Information Sciences

Modeling Electromagnetic Scattering From Complex Inhomogeneous Objects

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

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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 FOR-TRAN 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.

Visual Object Recognition and Tracking of Tools

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

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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 approach 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.