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Improving Rubber Cup Lump Production Process Efficiency Using IoT for Smart Farmers in Thailand

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Abstract

This research aims to develop a system to improve rubber cup lumps production by applying the internet of things technology instead of the traditional cup lump production by hand. The developed system was deployed at farmers' plantation in Surat Thani province, where are fifty-nine volunteers. The result has shown that the accuracy of the developed system is 97.67%. The system evaluation results have shown that the average means are 4.52 and 4.60, which are evaluated by experts and farmers. Besides, the standard deviation of 0.55 was evaluated by experts and 0.49 by farmers. All volunteers have a consistent opinion and are aligned in the same direction at the highest level. Therefore, the developed system based on IoT and sensor devices can improve rubber cup lump production for smart farmers in Thailand.

Keywords: *Arduino, rubber cup lump, ESP32-CAM, internet of things, smart farmer*

1. Introduction

Para rubber is the primary raw material for the rubber industry's production process of over 40,000 products [1], such as tires for cars or vehicles, shoes, sports equipment, medical devices. It is also a raw material for some chemicals and products used in construction and engineering. Para rubber, or natural rubber latex, is of Para rubber tree origin that is a perennial plant and plays an essential role in Thailand's economic crop. In 2019, Thailand produced 4,736,498 metric tons of natural rubber [2] and was the biggest export of natural rubber globally, around 4.1 billion U.S. dollars [3]. At present, Thailand has 36,189 square kilometers of rubber trees cultivation [4]. Nevertheless, harvesting natural rubber products that require human labor or tapper to operate, especially the production and harvesting of Para rubber called cup lump. The cup lumps are produced from the rubber production process in which a small amount of fresh latex drips into a cup-shaped container used to receive the latex from the rubber tree then coagulate in the cup. It then coagulates in the cup when it has been left for several hours or days. The sample of cup lumps and production processing by hand was shown in Figure 1.

In general, the process of producing cup lumps by villagers' traditional methods, which is done daily, consists of three main steps: 1) If there is an old cup lump that has been left since the previous day, side the old cup lump in the cup to allow the serum to flow out, then tapping for the fresh latex drip into the cup by starting from the first Para rubber tree until the last one in the block. 2) back to the first Para rubber tree again to pour the diluted formic acid into the cup, then use a spoon or clean wooden to stir the acid with the latex. 3) Keep the old cup lump (if any), then keep going until the last Para rubber tree. Therefore, in the production of cup lumps, each time farmer will have to spend at least two rounds of walking in the rubber tree farm, with the first round performing rubber tapping. In the second round, the farmer served to mix the formic acid in a latex cup and keep old cup lumps. In pouring formic acid and stirring the solution mixed with fresh

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latex, there may be a problem with the inaccuracy of the amount of acid poured by hand. Each day may have different amounts of latex, depending on the climate and the rubber tree's age. Thus, it requires a skilled person to apply the proper amount of diluted formic acid to each cup.

Figure 1. The Cup Lumps and Production Processing [5], [6]

Today, technology has made significant advancements, especially the internet of things (IoT) technology. IoT combines electronic devices and sensors with the Internet together and is widely used. For example, A walking stick helps guide the blind [7] or a walking stick for elderly health care [8] and face mask detection system [9]. For agriculture, IoT was used and applied to monitor and manage smart farming [10], [11], [12], such as temperature or water monitoring [13], chemical control [14], [15], crop monitoring [16], soil management [17]. Thus, this research aims to develop the application of IoT-based for improving the production processing of rubber cup lump. This method of adopting IoT will save time in the tapper's workflow and improve precision in filling formic acid into the latex cup.

2. Methodology

There are five stages to develop the application of IoT-based for improving the cup lump production process as follows.

2.1. Data Collection

The researcher collects the data related to rubber cup lump production in Surat Thani province, the largest Para rubber cultivation area in Thailand, and suitable as a pilot site. A total area of 4,250 square kilometers for Para rubber plantation in ten districts, includes Phunphin, Tha Chang, Khiri Rat Nikhom, Ban Na San, Chaiya, Wiang Sa, Don Sak, Ban Na Doem, Ban Ta Khun, and Ko Pha-ngan district [4]. According to the survey and data collection in this area, it was found that between 70 and 90 Para rubber trees were planted per block, which is a covered area of 1,600 square meters. In this research, fifty-nine volunteers included nine experts in information technology or agricultural development and fifty farmers with Para rubber plantations and ready to harvest. All volunteers were given documents explaining the protocols and research ethics that requesting their consent to participate. For this purpose, the researchers collected the time to produce and harvest the rubber blocks each day and recorded them to find the average time spent per rubber cum lump yield from the farmers or tappers. Thus, it can be used to calculate and compare the time obtained from the application of IoT with time spent on operations by farmers.

2.2. System Design IoT-Based

In this experiment, the ideal device was designed to mix the diluted formic acid into the latex cup and notify the status of latex in the cup to farmers. Thus, the system design is based on IoT conceptual, including electronic devices and sensors as following.

A. Central Controller

ESP32-CAM is the primary central processing unit to control the system in this work. It is a small experimental board or module which compact and cheap, and it is one of the microcontrollers in the ESP32-S series. ESP32-CAM has several built-in modules such as TransFlash (TF) card, Bluetooth, and WiFi modules that can connect to networks or the internet. Moreover, it comes with the OV2640 camera module, which has a resolution of two megapixels for capture images or videos. Furthermore, ESP32-CAM can put into deep sleep mode for saving power consumption.

B. Latex Volume Detection

This section is responsible for detecting the volume of fresh latex dripping into the latex cup. The first dripping until the latex stops dripping or almost no latex has dripped into the cup. This concept is based on the principle of measuring the distance between the surface of the latex in the cup and the sensors floating above the cup with the GY-530 Time-to-Flight (ToF) ranging module, which has a chip VL53L0X to measure the distance and operates in high infrared ambient light levels or laser of 940 nanometers wavelength. This module has a measurement resolution of 1 millimeter.

C. Formic Acid Volume Dilution

Formic acid is an organic acid that is readily biodegradable. Thus, it is impossible to pre-mix the water and formic acid for several days. In diluting the solution between 94% concentrated of formic acid and water, the survey data showed that the diluted formic acid solution had an average ratio of 94% formic acid and water at 1:30, and a mixture of 300 milliliters of fresh latex per diluted formic acid by average 15 milliliters. Therefore, the formic acid concentration of 94% in 0.5 milliliters is mixed with 15 milliliters of water for 300 milliliters of fresh latex. In measuring the reactant volumes to make a dilute formic acid solution, this is based on the peristaltic pump principle [18], [19] with a stepper motor. Thus, the stepper motor model 28BYJ-48 and the ULN2003 stepper motor driver module were used to inject and deliver water or formic acid according to the volume and proportion set above. In this work, tubes of different inner diameter sizes were used to determine the volume of water and 94% formic acid with a single stepper motor. The tube must also be resistant to corrosion from diluted formic acid.

D. Latex and Formic Acid Mixer

After the diluted formic acid solution's appropriate volume has been obtained, the solution is released and mixed with fresh latex in a latex cup. The stirrer unit consists of two main parts: 1) a rod or stick for stirring the solution in a cup, which uses the SG90 micro servo modified to rotate 360 degrees in both directions (clockwise and counterclockwise) and 2) the slack control unit, the rod is pulled for stirring or mixing the solution in a latex cup using a 28BYJ-48 stepper motor and ULN2003 stepper motor driver module to move in or move out of the cup.

E. Battery System

The 6-cells of 18650 Lithium-Ion battery is applied for the primary power supply in this system. Each 18650 battery cell has a voltage of 3.7 Volts. All battery cells were aligned and connected in parallel mode. However, most of the devices used in this system require a voltage of 5 Volts in direct current (DC). Therefore, the MT3608 DC-DC step-up module was applied for voltage conversion from 3.7 Volts to 5 Volts.

F. Notification System

For all rubber cup lump production processes, it was tracking and notify to farmers or tappers via internet WiFi connection by using the LINE Notify application on smart mobile. LINE Notify is a free application that is developed and provided by LINE Corporation [20]. In this system, the internet WiFi routers are required for providing network connectivity to the IoT kits installed in the rubber plantations.

All electronic devices and sensors based on IoT in this research are illustrated in Figure 2.

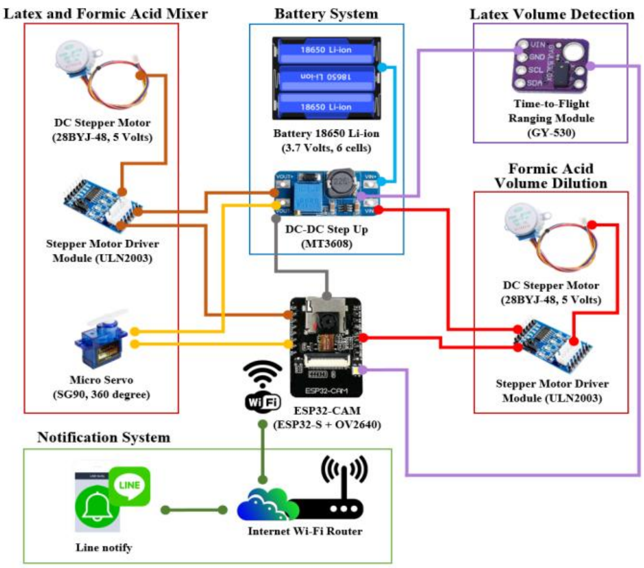

Figure 2. All Electronic Devices and Sensors based on IoT for Improving the Rubber Cup Lump Production

2.3. System Development

The system was developed based on IoT by using Arduino IDE version 1.8.12 in the C++ language. It has six main processes includes the following steps: 1) for every 15 minutes, checking the amount of latex in the cup until the latex stops dripping, 2) mix the solution to get the diluted formic acid, 3) pour the diluted formic acid into the cup, 4) use the rod or wooden stick for stirring in the cup, 5) stop stirring then remove the rod or wooden stick out of the cup, and 6) send a message notification to tappers or farmers.

For the first step, the latex's duration to dripping until they stop dripping depends on the climate, age of the Para rubber tree, and the number of scars on knife tapping. In this experiment, the latex dripping duration is between 3 and 5 hours on average. While the ESP32-CAM is in a deep sleep to save power, it uses a timer to wake the system up every 15 minutes to control the GY-530 ranging module to measure the latex volume. If the latex comes out (there is no increase in the volume of latex in the cup), then diluted formic acid solution will be mixed into the cup. It will notify the operational status and processing as following steps 2 to 6 that mentioned previously.

From collecting and analyzing data from the sample, it was found that the analysis of the fresh latex dripping rate was presented in the pattern of exponential decay function, the formula as in (1) [21].

$$y = A_0 (1-b)^x \tag{1}$$

Where
y refers to the remaining amount of data,
x refers to the duration in second (s), $x = 0, 1, 2, \ldots,$
A_0 refers to the original amount of data at $x = 0$,
b refers to the percentage of decay factor.

To calculate the fresh latex dripping rate, assume the total amount or the original volume of latex (V_0) was calculated as the cylinder formula (2) [22].

$$V_0 = \pi r^2 h \tag{2}$$

Where
V refers to the original volume of latex,
r refers to the radius of latex cup,
h refers to the distance from the GY-530 sensor to the bottom of the latex cup.

According to (1) and (2), let the time t instead of x. Let the original volume of latex V_0 instead of A_0, and let the decay rate d instead (1-b). Thus, the fresh latex dripping rate in function time series $f(t)$ can be calculated in (3) and (4).

$$f(t) = V_0 (1-b)^t \tag{3}$$

$$f(t) = \pi r^2 d^t \tag{4}$$

Where d refers to the exponential decay rate, and $0 < d < 1$.

After the fresh latex dripping rate f(t) is near zero, the ESP32-CAM will take a picture and notify the message via LINE Notify to the farmers. Moreover, the system will turn into a deep sleep mode for a new operation in the next day.

2.4. System Evaluation

The developed system was evaluated in the Black-box testing concept with five criteria indicators: functional test, usability test, compliance test, performance test, and a scalability test. All fifty-nine volunteers evaluate this system based on Likert-scale scoring [23], in which the score range between 1 and 5, as Table 1.

Table 1. The Scoring based on the Likert-scale

Scoring	Weighted Mean	Level of effective
5	4.51 – 5.00	The highest
4	3.51 – 4.50	The high
3	2.51 – 3.50	The medium
2	1.51 – 2.50	The little
1	1.00 - 1.50	The least

Besides, the developed system was determined in the quartile (Q) such as the first quartile (Q1), third quartile (Q3), interquartile range (IQR), and quartile deviation (QD) which based on mean, standard deviation (SD), and median (MED).

Moreover, the developed systems were also able to measure the accuracy in terms of 1) the dripping latex detection, 2) the mixing dilute formic acid solutions, 3) the ability to mix the solution with fresh latex in a cup, and 4) the system status notification. The accuracy was calculated in (5) [24], [25], [26], [27].

$$Accuracy = \frac{TP + TN}{TP + FP + FN + TN} \tag{5}$$

Where
TP refers to a true positive,
TN refers to a true negative,
FP refers to a false positive,
FN refers to a false negative.

3. Results

The system was developed and deployed for thirty days at Para rubber plantation of farmers who are volunteers in Surat Thani province. The results are shown as follows.

3.1. The Result of the Developed System Evaluation

Fifty-nine volunteers evaluated the developed system to improve the rubber cup lump production process efficiency based on Black-box testing. The experts' evaluation result has shown that the functional test, usability test, and performance test have mean values of 4.60 with a standard deviation of 0.55, while the compliance test and scalability test have the mean values at 4.60 and a standard deviation of 0.55. On average, it has a mean value of 4.52 and a standard deviation of 0.55.

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The system evaluated by farmers found that the functional test is the highest mean value at 4.72, with a standard deviation of 0.45. The performance test is the second order with 4.62 and 0.49 for mean and standard deviation, respectively. The compliance test, usability test, and scalability test are the following mean values of 4.58, 4.56, and 4.52, with a standard deviation of 0.50. For the average result by farmers, it has 4.60 of mean and 0.49 of standard deviation.

Besides, this developed system was determined to analyze the value of conformity by volunteers in quartiles. The result has shown that the interquartile range values are not over 1, and the quartile deviation has no more than 0.5. This means that all volunteers have a consistent opinion and are aligned in the same direction, as in Table 2.

Table 2. The Result of the Developed System Evaluation

Indicators	Mean	SD	Quartiles			IQR	QD
			Q1	MED	Q3		
By Experts							
Functional test	4.60	0.55	4	5	5	1	0.5
Usability test	4.60	0.55	4	5	5	1	0.5
Compliance test	4.40	0.55	4	4	5	1	0.5
Performance test	4.60	0.55	4	4	5	1	0.5
Scalability test	4.40	0.55	4	4	5	1	0.5
Total	**4.52**	**0.55**	**4**	**5**	**5**	**1**	**0.5**
By Farmers							
Functional test	4.72	0.45	4	5	5	1	0.5
Usability test	4.56	0.50	4	5	5	1	0.5
Compliance test	4.58	0.50	4	5	5	1	0.5
Performance test	4.62	0.49	4	5	5	1	0.5
Scalability test	4.52	0.50	4	5	5	1	0.5
Total	**4.60**	**0.49**	**4**	**5**	**5**	**1**	**0.5**

3.2. The Accuracy of Developed System

The system was deployed and tested at fifty Para rubber farms for thirty days. The result has shown that the system accuracy of 97.67%. When sorting for the accuracy of all four criterion topics, ‘the system status notification’ was found to have the highest accuracy, followed by ‘the mixing dilute formic acid solutions,’ ‘the ability to mix the dilute formic acid solution with fresh latex in a cup,’ and ‘the dripping latex detection’ which the accuracy of 98.00%, 97.33%, and 96.67%, respectively. The result of system accuracy has shown in Table 3.

Table 3. The Result of System Accuracy

Criterion topics	Accuracy (%)
The dripping latex detection	96.67
The mixing dilute formic acid solutions	98.00
The ability to mix the dilute formic acid solution with fresh latex in a cup	97.33
The system status notification	98.67
Average	**97.67**

4. Conclusion

Rubber planters have always used the process of producing rubber cup lumps by hand. If not a skilled person, mistakes can occur. For example, mixing the formic acid solution with a different consistency is not suitable for the amount of fresh latex in the cup. Also, it takes time to walk in the rubber plantation at least two times to produce rubber cup lumps. This research has applied the internet of things technology to increase the production process's efficiency to reduce rubber tapping farmers' working duration. The developed system has an accuracy value of 97.67%. The system evaluation results have shown that the average means are 4.52 and 4.60, which are evaluated by experts and farmers. Besides, the standard deviation of 0.55 was evaluated by experts and 0.49 by farmers. Moreover, finding the quartile, it was found that the results of the system performance evaluation of 59 volunteers were consistent at the highest level. Therefore, the developed system based on IoT and sensor devices can improve rubber cup lump production for smart farmers in Thailand.

For further work, this system will be developed to increase the capabilities by 1) developing a rubber tapping system based on the principles of controlling a 3D printer, 2) developing applications to be able to control and monitor via the Internet, and 3) design and manage issues power source for more prolonged usage, such as the solar cell system.

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