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Multi-agent based Model for Simulating Energy Consumption in College Dormitories

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ABSTRACT

In order to study the energy consumption of a university dormitory in Beijing, China, a multi-agent based model was introduced into campus buildings, the historical data of dormitory energy consumption and students' energy conservation awareness were collected. Combining DeST and Anylogic simulation software, a simulation model of student dormitory building energy consumption was established, and the impact of student energy consumption on energy consumption is simulated. This model can provide a theoretical reference for school energy management and building operation energy management.

Keywords: Multi-agent based model, Building energy consumption, College dormitory

1. INTRODUCTION

As an important part of social development, colleges and universities have become an important unit of energy consumption. Due to the randomness of personnel energy consumption behavior, the research on energy consumption factors has attracted more and more attention.

The impact of differences in energy consumption behavior on building energy consumption has already received extensive attention from scholars at an earlier time, and more fruitful research results have been achieved. Lyrian studied the impact of energy consumption behavior on low-energy buildings and found that the existing energy consumption behavior assumptions in the energy consumption simulation process were inaccurate and overestimated the energy consumption of low-energy households. Therefore, it is necessary to modify the behavior model in order to be more consistent with the real situation.

The influence of random energy consumption behavior is manifested in many aspects. For example, the difference between building simulation energy consumption and actual energy consumption depends to a large extent on the difference between the operation schedule in the simulation and the actual operation situation. Geun quantitatively analyzed the impact of energy consumption behavior, physical factors on household cooling energy consumption. The results show that the impact of people's energy behavior on energy consumption has exceeded the impact of climate on energy consumption.

Regarding the study of building energy consumption behavior, many scholars combined building-related software with computer-based modeling technology. Liu Handi combined EnergyPlus and NetLogo to establish an agent-based occupant adaptability model, which simulated some local adaptation actions taken by occupants with different heat and lighting preferences when the building's central control system did not respond.

The modeling method based on multi-agent opens up a new space for multi-factor simulation. The core of the modeling and simulation method of multi-agent model is model construction. There are three core elements in model construction, agent, environment and rules. The multi-agent-based model is a distributed and autonomous calculation method, which has good applicability in energy consumption calculation. Based on the CAS theory and ABM method, Zhikun Ding built a simulation model of the student dormitory energy management system and completed simulation experiments on behavioral energy-saving strategies, user interaction behaviors, and energy-saving publicity and education.

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2. METHOD

Energy consumption behavior is an important factor causing uncertainty in building energy consumption, and the whole process of generating building energy consumption is a complex system evolution process. Agent technology could be applied in the building environment to resolve possible conflicts between energy consumption and occupants' behavior . Fig 1 shows the technical route of the model.

Taking the student dormitory of a university in Beijing as the research object, the relevant energy consumption data of the student dormitory was collected and analyzed, and the interaction law between students and other subjects in the dormitory was sorted out. The indoor temperature and illuminance were simulated by DeST, the result was used as the environmental basic data for energy consumption simulation. The dormitory energy consumption simulation model was constructed by Anylogic. Finally, the simulation model was checked, and conclusions were drawn.

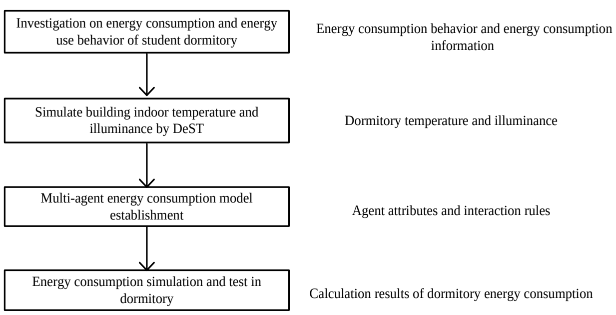

Fig 1 The technical route of the model.

3. DATA COLLECTION

Through the analysis and sorting of the energy consumption data of the student dormitory, the energy consumption characteristics of the student dormitory are determined macroscopically. In order to understand the situation of energy consumption in student dormitories, this paper built an energy consumption monitoring platform to monitor the situation of energy consumption in student dormitories. The experiment selected one male dormitory and one female dormitory, and performed hourly energy consumption monitoring for 7 consecutive days. Fig 2 shows the average hourly energy consumption of dormitories. It can be seen that, affected by the temperature and the situation of students in the room, the peak energy consumption of air conditioning in male and female dormitories appears at 11:00-13:00 and 17:00-19:00. The setting temperature of the air conditioner in the male dormitory is lower than that of the female dormitory, and the male dormitory prefers to turn on the air conditioner all day, while the female dormitory prefers to turn on the air condition intermittently.

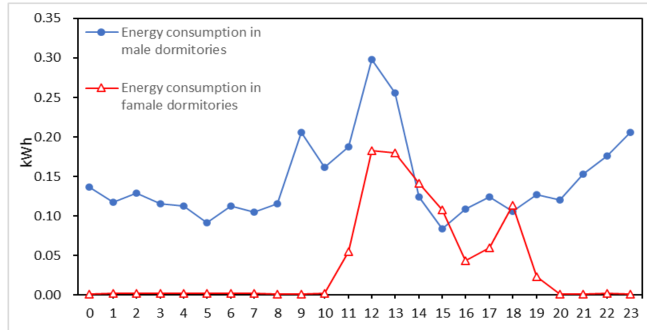

Fig 2 Energy consumption of dormitories

Even in the same dormitory, different students have different preferences. Fig 3 shows *the* energy consumption of sockets in a dormitory, the peak hours of student socket usage occur at noon and night. For example, students in bed 1 and 3 only use the socket at night. The students with bed 4 are used to studying in the dormitory, and the average power consumption of their sockets is higher than that of other students in the dormitory.

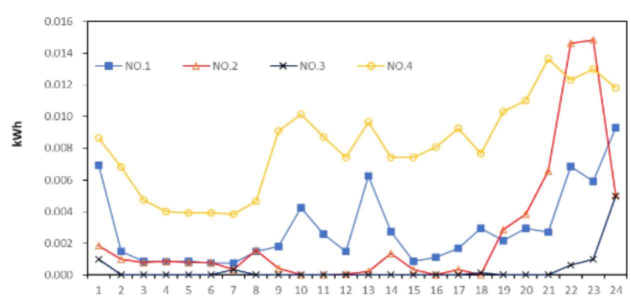

Fig 3 Energy consumption of sockets in a dormitory

4. ESTABLISHMENT OF MODEL

A three-story dormitory model was established in DeST, and the natural room temperature and light intensity of each dormitory were simulated and calculated. The simulation time step of the model is 1 hour. The system is divided into four parts: student agent, equipment agent, dormitory agent, and education department agent.

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$$E_{\text{total}} = E_{\text{havc}} + E_{\text{lighting}} + E_{\text{comuputer}} + E_{others} \qquad (1)$$

Where: E_{total} is the total energy consumption; E_{HAVC}, $E_{lighting}$,$E_{computer}$,E_{others} are the HAVC, lighting, computer and computer energy consumption respectively.

Multi-agent energy consumption simulation model hierarchy diagram is shown in the Fig 4. This article defined the attributes and behavior rules of various agents, such as parameters, variables, functions, events, and state diagrams in each agent.

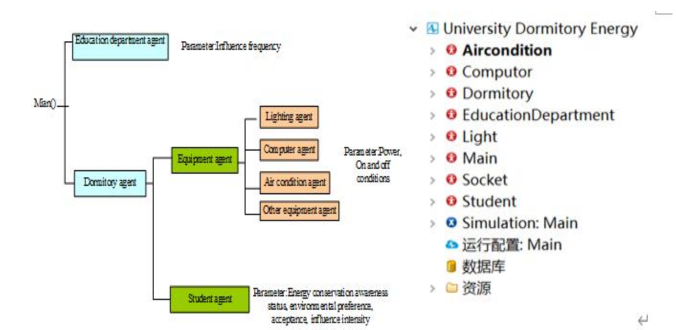

Fig 4 Multi-agent energy consumption simulation model

4.1 Student agent

The behavior of students has a vital influence on the energy consumption of the dormitory. Different students have differences in energy-saving awareness. The level of energy-saving awareness affects students' behavior when using various electrical equipment. The parameters related to students include preference temperature, acceptance of energy-saving behavior, burnout index, device preference behavior. According to the level of energy conservation awareness, students are divided into three categories. In the use of electric lights, the difference in energy-saving awareness is reflected in whether students can do "whether the lights are turned off when people leave". In the use of computers, the difference in energy-saving awareness is reflected in whether to "turn off the computer in time after using the computer." In the use of air conditioners, the difference in energy conservation awareness is reflected in the "set temperature of the air conditioner" and "whether the air conditioner is turned off in time when leaving the dormitory at the end".

Students with high energy-saving awareness have a positive impact on surrounding students, and students with medium and low energy-saving awareness have a certain probability to switch to a more energy-saving state. When the model is initialized, the students enter their respective states according to the proportion, and the students who receive the information will choose to keep the original state or increase their energy-saving awareness. Due to the negative effects of the decline of some students' energy-saving awareness and the burnout period of their energy-saving awareness, students may even shift to lower energy-saving awareness. Fig 5 is the transition of students' awareness of energy conservation.

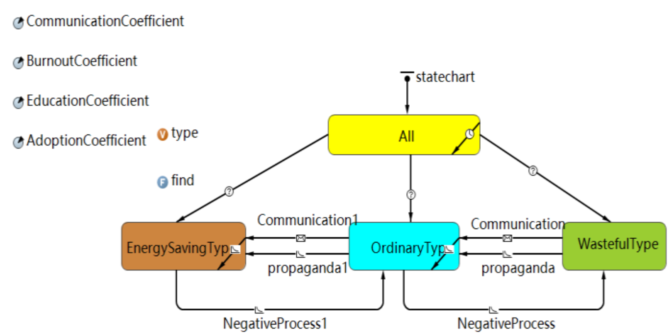

Fig 5 Transition of students' awareness

4.2 Light agent

The main parameter of the light agent is the power. The operating status of the lights is judged according to the presence of indoor personnel and energy-saving awareness. Dormitories with high energy-saving awareness will judge whether the lights are turned on based on the indoor

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illumination, while dormitories with low energy-saving awareness will choose to turn on the lights throughout the day. The probability that the dormitory turns on the lights according to the illuminance can be expressed as:

$$y = 0.008x + 0.544 \tag{2}$$

Where, *y* is the probability of the light turning on, and *x* is the indoor illumination

4.3 Computer agent

Computers mainly including three states: running, standby and shutdown. This paper used a combination of on-site measurement and questionnaire survey to evaluate the energy consumption behavior and energy saving potential of college students. The values of computer in different modes are shown in Tab 1.

Tab 1 The values of computer in different modes

pattern	Computer power value/ W		
running	minimum	average	maximum
	20	58	68
standby	1.4	4.3	25

4.4 Air condition agent

The power consumption of air condition in student dormitories is related to the indoor and outdoor environment, air conditioner power and operating time. It is judged whether the air condition is running according to the interactive result of the student agent and the air condition agent. If it is running, the opening time of the air condition is recorded and the corresponding power is selected for power consumption calculation according to the set temperature of the air condition. The probability of students turning on the air conditioner can be expressed as:

$$p = \begin{cases} 1 - e^{-\frac{(T-u)^{1.5}}{5}}, & T > u \\ 0, & T \le u \end{cases} \tag{3}$$

Where, T is the indoor dry bulb temperature, and u is the temperature tolerated by students.

According to the set temperature and indoor temperature, the hourly energy consumption of the air conditioner can be expressed as:

$$E = -0.0627T + 2.355 \tag{4}$$

Where, T is the setting temperature of the air condition.

4.5 Dormitory agent

The dormitory agent could count the information of the students in the dormitory. The dormitory agent plays a role of transmitting information between the student agent and the equipment agent. When the students use the equipment, they would pass the information to the equipment agent in the dormitory.

4.6 Education department agent

The concept of delivering energy saving is regularly delivered by the education department agent. Students choose whether to accept the concept of energy saving according to their own acceptance and the frequency and intensity of publicity activities, so as to control the transformation of the energy-saving consciousness of the student.

5. RESULTS

The main parameters of the model are shown in the Tab 2. The model can calculate the number of indoor students in each dormitory per hour and the energy consumption of various electrical equipment. Fig 6 shows the simulation interface of the multi-agent model of the student dormitory.

Tab 2 The main parameters of the model

Agent	Parameter	Value
Light	Power	0.0048 kW
Computer	Running Power	0.0058 kW
	Standby Power	0.0015 kW
Student	Preference temperature	H：（26，28）℃ M：（23，25）℃ L：（21，23）℃
	Tolerate temperature	H：29℃ M：28℃ L：26℃
Education department	Coefficient of propaganda	15%
	Publicity frequency	1

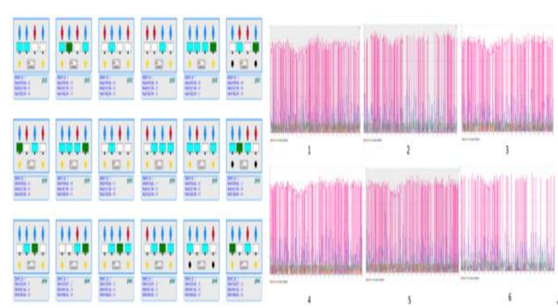

Fig 6 The simulation interface of the model

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5.1 *Results of students' energy saving consciousness*

The initial number of students is set according to the survey ratio. In addition, the coefficients of various energy-saving communication methods for the transformation of students' energy-saving awareness are different. The simulation experiment observes the changes in the number of students in each state over time by changing the communication coefficient, energy-saving propaganda coefficient, and burnout frequency coefficient of personnel. Fig 7 shows the changes in the number of students in each state.

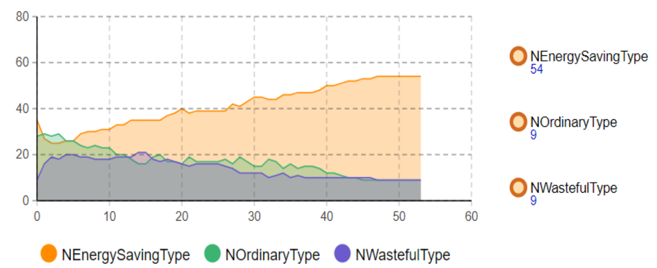

Fig 7 The number of students in each state.

Through the energy-saving awareness simulation experiment, the changes in the number of students in each state within 3 months are observed as shown in Tab 3. By comparing the data, it can be seen that for the same type of publicity and education method, increasing student participation in activities and increasing activity frequency will increase the energy-saving ratio, but the energy-saving effect of increasing activity frequency is better than increasing student participation in activities.

Tab 3 The number of students in each state

Coefficient	Frequency	Participation	NH	NM	NL
interpersonal communication	1/month	20%	28	26	18
	1/week	20%	57	10	5
Energy saving propaganda	2/month	15%	28	24	20
	1/week	15%	40	20	12
Burnout	2/month	25%	35	16	21
	1/week	25%	30	26	16

5.2 *Results of energy consumption*

The commonly used verification method for energy consumption simulation models is to compare the actual energy consumption values, and compare the simulated results with the measured results. By using a line chart to visually display the trend and overall characteristics of the data, and compare the output result of the model with the actual value. The results of the simulation of the total energy consumption are shown in Fig 8. The maximum energy consumption of the dormitory is 6.28kWh and the minimum value is only 1.24kWh within a week, indicating that the energy consumption behavior of people has a greater impact on the energy consumption of the room.

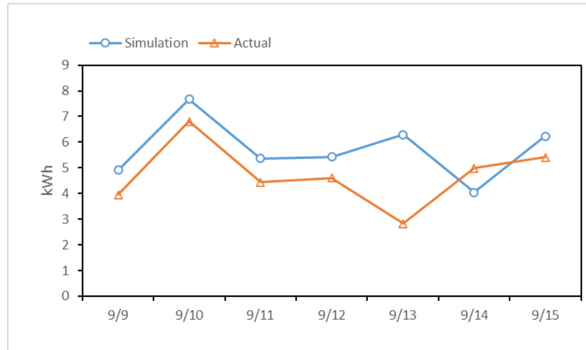

Fig 8 The result of the simulation of energy consumption

This paper proposes the RMSE and the ME to evaluate the accuracy of the model. Its mathematical expression is as:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(O_i - \hat{O}_i)^2}{N}} \quad (5)$$

$$ME = \frac{1}{N}\sum_{i=1}^{n}|\varepsilon_i| = \frac{1}{N}\sum_{i=1}^{n}|\hat{O}_i - Oi| \quad (6)$$

Where, O_i is Energy consumption simulation results; $\hat{O}_i$ is Energy consumption monitoring results; and N is total number of samples

The RMSE of the calculation results of the total energy consumption of the dormitory and the test results is 1.38, and the ME is 1.13, The energy consumption trends of the simulation results are similar to the actual monitoring results, and the model has certain practical significance.

6. DISCUSSION

This article is based on students' energy consumption behavior, collected and analyzed the historical data of college dormitory energy consumption and students' energy conservation awareness. Relying on DeST and Anylogic, a multi-agent modeling method is used to construct a simulation model of student dormitory energy consumption, so as to realize the coupling analysis of multi-agent energy consumption behavior and energy consumption simulation. In the future, the model can also be extended to the energy

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consumption simulation of different types of buildings to provide technical support for building energy conservation.

7. CONCLUSIONS

Taking students' energy behavior as a starting point, this paper analyzed the historical data of college dormitory energy consumption and students' energy-saving awareness. Relying on DeST and Anylogic, the simulation model of student dormitory energy consumption using multi-agent modeling method was constructed and verified. The following conclusions can be drawn:

(1) College students generally have a higher awareness of energy conservation, but there are differences between students' energy consumption behavior and their awareness. The difference in energy consumption behavior of students is reflected in the setting of air-conditioning temperature and the use time of energy consumption equipment. And students' energy consumption behavior is influenced by others and the external environment.

(2) The energy consumption generation process of the student dormitory is truly described by the simulation model. The model fully considers the interaction between the students, and the simulation results are similar to the actual monitoring results. Therefore, the model has certain practical significance.

(3) For the same type of publicity and education method, increasing the degree and frequency of student participation in activities will increase the proportion of energy-saving, but the energy-saving effect of increasing activity frequency is better than increasing student participation in activities.

Schools could strengthen the frequency and intensity of energy conservation publicity activities, and encourage students to exchange knowledge about energy conservation.

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