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Bluetooth Controlled Land Rover Robot Car Using 8051 Microcontroller

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Abstract : *This paper presents the design and implementation of a Bluetooth-controlled Land Rover robot car using an 8051 microcontroller. The vehicle is operated wirelessly from a smartphone through a Bluetooth module. Single-character commands are sent from a mobile Bluetooth terminal application: 1 for forward, 2 for right turn, 3 for left turn, 4 for backward and 5 to stop. The Bluetooth module passes each command serially to the 8051, which decodes it and drives an L293D motor driver IC connected to two DC geared motors. The proposed system removes the cable of wired control, the line-of-sight limit of infrared control and the separate transmitter hardware of RF control, because the smartphone itself serves as the remote. The firmware is developed in Keil and the circuit is simulated in Proteus. The hardware, the software, the command decoding and the motion of the vehicle are described, and the system is compared with the existing control methods. The design is low cost and simple to build, and it suits wireless robotics, surveillance vehicles, remote inspection and embedded-systems teaching.*

Keywords: Bluetooth, 8051 microcontroller, L293D motor driver, Land Rover robot, serial communication (UART), DC geared motor, Keil µVision, Proteus.

I. INTRODUCTION

Mobile robots are used in inspection, surveillance, material handling and education. A basic requirement for all of them is a dependable way for the operator to command the vehicle from a distance. The control link strongly affects the cost, the convenience and the usable range of the robot [1], [3].

Robots are commonly controlled in one of three ways: wired remote controls, infrared (IR) transmitters, or radio-frequency (RF) modules. A wired remote keeps the operator tied to the robot by a cable, which limits movement. IR control needs a clear line of sight between transmitter and receiver, so any obstacle blocks the command. RF control improves the range, but it usually needs a separate transmitter and receiver pair, offers a limited number of channels, may suffer interference and adds cost. Most of these systems also need a dedicated handheld remote. Table 1 compares these methods with Bluetooth control.

Feature	Wired remote	IR remote	RF module	Bluetooth (proposed)
Line of sight	Not needed	Required	Not needed	Not strictly needed
Range limit	Cable length	Short	Moderate	About 10 m (Class 2)
Extra hardware	Cable and remote	IR pair and remote	Tx/Rx modules, remote	Module only; phone is remote
Interference	None	Ambient light	Possible	Low (frequency hopping)
Cost	Low	Low	Higher	Low

Table 1: Comparison of robot control methods

Bluetooth is a short-range wireless standard that works in the 2.4 GHz ISM band and is built into almost every smartphone [1], [5]. A phone can therefore act as the remote control, and the robot needs only a small Bluetooth module as the receiver. The module exchanges data with a microcontroller over a simple serial (UART) link, so the programming effort stays small.

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The choice of control method matters for a low-cost robot, because it decides both the hardware needed and the ease of operation. In this work a Land Rover type robot is built around the 8051 microcontroller [9]. It receives the command characters 1 to 5 from a smartphone and sets the inputs of an L293D motor driver [12] to move the vehicle forward, backward, left, right or to stop it. This paper describes the complete Bluetooth-controlled design and sets it against the three common alternatives.

The rest of the paper is organised as follows. Section II reviews the related literature, Section III presents the proposed design, Section IV describes the hardware, Section V explains the software, Section VI gives the working and results, Section VII lists the advantages, applications and future scope, and Section VIII concludes the paper.

II. LITERATURE REVIEW

Wireless control of mobile robots has been studied with several kinds of links and controllers. This section reviews recent work on the wireless links used for robots and on Bluetooth and smartphone-controlled vehicles, and relates it to the present design.

A. Wireless Links for Mobile Robots

Seferagić et al. [3] surveyed the trade-offs between wireless technologies, and Sikimic et al. [4] gave an overview of the technologies used in IoT networks. Both show that the link must be chosen to suit the application, since range, power use, data rate and cost differ from one technology to another.

Abderrahmane et al. [1] compared Wi-Fi, Bluetooth, ZigBee and LoRa for mobile robots by measuring signal strength, signal-to-noise ratio and throughput against distance. They found that Bluetooth is sensitive to noise and to obstacles such as water, and that its throughput falls quickly in hostile surroundings, although it offers good information security. They therefore favour LoRa for hostile sites. For a short-range indoor vehicle such as the one in this paper, Bluetooth is still a suitable and low-cost choice.

Weinmann and Simske [2] designed a Bluetooth 5.1 angle-of-arrival homing controller for an autonomous mobile robot, which shows that Bluetooth can be used for direction finding as well as for remote control.

B. Bluetooth and Smartphone Controlled Vehicles

Iyer and Duchaniya [9] built robots around the 8051 microcontroller with a Bluetooth link and an Android application. Three versions were made: a line follower, a button-controlled robot and a voice-controlled robot, all driven by numeric data sent from the phone. This is the work closest to the present design, since it also combines the 8051 with a serial Bluetooth link.

Jain et al. [8] describe an Android-controlled robot car in which an Arduino, an HC-05 Bluetooth module and motor drivers receive the commands of the phone. Hussien et al. [6] built a voice-controlled robot vehicle with an Arduino and an HC-05 module, in which spoken commands from an Android application make the robot move forward, backward, left, right or stop. Ghanghoria et al. [7] combined voice and Bluetooth control of a robot car with an ultrasonic sensor and a GPS module for obstacle avoidance.

Bluetooth control has also been applied to special-purpose robots, such as the Arduino-based rover tank firefighting robot for closed areas of Murad et al. [10] and the tennis ball picking robot of Xiao et al. [11]. Table 2 summarises the main points of the reviewed vehicles and compares them with the proposed design.

Ref.	Year	Controller	Control method	Main feature
[9]	2020	8051	Bluetooth, Android app	Line follower, button and voice robots
[10]	2021	Arduino	Bluetooth	Firefighting rover for closed areas
[8]	2022	Arduino	HC-05, Android phone	Android-controlled robot car
[6]	2023	Arduino	HC-05, voice commands	Moves in four directions and stops
[7]	2024	Arduino	HC-05, voice and app	Ultrasonic sensor and GPS module

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This work	2026	8051	Bluetooth terminal app	Single-character commands 1 to 5

Table 2: Summary of reviewed Bluetooth-controlled robots

C. Observations and Research Gap

The following points can be drawn from the reviewed work. (i) The smartphone has largely replaced the dedicated remote control. (ii) Recent designs often add voice control, sensors or GPS, which needs more hardware or a custom application. (iii) Most of the vehicles reviewed here use Arduino boards, and the 8051 is used in [9]. (iv) Bluetooth has a short range and is affected by noise and obstacles [1], so it suits indoor and short-range use. (v) The L293D remains a common low-cost motor driver [12].

The present design uses the 8051 with a standard Bluetooth terminal application, so no application has to be developed. The robot is controlled by single characters, which keeps the program short. The paper also describes the hardware, the software and the test plan together, and compares the system with wired, IR and RF control.

III. DESIGN OF PROPOSED SYSTEM

The main objective of this work is to design a wireless Land Rover that is controlled from a smartphone through Bluetooth, using an 8051 microcontroller as the central unit. The smartphone acts as the transmitter and the Bluetooth module as the receiver. Fig. 1 shows the block diagram of the proposed system.

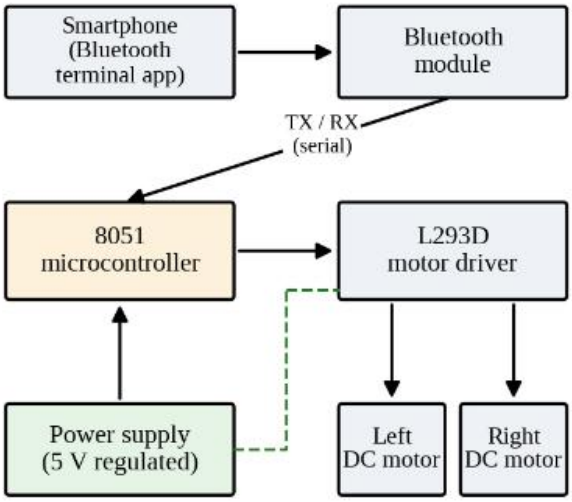


Figure 1. Block diagram of the proposed system

When the user presses a command on the Bluetooth terminal application, the character is transmitted to the module on the robot. The module sends it serially to the 8051, which compares the received character with the programmed command values and generates the control signals for the motor driver. The driver then rotates the two DC motors in the required direction. To move forward, both motors rotate forward. To turn right, the left motor runs forward while the right motor stops or rotates in the opposite direction. The left turn is the mirror of this.

A. Design Methodology

The design was carried out in the following steps.

1) Requirement analysis. The movements of the vehicle (forward, backward, left, right and stop) and the single-character commands 1 to 5 were defined. The vehicle had to be wireless, low cost and controllable from a common smartphone without a special application.

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2) Component selection. An 8051 microcontroller was chosen as the controller because of its on-chip serial port and its wide tool support. A serial Bluetooth module was chosen as the wireless link, an L293D as the motor driver and two DC geared motors for the wheels.

3) Power supply design. A regulated 5 V supply was designed for the logic, and a separate supply was kept for the motors so that the motor current does not disturb the controller.

4) Interface design. The serial pins of the Bluetooth module were matched to the UART pins of the 8051, with a resistor divider on the module input, and four port pins were assigned to the motor driver inputs.

5) Simulation. The circuit was drawn in Proteus and the program was run with a virtual terminal in place of the phone, so that faults in the logic were found before the hardware was built.

6) Firmware development. The program was written in embedded C and compiled in Keil. It sets up the serial port, waits for a character and sets the driver inputs for the matching command.

7) Assembly. The components were fixed on the chassis, the wheels were coupled to the motors and the connections were made as in Fig. 3.

8) Testing. Each command was tested in turn, as in the test plan of Section VI, and the stop command was checked for a prompt halt.

IV. HARDWARE DESCRIPTION

A. Power Supply

The power supply block provides the DC voltage needed by the microcontroller, the Bluetooth module, the motor driver and the motors. As shown in Fig. 2, it consists of a step-down transformer, rectifier diodes, a filter capacitor, a voltage regulator and an LED indicator. The transformer reduces the AC mains voltage, the diodes convert it to DC, the capacitor smooths the output and the regulator gives a stable 5 V supply. A battery can be used instead when the robot is to move freely.

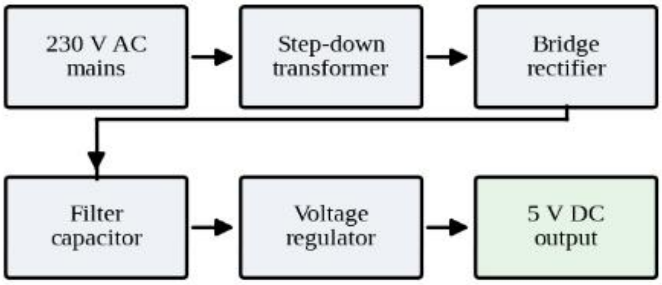


Figure 2. Block diagram of the power supply

B. Bluetooth Module

The Bluetooth module receives the wireless commands from the smartphone. Serial Bluetooth modules of the HC-05 or HC-06 type work as a wireless replacement for a serial cable and are commonly used at 9600 baud. The module is connected to the serial port of the 8051 through its TX and RX pins, and the received character is passed on to the microcontroller for processing. The RX pin of such modules usually accepts 3.3 V logic, so a resistor divider is placed between the 8051 TXD pin and the module RX pin.

C. 8051 Microcontroller

The 8051 is the central control unit. It has 4 KB of on-chip program memory, 128 bytes of data RAM, four 8-bit ports giving 32 input/output lines, two 16-bit timers and a full-duplex serial port. It receives the command from the Bluetooth module on its on-chip UART, compares it with the programmed values and sets the output pins that feed the motor driver. A crystal oscillator with two capacitors provides the clock, and a capacitor–resistor network provides the power-on reset. Its simple instruction set and wide tool support make it reliable and easy to program.

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D. Motor Driver (L293D)

The port pins of the 8051 cannot supply the current needed by a motor. The L293D is a 16-pin dual H-bridge driver that can deliver up to 600 mA per channel at a motor supply of 4.5 V to 36 V and has built-in diodes to absorb the voltage spikes of the motor [12]. It amplifies the low-current control signals so that the motors can be driven, and it allows the direction of each motor to be reversed or the motor to be stopped. Each motor is controlled by one pair of input pins, as listed in Table 3, while the enable pins are kept high.

IN1 / IN3	IN2 / IN4	Motor action (enable = high)
High	Low	Rotates in one direction
Low	High	Rotates in the opposite direction
Low	Low	Stops
High	High	Stops

Table 3: L293D input states for one motor

E. DC Geared Motors, Chassis and Wheels

Two DC geared motors drive the wheels of the Land Rover. The gearing lowers the speed and raises the torque. By changing the direction of current through the motors, the robot can move forward, backward, left or right. The chassis carries all the components and gives the vehicle its mechanical structure, and the wheels are coupled to the motors.

F. Circuit Connections

Fig. 3 shows the interconnection of the blocks and Table 4 lists the pin connections. The TXD pin of the Bluetooth module goes to the RXD pin (P3.0) of the 8051, and the TXD pin (P3.1) of the 8051 goes to the module RX pin through the divider. Port pins P2.0 to P2.3 are connected to the inputs IN1 to IN4 of the L293D, whose outputs drive the two motors. All grounds are joined together.

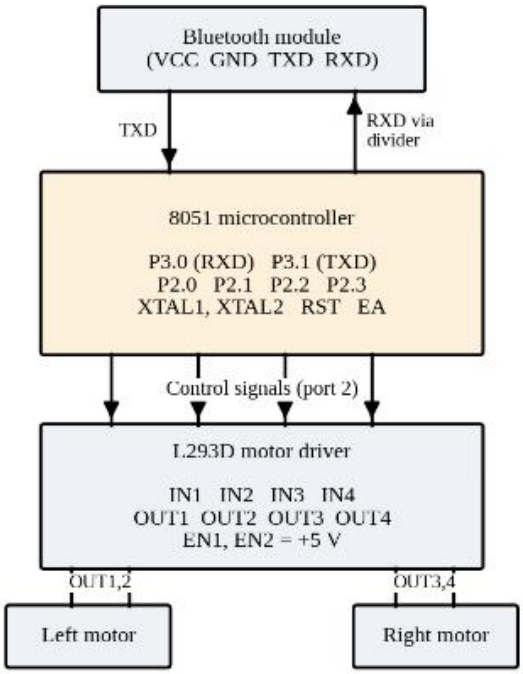


Figure 3. Circuit connection diagram of the robot

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From	To	Purpose
Module TXD	8051 P3.0 (RXD)	Receive command
8051 P3.1 (TXD)	Module RX (divider)	Serial link
8051 P2.0, P2.1	L293D IN1, IN2	Left motor
8051 P2.2, P2.3	L293D IN3, IN4	Right motor
L293D OUT1, OUT2	Left motor	Drive
L293D OUT3, OUT4	Right motor	Drive
L293D EN1, EN2	+5 V	Enable bridges

Table 4: Pin connections (port 2 used for illustration)

G. Design Considerations

The motors draw large and fluctuating current, so they are powered from a separate supply connected to the motor supply pin of the L293D, while the 5 V regulated supply feeds only the logic. The grounds of both supplies are joined to give a common reference, and a small capacitor near the supply pins of the microcontroller and the driver reduces electrical noise. The 8051 is reset at power-on so that all control pins start low and the vehicle does not move until a command arrives.

V. SOFTWARE DESIGN

The firmware is written in embedded C and compiled with the Keil compiler [13]. The circuit and the program are tested together in the Proteus simulator [14] before the hardware is assembled. At start-up the microcontroller configures its serial port for the baud rate of the Bluetooth module, then waits in a loop for a received byte. Each received character is decoded as in Table 6. Any other character leaves the motors unchanged. Fig. 4 shows the program flow.

A. Software Tools

Keil µVision is used to write, compile and debug the embedded C program, and it produces the hex file that is loaded into the program memory of the 8051 [13]. Proteus is used to draw the circuit and to simulate the microcontroller together with the motor driver and the motors, so that the logic of the program can be checked before the hardware is built [14]. In the simulation, a virtual terminal connected to the serial port of the 8051 replaces the smartphone. Any digit typed in the terminal is received by the program exactly as it would be from the Bluetooth module.

B. Serial Communication and Command Decoding

Serial communication between the Bluetooth module and the 8051 is configured as in Table 5. Timer 1 works as the baud-rate generator, and the serial port is set to 8-bit UART mode with reception enabled. The program checks the receive flag, reads the byte from the serial buffer and clears the flag. A decision structure then compares the byte with the characters 1 to 5 and sets the motor driver inputs for the matching action.

Register	Value	Purpose
TMOD	0x20	Timer 1 in mode 2 (8-bit auto-reload)
TH1	0xFD	Gives 9600 baud at 11.0592 MHz
SCON	0x50	Serial mode 1 (8-bit UART), receive enabled
TR1	1	Starts Timer 1

Table 5: Serial port configuration of the 8051

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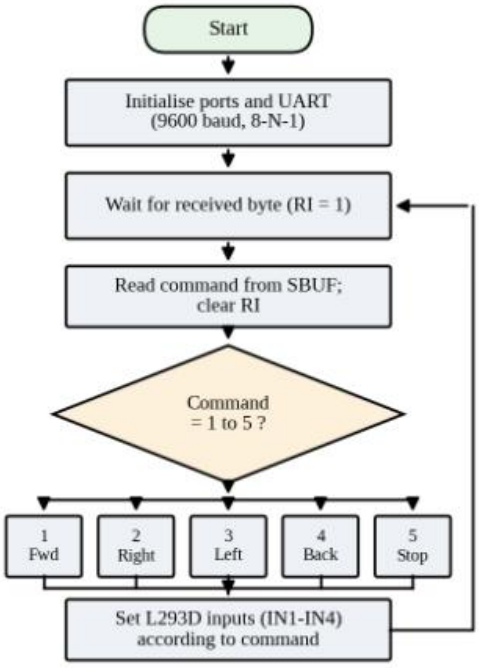


Figure 4. Flowchart of the control program

Cmd	Action	IN1	IN2	IN3	IN4
1	Forward	1	0	1	0
2	Right turn	1	0	0	0
3	Left turn	0	0	1	0
4	Backward	0	1	0	1
5	Stop	0	0	0	0

Table 6: Command decoding and L293D input states (IN1-IN2: left motor, IN3-IN4: right motor)

A minimal version of the control loop is given below. The crystal frequency (11.0592 MHz), the baud rate (9600) and the choice of port 2 pins are assumed here for illustration.

```
#include <reg51.h>
sbit IN1 = P2^0;  sbit IN2 = P2^1;
sbit IN3 = P2^2;  sbit IN4 = P2^3;
void drive(bit a, bit b, bit c, bit d) {
  IN1 = a; IN2 = b; IN3 = c; IN4 = d;
}
void main(void) {
  unsigned char cmd;
  TMOD = 0x20;  TH1 = 0xFD;   /* 9600 baud */
  SCON = 0x50;  TR1 = 1;
  drive(0,0,0,0);
  while (1) {
    while (!RI);  cmd = SBUF;  RI = 0;
    switch (cmd) {
```

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```
        case '1': drive(1,0,1,0); break;
        case '2': drive(1,0,0,0); break;
        case '3': drive(0,0,1,0); break;
        case '4': drive(0,1,0,1); break;
        case '5': drive(0,0,0,0); break;
      }
    }
}
```

VI. WORKING AND RESULTS

After power-on the robot stays at rest. The user pairs the smartphone with the Bluetooth module and opens a Bluetooth terminal application. Each digit sent from the phone produces the movement listed in Table 6 and drawn in Fig. 5, and the digit 5 brings the vehicle to a stop at any time. Because the stop command uses the same link as the motion commands, the operator can halt the robot instantly.

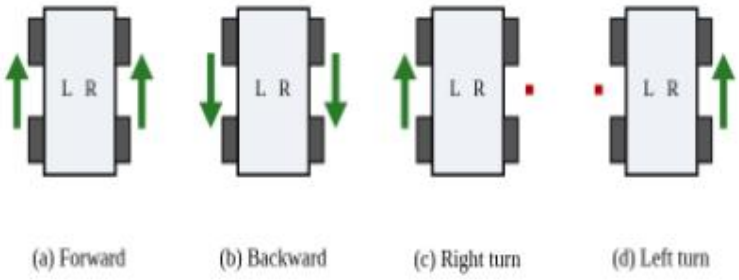


Figure 5. Motor action for each command

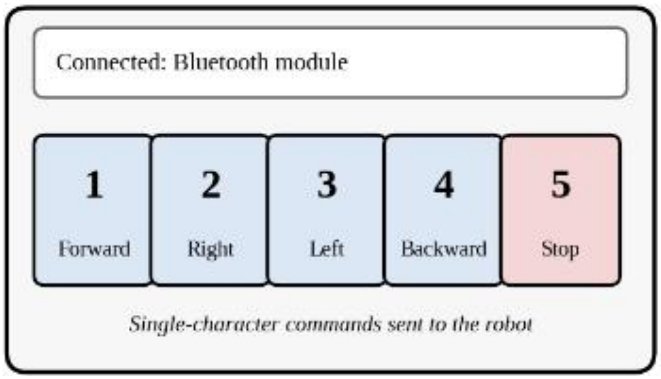


Figure 6. Command keys on the Bluetooth terminal application

For forward and backward motion both motors rotate in the same direction. For a turn, the motors on the two sides are driven differently, so the vehicle turns about its own axis. The same five commands cover all movements, which keeps the program and the operation simple.

Table 7 compares the proposed system with the existing control methods on the points identified in Section I. Table 8 lists the main specifications of the prototype, based on the rated values of the components used.

Feature	Wired	IR / RF	Proposed Bluetooth
Freedom of movement	Restricted	IR needs line of sight	Wireless
Remote device	Dedicated	Dedicated or extra module	Smartphone
Hardware cost	Moderate	Higher for RF	Low

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Command interface	Fixed buttons	Fixed buttons	Digits 1 to 5 from app

Table 7: Comparison of existing and proposed systems

Parameter	Value
Wireless link	Bluetooth, serial (UART)
Bluetooth range (Class 2)	Up to about 10 m
Serial baud rate	9600 baud
Logic supply	5 V DC regulated
L293D motor supply	4.5 V to 36 V
L293D output current	600 mA per channel
Number of commands	5 (digits 1 to 5)

Table 8: Main specifications of the prototype (rated values)

A. Operating Procedure

The robot is operated in the following steps: (i) switch on the power supply of the logic and the motors; (ii) turn on Bluetooth on the smartphone and pair it with the module; (iii) open the Bluetooth terminal application and connect to the module; (iv) send the digit 1 to move the vehicle forward, 2 to turn right, 3 to turn left and 4 to move backward; and (v) send the digit 5 to stop the vehicle. The vehicle keeps the last commanded motion until a new command arrives.

B. Functional Test Plan

Each command is checked in turn, first in the Proteus simulation and then on the assembled vehicle, as listed in Table 9. A command is accepted when the motors show the action expected for it and the vehicle stops promptly when 5 is sent.

Cmd	Action	Expected behaviour
1	Forward	Both motors rotate forward
2	Right turn	Left motor forward, right motor stopped
3	Left turn	Right motor forward, left motor stopped
4	Backward	Both motors rotate in reverse
5	Stop	Both motors stopped
Other	Ignored	Motors keep the last state

Table 9: Functional test plan for the commands

C. Discussion

The results of the design show that a single Bluetooth link is enough to give full directional control of the vehicle. The smartphone removes the need for a dedicated remote, and the five-command scheme keeps the program short enough for the small memory of the 8051. The main limit of the system is the range of Bluetooth, which is about 10 m for a Class 2 device, so it is best suited to indoor and short-range use. Obstacles such as walls can reduce the usable range. The speed is fixed, but pulse-width modulation on the enable pins would allow speed control.

VII. ADVANTAGES, APPLICATIONS AND FUTURE SCOPE

The main advantages of the system are: wireless control using widely available Bluetooth technology; no separate transmitter, since the smartphone is the remote; simple command operation with the digits 1 to 5; low cost and easy construction; and reliable control with simple programming on the 8051.

The robot can be used for wireless robotic applications, surveillance vehicles, remote inspection and the demonstration of embedded systems in teaching. Bluetooth range is short, so the vehicle must remain within the range of the phone. Future work can add obstacle-avoidance sensors, a camera for live video, PWM speed control and a longer-range wireless link.

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VIII. CONCLUSION

A Bluetooth-controlled Land Rover robot car was designed around the 8051 microcontroller, a Bluetooth module, an L293D motor driver and two DC geared motors. The robot moves forward, backward, left and right and stops on single-character commands sent from a smartphone. The design removes the cable, line-of-sight and extra-transmitter limits of wired, IR and RF control, and its low cost and simple programming make it suitable for wireless robotics and for teaching embedded systems.

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