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Method Article

A method for aesthetic quality modelling of the form of plants and water in the urban parks landscapes: An artificial neural network approach

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A B S T R A C T

This work presents a simplified method for the application of the Multi-Layer Perceptron (MLP) model that aims to predict the aesthetic quality of the landscape designed by water and plants in different forms and volume. The MLP was prepared by (Rosenblat) in the field of computer science, followed by the application of a MLP in landscape aesthetic quality prediction proposed by (Jahani). In the method of this research, the structure of MLP was structured for aesthetic quality prediction of plants and water in urban park landscapes. The accuracies of designed MLP structures were tested to achieve the most accurate one in aesthetic quality prediction. This method creates an environmental decision support system tool for landscape designers, and it is a platform to predict the quality of environment. In practice, the designed environmental decision support system tool is applied by landscape managers to predict the aesthetic quality of landscape in designing new urban parks.

- Applies Multi-Layer Perceptron method in landscape assessment.
- Accurate MATLAB extension for landscape aesthetic evaluation.
- Defined criteria for aesthetic value of landscape.

A R T I C L E I N F O
Method name: MLP-Aesthetic
Keywords: Urban parks, Aesthetic, Landscape, Multi-layer perceptron, Artificial neural network
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Specification table

Subject area:	Engineering
More specific subject area:	Landscape and urban park design. Urban Engineering
Method name:	MLP-Aesthetic
Name and reference of original method:	MLP Method: First preparation by [32] and developed for aesthetic quality evaluation by [16]
Resource availability:	MATLAB file

Method details

Background

Understanding different values and feelings in the structure of landscape is very important because people have a relationship with landscapes. In fact, they affect and are affected by the landscape. Landscape managers design the landscape according to human perception of the landscape beauty, and also, the landscape aesthetic quality influences people's feeling and mood. The way the landscape influence people's perception may affect how people act and behave in the landscape environment [1]. The recreational quality of an area is related to the perception of beauty [2] and this provides an opportunity to compete with other tourist destinations, so aesthetic assessment is really important to landscape designers and stakeholders [3,4]. The aesthetic value of landscape for human well-being has a special importance not only in public perception but also in socio-environmental research [5,6,7]. According to studies [8,9,10], the aesthetic quality of urban parks landscape is in cultural aspects and the natural elements of parks, including plants and water. The combination of plants and water in urban parks influences the aesthetic quality of the landscape. In objective approach, the combination of plants and water should increase the visual beauty in the landscape of urban parks. On the other hand, in order to achieve this goal, it is necessary to evaluate the perception of park visitors in facing landscapes that are composed of water and plants in different forms. The main question is how the combination of water and plants with different cover area and forms influence the aesthetic quality of the environment? To answer this question, many researchers developed the artificial intelligence and artificial neural network models. For instance, researchers [8] developed the landscape aesthetic evaluation model to predict aesthetic and mental restoration potential using data mining techniques. They detected support vector machines as the most accurate model in aesthetic and mental restoration prediction in urban parks. The result of this research prioritized trees, water bodies, buildings, flowers, and decorations in park landscapes as the most influential factors in landscape aesthetic and mental restoration prediction. However, they did not consider the design form of landscape elements (the shape and order of elements together) in their research work. In [11], researchers designed a Bayesian network to detect landscape elements influencing aesthetic quality perception. They discussed that the Bayesian network is a reliable model for landscape aesthetic quality assessment. In [12], authors found that an artificial intelligence system is a successful method to filter photos with more pleasing content in the eyes of the users. While, many aspects of landscape influence the aesthetic quality, the purpose of this study is to develop an artificial neural network model and tool to predict the aesthetic quality of the landscape based on the forms and land cover of water and plants. This paper aimed to (1) model aesthetic preference of urban parks; (2) landscape variables prioritization in aesthetic quality and (3) design graphical user interface to run the model.

Methodology

This methodology was followed in 5 steps, as shown in the graphical abstract:

Fig. 1. Four samples of photographs recording urban park landscapes.

Step 1: Calculating the percentage cover

As the proposed methodology for landscape aesthetic quality evaluation, we prepared 100 landscape colour photographs in the environment of 10 selected parks. The photographs were taken from landscapes along the main pathway of the parks (Fig. 1).

There were some fixed photographing regulations to allow an unbiased comparison amongst photographs. In this regard, a same camera with the resolution of 4608 × 3456 pixels and a fixed focal length at 50 mm were used. The shot height of 1.70 m, 2/3 of land and 1/3 of the sky, similar lighting and atmospheric conditions and summer season were observed. To control these conditions, we used camera tripod in selected sunny days of summer.

The form and composition of plants and water in landscapes were defined as the recent researches on the field of landscape aesthetic [9,13–18] which are: (1) Grass cover (%), (2) Hedge cover (%), (3) Trees cover (%), (4) Trees planting form (1: Individual; 2: Group; 3: Strip), (5) Water cover (%) and (6) Water body form (0: No water; 1: Strip or stream; 2: Polygonal; 3: Rounded). To quantify the variables on the photos, we used a 1 × 1 mm network to calculate the percentage coverage of each variable in the photos as independent variables of modelling. The form of trees in the photos were recorded as individual trees scattered in the environment, a group of trees side by side and trees in a strip along a line. The form of water bodies in the photos were recorded as without water, water stream, polygonal pools and rounded lake or pool.

Step 2: Landscape aesthetic scoring

We followed aesthetic perception as [19] defines “the scenery is beautiful enough to attract people to see” and [8] and [10] applied that in aesthetic landscape assessment. We used the landscape aesthetic quality scores achieved by one question for aesthetic perception. A five point Likert scale (1 to 5) was used to score landscape aesthetic quality of each photo. In the five point Likert scale, the respondents express personal opinion (score of photo regarding aesthetic quality) based on the linguistic quality of photo in five scale of decision which are very low (1), low (2), moderate (3), high (4), very high (5).

A questionnaire-based survey in the context of several workshops in selected urban parks was carried out. The respondents were selected from visitors in the studied parks. Totally 6343 individuals

Table 1
The demographic characteristics of participants.

Gender (%)	Male	44
	Female	56
living environment (%)	neighbourhood	77
	Other Districts	23
Age (%)	18–30	17
	31–40	16
	41–50	19
	51–60	35
	More than 60	13
Educational Level (%)	Below College	17
	BSc Degree or BSc Student	31
	MSc Degree or MSc Student	46
	PhD Degree or PhD Student	6

which were the visitors of urban parks along a day and invited to the workshops, 977 (15.4% of invitees) individuals attended in the workshops to cooperate in this research, and 300 (30.7% of attendees) individuals filled the questionnaire. In this process, 10 workshops were held in the 10 selected urban parks in the summer of 2020 (July to September). The demographic characteristics of participants were summarized in table 1.

The questionnaires were filled and the average and the variance of urban parks landscape scores were calculated after filling each one hundred questionnaires. We noticed that after 300 filled questionnaires, the average of landscape scores was fixed, and it was the end of questionnaire filling workshop. The average of respondent's scores (300 scores) for each photo was recorded as landscape score. Moreover, the demographic information of attendees was recorded consisting of age, gender, living environment, and educational level.

Step 3: MLP (Multi-Layer Perceptron) modelling

Artificial neural network is considered as an accurate approach in human perception modelling and it was applied in aesthetic preference prediction in recent research [16,20,21,8] in the field of landscape design and architecture. The MLP was prepared by [32] in the field of computer science. Multi-Layer Perceptron (MLP) neural network is one of the most accurate models in environmental modelling researches [20,22,23,24,25] and we used this technique to model landscape score as the aesthetic quality of landscape in our research.

MLP model is run in MATLAB 2018 Software and the structure of network should be optimized. In this method, we optimize three factors of model which are the number of neurons, activation functions and the number of hidden layers. Indeed, the values of independent variables are introduced to MLP as input layer. These values are weighted randomly in different number of neurons and they are summarized to create the matrix of input layer. This matrix is the input of activation functions in the structure of hidden layers. The number of neurons and hidden layers are determined by trials and errors [26]. In this methodology, three activation functions were tested to achieve the most accurate output of the MLP (landscape aesthetic value). These activation functions are hyperbolic tangent, logarithmic sigmoid, and linear transfer functions. In the hidden layers, the logarithmic sigmoid transfer function and in output layer, linear transfer functions were applied to achieve the most accurate values of landscape scores. In supervised learning process, we use Back Propagation (BP) method to revise the initial random weights and biases of neurons. In this process, BP adjusts the weights of neurons and layers based on the output of the MLP. The weights are optimized until the most appropriate weights are achieved and the MLP network learning process will be ended [27,28].

In the process of network training, the validation data set controls the generalization potential of model to avoid overtraining of the network. Then, we use the test data set (data which are not used in the learning process) to test the performance of the MLP in real world. In this method, the samples or landscape photos are divided into three data sets randomly namely training data set with 60% of samples, validation data set with 20% of samples and test data set with remained 20% of samples.

The developed optimized MLP model is defined in Eq. (1). This equation will be performed in MATLAB 2018 software and the input variables or the quantities for the plants and water in landscape will result in predicted landscape score. Appendix 1 contains the needed MATLAB files to perform developed MLP model with optimized weights, layers and functions.

$$\mathrm{MLP} = \mathrm{Purelin}\left(\mathrm{Logsig}\left(\sum \mathrm{LW}_{2,1}\mathrm{Logsig}\left(\sum \mathrm{IW}_{1,1}\mathrm{p}_{\mathrm{i}} + \mathrm{b}_1\right) + \mathrm{b}_2\right)\right) \tag{1}$$

In which,

p_i = input variables' value
w_{ji} = The weights of neurons
MLP = The output of model
Purlin = The linear transfer function in output layer
Logsig = The Log-Sigmoid transfer function in hidden layers

Step 4: Model accuracy evaluation

The performance of artificial neural networks is assessed by several statistical indicators such as Mean Squared Error (MSE), Root Mean Squared Error (RMSE), Mean Absolute Error (MAE) and coefficient of determination (R^2) [29,30].

Step 5: Sensitivity analysis

In MLP method for landscape aesthetic quality assessment, the sensitivities for plants and water variables have been detected by calculating sensitivity values for each input variable. MLP sensitivity analysis prioritizes the variables concerning their influence on the output of the network. In the sensitivity analysis, we try to detect the changes of model output (landscape score) in response the changes of each input variable (plants and water variables). We change a variable in the range of standard deviation, and the others are fixed at the value of average. The standard deviation of outputs is calculated as a value of sensitivity for that variable. This process is repeated for other plants and water variables one by one.

To develop and test the model, 10 parks with high coverage of plants and water bodies in the park environment were selected to be representative of Tehran urban parks. By choosing the parks with the most diversity in plants and water forms, we assured that the sample size is large enough to make inferences. These parks were determined using the data bank of urban parks management plans in Tehran Municipality [31]. The selected parks have different forms of plants including grasses, flowers, shrubs and trees, and also water forms including running and stagnant water. In these parks, the plants are planted artificially by human and the forms of the plants are naturally developed based on the genetics of the plant species. More than 70% of the parks area is covered with natural elements, including plants and water, and less than 30% of area is covered by buildings and Infrastructure. The source of water in the parks is multiple water wells and along the park design process, the water has been structured in the form of water streams, fountains, waterfalls (running water) and pools (stagnant water). The selected parks are public and are used by citizens for daily recreation; and the available facilities of parks are used during the day (without overnight accommodation facilities). Restaurants and shopping centers, sports equipment, playgrounds and cultural centers are other ancillary facilities of these parks.

In this method, we determined a study area for modelling and testing the results. The structure (design) of studied parks is the same structure of most public urban parks in Iran; therefore, designed MLP model will be applicable in the most of urban parks in Iran. However we focused on plants and water resources in the structure of urban parks, because we believe that these resources are some of the main elements of each urban park in the cities. Therefore, we assure that the model is generally implemented in other parks.

Table 2
The structure and performance of optimized Multi-Layer Perceptron.

Activation function	Logsig-Logsig-Purelin	
Training function	Levenberg–Marquardt algorithm	
Structure	6–19–19–1	
Test set	R^2	0.94
	MSE	0.073
	RMSE	0.269
	MAE	0.234
Training Data	R^2	0.98
	MSE	0.015
	RMSE	0.122
	MAE	0.095

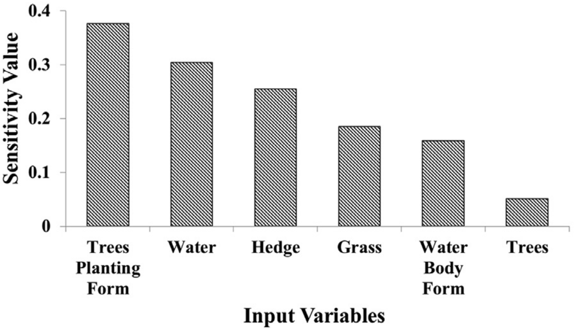

Fig. 2. Sensitivity analysis of MLP model.

MLP model structure and performance

T assess landscape aesthetic quality, we detected the most appropriate number of neurons and hidden layers, and the most accurate activation function (Table 2).

Table 2 shows the results of MLP model optimization and the optimized structure is '6–19–19–1′ for prediction of aesthetic quality of landscape based on plants and water characteristics. This resulted structure contains six variables as inputs, 19 neurons in the two hidden layers, and one neuron (aesthetic quality of landscape or landscape score) in the output layer.

Sensitivity analysis of the MLP model

Accordingly, the values of trees planting form, water, hedge, grass, water body form and trees are detected respectively as the inputs influencing the MLP method (Fig. 2).

In MLP method, a GUI was designed to run the MLP model by landscape managers who are designing new parks. In the process of park designing, the aesthetic qualities of landscapes are detectable before park design implementation. In this matter, the characteristics of plants and water in landscape are measurable on the site plan of the park. The park designer can easily predict the aesthetic quality of landscape or landscape score with the help of designed GUI. To perform this GUI in MATLAB software, users should apply MATLAB files in Appendix 1. As an example, Fig. 3 illustrates the results of 10 landscapes with different characteristics in urban parks. The characteristics of landscape are defined in an EXCEL file in Fig. 3. Landscape manager predict the aesthetic quality of landscape in these 10 landscapes just by pushing "Landscape Score" button in Fig. 3. Then, a data table appears on the screen illustrating the landscape score for 10 defined landscapes. Landscape designer changes the characteristics of landscape to achieve higher landscape score.

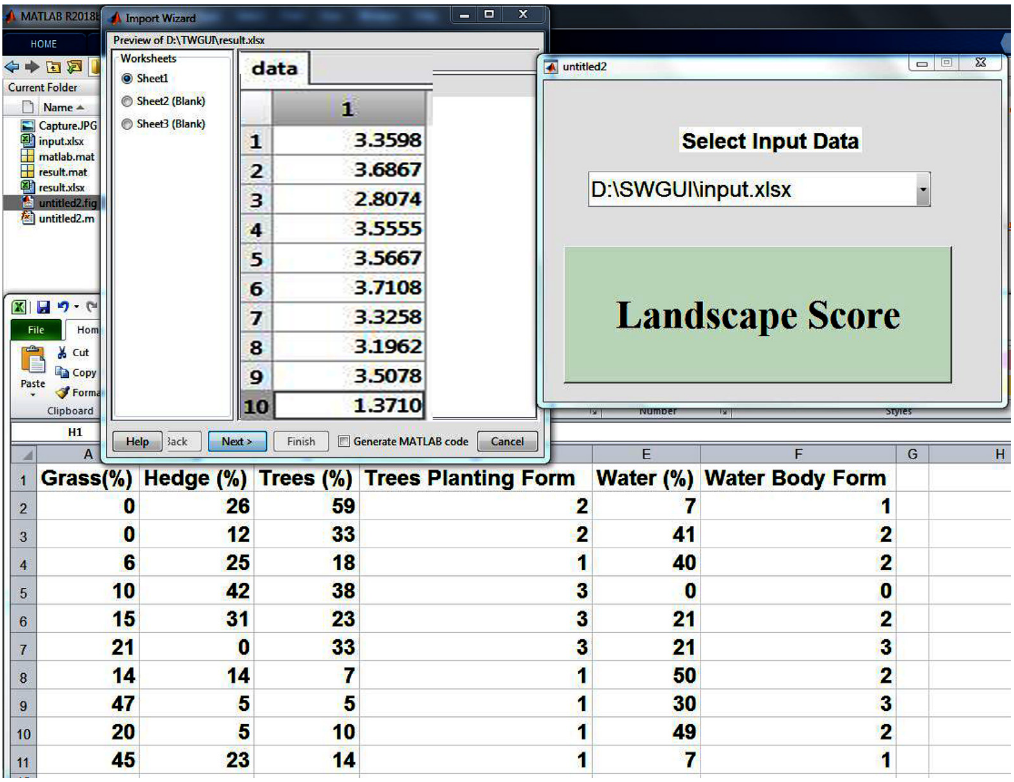

Fig. 3. The results of landscape aesthetic quality in ten urban park landscapes.

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Declaration of Competing Interest

The authors declare that there is no conflict of interest.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.mex.2021.101489.

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