Information Sciences

Safe Onboard Guidance and Control Under Probabilistic Uncertainty

NASA's Jet Propulsion Laboratory, Pasadena, California

An algorithm was developed that determines the fuel-optimal spacecraft guidance trajectory that takes into account uncertainty, in order to guarantee that mission safety constraints are satisfied with the required probability. The algorithm uses convex optimization to solve for the optimal trajectory. Convex optimization is amenable to onboard solution due to its excellent convergence properties.

The algorithm is novel because, unlike prior approaches, it does not require time-consuming evaluation of multivariate probability densities. Instead, it uses a new mathematical bounding approach to ensure that probability constraints are satisfied, and it is shown that the resulting optimization is convex. Empirical results show that the approach is many orders of magnitude less conservative than existing set conversion techniques, for a small penalty in computation time.

This work was done by Lars James Blackmore of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-46155

General Tool for Evaluating High-Contrast Coronagraphic Telescope Performance Error Budgets

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The Coronagraph Performance Error Budget (CPEB) tool automates many of the key steps required to evaluate the scattered starlight contrast in the dark hole of a space-based coronagraph. The tool uses a Code V prescription of the optical train, and uses MATLAB programs to call ray-trace code that generates linear beam-walk and aberration sensitivity matrices for motions of the optical elements and line-of-sight pointing, with and without controlled fine-steering mirrors (FSMs). The sensitivity matrices are imported by macros into Excel 2007, where the error budget is evaluated. The user specifies the particular optics of interest, and chooses the quality of each optic from a predefined set of PSDs. The spreadsheet creates a nominal set of thermal and jitter motions, and combines that with the sensitivity matrices to generate an error budget for the system.

CPEB also contains a combination of form and ActiveX controls with Visual Basic for Applications code to allow for user interaction in which the user can perform trade studies such as changing engineering requirements, and identifying and isolating stringent requirements. It contains summary tables and graphics that can be instantly used for reporting results in view graphs.

The entire process to obtain a coronagraphic telescope performance error budget has been automated into three stages: conversion of optical prescription from Zemax or Code V to MACOS (in-house optical modeling and analysis tool), a linear models process, and an error budget tool process. The first process was improved by developing a MATLAB package based on the Class Constructor Method with a number of user-defined functions that allow the user to modify the MACOS optical prescription. The second process was modified by creating a MATLAB package that contains user-defined functions that automate the process. The user interfaces with the process by utilizing an initialization file where the user defines the parameters of the linear model computations. Other than this, the process is fully automated. The third process was developed based on the Terrestrial Planet Finder coronagraph Error Budget Tool, but was fully automated by using VBA code, form, and ActiveX controls.

This work was done by Luis F. Marchen 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-47220.

Hidden Statistics of Schrödinger Equation

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Work was carried out in determination of the mathematical origin of randomness in quantum mechanics and creating a hidden statistics of Schrödinger equation; i.e., to expose the transitional stochastic process as a "bridge" to the quantum world. The governing equations of hidden statistics would preserve such properties of quantum physics as superposition, entanglement, and direct-product decomposability while allowing one to measure its state variables using classical methods. In other words, such a system would reinforce the advantages and minimize the limitations of both quantum and classical aspects, and therefore, it will be useful for implementation of quantum computing.

Recent advances in quantum information theory have inspired an explosion of interest in new quantum algorithms for solving hard computational problems. Three basic "non-classical" properties of quantum mechanics — superposition, entanglement, and direct tensor-product decomposability — were main reasons for optimism about capabilities of quantum computers and quantum communications as well as for a new approach to cryptography. However, one major problem is keeping the components of a quantum computer in a coherent state, as the slightest interaction with the external world would cause the system to decohere. Another problem is measurement: by the laws of quantum mechanics, a measurement yields a random and incomplete answer, and it destroys the stored state.

This proposed reinterpretation of quantum formalism opens up new advantages of quantum computers: if the Madelung equations are implemented on a classical scale (using, for instance, electrical circuits or optical devices), all the quantum effects important for computations would be preserved; at the same time, the problems associated with decoherence and measurement would be removed.

This work was done by Michail Zak of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-46731

Optimal Padding for the Two-Dimensional Fast Fourier Transform

Appending data to an optimum length decreases computing runtime.

Goddard Space Flight Center, Greenbelt, Maryland

One-dimensional Fast Fourier Transform (FFT) operations work fastest on grids whose size is divisible by a power of two. Because of this, padding grids (that are not already sized to a power of two) so that their size is the next highest power of two can speed up operations. While this works well for one-dimensional grids, it does not work well for two-dimensional grids.

For a two-dimensional grid, there are certain pad sizes that work better than others. Therefore, the need exists to generalize a strategy for determining optimal pad sizes. There are three steps in the FFT algorithm. The first is to perform a one-dimensional transform on each row in the grid. The second step is to transpose the resulting matrix. The third step is to perform a one-dimensional transform on each row in the resulting grid. Steps one and three both benefit from padding the row to the next highest power of two, but the second step needs a novel approach.

An algorithm was developed that struck a balance between optimizing the grid pad size with prime factors that are small (which are optimal for one-dimensional operations), and with prime factors that are large (which are optimal for two-dimensional operations). This algorithm optimizes based on average run times, and is not fine-tuned for any specific application. It increases the amount of times that processor-requested data is found in the set-associative processor cache. Cache retrievals are 4–10 times faster than conventional memory retrievals.

The tested implementation of the algorithm resulted in faster execution times on all platforms tested, but with varying sized grids. This is because various computer architectures process commands differently. The test grid was 512×512. Using a 540×540 grid on a Pentium V processor, the code ran 30 percent faster. On a PowerPC, a 256×256 grid worked best. A Core2Duo computer preferred either a 1040×1040 (15 percent faster) or a 1008×1008 (30 percent faster) grid.

There are many industries that can benefit from this algorithm, including optics, image-processing, signal-processing, and engineering applications.

This work was done by Bruce H. Dean, David L. Aronstein, and Jeffery S. Smith of Goddard Space Flight Center. Further information is contained in a TSP (see page 1).

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center, (301) 286-7351. Refer to GSC-15678-1.

Spatial Query for Planetary Data

This technology is extensible to Earth science and satellite monitoring and surveillance.

NASA's Jet Propulsion Laboratory, Pasadena, California

Science investigators need to quickly and effectively assess past observations of specific locations on a planetary surface. This innovation involves a location-based search technology that was adapted and applied to planetary science data to support a spatial query capability for mission operations software.

Conventional databases of planetary datasets are indexed and searchable by various metadata, such as acquisition time, phase of mission, and target. Searching these datasets will produce enormous datasets that are difficult, or impractical, to browse through to identify observations of very specific targets. For queries at specific locations, it is fundamentally more efficient to specify the location as the target of the query; and to have the database search based on the location of the data rather than metadata that is only indirectly or tangentially related to location.

High-performance location-based searching requires the use of spatial data structures for database organization. Spatial data structures are designed to organize datasets based on their coordinates in a way that is optimized for location-based retrieval. The particular spatial data structure that was adapted for planetary data search is the R+ tree. The R+ tree arranges data as a set of nodes that represents bounding rectangles. Every leaf