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Smart scanning and near real-time 3D surface modeling of dynamic construction equipment from a point cloud

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ABSTRACT

This paper introduces a framework of automatic object recognition and rapid surface modeling to aid the heavy equipment operation in rapidly perceiving 3D working environment at dynamic construction sites. A custom-designed data acquisition system was employed in this study to rapidly recognize the selected target objects in a 3D space by dynamically separating target object's point cloud data from a background scene for a quick computing process. A smart scanning method was also applied to only update the target object's point cloud data while keeping the previously scanned static work environments. Then the target's point cloud data were rapidly converted into a 3D surface model using the concave hull surface modeling algorithm after a process of data filtering and downsizing to increase the model accuracy and data processing speed. The performance of the proposed framework was tested with two different heavy equipment types at a steel frame building construction site. The generated surface model and the point cloud of static surroundings were wirelessly presented to a remote operator. The field test results show that the proposed rapid target surface modeling method would significantly improve productivity and safety in heavy construction equipment operations by distinguishing a dynamic target object from a surrounding static environment in 3D views in near real time.

1. Introduction

The interactions between workers, equipment, and materials can easily create visibility-related accidents. Visibility problems can lead to serious collisions without pro-active warnings. There have been a number of advances in vision-aid techniques because lacking full visibility is a major contributing factor in accidents at construction sites. 3D spatial modeling can help to optimize equipment control [1,24,26,29,30], significantly improve safety [2,3,26–29], monitor construction progress [4], and enhance a remote operator's spatial perception of the workspace [5–8,26,28,29]. However, the rapid processing of tens of thousand bits of range data in real time is still an unsolved problem requiring further investigation [9]. Unstructured work areas like construction sites are difficult to graphically visualize because they involve highly unpredictable activities and change rapidly. Construction site operations require real-time or near real-time information about the surrounding work environment, which further complicates graphical modeling and updating.

One commonly used method to obtain the 3D position of an object is based on 3D laser scanning technology [7,10,11]; this method, however, has some limitations, such as low data collection speed and low object recognition rates [12]. It has always been a challenge to recognize specific objects from a 3D point cloud in unstructured construction environments because it is difficult to rapidly extract the target area from background scattered noises in a large and complex 3D point cloud.

While rapid workspace modeling is essential to effectively control construction equipment [13], few approaches have been accepted by the construction industry due to the difficulty of addressing all the challenges of current construction material handling tasks with the current sensor technologies. Thus, an innovation in rapid 3D spatial information is necessary to meet the challenges. The main objective of this paper was to design, develop, and validate a 3D visualization framework to collect and process dynamic spatial information rapidly at a cluttered construction job site for safe and effective construction equipment operations. A multi-video camera integrated vision-based object recognition and tracking method has been developed, based on which, a smart laser scanning method was proposed to reduce data size and scanning time. Additionally, the proposed visualization methods were demonstrated and validated based on a real-time data transmission network using a wireless technology.

This paper is organized as follows. First, a literature review of state-of-the-art object tracking and visualizing techniques applied on construction job sites is discussed. Then, a dynamic, rapid surface modeling framework is introduced. After that, the validation tests in the construction field are presented, followed by conclusions and future work.

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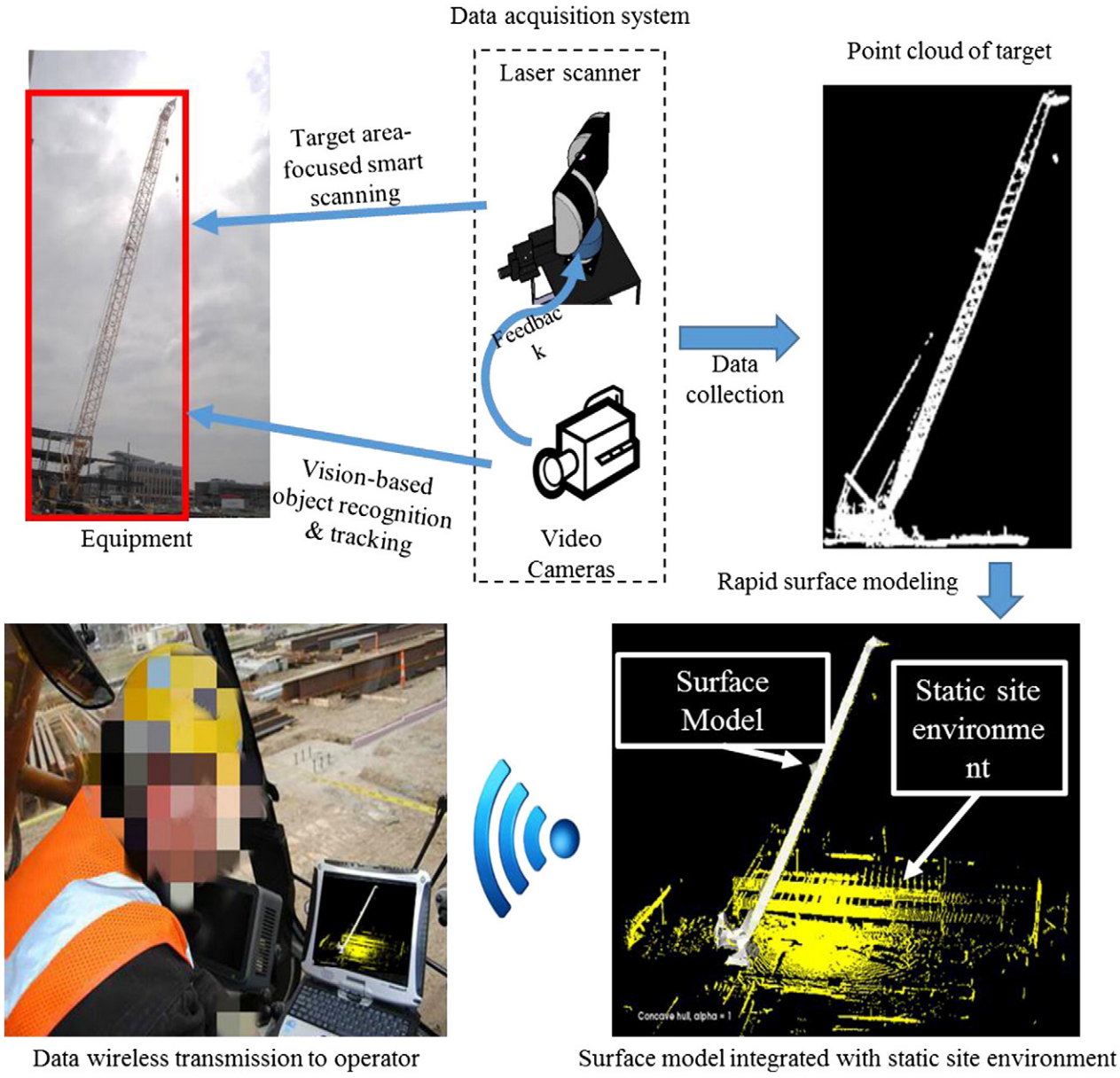

Fig. 1. Framework of the proposed method.

Fig. 2. Prototype data acquisition system (left) and a field data collection (right).