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Optimum Milling Parameters of Sugarcane Juice Production Using Artificial Neural Networks (ANN)

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Abstract. High population growth has an impact on increasing the need for sugar cane from year to year. Cintamanis as a sugarcane producer company continues to increase production by reaching the highest production target. In achieving the production target, Cintamanis has a sugarcane milling system consisting of 5 grinding machines that process sequentially. The five machines have three rollers of rollers, the top rollers, the front rollers, and the rear rollers that have a certain distance by the number of cane crops to be processed. The purpose of this research is to optimum milling parameters of sugarcane juice using artificial neural networks. The prediction of this sugarcane milling process uses the input variables of each roll that is found on the milling machine. The approximate procedure begins by calculating each distance between rollers. Then count the amount of sugarcane juice produced. Next, select the input variables that provide a significant correlation to the output variables. Then proceed with designing the optimum network structure and choose the learning rate and momentum. The validation process is performed on the optimum network structure to determine the accuracy level of the sugarcane milling process. The selected backpropagation neural network model is a model with eight inputs, 1 hidden layer (with 8 neurons), and 1 output using binary sigmoid activation in training and linear activation function at the output. Based on testing the maximum number of iterations obtained the lowest MAPE value of 17.85% with the number of iterations 800. Moreover, in the test of learning rate obtained the lowest MAPE value of 17.38% with the value of learning rate 0.4. If the maximum iteration value of 800 and the value of learning rate 0.4 it will result in MAPE value of 16.98%.

1. Introduction

The sugar industry in Indonesia is generally still semi-modern and uses a tandem system. It can be seen in the milling system from the sugarcane plant to the end of the milling process to produce liquid sugar. Generally, sugarcane milling system in Indonesia, which operates by the government, is the Dutch heritage. Population growth continues to increase, has caused the need for sugarcane in Indonesia to be high. Especially in South Sumatra, a sugarcane company, Cintamanis, continues to increase its production to reach the highest target so that the population's need for sugarcane can be met [1] [2].

To achieve the highest production target Cintamanis must have an effective and efficient production line. One of the most significant problems occurred in Cintamanis is the poor set up of



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milling stations. The existing parameter set up of milling stations was based on the worker experience. The result of this set up is low production in sugarcane juice.

To overcome of this problem, the optimum milling parameters are to be observed, in order to increase the production of sugarcane juice. In finding the optimum milling parameters of sugarcane juice production, the ANN model is used. These parameters include the distance between each milling roller. As in previous studies, ANN-based models were developed to predict roll force during plate rolling process [3] and to prediction of parameters in face milling of Al-6061 [4]. Therefore, the scope of this research is developing an ANN model that will be used to predict the distance between the three milling rollers used in producing sugarcane juice based on data from the three roller milling distances of the last two years. The ANN network is feedback with the backpropagation algorithm.

It is important to find the optimum milling process condition of sugarcane juice production. Therefore, in this study, the involved parameters setup of milling machine for the sugarcane juice process will be investigated. In addition, this research is necessary due to the lack of knowledge about the optimum distance of the three roller milling in the production of sugarcane juice in the Cintamanis sugar company. This condition could bring opportunity for research in determining the optimum milling parameters for the production of sugarcane juice.

2. Research methodology

This study was conducted using two essential method. Firstly, the observation of current data was collected in the milling process of the sugarcane plant Cintamanis. Secondly, the collected data were analysed and optimised using the Artificial Neural Networks (ANN). Moreover, the estimated sugarcane production will be validated by utilising the collected actual data through direct on-site observation.

The collected data in the milling process of the sugarcane plant Cintamanis were observed according to the mechanism of the process in the mill station. In the following section, the appropriate mechanism will be elaborated.

2.1. Process Mechanism at Mill Station

The sugarcane juice process begins from cane carrier and cane leveller, which regulate the feed of cane cutter station 1 and 2. In these stations the sugarcane stems were cut to smaller size before feed to semi hammer shredder station.

The output of the semi hammer shredder station will be further processed in mill station 1 as illustrated in **Figure 1**. In the mill station 1, the fine cut sugarcane will be rolled in order to gain the extracted sugarcane juice, which called the primary sugarcane juice (NPP). Moreover, the NPP will be streamed to the container A. The bagasse of the mill station 1, which contained 41 % dryness, will be transported through intermediate carrier 1 to the mill station 2 to be rolled once again. The results of the mill station 2 will also be flowed to the container A. The mixed sugarcane juice in container A is called raw sugarcane juice, it will be pumped to the filter for separating the sugarcane juice from the pulp. Moreover, the filtered raw sugarcane juice is streamed to the purification station and be added lime milk to maintain the pH neutrality.

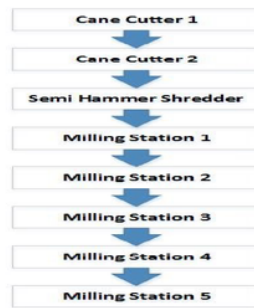


Figure 1. Process Flow of Sugarcane Mill in Cintamanis.

Furthermore, the bagasse of mill station 2 containing 44 % dryness, is rolled in mill station 3 and added imbibition water from the mill station 4. The produced sugarcane juice in mill station 3 flows to container B.

The bagasse of mill station 3, which contains 47% dryness, will be rolled in mill station 4 and added imbibition water from the mill station 5. The sugarcane juice, which is produced in the mill station 4 is streamed to container C. Moreover, it will be flowed to mill station 5 as an imbibition jamb.

The bagasse of mill station 4, which comprises of 50% dryness, will be rolled in mill station 5 and it also will be added 30% imbibition water of the available milling capacity with a temperature of 70-80 degrees Celsius, which is pumped from the evaporation station. The produced sugarcane juice in mill station 5 is flowed to container D and will be flowed as imbibition water for mill station 4. The bagasse of mill station 5, which is 50% dryness, will be carried to the bagasse silo separator by a conveyor belt. It can be used as a boiler fuel, where the steams is used to drive the mill turbine.

The result of milling process by the mill station 1 is the highest produced sugarcane juice. The more backwards of the milling process, the lesser sugarcane juice will be produced. Table 1 presents the data of sugarcane juice production at the Cintamanis milling stations in 2016-2017.

Table 1. The Output of Mill Station

Years	Output (TCD)				
	Mill 1	Mill 2	Mill 3	Mill 4	Mill 5
2016	2773	1553	823	1822	911
2017	2632	1395	697	1759	879

TCD = Ton Cane Per Day

2.2. Collecting of primary parameters

Based on observations obtained at the Cintamanis milling station, it was found that the prime parameters affecting the sugarcane milling process were the distance between the rollers. The existing mill stations are five neurons. Each neuron of the mill stations has three rollers, which consists of a top roller, a front roller and a rear roller, as shown in Figure 2.

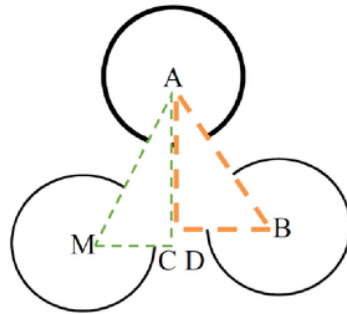


Figure 2. The Triangle Rolls Milling.

where

A: Top roller
 M: Front roller
 B: Rear roller

X₁: Distance A-M
 X₂: Distance A-B
 X₃: Distance A-C
 X₄: Distance A-D

X₅: Distance M-C
 X₆: Distance D-B
 X₇: Distance M-B

The following Table 2 presents the data on the distance between the dimensions of the three rollers, which has been collected from years 2016 to 2017.

Table 2. Distances between Rollers Milling (in mm)

Variables of Roller Milling	2016					2017				
	Mill Station 1	Mill Station 2	Mill Station 3	Mill Station 4	Mill Station 5	Mill Station 1	Mill Station 2	Mill Station 3	Mill Station 4	Mill Station 5
X ₁	988	972	966	965	976	986	967	968	978	971
X ₂	971	958	935	938	960	971	946	940	963	960
X ₃	746	734	729	729	737	744	730	731	738	733
X ₄	755	744	727	729	746	755	735	731	748	746
X ₅	649	637	634	633	640	647	635	635	642	637
X ₆	611	603	589	590	640	611	595	592	606	604
X ₇	1260	1240	1223	1224	1245	1258	1230	1227	1248	1241
Capacity Milling (TCD)	4700	4700	4700	4700	4700	4700	4935	4700	4700	4700

2.3. Data analysis using Artificial Neural Networks (ANN)

The ANN is one of the artificial representations of the human brain that always tries to simulate the process of human brain learning to create a generalisation of the mathematical model of human understanding (cognition) based on the assumption of information processing occurs on a simple element called neurons. In other words, ANN are data processing systems based on biological neural simulation structures by learning experimentally from produced data or using validated models [5].

This model is used to develop predictive models in finding the optimal value [6][7] to model surface machining roughness [8][9], to contribute the creation of a system that can support the company's decision-making process[10]. According to [11], there are three main steps to build the ANN-model:

- The first step is to determine the relationship of the pattern between neurons, which called as the network architecture.
- The second step is to choose a method for determining the weight value of each neuron with learning and training functions.
- The last step is to define the activation function for ensuring the output of a neuron.

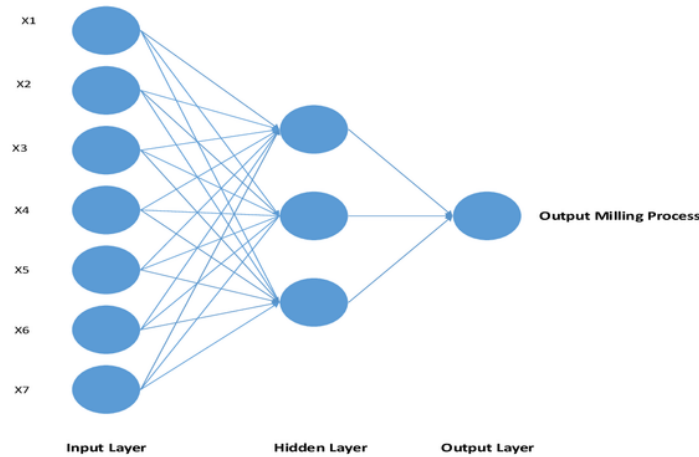


Figure 3. Structure of Artificial Neural Networks

2.4. Formulation of Artificial Neural Networks (ANN)

The output milling model of variable parameters depends on 7 inputs parameter. It is very clear that all 7 input variables are independent of each other.

Figure 1. shows that the ANN structure consists of 3 layers, namely input layer, hidden layer, and output layer. The input layer consists of 7 nodes representing 7 input variables, the hidden layer consists of 3 nodes, and the output layer represents the output of milling process. Lines that connect input nodes to hidden nodes and also connect hidden layers to the output layer represent heavy values. Vertical lines represent bias values. The values assigned to this weight and bias are initialized with a random number between 0 and 1. The final value of the weights and biases calculated during the training process are explained in the next section. The value on the hidden node is calculated by the following mathematical relation:

$$z_j = \frac{1}{1 + e^{-z_{in_j}}} \tag{1}$$

Where,

$$z_{in_j} = v_{0j} + \sum_{i=1}^n x_i v_{ij} \tag{2}$$

In this equation, z_j represents value i th hidden node, z_{in_j} represents the value at i th input neuron, v_{ij} represents the weight value from j th input neuron to i th hidden layer, and v_{0j} represents bias value of j th hidden layer.

For calculating of error value in training processes, Mean Absolute Percentage Error (MAPE) as illustrated in equation 13, is employed, where T_i = actual value in i -data, T'_i = value of forecasting result of i -data, and n = number of data.

$$\text{MAPE} = \frac{1}{n} \sum_{i=1}^n \frac{(T_i - T'_i)}{T_i} \quad (3)$$

Where,

T_i = Actual value in i data

T'_i = Value of forecasting results for i data

n = Number of data

2.5. Training and Validation of Artificial Neural Networks (ANN)

For training of ANN, toolbox of MATLAB software has been used. The result of the test performance will be described in the following section.

2.5.1. Maximum Iteration Testing

The maximum iteration tests were carried out by changing the iteration values to 100, 200, 300, 400, 500, 600, 700, 800, 900, and 1000. The learning rate parameter value used is 0.2. Each iteration was tested 5 times with a different initial random weights. The results of the maximum iteration tests are illustrated in Table 3.

Table 3. Maximum Iterations Testing

Number	Iteration Maximum	MAPE's value at the i -experiment					Average value
		1	2	3	4	5	
1	100	23.65	17.88	18.26	18.54	20.39	19.74
2	200	17.66	18.12	18.84	18.00	18.54	18.23
3	300	18.64	18.02	18.30	18.33	17.65	18.19
4	400	18.00	17.53	18.83	17.93	18.30	18.12
5	500	17.96	17.88	18.63	18.04	18.13	18.13
6	600	18.63	18.74	18.36	18.69	17.24	18.33
7	700	18.33	18.18	17.95	18.03	17.42	17.98
8	800	17.92	17.55	18.27	18.15	17.34	17.85
9	900	18.06	18.12	18.71	18.69	18.56	18.43
10	1000	18.08	17.92	18.18	18.33	18.04	18.11

It is obviously to recognized from Table 3, the average MAPE's values of the test results achieved the minimum value 17.85 when the iteration maximum equal to 800. This phenomenon demonstrated the best value in term of iteration accuracy. On the other side, the average MAPE's value at iteration maximum 100, indicates the maximum value 19.74. It implies that this iteration has the worst performance. In general, it might be concluded that the more iterations carried out, the better the backpropagation training performed.

2.5.2. Learning rate testing

The learning test level was conducted by changing the level to 0.01, 0.02, 0.03, 0.04, 0.05, 0.1, 0.2, 0.3, 0.4, and 0.5. The results of the learning rate tests are figured out in **Table 4**.

Table 4. Learning Rate Testing

Number	Iteration Maximum	MAPE's value at experiment i					Average value
		1	2	3	4	5	
1	0.01	37.96	39.69	36.57	39.51	39.75	38.70
2	0.02	24.77	21.34	31.19	33.06	21.63	26.40
3	0.03	23.67	18.35	18.63	18.08	20.55	19.86
4	0.04	19.19	18.87	18.87	18.31	18.76	18.80
5	0.05	18.36	18.72	18.58	18.31	18.28	18.45
6	0.10	18.74	18.63	18.51	19.21	18.24	18.67
7	0.20	18.22	17.71	18.46	18.16	18.36	18.18
8	0.30	18.54	17.07	17.48	18.17	17.42	17.74
9	0.40	17.54	17.80	17.47	17.36	16.75	17.38
10	0.50	17.88	17.92	17.15	17.58	18.24	17.76

It has been proven obviously from Table 4 that the lowest MAPE's value 17.38 was shown by the iteration maximum 0.4. In contrary, the highest MAPE's value was achieved by iteration maximum 0.01, which resulted on 38.70 of the average value.

Table 5. MAPE on the training and testing process to determine the optimum number of the neurons.

Number of Neuron	MAPE
1	0.3279
2	0.3042
3	0.2977
4	0.4167
5	0.2642
6	0.2664
7	0.2746
8	0.3403
9	0.3045
10	0.2340
11	0.2229
12	0.2944
13	0.2133
14	0.1509
15	0.2373
16	0.2345
17	0.2739
18	0.2364
19	0.3083
20	0.2217

3. Result and Discussion

Finally, the optimum number of neurons can be found using the parameter of the iterated training and testing processes as presented in Table 5 and Figure 4. The optimum number of neurons is 14 neurons, which resulted in 0.1509 of the MAPE’s value. Therefore, the found optimum value can be used in the network architecture.

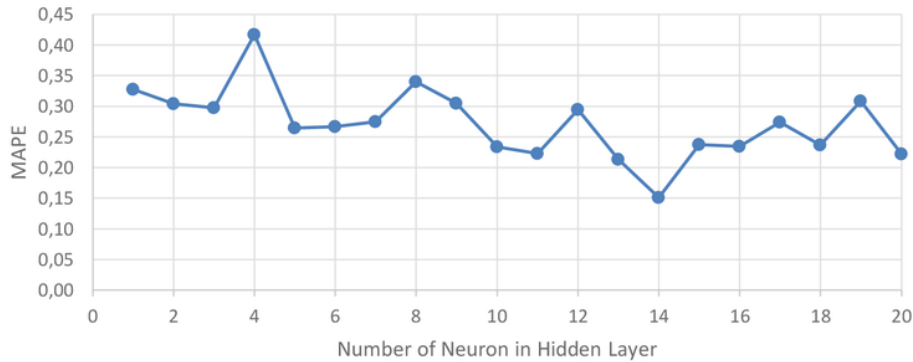


Figure 4. The MAPE values based number of neurons in the hidden layer

Further testing is carried out on the backpropagation algorithm to find the accuracy level of the network architecture. The results of the testing process were presented in **Table 6** and **Figure 5**, in form of error occurred between the targeted output and the network output. Moreover, the best MAPE’s value 0.004105 is revealed at the target 1394.96.

Table 6. Targets, Network Outputs, and Test Errors Values.

No	Targets	Network Outputs	Error
1	2773.00	2827.699	0.019726
2	1552.88	1220.731	0.213892
3	823.03	965.2388	0.172792
4	1821.51	1161.185	0.362516
5	910.76	978.8414	0.074756
6	2632.00	2657.33	0.009624
7	1394.96	1389.234	0.004105
8	697.48	1096.489	0.572072
9	1758.74	1769.529	0.006134
10	879.37	943.7556	0.073218

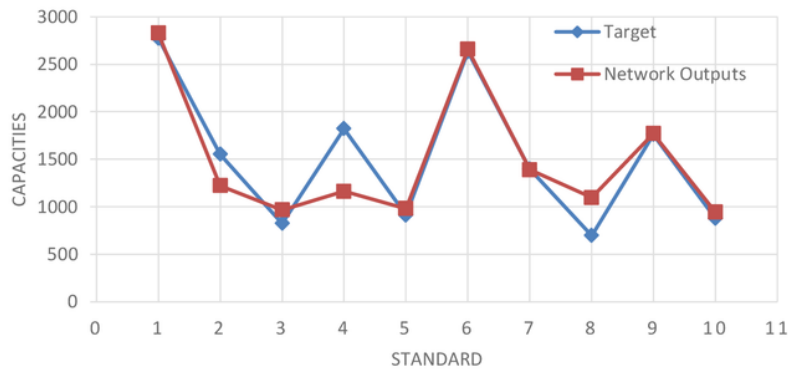


Figure 5. Comparison of the targets with network outputs

4. Conclusion

The artificial neural network architecture of milling process on sugarcane juice production in Cintamanis was successfully performed. The average MAPE's value of the iteration testing is 17.85 at iteration maximum equal to 800, while for the learning rate testing is 17.38 for iteration maximum according to 0.4. The optimum number of neurons is 14, which appropriate to the MAPE's value 0.1509. This number of neurons is recommended for utilised in the network architecture. The best performer was shown, when the network architecture used to find the production target 1394.96. This is recognised from the best MAPE's value 0.004105.

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