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RESEARCH ARTICLE

3D Holography Advertisement On Vehicle Using IoT

Fahad Farooq[1], Rana Javed Masood[2], Muhammad Aamir Khan[1], Amber Israr[1] and Faizan Zahid[3,*]

[1] Electronic Engineering Department, Sir Syed University of Engineering and Technology (SSUET), Karachi, Pakistan
[2] Electronic Engineering Department, Usman Institute of Technology, Karachi, Pakistan
[3] Department of Electrical, Electronics and Computer Engineering, University of Catania, 95125 Catania, Italy

Abstract

3D holographic displays on vehicles are a new out-of-home (OOH) advertisement technology offering an interactive and dynamic means of engaging consumers. They enhance advertisement visibility and viewer interaction through the projection of colorful, three-dimensional images in public areas. An Internet of Things (IoT) based holographic advertisement system is presented, integrating remote content management and personalized advertising control. The system includes an Android application that allows users to select and schedule ads displayed on moving vehicles. A GPS module provides real-time vehicle tracking, supporting security and targeted advertisements. Cloud-based storage ensures remote access and data management, allowing content updates from any location. By combining holography, IoT, and cloud computing, this approach modernizes traditional advertisement methods with a scalable, high-technology alternative suitable for contemporary digital marketing.

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***Corresponding author:**
Faizan Zahid
faizanzahid54@hotmail.com

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1 Introduction

Modern 3D visualization methods are widely used in many different sectors, such as education, healthcare, and entertainment [1]. There are several limitations with 3D visualization, many of which can be overcome with holographic technology [2]. Holographic technology has proven to be a valuable tool for out-of-home (OOH) advertising because of its better audience engagement. A hologram is a three-dimensional virtual entity that appears lifelike but is intangible and immaterial, preventing physical interaction. A hologram usually sits on a surface or seems to "float" in the air [2]. The majority of people do not often have the chance to interact with holographic technology in their daily lives, giving this technology an alluring quality that makes it a perfect marketing tool. Educational institutions can make use of holographic displays; on the other hand, people who are not well-versed in the potential of holographic technology might find the application and usage of such displays difficult in these kinds of situations [3].

In educational settings, visualization is essential. Installing 3D holograms, for example, can help students feel comfortable and get the most out of their time in the classroom. The aim of educational theater is to enable efficient learning at

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educational institutions. When building educational theaters that will use 3D holographic visualization technology, it is crucial to consider the age of the students in order to effectively increase their level of participation [4]. This article examines the use of holographic technology in the advertising sector with the goal of creatively and more successfully marketing a variety of businesses. The world is evolving quickly, and advances in artificial intelligence present many unexplored technical prospects [5]. However, a significant financial commitment is necessary for the equipment and research required. This study looks at digital holograms, augmented reality, and virtual reality as cutting edge technical developments. Furthermore, the sophistication of 3D holographic technology is still lacking. As a result, scientists and academic organizations are looking forward to more developments in the technology, especially when it comes to incorporating artificial intelligence into its working framework [6].

The paper suggests a pyramid structure for holographic displays [7]. This arrangement works especially well for entertainment and advertising. Mounting the acrylic pyramid on a car's roof is simple because of its light weight. Hologram displays can be produced using a variety of techniques, such as Layer-Based Methods [8], mirror lenses [9], and Spatial Light Modulators (SLMs) for single-phase [10] and double-phase [11] holography. This paper also discusses how holography is used in medical domains including laser technology and sonography.

The study mentioned in [12] claims that real-time item presentation using 3D holograms is made possible by holographic technology and artificial intelligence [13]. Applications for real-time gaming can also make use of it. Unity3D is used to accomplish this, dividing the screen into four halves to give the best possible holographic picture. Still, a lot more effort needs to be done to combine artificial intelligence and holographic technologies [14].

Although holographic advertising holds promise, certain technical and practical challenges persist. For instance, bright outdoor lighting conditions can diminish hologram clarity, specialized hardware can be costly to scale, and precise alignment of the acrylic pyramid is required for optimal 3D projection. Additionally, managing IoT connectivity on moving platforms demands robust networking and security measures.

The major contribution of this paper is the development of a holographic display module for advertisement projection, driven by an Android app and connected with the Internet of Things (IoT). The study is divided into three key components:

- Holographic Technology: Enables projection of advertisement logos, maximizing exposure and engagement.
- IoT Interfacing: Interfacing the application and car-mounted display to the internet using an online server, providing remote access and management of content.
- Android Application: Provides users with control of advertisement choice and presentation as well as enabling real-time vehicle tracking for security and targeting.

The manuscript is organized as follows: Section 1 presents the Introduction, which encompasses Motivation, Related Work, Contributions, and Organization. Section 2 addresses the Problem Statement and its proposed solution. Methodology is discussed in Section 3. Section 4 details the System Hardware, while Section 5 focuses on the System Software. Section 6 presents the Results and Discussion, and Sections 7 and 8 conclude with the Conclusion and Future Work.

2 Problem Definition and Solution

Many researchers have used different hologram display techniques to investigate hologram technology for a range of applications. The two escapements' movements are illustrated [12] using a basic pseudo-3D holography technology. This affordable gadget can be linked to a large-screen television for shop display applications or used in conjunction with a smart phone for portable display needs [13]. An innovative way to demonstrate the operation of complex mechanical clocks and other mechanical devices is offered by this method [14].

The main challenge lies in the watch's complex mechanical design, which is simplified by the proposed solution. In a different work [15], the researchers use a traditional engraver-laser setup to investigate the hologravure generalization of scratch holograms and laser sketching [16]. This development helps incorporate more audio channels on to a single crystal, which improves image quality produced using specialist software by a computer from a three-dimensional (3D) model [17]. The study's finding is that the computer-generated 3D image is

Table 1. Overview of holographic techniques and their limitations across different applications.

S.No.	Technique	Limitations	Reference
1	Pseudo-3D Holography	Limited clarity; may not fully capture Complex structures	[13]
2	Hologravure with Traditional Engraver-Laser Setup	Complexity in image quality and audio Channel integration	[14]
3	Multi-channel Acousto-Optic Modulator (AOM)	Requires high time-band width products for effective display	[15]
4	Layer-Based Methods for Hologram Generation	Speed and interactivity limitations in real-time applications	[10]
5	Mirror-Lens Holographic Optical Element	Challenges in transparency and brightness	[11]
6	3D Holographic Animation for Mechanical Devices	Requires simplification of mechanical designs	[13]
7	Digital Holograms in Biomedical Applications	Clarity issues in rendering complex Biomedical images	[13]
8	High Resolution Phase-Only Holographic Display	Dependence on advanced rendering Techniques	[17, 18]

not very clear. Nevertheless, the Blender program solves this problem. Another study [18] points out that time- bandwidth products required for any realistic holographic display system using the MIT synthetic aperture approach must be far higher than what can be achieved with single- channel acousto-optic modulators (AOMs). To overcome this difficulty, a multichannel AOM that takes advantage of the parallelism prevalent in optical systems offers a workable alternative. Table 1 highlights the techniques explored in previous studies, along with their associated limitations.

3 Methodology

Two technologies are the main components of the project: Internet of Things (IoT) and holography. An acrylic pyramid is used to create a 3D image in midair using hologram technology. This study uses an acrylic pyramid above a horizontal LCD to show the logos of different firms for advertising reasons on the roofs of vehicles using holography. The proposed system creates a holographic video that plays on the LCD in order to produce the hologram logo. Devices can communicate with each other over the internet thanks to the Internet of Things (IoT). This paper uses the Internet of Things to connect the mobile devices to the horizontal LCD to show videos advertisements. A GPS module is linked to the application for marketing purposes in order to track the whereabouts of the car. Every piece of information is kept on a web server and is accessible.

Two LCDs make up the entire display: one is positioned vertically to broadcast commercial videos, and the other is horizontally to display the holographic logo. The best holographic displays are able to precisely adjust wavefronts in ways that are not perceptible to humans, producing 3D scenes that are identical to real-world objects. However, the enormous optical modes required to create realistic 3D scenes are beyond the capabilities of existing wave front modulators, such as spatial light modulators (SLMs) [16]. Holographic 3D presentations are especially appealing because they can reconstitute the phase and amplitude information of 3D scenes in their entirety [17].

To create an application that offers alternatives for choosing ads and shows the location of the vehicle in order to display adverts on the LCD, this study uses the Eclipse IDE to design a graphical user interface (GUI) for the mobile app, and Java was used for the backend development. Different buttons for choosing an advertisement, pausing, restarting, and closing the app are all included in the app. Because of its user-friendly interface, anyone may use this program conveniently and with ease. While working at Procter & Gamble on a commercial supply chain optimization project that required senior administration's responsiveness through Radio Frequency Identification (RFID) technology in 1999, Kevin Ashton coined the term "Internet of Things" [18]. IoT interfacing is used to establish an internet-based connection between two devices. In this project, IoT interfacing is required for smooth connection between the LCDs and the Raspberry Pi, GPS module, and online server. Figure 1 presents the block diagram of the system.

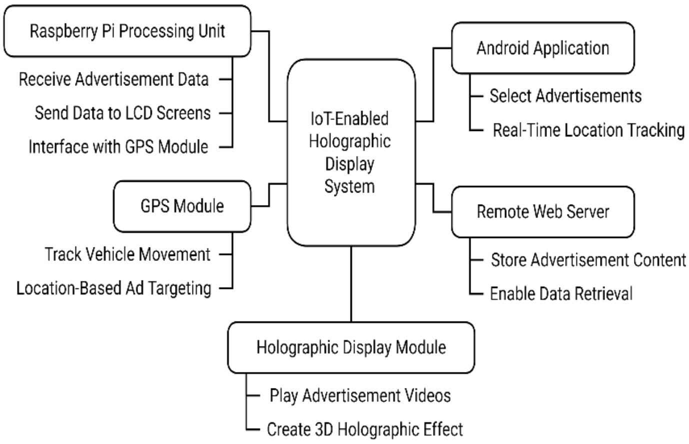

Figure 1. Block diagram of the system.

Figure 2 illustrates the flowchart of a location-based system for displaying holographic advertisements. After successful login, users are presented with a user- friendly interface which enables them to quickly choose their preferred advertisement from a carefully selected list of available possibilities. When an advertisement is selected, the system forwards the ad to the Raspberry Pi, then the system gives command of activation to the GPS module. This GPS module integrated into the vehicle improves the verbal relevance of the advertisements and system activations. This module records the user's precise location and enables the system to determine the most appropriate advertisement based on the user's demographics and surroundings. After the identification of which type advertisement will be displayed, the system starts the projection preparations. In order to make sure that the LCDs are properly configured and prepared to display the holographic content, the system first tests them by adjusting brightness, contrast, and other visual settings. Lastly, the chosen advertisement is projected as an intriguing hologram over an acrylic pyramid, which serves as the display's center point. An associated commercial video that plays in the background and creates a multisensory experience

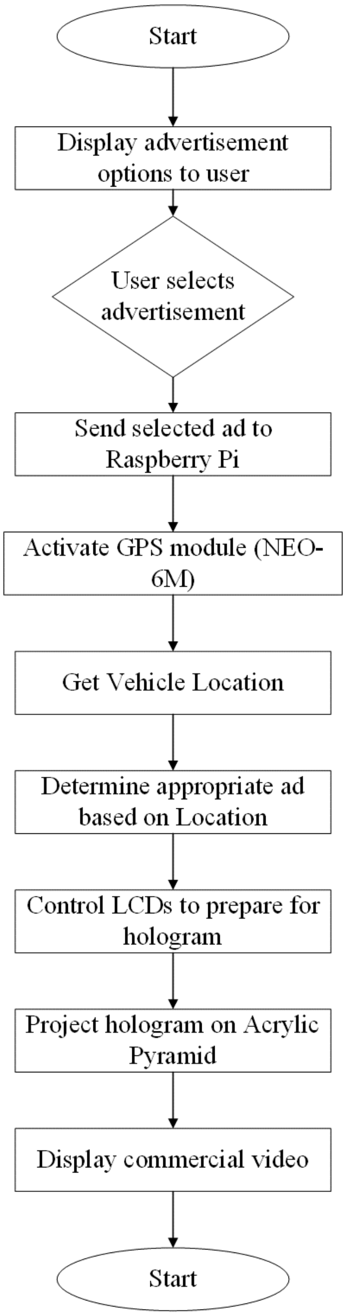

Figure 2. Flowchart of the location-based holographic ad system, showing ad selection, GPS activation, and hologram display process.

that attract the user's attention completes the task at hand. Furthermore, to increase user engagement, these processes guarantee that every interaction with the holographic ad system is engaging, captivating, and instantaneous.

4 System Hardware

The hardware components used in this study are thoroughly discussed in this chapter. Any experiment must carefully consider which hardware components to use. Determining the required hardware components and establishing the experiment's scope are essential components of a project plan. The following are the main pieces of hardware used in this project:

4.1 Raspberry Pi

Two Raspberry Pi units are used in the project; one has Wi-Fi enabled, and the other does not.

- Using a web server, a Raspberry Pi with Wi-Fi is used to project video on to an LCD. It is also linked to a GPS module, which improves security assurance by tracking the location of the car.
- A hologram of a company logo is projected on to an acrylic sheet using a Raspberry Pi without Wi-Fi and a horizontally oriented LCD.

4.2 LCD

A type of flat-panel display known as liquid crystal display (LCD) technology uses liquid crystals as its main visual output component. The basic idea of operation is to modulate light by sandwiching liquid crystal molecules between plastic or glass layers. These liquid crystals' orientations shift in response to an electric current, regulating the quantity of light that enters and creating the intended image. This technology is widely used in many different devices because of its ability to produce high-quality images with a comparatively low power consumption, such as computer monitors, televisions, and digital instruments. An LCD screen and an acrylic sheet are used to project the visual content as a holographic display. In this arrangement, the acrylic sheet functions as a reflective medium and the LCD as the image source, giving the appearance of a three- dimensional hologram. The holographic effect is produced by directing the light from the LCD at a certain angle onto the acrylic sheet, which causes the picture to be reflected and appear to be floating in space. An animated hologram with the brand's logo was created specifically to be shown above the car. The LCD screen must be positioned horizontally, and an acrylic sheet arranged in a pyramid shape must be placed on top of the LCD. Because of this configuration, the holographic projection of the logo can be reflected off the slanted surfaces of the pyramid, producing a three- dimensional visual illusion that makes the vehicle appear to float above it. The full commercial video is shown on a second LCD screen that is mounted vertically. By offering a continuous video feed, this vertically oriented LCD enhances the holographic display and guarantees that the audience can see the entire advertisement content in addition to the holographic projection of the brand's emblem.

4.3 GPS Module

This paper uses the NEO-6M GPS module, a high-performance, fully integrated GPS receiver, which has an integrated ceramic antenna measuring 25 x 25 x 4 mm that guarantees accurate positioning and efficient satellite acquisition. The module is appropriate for many applications that need GPS capabilities, including mapping, tracking, and navigation systems. This module can deliver precise position data.

Figure 3 depicts the hardware interfacing between a Raspberry Pi and a Neo-6M GPS module, established through jumper wire connections. The GPS module communicates with the Raspberry Pi via designated GPIO pins, facilitating the acquisition of real-time geolocation data. In the broader system architecture, an LCD display is integrated with the Raspberry Pi using an HDMI cable. In that setup, a strip of female header pins on the LCD is aligned with the Raspberry Pi's male header pins, enabling a secure mechanical and electrical connection through direct insertion.

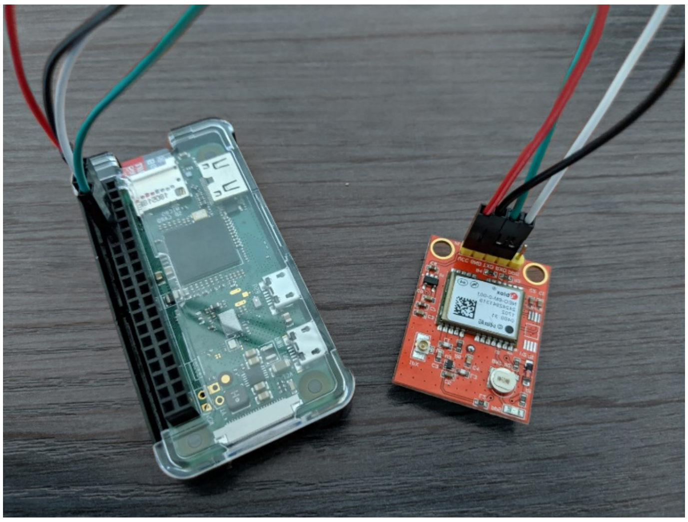

Figure 3. Hardware connection between the Raspberry Pi and the Neo-6M GPS module for real-time location tracking.

5 System Software

Choosing the right software that meets the experiment's unique needs is essential to its effective implementation. This choice is critical because of its immediate impact on the system's functionality, development process, and final results. Important elements including the option to choose and play promotional movies on the LCD screen and the capacity to track the location of the car using the built-in GPS module were included in an Android application. This software increases the adaptability and usefulness of the system by offering an intuitive interface for controlling display content and tracking real-time positioning. Users are able to upload data to the cloud and access it remotely from any location by connecting the software to an online server. Regardless of where they are physically located, users can engage with the system and view updates in real time due to this cloud connectivity, which makes data administration and retrieval simple. The Raspberry Pi 0 was set up to control an LCD screen hologram display. With this configuration, the Raspberry Pi can process and render the required visual content, which makes good use of the LCD as a projection medium for the holographic image. Concurrently, this study created the Raspberry Pi Zero W, which enables the streaming of commercial videos and connects to a web server. With this setup, the Raspberry Pi may connect to the mobile application from any place, guaranteeing the control of content and real-time changes for the advertising displays.

The goal is to create an Android application that puts an emphasis on ease of use and simplicity. By putting an emphasis on usability, developers can make sure that users can access features, manage content, and navigate the app with ease, all of which will improve the user experience in general. In the application for the users, there is a graphical user interface (GUI) to guarantee that the system software is easily understandable. By including logical visual components, this design decision improves usability and makes it easier for users to interact with the software's functions and explore it. Customers only need to enter their special ID and password to gain easy access to the application. This authentication procedure protects user privacy and data while guaranteeing safe access to the app's functionalities. Users can view real-time updates on their vehicle's whereabouts thanks to the prominent display of the vehicle's location information on the screen. This feature makes tracking and management easier and improves situational awareness.

The Internet of Things (IoT) can be used to show adverts anywhere. With the use of this feature, advertising content can be managed remotely and updated in real time, making it accessible and broadcast across a range of platforms and settings. This research paper successfully linked the two Raspberry Pi devices to a server after programming them for IoT interfacing. This setup makes it possible for the devices and the server to communicate and exchange data without any problems, allowing for remote system monitoring and control. An effective software system is created in order to accomplish these goals. To make this easier, a range of programming languages have been selected for the experiment's many components, guaranteeing top functionality and efficiency throughout.

5.1 Python

This study used Python to program the Raspberry Pi Zero to show holographic videos on LCD1, and set up the Raspberry Pi Zero W to stream internet-based advertisement videos to LCD2. This method improves the display system's overall functioning and allows for efficient video handling. In addition, Python was chosen as the programming language for the following reasons:

- Its simplicity of usage is facilitated by its user-friendly character.
- Both large-and small-scale programming projects can benefit from it.
- It is also compatible with systems with minimal configurations.
- Python has thousands of built-in libraries, which makes development much easier.
- Additionally, Python provides a wide range of networking options via different libraries.

5.2 Java

Java is used for designing the Android applications. This study implements a number of Java classes on the backend that cover video selection, GPS tracking of the car, and user authentication (including user ID and password). Java was used for the following purposes:

- In order to support user development, Java provides the right kind and amount of content inside the program.
- Provide a novel approach, a special use case, or an unforgettable experience that will set the software apart from the competitors.
- To strengthen user relationships and encourage greater involvement, cultivate communities and support user-generated content.

5.3 PHP

Server-side PHP programming is available as an open- source language. PHP is used to enable communication between the Raspberry Pi and the Android application with the web server. PHP is also used to send data from the GPS module to the server.

5.4 Eclipse

Eclipse IDE is used to develop the application's user interface using the. This enables reading and editing text, adding buttons for choosing a movie, adding ID and password fields, changing the size of the text, and entering images. Rich client applications, integrated development environments (IDEs), and other tools can be created with the Java-based Eclipse platform. With the availability of a relevant plug-in, Eclipse can function as an integrated development environment (IDE) for any programming language. This study uses Java, a programming language that falls under the category of integrated development environments (IDEs). The Eclipse Foundation is the software developer.

5.5 My SQL

An open-source, free relational database management system (RDBMS) is called My SQL. "My" is the daughter of co-founder Michael Widenius, and "SQL" is an acronym for Structured Query Language. The data is kept in a My SQL server database, which enables us to edit, pull, and upload the data as needed.

6 Results and Discussions

The proposed system successfully displayed the hologram logo, with the entire setup being controlled through the designed mobile application. The experimental work was organized into three distinct phases to ensure systematic development and evaluation.

In the first phase, the primary focus was on creating the holographic display. Acrylic was selected as the display material due to its lightweight properties, which made it ideal for mounting on a vehicle roof without significantly increasing the load. Initial testing was conducted on a small prototype designed for mobile displays, and subsequently validated on a larger LCD screen. A customized hologram video was developed by capturing images from four different perspectives and organizing them based on the dimensions of the acrylic pyramid. Adjustments to the center gap of the system and modifications to the acrylic pyramid were carried out to optimize the visual results when mounted on the vehicle.

The second phase concentrated on software development and hardware interfacing. A custom application was designed to control video playback and vehicle tracking functionalities through a Raspberry Pi. The Raspberry Pi Zero and Raspberry Pi Zero W units were configured to connect to a web server, the GPS module, and the LCD displays. This networked setup allowed for real-time transmission and reception of data over the internet, facilitating remote advertisement management and vehicle monitoring.

The final phase involved the full integration of all system components. A protective frame was built to house the vertical LCD and the holographic module, ensuring stability and safety during vehicle operation. Given the limited space and weight capacity on the car roof, meticulous planning was required to position and secure all components effectively. Ultimately, the system achieved its intended objective: projecting a dynamic holographic logo onto a horizontal LCD through an acrylic pyramid while simultaneously displaying commercial videos on a vertically mounted LCD screen, all controlled via the mobile application.

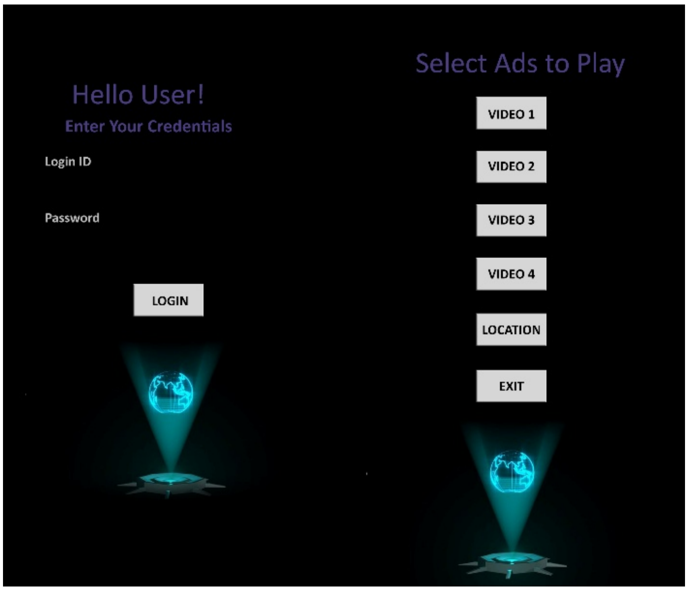

Figure 4. Android Application.

Previous studies have demonstrated that holographic displays positively impact spatial visualization skills. Moreover, research indicates that holographic imaging can contribute to the cognitive development and learning processes of children [17]. Holographic projections have also introduced new visualization challenges in engineering and medical imaging

Figure 5. IoT Interfacing.

domains [18], highlighting the need for further advancements in the field. Figures 4 and 5 illustrate the Android application's user interface and the IoT interfacing features developed for the system, respectively.

Figure 6. Hologram display module demonstrating real-world applicability of the proposed advertising system.

Figure 6 illustrates the practical implementation of the holographic advertising module as mounted on a vehicle. This setup projects dynamic three-dimensional advertisements onto an acrylic pyramid, allowing for visually engaging interactions with consumers in public environments. Its design underscores the effectiveness and feasibility of integrating IoT and holography in real-time outdoor advertising.

7 Conclusion

This study proposed a novel IoT-based holographic display system for advertising on vehicles by integrating cloud computing, holography, and IoT to transform the traditional advertising. The designed system allows the user to control the display of advertisements remotely with the help of a user-friendly Android application. This study successfully demonstrated the proposed system's feasibility, though some challenges remain in clarity of the display under different light conditions. This paper establishes a foundation for smart advertising and making use of the cutting-edge technologies to enhance the effectiveness and engagement of out-of-home advertising.

8 Future Work

With practically endless uses, the development of 3D holographic displays marks the next frontier in producing more user-friendly digital information. To improve presentations at meetings and conferences, for example, holograms might be used to project 3D prototypes of things, like cars, within a physical environment. Furthermore, during virtual meetings, the idea of holographic telepresence might allow people to project a holographic image of themselves thousands of kilometers away. The use of holograms can greatly improve the processes of training, design, and visualization in a variety of business and industrial contexts. The ability to work with, enlarge, and alter 3D models of ongoing designs has the potential to significantly improve workflow efficiency. Marketing departments can also use 3D holographic engagements and experimental marketing campaigns to create engaging experiences that captivate consumers. Such advancements may open the door to revolutionary approaches to product design and marketing, paving the path for fascinating new directions down the road.

Data Availability Statement

Data will be made available on request.

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Conflicts of Interest

The authors declare no conflicts of interest.

Ethical Approval and Consent to Participate

Not applicable.

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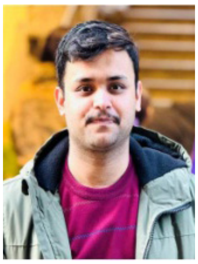
Fahad Farooq is a dedicated professional with a strong background in Electronic and Telecommunication Engineering. He earned his Bachelor's degree in Electronic Engineering from Sir Syed University of Engineering and Technology (SSUET) in 2008, followed by a Master's degree in Telecommunication Engineering from Hamdard University in 2012. His research interests lie in the fields of control systems and automation, with a particular focus on Wireless Sensor Networks (WSNs). Fahad has contributed to the academic community through several research publications. Notable among these are his works on real-time border monitoring systems using WSNs, grid-cluster size calculations in wireless sensor networks, and an online gas pipeline monitoring system integrated with Android applications. These contributions highlight his expertise in designing efficient and innovative solutions for complex telecommunication and control challenges. (Email: ffarooq@ssuet.edu.pk)

Rana Javed Masood earned his B.S. in Electronic Engineering from Sir Syed University of Engineering and Technology (SSUET), Karachi, in 2006, followed by an M.S. in Industrial Control and Automation from Hamdard University in 2011, and a Ph.D. in Control Theory and Engineering from Nanjing University of Aeronautics and Astronautics (NUAA) in 2018. He has been serving as Assistant Professor at Electronic Engineering Department of Usman Institute of Technology University Karachi Pakistan. (Email: Rana.javed@uit.edu.pk)

Muhammad Aamir Khan received his Bachelor's degree in Electronic Engineering from Sir Syed University of Engineering and Technology, Karachi, Pakistan, in March 2008. He is also completed his Master's degree in Electronics specialization in Telecommunication from Sir Syed University of Engineering and Technology in March 2013. He is currently pursuing a PhD degree in Electronic Engineering at the Department of Electronics Engineering from Sir Syed University of Engineering and Technology. Recently, he has successfully defended his research proposal titled as Maneuver Control of Swarm: A Multitasking LoRa Network based Reinforcement Learning focusing on Energy efficiency, optimized bandwidth utilization and effective path routing. (Email: maamirk@ssuet.edu.pk)

Amber Israr is an associate professor in the Electronic Engineering Department, Sir Syed University of Engineering and Technology, Pakistan. She specializes in designing and analyzing computer communication networks, computer network security, real-time computer systems, and artificial intelligence. She obtained a Ph.D. in Electronic Engineering from Sir Syed University of Engineering and Technology with her thesis, "Prediction-Based Greedy Routing Strategies for Wireless Networks of Moving Objects". (Email: aisrar@ssuet.edu.pk)



Faizan Zahid received his Bachelor's degree in Electrical Engineering from Quaid-e-Awam University of Engineering, Science, and Technology, Nawabshah, Pakistan, in December 2021. He is currently pursuing a Master's degree in Automation Engineering and Control of Complex Systems at the Department of Electrical, Electronics, and Computer Science Engineering, University of Catania, Italy. His research interests encompass Automation and Control Systems, Advanced Robotics Control, Multi-Agent Systems, and Cooperative Swarms of Unmanned Autonomous Vehicles, with a growing focus on Power Electronics and its applications in system design for enhanced control and efficiency. (Email: faizanzahid54@hotmail.com)