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Assessment of target types and layouts in 3D laser scanning for registration accuracy

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ABSTRACT

3D laser scanning technology is now widely and increasingly used in several construction tasks such as indoor mapping, project control, construction metrology and automation, development of as-built models, and resource management through scanning, data processing, and modeling stages. The accuracy of these stages affects the quality of the end product and can be improved by decreasing the errors caused by manual work processes. This paper focuses specifically on data acquisition errors caused by target setup, acquisition, and reorientation. The paper explores how different target types and target layouts affect registration accuracy. A total of twelve tests were conducted with phase-based and time-of-flight scanners in both exterior and interior scan scenes in order to assess registration errors and time inefficiencies associated with current scanning practices. The paper compares different target types (paper, paddle, and sphere) and presents the lessons learned to achieve optimal target layout design.

1. Introduction

3D laser scanners (LADAR: laser detection and ranging, LIDAR: light detection and ranging) capture geospatial information of a scene, delivering thousands of points with Cartesian (x-y-z) or spherical (Φ-θ-r) coordinates. Initially developed for surveying and mapping, today 3D laser scanning applications extend to numerous civil engineering and construction management applications, including indoor mapping [1], project control [2–9], construction metrology and automation [10–15], development of as-built 3D CAD models and building information models of existing facilities [16–18], resource management [19], and so on.

3D laser scanners emit an eye-safe laser beam and calculate its distance to the scanned object based on the phase difference between the emitted and return signal (phase-based) or based on light's round-trip time of flight (time-of-flight). Phase-based (PB) scanners deliver data faster than time-of-flight (TOF) scanners, but TOF scanners are more often used in outdoor settings, as they are capable of scanning distant objects. Laser scanners capture data from objects that are in their line of sight. To capture all aspects of the objects, scans from multiple locations are needed, which result in multiple point clouds. The process of transforming two or more point clouds into a single database is called registration. There are two categories of registration methods: target-free and target-based. Target-free registration uses control points and cloud-matching methods. The 3D laser scanner is set over a point with known coordinates (a control point) and the operator back-sights to another known point to measure the orientation. This method is not frequently used in current practice, since it requires accurate instrument installation over specific points and any error made in acquiring the position of a point makes the data collected at that point unusable. In addition, the need for data pre-processing, additional scans that provide large overlap areas, and extractable geometric features are the main disadvantages of this category of method [20]. Target-based registration uses artifacts known as targets to merge multiple point clouds. Paper, paddle, and sphere targets with a high-contrast or highly reflective surface are widely adopted target types in current practice [21]. This paper focuses on the target-based registration method, as it is widely used in the construction industry and it has the potential to address the needs of the industry in terms of accuracy required, scale of the problem, scope of work, and the resolution of the point clouds.

Though the construction industry is adapting 3D laser scanners with increasing speed, several errors occur during the data acquisition and data processing stages. This paper focuses on data acquisition errors resulting from manual work processes, as these errors lead to imprecise end products and also increase the time required for scanning operations. The authors aimed to provide appropriate results without the fine registration process, and framed the scope of the paper accordingly. The paper evaluates errors and inefficiencies associated with the three target types (paper, paddle, and sphere). It describes twelve tests conducted in interior and exterior settings with both TOF and PB scanners, and measures errors that occurred and also the time needed for each data acquisition step to quantify the effects of the different types of targets. The paper presents the findings and provides recommendations for an alternative target system for future research to overcome some of the drawbacks of the current target types and industry practices.

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