GEOMETRIC OPTIMIZATION OF MECHANICAL ELECTRICAL AND PLUMBING (MEP) INFORMATION MODELS

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1 Background and Identification of Problem / Knowledge Gap

Building information models of Mechanical, Electrical and Plumbing (MEP) systems are generally characterized by redundant information and a high density of components with irregular shapes. MEP information models, compared with those of other disciplines such architectural and structural, have (i) an extremely larger number of components, (ii) more complex and significant interrelations with other engineering domains, and (iii) more spatial constraints in general, especially when addressing design changes due to restrictions by other systems. Consequently, they require large storage spaces and are not conducive for exchange and interchange purposes. The geometric optimization of MEP information models can play a significant role in facilitating model exchange and handover by increasing the efficiency of their storage, transmission and display. To date, the body of knowledge on geometric optimization of MEP information models is still very limited. This paper aims to address this knowledge and technical gap as follows.

2 Research Aim and Methodology

This paper presents an approach for the geometric optimization of MEP information models, develop and test a corresponding prototype in real world projects. The approach comprises of:

- **IFC-based model description:** Data models such as IFC are not optimized for storage and their highly structured geometry is demanding in terms of computing cost, making it unsuitable for operations involving a large number of objects in a query (Beetz et al., 2010). The IFC schema, however, defines Boundary Representations (BREP), primitive geometry (e.g. profile sweeping), and Constructive Solid Geometry (CSG) methods. Since each of these methods has unique indispensable characteristics, a multi-form storage mode was adopted in this research: primitive geometry and CSG hold essential abstract information such as lengths, surface areas and profile shapes that are required for collaboration. BREP, a richer form that uses restored topological faces that are reverse engineered from the triangulated, is necessary to obtain the geometries of arbitrary shapes. Hence, model information is stored in two forms, namely IFC files and BIM databases, the former is intended for information sharing purposes with other relevant information systems and actors, while the latter is used to structure model information for storage purpose.
- **Storage optimisation**: it employs a mapping-based model description method and a novel Quadric-Error-Metric (QEM) mesh simplification algorithm, reducing the required storage for such models while maintaining the contour of components. The similarity mapping compares two triangles meshes and the result is compared with a threshold, δ. If the result does not exceed δ, then the two components are similar and the model data will therefore be mapped. The value of the pre-set threshold δ could be adapted according to actual conditions, where a larger value stands for a lower tolerance for matching errors, and vice versa. Quadric Error Metrics (QEM)-based edge-collapsing algorithm simplifies the geometry while controlling the level of simplification to avoid severe distortion of the original model. An edge collapsing cost considering historical errors and overall accumulated error were developed to achieve this goal.
- **Transmission and display optimisation**: to enable efficient compression of data and fulfil the need for cross-platform exchange, the transmission of models employs spherical compression algorithms, fixed-dictionary and GZIP compression. Display optimisation employs a clustering-based normal vector regeneration algorithm for triangle meshes. A multi-step iterative process is used for the normal vector regeneration.

3 Research Findings

Tested on a complex geometry such as that of fire pump, the simplification algorithm achieved a compression ratio of 80% while maintaining the geometry visually intact (Figure 1). The solution proposed in this study was also

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applied to a large-scale MEP project, the Hedong Station of Guangzhou Metro in Liwan District, Guangzhou, China. The components in the MEP systems are in large numbers and complex shapes, with the number of triangles reaching up to about 10 million and occupying a storage space of around 2 GB of space. Figure2 shows that the proposed techniques reduced the transmission volume by more than 80% which is considered a significant contribution in terms of time and costs associated with transmission and display of models. Some limitations related to specific algorithms i.e. the similarity-matching algorithm considers coincidences and similarities between meshes after translation, but not after any other geometric transformations such as rotation or scaling) were identified and some issues regarding the selection of certain algorithms (i.e. K-means clustering algorithm requiring as input the number of clusters which is not known in advance) are still open for debate. Moreover, the algorithms proposed are also not easily parallelized. The similarity matching algorithm involves iterating through all the meshes in the model and tests the similarity between each pair; and the mesh simplification algorithm seeks to identify the vertex with the least collapsing error globally, which rules out the potential for the two algorithms to benefit from parallelization. Therefore, this limitation is inherent in the problem addressed itself, instead of in the proposed implementation. The rendering of the models are parallelized and calculated on the GPU, which is implicitly implemented by the graphics facility. The practical use of the proposed solution is in all engineering and construction applications requiring the storage, transmission and display of large volumes of model data, or in the operation stage where the adoption of 3D models is still embryonic.

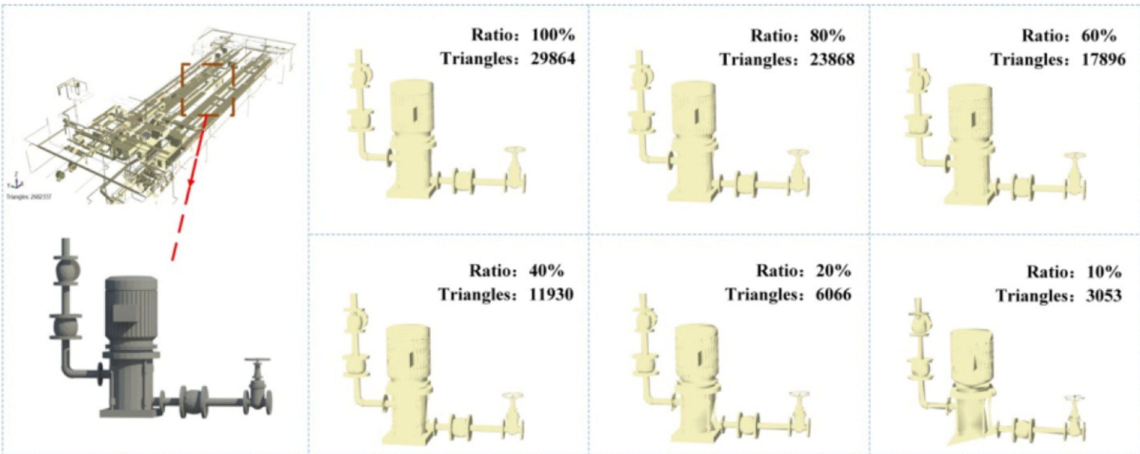

Figure 1: Different levels of Mesh Simplification for a Fire Pump

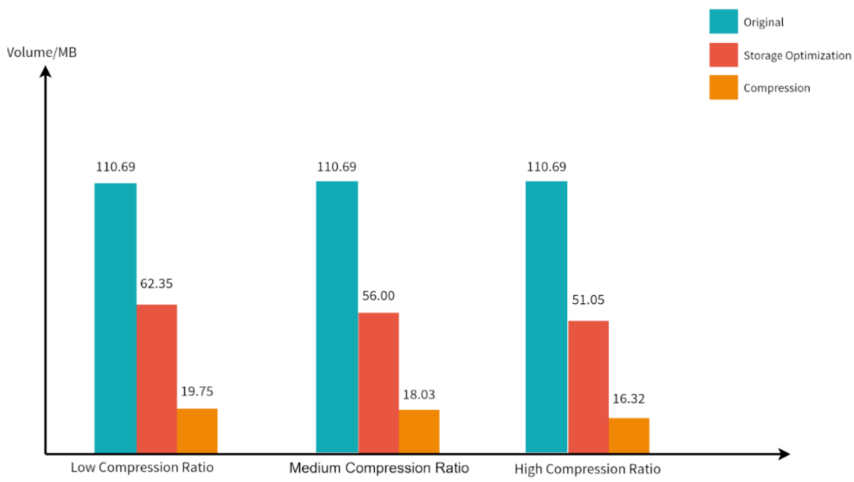

Figure 2: Storage optimization and compression of MEP models

4 REFERENCES

Beetz J., de Laat R., van Berlo L., van den Helm P. (2010) Towards an Open Building Information Model Server, Proceedings of the 10th International Conference on Design and Decision Support Systems in Architecture and Urban Planning, 19-22 July 2010, Eindhoven, The Netherlands.