Design And Control Of Agricultural Robot For Tomato Plants Treatment And Harvesting

Arnes Sembiring¹, Arif Budiman² and Yuyun D Lestari³
¹,²,³Teknik Informatika, Sekolah Tinggi Teknik Harapan, Medan, Indonesia
arnessembiring@gmail.com

Abstract. Although Indonesia is one of the biggest agricultural country in the world, implementation of robotic technology, otomation and efficiency enhancement in agriculture process hasn’t extensive yet. This research proposed a low cost agricultural robot architecture. The robot could help farmer to survey their farm area, treat the tomato plants and harvest the ripe tomatoes. Communication between farmer and robot was facilitated by wireless line using radio wave to reach wide area (120m radius). The radio wave was combined with Bluetooth to simplify the communication between robot and farmer’s Android smartphone. The robot was equipped with a camera, so the farmers could survey the farm situation through 7 inch monitor display real time. The farmers controlled the robot and arm movement through an user interface in Android smartphone. The user interface contains control icons that allow farmers to control the robot movement (forward, reverse, turn right and turn left) and cut the spotty leaves or harvest the ripe tomatoes.

1. Introduction
Although Indonesia is one of the biggest agricultural country in the world, implementation of robotic technology, otomation and efficiency enhancement in agriculture process hasn’t extensive yet. Indonesian’s tomato farm in the modern channel which adopt agricultural technology about 25% Indonesian’s tomato farm [1]. One component of modern farm is involving automation technology in farming such agricultural robot. Research in agricultural robot has begun since 1980 when citrus harvesting robot designed in University of Florida. Subsequently, numerous agricultural research (fruit and vegetable) were initiated and studied [2]. While many prototypes of agricultural robots have been design and developed for various plants, commercial deployment still inhibited by many challenges. The technical challenges include the unstructured environment of the field and the constantly changing field conditions. Obstruction of fruit by leaves or other fruit is one an other technical challenges because it limit fruit identification and robot effector reach. After that, the fragileness of fruit caused by pressure and bad handling also the important challenges [3].

The economic infeasibility and low return of agricultural robot also prevent commercial development [4]. One approach to improve the performance of agricultural robots is combining human workers (farmer) and agricultural robot synergistically. Human workers (farmer) collaborate with robot in target detection dan control of end effector. This approach has increased average target detection from 75-85% (robot only) to average of 94% (collaboration human and robot) and reduced the time required for detection by 20% [5]. An other approach is separating the system for environment sensing from agricultural robot (robotic harvester). The robot operate separately (independently) from the sensing system so the speed of operation is no longer limited by the sensing method but by its menchanical capabilities and the fruits susceptibility [4].
In this paper we introduce the new architecture of tomato harvesting robot. This robot contains wireless communication unit via radio wave combined with Bluetooth for communication to Android smartphone, low cost wireless video surveillance system unit, Arduino main controller unit to control arm, end effector and wheels and action unit which consist wheels, arm and end effector.

2. Work Environment
The work environment for the agricultural robot is shown in Fig.1. The space between rows about 70 cm. The field of robot working is uneven surface farm and sometime contain soft and moist soil. For harvesting, robot need to reach and cut the ripe fruit. In common tomato, maximum plant height is 2.5m but fruit to be harvested about 0.15m to 1m. For treatment, robot need to reach spotty leaves which contain blight. Spotty leaf must be removed from plant.

![Fig. 1 Tomato field condition](image)

3. Treatment And Harvesting Robot System
The proposed model of tomato harvesting robot is shown in Fig. 2. This robot has a vision unit for image acquisition, a jointed manipulator of 4 freedom degrees, 2 driven wheels and one omni wheel, the system controller and container. The vision unit consists a surveillance camera, video transmitter and receiver using 5.8 GHz radio frequency, a 7 inch monitor for real time displaying of tomato image and environment for user. The manipulator built from thick acrylic and end effector contain scissors for ripe fruit and spotty leaf cutting. The manipulator is jointed by 5 Servo and controlled by Arduino Uno. The motor servo has 10 kgf.cm torsion and 4.8 to 7.2 V operating voltage. The controller unit consists Arduino Uno, the 433 MHz radio frequency transmitter and receiver modul, the bluetooth modul for connecting data to Android smartphone. A user interface is built in Android smartphone and gives farmer full accessibility to control robot movment and action.
The structure of the agricultural robot is shown in Fig. 3. Main controller of the robot system is Arduino Uno which consists ATmega328 microcontroller. Arduino Uno controls 4 system consist velocity controlling of DC motor to drive the wheels and robot positioning, five servo motors to control arm and end effector position, environment surveillance system activation and wireless communication system between farmer and robot. A surveillance camera is mounted on the end of arm in order to give the farmer wide area and flexible surveillance.

Communication between farmer and robot is facilitated by radio wave. Farmer Android smartphone send farmer direction via Bluetooth to independent Bluetooth module. The independent Bluetooth module communicate serially to radio transmitter and the radio transmitter send the data via radio wave to radio receiver in robot side. The radio receiver communicate the data of farmer direction.
serially to Arduino Uno. Then, Arduino Uno control the wheels, arm and image capturing activation based on farmer direction.

If the farmer want to change the position of robot for farm surveillance or plant treatment, the farmer just open the installed application on smartphone which offer the interface to control the DC motor and each servo. The wheels driver are two 12-24 Volts DC motors which drived by 4 channel relay module. The relay continue and increase signal power from Arduino Uno. The differential driving technique is used to control the trajectory of robot. The robot trajectory depend on variation of two wheels velocities. To achieve the flexible movement, one omni wheel is used and placed in the center front of the robot.

The point that the robot rotates around is known as the Instantaneous Center of Curvature (ICC), shown in Fig. 4. The trajectory of robot movement is defined by each velocity of the two driven wheels. The rate of rotation (ω) about the ICC of two wheels must be the same because the two wheels have a common shaft. So, the following equation can be obtained:

\[ V_r = \omega \times \left( R + \frac{d}{2} \right) \]  
\[ V_l = \omega \times \left( R - \frac{d}{2} \right) \]

![Figure 4. Differential drive system](image)

Where \( d \) is the distance between the centers of the two wheels. \( V_r \) is right wheel velocity and \( V_l \) is left wheel velocity. \( R \) is the distance from the ICC to the midpoint between the wheels [6]. From equation (1) and (2), at any instance of time \( \omega \) and \( R \) can be obtain as follows:

\[ \omega = \frac{(V_r - V_l)}{d} \]  
\[ R = 0.5 \times \frac{(V_r + V_l)}{(V_r - V_l)} \]

From the above equations, the 4 following situation of control are valid:

1. If \( V_r = V_l \), then the robot move forward in straight line.
2. If \( V_r = -V_l \), then the robot rotate 360° about the midpoint of the wheel shaft.
3. If \( V_r = U \), then the robot rotate 360° and the midpoint is right wheel.
4. If \( V_l = U \), then the robot rotate 360° and the midpoint is left wheel.

4. Results

The main purpose of this agricultural robot is farm surveillance, treatment and harvesting tomatoes. Differential drive technique is implemented for robot navigation. Navigating between crop rows is enough fluent and the robot pass through the uneven land. The robot run in flat land easily but still face with a little difficult in steep grade land. The dimension of robot is 60 x 45 cm, maximum vertical distance from ground that the robot can reach is 80 cm and maximum horizontal distance from outer
body of robot is 95 cm. Experiments is implemented at a tomato field to test the robot performance. Test speed of the robot is 0.65 m/s and test load is 10 kg. Maximum distance from robot to Android smartphone and monitor (farmer side) in line of sight is 120 m. There is no significant delay time between user action in Android smartphone and robot responses. Average single harvest cycle from fruit cutting till fruit placing to container is 35 seconds. The captured image by camera and transmitted by radio wave still contain noise. The test field shown in Fig. 5.

5. Conclusion
In this study, agricultural robot, which could navigate between tomatoes rows, cut the ripe fruit and spotty leaves based on farmer order, was developed. The control interface in Android smartphone gave the farmer full control to robot movement and action. Although the image still contain noise, the farmer could survey the land and plants via monitor. The further work is mechanical structure enhacement, image restoration and processing, autonomous fruit identification and web based plant treatment (IoT).

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