Automated Vegetable Pricing and Replenishment Decisions based on PSO

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Abstract. The main aspects that supermarkets need to consider are the purchase volume and pricing, especially the freshness of vegetable products, so it is more important to determine the daily replenishment volume. This paper divides 251 typical vegetables into 6 categories for the market, collects the daily sales volume, daily sales unit price and cost price and loss rate of each vegetable in a typical supermarket within three years, and formulates replenishment and pricing strategies for the coming week to maximize the operating profit of the supermarket. This article constructs a "cost-plus pricing" model. First, the regression model is used to analyze the relationship between total sales and cost-plus pricing for different vegetable categories. Secondly, using the single-objective optimization model, taking revenue as the objective function, sales volume and cost markup as the decision variables, considering the constraints such as the relationship between total sales and pricing, and solving with particle swarm optimization to find appropriate replenishment and pricing strategies, so as to maximize the revenue of supermarkets in the coming week. Finally, using time series forecasting, the sales volume of each vegetable category in the next week is predicted by using the sales flow of the previous three years, and the replenishment volume obtained by the above optimization model is compared to detect the reliability of the model, and the results show that the reliability of the model results is high.

Keywords: Particle Swarms, Regression Models, Time Series Forecasting.

1. Introduction

Nowadays, people's demand and quality requirements for vegetables have increased as a whole. Customers' price expectations for vegetables also change dynamically with the freshness of the product. Controlling the purchase of vegetables is the primary condition for ensuring the freshness of vegetables. Therefore, for supermarkets, the pricing and replenishment of vegetable products directly determine the sales profit of supermarkets [1]. In order to further increase the revenue of supermarkets, it is necessary to formulate a reasonable purchase volume strategy and pricing strategy. For the pricing of various vegetables, the cost-plus pricing method is generally adopted [2]. Many supermarkets use manual forecasting to judge the number of vegetables to be purchased the next day based on the salesperson's own experience, but because the sales of vegetables are affected by a variety of factors, the accuracy of human objective judgment is very low, which greatly affects the income of supermarkets [3]. Regarding the pricing strategy of vegetable products, Nie Kai and other scholars based on the relationship between consumer demand and price, combined with the quality and price of products to construct the retail profit function, and proposed the optimal ordering and pricing strategy under different degrees and frequency price reductions [4]. Under the traditional cost-plus pricing model, this paper adds the relationship between sales volume and pricing of six major categories of vegetables and the constraints of category loss rate, constructs a single-objective optimization model, and uses particle swarm algorithm to solve the pricing and replenishment strategies corresponding to the maximum profit in the next week.

2. Establishment of a cost-plus pricing model

2.1. Establishment of a univariate linear regression model

Univariate linear regression analysis is mainly used to study the linear relationship between a single dependent variable and an independent variable, which focuses on examining a specific dependent variable, treating the independent variable as a factor affecting this variable, and expressing the relationship between variables reasonably and accurately by establishing an appropriate mathematical model [5]. In this paper, the relationship between cost-plus pricing and sales volume of six major vegetable categories is analyzed, and the significance test of the regression equation and the significance test of the regression coefficient are carried out on the predicted univariate linear regression equation.

2.2. Build a single-objective optimization model

2.2.1 Establishment of the objective function

In order to solve the total daily replenishment and pricing strategy of each vegetable category in the coming week and maximize the benefits of supermarkets, this paper uses an optimization model to solve the relevant variables.

Start by setting the decision variables Sales y_{ij} and Interest Rate w_{ij}, specifying i for vegetable categories, $i = 1,2,\cdots,6$, j for days, $j = 1,2,\cdots,7$, and use the formula

$$S_{ij} = y_{ij}c_{ij}w_{ij} \tag{1}$$

The profit of type i vegetables on day j can be calculated, where c_{ij} represents the total cost of type i vegetables on day j, b_{ij} represents the loss cost of type i vegetables on day j, and the pricing x_{ij} is determined by the total cost c_{ij} and interest rate w_{ij} and the loss rate λ_i, which can be obtained

$$x_{ij} = c_{ij}(1 + w_{ij}) \tag{2}$$

Substituting the formula into the formula yields

$$S_{ij} = x_{ij}y_{ij}\frac{w_{ij}}{1 + w_{ij}} \tag{3}$$

In summary, the total supermarket income can be set to

$$max\, S = \sum_{i=1}^{6}\sum_{j=1}^{7} S_{ij} \tag{4}$$

At this point, this is the objective function, which is to solve for the sales volume y_{ij} and interest rate w_{ij} of each vegetable category in the coming week to maximize the objective function [6].

2.2.2 Constraints

The first constraint is that according to the above one-dimensional linear regression model analysis, the regression equation of the total sales and cost-plus pricing of the six categories of vegetables can be obtained

$$y_i = A_i x_i + B_i \tag{5}$$

Where the cost-plus pricing is the independent variable x and the total sales volume is the dependent variable y.

The second constraint is to consider the influence of category loss rate on solving the objective function by analyzing the cost-plus pricing model, combined with the loss rate of weekly vegetables.

$$\lambda_i = p * n_i \tag{6}$$

Where n_i is the loss rate of the single product, and p is the weight, which is calculated from the ratio of the sales volume of the unit product to the total sales volume of the category.

The third constraint condition is that by analyzing the correlation between the total sales of various categories of vegetables, it is found that the correlation between cauliflower and flower and leaves is more significant, and it can be used as one of the constraints that affect the target function. Analysis of it, find out its linear regression equation

$$Y_1 = aY_2 + b \tag{7}$$

Y_1 means the total sales of flowers and leaves, and Y_2 indicates the total sales of cauliflower.

2.3. Solve the model based on particle swarm arithmetic

PSO is based on the observation of animal group activity behavior, using the sharing of information by individuals in the group, so that the movement of the entire group produces an evolution process from disorder to order in the problem solving space, so as to obtain the optimal solution [7]. The algorithm is initialized as a swarm of random particles and then iteratively finds the optimal solution [8]. In each iteration, the particle updates itself by tracking two "extremes." After finding these two optimums, the particle updates its speed and position through the following formula.

$$v_i = v_i + c_1 \times rand() \times (pbest_i - x_i) + c_2 \times rand() \times (gbest_i - x_i) \tag{8}$$

$$x_i = x_i + v_i \tag{9}$$

Where $i = 1,2,\cdots,N$ and N are the total number of particles in this swarm; v_i is the velocity of the particle, the maximum value of v_i is $V_{max} > 0$, if $v_i > V_{max}$, then $v_i = V_{max}$; $rand()$ is a random number between $(0,1)$; x_i is the current position of the particle; c_1 and c_2 are learning factors, usually $c_1 = c_2 = 2$ [9]. The flowchart of the particle swarm algorithm is shown in Figure 1.

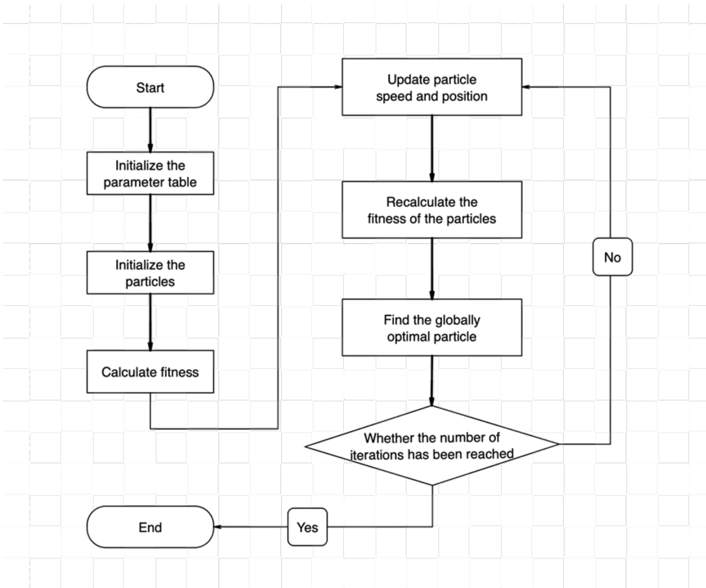

Figure 1. Flow chart of PSO algorithm

2.4. Build a time series forecasting model

Time series analysis is a prediction of the future based on existing data. Exponential smoothing models are one of the common methods of time series forecasting, which predicts future points based on a weighted average of historical data points, where the weights decrease over time [10]. This article uses an exponential smoothing model to predict daily sales for each category in the coming week.

The data obtained by particle swarm optimization is compared with it to detect the reliability of the optimization model.

3. Results

3.1. Establishment of a univariate linear regression model

The univariate linear regression equations predicted from the collected data for the six major vegetable categories are shown in Table.1.

Table.1. Predicted univariate linear regression equations

Category	Predicted univariate linear regression equation
Aquatic rhizomes	$Y = 68.1976 - 3.1580X$
Flowers and leaves	$Y = 259.3761 - 13.3642X$
Cauliflower	$Y = 64.8056 - 2.7979X$
Edible fungi	$Y = 111.9938 - 4.8082X$
Peppers	$Y = 104.8110 - 2.2123X$

The significance test of the regression equation and the significance test of the regression coefficient are carried out for the predicted univariate linear regression equation. All pass the test, indicating that the predicted univariate linear regression equation and regression coefficient are significant.

3.2. The solution result of the particle swarm algorithm

Finally, through the particle swarm algorithm, the maximum profit of supermarkets in the next week is 4975.27 yuan, of which the total replenishment and pricing strategy of flowers and leaves are shown in Table.2.

Table.2. Leaf replenishment totals and pricing strategy results

Date	Total daily replenishment (kg)	Pricing strategy
2023-7-1	89.7951	0.8252
2023-7-2	78.7183	0.6104
2023-7-3	28.1442	0.9442
2023-7-4	38.7528	0.2363
2023-7-5	69.1832	0.3155
2023-7-6	66.5478	0.6677
2023-7-7	98.6628	0.3063

From the comparison between prediction data and actual data, the BP neural network has better prediction performance and relatively small error, which can meet the demand completely, and has fast prediction speed and convenient operation.

3.3. Time series forecast alignment results

This article uses an exponential smoothing model to predict daily sales for each category in the coming week. Using the data obtained by particle swarm optimization to compare with it, the test results show that the reliability of the optimization model is high, and appropriate replenishment and pricing strategies can be formulated according to the optimization model, which is the largest revenue for supermarkets in the coming week.

4. Conclusions

In order to solve the problem of maximizing the supermarket's profit next week and the corresponding pricing replenishment strategy, the collected data is preprocessed, and a single-objective optimization function is constructed on the basis of considering the relationship between vegetable category sales and pricing, and particle swarm optimization is used to maximize profit value. The model solution results show that the maximum profit of the supermarket next week is 4975.27 yuan, and the pricing and replenishment strategies under the scenario of maximizing the profit of various categories of vegetables. Finally, the time series forecasting method is used to predict the sales volume in the coming week, and compared with the results obtained by the particle swarm algorithm, and it is found that the results have high reliability and reliability. The mathematical model established in this paper takes into account the relationship between sales volume and pricing of various categories, as well as the loss rate and other factors when constructing the single objective function, so that the model has higher performance. The particle swarm algorithm used in solving can find the global optimal solution, and the algorithm execution efficiency is high, which can be applied to various types of optimization problems. In general, the "cost-plus pricing" model established in this paper has certain reference value for automatic pricing and replenishment decisions of vegetables, and has high practicability.

References

[1] Zeng Minmin. Based on time situation A. Dynamic pricing strategy research on the fresh community supermarket [D]. Southwest University of Finance and Economics, 2022.

[2] Mao Lisa. The pricing strategy and production and marketing model of the vegetable wholesale market under the perspective of the supply chain [D]. Zhongnan Forestry University of Science and Technology, 2023.

[3] Zhang He. Vegetable sales forecast based on integrated learning [D]. Yunnan Normal University, 2021.

[4] Zhou Yilun. Research on the pricing strategy of fresh direct investment agricultural products based on customer perception value of customer perception [D]. Southwest University, 2022.

[5] Jiang Yajin, Cui Hong. Research on the influencing factors of the income influence of agricultural listed companies-the empirical test of regression analysis [J]. Rural economy and technology, 2023,34 (13): 252-256.

[6] Chen Qian, Li Lifeng, Shi Fenggai, etc. Deliner order decision-making analysis: Maximize profits [J]. Industrial Engineering and Management, 2006 (05): 32-35.

[7] Fan Huijing, Zhang Wenyi, Tian Miao Miao, etc. The satellite task ground station resource scheduling method based on the particle group algorithm [J]. Journal of the University of China, 2022,39 (06): 801-808.

[8] Yang Jiexia. The power distribution network based on the PSO algorithm is optimized [J].

[9] Qian Jiangbo, Zhang Jiaxing, Yao Dawei, etc. A group of particle group optimization algorithms based on improving inertia [J]. Computer and digital engineering, 2022,50 (08): 1667-1670.

[10] Wang Tian, Yan Jun, Gu Xiaoyang, etc.. The condatory network delay prediction based on the improved index smooth model [J]. Industrial control computer, 2023,36 (09): 101-103+114.