Nanotechnology Perceptions
ISSN 1660-6795
www.nano-ntp.com

A Study on Implementation Methods for Realistic 3D Web Services for Korea's Cultural Heritage Pagodas

Byong-Kwon Lee

Professor, School of Media Contents, Seowon University, Chaung-Buk, Korea

The information on traditional towers in Korea is primarily provided through 2D formats such as photos or videos. They are categorized based on regions and eras, accessible through museums and websites. However, precise details of Pagoda's structure cannot be ascertained as they are not available in a 3D format. This paper aims to address this gap by creating 3D models of various towers from different periods in Korea and implementing them on a web-based platform for immersive experiences using HMD devices and 360-degree services. To achieve this, we utilized the A-Frame language, which provides web-based 3D model APIs, and published them on the web. The web server used was Apache, and additionally, we developed support for virtual reality on the web in a two-way approach to provide immersive experiences. Through this, users can simultaneously access virtual reality and 360-degree services on the web, ensuring accessibility across various devices via responsive web services, rather than requiring installation on PCs.

Keywords: Traditional towers, 3D models, Web-based platform, Immersive experiences, Virtual reality

1. Introduction

Our traditional pagodas in Korea exhibit a diverse array of forms across different eras, with the Traditional Culture Portal offering services predominantly in the form of videos and 2D imagery. While some 3D models of pagodas are available, the provision of immersive virtual reality experiences remains lacking. In this study, we utilized 3D modeling tools to craft pagodas in a manner enabling users to explore them in 360 degrees, leveraging the A-Frame API to publish these assets as 3D web services. Furthermore, we ensured responsiveness to accommodate various devices. This facilitates easy access for users, whether through VR devices like HMDs or smart devices, allowing them to intimately engage with our traditional pagodas. With features such as panning, tilting, zooming, and more available through HMDs, users can experience a heightened sense of realism. The implementation process involved creating pagoda models using graphic-specific tools like Blender, integrating them into the Unity game engine, and then utilizing the A-Frame framework for web-based 3D model services. Ultimately, our platform offers users a convenient and immersive means to explore and experience Korea's traditional pagodas anytime, anywhere

2. Materials and Methods

In this section, we will describe the historical characteristics of traditional pagodas in Korea and explain the structure of pagodas. Additionally, we will discuss the configuration of the A-Frame API for web 3D services and the server setup required for publishing

2.1. The characteristics of traditional Pagoda in Korea.

Traditional towers in Korea come in various forms and designs. Some are cylindrical, while others have polygonal or square shapes. Historically, Korean towers were primarily constructed using wood and stone. These materials offer durability over time. Most traditional towers feature tall pillars[1][2]. Often located near temples or shrines, these pillars symbolize the importance and grandeur of the religious sites. Many traditional towers carry Buddhist significance. Some serve as pagodas to enshrine sutras or relics, while others honor bodhisattvas or revered monks. Traditional towers are often adorned with beautiful decorations and carvings, representing Korea's artistic and architectural heritage. During the Silla Dynasty (57 BC - 935 AD), many stone pagodas were erected, including notable examples such as the Seokguram Grotto stone pagoda and the Bulguksa Temple stone pagoda. Additionally, numerous stone pagodas were erected in connection with Confucian academies (hyanggyo), contributing to the development of Buddhism, arts, and scholarship. In the Goryeo Dynasty (918 AD - 1392 AD), the form of pagodas resembled the shape of barley stalks, often arranged in rows like barley stalks. Many tiered pagodas were constructed, with smaller pagodas mounted atop the main structure. During the Joseon Dynasty (1392 AD - 1910 AD), there was integration of stupas and pagodas: Many structures were erected in a combined form, incorporating both stupas and the traditional decorative ornaments known as moju (phoenix-shaped decorations). Representative examples include the stupa-moju. Additionally, wooden pagodas became prevalent, with fewer erected in the early Joseon period but an increase in construction during the later years. The Japanese colonial period (1910 AD - 1945 AD) witnessed damage to traditional architectural styles due to war and colonial rule, resulting in the deterioration of traditional architectural forms. Many cultural heritage sites were damaged or destroyed during this time[3][4].

Table 1: The characteristics of Pagoda in Korea

Characteristic
Unified Silla: Stone pagodas expanded nationwide and various styles appeared. Compared to the Three Kingdoms period, the scale was reduced and the height was lowered, and each part was reduced to a single stone.
   

Goryeo Dynasty: Inheriting the Unified Silla stone pagoda, various types were built. The number of stories increased, multi-story stone pagodas increased, and single-story stylobates became popular.
   
Joseon Dynasty: Due to religious activities focusing on Buddhist statues, the construction of stone pagodas was low, and stone pagodas were built with the support of the king and royal family. The overall scale is reduced, the number of floors increases, the stylobate tends to be simplified, the pagoda stones in the body of the pagoda are lowered, and the roof stones are set low.
   

2.2. A-Frame Web Service

A-Frame is a framework for creating virtual reality (VR) content on the web. It allows developers to build VR experiences that can be accessed through web browsers. A-Frame uses a markup language similar to HTML to structure VR scenes, and JavaScript can be used to add interactivity. A-Frame allows developers to write VR scenes using a markup language similar to HTML. This makes it easy for web developers to create VR content using familiar syntax. A-Frame uses an entity-component system to define various elements within a VR scene. This includes cameras, lights, shapes, animations, and more. Because A-Frame runs on web browsers, it can be accessed on a wide range of devices, including PCs, smartphones, and tablets. This makes it possible to deliver VR experiences to a broad audience. A-Frame has a vibrant community and a rich ecosystem of components and resources. This allows developers to share knowledge and leverage components and resources created by others. The A-Frame web service platform consists of three main layers: client, server, and database. Client Layer (Web browser: The interface through which users access the A-Frame web service[5][6]. A-Frame library: A JavaScript library used to create and manipulate 3D scenes., Custom JavaScript code: Used to add custom functionality, Server Layer (Node.js: The JavaScript runtime environment used to run the A-Frame web service. Express.js: A Node.js framework used to create web servers. Socket.io: A Node.js library that enables real-time communication), Database Layer(MongoDB: A NoSQL database used to store 3D scene data.). [Figure 1].

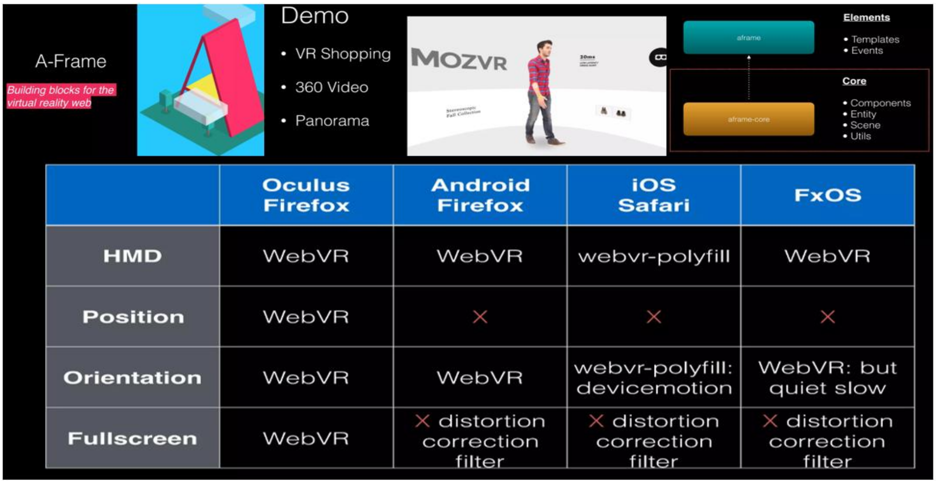
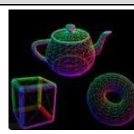


Figure 1. A-Frame Platform Service and Support Devices

2.3. WebXR Platform for Web Service

WebXR technology is currently experiencing rapid growth and is being utilized in various fields. Particularly, since the COVID-19 pandemic, there has been significant attention on its potential applications in contactless environments. The pandemic situation accelerated the need for remote participation solutions, and WebAR played a crucial role in addressing these issues. Moreover, by providing AR experiences without the need for special app installations, user engagement is increasing, and it is being utilized for online shopping through product visualization. Three prominent libraries for implementing WebAR are listed in Table 2. WebXR offers a variety of libraries and frameworks for web developers to implement VR and AR experiences, enabling the construction of virtual reality content on web pages and providing users with richer interactions[7][8].

Table 2: A Library for WebXR

Libraries	**Pros** / Cons	**App**
Three.JS	Rich 3D graphics capabilities. Strong community and ecosystem support. Flexibility for various web-based 3D projects.	
	Steeper learning curve, especially for beginners.	
AR.JS	Simple implementation, especially for marker-based AR. Real-time tracking and recognition using image markers.	
	Limited 3D graphics features compared to Three.js.	
AFrame	HTML-based syntax for easy web developer adoption. Simple implementation with components. Component ecosystem for easy feature additions.	
	Some advanced features may be lacking compared to direct use of Three.js. Limited customization for developers requiring high-level customization.	

3. Results and Discussion

This paper proposes a web-based Augmented Reality (WebAR) service for traditional towers. The proposed service operates on web browsers and investigates methods for implementing a system that provides users with real-time access to 3D models of traditional towers. [Figure 3] illustrates the tower creation and recognition process, with detailed steps described in the following section.

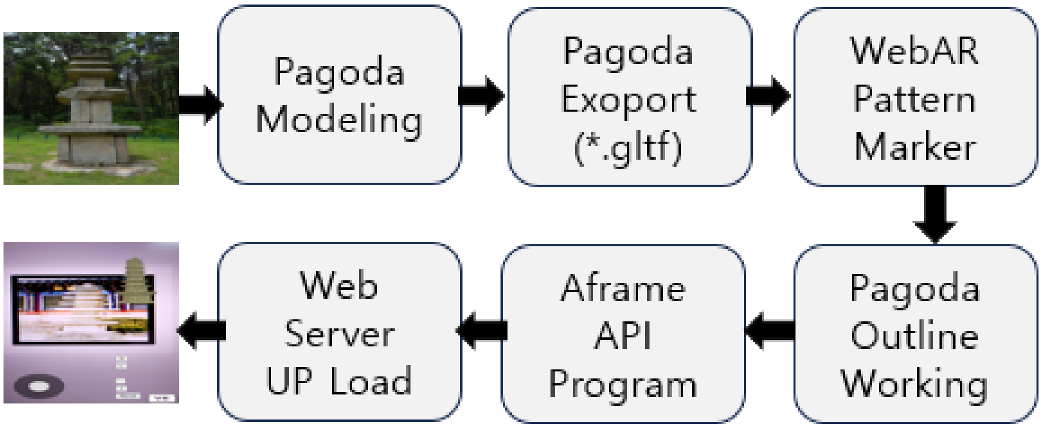


Figure 2. Process Pagoda AR for WebXR

3.1. System Architecture

In web-based augmented reality systems, there are three main components: data collection, data storage, and WebAR implementation. Table 2 presents the data collection process required for augmented reality (AR) of traditional towers, with data collected specifically for a traditional stone pagoda in the country.

Table 2: Used for displaying the Augmented Reality (AR) representation of traditional towers

Image	description	Image	description
	Ganghwa Jangjeongni Ocheungseok Pagoda		Cheongyang Seojeongni Gucheungseok Pagoda
	Gaeseong Namgyewonji Chilcheungseok Pagodap		Mungyeong Gimryongsa Samcheungseok Pagoda

	Iksan Wanggungni Ocheungseok Pagoda		himgoksa Chilcheungseok Pagoda
	Anseong Bongeopsaji Ocheungseok Pagoda		Gyeongju Jeonghyesaji Shipsamcheungseo Pagoda

In this study, the collected data is stored using a cloud-based server. As a final step, WebAR is implemented using HTML, JavaScript, and CSS as the technology stack.

3.2. Environment for using WebXR and Experiment analysis

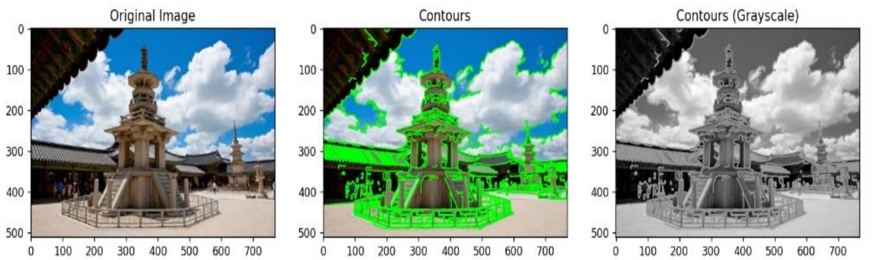
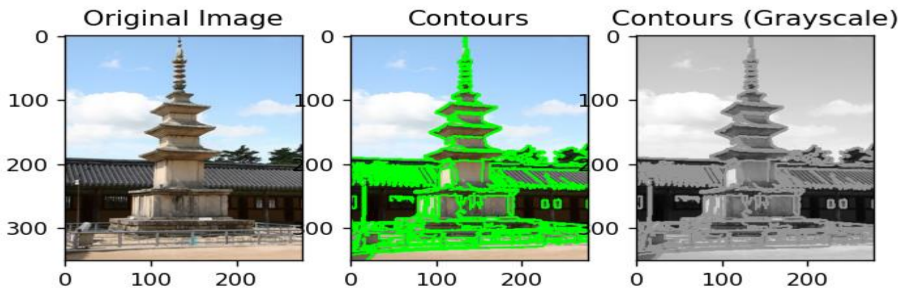
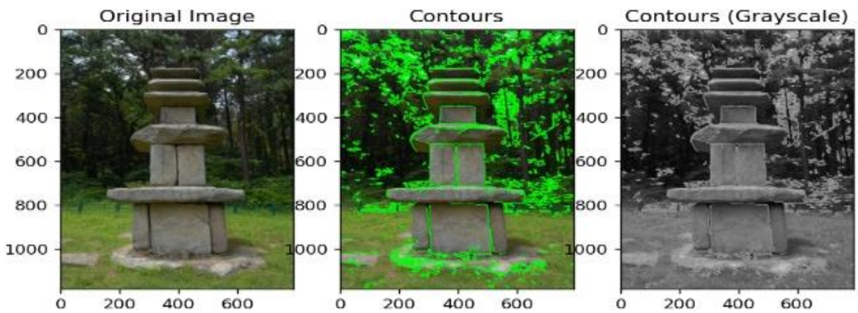
[Table 3] presents the web browser, mobile device, and server environment used for implementing the final WebAR based on the collected data. AR.js, used for WebAR implementation, is a markerless AR technology that utilizes sensor information to recognize environmental features such as walls or floors and tracks the device's position without relying on predefined markers. This approach employs a technique called Simultaneous Localization and Mapping (SLAM) to analyze images from the camera feed. Additionally, ARCore/ARKit, which serves as the foundation for the WebXR API discussed later, and 8th Wall, which implements an SLAM engine, fall under this category[9][10][11].

Table 3: Compilation Setting for WebXR

Div	Description
Sever	Synology NAS Sever(Web)
Browser	Chrome for Google V8 Engine
Platform	Windows,IOS, Android, Etc
Data	AR.js Pattern .patt data file
Web API	WebAROnARCore,
Source	Python, matplot, OpenCV2

In this study, to improve the recognition rate of traditional towers, a step for detecting the contours of tower images was included. For general images, there is a drawback in recognition rate depending on factors such as sunlight and surrounding environment. [Table 4] presents the main view for contour detection of traditional towers. The implementation utilized functions from OpenCV2 for image processing and matplotlib.pyplot module for mathematical calculations. Matplotlib.pyplot is commonly used as a tool for mathematical operations and graph plotting.

Table 4: Contour detection for traditional Pagoda

Dabotap Pagoda

Seokgatap Pagoda

Ganghwa Jangjeongni Ocheungseoktap


3.3. WebXR(AR) Recognition Speed for Web Service

The collected data indicates the object recognition speed when using WebAR. It was observed that the recognition was completed within 2.33 seconds in most cases. This evidence suggests that the loading speed of 3D data depends on factors such as network speed, camera angle, and resolution. However, traditional augmented reality tools such as Vuforia, ARCore, and ARKit rely on specific platforms (Android, Windows, iOS), which can affect the development process and user accessibility negatively. In contrast, web-based AR can be accessed easily via web browsers anytime and anywhere, making it more accessible[11][12][13].

Table 5: Comparison Speed Web XR(AR)

Target Pagoda	Web AR APP	Time (s)		
		Loading	Rec	Total
		2.0	0.3	2.3
		3.0	0.1	3.1
		1.5	0.8	2.3
		2.3	0.1	2.4

Based on the stone pagodas in Korea from the Goryeo, Baekje, Joseon, and Unified Silla periods, 3D models were created through modeling work. Blender, a graphic design tool, was used for the modeling process, with reference to 2D images. [Table 5] depicts the models created using Blender tools. [Figure 3] provides a comparison between the Web XR service for modeled traditional Korean towers. On the left is a basic 2D photo, while on the right, an image created through 3D modeling is presented [14][15][16]. Additionally, to provide an immersive experience, the implementation allows anyone to easily view traditional Korean towers in virtual reality on the web. The tools used for implementation include Blender for graphic design, Unity game engine for spatial arrangement, A-Frame for 3D model web service framework[17][18][19][20], and Apache server for web hosting. Furthermore, A-Frame's API was utilized for HMD (Head-Mounted Display) services. The script used is as follows: [<script src="https://aframe.io/releases/1.2.0/aframe.min.js"></script>][Table 6]

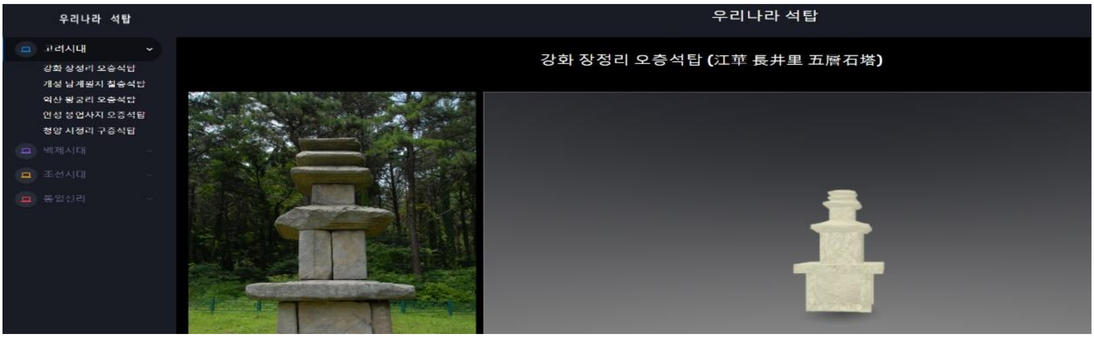
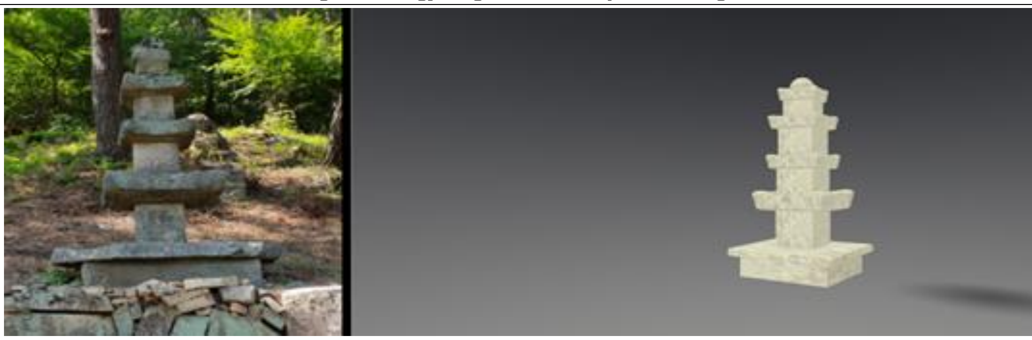


Figure 3. Web Site Service for Pagoda era.

Table 6: Pagoda Service 3d Model for Web Based(A-Frame)


Ganghwa Jangjeong-ri Five-story Stone Pagoda

Mungyeong Kimryongsa Three-story Stone Pagoda

Five-story Stone Pagoda at Jeongnimsa Temple Site, Buyeo

Thirteen-story Stone Pagoda at Jeonghyesa Temple Site, Gyeongju

4. Conclusion

For traditional pagodas in Korea, they are mostly provided through internet web services in the form of photos and videos. While some are available in 3D model formats, they often possess a drawback of consuming significant resources due to a high number of meshes and vertices, making them challenging to use for web services and modeling purposes. In this study, we aimed to minimize meshes and vertices through minimalistic modeling to enable real-time display on web services. Additionally, to enhance user accessibility, we implemented the models to be viewable through web services and provided an immersive experience using sensory technologies. As a result, anyone can easily explore historical Korean pagodas using low-spec systems. As future research tasks, ensuring the reliability of the researched models through validation is crucial, and it is conceivable that they could be used as part of Korea's cultural heritage in the future, For Korea's cultural heritage, traditional towers are categorized into wooden and stone pagodas, with most information being provided in 2D format. Additionally, when provided in 3D format, accessibility for users is often hindered as it depends on specific service platforms (Windows, Android, iOS). Moreover, traditional methods may suffer from poor recognition due to changes in the surrounding environment, especially in outdoor settings. In this study, we implemented WebAR, a WebXR-based component, to enable augmented reality directly through web browsers on web platforms. Furthermore, we implemented it to be viewable in virtual environments. The research results demonstrated that WebAR technology can rapidly and accurately recognize objects and represent 3D objects effectively. However, there are still some limitations to this technology. Firstly, WebAR based on web browsers may have performance limitations compared to typical apps. Secondly, there may be issues with complete support across all web browsers and devices. Thirdly, there may still be differences between the experience of real cultural heritage sites and WebAR, necessitating further research to bridge this gap. Future research directions include optimizing operations between web browsers and devices for higher performance and compatibility, developing new interaction designs or technologies to reduce differences in experiences between real cultural heritage sites and WebAR, and deeper analysis and understanding of cultural heritage itself to explore how WebAR experiences can better contribute to real cultural heritage experiences. In conclusion, WebAR presents a promising technology for various fields dealing with cultural heritage, offering diverse possibilities and futures. This technology not only expands understanding and respect for cultural heritage but also provides new avenues for more people to experience and learn about cultural heritage

References

1. G. Issini, D. Polverini and F. Pugnaloni, "Virtual Reconstruction and Real-Time Interactive Visualization of the Monumental Area between Thien Mu Pagoda and Van Thanh Temple in Hue City (UNESCO Site), Vietnam," 2009 13th International Conference Information Visualisation, Barcelona, Spain, 2009, pp. 561-567, doi: 10.1109/IV.2009.101.
2. Mendigochea, Pablo. "WebAR: creating augmented reality experiences on smart glasses and mobile device browsers." ACM SIGGRAPH 2017 Studio. 2017. 1-2.
3. National Cultural Heritage Portal, Search by Cultural Heritage Category, Cultural Heritage Administration, https://www.heritage.go.kr/heri/cul/culSelectDetail.do?ccbaCpno=1113700210000&pageNo=1_1_2_0, 2023.12
4. Nishi, K., T. Fujibuchi, and T. Yoshinaga. "Development of scattered radiation distribution visualization system using WebAR." Journal of Physics: Conference Series. Vol. 1943. No. 1. IOP Publishing, 2021.
5. L. Yang, H. Shu, W. Song and Z. Li, "Design of China's Ancient Silk Road Display System Based on WebXR," 2021 3rd International Conference on Machine Learning, Big Data and Business Intelligence (MLBDBI), Taiyuan, China, 2021, pp. 76-79, doi: 10.1109/MLBDBI54094.2021.00022.
6. Y. -T. Liu, P. -Y. Cheng, S. -P. Shih and T. -Y. Huang, "MetaClassroom: A WebXR-Based Hybrid Virtual Reality Classroom," 2023 IEEE International Conference on Advanced Learning Technologies (ICALT), Orem, UT, USA, 2023, pp. 280-281, doi: 10.1109/ICALT58122.2023.00088.
7. Z. Long, H. Dong and A. E. Saddik, "Interacting With New York City Data by HoloLens Through Remote Rendering," in IEEE Consumer Electronics Magazine, vol. 11, no. 5, pp. 64-72, 1 Sept. 2022, doi: 10.1109/MCE.2022.3165961.
8. Wibowo, Dimas Wahyu, et al. "Penerapan Library AR. JS untuk Pembuatan Augmented Reality Sebagai Media Pembelajaran Pengenalan Hewan." SMARTICS Journal 4.2 (2018): 52-55.
9. Marriott, Richard T., Sami Romdhani, and Liming Chen. "A 3d gan for improved large-pose facial recognition." Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition. 2021.
10. Z. Li, H. Shu, W. Song, X. Li, L. Yang and S. Zhao, "Design and implementation of traditional kite art platform based on human-computer interaction and WebAR technology," 2021 2nd International Conference on Intelligent Computing and Human-Computer Interaction (ICHCI), Shenyang, China, 2021, pp. 209-212, doi: 10.1109/ICHCI54629.2021.00051.
11. N. Liu, W. Chen, F. Wang, Y. Han, Y. Wu and H. Jiang, "WebAR Object Detection Method Based on Lightweight Multiscale Feature Fusion," 2022 5th International Conference on Pattern Recognition and Artificial Intelligence (PRAI), Chengdu, China, 2022, pp. 928-939, doi: 10.1109/PRAI55851.2022.9904173.
12. Jarvis, Ray A. "A perspective on range finding techniques for computer vision." IEEE Transactions on Pattern Analysis and Machine Intelligence 2 (1983): 122-139.
13. Jain, Vishal. "3D model of attitude." International journal of advanced research in management and social sciences 3.3 (2014): 1-12.
14. B. Wu, S. Zhang, W. Tian and H. Wang, "Application and Development Prospect of Monitoring Screen based on Three.js Unit Equipment Control System," 2022 IEEE 22nd

International Conference on Software Quality, Reliability, and Security Companion (QRS-C), Guangzhou, China, 2022, pp. 347-351, doi: 10.1109/QRS-C57518.2022.00058.

15. S. Panchal, P. Raval, S. Shetty and S. Ambadekar, "College 3D Model Rendering Using Three JS," 2022 5th International Conference on Advances in Science and Technology (ICAST), Mumbai, India, 2022, pp. 142-147, doi: 10.1109/ICAST55766.2022.10039553.
16. H. Li, "Contour Extraction of Hand-wrist Skeletal Based on Active Contour Model," 2009 WRI World Congress on Software Engineering, Xiamen, China, 2009, pp. 283-286, doi: 10.1109/WCSE.2009.101.
17. Z. Wang, Z. Liu, Z. Zhang, X. Yang and W. Lin, "A Practical Contouring Control Strategy Based on Accelerated Iterative Contouring Error Estimation," 2022 China Automation Congress (CAC), Xiamen, China, 2022, pp. 1728-1733, doi: 10.1109/CAC57257.2022.10055888.
18. Maltare, N. N., Sharma, D., Patel, S. (2023). An Exploration and Prediction of Rainfall and Groundwater Level for the District of Banaskantha, Gujrat, India. International Journal of Environmental Sciences, 9 (1), 1-17 https://www.theaspd.com/resources/v9-1-1-Nilesh%20N.%20Maltare.pdf
19. Min, P.K., Mito, K. and Kim, T.H. (2024). The Evolving Landscape of Artificial Intelligence Applications in Animal Health. Indian Journal of Animal Research. https://doi.org/10.18805/IJAR.BF-1742
20. Kim, T. H. and AlZubi, A.A. (2024). AI Enhanced Precision Irrigation in Legume Farming: Optimizing Water Use Efficiency. Legume Research. https://doi.org/10.18805/LRF-791