

Visualizing Products and Designing the Interior Using Augmented Reality for Mobile Application

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ABSTRACT

Augmented Reality (AR) is revolutionizing interior design by altering how individuals perceive and interact with spatial environments. This research focuses on collaborative efforts to develop an AR application that presents a novel method for visualizing and engaging with 3D designs within real spaces. The main goal is to enhance decision making processes for homeowners, designers and architects by harnessing smartphone capabilities. The application seamlessly integrates virtual objects into real environments, employing a unique methodology to showcase 3D house design using smartphone captured floor plan images. On the server side, advanced techniques such as deep learning are utilized to identify image corners and generate corresponding coordinates. These coordinates are then utilized by the smartphone application, powered by Unity 3D and integrated with Vuforia, to render 3D house model seamlessly onto the floor plan image. Rigorous testing validates the effectiveness of this application in generating accurate 3D house representations from various floor plans. This AR application provides users with fresh perspective on floor plans, simplifying comprehensive and active participation in the design process. By incorporating AR technology, this study signifies a significant advancement in how individuals approach and execute design ideas for their living.

Keywords:-Unity, Computer Graphics, Augmented Reality, Application, 3d visualization

INTRODUCTION

Augmented Reality (AR) stands at the forefront of computer graphics, ushering in a new era of immersive experiences by seamlessly blending digital content with the real world. Its impact extends far beyond novelty, making it an invaluable tool for home interior designing and visualization. AR's ability to overlay synthetic visual elements onto the physical environment provides a dynamic platform for envisioning and customizing living spaces.

In the realm of home interior design, AR emerges as a powerful ally, facilitating the creation of personalized and innovative living environments. The traditional approach to visualizing interior

designs is undergoing a significant transformation, and AR is playing a pivotal role in this evolution. The integration of synthetic visual objects, generated through computer algorithms, with real-world elements enables a realistic and interactive preview of potential home configurations. One of the compelling applications of AR lies in Human- Computer Interaction (HCI), a crucial aspect when developing solutions for portable devices like iPads. The objective is to assist homeowners and designers in simulating and previewing different decoration scenarios, demanding specialized HCI approaches to ensure a seamless and intuitive user experience.

The VR in motion platform exemplifies

this shift, offering a configurable and modular solution that leverages augmented reality technology for home interior design. This portable system seamlessly integrates virtual 3D models into real-world environments, providing a versatile tool for use in domestic settings. VR in motion aims to revolutionize the way we approach home interior design, offering a marketing tool that enables users to visualize and interact with 3D representations of furniture, de'cor, and spatial arrangements.

Augmented Reality, defined as the direct or indirect overlay of computer-generated sensory input onto the physical environment, becomes a dynamic component in the creation of personalized living spaces. By augmenting the real world with digital content through live camera feeds, AR transforms the visualization of interior design into a dynamic and interactive process.

AR can be categorized into two main types and six subtypes:

Trigger-based AR: Initiating augmentation through stimuli like papers, object markers, or GPS locations.

View-based AR: Dynamically manipulating digitized objects location without a reference field.

Delving deeper into specific types of AR, Marker-Based AR, Marker-less AR, Projection Augmented Reality, and Superimposition Based AR play distinctive roles. Marker-Based AR utilizes image recognition to provide detailed information about objects, Marker-less AR relies on location-based features, Projection AR uses light projection for interaction, and Superimposition AR replaces views with augmented perspectives.

The application of AR in the context of home interior design transcends traditional boundaries. The development of an app specifically tailored for home de'cor and interior design aims to leverage AR's capabilities to augment real-life 3D objects

into models, offering users a detailed and immersive preview of their envisioned living spaces. This innovative technology not only enhances the e-commerce experience but also serves as a transformative tool in making informed decisions about home furnishing.

Beyond interior design, AR addresses practical challenges associated with moving or buying a new house. Augmented Reality, particularly marker-based furniture placement, offers a solution where markers trigger the appearance of furniture in desired locations. This, coupled with the increasing capabilities of mobile devices, introduces a novel approach to house planning, overcoming the limitations of conventional methods. In conclusion, the fusion of Augmented Reality with home interior design and visualization marks a paradigm shift, providing individuals with unprecedented tools to shape and personalize their living spaces. This introduction sets the stage for a comprehensive exploration of AR's diverse applications, from revolutionizing home interior design to redefining how we plan and experience our living environments. As technology continues to evolve, the potential for AR to enhance our spatial experiences in the realm of home design remains boundless.

LITERATURE SURVEY

- 1) Augmented Reality (AR) has significantly altered the amalgamation of computer graphics into reality, enabling user interaction with virtual objects. AR spans Mixed Reality (MR), which includes Virtual Reality (VR) and telepresence. Critical components involve displays, graphic capture cameras, and application software, supported by diverse hardware like smartphones, PDAs, and HMDs. The ARToolKit library, utilizing computer vision, establishes a link between the real and virtual

- realms, finding applications across various domains.
- 2) AR technology is emerging as a distinctive design approach in architecture, facilitating extensive 3D virtual house walkthroughs and applications in archaeology and touring guides. These implementations empower users to visualize virtual heritage buildings within historical contexts, promising innovative applications in the field, including effective teaching methods.
 - 3) The application of AR in interior design aims to amplify creativity by dynamically adjusting virtual furniture properties. The proposed AR system efficiently employs CAD applications and AR software for database management and display in designed environments, aiming to provide flexibility in spatial design.
 - 4) The system structure involves the creation and management of a 3D database, displaying environments, and a user-friendly interface. Utilizing ARToolKit, CAD applications, and Building Information Modeling (BIM) applications enhances the efficiency of the proposed system. The implementation involves a standard PC with Windows XP and a webcam for image capture. Interaction methods, including occlusion markers, enrich the user experience.
 - 5) Traditional methods in interior design, such as manual furniture placement, are juxtaposed with AR approaches. Augmented Reality, particularly marker-based AR and planar object tracking, emerges as more advanced and efficient alternatives, providing users with the ability to virtually visualize and arrange furniture.
 - 6) This project extends AR applications to e-commerce platforms like Amazon and Flipkart, enabling users to virtually experience products in real-world environments before making purchase decisions. This aligns with the growing trend of enhancing online shopping experiences through AR.
 - 7) AR has evolved from an initial focus on hardware to the development of lightweight mobile AR systems. The rapid progress of mobile devices with enhanced processing capabilities and durable batteries has positioned mobile AR as a highly promising emerging technology.
 - 8) Planar object tracking, a relatively recent approach, utilizes natural features for effective estimation of object pose and position in AR systems. This method allows the overlay of furniture CG models on floor plans, contributing to applications in selecting rooms for rent or purchase.
 - 9) AR technology has exhibited remarkable growth, finding applications in entertainment, education, medicine, military training, engineering, and manufacturing. The adaptability and versatility of AR make it a valuable tool with continuous potential for innovative applications.
 - 10) While AR technology has experienced rapid growth, the early stages were marked by a focus on hardware rather than usability. However, the development of mobile AR devices has addressed these challenges, making lightweight mobile AR systems one of the most promising and accessible technologies.
 - 11) Marker-based AR applications involve recognizing predetermined markers or images for the system to operate effectively. This method offers a straightforward approach but is limited by the requirement of markers for spawning models. [12]Implementing AR systems practically involves integrating hardware and software components.

The AR system in this study is based on a standard PC with a Windows XP operating system, utilizing a webcam for image capture. Head-Mounted Displays (HMDs) enhance user interaction, allowing unrestricted movement around virtual furniture.

- 12) Tangible AR environments benefit from interaction methods like occlusion markers, detecting pointing actions by discerning the occlusions of tracked objects. This passive method of detecting pointing actions using predefined markers provides a natural and intuitive means of interaction in AR environments.
- 13) The literature emphasizes the limitations of traditional interior design methods, such as the physical method that requires manual lifting and placement of furniture. Augmented Reality, especially marker-based AR and planar object tracking, emerges as a more advanced and efficient alternative, offering users the ability to virtually visualize and arrange furniture.
- 14) This proposed project involves

A. Block Diagram

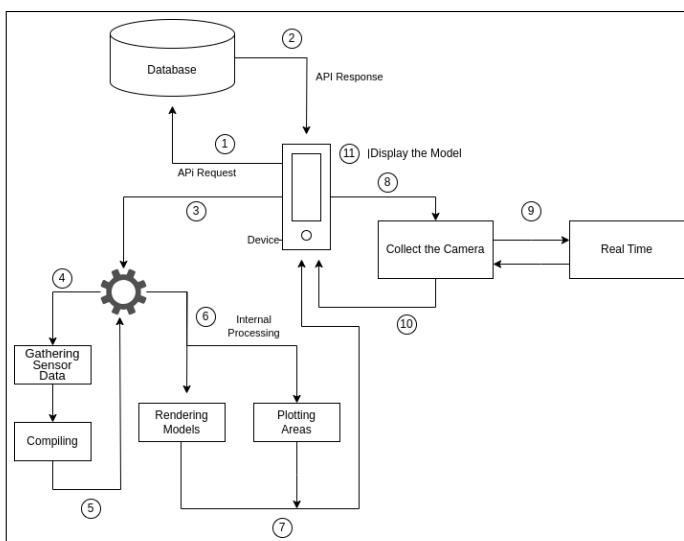


Fig.1:-Block diagram of Working and Processing in the Market

creating a mobile application extension for e-commerce platforms, such as Amazon and Flipkart, to visually represent products using AR. The system architecture encompasses modules for creating and managing a 3D database, displaying environments, and inter- facing with Firebase for backend connectivity. It offers users options to create new environments, embark on virtual tours, or load existing ones.

METHODOLOGY

This research employs a comprehensive mixed-methods approach to delve into the revolutionary impact of augmented reality (AR) on interior design, specifically focusing on the development of an innovative AR application. The methodological framework initiates with an exhaustive literature review aimed at identifying existing practices and discerning gaps in AR applications within interior design. Subsequently, a conceptual framework is meticulously formulated to strategically guide the development process.

B. Graph of Growth

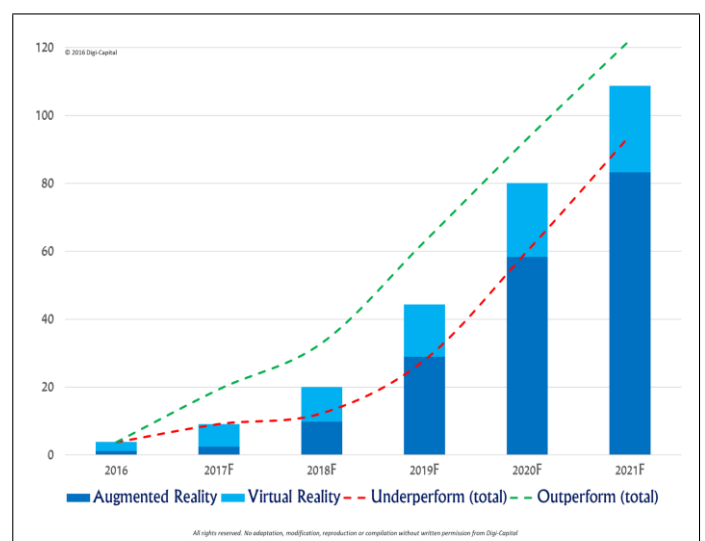


Fig.2:-Growth in AR and VR

The data collection phase encompasses the acquisition of a diverse set of floorplan images and the creation of an extensive training dataset for deep learning, facilitating precise identification of image corners. The research seamlessly integrates advanced deep learning techniques, embedding the model within Unity 3D and Vuforia for the seamless rendering of 3D house models onto floor plan images. Following the technical implementation, the development of the AR application ensues, coupled with rigorous usability testing involving homeowners, designers, and architects. The evaluation phase encompasses meticulous accuracy assessments and comparative analyses against traditional visualization methods. The research culminates in a comprehensive summary of findings, drawing nuanced conclusions regarding the effectiveness of the AR application. Furthermore, it furnishes robust recommendations for future applications and potential enhancements within the dynamic realm of interior design.

ENABLING TECHNOLOGIES

The progression of augmented reality (AR) technology has undergone a substantial development trajectory, characterized by an extended maturation period in comparison to virtual reality (VR). This prolonged evolution is primarily attributed to the heightened technological demands intrinsic to AR. Unlike virtual environments or VR, AR necessitates intricate components, contributing to its delayed maturation. Notably, the fundamental elements essential for constructing AR systems have endured since Ivan Sutherland's groundbreaking work in the 1960s. Core components, including displays, trackers, and graphics computing systems and software, continue to play pivotal roles in shaping the landscape of AR experiences.

In retracing the evolutionary path of AR, it is imperative to underscore the enduring

significance of display technologies, trackers, and user interfaces. Ivan Sutherland's seminal contributions laid the foundation for these components, which have maintained their essential status throughout the years. Display technologies, serving as the interface bridging the real and virtual realms, assume a particularly critical role. The accompanying figure illustrates the inaugural head-mounted display, known as the "Sword of Damocles," emblematic of the early endeavors to seamlessly merge virtual and real environments.

Displays

Among the diverse sensory modalities in human input, AR systems commonly exploit sight, sound, and touch. This discourse predominantly concentrates on visual displays, with a cursory acknowledgment of aural (sound) displays. Subsequent sections address haptic (touch) displays, while olfactory (smell) and gustatory (taste) displays, being less developed, fall outside the purview of this discourse.

Aural Display

Aural display applications in AR predominantly encompass mono (0-dimensional), stereo (1-dimensional), or surround (2-dimensional) headphones and loudspeakers. Although true 3D aural display currently finds greater prevalence in immersive simulations of virtual environments and augmented virtuality, it remains in the experimental stages for AR. Significantly, the concept of haptic audio, wherein sound is perceptible through touch, has gained momentum. Consumer devices such as Turtle Beach's Ear Force headphones already leverage haptic audio to augment realism and impact, extending its applications to user interfaces of devices like mobile phones. In delving into the historical narrative of AR technology, it becomes apparent that

its evolution has been molded by the persistence and refinement of pivotal components. The journey from Ivan Sutherland's pioneering work to contemporary applications mirrors a continuous pursuit of enhancing the synergy between the real and virtual realms in AR experiences.

Evolutionary Trends in AR Technology

Continuing our exploration of AR technology, it is crucial to examine how technological trends have shaped its trajectory. Over the years, there has been a discernible shift towards miniaturization and increased processing power. This evolution has allowed for the integration of AR capabilities into more compact and mobile devices, making the

technology more accessible to a broader audience. Advancements in sensor technologies, such as accelerometers and gyroscopes, have enhanced the accuracy of tracking user position and orientation, contributing to a more seamless AR experience.

Additionally, the convergence of AR with other emerging technologies, such as artificial intelligence (AI) and machine learning, has opened new possibilities. These synergies enable AR systems to better understand and respond to the user's environment, providing more dynamic and context-aware experiences. The integration of computer vision algorithms has furthered the capability of AR to recognize and interact with real-world objects.

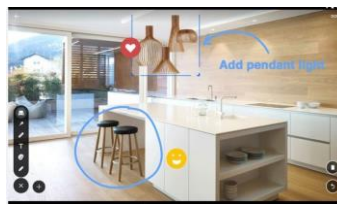


Fig.3:- Implementation Model

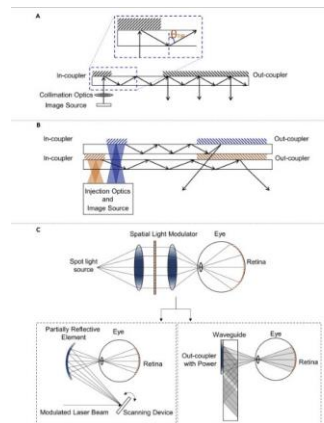


Fig.4:- Vision Control

Vision of AR on Mobile Devices

The vision for AR on mobile devices holds immense promise, transforming smartphones and tablets into powerful AR platforms. The ubiquity of these devices makes AR technology more accessible to a global audience. Mobile AR leverages the device's camera, sensors, and processing capabilities to overlay digital

information onto the user's physical surroundings.

The implementation of AR on mobile devices offers numerous practical applications. For instance, navigation applications can provide real-time, AR-enhanced directions by over-laying arrows or information onto the user's view of the street. In retail, consumers can use AR to

visualize how furniture or clothing items would look in their own homes before making a purchase. Educational applications can leverage AR to bring history or scientific concepts to life through interactive and immersive experiences.

Furthermore, AR on mobile devices fosters social interaction. Shared AR experiences, where multiple users can interact with the same virtual elements in a common physical space, open up possibilities for collaborative gaming, communication, and productivity applications. 5. Challenges and Future Directions

Despite the tremendous progress, challenges persist in fully realizing the potential of AR on mobile devices. Issues such as battery life, processing power, and data privacy need to be addressed to ensure a seamless and secure user experience. Ongoing research and development efforts are focused on overcoming these challenges, with innovations in hardware and software continually pushing the boundaries of what is achievable.

Looking ahead, the future of AR on mobile devices holds exciting possibilities. As technology continues to advance, we can anticipate more sophisticated AR applications that seamlessly integrate with our daily lives, augmenting our reality in ways previously unimaginable. The ongoing evolution of AR technology on mobile devices will undoubtedly contribute to a more interconnected and enriched digital and physical world.

IMPLEMENTATION

Augmented reality (AR) serves as a dynamic visualization tool, effectively blending real-world elements with virtual enhancements in a three-dimensional space (Azuma et al. 2001). This seamless integration of real and virtual components has diverse applications, ranging from interior design to construction project

visualization (Woodward et al. 2007; Golparvar et al. 2009). In the realm of interior design, AR applications often involve interactive three-dimensional augmentations within a real environment, aligning with the fundamental definition of AR.[1-7]

Mediated reality alters elements, while diminished reality removes existing components. Augmented virtuality (AV) integrates real elements into a virtual environment, and mixed reality encompasses systems ranging from reality to virtuality, including all permutations of real and virtual (encompassing AR and AV) (Milgram et al. 1994).

For clarity in our study, the term "augmented reality" encompasses a broader scope, referring to a system harmonizing real and virtual elements, inclusive of various AR-related technologies. This definition aims to simplify the terminology for a broader audience.

The implementation of AR applications involves diverse display technologies and devices. Our fictitious AR interior design service specifically targets consumer-level visualization applications, prioritizing compatibility with commonly available devices such as PC, laptop PC, or tablet PC. Figure 4 illustrates a prototype of an augmented reality interior design application on a tablet PC. In a comparative analysis conducted by Paweł Nowacki and Marek Woda, the capabilities of ARCore and ARKit were meticulously examined and compared.

The study involved the development of applications for both iOS and Android, leveraging the distinctive features of each framework. Functionality included flat surface detection, imaging of detected surfaces or special points, placement of 3D objects, adaptive scene lighting,

support for generating shadows, distance measurement, storage of information regarding detected planes, and measurement and display of frames per second. Comprehensive tests using various mobile devices, such as iPhone X, iPhone

8, Google Pixel 2XL, Google Pixel, Samsung Galaxy S9, revealed distinct strengths and weaknesses for each platform.



Fig.5:-Mobile Integration



Fig.6:-Surface Detection

The tests covered plane detection, error rates, initial detection, surface mapping times, surface impact, low light, and motion functionality for both ARKit and ARCore. Given the unique strengths of each platform, selecting between ARKit and ARCore is recommended based on market conditions and personal preferences.

User Interaction and Engagement: The effectiveness of an augmented reality implementation hinges on the seamless integration of virtual elements into the user's real-world environment. Designers must carefully consider how users will

interact with these augmented elements. Intuitive gestures, voice commands, or touch interactions can enhance user engagement and contribute to a more immersive experience. Striking the right balance between providing informative content and maintaining a natural user flow is essential for creating AR applications that captivate and hold the user's attention.

Data Security and Privacy: As AR applications often involve the use of real-world data, ensuring robust data security and privacy measures is imperative. Developers must implement encryption

protocols, secure data storage, and clear user consent mechanisms to safeguard personal information. Striking a balance between delivering a personalized AR experience and respecting user privacy is critical for building trust and compliance with data protection regulations.

Continuous Iteration and Updates: The landscape of AR technology is dynamic, with rapid advancements and evolving user expectations. Successful AR implementation requires a commitment to continuous iteration and updates. Regularly incorporating user feedback, addressing performance issues, and adopting new features or technologies keep the application relevant and competitive. This iterative process ensures that the AR experience remains cutting-edge and aligns with the latest industry standards.

Collaborative Development and Cross-Platform Compatibility: Collaboration between developers, designers, and content creators is key to a successful AR implementation. Cross-disciplinary teamwork ensures that the virtual elements seamlessly integrate with the real environment and deliver a cohesive user experience. Additionally, considering cross-platform compatibility is crucial to reaching a wider audience. Ensuring that the AR application functions smoothly across various operating systems and devices maximizes its accessibility and impact.

In essence, the implementation of augmented reality goes beyond technical considerations; it encompasses user engagement, data security, continuous improvement, and collaborative development. Embracing these aspects contributes to the creation of AR applications that not only meet technical requirements but also deliver compelling, user-centric experiences in the ever-evolving landscape of augmented reality. Surface detection is a pivotal aspect of augmented reality (AR) technology, playing a crucial role in creating realistic

and immersive user experiences. This capability enables AR systems to understand and interact with the physical environment by identifying surfaces such as floors, walls, and tables. Here are additional insights into the significance and advancements in surface detection within the realm of augmented reality:

Advanced Spatial Understanding: Modern AR platforms utilize advanced algorithms and sensor technologies to achieve precise spatial understanding. These algorithms, often based on simultaneous localization and mapping (SLAM) techniques, allow AR devices to map and recognize surfaces in real-time.

Enhanced Interaction with Surfaces: Surface detection goes beyond mere identification; it facilitates dynamic interaction between virtual and real-world elements. AR applications can anchor virtual content onto detected surfaces, allowing users to manipulate or engage with these augmented objects as if they exist in the physical space. This capability opens up opportunities for creative and practical applications, from interactive gaming experiences to practical interior design simulations.[8-12]

Challenges and Solutions: Despite significant progress, surface detection in AR is not without challenges. Variability in lighting conditions, reflective surfaces, and complex environments can pose difficulties in accurate detection. However, ongoing research and development efforts focus on addressing these challenges. Machine learning algorithms, improved depth sensing, and the integration of additional sensor data contribute to more robust surface detection algorithms, enhancing accuracy and reliability.

Applications Beyond Visual Enhancement: Surface detection extends beyond visual enhancements; it plays a critical role in diverse AR applications. For example, in industrial settings, AR devices equipped with precise surface detection can assist technicians by overlaying maintenance

instructions directly onto machinery. In healthcare, AR can use surface detection to project medical data onto specific anatomical surfaces during surgery, aiding surgeons with real-time information.

Mobile Devices and ARKit/ARCore Integration: The integration of surface detection in mobile AR applications has become more accessible through platforms like ARKit for iOS and ARCore for Android. These frameworks provide developers with tools to implement surface detection seamlessly in their applications. This democratization of AR development has led to a surge in consumer-facing augmented reality experiences, from interactive educational apps to furniture placement tools for interior design.

Future Directions: As AR technology continues to evolve, the future holds exciting possibilities for surface detection. Advancements in computer vision, sensor technologies, and artificial intelligence will likely lead to even more accurate and versatile surface recognition. This, in turn, will enable AR applications to provide increasingly realistic and context-aware experiences, further blurring the lines between the virtual and physical worlds.

In summary, surface detection in augmented reality is a dynamic and evolving field, enhancing the capability of AR systems to understand and interact with the real world. From gaming and design to healthcare and industry, the applications of surface detection are diverse and hold great promise for the future of augmented reality.

CONCLUSION

In summary, our augmented reality furniture visualization system represents a monumental stride forward in interior design technology, distinguished by its seamless integration of augmented reality. Through providing users with real-time immersive previews of furniture within

their physical spaces, it transcends conventional boundaries and fundamentally reshapes how individuals interact with furniture and participate in the design process. This transformative leap not only fosters creative exploration and facilitates informed decision-making but also carries profound implications for spatial decision-making, particularly in densely populated areas where optimizing available space is paramount for efficient living arrangements.

Furthermore, it revolutionizes the furniture industry by furnishing businesses with a potent tool to showcase their products in dynamic and engaging ways, thereby fundamentally transforming the consumer browsing and purchasing experience. Additionally, its adaptability and user-friendly features serve to enhance the efficiency of spatial planning, empowering users to make well-informed choices that harmonize aesthetics with functionality. Moreover, the system catalyzes collaborative design efforts, uniting diverse stakeholders in the creative process, thereby promoting inclusivity in design decisions and fostering a sense of community in shaping shared living spaces.

Upon reflection of its successes, it becomes increasingly apparent that the convergence of augmented reality and design has the potential to significantly redefine societal perspective on interior spaces, metamorphosing them into dynamic, adaptable environments that meticulously cater to individual preferences and evolving needs. Gazing towards the horizon, the augmented reality furniture visualization system emerges as a beacon for future innovations, setting a precedent for the seamless integration of digital tools into our daily lives and offering a tantalizing glimpse into a future where the fusion of design and technology becomes seamlessly interwoven into the

fabric of our homes and workplaces. Ultimately, our project not only signifies a breakthrough in design technology but also heralds a future where creativity and technological advancement converge to profoundly shape the way we experience and personalize our living environments.

REFERENCES

1. Use of Augmented Reality in the furniture industry Elizabeth Carvalho, Gustavo Mac,ães, Isabel Varajaõ, Nuno Sousa and Paulo Brito
2. Interior Design in Augmented Reality Environment Viet Toan Phan Seung Yeon Choo
3. The design and implementation of an interactive mobile Basma Al-Harbi, Nahla, Areej Alshutary , Ameen Banjar, Azida Zainol
4. Augmented Reality application for an improved furniture shopping experience Asmaa Alharbi, Sanaa Alghanmi, Shaza Mansour, Mram Ashehri
5. Yushan Siriwardhana , Pawani Porambage Madhusanka Liyanage and Mika Ylianttila
6. Emanuele Marino , Fabio Bruno , Loris Barbieri , Mau-Rizio Muzzupappa , Fotis Liarokapis
7. Mobile Augmented Reality Survey: From Where We Are to Where We Go DIMITRIS CHATZOPOULOS, CARLOS BERMEJO, ZHANPEN HUANG, AND PAN HUI
8. A Survey on Mobile Augmented Reality With 5G Mobile Edge Computing: Architectures, Applications, and Technical Aspects Yushan Siriwardhana , Member, IEEE, Pawani Porambage , Member, IEEE, Madhusanka Liyanage , Senior Member, IEEE, and Mika Ylianttila , Senior Member, IEEE
9. Background-Aware Colorization Technique for Augmented Reality Applications Emanuele Marino , Fabio Bruno , Loris Barbieri , Mau-Rizio Muzzupappa , Fotis Liarokapis
10. A Survey of Augmented Reality Technologies, Applications and Limitations D.W.F. van Krevelen and R. Poelman
11. Automatic Interior Design in Augmented Reality Based on Hierarchical Tree of Procedural Nodes
12. User-Centered Design of Augmented Reality Interior Design Service Sanni Siltanen and Virpi Oksman.
13. Deepak, N.R., Balaji, S. (2016). Uplink Channel Performance and Implementation of Software for Image Communication in 4G Network. In: Silhavy, R., Senkerik, R., Oplatkova, Z., Silhavy, P., Prokopova, Z. (eds) Software Engineering Perspectives and Application in Intelligent Systems. CSOC 2016. Advances in Intelligent Systems and Computing, vol 465. Springer, Cham. https://doi.org/10.1007/978-3-319-33622-0_10
14. N R, Deepak and G K, Dr. Suhas and B, Bhagappa and Kumar Pareek, Piyush, A Framework for Food recognition and predicting its Nutritional value through Convolution neural network (February 22, 2022). <http://dx.doi.org/10.2139/ssrn.4040968>
15. T. N and D. N R, "A Convenient Machine Learning Model for Cyber Security," 2021 5th International Conference on Computing Methodologies and Communication (ICCMC), 2021, pp. 284-290, doi: 10.1109/ICCMC51019.2021.9418051
16. Deepak NR, Bhagappa, and Suhas GK , Trans., "The Smart Sailing Robot for N avigational Investigation is Used to Explore all the Details on the Zone of the Water Pura", IJSP, vol. 1, no. 4, pp. 1–5, Dec. 2023, doi: 10.54105/ijsp.B1006.101321.
17. Deepak NR, Thanuja N, "Smart City

- for Future: Design of Data Acquisition Method using Threshold Concept Technique, International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249-8958 (Online), Volume-11 Issue-1, October 2021.
- 18.K. M P and D. N R, "Crop Prediction Based on Influencing Parameters for Different States in India- The Data Mining Approach," 2021 5th International Conference on Intelligent Computing and Control Systems (ICICCS), 2021, pp. 1785-1791, doi: 10.1109/ICICCS51141.2021.9432247
- 19.N. R. Deepak and S. Balaji, "Performance analysis of MIMO-based transmission techniques for image quality in 4G wireless network," 2015 IEEE International Conference on Computational Intelligence and Computing Research (ICCIC), 2015, pp. 1-5, doi: 10.1109/ICCIC.2015.7435774.
- 20.N R, Deepak & Sriramulu, Balaji. (2015). A Review of Techniques used in EPS and 4G-LTE in Mobility Schemes. International Journal of Computer Applications. 109. 30-38. 10.5120/19219-1018.
- 21.Suhas G. K., Charan K. V, Deepak N. R., Bhagappa Bhagappa, "An Approach to Smart Waste Segregation using IOT" Research and Applications: Embedded System, Volume 5 Issue 2, DOI: <https://doi.org/10.5281/zenodo.6965901>
- 22.Deepak N R, Thanuja N, " A Survey Smart IoT based Home Security using Integrated System" Research and Reviews: Advancement in Robotics, Volume 4 Issue 3, DOI: <https://doi.org/10.5281/zenodo.5808551>