

## AGRIBOT-MODEL: COMPACT SOLAR POWERED SPRAYER DEVELOPMENT

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### ABSTRACT

*Egyptian agriculture cannot face the modern challenges without introducing local technology to the industry. In this study, agrochemical sprayer robot model powered by photovoltaic solar energy rechargeable cells, was developed and evaluated as a step in this long path. The constructed robot model and its main components, operation software, tests, and final results are described in this work. It was constructed via simple and cost-effective manner. Controlling the robot was achieved through Arduino Bluetooth RC Car mobile application and Bluetooth module HC-06. Arduino C language sequential code was programmed on the microcontroller to allow full control in the robot movement and agrochemicals spray function. The battery was designed to be charged using solar panel. The results of the laboratory tests including: the remote controlling, the programming of the microcontroller unit, the consumed amount of energy by all electric components, the battery performance, the effective working time, and the spray function efficiency are presented. These data were comparable to the theoretical values described in the component's datasheets. This proves the reliability of the robot's design, which qualifies it to be used as is in a prototype production. It can undertake the task of autonomously spraying agrochemicals within greenhouses effectively and safely.*

**Keywords:** robot model, greenhouses, agrochemical spraying, Arduino C language, Bluetooth, solar energy, microcontroller, DC Motor, DC pump, remote control, photovoltaic.

### 1. INTRODUCTION

**M**odern farms are expected to produce more yields with higher quality at lower expenses in a sustainable autonomous way. During the next three decades, the agricultural industry will be fronting the challenge of meeting the demands of about 9.8 billion humans predicted in 2050 (King, 2017).

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Producing more food from less land in a sustainable way cannot be achieved without employment of digital farming and site-specific precision management. Integration of digital tools, sensors, and control technologies has enhanced developments of agricultural robots (Shamshiri *et al.*, 2018). With the advances in controls theory, applications of these robots in digital farming shift agricultural practices from told fashion tedious operations to continuously automated processes. Research efforts in this extent aiming to develop robots effectively able to perform tedious field tasks have grown significantly in the past decade (Shamshiri and Hameed, 2018).

The environment can be harsh or even deadly to plants, this fact is always in concern of plant production specialists. A greenhouse main function is to maintain the optimal growing conditions to the plants and to increase the yield (Aldrich and Bartok, 1994). During 2017/2018, the Egyptian government inaugurated the first phase of a project to build 100,000 greenhouses in order to face the challenges of climate change, population growth, and water shortage (Egypt's Sisi inaugurates water-preserving national greenhouse project, 2018). The optimal plant growth conditions within the greenhouses encourage unwanted pests which can damage 30-35% of the yield, making it obligatory to use pesticides and other chemical products that should be sprayed directly on plants (Berenstein and Edan, 2017).

Chemicals are sprayed in specific time periods, making the environment inside greenhouses highly toxic. In addition, the greenhouse temperature, carbon dioxide levels, and humidity are high (Aldrich and Bartok, 1994). As a result, labors in greenhouses always work under stress in uncomfortable and hazardous environment. Traditional manual spraying operations can be harmful to human due to direct exposure to the agrochemical's liquid work environment. In order to reduce that harm, the research and development of plant protecting machine focus on improving the mechanical work efficiency (Deng *et al.*, 2012; Dongare *et al.*, 2017; Berenstein and Edan, 2018).

Spray robot can effectively apply agrochemicals isolate away from direct contact with the human body. Because of the constraints of large

agricultural robot delicate and complex nature of development, operation, and cost small wireless controlled spray robot can be a rational solution for such challenges (Shamshiri *et al.*, 2018). There were several other trials in this direction during the past decade. Sammons *et al.* (Sammons *et al.*, 2005) described a robot that works independently in the spraying of agrochemicals inside the greenhouse with remote control in navigation based on the induction sensors that reveal metal pipes placed under the surface of the soil. However, such design needs special equipped greenhouses and it will not work effectively in normal ones. Patil *et al.* (Patil *et al.*, 2017) described a control system for automatic sprayer vehicle which sprays pesticide in any given fields. The system is powered using a solar-powered battery. The Control of the vehicle movement and spraying pesticide is performed through a Bluetooth device. Nevertheless, their concept system was not developed to be applied in a working model or prototype.

Upsurge the Egyptian agriculture industries competitiveness to reduce the importing of machines and technologies in this sector and depends on the local manufacturers. To achieve this, the aim of this work was to develop and to evaluate an agrochemical sprayer robot model powered by photovoltaic solar energy rechargeable cells to eliminate the physical fatigue and the health hazards on humans. That seeks to address some of the health concerns associated with agrochemicals spraying in greenhouses. Following drawbacks of various spraying techniques shows the need of our study.

To evaluate an agrochemical sprayer robot model powered by photovoltaic solar energy rechargeable cells to eliminate the physical fatigue and the health hazards on humans. That seeks to address some of the health concerns associated with agrochemicals spraying in greenhouses. Following drawbacks of various spraying techniques shows the need of our study.

## **2. MATERIALS AND METHODS**

### **2.1. Robot model design**

Robot model design is consisting of four main parts: a chassis with four motors, a controller unit, a power unit and a sprayer unit. The chassis

(platform) carries all of the main parts of the robot including electronic hardware, power supplies, electrical pump and the spraying units. Three cameras have been installed to add monitoring and scouting capability to the system. Figure (1) displays the main parts of the robot and all the hardware components.

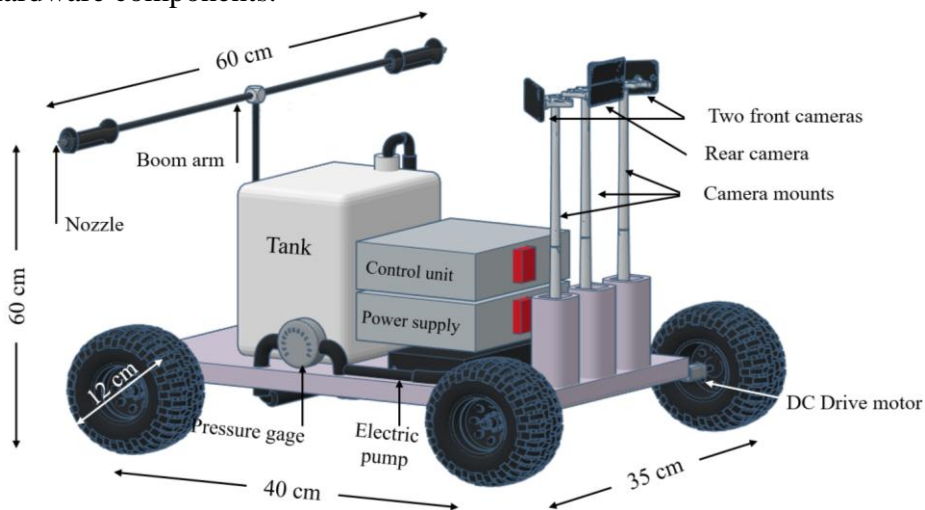


Fig. 1: Main parts and dimensions of the robot model.

Figure (2), illustrates the block diagram of the proposed robot model system and its elements. As can be seen, microcontroller is the main unit of the complete system. Four motors also have been incorporated for controlling the robot movement and directing process in narrow distances. An electric pump is included for spraying purpose.

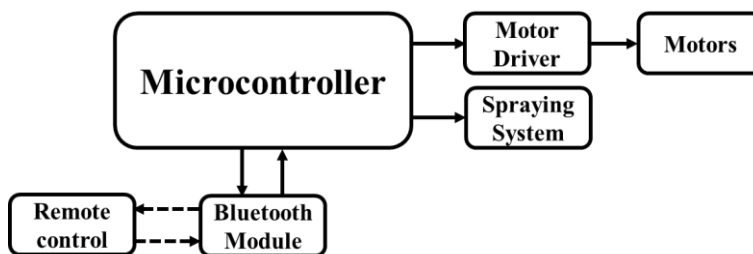


Fig. 2: The block diagram of the proposed system.

The microcontroller is the main unit of the complete system. It consists of two parts, one is transmitter and the other is receiver. The transmitter part

has a Bluetooth module. The solar panel, Bluetooth and storage battery make the input of the system. The receiver part consists of microcontroller, relays, *L293D* motors, and electric spray pump. The sun rays are collected by the solar cells, where it converts solar energy into electrical energy and it is stored in the battery. It can also use direct solar energy for spraying whereas battery can be used as backup for night time's usage. Bluetooth is used as the communication technology to send instructions to the microcontroller unit, and *L293D* motors. Two relays are used, one to connect the solar panel to the battery and another for the motor of the pump to spray the agrochemicals for the agricultural fields.

## 2.2. Hardware details

The robot model consists of electronic tools and equipment with international standards that are approved and available in the Egyptian market:

- Four DC motors gearbox (12V - 12 kg.cm - 210 rpm) is used for moving and distributing good load balancing to overcome obstacles, in addition to more accuracy in sharp turns (Datasheet 1).
- Four “Dagu Wild Thumper” wheels 120×60mm (chrome) (Datasheet 2).
- Two drive motor modules *L298n* dual channel used to control the direction of motors and interface the velocity with the microcontroller (Boxall, 2014).
- Microcontroller *ATmega328P* is used to process the data and send the pulses signals to the driver's modules (Datasheet 3).
- Three lithium battery 4V- 2800ma for each one (Datasheet 4).
- PV solar panel (12V, 4.5A, and 24W).
- Charger module, TP4056 (5V- 1A) (Datasheet 5).
- Bluetooth module (HC-06) was used to control the robot movement and spraying system from a computer or smartphone (Datasheet 6; Datasheet 7).
- Electric micro spray pump, 12V-15W - 6 bar working pressure and 1.5 liter/min flow rate with protective valve type and automatic pressure switch (Datasheet 8).
- Vertical spray booms with two hydraulic nozzles (Klein and Kruger, 2011; Grisso *et al.*, 2013).

- Bourdon tube pressure gauge, copper alloy, standard version (10 bar), model 111.10, lower mount (radial) (Datasheet 9).

### 2.3. Control system

Figure (3) shows the designed control circuits of the robot model. Icon components of the circuit according to the PROTEUS 7 professional (ISIS User Manual, 2002) and its specifications according to the datasheet of the components are given in Table (1).

### 2.4. Driver module

Four 12V DC motors are used to physically run the robot and to navigate it. They were configured in the software and a DC motor drive module called *LM298* (Boxall, 2014) is needed to control the speed of the robot by change the value of Pulse Width Modulation (PWM). An Android smartphone is used to control the robot using Bluetooth module *HC-06* and *89c2051* microcontroller (Pahuja and Kumar, 2014). Figure (4) shows the connection of the Bluetooth module *HC-06* and motor driver with the control circuits of the robot model.

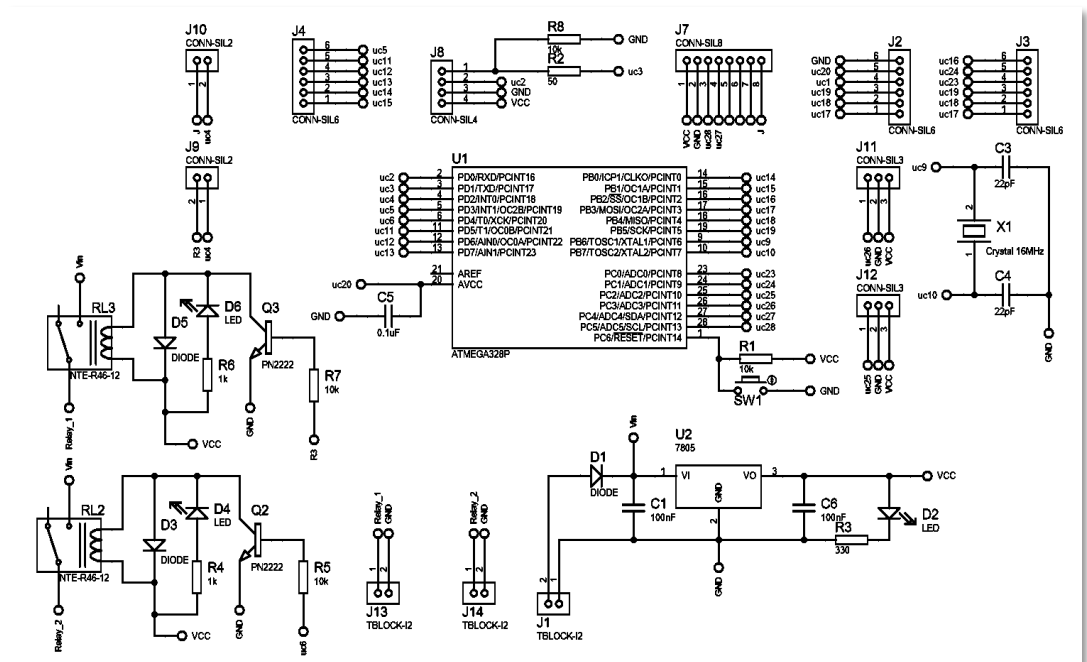


Fig. 3: The robot model control circuits.

Table 1: Icon components of the robot model control circuits

Icon	Specifications
U1	Microcontroller ATmega328P.
C3	Crystal 16 Mhz
R	Resistors 1k ohm
C	Capacitors 100 NF
Q	Transistor 2222
L2	Regulator voltage 5V LM 705
RL	Relay 5V
D	Switch bush button
SW1	Diode
J7,2,3,8	Pin output
J11,12	Pin input
J13,14	Output power of relay
J1	Input power of the circuit 12v

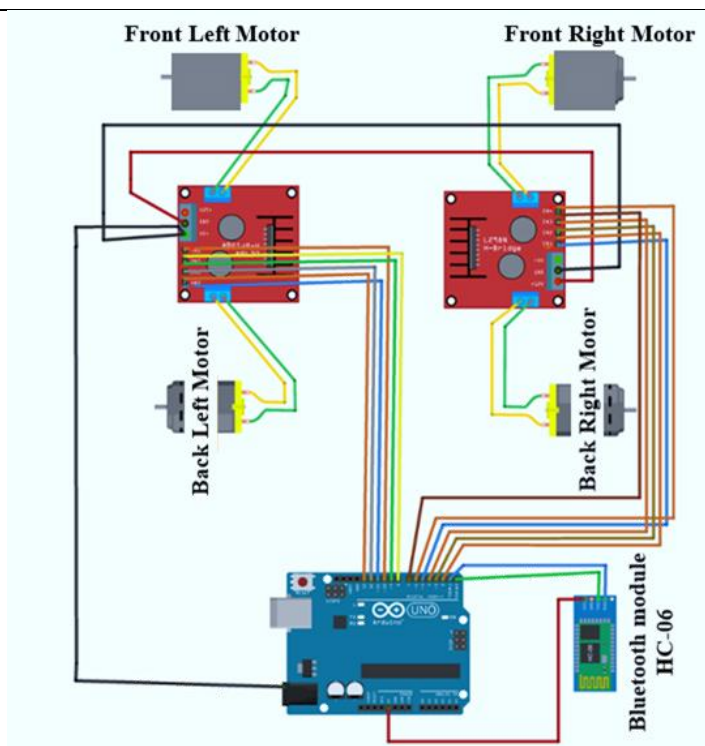


Fig. 4: Connection of the Bluetooth module HC-06 and motor driver with the control circuits of the robot model.

## 2.5. Spray module

The spray system consists of a small tank with a volume of 4 liters for holding the agrochemicals, Electric spray pump, 12V- 15W- 6bar as maximum operating pressure and 1.5 liters/min as maximum flow rate. Two nozzle tips (the standard flat-fan nozzles “11002”) were used, and have a 110-degree spray angle and can apply 0.75 liter per minute at rated pressure of 2.75 bar (Grisso *et al.*, 2013). The boom height was fixed at 60 cm, and the distance between the two nozzles is 60 cm. The nozzles are connected to electric micro spray pump which is controlled by the microcontroller.

## 2.6. Monitoring system

Three cameras (two front and one rear) are used for monitoring the operation inside the greenhouse. cameras were used to show and correct the robot's path as well as the targeted and treated areas through the remote control (smartphone). The cameras stream can be watched and/or recorded on a computer. “At Home Camera” application was used to connect the Camera with the computer (iChano Inc., 2018).

## 2.7. Robot power system design

The energy required to operate the robot parts depends on the power consumption for each part. The robot has four DC motors each one needs an electric current ( $I_m$ ) of 1.5 Ampere-hour (Ah) with voltage ( $V_m$ ) of 12 V. Therefore, the energy required to operate the motors ( $E_m$ ) can be computed as follows:

$$E_m = \sum I_m \times V_m = (4 * 1.5Ah) \times 12V = 72 Wh$$

The robot has an electrical motor sprayer pump that needs an electric current ( $I_p$ ) of 1.25 Ah with voltage ( $V_p$ ) of 12 V. Thus, the energy requirement to operate the pump ( $E_p$ ) can be computed as follows:

$$E_p = I_p \times V_p = 1.25Ah \times 12V = 15 Wh$$

The total maximum required energy ( $E_t$ ) can be computed as follows:

$$E_t = E_m + E_p = 72Wh + 15Wh = 87 Wh$$



Therefore, the total required current ( $I_t$ ) and voltage ( $V_t$ ) are 7.25 Ah and 12 V respectively.

According to the required operating energy for robot drive motor and sprayer pump, the battery is selected. The power supply system consists of three Lithium Ion battery cells each has a nominal open-circuit voltage ( $V_b$ ) of 4 V and current ( $I_b$ ) of 2.8 Ah. Therefore, the total available energy from the batteries ( $E_b$ ) can be computed as follows:

$$E_b = \sum I_b \times V_b = 2.8\text{Ah} \times (3 \times 4\text{V}) = 33.3 \text{ Wh}$$

The theoretical battery capacity able to run the robot model for 22 min. Relative reduction in the total run time will depend on the battery state of charge (SOC) value, which ranges between 30 to 50% (Zhang *et al.*, 2018).

Battery state of charge (SOC) is defined as the remaining capacity of a battery and it is affected by its operating conditions such as load, current and temperature. SOC is a critical condition parameter for battery management. SOC can be calculated as follow (He *et al.*, 2013):

$$\text{SOC} = \frac{\text{Remaining capacity}}{\text{Rated capacity}} = \frac{V_{b1} \times I_{b1}}{V_{b2} \times I_{b2}}$$

The PV solar panel (12V, 4.5A, and 24W) was connected to a charging module TP4056 to charge the three Lithium Ion batteries. The current produced by the solar panel ( $I_{sp}$ ) was calculated by knowing the maximum power of the solar panel ( $P_{sp}$ ) and the total voltage rating of the battery ( $V_b$ ) that is given by:

$$I_{sp} = \frac{P_{sp}}{\sum V_b} = \frac{24\text{W}}{12\text{V}} = 2 \text{ A}$$

The batteries charging time ( $T_b$ ) was computed by taking the ratio rating of battery in ampere-hour (Ah) to the total current of the solar panel (Amarapur, 2013; Charvani *et al.*, 2017).

$$T_b = \frac{\sum I_b}{I_{sp}} = \frac{8.4\text{A. hr}}{2\text{A}} = 4.2 \text{ hr}$$

The charging procedure is performed at constant voltage with current-limiting circuitry. The solar panel just used as a charger when batteries

need to be charged. Figure (5) shows the charger system of the power supplies and the robot power distribution system.

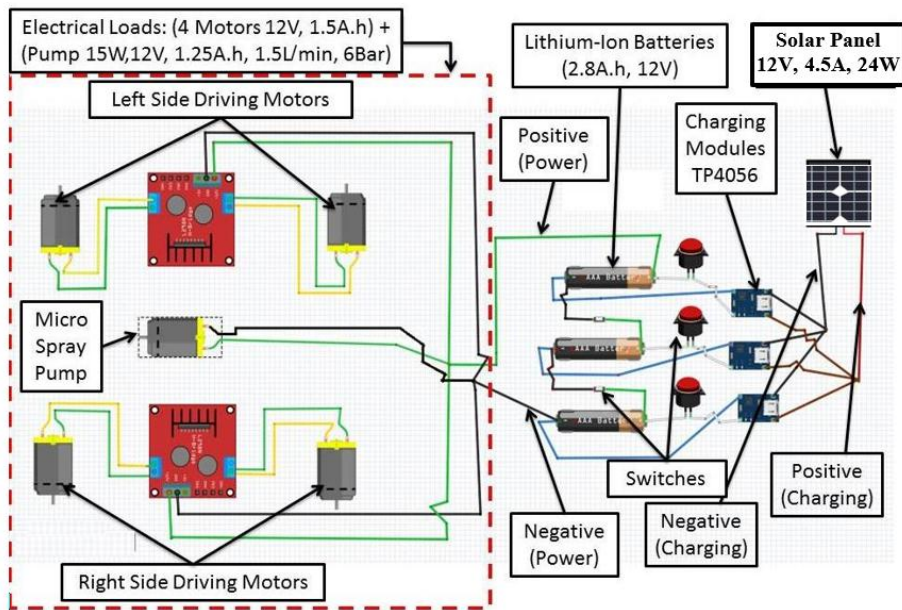


Fig. 5: Robot power distribution circuit.

## 2.8. Software details

### 2.8.1. Programming the control system

Arduino Bluetooth RC Car Android operating system-based application was used to control the robot as described by Yan and Shi (Yan and Shi, 2013). It is offering effective control dashboard with a human-friendly interface. Arduino C language is used to program the code with interface program Arduino 1.6.8. Figure 6 shows a program flowchart which is used to control all of the robot's functions.

### 2.8.2. Robot laboratory functionals test

The robot was tested in the laboratory at the Department of Agricultural and Biomechanical Systems Engineering, Faculty of Agriculture, Alexandria University. The test focused on the reliability and functionality of the electrical and electronic circuits as well as the programming of the operations that was implemented by the robot during the evaluation process. The electric current and voltage was measured for battery, movement DC motors, and the electric pump by using the data logger

module shown in Figure 7a and 7b, also Table 2: Icon components of the data logger module circuit. Simultaneously the following measurements were taken: the robot speed, pump delivery pressure head and discharge of hydraulic spray nozzle, then the percentage of the sprayed area was evaluated.

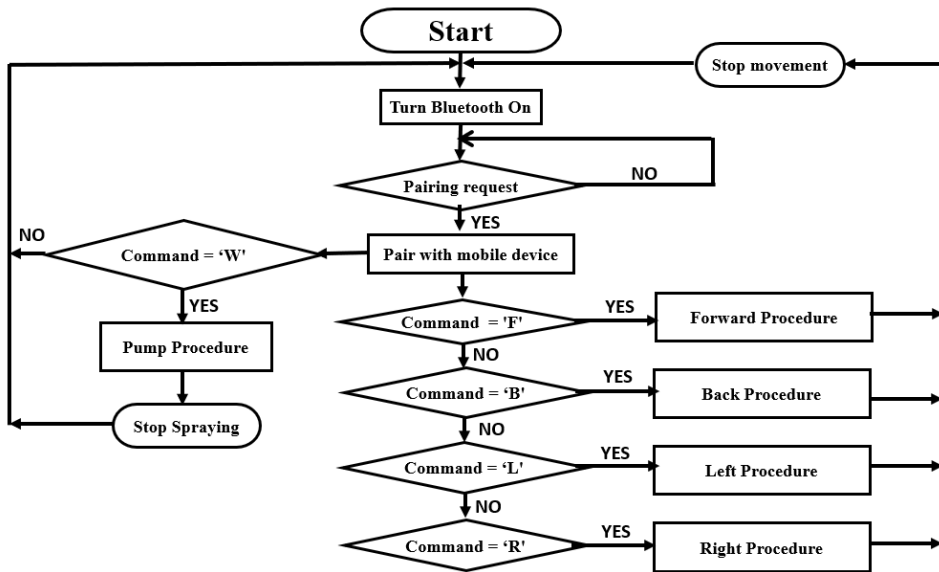


Fig. 6: Robot program flowchart.

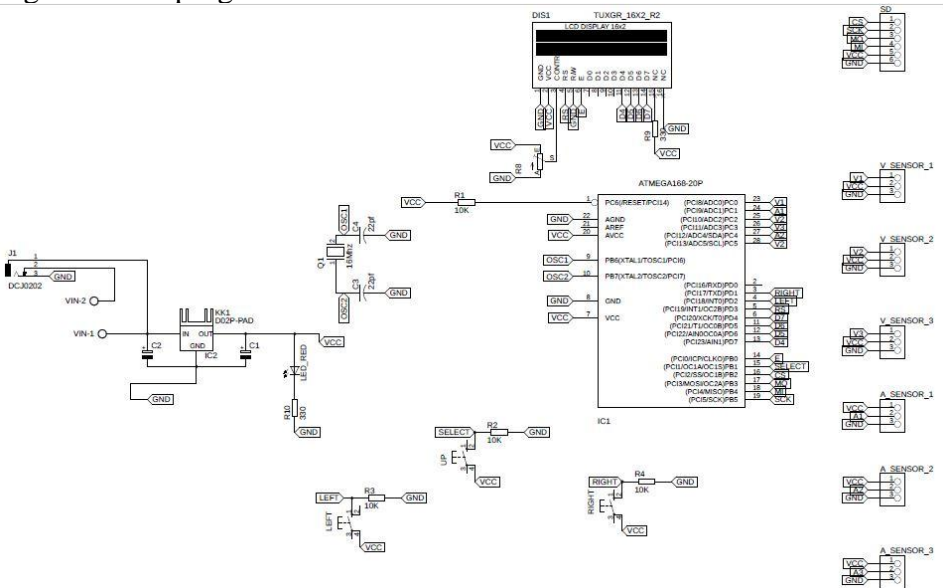


Fig. 7a: Design of voltage and current measurement data logger module.

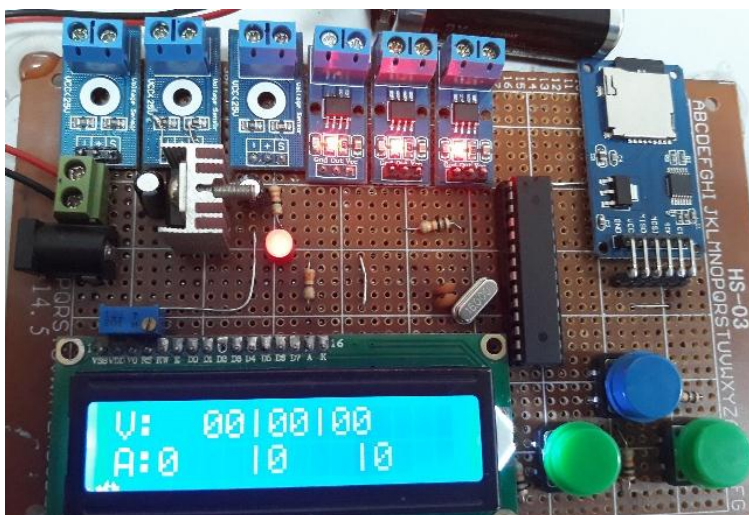


Fig. 7b: Implemented of voltage and current measurement data logger module.

Table 2: Icon components of the data logger module circuit.

Icon	Specifications
IC1	Microcontroller Atmega 328p (Datasheet 3, 2018)
A_SENSOR_1,A_SENSOR_2,A_SENSOR_3	Current Sensor Mosule (ACS712 Chip) (Datasheet 8, 2017)
V_SENSOR_1,V_SENSOR_2,V_SENSOR_3	Voltage Sensor Module
Q1	16 MHz Standard Clock Oscillators
KK1	LM7805 Voltage Regulator (2004)
R8	Potentiometer 10k
C3,C4	22 Pico Farad
LEFT,RIGHT,UP	Push Button
DIS1	LCD Module (Datasheet 10, 2008)
SD	SD Card Module
LED_RED	LED Red
R2,R3,R4	10k Resistance
R10,R9	330 Resistor
DCJ0202	Dc Socket 2.1mm

Each experimental test consisted of a single run down to the end of a row 30 m length and back to the starting point, while spraying blue water from both sides of the robot on white filter paper (9 cm Ø) at distance of 1.5 m.

These experiments were repeated until the robot was stopped working because the available battery capacity was not sufficient to operate the robot motors and the spray pump. Also, during each test, the spray tank was fully filled with blue water (4 liters). After every spraying test, four filter papers samples were collected randomly and photographed with a Canon digital camera (SX150 IS). The photographed images then transferred to the Image J imaging process program used to analysis the spray area for evaluation of the spray quality and uniformity. From each photograph a 1 cm<sup>2</sup> area was randomly cropped and analyzed for counting the white and blue pigmented pixels and then the average coverage area was calculated as percentage (Rafiq *et al.*, 2014).

### **3. RESULTS AND DISCUSSION**

#### **3.1. Constructed robot model**

The robot model was built on a chassis made from Acrylic rectangular plate (30 cm width and 40 cm length) 5 mm thickness. This provides strong lightweight platform. All hardware components were mounted and connected as described previously (see above, materials and methods). Figure (8) shows the constructed robot model and its main components. Control and power distribution circuits were implemented according to the design described in Figure (3;4;5). The actual implementation showed in Figure (9a and 9b).



Fig. 8: Robot model sprayer.



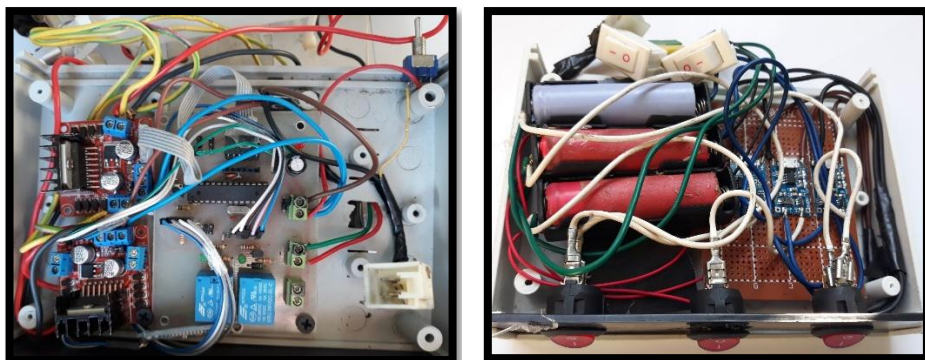


Fig. 9a: Implemented robot model control circuits      Fig. 9b: Implemented robot power distribution circuit

### 3.2. Controlling the robot

Controlling the robot movement and spray function was achieved through Arduino Bluetooth RC Car mobile application depending on a Bluetooth connection between the smartphone and Bluetooth module HC-06. Arduino C language sequential code was programmed on the microcontroller to allow full control in the robot movement, maneuvering and spray function remotely. In this case, the smartphone acting like a “Remote Control”. Activating the remote control through the smartphone were done in two steps as described in the application user manual (Andi Co., 2018): I- Upload code to microcontroller from the program Arduino 1.6.8.; II- Open application RC Car setting and press “connect to car”. Then, the following sequence of instructions should be followed:

1. Ensuring active pairing between HC-06 Bluetooth module and an android smartphone.
2. Select paired HC-06 Bluetooth module by clicking on “SELECT DEVICE” in setting and press “CONNECT TO CAR” icon on the mobile app.
3. Once press up-arrow “▲” it sends the data “F” to the Bluetooth module connected with the circuit. Subsequently, (Once microcontroller detects “F”) the robot moves FORWARD.
4. Once press down arrow “▼” it sends the data “B” to the Bluetooth module connected with the circuit. Subsequently, (Once microcontroller detects “B”) the robot moves REVERSE.

5. Once press left-arrow “◀” it sends the data “L” to the Bluetooth module connected with the circuit. Afterward, (As soon as microcontroller defects “C”) the robot turns LEFT.
6. Once press right-arrow “▶” it sends the data “R” to Bluetooth module connected with the circuit. Afterward, (As soon as microcontroller defects “D”) the robot turns RIGHT.
7. Once press STOP “■” key which is located in the center of the remote it sends the data “E” to the Bluetooth module connected with the circuit. Afterward, (As soon as microcontroller defects “E”) the robot gets stopped
8. Once press “LEFT CAR” it sends the data “W” to Bluetooth module connected with the circuit. Once the microcontroller detects “W” the sprayer-pump activates, when press “LEFT CAR” once more the spryer-pump deactivates.
9. Click on “DISCONNECT” icon to disconnect paired Bluetooth module.

Figure (10) shows the user interface of the used mobile app.

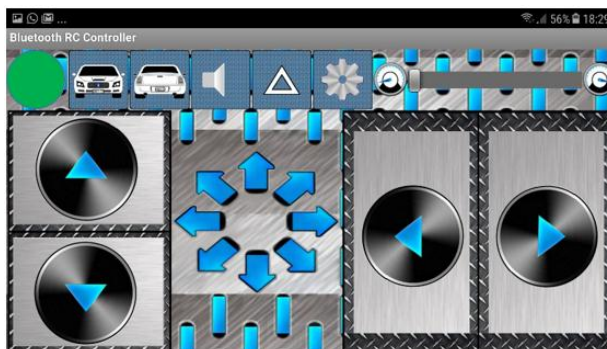


Fig. 10: Arduino Bluetooth RC Car application interface

The agrochemicals spraying function of the robot is controlled remotely through Bluetooth technology, which is expected to achieve better results compared to the previous methods when using human assistance. This would be an automatic mechanical model that would work automatically, powered by solar energy (PV cells) and rechargeable lithium ion battery cells this should reduce drudgery and protect the farmers from harmful pesticides and other chemicals.

### 3.3. Laboratory tests results

The results of the laboratory tests on the robot electronic components, as well as the programming of the microcontroller unit, showed that the robot executed through its programming all the commands as explained in Flowchart in Figure (6).

Figure (11) shows the relationship between time elapsed starting from the start of robot operation, when the battery capacity is full, (12.07V – 2.8 Ah - 33.8 Wh) to reach the insufficient battery capacity to operate the robot components (9.51V – 1.49Ah – 14.17Wh). The battery minimum state of charge (SOC) is a relative value below which the storage bank is never drawn, specified as a percentage of the total capacity. In our case, as presented in Figure (12), the minimum SOC recorded is 41.92%. This is comparable to the expected range. Most rechargeable batteries are not meant to be fully discharged. In fact, fully discharging some batteries can permanently damage them. The minimum SOC is typically set to 30-50% in order to avoid damaging the storage bank by excessive discharge (He *et al.*, 2013; Peng, 2014; Zhang *et al.*, 2018).

The calculated consumed energy by DC motors and the sprayer electric pump is 19.63W during 8.91 min of operation at full load. This reflects the energy availability of battery capacity which exceeded 58.08%. The results in Figure (11) showed the consumed amount of energy by DC-motor and the sprayer electric pump were comparable to the theoretical values described in the component's datasheets. This proves the reliability of the robot's power supply unit design, which qualifies it to be used as is in a prototype production. Additional modification will be necessary only if new functions are needed or different components were used.

The spray area coverage test results recorded 70.2% as average. Figure (13) shows that, spray coated the surface in adequate and consistent dosage. However, this value is pump pressure head ( $h_{\text{pump}}$ ) dependent. The  $h_{\text{pump}}$  decreased gradually as  $V_p$  decreased (Fig. 14). That led to subsequent decrease in nozzle discharge ( $Q_{\text{nozzle}}$ ) and the coverage area. When  $V_p \geq 8.6V$ , the  $h_{\text{pump}}$ ,  $Q_{\text{nozzle}}$ , and coverage area recorded 30 m, 0.335 L/min, and 91.0% respectively.



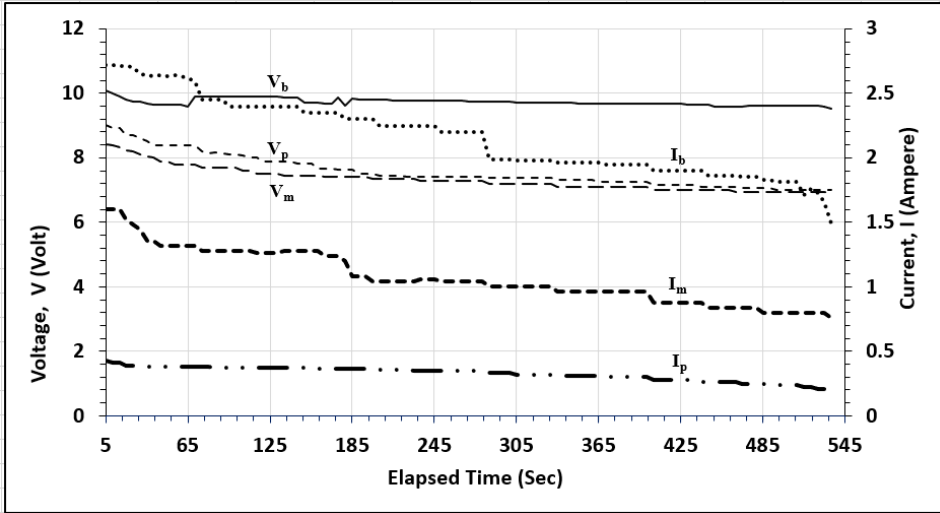


Fig. 11: Relationship between elapsed time and voltage and current of the robot main components (battery  $V_b$  &  $I_b$ , sprayer electric pump  $V_p$  &  $I_p$ , and DC motors  $V_m$  &  $I_m$ ).

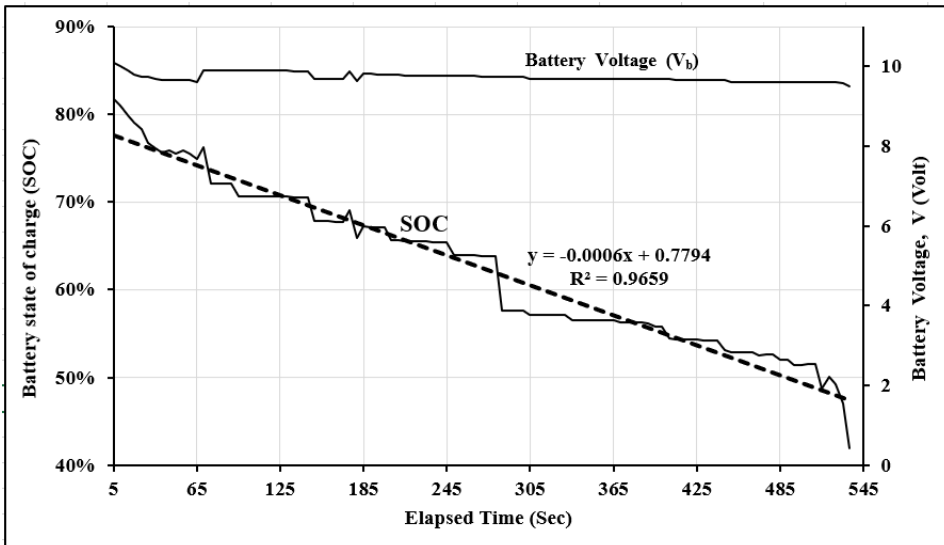


Fig. 12: Relative state of charge (SOC) in relation to battery volt and Time.

Subsequent decrease in all parameters was recorded as  $V_p$  was decreased during operation. Coverage area reached 50% when  $V_p=7.1V$  and the minimum value of 25.0% as  $V_p$  reached 7.0V. then the electric pump failed.

This is comparable to the work of Sammons *et al.* (2005), they reported the importance of consistent coverage of plants in spray test. The spray ratio can be regulated according to the application needs by controlling the pressure, flow rate and robot speed. However, the consistence coverage reflects the efficiency of the robot model as agrochemical sprayer.

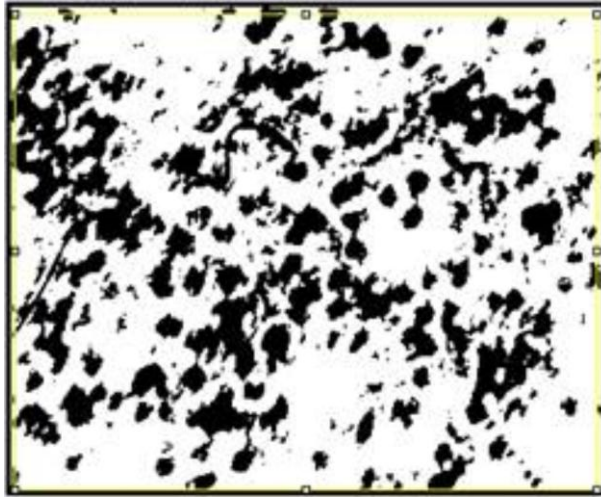


Fig. 13: White filter paper sprayed with blue water using the robot model.

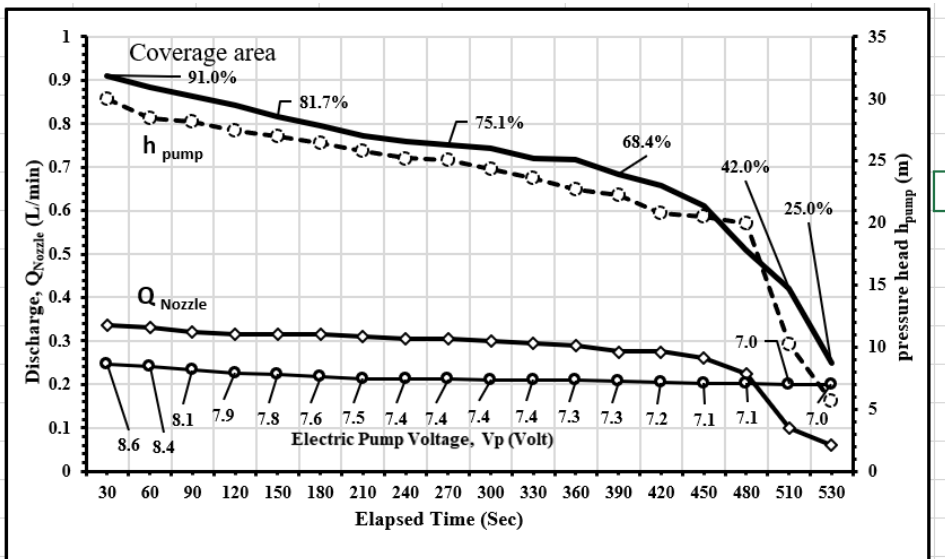


Fig. 14: Relation between electronic pump voltage and single nozzle discharge, pump pressure head, and coverage area.

Based on the experiments performed, it is found that the solar panel used provides 12 V, 4.5 Ah and 24 W. The scarcity of power can be overcome by this, on the other hand, the battery is rechargeable by supply available at homes. However, the effective working time will be extended under continuous solar charging (during daytime). Further work should be done to estimate the maximum operating range under various environmental conditions in the prototype production stage. The preliminary results obtained in this study for the evaluation of the constructed robot model indicated the proper and trustable operation of it for greenhouses applications as described by Rafiq *et al.* (2014).

Taking all together, this robot model allows the manual labor elimination within greenhouses during agrochemical spray. Constant and effective discharge is achieved which eventually increases productivity. There are no health hazards to the operator. These results are fulfilling the criteria required for such model which were specified in the aim of this study and by other researchers' in the recent years (Chavan *et al.*, 2015; Nithin *et al.*, 2016; Sharma and Borse, 2016; Adamides *et al.*, 2017a; Adamides *et al.*, 2017b; Londhe and Sujata, 2017; Poudel *et al.*, 2017).

#### **4. CONCLUSION**

The presented robot design concept and its successful constructed model using available commercial components can be built via a simple and cost-effective manner. It undertakes the task of autonomously spraying agrochemicals within greenhouses effectively and safely. Further work needs to be continued to scale up this model to be feasibly working prototype in real conditions.

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### المخلص العربي

## نموذج روبوت زراعي: تطوير رشاش مدمج يعمل بالطاقة الشمسية

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لا يمكن للزراعة المصرية أن تواجه التحديات الحديثة دون إدخال التكنولوجيا المحلية لهذه الصناعة. وفي إطار توجيه البحث العلمي لتعميق التصنيع المحلي فإن هذه الدراسة تهدف الي تطوير وتقييم نموذج لروبوت زراعي يعمل بالطاقة الشمسية لرش المواد الكيميائية والمبيدات داخل الصوب الزراعية. تم تصميم هذا الروبوت وبنائه وتجميعه بطريقة بسيطة وفعالة من حيث التكلفة من مكونات رئيسية وبرمجيات تشغيل وكذلك اجهزة اختبار للنتائج النهائية جميعها متوفر في السوق المصري. تم استخدام تطبيق متاح RC- Car لتشغيل وتوجيه الروبوت باستخدام الهاتف المحمول من خلال وحدة بلوتوث HC-06. كذلك تم برمجة وحدة التحكم الدقيقة باستخدام أكواد برمجة لغة اردوينو C وذلك للسماح بالتحكم الكامل في حركة الروبوت ووظيفة رش المواد الكيميائية الزراعية داخل الصوبة. كما تم تزويد هذا النموذج بثلاث كاميرات لمراقبة مسار الحركة والتوجيه اثنان الي الامام وثالثة للخلف وتم استخدام تطبيق اخر " At Home Camera" لنقل الحركة الي شاشة حاسب آلي. تم تصميم البطارية ليتم شحنها باستخدام الألواح الشمسية. ويعرض في هذا البحث نتائج الاختبارات العملية بما في ذلك: التحكم عن بعد، برمجة وحدة التحكم الدقيقة، كمية الطاقة المستهلكة من جميع مكونات الروبوت، أداء البطارية، وقت التشغيل الفعال، وكفاءة نظام الرش. كانت هذه البيانات قابلة للمقارنة مع القيم المرجعية ومتوافقة مع المعايير المطلوبة لاداء المهام المستهدفة. وهذا يثبت موثوقية تصميم نموذج الروبوت، الذي يؤهله لاستخدامه كما هو في إنتاج النموذج الأولي الذي يتولى مهمة الرش الذاتي للكيمواويات الزراعية في البيوت المحمية بفعالية وأمان.

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