基于萤火虫算法的塔吊选位布置智能优化

刘聪　讲师

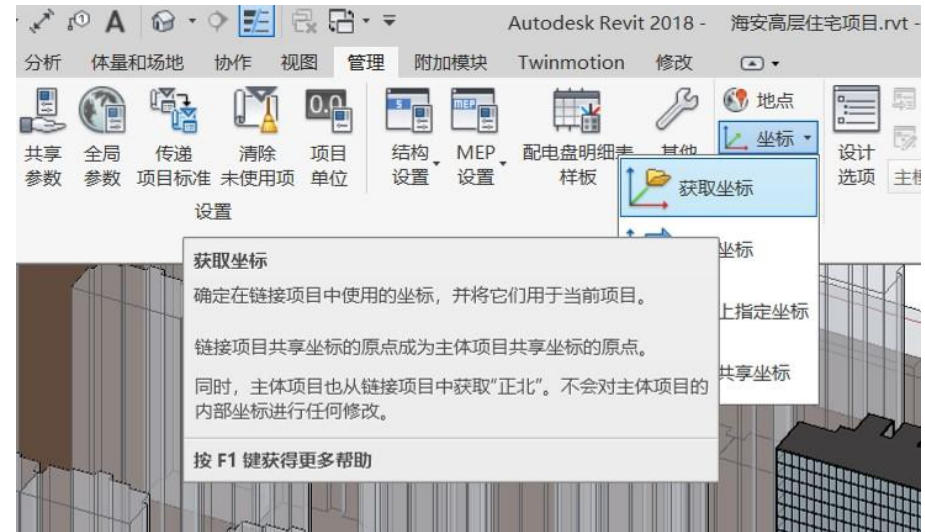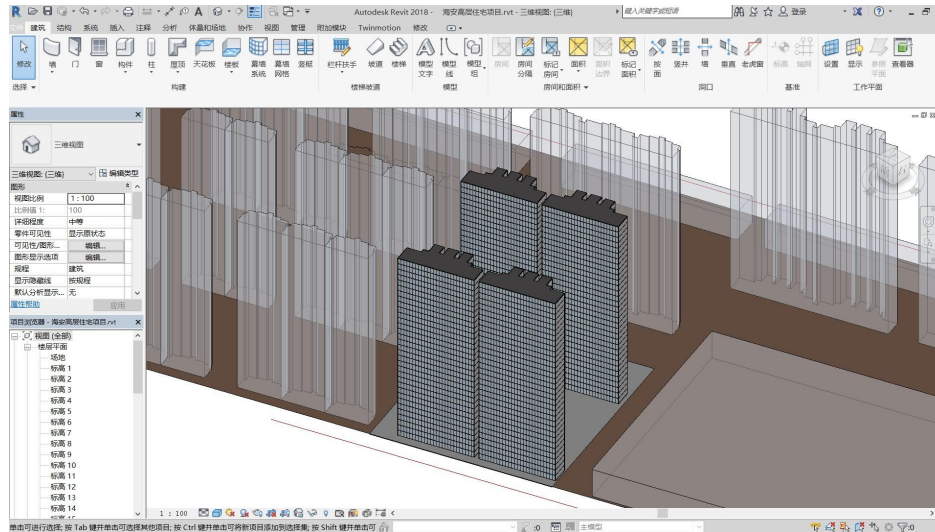# 基于萤火虫算法的塔吊选位布置智能优化

1.塔吊选位的重要性

2.BIM获取世界坐标信息

```
#6= IFCCARTESIANPOINT((0.,0.,0.));

#31= IFCAXIS2PLACEMENT3D(#6,$,$);

#32= IFCLOCALPLACEMENT(#311,#31);

#114= IFCBUILDING('1BNyUUMcj6ywEAW7k0zZlo',#41,'',$,$,#32,$,'',.ELEMENT.,$,$,#110);

#120= IFCAXIS2PLACEMENT3D(#6,$,$);

#121= IFCLOCALPLACEMENT(#32,#120);

#123= IFCBUILDINGSTOREY('1BNyUUMcj6ywEAW7j$2VSC',#41,'\X2\68079AD8\X0\
1',$,$,#121,$,'\X2\68079AD8\X0\ 1',.ELEMENT.,0.);

#310= IFCAXIS2PLACEMENT3D(#6,$,$);

#311= IFCLOCALPLACEMENT($,#310);

#312= IFCSITE('1BNyUUMcj6ywEAW7k0zZln',#41,'Default',$,'',#311,$,$,.ELEMENT.,
(42,21,31,181945),(-71,-3,-24,-263305),0.,$,$);

#165= IFCCARTESIANPOINT((-7318.22370947408,711.194038980438,0.));

#167= IFCAXIS2PLACEMENT3D(#165,$,$);

#168= IFCLOCALPLACEMENT(#121,#167);

#170= IFCCOLUMN('0Ae7iOjK982gh$h7PwMCca',#41,'M_\X2\77E95F6267F1\X0\:475 x
610mm:203111',$,'475 x 610mm',#168,#161,'203111');
```

方法 一

基于萤火虫算法的塔吊选位布置智能优化

2.BIM获取世界坐标信息

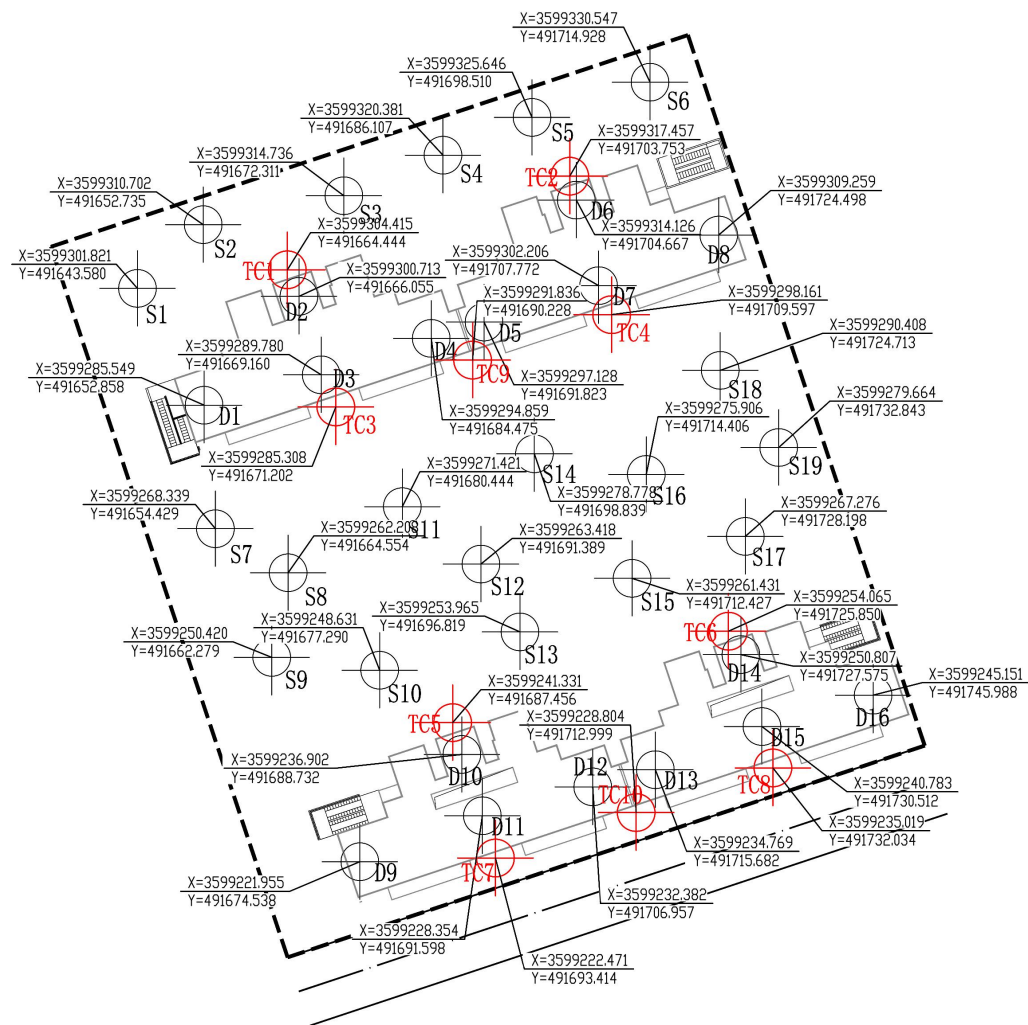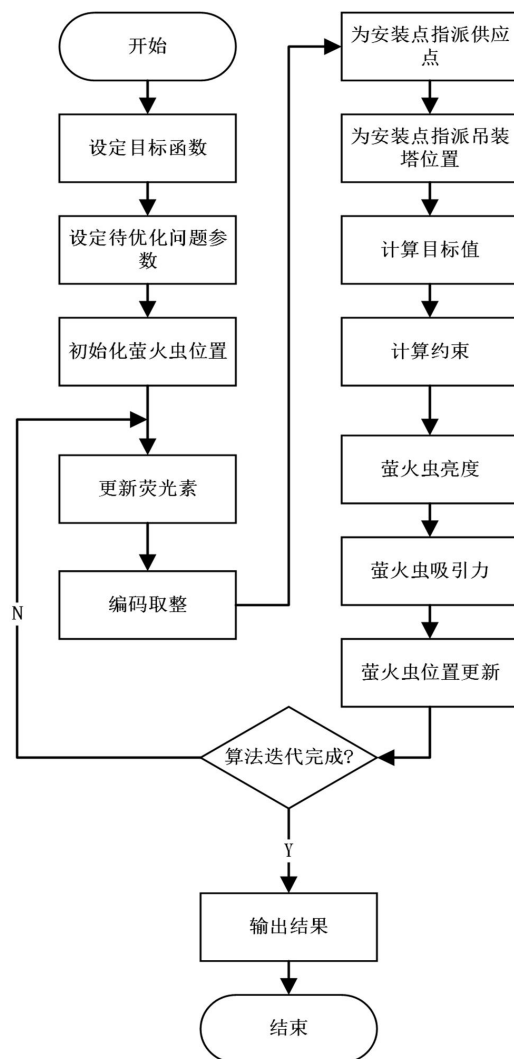方法 二

2.BIM获取世界坐标信息
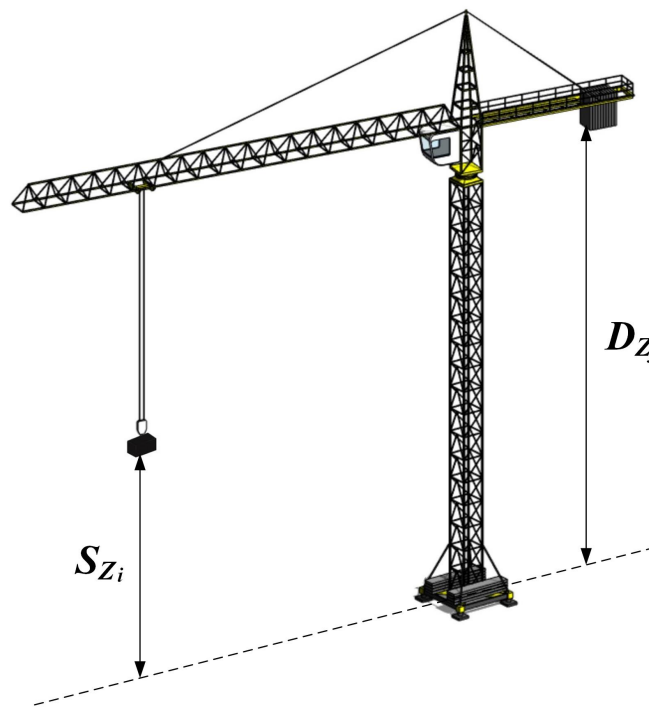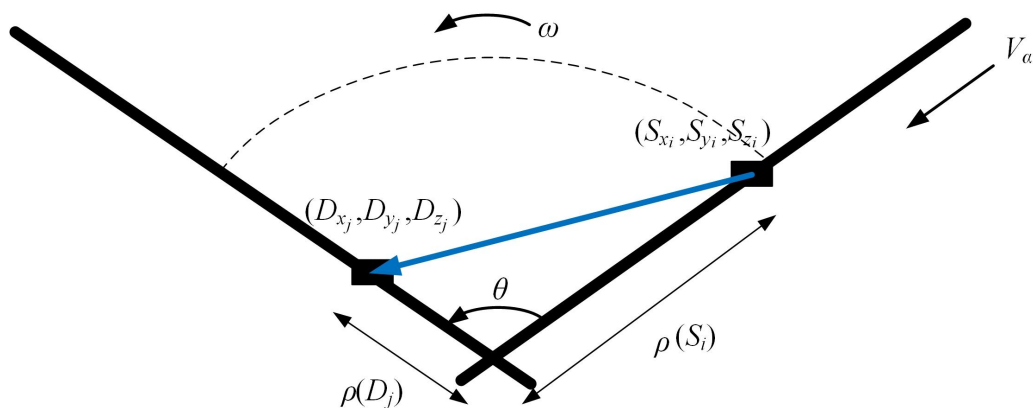
3.解决方法

步骤1： 初始化萤火虫的位置
步骤2： 更新荧光素
步骤3： 更新萤火虫的位置
步骤4： 计算萤火虫的最大亮度和吸引力
步骤5： 选择并判断算法是否迭代完成
步骤6： 输出结果

4.构建目标函数

$$\min TC = \min \sum_{k=1}^{K} \sum_{i=1}^{I} \sum_{j=1}^{J} T_{ij}^{k} \times Q_{ij}^{k} \times C^{k}$$

5.程序运行和结果分析

表1 选择的材料供应点坐标

	Coordinate (X)	Coordinate (Y)	Coordinate (Z)
S7	3599268.339	491654.429	0
S9	3599250.420	491662.279	0
S10	3599248.631	491677.290	0
S11	3599271.421	491680.444	0
S13	3599253.965	491696.819	0

表2 选择的塔吊定位点坐标

塔吊编号	X	Y	Z	选择结果	吊运时间s
T1	3599285.308	491671.202	0	TC3	1386624.8438171
T2	3599298.161	491709.597	0	TC4	1782787.85242233
T3	3599241.331	491687.456	0	TC5	5152019.24629754
T4	3599254.065	491725.850	0	TC6	17034181.8045609
Total					25355613.747098

5.程序运行和结果分析

基于萤火虫算法的塔吊选位布置智能优化

5.程序运行和结果分析
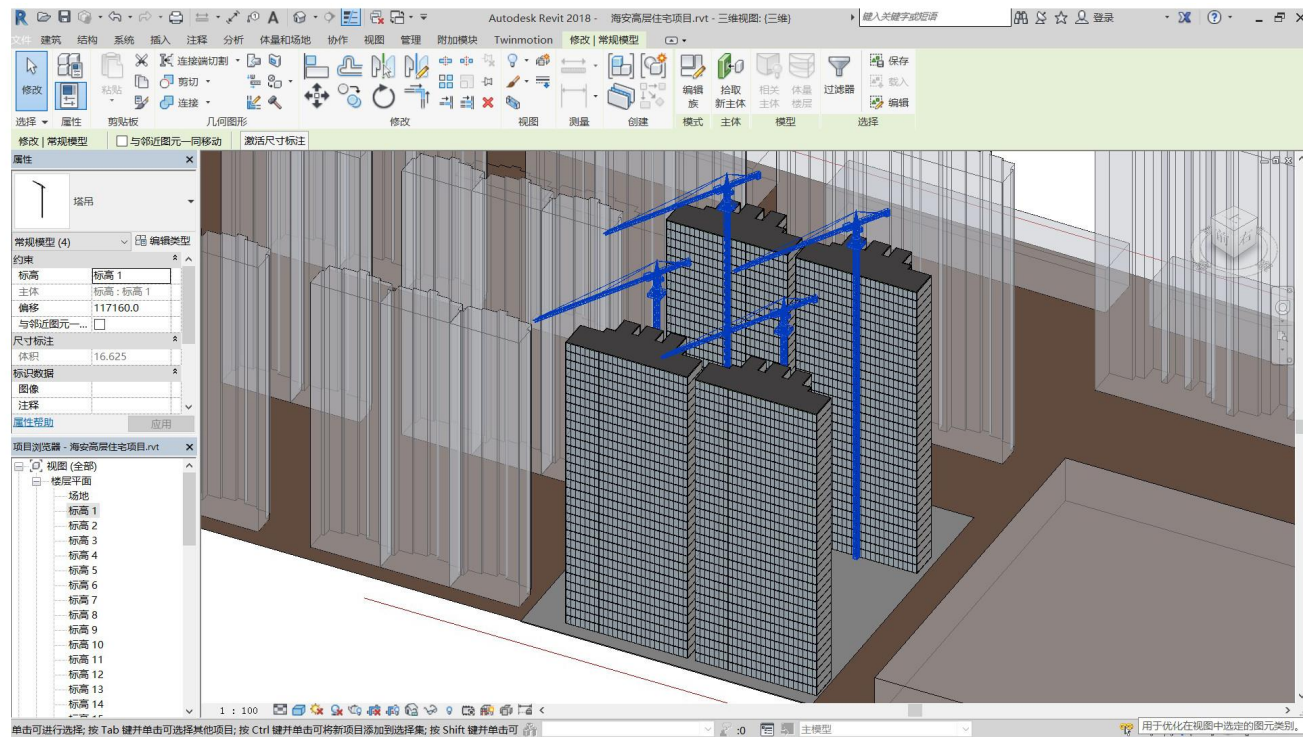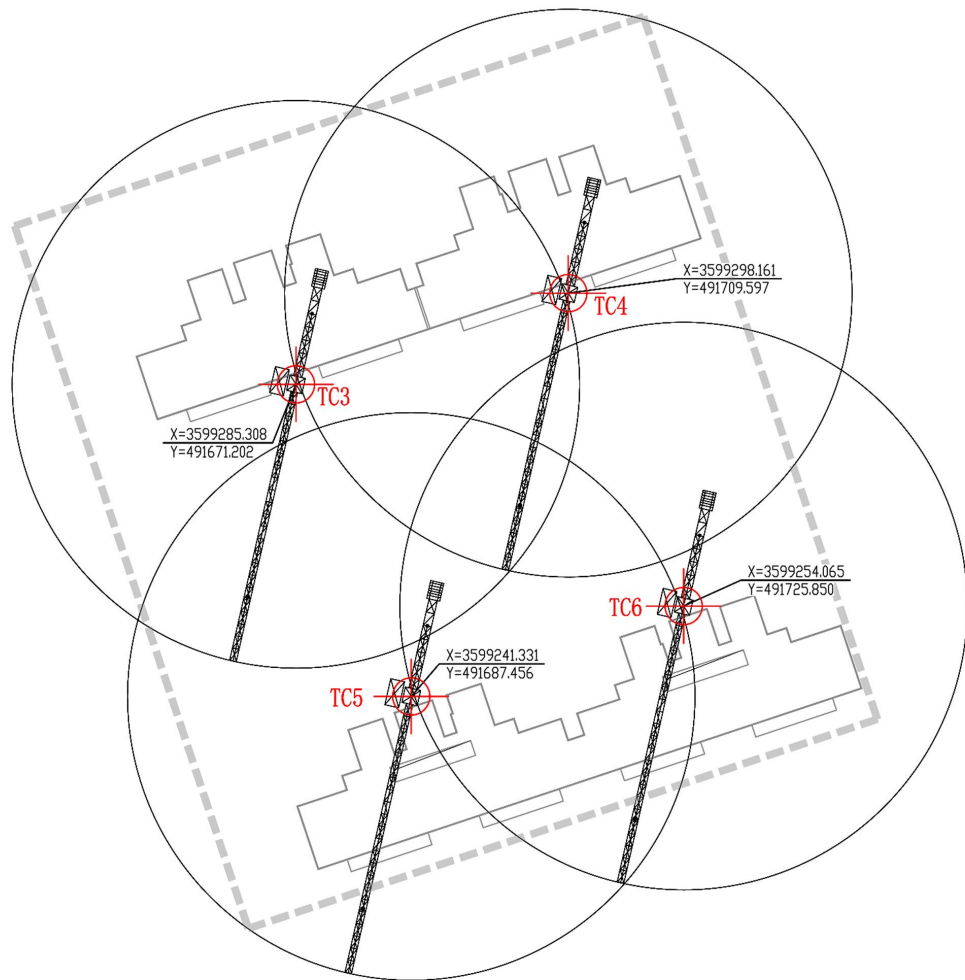
成果与展望

针对BIM软件只能获取构件相对坐标的现状，创新形成了BIM模型与CAD地形图结合获取构件定位世界坐标的关键技术。通过厘清构件材料供应点、构件初定位点和可选的塔吊定位点之间的传递关系，以及各定位点与塔吊运行的协同关系，形成塔吊定位优化模型，应用萤火虫算法解决了实际项目中的竖向转运定位布置优化问题。

GIS技术随着我国北斗导航系统日趋完善以及5G信息网络的大范围推广应用，其在获取世界坐标精准定位信息方面将愈加具有优势，相信GIS与BIM软件之间的数据传递标准会更加精准和完善，这将有利于充分发挥各自平台的优势。

成果发表

Research Article

Intelligent Optimization of Tower Crane Location and Layout Based on Firefly Algorithm

Cong Liu [1], Fangqing Zhang,[2] Xiaojian Han,[1] Hongyu Ye,[3] Zanxi Shi,[1] Jie Zhang,[1] Tiankuo Wang,[1] Jianjun She,[1] and Tianyue Zhang[1]

[1]College of Civil Engineering, Nanjing Tech University, Nanjing 211816, China
[2]Urban Planning and Design Institute, China Design Group Co., Ltd., Nanjing 210014, China
[3]School of Architecture, Southeast University, Nanjing 210096, China

Correspondence should be addressed to Cong Liu; cong.liu@njtech.edu.cn

The existing tower crane positioning layout mainly depends on the experience of construction personnel, and the best tower crane positioning can be found through a large number of manual data calculation. This manual method is time-consuming and impractical. In view of this, aiming at the current situation that building information modeling (BIM) software can only obtain the relative coordinates of components, this article puts forward the key technology of importing computer-aided design (CAD) graphics into geographic information system (GIS) software to automatically obtain the world coordinate information. By clarifying the transfer relationship between the component material supply point, the component initial positioning point, and the tower crane optional positioning point, as well as the cooperative relationship between each positioning point and the tower crane operation, the tower crane positioning optimization model is formed, and the firefly algorithm is used to automatically calculate and generate the best positioning layout method of the tower crane on the project site. In this study, the vertical transportation and positioning of components are studied, and intelligent construction is formed by integrating information technology. It can further enrich the functions of perception, analysis, decision-making, and optimization; realize the decision-making intelligence of industrial buildings; and achieve the organic unity of engineering construction execution system and decision-making command system.

1. Introduction

Tower crane is an essential equipment for the vertical transportation, installation, and positioning of prefabricated components in high-rise residential buildings. Because there are many types of components transported by tower crane, such as prefabricated components, reinforcement, formwork, and scaffold, and the location of material supply is complex, the positioning and layout planning of tower crane in the construction site of high-rise residence is a common construction technical problem.

The previous research on the optimal positioning method of tower crane mainly adopts two methods. The first method is to minimize the cross area between tower cranes.

Zhang et al. proposed a computer model to optimize the position of a group of tower cranes to determine the minimum crossing area [1]. Irizarry and Ebrahim integrated geographic information system (GIS) and building information modeling (BIM) to determine the location of the minimum crossing area of tower crane [2].

The second method is to minimize the lifting time and cost of the tower crane. Tam et al. and Wilson K. W. Chan proposed the optimization of supply points around tower cranes based on a genetic algorithm [3]. Huang et al. proposed the optimization of tower crane and material supply location in high-rise building site based on mixed-integer linear programming [4]. Lien and Cheng used particle swarm optimization algorithm to determine the location of

objective function is shown in formula (1) [14]. In order to maximize the effectiveness of the tower crane, it is necessary to understand the operating mechanism of the tower crane, master the following parameters, and make overall analysis.

$$\min TC = \min \sum_{k=1}^{K} \sum_{i=1}^{I} \sum_{j=1}^{J} T_{ij}^{k} \times Q_{ij}^{k} \times C^{k}, \tag{1}$$

where K is the number of tower cranes, I is the number of material supply points, and J is the number of initial positioning points of components. T_{ij}^{k} is the delivery time of the k tower crane from the ith supply point (S_i) to the jth component initial positioning point (D_j), which is calculated by equations (4)–(11). Q_{ij}^{k} is the lifting capacity of the k tower crane from the ith supply point (S_i) to the jth component initial positioning point (D_j). C^{k} is the unit time cost of operating the kth crane.

Assuming that Q_{S_i} is the total supply of the ith supply point (S_i), according to the relationship that the lifting capacity of all tower cranes is less than the total supply, there is the following conditional constraint formula:

$$\sum_{K=1}^{K} \sum_{j=1}^{I} Q_{ij}^{k} \le Q_{S_i}. \tag{2}$$

Assuming that Q_{D_j} is the total demand of the jth component positioning point (D_j), according to the fact that the lifting capacity of all tower cranes is equal to the total demand of each supply point, there is the following conditional constraint formula [14]:

$$\sum_{k=1}^{K} \sum_{i=1}^{I} Q_{ij}^{k} = Q_{D_j}. \tag{3}$$

Figures 3 and 4 show the free movement of the hook of the tower crane in the horizontal and vertical directions, which determine the total time and cost of an installation task. $(S_{x_i}, S_{y_i}, S_{z_i})$ and $(D_{x_i}, D_{y_i}, D_{z_i})$ refer to the coordinates of the supply point and the initial positioning point of the component for a single lifting task, respectively. $(C_{x_k}, C_{y_k}, C_{z_k})$ represents the positioning layout coordinates of the kth tower crane. The mathematical model of tower crane operation is shown in the following formulas [4]:

$$T_h^{k} = \max\left(T_\alpha^{k}, T_\omega^{k}\right) + \alpha \times \min\left(T_\alpha^{k}, T_\omega^{k}\right), \tag{4}$$

$$T_{ij}^{k} = \max\left(T_h^{k}, T_v^{k}\right) + \beta \times \min\left(T_h^{k}, T_v^{k}\right), \tag{5}$$

$$T_v^{k} = \frac{\left|D_{zj} - S_{zi}\right|}{V_h^{k}}, \tag{6}$$

$$T_\alpha^{k} = \frac{\left|\rho(S_i) - \rho(D_i)\right|}{V_\alpha^{k}}, \tag{7}$$

$$T_\alpha^{k} = \frac{1}{V_\omega^{k}} \times \arccos\left(\frac{l_{ij}^{2} - \rho\left(D_j\right)^{2} - \rho\left(S_i\right)^{2}}{2 \times \rho\left(D_j\right)\rho\left(S_i\right)}\right). \tag{8}$$
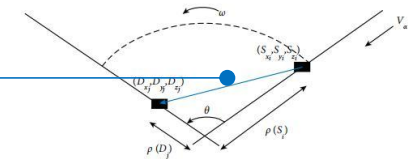

Figure 3: Horizontal movement mechanism of tower crane hook.
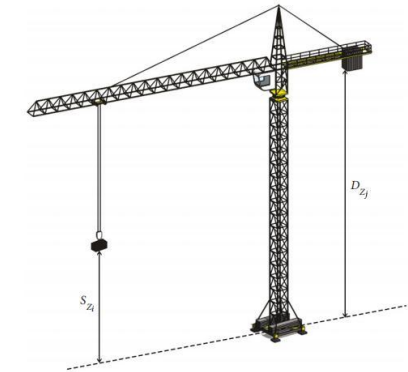

Figure 4: Vertical movement mechanism of tower crane hook.

For any lifting, the transportation distance of the hook can be calculated by the following formulas [4]:

$$\rho(D_i) = \sqrt{\left(D_{x_j} - C_{x_k}\right)^{2} + \left(D_{y_i} - C_{y_k}\right)^{2}}, \tag{9}$$

$$\rho(S_i) = \sqrt{\left(S_{x_j} - C_{x_k}\right)^{2} + \left(S_{y_i} - C_{y_k}\right)^{2}}, \tag{10}$$

$$1_{ij} = \sqrt{\left(D_{x_j} - S_{x_i}\right)^{2} + \left(D_{y_i} - S_{y_i}\right)^{2}}, \tag{11}$$

where T_h^{k} is the horizontal transportation time of the hook of the tower crane at position k, which is composed of T_α^{k} and T_ω^{k}. T_α^{k} is the movement time of the hook in the radial direction (along the radius of the circle), and T_ω^{k} is the movement time of the hook in the tangential direction (along the tangent direction of the circle). T_v^{k} is the vertical movement time of the hook at k position. α and β are two parameters between 0 and 1. α indicates the matching ability of the hook to move in the radial and tangential directions in the horizontal plane, and β reflects those matching abilities in the vertical and horizontal directions. When $\alpha = 0$, the radial and tangential directions of the hook move synchronously $\alpha = 1$, the radial and tangential

感谢各位专家批评指正！

刘 聪
东南大学建筑学专业工学博士
南京工业大学土木工程学院讲师
主要从事建筑信息模型、城市信息模型以
及装配式建筑设计建造方面的研究。
联系电话：15150561296