CLASSIFICATION OF MESHING ALGORITHMS AND ELECTROMAGNETIC SIMULATION MESH GENERATORS

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INTRODUCTION

Electronic design engineers now use sophisticated simulation software to accurately analyze and optimize designs prior to constructing a physical prototype. The rapid growth in the communication and high-speed electronics industries is demanding more electromagnetic simulation software. In particularly, the high-performance computer industry provides a good test case of the present and future demand for advanced electromagnetic simulation (EMS) software. In particularly, this paper focuses on the 2D electromagnetic field problems which are governed by Partial differential equations. It is well known that the accuracy of the solutions to the problem is mainly based on using an appropriate finite element mesh generator.

Since there are many mesh generators available to handle the electromagnetic field problems several analysis engineers and researchers still face problems in identifying suitable mesh generator for a certain class of the problems. Thus, this paper addresses this issue and overcomes the problem through a survey.

A new generation of finite element mesh generators is introduced every nine months or so, with growing speeds doubling every 18 months. Numbers of electromagnetic mesh generators have already reached about 50. Mesh generators will quite probably be available within the next few years. At those rates, even short transmission lines will act as antennas, producing unwelcome amounts of electromagnetic (EM) interference and cross-talk. If high-speed computer systems are to be designed that minimize this interference, success will certainly require rigorous EM analysis, in which simulation software plays a vital role.

This paper presents current trends and available finite element mesh generators for electromagnetic field problems. It will be very useful for researchers to identify the most popular mesh generator software to easily carry out their research in the area of electromagnetic field. It is further provided comparing some of the main features of currently available mesh generators.

Software vendors have already foreseen this need for good electromagnetic simulation tools. High-frequency simulators have been on the market since 1989 and low-frequency programs for even longer. Borne forward by rapid advances in computer hardware and new EM algorithms, software vendors have introduced over 20 diverse electromagnetic software packages in the past five years. The programs simulate applications that span the electromagnetic spectrum from the low-frequency band to microwave frequencies to optical problems.

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Before the rise of these programs, EM field calculations were the business of only a small population of electrical engineers who had special knowledge of numerical algorithms and the ability and patience to write page upon page of FORTRAN code. Today any engineer who can push a mouse around can start performing an electromagnetic analysis in a matter of hours. Good results from simulation software can be obtained with no expertise in numerical EM, but a basic understanding of numerical methods and their relative merits and faults is quite helpful for selecting and, of course, getting the most out of a simulator. Several good books on computational electromagnetic have been published. The shopper's challenge is in choosing a package that fits the application, computer resources (speed and type), and budget.

Besides the primary triad of features-application, platform, and budget-several more specific features can help narrow down the choices: how the package's major modules (input modeling, analysis, and output) interact; the ease of constructing the input model or the level of detail that can be represented; the specific algorithms used and the user's freedom to manipulate them; and the flexibility and capability of the output presentation-the most accurate data in the world are ineffective if you can't make any sense out of it.

It is impossible to classify all electromagnetic devices and problems that an engineer may wish to solve. Still, three broad classes of applications can be identified for which Mesh Generators for EM field problems are readily available. One class consists of low-frequency devices such as electric motors, transformers, and actuators. Broadband electronic circuits, such as computers, are another class of devices for available. Devices in the last category are those that require high-frequency electromagnetic analysis and include antennas, radar systems, and microwave components. In this case, electromagnetic simulators serve to predict S-parameters, radar cross sections, and radiation patterns. High-frequency devices are the toughest to analyze, because of the heavy computational demands they make. Other common problems in the Electromagnetic field are: Inverse Problems, Eigen Value Problem, Static Problem, Microwave Problem, Electromagnetic Induction, Transmission and Time varying Problems.

The iterative nature of Finite element analysis (FEA) makes the analysis of models impractical by hand but perfect for computers. Several electromagnetic FEA packages exist, ranging from fully three dimensional packages such as ANSYS and Maxwell 3D, to simpler 2-D packages like Maxwell 2D, Quickfield, and FEMM. All FEA computer simulations consist of three parts; the preprocessor, analysis, and postprocessor. The preprocessing consists of constructing the model from nodes, curves, and surfaces, defining boundary conditions and block labels, and generating the mesh. Analysis is the automated process where the model is solved using the prescribed conditions and computational procedures. Post processing involves the visualization, study, and analysis of results. In electromagnetic models, this often involves a flux density plot, and the determination of circuit characteristics.

METHODOLOGY

The journal articles, research papers relevant to the process of mesh generation are referenced in this survey. Currently over 30 journal articles are referenced from the International Meshing Roundtable, Symposium on Trends in Unstructured Mesh Generation, International Conference on Numerical Grid Generation in Computational Field for past twelve years. Information about the software could be obtained from software vendors, research labs and educational institutions via e-mail. The journal articles, research papers referenced in this survey all are relevant to the process of mesh generation. All materials needed for this project are readily available on the internet. Probably the simplest approach is to first break down the technology based on the shape of element generated. Triangle and quad generation methods in 2D and tetrahedral and according to type of the problem, element type of the mesh, algorithm used in mesh generator, post processing features and for a tight budget.

RESULTS AND DISCUSSIONS

Developers of EM simulation programs must perform a balancing act: develop an EM package general enough for different applications yet with enough special features to adapt it to one particular application. Users of programs that try to be "all things to all people" often have found that they lack the specific tools necessary to solve their particular problem. To circumvent this predicament, some vendors have turned to a modular style in developing their product line. Modularity lends itself well to the solution of EM problems, since the process itself can be broken down into several steps: the geometrical modeling of the physical object; the creation of an analytical mesh; the analysis proper; and finally the post processing.

Recent theoretical advances in computational electromagnetic have resulted in a host of new algorithms for EM analysis, many of which have entered commercial software. The programs investigated for this research utilized nine different numerical algorithms (see Table 1). These include finite-element method. This method offers advantages and disadvantages that fit it more to a certain class of problems than to the others.

Table 1: Meshing Algorithms and Electromagnetic Simulation Mesh Generators

Mesh Generators	Algorithms	Pckages
Tri/Tetrahedral Meshing	Octree	Nil
	Delaunay	EMAG, CADfix, EasyMesh, FELISA. GMSH, NETGEN
	Advancing Front	EMAG, CUBIT, EasyMesh, FELISA, GridTool, NETGEN, Preproc
Quad/ Hexahedral Meshing	Mapped Meshing	EMAG, CADfix, CUBIT. GMSH, TrueGrid
	Quad Meshing	EMAG, GMSH
	Hex Meshing	EMAG, CADfix
	Hex-Dominant	EMAG, CADfix

Surface Meshing	Parametric Space	EMAG, CADfix, FELISA, GMSH, GridTool, NETGEN
	Parametric mesh	Common algorithms [5,6]
	Direct-3D	CUBIT

Devices in the last category are those that require high-frequency electromagnetic analysis and include antennas, radar systems, and microwave components. In this case, electromagnetic

Table 2: Comparison of Electromagnetic Mesh Generators based on Some Constraints

(**Rating:** for *Used Algorithms*: (10- Very Efficiency Algorithm), for *Pricing*: (10- Very low price), for *others* (10- Very good))

Mesh Generators	Used Algorithm	Constructing Model	Presenting Results	Number of Users	Customer Support	Pricing	Platform Support	Input Support	**Average Rating**
EMAG	10	10	10	8	10	5	8	10	**8.875**
BAMG	8	8	8	2	5	10	6	6	**6.625**
CADfix	9	7	8	6	10	7	8	10	**8.125**
CUBIT	7	6	6	7	10	8	4	8	**7.000**
EasyMesh	7	6	6	8	5	10	2	6	**6.250**
FELISA	7	6	7	4	10	10	4	6	**6.750**
GMSH	8	8	7	3	10	8	8	7	**7.375**
GridTool	6	6	7	5	10	9	4	5	**6.500**
MAFIA-M	6	6	6	7	10	8	8	8	**7.375**
Mentat	6	6	7	9	10	7	8	8	**7.625**
NETGEN	7	8	8	6	10	10	8	5	**7.750**
TrueGrid	5	6	5	7	10	8	8	5	**6.750**

Simulators serve to predict S-parameters, radar cross sections, and radiation patterns. High-frequency devices are the toughest to analyze, because of the heavy computational demands they make.

CONCLUSION

This paper presents the updated database of the modern EM simulators suitable for modeling of Electromagnetic Field Problem. Most of the papers published in the past ten years are considered as references for this research study.

Some of the first EM simulation programs were intended for low-frequency devices, so that this category includes some truly mature products from vendors such as Ansoft, Magsoft, and Infolytica. Broadband electronic circuits, such as computers, are another class of devices for which EM software tools are available. Planar 2-D and 3-D circuit simulators are available from vendors like Sonnet Software, Bay Technology, and Hewlett-Packard. Devices in the last category are those that require high-frequency electromagnetic analysis and include antennas, radar systems, and microwave components. Recent advances in computationally efficient high frequency algorithms have found their way into several products from Ansoft, Hewlett-Packard, Remcom, Electromagnetic Applications, Vector Fields, and other vendors. Recently, a new algorithm with special mesh generator was introduced to handle electromagnetic transient problems. This generator ensures the continuity of object function thought the parameter optimization process.

The findingw of this research will be very useful for researchers to identify the most popular mesh generator to easily carry out their research in the area of Electromagnetic Field.

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