Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 196 (2017) 36 – 44

Procedia Engineering

www.elsevier.com/locate/procedia

Creative Construction Conference 2017, CCC 2017, 19-22 June 2017, Primosten, Croatia

Automated Method for Optimizing Feasible Locations of Mobile Cranes Based on 3D Visualization

Zaiyi Pan[a]*, Hongling Guo[a], Yan Li[a]

[a] *Department of Construction Management, Tsinghua University, Beijing 100084, China*

Abstract

The precise operation of mobile cranes contributes to the safety and efficiency of lift works, among which accurate location is one of the most critical aspects. Considering the complexities and dynamics of construction sites, this paper presents an approach for crane location determination based on the simulation of mobile crane operations. First a data processing method is developed to enable the automated conversion from BIM (Building Information Modeling) and schedule plan to the simulation system. Then the reachability and work radius of mobile cranes are examined for selecting the initial feasible location points. The bounding box method is used for the collision detection to ensure the safety of crane operations. Also, the minimum number of relocation and the lift time are taken into account to determine the final feasible location points of mobile cranes.

Peer-review under responsibility of the scientific committee of the Creative Construction Conference 2017

Keywords: mobile crane; location; automation; 3D visualization; collision detection

1. Introduction

Mobile crane is one of the most important equipment in construction sites, being widely used in the lifting work in various construction areas because of its flexibility and good load performance. Especially with the rapid development of prefabricated construction, on-site assembly of prefabricated components is becoming more and more necessary. The lifting of heavy components makes mobile cranes indispensable. Lifting operations are quite complicated with high risks, so a detailed lift plan is in need before lifting operations. Combined with virtual construction technology, lift planning could achieve visualization, high accuracy, and advanced simulation and optimization. Previous research mainly focuses on the path planning of mobile crane, however, rather than the

* Zaiyi Pan. Tel.: +86-10-62796507.
E-mail address: pzy15@mails.tsinghua.edu.cn

Peer-review under responsibility of the scientific committee of the Creative Construction Conference 2017
doi:10.1016/j.proeng.2017.07.170

location of mobile crane, which is also a significant part of lift planning. Unlike a tower crane which is fixed in a location and has a big working radius, a mobile crane moves around a construction site according to some specific lift requirements; and the boom of mobile crane is oblique rather than horizontal, so the collision problems are more likely to occur during operating. As a result, the locations of a mobile crane need to meet lifting requirements and safety requirements, as well minimize the number of relocation. In practice, identifying the locations of a mobile crane mainly relies on project managers' experience.

Previous research employed various mathematical or simulation algorithms to determine optimal crane locations. Some of them used two-dimensional (2D) drawings to calculate feasible crane location areas and location centers. By defining the existing structure and obstructions as well as the crane working radius, the overlapping areas can be calculated as the optimum crane location area [1,2]. But this didn't consider spatial factors. The others consider spatial conflict by verifying the clearance of crane booms or jibs and buildings in elevations [3]. When a construction site is small enough, a crane can be located at the center of all structures [4,5]. Han et al. [6,7] developed a methodology considering the distances between random points and the centers of each structures, and the crane location was determined by finding out the minimum distance. In addition, Genetic algorithms (GAs), as a heuristic random search technique, are also be used to determine the optimum location of cranes via considering safety, clearance, site conditions, etc. [8].

Based on the above possible locations determined by using 2D methods, some research used three-dimensional (3D) simulation methods to simulate the lifting operations and identify collision-free locations. For example, to define spatial conflicts utilizing the boom-line intersection and bounding box method [9], and optimize the results by minimizing the number of relocation [10] or the weight sum [11]. Both 2D and 3D methods are capable of determining crane locations by considering of the existing structure and work radii. 3D methods consider spatial factors via utilizing simulation methods such as box bounding, making the process of identifying conflict-free crane locations more valid and comprehensive than 2D methods. However, existing 2D and 3D methods both require a large amount of inputting or modeling manually, thus consuming lots of time in practice. In addition, most of the researches only utilized mathematical methods while calculating the working radius and lifting height, without taking actual operation limitations into account.

This paper develops an automated method for optimizing feasible locations of mobile cranes based on 3D visualization, which will take the practical restrictions of mobile cranes into account. The aim of this research is to improve the efficiency of automatically locating mobile cranes as well to ensure the safety operations. It will also contribute to the automated simulation of construction processes, thus increasing the safety of lifting operations and reducing equipment cost.

2. Automated approach to locating mobile cranes

The automated location approach for mobile cranes is presented in Fig. 1, involving the process of identifying optimal feasible crane locations of mobile cranes as well as three key constraints. The method generates a set of candidate locations and validates the three key constraints in turn, which aid in eliminating the locations where the cranes cannot access or cover expected working areas, even with safety problems. Finally feasible locations are identified and the lifting efficiency is analyzed for the optimal result.

The identification of feasible crane locations starts with data input and automatic conversion. The 4D BIM model of a construction project incorporated with the lift plan is required as input, containing the geometric and non-geometric information of the project, which are classified into lifting information (such as component ID, initial and final locations of components, and lifting time) and project site information (such as building bottom coordinates, material storage yard coordinates, and the building components linked build time). The model is imported and the data will be automatically acquired and used for 3D visualization and later calculations. The developed approach also requires the crane database involving crane configuration and the lifting performance data, and will reused this kind of information in different project.

Then a method of representing the location of a crane is developed. As the safety constraints and efficiency validation are considered in the locating approach by traversing each candidate locations and simulating the lifting operation, the locations should be represented as a set of discrete points rather than consecutive points in some areas. In this paper, the candidate locations of a crane are referred to as a set of points by the grid method. The developed