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Civil Building Generation System Based on the Human Space Dynamics

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Abstract: The theory of building generation system is built on the concept of human space dynamics. This paper analyzes the interaction of space utility - streamline - space combination, which is the driving force mechanism for generating building system. In the constitution of a community with building using human, the macro group behavior is ordered, but the microscopic behavior of individuals is random. Mining statistics law, exploring building generation system's theory based on human behavior, is necessary. This paper presents system software architecture and dynamics analysis of architectural functional areas, deepens the understanding of the combination of architectural space, and builds a solid foundation for building generation system analysis.

Keywords: Building generation, human dynamics, spatial dynamics.

1. INTRODUCTION

Building generation system is a dynamic complex system. The complexity and regularity of time and space for users has been the focus of research in the building field. Over the past two decades, computer system model technology based on human society Agent simulation has attracted more and more attention of scholars. At the micro level, building generation system consists of a number of relatively independent Agent, which has the intelligence, existing learning and adaptive behavior. There is a complex interaction between the Agent. In the process where Agents use the building as a dynamic system constituted by the interaction of the Agent, we use simulation tools to study them. First of all, we build a virtual construction by similar Agent use, set the initial conditions (such as system arrangement, distribution of Agent behavior, *etc*.), and then carry out the virtual building natural development, the root cause of which is the interaction between the Agents. Researchers look at the virtual building world, collect and analyze data, use intuitive description to make Agent decision and interaction. Its advantages are suitable for modeling by a group consisting of decision makers with different properties; Modeling the complicated relation between main body; Able to track the transition path between the different equilibriums; Introducing the learning algorithm to research main body behavior changes.

Barabási published an article on the pioneering work about human dynamics [1] in 2005, since then the relevant research work has become one of the hot spots of complex systems. Human dynamics focuses on peoples' daily behavior patterns, tries to dig the statistical rule and establishes corresponding dynamics mechanism, gives a quantitative analysis from the perspective of an external observer.

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Study sequence [2] includes: observation - data acquisition and analysis - mining statistical rule - modeling data rule. The interaction between buildings generate space and user Agent is the focus of the building generate design research, and building users using construction has a complex behavior. The digging statistical feature of time and space in the building generation system has important application value. Understanding the combination of generate space is important, not only to recognize its relative position of function area and the room arrangement, but also to understand the design of the function space combination; rule of all kinds of thinking reflects the natural and social influence on building generate design process. And the interaction of space utility, statistical behavior of the Agent and space combination constitute the mechanism of building generate design. In order for understanding the architecture design one must study this interaction.

A building generation system [3] can be constructed based on the state characteristics of the virtual building body and interaction of a group of Agent. Building using this process is along a certain path or route of time; space generate process should be a combination of time and space, that is space connection, space function and space form. The process of generating space function can be understood with decrease or increase process of the column grid unit components. Behavior of the Agent is behind the evolution of this function area. It is the process of the Agent behavior to gather spatial data to produce the combination of building generate space.

To fully understand the construction flow, we must consider the Agent cognitive role in a series consisting of function space, space utility (each function is useful to fulfill the needs of the Agent), the Agent's motivation and purpose, and the identity of the Agent. Space generated behavior refers to the interaction flow of the Agent's social, economic, physical characteristics (such as demand, value, emotion, feeling) with specific behavior perceived through external environment activity. In building generation system, Agent form the building space image through a value system, and then to build the work experience of space and time, show the external behavior. Building generate space is the result of the interaction of many Agents. Agent aggregation behavior in the function zone constitutes a space process, so the space process is actually the external manifestation of the Agent group behavior. Every Agent is a particle of building generation system, the operation of each particle trajectory constitutes the most subtle streamline, the result is to generate the evolutionary space combination. To understand the evolution of the space combination, we must not only study the human dynamics analysis of the Agent and the formation process of streamline generation, but also the dynamics of each type of Agent.

The space streamline model in Agent behavior constitutes the space combination and Agent's social, economic, physiological characteristics. It is the heterogeneity and difference of space function that produced space Agent using its behavior. Therefore, space combination affects the spatial behavior of the Agent. For open building generation system, the exchange of people stream, logistics, energy flow with outside system is uninterrupted [4]. The change of the space combination must create Agent space using the behavior change. Human dynamics behavior created the streamline and streamline shaped space combination. Space combination, in turn, affects the Agent behavior. The formation of architectural space structure is the result of this process.

2. SOFTWARE ARCHITECTURE OF THE CIVIL BUILDING GENERATION SYSTEM

The software architecture related to digital building generating system can use MVC mode in general, including the system frame, the user interface module, controller module, electronic map module, function module, bubble module, footprint streamline module, decorative information module, building generation engine [5], the IFC component module, cost module and scheme module, as is shown in Fig. (**1**).

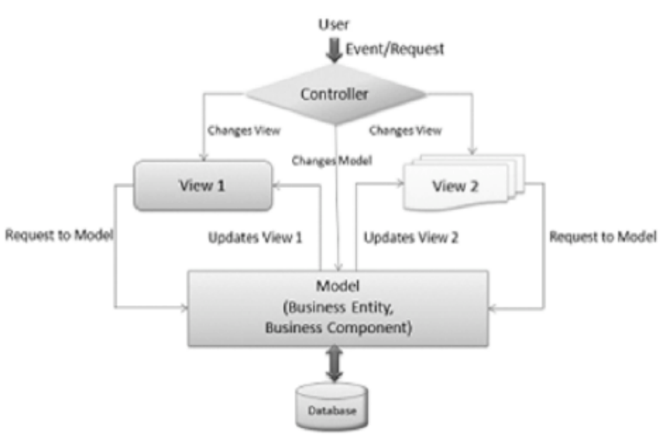


Fig. (1). MVC architecture.

System framework includes initialization module, radio monitoring module and message processing module. It manages coordination of various generated modules, and serves as the bridge between the various modules communication. At system startup, initialization module initializes the whole generation system. On the one hand, radio monitor module is created for listening to the radio before the system starts. On the other hand, after the system starts, system radio is operated with the control of the management system process; Message processing module is used to send each function module message through the message handle to the corresponding function module.

User interface can be run on a smartphone, tablet, notebook, desktop, such as terminal, including the display module and response module. Display module is used to display the whole generation system, whereas the response module is used to receive user interface information. The controller module is used to bridge the system framework and generation engine mutual communication. By listening to the GPS information of the intelligent terminal module and user input information, it has been passed to building generation engine, to realize real-time two-way information transmission, and display building generation real-time results in the user terminal devise. Electronic map module communication controls the whole system framework through the controller module and manages the map whole information, including location information management module and map data module. The former obtains information of the current user's geographic location through satellite positioning, and transfers the information. The latter is used to map.

Function module, bubble module and footprint streamline module are actually three main components of the function bubble chart in the architectural design, and the building generation engine will turn the function bubble chart into building structure information excluding decoration. Storing this information according to the international general standard IFC format is the role of IFC component module. Decoration module will add decoration information to specific components, and then according to the cost module respectively calculate the construction engineering cost, decoration engineering cost and individual project cost.

Scheme module provided the output of plan layout and the stereo effect on the electronic map. If electronic map itself is a 3D map, this system can provide renderings in harmony of surrounding environment.

There are two startup methods for the system: the first is when radio monitoring module receives the user terminal boot system broadcast successfully, it starts building generation system, initializes the controller, loads the default electronic map, and starts the building generated service. Second, if the building generating system didn't start, restart it, initialize the controller, load the default electronic map, start building generated service, and finally start the user interface.

In the user interface, the first choice is to generate a house in the virtual construction field or on the current users standing site, and then determine the building control lines. In the virtual construction field, we can cross or input control points coordinates on the electronic map. In the actual site, we can choose walking in the field to get the control lines through GPS positioning.

Next, we input ground conditions, block the attribute values around the control lines specific for the area, and then input single project cost limit, building structure types, and layers, each layer structure, area and height. The system automatically checks the cost, and prompts cost difference value and adjustment recommendations. In the overall characteristics, the cost is met under the condition of the limit, where the system shows the floor schematic diagram in electronic maps. The following interaction is operated through this sketch.

Enter the overall building user information, including the total expected usage number, categorizing users according to the status. The map shows users like ICONS, and a corresponding icon is created for each type of people. In turn, we completed each floor information input. When a floor is in the input state, the floor slab is highlighted, input column grid information, such as the room number, corresponding to the same number of bubbles generated. They represent the room, can be dragged and can change their size. Enter the bubble name, roughly the area, decorative requirements, and corresponding synchronous cost display in room bubbles. By dragging ICONS, crossed in room bubbles to determine each type of footprint streamline information, and entrances and exits of the building users. Such as in the field, we can identify a specific room and the position of the entrances and exits *in situ* by GPS positioning. For example, in some elderly care homes, the number of elderly are expected to reach 80 people, medical staff, 20 people, the management office staff, 10 people, logistics service personnel, 10 people, so that the endowment resident buildings users reach the total number of 120 people, plus a regular visitor to 5 people, making a total of 125 people. According to the status, we divide them into 17 categories: the self-care elderly, the life can not take care elderly, dean, acting staff, physicians, nurses, pharmacists, healers, nurses, logistics director, store clerks, cooks, kitchen staff, cleaners, laundries, and visitors. Functional partition includes: check work, disability curing unit and daily care, half a disability curing unit and daily nursing, management office, health care, ambulance and hospice, talk about communication, culture and entertainment, kitchen, laundry, making a total of 10 areas. Each area can be decomposed to specific use room (excluding traffic space and health auxiliary space). Elderly care homes are specifically divided into 60 categories, using a total of 166 rooms.

On the basis of the above input information, the system intelligently offers all kinds of abundant information about foundation, roof, epidermis, and equipment. Users can choose the corresponding building configuration, automatically generate the IFC data through server by calling the house generation engine code. The system provides the backup network for the outcome document, in order to display formal housing scheme on the electronic map. The building generation engine module firstly determines position of the function area traffic lines on each floor, and then determines relative configuration of the rooms on each floor function area, finally determines the exact location of the building components according to the column grid. The elderly care homes sketch plan is shown in Fig. (**2**).

3. DYNAMICS ANALYSIS FOR BUILDING SPACE FUNCTION

Agents action form streamline both inside and outside the building, which is connected to the different function areas [6]. Agents walk on the streamline, at a certain time, choosing a certain function area. There are two factors working behind this phenomenon: one is the group of internal variables, and the other is, external variables. Exogenous factors are not dependent on the behavior process, as they reflect the alternatives of community and economic and other characteristics, and describe the attributes of solution and decision making environment. Another group is the endogenous variable, which is determined by the behavior process itself.

The endogenous factors express the current situation of the Agent choice behavior that depends on the previous history. It suggests that the current situation of the Agent behavior depends on the previous behavior, and this is state dependent. The Agent has the ability of choosing empirical knowledge, which constitute the Agent cognitive environment, in order for the Agent to keep its cognitive consistency. Agents have different physiological, social and economic characteristics, therefore they must have different space choice behavior, which is called the spatial heterogeneity. Thus, building generation model must consider the difference between the Agents. Another important factor is the dynamics of spatial choice, as time changes, Agent attributes such as exogenous variables, decision making environment, must also change, so that the choice behavior of Agent must be changed accordingly.

The space choice behavior attribute set is a function of position. Changing the position necessarily changes attribute set of alternatives, this is the space connotation of generate behavior. The building space is divided into finite function area $\{p_i, i = 1,2,\cdots,n\}$, and area characteristic properties $q = \{1,2,\cdots,\mathrm{m}\}$. The Agent's choice of location includes finding the best of a set of attributes as far as possible in attribute collection, which is formed by the different combination. That is to say, the Agent choosing effect for space area is the function describing the space area properties. This is also the function describing the Agent's social and economic characteristics, i.e., the efficacy function for the i Agent selected area q can be described as:

$$E_q^i = f\left(\mathrm{X};\mathrm{Y}^i\right) + \varepsilon_{iq} \tag{1}$$

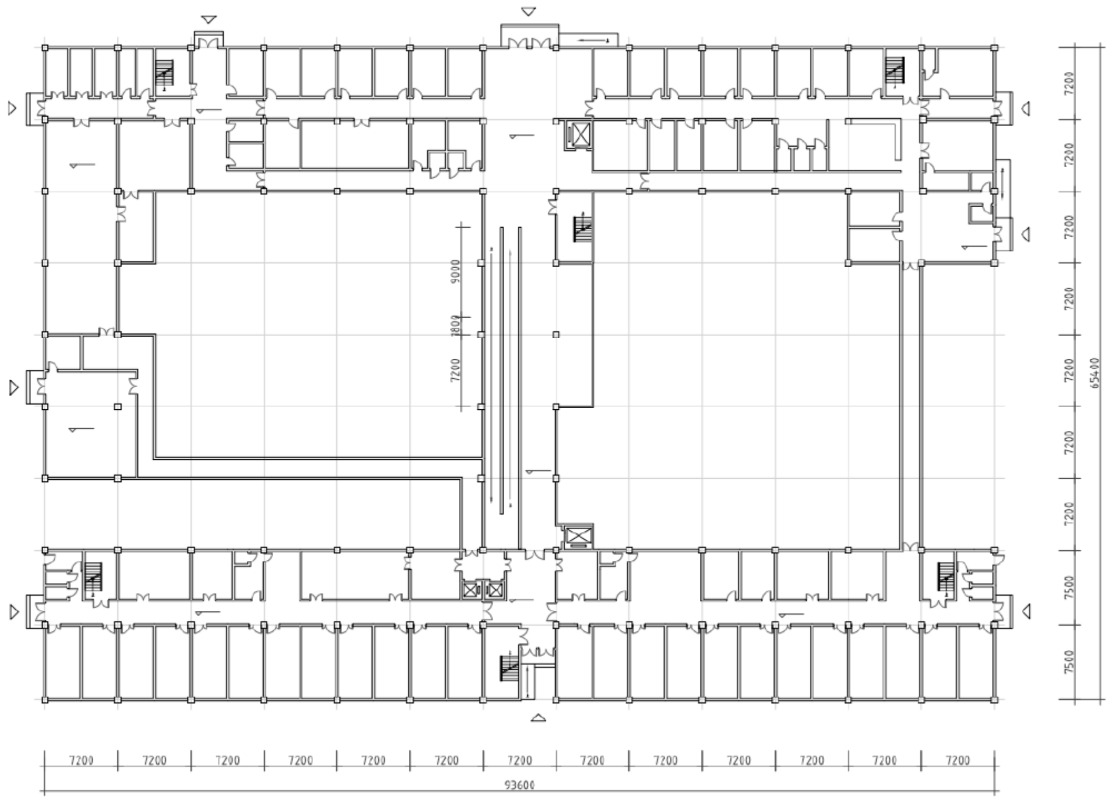
E_q^i is the i Agent choosing area effect; X is structure state vector of function area; Y^i is the i Agent feature vector; ε_{iq} is random disturbance due to the differences between the i type of Agents or unpredictable factors. As the state vector describing space area is a function of position, $l = \left(\mathrm{A,B,H}\right)$, and $X = X\left(l\right)$, so:

$$E_q^i = f\left[X\left(l_q\right), \mathrm{Y}^i\right] + \varepsilon_{iq} \tag{2}$$

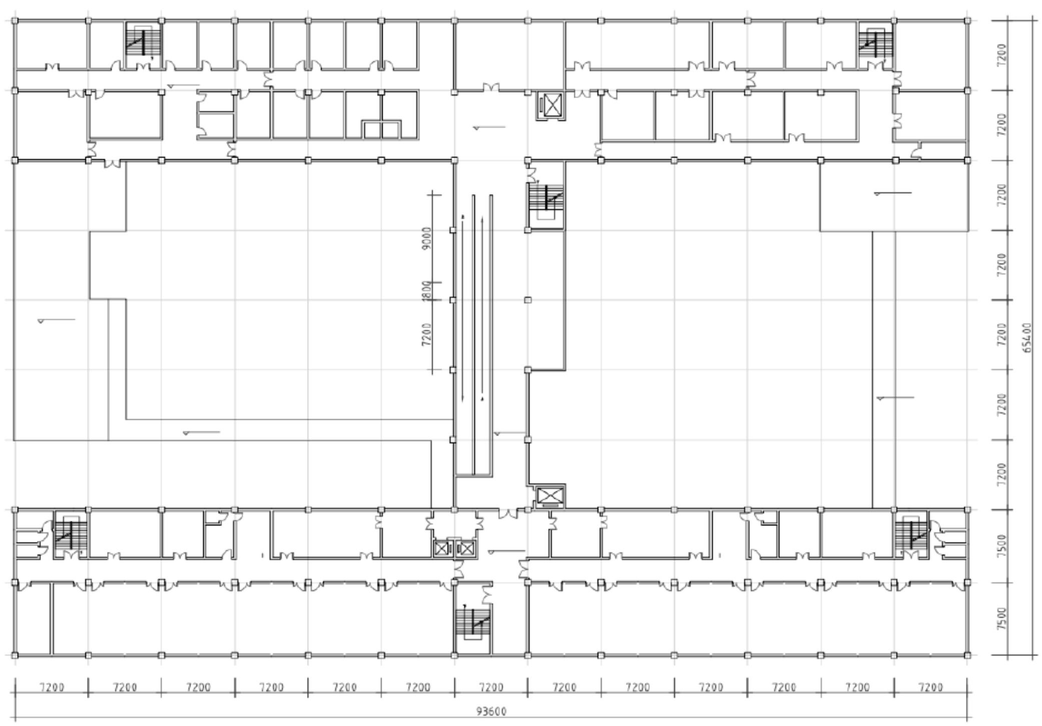
If we assume random variable E_q^i obeys pole distribution, and is independent of each other chosen programs, that we derive directly from the pole distribution:

$$P_q^i = \frac{e^{f\left[\mathrm{X}(\mathrm{l}_q),\mathrm{Y}_0^i\right]}}{\sum_q e^{f[\mathrm{X}(\mathrm{l}_q),\mathrm{Y}_0^i]}} \tag{3}$$

P_q^i is probability for the i Agent choice q program. Decision making choice has structure state dependence. Formula (3) embodies efficacy function in constructing the dynamic



(a)The first floor plan



(b)the second floor plan

Fig. (2). Elderly care homes sketch plan.

Agent for a scheme. It needs a lot of statistical data, and needs a large number of observations on individual dynamic choice behavior. For simulation of area choice behavior, we must consider heterogeneity, structure state dependence and dynamic. For the Markov effect, we can choose a continuous time series observation on Agent space, to solve the transition probability of space selection.

Introduced in hierarchical selection probability is the space choice behavior model:

$$P^i(\mathrm{l},t)=\frac{e^{\beta\left[E^i(\mathrm{q},t)+U^i(\mathrm{q},t)\right]}}{\sum_q e^{\beta[\mathrm{E}^i(\mathrm{q,t})+U^i(\mathrm{q,t})]}} \tag{4}$$

$U^i(\mathrm{q},t)$ is the greatest average expectation effect after the Agent i chooses the q scheme; q is the coefficient. Since $U^i(\mathrm{q},t)$ illustrates the gradation of space choice, we must treat the options stratifically. The choice effect of a layer will be affected by the efficacy function of the next layer.

Analyzing the function area, its development basically consists of three processes [7]: one is the Agent of one area transferred to the other area or the Agent of the other area transferred to one area. The transfer is determined by the Agent space behavior; the second is the increase or decrease process in area elements; the third is the increment of the Agent number in the area in order to hinder entry of the other Agent into the building. From the Agent space choice behavior, the transfer process is actually the transfer of the Agent from one to the other state, namely the m state of the Agent transferred to the n state. If understanding from probability theory, transition probability [8] is the state change of Agent i from the m state conditions at one point t to the n state in the next moment. Set $\{X^i(\mathrm{n},t)\}$ describes the area state variables, then:

$$\frac{dX(\mathrm{n},t)}{dt}=\sum_i\sum_m \alpha^i(\mathrm{mn},t)\mathrm{X}^i(\mathrm{m},t)-\sum_i\sum_m \alpha^i(\mathrm{nm},t)\mathrm{X}^i(\mathrm{n},t) \tag{5}$$

$dX(\mathrm{n},t)/dt$ is evolution of the moment t in a state of $n=(\mathrm{A,B,H})$; $\alpha^i(\mathrm{mn},t)$ is the transfer rate in moment t of class i Agent from m area to n area; $X^i(\mathrm{m},t)$ is the number of m area class i Agent in moment t; $\alpha^i(\mathrm{nm},t)$ is the transfer rate in moment t of class i Agent from n area to m area; $X^i(\mathrm{n},t)$ is the number of n area of class i Agent in moment t. Equation (5) describes the dynamics mechanism of area state evolution; $dX(\mathrm{n},t)/dt$ describes the evolution rate of the system Agent distribution; and $X^i(\mathrm{m},t)$ and $X^i(\mathrm{n},t)$ describe the function area interaction and mutual feedback structure of building generation system respectively.

The probability of m area transferred to n area depends on the difference between the values of area for the Agent, according to the logic model:

$$\alpha^i(\mathrm{mn},t)=\varepsilon(t)\exp\Delta E^i(\mathrm{n},t)-\Delta E^i(\mathrm{m},t) \tag{6}$$

$\alpha^i(\mathrm{mn},t)$ is the probability of i Agent transferred from m area to n area. $\Delta E^i(\mathrm{m},t)$ and $\Delta E^i(\mathrm{n},t)$ are the choice values of m area and n area respectively, Formulas (5) and (6) describe the dynamics of building generation system, so that the Agent function area choice behavior is associated effectively with building spatial dynamic process.

4. MOVEMENT SIMULATION OF THE BUILDING USERS

Social network [9] of building users is a set of actors and their relationship in the building. Actors can be individuals, groups and organizations. Relationships are various. Although there are many types of relationships, yet the building using function determines the main relationships between the building users. Analogous to the identity management of the state and city, for example, the elderly care homes in the second section; its building users have four categories of social identity: elderly people, health care workers, management office and logistics service personnel. In addition to the resident identity, there are temporary visitor status and regular temporary flow status, such as the status of civil servants to check the work of elderly care homes, enterprise staff to contact business, the community volunteers, the friends of old man, is temporary visitor status, whereas, the status of dustmen, logistics (goods, food, medical equipment) waiters, body transport servicers falls under the regularly temporary flow status. If all personnel are included in the overall network, four categories of the residents constitute four common blocks. We can use the current widely used UCINET software analysis for those ordinary social network relationships.

Each building user is treated as an Agent, each one has the following three attributes: physical properties, such as age, gender, weight, height, auxiliary facilities types; social identity and mental attributes, such as identity, familiarity with environment, behavior of inertia, group influence; conduct dynamic properties, such as the initial position, the current position, the next target, steps [10]. Using Repast and OpenMap as corresponding Agent moving model platform and spatial data platform, the development tool used is Java under the Eclipse. In the Repast simModel derived template, the MyModel template instance is generated. Using ArcGisEngine excellent spatial analysis ability to calculate model, the results are transmitted to the platform data classes, then the OpenMap is integrated into Repast platform for its data display capability. GIS data format is .Shp file which Repast integration Openmap and support for data classes. We set up and update Agent array through the corresponding spatial coordinates .Shp. In elderly care homes, for example, time step off value is of a second, a cycle is 86400 steps, and simulations of all kinds of human actions in care homes are performed within twenty-four hours(a day). Assuming normal speed of 1.24 m/s, people with their walking stick, 0.94 m/s, wheelchair 0.61 m/s, other personnel to assist, 0.89 m/s, and without auxiliary facilities 0.93 m/s. Above from the low resolution, Agents roam in a broader social network with spatial coordinates, that is the 17-layer special footprint streamline network. Each type of Agent walks separately in their footprint streamline network, without affecting each other.

In high resolution, we set up microscopic simulation action model with individual auxiliary facilities. The driving force of the action and occupying the space between the shape are taken into account. Using a commercial software, we analyzed peoples force (predict and avoid collision), whose actions interact with obstacles. We let Agents independently judge and choose their route, so as to reveal the profound traffic conflicts in the layout design of elderly care homes. A better approach is to use 3D engine modeling of human body engineering, on the basis of which we can analyze roaming.

Space Syntax [11] has been more than 30 years of the development history. It is roaming streamline analysis method in effect that has an important influence on the study of city and architecture. Its core theory is mainly divided into three points: first, to build the space for the system itself that simulates the characteristics of self-organization; but since the building is for a purpose, so it has its own property; Second, the system of building space is developed by the society in the process of economic activities, so it has some social attributes; Third, the space of the built environment once formed, can in turn act on human's behavior, producing different social effects. From the three points of view, it has a certain level of anastomosis with Chinese Feng Shui. But the foundation of Chinese Feng Shui theory is based on the five material source elements, whereas the basis of space syntax theory is the modern computer graph analysis and human psychology.

Using the space syntax to verify the optimization results of building generation. Through common Depthmap software, in view of achievements at every step of the two aspects, "practical" and "visible", we carried out the connection degree, the depth degree and integration analyses. This is to confirm the characteristics of the generalized social network, and to prove numerically that the designed specific space environment must reflect the social attribute of the space users, otherwise the building plane design will not give the most efficient results. If social attributes of space user (Agent), such as mental attributes, consumption or employment status, change, we adjust action time probability with the different space choice behavior, and calculate action time of each type of Agent with weighted different task activity route. Then, the summary is drawn based on action time of footprint flow line network, and empower weight is given to the social attribute of each type of Agent. Through the analysis of the disturbance, low resolution maximum entropy optimal solution can be obtained in generalized social network. This is the result of the analysis of multiple footprints flow line network.

CONCLUSION

There are many common statistical properties in human architectural space motion mode. Although both usage and walking behaviors are deeply affected and restricted by the functional space, yet it is the movement of people that promotes the evolution of the building generation system [12]. The core of model's dynamics mechanism given by this paper is the fractal network random walk in the construction flow with the weight. This paper sheds light on a unique human movement mode in the space of building. However, considering the high complexity of human behavior, there is no model that can explain all the statistical characteristics of the architectural space combination. The establishment of such a generation model based on human space dynamic is of great significance for building design calculation.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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