Using Natural Language Processing(NLP), Voice Recognition and Internet of Things(IoT) Technologies in the Multi-Tier Architecture for Controlling Smart Home Operations

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Abstract - Along with the arrival of the IOT(Internet of Things),many devices are attaching with the Internet with the aim to provide help to many people. In this paper, I generally introduced an IoT Agent, which is usually a Web application for observing and managing a smart home to a certain extent. The IoT Agent initiates a chat which is used to recognize the voice or text commands using NLP(Natural Language Processing). Along with the usage of Natural Language Processing(NLP), home devices are even much more user-friendly and managing them is a little bit easier, even when a command or the command/question is dissimilar from the presets, the system appreciates the user's desires and act upon accordingly. The solution exploits some of the available APIS(Application Programming Interfaces), whose name are: the Dialogflow API for the well-organized integration of Natural Language Programming(NLP),the Message Queuing Telemetry Transport(MQTT) for the lightweight management of the Firebase and many actuators for the purpose of dynamic data storage.

***Key Words*: Internet of Things, Natural Language Processing, Technology, Smart Home Operations, Voice recognition**

INTRODUCTION

A growing Internet-based architecture is IOT(Internet Of Things), it usually enables the data exchange and also the services that are present in a global network. Along with the arrival of the IOT(Internet of Things),many devices are attaching with the Internet with the aim to provide help to many people. In this paper, we generally introduced an IoT Agent, which is usually a Web application for observing and managing a smart home to a certain extent. The IoT Agent initiates a chat which is used to recognize the voice or text commands using NLP(Natural Language Processing). Along with the usage of Natural Language Processing(NLP), home devices are even much more user-friendly and managing them is a little bit easier, even when a command or the command/question is dissimilar from the presets, the system appreciates the user's desires and act upon accordingly. The solution exploits some of the available APIS(Application Programming Interfaces), whose name are: the Dialogflow API for the well-organized integration of Natural Language Programming(NLP),the Message Queuing Telemetry Transport(MQTT) for the lightweight management of the Firebase and many actuators for the purpose of dynamic data storage.

In this paper, I have proposed an application for managing the smart home to a certain extent. In my application I obtained the values of sensors and to manage the actuators I used natural language. In addition, any person could also even use the chatbot present in that main page of my application, with the purpose to communicate with it using free text. For the purpose of training of my NLP (Natural Language Processing) system, I had used an API which is Dialogflow Application Programming Interface.

1. System Architecture

Figure 1 which is shown below depicts the comprehensive architecture of my ecosystem, which is comprised of many subparts. The user makes use of the IoT Agent and a web application which can host all of the functionality, could monitor and control the actuators and the sensors , that are unified into the smart home.

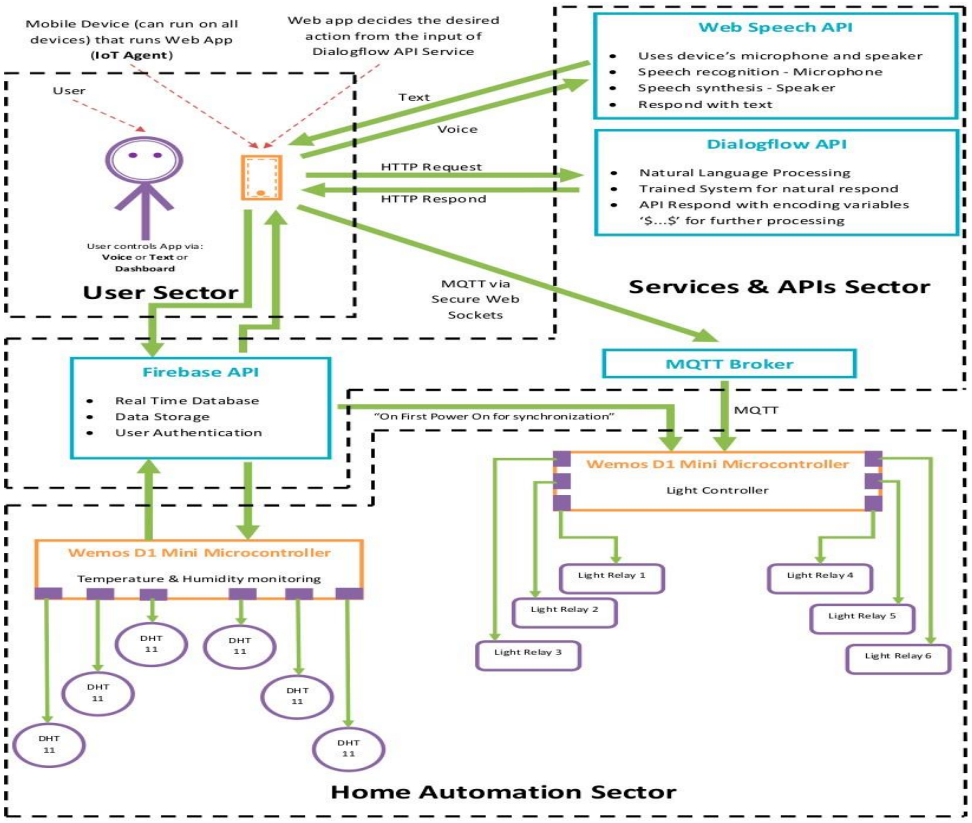


Figure 1. Main system architecture.

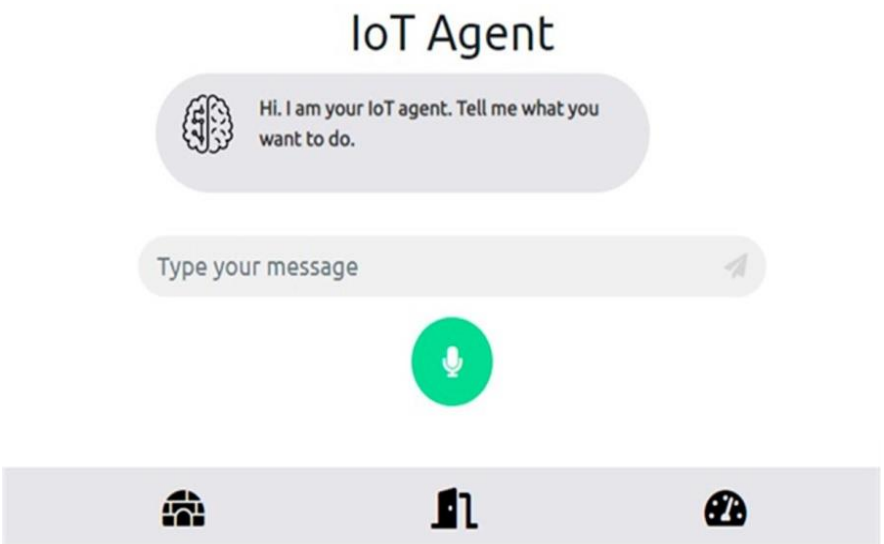


Figure 2. IoT Agent's welcome page

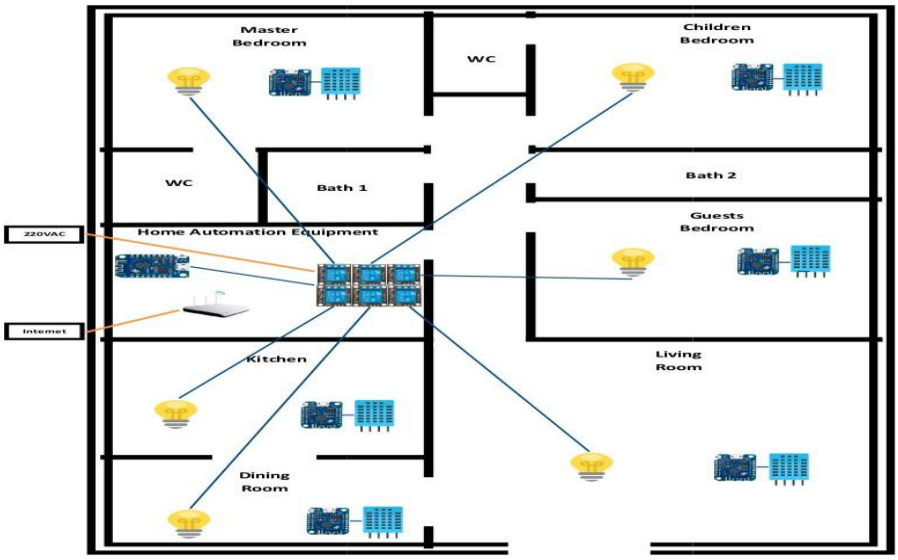


Figure 3. Generic interconnection of actuators and sensors with microcontrollers.

2. Natural Language Processing (NLP) System

My system is an extension of the usage of the NLP(Natural Language Processing). NLP(Natural Language Processing) is a part of AI(Artificial Intelligence) which uses computational techniques to understand, it observe and renew human natural speech. The IoT Agent uses NLP(Natural Language Processing) for the use of voice-chat feature,and for its text-chat system too. Dialogflow is a very amazing solution for NLP's convenient integration in the IoT system. Dialogflow API is also provided by Google and it uses techniques of machine-learning for the training process.

3. Microcontroller Implementation

This section represent the most important logic of the microcontroller's code which are at the maximum edge of my system. The code for both of the different microcontrollers is written at the Arduino IDE. I had divided my code into two separate code blocks.

```
void updateDB() {
  int error = 0;
  for (int i = 0; i < 6; i++) {
    int chk = DHT.read11(dhtPin[i]);
    digitalWrite(LED_BUILTIN, HIGH);
    if (chk == DHTLIB_OK) {
      if ((abs(DHT.temperature - temperatureHistory[i]) > 1) && DHT.temperature >= 0 &&  DHT.temperature <= 60) {
        setRoomsTemperature(DHT.temperature, i);
      }
      if ((abs(DHT.humidity - humidityHistory[i]) > 3) && DHT.humidity >= 10 &&  DHT.humidity <= 100) {
        setRoomsHumidity(DHT.humidity, i);
      }
    } else if (chk == DHTLIB_ERROR_CHECKSUM) {
      error++;
    } else if (chk == DHTLIB_ERROR_TIMEOUT) {
      error++;
    }
  }
  if (error > 0) {
    client.publish(MQTTOutTopic, "02");
  }
}
```

Figure 4. Microcontroller updated() function.

```
void setRoomsTemperature(float temperature, int counter) {
  String temperatureId = "temperature/room";
  temperatureId += String(counter + 1);
  temperatureId += "/value";
  Firebase.setFloat(temperatureId, temperature);
  if (Firebase.failed()) {
    client.publish(MQTTOutTopic, "03");
    ESP.reset();
  }
  delay(500);
  temperatureHistory[counter] = temperature;
}
```

Figure 5. Microcontroller setRoomsTemperature() function.

```
void setRoomsHumidity(float humidity, int counter) {
  String humidityId = "humidity/room";
  humidityId += String(counter + 1);
  humidityId += "/value";
  Firebase.setFloat(humidityId, humidity);
  if (Firebase.failed()) {
    client.publish(MQTTOutTopic, "04");
    ESP.reset();
  }
  delay(500);
  humidityHistory[counter] = humidity;
}
```

Figure 6. Microcontroller setRoomHumidity() function.

```
void callback(char* topic, byte* payload, unsigned int length) {
  if (length == 2) {
    int state = 0;
    char c = (char)payload[0];
    int id = c - '0';
    if ((char)payload[1] == '1') {
      state = 1;
      digitalWrite(lightPin[id - 1], HIGH);
    } else {
      state = 0;
      digitalWrite(lightPin[id - 1], LOW);
    }
  } else if (length == 3) {
    if ((char)payload[0] == '0' && (char)payload[1] == '0' && (char)payload[2] == '1') {
      ESP.reset();
    }
  }
}
```

Figure 7. Microcontroller callback() function.

4. Web Application Implementation

The main Web application is made by the use of the Angular framework. Angular is the common framework which is also developed by Google for the purpose of creating single-page applications which can be used for desktop, web or mobile also.

```
caseHandling(input) {
  if (input.includes('$temperature$')) {
    this.temperatureMeasuring(input);
  } else if (input.includes('$humidity$')) {
    this.humidityMeasuring(input);
  } else if (input.includes('$light$')) {
    this.lightHandling(input);
  } else if (input.includes('$light-state$')) {
    this.lightMeasuring(input);
  } else if (input.includes('$exit$')) {
    this.speakAndNotify('Bye!');
    this.authService.doLogout();
    this.ngZone.run(() => this.router.navigate(['/login'])).then();
  } else if (input === '') {
    this.speakAndNotify('Something went wrong. Try again.');
  } else {
    this.speakAndNotify(input);
  }
}
```

Figure 8. The IoT Agent caseHandling() method.

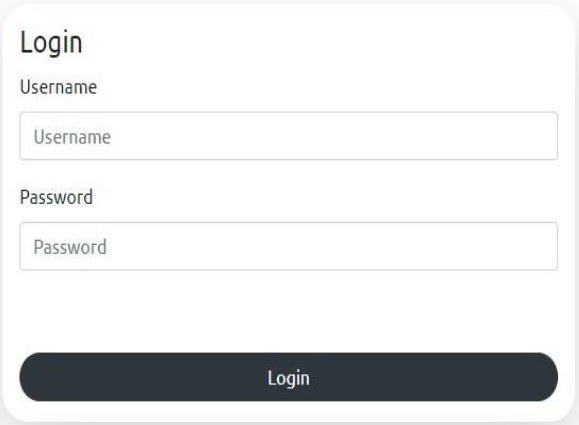


Figure 9. The IoT Agent login screen.

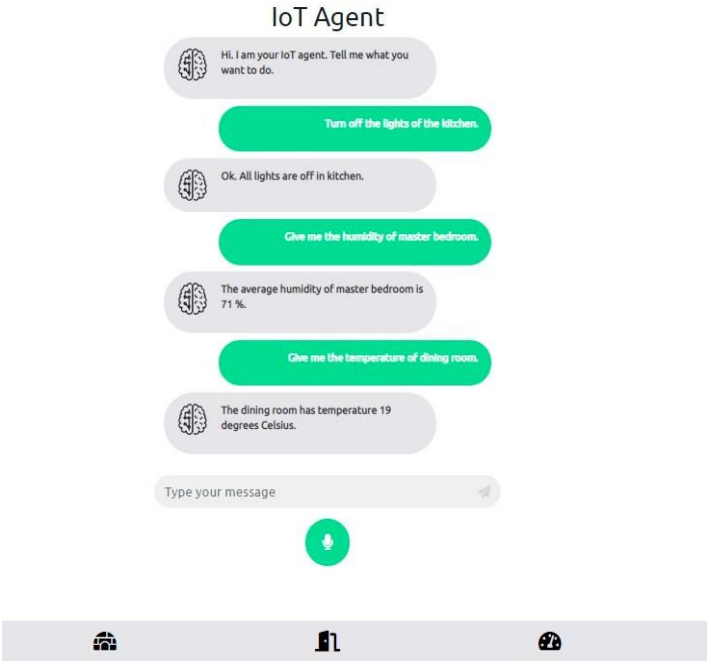


Figure 10. The IoT Agent Chatbot environment

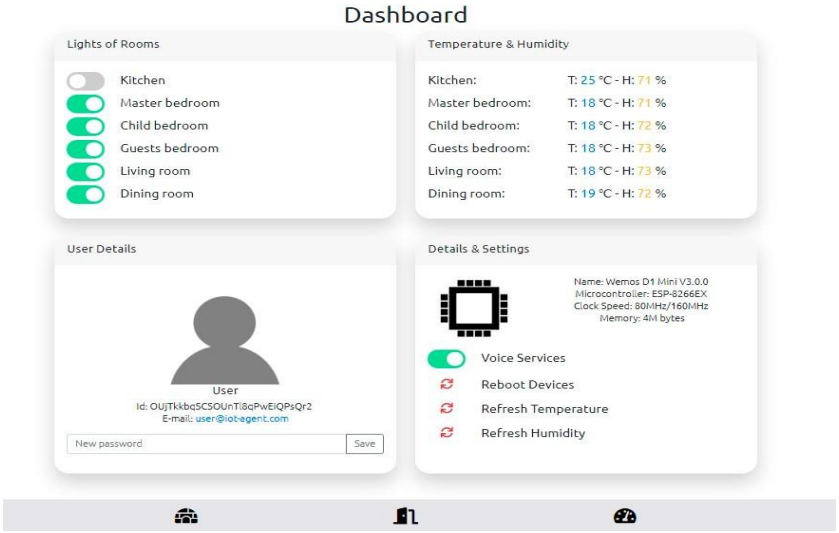


Figure 11. The IoT Agent Dashboard.

Below is the sample of test commands, by using these commands we will find decision-making time of IOT Agent, response time of various controllers and total response time.

Table 1. Sample of test commands.

Id	Test commands
C.1	Turn off the lights of dining room.
C.2	Turn on the lights of dining room.
C.3	Give me the temperature of the dining room.
C.4	Give me the humidity of the dining room.
C.5	Turn off the house lights.
C.6	Turn on the house lights.
C.7	Give me the temperature of the house.
C.8	Give me the humidity of the house.
C.9	Give me the information about microcontrollers.
C.10	How are you?

Figure 12: Given below illustrates the results.

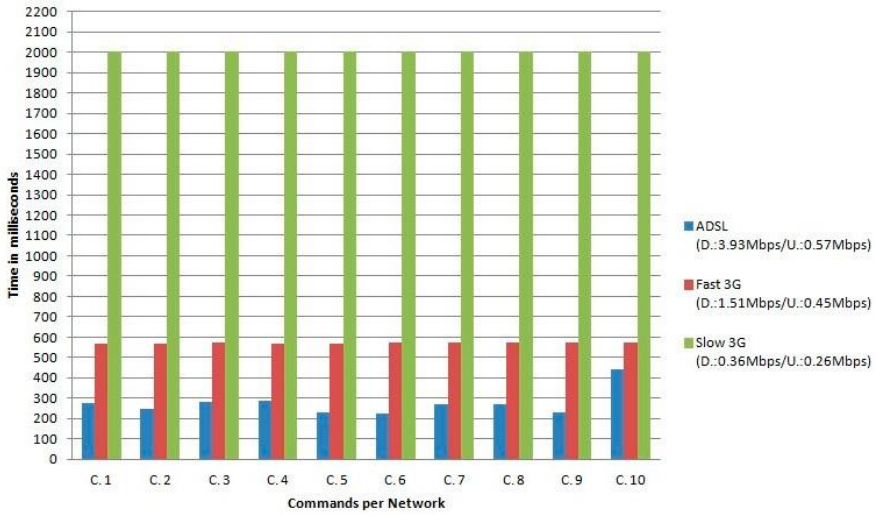


Figure 12. Response time of NLP engine per network bandwidth

Table 2. Data processing and decision-making time of the IoT Agent under di*ff*erent access networks.

C./B.	ADSL(D.:3.93) Mbps/U.:0.57 Mbps)	Fast 3G (D.:1.51 Mbps/U.:0.45Mbps)	Slow 3G (D.:0.36 Mbps/U.:0.26 Mbps)
C. 1	4 millisecond	7 millisecond	5 millisecond
C. 2	2 millisecond	2 millisecond	2 millisecond
C. 3	1 millisecond	1 millisecond	1 millisecond
C. 4	1 millisecond	1 millisecond	1 millisecond
C. 5	4 millisecond	4 millisecond	6 millisecond
C. 6	3 millisecond	3 millisecond	7 millisecond
C. 7	1 millisecond	1 millisecond	1 millisecond
C. 8	1 millisecond	1 millisecond	1 millisecond
C. 9	0.5 millisecond	0.5 millisecond	0.5 millisecond
C. 10	0.5 millisecond	0.5 millisecond	0.5 millisecond

Figure 13 illustrates the results

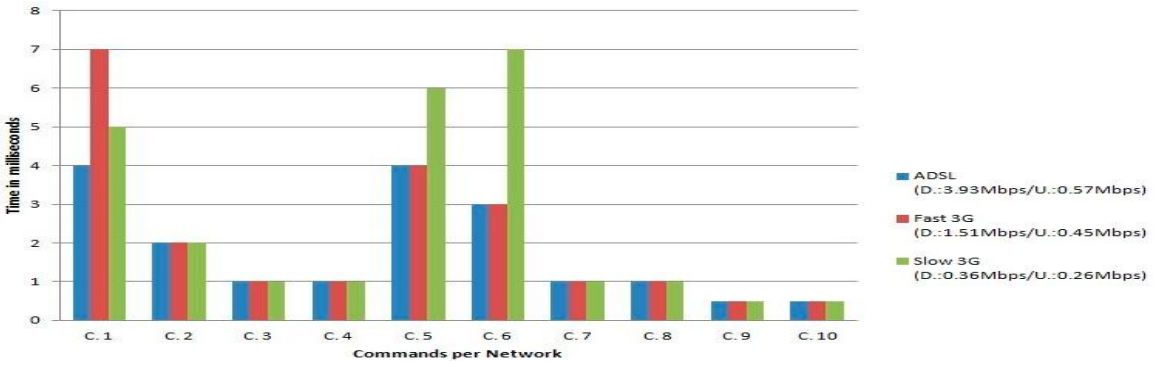


Figure 13. Data –making and data processing time of the IoT Agent.

Table 3. Response time of various microcontrollers under many access networks.

C./B.	**ADSL (D.:3.93 Mbps/U.:0.57 Mbps)**	**Fast 3G (D.:1.51 Mbps/U.:0.45 Mbps)**	**Slow 3G (D.:0.36 Mbps/U.:0.26 Mbps)**
C.1	20 millisecond	70 millisecond	730 millisecond
C.2	30 millisecond	100 millisecond	720 millisecond
C.5	40 millisecond	50 millisecond	156 millisecond
C.6	30 millisecond	30 millisecond	720 millisecond

Figure 14. Response time of microcontrollers under di*ff*erent access networks.

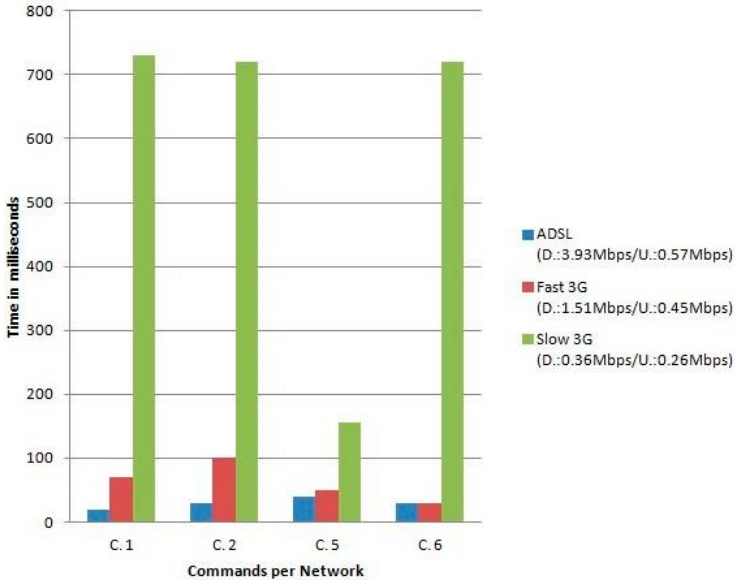
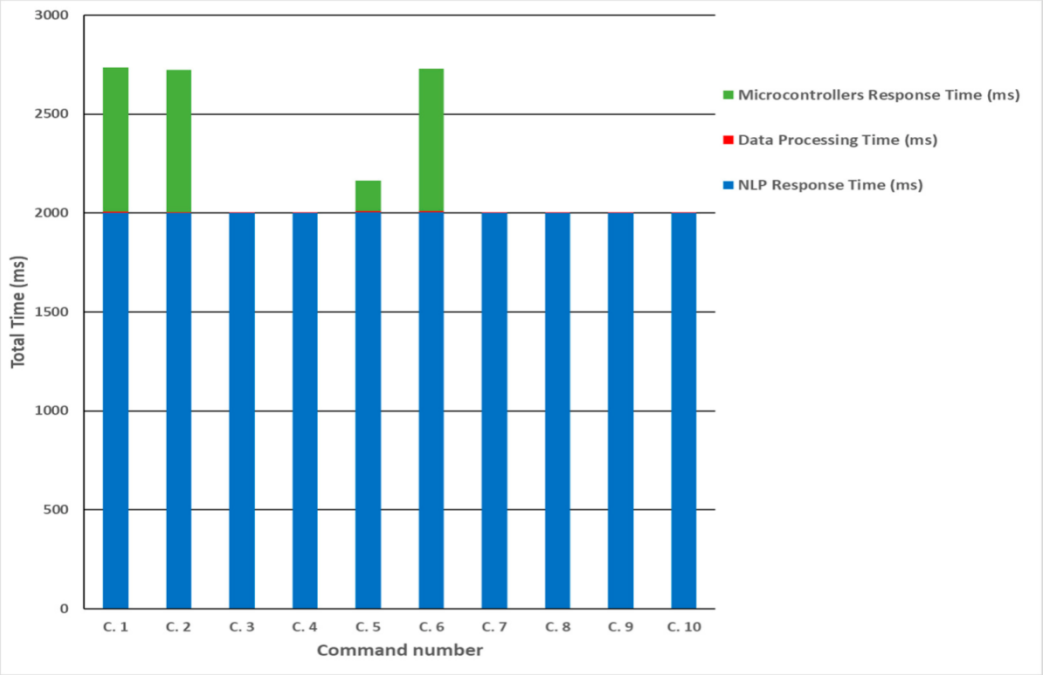


Table 4: Total response time

C./S.	**Response Time Of NLP**	**Data Processing Time**	**Response Time Of Microcontroller**
C. 1	2001 millisecond	5 millisecond	730 millisecond
C. 2	2001 millisecond	2 millisecond	720 millisecond
C. 3	2002 millisecond	1 millisecond	0 millisecond
C. 4	2001 millisecond	1 millisecond	0 millisecond

C. 5	2003 millisecond	6 millisecond	156 millisecond
C. 6	2003 millisecond	7 millisecond	720 millisecond
C. 7	2002 millisecond	1 millisecond	0 millisecond
C. 8	2002 millisecond	1 millisecond	0 millisecond
C. 9	2002 millisecond	0 .5 millisecond	0 millisecond
C. 10	2001 millisecond	0.5 millisecond	0 millisecond

Figure 15. End-to-end Response Time For Many Sample Commands.



Conclusions

The IoT Agent initiates a chat which is used to recognize the voice or text commands using NLP(Natural Language Processing). Along with the usage of Natural Language Processing(NLP), home devices are even much more user-friendly and managing them is a little bit easier, even when a command or the command/question is dissimilar from the presets, the system appreciates the user's desires and act upon accordingly. The solution exploits some of the available APIS(Application Programming Interfaces), whose name are: the Dialogflow API for the well-organized integration of Natural Language Programming(NLP),the Message Queuing Telemetry Transport(MQTT) for the lightweight management of the Firebase and many actuators for the purpose of dynamic data storage. In this paper, I have proposed an application for managing the smart home to a certain extent. In my application I obtained the values of sensors and to manage the actuators I used natural language. In addition, any person could also even use the chatbot present in that main page of my application, with the purpose to communicate with it using free text. For the purpose of training of my NLP (Natural Language Processing)system, I had used an API called Dialogflow Application Programming Interface.

My system is an extension of the usage of the NLP(Natural Language Processing). NLP(Natural Language Processing) is a part of AI(Artificial Intelligence) which uses techniques that are computational to understand, it observe and renew human natural speech .The IoT Agent uses NLP(Natural Language Processing) for the use of voice-chat feature, and for its text-chat system too. Dialogflow is a very amazing solution for NLP's convenient integration in the IoT system. Dialogflow API is also provided by Google and it uses techniques of machine-learning for the training process.

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