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AHP-Based Assessment of Developing Online Virtual Reality Services with Progressive Web Apps

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Abstract.
The study uses Progressive Web Apps (PWAs) technologies to construct online virtual reality services and utilizes the Analytic Hierarchical Analysis method to evaluate the design and system implementation results. With the development of the metaverse concept, the design and application of online virtual reality services are required. By conducting literature research, semi-structured interviews, and technical application analysis, this study first defines the requirements and framework for developing a prototype virtual reality system with PWAs technologies, following the quality function development analysis and developing the prototype system accordingly. A questionnaire on the prototype system's integration, usability, and cross-platform technology development was then used to evaluate proposed design elements from experts in digital content planning, design, and front-end and back-end engineering. Study findings revealed that cross-platform compatibility was a key feature when integrating PWAs with online virtual reality design, especially among experts from all fields. The results of this study can provide a reference for the development of online virtual reality immersive experiences with PWAs in the future. Further research can focus on collecting and analyzing digital footprints generated by users in progressive web technologies and improving the link between user experience and content in the future.

Keywords: Progressive Web Apps, Web-based Virtual Reality, Analytic Hierarchy Process, Quality Function Deployment, Cross-platform Technology Development.

1 Introduction

This research uses the integrated application of Progressive Web Apps (PWA) and Web-based Virtual Reality (WebVR) technology to provide installable, offline browsing, real-time update, and many other functions. Besides, we are also pursuing the optimization of the actual performance and deploying the advantages of WebVR in cross-platform and public sharing to strengthen the current data in navigation service, model framework development of the prototype system, and can be implied to the develop-

ment and usability purposes. In following the continuous technical evaluation and optimization, we put forward the input indicators and suggestions that meet the needs of end users, as well as future development and design.

Combining the progressive web technology and technical core of WebVR through the integrated application and evaluation function, we can find out the critical elements of development and evaluate the actual development and application. This project firstly organizes relevant literature to identify critical factors and uses the Analytic Hierarchy Process (AHP) method through pilot interviews and functional analysis. Frontline developers and designers have conducted qualitative questionnaire studies to obtain and analyze the possible vital factors. This research then proceeds on the importance of the appropriate prototype level, analyzes the performance of the relevant prototypes, and summarizes the results to provide the navigation experience, reference indicators, and suggestions for developers in future system development and design.

In summary, the objectives of this study include:

- Propose the development of progressive technology with WebVR, and provide guidance to the prototype to optimize the online experience in the integrating concept.
- Propose primary interface of rendering detection, advanced usage performance model detection, and scoring methods for the in-detailed goals and progressive technical support.
- Put forward suggestions on developing and constructing WebVR by applying progressive technology.

2 Literature Review

This research focuses on evaluating the application of progressive technologies to develop WebVR by investigating “Web front-end components,” “Web VR development,” “Progressive web technologies,” and “Information navigation trend analysis." We also disclose related literature, technological trends, and developments to accommodate concrete preliminary evidence.

2.1 Web front-end components

The era of multi-screen and cross-platform generates interactive experiences for users on various platforms, including smartphones, tablets, computers, and wearable devices have been providing various user experiences. Nevertheless, the user experience design that comes from different devices needs to be reviewed to support user’s demands and satisfactions (Nagel, 2016). On the other hand, the development of the front-end website no longer relies on static pages. Nonetheless, it is now getting broad to the dependencies integration of third-party libraries, automated testing, and packaging and compression code. The conventional front-end development process no longer requires these complex requirements, yet it is now moving to automatic construction. Automatic construction defines as an automatic compilation, merging, refresh, deployment, and

synchronization process of the front-end development (Zhang et al., 2017). It reduces the highly repetitive tasks and effectively improves development efficiency.

2.2 WebVR development

Along with the popularization of wireless networks and mobile devices, "mobility" has become one of the basic applications of consumer technology products. Based on the vigorous development of WebGL, virtual reality can no longer be operated through a single machine, but it is accessible through the WebGL drawing protocol in the web browser. In 2014, developers Mozilla and Google launched the JavaScript API for web virtual reality, which is not limited to a smartphone experience of virtual reality. The new development method of virtual reality devices also provides more advantages, from virtual reality devices such as HTC Vive, Oculus Rift, etc., to smartphone browsers. The WebVR advantages allow users to strengthen interactive navigation without requiring them to download additional applications to enhance users' willingness to explore VR. The implication of WebVR has been adopted by Morales (2022) in the education sectors, which showed the interactivity enhancement and motivation towards participants by integrating lively elements (Glasserman-Morales et al., 2022).

2.3 Progressive web technologies

Progressive web technologies is a webpage built of HTML, CSS, and JavaScript, along with its core technologies, service worker, manifest, application shell, and HTTPS, to provide a progressively enhanced experience (Behl & Raj, 2018). Current browsers such as Chrome, Firefox, Safari, and Edge can deliver access and optimize mobile-based websites (Malavolta et al., 2017). PWA offers some benefits, such as the ability of the engines to write the command once and then run it everywhere (Frankston, 2018). The easy integration of PWA makes the usability of this technology reachable in numerous applications. Shah (2021) performed the notion of combining the 3D interactive gaming with the immersive image to accommodate virtual tours for campus visitors, consolidating the PWA, this project has successfully demonstrated better compare results from the regular apps in both hybrid and native systems (Shah et al., 2021).

2.4 Information navigation trend analysis

The pandemic's impact has accelerated the digitization of information and online virtual tours, gradually moving towards a better in-depth experience. Digital tours today have proven to take advantage of digital technology assistance. The digital information guide breaks the limitations of the traditional guide in terms of region, space, and time and provides the viewer with an online viewing experience at any time. In terms of display and educational functions, digital exhibitions can effectively extend the life cycle of guided tours, utilize sustainable resources, and provide more diverse viewing methods and interactive content (Hong & Shiang, 2020).

Based on the case study analysis, we acknowledged that shifting virtual reality to the webpage mode will interrupt the experience in some browsers. Due to the platform's

advantages and interactive navigation, the problem of page switching is optimized by adopting a single-page webpage solution. By means of partial static caching, it solves the performance problems of web virtual reality and improves website functions, which serve as the technical basis for subsequent application service planning.

The rapid development of online information navigation has an impact on the rapid growth of the economy and the high popularity of terminal and mobile devices. The traditional navigation mode has been unable to meet the needs of users. Users are beginning to seek a completely online service experience. The integrated application of technology enables end-users to experience an undifferentiated and consistent online information navigation experience anytime, anywhere, and in any situation. Moreover, the cross-platform demonstration work by Lian (2022) has insight into the usage of a cross-platform-based system which can accommodate almost similar performance accuracy compared to the conventional system framework (Lian et al., 2022). This concept brings extended more complete cross-platform services to the navigation experience.

3 System Design and Evaluation Methodology

This research focuses on the PWA development of WebVR services, defines the development model framework of the overall system prototype, and evaluates the development of online information navigation services through the integrated application and evaluation function of the application.

This research provides a developer-oriented analysis. Through developer interviews with AT-ONE analysis and characterization scenario simulation, we find the intensive contact points and basic needs among developers and end-users. We then conducted the development process and filtered out the specifications of the prototype system in functional aspects. The following process showed a semi-structured expert interview and AHP expert questionnaires for the feasibility analysis. The overall research process planning is as follows. (Fig 1)

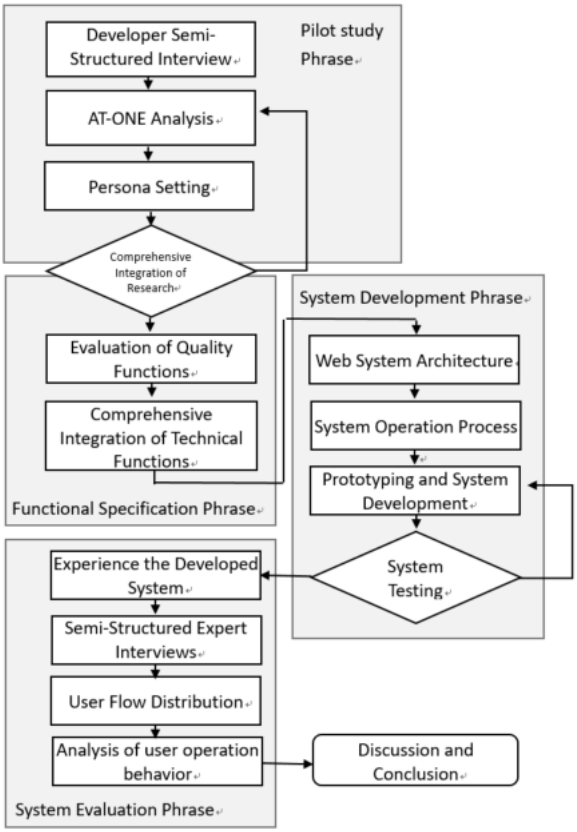

Fig. 1. Research Structure and Process

Through the semi-structured interview, we unveiled the conventional development and application process. We divided our process into four stages: planning stage, design stage, front-end, back-end development stage, and testing stage. The development goals and the modular inventory of existing technologies lead to divergence of development goals and repeated execution. Therefore, through AT-ONE analysis and situational simulation of persona, this research finds the three most intensive and most frequently interacted touch-points in technology development, as well as the three goals of service usage, immersive service, and cross-platform service.

According to the architecture description, three significant demand aspects of service, functional and technical, are summarized in the overall development process. The domain demand can be divided into three domains: digital content planning, design, and front-end and back-end engineering. This research takes the three major demand-oriented as the basic framework, matches the three major areas as the distinction of technical nature, and finally subdivides the demand and technical aspects by evaluating the quality function, as shown in Table 1.

Table 1. Development of Functional Specifications, Quality Functions, and Evaluations.

Function Requirement / Service Requirement		Planning-Oriented			Design-Oriented			Development-Oriented				Overall Score	Requirement Ordering
		Web Navigation Architecture	Operation Guide Process Optimization	Guided Topic Positioning	Interface Usability	Front-end Interactive Elements	Web VR	Pre-Loading cache Process	Cross-Platform Installation	Site Security	User Behavior Record		
Usability Service	System Cross-platform Compatibility	1	3		3	3	3	9	9	1		32	1
	Lightweight System Capacity					1		9	3			13	7
	Smooth Use Process	9	9		9			3				30	3
Immersive Service	Immersive Online Information Tour Experience	3	3	3	3	3	9	3	3	1		31	2
	Guided Image Experience			9	3	9	3				1	25	5
	Instant Installation and Uninterrupted Experience				3		1	9	9	3		25	5
Cross-platform Service	Personal Information Security						1	1	1	9	1	13	7
	Site Tracking									3	9	12	9
	System Scalability	3	1		9	3	9				3	28	4
Overall Score		16	16	12	30	19	26	34	25	17	14		
Ranking		7	7	10	2	5	3	1	4	6	9		

※9 for Strong Relationship, 3 for Moderate Relationship, 1 for Weak Relationship.

This study uses AHP as the basis for the expert questionnaire design. By calculating the weights of each element factor concerned by the issues of each specialized field, we can understand the problems faced by experts in different fields in practice.

According to the above research method description, firstly, we conduct semi-structured interviews with developers on exploratory issues and conduct a detailed understanding and contextual deconstruction analysis of how developers and end-users import PWA WebVR services. To summarize the results of the comprehensive exploration and problem stage, this research established persona, problem integration, and transformed the problem points in the simulated situation into service requirements. The quality function is put as the following step to expand the evaluation method in the technical fishbone diagram analysis application, integrate the above service planning, and list the design requirements and technical applications. Besides, we sorted out the overall detailed functional specifications and drew information architecture of system development. Afterward, an AHP expert questionnaire was created to measure the implementation. The final process shows as analyzing and evaluating the overall technical function and end-user behavior.

4 System Integration Design and Development

4.1 Development Lead Analysis

The integrated service system proposed in this study conforms to the cross-platform device application in the terminal vehicle interface. The five levels in the research are visualized as the elements of user experience: user-centered design for the Web and beyond are the main concepts in the development and design. The framework by Garet (2011) is the strategic level for collecting data requirements, the scope level, the structure level, the framework level for implementing the interface and information design, and the presentation level for visual design (Garrett, 2010). Planning analysis and system development are carried out on the contact points of development, the consistency and integrity of online channel service functions are considered. Thus, a system model for innovative experience is proposed.

In formulating the functional architecture, the primary service orientation is drawn regarding the overall operation experience and cross-platform maintenance services. The development process and the functional orientation of the operation requirements are formulated according to the service requirements. This research is trying to obtain the key areas required for the development needs. The technical aspects of the overall development project include the development process, technical management, interface design, use analysis of system performance, and application requirements. At the strategy level, we defined six target services: functional operation intuition, flow and use, process flow, brand feature experience, real-world preview experience, cross-platform tour, and personal data security.

4.2 System Design and Development Process

In the website system architecture, this research focuses on progressive technology to develop the virtual reality of the webpage. The PWA application technology is the webpage constructed by HTML, CSS, and JavaScript. Its core technologies, Service Worker, Manifest, Application Shell, and HTTPS, provide users with Progressively Enhanced Experiences (Gambhir & Raj, 2018).

Continue to achieve cached data through a service worker. Users can experience virtual experience in offline mode. Through Manifest and Application Shell, settings, and web elements provided, this system can be reliable and instantly process similar experiences to the native app.

The WebVR file is accessible on the cloud host, which reduces the cost of construction and maintenance. It is easier for users to experience virtual reality through the searchability of the webpage through a website search. PWA technology will capture some data during the application process. Therefore all data must have secure HTTPS to ensure website security and user data security. In such an environment, cross-platform web-based services can be provided.

During the overall operation stage, it is mainly distinguished into three major parts: the three major stages of the early basic guidance, the content-guided tour of the mid-

term, and entering the VR depth guide. Through the three stages mentioned above interaction, the gradual guidance allows terminal users a deep experience. According to the following operating flowchart, in this development, the user can clearly emphasize the initial guidance of key blockization and visual surface through content assistance and mid-term content guidance. The entire station is developed by gradual web technology, as well as at any page of the virtual reality experience, to ensure the stability of the terminal user on the system and experience integrity.

5 System Analysis and Evaluation

5.1 Web Operation Interface

The system development is based on web-based operation. In the presentation, the basic page is firstly used as a guide for the information entrance page, as a pre-travel awareness and preliminary information introduction, and then proceeds to the in-depth VR navigation experience. Hence that the end-users can explore the system and operate it more efficiently. Based on the results of the pre-travel interview and quality function, the functions of PWA application technology for WebVR services are integrated, and a multi-service page system platform is developed.

On the WebVR interface, our research takes a case study location in Taipei Dadaocheng. On the WebVR navigation screen, the user can see VR on the web page from the Taipei Dadaocheng field as the WebVR service platform. The general navigation page mainly provides the choice of scene theme (as shown in Figure 2). The prototype also provides three auxiliary functions: VR and panoramic screen activation, manual field view adjustment, visual screen size, and scene switching. Afterward (as shown in Figure 3), you can adjust and optimize the tour experience according to different VR equipment and personal focal length.

Fig. 2. Web VR Information Navigation System Interface

The overall panoramic theme and VR navigation enhance the end-user's in-depth navigation experience. The interface is designed to provide directional guidance, information about key buildings and cultural monuments, and supplementary functions in

the function bar and to maintain the scalability of future additions during the design process. A crosshair gaze and point-to-point depth of scene movement are used to improve the overall smoothness of the operation. In terms of auxiliary optimization, the auxiliary modes provided in the library software allow for modularized picture correction according to the needs of different VR devices and individual focal lengths.

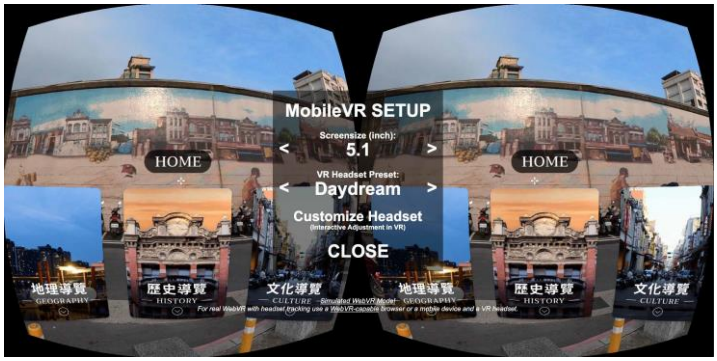

Fig. 3. Web VR Device Focus Adjustment Screen

5.2 AHP Questionnaire Analysis

Integration and development, the choice of the object of the questionnaire survey, according to the majors involved in the project, select the experts in the field to conduct a questionnaire survey. Therefore, the field of questionnaire survey is set in the three major professional fields of digital content planning, design areas, and front-end engineering fields. This process analyzed the weight and order of each evaluation criterion through hierarchical analysis methods. After the test, the subject's feedback questionnaire description function and the blurred zone were measured to understand the problematic points of filling in the process, adjust the questionnaire description and hierarchical project design, and complete the key elements in various fields, as shown in Table 2.

Table 2. The Key Elements in Various Fields.

First Level			Second Level			
Facet Elements	Relative Weights	＊Sorting	Evaluate Factor	Relative Weights	Absolute Weight	＊Sorting
A. System Integrity	0.55：0.44：0.49	1：1：1	A-1. Cross-Platform Compatibility	0.55：0.60：0.71	0.302：0.264：0.347	1：1：1
			A-2. PWA Application	0.22：0.19：0.12	0.121：0.083：0.058	3：7：8

			A-3. WebVR Integration	0.23：0.21：0.17	0.126：0.092：0.083	2：4：4
B. System Utility	0.23：0.36：0.33	2：2：2	B-1. WebApp Installation	0.42：0.61：0.48	0.096：0.219：0.158	5：2：2
			B-2. System Maintenance and Update	0.37：0.25：0.31	0.085：0.090：0.102	6：6：3
			B-3. Information Immersion Guide	0.21：0.14：0.21	0.048：0.050：0.069	8：8：6
C. Cross-Platform Development	0.22：0.20：0.17	3：3：3	C-1. Offline Operation	0.28：0.46：0.44	0.064：0.092：0.074	7：4：5
			C-2. Content Update and Expansion	0.51：0.32：0.36	0.117：0.102：0.061	4：3：7
			C-3. User Behavior Analysis	0.20：0.22：0.21	0.046：0.44：0.035	9：9：9

＊Digital Content Planning Field: Design Field: Front-End and Back-End Engineering Field.

The analysis of the domain mentioned above shows that the comparison of absolute weights may be different due to different dominant domains, which may lead to different results. However, when comparing the three domains at each level, the domain analysis results prove that "system integration" is the key development orientation at the main level. In addition, "WebVR integration application" and "WebApp installation" are highly recognized by two significant domains, respectively, and it can be inferred from the results that "cross-platform compatibility" is the core consideration in system integration, and the corresponding weight allocation in "WebVR integration application" and "WebApp installation" can be adjusted according to each domain. The "operation behavior analysis" can be a value-added item when the resources and human resources are sufficient.

6 Discussion and Conclusion

This study uses a visual page platform with immersive WebVR technology to achieve multi-platform integration and offline application through PWA to provide a contactless and spatially unrestricted experience. This study focuses on integrating online information navigation and design thinking integration of front-end development.

Through the advantages of progressive web technologies and cross-platform integration, WebVR navigation achieves an active immersive experience in a contactless mode. This research summarized the result and suggestions as the following items:

1. Technical integration and development: This study is mainly based on developing the front-end framework and digital navigation operations. In the future, we can consider the continuous development of the back-end system and database development so that developers can explore more information and build more flexible operations by establishing a complete back-end management module.
2. The completeness of data collection using Web operations: This study uses click events as a trigger record in the data collection section. Therefore it is necessary to capture usage data through explicit events, yet cannot comprehensively analyze the details of WebVR use to analyze the process. It is recommended that in the future, through the assistance of eye-tracking devices and other external detection devices, the browsing of motion information and emotional detail analysis data enhance end-user data collection. The future study proposes that data collection on the eye-tracking device and other external detection devices can enhance the accuracy and usefulness of end-use data collection by analyzing the motion information and emotional detail data.
3. Ease of use of interface design: This study is mainly based on the development technology evaluation and the development priorities of the functional and process aspects. It is suggested that interested researchers can propose further design studies on the functional aspects of the user experience in the scenario context, including the study of navigation motions, emotional interactions, and business model building. Therefore it can be deeply integrated and adopted.
4. Extension of PWA: This technology has been widely supported by major browsers in recent years and is an actively developing web technology. This study has also conducted several functional integration applications and technical evaluations through the advantages of this technology, suggesting that in the future, we can further deepen the best time of use of each feature, operation application context, and other related service applications. In the future, we suggest the best use time of each feature, operation application context, and related service applications. Thus this technology can be more closely related to the regular use of the terminal and formulate relevant standardized development criteria through the evaluation of terminal services.
5. Completeness of the business model: This study examines the service process and spatial experience of the in-person digital tour. The benefits and impacts can be explored in depth. In the actual implementation, the business model canvas can be employed for analysis and planning so that the design can attain a closer real environment.

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