node in the tree is a particular datum with coordinates. The root node represents a bounding box containing the entire set of data. Each level of the tree subdivides the search space into smaller and smaller bounding rectangles, each containing a smaller subset of the data. A query on the R+ tree for a set of coordinates will follow one unique path from the root to the leaf, and return the data contained in the coordinates. The complexity of the search is bounded by the depth of the tree, so the R+ tree insertion algorithm maintains a balanced tree such that the depth is minimized.

A map view provides an intuitive way to specify a set of coordinates for a location-based query. The software will let the user select any location on the map of the rover's traverse path to date and return all of the results in under a second. This was particularly useful during tactical activity planning when the question of "what data do we have of this location" is asked every day. The wrong answer to this question is very expensive: false negatives result in missed science opportunities that may never come again, while false positives results in a waste of spacecraft time and bandwidth resources.

This work was done by Khawaja S. Shams, Thomas M. Crockett, Mark W. Powell, Joseph C. Joswig, and Jason M. Fox of Caltech for NASA's Jet Propulsion Laboratory.

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-46637.

Higher Order Mode Coupling in Feed Waveguide of a Planar Slot Array Antenna

NASA's Jet Propulsion Laboratory, Pasadena, California

A simple technique was developed to account for the higher order mode coupling between adjacent coupling slots in the feed waveguide of a planar slot array. The method uses an equation relating the slot impedance to the slot voltage and a reaction integral involving the equivalent magnetic current of the slot aperture and the magnetic field coupled from an adjacent slot.

Most waveguide-fed slot antennas use centered-inclined coupling slots in the feed waveguides. In the proposed method, one uses the Elliott's design technique to determine tilt angles and lengths of the coupling slots. The radiating slots are modeled as shunt admittances, and the coupling slots are modeled as series impedances.

By using reaction integrals to account for higher order mode coupling between adjacent coupling slots, the "active impedance" of each coupling slot is obtained, which differs from the original impedance by a small amount due to higher order mode coupling. The tilt angle and length of each coupling slot are perturbed so that the active impedance of each slot is the same as the corresponding starting value of the impedance before the iterative process started. This process converges after three or four iterations and uses algebraic equations and fast reaction integrals.

Because of desirable features of waveguide arrays such as low volume, ease of design and manufacture, and ease of deployment, these antennas find applications in aeronautical and space activities. In addition, these all-metal antennas can withstand high radiation environments encountered in space.

This work was done by Sembiam Rengarajan of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-47419

Evolutionary Computational Methods for Identifying Emergent Behavior in Autonomous Systems

NASA's Jet Propulsion Laboratory, Pasadena, California

A technique based on Evolutionary Computational Methods (ECMs) was developed that allows for the automated optimization of complex computationally modeled systems, such as autonomous systems. The primary technology, which enables the ECM to find optimal solutions in complex search spaces, derives from evolutionary algorithms such as the genetic algorithm and differential evolution. These methods are based on biological processes, particularly genetics, and define an iterative process that evolves parameter sets into an optimum.

Evolutionary computation is a method that operates on a population of existing computational-based engineering models (or simulators) and competes them using biologically inspired genetic operators on large parallel cluster computers. The result is the ability to automatically find design optimizations and trades, and thereby greatly amplify the role of the system engineer.

The ECM technique is extremely effective at quickly finding not only individual best solutions, but also an entire collection of best solutions for all possible ranges of conditions. ECM provides an efficient standard of performance that specifies the best solution given a set of requirements or goals for all possible environmental variables. The ECM derived standard of performance can be directly compared to actual performance to provide a test standard of reference. Comparison of the ECM best solutions with actual performance will identify where the deviations from optimum occurred leading to localization of problem areas. This includes illuminating deficiencies in simulation capabilities. Examination of the full set of ECM derived best performance will enable the identification and characterization of unexpected or emergent behaviors.

This work was done by Richard J. Terrile and Alexandre Guillaume of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-46686