Rapid Calculation of Spacecraft Trajectories Using Efficient Taylor Series Integration

Software greatly accelerates the calculation of spacecraft trajectories.

John H. Glenn Research Center, Cleveland, Ohio

A variable-order, variable-step Taylor series integration algorithm was implemented in NASA Glenn's SNAP (Spacecraft N-body Analysis Program) code. SNAP is a high-fidelity trajectory propagation program that can propagate the trajectory of a spacecraft about virtually any body in the solar system. The Taylor series algorithm's very high order accuracy and excellent stability properties lead to large reductions in computer time relative to the code's existing 8th order Runge-Kutta scheme. Head-to-head comparison on near-Earth, lunar, Mars, and Europa missions showed that Taylor series integration is 15.8 times faster than Runge-Kutta on average, and is more accurate. These speedups were obtained for calculations involving central body, other body, thrust, and drag forces. Similar speedups have been obtained for calculations that include J2 spherical harmonic for central body gravitation. The algorithm includes a step size selection method that directly calculates the step size and never requires a repeat step.

High-order Taylor series integration algorithms have been shown to provide major reductions in computer time over conventional integration methods in numerous scientific applications. The objective here was to directly implement Taylor series integration in an existing trajectory analysis code and demonstrate that large reductions in computer time (order of magnitude) could be achieved while simultaneously maintaining high accuracy.

This software greatly accelerates the calculation of spacecraft trajectories. At each time level, the spacecraft position, velocity, and mass are expanded in a high-order Taylor series whose coefficients are obtained through efficient differentiation arithmetic. This makes it possible to take very large time steps at minimal cost, resulting in large savings in computer time. The Taylor series algorithm is implemented primarily through three subroutines: (1) a driver routine that automatically introduces auxiliary variables and sets up initial conditions and integrates; (2) a routine that calculates system reduced derivatives using recurrence relations for quotients and products; and (3) a routine that determines the step size and sums the series. The order of accuracy used in a trajectory calculation is arbitrary and can be set by the user. The algorithm directly calculates the motion of other planetary bodies and does not require ephemeris files (except to start the calculation). The code also runs with Taylor series and Runge-Kutta used interchangeably for different phases of a mission.

This work was done by James R. Scott and Michael C. Martini of Glenn Research Center. Further information is contained in a TSP (see page 1).

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-18445-1.

Efficient Kriging Algorithms

Goddard Space Flight Center, Greenbelt, Maryland

More efficient versions of an interpolation method, called kriging, have been introduced in order to reduce its traditionally high computational cost. Written in C++, these approaches were tested on both synthetic and real data.

Kriging is a best unbiased linear estimator and suitable for interpolation of scattered data points. Kriging has long been used in the geostatistic and mining communities, but is now being researched for use in the image fusion of remotely sensed data. This allows a combination of data from various locations to be used to fill in any missing data from any single location.

To arrive at the faster algorithms, sparse SYMMLQ iterative solver, covariance tapering, Fast Multipole Methods (FMM), and nearest neighbor searching techniques were used. These implementations were used when the coefficient matrix in the linear system is symmetric, but not necessarily positive-definite.

This work was done by Nargess Memarsadeghi of Goddard Space Flight Center. For further information, contact the Goddard Innovative Partnerships Office at (301) 286-5810. GSC-15555-1

Predicting Spacecraft Trajectories by the WeavEncke Method

Lyndon B. Johnson Space Center, Houston, Texas

A combination of methods is proposed of predicting spacecraft trajectories that possibly include multiple maneuvers and/or perturbing accelerations, with greater speed, accuracy, and repeatability than were heretofore achievable. The combination is denoted the WeavEncke method because it is based on unpublished studies by Jonathan Weaver of the orbit-prediction formulation of the noted astronomer Johann Franz Encke. Weaver evaluated a number of alternatives that arise within that formulation, arriving at an orbit-predicting algorithm optimized for complex trajectory operations.

In the WeavEncke method, Encke's method of prediction of perturbed orbits is enhanced by application of mod-