Parallel Scene Generation – Why Parallelize WIPL-D*P*?

Ralph Kohler
Unites States Air Force
Rome, New York, 13441, USA
Ralph.Kohler@rl.af.mil

Alan George
Black River Systems Co.
Utica, New York, 13502, USA
george@brsc.com

Tapan Sarkar
Syracuse University
Syracuse, New York, 13244, USA
tksarkar@ecs.syr.edu

Abstract: Electromagnetic analysis of large complex structures and structures in the environment requires massive processing memory and computational capability. The ever-increasing speed and memory size of today's computers is dwarfed by the need to solve complex problems. There exists a highly efficient commercial electromagnetic modeling tool called WIPL-D that partially addresses these problems. This paper will present a discussion of an effort that is currently underway to develop a parallelized WIPL-D that will expand the problem sizes that can currently be solved. The parallelized WIPL-D will provide exciting new design and research possibilities for electromagnetic analysis.

Keywords: WIPL-D, CHSSI, HPC, Parallel Processing, Method of Moments, Electromagnetic Modeling

1. Background

Electromagnetic analysis requires the solution of Maxwell's equations in either the time or frequency domain. In realistic applications, such as those that will be discussed, closed form solutions do not exist and numerical solutions to either the differential form or the integral form on Maxwell's equations must be employed. Finite Element Method (FEM), Finite Difference (FD), and Finite-Difference-Time-Domain (FDTD) are examples of differential equation techniques that can be employed. However, integral equation techniques are inherently better suited to the analysis of antennas and thick or thin dielectric/magnetic materials as required for the problems at hand. Of all the integral equation techniques available, the Method of Moments (MOM) solves Maxwell's equations directly, leading to more accurate analysis.

The electromagnetic modeling application WIPL-D (Wires, Plates and Dielectrics) is well known throughout the industry. WIPL-D uses Method of Moments for its solution to Maxwell's equations.[1] It has evolved from over ten years of research in numerical electromagnetics. The development of this code has been driven by the large demand for analysis of composite conducting and dielectric structures. During this time, it has experienced continuous evolution, growing from the original version WIPL which modeled conducting structures only (WIPL, commercially available tool from Artech House) to include the ability to analyze dielectrics (WIPL-D) with a powerful, friendly, graphical user interface.

WIPL-D's strength is in its efficient use of a bilinear quadrilateral entire domain technique, which greatly reduces the number of unknowns needed for large problems. It requires only 10-20 unknowns per square wavelength, as opposed to the 100 needed by subdomain approaches. This efficient methodology is critical for the solution of large problems where the required number of unknowns can grow unmanageably huge. This advantage can be observed by looking at a typical benchmark problem, the analysis of electromagnetic scattering from a 16 wavelength diameter conducting disk. The analysis using WIPL-D required 16 hours using 5320 unknowns and 144 MB of main memory. This same problem using a triangular patch subdomain approach on the same computer required 45 hours, 18000 unknowns and 2 GB of required memory.

2. The Need

While WIPL-D is one of the most efficient codes, there will forever be the desire to solver larger and larger problems. As one begins to include large mounting structures and more of the environment, the size of the problem grows geometrically. The problems that we propose to address can be 10 to 100 times larger in each linear dimension and therefore will require not only the most efficient code, but also advanced parallel processing techniques. The goal is to provide the user the ability to process more and more, limiting them only by their imagination, instead of what they are able to process.

This parallelized WIPL-D tool will be applicable to a wide range of end-user applications in the Army, Navy, Air Force, and Marines. This tool will support a broad range of users including researchers, algorithm developers, sensor and system developers, and the warfighter. It will also support weapons systems designers who need to fully understand how to optimize the designs for or against Camouflage, Concealment and Deception. The current commercial WIPL-D sequential software will be modified to provide a scalable, portable, parallel implementation.

Example DoD missions that will benefit from such a tool include:

- Detection of Targets Under Trees (propagation through foliage),
- Ship Radar Performance (multipath scattering from many structures),
- Strategic Subsurface Target Detection (discussed in detail below),
- Land Mine Imaging / Detection (propagation through and scattering from the soil),
- Ballistic Missile Discrimination (many simultaneous targets in counter-measures and disturbed propagation environment).
- Feature Aided GMTI Target Tracking (many complex targets in clutter and partial foliage cover).

The applications listed above have one unifying feature: the need to accurately model the scattering from a target (or the radiation form an antenna) within a complex scattering and propagation environment. These applications combine the issues of complex conducting surfaces with that of thick dielectric/magnetic layers. These technology thrusts can provide useful output if this accuracy can be achieved. As a specific example, radars exist for the detection of landmine but they are of limited utility if they only detect a ‘blob.’ If the imaging capability discussed under strategic subsurface target detection can be extrapolated to higher frequencies a landmine imaging radar may be possible that could provide a reasonable number of pixels on a landmine size target (thus providing a reasonable image of it rather than a ‘blob’). Such a capability would have many DOD and humanitarian applications, especially if provided in a fielded application.

3. The Project

This project is one of the CHSSI (Common High Performance Computing Software Support Initiative) sponsored by the DoD High Performance Computing Modernization Program. The purpose of this project is to develop a scalable, portable, parallel scene generation (PSG) tool that will provide the capability to quickly/rapidly generate scenes of radiating and scattering structures (targets and their surrounding environment) in realistically complex electromagnetic environments. This improvement will move users from accurate modeling of targets only to accurate modeling of targets in their environment. Because WIPL-D is a proven, commercially successful, very efficient analysis tool, it has been chosen to be the starting point for this effort. The results of this project will be a scalable software implementation that is capable of executing on a network of workstations, a general-purpose high performance computing architecture and an embedded real-time high performance computing architecture.

The parallelization of this analysis tool will concentrate in two areas, a simple but effective parallelization over frequency and position, and a more complex parallelization of the matrix generation and solution. This first implementation, while relatively simple to implement, solves a large number of problems with extreme efficiency. A very large percentage of applications require multiple frequencies or physical positioning of structures. This paradigm is the most direct approach to this processing. However, while this approach reduces the processing time for the wide band, multiple position problems, it does nothing to enhance the processing for large models with many unknowns. To handle this class of problems, the generation and more importantly the solution to the matrix of unknowns needs to be parallelized. Initially, this will be accomplished through the use of the widely used and available ScaLAPACK package. While there may be more efficient solvers available, this package is well known and understood, portable, and currently available on most HPC's. However, this is only a starting point. We are looking at alternative solution techniques such as wavelet and least squares techniques. Also being considered, but not is not currently part of this effort is to modify the core processing of WIPL-D to greatly enhance wideband processing through the integration of both the existing frequency domain processing with time domain processing. This merger of two techniques will use the early time response in time domain processing and low frequency response from frequency domain processing to create a wide band analysis with substantially smaller processing requirements.[2]

As of the writing of this paper (Oct 2002), we are at the end of the conversion from FORTRAN to C phase and beginning the parallelization. This phase scheduled to be completed June of this year (2003). At this point, the parallel version will be available for Alpha testing for a few test applications. The code will continue to be refined and optimized, including feedback from Alpha testers. The Beta release is scheduled for March 2004.

4. The Team

Sponsoring Organizations:	
HPCMO:	
Leslie Perkings	
CHSSI:	
Jere Matty	AEDC/DOT
Bonnie Heikkinen	Sverdrup Technology
Team Leader:	
Ralph Kohler	AFRL/SNRT
Development Team:	
Alan George	Black River Systems Co.
Milissa Benincasa	Black River Systems Co.
Dr. Tapan Sarkar	Syracuse University
Applications Team:	
Dr. Richard Schneible	Research Associates for Defense
Dr. Raviraj Adve	University of Toronto
Dr. Richard Plumb	Binghamton University
Dr. Eric Mokole	Naval Research Lab. (NRL)
Dr. Robert McMillan	US Army Space & Missile Defense Command (USASMDC)

5. Misc. Information

The parallel software generated under this effort will be subject to export regulations.

This effort is funded by the US government and as such, the government will receive a license to the software (both executable and source code) resulting from this project for DoD applications. This means that the government or its contractors may modify and use the code for use on government programs. The owners of the code (OHRN Enterprises) reserve the right to license the application (both parallel and serial) for non-DoD uses.

Learn more about WIPL-D and this project by visiting the following web sites:
www.wipl-d.com
www.brsc.com/CHSSI/WIPL-D.html

Contact Information:

Ralph Kohler	ralph.kohler@rl.af.mil	315.330.2016
Alan George	george@brsc.com	315.732.7385

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