COMPARISON BETWEEN CAPACITIVE AND PHOTO SENSORS IN DEPTH CONTROL OF ONION HARVESTER

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Abstract: Depth control system is important in bulb crop harvester. The higher the depth causes the greater amount of soil entering to harvesting system. A proper depth control leads to optimize energy consumption. A four-bar mechanism was used in order to move the blade of the machine and to control the operation depth while a DC electrical motor provided the movement of the blade. The four-bar mechanism consisted of a power screw, linkage bars, moveable pin and a blade. A control system was used to follow the uneven ground surface and control the displacement of the blade by sending commands to the DC electrical motor. The tests were carried out in laboratory on artificial uneven ground in sinuous curves as well as square and triangle shapes. The displacement of the blade was recorded by a digital camera and converted to image and analyzed using Matlab software. All the tests were replicated three times. The photo sensor responded better than the capacitive sensor for all obstacle shapes.

Keywords: onion harvester, depth control, automation, photo sensor, capacitive sensor.

1. INTRODUCTION

The bulb crops are located at different depth of soil. Plowing is needed to bring the bulbs out of the soil and the sharpness edge of the plowing tools might make crop damages. During recent years, a huge number of electronic control units with various types of sensors and actuators have been embedded in agricultural machines and processes [1].

The application of electronics in farm machinery has allowed the adoption of precise monitoring and control functions, which can influence many aspects of machine operation. Initially, electronics were used to monitor and control the machine functions in order to improve machine efficiency or operation rate. However, recently the electronic systems are being used to measure crop or field variables, such as crop yield, to control input application. In particular, the development of precision agriculture technology, which measures within-field variability of a parameter like crop yield and uses this information to target input application, has resulted in machine electronics playing a role in management decisions [2].

A depth control system is necessary to avoid or minimize crop damages during harvesting. The higher the depth of harvesting causes the greeter amount of soil entering in harvesting system. A number of immediate benefits will be achieved by improving the depth control system of primary bulb crop harvesting implements. In purely economic terms, the improved depth control will reduce energy consumption resulting from implement operation at a target depth. Higher system accuracy may also permit to select of shallower harvesting depths with

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confidence. If certain depth is required for harvesting of a crop, many people will apply a higher depth as a target to guarantee complete harvesting and they do not care energy consumption and expenses. By having a working depth within the normal range, the improved depth control system may well results in energy savings.

Researchers have already used instrumented skids, instrumented wheels and a noncontact sensor for this purpose, but it is likely that the end-user will favor non-contact methods for their apparent simplicity. These types of transducers, which typically utilize ultrasonic pulse reflection principles, require refinement to fully suit the diverse nature of agricultural operating conditions [3-6].

The high working depth causes an increase wear on the head of harvester components and more dirty harvested bulbs. Several attempts have been undertaken to reduce the effect of incorrect setting of the under-cutter height, by means of automatic control of the cutter height [7-10]. However, the success of these attempts has been greatly hampered by the unsatisfactory performance of the height used sensing methods.

Determination of a suitable height sensing method is the primary task which is required to successfully develop an automatic height control system. Musumeci (1983) provided a useful summary of various height sensing techniques. The ultrasonic pulse echo rang is considered to use for pressure fluctuations in order to drive the hydraulic motor driving the cutter blades, and promising for estimation of the base-cutter height [8]. Practical investigations by Garson (1992) on the later method showed that the response was greatly affected by soil type and soil conditions [9]. Lee et al. (1998) designed and constructed a tillage depth control system for rotary implements mounted on an agricultural tractor to improve accuracy of tillage depth. They found that the proposed foresight control system of tilling depth worked well, but there are still some problems such as reduction of tractor speed due to the load increase to the engine when the actual tillage depth increased [11].

The purpose of this research was to provide a new method to compare the capacitive and photo sensors in depth control of onion harvesters.

2. MATERIALS AND METHODS

A laboratory instrument was designed and constructed to control the depth of onion harvester by capacitive and photo sensors. The capacitive and photo sensors were mounted on the front of the chassis and performance of the sensors was evaluated by using the instrument (Figure 1).

Fig. 1. Head of onion harvester including control depth system.

The variation of the harvesting depth in bulb harvesting implements mainly occurs due to the variation of the blade angle. An electromotor provide the movement of the blade upward and downward by rotation of the blade about the pivot. A four-bar mechanism was applied to change the harvesting depth. The sensors sense the obstacle and send the command to the electromotor for adjusting the blade to follow the obstacle based on the response of the sensor (Figure 2).

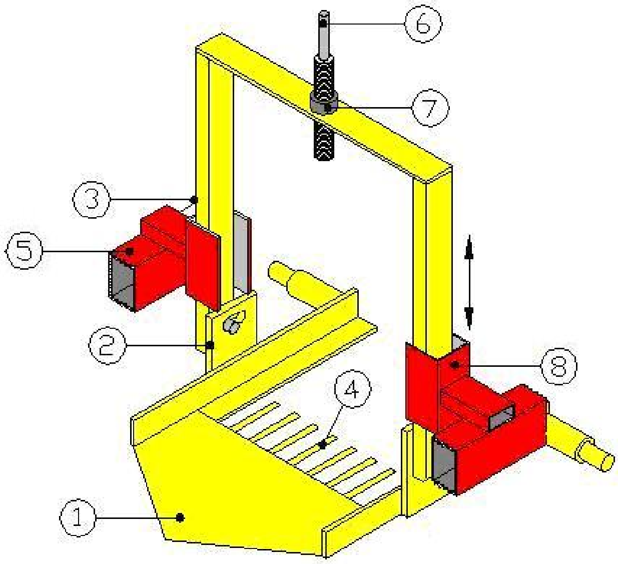


Fig. 2. Depth variable mechanism:
1) blade, 2) notched part, 3) linkage bars,4) finger separator, 5) chassis, 6) power screw, 7) power nut, 8) rail.

The mechanism was constructed in order to set up variation of harvesting depth with rotation of a power screw. The mechanism consisted of a power screw (DIN103, Tr 28×5), linkage bars, rail, and blade (Figure 2). The blade was adjoined to the linkage bars by notched parts with length of 20mm. The linkage bars move inside the rails by rotation of power screw to change the rake angle and depth of the blade. The power screw rotates by a DC motor (20V, 2A, 189 rpm). The angle of the lift arm varied within a range of zero (horizontal line) to 30 degree. The depth of the blade during the movement of linkage bar is shown in Figure 3.

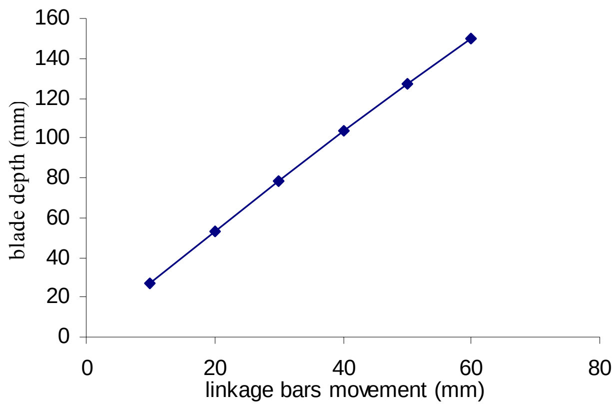


Fig. 3. Relationship between linkage bars movement and blade depth.

The range of the blade angle was between 12 to 30 degrees respected to harvesting depth of 5 cm. According to Figure 4, the amount of movement of blade apex can be expressed as:

$$\frac{y}{y_1} = \frac{L}{L_1}$$

or

$$y = \frac{y_1 \times L}{L_1} = \frac{n \times p \times L}{L_1} \tag{1}$$

where y is the movement of blade apex about pivot O (rotation center), n is the number of power screw rotation, p is the pith of power screw, L is the length of the blade, and L_1 is the distance between linkage bars to pivot O.

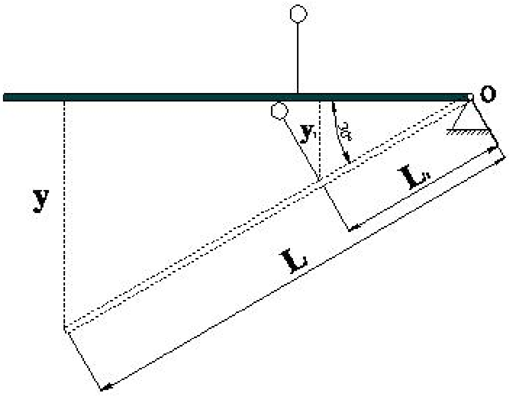


Fig. 4. Schematic of the blade movement.

Considering the Figure 5, the size of the notch in the notched part can be calculated as follows: when the blade rotates about pivot O, the points A and B move to the positions of A` and B`. The length of CA` will be find by having the triangles A`CO` and B`DO`.

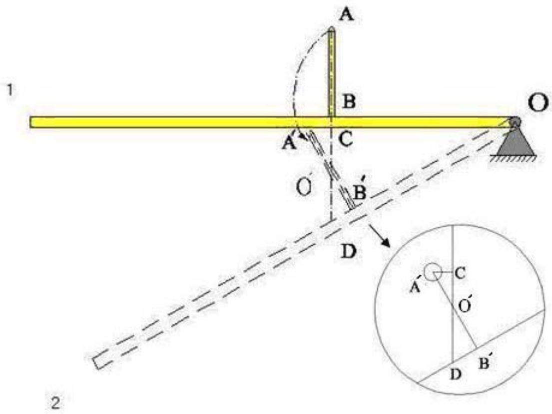


Fig. 5. Schematic of blade movement.

In Figure 5, the angles of DOB, DO'B' and CO'A' are 30° and the lengths of the links are OB= 155 mm, AB= 75mm and DC= 89.5 mm. So the length of groove guide (notch or A'C) will be equal to 16.75 mm.

A control system was used to follow the uneven ground surface and send the commands to the DC motor with 189 rpm rotation, to control the displacement of blade in order to have automation of blade movement of the onion harvester machine. The control system was composed of four main units as shown in Figure 6.

The tests were done by capacitive (Fotek, Model CP30-50C, Taiwan) and optical (Fotek, Model CDR-30X, Taiwan) sensors. Both optical and capacitive sensors were applied to detect the artificial obstacle. The sensors were mounted on the front of the chassis. The harvesting depth was controlled by changing the rotation direction of the DC motor and movement of the linkages upward or downward. The sensors send commands to the contactor of the DC motor for changing the rotation direction of the DC motor.

Since surface of farm isn't even and homogeny, therefore for considering performance of sensors in depth control of onion harvester the experiments were conducted indoors by using artificial obstacles in the shapes of sinusoidal curve, rectangular and triangles to investigate the transient response of the mechanism (Figure 7). The depths of the obstacles were 7 and 10 cm.

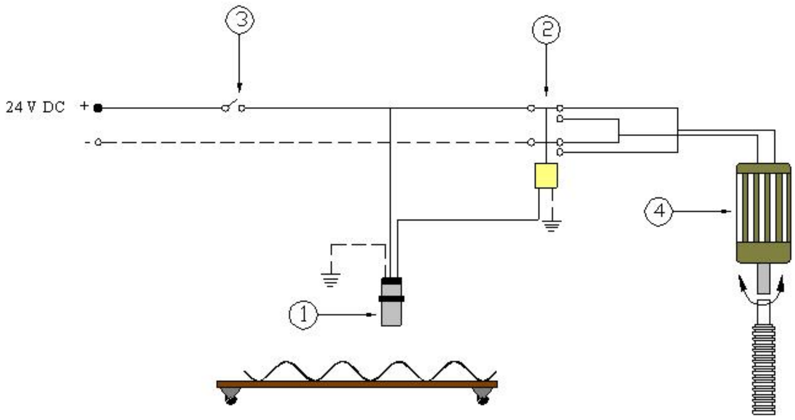


Fig. 6. Schematic of circuit of blade control:
1) sensor, 2) solenoid, 3) on –off switch, 4) DC motor.

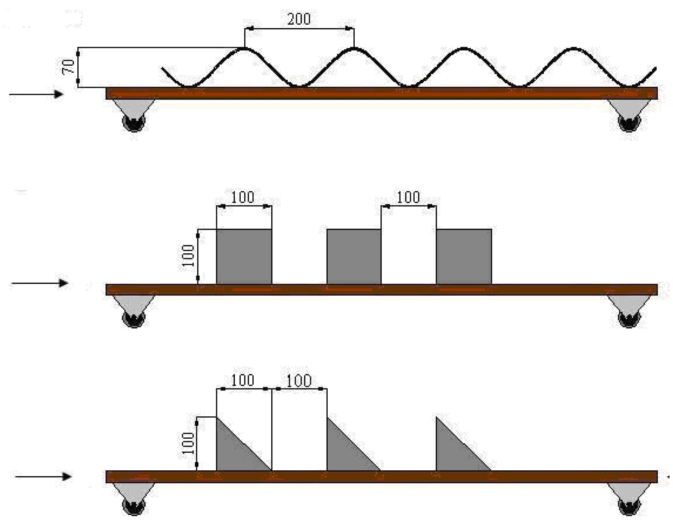


Fig. 7. Artificial obstacle shapes (units in millimeter).

The obstacles were pulled under the sensors by a DC motor with constant speed of 0.2 ms^{-1} while the head of onion harvester was stationary. The speed of puller motor was controlled by a PWM (Pulse Width Modulate) board and reactions of blade were recorded with a digital camera (Canon, DX, Japan) with 100 frames per second.

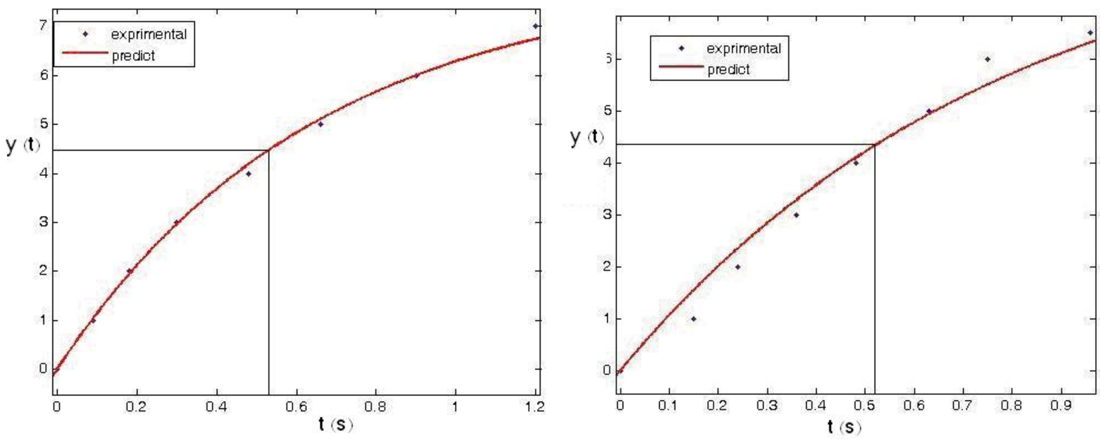
The captured films were conversed to images and then the movement times as well as the displacement of the blade were calculated using the Adobe Premiere software. The location of blade apex was registered during the time. The transient Response expressed by equation 2 [12].

$$C(t) = k\left(1 - e^{-\frac{t}{\tau}}\right).u(t) \tag{2}$$

Where k is the time of the whole movement, τ is the constant time and t is the time of movement at each place. The blade movement data were fitted to equation 2 using Matlab software, then the k and τ were derived. In other word τ was the time that 0.63 of the whole displacement of blade occurred.

3. RESULTS AND DISCUSSION

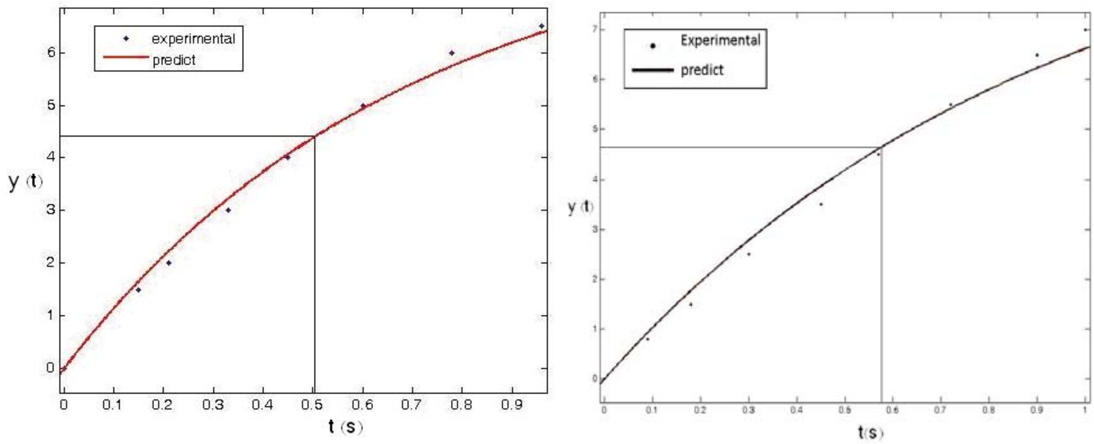
The Figures 8 and 9 show the transient response of the mechanism when the blade moves upward and downward. The results showed a transient response of about one second for both sensors. This time could be relevant to control the harvesting depth of onion.



a b

Fig. 8. Displacement of blade upward (a) and downward (b) with optical sensor replication.

Considering the Figure 8 the values for the optical sensor were R^2 = 0.99, τ = 0.5 s and k = 1.2 s for upward movement (Figure 8.a) and R^2 = 0.98, τ = 0.53 s and k =1 s for downward movement (Figure 8.b).



a b

Fig. 9. Displacement of blade upward (a) and downward (b) with capacitive sensor replication.

The values for the capacitive sensor were R^2 = 0.99, τ = 0.5 s and k = 1s for upward (Figure 9.a) and R^2 = 0.98, τ = 0.53 s and k = 1 s for the downward movement (Figure 9.b).

The results also showed similar values in stability and deviation from the set value. It is believed, however, that the control system has a sufficient response, because the onion harvesting operation is generally conducted at 0.67 m.s^{-1} ground speed.

In the second stage, the capability of the system was evaluated regarding to follow the artificial obstacles. The Figures 10, 11 and 12 show the results of the experimental responses which were conducted under the conditions with artificial obstacle of sinusoidal curve, rectangular and triangle shapes using optical sensor. All the experiments were replicated three times.

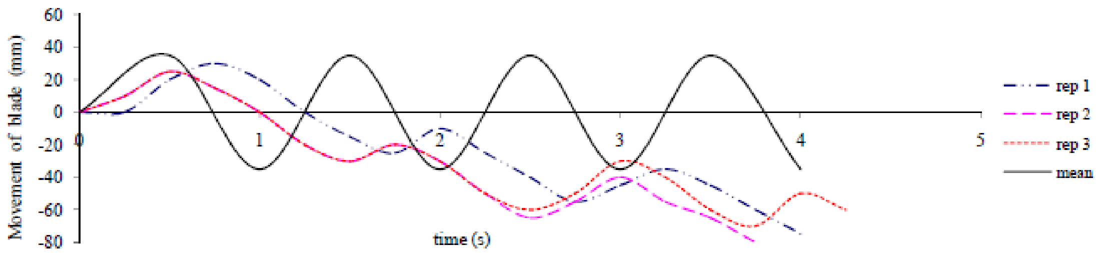


Fig. 10. Response of control system to sinusoidal curve obstacle using optical sensor in three replications.

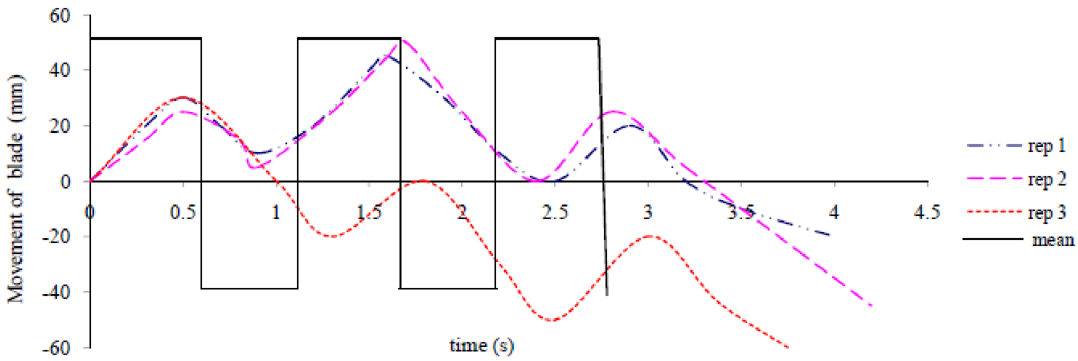


Fig. 11. Response of control system to rectangular obstacle using optical sensor in three replications.

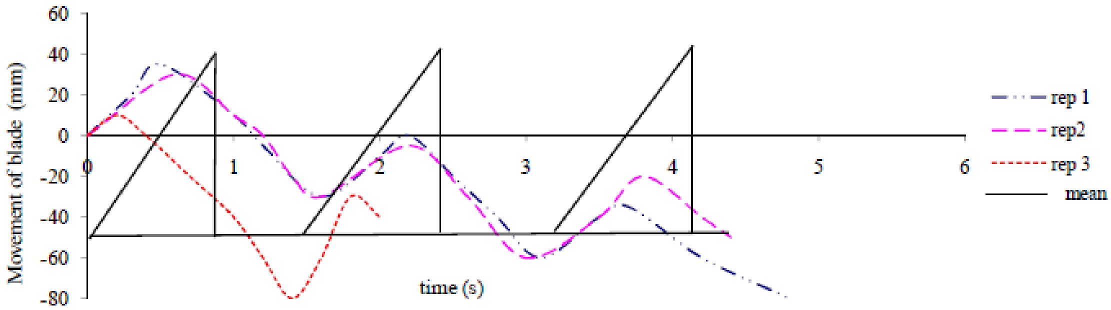


Fig. 12. Response of control system to triangle obstacle using optical sensor in three replications.

Considering the Figures 10, 11 and 12, the movement of the blade was inclined to down because the transient response of the optical sensor was not sufficient. Reflection of optical sensor to rectangular obstacle was the best among the three obstacles and reflection to triangle shape obstacle was the worst.

Reflections of control system with capacitive sensor to obstacles are shown in Figures 13 and 14. The capacitive sensor had no reflection to triangle obstacle.

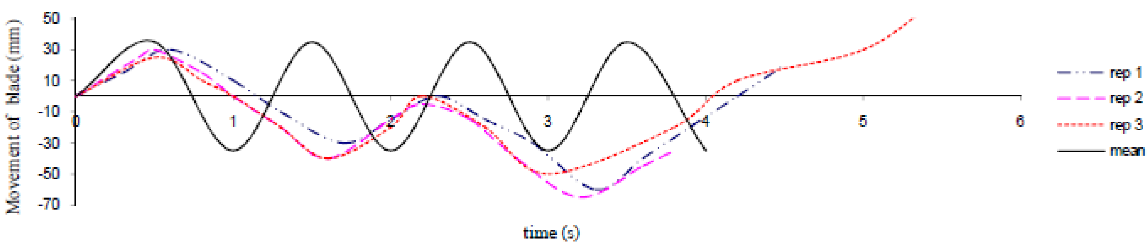


Fig. 13. Response of control system to sinusoidal curve obstacle using capacitive sensor in three replications.

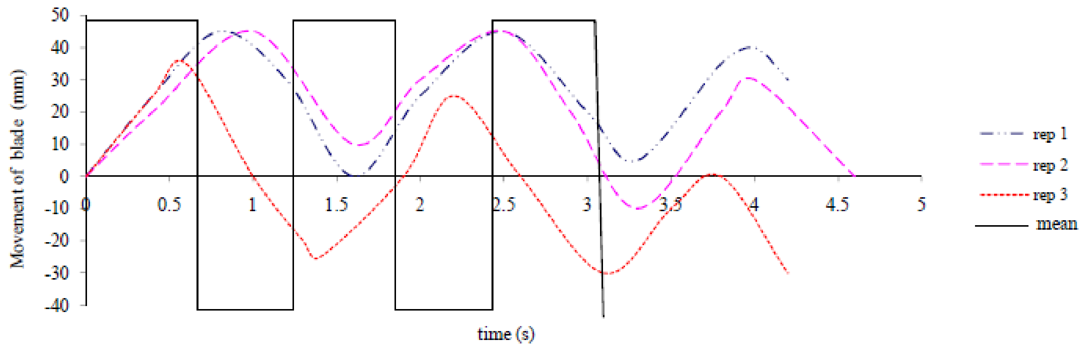


Fig. 14. Response of control system to rectangular obstacle using capacitive sensor in three replications.

Considering Figures 13 and 14, the reflection of control system with capacitive sensor to sinusoidal curve obstacle was worst and it was not able to recognize the whole obstacles. The reflection to rectangular obstacle was the best and it recognized the whole obstacles.

The average of depth error sensing was measured by sensors which the averages of the error percentages are shown in Table 1.

Table 1. The average of error percentages of optical and capacitive sensors for different obstacles.

Sensor	Sinusoidal curve obstacle	Rectangular obstacle	Triangle obstacle
Optical sensor	40	30	20
Capacitive sensor	9	38	100

The average of error percentages of capacitive sensor was lower than optical sensor but capacitive sensor did not recognize the triangle obstacle. In general the performance of optical sensor was well to recognize obstacle but the error of this sensor was not good to follow the obstacle.

4. CONCLUSION

The results of the experiments on the three obstacles showed that the transient response of the capacitive sensor was better than the optical sensor for upward movement of the blade and vice versa for downward movement. The ability of the optical sensor was better than the capacitive sensor to follow the obstacles because the capacitive sensor was not able to sense the triangle obstacles and follow the curves.

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