DESIGNING A PEPPER HARVESTER END EFFECTOR

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To my beloved family

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ABSTRACT

The cultivation of pepper (Piper Nigrum) is widely cultivated around the world including Malaysia. Malaysia is one of the major exporter of pepper in the world with Sarawak contributes 95% of the production. The harvesting process is normally done by local workers and there is no mobile robot solution. The development of mobile robot to harvest the pepper is still in research level. The purpose of this project is to design a pepper harvester end effector which able to pluck the pepper berries more efficiently. An axiomatic design approach has been used to accurately identify the needs and requirements in designing the end effector. Through this approach, the designer will be able to point out the limitation, function requirement and the design parameter by decomposing each function to multiple sub layers. The end effector developed in this research is to be attached to the existing design of mobile robots body. The end effector is made up a series of aluminum links which joint by universal joint. The actuator system being applied to this design is cable servo motor. The conceptual this design is hypothesize to be able to adapt to the pepper plantation.

ABSTRAK

Perusahaan lada diusahakan secara meluas di seluruah dunia termasuklah di Malaysia. Malaysia merupakan antara pengeksport terbesar dunia di mana negeri Sarawak menyumbangkan 95% daripada keseluruhan hasil. Kaedah penuaian buah lada biasanya dilakukan oleh tenaga buruh tempatan tanpa bantuan mesin penuai robotik. Kajian kini mengenai mesin penuai robotik masih dalam tahap penyelidikan. Tujuan penyelidikan ini adalah untuk mereka cipta sebuah *End effector* bagi mesin penuai robotik yang mampu memetik lada dengan lebih berkesan. Konsep *Axiomatic Design* digunakan untuk mengenal pasti dengan tepat keperluan dalam mereka cipta *End Effector*. Melalui konsep ini, pereka cipta dapat mengenal pasti had, keperluan fungsi dan parameter rekaan dengan menghuraikan setiap fungsi kepada beberapa sub-fungsi. Rekaan *End Effector* di dalam penyelidikan ini adalah untuk digabungkan dengan rekaan mesin penuai robotik yang sedia ada. *End Effector* ini diperbuat daripada sesiri struktur aluminum yang disambung dengan *Universal Joint*. System kawalan yang digunakan pula adalah *Cable Servo Motor*. Rekaan ini diharapkan dapat diadaptasikan di kawasan perusahaan lada.

TABLE OF CONTENT

Content **Page**

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Introduction

The introduction of robotic in agriculture sector seems to be less popular compared to manufacturing industry. Although robotics is one of the fastest growing engineering fields, the application of robotics in agriculture sector is not as much as manufacturing industry due to cost and adoption of the robot to the agriculture environment. But, in Japan for example, the agriculture robots widely applied to harvest fruits in the greenhouse.

Today, the development of robotics in agriculture sector is rapidly ongoing since more and more understanding in microelectronics and computer gained. The existence of some agricultural robots such as tomato, strawberry, and grapes harvester has giving a big impact in developing the other types of agricultural robots application.

Figure 1.1: Tomato Harvester (Gyimah, 2009)

However, many agriculture robots are currently not in the commercialization or diffusion stage (Sakai *et al.*, 2008). Thus, further research is needed in order to improve the performance and reduce the initial cost of these robots. Kong S. G., (2009) has come out with a conceptual design of mobile robot for pepper harvester. The study was focus on the whole parts of the robots and the effectiveness of the robots might be far from the target. The design of the end effector of the pepper harvester need more degree of freedom (DOF) since the pepper berries are often hidden by obstacles such as leaves, stems and twigs. Furthermore, the end effector must be able to going inside the shrub without destroying the leaves and stems.

1.2 The needs of the study

Agricultural tasks have been an important application area for different kinds of technologies to improve crops production, farm and their related operation. Good understandings about pepper plant are required in order to improve the harvesting process of pepper plant. In agriculture sector, the pepper plant normally growth vertically by climbing to wooden pole at about 4m high. The matured pepper plants are practically bushy and even manual harvesting process also facing difficulty in harvesting the pepper fruits. The pepper fruits usually located deep and hidden inside the plant. This condition leads to big challenge to design the end effector of the harvester.

Harvesting the pepper fruits is not as simple as harvesting others fruits such as tomato and apple. A harvester for tomatoes normally can easily recognize and harvest tomatoes compared to pepper berries which is hidden by the leaves and located deep inside the plant. The flexibility of a harvester is required in order to pluck the pepper berries without damaging the pepper plant.

As the world population increase, the food demand also will increase rapidly (FOA, 2009). The demand of pepper in food seasoning is also expected to increase. According to Kong. S. G., (2009) the rate of harvesting pepper by manual labor is considered low. The end effector of the harvester is the key to solve this problem. Furthermore, the labor cost in this sector also considered very high.

1.3 Objective of the study

The main objective of this project is to design the conceptual design of the end effector of pepper harvester. In order to achieve this objective, the author will design a new and redesign the previous research on pepper harvester robot.

This design is expected to be able to solve the problems regarding to the flexibility of the end effector. In addition, this study could serves as an inspiration for other researchers to develop any kind of agricultural robot's end effector. Furthermore, the end effector design also expected to be able to manufacture in the future.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter reviews the development and availability of the end effector in agriculture sector which possible to be adopted into the end effector of pepper harvester design. The study in this chapter is based on the objective mention in the previous chapter. The discussed information will be gathered and analyzed for solution in the design process in the following chapter.

2.2 Pepper plant feature and harvesting method

Pepper or piper nigrum originate from a region in the western coast of South India. This plant is under the family *Piperaceae* (Top Tropica, 2009). It have green leafy vine growing and spreading by climbing a vertical wooden post about 3m height or just spreading on the ground for wild pepper. With strong stem, the plant grows a lot of side shoots to create a bushy column. The berries of pepper are produced in solitary, unbranched and axilary spikes. The pepper berries consists of small green spherical fruits which is measuring about 5mm.

Figure 2.1: Pepper plantation (Raintree Nutrition, I. 1996)

The harvesting process of pepper berries normally done when several berries in the bunch started to become ripe which is in red color. In India, the harvest season begins on January and extends until March while in Malaysia in Sarawak especially, the harvest season begins from May to July (IPC, 2009). Usually the harvesting process is done manually using hand. The workers have to climb a ladder to harvest the berries located on top of the plant. The pepper berries then separated manually from its spike and dried under the sun for a few days. Harvesting of pepper berries is another labor intensive operation where it accounts more than 50% of the total labor requirement in pepper cultivation (Ibrahim *et al*., 1993).

2.3 Robot geometry and kinematic

Robot geometry is the study of robot kinematics that requires a unified methodology to identify the variables of a robot such as manipulator's joints and links (Crowder, R.M, 2010). The mechanism involved in robotics motion is a mechanical system that has the main purpose of transferring motion and/or forces from one or more sources to one or more outputs. For example, a linkage which is consisting of rigid bodies called links that are connected by either pin joints or sliding joints (Kumar, V, 2010).

2.3.1 Degree of freedom (DOF) or mobility

According to Norton, R.L (2004) a mechanical system's mobility can be classified according to the number of freedom (DOF) that a system possesses. The system DOF then is equal to the number of independent parameters that are needed to uniquely define its position is space at any instant of time with respect to a selected frame of reference. In order to determine the overall DOF of any assembly of links can be predicted from an investigation of the Gruebler condition and leads to Gruebler's equation:

$$M = 3L - 2J - 3G$$

Where: M = degree of freedom or mobility

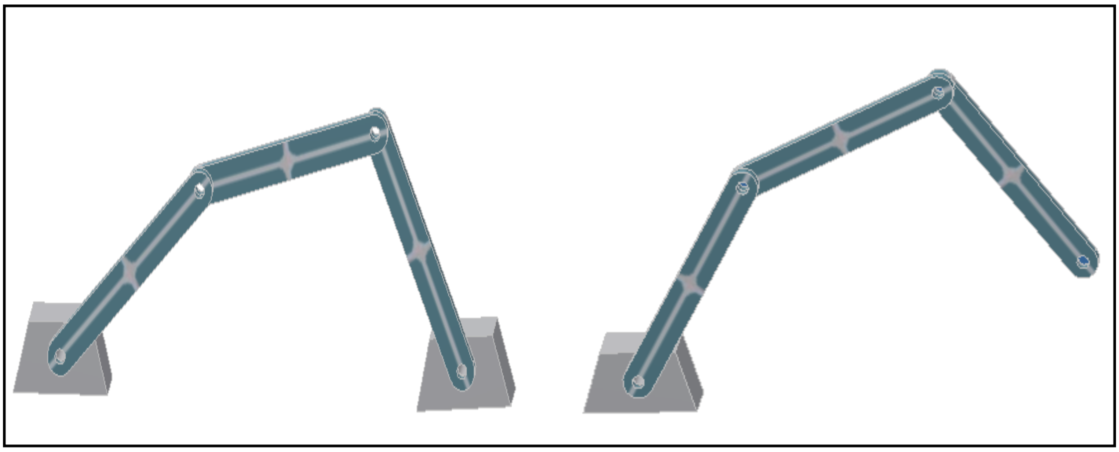
L = number of links

J = number of joints

G = number of grounded links

2.3.2 Kinematic chain

Kinematic chain is a system of rigid bodies connected together by joints. Kinematic chains or mechanisms as shown in Figure 2.2 may be either open or closed. A closed mechanism will have no open attachment points or nodes and may have one or more degree of freedom. An open mechanism of more than one link will always have more than one degree of freedom, thus requiring as many actuators as it has DOF.



(a) Closed mechanism chain **(b) Opened mechanism chain**

Figure 2.2: Mechanism chains

2.3.3 Joints

A joint is a connection between two or more links which allows some motion, or potential motion, between the connected links. There are mainly four types of joint that can be found in robot's manipulator.

1. Revolute, rotary or pin joint (R)

2. Prismatic or sliding joint (P)

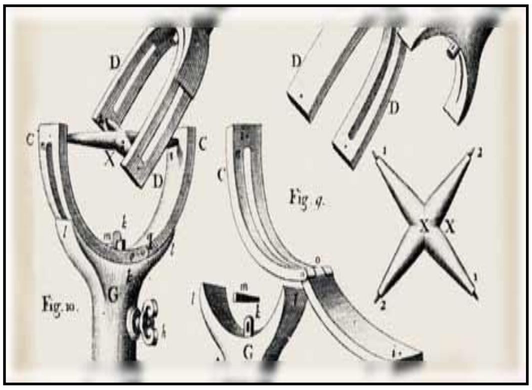
3. Spherical or ball joint (S)

4. Helical or screw joint (H)

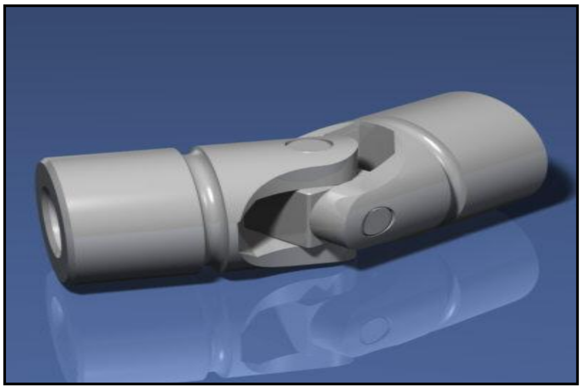
The revolute joints allow a rotation between the two connecting link. The best example of this is the hinge used to attach a door to the frame. The prismatic joint allows a pure translation between the two connecting links. The connection between a piston and a cylinder in an internal combustion engine or a compressor is through a prismatic joint. The spherical joint between two links allows the first link to rotate in all possible ways with respect to the second. The best example of this is seen in the human body. The shoulder and hip joints, called ball and socket joints, are spherical joints. The helical joint allows a helical motion between the two connecting bodies. A good example of this is the relative motion between a bolt and a nut (Kumar, V, 2010).

2.3.4 Universal joint

More than 2,000 years ago, the first known application of the universal joint occurred in china. The Chinese had invented “gimbals”, a series of interlocking rings within a device that allowed a candle placed in the center to remain upright regardless of the device’s position. The Figure 2.3 (a) shown the “gimbals” invented by The Chinese (Driveline Service of Portland, 2010).



(a)



(b)

Figure 2.3: Universal joint

Universal joints are seldom used or apply in robotics application. Universal joints allow rotation between two links allow four direction of motion. The universal joint is essentially a pair of hinges at 90 degrees from each other, allowing opposite sides of the joint to move in any direction from the axis (two degrees of freedom).The application of universal joint frequently used in military application and construction equipment. The Figure 2.3(b) shows the common design of universal joint (Turbosquid, 2010).

2.4 End effector

In the field of robotics, an end effector is known as a device or tool that is connected to the end of a robot arm functioning as a human hand and able to interact with the environment (TechTarget, 2008). Robotic end effector for agriculture operation such as harvesting, spraying and transplanting has been developed in recent years. To accomplish such task, the robots manipulators should have the ability to reach, grasp, pick and cut the biological object effectively. The end effector of agriculture robots is one of important components in the development of agriculture robots since the manipulator interact directly to the plants and could jeopardize the quality of the product. The end effector which is linked to the robots arm probably the most complex part while building any robots. Figure 2.4 below show the robots arm which is being use for palletizing (Global Robots, 2009).

Figure 2.4: End effector of ABB irb 640 a specialized handling robot (circle region)