WEP Warwick Evans Publishing

Transactions on Social Science, Education and Humanities Research
ISSN: 2960-1770, eISSN: 2960-2262 | Volume 9
SSMI 2024

Design of Consumer Confidence Prediction Index Model based on DEGWO Algorithm

Yijian Zhang

Wuhan Business University, Wuhan, Hubei Province, China

43591035@qq.com

Abstract. Based on the CCI index released by China Economic Information Network, combined with the DEGWO difference algorithm and BP neural network regression; Constructed a DEGWO-BP synthesis algorithm under machine learning mode to predict and fit consumer confidence index; The empirical results show that the cumulative error of the consumer confidence index using the DEGWO-BP algorithm is the lowest, only 37.8273; The average absolute error of the model is the lowest, and the model has the minimum level of deviation; The model with the minimum extreme deviation value has the strongest stability.

Key words: Consumer Confidence Index; BP Neural Network; DEGWO Algorithm; Error Analysis.

1. Introduction

Consumers are the core of economic life, and the sum of all consumer spending-saving decisions determines the state of economic prosperity and expected economic development, rather than a passive response of the actual economic structure. Consumer Confidence is a kind of view and expectation that consumers get from the comprehensive judgment of employment, income, price and interest rate according to the economic development situation of the country or region. The consumer confidence index (CCI) is an indicator of the strength of consumer confidence, it can comprehensively reflect and quantify consumers' evaluation of the current economic situation and their subjective feelings of economic prospect, income level, income expectation and consumer psychology. The consumer confidence index generally includes the consumer satisfaction index and the consumer expectation index. The Consumer Satisfaction Index reflects the consumer's evaluation of the current economic life, the Consumer Expectations Index reflects consumers' expectations of future changes in economic life. Because the change of people's mood and expectation precedes the change of action, consumer confidence is considered as a leading indicator to predict the consumption trend and economic trend of residents, it is also an important basis for monitoring business cycle changes and national policy making. Therefore, it is of great significance to forecast consumer confidence index accurately and effectively in national macroeconomic regulation and control.

Looking back the previous literature, we can find that the prediction of consumer confidence index is mostly based on a single prediction model, which can not fully mine the effective information of the data, thus affecting the prediction accuracy of the model, result in deviation of analysis result. Because each optimization algorithm has its own shortcomings, such as De algorithm and GWO algorithm alone to solve the optimization problem is prone to premature, poor stability, easy to fall into local optimal problems, etc. , in this paper, a more efficient hybrid optimization algorithm—DEGWO algorithm is proposed to improve the global search ability. The optimized prediction model based on artificial neural network has very effective prediction effect and good stability, and has been widely used in wind power plant wind speed prediction, environmental pollution prediction and other high-tech fields. Based on this, this paper combines BP neural network, CEEMD decomposition integration technology and DEGWO combination optimization algorithm to build the forecast model of Consumer Confidence Index, the combination model has high precision and good stability.

2. Model Design

Consumer Confidence Prediction Index model is based on DEGWO scoring algorithm design. DEGWO algorithm is an improved algorithm based on gray wolf optimization algorithm, which can effectively solve complex problems. In the consumer confidence prediction index model, DEGWO algorithm is used to find the optimal parameter combination to improve the accuracy and stability of the prediction model.

In order to improve the prediction accuracy of consumer confidence index, this paper improves the prediction model based on the classical BP neural network, and adds a more innovative difference gray wolf algorithm to improve the prediction performance of CCI. Through the empirical study, we can find that the combined forecasting model can significantly improve the forecasting accuracy of CCI, the model has strong generalization ability, can well capture the change of consumer confidence index information.

(1) BP Neural Network

BP neural network is also called error back propagation neural network, it is a multi-layer Feed forward neural network trained by an error back propagation algorithm and adjusted by a network weight threshold, proposed by Rumelhart and McClellan et al in 1986. Its outstanding advantage is that it has strong nonlinear mapping ability and flexible network structure. The number of intermediate layers and the number of neurons in each layer can be set arbitrarily according to the specific situation, and its performance varies with the structure. The basic idea of the BP algorithm is gradient descent, which uses a gradient search technique to minimize the mean square error between the actual and expected outputs of the network. In essence, the BP algorithm

is based on the network error square as the objective function, using gradient descent to calculate the minimum value of the objective function.

BP neural network algorithm is divided into the following steps.

Step 1: Network Initialization. According to the system input and output sequence (X,Y), the network input layer node number, hidden layer node number and output layer node number are set. Here we set (n,l,m) in turn. Let's say $X_1,X_2,...,X_n$ is the input value of the BP neural network, $Y_1,Y_2,...,Y_n$ is the input value of BP neural network, ω_{ij} is the weight from input layer to hidden layer, ω_{jk} is the weight from hidden layer to output layer, a is the threshold of hidden layer, and b is the threshold of output layer. Set the network learning rate η, the excitation function $f(x)$ and other parameters.

Step 2: implicit layer output calculation. According to the input vector of the system, the weight ω_{ij} of the initialized input layer to the hidden layer, the threshold a of the initialized hidden layer, and the set excitation function $f(x)$ of the hidden layer, the output H of the hidden layer is calculated.

$$H_j = f(\sum_{i=1}^{n} \omega_{ij} X_i - a_j) \qquad j = 1,2,...,l \tag{1}$$

Step 3: Output layer output calculation. The output H of the hidden layer and the connection weight ω_{jk} of the initialized hidden layer to the output layer and the initialized threshold b are calculated according to the previous step, and the output value O of the network is calculated.

$$O_k = \sum_{j=1}^{l} H_j \omega_{jk} - b_k \qquad k = 1,2,...,m \tag{2}$$

Step 4: Error calculation. The network output O and the real value Y are compared, and the network prediction error e is calculated.

$$e_k = Y_k - O_k \qquad k = 1,2,...,m \tag{3}$$

Step 5: Update the weights. The network error calculated in the previous step is used as a reference to update the network weights ω_{ij}, ω_{jk}.

$$\omega_{ij} = \omega_{ij} + \eta H_j (1-H) X_i \sum_{k=1}^{m} \omega_{jk} e_k \tag{4}$$

$$\omega jk = \omega jk + \eta H_j e_k \tag{5}$$

Step 6: update the threshold. Update hidden layer and output layer nodes a, b.

$$a_j = a_j + \eta H_j (1-H_j) \sum_{k=1}^{m} \omega_{jk} e_k \qquad j = 1,2,...,l \tag{6}$$

$$b_k = b_k + e_k \qquad k = 1,2,...,m \tag{7}$$

Step 7: for the error of the system settings to determine whether the iteration is over, if not up to the accuracy of the settings, return to step 2.

(2) DEGWO difference algorithm

DEGWO algorithm combines gray wolf algorithm and differential evolution algorithm, and it has the characteristics of fast convergence and high precision. The diversity of the initial population is ensured by the mutation of differential evolution, and then the convergence of the combined algorithm is ensured by the searching ability of the global optimal solution of Gray Wolf algorithm. Firstly, in order to avoid the phenomenon that the diversity decreases when the population iterates to a certain region, the DE algorithm is used to maintain the diversity of the population by means of crossover and selection operations, and then it is used as the initial population of GWO algorithm, the optimal three individuals $X_\alpha, X_\beta, X_\delta$ are selected by calculating the individual's objective function value, and then the positions of other gray wolves are updated by using the crossover and selection operations of the difference algorithm, iterate through the updates until the optimal output of the objective function value is selected. The hybrid algorithm not only improves the global search ability, but also can effectively avoid premature stagnation, falling into local optimal defects.DEGWO algorithm first needs to set algorithm parameters, corresponding parameters.

The implementation steps of the DEGWO algorithm are as follows.

Step1: The parameters of the hybrid optimization algorithm were set, as shown in table1.

Table 1. DEGWO algorithm parameters and corresponding symbols

population size	maximum number of iterations	cross probability	search dimension	upper bounds of the search range	lower bounds of the search range	scale factor
N	$t_{\max}$	CR	D	mb	nb	F

Step 2: The number of initial iterations is set to $t_i = 1$, and the results of the first iteration are calculated. The differential evolution algorithm is used to generate the mutation population through parameters, and the initial population is generated through competitive selection:

$$x_{j,i}^{0} = x_{j,L} + rand(0,1) \times (x_{j,v} - x_{j,t}) \tag{8}$$

Step 3: The objective function values of each gray Wolf individual in the population were calculated and sorted according to the size of the objective function values. The optimal first three individuals were denoted as $X_\alpha, X_\beta, X_\delta$ respectively.

Step4: Calculate the distance between other gray Wolf individuals in the population and the optimal $X_\alpha, X_\beta, X_\delta$, and update the current position of each individual gray Wolf.

Step5: The parameter values are updated through cross-operation and high-quality populations are generated through competitive selection. The cross-operation formula is as follows:

$$\mu_i^G = \begin{Bmatrix} v_{j,t}^G if(rand_{j,t} \le CRorj = j_{rand}) \\ x_{j,t} orherwise \end{Bmatrix} \tag{9}$$

Step6: Update the position of the top three grey Wolf individual $X_\alpha, X_\beta, X_\delta$ with the optimal value.

Step7: If the maximum number of iterations $t_{\max}$ is reached, the algorithm exits, and the objective function value of the global optimal X_α is output. Otherwise, $t = t + 1$ go to step 2 and continue.

3. Data sources and Processing

The Consumer Confidence Index (CCI) data used in this article is from the China Economic Statistics Network database (http://This study extracted 232 months of CCI year-on-year data from January 2007 to April 2023 (db. cei. gov.cn). Table 2 Presented descriptive statistical indicators of the raw data.

Table2. Descriptive statistics of samples

Indicator	Sample Size	Range	Minimum	Maximum	Mean	Variance	Mean Squared Error
CCI	204	29.3	85.5	127.28	109.287	128.98	0.317

The index is often influenced by specific economic periods and requires pre sorting, classification, and review work. Thus, it is determined that the corresponding noise modes for specific stages are based on the fully empirical mode decomposition method. Therefore, remove any possible noise from the data before modeling. This article defines the operator of the j th mode in the empirical mode as $E_j(\cdot)$; The zero mean white noise of the model is ω^i, which has unit variance; The coefficient is ε_k, and the signal-to-noise ratio can be selected according to the stage situation. Therefore, it can be inferred that the stages of complete empirical mode decomposition are as follows.

Step1: Implement I-fold repeated decomposition of empirical modes based on noise, and then calculate the average value of the model.

$$IM_1 = \frac{1}{I}\sum_{i=1}^{I} E_1(x + \varepsilon_0 \omega^i) \tag{10}$$

Sstep2: Calculate the first-order residual $r_1 = x - IMF_1$, continue to decompose to achieve $r_1 + E_1(\omega^i)$, where $i = 1,2,...,I$, Until their first IMF condition is met and the overall average is defined as the second IMF.

$$IMF_2 = \frac{1}{I}\sum_{i=1}^{I} E_1(x + \varepsilon_1 E_1(\omega^i)) \tag{11}$$

Step3: Calculate k -order residuals, $k = 2,3,...,K, r_k = r_{k-1} - IMF_k$, extract the first IMF component of $r_k + \varepsilon_k E_k(\omega_i)$, where i=1, 2,..., I. Calculate the overall average to obtain the IMF_{k+1} of the target signal.

$$IMF_{k+1} = \frac{1}{I}\sum_{i=1}^{I} E_1(rk + \varepsilon_k E_k(\omega^i)) \tag{12}$$

Step4: Continue the screening process until the obtained residuals can no longer be decomposed, and you can obtain:

$$R = x - \sum_{k=1}^{k} IMF_k \tag{13}$$

In the formula, R is the final residual and K is the total number of IMF. Therefore, the target signal x can be represented as:

$$x = \sum_{k=1}^{K} IMF_k + R \tag{14}$$

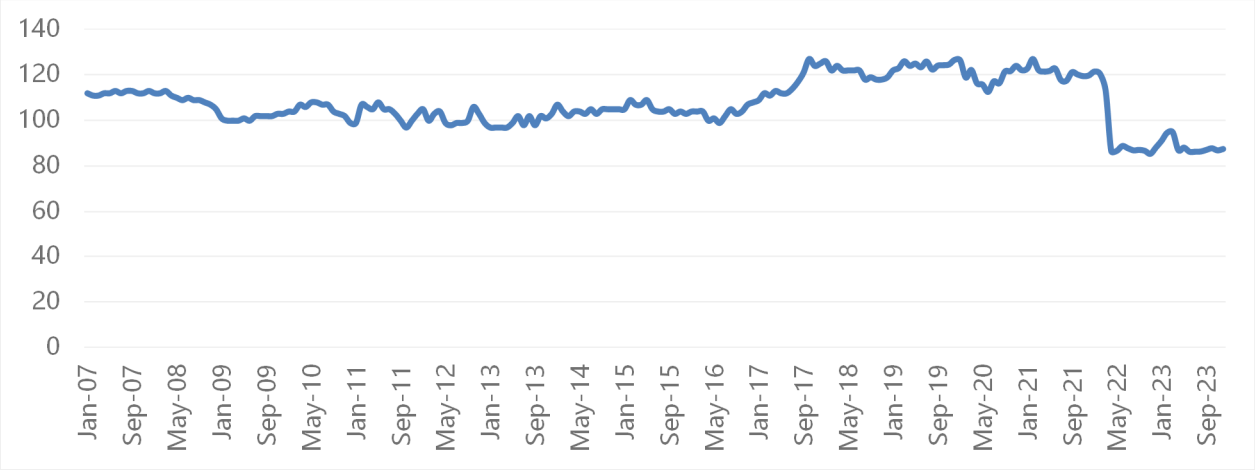

Figure 1. Comparison between CCI Raw Data and Denoised Data

4. Simulation and Simulation

The simulation model process in this article was conducted in the Matlab 2017b software environment. In order to demonstrate the superiority of the algorithm used in this article, a single BP neural algorithm, signal mode decomposition BP algorithm (CEEMD), and particle swarm optimization BP algorithm (BP) were simultaneously used for prediction. These algorithms are commonly used prediction algorithms in the indicator analysis process, and their specific operations in the differential process and denoising process are not consistent.

Table 3. Accumulated error values for four types of models

Name	BP	CEEMD-BP	PSO-BP	DEGWO-BP
Accumulated error value	153.9223	92.8987	84.9183	37.8273

According to the comparison of the main evaluation indicators of four types of consumer confidence prediction index models. It can be seen that DEGWO-BP has significant advantages in all four indicators. The superiority of this model method will be analyzed from each indicator below.

Firstly, from the perspective of Mean Absolute Error (MAE), as a fundamental indicator for evaluating the effectiveness of regression models, the consumer confidence index calculated in this article is based on a series of time series data, and the deviation of each data from the actual average can be inverted using MAE. The average deviation of a single BP model is 4.0590, indicating that the average operator deviates approximately 4 units from the actual operator. The problem of data noise clearly seriously affects the predictive performance of the BP neural network; Although the CEEMD-BP and PSO-BP methods reduce noise from the perspective of signal modality and community, the average error reduction is not significant. Compared with the BP method, the DEGWO-BP method has an overall error reduction of 1.0014, with the greatest overall improvement in the model and the closest average index.

Secondly, mean squared error (MSE) will further amplify the values with larger deviations in the predicted values, indicating the stability of the model. The main problems of a single BP model are

more clearly exposed by the MSE index. Due to the significant influence of basic input variables, the basic output analysis process of the BP neural network will generate significant fluctuations, resulting in significant estimation errors of the model; The CEEMD-BP model and PSO-BP model, while considering the core influencing factors of the main variables in the sequence, can reduce redundant fluctuations caused by irrelevant variables; DEGWO uses grey wolf difference to fix the distance between each variable and the three main variables, directly suppressing the influence of large deviation values, making the model more stable.

Thirdly, from the perspective of Mean Absolute Percentage Error (MAPE), the predicted value not only considers the error between the predicted value and the true value, but also takes into account the ratio of the true value to the predicted value, thereby better providing feedback on the relativity of the predicted value. For macroeconomic indicators, the larger error values analyzed through MAE and MSE may be due to the characteristics of larger measurement indicators, such as GDP often being based on billions of yuan, so the accuracy range considered in prediction should be appropriately increased, and consumer confidence index also has similar characteristics. The DEGWO-BP model is the only one among the four types of models mentioned above that controls the error percentage below 1%, indicating that the predictive characteristics of the model are far superior to other models and perform better in the macroeconomic field with larger base units.

Fourthly, based on the R-squared residual, the fitting degree of DEGWO-BP model reached 85.3810, which is much higher than its original value. Among the remaining three types of models, the residual squared value has always been regarded as the best model for observing the fitting level of the model. This model compares the benchmark model. The ratio of Baseline Model to mean solves the problem of inconsistent dimensions in model analysis.

5. Conclusion

The Consumer Confidence Index is the perspective of consumers on the economic market based on the macroeconomic situation, which has important reference value in the development of a market economy. Short term fluctuations in the index also have a negative impact on market expectations, especially during the important period of market transformation. The long-term prediction of consumer confidence index has become a major challenge in current academic research. This article is based on the CCI index published by China Economic Information Network, combined with the DEGWO difference algorithm and BP neural network regression, to construct a DEGWO-BP synthesis algorithm under machine learning mode, in order to predict and fit the consumer confidence index.

The consumer confidence prediction index obtained by using the DEGWO difference algorithm is closest to the actual information index, indicating that the calculation accuracy of the DEGWO-BP algorithm can be applied in practical analysis. According to the requirements of error analysis, the prediction of consumer confidence index needs to be controlled below the 1% level. Except for a single BP network algorithm, the other three types of algorithms have met the basic calculation requirements. However, the current consumer confidence index directly determines the demand side investment in the consumer economy market. If the accuracy cannot be controlled at a level of 0.5%, the overall predicted index value can only serve as a reference and cannot be applied to the estimation of long-term comprehensive economic benefits.

Through comparison with traditional single BP method, traditional signal modal BP algorithm, and particle swarm BP algorithm, it is found that the cumulative error of consumer confidence index using DEGWO-BP algorithm is the lowest, only 43.4631; The average absolute error of the model is the lowest,

The model has the minimum level of deviation; The extreme deviation value of the model is minimized, and the model has the strongest stability; The average absolute percentage error of the model is the smallest and can be applied to the calculation of economic indicators of different

dimensions; The overall fitting level of the model reaches 87.2610, which can be used for practical analysis of consumer confidence index and has certain guiding significance for predicting the economic environment.

Acknowledgments

This research was funded by (a) The 14th Five Year Plan for National Business Education, Training, and Research in 2024 (Grant No. SKKT-22026): “Research on Enhancing the Core Competence of Industry Education Integration in Local Applied Undergraduate Colleges under the Background of High Quality Development”;(b)Wuhan Business School Campus Teaching Reform Research Project(Grant No.2023Y015):Research on the New Form Textbook Construction of Consumer Economics Course for Cultivating Applied Talents.

References

[1] HUANG Qi, Chen Hanying, Liu Yan,et al. A Mobile Robot Path Planning Based on Multi-strategy Fusion Gray Wolf Algorithm[J]. Journal of Air Force Engineering University,3024,25(3):112-120.

[2] Dehghani M, Trojovsk Y P. Osprey Optimization algorithm: a new bio-inspired metaheuristic algorithm for solving engineering optimization problems[J]. FRONTIERS in mechanical engineering,2023,8:1126450.

[3] HE Z H, JIN G, Wang y j. A novel Grey Wolf Optimizer and Its Applications 5G Freguency Selection Surface Design[D].Frontiers of Information Technology,2022,23(9):1338-1253.