Development of a Wireless Sensor Network for Monitoring Husking and Whitening Process in Rice Mills

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Abstract. *The main machines in rice milling process that affect rice quality are a husking machine and a whitening machine. For instance, the distance between two rubber rolls and the temperature of the rubber rolls in the husking machine have an impact on the husking rate. Rice grains tend to be broken, if they are whitened excessively or their temperature is extremely high. Due to the above problems, for the husking machine, we developed a monitoring system to detect the wear and the temperature of the rubber roll. Seven distance sensors, 2.5 cm apart, were used to build the surface profile of the rubber roll, while a non-contact temperature sensor was employed to measure the temperature of the rubber roll. The experimental results showed that the errors of the distance sensors were less than 2%. The temperature sensor had an error of less than 1 degree Celsius. For the whitening machine, the rice samples were taken via a sampling mechanism due to high volume flow rate of rice coming out of the machine. The temperature and the whiteness of the rice samples were measured. The sensor data were transmitted to the office room via a wireless network in order that they were displayed on screen. The alarm was initiated when the temperature or the degree of whiteness was out of the acceptable range. The experimental results showed that the error of the temperature measurement was less than 2 degrees Celsius. The error of the whiteness measurement was less than 2 degrees of whiteness. All data were transmitted via the wireless network, recorded into the database server and displayed on screen correctly.*

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1. Introduction

The rice mill is the place where the paddy is processed through several machines and then it is transformed to milled rice. The primary requirement of rice milling is to achieve high head rice yield (HRY) and desired degree of whiteness [1]. Two main machines in the rice milling process affecting the rice quality are the husking machine and the whitening machine [2]. The husking machine is used to automate the process of removing the outer husks of the rice grains. Improper settings lead to lower husking rate or higher rice breakage. The whitening machine is used to automate the process of removing the bran layer of the brown rice by the action of grains rubbing together. The milling degree can be adjusted in order that the desired whiteness degree of milled rice is obtained.

Over the past several decades, there have been a number of research groups finding the optimal settings or modifying the husking machine in order to improve the husking rate. For instance, Alizadeh and Rahmati [3] studied the effect of the husking rate on the milling quality of rice varieties, namely Binam, Khazar, and Sepidroud. Somnuk et al. [4] studied the effect of rubber wear on the dehusking machine. They found that rubber wear resulted in lower husking rate and higher rice breakage. Baker et al. [5] studied the rubber roll material affecting the husking efficiency. The results showed that the rubber roll with low pressure and high friction rate, tended to lower rice breakage. Somkuan and Aphichat [6] studied the effects of temperature reduction in the husking process in order to increase HRY percentage. The results showed that when temperature in the husking machine was reduced, the rice breakage rate was reduced. Jindamanee and Aphichat [7] studied the effect of the distance between two rubber rolls, the roll speed ratio, the initial rubber hardness, and rubber roll temperature on the husking efficiency. They found that the optimal distance between the rubber rolls was 5 mm apart. The roll speed ratio was 8:2 or 9:1. The temperature of the rubber roll must not exceed 50 degrees Celsius and the initial hardness of the rubber was 86 shores.

Likewise, there have been several researchers working on improvement of the whitening machine. For example, Jangkajit and Khumboa [8] studied the relationship between the whiteness of the grains and the temperature of the grains. They used image processing algorithms to measure the whiteness of the grain, resulting in high cost and complex installation. Yadav and Jindal [9] also used image processing to calculate the average gray level of acquired image, leading to the same drawbacks as previously mentioned.

Traditionally, machine operators check the quality of rice flowing out of the machine occasionally. They adjust the machine if the rice quality is out of acceptable range. The problem is that the action is not taken immediately after the rice quality is out of acceptable range. Therefore, the main aims of the research are (1) to monitor the machine conditions and the rice quality and (2) to alarm the machine operator to resolve the problem in time. We focused on two machines, i.e., the husking machine and the whitening machine. We developed a monitoring system for rubber roll wear and the rubber roll temperature at the husking machine. We also developed a monitoring system for the degree of whiteness and the temperature of rice grains at the whitening machine. All data were sent to the database server via a wireless network. The rice mill owner can use these data to manage and operate the rice mill effectively.

2. Materials and Methods

From the objectives mentioned above, we developed two systems: (1) a monitoring system for the husking machine (see Fig. 1: A) and (2) a monitoring system for the whitening system (see Fig. 1: B). All details are given as follows:

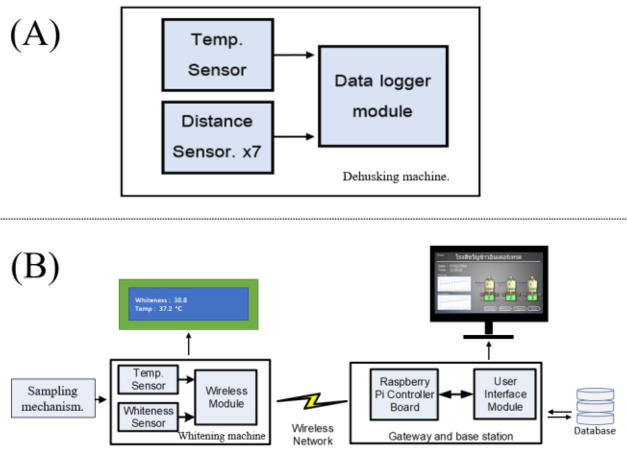

Fig. 1: Block diagram: (A) a monitoring system for the husking machine and (B) a monitoring system for the whitening machine

2.1 The Monitoring System for the Husking Machine

The wear of the rubber roll and the temperature of the rubber roll were monitored in this system. The wear was detected by seven GY-VL53L0X distance sensors installed inside the husking machine as seen in Fig.2. They were 2.5 cm apart and along the rubber roll. The surface profile of the rubber roll was created since the distance becomes longer when wear occurs. The temperature of the rubber roll was measured by the GY-906 sensor module pointing to the middle of the rubber roll surface, shown in Fig. 2. The GY-906 sensor module is a non-contact infrared temperature sensor. If the temperature is too high, the rubber roll is burnt.

The schematic of the system is shown in Fig.3. All data were recorded every 1 minute and the alarm was activated when the temperature was high or the wear was out of the acceptable range.

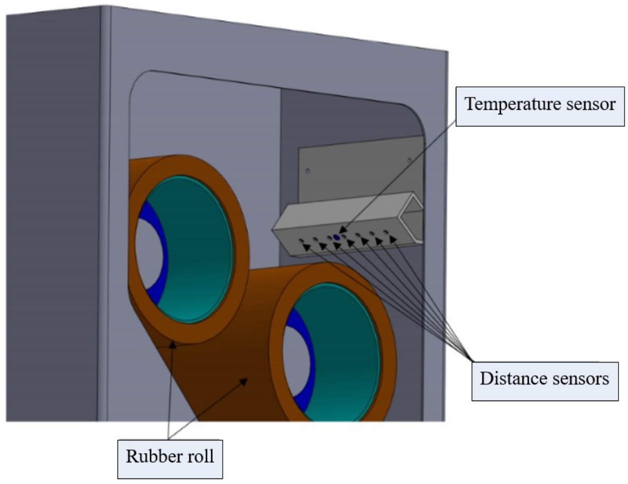

Fig. 2: The installation of the distance sensors and the temperature sensor inside the husking machine

2.2 The Monitoring System for the Whitening Machine

The degree of whiteness and the temperature of the rice grains were measured after the rice grains were released from the whitening machine. The degree of whiteness has to be within the acceptable range. If the degree of whiteness is lower than the acceptable range, it is unacceptable due to consumer preference. If the degree of whiteness is higher than the acceptable range, the rice grains tend to be broken. However, the volume flow rate of the rice being released is very high, a sampling mechanism was developed as seen in Fig. 4. It consisted of a short pitch conveyor screw driven by a 12V DC motor. The conveyor screw was tilted up about 20 degrees. The DS18B20 sensor was used to measure the temperature of the rice. Then, the rice samples were transferred and flown into the tray. Then the tray was driven by a servo motor to the location where the degree of whiteness was measured by the tcs3200 color sensor. After that the rice samples were returned to the next process.

The schematic of the degree of whiteness and temperature measurement, including the sampling mechanism is shown in Fig. 5. It consisted of 2 parts. On the left hand side, an Arduino Nano board was used to control the DC motor driving the screw and to control the servo motor driving the tray. It also read the degree of whiteness and temperature from the sensors and sent to the main controller on the right hand side.

The NodeMCU board was used as the main controller. It received sensor data and displayed them on screen. The user can set the acceptable range of the degree of whiteness and the temperature as seen in Fig. 6. It activated the audible/visual alarm when the sensor data were out of the acceptable range. Likewise, it sent sensor data to the database server via a wireless network.

The database server ran on the Raspberry Pi single board computer. It received the sensor data via a wireless network, displayed on screen and recorded into the database as shown in the Fig. 1 (B). The format of sensor data transmitted to the server consisted of the machine number, degree of whiteness, and temperature. For example, “1, 38.2, 36.4” stands for the machine number 1, the degree of whiteness is 38.2, and the temperature is 36.4 degrees Celsius. The comma symbol is used to separate the values.

Since the communication is based on the TCP/IP protocol, the IP address has to be known before starting communication. To solve this problem, a multicast message based on the UDP protocol is sent out from the server at every 5 seconds. Every device connected to the server receives this message and obtains the IP address of the server. Then, the message transmission based on the TCP/IP protocol can be started.

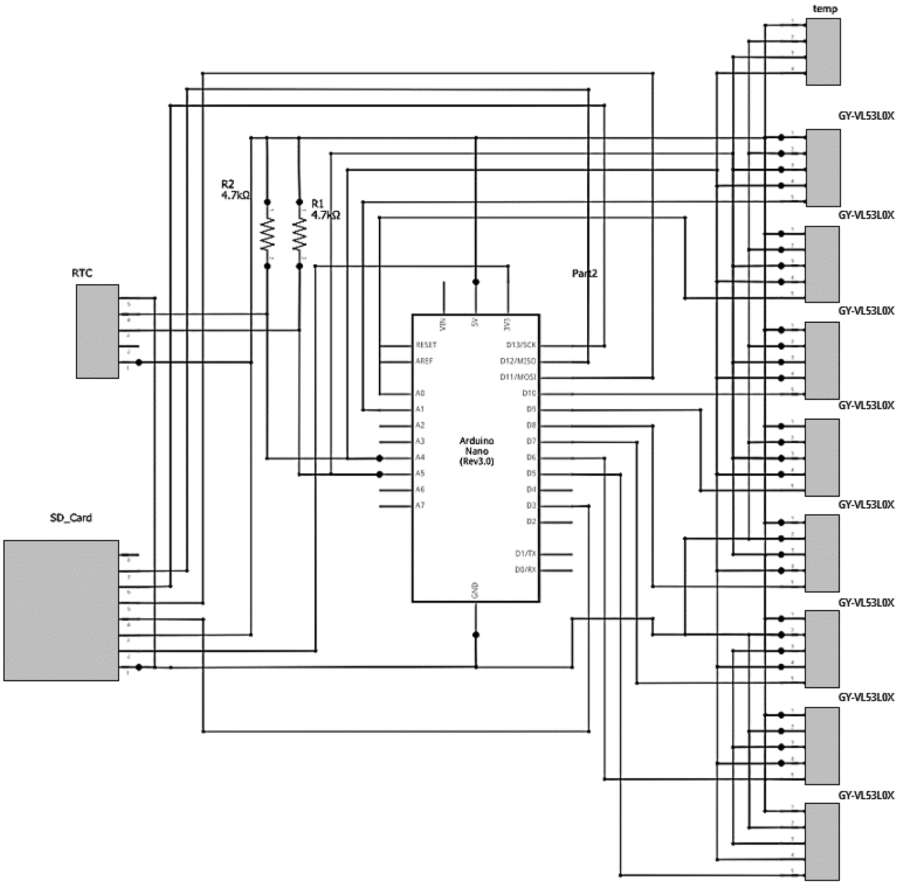

Fig. 3: The schematic of the monitoring system for the husking machine

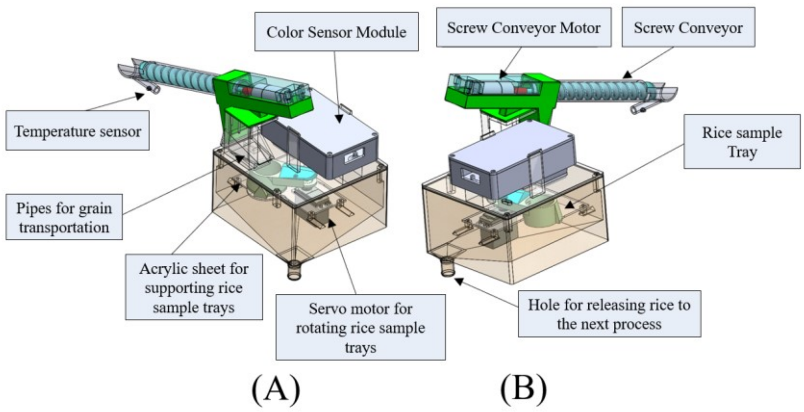

Fig. 4: The rice sampling mechanism: (A) servo motor at the opening position and (B) servo motor at the releasing position

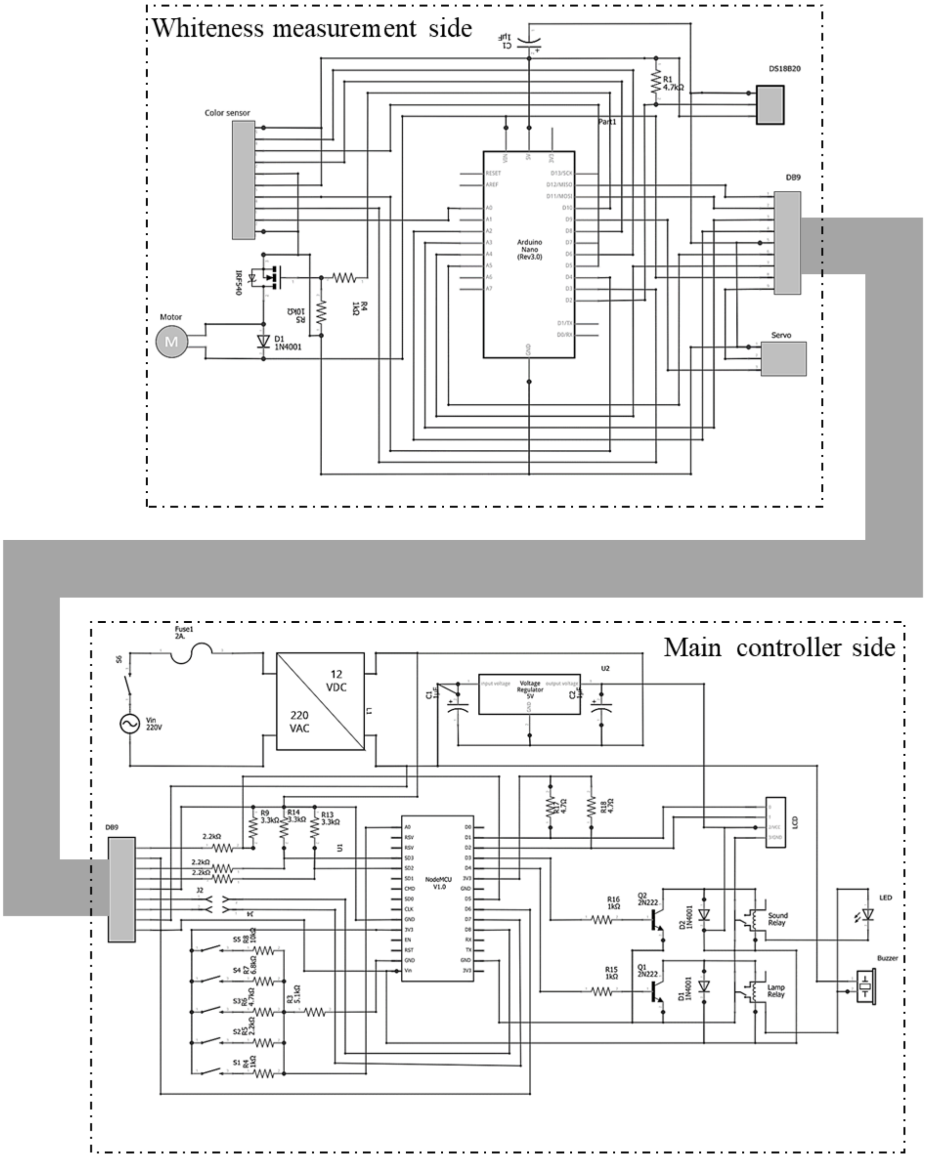

Fig. 5: The schematic of the degree of whiteness and temperature measurement, including the sampling mechanism

Fig. 6: Main controller cabinet

3. Experimental Results

In the experiments, sensors used in each monitoring system were evaluated. Then they were installed at the rice mill and the entire system was assessed.

3.1 The results of the monitoring system for the husking machine

The accuracy of the GY-VL53L0X distance sensor is shown in Table 1. Output signals from seven distance sensors were recorded and each sensor was repeated five times. Then, average and standard deviation (SD) of total 35 output signals were calculated. The accuracy of the GY-906 non-contact temperature sensor attached 5 centimeters away from the object is given in Table 2.

The measurement was repeated five times and then, the average and standard deviation were calculated.

Reference Distance (mm)	Actual Distance (mm)	Error (%)
50	50.0 +/- 0.7	0.1
100	99.3 +/- 0.9	0.7
150	149.6 +/- 0.9	0.3
200	200.4 +/- 1.0	0.2
250	249.9 +/- 0.7	0.0
300	299.5 +/- 0.7	0.2

Table 1 The accuracy of distance sensor

Reference Temperature (°C)	Actual Temperature (°C)	Error (°C)
10	10.4 +/- 0.3	0.4
20	20.2 +/- 0.3	0.2
30	30.0 +/- 0.5	0.0
40	40.3 +/- 0.5	0.3
50	50.5 +/- 0.2	0.5
60	60.1 +/- 0.3	0.1

Table 2 The accuracy of non-contact temperature sensor

Then, the monitoring system was installed inside the husking machine at the rice mill as shown in Fig. 7. The sensors were mounted about 100 mm far from the rubber roll. Figs. 8 and 9 show the surface profile of the rubber roll and the temperature of the rubber roll during the husking process, respectively. The wear of the rubber roll was obviously seen in Fig. 8 and rise in the temperature is apparently shown in Fig. 9. The alarm is activated if the surface profile is unacceptable. Similarly, the temperature of the rubber roll increased dramatically. If the temperature is higher than 60 degree Celsius, the alarm is activated as well in order to prevent burning.

Fig. 7: The installation of the monitoring system for the husking machine

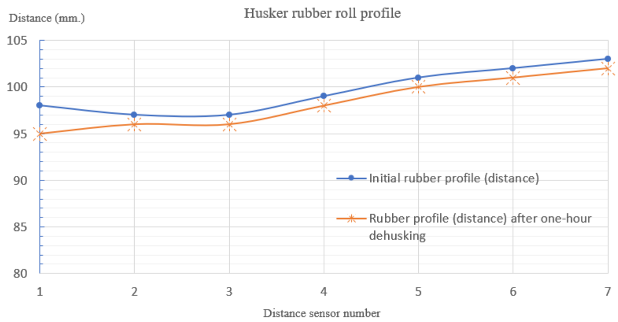

Fig. 8: The surface profile of the rubber roll based on the distance sensors

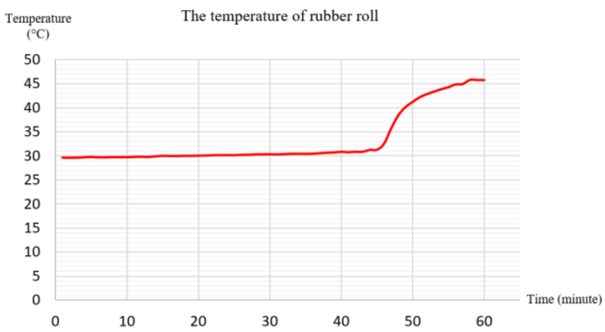

Fig. 9: The temperature of rubber roll inside the husking machine

3.2 The results of the monitoring system for the whitening machine

The degree of whiteness measurement was based on the TCS3200 RGB color sensor. The RGB color values were obtained from the rice samples (see Fig. 10) and used to calibrate with the standard degree of whiteness meter (kett c300-3). The relationship is given in Equation (1). Then, the accuracy was evaluated as seen in Table 3. The measurement was repeated three times and then, the average and standard deviation were calculated.

$$Y = 67.3293 - R(1.9634) + G(3.0415) - B(1.7976) \quad (1)$$

where Y is the degree of whiteness
R is the intensity of red color plane
G is the intensity of green color plane
B is the intensity of blue color plane

Fig. 10: The whiteness of rice samples measured by the kett c300-3

Reference kett c300-3 (degree of whiteness)	Average (degree of whiteness)	Error (degree of whiteness)
37.2	38.0 +/- 0.4	0.5
39.6	39.6 +/- 1.1	1.4
40.2	39.7 +/- 0.5	0.6
41.1	40.5 +/- 0.9	1.1

Table 3 The accuracy of the degree of whiteness measurement based on the RGB color sensor

The accuracy of the temperature sensor is given in Table 4. The temperature was measured with three time repeating and then, the average and standard deviation were calculated. The entire monitoring system including the sampling mechanism was installed at the whitening machine as shown in Fig. 11.

Reference Temperature (°C)	Average (°C)	Error (°C)
9	7.9 +/- 0.08	1.1
20.5	19.54 +/- 0.03	1
30	29.81 +/- 0.00	0.2
41	40.73 +/- 0.09	0.3
51	51.36 +/- 0.04	0.4
58.5	58.79 +/- 0.08	0.3
68	69.42 +/- 0.04	1.4

Table 4 The accuracy of the temperature sensor

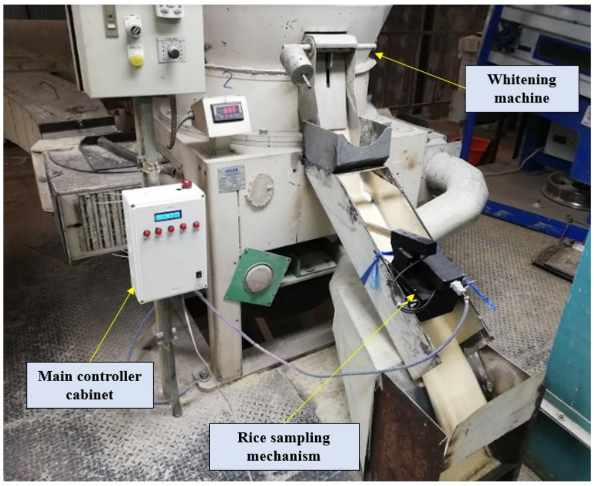

Fig. 11: The monitoring system installed at the whitening machine

Next, the sensor data were transmitted to the server located in the office room via the wireless network. They were displayed on the screen as shown in Fig. 12 and recorded into the database. The rice mill owner can monitor the degree of whiteness and the temperature of milled rice as illustrated in Fig. 13. The alarm is activated when the temperature is not in range of 25-50 degrees Celsius or the whiteness is not in range of 30-45 degrees of whiteness. Besides, the rice mill owner can retrieve the data and use them to manage the rice mill effectively as illustrated in Fig. 14.

Fig. 12: The display screen of the server located in the office

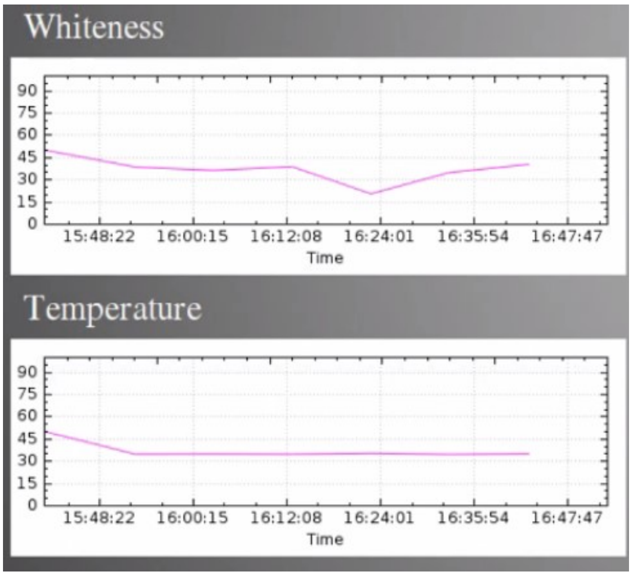

Fig. 13: Rice whiteness and temperature displayed on the screen

	Date	Time	ID_WT	Whiteness	Temp
1	2019-01-05	16:52:46	1	28.04	34.69
2	2019-01-05	16:42:46	1	40.45	35.19
3	2019-01-05	16:32:45	1	35.01	34.75
4	2019-01-05	16:22:45	1	20.64	35.5
5	2019-01-05	16:12:45	1	38.92	34.88
6	2019-01-05	16:02:45	1	36.46	35.06
7	2019-01-05	15:52:45	1	38.69	34.94
8	2019-01-05	15:24:36	1	39.37	-127
9	2019-01-05	15:14:36	1	38.61	35.13

Fig. 14: Sensor data retrieved from the database

4. Conclusions

The main aim of this work was to increase the rice quality, based on the HRY and the acceptable degree of whiteness. In this research work, we addressed two machines used in the rice milling process, i.e., the husking machine and the whitening machine. The wear of the rubber roll and the temperature of the rubber roll were monitored in the husking machine, whereas the temperature and the degree of whiteness for the rice were monitored in the whitening machine. The experimental results showed that the distance sensors were able to provide the surface profile of the rubber roll and the wear of rubber roll can be detected. Also, the temperature sensor was used to measure the temperature of the rubber roll to prevent burning.

For the whitening machine, the experimental results showed that the machine operators adjusted the machine settings immediately after the alarm was initiated. Also, sensor data were transmitted, displayed and recorded into the database correctly.

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Biographies

Noppachai Khongcharern was born in Roi-Et, Thailand, in 1992. He received his B.Eng. in Mechatronics Engineering from Mahasarakham University, Thailand, in 2015. Currently, he is a master degree student in mechanical engineering (in the field of Mechatronics Engineering) at Mahasarakham University. His current research interests include digital image processing, mobile robot control and wireless sensor networks.

Kiattisin Kanjanawanishkul was born in Trang, Thailand, in 1977. He received his B.Eng. in Electrical Engineering from Prince of Songkhla University, Thailand, in 2000. He received the M.Sc. in Mechatronics Engineering from University of Siegen, Germany in 2006. He received his Ph.D. in Computer Science from University of Tuebingen, Germany, in 2010. Since 2010, he has been employed at the Faculty of Engineering, Mahasarakham University, Thailand. His current research interests include cooperative and distributed control, model predictive control, robotic motion control, image processing, and computer vision.

Lamul Wiset was born in Yala, Thailand, in 1971. She received her Ph.D. in Food Science and Technology from University of New South Wales, Sydney, Australia, in 2007. At present, she is a lecturer in biological engineering in Mahasarakham University, Thailand. Her research interests include drying technology in particular quality of agricultural products such as rice, herbs, fruit and nut.