Chapter 7

Conclusion and Future Research

7.1 Contributions

7.1.1 Spatial Decomposition Based Mesh Generation

A spatial decomposition based scheme is proposed for generating mesh in both 2D and 3D. A new approach, the level control function, is used for controlling the mesh density distribution. This new approach overcomes the refinement propagation problem during the quadtree/octree generation process and guarantees the one-level difference. The one-level difference rule is fundamental in order to generate a suitable mesh for the numerical solution of the partial differential equations. We have shown that the proposed tree refinement algorithm is optimal with respect to the level control function.

A major drawback for the conventional quadtree/octree based mesh schemes is its inability to generate quality mesh along the boundary of a mesh region. A new improvement based on the δ-zone concept has been incorporated into our meshing algorithm. By separating the interior region from the boundary, the δ-zone triangulation method prevents small feature elements to be generated.

7.1.2 3D Informational Model and TCAD services

A 3D informational model based TCAD framework is prototyped. A major objective for such a framework is to facilitate tool development for 3D TCAD applications. The

Semiconductor Wafer Representation (SWR) is used as our informational model for capturing wafer states. The information model is built using a commercial geometry modeler ACIS.

As one integral part of the framework, various services are provided to application developers, which include the 3D geometric modeling (boolean operations, location queries and etc.) and the mesh generation. It has been demonstrated that the services provided are essential for 3D TCAD tool development. The applications integrated with the prototyped framework consists of a 3D device generator(ET3D), a 2D cross section device simulator(PISCES), a 2D mixed-mode (SPICE and PISCES), a 3D interconnect analysis tool (FASTCAP) and a 3D visualizer (AVS).

7.1.3 Experiment of Object-Oriented Programming

The implementation of the 3D mesh generator is based on the object-oriented programming paradigm. Various OO techniques are applied throughout the implementation, which include the encapsulation, the class hierarchy, the inheritance and the polymorphism. Instead of the procedure based data flow, the program is made of a set of objects. The execution of the program is accomplished by the interactions among objects. A major advantage of taking OO approach is that the design, the analysis and the development phases are closely integrated. This enables a fast turnaround time in the software development process. The other advantage is that the OO approach is more modular and the software testing and maintenance can be better handled.

7.2 Future Research

The current implementation of the 3D mesh generator only uses tetrahedron elements. For many device simulators, brick elements can save computing resources (the CPU time and the memory) and increase the accuracy. Since the octree data structure is cube based by nature, it is not difficult to enhance the program so that mixed element mesh can be produced.

In our implementation of the level control function, we assume that the function is a scalar integer function. However, the function can be extended to be a vector function. This enables the mesh density to vary according to the direction, a desirable feature for many semiconductor device simulation tools. It has been known that most of activities occur along the surface of a device. Ideally, the mesh should reflect such a phenomena and generate more mesh elements along the z-direction but less along the surface, as illustrated in Figure 7.1. Such non-isocentric mesh can be achieved if a vector based level control function is allowed. One major difficulty to use a vector-based level control function is to ensure the one-level difference rule among different directions.

In the implementation of the 3D mesh generator, the triangulation scheme for the δ-zone is based on the WOO's algorithm, which does not guarantee any optimality. We have shown that for the interior region, the generated mesh complies with the Delaunay criterion and is optimal with respect to the level control function. To improve the mesh quality, better tetrahedralization algorithm could be used for the δ-zone region.

During our effort of prototyping the 3D TCAD framework, we experienced a major difficulty because of the lack of the integration with a field server[1]. We developed an attribution scheme based on the ACIS attribution mechanism. Attribution can be attached to geometry objects. But a more consistent and coherent way for doing this is through the field server. Without a field server, the mesh generated can only be stored separately from the geometry server. This can cause a major consistency problem. Without a unified geometry and field server, the moving boundary problem cannot be solved.

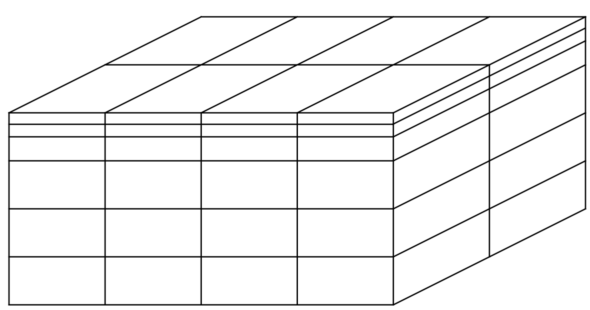

Figure 7.1 Non-isocentric mesh.

1. The effort of integrating Martin Giles' Field Server is currently under development.

It has been our experience that in order for a TCAD framework to be useful as a development framework, services provided are essential. This is specially true for 3D tool development. One service lacking in our prototyping is the 2D geometry modeling. ACIS is a good 3D geometry modeler. But a major drawback for ACIS is its inability to provide a good 2D support[1]. The other services which should be improved for the future 3D TCAD frameworks include the inter-tool communication, the graphical user interface and the persistent database.

1. We have been told that much improvements have been made for the new version of ACIS with respect to its 2D support.