Mixed Integer Programming and Heuristic Scheduling for Space Communication

NASA's Jet Propulsion Laboratory, Pasadena, California

Optimal planning and scheduling for a communication network was created where the nodes within the network are communicating at the highest possible rates while meeting the mission requirements and operational constraints. The planning and scheduling problem was formulated in the framework of Mixed Integer Programming (MIP) to introduce a special penalty function to convert the MIP problem into a continuous optimization problem, and to solve the constrained optimization problem using heuristic optimization.

The communication network consists of space and ground assets with the link dynamics between any two assets varying with respect to time, distance, and telecom configurations. One asset could be communicating with another at very high data rates at one time, and at other times, communication is impossible, as the asset could be inaccessible from the network due to planetary occultation. Based on the network's geometric dynamics and link capabilities, the start time, end time, and link configuration of each view period are selected to maximize the communication efficiency within the network.

Mathematical formulations for the constrained mixed integer optimization problem were derived, and efficient analytical and numerical techniques were developed to find the optimal solution. By setting up the problem using MIP, the search space for the optimization problem is reduced significantly, thereby speeding up the solution process. The ratio of the dimension of the traditional method over the proposed formulation is approximately an order N (single) to $2*N$ (arraying), where N is the number of receiving antennas of a node. By introducing a special penalty function, the MIP problem with non-differentiable cost function and nonlinear constraints can be converted into a continuous variable problem, whose solution is possible.

This work was done by Charles H. Lee and Kar-Ming Cheung 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 Dan Broderick at Daniel.F.Broderick@jpl.nasa.gov. Refer to NPO-48485.

Video Altimeter and Obstruction Detector for an Aircraft

Lyndon B. Johnson Space Center, Houston, Texas

Video-based altimetric and obstruction-detection systems for aircraft have been partially developed. The hardware of a system of this type includes a downward-looking video camera, a video digitizer, a Global Positioning System receiver or other means of measuring the aircraft velocity relative to the ground, a gyroscope-based or other attitude-determination subsystem, and a computer running altimetric and/or obstruction-detection software.

From the digitized video data, the altimetric software computes the pixel velocity in an appropriate part of the video image and the corresponding angular relative motion of the ground within the field of view of the camera. Then by use of trigonometric relationships among the aircraft velocity, the attitude of the camera, the angular relative motion, and the altitude, the software computes the altitude. The obstruction-detection software performs somewhat similar calculations as part of a larger task in which it uses the pixel-velocity data from the entire video image to compute a depth map, which can be correlated with a terrain map, showing locations of potential obstructions. The depth map can be used as real-time hazard display and/or to update an obstruction database.

This work was done by Frank J. Delgado of Johnson Space Center and Michael F. Abernathy, Janis White, and William R. Dolson of Rapid Imaging Software, Inc. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809. MSC-24246-1/7-1

Control Software for Piezo Stepping Actuators

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A control system has been developed for the Space Interferometer Mission (SIM) piezo stepping actuator. Piezo stepping actuators are novel because they offer extreme dynamic range (centimeter stroke with nanometer resolution) with power, thermal, mass, and volume advantages over existing motorized actuation technology. These advantages come with the added benefit of greatly reduced complexity in the support electronics. The piezo stepping actuator consists of three fully redundant sets of piezoelectric transducers (PZTs), two sets of brake PZTs, and one set of extension PZTs. These PZTs are used to grasp and move a runner attached to the optic to be moved. By proper cycling of the two brake and extension PZTs, both forward and backward moves of the runner can be achieved. Each brake can be configured for either a power-on or power-off state. For SIM, the brakes and gate of the mechanism are configured in such a manner that, at the end of the step, the actuator is in a parked or power-off state.

The control software uses asynchronous sampling of an optical encoder to monitor the position of the runner. These samples are timed to coincide with the end of the previous move, which may consist of a variable number of steps. This sampling technique linearizes the device by avoiding input saturation of the actuator and makes latencies of the plant vanish. The software also estimates, in real time, the scale factor of the device and a disturbance caused by cycling of the brakes. These estimates are used to actively cancel the brake disturbance. The control system also includes feedback and feedforward elements that regulate the position of the runner to a given reference position. Convergence time for small- and medium-sized reference positions (<200 microns) to within 10 nanometers can be achieved in under 10 seconds. Convergence times for large moves (>1 millimeter) are limited by the step rate.

This work was done by Joel F. Shields 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 Dan Broderick at Daniel.F.Broderick@jpl.nasa.gov. Refer to NPO-48213.