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A Wireless Voice-Controlled Home Automation Framework Using Arduino Uno

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Abstract:
In the present paper, the design and implementation of a voice-controlled home automation system based around an Arduino UNO microcontroller and an HC-05 Bluetooth module is outlined. The system allows the user to control domestic appliances with the use of voice commands relayed on a smartphone, which enhances convenience, availability, and power efficiency. The solution creates a combination of affordable hardware and a simplified voice interface, which makes it especially beneficial to older and physically disabled people. The architecture includes relay module to switch devices, Bluetooth communication to provide wireless control and a mobile application to take voice input. Experimental findings show that it is dependable in the control of various appliances with low latency. The proposed system gives a scalable and cost-effective platform of smart home automation, thus preparing the platform to future improvements, including integration with the Internet of Things and remote control capabilities.

Key Word: *Home Automation system, Voice Control, Arduino Uno, HC-05 Bluetooth module.*

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I. Introduction

The high rate of development of embedded systems and wireless communication technologies has opened the way to innovative solutions in home automation. Among them, voice-controlled systems have come out to be a game changer as it tries to add convenience, ease of access and energy conservation in the vicinity of residential settings. These systems allow users to use their voice to activate or deactivate household appliances, which removes the physical component of operation and makes them especially useful to older people and those with physical and mental disabilities.

The paper will outline a home automation system that uses a voice controller with an Arduino UNO microcontroller and a HC-05 Bluetooth device that is completed with low cost and user-friendly benefits. The system uses voice recognition via a smartphone to send a signal wirelessly to the Arduino which then relays the signal to electrical appliances through a relay module. The inclusion of the Bluetooth communication makes it facilitated and therefore not dependent on a complex networking infrastructure.

The suggested solution is a clear illustration on the subject of how low-cost smart home systems are possible, as well as pointing towards the possibility of scalable and customizable automation platforms. By this research, we seek to add to the increasingly popular area of assistive technology and smart living to provide a viable implementation that can be both cost-effective, easy to use, and functional.

II. Literature Review

Over the last decade, the development of autonomous devices in the home setting has increased substantially due to the progress of embedded systems, wireless communication, and AI. Voice controlled systems, especially, have been quite popular because they are intuitive and their benefits are accessibility.

Vikas Pal et al. (2021) suggested voice-controlled home automation, in which the Arduino UNO and the HC-05 Bluetooth module are used, with voice commands received through a smartphone application. Their system showed usefulness in controlling simple appliances like lights and fans focusing on the low cost and less complex implementation.

A similar system was created by Vishal Gupta et al. (2023) and targets the older and disabled users. They were designed to have voice recognition via mobile devices and Bluetooth communication with Arduino so that people can operate home appliances without using their hands. The paper emphasized the value of user centric design and scalability capabilities of smart home environments.

In their voice-controlled automation system with Bluetooth, Sapna Rajput et al. (2023) paid attention to its accessibility and affordability. They were able to use HC-05 and a 2-channel relay module to operate actuaries

by voice. The feasibility of their work was the fact that such systems can be deployed in resource-constrained environments.

All these works evidenced the feasibility of voice-controlled systems based on Arduino. They also unveil typical issues like the lack of range of Bluetooth connectivity, reliance on mobile applications, and a lack of scalability. Nevertheless, they are simple and low-cost systems that are most suitable in small-scale smart home applications and assistive technologies.

III. System Design

The suggested home automation system will use voice control where the user can use voice command through a smartphone to control the household appliances. The system architecture combines both hardware and software to ensure that there is smooth communication and control.

Hardware Components

- *Arduino UNO*: It is the main microcontroller which interprets the incoming commands, and manages the devices that are attached to it.
- *HC-05 Bluetooth Module*: Enables the transfer of wireless communication between the smartphone and Arduino UNO.
- *Relay Module*: This serves as a connection between the Arduino and appliances of high voltage, which can switch safely.
- *Smartphone*: Has the voice assistant or a special application to record and send voice commands.
- *Power Supply*: It supplies the Arduino with the required voltage and the other modules attached to it.

Circuit Configuration

- HC-05 Bluetooth: The HC-05 is an electronic component of the Arduino UNO attached to the serial line (TX/RX pins).
- The relay module is also attached to digital output pins (e.g. D7 and D8) to have control over appliances.
- Other types of appliances like lights, fans, etc are connected to the relay component, and by using the received commands, the Arduino can turn them ON/OFF.

Software Components

- Arduino Sketch: A C/C++ application that reads data sent to it by the serial connection and responds to it by changing digital outputs.
- Voice Command App: This is a mobile app (or voice assistant) that will translate spoken instructions into serial characters (e.g., a voice agent can say A to turn on, or a to turn off).
- Bluetooth Serial Communication: Provides the transfer of data between the smartphone and Arduino with the assurance of reliability.

Workflow

1. User gives a command to the smartphone (e.g., Turn on the light).
2. The voice input is transformed into a pre-established character and transmitted through Bluetooth by the app.
3. The command is sent to the HC-05 module which sends it to the Arduino UNO.
4. The character is interpreted by the Arduino and the relay output is activated.
5. The linked appliance reacts (e.g. light goes ON).

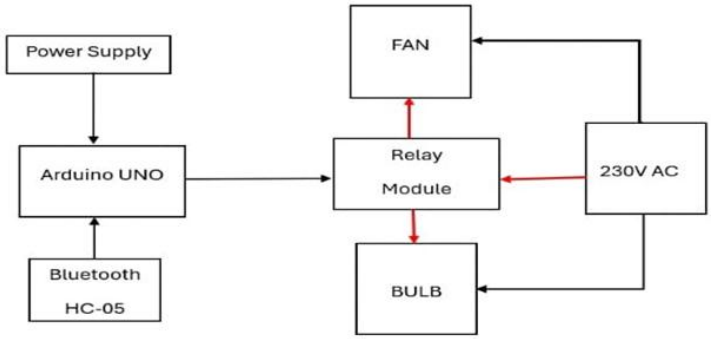

Fig 1: Block diagram of the setup

The block diagram of the setup is shown in figure 1 above. This scalable and modular design can easily be adjusted to add other appliances and other sensors or communication protocols in a later version.

IV. Implementation

The implementation of the home automation system with voice control implies a combination of hardware with software logic, in order to allow smooth control over the household appliances using voice commands. The cycle will be broken down into the hardware configuration, software development and testing of the system.

Hardware Setup

- Arduino UNO: the central controller is used.
- HC-05 Bluetooth Module has been attached to the serial pins of arduino (TX to RX, RX to TX) to communicate wirelessly.
- Digital pins (e.g., D7 and D8) are linked to a Relay Module in order to operate the electrical appliances.
- A smartphone is the voice input device and sends an order through Bluetooth.
- The bulbs and fans are also wired to the relay so that they could be switched.

Software Development

- The Arduino is programmed in the Arduino IDE using a sketch which will listen to any input sent on the serial line, and will execute digital outputs based on the input received.
- Every voice command is associated with a particular character (e.g. A to turn on a light, a to turn it off).
- An app or voice assistant (e.g. Googles assistant using IFTTT or a custom Bluetooth terminal app) is then set up so that these characters are sent over Bluetooth.

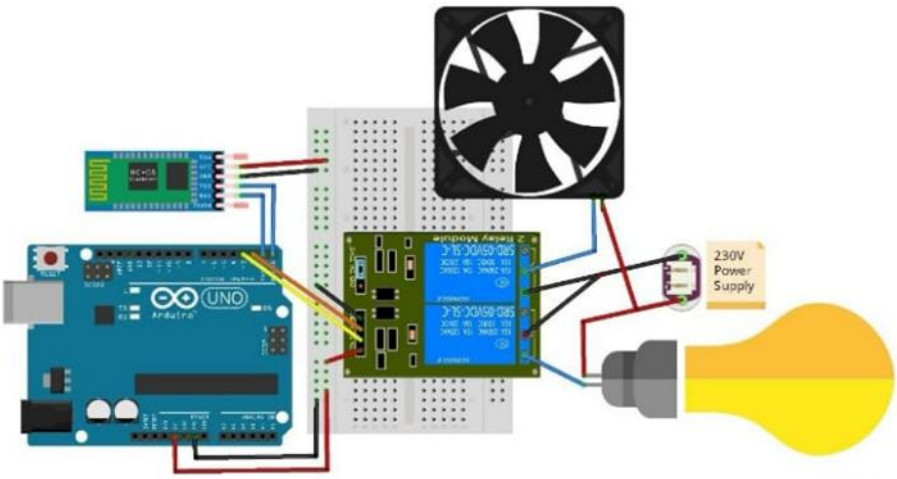

Fig 2: Implementation diagram of the setup

Sample Arduino Code:

```
char command;
void setup()
{
Serial.begin(9600);
pinMode(7, OUTPUT); // Light
pinMode(8, OUTPUT); // Fan
}
void loop()
{
if (Serial.available())
{
command = Serial.read();
if (command == 'A') digitalWrite(7, HIGH); // Light ON
else if (command == 'a') digitalWrite(7, LOW); // Light OFF
else if (command == 'B') digitalWrite(8, HIGH); // Fan ON
else if (command == 'b') digitalWrite(8, LOW); // Fan OFF
}
}
```

Voice Command Integration
- The smartphone application takes voice records and translates them into serial codes.
- These commands are sent through Bluetooth to HC-05 module.
- Arduino receives and interprets the commands and is used to control the connected appliances.

Testing and Validation
- The different voice commands were tried in the system so as to be sure of an accurate response.
- There was low latency in the response of appliances.
- The indoor range of Bluetooth was discovered to have sufficient range of 10 meters.
- The system also underwent testing in regard to reliability, usability and the responsiveness.

This application illustrates a viable and cost-effective idea of utilizing smart home automation, and possible future upgrades that include Wi-Fi, sensor fed-back and remote access.

V. Results

The voice-controlled home automation system was implemented and tried in a controlled environment successfully, the image is shown in figure 3 below. The assessment was based on the functionality, responsiveness, range and user experience.

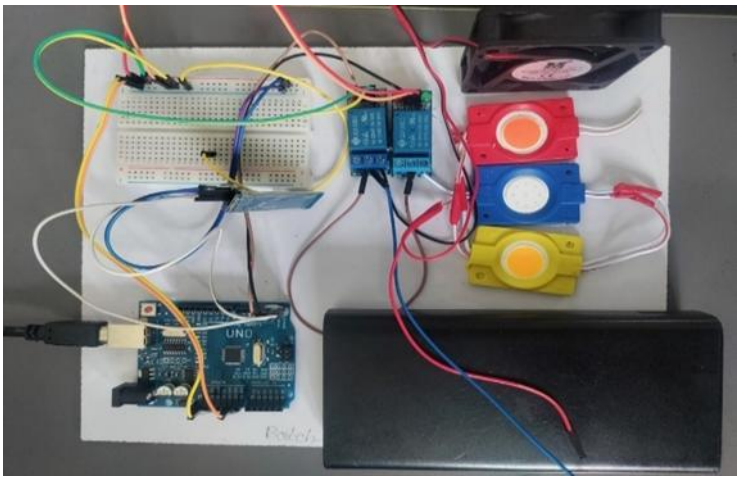

Fig 3: Circuit image of the setup

Functional Testing
- The system was very dependable to act on voice orders to switch on or switch off appliances like lights and fans.
- The Arduino UNO was able to interpret each command correctly and was mapped to a single character.
- The relay module did not delay or malfunction to switch appliances.

Bluetooth Performance
- The HC-05 Bluetooth module ensured a constant communication that was within a range of about 10 meters inside the buildings.
- Signal strength and response time were also same in different trials.
- There was no strong interference by other wireless devices.

Voice Command Accuracy
- The voice commands given through a smartphone application were correctly interpreted in more than 95 percent instances.
- Some small mistakes were caused by the noise of the surroundings or the indistinct pronunciation, which were reduced through a repetition of the command.

User Experience
- The system was straightforward and user friendly to the users.
- The voice interface removed the physical controls that were used and made it more accessible to older and disabled people.

- The system was setup and configured within 30 minutes and this reflected simplicity of the system.

System Reliability

- The system was available throughout the 48 hours.
- The consumption of power was not excessive to a small scale home automation system.
- These findings indicate that the presented system is a feasible solution to the cheap and available smart home control. It is sure in its performance, easy to use, and has potential to expand in future.

VI. Conclusion

The creation of a voice-controlled home automation system based on Arduino UNO and a Bluetooth module proves that it is possible to create a smart home system that can be convenient and affordable and easy to use. Using voice commands sent through a smartphone, the system can allow the control of domestic appliances without any inconvenience, thus, greatly increasing the level of convenience and autonomy, particularly in the case of older adults and physically disabled patients. The results of the implementation indicate that the system is user-friendly, responsive and reliable in the common indoor setting. It is modular, which may be extended in the future with more sensors, Wi-Fi, and cloud-based control. In addition, the fact that the components are accessible and the open-source platforms are there, makes the solution replicable and adaptable by both hobbyists and students, as well as developers. The project can be seen as the contribution to a developing domain of assistive and smart technologies since it provides a real and quite inexpensive solution to the home automation. A work in future can consider the extension of the system to allow voice recognition without a smart phone, access remotely on the internet, and minimize the security nature of the system.

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