IOT for Performance Arts

Rupanagudi Rakshith

March 2019

Contents

1 Introduction **2**

2 State of the art **2**
2.1 Why this Project? 2
2.2 Initiation 2

3 Device Understanding **3**
3.1 Sensors 3
3.2 Micro-controller 5
3.3 Sloeber Eclipse IDE 6

4 Phase 1 **6**
4.1 Pattern Acquisition 6
4.2 Software Architecture 6
4.3 Hardware Architecture 8
4.4 MQTT Protocol 8

5 Phase 2 **11**
5.1 Pre Pattern Analysis 11
5.1.1 Multiple Wearable Devices 11
5.1.2 Technicality of the multi-devices 12
5.2 JSON-CSV 13
5.2.1 Issues faced and Solutions 16
5.3 Forming a data set 16
5.4 Pattern Analysis 18

6 Functional Mapping **18**

7 Conclusion **19**

References **21**

1 Introduction

Dance is an art. It is the form of expressing ones feelings symbolically using mental and physical aspects.Technically portraying an art like Dance is the recent ideas which has evolved out to be a challenging tasks from the past decade. On the other hand, technologies like IOT(Internet of Things) is in a huge demand, wherein the world is looking to integrate IOT with everything. The bridge between Art and technology is IOT. The Dance IOT is a project where the dance arm movements are analysed and mapped onto several functional platforms(may be control of the auditorium's lighting system,volume system etc..), so that the performance is enhanced and makes the audiences awestruck. This is more constrained to bring up new era in the performing arts like dance,theatre plays,magic shows and circus as well. The whole idea is the please the audiences with the innovative technologies that lead to great performances.

2 State of the art

2.1 Why this Project?

Performing Arts in an aspect of entertainment is growing in all the dimensions. As per the survey conducted by Quentin Fottrell, a US based surveyor, it is observed that people spend most of their time in getting entertained, both through live performances and through internet and still want for entertainment. People now a days expect entertainment in new manners, totally updated to the interest of current generation and surely expect a WOW factor in it. Creating such thing in an innovative manner requires the proper usage of technology.

Collaborating technologies like IOT with Performing Arts is both challenging as well as interesting.So, we using technology to further add up to the growth of already growing performing arts is the task .

2.2 Initiation

Before going to the existing methods and stuff like that, the project must be initiated and analysed. This project is a collaboration of art and technology. The main motto lies in using IOT as the combining tool.There would be possibly four main domains in this project,categorised on the basis of modular functionality in achieving it.The following are the functionaries:

1. Pattern Acquisition
2. Pattern Analysis
3. Performance analysis

Pattern Acquisition:

Pattern acquisition is the process of reading data in the form of samples.There are various methods in doing so. Taking data in the forms of samples manually,

or even computerised data acquisition. We are doing it as combination of both Manual-computerised data acquisition.The result of using this method would be discussed later in the Performance section.

Pattern Analysis:

Pattern Analysis is the process of understanding the read data. Here in our project there is not only a need for understanding data but also the need for differentiating data. Differentiating here refers to the process of the microcontroller understanding which sample is required for the task and which is not.

The usage of Hidden Markov Models(HMM) [2] found to be the most accurate models in this kind of usages and applications.This should also be determined only when the performance is fully studied.

Figuring all the possible ways, this can be further extended to find out a mathematical mapping relation between the sensed data and the assigned specific task .The process of designing such a system requires the perfect understanding of the components and their outcomes.

For better understanding and also to uphold the terms of modularity, I have divided the project into three phases,they are:

1. Phase 1 - Pattern Acquisition
2. Phase 2 - Pattern Analysis
3. Phase 3 - Performance

3 Device Understanding

3.1 Sensors

Generally , there are sensors which can sense motion and detect its path of movement as well.Out from various available sensors we are using APDS9960 and LMS9DS1. They are the two most common sensing devices used in motion detection.They bring out a great user-friendly environment with standard accuracy.

1. APDS9960 :

   APDS9960 as in figure 1 [1] is a multi-functional sensor that mainly senses proximity,RGB, light and gesture of an object. It is the most popular sensor used in gesture detection.It is to be connected to a microcontroller for the action and control process of it.It generally returns the gesture detected(right,left,up,down) and even complex gestures such as zigzag,near,far,etc.. It also returns the values in Red, Green, Blue attributes of the object that it detects.When coming to the terms of proximity it returns the distance of the object detected with up to 8 bit resolution. As mentioned above it is a multi-functional sensor. It has six pins

[1](for specifications: https://cdn-learn.adafruit.com/downloads/ pdf/adafruit-apds9960-breakout.pdf)

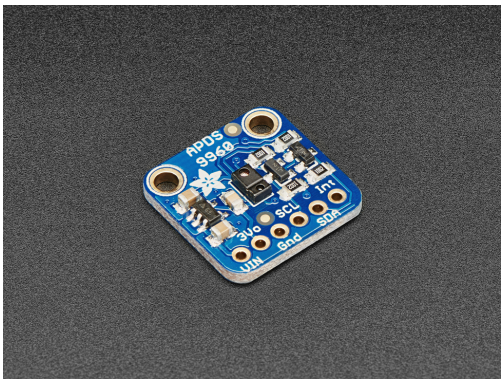


Figure 1: APDS9960

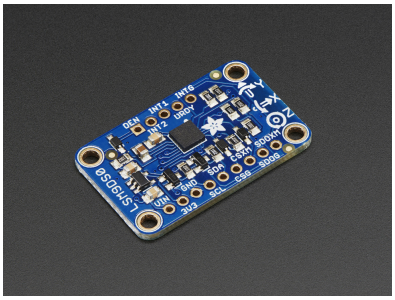


Figure 2: LMS9DS1

where VIN is for the input voltage, 3Vo is to power up the sensor, Gnd to ground the sensor so as the unwanted voltages are grounded, SCL is the serial clock, SDA is serial Data and, INT is the interrupt.

2. LMS9DS1:

   LMS9DS1 as in figure 2 [2] is a motion sensing sensor. It is a combination of accelerometer, gyroscope and magnetometer.In depth it has a 3-axes accelerometer, 3-axes gyroscope and 3-axes magnetometer.So collectively its good for all the possible 9 degrees of freedom(DOF). It supports both I2C and SPI. It measures angular velocity, acceleration and magnetic heading and returns them to the micro-controller.It measure the above mentioned parameters in a three dimensional field resulting in 9 outcomes i.e angular velocity in x,y,z, and acceleration in x,y,z, and magnetic heading in x,y,z. Thus, this sensor outcome is more reliable and best to analyse.

[2](for details: https://www.adafruit.com/product/2021)

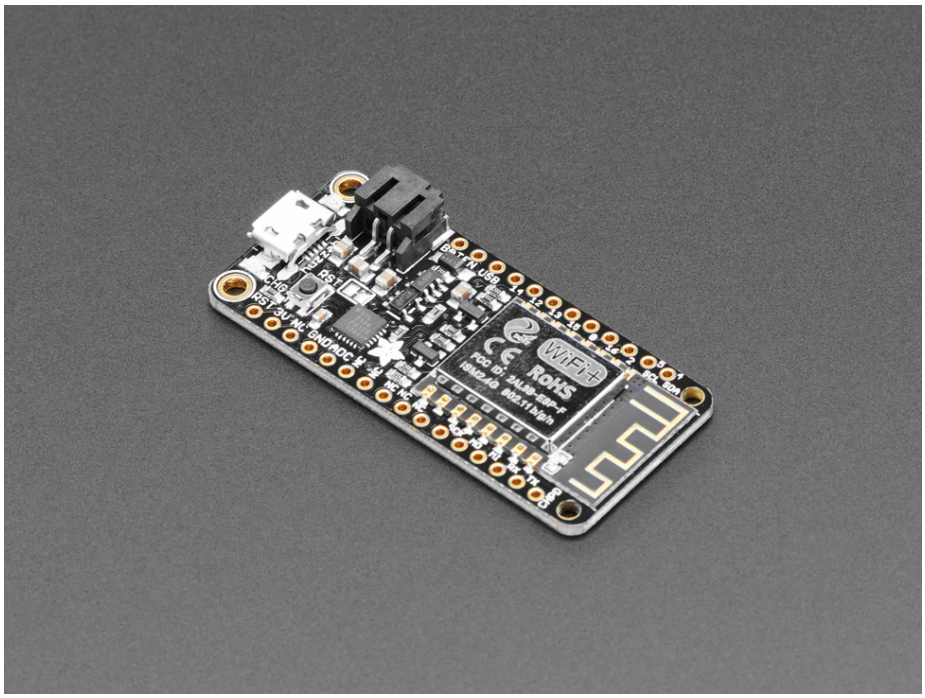


Figure 3: ESP8266

3.2 Micro-controller

A micro-controller is a user friendly electronic device which is generally used to perform a specific task. Here, task may be either one time or an infinite number of times, it is user controllable. User will have to code the required task in the form of an assembly language (or language with effective to the micro-controller, mostly a high level language). The micro-controller converts the code written into its understandable language and performs the task as per the code written by the user.

In our project we are using ESP8266 as a micro-controller. An ESP8266 as in figure 3 is a versatile micro-controller, it has an on-chip wifi module which gives the option to the user to connect to a cloud or server based on his need. This is similar to an arduino micro-controller but has more performance stability and advanced features than an arduino has. This is the main reasons for the usage of it in complex projects. Projects filled with real time robotics, real time analysis prefer ESP8266 over other micro-controllers that are available in the market.

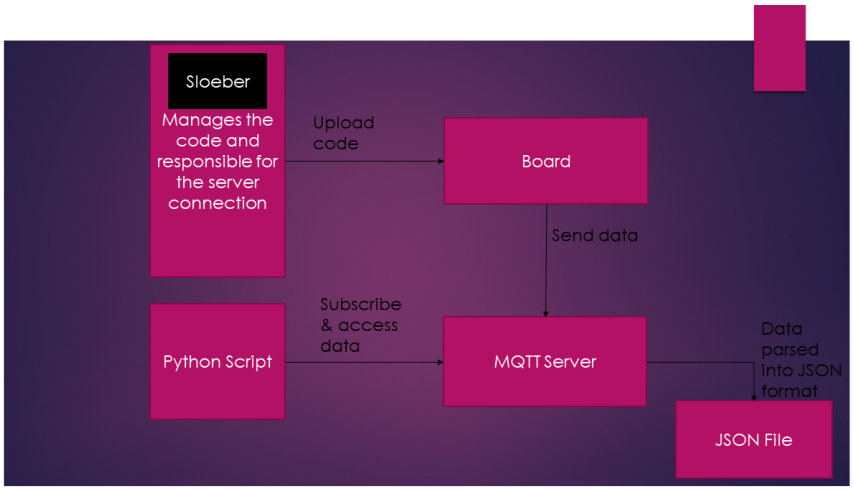


Figure 4: Software Architecture

3.3 Sloeber Eclipse IDE

Sloeber Eclipse IDE is an open source user-interface, generally a tool that is used to code and manage the micro-controllers.Sloeber is used in our project to manage the code that is used to perform our project. It has code files that are in cpp format and as well as python format. It is multi-disciplinary tool,since it can mange code of different formats. We also use sloeber to set a connection for the module and the server precisely speaking, setting a wifi connection.

4 Phase 1

4.1 Pattern Acquisition

Pattern acquisition is the process of collecting a large number of data sets relevant to the task to be performed. Pattern Acquisition is a result obtained by the sensors through control by the micro-controller.

4.2 Software Architecture

From the above figure 4,it can be inferred that the total process of data acquisition involves multiple tasks. Considering each element represents a task, the element's description as below:

- Sloeber: Sloeber is a user-friendly software that is generally used to operate-on with advanced,smart micro-controller devices. Generally this is analogous to an Arduino IDE, but as mentioned above it is used to program high end micro-controllers. Here, Sloeber is used to code the required

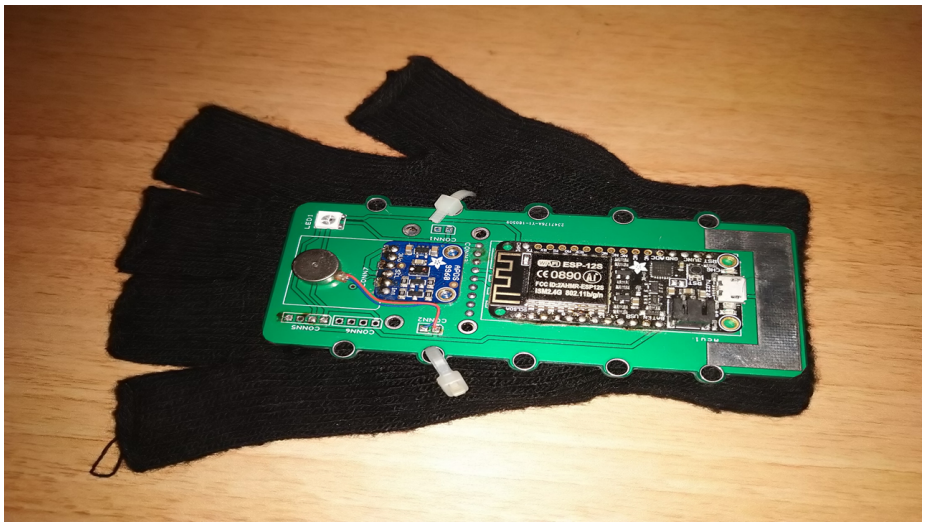


Figure 5: Wearable Device

lines that program the task required and manage the code. Set up the wifi connection. This is totally responsible in managing the action of the wearable device(Board). Uploading the code through sloeber to the board has to be done.

- Board: Board is a wearable device as in figure 5 that comprises of the different sensors,and the micro-controller.This physical device is responsible for interacting with the server as it has been programmed using Sloeber.Data measured, is sent to the server from the board. Measuring data is by moving/rotating/positioning the board. Everything is counted as data. This is sent to the MQTT server.

- MQTT server: MQTT server,simply a server is a cloud that stores data in it collectively in the form of topics. Access is granted when the user/device is subscribed to the topic inside the server. As this project uses MQTT protocol for the storage of data,connection and access of stored data it is called as a MQTT server. MQTT server is clearly explained in the next section.

- Python Script: Python script here is precisely the code responsible for accessing and receiving the data that is stored in the server.Apart from the sloeber code; the code responsible for writing the sensed data on to the server, the python script must be run parallelly so that the data stored in the server can be retrieved or read back. The code is written such that the data read is appended into a JSON file. JSON file stores all the data coming from the server and keeps on appending the data into itself.

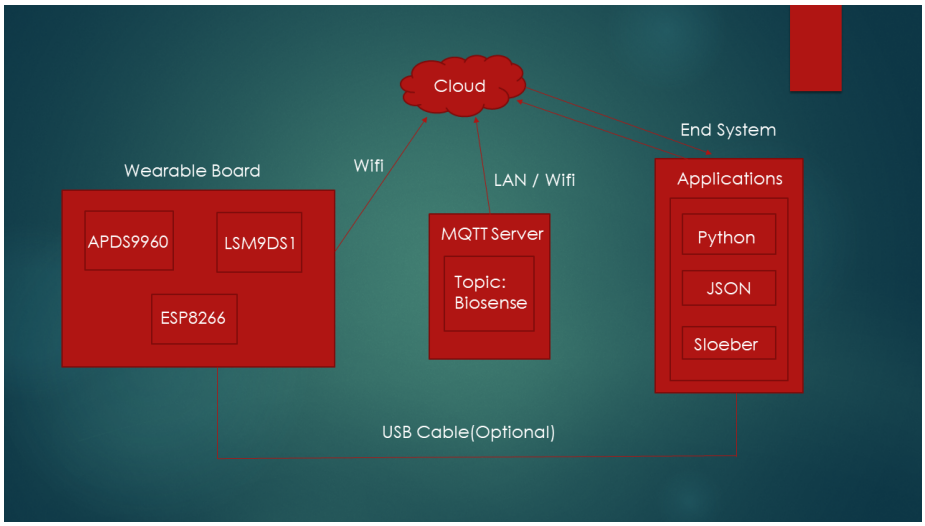


Figure 6: Hardware architecture

4.3 Hardware Architecture

From Figure 6 we can see the hardware architecture diagram. The action performed between the board and the server systematically is represented in the figure above.

When the code is uploaded onto the module(combined micro-controller connected with the servers), the program runs and the results are obtained on successful compilation.The results are sent to a server using MQTT protocol. Once the server starts storing data, we can retrieve it back. This set of data received is called a pattern. Depending on the action or movement of the wearable module,the values change. so,in case of waving a hand, the action must be performed so that the server stores the action and the user can then successfully retrieve data. This action is one sample of a pattern. With varied acceleration and speed we need tor record as many as samples as required for a single pattern. The pattern is obtained in a JSON format.Java Script Object Notation popularly known as JSON is a flexible text format that can store data and communicate it with other devices. So, anything related to a cloud or server based data system a JSON format must be used and hence we are using it. Finally my Pattern is acquired in the form of JSON.

4.4 MQTT Protocol

As mentioned above, we have to use a platform for sending data, storing it onto the server(may be cloud also) and retrieve the data from the server, function it.This so called platform works on some set of rules called protocol. The protocol used here is MQTT.

Message Queuing Telemetry Transport, shortly known as MQTT [3] is an International Standard Organisation(ISO) publish-subscribe based messaging protocol.It works on top TCP/IP protocol i.e. apparently works in the application layer of the TCP/IP protocol.It is a publish-subscribe messaging pattern,and thus requires a messaging broker.It contains no.of clients communicating with the server, often called a "broker". A client can be either a publisher of message or a subscriber who generally expects and accepts data or messages from the server. All clients can connect to the server through proper subscription.

In order to have a connection,the publisher need not have any information on the number of subscribers or location info about the subscribers. Similarly the subscriber also need not have to be configured with any data of the publisher.This turns out to be an advantage for the usage of this protocol.

MQTT relies on TCP/IP for data transmission. In case of UDP or Bluetooth MQTT-SN is used. For transmission of data, there must be a connection between the two entities i.e the client and server.There is a separate set of data that controls the action of connection and other stuff related to it called as "Message Type". This is generally a control message.The minimal size of a control message would be 2 Bytes which can be maximum extended upto 256 Mega-bytes. There are 14 pre-defined Message Types. A few of them include commands to connect and disconnect a client from a broker, to publish data, to acknowledge receipt of data, and to supervise the connection between client and server.

Connect: Waits for a connection to be established with the server and creates a link between the nodes.

Disconnect: Waits for the MQTT client to finish any work it must do, and for the TCP/IP session to disconnect.

Publish Returns immediately to the application thread after passing the request to the MQTT client.

The figure 7 represents the MQTT server-client handshaking protocol.

MQTT just sends connection credentials in text format, there is no measure of security or authentication involved in it. TCP is the most reliable protocol used in today's world. As we are using TCP, it is responsible for the security and measure to protect integrity of the transferred information from interception and duplication. The connection alone is not sufficient, for a better communication one must know the Quality-of-Service(QOS) of the connection formed. The QOS is a measure of wellness i.e how good a connection is established and the how good the bandwidth is utilised. The quality of service measures are as follows: At most once - the message is sent only once and the client and broker take no additional steps to acknowledge delivery (fire and forget). At least once - the message is re-tried by the sender multiple times until acknowledgement is received (acknowledged delivery). Exactly once - the sender and receiver engage in a two-level handshake to ensure only one copy of the message is received (assured delivery).

[3](https://en.wikipedia.org/wiki/MQTT)

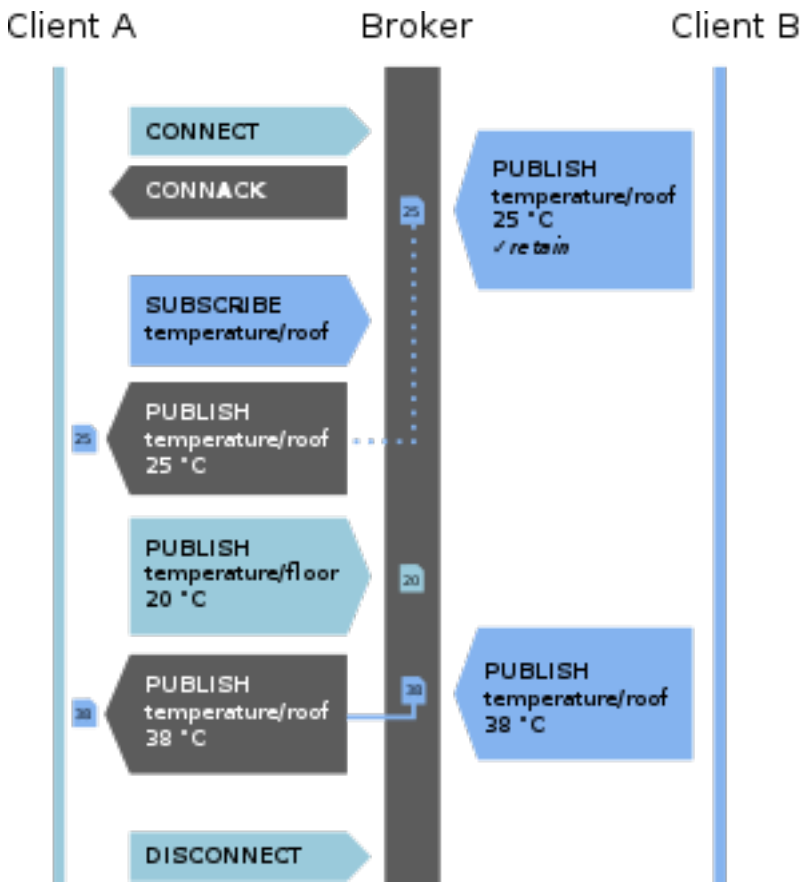


Figure 7: MQTT Protocol Handshaking

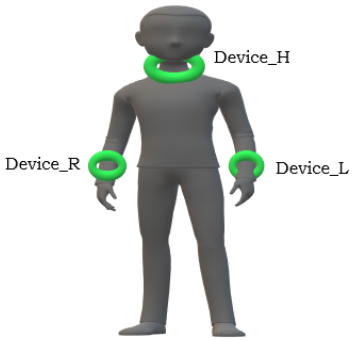


Figure 8: Person with 3 wearable devices

5 Phase 2

5.1 Pre Pattern Analysis

5.1.1 Multiple Wearable Devices

Coming to the point; as discussed earlier, we expect this project to be a real time case, wherein the primitive essence lies in the data/pattern read or recorded accordingly. We can firmly tell that the data is the main concern here because it is quite obvious that data read is to be mapped on to, either the robot or a task. Say,there would be an error or misread of data i.e the pattern acquisition part failing partially/fully, the whole process of mimic or task would be an epic fail.

We have discussed earlier that our technical team has readily built a wearable device, which includes all the modules as discussed in the chapter 2, and performs accordingly as discussed in chapter 4.The complexity begins here,now we have decided to include multiple wearable devices(say 3), in order to make it more realistic.

We can give an example, consider an artist using both his hands and face(precisely head) for portraying a dance move or an expression in the dialogue of a play, if each of this is symbolising something either collectively or individually, we can treat this as the indication for us to make either the robot mimic as the artist or perform a specified task.

Consider me in a dance performance wearing three devices as shown in figure 8, where I'm widening my both hands and waving them to and fro towards each other, it symbolises something, may be happiness. Now the act actually is responsible for the data recording process(since we have the devices worn).If I have only one device worn, the data from the alternate hand or head cannot be read, which is incomplete and does not meet the project's real time views. Considering this, we can understand the importance of multiple devices usage. Hence, we would now start the usage of multiple devices.

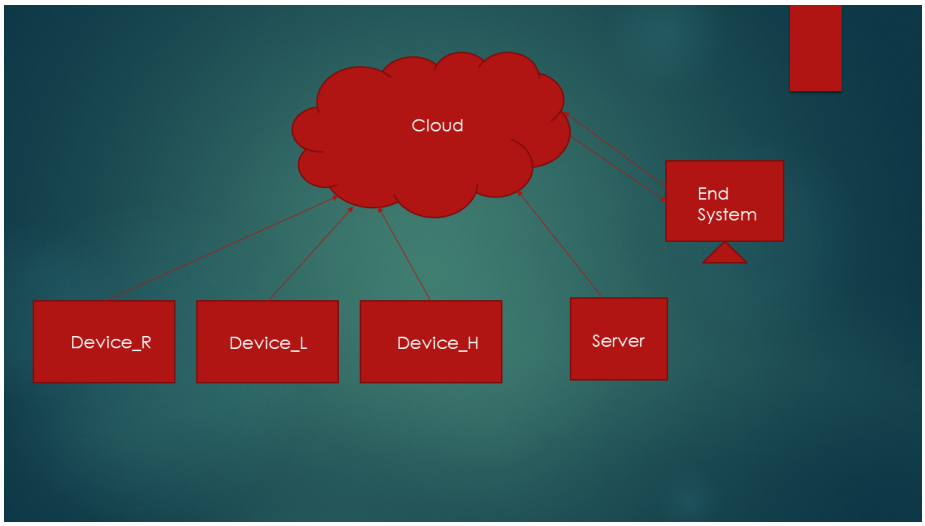


Figure 9: Multiple devices Server Access

5.1.2 Technicality of the multi-devices

Now the technicality here, focuses on the configuration and connectivity of the multiple devices. We being human beings having our brains can manually identify and separate the devices based on some aspects. But the issue arises, when it comes to the server accession.

The device uses MQTT protocol to access the server as mentioned above in the chapter 4.So, according to the MQTT protocol, the server grants access to data if subscribed to the topic correctly irrespective of the number of clients. Similarly the client(i.e the wearable device) also need not require any information about the publisher. This would not be a problem for server.

As shown in figure 9,once the data is received from the server, for the so called process of analysis, it would be difficult for us to understand which data has come from which device. In order to eliminate such confusions, we configure each device with a different board id.

Now, each of the three devices are assigned with separate board ids, readily access the topic Biosense in the server,for publishing the data. It is now a process where you configure the devices by uploading the code onto them. Uploading code to each device,connecting to the prescribed wifi network(this is also inclusive in the code) then powering them with battery, makes the device ready to work.

Caution: If the network of transfer i.e wifi is changed(generally the wifi changes with the place or location changes made for the devices), all three devices must be reconfigured(i.e the code must be uploaded once again) individually and follow the rest of the steps as mentioned above exactly then same manner.

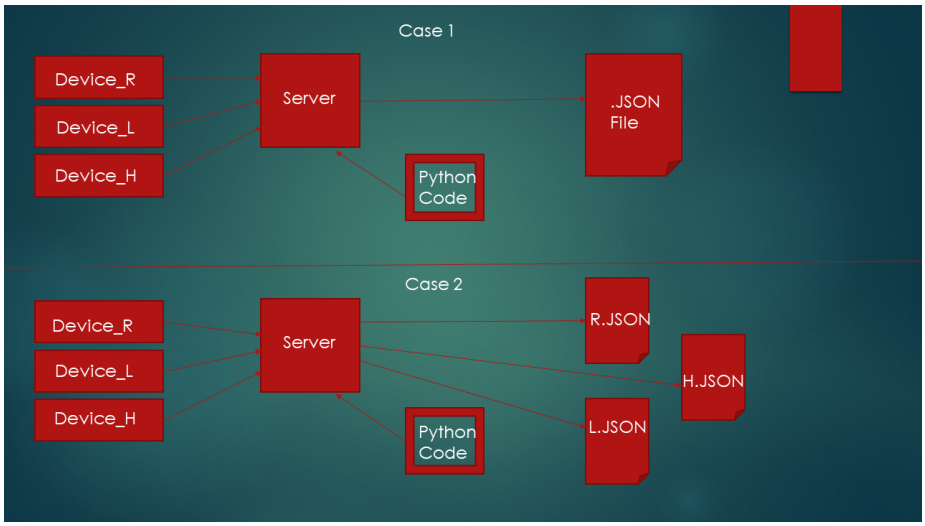


Figure 10: Cases of dumping read data into JSON format

Once the devices are ready to act, the code responsible for reading data from the server must be run so that the data published by the devices onto the server can be read back and dumped into some readable file(here we read it in JSON format so, we dump into a JSON file).

5.2 JSON-CSV

According to me, here, reading the data from server can be done in two possible ways:(as shown in figure 10) i) All the data read irrespective of the device's board-id into a single file ii)Separation of data based on board-id and dumping into three separate files.

Considering the facts, that the project to be realistic, it is impossible for us to surely say that the data can be published and received in an exactly particular way. It all depends on the sequence of action of the performer. So, Case 2 wouldn't be the best solution for this issue. Which indeed results the case 1 to be the optimal one.

Now, the data read from the server is dumped into a single file. The data is in JSON format as shown in figure 11.The below picture represents the data read that is dumped into a JSON file. One can find the three devices data that is random to see, but actually based on the movement of the user.

From the figure, we can notice that the data is random(like hoe it is recorded) and there are different board ids for different devices. Say Sensor-Test-R for Device R, Sensor-Test-L for Device L and Sensor-Test-H for Device H respectively.

The JSON file obtained after the dump,is unclear and physically untidy, unorganised to watch. For analysis, this would not be fruitful.So using a CSV file would be a better solution for this.

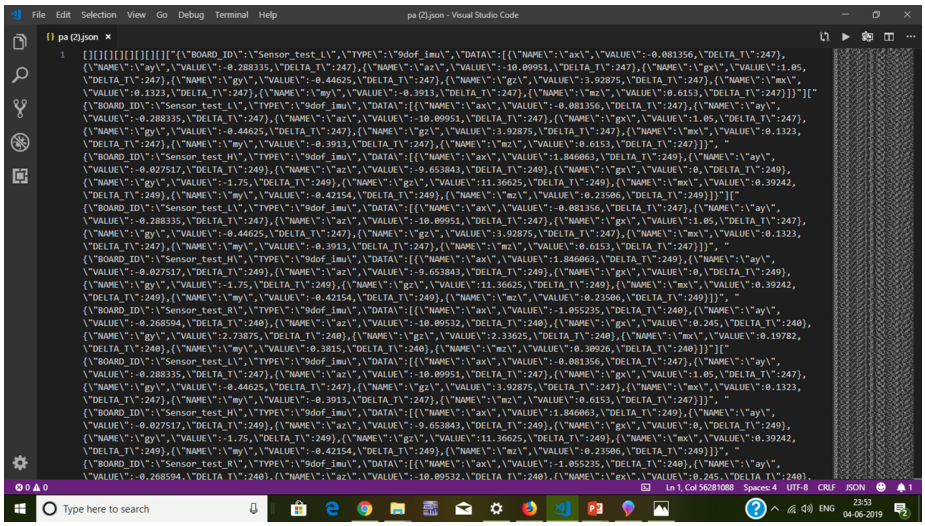


Figure 11: JSON File after dump

A CSV(Comma Separated Value) as shown in figure 12 is a file which contains organised data in the form of tables. Data inside data types such as list,tuple,dictionary in python can be converted into a CSV format.This makes the data more clear and easy to analyse.

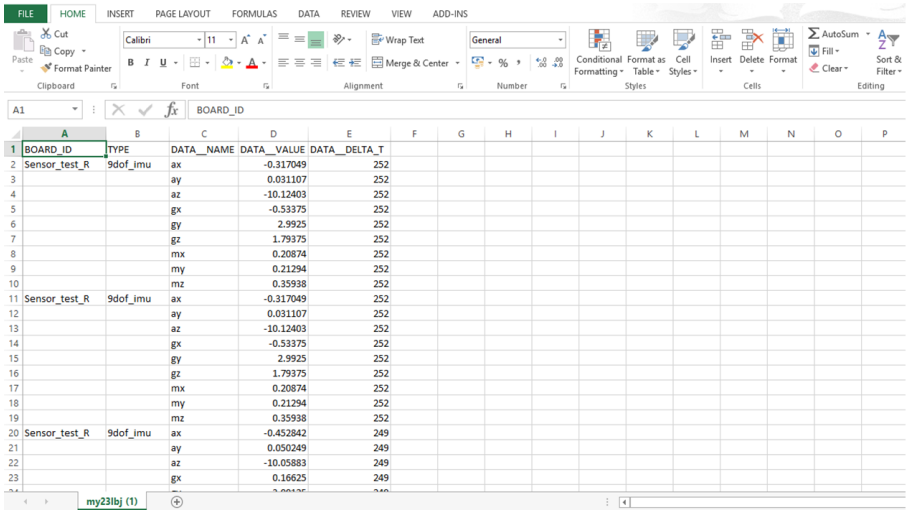
In python programming language, there is a data type called dictionary. A dictionary is analogous to a real life dictionary, basically a dictionary has a word and adjacent to it after a ":" there would a description of the word precisely the meaning of the word. The python dictionary is quite similar it has key followed by ":" and its corresponding value.

Now, coming to the point, the value can be accessed with the help of the key. If the data set is the same i.e. the key name is the same for all entries but only the value is different, it can be accessed with the index. A list of dictionaries separated by commas is JSON data on whole.

Each dictionary being a single entity of data, further each key:value pair being the ultimate data member of the dictionary. As mentioned above a CSV file is file which contains data separated by commas and displays the data in a tabular format. Now the values in the dictionary will take their corresponding place in the display, after the commas based on their position with respect the comma under a header field which is the key. This way a CSV-converted JSON file is obtained.

The figure 13,the upper part describes the analogy between a word-dictionary and a python dictionary. The lower part describes the JSON-CSV conversion.

JSON to CSV conversion can be done either with existing online software or a python code. In order to prove our accuracy we tried both the methods and our csv file was the same in both cases. Thus w



BOARD_ID	TYPE	DATA__NAME	DATA__VALUE	DATA__DELTA_T
Sensor_test_R	9dof_imu	ax	-0.317049	252
		ay	0.031107	252
		az	-10.12403	252
		gx	-0.53375	252
		gy	2.9925	252
		gz	1.79375	252
		mx	0.20874	252
		my	0.21294	252
		mz	0.35938	252
Sensor_test_R	9dof_imu	ax	-0.317049	252
		ay	0.031107	252
		az	-10.12403	252
		gx	-0.53375	252
		gy	2.9925	252
		gz	1.79375	252
		mx	0.20874	252
		my	0.21294	252
		mz	0.35938	252
Sensor_test_R	9dof_imu	ax	-0.452842	249
		ay	0.050249	249
		az	-10.05883	249
		gx	0.16625	249

Figure 12: CSV File Example

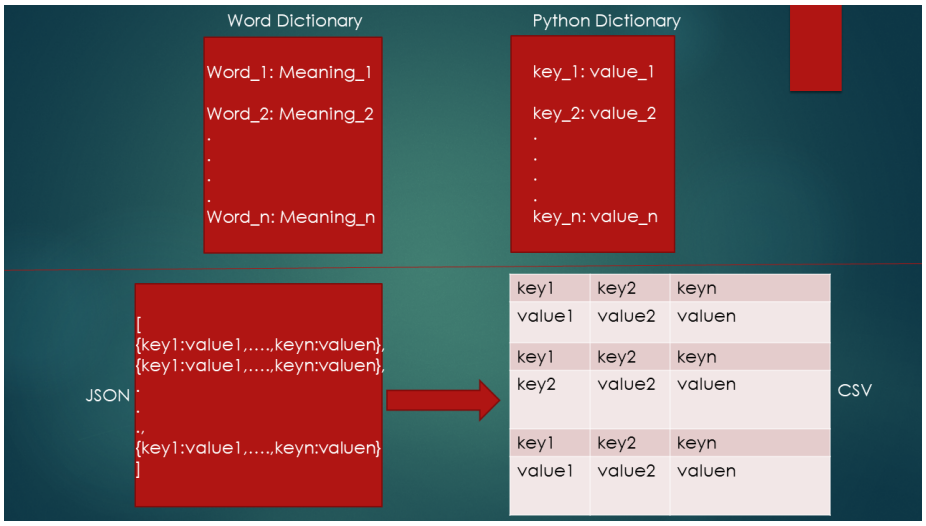


Figure 13: Part 1: Analogy between dictionaries Part 2: JSON to CSV conversion

5.2.1 Issues faced and Solutions

Coming to the accession of the devices to the server, the devices use MQTT protocol as discussed in chapter 4. This is pure advantage that any number of devices can access the server. Every device has the same importance.If at all something matters the device accession to server that would either be physical issue of the device such as battery connection, aging, quality of connectivity to the local area network. All the devices can publish data with almost same frequency.

In our earlier trails in succeeding this, we faced issues of data being non uniform, asynchronous, delay in either of the devices when compared to the other. What we could figure out from this was only that the data was non uniform, asynchronous because it has to be non uniform. Clearly putting it, the user may first raise his right hand so R data is read, then his head moved so H data read, then his right hand again so R again, then moves his left so L. Here it is quite observable that its all in the users hand how he recorded you cannot expect data to be in RLH,RLH,RLH,RLH format. The data would be non uniform say,RRHLRHLLHLHLRLHLHLHLRLHLLHRR.

Coming to the issue of time lapse/delay, the devices are configured such that they have equal priority in publishing onto the server. The server is such that it provide equal bandwidth to the publishers and the clients. Then we understood that the device's aging, quality of connectivity the local area network also mattered to the time delay.

5.3 Forming a data set

Now that we have all the pre-requisites ready. The thing is to read data in the form of a data set and then process it. We have considered that the human actions are to be mapped into a function that performs a specific task.

Let the task be displaying a particular colour on a screen for a particular condition. If the person's acceleration is some range or less accelerated it will display a colour, if it is in a moderate range one colour, and if it is in high range it will display the specified colour respectively.

For taking up the data now lets consider three patterns say;

1. Hand at rest
2. Hand while running
3. Hand while jumping

For experimental purposes, now we are using only one wearable device. The data sets for each pattern are to created separately. Separate observations and conclusions must be drawn from each pattern.

The figures 14, 15,16 represent the action of collecting data in respective postures.

We collected data sets for each posture i.e resting, running, jumping respectively. Each data set was collected at an equal interval of time. For increasing

Figure 14: Man resting with the wearable device on right hand

Figure 15: Man running with the wearable device on right hand

Figure 16: Man jumping with the wearable device on right hand

accuracy, each posture was recorded for 3 times, so as to compare each attempt of same postures. We further write this data into a text file. The text file consists of only data i.e values of 9 parameters. This is used as a database for future uses.

5.4 Pattern Analysis

However,we found that this is not the way how we want our data to be represented. This is said because we initially said that we have to map data into a robotic arm or a function that performs a specific task. So, the file should contain only data in an order such that it is fed as required depending on the functions. It is generally using one data set to many functions; a one to many technology. So, having only data precisely in a data set without any other parameters like headers and keys for each values(we extract data from a dictionary in python).

So, we have come to a conclusion in achieving it in the form of writing a python code in extracting our required data, arrange it in the required manner and write it into a file(say text file) and keep on appending it from the messages received from the server directly.

Now, we have a data set. For time being we are focusing on the methods and functionaries in mapping the data into a task. Further scope of this project, we would store the data sets in the form of text files, extract them when required in the future and analyse the data set using proper data-analysis models and algorithms.

6 Functional Mapping

It is one of our primary concerns in achieving this phase of the project. Till now, we have successfully extracted our required data, stored in the form of a data set into a file(using it in future). Now we have written a code such that the extracted data simultaneously is used in a function to perform a specific task and store the same extracted data in to a file.

This is a method of live movement and its mapping. So, we are connecting the wearable device and performing the task on the internet.

There is an article on robotic choreography [1] [3], which includes the methods of functional mapping and performance based stuff in it. In order to verify the existing methods which they followed, we are going through it.

For performing the, mapping we are considering a task in displaying colours on a window screen based on specific conditions of the data. Based on the live movements made in the wearable device, corresponding conditional check is made in the function and specified action is taken i.e corresponding colour is displayed on the window screen. It forms a blinking colour pattern based on the live movements on the wearable device.

Now, we have a call back function which is called "function", that is responsible for performing a specific task. We are including this function as a separate

file which is imported in the Client library.

This function is called from the library. The parameters of the function is a list of values i.e the data that we get in the form of ax,ay,az,gx,gy,gz,mx,my,mz. and the file name. Now we use python inbuilt function called split; which splits the list of 9 values into individual float values. Now, we have 9 data.

We have written the code to display colours on a window based on our specified conditions. Say, if the acceleration in x axis is greater than a threshold value it displays red colour, if the acceleration in y axis is greater than a specified threshold it displays blue colour.This way we found out that the method we wrote is working.

As a result we also obtained other form of output as well. We are reading the data directly from the messages received and using that simultaneously in monitoring the output. This means, when the wearable device is moved in live, the colour is displayed in live. A real-time system.

We are happy that the model is working correctly and we have achieved a real time system as mentioned above.

We further modified few of the methodologies and functions. As discussed earlier, anything related to this project, we used to modify the "Client Library" in order to achieve the specified task. Now, we made the similar changes in the existing python code that is used to receive messages from the server. We observed that the task is done in the same manner. It is always not recommended to change anything in the inbuilt existing libraries. So, we are going with the python code changes.

We further modified, the form of output. We now try to print the output in a particular format. Each axis represented by its own form of output. Say, if the wearable device is moved in x axis; it shows the output stating as x axis and its corresponding value i.e ax. This way , it applies for all the axis and if the device is at rest it shows no movement.

The figure 17 is the output form of our project.We can see that it is clearly displayed, in which direction the wearable device is moved and its corresponding axis element is also displayed. If the movement is in x direction, it shows x axis and ax , similarly for y and z if the movement is found in that particular direction.

7 Conclusion

This project, has proved that it is a foundation for IOT in entering the field of Performance Arts. It was not a cake walk, lot of unpredictable issues were faced and we successfully troubleshooted them and solved them. It is also observed that the the above is the real time application. Output is obtained in live conditions.

When it comes to its quantitative and qualitative analysis; Quantitative: The number of messages sent per second were 5 and the number of messages received per second was 5. There was no notable delay in the message path to and fro of the server. If it all there was a delay it was very minute and negligible.

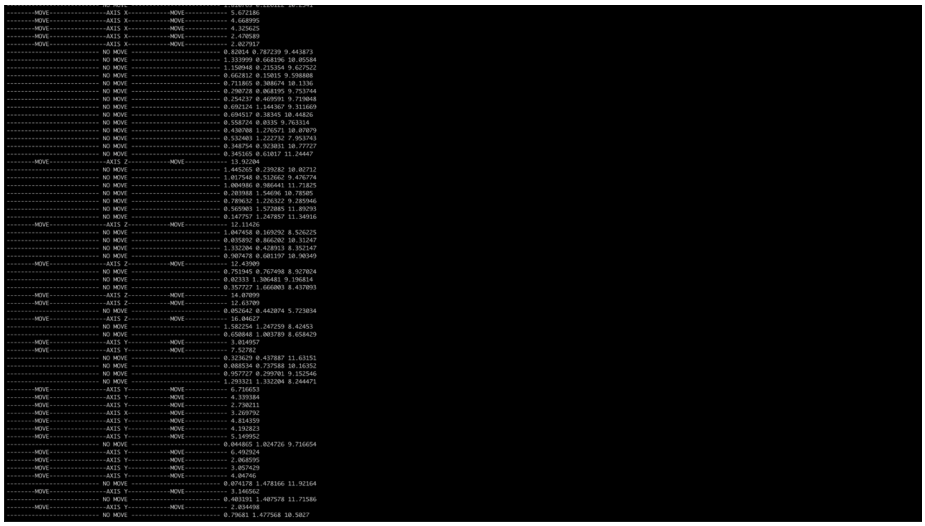


Figure 17: Output

Qualitative: It is very important that the local area network must be a good one in it strength. It is observed that poor connection leads to delay in the messages transmission and reception. It is more required that, both the wearable device and the end system must be connected to the same LAN, so as to improve the message quality and eliminate delay as much as possible.

Further Progress: As this project laid foundation for using IOT for performing arts, and this was successful; we further want to include a similar kind of application. In every possible performance arts we want to include this kind of similar application in order to make the world entertained.

References

[1] Margo K Apostolus. Robot choreography: Moving in a new direction. *Leonardo*, 23(1):25–29, 1990.

[2] Holger Junker, Oliver Amft, Paul Lukowicz, and Gerhard Tröster. Gesture spotting with body-worn inertial sensors to detect user activities. *Pattern Recognition*, 41(6):2010–2024, 2008.

[3] Barıs Kurt. Imitation of human arm movements by a humanoid robot using monocular vision. *Bogaziçi University, Master of Science*, 2009.