Construction and development of an automatic sprayer for greenhouse

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Abstract: This paper presents design and construction of an autonomous robot for using in greenhouse condition. The robot designed to prevent human hazards involved in spraying potentially toxic chemicals in the confined space of a hot and steamy glasshouse. In order to navigate the robot, hot water piping rails along the rows were used as a method of guidance for autonomous robot. The robot is able to force and back along the hot water piping rails of rows in greenhouse avoiding the expensive and complicated navigation systems. Power was transmitted from two DC motors to two driving wheels through a gearbox and shaft system. The AVR microcontroller controls all of the inputs and outputs of the system. To program the micro used from BASCOM-AVR version 1.11.9.8 and for circuit simulating used from PROTEUS 7 professional. The obtained Results indicated that the robot is capable to cover more than 90% of surface which needed to spray.

Keywords: Autonomous robot, human hazards, design, spraying, greenhouse, AVR Microcontroller

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1 Introduction

The function of a greenhouse is to create the optimal growing conditions for the full life of the plants (Badgery-Parker, 1999). The favorable atmosphere created inside greenhouses for plant growth causes pests and undesirable organisms to thrive as well, making necessary the use of pesticides and other chemical products that must be sprayed directly on the plants. Today solutions massively depend on heavy chemicals, plentifully distributed at given time intervals, making the greenhouse indoors highly toxic, with operator health shocks and forbidden re-entry long lasting delays. Recent studies reported confirmation that spraying operations have hazardous effects on the health of knapsack sprayer human operators, who are specially exposed when working inside greenhouses, in conditions of high temperature and poor ventilation (Gan-Mor et. al., 1997). The ideal time to spray plants within a greenhouse is in the early evening as a result of some chemicals used on plants adversely reacting to ultraviolet light and intense heat. An automatic spraying system could be set to begin operation at night avoiding out-of-hours work whilst ensuring that the plants are sprayed in conditions that cause the least amount of damage to the plants (Sammons et. al., 2005). Figure 1 shows a typical crop of greenhouse tomatoes. Contemporarily, a human worker would walk down these confined rows with a pesticide spraying gun, in an attempt to cover the foliage of the plants with an even coat of spray.

Therefore, the automation of spraying, as well as other greenhouse operations like monitoring and control of environmental conditions, harvest support, plant inspection, and artificial pollination, has a dramatic social

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and economical impact. In the recent past some few robotic solutions for greenhouses automation have been proposed.

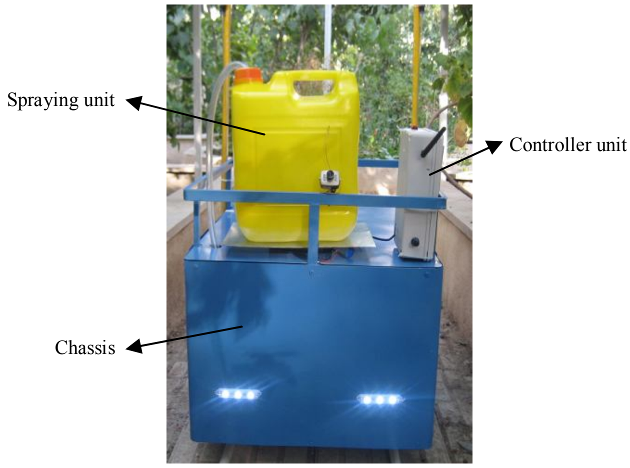
Figure 1 Typical crop of greenhouse tomatoes

Sammons et al. (2005) described an autonomous spraying robot with navigation control based on inductive sensors which detect metal pipes buried in the soil. Shariati (2004) described the mechanical arm robot for fruit detection in a particular direction. Mandow et al. (1996) described an autonomous vehicle (Aurora) for spraying tasks. The navigation control of this robot depends on a previous sequence of behavior established by an operator. Subramanian et al. (2005) and Singh et al. (2005) also described a mini-robot to perform spraying activities, for which navigation is controlled by algorithms based on fuzzy logic (Singh et al., 2005 and Subramanian et al., 2005). Some of researcher presented the Agrobot Project, a robotic system for greenhouse cultivation of tomatoes (Sandini et al., 1990 and Dario et al., 1994). This involved a mobile robot with a color stereoscopic vision system plus an anthropomorphic arm with a gripper/hand and six degrees of freedom.

This paper presents the design and construction of an autonomous robot that seeks to address some of the human health concerns associated with greenhouses. The robot is designed to enable the automation of greenhouse spraying of pesticides.

2 Methods and Material

The constructed robot consists of three main parts: a controller unit, a chassis with motor unit and a sprayer unit, see Figure 2a. The chassis (platform) carries all of the main parts of the robot including power supplies, electrical pump, electronic hardware for data-acquisition, the camera and the spraying units (Figure 2b).



a

b

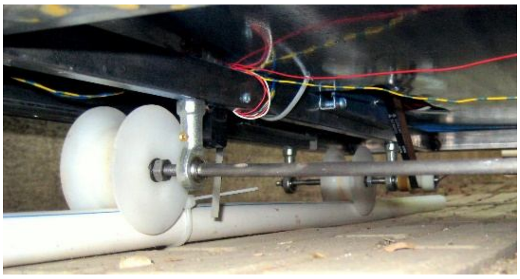
Figure 2 Photograph of the constructed robot with three main parts (a), and the constructed chassis (b)

The spray system consists of a large tank for holding the pesticides (Figure 2a), vertical spray booms with several nozzles, two pump and four valves to direct the allocated spray to the sections of plant either side of the robot as it moves past the desired spray area. The valves are electronically controlled by the on-board microprocessor which receives input signals from micro switch on the underside of the robot. As the robot passes over reflective markers placed on the ground, the pump is turned on and off to enable selective spraying of the greenhouse plants. During spraying, micro switches can shut down the right or left side of the vertical spray boom by actuating solenoid valves. This allows the robot to spray rows next to walls without wasting chemicals. Also a pesticide level control was designed using a L6D Single Point Load cell with 10 kg capacity.

The distance between the two rows on each side of the aisle was 0.8 m. An aisle is available between rows of plants, called a path, see Figure 3a. The autonomous vehicle transports the spraying unit along the aisles of the greenhouse.

Gan-Mor et al. (1997) and Michelini et al. (1998) realized the potential of steel pipes as a method of guidance for their autonomous robots. The hot water piping shown in Figure 3, is a standard installation for most modern greenhouses; therefore the same method was used in this study for the movement and guidance of the constructed robot. During a spraying operation, the constructed robot moved on the hot water pipes with 4 linearly actuated struts, driven by two 12V DC motors, see Figure 3b. The two sets of wheels were arranged in a way that there was a seamless transition in moving onto the rails, allowing the robot to drive along without the need for any expensive and complicated navigation ability.

a



b

Figure 3 Hot water piping inside the greenhouse (a), and movement of the constructed robot on the hot water pipes (b)

The user interfaces have control over the running of the microcontroller and are fed back information about the status of the robot. In the constructed robot, An ATmega32 microcontroller from ATMEL Company reads the information and controls the movements of the robot and actions of the spraying system. The microcontroller was used as the arithmetic and logic unit of the robot, see Figure 4.

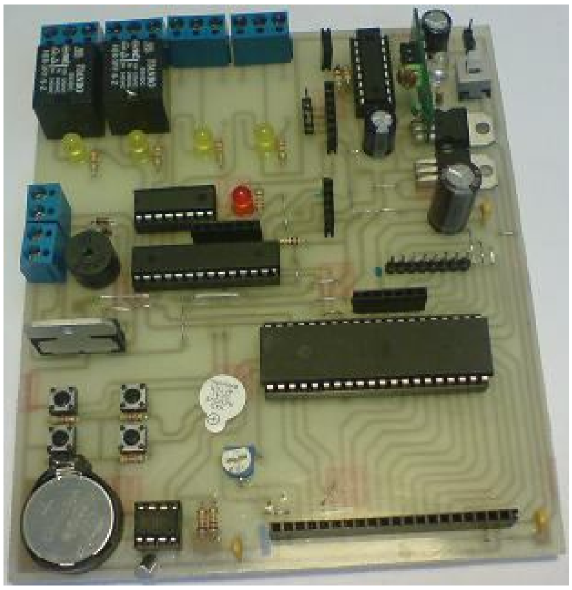


Figure 4 The electronically control unit of the constructed robot

Autonomous control and operation of the mobile robot relies on the external sensor information; therefore the performance of the navigation and spraying controller depends significantly on the installed sensors on the platform, see Figure 5. For this aim, several sensors were installed on the platform. The position of each sensor has also been studied in order to determine the best location of the sensors depending on the mechanical structure and the environment. For the commercial version of this mobile robot, only the most useful and appropriate sensors will be installed. The LCD/Keypad module shows the user relevant information on the robots status and allows the user to easily control the robot.

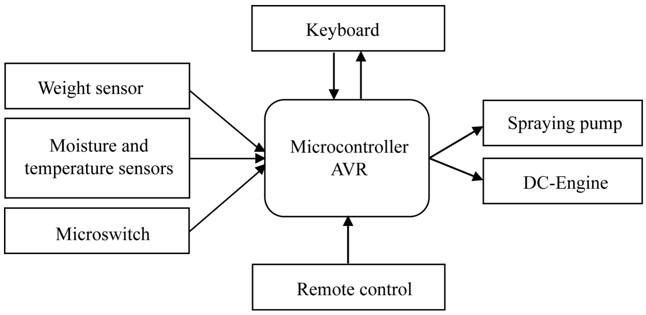


Figure 5 The electronically connection of the sensors, microswitch and other components to the AVR-Microcontroller

The AVR microcontroller controls all of the inputs and outputs of the system. The software running on the controller is Dynamic basic. The BASCOM-AVR version 1.11.9.8 and PROTEUS 7 professional were used for programming the micro and for circuit simulating, respectively.

3 Results and discussion

The robot was tested in the research greenhouse at The Tehran Technical and Vocational Center where tomato plants were grown. Each experimental test consisted of a single run down to the end of a row and back to the starting point while spraying the plants with water. Along the run, sections of tomato plants were marked out to be sprayed on both sides of the robot. Water sensitive papers shown in Figure 6 (which turns from yellow to blue when water contacts it) were placed in three locations in the tomato canopy: directly behind the fruit and facing the sprayer, upside down (exposing only the edge of the card to the sprayer) and sideways (exposing the thin edge of the card to the sprayer). When the spraying system engaged, the sprayer flew down the 125 meter alley, riding on the hot water pipes and emitting a spray pattern that appeared to completely envelop the target row. Summary of the obtained results are shown in Table 1. The presented results in this table were obtained during the spraying of two independent tomato rows, labeled with "Test 1" and "Test 2" in this table. Each experiment was conducted in 20 replications (placement of the 3×7 cm^2 water sensitive carts with distance of 50 cm in row) for the statistical certainty. During the spraying, correct triggering of the sensors and microswitches were evaluated. Every fault operation of the sensors and fluid flow microswitches were recorded. For the proper operation of the robot, microswitshes should detect the start and end triggers and immediately turn on/off the fluid flow from pump to the nozzles. At the end of the row, microswitshes should turn off the water flow. After every spraying test, water sensitive papers were collected and photographed with a canon digital camera (SX150 IS). The photographed images then transferred to the ACDSee Pro 3 software for evaluation of the spray quality and uniformity. From each photograph in the software, a 1×1 cm^2 area were randomly cropped for counting the sprayed pixels. The ratio of blue-to-yellow pixels indicated the sprayed area, see Table 1. Preliminary results obtained in this study for evaluation of the constructed robot indicated the proper and trustable operation of the robot for the greenhouse applications. More details of the generated spray by the constructed robot can be found in Kalantari et al., (2014).

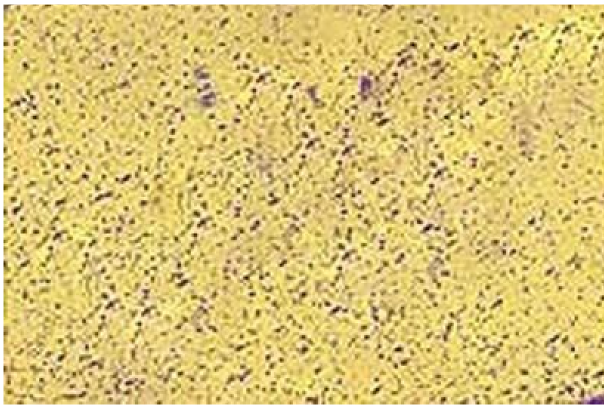


Figure 6 Water sensitive paper sprayed with water using a variety of sprayer parameters (Card is yellow until contacts with water turns them blue)

Table 1 Results of the first and second test for evaluation of the constructed robot

	TEST 1 (20 replications)	TEST 2 (20 replications)
Yellow-to-blue percent of the sprayed area (Fig.6)	92.4%	95%
Run Success (correct triggering of the sensors and microswitches)	98%	100%

4 Conclusions

The described robot was designed and constructed for simplicity and value for money, while still being able to effectively spray plants in the greenhouse. The robot was capable of driving to the end and back along the hot water piping rails of the rows in greenhouse. The platform was able to successfully and smoothly drive up and back along a row in the greenhouse and return to the work area at the end of the row. According to the experimental results obtained in this study, most of the leaves were correctly sprayed with water.

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