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On-site visualization of building component erection enabled by integration of four-dimensional modeling and automated surveying

Xiong Liang [c], Ming Lu [a,*], Jian-Ping Zhang [b]

[a] Department of Civil and Environmental Engineering, University of Alberta, Edmonton, Canada
[b] Department of Civil Engineering, Tsinghua University, Beijing, China
[c] Department of Civil and Structural Engineering, Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong

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ABSTRACT

This research develops a new methodology for seamless integration of automated construction surveying with four-dimensional (4D) modeling in order to improve current practices of building component positioning and erection in terms of efficiency and quality. The building production models are represented in 4D and generated in consideration of construction engineering constraints, such as lifting capacity of tower cranes, construction method and activity sequence. The surveying data include identification, surveying time and coordinates of a limited quantity of tracking points that are marked on a building component. The data are processed using a special algorithm to derive transformation matrices, which encode movements and rotations of a solid object in the 3D space. As a result, the 3D model of the building component is updated to mirror its actual motion in the site during installation operations. Furthermore, by comparing the as-designed model and the actual model of the building product, any deviations between them are determined in terms of position offsets and rotation angles, which facilitate follow-up adjustment operations. A software system named as 4D-PosCon (acronyms of four-dimensional positioning controller) was prototyped based on the proposed methodology. Laboratory experiments were designed and carried out, validating the proposed methodology and demonstrating the prototype system of 4D-PosCon. In conclusion, the resulting 4D visualization is effective to facilitate positioning control in erecting a building component by providing intuitive perception and accurate comprehension of the relative orientation and position of the building component in reference to its final as-designed state.

1. Introduction

Locating and positioning building components in the three-dimensional space of a construction site is the fundamental construction operation [1]. Accurate positioning of bulky building components such as structural steel members are labor-intensive, highly repetitive and time consuming tasks, which are normally conducted by laborers exposed in a potentially hazardous environment like an elevated location [2,3]. In an American Institute of Steel Construction report, decreasing fabrication and erection time for steel frame building while increasing the safety of workforce during construction are identified as two crucial issues on automated steel construction, while time required to erect a steel frame structure needs to be reduced by 25% for the steel construction industry to remain competitive [3]. At present, it is imperative to improve positioning control practices during the process of erecting bulky building components, aimed at better productivity, enhanced safety and higher quality.

On the other hand, automated reality capturing technologies and computer technologies have been rapidly advancing, making construction sites more intelligent and integrated [4]. In recent years more and more construction projects have used three-dimensional/four-dimensional (3D/4D) models to support management tasks [5]. While these models contain accurate spatial information of the building products to be constructed, when it comes to the setting of an actual construction field, those spatial models have not yet found much value-added applications [2]. One main reason is that these models lack the integration of "reality" information enabled by cost-effective methodologies so as to materialize seamless integration with automated reality capturing technologies [6].

This research develops a new methodology for integration of automated construction surveying with 4D modeling in order to improve current practices of building component positioning and erection in terms of efficiency and quality. Given a building component being installed, any deviations between its actual position state and its as-designed final position state are computed according to site surveying data and visualized in a 4D system. 3D models for both the current site state and the final as-designed state are contrasted in the same screen. This enables site engineers to make

* Corresponding author. Tel.: +1 780 492 5110; fax: +1 780 492 0249.
E-mail address: mlu6@ualberta.ca (M. Lu).

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