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Application of General Regression Neural Network Algorithm in Data Mining for Predicting Glass Sales and Inventory Quantity

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Abstract

FF Jaya Glass is a shop that supplies and installs 3 mm to 12 mm glass. The store obtained glass from suppliers to be processed in shape and size according to the order. After completing the the order, the shop worker will install the glass at the requested location. Unfortunately, currently stores do not utilize sales data to predict sales either manually or by utilizing technology. As a result, the store cannot predict when the number of glass orders will increase or decrease. In addition, errors often occur when ordering glass for the next period. As a result, stores often run out of glass supplies due to the large number of glass orders so that the achievement of profits is not optimal. This study aims to identify sales variables in glass sales data and build a general regression neural network model as a data mining method. In addition, this study aims to iterate to find the best value in the sales data training process, design and create applications according to user needs, and conduct system validation tests. The general regression neural network method is used to predict sales. The results of this study indicate that the application of general regression neural networks can be used to predict sales. This will make it easier for the store to provide glass supplies in the coming months with an accuracy of 98.1%.

Keywords: Data Mining; General Regression Neural Network; Predicting; Sales; Supply.

Introduction

The goal of a company or otrading business is to obtain maximum profit as well as to maintain and increase the business the in the long run. To achieve this goal, sales should be properly considered in the company's plan. Sales volume is the result of trading activities by a company. Regarding this, consumers are the important component interesting question to address is whether the company has put consumers in their effort to achieve such goal? [1].

Sales activity is strongly influenced by inventory. Inventory can be defined as goods stored for use or sale for the next period [2]. Inventories consist of raw material, semi-finished goods (work-in-process), and finished goods inventories. Inventory facilitates the operation of a company. According to T. Hani Handoko in his book, companies store inventory for various functions, namely [3]:

1. Decoupling function
2. Economic Lot Sizing Function
3. Anticipation function

FF jaya glass shop is a shop engaged in the procurement and installation of 3 mm to 12 mm glass. The shop obtains glass from suppliers which will later be processed into shapes and sizes according to orders received from customers. After completing the order, the shop will install the glass at the customer's requested location. To maintain and improve business continuity, FF jaya glass store has carried out promotions through social media to introduce it's business. FF jaya glass shop has made many sales transactions with customers generating data on glass sales. However, the data has not been properly used. Rather, it is only stored as a sales report.

Consequently, the store could not predict when the number of glass orders will increase or decrease by using the sales report. In addition, errors often occur when ordering glass for the next period. The delivery time of glass takes two to five days. It could potetially cause an out-of-stock of large number of glass orders which in turn lead to losing maximum profit.

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In 2021, the shop has successfully sold up to 248 units of glass. This figure has increased by 5% from 2020 with a total sales of 226 units. This higher order has led to glass out-of-stock imposing FF jaya glass store to re-supply glass out of ordering schedule that has been made. Consequently, the customers'order was delayed which sometimes causing order cancellation from customers. Another issue is when the supplier cannot provide the shop's order. These problems can affect the finances and performance of a business [4].

Based on these problems, a web-based data mining application is needed to predict glass sales. Data mining is used to extract information from sales data so that this information can be used to predict glass sales. After the data mining stage, calculations are made on sales data that has been inputted using the General Regression Neural Network (GRNN) algorithm. GRNN is known to be faster in the calculation process and does not require data assumptions [5]. Several previous researches have been conducted to prove that GRNN is proper model for making predictions [6]. This application predicts glass sales based on data taken from the FF jaya glass store sales report for the last two years, 2020 and 2021.

This study differs from previous studies in several ways. The prediction process of the number of sales and inventories applied different method, namely the GRNN based on data indicators using the number of sales and inventory from 2020 to 2021. The accuracy and error rate are 98.125%, and 1.875% respectively. Several researchers carried out sales and inventory prediction using the Double Exponential Smoothing forecasting method from Brown (DESB) and the Economic Order Quantity (EOQ) method to optimize inventory planning. This study, on the other hand, employed historical data of the last two years [7]. Another research used the naive bayes method in making predictions about sales and supplies of textile cloth. In this research, the data used is demand or sales data from 2018 to 2020. Decision is made using the application of data mining which prepared predictions on product sales and supplies [8]. Another research used algorithm C4.5 with the decision tree method to obtain sales prediction rule information that described the processes associated with sales prediction [9]. Other related research applied the Recurrent Neural Network (RNN) method to predict retail sales of goods per day based on sales data from January 2019 until December 2022 [10]. Several studies used the GRNN algorithm for instance in predicting house prices using the variable transaction date, distance to the house, number of shops, house age, geographical location, and house price. This research resulted in a mean square error of 58.61 [11]. Other research predicted the people's welfare level based on indicator data in population, education, and employment [12]. The data indicator used from 2012 to 2015 produced an average error rate of 0.26 in Absolute Percentage Error (APE).

This research aims to identify sales variables that exist in glass sales data, to create a GRNN model as a data mining method and to iterate to find the best value in the sales data training process of data training [13], to design and create software suitable for users, as well as to perform performance testing on the system.

Several benefits of this research are to predict glass sales for the next period, to provide additional information about potential glass sales, and to be used as a reference or recommendation in related research. With the existence of a web-based data mining application using the GRNN algorithm, it is expected that it can help the store make a planning for glass stock in order to maximize profit by processing customer orders smoothly.

Method

There are several stages of making a data mining application using the GRNN algorithm to predict glass sales. Firstly, an analysis of the data that has been collected from the object of research is carried out in the form of hard files or sales report. The data analysis process is described as follows **Figure 1**:

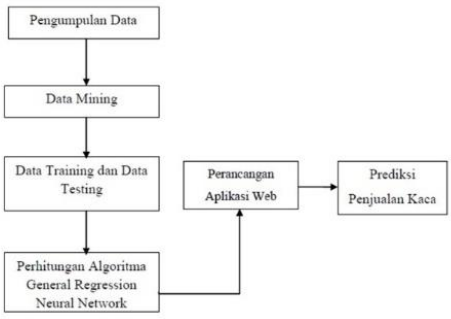

Figure 1. Data analysis process

Data analysis process in this research consists of:

1. Data Collection

   In collecting data, a survey was carried out through direct observation at the FF jaya glass store to collect the data needed in the research. Then, interview with the owner was conducted to collect the required data. In addition, the data was also taken from the sales report that comes from the research site.

2. Data Mining

Data mining is a scientific field that finds techniques from machine learning, pattern recognition, statistics, databases, and visualization to handle the problem of retrieving information from large databases [6]. At this stage, data mining such as data cleaning, data selection, and pattern evaluation was carried out on the data that has been collected to identify interesting information in the data so that it can be used in predicting glass sales.

3. Data training and testing

   The data used as training data was glass sales data in 2020 while the data used as testing data was glass sales data in 2021.

4. Calculation of the GRNN algorithm

   At this stage, calculations was carried out on sales data using the GRNN algorithm using Formulas 1 to 8 to obtain a predictive output from the number of sales and the amount of inventory for the next period.

5. Application design

   Application design consists of interface design based on keywords and application names in visual processing [14], database design which is a process for determining the details of the content and data settings [15], and calculation of the GRNN algorithm

6. Glass sales prediction

   At this stage, the application can show output which is a prediction of the number of glass sales in the next period. It can be used by users to prepare the inventory plan for the next period. After doing the analysis, a software design [16] is carried out that will be built for implementation into a web-based application.

The GRNN algorithm is used in the prediction stage after the sales data is input into the application. The algorithm for the GRNN can be seen in **Figure 2**.

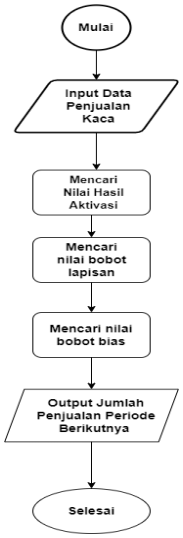

Figure 2. Flowchart System

The data used is glass sales report obtained from the research object. These data are divided into training data and testing data. The variables used in the calculation are sales volume, period or time to make predictions, glass size, glass type, and purchase amount. Furthermore, these variables are used to predict sales by using the calculation of the GRNN algorithm. The results of the prediction are in the form of the number of sales and the amount of inventory required for the next period. The predicted results of glass sales will be compared with actual data or testing data. How the GRNN algorithm works can be described as follows:

1. Searching for the i-th data distance using the following Formula 1:

$$D_i^2 = \sqrt{\sum_{i=1}^{p} (x_i - v_{ij})^2} \quad (1)$$

   where $i = 1, 2, 3, .., n$ and $j = 1, 2, 3, .., p$.

2. Calculating the value of the activation function by multiplying the value of the distance and the data using the following Formula 2, 3 and 4:

$$\theta_i = e^{-n^2} \quad (2)$$

   where:

$$n = b.d_i \quad (3)$$

with:

$$b = \frac{0{,}8326}{spread} \quad (4)$$

3. Calculating the sum on the activation function (θ_i) using the Equation 5.

$$Ss = \sum_{i=1}^{n} \theta_i \quad (5)$$

4. Calculating the sum on the weight value, where the weight value is the target vector value using the Equation 6.

$$Sw = \sum_{i=1}^{n} \theta_i w_i \quad (6)$$

5. After obtaining the sum of the activation function (θ_i) and the sum of the weight values, the next step is to determine the output using the Equation 7.

$$y = \frac{Sw}{Ss} \quad (7)$$

The accuracy prediction metric was also known as the measure of error or uncertainty. It is the result between the predicted value and actual data due to an error that occurs during prediction. The accuracy prediction metrics in this research used the Mean Square Error (MSE) with the following Formula 8.

$$MSE = \frac{\sum(Y' - Y)^2}{n} \quad (8)$$

where Y' is the predicted data, Y is the actual data and n is the amount of data.

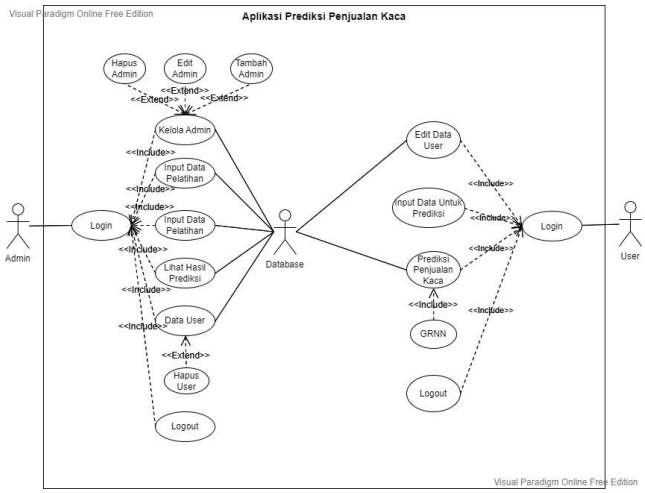

Figure 3. Case Diagram System

Figure 3 portraits that there are two actors in the process, namely admin and user. Admin and user must first log in into the system using their username and password. Admin may input training and parameter data, view and delete user data. The training data and parameter data entered will be used to calculate glass sales predictions. On the other hand, the user can predict glass sales by inputting data in the form of the month to predict and the sales volume of the previous two months. These data will be processed to produce a sales prediction data in the form of the number of sales for the following month and the total inventory that must be ordered. Both admin and user can see the results input by the user.

Results and Discussion

A. Data Selection

Data Selection is a process of minimizing the amount of data for the mining process while still representing the original data [17]. The data used in this research are sales data of glass sizes 1×2 meter and 1.2×1.5 meter in the last 2 years. The data can be seen in the following **Table 1**.

Table 1. Sales Data

Number	Period	Sales Amount	
		Cut Size* 1 × 2 *meter	***Cut Size* 1.2 × 1.5 *meter***
1	January 2020	5	8
2	February 2020	4	5

Number	Period	Sales Amount	
		Cut Size 1 × 2 *meter*	*Cut Size* 1.2 × 1.5 *meter*
3	March 2020	2	8
4	April 2020	5	9
5	May 2020	6	7
6	June 2020	9	10
7	July 2020	11	6
8	August 2020	9	11
9	September 2020	9	20
10	October 2020	7	10
11	November 2020	9	9
12	December 2020	7	17
13	January 2021	5	15
14	February 2021	7	10
15	March 2021	15	14
16	April 2021	7	4
17	May 2021	7	10
18	June 2021	5	10
19	July 2021	6	12
20	August 2021	5	17
21	September 2021	6	11
22	October 2021	9	13
23	November 2021	4	10
24	December 2021	8	6

B. Data Cleanup

Data Cleaning is a process to overcome missing values, noise, and inconsistent data [18]. After the data selection stage, the next stage is data cleaning [19]. This stage eliminates duplication of data, noise, and missing values in the data. Noise is data that cannot be used in the data mining process while the missing value is a condition where data is missing or incomplete. At this stage, the glass sales data collected has no missing value nor noise so it can be processed in the data mining process.

C. Preprocessing Data

At this stage, glass sales data that have been collected and passed the data cleaning stage will be grouped by size and year of sales volume to make the calculation of the glass sales predictions easier. The glass sales that has been grouped is shown in **Table 2** and **Table 3** as follows.

Table 2. Glass Sales Data of 1 × 2 meter in Cut Size

Number	Month	Sales Amount	
		2020	*2021*
1	January	5	5
2	February	4	7
3	March	2	15
4	April	5	7
5	May	6	7
6	June	9	5
7	July	11	6
8	August	9	5
9	September	9	6
10	October	7	9
11	November	9	4
12	December	7	8

Table 3. Glass Sales Data of 1.2 × 1.5 meter in Cut Size

Number	Month	Sales Amount	
		2020	*2021*
1	January	8	15
2	February	5	10
3	March	8	14
4	April	9	4
5	May	7	10
6	June	10	10

Number	Month	Sales Amount	
		2020	*2021*
7	July	6	12
8	August	11	17
9	September	20	11
10	October	10	13
11	November	9	10
12	December	17	6

D. Data Transformation

Data transformation is a process to change the shape and format of the data. This makes it easier for users in the mining process as well as to understand the results obtained [20]. This process divides the training data and data testing into the data that have been obtained from the previous stages. The training data used can be seen in the following **Table 4**.

Table 4. Sales Training Data Glass of 1 × 2 meter in cut size

Number	x_1	x_2	Target
1	5	4	2
2	4	2	5
3	2	5	6
4	5	6	9
5	6	9	11
6	9	11	9
7	11	9	9
8	9	9	7
9	9	7	9
10	7	9	7
11	9	7	5
12	7	5	7
13	5	7	15
14	7	15	7
15	15	7	7
16	7	7	5
17	7	5	6

Table 5. Glass Sales Training Data of 1.2 × 1.5 meter in cut size

Number	x_1	x_2	Target
1	8	5	8
2	5	8	9
3	8	9	7
4	9	7	10
5	7	10	6
6	10	6	11
7	6	11	20
8	11	20	10
9	20	10	9
10	10	9	17
11	9	17	15
12	17	15	10
13	15	10	14
14	10	14	4
15	14	4	10
16	4	10	10
17	10	10	12

In **Table 4**, the training data used are taken from the sales data of 1 × 2 meter glass. x_1 and x_2 as input weights are to be used in the search for the activation function while the target data are used in the search for the sum of the weighted activation functions. Data x_1 is taken from sales of 1 × 2 meter glass from January 2020 to May 2021, data x2 is taken from sales data of 1 × 2 meter glass from February 2020 to June 2021 while target data is taken from sales data of 1 × 2 meter glass from March 2020 to July 2021. In table 5, the training data used are taken from the glass sales data 1.2 × 1.5 meter. Data x_1 is taken from sales of 1.2 × 1.5 meter glass from January 2020 to May 2021, data x2 are taken from sales data of 1.2 × 1.5 meter glass from February 2020 to June 2021. Meanwhile, target data are taken from sales data of 1.2 × 1.5 m glass from March 2020 to July 2021.

The testing data used can be seen in **Table 6** below.

Table 6. Glass Testing Data of 1 × 2 meter in cut size

Number	x_1	x_2	Target
1	5	6	5
2	6	5	6
3	5	6	9
4	6	9	4
5	9	4	8

Table 7. Glass Testing Data of 1.2 × 1.5 meter in cut size

Number	x_1	x_2	Target
1	10	12	17
2	12	17	11
3	17	11	13
4	11	13	10
5	13	10	6

E. Calculation of General Regression Neural Network

After going through several stages of data mining, the next step is to determine the spread. The GRNN has a parameter which is the spread parameter to be used for data smoothing. Variations use the range from 0.1 to 0.5. Several experiments on spreads can be seen in the following Table 8.

Table 8. Glass Sales Data Training Spread of 1 × 2m in cut size

Number	Spread	MSE	
		Training	*Testing*
1	0.1	8.730735713	9.175232669
2	0.2	8.358625498	7.984520635
3	0.3	8.590131846	6.983277536
4	0.4	8.678886114	6.317327665
5	0.5	8.714671371	5.922002425

Based on Table 8, the spread value on the sales data of glass 1 × 2meter which produces the lowest MSE during network training is 0.2 with an MSE value of 8.358625498 and 0.5 with an MSE value of 5.922002425 on training data and test data respectively. Therefore, a spread value of 0.2 will be used to predict sales of 1 × 2 m glass because the resulting MSE is smaller.

Table 9. Glass Sales Data Training Spread of 1.2 x 1.5 m in cut size

No	Spread	MSE	
		Training	*Testing*
1	0.02	38.46907092	40.85068007
2	0.03	38.403162	40.85068007
3	0.04	38.14378009	40.8506796
4	0.05	37.54565969	40.85059941
5	0.06	36.6011004	40.84937131

Based on Table 9, the spread value of the sales data of glass 1.2 × 1.5 meter which produces the lowest MSE during network training is 0.06 with an MSE value of 36.6011004 and 0.06 with an MSE value of 40.84937131 on training data and test data respectively. Therefore, a spread value of 0.06 will be used to predict sales of 1.2 × 1.5 meter glass because it produces the smaller MSE. After determining the spread value for smoothing data, the next step is the prediction stage. In this stage, the data used is the number of sales of 1 × 2 meter and 1.2 × 1.5 meter glass in August and September 2021. The prediction of the number of sales of both sizes will be carried out separately. Prediction input from 1 × 2 meter glass and 1.2 × 1.5 meter glass used is Table 10 as follows:

Table 10. Input Data for Prediction

Period	Glass Sales Amount		Normalization	
	1 × 2 meter	*1.2 × 1.5 meter*	*1 × 2 meter*	*1.2 × 1.5 meter*
August 2021	5	17	0.2308	0.8125
September 2021	6	11	0.3077	0.4375

The first prediction is made for sales of 1×2 m glass. The initial step to predict glass sales is to determine the data distance between the input data and the weights.

$D_1 = \sqrt{(0.2308 - 0.2308)^2 - (0.3077 - 0.1538)^2} = 0.1539$

$D_2 = \sqrt{(0.2308 - 0.1538)^2 - (0.3077 - 0.0000)^2} = 0.3171$

$D_3 = \sqrt{(0.2308 - 0.0000)^2 - (0.3077 - 0.2308)^2} = 0.2432$

$D_4 = \sqrt{(0.2308 - 0.2308)^2 - (0.3077 - 0.3077)^2} = 0$

$D_5 = \sqrt{(0.2308 - 0.3077)^2 - (0.3077 - 0.5385)^2} = 0.2432$

$D_6 = \sqrt{(0.2308 - 0.5385)^2 - (0.3077 - 0.6923)^2} = 0.4925$

$D_7 = \sqrt{(0.2308 - 0.6923)^2 - (0.3077 - 0.5385)^2} = 0.5159$

$D_8 = \sqrt{(0.2308 - 0.5385)^2 - (0.3077 - 0.5385)^2} = 0.3171$

$D_9 = \sqrt{(0.2308 - 0.3846)^2 - (0.3077 - 0.5385)^2} = 0.2773$

$D_{10} = \sqrt{(0.2308 - 0.5385)^2 - (0.3077 - 0.3846)^2} = 0.3171$

$D_{11} = \sqrt{(0.2308 - 0.3846)^2 - (0.3077 - 0.2308)^2} = 0.1719$

$D_{12} = \sqrt{(0.2308 - 0.2308)^2 - (0.3077 - 0.3846)^2} = 0.0769$

$D_{13} = \sqrt{(0.2308 - 0.3846)^2 - (0.3077 - 1.0000)^2} = 0.7091$

$D_{14} = \sqrt{(0.2308 - 1.0000)^2 - (0.3077 - 0.3846)^2} = 0.773$

$D_{15} = \sqrt{(0.2308 - 0.3846)^2 - (0.3077 - 0.3846)^2} = 0.1719$

After finding the data distance between the input and the weights, the next step is to define the activation function. The predetermined spread value is 0.2, then the value of the bias weight is 4.16.

$\theta_1 = e^{-(4.16 \times 0.1539)^2} = 0.663725399$

$\theta_2 = e^{-(4.16 \times 0.3171)^2} = 0.175499377$

$\theta_3 = e^{-(4.16 \times 0.2432)^2} = 0.59313084$

$\theta_4 = e^{-(4.16 \times 0.0000)^2} = 1$

$\theta_5 = e^{-(4.16 \times 0.2432)^2} = 0.359313084$

$\theta_6 = e^{-(4.16 \times 0.4925)^2} = 0.015031888$

$\theta_7 = e^{-(4.16 \times 0.5159)^2} = 0.009992364$

$\theta_8 = e^{-(4.16 \times 0.3846)^2} = 0.077320574$

$\theta_9 = e^{-(4.16 \times 0.3171)^2} = 0.175499377$

$\theta_{10} = e^{-(4.16 \times 0.2773)^2} = 0.264287136$

$\theta_{11} = e^{-(4.16 \times 0.3171)^2} = 0.175499377$

$\theta_{12} = e^{-(4.16 \times 0.1719)^2} = 0.599671226$

$\theta_{13} = e^{-(4.16 \times 0.0769)^2} = 0.902723865$

$\theta_{14} = e^{-(4.16 \times 0.7091)^2} = 0.000166311$

$\theta_{15} = e^{-(4.16 \times 0.7730)^2} = 3.2295 \times 10^{-5}$

$\theta_{16} = e^{-(4.16 \times 0.1719)^2} = 0.599671226$

$\theta_{17} = e^{-(4.16 \times 0.17019)^2} = 0.599671226$

After defining the activation function, the next step is to calculate the output in the summation layer, namely the sum of the activation functions (Ss) and the sum of the weighted activation functions (Sw).

$$Ss = 0.663725399 + 0.175499377 + 0.359313084 + 1 + 0.359313084 + 0.015031888 + 0.009992364 + 0.077320574 + 0.175499377 + 0.264287136 + 0.175499377 + 0.599671226 + 0.902723865 + 0.000166311 + 3.2295 + 10^{-5} + 0.599671226 + 0.599671226$$

$Ss = 5.977417809$

The sum of the weighted activation functions is calculated as follows:

$$Sw = (0.663725399 \times 0) + (0.175499377 \times 0.2308) + (0.359313084 \times 0.3077) + (1 \times 0.5358) + (0.359313084 \times 0.6923) + (0.015031888 \times 0.5383) + (0.009992364 \times 0.5385) + (0.077320574 \times 0.3846) + (0.175499377 \times 0.5385) + (0.264287136 \times 0.3846) + (0.175499377 \times 0.2308) + (0.599671226 \times 0.3846) + (0.902723865 \times 1) + (0.000166311 \times 0.3846) + (3.2295 \times 10^5 \times 0.3846) + (0.599671226 \times 0.2308) + (0.599671226 \times 0.3077)$$

$Sw = 2.674544654$

The next step is to calculate the output layer value by dividing the weighted activation function (Sw) to the sum of the activation functions (Ss).

$$yt = \frac{Sw}{Ss} = \frac{2.674544654}{5.977417809} = 0.447441477$$

The prediction result is the result of normalization of the predictions obtained. Therefore, denormalization is then carried out on the output value in order to obtain the actual value. The predicted result for sales of 1×2 m glass in October 2021 after denormalization is 7.816739202, rounded up to 8.

Furthermore, the next step is to predict sales of glass 1.2×1.5 m. The initial step for predicting sales of glass 1.2×1.5 m is to define the data distance between the input data and the weights.

$D_1 = \sqrt{(0.8125 - 0.2500)^2 - (0.4357 - 0.0625)^2} = 0.6760$
$D_2 = \sqrt{(0.8125 - 0.0625)^2 - (0.4357 - 0.2500)^2} = 0.7731$
$D_3 = \sqrt{(0.8125 - 0.2500)^2 - (0.4357 - 0.3125)^2} = 0.5762$
$D_4 = \sqrt{(0.8125 - 0.3125)^2 - (0.4357 - 0.1875)^2} = 0.5590$
$D_5 = \sqrt{(0.8125 - 0.1875)^2 - (0.4357 - 0.3750)^2} = 0.6281$
$D_6 = \sqrt{(0.8125 - 0.3750)^2 - (0.4357 - 0.1250)^2} = 0.5376$
$D_7 = \sqrt{(0.8125 - 0.1250)^2 - (0.4357 - 0.4375)^2} = 0.6875$
$D_8 = \sqrt{(0.8125 - 0.4375)^2 - (0.4357 - 1.0000)^2} = 0.6760$
$D_9 = \sqrt{(0.8125 - 1.0000)^2 - (0.4357 - 0.3750)^2} = 0.1976$
$D_{10} = \sqrt{(0.8125 - 0.3750)^2 - (0.4357 - 0.3125)^2} = 0.4550$
$D_{11} = \sqrt{(0.8125 - 0.3125)^2 - (0.4357 - 0.8125)^2} = 0.6250$
$D_{12} = \sqrt{(0.8125 - 0.8125)^2 - (0.4357 - 0.6875)^2} = 0.2500$
$D_{13} = \sqrt{(0.8125 - 0.6875)^2 - (0.4357 - 0.3750)^2} = 0.1389$
$D_{14} = \sqrt{(0.8125 - 0.3750)^2 - (0.4357 - 0.6250)^2} = 0.4760$
$D_{15} = \sqrt{(0.8125 - 0.6250)^2 - (0.4357 - 0.0000)^2} = 0.4760$
$D_{16} = \sqrt{(0.8125 - 0.0000)^2 - (0.4357 - 0.3750)^2} = 0.8149$
$D_{17} = \sqrt{(0.8125 - 0.3750)^2 - (0.4357 - 0.3750)^2} = 0.4419$

After defining the data distance between the input and the weights, the next step is to determine the activation function. The spread value that has been determined for the prediction of 1.2×1.5 m glass is 0.06, while the value of the bias weight is 13.88.

$\theta_1 = e^{-(13.88 \times 0.6760)^2} = 5.8263 \times 10^{-39}$
$\theta_2 = e^{-(13.88 \times 0.7731)^2} = 9.83023 \times 10^{-51}$
$\theta_3 = e^{-(13.88 \times 0.5762)^2} = 1.66509 \times 10^{-28}$
$\theta_4 = e^{-(13.88 \times 0.5590)^2} = 7.16321 \times 10^{-27}$
$\theta_5 = e^{-(13.88 \times 0.6281)^2} = 9.8147 \times 10^{-34}$
$\theta_6 = e^{-(13.88 \times 0.5376)^2} = 6.5854 \times 10^{-25}$
$\theta_7 = e^{-(13.88 \times 0.6875)^2} = 2.84083 \times 10^{-40}$
$\theta_8 = e^{-(13.88 \times 0.6760)^2} = 5.8263 \times 10^{-39}$
$\theta_9 = e^{-(13.88 \times 0.1976)^2} = 0.000540867$
$\theta_{10} = e^{-(13.88 \times 0.4550)^2} = 4.76956 \times 10^{-18}$
$\theta_{11} = e^{-(13.88 \times 0.6250)^2} = 2.07442 \times 10^{-33}$
$\theta_{12} = e^{-(13.88 \times 0.2500)^2} = 5.89798 \times 10^{-06}$
$\theta_{13} = e^{-(13.88 \times 1398)^2} = 0.02316193$
$\theta_{14} = e^{-(13.88 \times 0.4760)^2} = 1.10324 \times 10^{-19}$
$\theta_{15} = e^{-(13.88 \times 0.4760)^2} = 1.10324 \times 10^{-19}$
$\theta_{16} = e^{-(13.88 \times 0.8149)^2} = 2.74642 \times 10^{-56}$
$\theta_{17} = e^{-(13.88 \times 0.4419)^2} = 4.58707 \times 10^{-17}$

After calculating the activation function, the next step is to calculate the output in the summation layer, namely the sum of the activation functions (Ss) and the sum of the weighted activation functions (Sw).

$$Ss = 5.8263 \times 10^{-39} + 9.83023 \times 10^{-51} + 1.66509 \times 10^{-28} + 7.16321 \times 10^{-27} + 9.8147 \times 10^{-34} + 6.5854 \times 10^{-25} + 2.84083 \times 10^{-40} + 5.8263 \times 10^{-39} + 0.000540867 + 4.76956 \times 10^{-18} + 2.07442 \times 10^{-33} + 5.89798 \times 10^{-06} + 0.02316193 + 1.10324 \times 10^{-19} + 1.10324 \times 10^{-19} + 2.74642 \times 10^{-56} + 4.58707 \times 10^{-17}$$

$Ss = 0.023708695$

The sum of the weighted activation functions is as follows:

$$Sw = (5.8263 \times 10^{-39} \times 0.2500) + (9.83023 \times 10^{-51} \times 0.3125) + (1.66509 \times 10^{-28} \times 0.1875) + (7.16321 \times 10^{-27} \times 0.3750) + (9.8147 \times 10^{-34} \times 0.1250) + (6.5854 \times 10^{-25} \times 0.4375) + (2.84083 \times 10^{-40} \times 1) + (5.8263 \times 10^{-39} \times 0.33750) + (0.000540867 \times 0.3125) + (4.76956 \times 10^{-18} \times 0.8125) + (2.07442 \times 10^{-33} \times 0.6875) + (5.89798 \times 10^{-06} \times 0.3750) + (1.10324 \times 10^{-19} \times 0.6250) + (1.10324 \times 10^{-19} \times 0) + (2.74642 \times 10^{56} \times 0.3750) + (4.58707 \times 10^{17})$$

$$Sw = 0.014647439$$

The next step is to determine the output layer value by dividing the weighted activation function (Sw) to the sum of the activation functions (Ss).

$$yt = \frac{Sw}{Ss} = \frac{0.0146474394}{0.023708695} = 0.61780874$$

The prediction value is the result of the normalization of the predictions obtained. Therefore, the output value obtained is denormalized to obtain the actual value. The sales prediction result for glass size of 1.2 × 1.5 m in October 2021 after being denormalized is 10.79192288, rounded up to 11.

The validation of system results with actual data are in **Table 11**.

Table 11. The validation of system results

Number	Period	Actual data			Data from the system			Error
		Glass Sales Cut Size 1 × 2 meter	*Glass Sales Cut Size 1.2 × 1.5 meter*	*Amount of stockpile*	*Glass Sales Cut Size 1 × 2 meter*	*Glass Sales Cut Size 1.2 × 1.5 meter*	*Amount of stockpile*	
1	June 2021	5	10	12	5	10	7	1,66%
2	July 2021	6	12	11	15	12	11	3%
3	August 2021	5	17	9	9	8	7	2,33%
4	September	6	11	6	6	15	9	2,33%
5	October 2021	9	13	7	9	14	10	1,33%
6	November	4	10	3	11	4	6	1,33%
7	December	8	6	8	6	14	9	2,33%
8	January 2021	6	4	7	7	4	4	0,66%
Error Average								1,875%
Accuracy								98,125%

Based on **Table 11**. the average e to be predicted and error obtained is 1.875%. Based on the validation result of eight actual data compared to output generated by system, it can be concluded that an accuracy score is 98.125%.

Conclusion

The prediction process went through several stages which are data selection, cleaning, preprocessing, and data transformation. The data indicators used were the time or month of sale which was January 2020 to December 2021, and the two years number of sales for glass sizes of 1 × 2 meter and 1.2 × 1.5 meter divided as training data and testing data.

The GRNN calculation used a spread parameter for smoothing data. In the training data, the spread value of the sales data of the 1 × 2 meter glass producing the smallest MSE of 8.358625498 was 0.2. Meanwhile, the sales of 1.2 × 1.5 -meter glass produce the smallest MSE of 36.6011004 at a spread of 0.06.

Glass sales data and inventory predictions may help store to minimize out of stock position. This information could be used to by store to prepare the inventory at the maximum level for the purpose of maximizing profit from glass sales.

Based on the test and analysis of the results, it can be concluded that the GRNN method can be employed in predicting sales and inventory quantities to optimize profits at FF jaya glass stores with an accuracy of 98.125%.

For further research, it is suggested to increase the number of datasets so that the network can recognize patterns better and produce better accuracy. Research can be carried out by adding other related indicators such as consumer needs, and purchasing power. Prediction can be calculated using other methods such as K-Means, cascade forward backpropagation neural networks, feed forward backpropagation neural network or a combination of GRNN with these methods.

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