Design of Automated Rubber Tapping Mechanism

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Abstract. Natural rubber is widely used in daily human life because of its excellent properties. At present, manual tapping is the main method to obtain natural rubber. Since the growth of the industrial sector is in line with the national economy, the demand for rubber resources has also increased. However, natural rubber production countries are now lacking their workforce because tapping rubber trees can be considered a high skill-oriented task. The lack of trained tappers will affect rubber production. Hence, this paper proposes a new mechanism for an automated rubber tapping mechanism. The experimental results showed the effectiveness of the developed device, with accurate 30 degrees diagonal cuts.

1. Introduction

As a fundamental strategic asset, natural rubber and its products are applied in various industries, medical treatments, and transportation. At present, synthetic rubber materials have not been able to surpass the excellent properties of natural rubber [1-5]. The growing economies and industries has increased the demand for natural rubber products [6]. Currently, the method for tapping rubber trees is still dominated by manual labour [7]. Due to technical difficulties, aging in the working population, and poor working environment, an intelligent rubber tapping device is needed [8, 9]. The autonomous technique is important to make such devices intelligent. In addition, the diameter and spacing of the trees are important aspects for a rubber tree plantation. These aspects will affect the growth, biomass, and water consumption of the trees. However, accurate mapping and monitoring of rubber trees can be challenging [10, 11].

In industrial applications, natural rubber is obtained mainly from Hevea Brasilienses trees, mostly grown in Southeast Asia, Southern America, and Western Africa. Synthetic rubbers are artificial elastomers made from the polyreactions of petroleum by-products. Their applications and basic properties can be classified as general and specific. Generally, their properties satisfy the requirements of various products. However, requests for rubber are still high and cumulative in every sector because rubber is very cheap and easy to obtain. Natural rubber is preferred for its various unique features, such as resistance to aging, resistance to high or low temperature, and resistance to chemical [12].

Rubber tapping is the process by which the latex is obtained from a rubber tree without damaging its cambium. In Malaysia, a rubber tree is usually tapped using a manual tapping knife, known as Jebong. This knife will cut through the outer layer of the tree called the bark. Rubber tappers would start tapping early in the morning because during these hours, the quantity of water in the rubber is high and it can directly increase the amount of rubber production. A 5 to 7-year-old rubber tree with a trunk exceeding 30 cm is ideal for open drainage systems.

Generally, the number of rubber trees in a rubber estate will range between 500 and 800 trees. For someone to tap 800 trees per day is quite impossible. Therefore, rubber entrepreneurs need a bigger...
workforce. However, this problem is faced by most countries, where the demand for a product is high, but there is a shortage of manpower. In terms of rubber tapping, the work is very exhausting and time-consuming. Nonetheless, to take a random person to work as a tapper is quite risky because the wrong technique may harm and affect the quality of the rubber. Usually, a new tapper would need to attend a preparation programme, which could take about three to six months. Such programmes will offer guidance to a new tapper, including knowledge about rubber tree care.

This project was conducted to design an automated rubber tapping mechanism. It is expected that the device can automatically imitate and produce the same pattern as a conventional procedure. The device will be attached to the rubber tree and it will start the tapping process without human help. By having this device, rubber tappers can increase their tapping work, and can save energy and time for other tasks.

2. Feasibility study

A rubber tree can be tapped after five years, with a trunk exceeding 30 cm. The trunk consists of three layers, namely, the outermost layer (bark), the middle layer (cambium), and the inner wood. The bark is usually around 6 mm thick and consists of lactiferous vessels where latex is produced. The cambium layer is the layer that tappers need to avoid damaging since the cambium helps to boost the growth of the rubber tree. Figure 1 shows the cross-sectional view of a rubber trunk.

Rubber tapping process usually starts early in the morning because the bark of the tree would have less torque pressure, which would allow the tapper to use less force to tap the bark. The tapping process starts with the tapper marking the tapping area first. A tapping panel will be created approximately one meter above the union to make the tapping process more efficient. A tapping knife will be used to make a 30° diagonal cut from the higher left towards the lower right of the bark or vice versa. Figure 2 shows the pattern of the diagonal cut. The latex will flow through the path of the diagonal cut and straight into the cup. The cup will be left for at least three hours to get the maximum amount of latex. By using the right method and wise care for the rubber tree, it can be tapped and produce latex for at least 20 years.

![Figure 1. The cross-sectional view of the trunk [13]](image)

![Figure 2. Rubber tree with diagonal cuts](image)
3. Tapping module
This system consists of two linear guides, two stepper motors, and three infrared sensors that are controlled by an Arduino Uno microcontroller. This microcontroller will monitor the system using the Arduino IDE v1.8.2 software. Since this machine is for outdoor usage, it will be more practical if the device uses a solar panel module as its power supply. Figure 3 shows the newly designed tapping module. The aim of the system is to copy the manual hand tapping motion by tappers and to increase latex production, which could also save human energy and time.

![Automated tapping module](image)

Figure 3. Automated tapping module

Two linear guide mechanisms are attached together in x-y axes to produce the desired diagonal cut. The vertical linear guide that lies on the y-axis is called Linear Guide A, while the diagonal linear guide that lies on the x-axis is called Linear Guide B. The movement of these linear guides is controlled by stepper motors that are connected to the Arduino Uno.

3.1. Vertical linear guide (linear guide A)
Linear guide A is used to control the upwards and downwards movements. This linear guide can control the distance between two lines or more during the tapping process. Both linear guides are synchronised, so that the tapping process can go smoothly.

When the system receives the signal to start the tapping process, linear guide A will return to its original position. Once linear guide A reaches its original position, linear guide B will start the tapping process. Once linear guide B has completed one tapping line, linear guide A will move downwards to another stage. The system will repeat these steps and will only stop when linear guide A has reached the final stage.

3.2. Diagonal linear guide (linear guide B)
Linear guide B is attached to the carriage of linear guide A, as shown in Figure 4. This linear guide is attached diagonally at approximately 30° from the x-axis to get the same cutting pattern as a conventional method, as shown in Figure 2. The carriage of linear guide B is attached with a small metal plate. The traditional tapping knife is modified by wielding the knife to this metal plate. The red circle in Figure 4 shows the tapping knife that is attached to the metal plate.
Figure 4. A metal plate attached to linear guide B

Since linear guide B is diagonally attached to linear guide A, the obtained cutting pattern is exactly the same as the manual tapping pattern. Linear guide B can move freely to the left and right on the diagonal line. By using this system, the tapping depth can be controlled and it can work smoothly since the force used to remove the bark of the rubber tree is always constant.

3.3. Stepper motor

The stepper motors used in this system are attached to the top of each linear guide. These stepper motors control the movement of each linear guides to keep them synchronised. The movement of the linear guides depends on the coding set up in the Arduino language. The steps taken by the stepper motors will decide the range of the linear guides’ movements to travel upwards and downwards, or left and right. Figure 5 shows the stepper motors attached to each linear guide.

Figure 5. Stepper motors with the attachment for the linear guides

3.4. Infrared sensors (IR sensors)

The function of the infrared sensors is to limit the movement of the linear guides within the tapping area. In this system, three IR sensors are used and attached on the linear guides. Two sensors are placed on the top and at the end of linear guide A. These sensors will limit linear guide A to move only upwards and downwards. As for linear guide B, the IR sensor is only placed on the top. Table 1 lists the linear guides’ movements in reaction to the IR sensors.
Table 1. Linear guide movement

| Sensor 1 | Stepper Motor B Comment | Motor Movement | Sensor 2 | Sensor 3 | Stepper Motor A Comment | Motor Movement |
|----------|-------------------------|----------------|----------|----------|-------------------------|----------------|
| 0        | The motor is activated  | (The linear    | 0        | 0        | The motor is activated  | (The linear    |
|          |                         | guide B is     |          |          |                         | guide A is     |
|          |                         | moving along   |          |          |                         | start moving   |
|          |                         | the axis)      |          |          |                         | stage by stage |
| 1        | The motor is stop       | (The linear    | 1        | 0        | The motor is stop       | (The linear    |
|          |                         | guide B is     |          |          |                         | guide A is     |
|          |                         | stop at point  |          |          |                         | stop at the    |
|          |                         | A of linear    |          |          |                         | point of sensor|
|          |                         | guide B)       |          |          |                         | 2)             |
|          |                         |                |          | 1        | The motor is activated  | (The linear    |
|          |                         |                |          |          |                         | guide A will   |
|          |                         |                |          |          |                         | directly move  |
|          |                         |                |          |          |                         | upward until   |
|          |                         |                |          |          |                         | get back to    |
|          |                         |                |          |          |                         | sensor 2)      |

4. Experimental results

The device was tested by making it cut a piece of polystyrene to observe the cutting pattern. Figure 6 shows the results obtained from the tapping process. The red dash lines show that this device can imitate the manual tapping procedure. The tapping line was created by linear guide B, where the carriage is attached with the tapping knife. The tapping knife was able to tap the surface of the polystyrene with diagonal cuts. Based on the figure, the X shows that the distance between the lines is constant, which means that it can be precisely controlled. Thus, linear guide A has successfully controlled the distance between these lines.

![Figure 6. Tapping result](image)

By successfully controlling these two linear guides, this automated rubber tapping machine has proven that the tapping process can be performed in automation without needing human involvement in this weary and exhausting task. Figure 7 shows how the rubber tapping model in this project is attached to tree.
5. Conclusion

This study has successfully developed another framework for tapping rubber trees. A total mechanisation of the structure has been accomplished and the outline turned out to be realistic. This new system ensures that the automated tapping process can be used in rubber tree estates. This system can be beneficial to the rubber tapping industry since it requires minimal human involvement. Rubber tappers can save their energy and time to do other tasks since this machine can operate independently and will only take 20 seconds to complete its task compared to manual tapping that can take approximately 45–50 seconds. The system has been proven to offer great advantages.

5.1. Future work

Although this system is functioning well, this method needs to be improved to increase the performance of the mechanism. The currently implemented idea involves using a microcontroller for the control and automation of the system. Fuzzy logic or a PID controller for monitoring the system can be implemented in the future, which would be more beneficial. Since this device will be placed outdoors and would need a power supply to run the programme, this system should be integrated with a solar panel.

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