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Solar Powered Automatic Pattern Design Grass Cutting Robot System using Arduino

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ABSTRACT We present an Arduino-based automatic robotic system which is used for cutting grass or lawns, mostly healthy grass which needs to cut neatly like in a public park or a private garden. The purpose of this proposed project is to design a programmable automatic pattern design grass cutting robot with solar power which no longer requires time-consuming manual grass-cutting, and that can be operated wirelessly using an Android Smartphone via Bluetooth from a safe distance which is capable of cutting the grass in indeed required shapes and patterns; the cutting blade can also be adjusted to maintain the different length of the grass. The main focus was to design a prototype that can work with a little or no Physical user interaction. The proposed work is accomplished by using an Arduino microcontroller, DC geared Motors, IR obstacle detection sensor, motor shield, relay module, DC battery, solar panel, and Bluetooth module. The grass-cutting robot system can be moved to the location in the lawn remotely where the user wants to cut the grass directly or in desired patterns. The user can press the desired pattern button from the

mobile application, and the system will start cutting grass in the similar design such as a circle, spiral, rectangle, and continue pattern. Also, with the assistance of sensors positioned at the front of the vehicle, an automatic barrier detection system is introduced to enhance safety measurements to prevent any risks. IR obstacle detector sensors are used to detect obstacles, if any obstacle is found in front of the robot while traveling; it avoids the barrier by taking a right/right turn or stop automatically appropriately, thereby preventing the collision. Also, the main aim of this project is the formation of a grass cutter that relieves the user from mowing their own grasses and reduces environmental and noise pollution. The proposed system is designed as a lab-scale prototype to experimentally validate the efficiency, accuracy, and affordability of the systems. The experimental results prove that the proposed work has all in one capability (Simple and Pattern based grass cutting with mobile-application, obstacle detection), is very easy to use, and can be easily assembled in a simple hardware circuit. We note that the systems proposed can be implemented on a large scale under real conditions in the future, which will be useful in robotics applications and cutting grass in playing grounds such as cricket, football, and hockey, etc.

Keywords: android; arduino; bluetooth; grass cutter; sensors; speech recognition

1. INTRODUCTION

A robot [1] is a machine that can communicate with its physical environment and which can be controlled or programmed electronically to perform specialized tasks. All robots have features of a mechanical and adjustable structure under some form of control, and they mainly have three separated phases: understanding, processing, and action. Commonly, the understandings are done by the sensors mounted on the robot, the onboard micro-controller or processor do processing, and lastly, the operation is performed using motors, engines or with some other actuators. Intelligent robots have a vision [2] and work accurately, using multiple degrees of coordinated action, do

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something like a living human, and learn from humans without making mistakes. Robots can be operated by different methods such as some of them can be controlled with gestures [3–6], some with mobile applications [7–9], special remote [10–13] and autonomously [14,15], etc. Grass cutter helps us cutting lawns at length; people can easily manage and beautify their gardens and lawns without any trouble. The grass is a beautiful gift from nature, which helps us to survive in various conditions, and so, the need to lessen their growth is essential to enhance the beauty and attractiveness of our environment. As humankind developed intellectually, grass cutting became an art. Grass cutting tradition starts with the use of hoes, machetes, and cutlasses, and later, advance technology and more reliable techniques of grass cutting were introduced and continuously improved. A robotic lawnmower [16] is an autonomous robot which used to cut grass of lawns or parks, mostly healthy grass which needs to cut neatly like in a private garden or public park. The first lawn mower born in 1830 by Edwin Beard Budding [17], by having an idea from a cloth mill where a cutting barrel machine is used to trim clothes after production for a smooth finish. He noticed that a similar concept might be used to cut grass if the blade can be fixed in the wheel to rotate close to the lawns surface and then he designed a mower primarily to mow the grass on ample gardens and sports ground. In 1867, a scientist introduced an important innovation with a new design of the automatic lawnmower [18] because land roller was removed and replaced by two land wheels on the outside of the structure and this became an instantaneous success with the sold of over 1,000 machines.

In the late 1890s, motor-driven mowers arrived as lightweight petrol engines and became available in 1914, invented by “Ideal Power” [1]. Electric powered mowers [19] and rotary grass cutting machines [20] appeared in the era of 1920s to 1930s. An ideal grass cutter robot requires to set up a boundary wire that defines the area of grass to cut in the lawn. Robotic grass cutters are

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the second biggest category of domestic manufactured robots used by the end of 2000, and first commercial grass cutter was the "MowBot" [21] that introduced and licensed in 1969 which shows many features of most popular grass movers of today's. The sales of the latest robotic lawn mower increased about 15 times [22] more than traditional robots in 2012. With the evolution of smartphones, grass cutting robots have integrated with custom apps features to adjust scheduled mowing times, adjustments of the cutter and also manually control the grass cutter. Grass cutters have three types; Walk-Behind Mower [23], Tow-Behind Mower [24], and Riding Mower [25]. Walk behind lawn mower are further classified into three types [26] follow as Gas Powered Lawn Mowers, Electric Lawn Mowers, and Manual Reel Lawn Mowers. Rotary grass cutters [27] are manually operated, only spinning the cutting blades are usually powered with internal combustion engines or with an electric motor, having opened sides to discharge cut grasses, and some mowers have a grass collector to store cut grasses. The blade is seldom sharp enough to give an exact cutting point. There have been countless improvements in lawn mower technology in latest years, but with this progress, there are issues with the need to verify the environmental impression of machines.

Pollution is human made and can be viewed in our own homes as well as in daily lives. Pollution is the primary concern with the conventional fuel and gas-powered lawn mowers. Riding and Motor-powered push grass cutters have a loud engine, which creates noise pollution and air pollution because of combustion in the engine. Traditional grass cutters are heavy machinery that requires a lot of strength and energy to operate. Along with motor-powered grass mowers, electrical lawn mowers are cannot be easily used in daily lives due to dangerous belts and motors [28], so the dream to cut grass cannot be efficiently fulfilled by the elders, younger, or disabled people. Therefore, human effort is another factor that needs to be reduced. Mowing the grass with

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a standard motor is disturbing, and no one takes satisfaction in it due to massive engines combustion, which creates much air pollution and required regular maintenance such as engine oil and greasing. Gas-powered lawn mowers are also not much efficient and responsible for air pollution due to the massive emission of gases, and mainly the price of fuel and gases are increasing rapidly. According to world energy report [29], we gain the energy of around 80% from fossil fuels like oil (36%), coal (23%) and natural gas (21%), 70% of Malaysian home citizens are using fuel-powered to cut grass in daily routine. That time is not far when all energy sources will be consumed so alternative sources can be utilized such as solar energy to avoid an energy crisis in the future. A solar panel [30] contains cells and designed to produce electricity by capturing sunlight and does not make any pollution like fossil fuels and nuclear energy. Solar grass cutting robots are convenient to mow grass and cost-effective because of cordless electric mowers and cutter powered of solar cells that last a long time and have low running costs.

A pattern [31] is a regularity in the world, in human-made design, or abstract ideas. As such, the elements of a pattern repeat predictably. Geometric patterns or shapes are generally repeated like a wallpaper design that can be seen directly, but complex patterns in science, mathematics, or any language may be visible only by analysis. Natural patterns include spirals, foams, waves, tiling's, cracks and those generated by symmetries of rotation but, Observable patterns in nature are disorganized, never exactly repeating. There are many pattern categories, in architecture, designs or visual themes may be merged and repeated to create patterns; a software design pattern in computer science is a solution to programming issues, and in fashion, the pattern is a model used to produce any number of similar garments. In a football or cricket grounds, the fields are beautifully trimmed; the turf is created with perfectly straight green lines of dark and light colors that look painted on the playground. Game spectators may ask how the grounds supervisor creates

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such intricate designs, and some of them assume it is done with paint. No matter how complicated or easy patterns are, it should be time-efficient and safe on the grass, but complicated patterns take a little longer, and extra effort is needed to demonstrate that such designs to attract attention. Efficient striping equipment is needed to perform patterns grass cutting such as a reel-type mower or a gardener. Drawing or cutting grass in particular patterns is such a challenging task because due to lack of efficiency and attention of the gardener, the pattern on grass may not have been correctly accurately trimmed.

The conventional grass cutting robot has been limited to a particular remote [10–13, 32–35] through the desired actions can only be performed. In this scenario, the robot will lose control if the user lost or broke the remote, leading to hazards, and the user will also waste money. To overcome this remote-control concept, controlling the grass cutting robot by using a Bluetooth Android mobile application along with Arduino is proposed [36–41]. Using the Ultrasonic sensor, the method of identifying the barrier in front of the robot is also proposed [42–49] in which the robot and the cutter stop their motion. In previous literature, most of the grass cutting robots are push mowers controlled with handheld [50–58]. Also, the ZigBee mechanism [59–60] is used to control the movement of the lawnmower. Moreover, an automated grass cutter robot has also been implemented with a Raspberry pie [61–63], and development of grass cutting machine using DFMA (Design for Manufacturing and Assembly) [64–66] is also discussed. A Solar panel system [67–69] is also deployed to make robot energy efficient. Besides these, Specific pattern drawing robots on paper and boards is also accomplished [70–73].

Apart from the traditional grass cutting robot system, the term “internet of things” (IOT) [74–77] is also essential for connecting robot with the internet to allow users to control grass cutter from anywhere and anytime. These wireless systems are contributing essential help to robot self-

regulation systems by utilizing Wi-Fi and cloud computing mechanism etc. As far as we know, no such system is developed that have all in one capability (Android mobile application with touch and voice recognition system, solar powered, monitoring the obstacles, cutting grass in special patterns). So, a need still exists for the design of solar powered automatic pattern design grass cutting robot system that supports various tasks (e.g., android mobile application control and voice recognition concepts, obstacle detection and patterns cutting) and very easy to use and can be easily assembled in a simple hardware circuit.

In this paper, we introduce the design and experimentally demonstrate that a grass cutting robot system can be controlled by just a click on the cellphone with an Android operating system, and voice recognition via Bluetooth technology which reduces human effort so that elderly users and disabled persons can fulfill their tasks by themselves, and there is no need for gas, oil, and engine to use this device because it is solar powered. This prototype is user-friendly, cost-effective, secure and eco-friendly; with its control capability, the grass cutter robot will stay within the boundaries of the lawn because the user can have control over the lawn mower with the controller and the working range is also increased due to the absence of main supply wires. The user can trim the grass with different length because the cutter is fully adjustable.

This work is achieved with the proper arrangements of the Arduino Uno microcontroller, solar panel, IR obstacle detection sensor, simple DC motors, geared DC motors, android mobile-application, Bluetooth module, and relay module, where motors are connected to gear motor drives so that less speed and more power can be attained. The robot is dual powered with a Hybrid Solar panel & a Lithium-Ion rechargeable battery which provides power supply to the Circuit, Motors, etc. When sufficient sunlight is falling on the Solar panel, the robot runs on Solar Power, and whenever there is no light or low intensity of sunlight, the robot runs on Battery power. The battery

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is also recharged when the robot is in Light, thereby avoiding the robot from frequent recharging and provides an uninterrupted power. There are two main controllers in android the application. The first one is the touch buttons in which the robot will move accordingly as the user touches the button and the second one is voice recognition in which the grass cutting robot will follow and move accordingly as the user says the operating command. Most importantly, the mower will mow grass in patterns accordingly as the user pressed pattern button and an obstacle detection sensor is set to detect the obstacle in front of it, and when a sensor detects the barrier, it stops moving, and the cutter will be turned off. Hence, the proposed systems of controlling the grass cutting robot with android application control and voice recognition are performed and displayed in a lab-scale prototype to confirm that the proposed designs can be easily implemented in large and real-scale conditions in the future.

The innovative component of the proposed work in this system is an Arduino that is a user-friendly microcontroller that can be readily available. On the other hand, automated grass cutting systems can be designed with raspberry pie, ZigBee, and other microcontrollers that are costly and complicated for the process to unite the various functionalities in a single hardware circuit. Furthermore, the motivation for conducting this research is to facilitate the old-age and physically disabled people to cut grass which cannot walk and also make patterns on grass easily without difficulty.

The remaining content of the paper is ordered as follows. In Section 2, the idea of the automatic pattern design grass cutting robot car is introduced with a detailed explanation of the electronic components that are used in the proposed system, based on an android mobile application. More, the experimental results of a lab scale production model are shown in Section 3, and the conclusion is given in Section 4. Lastly, Section 5 presents future work.

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2. MATERIALS AND METHODS

For the simplicity of analysis, Figure 1 demonstrates the complete working mechanism and the features of the proposed automatic robot car whereas I/P and O/P represent the flow of the system as input and output. There are two modes of transmission and controlling of the grass cutter. The first one is the arrow touch buttons with an android mobile application, which is specially designed for Android mobile and available and can be easily downloaded [77]. In this system, when the user presses the corresponding touch button, a signal is transferred to the Arduino UNO that is attached to the car through the built-in mobile Bluetooth device. After receiving the following signal command, Arduino will check this signal with a predefined instruction that is programmed via coding and send the following signal to the motor module to move the wheels of the robot, make grass pattern, or relay to turn ON/OFF Cutter accordingly to the received signal. The second mode is to control a robot car with a Voice recognition system with the Android application. In this system, when the user speaks the corresponding keyword, the google voice recognition system recognizes the spoken keyword and send it Arduino UNO, after receiving the following command, Arduino will check this keyword with a predefined keywords that are already programmed for movement of grass cutter. If the keyword matches with predefined, the corresponding signal is sent to the motor module to move the grass cutter, or to relay for switching of the cutter. Also, Solar panel will charge the battery with solar rays to reduce the consumption of electricity.

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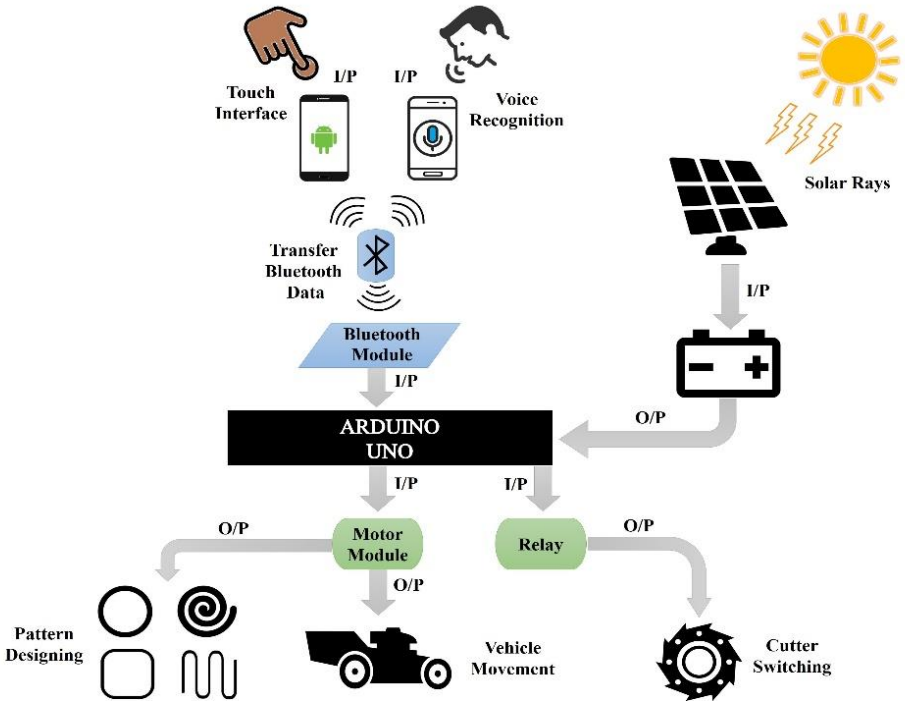

Figure 1. The architecture design of pattern design grass-cutter controlling with touch buttons and voice recognition of mobile application.

2.1. Electronic Components

Various electronic components are used for creating electronic circuits. Consequently, our proposed circuit diagrams also contain those components that are specified in Table 1.

Table 1. Specification of electronic components used in to design the proposed system.

Components	Specifications
Arduino UNO [78,79]	28 pins; Operating voltage: 7–12V
Bluetooth Module HC-05 [80]	6 pins; Operating voltage: 3.3–5V; Transmission range: 100 m

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L298N Motor Module [81]	Operating voltage: 5V; Max power: 25W
IR Obstacle Detection Sensor [82]	Voltage: DC 3–5V; Range 2–30 cm; Angle: 35º
Geared DC Motor with Encoder [83] / Simple DC Motor [84,85]	Geared Motor (6 Wires; Operating voltage: 12V; Speed: 600 rpm), Simple Motor (2 pins, Operating voltage: 12V; Speed: 46000)
DC Battery [86]	Input Voltage: 12V; Capacity: 7A; Battery type: Rechargeable
Solar Panel [87]	Operating Voltage: 12V; Max. Power:5W
Relay Module[88]	Pins: 6; Operating Voltage: 5V DC
Android Mobile Application [77]	Android compatible

2.1.1. Arduino UNO

The Arduino Uno microcontroller board [78,79] is generally based on the ATmega328 microcontroller's series and has a desktop, and web IDE (integrated development environment) to write, compile and uploads the programming languages codes to memory. Different sensors forward the observed data as an input to the microcontroller and send output to different devices such as motors, LED, relay module, etc. It contains a total of 28 pins from which 14 digital input/output pins (six are PWM pins (pulse width modulation)) and six are analogs pins which used for interaction with the electronic components like LDR sensor, ultrasonic sensors, etc., 3 pins for grounding and other pins for 5V, 3.3V, VIN, RESET and AREF (analogue reference).

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Arduino microcontroller have 32 KB of storage memory, 2 KB storage of SRAM (static random-access memory) and only 1 KB of EEPROM (electrically erasable programmable read-only memory). Arduino principally supports C/C++ programming language compiler (supports other languages like Python, java through libraries), macro-assemblers, and evaluation kits. Additionally, it has a USB connection jack for connecting with computer, a jack for external power supply, 16 MHz ceramic resonators an ICSP (in-circuit serial programmer) header, a reset button to reset to factory setting. Its operating voltage is 7 to 12V with a limit up to 20V.

2.1.2. Bluetooth Module HC-05

The HC-05 [80] Bluetooth module is designed for personal wireless serial connectivity and used in a Master or Slave configuration, providing it with an excellent solution for wireless communication. This serial port Bluetooth module is fully adequate Bluetooth V2.0 + EDR 3 Mbps Modulation with 2.4 GHz radio transceiver and baseband. It contains total six pins; ENABLE pin to toggle within AT and Data command mode, VCC pin for giving voltage, Ground pin, TX-Transmitter and RX-receiver for sending and receiving serial data and lastly, a State pin for checking of Bluetooth pairing/un-pairing). Its operating voltage is 3.3–5V and transmitting range is up to 90 m.

2.1.3. L298N Motor Module

An L298N dual H-bridge motor [81] controller is used to manage the direction and speed of one or two DC (direct currents) motors of up to 2A current each with a voltage between 5V to 35V. It has basically four input pins to receive the signal from the microcontroller and four output pins for the connection of the DC motors, two EN jumpers (Enable pins control the speed of DC motors). It has a built-in 5V regulator which is removed when the supply voltage is up to 12V.

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2.1.4. IR Obstacle Avoidance Sensor

An IR obstacle detection sensor [82] is a heat sensitive sensor used for the detection of an obstacle. It consists of an infrared transmitter, receiver and a potentiometer for distance adjustment. When an object crosses in front of it, the emitted rays collide with the surface of an obstacle and reflect to the receiver, and it will recognize this a motion.

2.1.5. Geared DC Motor with Encoder / Simple DC Motor

An encoder [83] provides an electrical signal that is used to control speed and position. It turns the mechanical signal into an electrical which is managed by the control system to control special parameters of the application and make corrections if necessary. These parameters are defined by the type of application, which includes RPM, distance, speed, position between others. Cylindrical geared motor have six pins; Encoder A phase and B phase, Motor power supply Negative and Passive, Encoder power supply Negative and Passive.

A simple DC motor [84,85] converts electrical energy into mechanical and have four basic types that are series-wound, shunt-wound, compound-wound, and permanent magnet motors. A DC motor contains an armature, a stator, a rotor and a commutator with brushes. The opposite polarity within the two magnetic fields of the motor causes it to run. DC motor is the most common type of motor used in many household appliances, such as cooling fans and shaving machines, etc. It have only two wire; one for 12V VCC and the other one is for grounding.

2.1.6. DC Battery

A battery [86] transforms chemical energy into electrically a chemical reaction that is kept inside the battery and used to power other components such as bulb, fan, etc. A battery provides direct

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current (DC) electricity (electricity that flows only in one way and does not reflect). When a battery is giving electric power, red is for supplying DC voltage, and black is for grounding.

2.1.7. Solar Panel

Solar panels [87] absorb sun rays energy to generate DC electricity, and this electricity is supplied to the battery via regulator which assures the battery is charging correctly and not damaged. Photovoltaic modules contain the cells that absorb the solar rays, and that generates and provides solar electricity. AC appliances first need an inverter to convert the DC electricity into AC 220-240V, but DC appliances can be powered from the battery directly.

2.1.8. DC Relay Module

Relay Driver (RD-1) is a totally programmable one channel logic controller is used to manage solid or mechanical state relays in DC and AC voltage power systems. It mainly works as a switch for electronics for on and off. It has 6 pins; VCC, GND, Input pin, normally open, normally closed and common pin.

2.1.9. Android Mobile Application

An Android mobile application is an application software developed in a computer programming language (C, C++, Java, etc.) which run on the Android platform. The application for controlling the grass cutting robot system is available [77] and can be easily downloadable.

3. DESIGNING METHODOLOGY

Figure 2 shows the circuit design of the grass cutter system, which is control by an android mobile application using Bluetooth. In this scenario, the robotic grass cutting system will move in the same direction as the user presses the arrow touch button or speaks the corresponding keyword. In

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this task, one Arduino UNO, an HC-05 Bluetooth module, an L298N motor module, IR obstacle detection sensor, geared DC motor with encoder, simple DC motor, DC battery, solar panel, and a relay module were used. The RX pin of the HC-05 module is attached to the Arduino PIN D0/RX, TX to the D1/TX, Ground pin to the GND and VCC (voltage at the common collector) pin to the 5V pin of the Arduino. IN pin of the IR obstacle detector sensor is attached to the Arduino PIN D2, VCC pin to 5V and ground pin to GND port, as shown in Figure 2. ENA and ENB pins of L292N motor module are connected to the digital pins A3, A6; IN1-4 pins to Arduino Pin 4, 5, 7, 8; 5V and GND pin to Arduino 5V and GND pins, 12V pins to Battery positive terminal.

Further, OUT1 pin is attached to the negative terminals of LWF (Left wheel front) and LWB (Left wheel back), OUT2 pin of the motor module is connected to the positive terminals of the LWF and LWB motors. Similarly, OUT3 of the motor module is connected to negative terminals of RWF (Right wheel front) and RWB (Right wheel back), and OUT4 is connected to positive terminals of RWF and RWB. In this way, VCC, GND and IN terminal of relay driver is connected to Arduino 5V, GND and digital pin D9 and at last, NO (Normally open) pin to the positive terminal of Cutter, COM pin to the positive terminal of the battery and negative terminal of Cutter to negative terminal of battery. Positive and negative terminals of the solar panel are connected to +VE and –VE terminals of the battery. The complete software code of this case is presented in Figure S1 of the supplementary materials.

3.1. Movement of Motors with Mobile Application

As the user presses the touch arrow buttons or speaks the keywords, the mobile application will recognize that keywords and a signal is sent to the Arduino. There are genuinely seven values: Forward, Backward, Left, Right, Stop, OFF and ON for each function of the grass cutter. In simple words, the set of keywords are defined for the movement of the grass cutter in a specific way. If

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the received data by the application lies within these specified values, then the corresponding decision will be made. This decision value will be sent to the microcontroller, which then processes it to understand the keyword, and it will send a signal to move the robotic grass cutter accordingly.

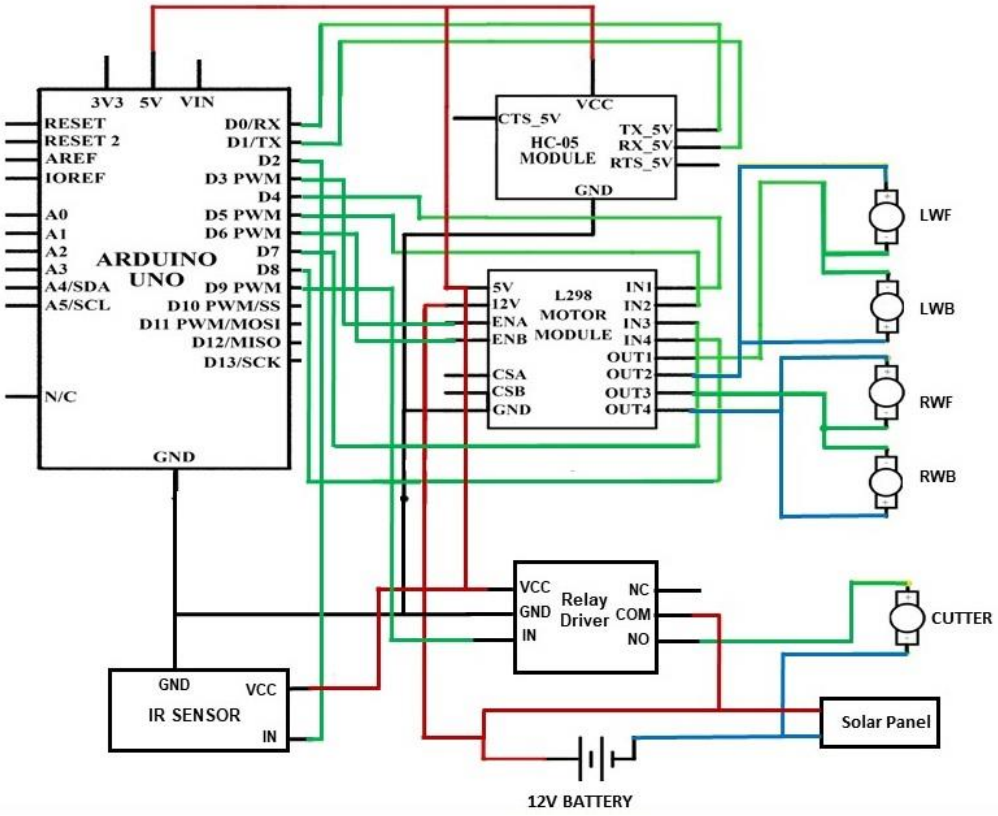

Figure 2. The circuit design of pattern design grass cutter controlling system with Android mobile application using Bluetooth.

There is a total of two DC geared motors and three simple DC motors; Both geared motors (600 RPM) for left back wheel, and for the right back wheel, two simple DC motors (400 RPM) for the left front wheel and right front wheel, and third simple DC motor (46000 RPM) for the blade (cutter) is used in the construction of this grass cutter. The motors are controlled by the L298D motor shield and relay driver.

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Figure 3 represents the main idea of Bluetooth communication and motors movement. When the user presses the upward touch arrow button or speaks the Forward keyword in voice recognition mode, it is recognized as the forward movement, all the four wheels of motors will rotate forward and the grass cutter will move in the forward direction which can be easily seen in the Figure 3a. Figure 3b illustrates the case when the user presses the downward touch arrow button or speaks the "Backward" keyword in voice recognition mode, the signal is recognized as the move backward, and all the four wheels of motors will rotate backward, and the grass cutting robot moves in the backward direction. In Figure 3c, the user pressed the ON touch button or spoke ON keyword in voice recognition mode, the signal is recognized as to switch ON the cutter, and none of the wheels of motors will rotate, only cutter motor will rotate. When the user presses the Red touch button or speaks the Stop keywords in voice recognition mode, the signal is recognized as to stop the car; all the four wheels will stop moving as shown in Figure 3d. When the user pressed the OFF touch button or spoke OFF keyword in voice recognition mode, the signal is recognized as the turn OFF the cutter, and the cutter motor will stop rotating as illustrated in Figure 3e. In Figure 3f, when the user pressed the Right arrow touch button or spoke Right keyword in voice recognition mode, the signal is recognized as to turn Right, left diagonal motors (front left and back left motors) will rotate forward, and the grass cutter moves in the right direction. Similarly, when the user pressed the Left arrow touch button or spoke Left keyword in voice recognition mode, the signal is recognized as the Left turn, so the right diagonal motors (front right and back right motors) will rotate forward and the grass cutter will moves in the left direction, as represented in Figure 3g.

The values of an each signal will never lie within the two keywords (the values for each action is defined differently from another step), i.e., the value of turn right will not lie in the values of

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two directions (left turn and forward, left turn and backward, right turn and forward, right turn and backward).

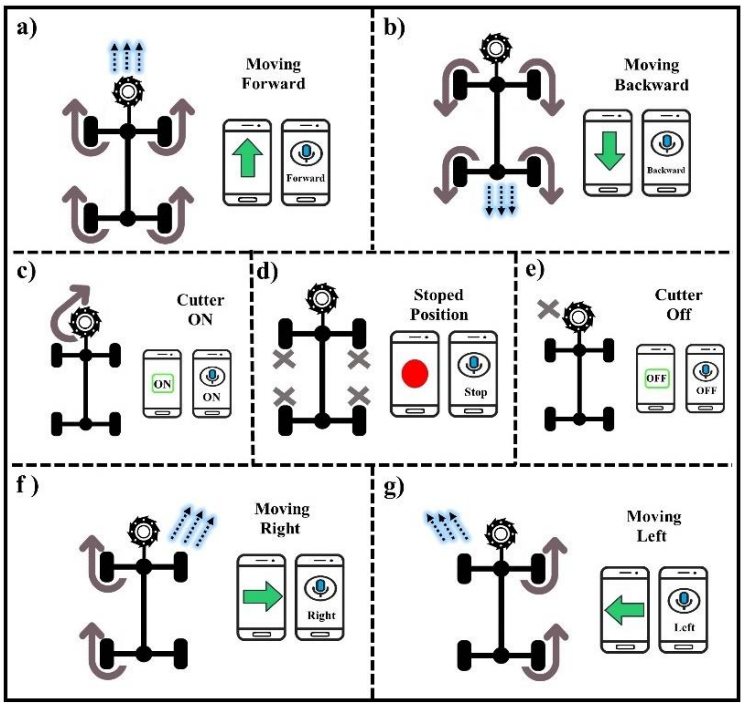

Figure 3. The theme of Android Application (i.e., Working of Android application, motors, and cutter): (**a**) Vehicle moving forward with arrow and voice recognition system; (**b**) Moving backward; (**c**) Cutter ON; (**d**) Vehicle stopped; (**e**) Cutter OFF; (**f**) Moving to right; (**g**) Moving to left.

3.2. Android Mobile Application

MIT App Inventor [89] is a visual programming drag and drops platform for designing and development of fully functional android mobile application. App Inventor's user interface is consists of two parts: a Designer for selecting the components of the app and a BlocksEditor for setting the operations and working for the application. App Inventor's building blocks are simple user interface contains elements such as buttons, labels, list pickers, images, etc., linked with the

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mobile device's features (Bluetooth, texting, NFC, GPS, etc.) Therefore, the fundamental structures of this drag and drop enabled app developer to efficiently manage the functionalities of this portable, touch-enabled sensing devices. By concentrating on the device's services, App Inventor presents an automatic programming metaphor. A Texting component is used for an application that sends and receives texts. The block for identifying an incoming text is "Texting.MessageReceived". This understandable, action based, drag and drop, event-driven, programming model reduces the difficulty level that usually experienced in traditional text-based programming environments. In our application, we have used Bluetooth client component, Speech recognition component, Notifier component, Text to speech component, button component, label, and title components. Figure 4a shows the main designer view of the MIT application development platform includes the user interface menu, viewer, components menu, and properties menu. In Figure 4b, the blocks for all the components are shown, such as in screen 1, Bluetooth components blocks having Bluetooth connection, show alert notifier, label component and speak message components as shown in Figure 4b i . In Figure 4b ii, the blocks for speech recognition page is shown having a speech recognition component, send text, and speak message components. In Figure 4b iii, the blocks for pattern one buttons is illustrated having sent text component and label component which will send "I" when the button is pressed and set a label to forwarding. The blocks for UP button is shown in Figure 4b iv, in which the send text component and label component is used which will send "A" if the user pressed the button and set a label to forwarding.

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Figure 4. Design view and Blocks editor of Android Application for pattern design grass cutter. (**a**) Design view window. (**b**) i. Bluetooth module component. ii. Speech recognition component. iii. Send text component for the pattern. iv. Send text component for up arrow button.

There are total three ways to move grass cutter; Touch arrows buttons, voice recognition, and Pattern cutting as shown in Figure 5a which is the home page for the Android application also having a status bar for displaying the status of Bluetooth connectivity and status view for wheels and cutter. In Figure 5b, there are a total of 8 buttons; forward, backward, stop, left and right for wheels movement, Cutter ON and OFF for switching of cutter, home button for navigating back to home page of application and also having a status view for wheels and cutter whose value will be changed accordingly to the button pressed by user.

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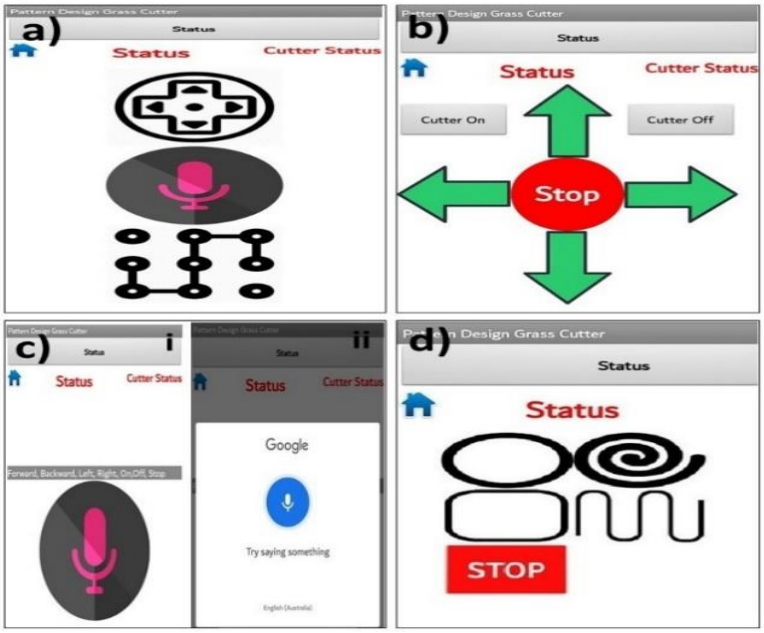

Figure 5. Design view and Blocks editor of Android Application for pattern design grass cutter. (**a**) The homepage of an android application showing three different option of grass cutter control. (**b**) Touch arrow buttons interface for controlling grass cutter. (**c**) Voice recognition mode; i. The window of voice recognition before the button press. ii. Voice recognition window after the button pressed. (**d**) Pattern designing interface having four different patterns.

For example if the user press forward arrow button, the "Status" text will be change to "Forward" text or if user press Cutter ON button, "Cutter Status" text will be change to "Cutter ON" and this will mechanism will work correspondingly for all buttons. In this way, figure 5c represents voice recognition interface where Figure 5c i is the starting screen where the user presses the voice recognition button to open a new sub-window to speak the keyword which is illustrated in Figure 5c ii. Figure 5d represented with a screen of having four patterns buttons such as "circle, spiral, rectangle, and continue" shapes cutting, and a status bar for displaying corresponding text. The method to operate the grass cutting system via an android system is as

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follows: Firstly, download [77] and install the app on the mobile phone. Turn on the mobile's Bluetooth, run the application. Here, make sure that the Bluetooth of grass cutter is switched on, select connect to the HC-05 to authenticate the pairing (pairing password is 1234 or 0000). Finally, click on the arrows touch buttons or microphone symbol on the voice recognition interface and give the voice commands. If the user speaks anything, given command will convert into text. As the phone is connected to the microcontroller using a Bluetooth module. After the conversion of the voice command into the text, the app will send the necessary data to the microcontroller using Bluetooth of the phone. According to the command, the grass cutter will move forward, backward, stop, right, left, cutter ON, and cutter OFF.

3.3. Pattern Design Mechanism

To successfully achieve the desired pattern, we will use the motor and wheels movement technique to generate a pattern cutting on the grass. There are mainly four different types of design that our system can create on the lawn, such as circle, spiral, rectangular, and continue shape. Wheels movement is controlled with programming to move in a special position and direction to generate these patterns. To generate a circle pattern, we only programmed left diagonal motors to rotate in full speed for the fixed time accordingly to circle diameter, while right diagonal will move freely so that the grass cutter will move in a right circle position and the cutter will cut the grass in the desired circle shape.

```
digitalWrite(LeftMotors_P, HIGH);
digitalWrite(LeftMotors_N, LOW);
analogWrite(SpeeDControl, 255);
digitalWrite(RightMotors_P, LOW);
```
(1)

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```
digitalWrite(RightMotors_N, LOW);
analogWrite(SpeeDControl, 0);
digitalWrite(Cutter, HIGH);
Delay(5000);
```

In Programming Equation 1, left diagonals motor are high and given maximum speed (0 means no speed, and 255 maximum means speed), Cutter is HIGH, and the delay given is 5000 milliseconds (time required for a 2 feet diameter circle is carefully calculated). So, the left diagonal motors of grass cutter will move in full speed for 5 seconds to generate a circle shape pattern on grass. To generate a spiral pattern, we programmed left diagonal motors to rotate in full speed and right diagonal motors in speed incrementing loop for the fixed time accordingly to spiral diameter, so that the grass cutter will move and the cutter will cut the grass in the desired spiral shape.

```
digitalWrite(LeftMotors_P,HIGH);                                    (2)
digitalWrite(LeftMotors_N, LOW);
analogWrite(SpeeDControl, 255);
digitalWrite(RightMotors_P, HIGH);
digitalWrite(RightMotors_N, LOW);
for (int i = 0; i <= 20; i++) {
analogWrite(SpeeDControl, i);
digitalWrite(Cutter, HIGH);
delay(50); }
delay(10000);
```

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In Programming Equation 2, left diagonals motor are high with maximum speed, and right diagonals motors are also high but initially have 0 speed with incrementing loop to 20 (each increment have a delay of 50 milliseconds) and grass cutter will move for 10000 milliseconds (time required for a 5 feet diameter spiral that is carefully calculated). So, the grass cutter will move for 10 seconds to generate a spiral shape pattern on grass. Similarly, to create a rectangle pattern, firstly we programmed all wheel motors to rotate for 3 seconds to go straight, then only left diagonal motors will rotate for 1 second to take a right turn, and this mechanism will run three times more, so that the grass cutter will cut the grass in the desired rectangular shape. Lastly, we programmed all wheel motors to rotate for 3 seconds to go straight, then only left diagonal motors will rotate for 2 seconds to take a right U-turn, again all wheel motors to rotate for 3 seconds to go straight and then only right diagonal motors will rotate for 2 seconds to take a left U-turn, and this mechanism will run two times more (programming for all patterns are presented in supplementary material file) and in this way the grass cutter will cut the grass in the desired Continue pattern shape.

3.4. Results and Discussions

In the beginning, the Android mobile application provides three modes (touch button, voice recognition, and pattern design) of controlling grass cutter, as illustrated in Figure 6. Firstly, connect the Android mobile application with Arduino by the Bluetooth module, when the user presses any touched button or speaks some keyword in voice recognition in the app, it will consequently transfer the data to Arduino that is placed on grass cutter via Bluetooth module. After receiving the data, Arduino will measure these with predefined Keywords.

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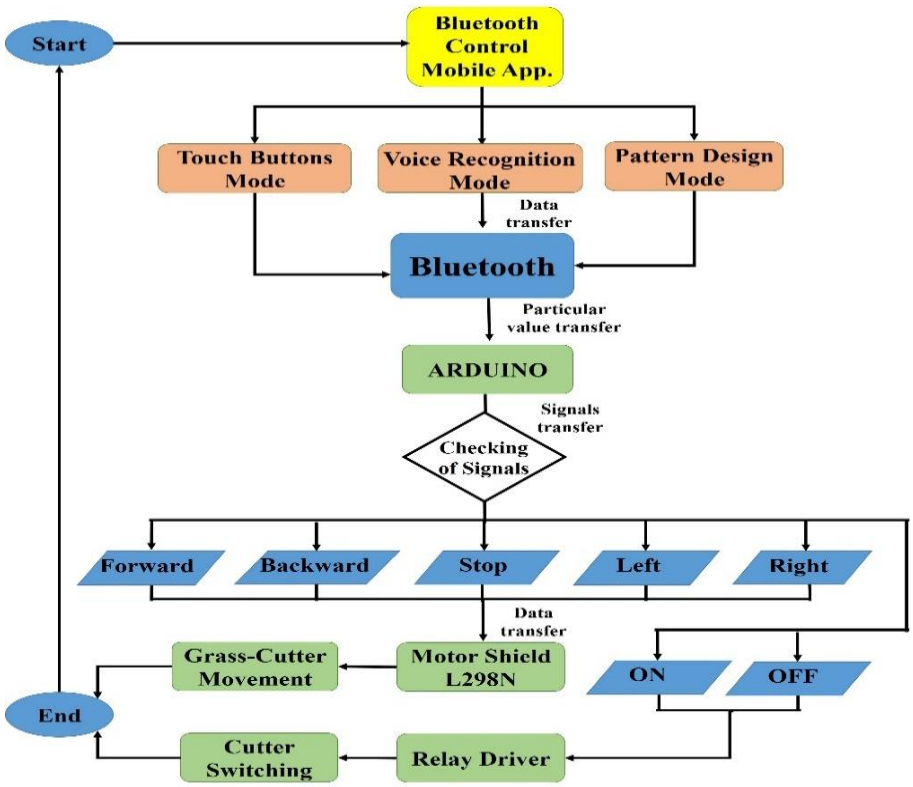

458

459 **Figure 6.** The flow diagram of the Android application based grass cutter control

460 system.

461 Arduino Uno will check if the user speaks or press “Forward” touch button, it will send a

462 forward signal to the motor shield. If Arduino founds that user press the backward or speaks a

463 backward keyword, it will send a back message to the motor shield. Similarly, if the user pressed

464 the right arrow or speak Right, Arduino will send a Right signal to the motor shield. Furthermore,

465 if keywords are recognized as left move if user press left arrow or speaks left, Arduino will send a

466 Left signal to motor shield, and if user press stop button or speaks stop, Arduino will send a stop

467 signal to the motor shield. Thus, after obtaining the signal, the motor module will check and control

468 the grass cutter’s movement. Similarly, If Arduino found that user speaks or press the ON/OFF

469 touch button, it will send a signal to the relay module to turn ON or OFF cutter. Furthermore, It

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Arduino founds that the user pressed any patterns button; it will send a signal to the motor module to move in corresponding patterns and relay module to turn on the cutter.

Initially, the grass cutter robot will not move and stayed motionless when it does not receive any signal from an android application. Whenever the user pressed or speaks the keyword, the signal will be measured of that direction by an Arduino and command will send to the motor shield to turn on corresponding motors and the grass cutter robot will start moving in the similar to the keyword.

Figure 7 shows the final presentation of the proposed pattern design grass cutting robotic system that controlled via touch arrows buttons of android application. Figure 7a represents that the grass cutter is moving to the forward direction (all the four wheels is moving) because the user pressed the Up arrow button on the android application. In Figure 7b, the grass cutter is moving in a backward direction as the user pressed the Down arrow button. The cutter is working because the user pressed the Cutter ON button, as illustrated in Figure 7c. In Figure 7d, the grass cutter is not moving because the user presses the stop button (brake command). In Figure 7e, the cutter is not working as the user pressed Cutter OFF button. The grass cutter is moving in the right direction because the user pressed the right arrow button in the android application, which is seen in Figure 7f. Similarly, in Figure 7g, the grass cutter is moving to the left direction because the user pressed the left arrow button.

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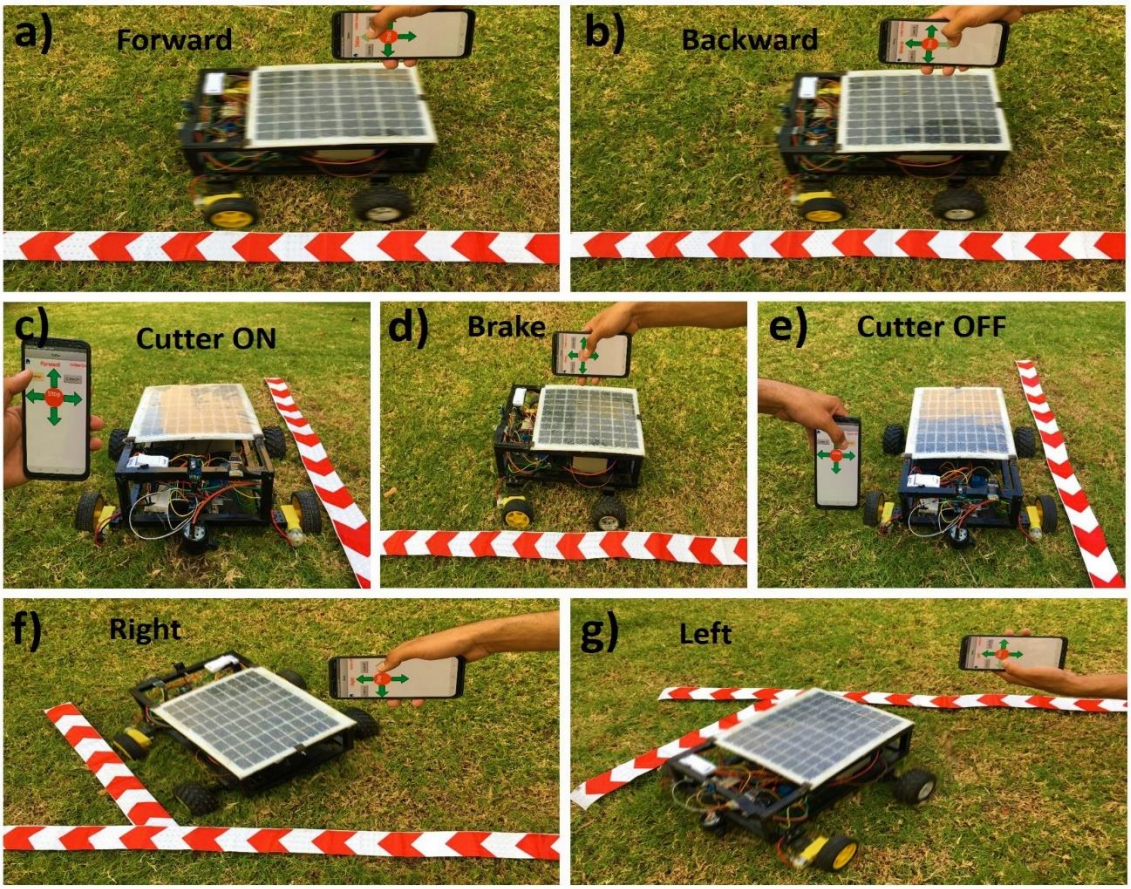

Figure 7. Result diagrams of the automatic pattern design grass cutting robot system using touch arrows button. (**a**) The up arrow button is pressed, so the grass cutter is moving forward. (**b**) The down arrow button is pressed, so the grass cutter is moving backward. (**c**) The cutter is working when Cutter off button is touched. (**d**) The grass cutter is not running as the stop button is pressed (**e**) the cutter is not working when the cutter OFF button is pressed. (**f**) The right arrow button is pressed, so the grass cutter is moving to Right direction. (**g**) The grass cutter is moving to left as the Left arrow button is pressed.

Moreover, mobile-application for voice recognition is also used, and the voice recognition module in the system is limited mainly to the seven voice commands such as Forward, Backward,

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Stop, Right, Left, Stop, Cutter ON and OFF. This voice recognition system uses google speech to text [90] to recognize and process the human voice. Figure 8 shows the result diagrams of the proposed pattern design grass cutting robot system that is controlled via voice recognition through a Bluetooth mobile-application. In this process, Figure 8a represents that the grass cutter is moving to forward direction after recognition of voice because the user inputs the forward move voice command to the mobile application. Similarly, the car is moving in a backward direction after voice recognition because the user inputs the backward move voice command, as seen in Figure 8b. In Figure 8c, the cutter is moving because the user inputs the Cutter ON voice command. Meanwhile in Figure 8d, the user input the Stop voice command to the application, the grass cutter is not moving. The cutter is not moving because the user inputs the Cutter OFF voice command, as seen in Figure 8e. On the other hand, in Figure 8f, the grass cutter is moving in the right direction after recognition of voice because the user inputs the right voice command. Similarly, the grass cutter is moving to left direction after recognition of voice because of user inputs the left voice command, can be viewed in Figure 8g.

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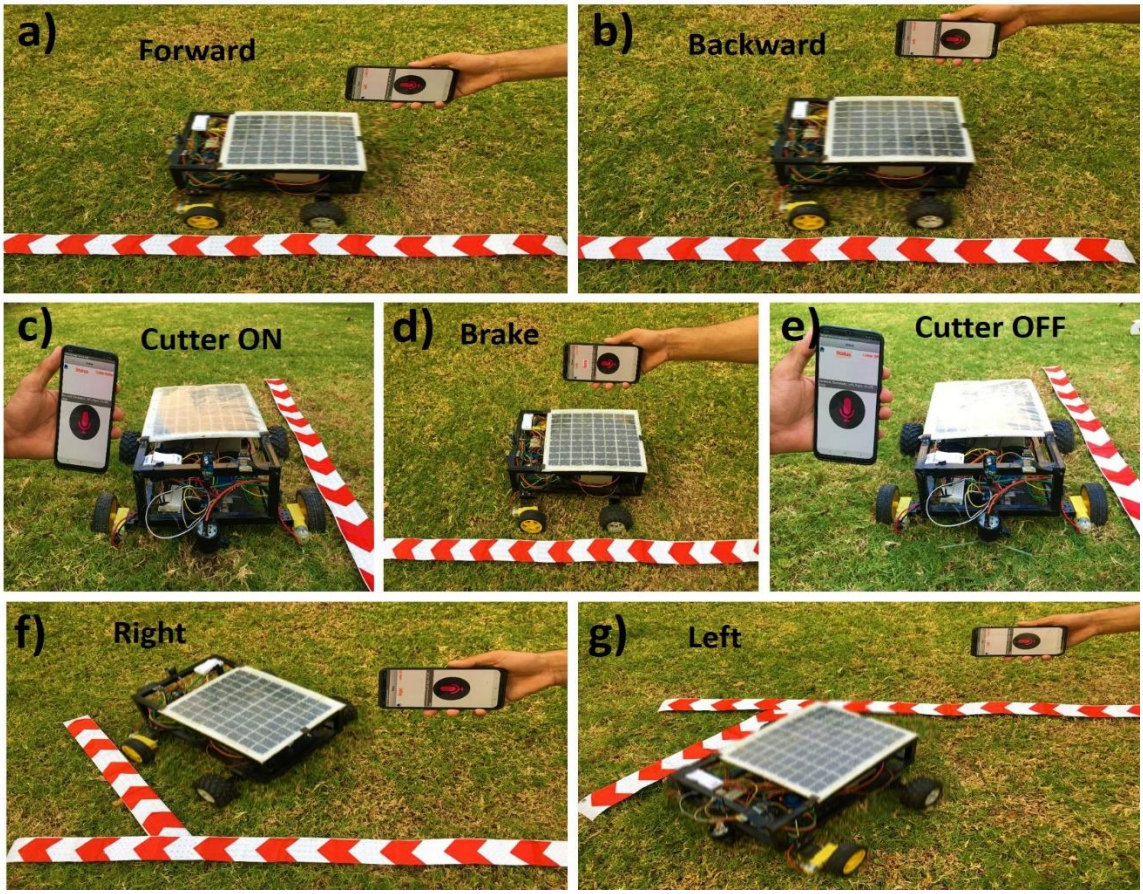

Figure 8. Results diagrams of the automatic pattern design grass cutting robot controlled with voice recognition of mobile- application. (**a**) Grass cutter is moving forward because the voice is recognized as a forward command (**b**) The grass cutter is moving reversely as the voice is identified as a backward command. (**c**) The cutter is working because the voice is recognized as Cutter ON. (**d**) The grass cutter is not moving (stopped) because the voice is recognized as a Stop. (**e**) The cutter is not working because the voice is recognized as Cutter OFF. (**f**) The car is moving in the right direction as the voice is identified as a right move command. (**g**) The voice is recognized as a left command, so the car is moving to left direction.

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Figure 9 presents the final demonstration of the proposed grass cutting robotic system with four different types of pattern designing on the grass. Figure 9a represents that the grass cutter is moving and cutting grass in circle shape because the user pressed the "circle" pattern button on the android application. In Figure 9b, the grass cutter is moving and cutting grass in a spiral shape as the user pressed the "spiral" pattern button. The user pressed the "continue" pattern button, so the grass cutter is moving and cutting grass in continue shape, as illustrated in Figure 9c. Similarly, in Figure 9d, the grass cutter is moving and cutting grass in rectangle shape because the user presses the "rectangle" pattern button.

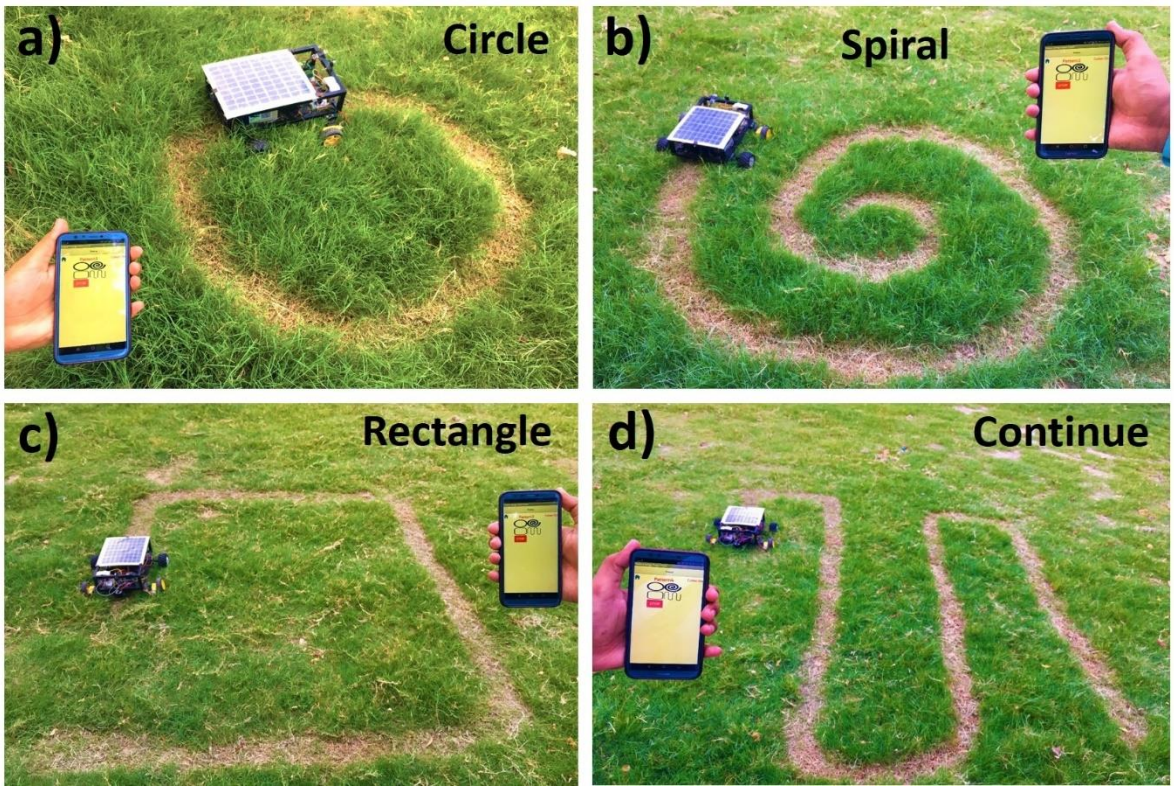

Figure 9. Results diagrams of the automatic pattern design grass cutting robot controlled with mobile- application. (**a**) Grass cutter is mowing grass in circle shape as user pressed "pattern 1" button. (**b**) Grass cutter is cutting grass in circle shape after getting command

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from mobile. (**c**) Grass cutter is cutting grass in continue shape. (**d**) Grass cutter is cutting grass in rectangle shape.

We used the Arduino-based control systems with wireless connectivity, in which the pattern design grass cutting robot system could be automatically controlled based on Android application (touch buttons and voice recognition), to avoid any limitations of the specifications, wireless range, etc. In some cases, we required wireless connectivity (WI-FI module) to make the system more scalable for easy integration of new devices. Wi-Fi module could be replaced with the Bluetooth module to extend the wireless range for this system further. Besides, the described systems are presented as lab-scale prototypes, to improve safety measurements, the obstacle detection feature can make it possible for the full-scale facilities and can also be managed by applying other technologies like camera [91].

It is worth noting we should consider the cases when the grass cutting robot collides with any obstacle in front of it while moving with mobile-application. Thus, for improving the safety measurements, we proposed a system to avoid the grass cutter from a collision with an obstacle by the help of sensor (the car will stop before the obstacle) as illustrated in Figure 10. In Figure 10a, the grass cutter is not moving to forward direction, whereas the Up arrow button is pressed. Similarly, the grass cutter is not moving to forward direction, although the user speaks the forward keyword in mobile-app because the sensor senses that there is an obstacle in front of the car as seen in Figure 10b.

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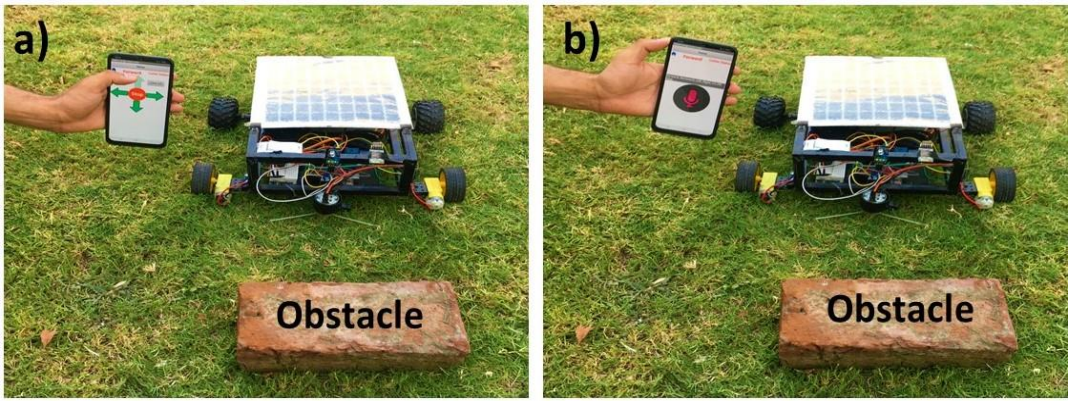

Figure 10. Avoidance of grass cutting robot system from obstacles using android mobile application; (**a**) Touch arrow buttons (**b**). Voice recognition system.

The effectiveness of the proposed mobile-application technique has much effective for different purposes such as, in the grass cutting field it can be used by disabled patients to cut simple grass or in different complex patterns easily just pressing a single button on the mobile application.

4. CONCLUSIONS

In this article, a design scheme for android mobile application system for controlling a pattern design grass cutting robot having solar energy capability based on Arduino has been explained, which is programmed to respond to events (based on the touch arrow buttons, voice recognition and pattern designing with Android mobile application as described above) and to make corresponding actions. The proposed project presented with mainly three operational modes in which the system is using a mechanism of controlling the grass cutting robot based on touch arrow buttons (grass cutter moves similarly to the direction of the button presses) and a voice recognition system(grass cutter moves accordingly to the keyword spoken by the user). This system is further expanded into composing the different complex patterns on the grass with touch buttons on mobile-application. Meanwhile, it is presented that the proposed systems have capabilities to

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identify the obstacles in front of the grass cutting robot. The hardware implementations of the proposed systems are provided at a lab-scale model to prove the simplicity, dependability, integrity, adaptability, and inexpensiveness of the system. As a lesson learned, we confirm that the introduced systems can be easily implemented under real conditions at great-scale in the future.

Meanwhile, the proposed pattern design grass cutting robot system have the advantages such as user-friendly, low-power consumption, low-cost approach, easy to use, simple and the system is less in size, so the little space is needed to adjust in hardware circuits. Besides, the proposed prototype is highly robust against unforeseen problems and can be easily extended further in the hardware section, and multiple applications can be attached to reduce the personal effort of upgrading. Similarly, voice commands are sent and received wirelessly with the help of Bluetooth technology but on the other hand, Bluetooth technology have only ranged up to 10–15 m only, the distance of processing in the system is less. If the Bluetooth connection gets dropped frequently, it will cause much delay or loss in the transmission and reply of commands. Further, the number of errors will increase in the presented voice-recognition system, if there is any background noise or other sounds in the surroundings. A limited number of patterns are manifested here, but the algorithm can be extended in several ways, and more patterns can be added into the system.

5. FUTURE WORK

This project is completed with the available sources, and the results are good enough but are not up to the expectations. Future work will build upon the improvement of the recognition system to increase accuracy and more patterns. Efficiency in pattern design grass cutting can be improved by using some other mechanism such as using the compass to fix angles of patterns or with an

array of the programmed matrix. Speed of motor is decreased due to the usage of heavy materials, so the more speed of motors can be achieved by using lightweight material and battery. Geo-Fencing technology [92] can make grass cutter more capable of tackling complex boundary shapes with higher precision, and Boundary area can be calculated more accurate by more complex algorithm, so the time and energy required can be easily maintained and can mow multiple gardens in the same session by traveling to the next lawn automatically using satellite tracking. GPS can be added to the proposed grass cutting system to track its location. GSM module can be used to make capable of sending and receiving messages from the user's mobile phone through SMS if someone does not have an android mobile. By utilizing Wi-Fi, the communication range can be increased by installing routers, and a wireless camera can be used which will provide live streaming and can be used for controlling the grass cutter from faraway places.

Supplementary Materials: The following are available online at www.mdpi.com/xxx/s1, Figure S1: The circuit design of solar powered automatic pattern design grass cutting robot system using Arduino.

Author Contributions: All of the authors contributed in literature search, figures, study design, data collection, data analysis, data interpretation, and writing etc. Such as, Z.M., M.S., Z.I., Q.M., and S.U. designed the devices, android application, and carried out the experimental work. Z.M. and S.U. analyzed the data and interpreted the results. S.U. and Z.M. drafted the manuscript with the input from the others. S.U. supervised the project.

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