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MEP PROGRESS MONITORING: CHALLENGES AND SOLUTIONS

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Introduction

MEP systems are crucial interior assemblies, encompassing various installations such as HVAC, piping, sprinklers, and electrical trays. Traditional progress monitoring of these systems is often challenging (Bosché et al., 2014). The layered nature of MEP installations and frequent occlusions can lead to difficulties in data interpretation. Furthermore, MEP environments commonly feature a high density of components, such as pipes and ducts, with significant variations in size and orientation (Pan et al., 2022). These factors collectively complicate the task of accurately assessing MEP installation progress. The aim of this study is to achieve progress monitoring of MEP, identify related challenges and propose potential solutions.

Related work

Vision-based technologies, including cameras and laser scanners, have been employed for MEP works progress assessment. A significant portion of research has focused on utilizing point cloud data for 3D reconstruction of MEP elements (Bosché et al., 2015; Patil et al., 2017; Wang et al., 2022). Several studies have also explored deep learning-based techniques for MEP component extraction from building point clouds, including classification (Xu, Kang, and Li, 2022; Kim, Nguyen, and Choi, 2020) and segmentation (Dimitrov and Golparvar-Fard, 2015). The quality of point cloud data for Scan-to-BIM applications in MEP scenes has also been investigated (Wang et al., 2022). However, a limited number of studies provide an end-to-end pipeline for MEP progress detection in real-world construction settings. Existing research has primarily focused on extracting accurate geometric and semantic information of MEP elements for Scan-to-BIM or Scan-vs-BIM comparisons (Bosché et al., 2014). This study addresses this gap by employing an occupancy-based method to compare as-designed BIM with as-built data, to determine MEP progress on a construction site in Finland.

Method

The data for this study was collected from a multi-facility sports construction site in Finland. As-designed data was obtained from the construction company in the form of BIM. As-built data was acquired through laser scanning, using a Trimble X7 scanner with a reported accuracy of 2mm at a range of up to 80m. A methodology was developed to perform a 2D comparison between the as-built point cloud and the as-designed BIM. The original

BIM data comprised three IFC files: Architecture, MEP, and SPR (Sprinkler). These files were combined to generate a 2D as-designed point cloud. This process involved converting the IFC files to .obj format, followed by point cloud conversion. The as-built point cloud was transformed into a 2D representation by setting the z-values of all points to zero. Registration of the as-built and as-designed point clouds was achieved using a combination of the Hough Transform and the Damer-Douglas-Peucker Algorithm (Ramer, 1972). Coarse alignment was performed by aligning the principal axes of the two point clouds. Subsequently, convex hulls were generated, and their corners were extracted to identify corresponding room and corridor locations. This step enabled fine registration of the as-designed and as-built point clouds. The Iterative Closest Point (ICP) algorithm was then applied for further fine-tuning of the registration. Following alignment, the progress of MEP installations was determined by comparing the registered 2D point cloud with the 2D representation of the BIM.

Results

The 2D registration of the as-built point cloud and the 2D representation of the BIM model was achieved automatically, as illustrated in Figure 1. Accurate alignment is crucial for effective comparison of as-built and as-designed MEP work. As shown in Figure 1, the MEP elements are not clearly distinguishable in the registered point clouds. This is attributed to the layered nature of MEP installations, which results in dense and overlapping point clouds when projected onto a 2D plane. To facilitate a clearer comparison, both the BIM model and the scanned point cloud were sliced at multiple, corresponding heights to isolate sections containing specific MEP elements. Figure 2 and Figure 3 show examples of these comparative sections at heights of z=3.2m and z=3.3m, respectively.

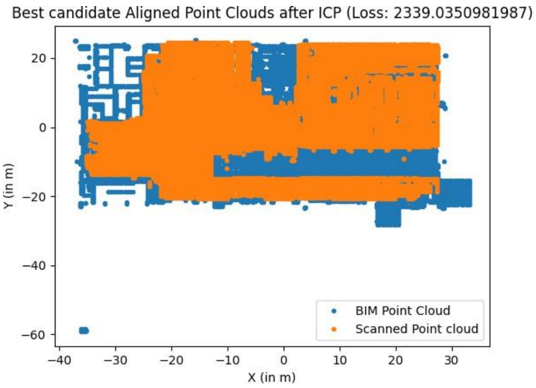

Figure 1: Registered point clouds in 2D

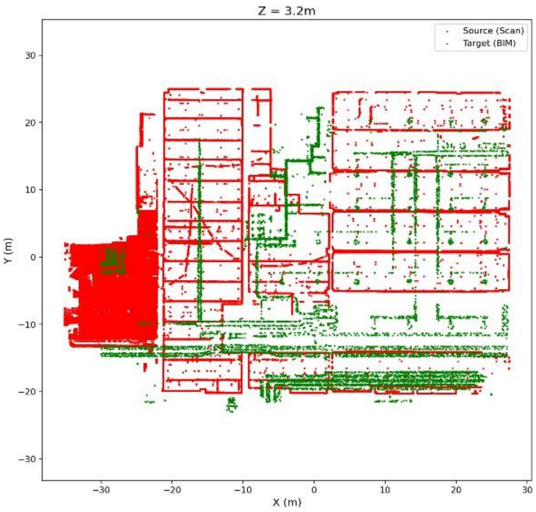

Figure 2: Sections compared at z = 3.2 m

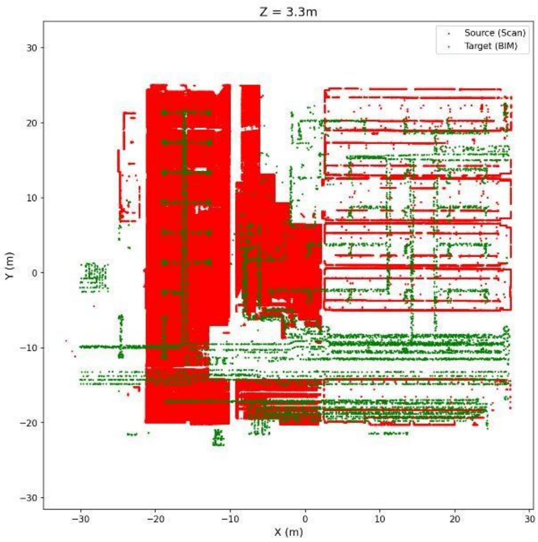

Figure 3:Sections compared at z = 3.3 m

Discussion

Occupancy-based methods generally provide effective results for end-to-end progress monitoring of MEP installations. The choice of a 2D representation facilitated increased processing speed, improved accuracy, and direct comparison of as-built and as-designed states. However, the study encountered limitations in specific scenarios. In cases where on-site installations, such as sewer layouts, deviated significantly from the BIM design, the occupancy-based method proved inadequate. The direct comparison of the as-built point cloud and the as-designed BIM, in these instances, did not accurately reflect the actual installation progress.

To address this limitation, future research should explore the integration of deep learning-based computer vision techniques. Classification of point cloud data to identify installed MEP components would provide a more robust solution. This approach, however, necessitates data fusion and, critically, a substantial volume of labeled point cloud data. The manual labeling of point cloud data is a labor-intensive and time-consuming process. Therefore, the development of novel and efficient solutions for automated point cloud labeling is a key area for future investigation.

Conclusion

MEP works form an important part of interior construction of a building. Though many researchers have explored the extraction of MEP elements from point cloud, there remains a gap regarding end-to-end progress monitoring. This work narrows this gap by using computer vision algorithms like Hough transform, convex hull and ICP to register the 2D point cloud to the 2D BIM automatically. It was observed that as-built MEP work differs from as-designed significantly. There is need to devise methods which can identify different components of MEP and determine the progress.

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