Research Article

Layout Simulation of Prefabricated Building Construction Based on the Markov Model

Xin Jiao

Shenyang Institute of University, Shenyang, Liaoning 110000, China

Correspondence should be addressed to Xin Jiao; 15221020896@stu.cpu.edu.cn

Received 19 July 2022; Accepted 8 September 2022; Published 20 September 2022

Academic Editor: Hengchang Jing

Copyright © 2022 Xin Jiao. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

In order to meet the needs of the simulation function of prefabricated building construction layout, the author proposes a technology based on the Markov model. The main content of this technology is based on Markov model technology and takes Jinzhong Zhaimen as an example to conduct spatial scale research, according to the sensitivity of spatial scale, and finally through analysis, a systematic research method is constructed. Experimental results show that in the cell size range used, 80 m and 400 m can be regarded as the cell size threshold and limit value affecting the simulation accuracy, and when the cell size is below 80 m, the simulation result coefficient values are all more accurate.

Conclusion. A technical study demonstrates that the Markov model can meet the needs of prefabricated building construction layout simulations.

1. Introduction

The prefabricated type adopts standardized design, factory production, prefabricated construction, information management, and intelligent application, and a large number of on-site operations in traditional construction methods are transferred to modern industrial production methods in factories, and it is an important measure to promote the transformation and upgrading of China’s construction industry, realize the development of new urbanization, and implement the strategy of energy conservation and emission reduction [1]. The development of prefabricated buildings is not only a fundamental way to solve a series of major problems such as quality, performance, safety, efficiency, energy saving, environmental protection, and low carbon in the process of traditional housing construction but also an effective means to solve the problems of disconnection between architectural design, parts production, construction, maintenance and management, and backward production methods, and it is an inevitable choice to solve the current rising cost of China’s construction industry and the shortage of labor and skilled workers and to improve the production and living conditions of construction workers. Prefabricated buildings refer to buildings assembled on-site with prefabricated parts, mainly including prefabricated concrete structures, steel structures, and modern wood structures, as shown in Figure 1. At present, China is actively promoting the development of prefabricated buildings, but the development of prefabricated buildings is still in its infancy and still faces many difficulties and challenges. In the future, we will learn from the development experience of foreign prefabricated buildings and explore and improve the technology and management system suitable for national conditions. Prefabricated buildings are the key to the transformation and upgrading of the construction industry and the future development direction of the construction industry; through continuous research and development, prefabricated buildings will gradually become mature and help the transformation and upgrading of the construction industry. Simulation of the indoor space layout plays a huge role in improving people’s quality of life because people spend 87% to 90% of their time indoors [2]. The simulation of indoor space feature layout has always been the focus of related scholars’ research. The indoor spatial feature layout can be completed by 3D laser scanners or sensors, but due to its poor clustering effect, the overall deviation does not meet the ideal requirements, resulting in low data accuracy. The assembly type adopts standardized design, factory
production, assembly construction, information management, and intelligent application and transfers a large number of on-site operations in the traditional construction method to the factory, and it is a modern industrial production method. Architecture is a form of artistic expression; in the spatial layout of the interior environment of the building, the safety of the building should be ensured, and the integration of practicality and artistry should be realized. The layout results obtained by the current building indoor environment space layout method have problems of high energy consumption and low rationality, and it is necessary to study the building indoor environment space layout method [3].

2. Literature Review

In the current society, prefabricated buildings have not yet formed a large enough market scale, and the upstream and downstream supporting industries are not yet mature. The design, production, construction, and supporting materials enterprises in the industrial chain cannot keep up with the pace of market expansion, and the electromechanical parts, decoration parts, and accessories have also not formed modular, general and collaborative design standards, production standards, and installation standards; design, production, and assembly are disconnected from each other, and the industrial chain needs to be improved and integrated [4]. The relevant supporting policies for the exhibition of prefabricated buildings are not perfect enough, and there are many policies in various regions that set development goals and development directions, and the specific industrial support measures need to be further improved. The supervision system of prefabricated buildings is not synergistic enough, and the promotion of management innovation of prefabricated buildings is still lagging behind, and the implementation of the general contracting management model of prefabricated construction projects is not powerful enough. Due to the lack of independent research and development capabilities of enterprises, there are still relatively few enterprises that can fully open up the technology system of the whole industry chain; the research and development focuses of enterprises in different links of the industry chain are different, and the research and development lacks synergy. The R & D focus of each enterprise is still focusing on individual technologies such as connection, waterproofing, and earthquake resistance, and the research and development of the full decoration technology of prefabricated buildings is not enough, and there is a lack of systematic research on the integration of the whole industry chain. In domestic and foreign research, the multilevel layout simulation method of indoor space features is yet to improve the convergence and efficiency, but the accuracy is insufficient [5]. The main purpose of the layout design of the interior environment of modern buildings is to consider the harmonious relationship between people and interior design within the scope of living space to the greatest extent. Construct a living environment space that meets the psychological and physiological needs of contemporary human beings through modern technology. The layout design of architectural indoor environment space refers to the use of structural language to describe what professional engineers and architects want to express and to provide high-quality architectural indoor environment space for human beings. Interior textiles, family structure, furniture, lifecycle, electrical safety requirements, hobbies, and interests should be considered when arranging the indoor environmental space of the building. In addition, the floor, ceiling material, wall, and lighting of the building interior should also meet the customer’s requirements. Aiming at the above problems, the author proposes a simulation study of prefabricated and building construction layout based on the Markov model [6]. The main content of this technology is based on the Markov model technology and takes Jinzhong Zhaimen as an example to conduct spatial scale research, according to the sensitivity of spatial scale, and finally through analysis, a systematic research method is constructed. Combined with the current application status of the Markov model in simulation and the needs of the simulation research and development of prefabricated and building construction layout, the research on basic theory and model should be continuously strengthened in future research, combining cellular and Markov models into practice, providing more scientific and effective methods for future research.
3. Research Methods

3.1. Research on the Markov Model

3.1.1. Markov Model. The Markov model is a method for predicting the probability of events based on the Markov process theory, through the study of the initial probability of different states and the frequency of transitions between states, and the changing trend of the state is determined so as to achieve the purpose of predicting the future [7]. In the study of land use change, the process of land use change can be regarded as a Markov process, and the land use type at a certain moment corresponds to the possible state in the Markov process, which is only related to the land use type at the previous moment, and the number or proportion of the area of mutual conversion between utilization types is the state transition probability [8]. Markov models are widely used in land use change prediction research. Since the 1960s, it has been used in hydrology and meteorological prediction research, and in the 1970s, it has been used in earthquake prediction and research. In recent years, it has been widely used in land use change prediction and other aspects. In the study, due to the complex factors and driving forces affecting the future land use status, the future trend of land use change cannot be completely predicted based on the data in the early stage of the forecast period. Therefore, only by continuously adjusting and improving the Markov model and calculation method, it is possible to have a better and more accurate prediction on the changing trend of land use in the future. At this stage, the research of Markov model in land use change is more combined with other models, such as GIS, spatial logistic model, and cellular automata model [9]. Only when the Markov model and other models are combined and applied to the simulation of land use, can the characteristics of the Markov model be brought into full play and complement each other.

3.1.2. CA-Markov Model. A cellular automaton (CA) is a dynamical system that is discrete in time and space. The study area is divided into several units (rasters), and these units are called cells, and each cell corresponds to a certain land use type. The land suitability, related policies, and socio-economic factors of land use change constitute rules, and the rules determine the possibility of land use type conversion in each cell, and when the possibility exceeds the control threshold, the land use type will be converted [10]. Using the local transformation rules of cells, the complex evolution of land use can be simulated. Its formula (1) is given as

\[ S_{i(t+1)} = f(S_t, N), \]

In the formula, \( t \) and \( t + 1 \) are the time before and after the cell; \( S \) is the state set of the cell; \( f \) is the cell transformation rule; and \( N \) is the cell neighborhood.

The Markov model is a classic method for land use change simulation. Based on the assumption of no after-effects, the state of land use types at time \( t + 1 \) only depends on the state of land use types at time \( t \), and the land use change process can be represented by

\[ S_{i(t+1)} = P_{ij} \cdot S_t. \]  

In the formula, \( P_{ij} \) is the state transition probability matrix, which represents the probability of land type \( i \) transitioning to land type \( j \).

3.2. Shanxi Jinzhong House Gate

3.2.1. The Location and Shape Characteristics of the Ancient City of Pingyao. The ancient city of Pingyao, located in Pingyao County, south of Jinzhong city, was built during the period of King Xuan of the Western Zhou Dynasty, and it is an outstanding representative of Han culture in the Ming and Qing dynasties of China. The ancient city of Pingyao is one of the only two cases in China that successfully declared the world cultural heritage with the entire ancient city, and it has a high historical and cultural value, as well as a theoretical reference for the protection and activation of traditional dwellings, and the typical demonstration role is self-evident. The ancient city of Pingyao is located on the eastern edge of the Loess Plateau, with a square shape, sitting north facing south. According to the factors of terrain and sunshine, it is 15° eastward. There is one gate on the north and south walls of Pingyao, and two gates on each of the east and west walls. Due to its geographical advantage, agriculture and commerce in Jinzhong area are highly developed. During the period of Ming and Qing dynasties, Jinzhong merchants accumulated a lot of wealth, and the houses were large in scale and beautifully decorated, and the buildings they lived in all showed their status and wealth, and at the same time, they also showed the cultural concept and value orientation of Jin merchants. In addition, the residents of Jinzhong follow Confucianism, the folk customs are simple, and they abide etiquette and law, and in architecture also, they reflect the strict principles of etiquette and norms [11].

3.2.2. Features of Jinzhong House Gate. In terms of architectural form, Jin merchants respect Confucianism, and the houses they live in strictly abide by the norms of ancient etiquette and laws, and the courtyard space is square and neat, with a compact layout and a clear longitudinal axis. Jinzhong residential buildings break through the traditional single and second courtyard and develop into a horizontal and vertical multigroup. The traditional houses in the ancient city of Pingyao have several types of courtyards. One is a one-entry triplex or one-entry quadrangle where ordinary people live, and the other is a commodity shop opened along the street, and there is also an escort ticket type for business in the front room, vertical multientry serial courtyards for sleeping in the back room, horizontal multispans parallel courtyards, and horizontal and vertical multientry multispans group courtyards [12]. Residential color and shape decoration art also had certain norms. Although the use of colors in Shanxi dwellings is strictly restricted, the colors of their appearance are simple, natural, and varied, showing their natural colors. The blue-gray bricks, tan wood, yellow-
brown clay, green-yellow stone, and black-gray tiles constitute the harmonious tone of the local dwellings.

3.3. Study on the Spatial Scale Taking Jinzhong Zhaimen as an Example

3.3.1. Landscape Space. All planning is inseparable from solid data support; therefore, technology should be used to dynamically monitor the current situation of the landscape pattern in the study area in real time, obtain time-sensitive landscape pattern data, and control the evolution process and direction of the landscape pattern so as to take relevant measures, adapted planning programs, or related policies, and timely guidance and regulation for unreasonable places [13]. The landscape structure of the study area changed obviously in the early stage of the study section and gradually tended to be balanced in the later stage. The areas of urban residential landscapes, urban green space landscapes, road landscapes, and other construction landscapes show an increasing trend, while the areas of residential landscapes, agricultural landscapes, and woodland landscapes show a decreasing trend, all of which will be balanced and stable in 2025. The water landscape area fluctuates greatly every year, which is related to the water level, and the area change trend is not obvious [14].

3.3.2. Spatial Scale Sensitivity. Based on the type map, the sampling function of the software was used to obtain data of different resolutions in 2010, 2015, and 2020, and the sampling algorithm was the nearest neighbor pixel method. The resampling resolution was set to 100, 150, 200, 300, 400, 500, and 800 m, trying to cover cell size commonly used in research. Obtain the transition area and transition probability data from 2015 to 2020 through the Markov module in the software. Based on this data, the 2020 land use classification was simulated using the Markov model. Neighborhood types are set to $5 \times 5$ mole neighborhood, $3 \times 3$ mole neighborhood, and $3 \times 3$ von Neumann neighborhood [15]. The accuracy evaluation of the simulation results uses the validate module to obtain the quantitative Kappa coefficient ($K$), the location Kappa coefficient ($K_{location}$), and the standard Kappa coefficient ($K_{standard}$). The landscape pattern analysis of the simulation results is carried out by software, and the number of patches (NP), patch density (PD), landscape shape index (LSI), average patch shape index (SHAPE_MN), average patch fractal dimension index (FRAC_MN), and other indicators are selected for analysis [16].

As can be seen from Figures 2–4, regardless of the use of any of the three neighborhoods, the Kappa coefficient values of the simulation results show very similar trends. When the cell size is increased from 30 m to 80 m, $K$, $K_{location}$, and $K_{standard}$ all remain almost unchanged. When the cell size increased to 90 m, the Kappa coefficient values of the simulation results decreased rapidly, $K$ decreased from 0.74 to below 0.7, $K_{location}$ decreased from 0.73 to about 0.64, and $K_{standard}$ also decreased from 0.65 to about 0.58 [17].

4. Analysis of Results

It can be seen from Table 1 that for the three selected neighborhood types, as the cell size increases from 30 m to 400 m, the Kappa coefficient value of the simulation results decreases continuously. When the cell size continues to increase to 500 m, the Kappa coefficient of the simulation results increases, which is significantly higher than the value at 400 m [18]. When it continues to increase to 800 m, the Kappa coefficient value of the simulation results decreases again, but it is still higher than the value at 400 m. By comparing the simulation results and the actual classification results at 400, 500, and 800 m by visual observation, it is found that the accuracy of the simulation results at the
resolutions of 500 and 800 m is much lower than that of the 400 m. It can be seen that the Kappa coefficient cannot simply be used as a standard for evaluating the quality of the simulation results. When the cell size exceeds a certain limit value, the Kappa coefficient value of the simulation result may be relatively large, but the accuracy of the actual simulation result is very low. Therefore, we believe that when using the Markov model to simulate the evolution of land use, we should pay attention to the limit value of the cell size in the simulation. When this limit is exceeded, the Kappa coefficient cannot simply be used as a criterion for evaluating the simulation results. From the perspective of neighborhood types and the simulation results generated by the three neighborhoods, there is no significant difference in the Kappa coefficient values, which to a certain extent indicates that when using the CA-Markov model to simulate the evolution of land use, the use of these three neighborhoods may have little effect on the Kappa coefficient of the simulation results [19]. In addition, the Kappa coefficient value of the simulation results generated by the $3 \times 3$ molar neighborhood is slightly higher than that of the simulation results of the $5 \times 5$ molar neighborhood, which also indicates that with the increase of the neighborhood size, the Kappa coefficient value of the simulation results also decreased accordingly.

From the analysis of the landscape pattern index of the simulation results (Table 2), the fine-scale simulation results are very similar to the coarse-scale results. The reason may be that due to the increase of the neighborhood size, more neighboring cells are included in the cell transformation rule, and the number of isolated cells is reduced so that more cells can aggregate to form patches, and this results in a decrease in plaque number and plaque density. However, since the author only selects three kinds of neighborhoods for comparison, it is not easy to think that the von Neumann neighborhood must form a larger number of patches and a higher density of patches than the Moore neighborhood [20].

Combined with the previous analysis, it can be seen that in the range of cell size used for sitting, 80 m and 400 m can be regarded as the cell size threshold and limit value that affect the simulation accuracy; when the cell size is less than 80 m, the Kappa coefficient values of the simulation results all have high accuracy. Therefore, when performing CA-
Markov simulation, for cell size selection, we must pay attention to the existence of cell size thresholds and limit values.

5. Conclusion

The research study is based on the simulation of prefabricated building construction based on the Markov model, and the main content is based on Markov model technology, taking Jinzhong Zhaimenasan as an example to study the spatial scale, according to the sensitivity of the spatial scale, and finally through analysis, a systematic research method is constructed. Combined with the current application status of the Markov model in simulation and the needs of the research and development of prefabricated building layout simulation research, the research on basic theories and models should be continuously strengthened in future research, and the combination of cell and Markov model should be applied in practice in order to provide more scientific and effective methods for future research.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] M. Ma, K. Zhang, L. Chen, and S. Tang, “Analysis of the impact of a novel cool roof on cooling performance for a low-rise prefabricated building in China,” Building Service Engineering Research and Technology, vol. 42, no. 1, pp. 26–44, 2021.
[2] Y. Zhang, J. Chen, S. Guo, X. Yang, and G. Cui, “Building layout tomographic reconstruction via commercial wifi signals,” IEEE Internet of Things Journal, vol. 8, no. 1, pp. 15500–15511, 2021.
[3] H. D. Islam, I. W. Y. A. Putra, and N. W. A. Utami, “Redesain interior pasar ngentak desa di kabupaten blitar,” Jurnal Patra, vol. 2, no. 1, pp. 27–36, 2020.
[4] U. D. S. Perera, U. Kulatunga, F. N. Abdeen, S. M. E. Sepasgozar, and M. Tennakoon, “Application of building information modelling for fire hazard management in high-rise buildings: an investigation in Sri Lanka,” Intelligent Buildings International, vol. 14, no. 2, pp. 207–221, 2021.
[5] Q. Zhang, “Relay vibration protection simulation experimental platform based on signal reconstruction of MATLAB software,” Nonlinear Engineering, vol. 10, no. 1, pp. 461–468, 2021.
[6] S. Ritter, G. Giardina, A. Franzia, and M. J. Dejong, “Building deformation caused by tunneling: centrifuge modeling,” Journal of Geotechnical and Geoenvironmental Engineering, vol. 146, no. 5, pp. 1–17, 2020.
[7] B. Nowogonska, "Consequences of improper renovation decisions in a 17th century half-timbered building," Scientific Review Engineering and Environmental Studies (SREES), vol. 29, no. 4, pp. 557–566, 2020.
[8] R. Huang, P. Yan, and X. Yang, "Knowledge map visualization of technology hotspots and development trends in China’s...
textile manufacturing industry,” *IET Collaborative Intelligent Manufacturing*, vol. 3, no. 3, pp. 243–251, 2021.

[9] C. Zhu, G. Xie, and Y. Zhang, “Design and implementation of programmable logic array using crossbar structure in quantum-dot cellular automata,” *International Journal of Circuit Theory and Applications*, vol. 49, no. 11, pp. 3669–3682, 2021.

[10] P. Khosravani, A. A. Moosavi, and M. Baghernejad, “Spatial variations of soil penetration resistance and shear strength and the effect of land use type and physiographic unit on these characteristics,” *Soil and Water Research*, vol. 52, no. 4, pp. 1041–1057, 2021.

[11] A. Jc, B. Jl, L. B. Xin, A. Wg, Z. Jing, and C. Eza, “Degradation of toluene in surface dielectric barrier discharge (SDBD) reactor with mesh electrode: synergistic effect of UV and TiO2 deposited on electrode,” 2021.

[12] S. H. Wahyuningrum and M. K. Wardhani, “Efficiency of inpatient layout in private hospital (case study: bhakti asih hospital, brebes central java),” *MODUL*, vol. 20, no. 1, pp. 1–9, 2020.

[13] C. J. C. Ha-Sung Kong, “A study on the optimization of high school buildings for evacuation safety: classroom layout and ramps in korea,” *Turkish Journal of Computer and Mathematics Education (TURCOMAT)*, vol. 12, no. 5, pp. 358–368, 2021.

[14] G. Triscari, M. Santovito, M. Bressan, and D. Papurello, “Experimental and model validation of a phase change material heat exchanger integrated into a real building,” *International Journal of Energy Research*, vol. 45, no. 12, pp. 18222–18236, 2021.

[15] A. Grigorenko and D. Gandilyan, “Basic stages of reconstruction in building,” *Bulletin of Science and Practice*, vol. 6, no. 5, pp. 305–309, 2020.

[16] M. Bradha, N. Balakrishnan, S. Suvi et al., “Experimental, computational analysis of Butein and Lanceotelin for natural dye-sensitized solar cells and stabilizing efficiency by IoT,” *Environment, Development and Sustainability*, vol. 24, 2021.

[17] P. J. Rodriguez, Z. J. Ward, M. W. Long, S. B. Austin, and D. R. Wright, “Applied methods for estimating transition probabilities from electronic health record data,” *Medical Decision Making*, vol. 41, no. 2, pp. 143–152, 2021.

[18] N. Yuvaraj, K. Srihari, G. Dhiman et al., “Nature-inspired-based approach for automated cyberbullying classification on multimedia social networking,” *Mathematical Problems in Engineering*, vol. 2021, Article ID 6644652, 12 pages, 2021.

[19] T. Løken, “Bronze age and early iron age house and settlement development at forsandmoen, south-western Norway,” *AmS-Skrifter*, vol. 28, pp. 1–300, 2021.

[20] Z. Wang, W. Hu, S. Yin et al., “Building a post-layout simulation performance model with global mapping model fusion technique,” *Tsinghua Science and Technology*, vol. 27, no. 3, pp. 512–525, 2022.