Farmer Robot for Harvesting and Maintaining Plants

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Abstract* — Agriculture falls vulnerable to the impacts of climate change, which implies that any change in the climate can significantly affect the quality of the crops produced. Moreover, issues like labour problems, labour costs, productivity problems, etc. are stumbling blocks of traditional cultivation systems. Also, farmers need to produce more, at a higher quality, and in a sustainable manner to feed the increasing population. All these complications necessitate an automated system in this sector. In this project, we have built an autonomous robot that can detect ripe fruits or vegetables using colour detection mechanism and successfully harvest those with a robotic hand. The system can be sub-categorized into three units– fruit picker, watering pump and sensing unit. The function of fruit picker is the identification of ripe fruits or vegetables by their colour, cut them off of the tree and then store them into suitable storage. The watering unit will pump water and necessary elements from the source tank and spread it in the field. The sensing unit is for the indication of the instant state of surroundings to help a farmer to choose the right steps to be taken. Although there are some initial costs to implement this system, this robot can precisely detect the right fruit (e.g. tomato or pepper) to be harvested and hence it can be used to pace up harvesting speed and save the labour and other associated costs. In this study, we have described the detailed processes followed to build this robot; hardware used; software implemented and assembly of the whole system as a functional unit.

***Keywords* — Robotic arm, Convolution Neural Network (CNN), ATMega 2560 processor**

I. INTRODUCTION

Bangladesh is an agricultural country. At the same time, it has a large number of populations. So, automation in the agricultural sector is badly needed as we have to produce more harvests to feed more population. Moreover, youth are turning away from this profession, so less man-power is available to drive the vision forward [1]. Improper distribution of seed and fertilizer is one of the new discovered problems in Bangladesh. This problem has recently found by many researchers and agriculturists. Our seed and fertilizer aren't properly distributed and as a result each year farmers face severe crisis having adequate stock. There are many faults occurring at the time of picking harvest and also those farmers can't pick harvest at in time. This affects harvest quality too much. The traditional agricultural system suffers from labour problems, labour cost problem, productivity problems etc. On the contrary, a robot can be efficiently operated all day long without any fatigue. So, the labour problem and its associated costs can be greatly reduced by introducing robotics and automation in traditional farming [2], [3]. In fact, some phenomena are especially considerable and important for developing countries like Bangladesh. Mostly used agricultural machines in developing countries are either irrigating machines or pesticide-spraying machines. This study represents a combination of some common robotic technologies that can be used in the agricultural sector of developing countries like Bangladesh [4].

The main objective of this study is to investigate how robotics can be utilized in a farming context in a developing country. Moreover, the robot will replace hand-based farming by a device, working autonomously at field level and reduce chemical usage and labour needs and after enabling small farms with limited numbers of workers to compete globally. The concept of this farmer robot is inspired by the worldwide implementation of robotic manipulators in agricultural sector including very recent research works done in Bangladesh like design and simulation of a robot-farmer by the students of Khulna University of Engineering and Technology in 2014 [5]. Recently, a French company has designed an autonomous harvesting robot called "Vitirover" which uses the solar power for the electrical motors which could work for hours without any pause and used for cutting grass and weeds in vines within 2 to 3 cm of the vine and has a speed of 500m/hr [6]. For farmers, it is very important to use technology-friendly devices in the vines. "Vitirover" uses sensors and GPS system that keeps the robot away from grapevines [7]. Another system has designed to collect, monitor and control the tomato field but the watering system of that bot is manually controlled [8]. In this project, we have built a fully autonomous robot that can do these three works simultaneously: harvesting, watering, and sensing and have tested the bot for a pepper plant with red peppers.

METHODOLOGY

Our primary purpose is to build a prototype robot, driven by 4 high-torque DC motors with 200-RPM speed, and 30kg carrying capacity. The robot body has made from an aluminium sheet [9]. Wheels each of 5-inch diameter are used to run the bot. A circuitry section has set up to supply the necessary power to run communication modules and processing units. The fruit picker is situated in front of the circuitry box. A robotic hand, attached to the robot, extends nearly 30-inch, having base, shoulder, elbow, wrist, and gripper. Base consists of servo motors with bearing. Grippers are designed to grab a fruit [10]. A cutter has also attached with it to cut the peduncle of the fruit. A camera with a video transmitter has placed beside the base. An attached-box upon the body has placed which carries fertilizer and water. Some sensor modules are also connected with the bot to give real-time data of its surroundings. As shown in Fig. 1, the units used in this robot are interconnected, hence making it a reliable system.

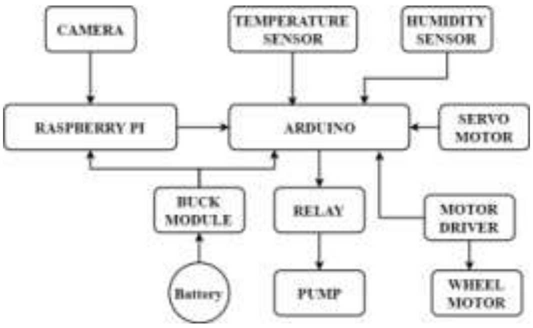

Fig 1: Interconnected system diagram of farm-bot

This robot is able to recognize harvest efficiently by its processing unit which uses the colour detection method [11]. When the robot is in its operational mode, it decides automatically what to do. The camera sends a video signal to the processing unit received by a video receiver. Then the processor sends it a command and the robot will be operational. This robot can be used for watering, fertilizing etc. Alongside these, the temperature and humidity sensor module measures temperature and humidity and check the need for water for the plants. Two 24-V rechargeable led-acid DC battery supply the necessary power to the robot, a solar panel also can be attached with the robot. This automated mobile robot shown in Fig. 2 can move around in a given area and explore the area for identifying different objects and find out the appropriate fruit/vegetable to be picked, when the localization is completed, the bot simply goes to the right co-ordinate and by using its 4 servo motor-based arm system, it picks up the harvest. Moreover, the bot will show the current states of surroundings by using its sensing block and supply water and fertilizer when needed.

Fig 2: Farm-bot

II. ROBOT DESIGN SPECIFICATIONS

A. Mechanical Structure

Stability and machinability, as well as fatigue strength, are important factors in agricultural robots as those will be operated on direct soil. The main wheel motors should have enough weight carrying capacity as the bot will carry water, fertilizer and obviously, its own control and processing components. To meet these all needs, we have chosen aluminium as the base frame and body material. Aluminium is a cheap metal with reasonable mechanical properties [5]. Alongside this, we have used 4 DC motors with 30 kg-cm torque capacity and 200 rpm speed. Moreover, the wheels have stainless-steel-guard ring which will protect it from external damage factors and all of the DC motors are separately controlled by a motor driver. The base dimension is 43.18 cm width and 35.56 cm length and 76.2 cm in height. That means the robot consumes a total of 0.11 m^3 volume. As a result, this robot can move into the field without affecting the plants. Fig. 3 shows the base structure of robot.

B. Robotic Arm

The robotic arm shown in Fig. 4 consists of four MG995 servo motors with proper mountings and aluminium-built rectangular pipe. Servos used in this arm are arranged in such a way that the arm can move in all the possible directions needed. This robotic hand has 6 degrees of freedom which is much greater than other commonly used robotic arms [12]. Not only that, the radius of the working zone of this robotic hand is around 60 cm. A servo motor-controlled cutter is attached with this robotic arm to cut fruit/crop. Before the practical implementation, the arm design was simulated in Solidworks™ environment to test its feasibility.

Fig 3: Chassis of farm-bot

Fig 4: Robotic arm with cutter

C. Water pumping and sensing unit

As this robot is a prototype of the real one, we've used a 6W mini-pump to water the plants when needed. A water reservoir is attached to the bot and the machine pumps water from the reservoir to spread on the field. To prevent unbalanced watering, the pumping machine is automatically controlled by the Arduino™ board. Actually, the timing of pumping operation is based on humidity and temperature sensor data processed by the ATMega 2560 processor. Pump run-time is calculated by this formula: $R = (T \times H) \times (100\text{-}Sm)$, here R is the pump rum-time, T is temperature, H is humidity, and Sm is soil moisture [8].

D. Software Architecture

Convolution Neural Network (CNN) has used to train our bot for identifying the location of fruit and in this case, python has used as programming language. For colour detection, the masking parameter has set to {(0, 50, 20), (5,255,255)}. The image processing unit separates the object coloured within this range. The input shape of training is (64, 64, 3). The loss function used here is "categorical_crossentropy" and the optimizer is "rmsprop". All the images run 100 epoch, that means it runs 100 times for a single image. As an example, we have selected a red pepper to be detected and the detection technique is illustrated in Fig. 5. The total detection flow-chart is illustrated in Fig. 6.

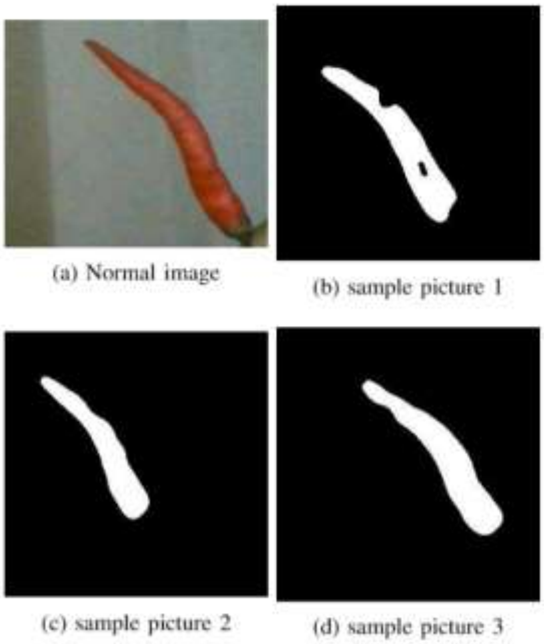

Fig 5: Pepper extraction by colour detection method

III. RESULTS AND DISCUSSION

The firming robot built in this study is a prototype of the farm-bot which will help a farmer for harvesting, irrigation process, fertilizing a lot. In the case of the harvests whose are not detectable by color-detection method, can be picked up in their ripping season. This farm-bot has been tested and its performance measurements have measured using a pepper plant. It successfully detects the ripe pepper and collects it using its robotic-arm scissor which is illustrated in Fig. 7. Alongside these, the temperature and humidity sensor module measure temperature and humidity and also check the need for water to the plants.

Fig 6: Flow chart of Farm-bot

Moreover, the bot is rechargeable and can be recharged by a solar panel if added. So, it can be used in those rural areas where electricity supply isn't available. The voltage, current rating and power consumption by each of the components used in this robot has been presented in Table.I.

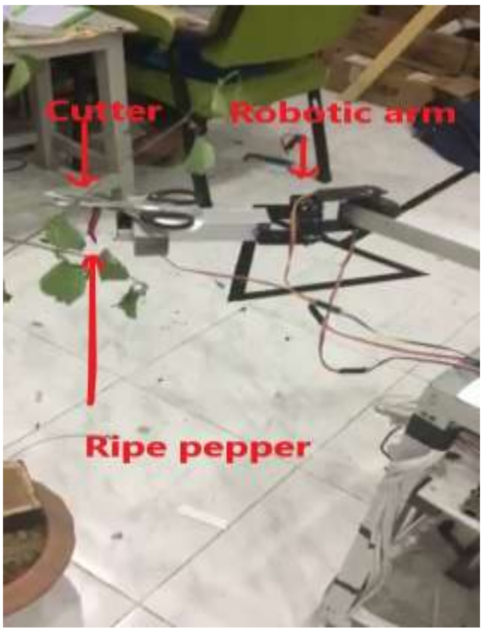

Fig 7: Farm-bot cutting ripe peeper

TABLE I: VOLTAGE/CURRENT RATINGS AND POWER CONSUMPTION BY DIFFERENT UNITS

Item name	**Rating/Power consumption**
Operating voltage	24 V
Pump power	6 W
Wheel motor voltage	24 V
Wheel motor power	24 W
Processing unit devices voltage	5 V
Processing unit devices power	2.5 V
Servo motor voltage	5 V
Servo motor current	550 mA
Servo motor power	2.75

IV. CONCLUSION

This study has presented a design for a four-wheeled, rechargeable agricultural mobile robot for harvesting and maintenance in ecologically grown fields. A forward-looking camera system for crop position estimation, based on convolutional neural network, that is able to recognize crop rows at high speed has used in this system. Not only that, a sensor-based watering system has implemented. This study reviews the possibility of the implementation of computer vision technology in the agricultural and fruit-picking industry. Day by day, computer vision-aided systems have been implemented increasingly in the industry for detection and operations as they can provide rapid, economic, and consistent performance. However, difficulties still exist, evident from the relatively slow uptake of computer vision technology in field-level farming in Bangladesh. But this type of affordable robots can be a companion of poor farmers as the initial and maintenance cost is quite low. The power rating of the robot is only 115.25W when it is in its full operational mode.

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