FINITE ELEMENT MODEL GENERATION OF SHEAR WALL-FRAME SYSTEMS WITH VARYING CONFIGURATIONS USING A COMBINED QUADTREE-OCTREE PARTITIONING

Pher Errol B. Quinay[1*], Tsuyoshi Ichimura[2]

[1]Institute of Civil Engineering, University of the Philippines Diliman, Quezon City, Philippines

[2]Earthquake Research Institute, The University of Tokyo, Tokyo, Japan

[a]pbquinay2@up.edu.ph, [b]ichimura@eri.u-tokyo.ac.jp

ABSTRACT

Shear wall-frame systems are lateral force-resisting systems that are widely-used in mid-rise and high-rise structures. The objective of the study is to develop a finite element model generation procedure for these systems using a combined quadtree and octree partitioning. The procedure uses multiresolution mesh (hexahedron and tetrahedron) elements to accommodate varying column and shear wall layouts with regular geometry. Two models of a 10-story structure with different arrangement of shear walls and columns were considered as demonstrative examples. The results show that the procedure is capable of generating meshed models with high resolution, thereby capturing the local variations in structure response. In automating the developed procedure, the obtained low computation time in generating million finite elements shows that the procedure can contribute in improving the efficiency of the design process, specifically in CAD-CAE integration.

METHODOLOGY

The objective of the study is to develop an FE model generation procedure for shear wall-frame systems. The procedure modifies the framework of hybrid-grid FE model generation of Ichimura et al. (GJI, 2009) by using quadtree and octree structure to set the mesh elements and resolutions where columns and shear walls are located. The procedure for mesh generation is illustrated in **Figure 2**:

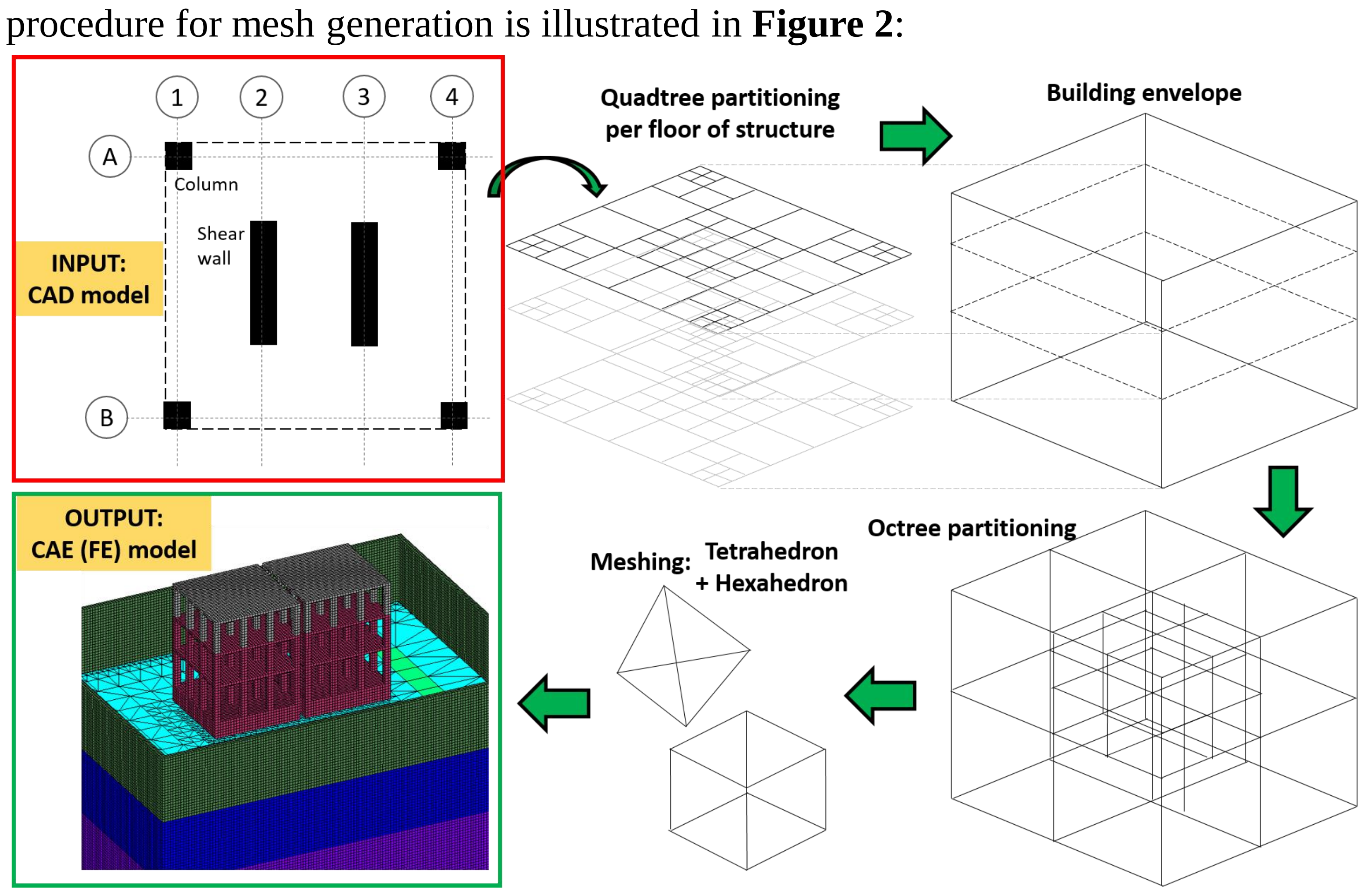


Figure 2. Developed procedure

Key features:

1. **Satisfying CAD-specified dimension of member sections** – recursive coarsening from background cells directly applies the geometry information from CAD model;
2. **Applicability to varying column-shear wall layouts and dimensions** – using multiresolution mesh elements satisfies the node-to-node connectivity in FE model;
3. **Reduction in memory usage in modeling and analysis stage –** using cubic hexahedron requires only to store representative elements and their addresses;
4. **Parallelizable** – since the procedure can be fully automated, multiple models can be executed in parallel in available high performance computers.

Limitation: Applicable only to structures and sections with **regular geometry**

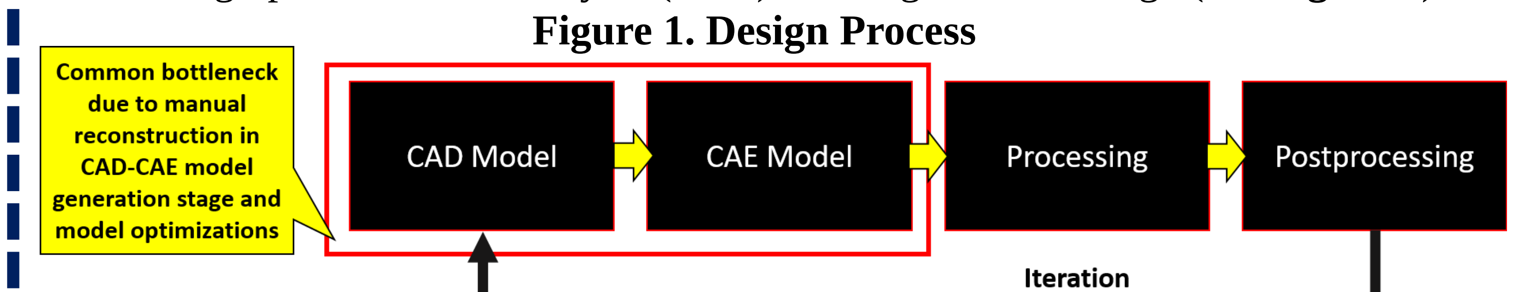
CONCLUSIONS

A finite element model generation procedure for shear wall-frame systems has been developed by using quadtree and octree partitioning to set the multiresolution hexahedron and tetrahedron elements. The procedure is applicable to varying column and shear wall layouts with regular geometry. Application to two models with different layouts showed that the procedure is capable of generating FE models with million elements but with low computation time. The procedure eliminates tedious and time-consuming manual reconstruction work in CAD-CAE model generation stages, which can lead to substantial savings in man-hours and use of resources.

INTRODUCTION

With the current shift to digitalization in the construction industry, there is an increasing demand for efficient procedures for Computer-Aided Design and Computer Aided-Engineering (CAD-CAE) integration. One of the major bottlenecks in the design process is the analysis (CAE) model generation stage (see **Figure 1**).

Figure 1. Design Process



The need for efficient procedures is highlighted in the case of shear-wall frame system – a system consisting of a moment-resisting frame combined with shear walls, and is designed to resist the lateral forces due to wind or earthquake. Finding the optimal arrangement of columns and walls is a highly iterative process which directly equates to man-hours and use of resources. Introducing automated model generation of the finite element (FE) models will lead to huge savings.

Quadtree and octree partitioning methods use the Cartesian grid to partition the space. Application of these methods to set the mesh elements can lead to automation of the procedure and reduction in computation cost (memory and time).

RESULTS AND DISCUSSIONS

A 10-story structure with 6 and 11 bays, is considered for demonstration of the application of the developed procedure. **Figure 3** shows the base frame model (without any shear walls) and plan views of two arrangements of shear walls for the base model, named as Model1 (without opening) and Model2 (with opening).

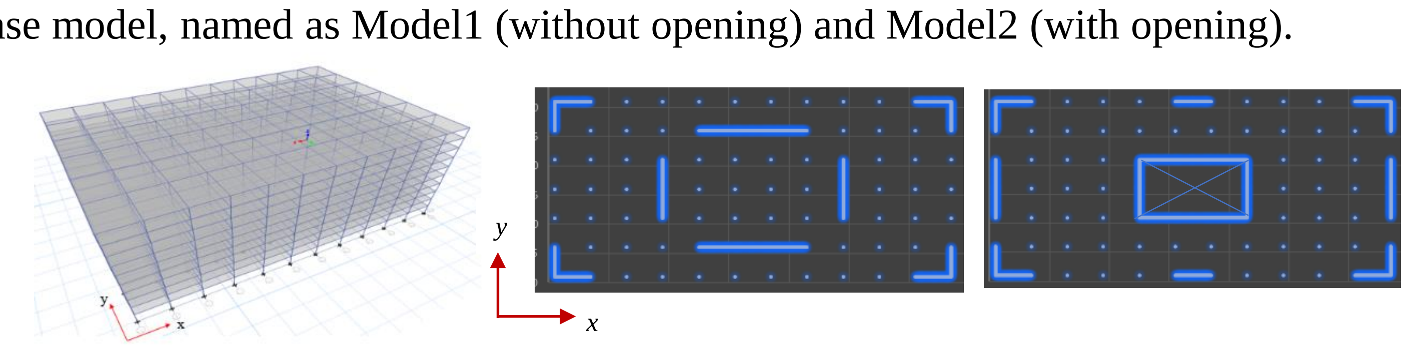


Figure 3. (Left) the base model; Plan views of (center) Model1; (right) Model2

Figures 4 and **5** shows the generated meshed models for Model 1 and Model 2, respectively, and a time snapshot of their deformation response (along the weak axis) to a dynamic load inputted at the bottom. **Table 1** lists the computation time.

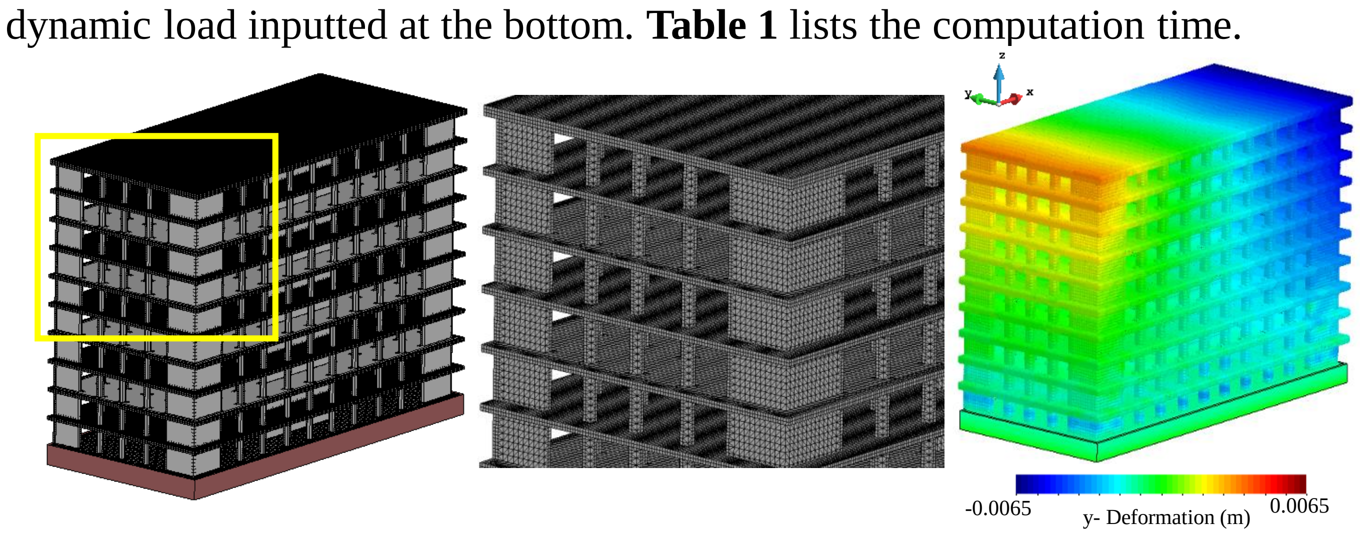


Figure 4. (Left) Generated FE model of Model1; (center) magnification showing the multiresolution mesh; (right) time snapshot of amplitude of deformation along the y-axis

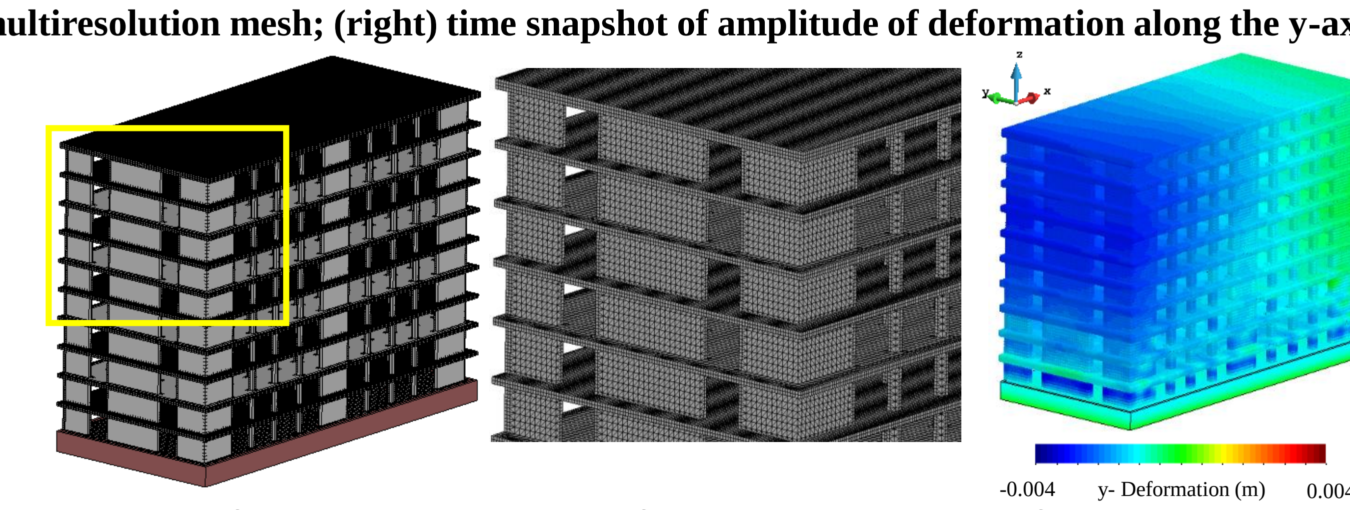


Figure 5. (Left) Generated FE model of Model2; (center) magnification showing the multiresolution mesh; (right) time snapshot of amplitude of deformation along the y-axis

Table 1. Computation time of automated procedure using DOST-ASTI CoARE HPC, showing capability to generate million-order finite elements in minutes.

Model	Number of mesh elements	Mesh generation time
Model1	**1,193,746** (612,772 hex + 580,974 tet)	**4 min 28 sec**
Model2	**1,253,886** (665,427 hex +588,459 tet)	**4 min 46 sec**