Information Sciences

Base Flow Model Validation

Marshall Space Flight Center, Alabama

A method was developed of obtaining propulsive base flow data in both hot and cold jet environments, at Mach numbers and altitude of relevance to NASA launcher designs. The base flow data was used to perform computational fluid dynamics (CFD) turbulence model assessments of base flow predictive capabilities in order to provide increased confidence in base thermal and pressure load predictions obtained from computational modeling efforts. Predictive CFD analyses were used in the design of the experiments, available propulsive models were used to reduce program costs and increase success, and a wind tunnel facility was used.

The data obtained allowed assessment of CFD/turbulence models in a complex flow environment, working within a building-block procedure to validation, where cold, non-reacting test data was first used for validation, followed by more complex reacting base flow validation.

This work was done by Neeraj Sinha and Kevin Brinckman of Combustion Research and Flow Technology, and Bernard Jansen and John Seiner of the University of Mississippi for Marshall Space Flight Center. For more information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-32779-1.

Minimum Landing Error Powered-Descent Guidance for Planetary Missions

NASA's Jet Propulsion Laboratory, Pasadena, California

An algorithm improves the accuracy with which a lander can be delivered to the surface of Mars. The main idea behind this innovation is the use of a "lossless convexification," which converts an otherwise non-convex constraint related to thruster throttling to a convex constraint, enabling convex optimization to be used. The convexification leads directly to an algorithm that guarantees finding the global optimum of the original nonconvex optimization problem with a deterministic upper bound on the number of iterations required for convergence.

In this innovation, previous work in powered-descent guidance using convex optimization is extended to handle the case where the lander must get as close as possible to the target given the available fuel, but is not required to arrive exactly at the target. The new algorithm calculates the minimum-fuel trajectory to the target, if one exists, and calculates the trajectory that minimizes the distance to the target if no solution to the target exists. This approach poses the problem as two Second-Order Cone Programs, which can be solved to global optimality with deterministic bounds on the number of iterations required.

This work was done by Lars Blackmore and Behcet Acikmese of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov.

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 NPO-46647, volume and number of this NASA Tech Briefs *issue, and the page number.*

Framework for Integrating Science Data Processing Algorithms Into Process Control Systems

This technique can be used for data processing and management systems.

NASA's Jet Propulsion Laboratory, Pasadena, California

A software framework called PCS Task Wrapper is responsible for standardizing the setup, process initiation, execution, and file management tasks surrounding the execution of science data algorithms, which are referred to by NASA as Product Generation Executives (PGEs). PGEs codify a scientific algorithm, some step in the overall scientific process involved in a mission science workflow.

The PCS Task Wrapper provides a stable operating environment to the underlying PGE during its execution lifecycle. If the PGE requires a file, or metadata regarding the file, the PCS Task Wrapper is responsible for delivering that information to the PGE in a manner that meets its requirements. If the PGE requires knowledge of upstream or downstream PGEs in a sequence of executions, that information is also made available. Finally, if information regarding disk space, or node information such as CPU availability, etc., is required, the PCS Task Wrapper provides this information to the underlying PGE.

After this information is collected, the PGE is executed, and its output Product file and Metadata generation is managed via the PCS Task Wrapper framework. The innovation is responsible for marshalling output Products and Metadata back to a PCS File Management component for use in downstream data processing and pedigree. In support of this, the PCS Task Wrapper leverages the PCS Crawler Framework to ingest (during pipeline processing) the output Product files and Metadata produced by the PGE.

The architectural components of the PCS Task Wrapper framework include PGE Task Instance, PGE Config File Builder, Config File Property Adder, Science PGE Config File Writer, and PCS Met file Writer. This innovative framework is really the unifying bridge between the execution of a step in the overall processing pipeline, and the available PCS component services as well as the information that they collectively manage.

This work was done by Chris A. Mattmann, Daniel J. Crichton, Albert Y. Chang, Brian M. Foster, Dana J. Freeborn, David M. Woollard, and Paul M. Ramirez of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov.

This software is available for commercial licensing. Please contact Daniel Broderick of the California Institute of Technology at danielb@caltech.edu. Refer to NPO-47160.

Time Synchronization and Distribution Mechanisms for Space Networks

NASA's Jet Propulsion Laboratory, Pasadena, California

This work discusses research on the problems of synchronizing and distributing time information between spacecraft based on the Network Time Protocol (NTP), where NTP is a standard time synchronization protocol widely used in the terrestrial network. The Proximity-1 Space Link Interleaved Time Synchronization (PITS) Protocol was designed and developed for synchronizing spacecraft that are in "proximity" where "proximity" is less than 100,000 km distant. A particular application is synchronization between a Mars orbiter and rover. Lunar scenarios as well as outer-planet deep space mother-ship-probe missions may also apply.

Spacecraft with more accurate time information functions as a time-server, and the other spacecraft functions as a time-client. PITS can be easily integrated and adaptable to the CCSDS Proximity-1 Space Link Protocol with minor modifications. In particular, PITS can take advantage of the timestamping strategy that underlying link layer functionality provides for accurate time offset calculation. The PITS algorithm achieves time synchronization with eight consecutive space network time packet exchanges between two spacecraft. PITS can detect and avoid possible errors from receiving duplicate and out-of-order packets by comparing with the current state variables and timestamps. Further, PITS is able to detect error events and autonomously recover from unexpected events that can possibly occur during the time synchronization and distribution process. This capability achieves an additional level of protocol protection on top of CRC or Error Correction Codes. PITS is a lightweight and efficient protocol, eliminating the needs for explicit frame sequence number and long buffer storage.

The PITS protocol is capable of providing time synchronization and distribution services for a more general domain where multiple entities need to achieve time synchronization using a single point-to-point link.

This work was done by Simon S. Woo, Jay L. Gao, and Loren P. Clare of Caltech, and David L. Mills of University of Delaware for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-47403

Local Estimators for Spacecraft Formation Flying

NASA's Jet Propulsion Laboratory, Pasadena, California

A formation estimation architecture for formation flying builds upon the local information exchange among multiple local estimators. Spacecraft formation flying involves the coordination of states among multiple spacecraft through relative sensing, inter-spacecraft communication, and control. Most existing formation flying estimation algorithms can only be supported via highly centralized, all-to-all, static relative sensing. New algorithms are needed that are scalable, modular, and robust to variations in the topology and link characteristics of the formation exchange network. These distributed algorithms should rely on a local information-exchange network, relaxing the assumptions on existing algorithms.

In this research, it was shown that only local observability is required to design a formation estimator and control law. The approach relies on breaking up the overall information-exchange network into sequence of local subnetworks, and invoking an agreement-type filter to reach consensus among local estimators within each local network. State estimates were obtained by a set of local measurements that were passed through a set of communicating Kalman filters to reach an overall state estimation for the formation.

An optimization approach was also presented by means of which diffused estimates over the network can be incorporated in the local estimates obtained