



Modeling Electromagnetic Scattering From Complex Inhomogeneous Objects

Complex, inhomogeneous objects can be easily modeled using commercial CAD packages.

NASA Langley Research Center, Hampton, Virginia

This software innovation is designed to develop a mathematical formulation to estimate the electromagnetic scattering characteristics of complex, inhomogeneous objects using the finite-element-method (FEM) and method-of-moments (MoM) concepts, as well as to develop a FORTRAN code called FEMOM3DS (Finite Element Method and Method of Moments for 3-Dimensional Scattering), which will implement the steps that are described in the mathematical formulation. Very complex objects can be easily modeled, and the operator of the code is not required to know the details of electromagnetic theory to study electromagnetic scattering.

Consider a complex inhomogeneous object geometry, the electromagnetic scattering characteristics of which are to be estimated when illuminated by a plane electromagnetic wave. To facilitate the mathematical formulation using the hybrid FEM/MoM, the object is assumed to be enclosed by a surface indicated as a fictitious outer boundary. Inside the boundary, the electromagnetic fields are obtained using the

FEM, whereas the electromagnetic fields outside the fictitious boundary are obtained using the assumed equivalent electric and magnetic currents flowing on the fictitious boundary. Continuity of the electromagnetic fields across the fictitious boundary results in partly sparse/dense matrix that is solved for the unknown fields inside the fictitious boundary including the boundary surface.

The steps laid out in the mathematical formulation are carried out in FEMOM3DS. Along with the main FEMOM3DS, the innovation uses a commercial computer-aided-design (CAD) package for geometrical modeling, and a post-processing package such as Techplot for displaying graphically the results obtained using FEMOM3DS. In the present FEMOM3DS code the COSMOS/M commercial software is used as a CAD tool to model the geometry of a given problem. The COSMOS/M is also used to discretize the FEM region using the tetrahedral elements. Various inhomogeneous regions are taken care of by having many parts in the FEM region. Using the COS-

MOS/M, common boundaries where boundary conditions are to be implemented are also identified. The data file created by the COSMOS/M for node and element information is then generated and processed through the preprocessor part of FEMOM3DS code to create edge information and node information. The preprocessed data are then run through the main part of FEMOM3DS to obtain electromagnetic scattering. The output files from the FEMOM3DS can be used for displaying the results in a graphical format.

The FEMOM3DS is written in FORTRAN 77. The code was successfully compiled on a CONVEX machine. However, the code can be compiled on any 32-bit machine like PCs or SUN, SGI UNIX Station. To get correct results, dimensions must be given in centimeters, frequency of operation must be given in GHz and incident and observation angles must be specified in degrees.

This work was done by Manohar Deshpande and C. J. Reddy of Langley Research Center. Further information is contained in a TSP (see page 1). LAR-17090-1

Visual Object Recognition and Tracking of Tools

This method can be used to track tools held and used by humans, such as surgical tools.

Lyndon B. Johnson Space Center, Houston, Texas

A method has been created to automatically build an algorithm off-line, using computer-aided design (CAD) models, and to apply this at runtime. The object type is discriminated, and the position and orientation are identified. This system can work with a single image and can provide improved performance using multiple images provided from videos.

The spatial processing unit uses three stages: (1) segmentation; (2) initial type, pose, and geometry (ITPG) estimation;

and (3) refined type, pose, and geometry (RTPG) calculation. The image segmentation module files all the tools in an image and isolates them from the background. For this, the system uses edge-detection and thresholding to find the pixels that are part of a tool. After the pixels are identified, nearby pixels are grouped into blobs. These blobs represent the potential tools in the image and are the product of the segmentation algorithm.

The second module uses matched filtering (or template matching). This ap-

proach is used for condensing synthetic images using an image subspace that captures key information. Three degrees of orientation, three degrees of position, and any number of degrees of freedom in geometry change are included. To do this, a template-matching framework is applied. This framework uses an off-line system for calculating template images, measurement images, and the measurements of the template images. These results are used online to match segmented tools against the templates.

The final module is the RTPG processor. Its role is to find the exact states of the tools given initial conditions provided by the ITPG module. The requirement that the initial conditions exist allows this module to make use of a local search (whereas the ITPG module had global scope). To perform the local search, 3D model matching is used, where a synthetic image of the object is created and compared to the sensed data. The availability of low-cost PC graphics hardware allows rapid creation of synthetic images. In this approach, a function of orientation, distance, and articulation is defined

as a metric on the difference between the captured image and a synthetic image with an object in the given orientation, distance, and articulation. The synthetic image is created using a model that is looked up in an object-model database.

A composable software architecture is used for implementation. Video is first preprocessed to remove sensor anomalies (like dead pixels), and then is processed sequentially by a prioritized list of tracker-identifiers.

This work was done by James English, Chu-Yin Chang, and Neil Tardella of Energid Technologies for Johnson Space Center.

Further information is contained in a TSP (see page 1).

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 MSC-23947-1, volume and number of this NASA Tech Briefs issue, and the page number.

Method for Implementing Optical Phase Adjustment

Goddard Space Flight Center, Greenbelt, Maryland

A method has been developed to mechanically implement the optical phase shift by adjusting the polarization of the pump and probe beams in an NMOR (nonlinear magneto-optical rotation) magnetometer as the proper phase shift is necessary to induce self-oscillation. This innovation consists of mounting the pump beam on a ring that surrounds the atomic vapor sample. The propagation of the probe beam is per-

pendicular to that of the pump beam. The probe beam can be considered as defining the axis of a cylinder, while the pump beam is directed radially. The magnetic field to be measured defines a third vector, but it is also taken to lie along the cylinder axis. Both the pump and probe beams are polarized such that their electric field vectors are substantially perpendicular to the magnet field. By rotation of the ring supporting

the pump beam, its direction can be varied relative to the plane defined by the probe electric field and the magnetic field to be measured.

This work was done by David C. Hovde of Southwest Sciences and Eric Corsini of the University of California, Berkeley, for Goddard Space Flight Center. For further information, contact the Goddard Innovative Partnerships Office at (301) 286-5810. GSC-15608-1

Visual SLAM Using Variance Grid Maps

This algorithm is suitable for real-time navigation on irregular terrain.

NASA's Jet Propulsion Laboratory, Pasadena, California

An algorithm denoted "Gamma-SLAM" performs further processing, in real time, of preprocessed digitized images acquired by a stereoscopic pair of electronic cameras aboard an off-road robotic ground vehicle to build accurate maps of the terrain and determine the location of the vehicle with respect to the maps. Part of the name of the algorithm reflects the fact that the process of building the maps and determining the location with respect to them is denoted "simultaneous localization and mapping" (SLAM). Most prior real-time SLAM algorithms have been limited in applicability to (1) systems equipped with scanning laser range finders as the primary sensors in (2) indoor environments (or relatively simply structured outdoor environments). The few prior vision-based

SLAM algorithms have been feature-based and not suitable for real-time applications and, hence, not suitable for autonomous navigation on irregularly structured terrain.

The Gamma-SLAM algorithm incorporates two key innovations:

- Visual odometry (in contradistinction to wheel odometry) is used to estimate the motion of the vehicle.
- An elevation variance map (in contradistinction to an occupancy or an elevation map) is used to represent the terrain.

The Gamma-SLAM algorithm makes use of a Rao-Blackwellized particle filter (RBPF) from Bayesian estimation theory for maintaining a distribution over poses and maps. The core idea of the RBPF approach is that the SLAM problem can be factored into two parts: (1) finding the distribution over robot tra-

jectories, and (2) finding the map conditioned on any given trajectory. The factorization involves the use of a particle filter in which each particle encodes both a possible trajectory and a map conditioned on that trajectory. The base estimate of the trajectory is derived from visual odometry, and the map conditioned on that trajectory is a Cartesian grid of elevation variances. In comparison with traditional occupancy or elevation grid maps, the grid elevation variance maps are much better for representing the structure of vegetated or rocky terrain.

This work was done by Andrew B. Howard of Caltech and Tim K. Marks of the University of California San Diego for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-46114