2D Mesh Generator for Electromagnetic Fields Simulation

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***Abstract*—This paper presents an image based mesh generator used to create the two-dimensional environment model for electromagnetic fields simulation with the transmission-line modeling method (TLM). At first, the TLM two-dimension shunt node formulation is briefly introduced. Then, the mesh generator program is described and its functioning is explained. Finally, the validated results are shown and the authors present a brief discussion over the program benefits.**

I. Introduction

The Transmission-Line Modeling Method (TLM) [1] is a time-domain differential numerical simulation method first cited by Johns and Beurle [2], created for solving two-dimensional electromagnetic field scattering problems. Since then, TLM has evolved, other formulations were proposed and it has been successfully applied for modeling electromagnetic fields in one, two and three dimensions.

Nevertheless, due to its scattering formulation, and to the growing complexity of the problems being analyzed, sometimes it is a great challenge to efficiently mesh the environment or objects of interest. Several works have attempted to establish easier ways to deal with this problem, some even have developed different types of mesh grids [3], [4], what only corroborates the importance of this issue to efficiently model the most diverse existing situations.

It is not the intention of this paper to explain the TLM method in detail, but an overview of the method should be presented in order to facilitate general understanding. Therefore, the main focus will be directed to the mesh generator itself, then its application and results.

II. The TLM Two-Dimensional Formulation

The TLM method physical basis is the Huygens light propagation principle, stating that a punctual wave source propagates spherically, and each wave acts as a new source, forming a network of spherical wave fronts [5]. Its formulation is established from the analogy between transmission-lines and electromagnetic field theories. The space is modeled by a grid of interconnected transmission-lines in each direction, and the transmission-lines are represented by a combination of equivalent lumped circuit components (see Fig.1). The properties of the materials to be modeled define the parameters of the lumped circuit components.

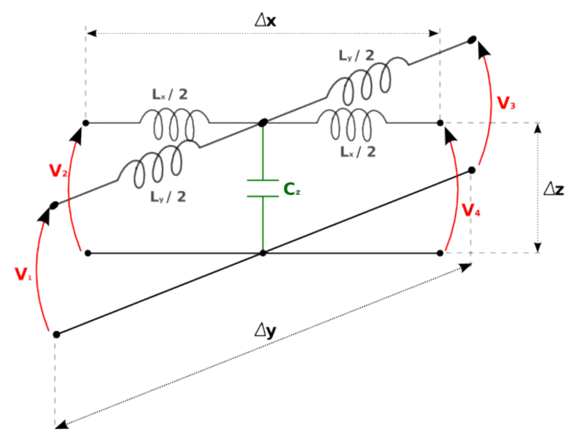


Fig. 1. Two dimensional TLM shunt node.

The meshing procedure consists in discretizing space in differential Δl and time in differential Δt respectively, so, the wave propagates at speed $v = \Delta l / \Delta t$. The Δl is chosen as small as possible to reduce the discretization error. A common acceptable value is $\Delta l = 0.1\lambda$. The Δt is calculated according to the wave frequency and medium electric properties, so $\Delta t = \Delta l \times \varepsilon \times \mu$.

The appropriate development of time domain Maxwell's equations and Kirchhoff's laws show the relation between electric field and voltage, and also between magnetic field and current, which are:

$$E_z = V_z/\Delta l \quad H_x = I_y/\Delta l \quad H_y = \text{-}I_x/\Delta l \tag{1}$$

$$\mu = L_d/\Delta l \quad \varepsilon = 2C_d + C_s/2 \quad \sigma = G_s \tag{2}$$

Having situated the TLM method, the next section defines the main subject of the paper, which is the development of a mesh generator based in bitmap colors identification.

III. The Mesh Generator

In order to simulate a problem, a color image is created using a generic graphic design program modeling the environment of interest. The the mesh generator receives this image, and converts it into a grid based model, which is later used in the simulation by the TLM program. Each color of the image represents a homogeneous region from the environment being modeled. This digest deals only with the mesh generator, the image creation and the TLM simulation are not discussed here. The mesh generator was developed under Mathworks Matlab® (Version 7.5.0.342), and it is composed of three main modules: a pre-processor, the processor itself and a post-processor.

A. *Pre-processor*

This module analyzes the image and, if necessary, modifies it to become compatible with the processor. The modification is done, for example, when the image is not in the adequate resolution nor the desired size. It also converts the image to a 24-bit depth color resolution, if it is not already in that format.

In the studied process, the mesh size is based on the image size, where each pixel corresponds to a node. Consequently, to create a mesh with m by n nodes, the image shall have m by n pixels. The actual corresponding size modeled is determined combining the number of nodes with the node real size.

B. *Processor (Mesh Generator)*

This is the main module, which analyzes the image searching for homogeneous regions, then storing the regions in a pre-defined formatted file, which includes the regions physical properties. This file is the input to the TLM simulation program, and it contains the following parameters:

- The number of iterations to be used in the simulation;
- The pixel equivalent real size in meters;
- Each boundary behavior (as total reflexive or total absorbent);
- Each medium relative electric permittivity;
- Each medium relative magnetic permeability;
- Each medium electrical conductivity;
- Each medium electrical resistivity;

The parameters are entered in the main interface (See Fig.2).

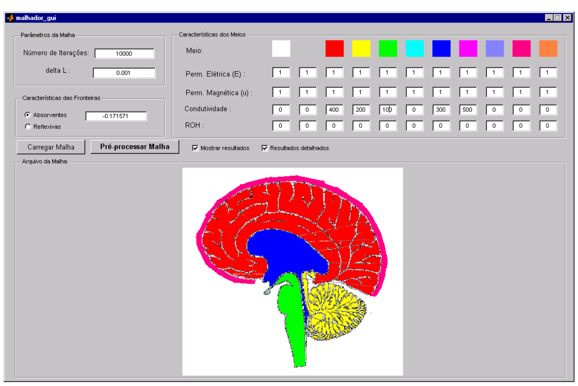
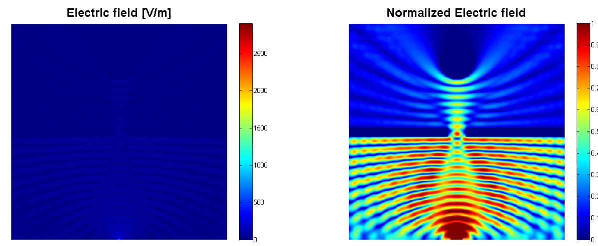


Fig. 2. The mesh generator main interface.

C. *Post-processor*

This module analyzes the result from the TLM simulation program and generates a graphical representation of its outputs. Additionally, it presents a normalized version of the same result. This is done to enable visualization of some subtle properties of the resulting field. For example, when the highest and the lowest values are in very different orders of magnitude, small field variations are not visually perceived, Fig.3 (a) and (b) compare the two types of output, regular and normalized.

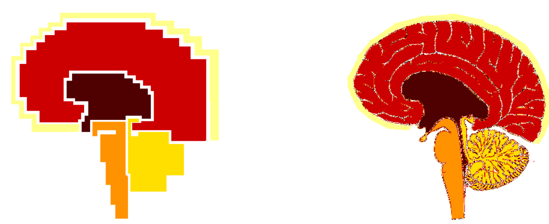


(a) Original output (b) Normalized output

Fig. 3. Post-processed TLM output.

IV. Results

With the assistance of the mesh generator the problem modeling becomes much more efficient. In consequence, the time spent on designing the mesh is significantly reduced, and it enables the study of more complex systems and geometries. For example, it made possible modeling the human brain with greater detail level (see Fig.4 (a) and (b)).



(a) (b)

Fig. 4. Image processed without (a) and with (b) the mesh generator.

It also allows visualization detail as shown in Fig.3, what was not possible to achieve without the mesh generator. In the full paper the simulation quality aspect is analyzed, as the influence of the mesh generator on the simulation results.

References

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