

# HOBBIES: Higher Order Basis Based Integral Equation Solver with Automatic Goal Oriented Optimization

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**Abstract**— This paper presents a new electromagnetic simulator called HOBBIES (Higher Order Basis Based Integral Equation Solver). HOBBIES is based on a parallel In-Core and Out-of-Core integral-equation solver and a personal pre- and post-processor called GiD<sup>®</sup>. HOBBIES presents some important features such as multiplatform and multilanguage environment, definition of models using symbolic variables, automatic goal oriented optimization and the option of executing simulations on a high performance cluster.

## I. INTRODUCTION

Nowadays, there is a large variety of electromagnetic simulators based on different numerical methods that are being used by researchers in various fields. These electromagnetic simulators present different features such as multiplatform and multilanguage environments, friendly graphical user interfaces (GUI) or/and compatibility with computer aided design (CAD) software packages. In this context, a new electromagnetic simulator should integrate and improve all the above mentioned features.

The aim of this paper is to present a new electromagnetic simulator called HOBBIES (High Order Basis Based Integral Equation Solver). The kernel of HOBBIES is a general-purpose parallelized In-Core (just computer RAM is used by the solver) and Out-of-Core (computer hard disk is used in addition to RAM, to solve projects that are too large to be solved by the In-Core version) integral-equation-based MoM solver already presented [1]. Thus this paper is focused on other unique features of HOBBIES: the applications available to the user through the GUI and, especially, in the automatic goal oriented optimization. The reader may find more information about the solver in [2].

## II. GRAPHICAL USER INTERFACE

The GUI of HOBBIES is based on a personal pre- and post-processor called GiD<sup>®</sup> [3] developed at CIMNE [4]. Starting from GiD<sup>®</sup> a multiplatform, multilanguage and user friendly GUI has been developed. Some of its most important features are the possibility to define a model using symbols enabling the use of an automatic goal oriented optimizer and the option to execute simulations on a high performance parallel computing cluster. Several optimization methods are available, such as, for example, Powell's Method [5] or the Simplex Method [6].

An example of optimization process is shown in Figures 1 to 4. The example illustrates the optimization process of the dimensions of a horn antenna to obtain a 20 dB gain along the broadside direction. To demonstrate that the planned goal has been reached, the computed radiation pattern of the antenna after 300 iterations is shown in Fig. 4. More details and examples will be given in the full version of this paper.

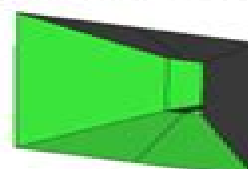


Fig.1 Horn antenna after 1 iteration

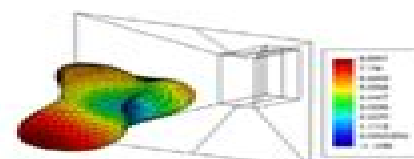


Fig. 2 Computed gain (dBi) after 1 iteration

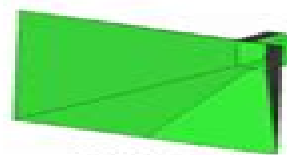


Fig.3 Horn antenna after 300 iterations

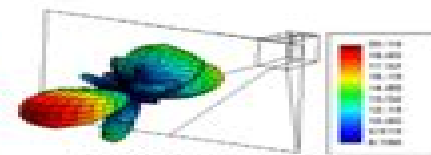


Fig. 4 Computed gain (dBi) after 300 iterations

## III. REFERENCES

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# Higher Order Basis Based Integral Equation Solver Hobbies

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## **Higher Order Basis Based Integral Equation Solver Hobbies:**

**Higher Order Basis Based Integral Equation Solver (HOBBIES)** Yunong Zhang, Tapan K. Sarkar, Xunwang Zhao, Daniel Garcia-Donoro, Weixin Zhao, Magdalena Salazar Palma, Sioweng Ting, 2012-06-19 The latest in parallel EM solutions with both in core and out of core solvers The solution of complex electromagnetic EM problems requires one to address the issues related with numerical accuracy and efficient distribution of the solution procedure over multiple computational nodes With the advent of multicore processors and high performance computing HPC technology the EM software designers need to know how to add new functionality to computational EM codes so that they can run efficiently on these new processors Higher Order Basis Based Integral Equation Solver HOBBIES presents a road map for the analysis of complex material structures using the high performance parallel simulation software known as HOBBIES Focusing on the Method of Moments MoM the book features new parallel programming techniques and user friendly code with superior capabilities for solving challenging EM radiation and scattering problems It provides readers with complete guidance on how to extend the capability of MoM and achieve faster and more accurate EM analysis and utilize multicore CPUs on desktop computers Complete with an academic version of the HOBBIES software this book Explains the unique features of the higher order basis functions in the solution of integral equations in a MoM context Shows how to generate a properly load balanced parallel computational procedure for MoM matrix filling and matrix equation solving in both in core and out of core implementation Presents a professional graphical users interface GUI for generating the geometrical structure based on NURBS modeling Illustrates various automatic meshing procedures based on an a priori defined error between the actual geometry and the meshed structure Outlines all the key features of the HOBBIES software including multiple optimization procedures for EM synthesis The bottleneck of traditional MoM arises from the lack of memory in computers for solution of large problems This is mitigated by using higher order basis functions and out of core solver in HOBBIES HOBBIES has the capability to perform numerically accurate EM simulations using thousands of CPU cores in an HPC environment using a properly load balanced out of core solver In this way it provides a cost effective choice for addressing modern engineering and scientific challenges that arise from the extremely complicated real life applications

**Modern Characterization of Electromagnetic Systems and its Associated Metrology** Tapan K. Sarkar, Magdalena Salazar-Palma, Ming Da Zhu, Heng Chen, 2021-08-24 New method for the characterization of electromagnetic wave dynamics Modern Characterization of Electromagnetic Systems introduces a new method of characterizing electromagnetic wave dynamics and measurements based on modern computational and digital signal processing techniques The techniques are described in terms of both principle and practice so readers understand what they can achieve by utilizing them Additionally modern signal processing algorithms are introduced in order to enhance the resolution and extract information from electromagnetic systems including where it is not currently possible For example the author addresses the generation of non minimum phase or transient

response when given amplitude only data Presents modern computational concepts in electromagnetic system characterization Describes a solution to the generation of non minimum phase from amplitude only data Covers model based parameter estimation and planar near field to far field transformation as well as spherical near field to far field transformation Modern Characterization of Electromagnetic Systems is ideal for graduate students researchers and professionals working in the area of antenna measurement and design It introduces and explains a new process related to their work efforts and studies

*The Physics and Mathematics of Electromagnetic Wave Propagation in Cellular Wireless Communication* Tapan K. Sarkar, Magdalena Salazar Palma, Mohammad Najib Abdallah, 2018-07-18 An important resource that examines the physical aspects of wireless communications based on mathematical and physical evidence The Physics and Mathematics of Electromagnetic Wave Propagation in Cellular Wireless Communication describes the electromagnetic principles for designing a cellular wireless system and includes the subtle electromagnetic principles that are often overlooked in designing such a system This important text explores both the physics and mathematical concepts used in deploying antennas for transmission and reception of electromagnetic signals and examines how to select the proper methodology from a wide range of scenarios In this much needed guide the authors noted experts in the field explore the principle of electromagnetics as developed through the Maxwellian principles and describe the properties of an antenna in the frequency domain The text also includes a review of the characterization of propagation path loss in a cellular wireless environment and examines ultrawideband antennas and the mechanisms of broadband transmission of both power and information This important resource Includes a discussion of the shortcomings of a MIMO system from both theoretical and practical aspects Demonstrates how to deploy base station antennas with better efficiency Validates the principle and the theoretical analysis of electromagnetic propagation in cellular wireless communication Contains results of experiments that are solidly grounded in mathematics and physics Written for engineers researchers and educators who are or plan to work in the field The Physics and Mathematics of Electromagnetic Wave Propagation in Cellular Wireless Communication offers an essential resource for understanding the principles underpinning wireless communications

**Intelligent Multi-Modal Data Processing** Soham Sarkar, Abhishek Basu, Siddhartha Bhattacharyya, 2021-04-08 A comprehensive review of the most recent applications of intelligent multi modal data processing Intelligent Multi Modal Data Processing contains a review of the most recent applications of data processing The Editors and contributors noted experts on the topic offer a review of the new and challenging areas of multimedia data processing as well as state of the art algorithms to solve the problems in an intelligent manner The text provides a clear understanding of the real life implementation of different statistical theories and explains how to implement various statistical theories Intelligent Multi Modal Data Processing is an authoritative guide for developing innovative research ideas for interdisciplinary research practices Designed as a practical resource the book contains tables to compare statistical analysis results of a novel technique to that of the state of the art techniques and

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**Fast Integral**

**Equation Solver for Variable Coefficient Elliptic PDEs in Complex Geometries** Dhairya Malhotra,2017 This

dissertation presents new numerical algorithms and related software for the numerical solution of elliptic boundary value problems with variable coefficients on certain classes of geometries The target applications are problems in electrostatics fluid mechanics low frequency electromagnetic and acoustic scattering We present discretizations based on integral equation formulations which are founded in potential theory and Green s functions Advantages of our methods include high order discretization optimal algorithmic complexity mesh independent convergence rate high performance and parallel scalability First we present a parallel software framework based on kernel independent fast multipole method FMM for computing particle and volume potentials in 3D Our software is applicable to a wide range of elliptic problems such as Poisson Stokes and low frequency Helmholtz It includes new parallel algorithms and performance optimizations which make our volume FMM one of the fastest constant coefficient elliptic PDE solver on cubic domains We show that our method is orders of magnitude faster than other N body codes and PDE solvers We have scaled our method to half trillion unknowns on 229K CPU cores Second we develop a high order adaptive and scalable solver for volume integral equation VIE formulations of variable coefficient elliptic PDEs on cubic domains We use our volume FMM to compute integrals and use GMRES to solve the discretized linear system We apply our method to compute incompressible Stokes flow in porous media geometries using a penalty function to enforce no slip boundary conditions on the solid walls In our largest run we achieved 0.66 PFLOP/s on 2K compute nodes of the Stampede system TACC Third we develop novel VIE formulations for problems on geometries that can be smoothly mapped to a cube We convert problems on non regular geometries to variable coefficient problems on cubic domains which are then solved efficiently using our volume FMM and GMRES We show that our solver converges quickly even for highly irregular geometries and that the convergence rates are independent of mesh refinement Fourth we present a parallel boundary integral equation solver for simulating the flow of concentrated vesicle suspensions in 3D Such simulations provide useful insights on the dynamics of blood flow and other complex fluids We present new algorithmic

improvements and performance optimizations which allow us to efficiently simulate highly concentrated vesicle suspensions in parallel

*Surface Integral Equation Methods for Multi-scale and Wideband Problems* Jiangong Wei, OhioLINK Electronic Theses and Dissertations Center, 2014

[A Course on Integral Equations with Numerical Analysis](#) Tofiq Allahviranloo, Armin Esfandiari, 2021-10-30 This book suggests that the numerical analysis subjects matter are the important tools of the book topic because numerical errors and methods have important roles in solving integral equations Therefore all needed topics including a brief description of interpolation are explained in the book The integral equations have many applications in the engineering medical and economic sciences so the present book contains new and useful materials about interval computations including interval interpolations that are going to be used in interval integral equations The concepts of integral equations are going to be discussed in two directions analytical concepts and numerical solutions which both are necessary for these kinds of dynamic systems The differences between this book with the others are a full discussion of error topics and also using interval interpolations concepts to obtain interval integral equations All researchers and students in the field of mathematical computer and also engineering sciences can benefit the subjects of the book

**The Method of Moments in Electromagnetics** Walton C. Gibson, 2021-09-06 The Method of Moments in Electromagnetics Third Edition details the numerical solution of electromagnetic integral equations via the Method of Moments MoM Previous editions focused on the solution of radiation and scattering problems involving conducting dielectric and composite objects This new edition adds a significant amount of material on new state of the art compressive techniques Included are new chapters on the Adaptive Cross Approximation ACA and Multi Level Adaptive Cross Approximation MLACA advanced algorithms that permit a direct solution of the MoM linear system via LU decomposition in compressed form Significant attention is paid to parallel software implementation of these methods on traditional central processing units CPUs as well as new high performance graphics processing units GPUs Existing material on the Fast Multipole Method FMM and Multi Level Fast Multipole Algorithm MLFMA is also updated blending in elements of the ACA algorithm to further reduce their memory demands The Method of Moments in Electromagnetics is intended for students researchers and industry experts working in the area of computational electromagnetics CEM and the MoM Providing a bridge between theory and software implementation the book incorporates significant background material while presenting practical nuts and bolts implementation details It first derives a generalized set of surface integral equations used to treat electromagnetic radiation and scattering problems for objects comprising conducting and dielectric regions Subsequent chapters apply these integral equations for progressively more difficult problems such as thin wires bodies of revolution and two and three dimensional bodies Radiation and scattering problems of many different types are considered with numerical results compared against analytical theory as well as measurements

**A Higher Order Global Approximation Method for Solving an Abel Integral Equation Byquadratic Splines** Hing-Sum Hung, 1979

**Integral Equation Analysis with Characteristic**

**Basis Functions** Jaime Laviada, 2012 Integral Equation Analysis with Characteristic Basis Functions      Comparison of Basis Function and Iteration Solutions to the Fredholm Integral Equation of the First Kind Michael E. Carter (CAPT, USAF.), 1989      **Sommerfeld-Watson Transformation in 3D and Volume Integral Equation Solver** Maokun Li, 2004

*A Higher Order Global Approximation Method for Solving an Abel Integral Equation by Quadratic Splines* Hing-Sum Hung, WISCONSIN UNIV-MADISON MATHEMATICS RESEARCH CENTER., 1979 In the present paper a global approximation method is developed for obtaining higher accuracy results involving higher order splines with full continuity. The quadratic spline case is investigated in detail. The technique is to differentiate the original equation and solve the differentiated equation by using a quadratic spline in  $C^1$ . The computational effort required is only marginally greater than that required for a linear spline solution of the original equation. Convergence is obtained not only for the approximate solution but also for its first two derivatives at each point in the interval of integration      **Multiscale Methods for Fredholm Integral Equations** Zhongying Chen, Charles A. Micchelli, Yuesheng Xu, 2015-07-16 Presents the state of the art in the study of fast multiscale methods for solving these equations based on wavelets

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