Nerambum: A Virtual Exhibition Platform

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Abstract—In the wake of the global pandemic, industries worldwide faced a disruptive challenge, particularly those thriving on physical exhibitions essential for expanding market share, unveiling new products, and forging valuable connections. The health crisis and consequent strict guidelines rendered traditional exhibitions untenable, causing a catastrophic loss of audience and opportunities for businesses. This unprecedented situation accelerated the adoption of virtual alternatives, but existing platforms failed to capture the essence and dynamism of live, in-person interactions, leading to a palpable gap in the user experience. "Nerambum" emerges as a transformative solution in this landscape, offering a sophisticated online exhibition platform that recreates the authentic feel of physical events. It seamlessly integrates a 3D environment in an immersive virtual space for attendees with a multifunctional web application, supporting various user roles. The platform not only adapts to the current necessity for remote interaction but also anticipates the enduring relevance of virtual engagements in the exhibition industry's future.

Index Terms—Virtual Exhibitions, Human Computer Interaction (HCI), Humanoid Avatar, Interactive experience, Metaverse, Spatial Audio, Microservices

I. Introduction

Exhibitions and trade shows have become an indispensable part of the globalised business world. However, traditional physical exhibitions are fraught with several challenges, including high costs, limited reach, and environmental sustainability issues [1]. However, the exhibition industry faced significant challenges due to the COVID-19 pandemic.While some exhibitions have moved to virtual platforms, most of these platforms are limited in their interactivity, limited customization, limited camera viewpoints and are unable to replicate the experience of a physical exhibition. They lack the feel of a real-life exhibition [2].

In response to these challenges and the significant impact of the COVID-19 pandemic on the exhibition industry, we propose an advanced 3D technology-based solution called "Nerambum". This virtual exhibition platform aims to solve the existing problems of the traditional physical exhibition industry while mimicking a real-life stall-like experience for exhibitors, attendees, and event organisers in a virtual space.

Our solution is composed of a desktop application and a web application, each designed to provide a personalised user experience with limited clicks for navigation, realistic sound environments, and humanoid avatars. The desktop application offers an engaging experience with multiple camera views, customizable three stall tiers, marketing material uploads including 3D exhibits. Furthermore, the live streaming feature enables exhibitors to broadcast from remote locations, while the video rendering feature provides spatial audio with video content on screens and 3D spatial audio for conversations. The web application manages critical functionalities of the virtual exhibition platform, including user authentication, stall customization, avatar customization, exhibition management, ticketing, and payment processing, utilising microservices architecture for the backend.

"Nerambum" offers a more convenient and sustainable alternative to physical exhibitions, with global reach that allows attendees from anywhere in the world to access the platform. Our solution aims to elevate businesses and create more engaging and interactive exhibition experiences. Overall, "Nerambum" is designed to address the challenges of physical exhibitions and provide a new norm for the exhibition industry, offering a realistic virtual experience that is both engaging and accessible.

In this article, we'll describe the already-available platforms and their limitations, the architecture and features, results, discussion related to the features and limitations and the appropriate future work to make this application a new benchmark in the digitalized world.

II. Related Work

Virtual applications and metaverses have become increasingly popular in recent years as a means of providing immersive and interactive experiences to users. In this literature review, we will discuss different virtual applications and metaverses, and explore their features and benefits.
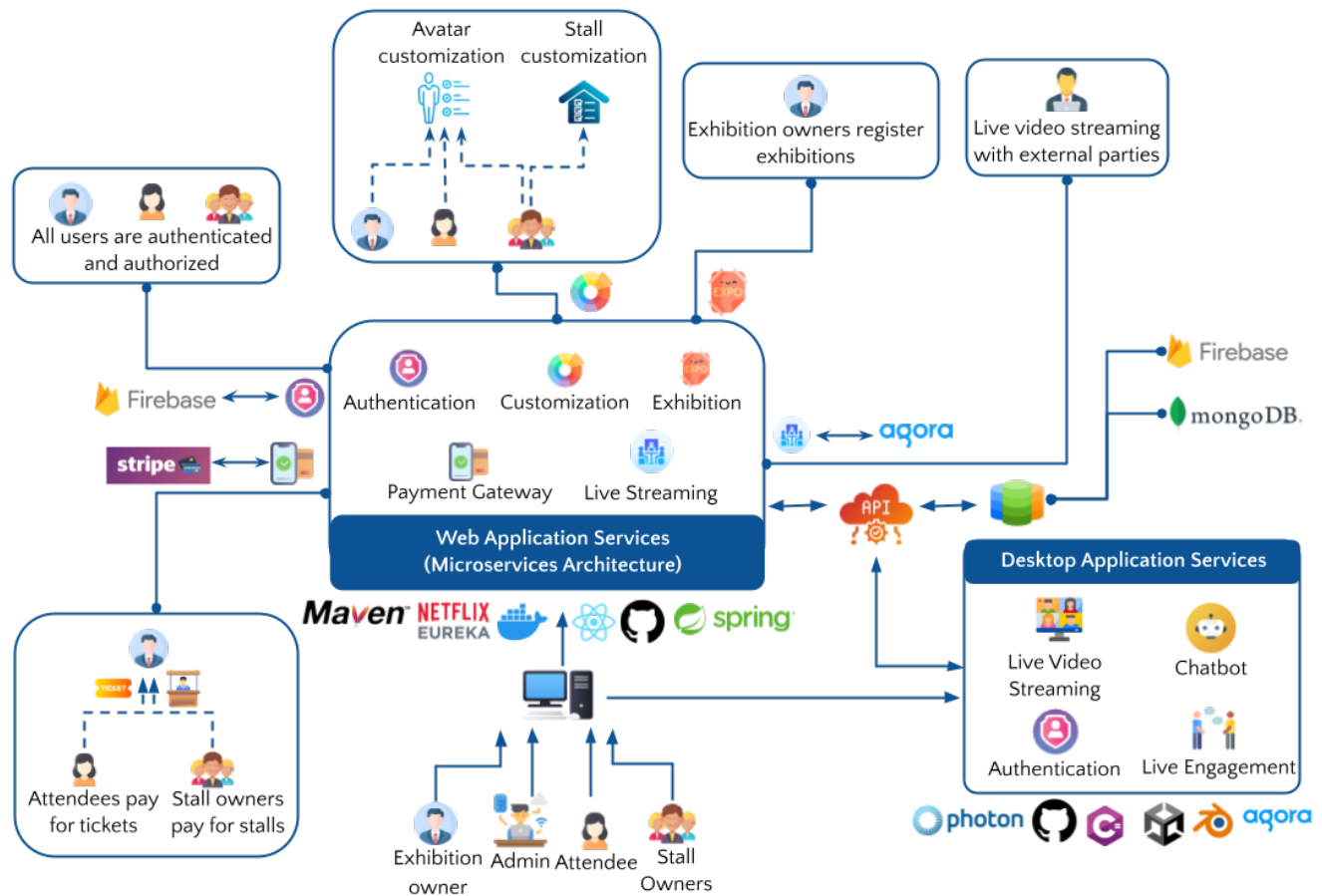
Fig. 1: Architecture diagram of the proposed system.

Futureverse is a metaverse that was introduced by Dialog Axiata PLC, which is the first fully immersive and interactive virtual world in Sri Lanka [3]–[5]. The metaverse enables visitors to access all Dialog products and services available at any Dialog Experience Centre, socialise with friends, watch movies, take part in workshops, visit exhibitions, and more. However, it contains a voice call type audio communication between users inside the exhibition hall and also has only third person perspective camera angle.

6Connex is another platform that provides a virtual environment and enables users to reach customers, talent, and internal employee communities globally [6]. The platform offers modern features and technology to create unique and engaging programs that enhance user experience, drive engagement, and increase event ROI. Users can combine any number of spaces and designs, such as lobby, auditorium/theatre, exhibit hall and booth, networking lounge, and classroom but still it has the above mentioned limitations of Futureverse, and in addition to that it doesn't have automated stalls and avatar customization [7].

VIRTUP is a platform for exhibitors, panellists, and sponsors to interact with attendees and with each other to create a seamless virtual event experience that functions smoothly [8]. The platform enables the organisation to deliver a unified, fully branded experience across the event-related touchpoints, including the website, registration, video sessions, and virtual trade exhibits. However, VIRTUP also lacks with above mentioned limitations of Futureverse and also has live chat apart from a chatbot inside the exhibition hall [9].

vFairs is a virtual event management platform that specialises in delivering customised virtual career fairs, job fairs, online trade exhibits, and onboarding fairs [10]. The platform fosters event engagement by allowing hosts and exhibitors to employ rich interactive capabilities such as text/audio/video chat, webinars, and discussion boards. The platform offers immersive 3D exhibit halls and entertaining gamification opportunities for virtual events [11].

VIRTUE is a virtual reality application that takes users on a tour of a museum. Users can enjoy the artifacts in this application as if they were in a museum [12]. The VR system is linked to the database, so if a new object needs to be presented in the museum, it can be done immediately on the back end and promptly updated in the VR application [13].

V-Museum is an augmented reality and virtual reality mo-

bile application that allows users to transition from a physical site to a virtual museum. The app spawns a 3D door that leads to the museum when the user taps on the screen. Inside, users can explore galleries of vintage Fez images, watch videos about Fez's legacy, and explore 3D monuments. However, the app's performance needs to be evaluated due to potential instability caused by large 3D objects, which could be resolved by optimising the objects' dimensions [13].

III. METHODOLOGY

A great virtual exhibition platform should have a virtual environment that promotes human interaction, has great networking features, and provides endless value to exhibitors, sponsors, and attendees. Our virtual exhibition platform contains all the right tools to attract exhibitors and attendees and bring the classic exhibition experience beyond the halls.

The virtual exhibition platform was implemented as a desktop application and a separate web application that manages the virtual exhibition. The downloadable link to the desktop app is available in the web application. Desktop application implementation started first, with designing the exhibition hall with different tiers of stalls in the Unity game engine. Unity is the best game engine that can be used to design this virtual exhibition, as 3D graphics can be used with a relatively small amount of work, a low entrance level, the availability of assets with their asset store, and a great community to help clarify issues.

The live engagement feature for the users was added in a client-server architecture, as shown in Fig. 2. This was done through the partnership with Photon Fusion. After doing some research, we found out that Photon Fusion is the best network library that can be used to design our virtual exhibition. It is a new high-performance state synchronization networking library for Unity built with simplicity in mind to integrate naturally into the common Unity workflow while offering advanced features like data compression, client-side prediction, and lag compensation out of the box. It offers subscription plans to implement live engagement for the users with its support for 3D audio, which is one of the most unique features that is included in "Nerambum". This ensures that users experience a realistic feeling inside the hall with the options for muting/unmuting microphone and speaker features by just clicking a button.

The virtual exhibition platform has video display screens that are equipped with 3D spatial audio to simulate the experience of real-life video screens. The audio is attenuated based on the distance from the viewer to the screen, creating a more realistic and immersive experience.The video display screens within the virtual exhibition platform serve multiple purposes. First, stall owners can use these screens to showcase their own videos. Additionally, there are dedicated screens for sponsor videos, which can be used to promote their products or services.

With live streaming, exhibitors can showcase their products and services in real-time, providing attendees with an immersive experience that is similar to that of a physical exhibition. The virtual exhibition platform includes a separate portal within the web application that enables exhibitors to conduct live streaming. The virtual exhibition platform allows attendees to join live streams within the virtual exhibition. Each stall is equipped with a separate video screen that renders the live stream into the virtual exhibition. As attendees approach the screen, they are automatically joined to the live stream, and when they move away, they are disconnected. To implement the live streaming functionality, the Agora Video SDK was used, as shown in Fig. 3. To start a live streaming session using Agora SDK, the channel profile and role should be set, and a token should be retrieved to authenticate users. Then, the users can join a channel, with the same channel name for all participants. Hosts can publish their local video and audio to the channel, while audience members can subscribe to the content published by the hosts. Exhibitors can start a live stream for their stall on the Agora server using their stall's channel name and token, which they can access upon logging into the web application. Attendees can view the live stream by joining a stall's channel with the provided token and channel name. The token and channel name are generated and provided to exhibitors and attendees via API calls. Exhibitors can see their own video feed in the live stream portal upon joining as a host, while attendees can view the host's video feed when they join as an audience member from the virtual exhibition platform.

Humanoid avatars from Mixamo were incorporated into the virtual exhibition platform to create non-player characters (NPCs) that resemble real-life attendees. NPCs are added to a virtual exhibition platform to enhance the user experience and create a more realistic environment. NPCs can be used to simulate the presence of real people, such as attendees, and provide a more engaging experience for users. Some of the NPCs inside the virtual exhibition platform are programmed to simulate walking or moving around the space, while others are designed to remain idle or sit in a stationary position.

A chatbot at the reception was designed to guide users inside the exhibition hall with Dialogflow, which is a natural language understanding platform that makes it easy to design and integrate a conversational user interface into the desktop application through its APIs. All the users have the option to use the chatbot in the reception, and they can either ask queries from the chatbot through a typed message or voice message. The Google speech-to-text API feature was used to ask queries through voice messages, and the text-to-speech API feature was used to output the response as an audio clip apart from the text display as displayed in Fig. 4.

It will be really difficult for the user to find which user is speaking when there are many around them if there's no such way to find it. To resolve that, lip syncing was added for all the avatars. This was designed using Blender as shown in Fig. 5. The humanoid avatars in the Mixamo don't allow them to blend their lips. Therefore, all the avatars were modified to blend the lips using Blender. Then, with the added recorder of each user, the intensity level was detected, and if it was greater than 0.1, lip syncing was enabled by blending the modified
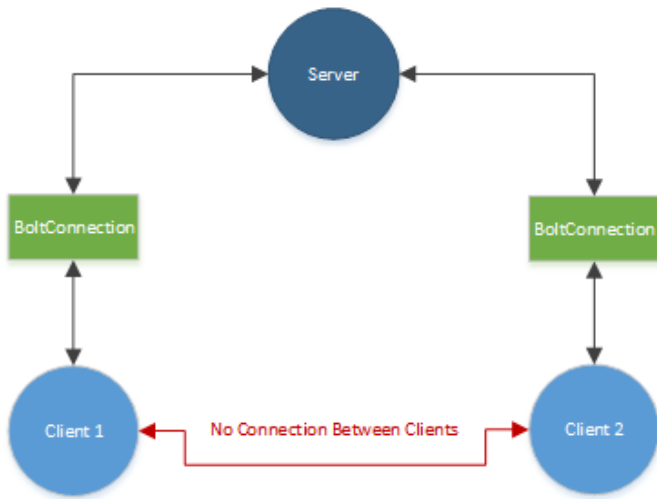
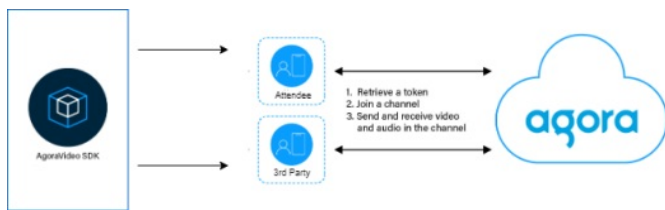Fig. 2: The server client model that used with the proposed system.

Fig. 3: Live video streaming with Agora

Fig. 4: API Interaction with the Chatbot

Fig. 5: Implementation of Lip Syncing of Avatars

parts of the avatars. Apart from the lips, the eye brows were also blended in the same way as described above to make it more realistic. In this way, only local users can observe that the lips of their avatars are synced when they are audible. However, to see remote players lip-syncing, first detect the users who were talking at that moment and then use Blender to blend the lips and eye brows of the surrounding avatars to make the live engagement more realistic. However, this is not accurate lip-syncing, as this feature was developed to make conversations more realistic and show the user speaking inside the exhibition hall.

A map showing the directions to the destination they are willing to go to was designed. The 3D models can be uploaded to the database so that they will be rendered at each runtime in the desktop application. Image rendering, video rendering, 3D model rendering, and connecting users from different networks around the world with Photon Fusion are the major reasons why the Unity game engine was chosen to design this virtual exhibition, as it offers all these functionalities with great community support. In the modern day, we can observe several multiplayer games' performances decreasing due to frame drop issues with their assets' rendering. However, "Nerambum" will be designed to minimize those issues with its integrated features and ensure that each user gets a better user experience without any issues.
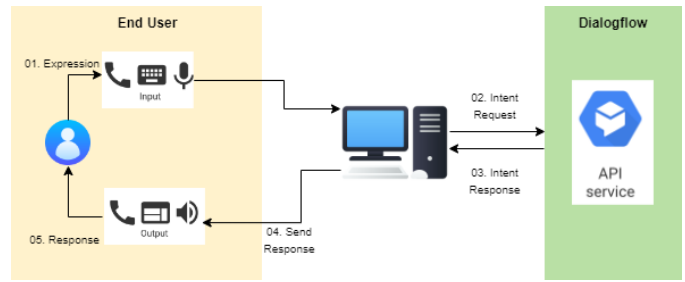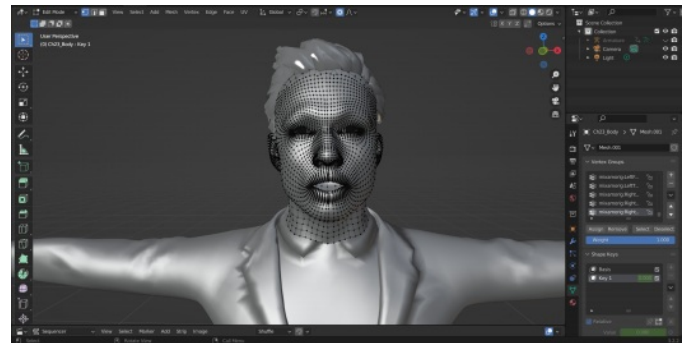
Users can enjoy a more immersive experience through the implementation of multiple camera views. This feature enables them to explore virtual exhibits and environments from various angles, adding depth and realism to their virtual exploration. By offering different camera perspectives, users can gain a greater sense of presence and interactivity within the virtual exhibition, enhancing their overall immersion and engagement. Utilized the Unity Cinemachine package to implement first-person and third-person cameras. Cinemachine is a powerful tool that simplifies camera management and allows for smooth transitions between different camera perspectives. In a first-person camera perspective, the camera is positioned at the avatar's viewpoint, giving the impression of seeing the exhibition environment through their eyes. In a third-person camera perspective, the camera is positioned behind and slightly above the avatar. It provides a view of the avatar from an external perspective, allowing the player to see the character and the surrounding environment.

In the exhibition hall, users can interact with each other through a gesturing feature. By clicking an emote button or pressing the "X" key, users can send a wave signal to other users. This feature was designed to enhance the realism and user-friendliness of the exhibition. Once the emote is enabled, an animation is triggered, which is then broadcasted by the server to all the clients using a remote procedure call (RPC). This allows all remote users to observe the animation.

Before entering the exhibition hall, users are prompted to enter a name. This name is displayed above the user's head using a text component. However, it is only visible to the
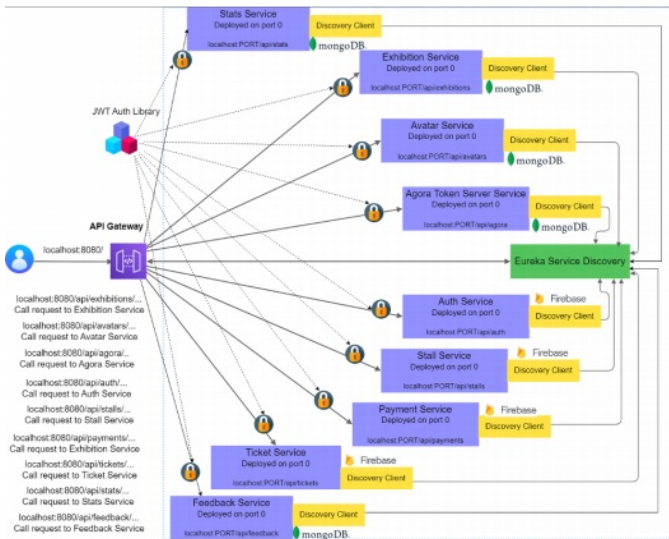
Fig. 6: Microservices Acrhitecture.

Fig. 7: Data Flow Diagram.

local user. To make the name observable to other remote users, RPCs are used. The method call is sent to the server, which then displays the name to all the clients present in the exhibition hall.

The web application was designed separately by implementing the backend and frontend using SpringBoot, Maven, Netflix stack and React in a microservices architecture as shown in Fig. 6. Thus, for each service, designed APIs can be invoked in desktop and web applications. Then the two applications were connected such that the data inside the database would be retrieved by the desktop application at runtime through the designed API calls. Netflix Eureka was used as the discovery server. It basically acts as a centralized registry of all the available services, including their IP addresses, ports and other metadata. Services can be added or removed dynamically without requiring changes to the configuration of other services. To implement the API gateway, Spring Cloud Gateway was used. It provides a library for building API gateways on top of Spring and Java, configured on port 8080. Routes were configured for the services, allowing the Spring Cloud Gateway to proxy and forward requests to the appropriate services based on the defined routes. A filtering method was implemented in the Gateway Filter interface to perform the actual filtering logic for incoming requests. The JWT authentication filter for the API Gateway ensures that incoming requests to protected API endpoints are authenticated by validating the JWT tokens. All the services are deployed in Docker using Docker-compose, where each service contains a container that is pushed to the Docker hub.

First, an exhibition owner should register an exhibition through the web application, and to run it in the desktop application, he or she should wait for approval from the admin side. Stall owners can register themselves for an exhibition by inquiring with the exhibition owner about the stall they want
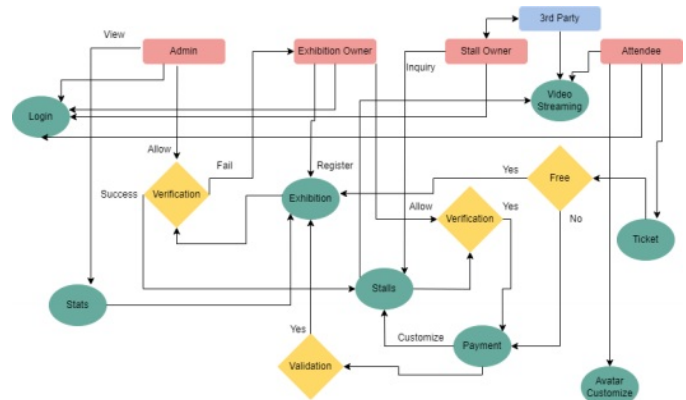
and should upload the required items (preferred colors for the stalls, banner images, PDFs, 3D models, and video clips of the products) to the database through the web application. Once they run the virtual exhibition through the desktop application, all the uploaded items will be rendered from the database at runtime to the stalls. These technically automated processes, including a user-friendly web application, will help the users use this application without much difficulty. Mainly, there are three tiers of stalls: gold, platinum, and diamond. In gold-tier stalls, only the banner images and pdf-type banners can be uploaded and modified through the web application. In platinum-tier stalls, options will be given for video streaming other than the above option. In diamond-tier stalls, an option other than the previous three will be given to upload the 3D model of a product through the web app. Moreover, each user can customize their avatar through the web application once they've created an account, and just before joining the exhibition, they can provide a name through the desktop application, which displays inside the exhibition. However, an attendee doesn't need to create an account if the exhibition entrance is free, and the attendee won't get the option to customize the avatar in that case. Firebase is used as one of the databases in this application because authentication, storage, hosting, functions, and more real-time features can be easily used with Unity. Apart from Firebase, MongoDB was also used to design the required services. Before running the desktop app, users who need to attend exhibitions where the entrance is not free should log into the desktop application. Then the exhibition ID and ticket, which they will get from the web application, should be provided in the desktop application, and after verification, they will be able to get access to the virtual exhibition. However, an attendee doesn't need a ticket if the exhibition entrance is free, and in that case, they can opt for the "join as a guest" option provided in the desktop application. An admin can view all the stats, such as the number of users who visited an exhibition, time spent in the exhibition, and other stats, through the web application, and stall owners have the option to submit feedback regarding the exhibition to the exhibition owner and regarding the platform
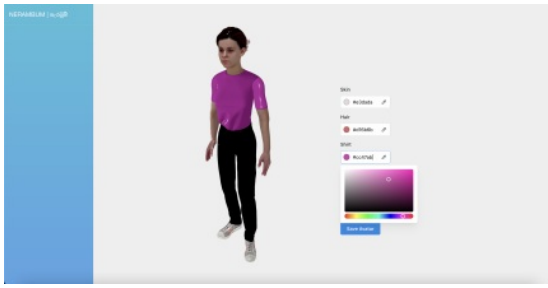
(a) Avatar Customization
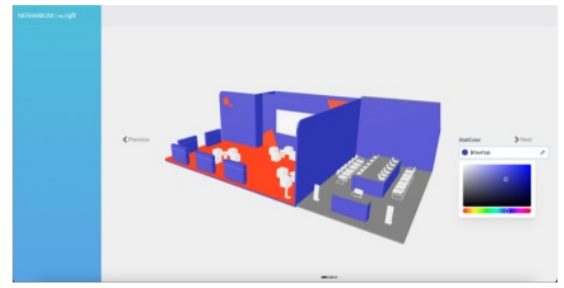
(b) Stall customization

Fig. 8: Customization Options through Web Application

IV. RESULTS

The virtual exhibition platform developed in this project consists of a desktop application and a web application, both of which were tested successfully with positive feedback from attendees and exhibitors.

The web application proved to be an effective tool for managing exhibitions, providing exhibition owners and exhibitors with attendance statistics and customizable stall tiers. Exhibitors were able to upload various marketing materials, such as banners, videos, and 3D models, through the web application. Additionally, the web application allowed attendees to customize their avatars as shown in Fig. 8.

The desktop application provided a realistic and immersive experience for attendees, with 3D spatial audio, humanoid avatars, and interactive features such as a chatbot as shown in Fig. 11 and game map for navigation. The platform also enabled live streaming sessions for product demos from remote locations. Overall, the platform performed well and provided a successful virtual exhibition experience.

During the development phase, we tested the platform with beta testers who provided feedback, resulting in improvements to the user interface and layout. The platform underwent technical performance testing on various devices and operating systems to ensure compatibility and smooth performance. Scalability was also tested to ensure the platform could handle the expected number of users without issues. Our performance testing also focused on the speed and responsiveness of the platform, ensuring that users could move around the exhibition seamlessly and without delay.

The virtual exhibition platform underwent thorough functionality testing to meet the needs of exhibition owners, exhibitors, and attendees. Testing of the web application included various processes, such as the registration process for different user levels, stall customization, avatar customization, ticket purchasing, and generating statistics. The registration process was designed to be user-friendly and intuitive, enabling exhibition owners to register their exhibitions with ease, exhibitors to register their stalls seamlessly, and attendees to register themselves without difficulty.

The stall customization process was also found to be highly intuitive and user-friendly. Exhibitors were able to customize their stalls by changing the stall color and uploading marketing materials like banners, videos, and 3D models with ease. The avatar customization process was also highly intuitive, enabling attendees to customize their avatars with ease.

The ticket purchasing process was designed to be straightforward and user-friendly, allowing attendees to purchase tickets for exhibitions with ease. The generated statistics provided valuable insights to exhibition owners regarding attendees' engagement and interactions.

In the desktop application testing phase, users found the platform easy to navigate and use. The virtual environment and 3D spatial audio features provided a realistic experience, enabling attendees and exhibitors to interact with each other as if they were in a physical exhibition. The attendee experience was tested by visiting different stalls, interacting with other attendees and exhibitors, and using the chatbot for assistance. The 360-degree view feature for 3D product models was highly appreciated by attendees, as it allowed them to examine the product from all angles, similar to a physical exhibition.

One of the most appreciated features was the live streaming feature for product demos, which enabled exhibitors to showcase their products to a broader audience without needing a physical presence as shown in Fig. 12. The functionality of the game map was tested to ensure that it provides easy navigation for both attendees and stall owners, enhancing the attendee experience.

Overall, the virtual exhibition platform was found to be highly functional and user-friendly, meeting the requirements of the exhibition owners, exhibitors, and attendees. The platform provided a realistic and immersive virtual environment that allowed for a seamless and engaging virtual exhibition experience.

V. DISCUSSION

The "Nerambum" platform revolutionizes the virtual exhibition experience with its state-of-the-art features, offering participants a deeply immersive environment crafted using the Unity Game Engine. A standout finding from our analysis is the platform's ability to transcend geographical boundaries, making global accessibility and reach its cornerstone. This feature not only broadens market reach for businesses but also fosters real-time interaction among users worldwide, creating
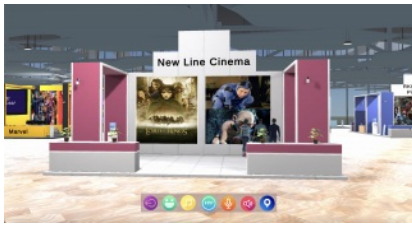
(a) Gold

(b) Platinum

(c) Diamond

Fig. 9: Stall Tiers

Fig. 10: Live Engagement
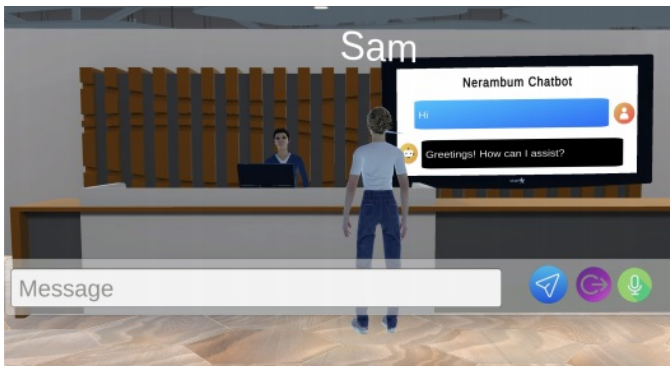

Fig. 12: Live Streaming

Fig. 11: Chatbot Feature

a sense of a unified global community within the virtual exhibition space.

Enhancing the interactivity and user engagement of "Nerambum" has been pivotal. The platform's dynamic nature, underlined by its capacity for live presentations, real-time chats, and virtual booths, is a magnet for engagement between exhibitors and visitors. Such interactive features, coupled with the strategic use of Photon Fusion technology, enable the hosting of multiple users simultaneously, setting "Nerambum" apart as a scalable and robust virtual exhibition solution.

Striving for realism, "Nerambum" integrates advanced technologies to enrich the user experience. The introduction of lip-syncing avatars adds a layer of authenticity to virtual interactions, a move that simulates face-to-face conversations. The presence of non-player characters (NPCs) within the

virtual halls, programmed via C# scripts, further bridges the divide between virtual and physical exhibitions, adding to the platform's dynamic atmosphere.

A groundbreaking addition to "Nerambum" is its dimensional audio feature. This innovation places "Nerambum" leagues ahead of counterparts, providing participants with an immersive audio experience that accurately mimics real-life environments. Such a feature is absent in other platforms analyzed, such as "6Connex," "VIRTUP," "Dialog," and "Expogun," underscoring "Nerambum's" distinctiveness and technological superiority.

In terms of practical features, "Nerambum" excels with its automated rendering of stalls and avatars, a stark contrast to the manual customization required in other platforms. This automation, facilitated by C# scripts, simplifies the user experience by autonomously integrating user preferences and marketing materials into the virtual exhibition space. Moreover, the platform's video and audio streaming capabilities, enhanced with 3D spatial audio, replicate the experience of viewing presentations in person, offering a richer, more engaging multimedia experience.

User navigation is streamlined with the inclusion of a map feature, aiding participants in efficiently locating and transitioning between booths — a nod to the convenience offered in physical exhibitions. Additionally, "Nerambum" accommodates user preferences by offering multiple camera perspectives, enhancing the sense of control and personalization within the virtual space.

Lastly, our study highlights the effective role of chat-

bot assistance in "Nerambum," implemented via Dialogflow. The chatbot feature stands as a testament to "Nerambum's" commitment to providing seamless, on-the-spot assistance, addressing FAQs, and offering navigational support, thereby significantly enhancing the overall participant experience.

This application will only be compatible with desktops and laptops and is supported for MacOS, Windows and Linux operating systems. Since it has several features that require high hardware resources, several tests have been done, and according to those requirements, the user needs an uninterrupted internet connection (min 20 Mbps), a minimum i5 7th Gen processor, a minimum of 8GB RAM and a minimum of 1.5GB disk storage. However, the application was developed by considering lag compensation and other multiplayer game theories to provide a better user experience.

VI. Future Work

The evolution of the "Nerambum" virtual exhibition platform is poised for transformative advancements, enhancing user engagement and inclusivity. A paramount upgrade involves the integration of Virtual Reality (VR) to create an immersive experience, appealing to a diverse audience seeking forefront virtual engagements. Anticipating increasing popularity, scaling the platform for concurrent users is imperative. Optimizing Photon Fusion technology is key to supporting real-time interaction and synchronization, crucial for hosting large-scale exhibitions. To enhance realism, precise lip synchronization of avatars with user speech is sought, contributing to a more lifelike communication experience.

Inclusivity efforts involve embedding specialized chatbots in exhibition stalls to assist attendees with hearing impairments, ensuring barrier-free, text-based interactions. Lastly, transitioning to a dedicated server infrastructure is pivotal for improved performance, accommodating increased user loads and underscoring "Nerambum's" commitment to accessibility and superior virtual engagement.

VII. Conclusion

Nerambum redefines the landscape of virtual exhibitions, merging innovation with practicality. This desktop application transforms traditional showcasing with its high-degree of personalization, empowering exhibitors with interactive 3D booths and dynamic live streaming capabilities. Attendees are transported into an immersive environment where customizable humanoid avatars become their conduit to global events, mitigating environmental impact and travel costs.

Beyond the attendee experience, Nerambum streamlines event organization via a comprehensive web interface. This centralized hub, fortified by a robust microservices architecture, facilitates seamless management of exhibitions, stalls, and tickets, while promising scalability and resilience. Nerambum stands out in the digital arena with unparalleled features: life-like stalls, 3D spatial audio, diverse camera angles, and intuitive customization options for booths and avatars.

As societal trends pivot towards virtual engagement, Nerambum emerges as a sustainable, cost-efficient harbinger in the exhibition sector. Its fusion of unique immersive attributes and user-centric design not only enhances virtual interaction but is also set to become the new benchmark in digital showcasing.

ACKNOWLEDGEMENT

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