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Kindergarten space design based on BP (back propagation) neural network

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BP 신경 망 기반 유치원 공간 설계

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Abstract In the past, designers relied primarily on past experience and reference to industry standard thresholds to design spaces. Such design often results in spaces that do not meet the needs of users. The purpose of this paper is to investigate the process and way of generating design parameters by constructing a BP neural network algorithm for spatial design. From the perspective. This paper adopts an experimental research method to take a kindergarten with a large number of complex needs in space as the object of study, and through the BP neural network algorithm in machine learning, the correlation between environmental behavior parameters and spatial design parameters is imprinted. The way of generating spatial design parameters is studied. In the future, the corresponding spatial design parameters can be derived by replacing specific environmental behavior influence factors, which can be applied to a wider range of scenarios and improve the efficiency of designers.

Key Words : Spatial design, Design parameters, Environmental behavior parameter, BP neural network algorithm, Algorithm formula

요 약 과거에 설계자는 주로 과거의 경험과 설계 공간에 대한 산업 표준 임계값에 대한 참조에 의존했습니다. 이러한 설계는 종종 사용자의 요구를 충족하지 않는 공간을 초래합니다. 공간설계를 위한 BP신경망 알고리즘을 구축해 설계 매개변수를 생성하는 과정과 방법을 조사하는 것이 목적이다. 그런 관점에서. 본 논문은 공간 내 복잡한 욕구가 많은 유치원을 연구 대상으로 삼고 있으며, 기계학습의 BP신경망 알고리즘을 통해 환경행동변수와 공간설계변수의 상관관계를 각인하고 있다. 공간 설계 매개변수를 생성하는 방법을 연구합니다. 미래에는 특정 환경행동영향요소를 대체하여 해당 공간설계 매개변수를 도출할 수 있어 보다 광범위한 시나리오에 적용할 수 있고 설계자의 효율성을 높일 수 있다.

주제어 : 공간 설계, 설계 파라미터, 환경 행위 파라미터, BP 신경망 알고리즘, 알고리즘 공식

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1. Introduction

1.1 Research background

American psychologist J. Gibson, 1904-1979) argues that children learn how to detect specific information in their environment to describe objects, events, and distribution in their environment and apply it to everyday activities. Environmental behavior emphasizes that space is basically formed by the interrelationship between an object and the person who feels it. Understanding the relationship between human behavior and space is the basis of space design practice[1]. Environmental Behavior uses the theory of psychology to study human activity in architectural space, summarize experience, and feedback to spatial design. The "environmental behavior parameters" mentioned in the article refer to the child's body data such as height, weight, arm span, seat height, stride. "Spatial design parameters" refer to spatial scale data such as spatial height, width, length, area, and so on.

Traditional spatial design methods study the laws of spatial perception through observation, access, and experimentation, but often these data are static and local and do not reflect multidimensional and complex dynamics in real space. This information can only provide a broad range of references to the designer and does not generate data that can be used directly in the design[2]. The lack of scientificity is also evident in the way designers design based on experience or existing models .The use of scientific methods to study the laws of perception and behavior in architectural space is becoming an important development [3].

1.2 Current Status of Traditional Kindergarten Space Design Method

The spatial form of kindergarten is a very typical complex space design, the audience is unified age groups of children who need to be met the needs of various static and dynamic activities in indoor and outdoor space, and it is relatively closed and independent. It is a good research object to study the relationship between human behavior and space design.

Good kindergarten design emphasizes a good experience of space for children, it is a potential, difficult to describe but ubiquitous feeling. A good space design is not simply expressed in the change of decorative materials and the improvement of color level, but in the light of the child's physical and psychological needs, the control of scale is especially important [4]. For traditional kindergarten space designers, designing a highly recognized kindergarten requires precise control and flexibility of the vast and complex scale system.

In this design, about 40 kindergarten-related space designers, parents, and children from various parts of China were randomly selected and questionnaires were conducted using online questionnaires and street interviews were used. The contents of the survey include surveys on issues related to the kindergarten space experience. A total of 50 people participated in the survey, and the data were obtained as follows 〈Table 1〉

Table 1. Questionnaire on Problems in Kindergarten Space Experience

Problem	% (Number of persons)
Single form of activity space	78% (39)
Space occlusion, lack of openness	66% (33)
Poor environmental aesthetics	24% (12)
Lack of social activity venues	56% (28)
Rigid activity space division	54% (27)
Insufficient safety protection	18% (9)
Low interaction between people and space	72% (36)
Inadequate environmental education	42% (21)
Insufficient activity area per capita	48% (24)

The survey results show that there are still many areas in the current kindergarten planning and design that cannot satisfy the vast majority of respondents, and the rationality of space allocation is the most prominent problem. At the same time, in response to the survey results, we communicated with some kindergarten space designers. They generally believe that kindergartens designed based on designer experience or existing models often have a huge gap between actual space needs and increase the designer's ineffective work. quantity. Cause the phenomenon of waste of resources.

1.3 Machine learning algorithm and space design

Nowadays, the development of positioning and networking technology has made it very easy to obtain large amounts of time and space data. Both human body data and human behavior in the environment can be regarded as data, the improvement of computer computational and storage capabilities has helped to improve data resolution. Algorithmic references allow us to find laws and discover knowledge from a large amount of data, and scientific interpretation of data is widely used in urban construction research and intelligent architecture. Based on "geographical fence" positioning techniques such as Wi-Fi, ultra-broadband, ultrasound, and Blue tooth [5], these technologies provide important evidence for environmental behavior research by systematically recording human space-time location data. At the same time, through user thinking, iterative thinking, process thinking, big data thinking and cross-border thinking, designers can innovate in design methods [6]. In recent years, with the development of artificial intelligence (AI), computers have been widely used to find solutions to real-space problems, mapping real-world information into quantized data and finding their relationships. In architectural designs involving artificial intelligence, designers provide cases to represent the initial and final state of the design, and computers build machine learning models to fit design rules and then apply trained models to the creation of new designs.

2. Situation of Kindergarten space

2.1 Neural Network Model

Neural networks are machine learning techniques that simulate the workings of the human brain, enabling artificial intelligence-like processing of various types of data, such as images, text, speech, and sequences, and can be categorized, regressed, and so on. In the field of space design, artificial intelligence solves problems differently from the designer's perceptual understanding of space design. Its capability in the face of vague objective function of complex design problems, make the design a descriptive, controllable, and optimizable process. But designers have limitations when facing the same problem. But their starting point is the same, they are summarizing and applying rules.

In the course of research on designers, we find that designers generally have difficulties in blurring the target function. In combination with the data ability of machine learning algorithms, we can hypothesize that children's environmental behavior parameters are related to spatial design parameters according to rough set theory. By dataizing and labeling children's physiological data with environmental behavior data, we can rely on current machine learning domain algorithms to find a correlation between children's environmental behavior parameters and the existence of spatial design data [7].

The characteristics of different environmental behavior parameters such as height, weight, arm spread, seat height, walking width, activity frequency, activity form and interpersonal distance can be used. Using this as a basis for distinguishing different groups of people, after splitting the data into a series of data labeling and digitizing, integrating it into machine learning algorithms, and analyzing the needs of different target groups for different spatial parameters: such as floor height, space area, corridor Length width etc. The ability of the neural network to reveal the non-linear relationship between the self-organization and self-adaptive characteristics of data samples is used to realize the prediction of spatial design parameters [8]. This will be a new design method that is different from the traditional design method.

2.2 Principles of Neural Network Algorithms

2.2.1 BP Neural Network

BP neural network learning algorithm can be said to be the most successful neural network learning algorithm, BP neural network is like a "universal model with error correction function", each time according to the training results and the expected results of the error analysis, and then modify the weights and thresholds, step by step to get the output and the expected results of the model consistent. The model is then modified by modifying the weights and thresholds, step by step, to produce a model that matches the expected results.

Multi-Layer Perceptron (MLP) is also called Artificial Neural Network (ANN). The MLP model has an input layer, a hidden layer and an output layer, as shown in Fig. 1. Here, five environmental behavior parameters of height, weight, seat height, interpersonal distance and arm span are taken as input. The neuron module is set in the hidden layer. By setting the weight and activation function of each parameter, in the form of bionic electrical signals, two space design parameters, the height of the classroom and the area of the classroom, are finally output.

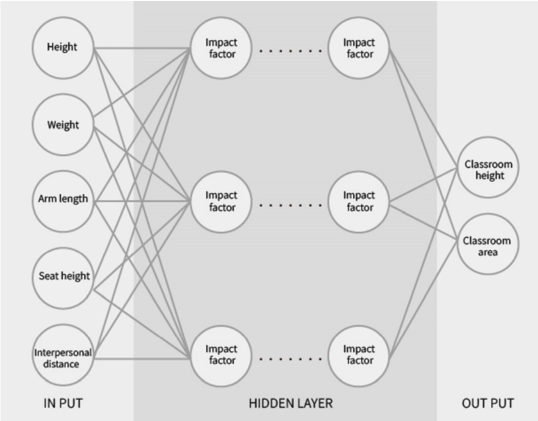
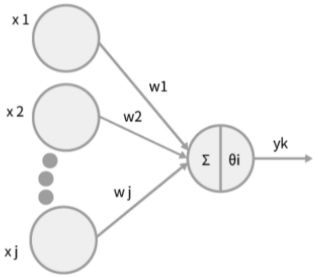


Fig. 1. MLP Multi layer Sensor

2.2.2 Working principle of the BP neural network

The core of BP neural network is neuron module. The purpose of this experiment is to eliminate the linear relationship between two spatial design parameters. Because this experiment uses five environmental behavior parameters as inputs to derive two space design parameters, we can think that all five environmental behavior parameters have a certain effect on any space design parameter. This is a nonlinear problem. Consider one of the neurons: We consider “x1~xj”to be all upper-layer influencers, and we set a weight for each influencer (representing the importance of each influencer in the upper-layer) “w1~wj”〈Figure 2〉. The signal received by this neuron from the previous layer is then written as “y” by adding a bias value “b” to the product of each image factor and its respective weight. When this neuron transmits an electrical signal to the next layer, it must be activated by an activation function θ and transmitted to each neuron in the next layer. This makes it possible to non-linearize the correlation between the data well.



$$y(i) = w(i) * x(i) + b$$
$$y = \Sigma w(i) * x(i) + b$$
$$y(k) = \theta(y)$$

Fig. 2. Schematic diagram of neurons

3. Construction of BP Neural Network Algorithm for Spatial Design

3.1 Experimental flow

The main goal of this algorithm design is to build a regression prediction model about children's environmental behavior parameters and kindergarten space design parameters. After collecting the kindergarten environmental behavior parameters through research in advance, it can predict the space design that satisfies the space participants Parameters. BP neural network algorithm model is based on the standard data set. The data set is the "experience" of the neural network, so it is necessary to take a rigorous attitude in data collection [9].

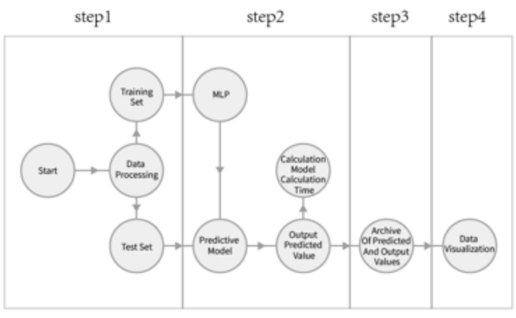


Fig. 3. Experimental flowchar

As shown in Fig. 3, the overall flow of this experiment is divided into four steps.

1. determine the dataset to be analyzed. the BP neural network model is to predict the spatial design parameters that satisfy the spatial participants, so when selecting the samples, 40 kindergartens with high spatial participant satisfaction were selected and the environmental behavior parameters were collected categorically as the dataset.

2. Then they were randomly classified and divided into training set and validation set. And the dataset is standardized to eliminate the outline difference between different data latitudes to accelerate the model fitting speed.

3. The BP neural network model is trained by the training set, and the standardized training set is used as known conditions for the BP neural network. The training set is a known mapping group, and when the standard data set is loaded in the BP neural network, a set of degree matrices will be randomly generated, and after processing the input set in the standard set with the matrices, the result will be compared with the standard output set, and the error will be proposed and the matrix set will be modified in the direction of reducing the error, and then after repeating several times, the error will be reduced to a certain degree, and the standard output set can be obtained after the standard input set is input to the network, and the training is The training is completed. And the application of this BP neural network is to summarize the experience on the standard data set to map the new input[9].

4. The test set is input to the trained BP neural network, and the result obtained from the BP neural network is used as the predicted value. The output value of the test set is used as the actual value, and the actual value is visualized and compared with the predicted value to evaluate the effectiveness of the BP neural network model.

3.2 Selection of spatial design parameters and environmental behavior parameters

This experiment uses the two “spatial design parameters” of classroom area and floor height as the output values, because the relevant industry standards only calibrated the limit values for these two space design parameters. The specific design parameters are derived by the designer based on subjective experience. Very difficult to grasp. Five "environmental behavior parameters" of height, weight, arms span, seat height, and interpersonal distance are used as input values. Because these five physical data typically reflect the characteristics of children's groups.

When the input value and output value are determined, the prediction model of spatial design parameters based on BP neural network can be established[10].

3.3 Relevance display of space design parameters and environmental behavior parameters

The data displayed this time is the data after normalization. The difference between the data dimension and the data size is removed, to ensure that the data is compared in the same dimension or the same order of magnitude, and to ensure that the larger numerical data will not occupy the larger Weight: In the training of this algorithm, it can speed up the convergence of the model and prevent overfitting[11]. As you can see from the figure below, the significance of the parameter floating between [0,1] is to indicate that the space design parameters and environmental behavior parameters are related. The closer the value is to 1, the stronger the relationship. As a designer Reference indicators are also more convenient〈Figure 4〉.

	Height	Weight	Arm Length	Seat Height	Interpersonal Distance
1	0. 692308	0. 5	0. 192308	0. 461538	0. 384615385
2	0. 653846	1	0. 269231	0. 461538	0
3	0	0. 076923	0. 692308	0. 730769	0. 153846154
4	0. 538462	0. 615385	0. 653846	0. 884615	0. 423076923
5	0. 076923	0. 576923	0. 346154	0	0. 192307692
6	0. 961538	0. 346154	0. 884615	0. 807692	0. 346153846
7	0. 5	0. 807692	0	0. 230769	0. 961538462
8	0. 923077	0. 307692	0. 461538	0. 076923	0. 923076923
9	0. 269231	0. 038462	0. 5	0. 923077	0. 461538462
10	0. 192308	0. 846154	1	0. 384615	0. 807692308
11	0. 346154	0. 884615	0. 230769	0. 846154	0. 538461538
12	0. 153846	0. 269231	0. 807692	0. 192308	0. 884615385
13	0. 423077	0. 961538	0. 615385	0. 307692	0. 230769231
14	0. 692308	0. 423077	0. 846154	0. 346154	0. 730769231
15	0. 307692	0. 230769	0. 423077	0. 653846	1
16	0. 846154	0. 538462	0. 923077	0. 269231	0. 076923077
17	0. 807692	0. 153846	0. 538462	0. 5	0. 115384615
18	0. 615385	0. 769231	0. 076923	0. 615385	0. 615384615
19	0. 115385	0. 461538	0. 961538	0. 538462	0. 769230769
20	0. 038462	0. 692308	0. 115385	0. 769231	0. 307692308
21	0. 384615	0. 384615	0. 576923	0. 423077	0. 038461538
22	0. 884615	0. 192308	0. 384615	0. 153846	0. 692307692
23	1	0. 115385	0. 153846	0. 961538	0. 576923077
24	0. 230769	0	0. 038462	0. 038462	0. 269230769
25	0. 730769	0. 730769	0. 307692	0. 576923	0. 653846154
26	0. 576923	0. 923077	0. 730769	1	0. 846153846
27	0. 769231	0. 653846	0. 769231	0. 115385	0. 5

Fig. 4. Display of environmental behavior parameters: height, weight, arms span, seat height, interpersonal distance)

As shown in the figure above, the experimental data of 27 kindergartens are extracted from the survey sample, and all environmental behavior parameters fluctuate between [0,1]. We take the design parameters of the first kindergarten shown in the figure above as an example to analyze: among all "environmental behavior parameters", the highest correlation is that the average height reaches 0.69. This sends a message to the designer: in this kindergarten design case, the highest priority is the floor height closely related to height. If the average height of children in the kindergarten is too high, the floor height shall be given priority.

4. Experimental methods and results

4.1 Experimental methods

In this experimental study, 80% of the data set in the survey sample was used as the training set of the BP neural network model, and 20% of the data was used as the verification set. That is: the environmental behavior data in the remaining 20% of the data is used as input parameters, and the BP neural network model is used to calculate, and the output value obtained is used as the predicted value of the space design parameter. Use the predicted value of the space design parameter to compare with the actual value of the case, and compare the error to confirm the feasibility of the model. Through the picture display, we can see that the actual value and the error value are not large, and it can be proved that this BP neural network model can obtain relatively correct space design parameters through specific environmental behavior parameters.

As shown in Fig. 5 : according to the analysis comparison of each case, the actual value of the floor height is very close to the predicted value of the floor height. It indicates that there is a certain correlation between the environmental behavior parameters set in the experiment and the spatial design parameters. the BP neural network model helps us to reveal this law.

	Actual Value Of Height	Actual Value Of Storey Area	Predicted Value Of Storey Height	Predicted Value Of Area
1	0.442475203	0.305640654	0.344988907	0.547554955
2	0.690261041	0.542833427	0.606048718	0.106768472
3	0.44771313	0.502110129	0.477981576	0.321017356
4	0.777132741	0.704327643	0.73241075	0.48199874
5	0.34049019	0.401357765	0.408101108	0.217130158
6	0.97496245	0.848637538	0.863456877	0.355991315
7	0.353588096	0.258459772	0.314964819	0.908085327
8	0.601655529	0.508104933	0.525417065	0.763350835
9	0.433719825	0.375134048	0.372551108	0.64377707
10	0.829890713	0.999704333	0.998552121	0.573552166
11	0.541167277	0.440439659	0.497300644	0.650811124
12	0.519671056	0.668879439	0.641948586	0.71309524
13	0.756356695	0.768491865	0.800055001	0.180214247
14	0.804534825	0.810786681	0.811999658	0.570214894
15	0.399832432	0.380539985	0.387274386	1.000225135
16	0.96129392	0.924038553	0.93110868	0.001155076
17	0.65111345	0.505310412	0.516154003	0.229581544
18	0.489729602	0.319230141	0.382300465	0.700446304
19	0.691460918	0.841664286	0.823112042	0.637405632
20	0.315631609	0.255383488	0.295938713	0.522848061
21	0.58083014	0.555461975	0.56007059	0.136777217
22	0.533973286	0.408715958	0.424461173	0.635795096
23	0.526625829	0.221606154	0.267330282	0.784985217
24	0.062733455	0.005160631	0.003942834	0.42698179
25	0.640727173	0.498061882	0.550134183	0.660955333
26	0.911548652	0.863281806	0.90720856	0.778438406
27	0.841239475	0.832715237	0.847702814	0.327851387

Fig. 5. Comparison of actual and predicted values, actual value of floor height, actual value of area, predicted value of floor height, predicted value of area

4.2 Visualization of experimental results

After visualizing the results of comparing the actual and predicted values of classroom area as shown in Fig. 6, the x-axis is the predicted value of area from the BP neural network, and the y-axis indicates the actual value of area for the high satisfaction design scheme in the research sample. The distribution of observation points shows that the predicted and actual values of classroom area do not correspond exactly to each other. This indicates that the selected environmental behavior parameters do not perfectly guide the satisfactory area design scheme and need to be improved subsequently.

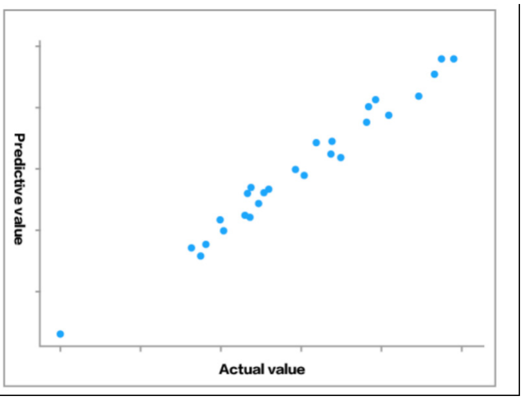


Fig. 6. Comparison of actual and predicted room area values

The results of the comparison between the actual and predicted classroom floor heights were visualized as shown in Fig. 7, with the x-axis representing the predicted floor heights of the BP neural network and the y-axis representing the actual floor heights of the satisfaction height design solutions in the research sample. The distribution of the points shows that each point corresponds to the actual value and the axes correspond to the same value. This indicates that the prediction of the spatial design parameter of layer height by BP neural network is accurate. This indicates that the BP neural network is a practical solution for the prediction of spatial design parameters after the analysis of environmental behavior parameters[12].

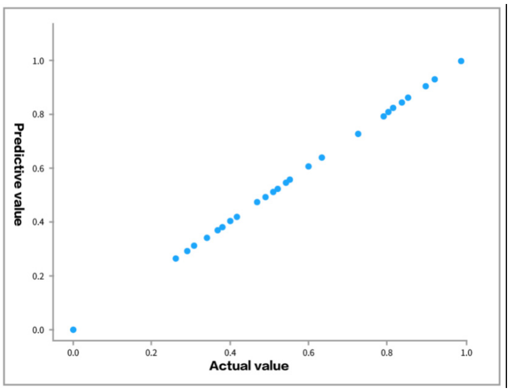


Fig. 7. Comparison of the actual and predicted values of the room layer height

4.3 Evaluation of experiments

The experimental data are from the spatial design parameters of many kindergartens with high satisfaction in China, covering different regions. Mainly considering the differences of people in different regions, there will be different environmental behavior parameters: it eliminates the contingency of the experiment and increases the reliability of the experimental results.

In this experiment, it shows how machine learning is applied in space design. Designers provide case parameters to represent the initial and final state of design. The computer constructs a machine learning model to fit the design rules, and then applies the trained model to the generation of new design. Computer will not only be a design assistant, but also a design partner to help designers make decisions according to design rules[13].

When human designers encounter the complex logic summarized since the lack of simple rules they can create, for example, abstract design experience can not provide accurate spatial design parameters. After the training of design data, BP neural network model can produce more accurate design parameters than human designers can describe[14]. The strong learning ability of artificial intelligence will bring a new breakthrough to the design industry and turn design into a descriptive, controllable and optimized process.

This experiment takes the multi-dimensional data of environmental behavior (average height, weight, arm span, seat height and interpersonal distance) as a reference to study the correlation between multi-dimensional design parameters (two-dimensional area and one-dimensional height). At the same time, we take 80% of the data set as the training set and 20% of the data set as the verification set. Through the comparison of verification sets, BP neural network algorithm can well predict the spatial design parameters of kindergartens with high satisfaction [15].

Therefore, the following conclusions can be drawn from this experiment:

1) After normalizing the data, the environmental behavior parameters were analyzed from the numerical point of view, and the predicted value of layer height was obtained after prediction by BP neural network, and this predicted value of layer height was the same as the actual value of layer height under the same parameters. And the success of this regression prediction model was verified by visualizing the data.

2) By collecting the environmental behavior parameters of kindergarten population, the spatial design parameters calculated by BP neural network have high guiding value. And by comparing its relevance, fine tune the spatial parameter design of the park, so as to help the designer design a kindergarten design scheme satisfactory to the spatial participants.

5. Conclusion

This research uses the BP neural network model in machine learning as a predictive tool.

The data obtained by investigation is brought into the model after data standardization, and pre-processing is carried out. It is concluded that there is a correlation between environmental behavior parameters and spatial design parameters , and confirmed that the BP neural network model can derive the optimal design parameters through calculations. This design method will improve the designer's work efficiency in the design work. It is an tentative application of artificial intelligence in space design.

In the future, under the influence of artificial intelligence, the role of human designers in the future is changing, thus forming a new relationship of cooperation and coexistence. Artificial intelligence will replace some design functions, such as draftsmen, and auxiliary positions such as investigators, but it puts forward higher requirements on designers, requiring future human designers to be more decisive and creative, and become organizers , decision makers, and creators. The cooperation between artificial intelligence and designers promotes the evolution of human designers to achieve a higher level of design intelligence and design thinking. The ultimate goal of this cooperative relationship is to continuously improve the overall level of architectural design, thereby simplifying the original complex space design process.

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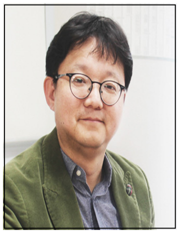

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