Edited by H. Ryssel, P. Pichler - September 1995

Unified Grid Generation and Adaptation for Device Simulation

G. Garretón L. Villablanca N. Strecker W. Fichtner

Integrated Systems Laboratory, ETH–Zürich, Switzerland
Phone: +41 1 632 49 50, FAX: +41 1 252 09 94
E-mail: gilda@iis.ee.ethz.ch

Abstract

This paper describes the design and development of a dimension-independent grid generator suitable for device simulation. The purpose of this work is to describe a modular, flexible and dimension-independent approach for the generation of grids with complex boundary restrictions.

1. Introduction

The increasing complexity of modern semiconductor devices and the need for powerful simulation have led to stringent requirements for grid generation. Without doubt, the grid becomes one of the most critical issues in the device simulation environment. A proper and suitable mesh is the key for success in any device simulation.

In the past, several techniques have been applied based on structured and unstructured meshes. For structured meshes, qtrees in 2-D and octrees in 3-D are the typical techniques. Delaunay-type algorithms, bisection-type approaches and advancing-front methods have been utilized for unstructured meshes.

Some of the techniques used for generating grid suitable for device simulation include octrees, modified 2-4-8 trees [1] and mixed elements [2] grid generators. However, many complex non-planar non-convex geometries can not be treated with these concepts.

Complex geometries could be treated if a set of basic properties is considered in the generation of the grid. Among others, these properties are an intersection-based algorithm, n-irregular elements and the construction of the first coarse grid for complex devices (initial grid) [3].

In the past few years, we have developed a series of grid generators for one, two and three dimensions (GRID1D [4], MESHBUILD [5] and OMEGA [6]). Our experience with these grid generators together with our successful research on those basic properties have motivated the unification of mesh-building algorithms in a modular and dimension-independent procedure, presented on this paper.

The basic steps and algorithms described here have been designed and grouped in a set of exchangeable modules. A modular implementation allows us to incorporate new basic elements and properties without losing generality. These modules can be arranged depending on the grid requirements for the specific application. This contribution describes: 1. A set of important properties and concepts to build up a powerful and flexible grid generator. 2. The effort spent on the design and development of MESH-LIB, a modular and dimension-independent grid generator. 3. Suitable meshes for the device simulator DESSIS [7] and the thermo-mechanical simulator SOLIDIS [8] obtained using MESH-LIB. 4. Preliminary results for 3-D modules.

2. General Concepts for an unified grid generator

From a large series of different 1-D, 2-D and 3-D examples, we are able to define some key elements which must be present in order to have success with any arbitrary geometry. These elements allow us to define the general algorithms to be implemented as the kernel of the tool (see Fig. 1).

These elements or properties have been identified as: 1. Construction of an initial grid. 2. Intersection-based and iterative algorithms. 3. The choice of the proper set of basic elements to use. 4. Adequate representation and adaptation to user inputs. 5. Templates management for boundary conditions and point propagations. 6. The definition of final grid properties depending on the next application to be used (Delaunay meshes for process simulators or Box-Method conditions in device simulators).

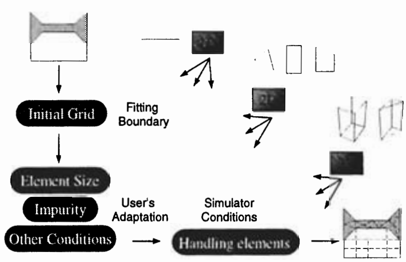


Figure 1: General overview of an unified and modular grid generator MESH-LIB.

3. Construction of the initial grid

The initial grid is the first coarse mesh which exactly fits the boundaries of the geometry. The quality of final grids depends strongly on this initial grid. Tensor-product grids or octree approaches are not sufficient to handle complex geometries.

We propose a set of heuristics to fit the given boundary description using a set of segments in 1-D, polygons in 2-D and polyhedra in 3-D.

4. Grid Adaptation

The conditions for grid adaptation are given by desirable points densities according to the supplied density functions. At this point, suitable oriented meshes (meshes with locally anisotropic point densities) are required.

Grid adaptation can be performed conforming to data obtained either from process or device simulation. Results in 1-D and 2-D confirm that the adequate accuracy and quality can be achieved using this technique (see Fig. 3.a).

5. Intersection-based Algorithms

In order to avoid the shortcomings of bisection-based approaches, intersection-based algorithms allow to refine elements at any arbitrary point. This property adds flexibility to grid generation since the best point can be chosen at each refinement step. The approach is useful for readaptation because it permits better mesh orientation. A good intersection-based algorithm reduces the overall point propagation considerably.

In contrast to previous grid generators [2], MESH-LIB handles n-connected elements which are the base for intersection-based algorithms [3]. These elements allow to have more than one neighboring element per edge in 2-D or per face in 3-D.

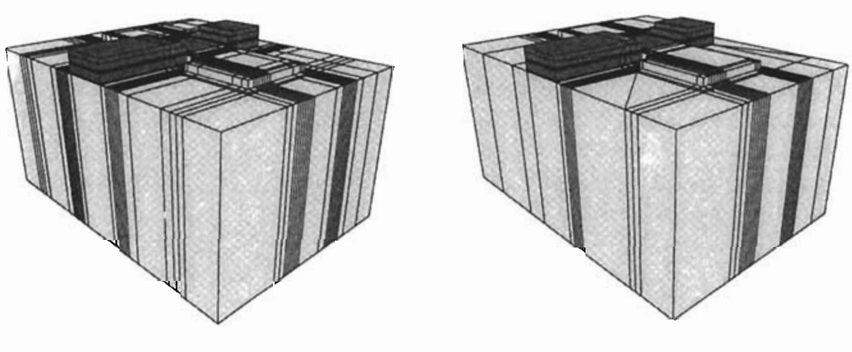
6. The Proper Set of Basic Elements and Templates

The main concept is to manage different types of elements according to the need of a particular physic problem. To illustrate this with an example in two dimension, the actual version of MESH-LIB has the flexibility to generate triangles and arbitrary quadrilaterals. For an application in semiconductor device simulation, this generality has been reduced to triangles and rectangles. For the multi-dimensional thermo-mechanical simulator SOLIDIS [8], MESH-LIB produces quadrilaterals but not triangles.

After the initial grid generation and grid adaptation, it is necessary to create the final elements from the n-connected elements. This last step is typically called *handling green points* (non-vertex points) or *handling n-connected elements.* The appropriate use of templates in this step allows to limit point propagation and to avoid redundant grid points in inactive regions of the device.

7. Comparison Between Two Approaches for the Initial Grid in 3-D

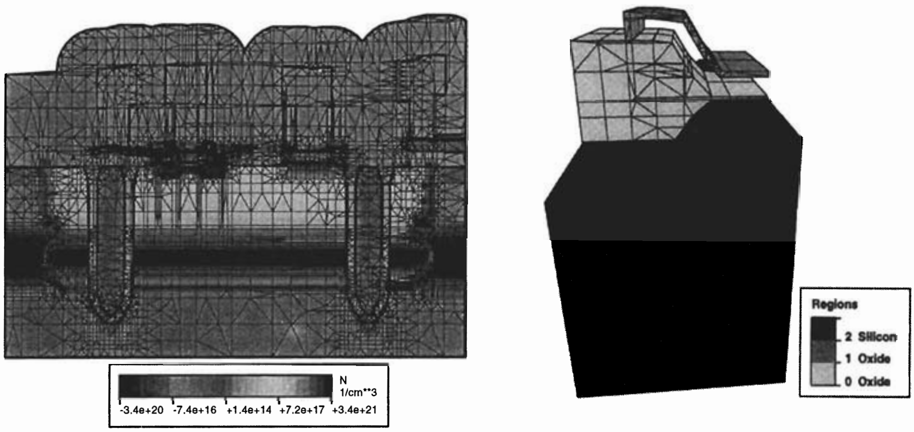
The Figure 2 shows the difference of having a tensor-product as initial grid as in OMEGA and having a intersection-based ones as in MESH-LIB. A simple Manhattan geometry displays the redundant refinements using tensor-product approach.



(a) (b)

Figure 2: (a) Tensor-product approach: 1254 elements. (b) Intersection-based approach: 805 elements

And finally the Figure 3.b shows part of a complex 3-D EEPROM. This geometry can not be handled using the tensor-product available in OMEGA. The new approaches in MESH-LIB allow us to fit more complex geometries as the ones shown in 3.b.



(a) (b)

Figure 3: (a) 2-D adaptation according to data from process simulation obtained by MESH-LIB. (b) Fitting a complex 3-D geometry with MESH-LIB: 948 elements.

Acknowledgments
This work has been financially supported by the ESPRIT-6075 (DESSIS) Project and by the ESPRIT-8150 (PROMPT) Project.

References

[1] P. Conti, M. Tomizawa, and A. Yoshi, "Generation of oriented Three-Dimensional Delaunay Grids Suitable for the Control Volume Integration Method," *Int. J. Numer. Methods Eng.*, vol. 37, pp. 3211–3227, 1994.

[2] N. Hitschfeld, *Grid Generation for Three-Dimensional Non-Rectangular Semiconductor Devices*. PhD thesis, ETH Zurich, Switzerland, 1993. publ. by Hartung-Gorre Verlag, Konstanz, Germany.

[3] G. Garretón, L. Villablanca, N. Strecker, and W. Fichtner, "A new approach for 2-d mesh generation for complex device structures," in *NUPAD V - Technical Digest*, (Honolulu, USA), June 1994.

[4] ISE Integrated Systems Engineering AG, *GRID1D - User's Guide*, 1994.

[5] S. Müller, K. Kells, and W. Fichtner, "Automatic Rectangle-based Adaptive Mesh Generation without Obtuse Angles," *IEEE Trans. Computer Aided Design*, vol. 11, pp. 855–863, July 1992.

[6] ISE Integrated Systems Engineering AG, *OMEGA - User's Guide*, 1994.

[7] ISE Integrated Systems Engineering AG, *DESSIS - Manual*, 1994.

[8] J. Funk, J. Korvink, M. Bächtold, G. Garretón, and H. Baltes, "An efficient simulation toolbox for coupled field analysis," in *XV CILAMCE Proc.*, (Belo Horizonte, Brasil), pp. 181–189, 30. 11 - 2. 12 1994.