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DEVELOPMENT AND APPLICATION OF THE ONE-STOP FLOW ANALYSIS FRAMEWORK ENABLING RAPID DIGITAL ENGINEERING

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ABSTRACT

This paper proposes a one-stop simulation framework from point cloud acquisition through flow analysis. Conventional flow analysis starts with computer-aided design (CAD) software to define the object shape and any mesh generator to build computational grids. However, CAD data of old buildings and rooms, including furniture, is hardly available. Thus, CAD data creation, which takes a lot of time, is required when conducting flow simulations of existing buildings first. The present study illustrates a simplified flow analysis procedure, which reduces this lead time by defining the object shape with point clouds and using a Cartesian-based flow solver. The proposed framework simplifies the design of heating, ventilation, and air conditioning (HVAC) and could improve its existing process and quality.

1 INTRODUCTION

The development and spread of digital engineering, such as CAD and computer-aided engineering (CAE), is a driving force for quality improvement and cost/lead time reduction in engineering. With the development of these technologies, the requests for analysis of the field are becoming more complex. For example, if we can quickly know the airflow condition in the existing building whose CAD data is unavailable, we can easily plan to improve HVAC system design. However, in conventional CAE procedure, preparing a CAD model and generating a computational grid takes time and effort and occupies a large proportion of the total work time. It is necessary to shorten the time of these processes to improve the efficiency of the whole process. On the other hand, acquiring high-density point cloud data of existing objects with high accuracy is becoming possible because of recent progress in measurement technology, such as laser scanners. Point-cloud measurement technology enables the quick creation of 3D shapes in digital space. In the present study, we construct a framework that conducts the whole CFD process from the 3D measurement of existing objects to fluid simulation and performs the flow analysis of the existing room using the point cloud measurement data and the orthogonal solver.

2 METHODOLOGIES

Laser scanners and laser trackers are used to measure the shape of objects, and the output measurement data is a set of coordinate values called a point cloud. Since the point cloud does not directly represent the object's shape, it needs to be converted into shape data consisting of polygon meshes. The conversion from measured point cloud data to polygon mesh is performed through noise removal, outlier removal, registration, segmentation, and polygon surface mesh creation. We used CloudCompare and MeshLab for point cloud processing, which are widely used. This study used the orthogonal grid solver HINOCA as the flow solver (Mizobuchi et al., 2019). In HINOCA, a uniform orthogonal grid is used in the entire computational domain, and the immersed boundary method, which gives the presence of an object as a boundary condition for analysis, is applied. When a polygon mesh represented by STL data is provided to HINOCA, the existence of an object is automatically detected, and the user does not need to edit the computational grid around the object directly. In the airflow analysis of offices and halls, the influence of the boundary layer would not be so important; rather, there is a lot of demand to know the state of the entire airflow quickly without strictly treating the boundary layer's existence. Therefore, the uniform grid was used even near the wall surface in this study. In HINOCA, the Navier-Stokes equation is solved, and RANS and LES can be applied as turbulence models, but LES was used in this study.

3 RESULTS AND DISCUSSION

Figure 1 is a point cloud, acquired by a laser scanner, of the digital twin laboratory on the Katsushika Campus, Tokyo University of Science. We used Leica RTC360 as equipment to acquire the point cloud. The measurement time, including data alignment, was about 2 hours, and approximately 320 million points (7.2 GB) of point cloud data were obtained. The polygon mesh was created using MeshLab after processing, such as noise removal from the point cloud data in the laboratory, and MSC Apex was used for its correction. Such requirement of human procedure for the polygon mesh correction is a problem to solve in terms of continuous processing. The mesh size is 2.5cm against the laboratory size of 12m × 5.6m × 4.8m, and approximately 22 million computational grid points are used to solve the flow field. The computational time for 10,000 steps was approximately two days on a workstation (AMD Ryzen 9 3900X 12 cores, memory 64GB). To confirm the validity of the simulation, we measured the airflow velocity with a vane anemometer (Satotech AM-4207SD, measurement range: 0.4-25m/s, resolution: 0.1m/s).

Figure 2 shows the instantaneous streamlines of the obtained results and the measured flow speed value. The air flows into the room from the central ventilation port at about 3m/s and is discharged from the left ventilation port. The airflow from the ventilation hits the floor and spreads radially. The room divider obstructs the diffusion of the airflow, and the air concentrates on the floor surface. The results show the framework constructed in this study can give us the approximate flow state of the existing room from the point cloud measurement to the flow simulation in a few days. The process of creating an accurate polygon mesh from the measured point cloud without correction is a future issue.

Figure 1: Measured point cloud.

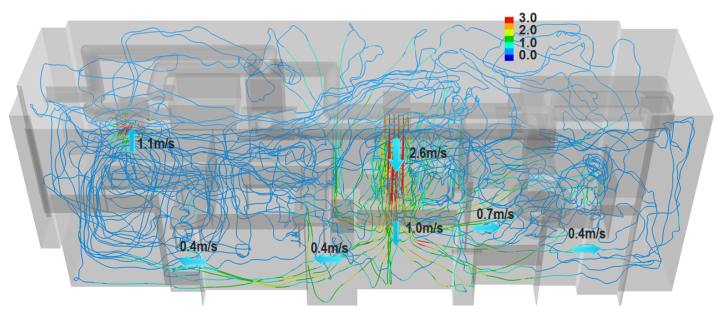

Figure 2: Instantaneous streamlines obtained by the simulation.

REFERENCES

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