Design of an Arduino-Based Bluetooth-Controlled Car for Environmental Data Detection (Postprint)

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Date: 2023-10-08T00:00:00+00:00

Abstract

Environmental monitoring constitutes a crucial approach to environmental protection, and establishing a rapid, simple, and accurate environmental monitoring methodology facilitates effective environmental supervision and control. This design employs the Arduino software and hardware development platform to achieve wireless control of the mobile platform and detection of various environmental parameters—including temperature, humidity, and concentrations of combustible gases—through a Bluetooth module. The acquired data is transmitted back to a mobile Bluetooth serial assistant application via the Bluetooth module, thereby enabling real-time monitoring of environmental parameters and control of the vehicle's forward, backward, and directional movements through the mobile device. The detection rover integrates multiple functions including Bluetooth control, data acquisition, and alarm capabilities into a unified system. It can substitute for human operators in environmental data collection tasks under unspecified or adverse conditions, thereby demonstrating considerable promotional value and promising application prospects.

Full Text

Design of an Arduino-Based Environmental Data Detection Bluetooth-Controlled Vehicle

Research · Technology and Applications ChinaXiv Cooperative Journal

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Abstract

Environmental monitoring is a crucial component of environmental protection, and establishing a rapid, simple, and accurate environmental detection method facilitates effective environmental supervision and control. This design utilizes the Arduino software and hardware development platform to achieve wireless control of the vehicle via a Bluetooth module while simultaneously detecting various environmental parameters such as temperature, humidity, and combustible gas concentration. The collected data is transmitted back to a mobile Bluetooth serial assistant app through the Bluetooth module, enabling real-time monitoring of environmental parameters and control of the vehicle's forward, backward, and directional movements from a smartphone. The detection vehicle integrates Bluetooth control, data acquisition, and alarm functions into a single system, capable of performing environmental data detection tasks in hazardous or adverse conditions as a human replacement, thus demonstrating significant potential for promotion and practical application.

Keywords: Arduino microcontroller; Bluetooth; environmental detection; mobile phone

Introduction

With scientific advancement and continuous improvement in social productivity, environmental monitoring has evolved from industrial pollution source surveillance to broader environmental monitoring [1]. Environmental monitoring is receiving increasing attention, yet the integration of new technologies and methods remains in the research and development stage, with manual and semi-automatic approaches still predominantly used for collecting environmental factors, resulting in low efficiency and poor accuracy [2]. Establishing a rapid, simple, and precise environmental detection method is essential for effective environmental supervision and control. Arduino is an open-source microcontroller electronic design platform whose hardware development boards feature numerous pre-designed interfaces for sensor modules. By simply plugging in the corresponding encapsulated modules, the system can read signals obtained by sensors from the environment and provide appropriate feedback under program control, thereby enhancing development efficiency [3]. This paper proposes a design for an Arduino-based environmental data detection Bluetooth-controlled vehicle that enables smartphone Bluetooth control of the vehicle's left/right and forward/backward movements, real-time transmission of environmental data collected by onboard sensors, and triggers an alarm mechanism when concentration values exceed predetermined thresholds.

2. Hardware Design

The hardware components primarily include the Arduino development board, HC-05 Bluetooth module, DHT11 temperature and humidity sensor, MQ-2 smoke gas sensor module, L298N motor driver module, and DC geared motors. The Arduino development board serves as the control center of the vehicle system, while the Bluetooth module facilitates communication between the smartphone and the vehicle. The motor driver module controls the forward and reverse rotation of the DC geared motors to alter the vehicle's motion state, and the DHT11 temperature and humidity sensor together with the MQ-2 smoke gas sensor constitute the environmental data acquisition module for detecting temperature, humidity, and smoke or combustible gas concentrations.

1. System Design

The system employs an Arduino microcontroller as the core control board, simultaneously accomplishing vehicle state control and environmental data transmission/reception/display via smartphone Bluetooth. The system architecture block diagram is shown in Figure 1 [Figure 1: see original paper]. In this design, Arduino control board pins 0 (RX) and 1 (TX) are connected to the TX and RX pins of the Bluetooth module, respectively. The IN1, IN2, IN3, and IN4 interfaces of the L298N motor driver module are connected to pins 6, 9, 10, and 11, which feature pulse width modulation (PWM) capability. The temperature and humidity module is connected to digital pin 5. The smoke gas sensor requires connection to an analog port, thus it is interfaced with port A0, while the functionally associated buzzer is connected to pin 2. Following pin allocation on the Arduino development board, the OUT1 and OUT2 output ports of the L298N motor driver module are connected to the left DC geared motor, with the right motor connected similarly on the opposite side. The specific serial port configuration for hardware connections is illustrated in Figure 2 [Figure 2: see original paper].

As shown in the diagram, the power supply consists of a lithium battery pack and linear DC regulated power supply, providing stable drive current for the vehicle system's motors. The chassis employs a conventional four-wheel structure, with DC motors installed on the two front wheels to control left/right turning, forward movement, backward movement, and stopping. The temperature and humidity sensor and combustible gas sensor connect to the Arduino main controller for environmental data acquisition. The Bluetooth module enables communication between the vehicle and smartphone, allowing the vehicle to receive commands from the phone and transmit collected data back, while also enabling smartphone-based control of the vehicle's movements.

2.1 Arduino Main Controller Unit

The Arduino controller [4,5] primarily comprises a microcontroller, digital serial ports, analog serial ports, a crystal oscillator, and a 5V voltage regulator, among other components (as shown in Figure 3 [Figure 3: see original paper]). The development board connects to a computer via a USB data interface for program compilation and uploading. After writing the program code in the IDE, the program is uploaded to the Arduino development board through the USB interface, where the onboard microcontroller executes the program and processes data. In this design, pins 3, 5, 6, 9, 10, and 11 of the Arduino UNO development board feature pulse width modulation (PWM) functionality, enabling speed regulation for servos, motor driver modules, and other components.

2.2 Data Acquisition Unit

The environmental data acquisition function primarily relies on a digital temperature and humidity sensor and an MQ-2 smoke gas sensor to detect temperature, humidity, and smoke or combustible gas concentrations.

2.2.1 DHT11 Temperature and Humidity Sensor The DHT11 digital temperature and humidity sensor integrates acquisition and sensing technologies, incorporating a humidity-sensitive resistor and an NTC thermistor. Its internal schematic is shown in Figure 4 [Figure 4: see original paper]. The humidity-sensitive resistor consists of a substrate coated with a moisture-sensitive material. When this sensing film contacts water vapor in the air, the component's resistance varies with changes in hydrogen ion concentration during moisture absorption and desorption processes. The built-in conversion circuit calculates the resulting voltage changes and correlates them with humidity variations, thereby enabling environmental humidity measurement [6]. The NTC resistor, or Negative Temperature Coefficient thermistor, exhibits decreasing resistance with increasing ambient temperature, causing the voltage output to rise accordingly. The conversion circuit then maps these voltage changes to corresponding temperature values. The main parameters of the DHT11 temperature and humidity sensor are listed in Table 1 .

2.2.2 MQ-2 Smoke Gas Sensor The gas-sensitive resistor is the core component of the MQ-2 smoke gas sensor for measuring combustible gas concentrations, converting detected gas concentrations into voltage signals transmitted to the microcontroller. Gas-sensitive resistors are available in both P-type and N-type semiconductor variants. Under normal conditions, N-type semiconductor gas-sensitive resistors exist in a state of anion vacancies. When the gas-sensitive resistor contacts combustible gas molecules, electrons transfer from the gas molecules to the N-type semiconductor, reducing the semiconductor's resistance and thereby altering the circuit voltage [7]. For P-type semiconductor gas-sensitive resistors with cation vacancies, the semiconductor resistance increases upon gas contact. Since temperature significantly affects semiconductor conductivity, the MQ-2 smoke gas sensor must be heated when measuring combustible gas concentrations.

2.3 Communication Unit

The smartphone communicates with the detection vehicle through a Bluetooth module, which transmits the collected environmental data back to the mobile Bluetooth serial assistant app, enabling real-time monitoring of environmental parameters and control of the vehicle's forward, backward, and directional movements. The HC-05 Bluetooth module pairs with the smartphone's Bluetooth to establish communication. The HC-05 module features six pins: VCC, GND, TXD, RXD, KEY, and LED. The module's indicator LED displays different blinking patterns corresponding to various communication states, allowing users to easily verify proper operation. When the KEY pin is set to high level before or simultaneously with powering the module, the LED blinks slowly at one-second intervals, indicating AT mode where pairing is disabled. When KEY is left floating or grounded, the LED blinks rapidly at two-second intervals; upon successful pairing, the LED switches to a double-flash pattern, blinking once every two seconds. Setting KEY to high level while in pairable mode exits the pairable state and returns to AT mode, though the LED blinking frequency remains consistent with the pairable state. In this design, the KEY pin is left floating, and the functions of each pin are detailed in Table 2 .

2.4 Car Motion Unit

The vehicle's motion functionality is primarily realized through the L298N motor driver module and DC3V-6V geared motors. The L298N module [8,9] (shown in Figure 5 [Figure 5: see original paper]) incorporates two built-in H-bridges to maintain the motor terminal voltages between high and low levels. In addition to converting 12V power supply to 5V for the development board, the module can drive and control two motor channels. When the enable pins ENA and ENB are both set high, different combinations of IN1 and IN2 states control various motion states of the DC geared motors. Before applying pulse width modulation to regulate motor speed, it is necessary to first establish the connection between the IN1 and IN2 ports and the DC motors to determine their rotation directions. After determining the motor rotation directions, the program establishes the correspondence between microcontroller pins and left/right motors. PWM pulses are then output for speed regulation when adjusting the DC geared motor speeds is required. When both IN1 and IN2 interfaces are in either the 0 state or the 1 state simultaneously, the corresponding DC motors controlled by the two output interfaces are braked. The schematic diagram of the vehicle motion unit is shown in Figure 6 [Figure 6: see original paper].

3. Software Design

The software adopts a modular design approach, consisting of four main components: the main program, data acquisition program, Bluetooth communication program, and vehicle motion control program. The program design flowchart is illustrated in Figure 7 [Figure 7: see original paper]. Each functional module is designed and uploaded to the Arduino development board individually. After uploading, the functionality is tested; if it operates correctly, the next functional program is developed. If functionality is not properly realized, the program section is debugged and revised. Once all four functional modules are completed, they are integrated and combined, with continuous uploading and debugging until all functions are successfully implemented, at which point the software design is complete.

The Bluetooth serial assistant is configured as shown in the left panel of Figure 8 [Figure 8: see original paper]. The smartphone communicates with the detection vehicle via the Bluetooth module, sending different commands to control the vehicle and enabling smartphone-based control of forward, backward, and directional movements. The collected environmental data is transmitted back to the mobile Bluetooth serial assistant app (right panel of Figure 8 [Figure 8: see original paper]), with alarm activation triggered when environmental data exceeds predetermined thresholds.

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Funding: Xuzhou Science and Technology Project for Social Development—Medical-Engineering Integration Projects (KC16SY149, KC16SY153, KC16SY154); Xuzhou Medical University Excellent Talent Research Startup Fund Project (D2015015)