. The cost is in the additional complexity required in the encoder. If extra computation resource is available at the transmitter, image, voice, and video transmission quality in terrestrial and space communications can benefit from accurate use of redundancy in protecting data with varying priorities.

⟫ Fast Image Texture Classification Using Decision Trees

The algorithms used can be applied to robotics, image retrieval for Web searching, and computer vision for electronic devices.

NASA's Jet Propulsion Laboratory, Pasadena, California

Texture analysis would permit improved autonomous, onboard science data interpretation for adaptive navigation, sampling, and downlink decisions. These analyses would assist with terrain analysis and instrument placement in both macroscopic and microscopic image data products. Unfortunately, most state-of-the-art texture analysis demands computationally expensive convolutions of filters involving many floating-point operations. This makes them infeasible for radiation-hardened computers and spaceflight hardware.

A new method approximates traditional texture classification of each image pixel with a fast decision-tree classifier. The classifier uses image features derived from simple filtering operations involving integer arithmetic. The texture analysis method is therefore amenable to implementation on FPGA (field-programmable gate array) hardware.

Image features based on the "integral image" transform produce descriptive and efficient texture descriptors. Training the decision tree on a set of training data yields a classification scheme that produces reasonable approximations of optimal "texton" analysis at a fraction of the computational cost. A decision-tree learning algorithm employing the traditional k-means criterion of inter-cluster variance is used to learn tree structure from training data. The result is an efficient and accurate summary of surface morphology in images.

This work is an evolutionary advance that unites several previous algorithms (k-means clustering, integral images, decision trees) and applies them to a new problem domain (morphology analysis for autonomous science during remote exploration). Advantages include order-of-magnitude improvements in runtime, feasibility for FPGA hardware, and significant improvements in texture classification accuracy.

⟫ Constraint Embedding Technique for Multibody System Dynamics

This approach is applicable to multibody dynamics modeling of vehicles and robots.

NASA's Jet Propulsion Laboratory, Pasadena, California

Multibody dynamics play a critical role in simulation testbeds for space missions. There has been a considerable interest in the development of efficient computational algorithms for solving the dynamics of multibody systems. Mass matrix factorization and inversion techniques and the $O(N)$ class of forward dynamics algorithms developed using a spatial operator algebra stand out as important breakthrough on this front. Techniques such as these provide the efficient algorithms and methods for the application and implementation of such multibody dynamics models. However, these methods are limited only to tree-topology multibody systems.

Closed-chain topology systems require different techniques that are not as efficient or as broad as those for tree-topolgy systems. The closed-chain forward dynamics approach consists of treating the closed-chain topology as a tree-topology system subject to additional closure constraints. The resulting forward dynamics solution consists of: (a) ignoring the closure constraints and using the $O(N)$ algorithm to solve for the "free" unconstrained accelerations for the system; (b) using the tree-topology solution to compute a correction