COARSE-TO-FINE MULTI-SOURCE POINT CLOUD REGISTRATION METHOD FOR URBAN ENVIRONMENT RECONSTRUCTION

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ABSTRACT: To create a comprehensive urban scene point cloud with improved precision, higher density, and superior geolocation accuracy, we propose a coarse-to-fine registration method for urban scene point clouds acquired from multi-sensors. Experimental results demonstrate that the proposed algorithm can achieve more precise registration of urban scene point clouds compared to existing methods.

1. INTRODUCTION

Smart cities are emerging as influential urban platforms that can address urban challenges and enhance the overall quality of life. A crucial element in realizing a smart city is the establishment of a real-time connection between the physical and virtual realms through a digital twin. The initial step towards creating a digital twin involves the reconstruction of the physical world into an immersive 3D virtual environment. UAV (Unmanned Aerial Vehicle)-based photogrammetry has emerged as a robust technique for reconstructing urban environments in 3D. However, it does come with certain limitations, including lower geolocation accuracy and challenges in capturing complete building facades and occluded areas. To address these limitations, this study introduces a novel method that employs a coarse-to-fine approach to register point clouds obtained from MMS (Mobile Mapping System) and TLS (Terrestrial Laser Scanning) with UAV-based photogrammetric point cloud.

2. METHOD AND RESULTS

We focus on the registration of 4 degrees of freedom (DOF) point clouds, as we can obtain high-accuracy gravity direction from MMS, TLS, and UAV-based photogrammetry. We propose BEWB-PCR (Building Exterior Wall Based Point Cloud Registration) as a coarse registration method. In urban environments, building exterior walls play a crucial role in shaping the cityscape. Hence, BEWB-PCR initially extracts points corresponding to the building exterior walls from both point clouds. These extracted exterior walls are then utilized to identify feature points using the FPFH (Fast Point Feature Histograms) algorithm, resulting in the generation of putative corresponding points between the two point clouds. However, due to limitations in the 3D feature point algorithm, a considerable number of outliers exist among the putative corresponding points. To mitigate this, we employ an AM-estimator and RANSAC to remove outliers from the putative corresponding points. Finally, the two point clouds are roughly aligned using the corresponding points identified as inliers. We introduce BOB-PCR (Building Outline Based Point Cloud Registration) as the fine registration method, which leverages building outlines to achieve precise alignment between the two point clouds. Initially, points corresponding to the building exterior walls are extracted from both point clouds. These extracted points are then projected onto the XY plane to generate the outlines of the building exterior walls. Subsequently, the ICP (Iterative Closest Point) algorithm is employed on the building outline data to perform a 2D transformation. Additionally, the SMRF (Simple Morphological Filter) algorithm is applied to extract the points corresponding to the ground. By utilizing these extracted ground points, the Z-offset is accurately corrected.

The experimental results demonstrate the superior robustness of BEWB-PCR against outliers and noise when registering multi-source point clouds in large-scale urban environments, outperforming existing coarse registration algorithms. Moreover, BEWB-PCR achieved a higher registration success rate compared to the existing methods. Additionally, the evaluation of BOB-PCR registration results using RMSE (Root Mean Square Error) and M3C2 (Multiscale Model to Model Cloud Comparison) distance confirmed its capability to achieve more precise registration of multi-source point clouds in large-scale urban environments compared to existing fine registration algorithms.

3. CONCLUSION

This study proposed coarse-to-fine approach algorithms, namely BEWB-PCR and BOB-PCR, to register urban scene point clouds acquired by multi-sensors. The experimental results demonstrated that the proposed algorithms could achieve more precise registration of urban scene point clouds compared to existing methods. We can generate a comprehensive urban scene point cloud with enhanced precision, higher density, and superior geolocation accuracy using the proposed algorithm.

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