

Numerical Computation and Visualization of Electromagnetic Fields Using MATLAB based Integrated Programming Language

Junwei Lu, School of Microelectronic Engineering, Faculty of Engineering, Griffith University, Nathan, Qld 4111, AUSTRALIA, e-mail: J.Lu@me.gu.edu.au

Abstract — This paper presents the numerical computation and visualization of electromagnetic fields using the MATLAB based integrated programming language (IPL). ACVEM - a Computer Aided Teaching and Learning (CAT/CAL) tool is developed by using IPL for engineering courses. A modularized interactive computation system is designed and built into ACVEM, where a number of numerical methods such as FDM, FEM, MOM and BEM are employed as the numerical computation modules. Two-dimensional and three dimensional static, quasi-static field and wave propagation problems can be solved and visualized by using this integrated programming language.

I. INTRODUCTION

Applied computational and visual electromagnetics software packages are now widely used in engineering practice. The rapid growth in the communications and high-speed electronics industries is demanding more and more electromagnetic simulation software packages. It is very important to introduce the concept of computational electromagnetics in undergraduate engineering courses. Without a detailed knowledge of computational electromagnetics, graduate engineers could not use these commercial available software packages to design the electromagnetic products efficiently. Most commercial software packages are "black-box" based packages and designed for electromagnetic simulation for

product development. Vendors do not consider the need for teaching and learning of computation methods and algorithms in the classroom. Inexperienced engineers may need a few months or more to learn how to use these packages properly. To overcome such problems, a new educational program in computational electromagnetics (CEM) should be introduced into engineering courses. This paper introduces ACVEM, a CAT/CAL tool that is developed for the teaching and learning of computational and visual electromagnetics. MATLAB based integrated programming language (IPL) makes it easy for students to learn and understand the computational techniques [1,2].

II. DESIGN CONSIDERATION AND IPL

Traditional programming languages such as Fortran and C have been widely used for computational science and engineering applications. Such languages will surely continue to be used because they are familiar and have excellent compilers and tool support. Integrated programming languages that combine attractive, easily produced graphics with powerful support for mathematical modeling have recently become popular. Typically, these languages support both a high-level programming language and extra packages for symbolic or algebraic manipulation, matrix operations, and visualization [3].

ACVEM as shown in Fig. 1 is implemented by using the MATLAB based integrated programming language and its built-in plot functions. To help the teaching and learning of numerical computation techniques and computation algorithm in electromagnetics, the following features have been considered:

- Data input using GUI,
- Choice of different numerical methods
- Pre-process with mesh generation features
- Modularized numerical methods or PDE solvers
- Post-process and visualization functions

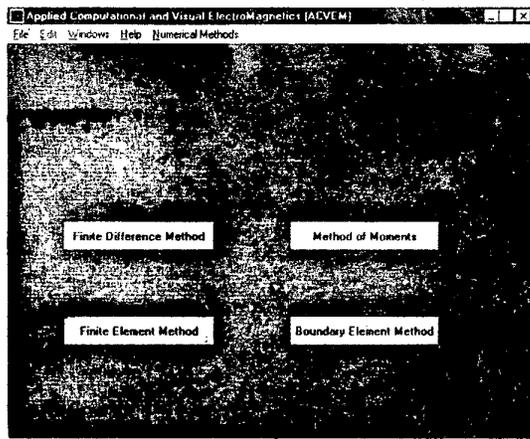


Fig. 1 ACVEM and its GUI

III. PRE-PROCESS USING COMMON GUI FEATURES

ACVEM has interactive GUI features for pre-process. The user can add a self-developed numerical method or PDE solver as a module into ACVEM for different applications under the same GUI working platform. The ACVEM allows the user to choose particular numerical method from **Numerical Techniques** in the GUI working platform. After the user selects a particular numerical method, the model attributes can be

defined on the common GUI working platform as shown in Fig. 2.

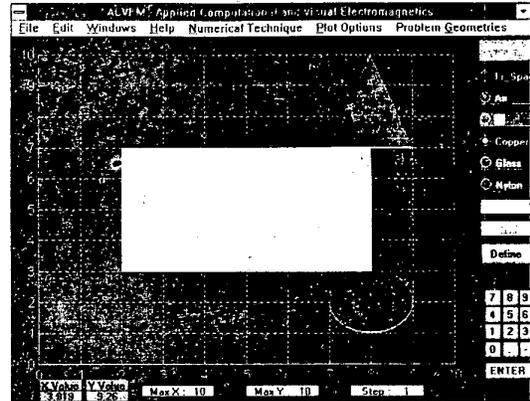
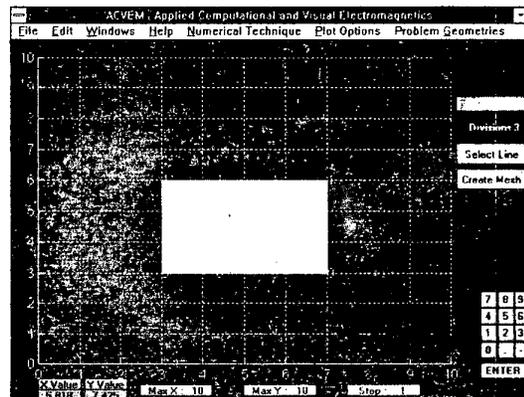


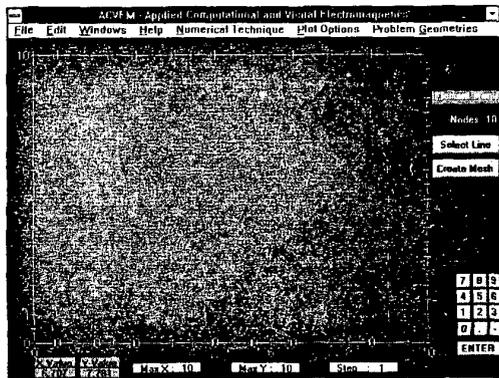
Fig. 2 GUI features for defining model attributes and pre-processes

The following GUI features have been designed into the ACVEM pre-process section:

- Select from numerical methods such as FDM, FEM, MOM and BEM, (or other methods added into GUI by user)
- Define the model attributes such as geometry, material properties, constraints and boundary conditions, and excitations
- Generate mesh or grid and check the model



(a) FEM mesh generation



(b) BEM element generation with internal grids

Fig. 3 FEM mesh and BEM element generation features

The mesh generation features are developed for defining the model attributes when the user chooses a different numerical method as shown in Fig. 3. ACVEM uses “open-box” based MATLAB M files for the common GUI features and modularized numerical computation system.

IV. MODULARIZED INTERACTIVE COMPUTATION SYSTEMS

Since ACVEM is a modularized computation system, various numerical methods can be added or built into ACVEM system by the user. Unlike the “black-box” based program structure in traditional computation software packages, the numerical computation module in ACVEM uses an “open-box” structure [4]. Each numerical computation module has the basic modeling steps, such as construct a model, check the model, specify the solution procedure, solve the mathematical problem and validate the solution. The user can open the MATLAB based integrated program file to modify the program codes and add more features into ACVEM. Under each numerical computation module, many other modularized computation features for different application problems such as static or quasi-static field

problems, time domain or frequency domain field problems can be added in. The flexibility of the modularized computation systems in ACVEM is shown in Fig. 4.

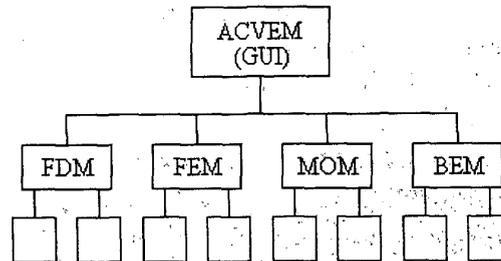


Fig. 4 Block diagram of modularized computation systems

V. VISUALIZATION OF EM FIELDS

Advances in electromagnetic computation are allowing mathematical model and simulations to become increasingly complex and detailed. This results in a closer approximation to reality thus enhancing the possibility of acquiring new knowledge and understanding. After the appropriate representations of the data have been constructed, information can be superimposed onto the surface, to provide further insight into the complex character of electromagnetic phenomena.

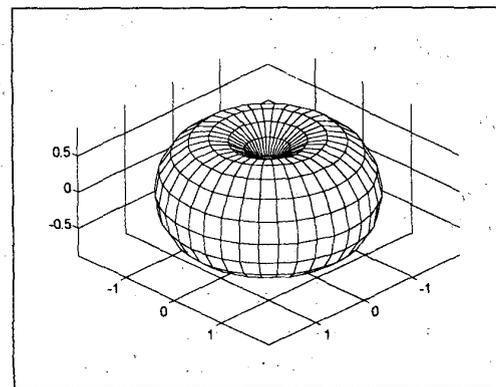


Fig. 5 3-D Radiation pattern plot from MOM computation result

ACVEM visualization system will simplify the task of interpreting results [4,5,6]. MATLAB built-in plot functions are implemented into the ACVEM program. Figure 5 shows the 3-D radiation pattern calculated by the method of moment. Figure 6 shows the computation results calculated by FDM. The MATLAB built-in plot functions are used in the ACVEM program.

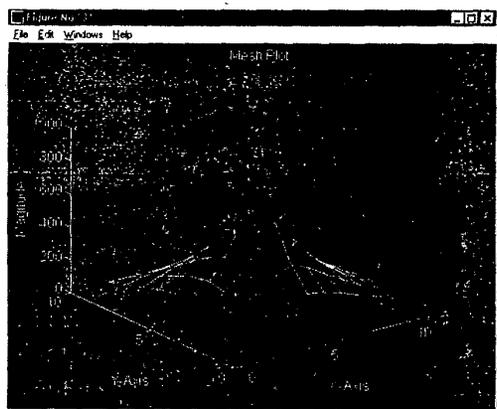


Fig. 6 Potential contour plot based on FDM computation result

VI. CONCLUSIONS

The development of ACVEM – a CAT/CAL tool for numerical computation and visualization of electromagnetic fields is discussed. Various numerical methods have been modularized and built into ACVEM, which can be used to solve application problems in the classroom. GUI features and the modularized computation systems are developed for choosing numerical computation methods, the pre-process and adding more numerical computation features in ACVEM. Several application problems as the examples are shown and visualized by using a MATLAB based integrated programming languages in ACVEM. Future work will concentrate on developing 3-D computation systems, interactive visualization and animation systems.

ACKNOWLEDGEMENT

This work is partly supported by Griffith University Teaching Development Grant. The author would like to thank Mr. S. Martin and Mr. J. Thai for their contributions to the ACVEM package.

REFERENCES

- [1] A. Biran and M. Breiner, 'MATLAB for Engineers,' Addison-Wesley Publishing Companies, 1995
- [2] D. V. Thiel, J. Lu, "Numerical Techniques in Electromagnetics and Communications - A PC based third year undergraduate subject for Microelectronic engineering," IEEE AP-S International Symposium and URIS Radio Science Meeting, USA . pp111-114, Jun., 1994
- [3] L. K. Kale, "Programming Languages for CSE:The State of the Art", IEEE Computational Science & Engineering, pp18-26, April, 1998
- [4] J. Lu, D. Thiel, and et. al, "High Performance Numeric Computation and Visualization of Electromagnetics using MATLAB," The Seventh Biennial IEEE Conference on Electromagnetic Field Computation, IEEE CEFC'96, April, 1996
- [5] J. R. Brown and et.al., Visualization - Using Computer Graphics to Explore Data and Present Information, John Wiley & Sons, 1995
- [6] J. Lu, D. Thiel, and S. Sarrio: Applied Computational and Visual Electromagnetics in Undergraduate Engineering Courses, Proceedings of The Eighth Biennial IEEE Conference on Electromagnetic Field Computation, IEEE CEFC'98, June, 1998