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Voice Controlled Home Automation System using Natural Language Processing (NLP) and Internet of Things (IoT)

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Abstract : The primary goal of the project is to build a fully functional voice controlled Home automation system using Internet of Things and Natural Language Processing in order to provide a cost-effective, efficient way to interact with home appliances. There are many smart home automation systems in the market that aim to automate the basic operations of these home appliances using various technologies such as GSM (Global System for Mobile), NFC (Near-Field Communication) etc. However, most of these systems focus on mimicking the basic operation of the electrical switch. Our project aims at providing a fully automated voice based solution that our users can rely on, to perform more than just switching on/off the appliances. The user sends a voice command to the mobile device, which interprets the message and sends the appropriate command to the specific appliance. We plan on implementing four basic home appliances as a "Proof-of-Concept" for this project which includes Fan, Light, Coffee Machine and Door Alarms. The voice command given by the user is interpreted by the mobile device using Natural Language processing. The mobile device acts as a central console; it determines what operation must be done by which appliance to fulfil the user's request. The central console can also be either a desktop application, web application or a smart phone application as all of the data transferred can be processed by the cloud. However, for the convenience of the user and increased mobile capabilities we will be using a smart phone in this project. The appliances are connected to the mobile device through an Arduino Board that establishes the concept of Internet of Things. The Arduino Boards are interfaced with the appliances and programmed in such a way that they respond to mobile inputs.

Keywords: *Home Automation System, Arduino Boards, Natural Language Processing (NLP), Artificial Intelligence (AI), Internet of Thing (IoT).*

1. INTRODUCTION

Our project heavily relies on the concept of Internet of Things. We aim to implement seamless integration of all the appliances in the home via a central console. The project greatly changes the way in which we interact with our home appliances. It also reduces the need for any personal contact with any of them as it provides a

wholesome experience of wireless, voice controlled system. We plan to Implement this project with the help of Arduino boards with the capability to perform IoT (Internet of Things) operations. Installing the Arduino board in every appliance of the house will allow us to establish real-time communication with them via Wi-Fi. We plan to implement this project with the help of Arduino boards with the capability to perform IoT (Internet of Things) operations. Installing the Arduino board in every appliance of the house will allow us to establish real-time communication with them via Wi-Fi. We plan on using Arduino Uno Wi-Fi, known as Genuino Uno Wi-Fi outside of the United States to implement this project. Arduino/Genuino is primarily a microcontroller board that is based on the Atmega328P board datasheet. The Uno possess 14 digital input and output pins:

1. Six Analog Inputs
2. Six PWM Outputs
3. A 16MHz Quartz Crystal
4. A USB Connection
5. A Power Jack
6. An ICSP header and a Reset Button

It contains all the peripherals needed to support the microcontroller, which makes it easier to connect it to a computer through a USB cable or power the board through a AC to DC adapter or a battery to get started. This characteristic of the Arduino Uno makes it more viable and easier to use. The Arduino Uno Wi-Fi is an integration of Arduino Uno with a Wi-Fi module. The microcontroller board is based on Atmega328P board with an integrated ESP8266 Wi-Fi Module. The Wi-Fi module integrated with Arduino Uno is ESP8266 which is a self contained SoC that has the integrated TCP/IP protocol stack that enables access to your Wi-Fi network, or any other device that acts as an access point. The most useful feature of the Arduino Uno Wi-Fi has support for over the air (OTA) programming, either for Wi-Fi firmware or Arduino sketches. The Arduino Uno Wi-Fi has two different power options – either through USB or an external power supply. The external power source can either come from AC to DC adapter or a battery and the board has the ability to select the power source automatically. The AC to DC adapter can be used to power the board by plugging in a 2.1mm center positive plug into the power jack of the board. When a battery is used to power the board, it can be inserted in the Gnd and V_{in} pin headers of the connector in the board. The board works on a broad range of external power supply of 6 to 20 volts. When the board is supplied with less than 7V the board becomes unstable and responds erroneous results. When the board is supplied with more than 12V, the voltage regulator may overheat which leads to damage of the board. The optimal power supply for the board ranges from 7V to 12V.

The power pins of the Arduino Uno Wi-Fi are as follows:

1. **V_{in} pin:** This pin provides the input voltage to the Arduino board when it is utilizing an external power source. We can either supply voltage through this pin or supply it through the power jack and it through this pin.
2. **5V output pin:** This pin is responsible for the regulated 5V output from the regulator on the board. This pin must not be used as a connector to the external power source, as it might bypass the regulator and cause damage to the board.
3. **3V input pin:** A 3.3V supply generated by the regulator on-board acts as an input pin to the Arduino board.
4. **GND pin:** The ground pins are vital to the board.
5. **IOREF pin:** This pin provides the voltage reference in the Arduino board with which the concerned microcontroller operates. A well configured shield can procure the IOREF pin voltage value and select the appropriate power source or enable specific voltage translators for working with 5V and 3.3V supplies.

The Arduino Uno Wi-Fi board is based on the Atmega328 and thus posses a 32KB Flash out of which 0.5KB is used of the boot loader. It also consists of 1KB of EEPROM and 2KB of SRAM . The EEPROM memory can be read and written with the EEPROM library. The IO of the Arduino board consists of 14 digital pins that can either be used as an input or output by specifying them with any of the three functions – pinMode(), digitalWrite() and digitalRead(). The IO pins operates at 5 volts. Every IO pin has an internal pull-up resistor of 20-25 kOhms. which is disconnected by default and can provide or receive a maximum of 40 mA. Certain IO have specialized functions and are described as follows:

1. **Serial pin:** Serial pins in the boards are pin 0(RX) and 1(TX). The pin is used to receive (RX) and transmit (TX) serial data. The serial pins are connected to the corresponding pins of the Atmega8U2 USB to TTL serial chip.
2. **External Interrupts pin:** External interrupts in the boards are pin 2 and 3. The external interrupt can be configured in such a way to trigger an interrupt on a low value, a rising edge or a change in the value. The attachInterrupt() function is used to program this specific pin.
3. **PWM pin:** The PWM pins in the board are pins 3, 5, 6, 9, 10 and 11. They provide 8bit PWM output with the help of analogWrite() function.
4. **SPI pin:** The SPI pins in the board are pins 10(SS), 11(MOSI), 12(MISO), 13(SCK). The SPI pins support communication by using the SPI library.
5. **LED:** The Arduino board has a built in LED connected to the digital pin in 13. The LED is on when the pin is at HIGH, and the LED is off when the pin is at LOW. The Arduino Uno Wi-Fi has 6 analog input which are labeled A0 through A5, where each provide 10 bits of resolution. The LED pins by default measure from ground to 5 Volts, though it is possible to change the higher end of the spectrum through the AREF pin and using the analogReference() function.
6. **TWI:** The Arduino Boards have two TWI pins, A4 or SAD pin and an A5(SCL) pin. It supports TWI communication through the Wire library. These pins can also be used to expand the IO of the board as it can be used by Expander SC16IS750IBS.
7. **AREF:** This pin is used by the analog inputs for reference voltage. It can be used by specifying the function analogReference().
8. **RESET:** When this pin is set to LOW the microcontroller is reset. It is also used to install another reset button to shields which block one on the board.

The board has various methods to communicate with a particular computer or another Arduino or a different microcontroller. The Arduino Uno Wi-Fi has UART TTL serial communication (Pins 0(RX) and 1(TX)). The serial communication over USB is managed by the ATmega16U2 on the board and becomes a virtual port to the software written on the computer. The board's firmware does not use any external driver and only utilizes the standard USB COM drivers. However, while working on a Windows based computer an .inf is required. There is a serial monitor included in the Arduino IDE that enables simple textual data that is transmitted to and from the Arduino Uno Wi-Fi board. When the data is being transmitted via the USB to the Arduino board the RX and TX LEDs on the Arduino board flashes, but does not respond for any serial communication on pins 0 and 1. The serial communication of the Arduino Uno board is enabled through the digital pins by the SoftwareSerial library. The ATmega328 in the board also has extended for 12C and SPI communications. To reduce the complexity of using a 12C bus, the Arduino software includes a Wire library; for simplifying the use of SPI communication the software also includes a SPI library. The communication between ATmega16u2,

ATmega328p and ESP8266EX in the Arduino board is facilitated by a SC16IS750IBS Expander Single UART with a 12C bus and a SPI interface. As the board is Wi-Fi enabled it allows us to communicate to other sensors, actuators and other devices via Wi-Fi which creates a simple IoT system. This Arduino board can be connected to an existing Wi-Fi network, Wi-Fi enabled router or can also be used to create a Ad-Hoc Wi-Fi connection. The Arduino board can also be connected to the internet using various open source libraries such as the Ciao Library and a REST connector. The relatively new feature of the Arduino Uno WiFi allows us to upload a sketch without any wired connections and directly through the Wi-Fi. The ATmega328 in the board communicates through Wi-Fi using the original STK500 protocol .The natural language processing (NLP) is a field of computer science that helps us to infer what the user is trying to say through his voice commands. The NLP in our project gives the user the freedom to interact with the home appliances with his/her own voice and normal language rather than complicated computer commands .Natural Language Processing (NLP) is a field of computer science, artificial intelligence, and computational linguistics that helps computer system understand and respond to commands given in natural (human) language. NLP is can be categorized in the field of human-computer interaction. Most of the challenges in NLP are listed as follows: human language understanding, enabling computers to derive meaning from the voice commands given to it through human (natural) language, and others involve natural language interaction between computers and humans. Most of the latest NLP algorithm heavily relies on machine learning, especially statistical machine learning.

2. RELATED WORKS

The industry and the Academicians have worked together in perfect harmony to make great strides in the field of Home Automation Systems. Many technology giants including Apple, Amazon and Google have been keen on making viable consumer products for the common man. Most of these gadgets have been released during the course of this year, some of them include: Amazon Echo, Apple HomeKit and Google Home. However none of these systems aim to possess omnipresence or include artificial intelligence to predict the user's commands. Most of these advancements have come only in the past year (2016) urging both companies and academicians to make further advancements in this particular field.

Certain home automation systems have suggested complete dependence on wireless sensors and nothing else. These systems also use very primal technology such as HTML web pages to coordinate between these Arduino boards. They have also indicated the use of mobile platform which does not add any functionality to the existing proposed system, rather increase the complexity of implementation. The high dependence on wireless sensors may also lead to erroneous results. [1]

Other home automation systems insist on using Arduino boards as the only solution. Most of these systems can also be replaced by either ZigBee, Raspberry Pi or any other programmable board as their functionalities are not altered. These systems also have a heavy reliance towards using mobile device as their central console alone, giving very less flexibility of changing this. This is a concern for the user, because most of the time mobile devices are carried along with the user everywhere they go rather than statically staying in the house. They also do not support voice commands from the user. [2]

The noblest causes of the home automation is to help make the lives of paralyzed people much easier. These voice recognition based home automation system are for the physically challenged people suffering from quadriplegia or paraplegia (who cannot move their limbs but can speak and listen) and it enables them to control the various home appliances and can actuate the bed elevation just by the voice commands according to their need and comfort. The proposed system consists of a voice recognition module, Arduino Uno microcontroller, relay circuit to and an adjustable bed. The voice recognition module needs to be trained first before it can be used to recognize commands. However all of the listed functionalities are limited to adjustable beds. The proposed concept is extremely clichéd and lacks sound design principles. [3]

Most of the other home automation systems use Bluetooth in their mobile device for implementation. This has various demerits in every aspect. Primarily the Bluetooth has a very small range and the proposed system could only work in small homes, excluding homes with larger area. Bluetooth does not support remote operations, (i.e.) the appliances cannot be controlled by Bluetooth from a remote geographical area. Many appliances within the same range may pick up the commands given to particular device resulting in erroneous behaviour. They also do not use Natural Language Processing and artificial intelligence to understand what the user is trying to perform. [4]

Most of the other home automation systems purely depend on GSM technology for implementation. Even though their remote capabilities are tremendous, the overhead of operating it in a small home environment is huge. The boards are tough to be compliant to GSM technology and increase the cost of implementation exponentially. [5]

2.1. Existing System

The existing technologies, in these regard are far outdated than what we have proposed. Most of the smart home automation systems that are existing only automate the basic process of changing the state of the appliances to ON/OFF. There are many smart home automation systems in the market that aim to automate the basic operations of these home appliances using various technologies such as GSM (Global System for Mobile), NFC (Near-Field Communication)and Wi-Fi. The existing smart home systems that have either been implemented or proposed have an elaborate procedure to interact with the home appliances. Some include pressing a button in a static location while some others include giving commands through a mobile device. Various technology companies have been trying to create amazing products in the field of home automation system since a decade ago. However, the Internet of things has become a rapidly growing field only in the recent past. Many viable consumer products are being sold by various technology giants in order to bring the technology to the common man. Most of these gadgets have been released during the course of this year, some of them include: Amazon Echo, Apple HomeKit and Google Home. However none of these systems aim to possess omnipresence or include artificial intelligence to predict the user's commands.

2.2. Proposed System

Our project aims to provide the easiest and most efficient way to interact with home appliances by giving voice commands in human (natural) language. We plan on eliminating the tedious process of clicking through various application screens with just one voice command. The natural language processing in the project provides a personal connection with our system. Primarily the user is authenticated by entering the specified username and password in the mobile device. The user authentication system is a one-time process, that increases the credibility of the system. The user sends a voice command to the mobile device, which interprets the message and sends the appropriate command to the specific appliance. The voice command given by the user is interpreted by the mobile device using Natural Language processing. The obtained set of words is then subjected to keyword stemming. The keywords are identified by first subjecting the words to prefix-suffix stripping algorithms and later realizing the exact command through the lemmatization algorithm. The mobile device acts as a central console; it determines what operation must be done by which appliance to fulfil the user's request. The central console can also be either a desktop application, web application or a smart phone application as all of the data transferred can be processed by the cloud. However, for the convenience of the user and increased mobile capabilities we will be using a smart phone in this project. The appliances are connected to the mobile device through an Arduino Board that establishes the concept of Internet of Things. The Arduino Boards are interfaced with the appliances and programmed in such a way that they respond to mobile inputs. The Arduino Uno only outputs a power voltage of 5V, is given to the relay circuit that is then connected to the appliance. Our project automates the operation of every single appliance in the house, which greatly reduces the power consumption due to excess use/wastage of the appliance's services.

2.3. Architecture Diagram

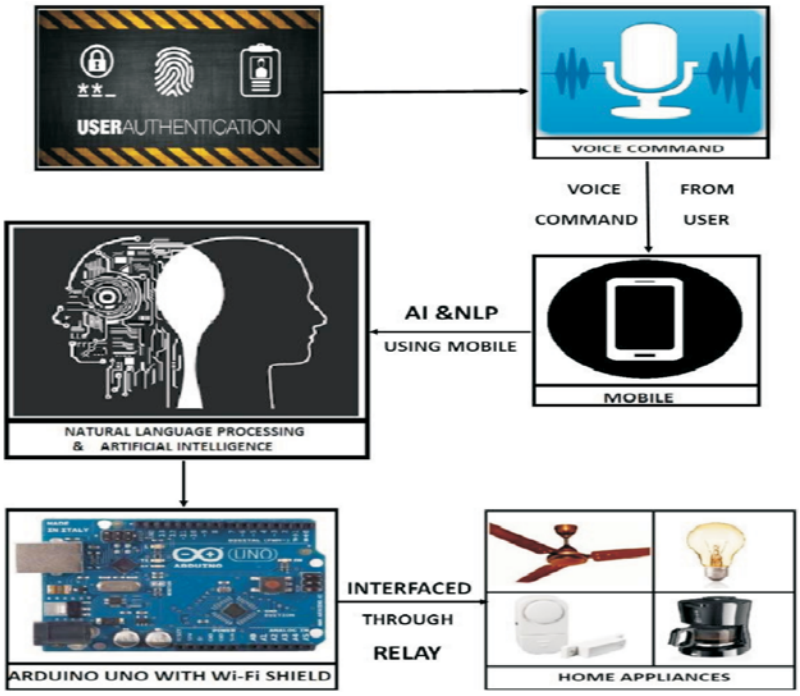

Figure 1: Architecture diagram using Arduino uno with Wi-Fi Shield

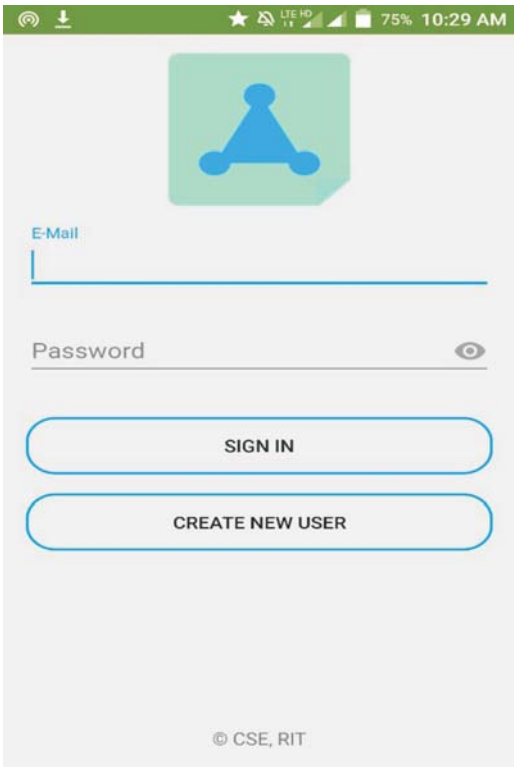

Figure 2

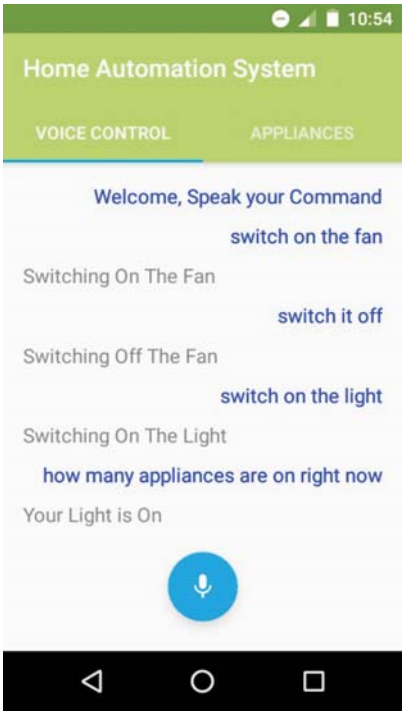

Figure 3: Screenshot of the Mobile Application

3. CONCLUSION

Most of the existing automation systems follow a specific set of commands or procedures in order to interact with their home appliances. These cumbersome procedures distance the users away from the technology. To overcome all of the existing issues and address the solution our project proposes voice commands to interact with home appliances using Arduino and a mobile device. These voice commands which are processed by Natural language processing helps the users to build a better connection with the technology and encourages them to use it more. It also eradicates the mundane task of operating home appliances manually.

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