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Agricultural Commodity Sales Recommendation System For Farmers Based on Geographic Information Systems and Price Forecasting Using Probabilistic Neural Network Algorithm

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Abstract. Since the implementation of social distancing and physical distancing due to the outbreak/pandemic of the Coronavirus (Covid-19), direct sales in the market have experienced a shortage of buyers. Farmers also share this in Indonesia, where the price game offered by collectors does not match the market price. The second problem is the mismatch of prices in each market, forcing farmers to check locations to sell their agricultural products. This problem is also experienced by the O'reng Rembangan Community Information Group (KIM), one of the community groups engaged in production to cultivate vegetable and fruit gardens in Kemuning Lor Village, Arjasa District, Jember Regency. The purpose of this research is the creation of an information system that can help farmers, especially KIM O'reng Rembangan, to obtain current market price information, receive market recommendations for agricultural products, get the nearest market from the location of farmers, and can be used by sellers to make purchases, optimize stock merchandise. This research also focuses on the prediction of agricultural commodity prices. The method used is the Probabilistic Neural Network (PNN) method to estimate the price of agricultural commodities. The resulting system in this study consists of 2 parts. The first part is the input device, which officers can use to enter the price of each agricultural commodity directly from each market. The second part is a Geographic information system used to display the forecasting results of agricultural commodity prices in each market. The forecast of agricultural commodity prices in this study has an accuracy of 98.3%.

1. Introduction

Agriculture is one of the important sectors in the national economy. National development in the 21st century will still be broadly based on agriculture, with services and business activities based on agribusiness being leading in national development. For the reconstruction of the post-covid-19 Indonesian economy towards SDG'S 2030 in the perspective of supporting business and business development, all sectors must be developed optimally. However, there are several problems faced by farmers that affect the welfare of farmers in Indonesia. The first problem faced by farmers in Indonesia is that the price game offered by collectors does not match the market price. The second problem is the incompatibility of prices in each market, making farmers have to check the location to sell their agricultural products. This problem was also experienced by the O'reng Rembangan Community Information Group (KIM). KIM O'reng Rembangan is one of the community groups engaged in production to process vegetable and fruit gardens in Kemuning Lor Village, Arjasa District, Jember Regency [1].

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2. Review of Related Literature

2.1. Probabilistic Neural Network

Probabilistic Neural Network (PNN) or Probabilistic Neural Network was first developed by Donald F. Specht in 1988. PNN is an artificial neural network method that uses supervised training. PNN is included in the Feedforward structure. PNN is derived from a Bayesian network and statistical algorithm named Kernel Fisher Discriminant Analysis [2]. Bayes's rule can be used to classify a number of categories. Decision-making is based on calculating the distance between the probability density function of the feature vector. PNN has four layers, namely input layer, pattern layer, summation layer, and output layer [3], as shown in Figure 1 as follows.

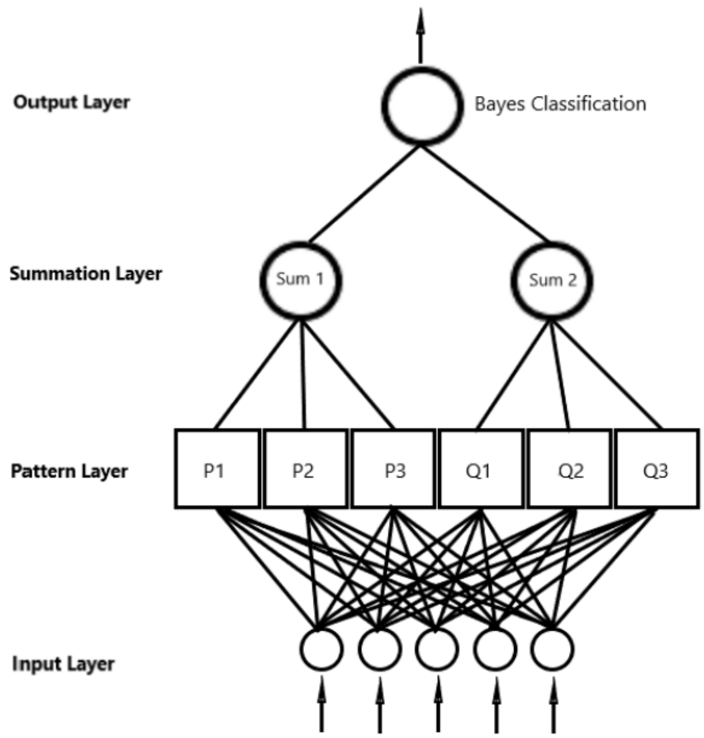

Figure 1. PNN Architecture

2.2. State of the Art

The first study using the K-NN and Particle Swarm methods [4], with an accuracy result of 98% but cannot be applied to other commodities. Meanwhile, the second study using the Arima ArchGarch method and the Single Moving Average [5] has not been implemented for other regional datasets. So it is necessary to refine the algorithm using machine learning that distinguishes the training and real datasets with the Probabilistic Neural Network (PNN) method, which is the State of The Art of this study [6][7].

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3. Research Method

The methods applied in this research are shown in Figure 2 as follows

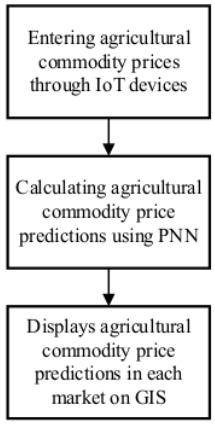

Figure 2. Research Method

3.1. Entering agricultural commodity prices through IoT devices

At this stage, an IoT is created that officers can use to enter the price of each agricultural commodity directly from each market.

3.2. Calculating agricultural commodity price predictions using PNN

The data obtained in the first dance stage is used as training data to predict prices using PNN. The data used in this predicting process is data on prices of agricultural commodities in each market since 2012. The data training is obtained from the average price of agricultural commodities every year. Every newly entered data will become training data for the prediction process. in the next period.

3.3. Displays agricultural commodity price predictions in each market on GIS

The prediction results of agricultural commodity prices in each market will be presented in a Geographic Information System.

4. Result and Discussion

4.1. IoT Devices

The device used to make this IoT device is a Raspberry Pi 3, equipped with GPS and an LCD screen. In this device, an application is built using Python, which records the price of each agricultural commodity in each market and sends the data to a web server. This device is as shown in Figure 2.

Figure 3. Raspberry Pi 3

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4.2. Calculating agricultural commodity price predictions

Calculating the price predictions using PNN is carried out in the following steps [8]:

4.2.1. Input Layer

Layer input contains training data which is an input-target vector pair [9]. Table 1 shows 16 pairs of input-target data vectors to be trained.

Table 1. Input-Target Data Vector Pair to be Trained

No.	Climate/Season	Holiday	Origin of the Products	Decision
	(X_1)	(X_2)	(X3)	Class
1	Rainy season	Eid Al-Fitr	Local products	Price prediction
2	Dry season	Chinese New Year	Products from out of town	
3		New Year		
4		Normal		

Since the target consists of 3 classes, the input vector will be worth: (1, 0, 0) for class 1; (0, 1, 0) for class 2; and (0, 0, 1) for class 3.

4.2.2. Pattern Layer

The probabilistic network built has 16 neurons in the hidden layer. The network is depicted in Table 2 below.

Table 2. Probabilistic Network

Climate/Season	Holiday	Origin of the Products	Decision
Rainy season	Eid Al-Fitr	Local products	Price goes up
Rainy season	Chinese New Year	Local products	Price goes up
Rainy season	New Year	Local products	Price goes up
Rainy season	Normal	Local products	Price stays
Rainy season	Eid Al-Fitr	Products from out of town	Price goes up
Rainy season	Chinese New Year	Products from out of town	Price goes up
Rainy season	New Year	Products from out of town	Price stays
Rainy season	Normal	Products from out of town	Price goes down
Dry season	Eid Al-Fitr	Local products	Price stays
Dry season	Chinese New Year	Local products	Price stays
Dry season	New Year	Local products	Price stays
Dry season	Normal	Local products	Price stays
Dry season	Eid Al-Fitr	Products from out of town	Price stays
Dry season	Chinese New Year	Products from out of town	Price goes down
Dry season	New Year	Products from out of town	Price goes down
Dry season	Normal	Products from out of town	Decreased price

4.2.3. Summation Layer

The Summation Layer receives input from the pattern layer nodes associated with the existing class [10]. The equation used in this layer is as shown below.

$$\sum_{i=1}^{N} \exp\left[\frac{(x-x_{ij})^T\,(x-x_0)}{2\sigma^2}\right] \quad (1)$$

This study uses training data on agricultural commodity prices starting from 2012 to 2021. In this data, the average value is sought from each year. The calculation results can be seen in Table 3 as follows.

Table 3. Training Data

Year	Amount per Year	Amount of Data	Result
2012	5.448.000	366	14.885
2013	10.847.500	365	29.719
2014	10.929.000	365	29.942
2015	10.683.000	365	29.268
2016	10.132.123	366	27.683
2017	16.692.533	365	45.732
2018	10.683.205	365	29.269
2019	11.257.551	365	30.842
2020	9.444.593	366	25.804
2021	10.654.611	176	60.537
Sum of Results			323.681

The value of h_{jk} in the Normal Pattern can be calculated as follows

$$h_{jk} = \frac{323.681}{10} = 32.368$$

4.2.4. Output Layer

The output layer produces a binary output (0,1) and only has a single weight variable Ck. Ck is calculated using the equation as follows.

$$C_k = \frac{h_{jk} l_{jk}}{h_{ik} l_{ik}} \cdot \frac{m_{ik}}{m_{jk}} \quad (2)$$

notes:
m_{ik} = Number of pattern training from Θ_{ik} class
m_{jk} = Number of pattern training from Θ_{jk} class

Suppose there is a condition where at that time it is the rainy season, Eid al-Fitr, and the product comes from local production, then:

The average value of the last year's price minus the first year's price is

$$Average = \frac{(60.537 - 14.885)}{10} = 4.565$$

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According to the pattern layer for this condition, these conditions resulting in the price increase. The h_{jk} value is taken from the enormous value from the previous ten years and then added to the average value.

$$60.537 + 4.565 = 65.102$$

Then the prediction of the commodity price is Rp. 65.102.

4.3. Prediction Result Accuracy

The evaluation carried out on this system uses three agricultural commodities in the last ten years, as described in Table 3. These data are used as a training dataset to predict the test data. Furthermore, the test data will be used to predict agricultural commodity prices for the next 60 days.

Table 4. Testing Data

	PNN Prediction								
Day	**System price prediction for commodity 1**	**Actual price of commodity 1**	**The truth of the results**	**System price prediction for commodity 2**	**Actual price of commodity 2**	**The truth of the results**	**System price prediction for commodity 3**	**Actual price of commodity 3**	**The truth of the results**
1	Up	Up	True	Up	Up	True	Up	Up	True
2	Up	Up	True	Up	Up	True	Up	Up	True
3	Up	Up	True	Up	Up	True	Stays	Stays	True
4	Up	Up	True	Stays	Stays	True	Stays	Stays	True
5	Stays	Stays	True	Stays	Stays	True	Stays	Stays	True
6	Stays	Stays	True	Stays	Stays	True	Stays	Stays	True
7	Stays	Stays	True	Stays	Stays	True	Stays	Stays	True
8	Stays	Stays	True	Stays	Stays	True	Down	Down	True
9	Stays	Stays	True	Down	Down	True	Down	Down	True
10	Down	Down	True	Down	Down	True	Down	Down	True
11	Down	Down	True	Down	Down	True	Stays	Stays	True
12	Down	Down	True	Stays	Stays	True	Stays	Stays	True
13	Stays	Up	**False**	Stays	Stays	True	Down	Down	True
14	Stays	Stays	True	Down	Down	True	Down	Down	True
15	Down	Down	True	Down	Down	True	Down	Down	True
16	Down	Down	True	Down	Down	True	Up	Up	True
17	Down	Down	True	Up	Up	True	Up	Up	True
18	Up	Up	True	Up	Up	True	Up	Up	True
19	Up	Up	True	Up	Up	True	Up	Up	True
20	Up	Up	True	Up	Up	True	Up	Up	True
21	Up	Up	True	Up	Up	True	Up	Up	True
22	Up	Up	True	Up	Up	True	Up	Up	True
23	Up	Up	True	Up	Up	True	Up	Up	True
24	Up	Up	True	Up	Up	True	Stays	Stays	True
25	Up	Up	True	Stays	Stays	True	Stays	Stays	True
26	Stays	Stays	True	Stays	Stays	True	Stays	Stays	True
					…				
58	Stays	Stays	True	Down	Down	True	Down	Down	True
59	Down	Down	True	**Down**	Up	**False**	Down	Up	**False**
60	Down	Down	True	Down	Down	True	Stays	Stays	True

Testing the system in predicting prices for 60 days showed three errors occurred on the 13th and 55th days, as seen in Table 4. So the accuracy can be calculated as follows.

$$Accuracy = \frac{Number\ of\ correct\ answers}{Amount\ of\ data}\ x\ 100\%$$

$$= \frac{\mathbf{177}}{\mathbf{180}}\ \boldsymbol{x}\ \mathbf{100\%}$$

$$= \mathbf{98,3\%}$$

4.4. Geographic Information System

The prediction of agricultural commodity prices produced by this system is presented in a Geographic Information System, which displays as shown in Figures 4 to 7. On the Figure 4 shows landing page result for introducing the system that already build.

Figure 4. GIS Homepage View

Figure 5 shows information some market location and commodities that already calculated for prediction analytics on this research. Recently market location were in Jember regency, there are three market's data that have been collected as training data.

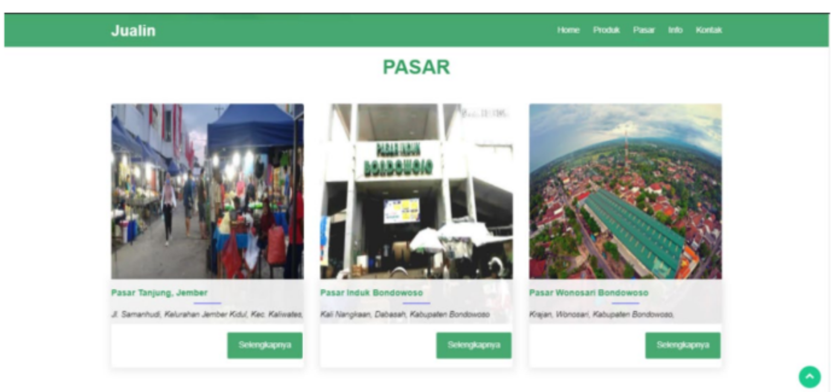

Figure 5. Market Selection Menu

Figure 6 show recommendation result from PNN algorithm in three spices commodities, on the recent research prediction information show location of the market and prediction prices (up/down/fixed). After we know which one market that have best price, the user can see location of market through Google Maps API in Figure 7.

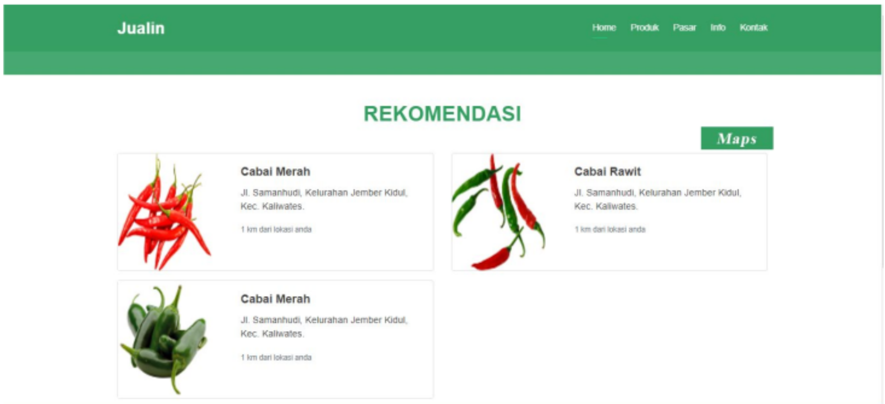

Figure 6. Product Recommendations from The Selected Market

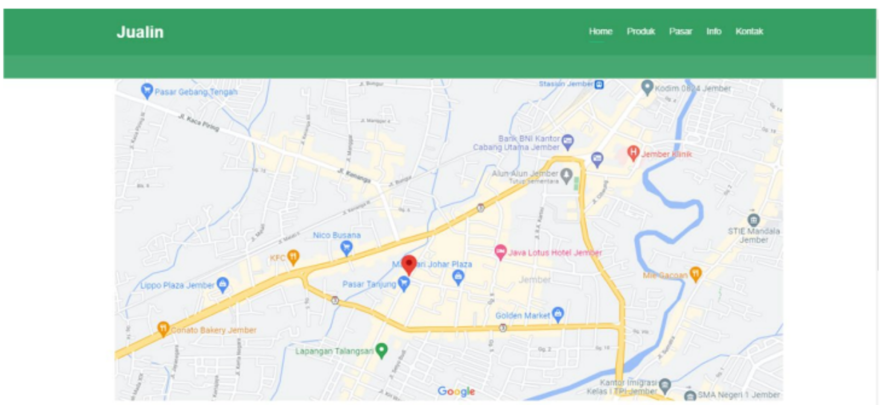

Figure 7. Display Market Location via Maps

5. Conclusion

From this research, it can be concluded that a system to obtain price information, predict prices of agricultural commodities, and get the nearest market from the location of farmers has been successfully built. The prediction of agricultural commodity prices in this study has an accuracy of 98.3%.

On the following research, prediction model can also be applied on several agricultural commodities. Big Data implementation are needed to build Datawarehouse that can store agricultural price information in real time. Furthermore, other Artificial Intelligence (AI) prediction also can be testing on various agricultural commodities because of various price's characteristic based on some factors.

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