Enhancing Extended Reality(XR) By Using Mobile Devices Emphasizing Universal Usage

by

Saadman Ahmed
17201140
Asif Fahad Kingshuk
17101476
Seyam Rabbi
17301159
Zaid Ibne Hasan
16201105
Sayma Shultana Nishi
16201044

A thesis submitted to the Department of Computer Science and Engineering
in partial fulfillment of the requirements for the degree of
B.Sc. in Computer Science

Department of Computer Science and Engineering
Brac University
September 2021

Declaration

It is hereby declared that

1. The thesis submitted is my/our own original work while completing degree at Brac University.
2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. We have acknowledged all main sources of help.

Student's Full Name & Signature:

Saadman

Saadman Ahmed
17201140

Kingshuk

Asif Fahad Kingshuk
17101476

Seyam Rabbi

Seyam Rabbi
17301159

Zaid

Zaid Ibne Hasan
16201105

Sayma Shultana Nishi

Sayma Shultana Nishi
16201044

Approval

The thesis/project titled “Enhancing Extended Reality(XR) By Using Mobile Devices Emphasizing Universal Usage” submitted by

1. Saadman Ahmed (17201140)
2. Asif Fahad Kingshuk (17101476)
3. Seyam Rabbi (17301159)
4. Zaid Ibne Hasan (16201105)
5. Sayma Shultana Nishi (16201044)

Of Summer, 2021 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of B.Sc. in Computer Science on October 02, 2021.

Examining Committee:

Supervisor:
(Member)

Mostafijur
Rahman Akhond

Digitally signed by Mostafijur Rahman Akhond
DN: C=BD, OU=CSE, O=Jashore University of Science and Technology, CN=Mostafijur Rahman Akhond, E=mr.akhond@just.edu.bd
Reason: I am approving this document
Location: your signing location here
Date: 2021.10.05 17:49:57+06'00'
Foxit Reader Version: 10.1.1

Mostafijur Rahman Akhond
Lecturer
Dept. of Computer Science and Engineering
Jashore University of Science and Technology

Program Coordinator:
(Member)

Dr. Md. Golam Rabiul Alam
Associate Professor
Department of Computer Science and Engineering
Brac University

Head of Department:
(Chair)

Sadia Hamid Kazi
Chairperson and Associate Professor
Department of Computer Science and Engineering
Brac University

Abstract

XR, MR, VR are some avant-garde technologies set forth a few decades back and have occupied a paramount role in the technological areas within a short gamut of time. The circumscription of this cutting-edge field is the availability of a limited number of empirical research papers about its programming explication and workarounds for commonplace implementation issues. Almost all research papers are academic and lack application, including practical illustrations. Extended reality is a surreal environment having three premier features viz. immersion, presence, interactivity that render users a phantasmagorical experience by dint of special human-computer interface equipment. Our work propounds a vanguard framework for employing extended reality in cellular mobile phones. Our work will bring that off just at hand with a very small ransom, what is conceived to be a big ticket today. With this ergonomic framework, accession to augmented reality that has been presumed to be sophisticated to date will be palpable and straightforward. The proposition, including speculation upon the framework as well as its actuation, is complete and described with saturation in the paper. The hardware-level implementation is yet to be tested and fulfilled. In the coming days, the framework is intended to get integrated with IoT and AI being blossomed as a cross-platform extended reality application.

Keywords: Extended reality, XR, Mobile application, Framework, Android, Mixed reality, Augmented reality, Low-cost

Dedication

This thesis is dedicated towards our beloved parents without whom we would not be able to pursue our dream and fulfil our cherishment in all facet of our lives.

Acknowledgement

First and foremost, all Excellence and Glory be to Almighty, for whom we are capable of accomplishing and executing the entire thesis successfully.

Secondly, we would like to enunciate our sincere gratitude to our supervisor Mostafijur Rahman Akhond (Lecturer, Dept. of Computer Science and Engineering, Jashore University of Science and Technology) for mentoring us smoothly throughout thesis. This thesis would have been nearly impossible to consummate without his appropriate guidance and encouragement.

Table of Contents

List of Figures

List of Tables

Chapter 1

Introduction

Reprising AR that is an acronym for Augmented reality, MR that is an acronym for Mixed Reality and VR that is an acronym for Virtual reality including everything amongst them, XR which is the acronym for Extended Reality, has now been an 'Umbrella' [1] term which enlightens this whole immersive world. By 2022, Statista [2] foreshadows that AR and VR scientific know-how will monopolize a global net worth of $209.2 billion in the whole nine yards. Human-computer interfaces that confect a lifelike world are called virtual reality. In the virtualized environs, participants may roam around freely and stroll around hither and tither. [3]. A research associate at the University of Washington named Jerry Prothero, working at the Human Interface Technology Laboratory, expounds that it (VR) is a constellation of peripherals and high-end microprocessor units that excite a substantial chunk of human visual or auditory organs via rendering a plenary and wide-ranging visual field of vision along with stereo reverberation. It is a montage of neural signals embellished with sensory experiences that facilitates the semblance illusions and sensations of being in multimedia simulated eco-sphere pursuant to psychology" [4]. Simulated and synthetic computer embedded objects are deployed and anchored to a corporeal, real-time environment to extenuate, or augment it in that very real environment, which is what Augmented Reality is [5]. While AR tends to focus on reality as the measurable impact and overlays computer-generated contexture on top of it, VR nestles the supereminent focus on virtual systems and hornswoggles users by gulfing them in a semblance real environs. [6]. Mixed reality is a technology that seamlessly integrates augmented reality with virtual reality technologies in order to yield such a phantasmagoric atmosphere in which physical (real) and digital (virtual) entities can be superposed one upon another coataneously. This is pursued by texturing and coalescing real objects into virtual dynamic worlds, or virtual holographic views into real milieus, or even virtual elements being superimposed upon virtual simulated environs [1].

The extent research papers have some circumscriptions while analyzing this tech field. The papers have not been explored to the VR, AR, and MR intersectional ideas [1] and connecting them under a single platform. The virtual video latency [6] issue during immersion has just been broached upon without any workaround. Augmented reality in some small platforms like mobile devices or non-expensive devices is not illustrated in the papers, while most are highly costly. The position estimation for IMU sensor [7] values are substantially complex with available market processors. None of the papers have fully brought into the discussions how the current imminent VR products have been developed like Microsoft Hololens, Facebook Oculus, HTC's HTCVive, and Magic Leap One. Network throughput of 5.2 Gb/s [1] for for 720 million pixels for full coverage [1] is next to impossible with viable resources that are barely dwelt upon in the current papers. Besides, the cloud computing methodology with optimization is not delivered at all in the papers.

The proposed framework is an XR mobile application. This novel cross-platform framework approach is very panoramic that indents to alleviates the existing vacuum of the virtual reality field. The framework has a three layers security configuration Fig. 4.8 with users' safety and ease of usage. The API in Table 4.1 with the framework has been synchronized with correct optimization and programming to present the immersive simulated environment with nicety. The prime feature, which is an extended immersive output image, has been worked around by the SFM method in Fig. 4.9. The cloud-based architectural design, which was a challenging allotment for this framework, is maneuvered exquisitely by Fig. 4.10. The artificial intelligence collaboration within the framework is one of our highly anticipated future intentions.

To deconstruct the paperwork having subsumed the whole nine yards, Chapter **??** delineates the introduction. Chapter **??** has discoursed and interpreted this research's premiere objectives and contributions. Chapter **??** demonstrates the literature review with categorization and citations being properly notified. The most riveting portion of the paper, which is the cadre and armature of this system that is System Architecture, is illustrated in Chapter **??**. This Chapter **??** comprises of three prime and puissant subsections regarding the framework. Then comes hardware integration explication which is Chapter **??**. Chapter 6 is named as performance analysis which can be interpreted as the denouement of this research aftermath. Some practical fields for deploying such technology and this application is exquisitely construed in Chapter **??**. Moreover, Chapter **??** the very last portion of the paper that brings the paper's epilogue. After that, the bibliography part is appended with the paper.

Chapter 2

Research Objectives and Contribution

Researchers of this field speculated that it is possible to create an effective new virtual world with essential real-world components with extended reality. There are gadgets like Microsoft Hololens to understand the essence and power of extended reality. However, researchers agree with the lack of availability of such tools and studies in the field. Looking at these limitations of previous work of researchers around the world, we are proposing a potential solution regarding both the hardware and software integration to improve the lack of availability and increase general purpose usage of the technology in day-to-day life.

- Users with meager technological cognizance should be comfortable with this app.
- AR,VR and MR in one single platform
- Welfare for human life and benefits
- Orient the new generation with this trailblazing tech field

Perpending upon these points,we have move forward in this holy grail.

The accentuated and prime contribution we have endeavored for this research is to take down the sophisticated Extended Reality (XR) technology (i.e augmented reality) to a shoestring (low budget) phenomenon. Inside a USD 150 to 200 budget android phone maneuvering MR(mixed reality) with a banal (simple) android application package (Android APK) which caters to the Unity 3d modeling for immersion, incarnates our contribution. Here, the lay-offs are Microsoft Hololens's state-of-the-art features and elision (elimination) of any external high-end CPU or GPU that is believed to be integral to the virtual reality (VR) field. We have investigated several commensurate research papers in order to distinct freshness in this project.

Anthony Steed has illustrated An iPhone-based, very alike approach, Simon Julier [8]. Nevertheless, iPhone is not so minimal budget product, and the output of immersiveness is ambivalent in that paper [8], but in our output, we have interpreted foolproof augmented immersion in a viable cost range. Moreover, the paper [8] is solely on VR, unlike MR or AR as ours. Yaping Sun, Zhiyong Chen, Meixia Tao, and Hui Liu [9] have discoursed 360-degree video rendering for VR mobile platforms, but the processing power used is ultra-high with the Multi-access edge computing server (MEC Server) [9]. Further, the paper [9] says nothing about the mobile input and mobile configural installation in the implementation. On the other hand, our paper revolves around explicit mobile simulated mixed reality. The 360 video concept [9] can be similar to our mixed reality implementation to some extent, but on a broader view that is not aligned with our purpose and implementation. Kevin Boos, David Chu, Eduardo Cuervo of Rice University [10] have harnessed the HP Pavilion mini laptop as a mobile device which is totally antithesis to our low configuration mobile device in comparison. They explicated on caching frames and memoization [10] in the Flashback framework for virtual immersion. Conversely, we discussed Unity XR SDK for real-time 3d object rendering on mobile output screen for immersive AR. Most importantly, the paper [10] illustrated nothing about how the Flashback is integrated into the HP pavilion as if two components are separate but in our research, we have exquisitely portrayed the APK integration by ARcore (android toolkit) and ARKit (IOS toolkit). Fu-Yuan Chiu [11] seems to be equivocal between VR camera and 3d VR scene to be output device, but our paper is transparent of the android phone being the output end. Further, Reallusion iclone 6.5 [11] is not supported in low-priced android mobile to create a 3D model where we have used Unity-based dedicated android application for this purpose. The sphere surface [11] notion cannot provide immersion for all virtual objects from controller or sensor. Contrariwise, AR foundation and Interaction toolkit can even provide augmentation, let one virtual object. Paper [12] has a good correlation with our augmented reality perspective, but the paucity of any framework overrides its positive consequences. For instance, during 3d gaming, an upscale mobile is a prerequisite, along with how navigation [12] and mobilization at run time would sync to the framework is untouched in the paper, which garbles the 3d gaming [12] so-called augmentation concept. Contrarily, we ushered in new infrastructure for augmentation in real-time, thereby maintaining cost and user convenience.

Chapter 3

Literature Review

El-Jarn and Southern (2020) [13] edify the definitions and feasibility of the eXtended Reality in collaborative production-centric design processes. This article “Can co-creation in extended reality technologies facilitate the design process?” reviewed the current literature to find insight into the relation between technologies and works in the report. El-Jarn and Southern also showed some academic-professional approaches to XR technologies. Digital games along with mobile gaming have made XR more readily accessible and financially viable. It is currently utilized widely in the entertainment world as well as architecture, art, medicine, and academia. XR has lately become more increasingly available and commercially sustainable. The paper gives a glimpse of the benefits of XR in day-to-day life work experiences such as education, collaborative working, and so forth. When it comes to VR, one gets a clearer insight into the virtual world because of the use of a giant screen, head-mounted display (HMD), or goggles. It’s customary to create highly immersive VR content utilizing a cave-like automated virtual milieu that’s meant to be undergone by many people at the same time. They also mentioned that XR being at the initial stage has some limitations, such as a lack of traditional methods to fulfill the co-creational virtual environment. The authors conducted a quantitative assessment upon a montage of VR integrated products and services circumcenter the research paradigm upon their professional and scholastic facets and emprises. For specimens, Towards the end of 2019, Facebook’s Medium voxel app had been procured by Adobe. In order to confect and mold 3D objects totally and utterly from three-dimensional cubic shaped objects, or from three-dimensional grids, the voxel-based contouring program medium is harnessed. Moreover, Over the last five years, multitudinous new product innovations have popped up in the global tech valley. The potency and eventuality of infusing augmented reality’s (AR) or virtual reality’s (VR) functionality as well as components into some of those newly emanated inventory’s subsequent versions were a silver lining, as the authors described. These newfangled products are streamlining and unclogging paths for futuristic disquisitions for the emerging AR aficionados and dilettantes. VR controllers warrant artisans and designers to embody geometry within the lattice and three-dimensional matrix, conceding them to the sensation of contouring as well as modeling in virtual spatial contextures. Since this paper talks about till-today approaches and scenarios, it has further prospects to solve problems like lack of equipment, software, and exploration. However, the paper illuminates an efficient overview for researchers to carry forward virtual reality technology in researches.

"Extended reality in spatial sciences: A review of research challenges and future directions" is a classical spatial prolegomenon of the XR framework that explicitly and implicitly connects the real world to a simulation. Çöltekin, Lochhead, Madden, *et al.* [14] stated that effective interaction must be possible if the virtual and real objects belong to the same spatial reference frame. Since there is an abundance of 3D geographical data, interoperable technologies are becoming more mainstream, and advancements in computer graphics facilitate more realistic simulations, it is imperative that the present status of XR and research problems be reexamined. Along with self-contained photorealistic models having three-dimensional stereo augmentation and current climatic portrayals, the authors also addressed enhanced ideologies of geographic data. To entitle XR interfaces to function effectively, it is essential to keep track of the user's head and hands as well as their eye, proprioception, and to pull the string gadget's orientation. For spatial correlation in digitally augmented space to operate, this kind of tracking is vital. As long as the search process goes well, the display may change in response to the user's point of view and react appropriately to any engagements and interactions the user initiates either actively or passively. The diffusion and realism of being immersed would be shattered if the tracking was disrupted. Moreover, the paper includes a survey of experiencing XR in learning Geography whether XR stands first among XR, MR, and AR in terms of knowledge. Formulating a graphic embodiment of a physical object that is both lifelike and mathematically accurate entails a number of steps. Input data is usually obtained via imaging and searching modalities like LIDAR, photogrammetry, ultrasound as well as computed tomography (CT), and so forth. These pathways require a substantial amount of computing power as well as meticulous human labor, all while using many dissimilar pieces of software. These mechanisms have bottlenecks, for specimen picture segmentation, following topological impairments, and designed tools for polygonal interpretations and characterizations of solid surfaces. However, the authors stated some difficulties regarding the simulation might not be completely representative of a real scenario. Also, the hardware part of the graphics rendering unit might not be fully functional because real-time interaction and visualization might be delayed. The authors suggested that further prospective research could enable XR for multiple simultaneous users.

The litterateurs[15] focuses on implementation strategies for XR technology in manufacturing and relevant case studies from the academy and industry. Throughout this case study, the authors separately stated several advantages and limitations of AR, VR, and: The advanced setup in calibration is complex so that it might drop the quality of AR. MR has the most miniature developed tools in the market. VR is the most progressive and beneficial technology among users with its vast area of use. It is sufficient to characterize Mixed Reality as a conjunction of the physical and the imaginary virtual universe, where one superimposes upon another. When we talk about Augmented Reality, we're alluding to a technology that augments the HMD wearer's visual facet with pertinent information for the job in question. The authors have elucidated some very sui-generis examples of VR devices. In the paper, pictorial representation has also been commingled to underpin the illustrations. This is one of the best perks of this paper. To sum it up, AR mixes actual and augmented things, executes in real-time, and ledgers both real as well as augmented entities with one another. Associative cognitive data processing supplement each other in human brains, making it easier for humans to make this transition. However, the authors suggested using the advantages of the mentioned technology in XR. By them, a complete XR framework will consist of design, learning, operational and disruptive phases in a manufacturing system. In the design phase VR, AR, and MR can be used, then in the learning phase AR and VR, then in the operational mood Ar and MR, and lastly in the disruptive phase, AR and MR can be used. The suggested XR framework will consist of all those mentioned technologies.

The prolegomenon[16] puts a fly in the ointment of the mixed reality technology, describing some security and privacy issues this technology may arise, very exquisitely through this paper. The general security and privacy features, for example, integrity, non-repudiation, confidentiality, plausible deniability, etc., have some significant menace by XR. De Guzman, Thilakarathna, and Seneviratne [16] classify such threats into different categories, namely data protection, input protection, user interaction protection. Furthermore, many preventive approaches have also been expatriated throughout the paper for such substantial threats and loopholes of MR. Among all threats, user interaction protection is the most vital. Despite the application cases for visual cryptography with augmented or mixed reality displays, the technique’s usefulness is still limited to certain sensitive use situations owing to alignment constraints. Visual cryptography methods like visual secret sharing (VSS) systems have also included secret display techniques. Employing SS, secrets may be easily and quickly decrypted by placing a visual cipher over a visual key. For even AR and MR projections, such as handhelds and head-mounted displays, traditional VSS was designed for printed material, not digital. Leveraging code-based encryption algorithms, such as barcodes, QR codes, and 2D barcodes, it is possible to loosen the VSS method. The ciphers are available for everyone to see, but the solution is kept private. Once the encryption is deciphered, an AR device may be used to augment the decrypted information on top of it. The visual cryptography used in both printed and digital displays has been developed. This article does a great job of including both offensively and defensively protection methods, along with proactive and reactive ones. However, malicious programs that have exposure to the exhibit may target electronic displays. Multiple cipher rearrangement is one of the potential attacks. If the ciphers have been rearranged, a visual ordinal cue may be used in conjunction with them to provide further participants an instant indication to prevent such untrusted electronic displays. Nevertheless, the paper is something of a theoretical analysis than an accost experiential illustration. The authors could gravitate their interpretation to any practical AR project or throw some ideas for future implementation about such security approaches. To conclude, The paper is an insightful study material for researchers, learners who intend to work with this booming technology coevally being fully protective about privacy and safeguarded.

Kopsida and Brilakis [17] construe the idea of further adaptation of Microsoft’s Hololens, alluding to some critical drawbacks of the current product in the market. Some of the downsides are heavyweight hardware, shorter life span battery, low speed of HPU(Holographic Processing Unit) making image rendering very slow, and so forth. The authors [17] have provided an excellent proposal for improving image rendering being slow in execution along with how to dwindle the blurriness of holographic 3D images. However, the illustrations of the other mentioned limitations in the paper about the very product are minimal and insufficient to give a detailed overview to the reader. The research's major goal is to employ HOLOLENS to execute operations while increasing time intervals and managing feature extraction while retaining the truth of client liver data for the integration liver 3d model during surgery. Following that, we will go through a new technique that increases the number of light points, with the higher the 3D intensity, the brighter the pictures, and the simpler it is to interact with them. Holographic density is also used to avoid picture fading to the point where the viewer knows through clear HOLOLENS glasses. This enhances the sensitivity of the Intervals lens as well as user detection in the surroundings. Moreover, the authors have tried to incorporate medical surgery into these mixed reality-based Hololens. How liver, heart surgery being very much intricate for even practitioners to carry on, can be made amenable with holographic motion pictures in operation theater has been narrated with necessary pictorial views in the paper. So this paper can be a great motivation for future researchers, students, or tech geeks to improve and strengthen the functionality of Hololens.

The paper[18] proposes to introduce a framework for the creation of software for collaborative extended reality. We precisely explored collaborative processes in this paper about augmented reality, object distortion. Whenever four VR and AR users shared a workstation, they were able to interact with each other in real-time together in the same virtual space. Pereira, Matos, Rodrigues, *et al.* [18] suggested a tool for growth that accepts several Multidisciplinary applications. The article provides an overview of how to boost the sense of being involved in a shared VR world and develop collaboration characteristics that help users run In VR Together. Virtual reality (VR) allows users to teleport about the virtual environment to reach distant things and accommodate for the constraints of actual space. To begin, users would travel to preset locations by sussing at them. However, due to the fact that some items were virtually inaccessible, we provided the option for players to make teleportation to a preset location. Since the user just had to point in the direction they wanted to go, they had more control over their location. Because pointing with a straight line is difficult in congested areas, a curled line would have been used. Markers are used in augmented reality to determine a user's current location. Because each schism in a virtual environment does have its own marker, users must synchronize their location with a different one in order to travel to another area in the VE. A framework for developing collaborative XR applications was described in this article, which allows many distant users to tether to that very same shared environs through compatible XR devices. The framework was implemented in this paper. The researchers are in favor of using VR and AR gear in the case of the production version that was built. According to the empirical results of the literature evaluation, further study is entailed in this area. As a result, many collaborative methods for object manipulation were described in detail in the study. This study seeks to investigate VR application collaboration methods. The prototype was well-received by users, as shown by the results of the testing. Users said the interactions were simple to carry out with the exception of the tool wear. They felt more at home in a consolidation phase since other users could be seen in real-time, and they could see how they engaged with the immersive ecosphere. To overcome the challenges, they also built a shared XR application platform in which developers depending on the computer, can adopt various interfaces.

In the prominent prolegomenon [19], Zepernick (2018) dissected the basics, addressing prospects, threats, and enablers for connected immersive mobile technology. An assessment of virtual mobile content, including mobile video, 360-degree movies, virtual reality (VR), augmented reality (AR), and mixed reality (MR), as well as sub-components of associated immersing smartphone interactive media, is delivered in this research study in specifically. issues in delivering content in an immersive manner Mobile XR applications may be identified by their operation's integrity, which includes display specifications, transfer speeds, and delays similar to those found in traditional mobile apps. To illustrate the basics, Zepernick [19] have identified and discussed possibilities for linked immersive mobile multimedia, as well as barriers to overcome. Two recent technological developments, seamless smartphone XR and 5G cellular connectivity have been employed as patrons for this venture. The foundations and difficult needs of personalized mobile XR have been identified, but future 5G mobile networks, mobile computing platforms, and standardization initiatives may help to enable them. Mobile XR technologies seem to have the ability to facilitate a plethora of fresh maladaptive apps across many vertical industries. In this regard, 5G mobile networks may be indispensable for the diversification of mobile XR's market outside the video game sector. As an alternative, smartphone and cellular phone XR may be a promising platform for 5G mobile networks that fully utilize ultra-reliable low bandwidth connectivity. As a consequence, cellular network operators or telecommunication companies and the larger and more diverse ecology of wireless XR apps stand to benefit greatly. Additionally, the authors demonstrated how mobile XR applications could be used in a variety of fields including education, emergency response and entertainment, healthcare, industry and manufacturing, marketing, and retail. By focusing on major standardization activities pertaining to the more popular immersive smartphone entertainment apps, the authors were able to cut down industry fragmentation and development costs.

Ping, Liu, and Weng (2019) [20] experiment to compare the efficiency of users' perception of depth in the VR and AR seamless reality the head-mounted optical see-through display head-mounted display. The authors noted some significant issues: a vindication that virtual items are in the proper and apposite locations and that the scenario is precise and reliable. Also, users should be able to see virtual items in context with real and virtual ones in a scenario. As previously mentioned, correctly detecting the location of virtual objects is still a significant issue, and this article creates a simulated shuffleboard experiment to evaluate participants' perception of depth in Virtual and Augmented reality. This paper can be recognized as a quintessential analysis since few papers on virtual reality illustrate experiments. The authors not only experiment but also added visual aid for readers to decipher it lucidly. In the demonstration, two display types are on exhibit: virtual reality (VR) and augmented reality (AR). There seems to be a substantial dissimilarity between Virtual and Augmented reality in the matching inaccuracy in augmented reality display settings, F (1,42) =0.929; P=0.0280 which is obviously less than half. As a consequence, the inaccuracy in VR is greater than in AR in terms of matching. To put it another way, accuracy in AR displays is much better than in VR. As the distance proliferates, the frequency of depth matching assignments diminishes, except for the furthest one. It’s possible that this is because the furthest target is located at the very end of the game board. From that point of view, this paper evinces something new. As a consequence, they discovered that AR display settings had better depth estimate accuracy than VR display conditions.

In the journal named “Photorealistic rendering for augmented reality: A global illumination and brdf solution,” for the photorealistic depiction of synthetic objects in sophisticated virtualization in augmented reality applications, numerous realistic rendering methodologies are integrated into a single pipeline. Shaders were responsible for most of the difficult GPU calculations, allowing the CPU to focus on software development. This achievement would not have been possible without their assistance. In addition, the objective is to produce a rendered item that blends smoothly with the real-world surroundings in the final product. Image-based lighting is utilized in this article to accomplish this goal by creating atmosphere maps with varying degrees of glossiness for each virtual item in the scene during rendering. As a result, virtual objects can accurately mimic light effects like color leaking and chromatic aberration. Modern GPU processing power and its modern programming functionality have enabled methods that were previously only suited for non-real-time applications now possible at interactive rates. IBL is an example of a technique that uses HDR environment maps to simulate the look of a global illumination effect. The irradiance atmosphere map was efficiently represented by Ramamoorthi and Hanrahan. Any unifying sampling technique for the hyperbolic oscillations modification pass is also employed, as shown in the publication. Because it isn’t reliant on the map format, it can handle a variety of sample sizes without having to change the weights. As a result of the new developments in methodology, a more advanced version of Lafortune Spatial BRDF is used, which includes revolutionary changes to tangent rotation and the Fresnel effect.. Static maps should be used for GH environments. However, in Augmented reality applications, physical and virtual things may move independently; as a result, the look of virtual items may vary as the accompanying camera moves. They may be seen as effects such as light bleeding or dynamic specular reflections because of these modifications. A fresh environment map is collected from the central point of each virtual item in order to provide support for such goods. By concealing its proprietor as well as rendering the encompassing landscape from its center, this environment map may be obtained. Other virtual items, phantasm artifacts, and indeed the skybox with both the physical real-world map make up the backdrop. When we talk about phantom things, we’re talking about pre-modeled representations of actual things. It’s used to record things like shadows, interreflections, and occlusions—interactions between actual and virtual objects. The authors’ intention to prove every hypothesis using mathematical calculations and appropriate algebraic expressions is a huge plus in this article. The authors claim that the most difficult aspect was the requirement for global lighting. Using light-absorbing materials, objects in the scene may be made to seem like they are part of their real-world surroundings. They developed an augmented reality (AR) photorealistic system that renders dynamic sceneries and high-end materials consistently. In this way, the authors concluded that the settings’ pleasing visual features and attained frame rates made them ideal for augmented reality applications like augmented reality games.

To pervade and illuminate the ambit of the tech project, Sharma, Mehra, Kaulgud, *et al.* [22] prescribes using advances of AR to anchor observations around and on genuine and cognizant office items. The approach focuses on extracting useful data from software systems and manufacturing infrastructures' data exhaust that is distributed data sources and logs in order to provide observations tailored to the XR headset user and the team. Workspace components (such as floors, seats, and ceilings) are located in the user's field of vision, whereas spatially microscopy and imaging is used to overlay appropriate representations of the insights around them. Extended Reality may impact different software engineering processes, according to the authors, and it offers a non-intrusive foundation for infusing ”smartness” into physical workplaces. Immersive Mixed Reality techniques may provide a wealth of information on the wearer's location, what's in their range of view, and what they're experiencing.. etc.. Annotating the field of vision may be done by using this visual context in conjunction with the wearer's identity/role and project context, as well as in-process project information. As a result of classifying insights and understanding for different roles inside a software company, the authors come up with a novel concept by looking at how they interact with the projection bay. In order to focus on certain kinds of understanding/awareness needed in various job domains, they proposed three categories of immersive insights depending on the placement of visualizations. This is an excellent piece of work for researchers since it contains a lot of useful information. According to the authors' explanation, the study's relation to the title has been thoroughly explored. As previously said, Blended Reality is typically used in visualizations. For it licenses for spatial projection, the integration of simulated items with the real scene, and more sophisticated experiences than either AR or VR can provide. There are many cognitive and behavioral benefits of being immersed in a three-dimensional world

Luck and Aylett (2000) [23] prorate a satisfactory conflation of today's trending artificial intelligence and virtual reality's thesis topic. The authors have depicted the fusing of AI in virtual reality systems exquisitely. The very positive aspect of this paper is that authors have gravitated their discussion toward hardware setup by drawing robotics concepts. Moreover, the litterateurs have expounded their analysis from a real timing scenario rather than only just from a particular viewpoint that most research papers usually do. A vindication is that the virtual environment toolkit and agents with adequate artificial intelligence illustration have been evinced in the paper. Virtual worlds and robots have at least one element in common. The requirement to adhere to real-time processing limitations is one example of this. A VE is a technology powered by a graphics cycle that runs at 50 or 60 Hertz to make change look like seamless animation instead of jerks. It becomes hard to maintain the impression of the physical world that is so crucial to the user's sense of immersion at frame speeds below 10 Hertz. Among agents, the degree to which virtual perception is modeled after real-world perception varies significantly. Perception is a tough issue in the actual world because anybody who deals with machines quickly learns. However, in a virtual environment, there are no issues with uncertainty, noise, or slow processing. Virtual sensing can be expounded so elementary as disseminating a string from of the informant's glasses comprising of metadata on everything it perceives in the simulated environment, using the datatypes that define the object to assess and evaluate its attributes. We want to enunciate that the ’agent-world coupling’ part of this paper has seemed very riveting, so we have felt to infuse this paper in our review. Humans engage with the virtual environment using a head-mounted display and a 3D mouse or dynamic globe. In the area of agents, the confluence between AI and AL and VEs is most apparent. In the last few years, the field of autonomous agents has seen a flurry of activity. The autonomy of other agents may be configured to work, but they all have a very significant level of autonomy. Autonomous action is based on the interplay between the agent’s internal drives and external stimuli when there are more physical agents. Since the agent’s motivations influence its behavioral patterns and the climate (immersive world), a feedback loop is created. Although this paper is perfect, there are loopholes for further embellishments. The authors could add up some mathematical analysis of the agents that have been derived. To conclude, we would like to bring around that we may take leverage of these caveats and further improve the paper with computational expurgation.

Chapter 4

System Architecture

The system is consists of a Handheld Controller Unit for the user's tactile, gesture, and movement input and haptic feedback to the user, a Smartphone for the user's perspective and orientation input, and audio-visual feedback and Unity Engine for processing input data and generating output feedback.

4.1 Hardware Components

4.1.1 HCU (Handheld Controller Unit)

In the Handheld Controller Unit, there are sensors to take tactile and motion inputs from the user to take action in the system. There is a haptic feedback mechanism for the user to sense kinaesthetic communication or 3D touch feedback from the system.

Sensors

There is IMU (Inertial Measurement Unit) sensor to track movement, speed, gravity, orientation, and footsteps from the user's hands for determining gestures, positions, and Omni-directional motions in the HcU.

IMU (9-DOF)

Inertial measurement unit Fig. 4.1 is the electromechanical tool used to monitor and analyzes a body's force, rotation rate, and frequently the orientation of the object using just a composite of accelerometer senosrs, gyroscope sensor,magnetometer sensors.

a. 3-axis accelerometer

By measuring the amount of acceleration due to gravity, an accelerometer can figure out the angle it is tilted at with respect to the earth. By sensing the amount of dynamic acceleration, the accelerometer can find out how fast and in what direction the device is moving Fig. 4.2

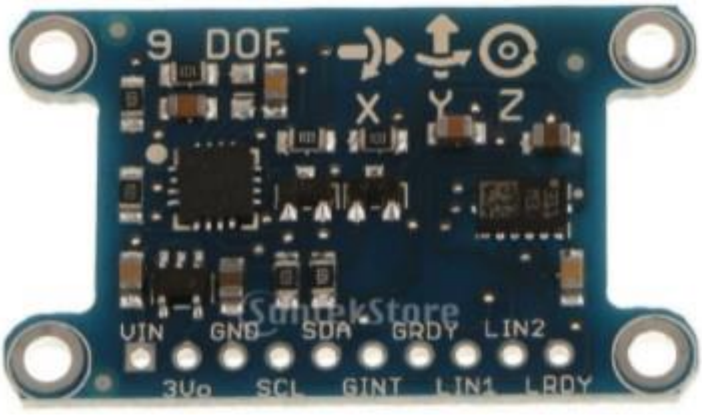

Figure 4.1: IMU sensor

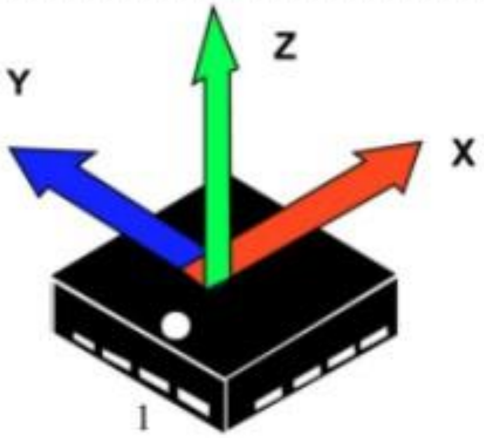

Figure 4.2: 3-Axis Accelerometer

b. 3-axis magnetometer

Magnetoscopes detect magnetic north by gauging the field strength, although they may also be used to measure magnetic fields. Magnetometers can detect magnetic north Fig. 4.3

c. 3-axis gyroscope

Gyroscopes, often known as gyros, Fig. 4.4 are electronic devices that diagnose or perdure rotational motion. These tiny, low-cost sensors, known as MEMS gyros, are used to quantify the angular velocity of a rotating rotor. There are two ways to express angular velocity namely degrees per second and revolution per second that is RPS. Angular velocity seems to be just a way of expressing how fast anything is rotating. Orientation may be ascertained with its help.

Buttons and Joystick

There are some tactile buttons for multipurpose click, press, select, etc events and a joystick for cursor positionings.

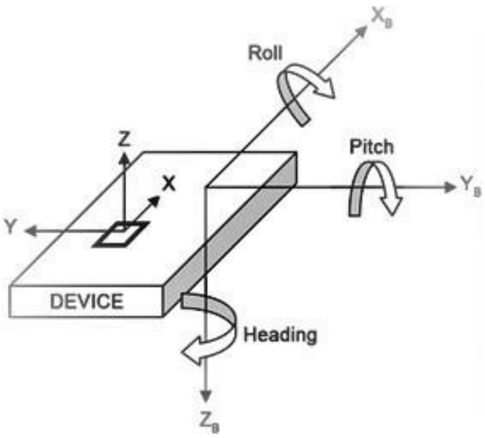

Figure 4.3: 3-Axis Magnetometer

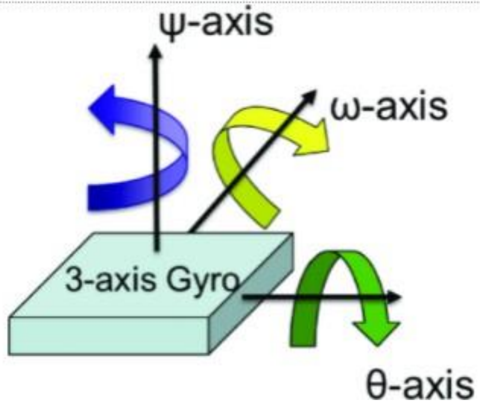

Figure 4.4: 3-Axis gyrometer

a. Tactile

There will be 4 buttons for multipurpose actions, 3 buttons to select, backward, and forward and another button for going in the main system options.

b. 2-axis movement and press

There is a joystick to move in the x-direction and y-direction. It can be used for 2-dimensional movement such as moving the cursor along with the screen Fig. 4.5.

Haptic Feedback

When one uses or comes into contact with a touch screen interface, one n may experience something that is referred to as haptic feedback or haptics for short. When the user touches the screen, physical response is elicited, most often in the context of a vibration. We endeavor to use haptic feedback to augment the nexus between technologies and subjects.

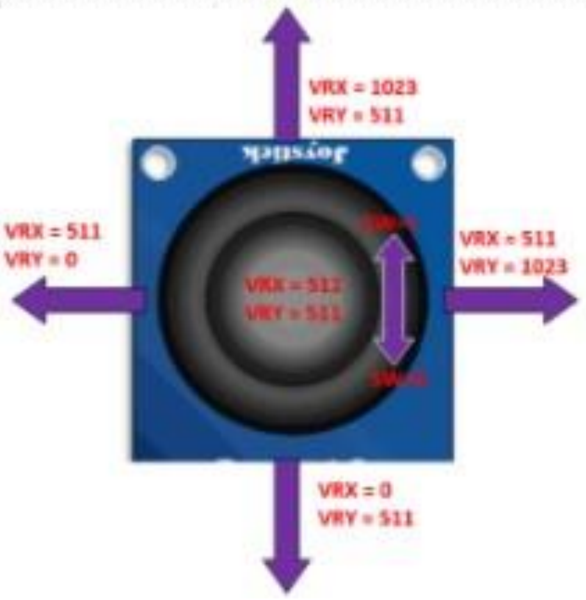

Figure 4.5: 2-axis movement and pass

4.1.2 Smartphone

IMU

Smartphone’s built-in IMU will provide a 3-axis accelerometer, a 3-axis magnetometer, and a 3-axis gyroscope data stating the phone’s movement, direction, orientation, and speed. From this data, the system gets the exact status of the user’s head and body positions and orientations.

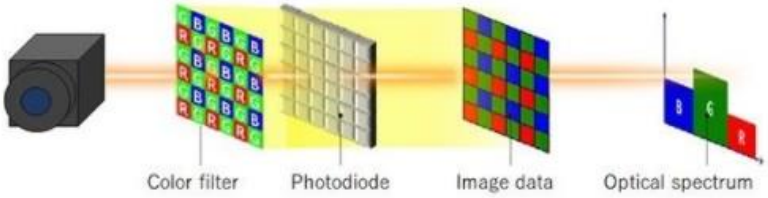

Figure 4.6: RGB camera feed

RGB Camera Feed

A camera embellished with typical CMOS sensing tools by which colorful and multifarious images contextual and typically 3 colors viz. Red, blue, green combination per unit pixel that is standard use in-camera of real-world scenarios are acquired Fig. 4.6

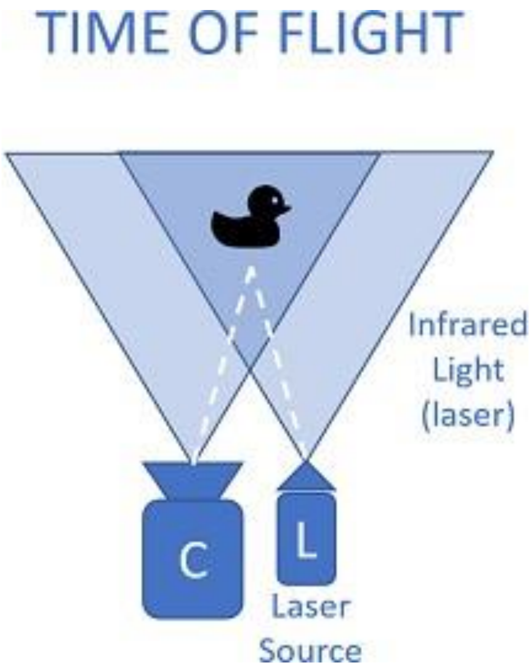

Figure 4.7: depth camera feed

Depth Camera Feed

Depth sensors are a kind of 3D range finder Fig. 4.7. For they scoop up distance data from many points across a broader field of view. Distance is typically assessed by one or more sensors with relatively limited Fields-of-View in standard distance sensing systems. For additional augmentation, we're making use of the smartphone's built-in depth camera to figure out how far things are apart in the actual world.

4.2 Proposed Framework

Fig. 4.8 portraits the fundamental of our VR apps. How a user interacts with this application through mobile and how output would appear is explicitly understandable by Fig. 4.8 figure. This framework sync with the hardware level through API illustrated in Table 4.1.

4.2.1 Input Layer

To simulate an accurately mixed reality scenario 3 types of information is needed such as real-life environmental scenario, user's ergonomics, movements, locomotion, and user's cognitive intention to control the extended reality. In Fig. 4.8 framework, the user's inputs are collected from two different devices that are called Head Device Unit (HDU) and Handheld Control Unit (HCU). From the two devices, the framework will be feed three types of data simultaneously for creating the artificial environment for the user in real-time. In the input mechanics of the framework, as shown by Fig. 4.8, there is a 9-Degree of Freedom Inertial Measurement Unit (9-DOF IMU) that is common in both the HDU and the HCU devices to increase

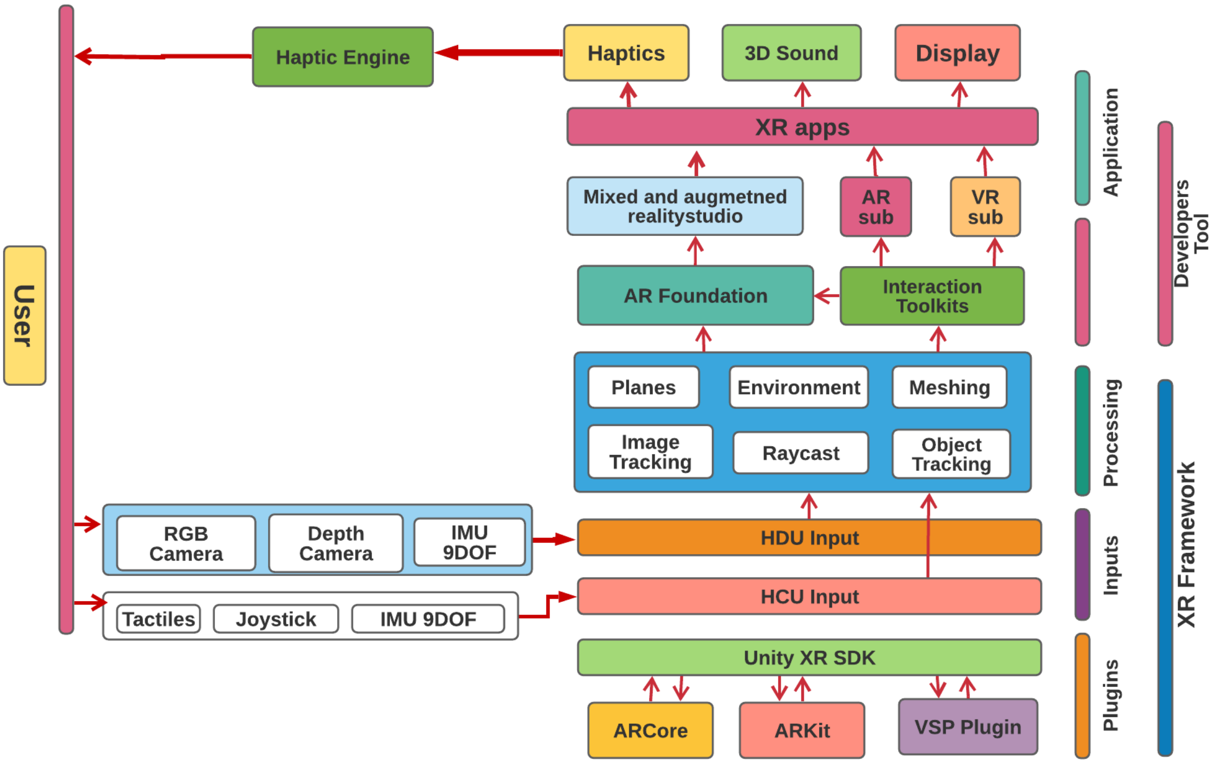

Figure 4.8: Proposed framework to support XR

the accuracy of the user's ergonometric, locomotive, and action data. From the HDU the framework collects digital RGB Camera feed from the built-in camera module(s) and a monochromatic Depth Camera feed from a built-in depth sensor module for augmentation of the real-life environmental perspectives of different objects' positions and distances among themselves. For navigation and control of the user interface of the system, the framework (Fig. 4.8) collects tactile buttons input and joystick input interruptions from the HCU device.

4.2.2 Processing layer

Augmented Reality consists of Virtual Reality, a computer-generated environment with digital graphical objects, and Real Reality with natural environments with real objects. The framework collects real environments in the input layer. In the processing layer, it creates virtual environments and objects using the unity engine's components. There are many methods for creating physical space meshes, but the most common is 'Meshing' (Fig.ref fig framework), which generates triangular meshes that match the actual space. 'Planes' evaluate horizontal and vertical planes, surfaces, edges. It also quantifies their sizes and locations. 'Environment' includes a selection of tools that can create environmental features such as landform and vegetation. 'Image Tracking' subsystem detects and further formulates color shading and enables 3D contents to blend seamlessly with the environment. 'Object Tracking' position in 3D space using the 2D area of the object and position on the reference frame for navigation guidance, et, thoroughly. Raycast controls light bounces at the colliding surfaces concerning the point of origin, direction, and length. XR interaction Toolkit makes 3D and UI interactions available from the Unity input events.

AR Foundation(Fig. 4.8) licenses to collaborate with the AR platform within Unity collecting all real, virtual, and interaction data from user input, virtual objects, and interaction toolkit. Unity Mixed and Augmented Reality Studio (Unity MARS) builds rational mixed and augmented reality experiences that fully combine with the real world. Unity MARS brings the circumstances and sensor data into the production workflow so that the framework can develop acute AR applications that are context-aware and responsive to material space, working in any location and with any variety of data. VR and AR subsystems are packages to provide the interface for various other subsystems, implementations for providers found in other packages, and plugins. XR application compiles all the subsystems, plugins, interactions and provides outputs to the user.

4.2.3 Output layer

After processing all the inputs, the XR application generates 3-Dimensional augmented visual that will be feed into the user's viewing display, 3-Dimensional audio to the user's hearing arrangements, and mono-dimensional dynamic tactile, haptic feedback as a secondary communication medium for a more realistic extended reality experience.

4.3 Data Modeling

The framework contains some native applications programming interfaces (API), illustrated in Table 4.1, to interact with Android systems. The APIs involve a standard android SurfaceView, with the Content and layers controlled entirely in native code, bypassing Android cycle updates. The input API of Table 4.1 enables API-connected apps to identify and check the status of devices attached to a Mobile VR device. The API may be used to query the current status of a device once it has been identified. The API may be used jointly by many Android activities that share the same address space. Nevertheless, only one application at a time can be in XR mode. While there is a functional Android platform, an Android application must be in XR mode.

Images production has been accomplished so that it seems like virtual objects overlaying in a natural scene. The conventional way of doing this is Euclidean Computer Graphics(CG) models. However, we are using Structure-From-Motion(SFM) method explicated via Fig. 4.9 where objects and scenes are projected through the camera matrix. This method helps to reduce the re-projection error. Texture mapping in Fig. 4.9 on a triangular mesh with numerous (homogeneous coordinate) node points has been maneuvered to depict objects and situations in the same way as computer graphics do. A geometric transformation specified by the user adequately calibrated would convert the points(data set) in a 3D spatial coordinate. The 3D structure of a particular data set using the SFM technique showed in Fig. 4.9 is

Table 4.1: Used Apis

API Names	Description	Values
Android.connected	An API to check whether the device is connected or not	Boolean
Android.displayId	Returns the displayId of an associated VRDisplay	String
Android.index	An API that is auto-incremented to be unique for each device currently connected to the system	Integer
Android.mapping	Indicating whether the browser has remapped the controls on the device to a known layout	String
Android.axes	An array of floating-point numbers illustrates the current status of each axis	Integer
Android.getFrame	Represents all information needed to render a frame of a VR scene	String
Android.timeStamp	Represents the last time the data for this device was updated	Integer
Android.Buttons	The pressed value of buttons are represented by an array of JoystickButton objects	Integer
Navigator.VRDisplay	It is used to get a reference to your VR display	Integer

then redeemed. Instead of utilizing a single texture picture for each view, a constantly time-changing texture is adjusted in the rendering stage, visually playing a little ”movie” on each concept triangle. The movie accommodates for differences in detail and alignment issues with the real object.

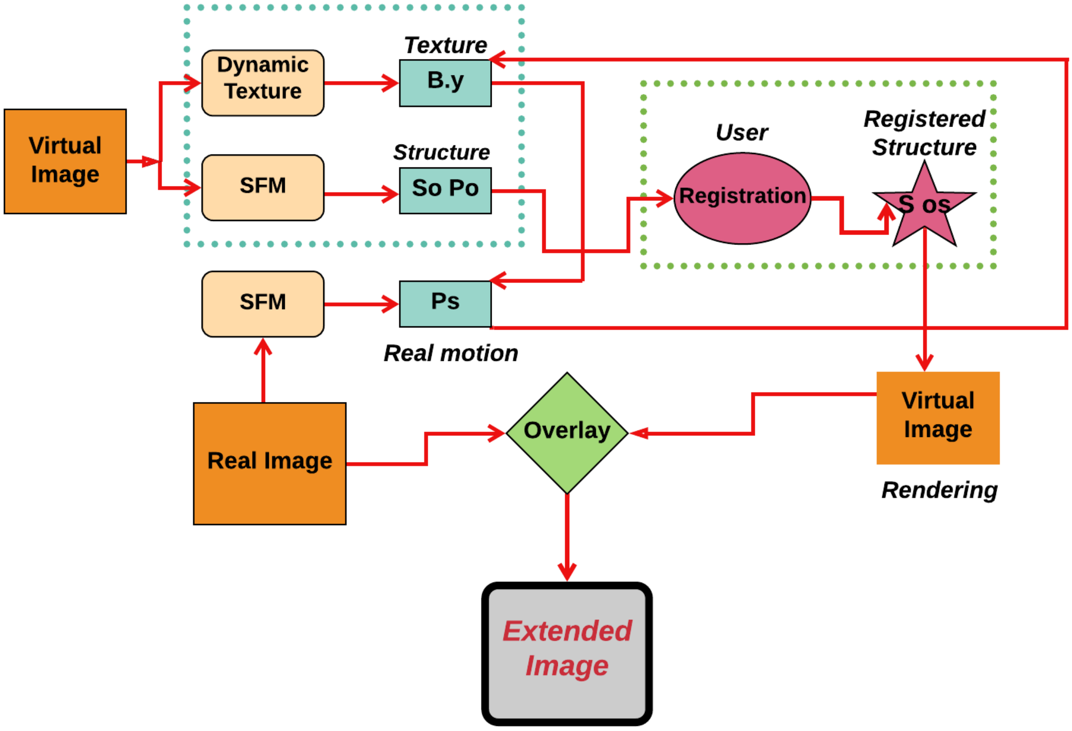

Figure 4.9: Transformation mechanism into VR

4.4 Privacy and security

Amongst all significant concerns in information technology, security is an essential one. A primary concern of our research was keeping the system safe and invulnerable. User security and to forfend any sort of infringement in the app data and users’ data has been one of our exigencies throughout the work. Firstly, the VR eye-wear may scrape any sensitive data from photo galleries, emails, contact, any text message from Facebook, WhatsApp of users’ mobile (XR client app) Fig. 4.10. One’s retinal scan (eye-scanning) info can be made barged into iniquitous issues like fake national identity, passport if data is not stored with outclass security in the database. Every so often, applications might in visceral ingress to the output of others applications. One application’s output data may presumably be an input of another application. Now, if any nuisance can tailor or interpolate these outputs, then all those applications being able to be made accession via that single input will be vulnerable and unreliable [16]. Having input, thenceforward the accumulated data must be reinforced in the Global ServiceDB Fig. 4.10. An immersive environment necessitates a real-time video feed (streaming) in virtual reality where many users can participate. MR video-conferencing [16] is such an environment where the security concern also becomes holistic and collaborative for all participants rather than one individual's privacy, for example, meeting id in Fig. 4.10. There comes in the role a privacy-aware video analytic mechanism called 'OpenFace-RTFace'[16].

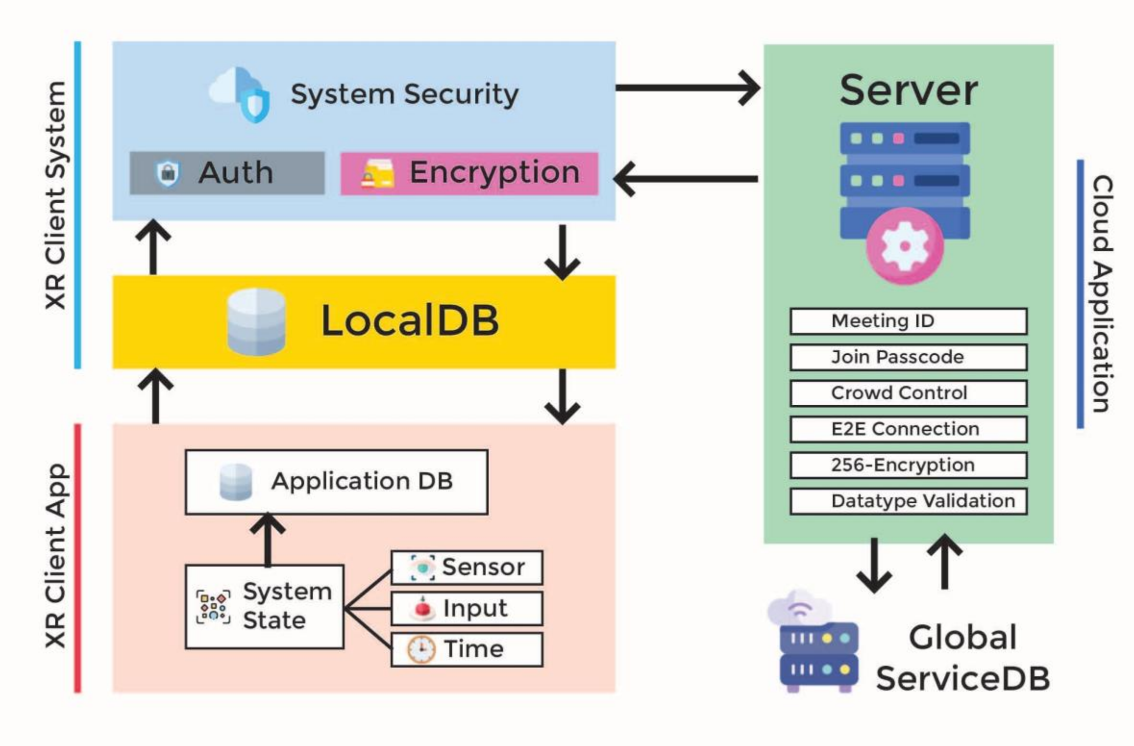

Figure 4.10: Security and privacy model

Secondly, the physical VR hardware system (device and set-up) must have a bolstered non-infringement by admin access control and authorization along with encryption as showed in Fig. 4.10. Furthermore, the network of the devices (wireless or cable) connectivity should be in stewardship 24/7, the whole configuration being supervised under the network administrator(System security) Fig. 4.10. This hardware or device level security implicitly subsumes the user's technology which is inside XR client system Fig. 4.10.

The security and privacy thus have embellished this architecture and bestowing on it an iconic aura while making the project impervious to malicious and iniquitous activities simultaneously. The end-to-end encryption has also made the Augmented Reality (AR) feature innovative.

Chapter 5

Hardware Integration

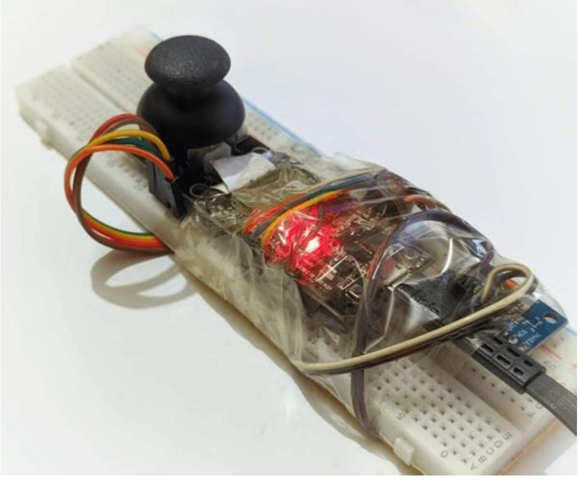

Figure 5.1: Handheld Controller Unit

The hardware has been coalesced and amassed minutely in pursuit of the blue-ribbon accomplishment of our destination and to educe the maximum success. This phase was the chronic one in the overall sprint of our design and implementation.

Table 5.1: Minimum Hardware Requirement

Hardwares	Minimal value
Processor (CPU)	arm64-v8a equivalent or newer
Graphics Processor (GPU	Supports OpenGL ES 3.0
Operating System	Android 7 or newer
Memory	3 GB RAM
Display	HD or higher
Peripherals	At least 1 RGB Primary Camera with at least 1 Depth sensor camera, Bluetooth 4.2 or higher, 6-DOF IMU

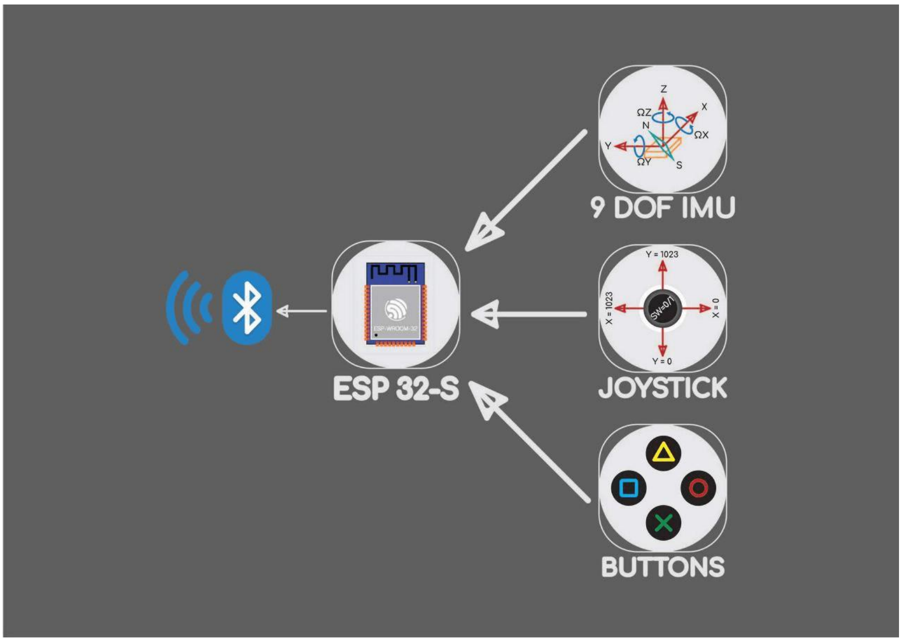

Figure 5.2: Bluetooth ESP-32 SoC

The very first hardware component that comes into the picture beyond that the user interactivity becomes inconceivable is the Handheld VR controller or, simply controller unit Fig. 5.1 The joystick in the user's hands and 9DOF IMU sensors align with adjuvant buttons respires real-time inputs from the user. This handheld controller unit is embraced with the output entity android mobile phone via BlueTooth serial communication protocol.

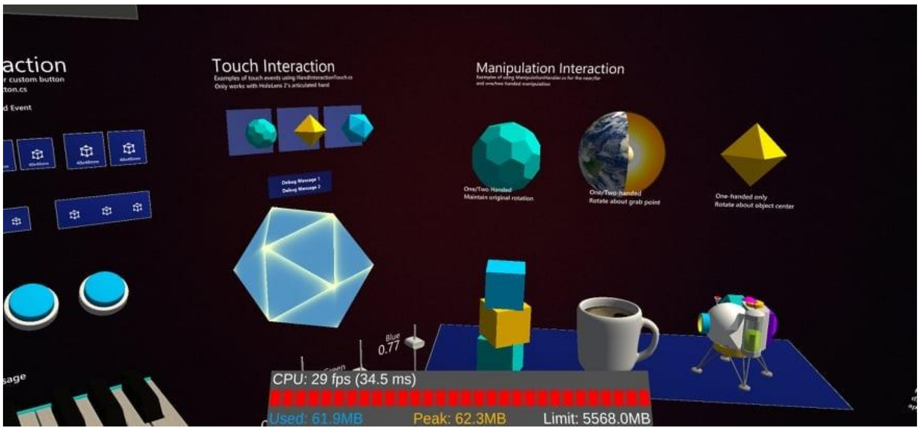

Figure 5.3: Mobile rendered Augmentation

The controller will get a power supply from the rechargeable battery in-built. So no external power supply is required. Hand tracking accedes to users to submerge into the AR phantasmagoric with the VR goggles, the environment texture being an immersive one. IMU sensors and auxiliary sensors enmesh data on the positions, orientation, and velocity of the user's hands in spatial coordinates, whereas this end-user emprise of virtual reality hand tracking seems straightforward. It is the culmination of layers of sophisticated tools. A real-time virtual embodiment of the inputs is rebound to the user by VR goggles. The inputs being mobilized in the

Figure 5.4: Mobile rendered Augmentation

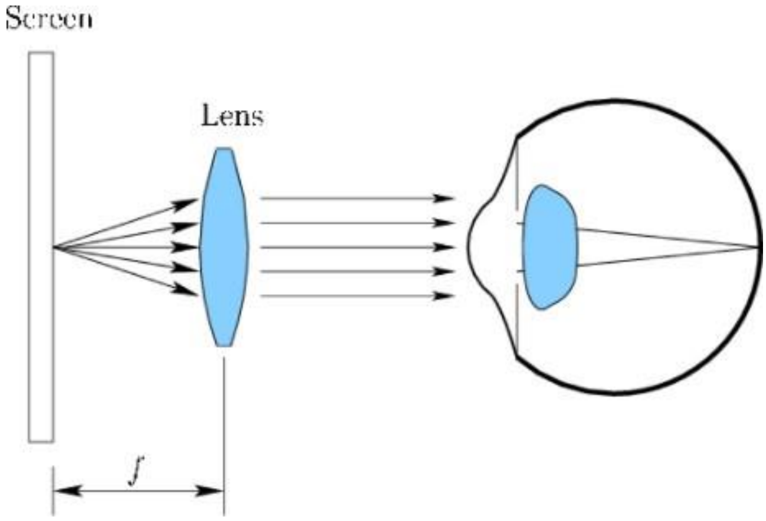

Figure 5.5: Vision mechanism in augmentation

controller by the user are also accosted by ESP32 Fig. 5.2 (a system on chip (SoC) with an integrated Wi-Fi and Bluetooth chip) before reaching mobile. The built-in Bluetooth chip in the SoC acts as an output terminal in this very precinct, then transmits and consigns the data to mobile. The mobile device feeds the controller's input data to the application to create interactions, immersions and manipulate the scene accordingly.

The synthesized Unity semblance framework modulates this data from the user for modeling into MR objects. The discourse on data modeling has been meticulously explained in the Data Modeling section in 4.3. The android phone's built-in CPU as well as GPU are utilized. Here goes a tiny pinpoint that no external hardware has been adjoined for processing. The android operating system's default design and integration with the mobile processor have been harnessed. The minimum required configuration of the phone is delineated in Table 5.1 and more in-depth processor requirements are illustrated in Chapter 6.

Android mobile's camera has been a pivotal hardware component because no exterior

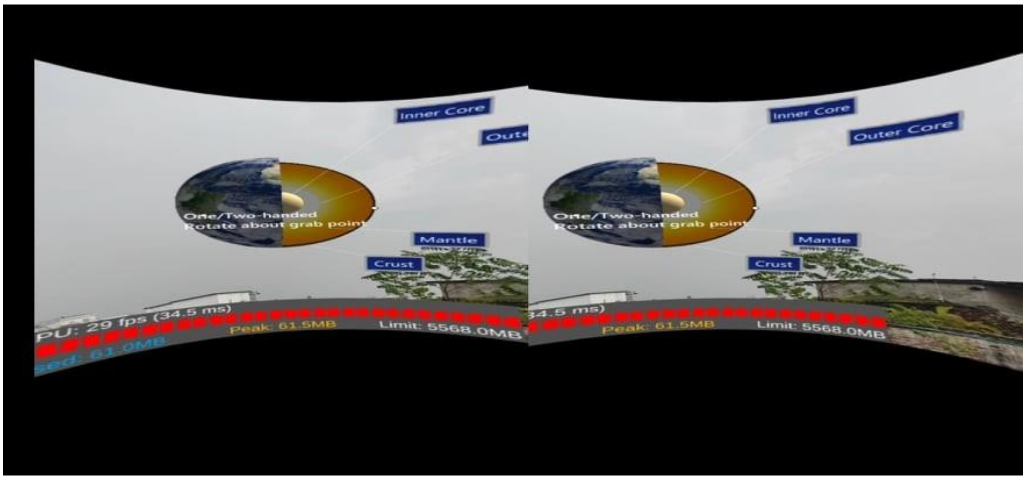

Figure 5.6: Rendered view in stereo by screen split

Figure 5.7: Mobile application interacting with hand controller

high-end dedicated videography and photography device has been touched. The camera bags the outer ambiance for the confluence with the user has given controller input. This usher in the AR phenomenon. The augmentation is personalized and embodied inside the camera display as output that will be experienced by VR glass Fig. 5.4. All the CPU activity and abstraction of this AR are exemplified in the Chapter **??**.

The camera's orientation or simply the mobile in the spatial region (open space) has no constraint and stricture. That means the mobile can be rolled in any direction as per the user's human factors and ergonomics. Our proposed framework in Chapter 4.2 can maneuver and acclimate with any spatial position in third-dimensional vector space. Mobile's native IMU sensors naturally manipulate these indiscriminate movements. So the adduced and outlined mobile configuration is a prerequisite for this. If the hardware (mobile) specification is not fulfilled, the IMU sensor will not work calculatively. Consequently, the framework will flunk to epitomize and reify augmented reality(AR) Fig. 5.3. AR cherishment in low-cost android devices comes true in this very step.

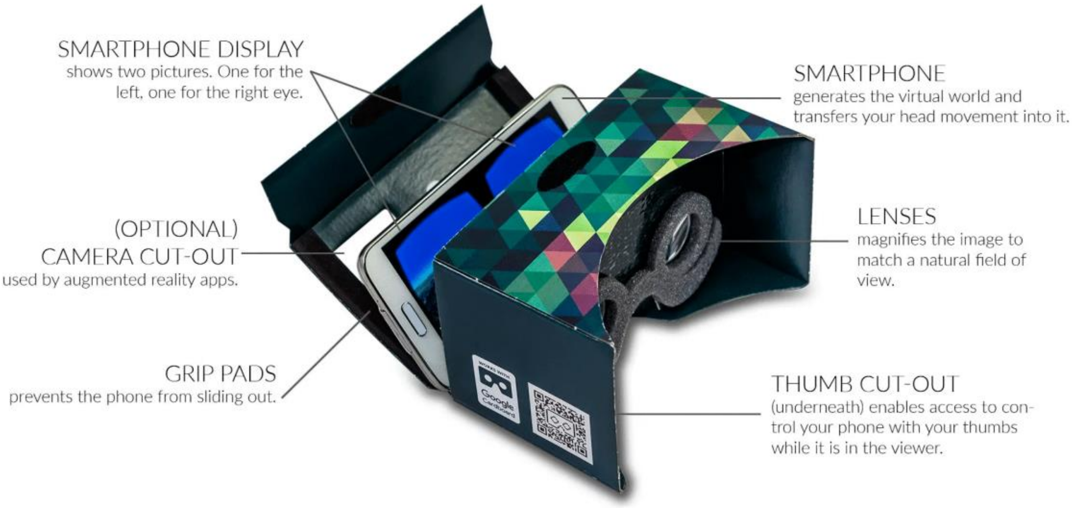

Figure 5.8: Headset with mobile joined view

Figure 5.9: Headset

Finally, the VR headset Fig. 5.9 mounted on the user’s head, will render the relish of augmented reality betiding afore the user’s own sight and vision. Fig. 5.5. This VR headset is the sole hardware that is independent of any interfacing in the complete set-up. The user will just mount it, and it will function as a goggle. Forsooth, the headset will be a peephole into the phantasmagorical immersive cosmos (augmented virtual world) for the user’s eye Fig. 5.8.
There is typically two types of VR headsets viz. Standalone VR and PC VR available in market. Several getatable and appropriable headsets, that are prevalent in today’s VR world, have been enumerated in Fig. 5.11.
In addition to, there is another type of VR headset that can be referred to as self-contained VR headset. In this project, we have harnessed this very self-contained type one headset, named as ”BRACU xReality” in Fig. 5.11.It is not like PC VR because we have not delineated any computer connectivity with headset in this project till now nor it is similar to standalone one. For in standalone headset, there is no need of any sort external mobile or computer or processing unit.But from discourse

Figure 5.10: Google cardboard : a VR headset

NAME	OCULUS QUEST	HTC VIVE PRO	HTC VIVE COSMOS	VALVE INDEX	Microsoft HOLOLENS 2	BRACU xReality
IMAGE						
TYPE	Self contained	PCVR	Wireless PCVR	PCVR		Self contained
DISPLAY	OCLED 1680 x 1400 2x	OCLED 1680 x 1400 2x	LCD 1440 x 1600 2x	LCD 1440 x 1600 2x	1440x936	1080 x 2340 +
REFRESH RATE	72 Hz	90 Hz	90 Hz	80-144 Hz	60 Hz	60-120 HZ
FIELD OF VIEW	110'	110'	110'	130'	43° horizontal 29° vertical 52° diagonal	2 x 62.5° diagonal
IPD	56 - 74 adjustable	60 - 63 adjustable	61 - 72 adjustable	58 - 70 adjustable		55-65 adjustable
WEIGHT	571g	470g	645g	500 - 600 g	556 g	554 g*
BATTERY	2 - 3 Hours	PC Powered	PC Powered	PC Powered	2-3 hours	Mobile's Battery
DEGREE OF FREEDOM	6 DOF	6 DOF	6 DOF	6 DOF	6 DOF	9 DOF
PRICE	$499	$599	$699	$999	$3,500	$35
RELEASE DATE	May 2019	January 2018	October 2018	June 2018	November 2019	N/A

Figure 5.11: Headset analytics

so far here, it is evident that ours are interfaced with android phone.

A standalone virtual reality headset is the monolithic device that includes a display, a processor, a battery, as well as many viewfinders on its body that licenses consistent spatial navigation and positioning detection with regard to coordinates of other peripheral devices. It is often used conjointly with two or one controllers system, each having six degrees of freedom. The Oculus Quest, Vive Focus, Skyworth VR S801, Google Cardboard Fig. 5.10 are excellent examples of such headsets.On the other hand, a computer is required to use PC VR glasses since that's what they're called by name. PC VR glasses have the benefit over standalone VR in that they make use of your computer's graphics capability rather than the power of the glasses themselves. This optimizes the look and feel of graphics-intensive apps by making them run more smoothly. Virtual reality games and other computer apps are becoming more popular due to developers concentrating their efforts on PC applications rather than mobile ones.HTC Vive Pro Pro Eye, Oculus Rift, Valve Index are some specimens of PC VR Fig. 5.11.

Two LCD screens (one for each eye) are used in VR headsets, or two feeds are delivered to a single screen. The second approach, which involves sending two feeds to a single display, is testing. There are additional lenses in headsets that are put between the user's eyes and the screen to focus and reshape the image for each of the user’s eyes portrayed in Fig. 5.6. By angling the two 2D pictures, they can produce a stereoscopic 3D picture. Our two eyes perceive things with very little difference, and the lenses imitate that.

Since in this project we intend to use affordable and bargain-basement costs (approx. price estimation in Fig. 5.11), we have espoused the ”BRACU xReality”. The specifications and comparative cost analysis of ”BRACU xReality” headset are depicted in Fig. 5.11. The mobile phone (as an augmentation rendering device) will be nestled inside the VR headset like showed in Fig. 5.8, Fig. 5.10. The screen is attached directly to the user’s head in some way Fig. 5.7. The screen moves with the user’s head. This implies that the controllers and headset may now provide feedback about relocation in relation to world coordinates, in addition to rotational information. There it can at full throttle settle upon six degree of freedom of user’s relocation corresponding to hand controller’s motion and motility.

Chapter 6

Performance Analysis

Having gone the whole hog in design and implementation, it is now the moment to consummate our ingeniosity running our developed XR system on various mobile devices and personify our achievements. This performance analysis part can be considered as cognate to the testing phase of software development clumsily. A positive result of testing upon various configurations of android phones will vindicate high-quality assurance on the product.

Table 6.1: Precision/Recall and Completeness of the requirement-to-method Traces Output by our approach

Android Device	Operating System	RAM	CPU	GPU	RT in ms	Memory Peak	Rendered FPS	App Start up delay in s	Display Resolution	Camera Setup
MI Note 10 Lite	Android 11	6 GB	Qualcomm SDM730 (8 nm)	Adreno 618	35	65.5	35	6	1080 x 2340	64 MP, f/1.9, 26mm (wide) 8 MP, f/2.2, (ultrawide) 2 MP, f/2.4,(macro) 5 MP, f/2.4, (depth)
Galaxy M21	Android 11	6 GB	Exynos 9611(10nm)	Mali-G72 MP3	34	63.6	29	4	1080 x 2340	48 MP, f/2.0, 26mm (wide) 8 MP, f/2.2, 12mm (ultrawide) 5 MP, f/2.2, (depth)
MI A3	Android 11	4 GB	Qualcomm SDM665 (11 nm)	Adreno 610	33	62.4	32	5	720 x 1560	48 MP, f/1.8, (wide) 8 MP, f/2.2, 13mm (ultrawide) 2 MP, f/2.4, (depth)
Mi A2	Android 10	4GB	Qualcomm SDM660(14 nm)*	Adreno 512	N/A	N/A	N/A	N/A	1080 x 2160	12 MP, f/1.8, 1/2.9 1.25µm 20 MP, f/1.8, 1/2.8 1.0µm,
Nokia 2.2	Android 11	2GB	Mediatek MT6761 Helio A22 (12 nm)	PowerVR GE8320	N/A	N/A	N/A	N/A	720 x 1520	13 MP, f/2.2,1.12µm, AF
Redmi 9a	Android 10	2 GB	MediaTek Helio G25 (12 nm)	PowerVR GE8320	N/A	N/A	N/A	N/A	720 x 1600	13 MP, f/2.2, 28mm (wide), 1.0µm, PDAF
Realme C21	Android 10	3 GB	MediaTek Helio G35 (12 nm)	PowerVR GE8320	32	63	31	6	720 x 1600	13 MP, f/2.2, 26mm (wide), 2 MP, f/2.4, (macro) 2 MP, f/2.4, (depth)
Oppo A52	Android 10	4 GB	Qualcomm SM6125	Adreno 610	39	56	33	5	1080 x 2400	12 MP, f/1.7, (wide), 8 MP, f/2.2,119(ultrawide), 2 MP, f/2.4, (macro) 2 MP, f/2.4, (depth)
Nokia 3.4	Android 11	3GB	Qualcomm SM4250	Adreno 610	34	60	31	6	720 x 1560	13 MP, (wide), PDAF 5 MP, (ultrawide) 2 MP, (depth)
Realme 5i	Android 10	3GB	Qualcomm SDM665	Adreno 610	40	66	34	10	720 x 1600	12 MP, f/1.8, (wide), 8 MP, f/2.3, 13mm (ultrawide) 2 MP, f/2.4, (macro) 2 MP, f/2.4, (depth)

We have put our system through its paces on various mobile phone handsets from a variety of well-known manufacturers. We did our best to maintain diversity as far as CPU, GPU, RAM, and display resolutions go. We used ten different devices to conduct our research. Because six devices could operate our system without a hitch, three devices could do so while experiencing several problems, such as not processing the camera feed in the system. However, the system runs without the camera feed. Moreover, just three users' devices failed to do so because they satisfy the system's minimal criteria, we anticipate positive results. A 64-bit chipset, at least 3 GB of

RAM, and a depth sensor camera with the primary RGB Camera are required for the system to function, as previously mentioned. Devices without these specifications will be unable to run the system. Note that these specifications are almost outdated, and even entry-level budget phones can meet these needs. Table 6.1 beacons the threshold points for a set of the required hardware. If any one of the hardware fails to fulfill the requirement of Table 6.1, then that hardware system will not support this VR application. We have performed testing on an ascending pattern embarking upon from a very low-end android phone up to our project constraint. Nokia 2.2, having Android 11, Ram 2GB with Mediatek MT6761 Helio A22 (12 nm) depicted in Table 6.1 was not able to run the application. The app was initiated on Nokia 2.2, but the camera did not open. So it was a failure case. Similar consequences have come in the case of Redmi 9a with its Android 10, 2 GB Ram, MediaTek Helio G25 (12 nm) CPU, and PowerVR GE8320 GPU portrayed in Fig. 6.1. All these same configured devices like Redmi and Nokia have rendered the same failure output.

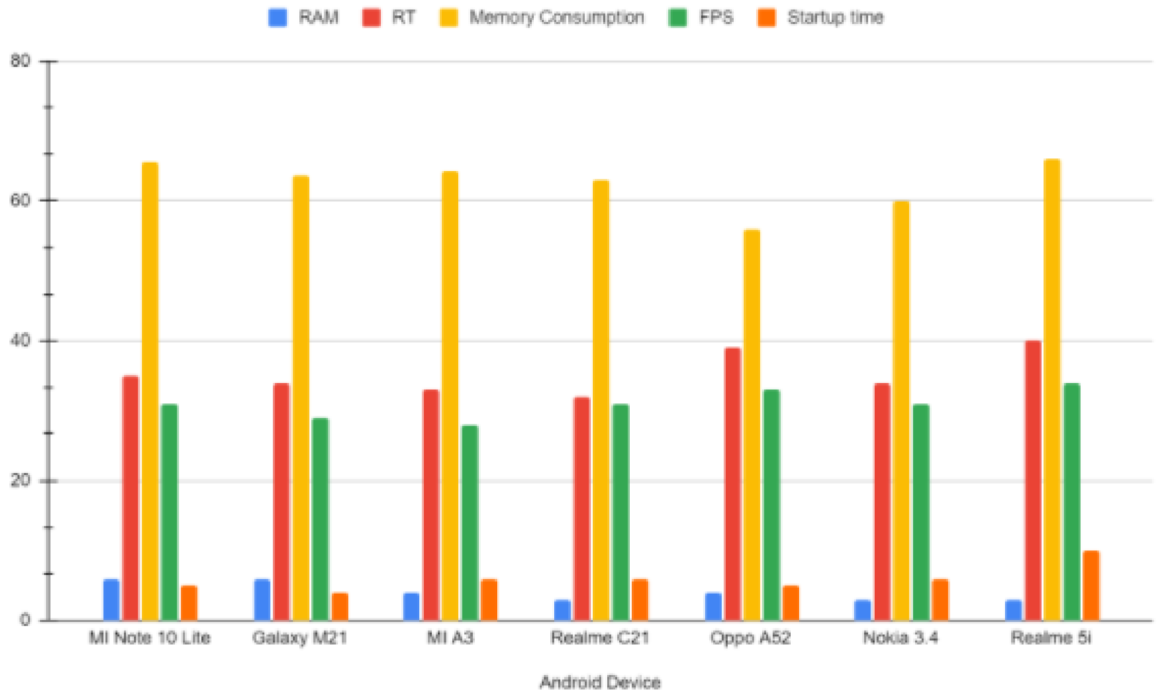

Figure 6.1: Test output (Augmentation) comparison on Android devices

So it is needless to induce that any further low-end or downgrade than those will not pass the test run. Furthermore, even with just 3 GB of RAM, the Realme 5i and Nokia 3.4 could run the program. These two devices’ CPUs, graphics cards, and camera configuration all satisfy the minimal requirements. That way, the system would operate smoothly. Inside Table 6.1), we can see that Mi A3 and Mi A2 both possess 4GB Ram, but Mi A2 fails the test due to GPU downgrades compared to the A3 phone. So GPU is a very significant parameter concerning passing or failing the test on a phone. Side by side, the MI A3, Samsung Galaxy M21, and MI Note 10 Lite could run the program efficiently, and no noticeable latency or lag was noticed. As a result, we recommended a hardware setup for a pleasant user experience. Thus performing immense meticulous trials and tests on a variety of devices, we have deduced the Table 5.1. Now, if any user having any device needs to use this app, then the parameters in the table must match its magnitude with the user’s phone hardware configuration. So able 5.1 will work as a prerequisite hardware configuration for any user. Furthermore, we will like to highlight and enunciate that our research work is complete and consummate because we can incarnate what we intended to implement. A complete video demonstration is available here https: //m.youtube.com/watch?v=afoOPGUxzS0&feature=youtu.be

Chapter 7

Field of application and exemplifications

With the emanate of Youtube and social media, videography has become an avocation. The full display mirror(FDM) camera is a handsel of VR technology by which seamless 360°video [24] capture is possible. The Construct3D [25], an augmented reality application for mathematics and geometric pedagogy, is humongous, facilitating the 3d geometric(spatial concepts) learning paradigm for college and high school students. Online gaming platforms are nowadays streaming virtual reality live games and selling virtual one-day tickets for gaming contests so that anyone from anywhere in the world can join any sports event. Using VR headset, physicians can intuitively see patients' bodies with their internals from diversified angles for chemotherapy of cancer ailments in clinical epidemiology [26]. The immersive environment has expedited the military with battlefield simulations, long-range and shoulder-launched Surface to Air Missiles (SAM), Search and rescue (SAR), Distributed mission training (DMT) presently investigated by US air force [27].In the year 2003, North Atlantic Treaty Organization (NATO) evinced an important report titled "Virtual Reality: State of Military Research and Applications in Member Countries" [27]. IoT is now transmogrifying into Virtual Environment of Things(VEoT) [2] by connecting extended reality topology.Scientific data modeling and visualization of civil engineers for CFD(computational fluid dynamics) necessitating colossal computation power with millions of data sets can nimbly be simulated in real-time by VR [28].

Chapter 8

Future work and Conclusion

We have beavered away at the project as well as our grail, yet the resources were constraint. The current echelon of the application is consummate and we have accomplished the implementation. Therefore, we are very propitious of the impending features. On the deployment, we will highly spotlight over users' health safety and assurance. Now having successfully taken off to our grail, we would like to reiterate that our motive was to provide the extortionate features of augmented reality to maximum customers affordability with as minimal cost as possible. That's where the whole nine yards interminable maneuvering or engineering of us so far has betided. Being in the clover, we would not knock off this project nor we would retract rather we fervently cherish to evolve it further and to transmogrify it into something larger-than-life. Following these as catalyst, the newfangled forthcoming endeavors will be embodying VRITESS [2] with this app that will outclass user satisfaction to some inconceivable extent. We also intend to snag educational sponsorship by enticing students with our product by its consummation. In the very proximate step of our idea amplification for this research, we aim to implement and enhance network collaboration which will sanction it to be used by multiple users unlike current condition. Into the bargain, we plan to launch this product in the industry and current market in denouement having maximum milestones been carried through. We would like to foreground that money-spinning upon this project is not our sole yeast now. Moreover, AI integration in the app like Facebook oculus is another challenge in the offing for us. Because the computational complexity of DNN (Deep Neural Network) and implementation with extensive paper study is cumbersome, sometimes the necessary study material eventuates being scanty, as it is a state-of-the-art technology. For machine learning programming, the unity coding already being used in API interfacing, we would bring into play python . Finally, we want to ascend from this mobile(android) applications to a cross-platform application (MacOs, iOs, Linux, Windows). We have not ruminated over web application yet, but that is in the pipeline for our future research.

Bibliography

[1] A. D. Kaplan, J. Cruit, M. Endsley, S. M. Beers, B. D. Sawyer, and P. Hancock, “The effects of virtual reality, augmented reality, and mixed reality as training enhancement methods: A meta-analysis,” *Human factors*, vol. 63, no. 4, pp. 706–726, 2021.

[2] T. Andrade and D. Bastos, “Extended reality in iot scenarios: Concepts, applications and future trends,” in *2019 5th Experiment International Conference (exp. at’19)*, IEEE, 2019, pp. 107–112.

[3] J. Zheng, K. Chan, and I. Gibson, “Virtual reality,” *Ieee Potentials*, vol. 17, no. 2, pp. 20–23, 1998.

[4] S. Mandal, “Brief introduction of virtual reality & its challenges,” 2013.

[5] J. Carmigniani, B. Furht, M. Anisetti, P. Ceravolo, E. Damiani, and M. Ivkovic, “Augmented reality technologies, systems and applications,” *Multimedia tools and applications*, vol. 51, no. 1, pp. 341–377, 2011.

[6] E. Bastug, M. Bennis, M. Médard, and M. Debbah, “Toward interconnected virtual reality: Opportunities, challenges, and enablers,” *IEEE Communications Magazine*, vol. 55, no. 6, pp. 110–117, 2017.

[7] A. Poulose, O. S. Eyobu, and D. S. Han, “An indoor position-estimation algorithm using smartphone imu sensor data,” *Ieee Access*, vol. 7, pp. 11 165–11 177, 2019.

[8] A. Steed and S. Julier, “Design and implementation of an immersive virtual reality system based on a smartphone platform,” in *2013 IEEE Symposium on 3D User Interfaces (3DUI)*, IEEE, 2013, pp. 43–46.

[9] Y. Sun, Z. Chen, M. Tao, and H. Liu, “Communications, caching, and computing for mobile virtual reality: Modeling and tradeoff,” *IEEE Transactions on Communications*, vol. 67, no. 11, pp. 7573–7586, 2019.

[10] K. Boos, D. Chu, and E. Cuervo, “Flashback: Immersive virtual reality on mobile devices via rendering memoization,” in *Proceedings of the 14th Annual International Conference on Mobile Systems, Applications, and Services*, 2016, pp. 291–304.

[11] F.-Y. Chiu, “Virtual reality for learning languages based on mobile devices,” in *2017 16th International Conference on Information Technology Based Higher Education and Training (ITHET)*, IEEE, 2017, pp. 1–3.

[12] W. Hürst and M. Helder, “Mobile 3d graphics and virtual reality interaction,” in *Proceedings of the 8th international conference on advances in computer entertainment technology*, 2011, pp. 1–8.

[13] H. El-Jarn and G. Southern, “Can co-creation in extended reality technologies facilitate the design process?” *Journal of Work-Applied Management*, 2020.

[14] A. Çöltekin, I. Lochhead, M. Madden, S. Christophe, A. Devaux, C. Pettit, O. Lock, S. Shukla, L. Herman, Z. Stachoň, *et al.*, “Extended reality in spatial sciences: A review of research challenges and future directions,” *ISPRS International Journal of Geo-Information*, vol. 9, no. 7, p. 439, 2020.

[15] Å. Fast-Berglund, L. Gong, and D. Li, “Testing and validating extended reality (xr) technologies in manufacturing,” *Procedia Manufacturing*, vol. 25, pp. 31–38, 2018.

[16] J. A. De Guzman, K. Thilakarathna, and A. Seneviratne, “Security and privacy approaches in mixed reality: A literature survey,” *ACM Computing Surveys (CSUR)*, vol. 52, no. 6, pp. 1–37, 2019.

[17] M. Kopsida and I. Brilakis, “Real-time volume-to-plane comparison for mixed reality–based progress monitoring,” *Journal of Computing in Civil Engineering*, vol. 34, no. 4, p. 04 020 016, 2020.

[18] V. Pereira, T. Matos, R. Rodrigues, R. Nóbrega, and J. Jacob, “Extended reality framework for remote collaborative interactions in virtual environments,” in *2019 International Conference on Graphics and Interaction (ICGI)*, IEEE, 2019, pp. 17–24.

[19] H.-J. Zepernick, “Toward immersive mobile multimedia: From mobile video to mobile extended reality,” in *2018 Third International Conference on Informatics and Computing (ICIC)*, IEEE, 2018, pp. 1–6.

[20] J. Ping, Y. Liu, and D. Weng, “Comparison in depth perception between virtual reality and augmented reality systems,” in *2019 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*, IEEE, 2019, pp. 1124–1125.

[21] S. Pessoa, G. Moura, J. Lima, V. Teichrieb, and J. Kelner, “Photorealistic rendering for augmented reality: A global illumination and brdf solution,” in *2010 IEEE Virtual Reality Conference (VR)*, IEEE, 2010, pp. 3–10.

[22] V. S. Sharma, R. Mehra, V. Kaulgud, and S. Podder, “An extended reality approach for creating immersive software project workspaces,” in *2019 IEEE/ACM 12th International Workshop on Cooperative and Human Aspects of Software Engineering (CHASE)*, IEEE, 2019, pp. 27–30.

[23] M. Luck and R. Aylett, “Applying artificial intelligence to virtual reality: Intelligent virtual environments,” *Applied artificial intelligence*, vol. 14, no. 1, pp. 3–32, 2000.

[24] D. You, B.-S. Seo, E. Jeong, and D. H. Kim, “Internet of things (iot) for seamless virtual reality space: Challenges and perspectives,” *IEEE Access*, vol. 6, pp. 40 439–40 449, 2018. DOI: 10.1109/ACCESS.2018.2829194.

[25] M. T. Schultheis and A. A. Rizzo, “The application of virtual reality technology in rehabilitation.,” *Rehabilitation psychology*, vol. 46, no. 3, p. 296, 2001.

[26] M. Javaid and A. Haleem, “Virtual reality applications toward medical field,” *Clinical Epidemiology and Global Health*, vol. 8, no. 2, pp. 600–605, 2020.

[27] A. Lele, “Virtual reality and its military utility,” *Journal of Ambient Intelligence and Humanized Computing*, vol. 4, no. 1, pp. 17–26, 2013.

[28] S. Bryson, “Virtual reality in scientific visualization,” *Communications of the ACM*, vol. 39, no. 5, pp. 62–71, 1996.