Rapid Prototyping of the SmartAR Augmented Reality Control Platform for multiple use cases

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***Abstract*—The technology of augmented reality (AR) is still in its infancy, but given the significant influence of mobile devices like smartphones and tablets, it can be said to be the next big thing for the next generation. The goal of this study is to create, utilizing fast application development approaches, a low-cost platform that can be applied to a variety of Smart City and Smart Building use cases. The many AR use cases discussed in this paper are all implemented using the same methodology. The Node-Red platform, which is perfectly suited to the Internet of Things and online applications, was used to swiftly construct a number of augmented reality use cases for the platform.**

***Keywords*—Virtual and augmented reality, Evolutionary prototyping, User interfaces, Mobile Applications**

I. Introduction

As from the early 1900s, the phrase "augmented reality" has been in some form of development. In 1901 Baum [1] described in the The Master Key, the first real reference of augmented reality. The book, mentions a pair of "character marker" electronic eyeglasses that, when worn by a person, reveals a letter on their forehead indicating their character. Every person thus encountered whilst wearing them had a letter expressing his or her personality tattooed virtually on their forehead. The letter "G" will stand for the good, and the letter "E" for the evil. As can be seen, from the early 1900s, augmented reality was imagined and since has been continuously developed for a variety of uses, including but not limited to tourism. [2],education [3], military [4] and health [5].In reaction to recent changes in the internet and mobile phone industries, AR started a second wave. Augmented reality is a revolutionary form of media that incorporates aspects of social computing, pervasive computing, and physical computing. It establishes novel linkages between the real world and the digital one, giving users continuous, implicit control over the interaction and point of view. [6].

In this paper, we define augmented reality as an interactive method of displaying digital data in the physical world. In order to broaden the impression of the real world and make it more appealing and engaging, it superimposes virtual information such as sounds, photos, movies, and messages over actual items. In augmented reality (AR), the user is situated midway between the real world and the virtual one, allowing him to experience a new kind of semi-digital world.

The field of virtual reality, on the other hand, has made enormous advancements. The use of computer technology to recreate a virtual environment in which the user is ignorant of the real world around them is what is known as virtual reality (VR). Users can engage with trackers in a realistic virtual world. Computerized systems that create convincing sights, sounds, and other sensations to represent an immersive environment and to simulate a user's physical presence in that environment are known as virtual reality (VR) systems. [7].

A recently created technology is mixed reality, sometimes referred to as MR. It can be described as the melding of the actual world with the virtual world that occurs in the middle of the mixed reality spectrum. [8]. Virtually augmented reality (virtual 3D items in an immersive environment) and augmented reality are both components of mixed reality (captured features of reality in immersive virtual 3D environments). This paper will be outlined as follows. The next section covers the background, Section 3 discusses the Methodology, Section 4 will describe the results obtained and Section 5 will conclude the paper.

II. Background

This section will elaborate on the current state of the art.

A. Smart Cities

In [9] the authors concentrated on three of the six primary components of smart cities that had the greatest potential for adopting virtual assistants: mobility, economy, governance, environment, living, and people (mobility,environment, and living). [10] showed the potential of augmented reality methods in the context of smart cities. To assess several aspects of the Augmented Reality technology in the context of a Smart Campus, including performance, usability, efficacy, and satisfaction, a multi-platform mobile app with Augmented Reality capabilities coupled to GIS services was developed. In [11] the author created a prototype called HoloSensor with the intention of using Augmented Reality technology to improve the visual analytics and visualisation data collected from different sensors, allowing users to anchor information throughout various regions inside a building. The project's final product is an application that links networked sensors (Arduino boards with temperature, humidity, and light sensors) and transmits data using a Python server. Users were able to engage with this data presented as holograms in real-time using the Microsoft HoloLens. Furthermore [12] described the use of augmented reality with the Internet of Things (IoT) to give service users and providers contextual information, and they provided a demonstration of an augmented reality application they had developed as well as three predictions for how users might interact with upcoming context-aware apps.

In [13], an Augmented Reality-based Smart Building and Town Disaster Management System was suggested in order to gather information and save citizens in the event of fire disasters in structures. The solution provided visualization information and an optimal guide for a successful initial response by integrating the physical virtual domain in the building with smart elements AR-based disaster management services.

1) Smart AR Campus: In [14],the authors suggested a method that utilized augmented reality to integrate indoor and outside navigation into a single system. The system calculated the direction of the target point of interest on the journey and represented this direction in augmented reality. It did this using highly specialized points of interest. The user's current position was taken into account when updating this direction. The theory was that a visual representation in the real environment using augmented reality directions might offer a solution for precise indoor and outdoor navigation. Correspondingly in [15],an augmented reality program's conception and implementation were described. On the smartphone, it displayed a user's surroundings in real time while utilizing the built-in camera and GPS. The proposed system provides the user with basic information on a building they are looking for or one in their immediate area by fusing location-based technology, virtual trace technology, and other components.

2) Smart AR Car: In [16], the authors underlined that in order for users to interact with the pervasive computing environment naturally, the necessary AR equipment must be seamlessly merged into their surroundings and gave an approach to essentially make it easier to interpret digital information. This essential premise is taken into account in the study, which posits the car as an AR apparatus and presents a fresh visualization paradigm for navigation systems. This is done with the intention of increasing user engagement.

3) Smart AR Air Quality: [17] provided a novel method for managing air pollution in cloud storage that utilised augmented reality. IoT-based sensors are used to remotely load data into a cloud storage system for real-time monitoring of air pollution. Authorized public and private organizations used this system. Citing the work of [18], in order to intuitively visualize the internal thermal climate for building rehabilitation projects, a new AR-based methodology was developed. The suggested system's simple-to-understand CFD results visualization enhances real scenes to give customers interactive information about the thermal consequences of their restoration design options. Based on a similar rapid prototyping methodology an example of this can be further seen in [19].

B. Smart Building

In [20], the authors developed the idea of self-aware smart buildings, wherein structures may consciously produce physical representations of themselves (e.g., incorporating building structures and materials, and thermal flow dynamics). The report presented a novel approach based on augmented reality. Augmented reality's extensive user-environment interactions may adequately record the physical structures and possibly even the materials of buildings in addition to providing straightforward user interfaces for building systems, enabling real-time building simulation and control. The article demonstrated an augmented reality building system prototype and addressed applications for it. [21] designed and implemented a novel building information screated and implemented a distinctive building information system that gives users a 3D map that reveals their location and all target buildings nearby in real-time, allowing users to easily comprehend their location. In response to the user's location and the locations of the target buildings, this system actively displays the location and size of information objects. [22] introduced MARVEL, a mobile augmented reality (MAR) system that offers a notation display service on common mobile devices with negligible latency (100 ms) and minimal battery consumption. MARVEL proposed a system architecture that used local inertial tracking, local optical flow, and visual tracking in the cloud synergistically. This was in contrast to traditional MAR systems, which identify objects using image-based algorithms executed in the cloud. Instead, MARVEL largely used a mobile device's local inertial sensors for object recognition and tracking while computing local optical flow and offloading photos only when necessary. Furthermore [23] revealed how they enhanced current tools that aim to influence students' behavior toward energy conservation in schools using augmented reality. The GAIA project, which aimed to enhance current technologies that target behavioral changes, was the reason for doing this. They combined real-time IoT data from a sensing infrastructure inside a fleet of school buildings with AR software running on tablets and smartphones as an addition to a series of instructional lab exercises meant to improve energy awareness in a STEM setting.

1) Smart AR Energy Monitoring: Nicholas and Chui [24] provides an innovative, augmented reality (AR) and Internet of Things (IoT)-based conceptual design for energy monitoring that intends to give customers the choice of not only seeing the workcell's total energy consumption, but also seeing the energy consumption of individual pieces of equipment in the field. Moreover in [25] the authors demonstrated a proof-of-concept for a user-friendly power consumption awareness monitoring system based on the Internet of Things and Augmented Reality, which makes use of widely available devices like smartphones in conjunction with appropriate measurement nodes and a suitable app. This system enables consumers to view in an augmented reality environment the electrical consumption of their domestic electrical loads and consciously choose whether to turn them off.

2) Smart AR Desk: [26] provided a tool for the user-friendly visualization of anomalous network events using colors, sound, and information scrolling. [27] employed Augmented Reality to superimpose visual partitions, often known as virtual partitions. They carried out two user trials with a total of 48 individuals to assess the effect of virtual partitioning on the occupants' cognitive function. Interviews they had with 11 experienced space designers helped them construct the evaluated virtual partitions. The study of the data indicates that virtual partitions could improve the experience of shared workspaces by minimizing visual distractions and enabling users to customize the visual elements of their environment.In [28] by projecting a virtual touchscreen onto a flat surface, like a desk or the user's lap, and enabling touch operation on the surface, the authors proposed a user interface that expands a smartphone's workspace. The information was not only provided on the flat surface but also outside and above the surface and was fixed in actual space, allowing the user to effectively use the available space and quickly change the area to be displayed by moving the device. The user could move objects that were outside the surface or out of reach toward them by dragging the entire workspace with motions in the air or by swiping the surface.

3) Smart AR Fan (appliance control): In [29] the author explained how he used voice control, augmented reality, and a web server to create these electrical appliance controls for the elderly and disabled. Likewise in [30] the study included another digitized Internet of Things function, which was digital wires rather than physical cables, allowing the author to connect inputs to one or more outputs using digital cables via AR. That is, the physical function of any device may also be shared with another physical device. For example, a fan controller may be used to control the speed of a fan as well as the intensity and brightness of light by digitally connecting it to a light bulb.In [31] the authors created a prototype that allows users to manipulate electrical appliances with hand gestures, including fans, motors, and air conditioners. A virtual plane was displayed between the user and the display, and it was possible to operate up to 8 electrical items. The display's buttons that were used to choose a certain device and switch it on or off according on the user's needs were selected using gestures. People with physical restrictions, such as the elderly and physically disabled, as well as those who work in the office and industry, greatly benefited from the project.

4) Smart AR Indoor Garden : In [32], a proposal was made for an information management system for agricultural facilities based on augmented reality (AR). The system was able to add to the sensed data and show them on the user's smartphone screen to deliver visualized information to the user using a variety of sensed data supplied by Lora-based wireless networks installed at the agricultural site. The environment data gathered from multiple sensors deployed at the agricultural facility would be depicted and presented on the screen when users pointed their smartphone camera at the site. The proposed system displays the information on a smartphone screen by augmenting it with real images taken by a camera instead of requiring the user to go through a series of laborious selection processes like searching for a specific facility and then selecting sensors to obtain the environment information as is the case with traditional systems. Since the way of acquiring information is through image or video, this system contributes to convenient monitoring and efficient management for agricultural facility.

III. Methodology

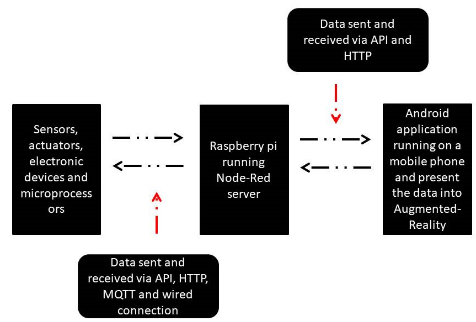

Fig. 1. System architecture

This section will elaborate on the development and implementation of the SmartAR platform composed of various sub-systems as shown in Fig. 1. Each sub-system was designed and developed independently, after which there was an integration stage. The different phases of the project are further described in the next sections of the proposal. Each case was rapidly prototyped. Essentially, the Node-Red framework running on a Raspberry Pi served as the foundation for the holistic system. As part of the Internet of Things, the flow-based development tool Node-Red was created for connecting hardware devices, APIs (application programming interfaces), and web services (IoT). Additionally, various communication protocols were employed to link up heterogeneous devices, such as an Arduino connecting to a Raspberry Pi that was operating as a gateway. In order to facilitate the development of augmented reality interfaces with UI buttons making queries to Node-Red APIs primarily through HTTP, a bespoke Android application utilizing the Unity framework was designed.

A. Raspbery Pi IoT Control

Raspberry pi was used as a communication and protocol translator allowing different communication protocol to connect to a single server.

B. Vuforia

Using the Vuforia SDK, the augmented interface was created [33] in Unity3d [34] running on an Android [35] mobile phone. Vuforia [36] displays digital information on actual objects in the real world using cutting-edge computer vision technology with calibrated performance.

C. Unity3D

Android-compatible augmented reality mobile apps were created using Unity3D. For the creation of augmented reality mobile apps, the program allows for the simple integration of different AR plugins. The unity platform uses scripts written in the C++ programming language to connect many systems with Node-Red. [19].

D. Node-Red

Node-Red [37] enables the development of scalable embedded systems for network device control.

E. Philips Hue Lightstrip

The Zigbee protocol and the light strip are the foundations of Philips Hue. [38] providing RGB color control wirelessly. This was amply illustrated in order to create smart rooms in [39].

F. Philips Bridge

The Hue Bridge, which serves as the primary control panel for the Philips Hue smart lighting system [40] allows for up to 50 lights and accessories to be controlled. It serves as the gateway for Zigbee.

G. Arduino

Arduino [41] is an open-source platform is used to create electrical projects. Here the arduino was used to interface to various sensors.

H. System architecture

The system's architecture is built on Node-Red whereby, nodes consisted of various sensors and actuators, which were connected to the server running on a Raspberry pi which can be considered to be the backbone of the whole platform Various communication protocols such as MQTT, HTTP, HTTPS over both wired and wireless (e.g. Zigbee) connections were used to link the different nodes to the server, using secondary gateways where necessary (e.g. Hue Bridge).

After capturing the data, from the different nodes ,they were extracted and manipulated on the node-red server and pushed via API calls using the HTTP protocol. The custom developed AR mobile app captured the HTTP information and then projected the digital data into the physical world which allowed the user to view and interact with the data in augmented reality. Images, videos and text were also integrated in the mobile AR interface to create a user GUI. All the data recorded were further stored into InfluxDB and used by Grafana for data presentation and historical review.

IV. Results

This section presents the various implementations of the use cases explored through rapid prototyping.

A. Application of AR in several prototypes

1) AR and energy monitoring : With the capacity to visualize energy use in augmented reality and control functionalities, the goal of this prototype was to provide a platform for smart home control and energy monitoring. As a result, the prototype enabled mobile phone control of AR gadgets.

A smart phone running Android and Vuforia with an internal image recognition database is used to illustrate the concept in Fig. 2.

The mobile phone's camera image frames were compared to the image recognition database. After performing picture identification, the mobile phone's software asks the Node-Red server for the live data.

Fig. 2. Energy monitoring

2) AR and control of electrical appliances : The prototype was further extended for individual appliance control whereby the energy consumption of a fan as shown in Fig. 3 could be obtained on the augmented reality software. The speed of the fan could be changed accordingly and the change of energy use was updated on the android software in augmented reality. The augmented reality android application provided the user with the ability to select three different speeds of the fan together with its real time energy consumption at the selected speed. In this case the fan was directly interfaced with a Raspberry Pi.

Fig. 3. Electrical appliance control

3) AR and Smart Desk: The goal of this prototype was to create a cutting-edge smart desk system with an augmented reality interface. Users of the prototype can employ an intelligent lighting system projected into AR to illustrate their availability status in real time. The hue of the light strip changes depending on the user's availability. A smart area in an augmented reality could also be created by manipulating the user's state through an interactive GUI. Users were able to schedule a meeting right from the augmented reality app thanks to the technique. Fig. 4 illustrates the prototype's overall layout. The details of this work were provided in [39].

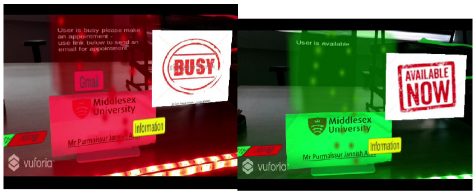

Fig. 4. Smart Desk

4) *AR and Campus Orientation:* Prior to the start of the academic year at a university or other higher institution, there is a time known as student orientation or new student orientation. During this time, a range of activities are held to orient and welcome incoming students. This prototype's orientation program makes use of augmented reality (AR). For this project, Middlesex University Mauritius served as a test site where the campus map was enhanced with data to create augmented reality. The many buildings on the campus map were enhanced to give the user a better picture of the campus buildings, such as the welcome area, the classrooms, the parking areas, and many other areas. The system disperses digital materials throughout the school, giving students access to crucial information everywhere they are. Fig. 5 shows an overview of the described prototype.

Fig. 5. Campus Orientation in AR

5) *AR and Smart Plant Nursery:* With the rise of the world population, the field of agriculture is in a crucial stage.The agricultural field is adopting new technologies such as IoT and artificial intelligence to solve the problem of food shortage in the world.

The prototype shows how a system can be used to monitor and control the environment, energy utilization, and plant growth inside a growing chamber using robotic devices. An active air monitoring system has been added in addition to the variables that can be regulated, such as carbon dioxide, air temperature, humidity, pH, and root-zone temperature. The user was able to view real-time data within the growth chamber thanks to the projection of all the collected data into augmented reality. Fig. 6 showcases the work developed.

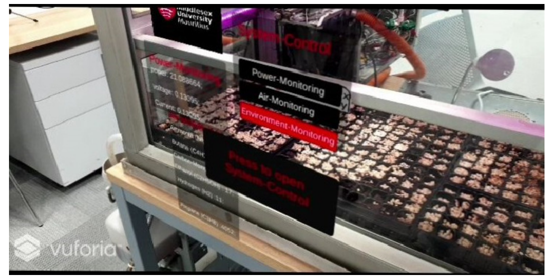

Fig. 6. AR Smart Nursery

6) *AR and Vehicle Dashboard:* While AR is still in the development phase, industries are evaluating its potential and impact. When it comes to complicated operations in the sphere of industrial applications, such as construction or maintenance in the automobile industry, augmented reality (AR) solutions are positioned to have enormous potential for businesses. Major corporations like BMW, Mercedes, Volkswagen, and Volvo have already started to implement AR. A specific targeted object is displayed in 3-D context-specific data in a real world via human-centered technology. The quality of training, task efficiency, and maintenance goals are all predicted to improve with immersive experiences. Our prototype uses AR to display sensors data from a car into AR on its dashboard Fig. 7 shows sensors data being projected in AR.

Fig. 7. AR Dashboard

V. Conclusion

The use of AR is not new. It has been used for many years in the military and for entertainment purposes. However, the recent proliferation of smartphones and tablets has led to a significant increase in the number of AR applications being developed. New sensors, protocols, and technologies are developing as a result of the dynamic expansion of automation, the Internet of Things, computer vision, and artificial intelligence.

In the future, it is hoped that we can create a new type of augmented reality system that will be able to provide the user with a more realistic and natural experience.

However,the main goal of the research was to explore and demonstrate the capabilities of these new technologies and new methods of creating them with rapid prototyping in mind. By using new tools and new methods, it will be possible to create multiple rapid prototypes that can be used for future projects and will allow the creation of new platforms for the development of new AR technologies and applications with superior user experiences.

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