First Stage Project

on

IoT-VR Synchronization in Home Automation

Submitted In Partial Fulfillment of Requirements
For the Degree Of

Master of Technology

(Electronics and Telecommunication Engineering)

By

Ishan Haldankar

Roll No: 16030920004

Guide

Dr. Bharti Singh

Co-Guide

Prof. Kartik Patel

S K Somaiya College

Somaiya Vidyavihar University

Vidyavihar, Mumabi - 400 077

2020-22

Somaiya Vidyavihar University

K. J. Somaiya College of Engineering

Certificate

This is to certify that the first stage project report on dissertation report entitled IoT-VR Synchronization in Home Automation is bonafide record of the dissertation work done by Ishan Haldankar in the year 2021-2022 under the guidance of Dr. Bharti Singh in partial fulfillment of requirement for the Masters of Technology degree in Electronics and Telecommunication of Somaiya Vidyavihar University.

_____ _____

Guide / Co-Guide Head of the Department

_____

Principal/Director

Date:

Place: Mumbai-77

Somaiya Vidyavihar University

K. J. Somaiya College of Engineering

Certificate of Approval of Examiners

This is to certify that the first or second stage project report on dissertation / internship report entitled IoT-VR Synchronization in Home Automation is bonafide record of the dissertation work done by Ishan Haldankar in partial fulfillment of requirement for the Masters in Technology degree in Electronics and Telecommunication Engineering of Somaiya Vidyavihar University.

_____ _____

Expert / External Examiner Internal Examiner / Guide

Date:

Place: Mumbai-77

Somaiya Vidyavihar University

K. J. Somaiya College of Engineering

DECLARATION

I declare that this written thesis submission represents the work done based on my and / or others' ideas with adequately cited and referenced the original source. I also declare that I have adhered to all principles of academic honesty and integrity as I have not misinterpreted or fabricated or falsified any idea/data/fact/source/original work/ matter in my submission.

I understand that any violation of the above will be cause for disciplinary action by the university and may evoke the penal action from the sources which have not been properly cited or from whom proper permission is not sought.

_____

Signature of the Student

Ishan Haldankar

Name of the Student

16030920004

Roll No.

Date:

Place: Mumbai-77

Abstract

Internet of Things or IOT is a topic emerging a lot of importance in field of business, infrastructure and real-time applications. Bringing the simplicity to the way of life Internet of Things or IOT is coming out as a hot topic. Virtual Reality on the other hand, is defined as generating a virtual world which can be similar to the real-world depending on the creator along with the scenes and environment.

Literature survey is done on IOT-VR system shows that a lot of work is being carried out in studying the basic architecture required in the synchronization of both Internet of Things (IOT) and Virtual Reality (VR), its effect on the ongoing market and also the impact it will have on the environment and the market.

This article presents the brief idea of basic building block of Internet of Things and Virtual Reality, how to incorporate both the technology and its application in real-life scenarios. It also presents the use of cloud-based algorithm and system for further use of the IOT-VR data exchange. This includes VR IOT Environmental Synchronization scheme (VRITESS) used to provide a stable and fresh experience to the users by ensuring the control of IOT objects with the use of VR headsets. There are some extreme environment or devices which are complex to get assess but with the help of Virtual Reality and cloud-based system, it can be helpful to control and maintain such types of IOT sensors, devices and other appliances. Further, it also provides a fast and safe maintenance and servicing of the parts and equipment

This report gives exhaustive study on IOT-VR Architecture and their effect on Home Automation application is presented. This article presents different case studies which includes the network of Internet of Things and Virtual reality and the application of the same. Applications includes smart education bringing an innovative change in the field of education and further development proves an important aspect that can be brough in this field. Other applications like Municipal Utility Tunnel Facility Management are presented to showcase the use of VR in IOT for facility management to conduct test and obtain experience of operation and maintenance system in advance.

***Key words*:** VR IOT Environmental Synchronization scheme, Municipal Utility Tunnel Facility Management

Contents

List of Figures

List of Tables

Nomenclature

VR	Virtual Reality
IoT	Internet of Things
VRITESS	VR IoT Environment Synchronization Scheme
ITINP	IoT Integration Platform
VRITIP	VR IoT Platform

Chapter 1

Introduction

This Chapter gives the brief explanation of the topic Internet of Things (IOT) and Virtual Reality (VR). Types of applications and its uses in real-time processes. Equipment required to connect a user to a Virtual Environment and how to control things in that environment. It also gives a basic idea of what can be achieved from the design system. Advantages of the system is listed to show the idea of the Synchronization. And the methods used for Design and Synchronization

1.1 Internet of Things (IoT)

The Internet of Things influences the way we live. This helps us to better understand our surroundings. The Internet of Things is a system of connected devices connected to the internet in order to transfer and receive data from one to another. An intelligent house is the best example. Domestic appliances such as air conditioning, doorbell, thermostat, smoke detector, water heaters and security alarm can be interconnected to share data with the user on mobile application. The user can now obtain detailed information on how the devices around him works.

IOT Devices are classified into two types:

A) General Devices:

The general Devices are the components of data hub and the information exchange. They are connected by either wired or wireless information. This main function is to exchange data, receive data and store data between data hub and information exchange. Home appliances is one of the examples of such devices.

B) Sensing Devices:

This Devices includes sensor and actuator. They perform the functions like measure the temperature or measure the light intensity and many more.

These devices are connected with a help of gateway which provides information processing and transfer it to the cloud. Cloud stores and process the data and after that, action are performed on the stored data for further experiments. Wired and wireless interfaces such as Bluetooth, ZigBee, Wife, GSM, etc. are used to provide the required connection.

1.2 Virtual Reality (VR)

The idea of virtual reality is to replace your reality with some new virtual computer-generated environment. This includes some game, some environment we work around or some video that is playing around you when you look around. But the idea is to trick you brain that 'this is your new reality'. Earlier, VR started as an air force activity as a part of their training program and its flight simulation. That is much easier and cheaper to have new pilot practicing stuff like fighting menu over and shooting, ejecting and crashing, all without shooting, ejecting and crashing the actual million dollars planes. In recent years, companies are making their personal VR experience that we can just buy for our entertainment. It includes Devices like VR Headset, just like our headphones, this headset totally takes over our vision, inside it includes pair of lenses and a place to hold our smartphone which becomes your screen and our VR engine. There are two kinds of VR headsets, Type1 is the accessory that you plug your smartphone into that becomes the screen, like Samsung's gear VR. Type2 is the standalone unit that does everything. It has the gyroscope, the screen and other things build-in, like oculus rift or HTC Vive. Both types have the lenses that focuses your eye on stereoscopic images. It includes gyroscope and accelerometer that help track your head movement and that help put us in our world.

Virtual Reality Equipment

1. Headset

Table 1.2: VR headset and their specifications

	Google Cardboard	Oculus Rift	HTC Vive	Samsung HMD Odyssey	Valve Index
Appearance					
Company	Google	Facebook	HTC	Samsung	Valve
Initial Cost	Rs.2599	Rs.75990	Rs.74990	Rs.36800	$999
Type	Mobile	Standalone	PC	PC	Standalone
Platform	Android	Oculus Home,Steam VR	Steam VR, Viveport	Windows Mixed Reality	Steam VR
Resolution	Smarphone Resolution	2160x1200	2160x1200	2880x1600	1440x1600
Display Type	Smartphone	OLED 80Hz	OLED 90Hz	AMOLED	120Hz IPS

2. Controller

Function of the controller is simply to control the object or environment in the Virtual Reality. In simple words, the controller acts as our virtual hand in virtual environment. With it, we can change the settings, contents and modify the required area according to us. Below figure shows the image of controllers.

Figure1: VR Controller, www.google.com

Chapter 2

Literature Survey

This chapter provides the survey done on IEEE papers of different author on the work done on IoT and VR system. Five different papers are considered giving brief knowledge on IoT-VR architecture and its application design by using the two system. Furthermore, it gives the advantages of such application in real-world scenarios, bringing the complexity to the life.

[1] provides the basic architecture of IOT-VR integration with each other and the cloud system. This includes, explanations of IOT-VR architecture, use of such architecture in the application-based interface and giving control to the user the remote IOT devices in virtual world. A proposed design shows the impact of using IOT devices in Virtual world to the IOT devices in real world and vice versa. The basic principle is to make a virtual environment which will include all the surrounding and objects similar to the real-world surrounding and things. Once it is ready, surrounding of both the world will be synchronized so that when there is change in either of the environment, it will have the same change or impact on the other environment. Purpose of such design is done because in some critical condition, where control of IOT devices is not possible, we can make use of VR system to do the same. VR-IOT synchronization scheme is used to facilitate the synchronization process between the two environments. It helps maintain the status of the real-world object updated following the changes or instructions given to the same objects in the virtual world and vice-versa. The test includes the use of VR headset and IOT devices on local-based network as well as cloud-based network.

Interconnection between human, device and space is published in [2]. It consists of IOT-based system and VR contents. The main objective mentioned in the paper is to give a user access to customizable and intuitive remote services. Service like controlling a devices like fan, AC, etc. And data collecting sensor modules can be added. It also includes the use of WEB servers so remove the limitation of the distance.

Paper [3] provides the further explanation and design of IOT-VR based system. The test has been done on the application of smart education. Now education is a vital role in each and every individual, but we cannot adopt the same old habit of learning in a closed 4 walled room called classroom as the concepts is increasing with recent years. This paper provides the basic definition of IOT, integrated with VR and using the system in the so-called purpose education.

The design architecture is set-up for student having the learning disabilities. It helps making a suitable environment for such student without having to worry about their inabilities to intervene. Augmented Reality/Virtual Reality enables teachers to bring concepts to life. We can now use such realities to create a tornado and bring it into the classroom to see what it actually looks like or we can have a virtual beehive in the classroom and see how it works. We can dive into the beehive to see the inner workings of it.

Creating an environment equipped with digital components to create a better, more efficient and smoother learning process is the objective of the paper. Bringing the reality of a concept to the student, helping them to understand that particular concept.

Architecture for the design is included in [3], thus fulfilling the concept of the paper published. No further design experiment is shown in the paper, but can be used to create a prototype using the same design. Some of the main feature will be like tracking the homework, whether it is done or not, correcting the mistakes and grading will be done using the same design which will enable the teachers and help the student in the same manner. For modelling, tools like CAD (Computer Aided Design) are used, with the use of mobile device app, PLC and sensors and integrating it to the cloud-based system.

We have seen the integration of IOT with VR and some of its applications. But how can we user the IOT devices in the virtual environment. [4] paper solves this problem by bringing the concept of hand gesture. IOT is on the verge of global increase, but many users are still using the same old mobile devices and web interfaces. VR experience provide a user an immersive interaction. This paper provides a prototype of such system with a slightly different approach. This approach includes the use of hand gesture to interact. A standard 2D convolution neural network (CNN) is implemented for real-time hand gesture recognition. Object detector identifies the object within a certain range by analyzing the gesture function.

Management and maintenance are the key for healthy operation of a device. One such application is mentioned in the paper [5]. Paper proposes the integration of Building Modeling Technology (BIM) with Virtual Reality (VR) technology. By creating a Three- Dimensional environment of a facility management in the utility tunnel, it will become a matter of time to maintain the services in such area where it is difficult

or quite harmful for a human to get access to. Fire alarm system of the utility tunnel is tested and implemented by the author. Lighting, ventilation, Drainage, fire alarm, CO, and CO2 detection, extinguishing and maintenance hole cover is some of the application of the design in [5].

[6] proposes the use of 6G technology for the connection and integration of IoT and VR system. Thus, will be helpful in fast connectivity and low latency/ping while using IoT-VR based application. Author provides the design methodology for the same.

[7] provides the use of VR based spectacle in application of low vision. Authur proposed a design of spectacle which will be useful in identifying objects and navigation in terms of low vision individual. This system is a software based IoT application integrated with VR. There is no need of controller to control the environment. Also, the need to create an environment is eliminated in this application.

One of the applications of IoT-VR synchronization is Health application given in [8]. The paper proposes the use of IoT, VR and radio resource management (RRM) in rural and under-privileged areas. Thus, allowing the use of VR to guide a patient remotely in situation of emergency.

[9] provides the use of VR in different application like farming robot. VR headset is used to get the view of the field in farming, thus helping in monitoring and collecting the data. Using the data, one can know the light, temperature, and weather condition. Helping the farmer to know the state of the crops. Other application mentioned in the paper is smart education.

Providing a proper Experimental setup equally essential in case of Smart Education and also for medical sector. [10] showcases demo experiment of a chemistry lab for students and teachers and to monitor the result in spectator point of view. Use of VR-based massive open online course for the students. It consist of two system- Client (student), server (supervisor) and an extra database for data analysis. Client system is used for the student for hand on experience, sever system is used by teacher for monitoring and database to provide future improvements and behavior.

Sometimes, VR equipment might be troublesome, which can cause pain in hand on continuously use. In [11], use of novel ultrasonic haptic device, this can reduce the use of VR equipment and thus can become touchless. Spatial audio plays an important role in improving the communication related technical features in VR system. This is demonstrated in [12] and this system is used in UK military.

Meeting conducted in VR can provide a massive boost to a company or organization, if the meeting is schedules for any urgent case. In that case a 360-degree Photo realistic framework VR conferencing is

provided in [13]. Equipment like camera, Depth-based background removal, WebRTC and Oculus Rift are used.

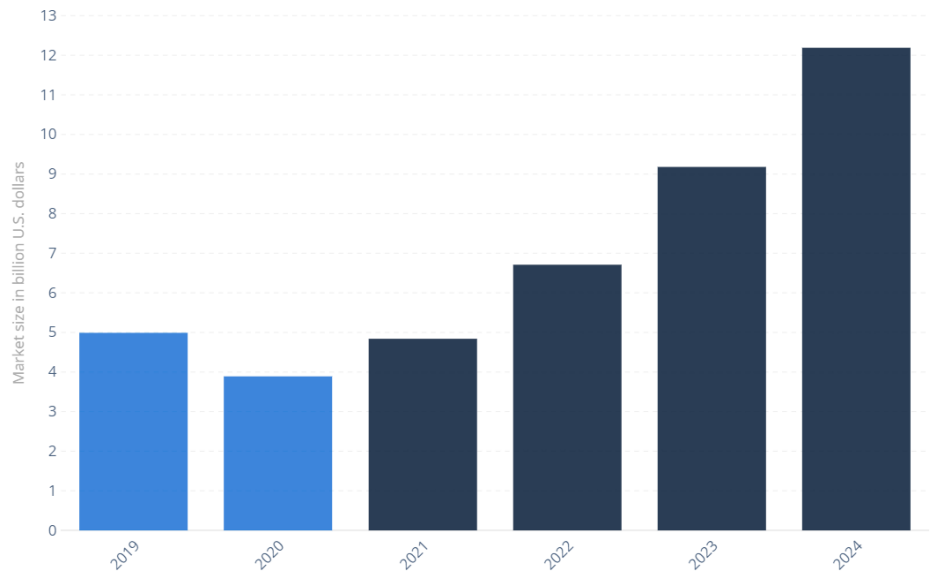
Chapter 3

IoT-VR

3.1 Purpose of IoT-VR Integration

As explained earlier IOT is an emerging technology but is limited using just a smartphone to the user. Virtual Reality is still a recent technology but has seen quite a drift up in market.

Figure 2: Virtual Reality current and future market estimation in terms of US Dollars, https://www.grandviewresearch.com/industry-analysis/virtual-reality-vr-headset-market



In the above figure, we can clearly see the rise of market for Virtual reality and what it can bring in terms of services.

The main question or the main objective of this entire report is- can we use VR and IOT together? what are the applications? how it can be done to bring the two emerging technologies together? What are the challenges? And Future innovation in this field?

From 2021 to 2024, it is expected for market to increase which will bring the new innovation.

3.2 IoT-VR Environmental Synchronization Scheme (VRITESS) architecture

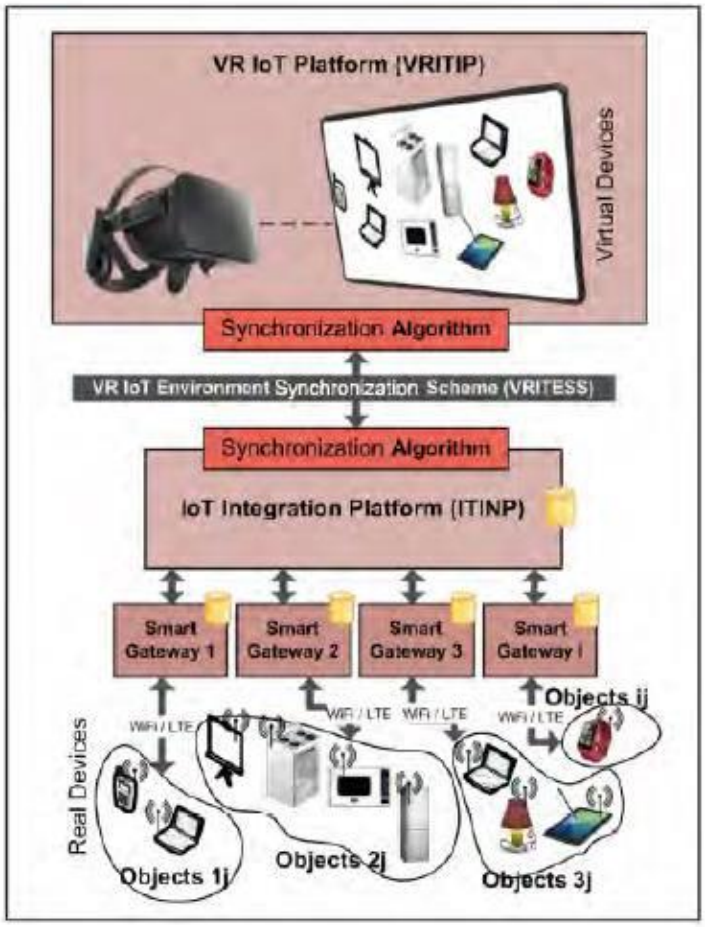


Fig 3: VRITESS Architecture [1]

3.2.1 VR IoT Environment Synchronization Scheme (VRITESS)

VR IOT Environment Synchronization Scheme is at the top of the architecture. It provides the necessary Synchronization of IOT devices in Real-world and Virtual-world environment. The architecture consists of IOT devices which is similar in both real-world and virtual world as shown in the figure.

3.2.2 IoT Integration Platform (ITINP)

IoT integration platform (ITINP) is connected to the IoT devices in real-world with the help of the smart gateway. Smart Gateway provides the communication of IOT devices with ITINP and also with each other.

3.2.3 VR IoT Platform (VRITNP)

VR IoT Platform includes the IoT devices generated in a virtual world. It can be accessed using a VR headset. ITINP contains a cloud-based server for the integration of the services. VRITNP also maintains the status of IoT object in virtual world with the IoT devices in Real-world and vice versa. VRITNP and ITINP communicate over a local network or cloud. MQTT is the IoT Protocol used. In local network, a databased keeps track of all the operation and store it. Depending on the timestamps, its function is to keep both device update. While in cloud-based approach, IoT protocol keeps the operation and timestamp, while both ITINP and VRITIP access the data. In this way, Synchronization process is concluded.

3.2.4 Smart Gateway

It provides the connectivity and communication between IoT devices and IoT Integration Platform (ITINP) and also allows communication between IoT devices.

3.3 Web Server Employment

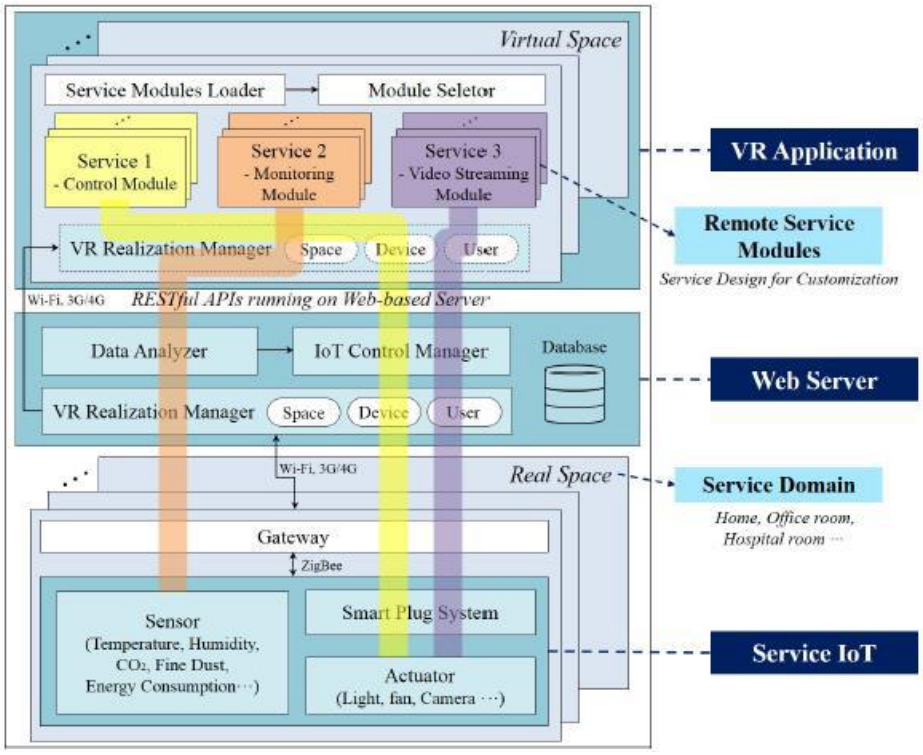


Fig 4: 'HI Platform Design Architecture' [2]

There is a limitation of distance between the use of IOT-VR network. This limitation can be removed by making use of Web Servers.

Fig 6 shows the hyper connectivity platform design architecture. In this architecture, IOT devices like Sensor are integrated as a monitoring module in VR application and devices like actuators are used as Control module and Video Streaming module in VR application. Actuators thus can be controlled in VR and monitoring at the same time. Now a Web-server is introduced in between to remove the limitation called distance. This creating a remote service, where user don't need to be close to IOT device when using VR system. All the other application and process remains the same as mention through figure.

3.4 Hand Gesture Recognition

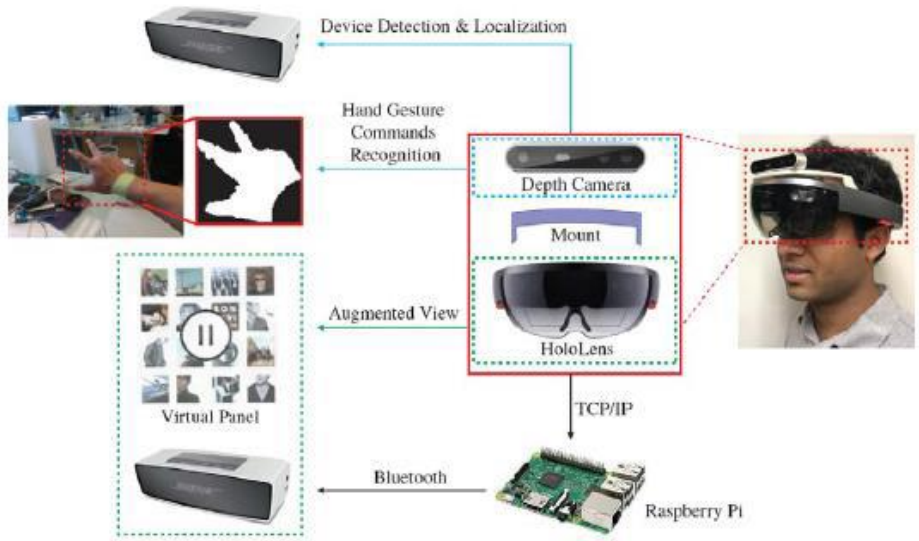


Fig 5: 'proposed VR Architecture for controlling IoT Devices' [4]

The above figure shows the architecture of controlling IoT devices with the help of hand gesture. Here we make use of Raspberry Pi to connect VR headset with External projector connected to VR headset using Bluetooth. Virtual world is generated containing all the IoT Devices and hand gesture commands recognition is created.

Users can use simple gesture to control or interact with devices without physically touching them. Many approaches have been made using cameras and computer vision algorithms to interpret sign language. Gesture recognition can be seen as a way for computers to begin to understand human body language thus building a richer bridge between machines and humans and primitive text user interface or even gifts graphical user interfaces which still limit the majority of input to keyboard and mouse.

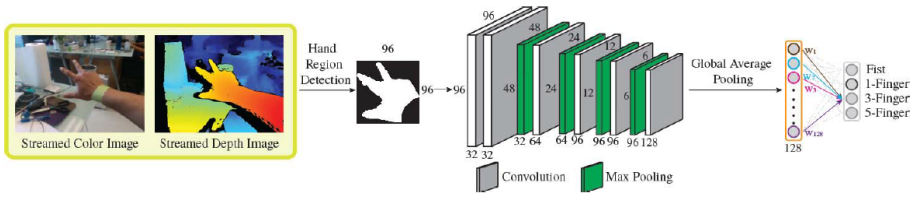


Fig 6: "MagicHand: Interact with IoT Devices in Augmented Reality Environment"[4]

The whole process is shown in the above figure. The hand gesture is found using the depth of the image as the contour whose values fall into the depth range starting. We can use different hand control gesture like a pinch or slide left.

3.5 Home Automation

Home Automation is all about two concept- Automation and Remote Control. By applying these two concepts in application like Home Automation, it can reduce the complexity of usage. Like controlling fan to controlling Air-conditioner with a tip of our finger. In Internet of Things (IoT), home automation is one of the applications, where we can use smartphone or remote controll to control different devices. But by integrating IoT with Virtual Reality system, once can control the device by fully getting immerse in that environment. Advantages of IoT and VR is that one can control the devices from anywhere, as long as he is connected to the internet.

First, IoT Home Automation system is needed to be configured. After successful configuration, using CAD or any other software, a virtual environment needs to be created along with the device configuration. Implement a software which will give assess to IoT services in VR system and vice-versa. Using the example of application in [1], we create a system which will allow us to control home devices like AC, Fans, Lights, Doorbell, Home Desktop, etc.

Chapter 4

Implementation

4.1: IoT based Home Automation System:

Components:

1	Atmega Microcontroller
2	Wi-Fi Modern
3	Diodes
4	Transformer
5	Relays
6	Voltage Regulator
7	Crystal
8	Lamps
9	LED
10	Relay Driver IC

Wi-Fi ESP8266:

Fig 7 : Wi-Fi ESP8266

The ESP8266 Wi-Fi Module is a self-contained SOC with integrated TCP/IP protocol stack that can give any microcontroller access to your Wi-Fi network. The ESP8266 is capable of either hosting an application or offloading all Wi-Fi networking functions from another application processor.

Atmega328p

ATmega328P is a high performance yet low power consumption 8-bit AVR microcontroller that's able to achieve the most single clock cycle execution of 131 powerful instructions thanks to its advanced RISC architecture. It can commonly be found as a processor in Arduino boards such as Arduino Fio and Arduino Uno.

16x2 LCD Display

A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. The 16 x 2 intelligent alphanumeric dot matrix display is capable of displaying 224 different characters and symbols.

Setup:

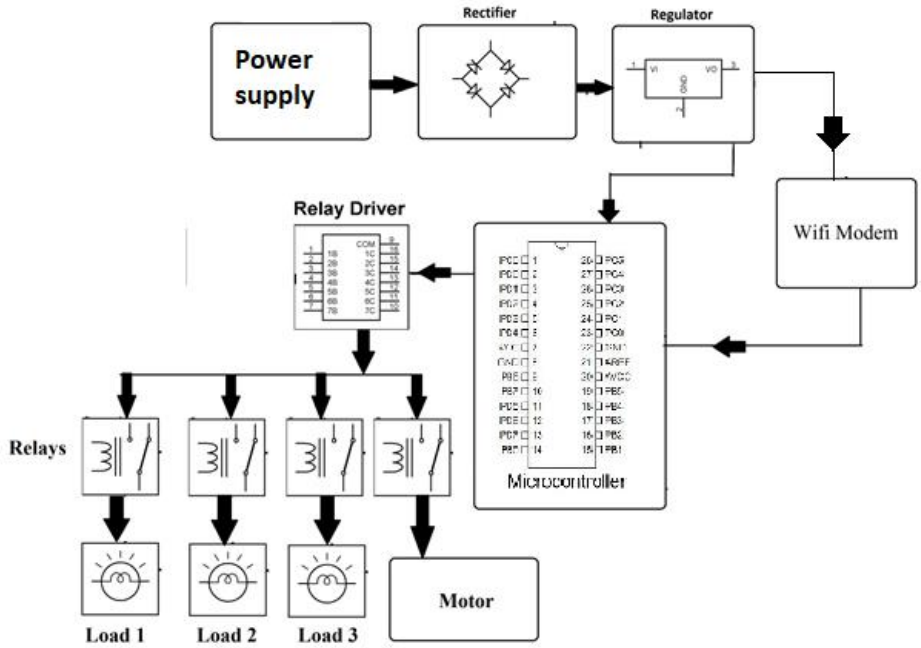


Fig 8 : Block diagram of IoT Home Automation System

All the connection is done as shown in the block diagram. Load 1,2 and 3 is connected by light bulb, Motor is connected with a small Fan. Wi-Fi Modern is connected to the Atmega microcontroller.

Below figure shows the 2D representation of a room. Each room will control one of the 4 devices namely- bulb and motor. We will create a similar rooms but in 3D using unity 3D software in Virtual Reality System

Fig 9 : 2D model of a virtual Home.

4.2 Virtual Reality Setup:

In this step, we will first create a virtual environment with the help of Unity 3D software or any other software. We create a new project which will include assets like plane which represent the floor, cube for the wall and other electronics and furniture component. Taking the proper measurement of a house, a virtual environment is created which is then can be integrated with oculus quest 2 VR system using the same unity3d application.

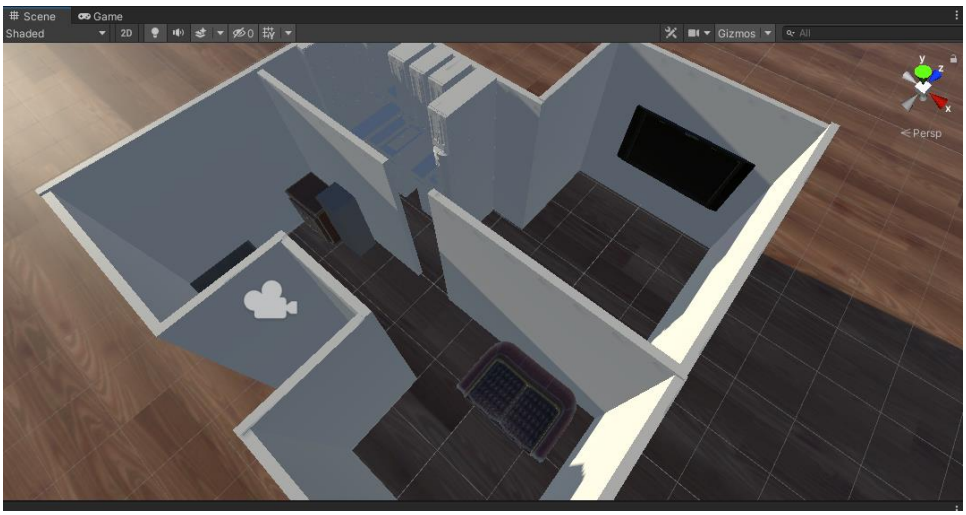


Fig 10: Virtual Apartment

In figure 10, virtual environment is created which replicates a house and the camera icon in the figure indicated the origin point from where we can start and utilize the VR system and can interact and move along the different rooms.

Future Work

Once both the system is working, design will be done such that on activating a light or fan in VR based environment, system will activate the IoT based lights and fan shown below. Software will be implemented to integrate both the system together.

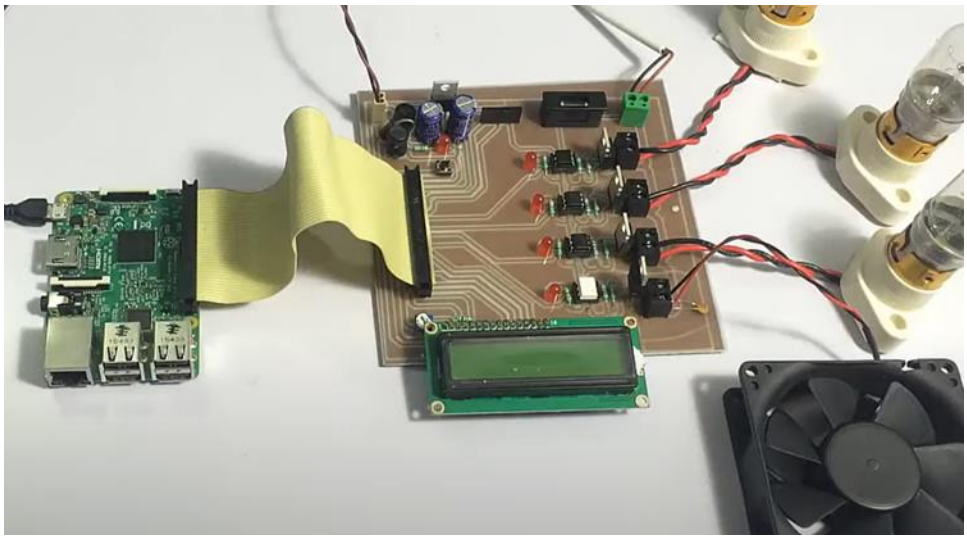


Fig 11: IoT-base Home Automation System.

Conclusion

IOT-VR synchronization be an emerging technology bring a new application which in turns bring a new way of understanding certain things and how we look to a thing with a different prospective. It will enable us to understand a concept with our own point of view rather than just hearing or reading it in a book or article. It will give creators an innovative way of explaining things. Use of Hand gesture to control the device can be a useful application in new inventions. Controlling a device which was impossible to get access to an extreme condition will be easier and also safe. Maintenance is possible from anywhere in the world.

Some of the advantages of IOT-VR integration are:

1. No risk

2. Testing in a controlled and safe environment.

3. Realistic scenarios

4. Can be done remotely

5. Saves time and money.

6. Improve retention and recall.

7. Simplifies complex problems.

8. Suitable for different learning styles.

9. Innovative and enjoyable.

Along with the advantages it has some disadvantages too like it can be quite expensive, can affect human health, eye-problems, addiction to virtual world, functionality problems.

References

[1] A. A. Simiscuka, T. M. Markande and G. -M. Muntean, "Real-Virtual World Device Synchronization in a Cloud-Enabled Social Virtual Reality IoT Network," in IEEE Access, vol. 7, pp. 106588-106599, 2019, doi: 10.1109/ACCESS.2019.2933014.

[2] Myeong-in Choi, Lee Won Park, Sanghoon Lee, Jun Yeon Hwang and Sehyun Park, "Design and implementation of Hyper-connected IoT-VR Platform for customizable and intuitive remote services," 2017 IEEE International Conference on Consumer Electronics (ICCE), 2017, pp. 396-397, doi: 10.1109/ICCE.2017.7889368.

[3] S. Paul, S. Hamad and S. Khalid, "The Role of AR/ VR in an IoT connected digital enterprise for smart education," 2019 Sixth HCT Information Technology Trends (ITT), 2019, pp. 305-308, doi: 10.1109/ITT48889.2019.9075102.

[4] Y. Sun, A. Armengol-Urpi, S. N. Reddy Kantareddy, J. Siegel and S. Sarma, "MagicHand: Interact with IoT Devices in Augmented Reality Environment," 2019 IEEE Conference on Virtual Reality and 3D User Interfaces (VR), 2019, pp. 1738-1743, doi: 10.1109/VR.2019.8798053.

[5] C. -M. Wu, L. -Y. Li, Y. Lai and C. Xiao, "Development and Application of Municipal Utility Tunnel Facility Management Based on BIM and VR," 2020 IEEE Eurasia Conference on IOT, Communication and Engineering (ECICE), 2020, pp. 205-208, doi: 10.1109/ECICE50847.2020.9301916.

[6] S. Liao, J. Wu, J. Li and K. Konstantin, "Information-Centric Massive IoT-Based Ubiquitous Connected VR/AR in 6G: A Proposed Caching Consensus Approach," in IEEE Internet of Things Journal, vol. 8, no. 7, pp. 5172-5184, 1 April1, 2021, doi: 10.1109/JIOT.2020.3030718.

[7] V. K. Shukla and A. Verma, "Model for User Customization in wearable Virtual Reality Devices with IoT for “Low Vision”," 2019 Amity International Conference on Artificial Intelligence (AICAI), 2019, pp. 806-810, doi: 10.1109/AICAI.2019.8701386.

[8] W. B. Owais and E. Yaacoub, "On Accommodating VR Traffic for mHealth Applications in Rural Areas with Limited Impact on IoT Traffic," 2020 IEEE International Conference on

Informatics, IoT, and Enabling Technologies (ICIoT), 2020, pp. 389-393, doi: 10.1109/ICIoT48696.2020.9089469.

[9] N. Soujanya, Y. M. Roopa and D. K. Babu, "Virtual reality meets IoT Through Telepresence," 2019 3rd International Conference on Trends in Electronics and Informatics (ICOEI), 2019, pp. 972-976, doi: 10.1109/ICOEI.2019.8862746.

[10] H. Kim, S. Nah, J. Oh and H. Ryu, "VR-MOOCs: A Learning Management System for VR Education," 2019 IEEE Conference on Virtual Reality and 3D User Interfaces (VR), 2019, pp. 1325-1326, doi: 10.1109/VR.2019.8798106.

[11] J. Martinez, D. Griffiths, V. Biscione, O. Georgiou and T. Carter, "Touchless Haptic Feedback for Supernatural VR Experiences," 2018 IEEE Conference on Virtual Reality and 3D User Interfaces (VR), 2018, pp. 629-630, doi: 10.1109/VR.2018.8446522.

[12] B. N. Balint, "[DC] Designing VR for Teamwork: The Influence of HMD VR Communication Capabilities on Teamwork Competencies," 2019 IEEE Conference on Virtual Reality and 3D User Interfaces (VR), 2019, pp. 1365-1366, doi: 10.1109/VR.2019.8798147.

[13] S. N. B. Gunkel, M. D. W. Dohmen, H. Stokking and O. Niamut, "360-Degree Photo-realistic VR Conferencing," 2019 IEEE Conference on Virtual Reality and 3D User Interfaces (VR), 2019, pp. 946-947, doi: 10.1109/VR.2019.8797971.

[14] https://elearningindustry.com/pros-cons-using-virtual-reality-in-the-classroom

[15] https://www.statista.com/topics/2532/virtual-reality-vr/#dossierKeyfigures