Information Sciences

Thermal Management Tools for Propulsion System Trade Studies and Analysis

Applications include modeling and simulation in building and data center cooling analysis, and in ground-based vehicle studies.

John H. Glenn Research Center, Cleveland, Ohio

Energy-related subsystems in modern aircraft are more tightly coupled with less design margin. These subsystems include thermal management subsystems, vehicle electric power generation and distribution, aircraft engines, and flight control. Tighter coupling, lower design margins, and higher system complexity all make preliminary trade studies difficult. A suite of thermal management analysis tools has been developed to facilitate trade studies during preliminary design of air-vehicle propulsion systems.

Simulink blocksets (from MathWorks) for developing quasi-steady-state and transient system models of aircraft thermal management systems and related energy systems have been developed. These blocksets extend the Simulink modeling environment in the thermal sciences and aircraft systems disciplines. The blocksets include blocks for modeling aircraft system heat loads, heat exchangers, pumps, reservoirs, fuel tanks, and other components at varying levels of model fidelity.

The blocksets have been applied in a first-principles, physics-based modeling and simulation architecture for rapid prototyping of aircraft thermal management and related systems. They have been applied in representative modern aircraft thermal management system studies. The modeling and simulation architecture has also been used to conduct trade studies in a vehicle level model that incorporates coupling effects among the aircraft mission, engine cycle, fuel, and multi-phase heat-transfer materials.

This work was done by Kevin McCarthy of PC Krause & Associates and Ernie Hodge of Modelogics for Glenn Research Center. For further information contact Dr. Jeffrey Dalton, Avetec Chief Technology Officer, jdalton@avetec.org.

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-18463-1/4-1.

Introduction to Physical Intelligence

NASA's Jet Propulsion Laboratory, Pasadena, California

A slight deviation from Newtonian dynamics can lead to new effects associated with the concept of physical intelligence. Non-Newtonian effects such as deviation from classical thermodynamic as well as quantum-like properties have been analyzed.

A self-supervised ("intelligent") particle that can escape from Brownian motion autonomously is introduced. Such a capability is due to a coupling of the particle governing equation with its own Liouville equation via an appropriate feedback. As a result, the governing equation is self-stabilized, and random oscillations are suppressed, while the Liouville equation takes the form of the Fokker-Planck equation with negative diffusion. Non-Newtonian properties of such a dynamical system as well as thermodynamical implications have been evaluated.

This work was done by Michail Zak of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-47165

Technique for Solving Electrically Small to Large Structures for Broadband Applications

Methods are combined.

Lyndon B. Johnson Space Center, Houston, Texas

Fast iterative algorithms are often used for solving Method of Moments (MoM) systems, having a large number of unknowns, to determine current distribution and other parameters. The most commonly used fast methods include the fast multipole method (FMM), the precorrected fast Fourier transform (PFFT), and low-rank QR compression methods. These methods reduce the $O(N)$ memory and time requirements to $O(N \log N)$ by compressing the dense MoM system so as to exploit the physics of Green's Function interactions.

FFT-based techniques for solving such problems are efficient for space-filling and uniform structures, but their performance substantially degrades for non-uniformly distributed structures due to the inherent need to employ a uniform global grid. FMM or QR techniques are better suited than FFT techniques; however, neither the FMM nor the QR technique can be used at all frequencies.

This method has been developed to efficiently solve for a desired parameter of a system or device that can include both electrically large FMM elements, and electrically small QR elements. The system or device is set up as an oct-tree structure that can include regions of both the FMM type and the QR type. The system is enclosed with a cube at a 0-th level, splitting the cube at the 0-th level into eight child cubes. This forms cubes at a 1-st level, recursively repeating the splitting process for cubes at successive levels until a desired number of levels is created. For each cube that is thus formed, neighbor lists and interaction lists are maintained.

An iterative solver is then used to determine a first matrix vector product for any electrically large elements as well as a second matrix vector product for any electrically small elements that are included in the structure. These matrix vector products for the electrically large and small elements are combined, and a net delta for a combination of the matrix vector products is determined. The iteration continues until a net delta is obtained that is within the predefined limits. The matrix vector products that were last obtained are used to solve for the desired parameter. The solution for the desired parameter is then presented to a user in a tangible form; for example, on a display.

This work was done by Vikram Jandhyala and Indranil Chowdhury of the University of Washington for Johnson Space Center. For further information, contact the Johnson Technology Transfer Office at (281) 483-3809.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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Refer to MSC-24439-1, volume and number of this NASA Tech Briefs *issue, and the page number.*

Accelerated Adaptive MGS Phase Retrieval

NASA's Jet Propulsion Laboratory, Pasadena, California

The Modified Gerchberg-Saxton (MGS) algorithm is an image-based wavefront-sensing method that can turn any science instrument focal plane into a wavefront sensor. MGS characterizes optical systems by estimating the wavefront errors in the exit pupil using only intensity images of a star or other point source of light. This innovative implementation of MGS significantly accelerates the MGS phase retrieval algorithm by using stream-processing hardware on conventional graphics cards.

Stream processing is a relatively new, yet powerful, paradigm to allow parallel processing of certain applications that apply single instructions to multiple data (SIMD). These stream processors are designed specifically to support large-scale parallel computing on a single graphics chip. Computationally intensive algorithms, such as the Fast Fourier Transform (FFT), are particularly well suited for this computing environment. This high-speed version of MGS exploits commercially available hardware to accomplish the same objective in a fraction of the original time. The exploit involves performing matrix calculations in nVidia graphic cards. The graphical processor unit (GPU) is hardware that is specialized for computationally intensive, highly parallel computation.

From the software perspective, a parallel programming model is used, called CUDA, to transparently scale multicore parallelism in hardware. This technology gives computationally intensive applications access to the processing power of the nVidia GPUs through a C/C++ programming interface. The AAMGS (Accelerated Adaptive MGS) software takes advantage of these advanced technologies, to accelerate the optical phase error characterization. With a single PC that contains four nVidia GTX-280 graphic cards, the new implementation can process four images simultaneously to produce a JWST (James Webb Space Telescope) wavefront measurement 60 times faster than the previous code.

This work was done by Raymond K. Lam, Catherine M. Ohara, Joseph J. Green, Siddarayappa A. Bikkannavar, Scott A. Basinger, David C. Redding, and Fang Shi of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov.

The software used in this innovation is available for commercial licensing. Please contact Daniel Broderick of the California Institute of Technology at danielb@caltech.edu. Refer to NPO-47101.

Large Eddy Simulation Study for Fluid Disintegration and Mixing

This work is directly applicable to simulations of gas turbine engines and rocket engines.

NASA's Jet Propulsion Laboratory, Pasadena, California

A new modeling approach is based on the concept of large eddy simulation (LES) within which the large scales are computed and the small scales are modeled. The new approach is expected to retain the fidelity of the physics while also being computationally efficient. Typically, only models for the small-scale fluxes of momentum, species, and enthalpy are used to reintroduce in the simulation the physics lost because the computation only resolves the large scales. These models are called subgrid (SGS) models because they operate at a scale smaller than the LES grid.

In a previous study of thermodynamically supercritical fluid disintegration and