Calculation of golf course environmental cost based on BP neural network

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Abstract. Golf is an elegant outdoor sport, but it is not popular with the Chinese people, largely because the construction of golf courses will cause a series of environmental problems. In this paper, the Cost-significant(CS) is introduced to calculate the environmental cost of golf course construction. According to the data of 14 golf course constructions consulted and sorted, the Cost-significant Items(CSIs) in golf course construction project is identified, and innovatively integrate data into the index of the project. Using the strong nonlinear mapping ability of Back-Propagation Neural Network(BPNN) Algorithm, a general environmental cost estimation model for golf course construction is trained. The comparison between the model fitting results and the original data shows that the model not only has high fitting accuracy, but also avoids involving complex data operation and complicated processing steps, which greatly simplifies the calculation process.

1. Introduction
In China, the government’s policies on the golf industry have changed from encouragement to restriction, from restriction to severe punishment and from severe punishment to regulation. Many local governments and people in China believe that golf courses cover a large area. In order to keep the lawns of golf courses green all year round, the amount of water used for irrigation is very large, and more pesticides and fertilizers are inevitably used. In order to better standardize the development of the golf industry, it need to calculate the environmental cost of the golf course project in the construction process, and estimate the environmental cost of the proposed project before construction.

At present, there are still less research on the environmental cost of golf courses. Most of the research on the calculation of the environmental cost of golf courses use traditional cost accounting methods such as alternative engineering method, shadow price method, carbon tax law method, protection cost method. However, the calculation process of these accounting methods is so complex that it requires a lot of manpower and material resources.

The combination of the CS and BPNN Algorithm is applied to solve the complex problem of calculation, so as to get the environmental cost of golf course construction faster and more accurately.

2. The environmental cost of golf course construction

2.1. The CS
The CS refers to the phenomenon that about 20-30% of the project amount accounts for 80% of the total project cost, which is called CSIs, and the remaining 80-70% of the project is called non-CSIs. Through this theory, CSIs can be selected from similar projects and the Cost-significant Factor(csf) can be
calculated, so as to infer the cost of the proposed project and the cost of similar projects, which not only simplifies the calculation, but also ensures a certain degree of accuracy.

2.2. Apply the CS
The steps of applying the CS theory to similar golf course construction projects are as follows:
• Using the average value regression theory, CSIs are selected from the environmental costs of similar golf course construction projects.
• Due to the lack of data, the significance factor csf of similar golf course construction projects was calculated by the Cross-validation method.
• Calculate the CSIs cost of the project to be built.
• Obtain the estimate of environmental cost of the golf course project to be built.

2.3. The CSIs in golf course construction project
According to different functions, environmental cost can be divided into the environmental pollution compensation cost, the environmental loss cost, the environmental governance cost, the environmental protection maintenance cost and the environmental protection development cost. After the application of CS, three significant costs in the environmental cost of golf course construction are the environmental pollution compensation cost, the environmental protection maintenance cost and the environmental loss cost, which includes eight significant cost items:
• Cost of sewage treatment cause by chemical fertilizers and pesticides. In order to maintain the lawn of golf course, lots of chemical fertilizers and pesticides are needed every year. Therefore, excessive chemical fertilizers and pesticides will cause the pollution of water resources.
• Irrigation system cost. The water used in golf course is listed as a special industry water, it is very expensive and its consumption is very large, so a good irrigation system can greatly reduce the amount of water consumed by golf courses.
• Drainage system cost. A good drainage system can store rainwater when it rains, and prevent the lawn from being flooded, and recycle the collected rainwater, greatly reducing the need for running water in golf courses.
• Cost of preventing soil loss. In the process of construction, vegetation destruction and soil digging for many times are easy to lead to soil loss.
• Animal migration cost. In the proposed golf course, there are likely to be many animals that have lived here for many years, and the placement of these animals will cost some money.
• Vegetation removal cost. During the construction of the golf course, some vegetation unsuitable for golf needs to be removed.
• Ecological restoration cost. After removing some unsuitable vegetation, it is necessary to add some suitable vegetation.
• The construction of artificial lakes. Artificial lake is an important part of golf course, it is not only a beautiful landscape on the golf course, but also has the function of water conservation and anti-seepage.

3. Back-Propagation Algorithm
BPNN is a kind of multi-layer feedforward network trained by reverse algorithm, which includes input layer, hidden layer and output layer. In this paper, a three-layer BP network model is adopted and Sigmoid function is selected as the activation function. In the input layer of the model, there are 8 significant projects of golf course construction. The number of neurons in the hidden layer of the model is determined as 10 on the basis of the formula hid_num = \sqrt{m + n + a} (constant a \in [1,10]) and the trial calculation. The output layer of the model is the cost of CSIs and csf. Levenberg-Marquardt (LM) Algorithm is used in back propagation because it combines the advantages of gradient descent method with the advantages of Gauss-Newton method. It has a penalty factor \(\mu (0 \leq \mu \leq 1)\) which control the iteration direction of algorithm. When \(\mu\) is large it is equal to gradient descent method. When \(\mu\) is small it is equal to Gauss-Newton method. The basic steps of BP Algorithm are as follows:
• Initialize the edge weights $W$, bias $b$ and the error $\varepsilon$.
• Calculate the state $z^{(l)}$ and activation $a^{(l)}$ values of each layer from the second layer to the last layer which is called the forward propagation.
• Calculate the error of each layer with LM Algorithm from the last layer to the second layer which is called the back propagation of the error.
• Update the edge weights $W$ and bias $b$, repeat steps 2 and 3 until the stop criteria is satisfied.

The core formula of BP Algorithms are as follows:

**Forward propagation ($2 \leq l \leq 3$):**
\[
z^{(l)} = W^{(l)}a^{(l-1)} + b^{(l)} \quad (3.1)
\]
\[
a^{(l)} = f(z^{(l)}) \quad (3.2)
\]

**Back propagation ($2 \leq l \leq 3, N = 13$):**
\[
E^{(l)} = \frac{1}{2} \sum_{k=1}^{N} (y_k^{(l)} - a_k^{(l)})^2 \quad (3.3)
\]
\[
E_{\text{Total}} = \frac{1}{N} \sum_{l=1}^{L} E^{(l)} \quad (3.4)
\]
\[
W^{(l)} = W^{(l)} - ((J(W^{(l)}))^T J(W^{(l)}) + \mu_1 I)^{-1} \frac{\partial E_{\text{Total}}}{\partial W^{(l)}} \quad (3.5)
\]
\[
b^{(l)} = b^{(l)} - ((J(b^{(l)}))^T J(b^{(l)}) + \mu_2 I)^{-1} \frac{\partial E_{\text{Total}}}{\partial b^{(l)}} \quad (3.6)
\]
\[
J(W^{(l)}) = \begin{pmatrix}
\frac{\partial E^{(l)}}{\partial w_{11}^{(l)}} & \ldots & \frac{\partial E^{(l)}}{\partial w_{1n_l}^{(l)}} \\
\vdots & \ddots & \vdots \\
\frac{\partial E^{(l)}}{\partial w_{n_l1}^{(l)}} & \ldots & \frac{\partial E^{(l)}}{\partial w_{n_ln_l}^{(l)}}
\end{pmatrix} \quad (3.7)
\]
\[
J(b^{(l)}) = \begin{pmatrix}
\frac{\partial E^{(l)}}{\partial b_{1}^{(l)}} & \ldots & \frac{\partial E^{(l)}}{\partial b_{n_l}^{(l)}} \\
\vdots & \ddots & \vdots \\
\frac{\partial E^{(l)}}{\partial b_{n_l1}^{(l)}} & \ldots & \frac{\partial E^{(l)}}{\partial b_{n_ln_l}^{(l)}}
\end{pmatrix} \quad (3.8)
\]

In the formula:
• $n_l$ denotes the number of neurons in $l$th layer.
• $W^{(l)} \in \mathbb{R}^{n_l \times n_{l-1}}$ denotes the weight matrix from $(l-1)$th layer to $l$th layer.
• $b^{(l)} = (b_2^{(l)}, \ldots, b_{n_l}^{(l)})^T \in \mathbb{R}^{n_l}$ denotes the bias from $(l-1)$th layer to $l$th layer.
• $z^{(l)} = (z_2^{(l)}, \ldots, z_{n_l}^{(l)})^T \in \mathbb{R}^{n_l}$ denotes the status of the neurons in $l$th layer.
• $a^{(l)} = (a_2^{(l)}, \ldots, a_{n_l}^{(l)})^T \in \mathbb{R}^{n_l}$ denotes the output value of the neurons in $l$th layer.
• $J(W^{(l)})$ and $J(b^{(l)})$ denotes the jacobi matrix.
• $I$ denotes the identity matrix.
• $\mu_1$ and $\mu_2$ denotes the penalty factor.

4. Application

4.1. Choose CSIs and the index of the engineering performance

Based on the analysis of the engineering data of the golf course construction project, there are 8 engineering characteristics that affecting the environmental cost of the project shown in table 1.

| Table 1. Quantified of environmental cost of golf course project. |
|---------------------------------|--------------------------|
| **Project** | **Quantitative values** |
| **Area/mu** | 1-(0,1000); 2-(1000,2000); 3-(2000,3000); 4-(3000,4000); 5-(4000,5000); 6-(5000,6000); 7-(6000,7000); 8-(7000,8000); 9-(8000,\infty) |
Table 2. Environmental cost of golf course project.

| No | Project                                      | No | Project                                      | No | Project                                      |
|----|----------------------------------------------|----|----------------------------------------------|----|----------------------------------------------|
| 1  | Cost of sewage treatment cause by chemical    | 9  | Road sprinkling cost                         | 17 | Greening project cost                        |
|    | fertilizers and pesticides                   |    |                                              |    |                                              |
| 2  | Irrigation system cost                       | 10 | Noise reduction cost                         | 18 | Planting artificial grass cost               |
| 3  | Drainage system cost                         | 11 | Shock absorption cost                        | 19 | Supervision fee                              |
| 4  | Cost of preventing soil loss                 | 12 | Air pollution control cost                   | 20 | Monitoring cost                              |
| 5  | The construction of artificial lakes         | 13 | Solid pollution treatment cost               | 21 | Construction worker health cost              |
| 6  | Animal migration cost                        | 14 | Construction waste disposal cost             | 22 | Sedimentation tank project cost             |
| 7  | Ecological restoration cost                  | 15 | Domestic garbage disposal cost               | 23 | Temporary shelter facility cost             |
| 8  | Vegetation removal cost                      | 16 | Dust removal facility fee                    | 24 | Others                                       |

4.2. Calculate the cost of CSIs and csf by using BPNN prediction model

4.2.1. Environmental cost data. With the BPNN prediction model, the cost of CSIs and csf were calculated. First, the collected index data were quantitatively scored according to table 1 and used as the input value of the environmental cost of BPNN prediction model. The 1st to 10th golf engineering sets were used as training sets, the 11th to 13th as test sets and the 14th as prediction sets. The result was shown in table 3.

Table 3. BPNN input and output table.

| No | $I_1$ | $I_2$ | $I_3$ | $I_4$ | $I_5$ | $I_6$ | $I_7$ | $I_8$ | Output $O_1$ | $O_2^b$ |
|----|-------|-------|-------|-------|-------|-------|-------|-------|--------------|--------|
| 1  | 8     | 6     | 4     | 5     | 6     | 4     | 5     | 5     | 9210.43      | 78.52  |
| 2  | 9     | 7     | 5     | 8     | 1     | 3     | 3     | 4     | 10968.78     | 79.81  |
| 3  | 8     | 4     | 1     | 5     | 1     | 3     | 4     | 1     | 11676.03     | 78.7   |
4.2.2. Environmental cost data. According to the above analysis, the BPNN is a three-layered neural network which has 8 neurons in the input layer and 2 neurons in the output layer. The LM Algorithm was chosen to train the neural network. In the BPNN, the activation function is Sigmoid and the loss function is the square function.

A better training result would appear when there were ten neurons in the hidden layer by trial and error. Then, BP neural network was constructed, and the number of iterations was set at 2500. The error should be within 0.001. The result was shown in figure 1 and figure 2.

![Figure 1: The fitting curve of $O_1$.](image1)

![Figure 2: The fitting curve of $O_2$.](image2)

4.2.3. Result analysis. According to the figure 1 and figure 2, the errors between the actual value and the predictive value are small. The correlation coefficient between $O_1$’s actual value and the predictive value is 0.98494 which is close to 1, and so does $O_2$ that its correlation coefficient is 0.96197. Therefore, the preliminary results are considered to be ideal.

After that, the convergent BPNN obtained above was used to test the data of 11th, 12th and 13th. Due to a certain randomness, the prediction results of 20 times were taken and the average value was obtained, as shown in table 4:

| No  | Predictions of $O_1$ | Actual values of $O_1$ | Relative error of $O_1$ % | Predictions of $O_2$ % | Actual values of $O_2$ % |
|-----|----------------------|------------------------|---------------------------|------------------------|------------------------|
| 11  | 4127.36              | 4117.36                | 0.2428                    | 82.73                  | 82.72                  |
| 12  | 2990.68              | 2989.89                | 0.0264                    | 80.58                  | 81.18                  |
| 13  | 5024.52              | 5341.25                | -5.9299                   | 80.42                  | 80.95                  |

$^a$ $O_1$ is the amount of environmental project costs.

$^b$ $O_2$ is the coefficient of significance csf.

$^c$ $/$ represents the part of the prediction set to be output.
According to the analysis of table 4, it was found that the largest error was less than 6% which within plus or minus 10%, so the result was considered reasonable.

4.3. Prediction
The next step was to predict the 14th project in prediction set.

Table 5. Input of prediction set.

| No | $I_1$ | $I_2$ | $I_3$ | $I_4$ | $I_5$ | $I_6$ | $I_7$ | $I_8$ |
|----|-------|-------|-------|-------|-------|-------|-------|-------|
| 14 | 4     | 1     | 1     | 4     | 3     | 7     | 5     | 2     |

Similarly, the convergent BPNN was used for 20 repeated predictions, and the average value was taken. The predicted results were shown in table 6:

Table 6. The output of the prediction set.

| $O_1$  | $O_2$ | $O_1/O_2$ |
|--------|-------|-----------|
| 5267.11| 80.12 | 6574.0265 |

As can be seen from table 6, the environmental cost of the project is about 6,574,02.65 million yuan.

5. Conclusion
The research shows that the CS extracts the CSIs of golf course projects, greatly simplifying the complexity of the estimation of the environmental cost of the proposed golf course projects. BPNN Algorithm has a strong applicability in environmental cost estimation of golf course project. In addition, the perfection of the environmental cost database of golf course project has an important influence on the accuracy of environmental cost estimation.

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