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Research Paper

Evaluating the effectiveness of MAR apps in enhancing public participation in architectural design (An augmented experiment at the University of Basra)

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ABSTRACT

AR technique is one of the innovative techniques of our time, which is increasingly used in the field of architecture at several levels and for multiple purposes. One of these is to enhance public participation in architectural design in an easy and understandable way. Due to limited attention to this emerging technique in our local context, including the academic one in Iraqi universities, and the scarcity of research contributions addressing it, this paper explores the concept of AR, its utilizations in architecture, and its role in promoting public participation in design. Also, it involved developing a mobile AR app "BUMAR änd testing it in real-world settings, all with the goal of introducing this technology and exploring its potential to facilitate and achieve public participation in design. To achieve this, a proposed virtual model was created as a hypothetical building for the Petroleum Engineering Department, intended to be built. The model was exported to the app, which was shared on social media for the target audiences. The app was tested in displaying and evaluating the model, with experiments conducted over several days by students, faculty, and others. This was accompanied by a questionnaire to gather opinions on BUMAR 's effectiveness, specifically, and the importance of the AR technique in achieving understanding and interaction with the proposed design and its role in facilitating participation and expressing opinions. BUMAR achieved good results, as indicated by the questionnaire results showing acceptance, satisfaction, interaction, interest, requests for further development of the app, and willingness to participate in future augmented experiments. This supports the claim of the importance of AR technique and the success of BUMAR in explaining it to users, suggesting further development of the app and its use in evaluating real construction projects in the future.

1. Introduction

Technology is a fundamental factor in the evolution of architecture and its transformations throughout history. Today, we are transitioning from one technological era to a new one, as we move from the Internet era to an augmented era called the metaverse, where communication takes place through immersive spaces blending the virtual and real world. Metaverse technologies have reshaped thinking patterns, replacing temporal and spatial relationships based on geography with new patterns based on the integration of virtual worlds and real environments, allowing users to have multi-sensory interactions [1]. Among these rapidly evolving technologies in recent decades, augmented reality stands out as a key interactive innovation that attracts a lot of attention in various fields, developing many applications by many institutions and companies. According to market research expectations, the AR market is projected to reach $88.4 billion by 2026, a 31.5% increase from 2021 [2]. Augmenting the physical environment with virtual information and presenting it to the user in a realistic way reshapes the human-material relationship within space, where information becomes a mediator in it. Hence, some confirm that the conscious use of this technique can offer new perspectives on the environment, bridging the gap between real and virtual spaces, providing innovative perceptions of architecture [3]. Thus, the popularity and use of AR in the architecture industry, as expected, will increase in the future. Many researchers have concluded that the use of augmented techniques can contribute to improving the design process and increasing user interaction with it [4]. This has prompted many leading architectural firms to adopt AR in developing their projects, improving the design quality and offering clients a comprehensive view of proposed project [5]. AR applications have been used in architecture to provide interactive experiences for designers and clients alike, creating 3D models of buildings and using augmented apps to place them in the context of real worlds, allowing all to explore and interact with these models using smart devices, such as phones and tablets [6]. Conversely, there is no clear interest highlighting this technique and its importance in architectural practice in the local context at all levels, including the academic level in Iraqi universities, where libraries contain only a limited number of theoretical research papers that address the topic through mere description and analysis. However, it should be noted that there are very few contributions that discuss the technique in terms of practice or practical application, particularly within the context of digitizing local architectural heritage, re-modeling it virtually, and re-presenting it to users through digital display technologies. Some of these studies have utilized VR techniques [7], while others have employed AR techniques as an interactive display method to present virtual heritage models integrated with their real surroundings [8]. However, these contributions have not produced their own specific applications; their work has been limited to exporting virtual models of heritage buildings to interactive platforms and sites available for public use in virtual and augmented reality. Accordingly, this research paper comes as an attempt to provide a general theoretical idea about AR and its multiple uses in architecture, particularly its active role in enhancing public participation in architectural design.

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Nomenclature

App	Application	*SDKs*	Software development Kits
Apps	Applications	*H*	Hight of building (m)
AR	Augmented reality	*VR*	Virtual reality
BUMAR	Basrah University mobile augmented realty	*X*	non-dimensional X-coordinates
HMDs	Head-mounted displays	*Y*	non-dimensional Y-coordinates
MAR	Mobile augmented reality	*Z*	non-dimensional Z-coordinates
SAR	Special augmented reality	$2D, 3D$	Tow and Three-dimensional

It also aims to present a practical application through real-world experience using a mobile augmented reality app developed with the help of some students from the Department of Architecture at the University of Basra. The goal is to highlight AR and introduce its importance in developing architectural design activities and enhancing public participation while exploring the extent of local community interaction with the technique and its applications, as well as their willingness to use it and understanding the role it can play in promoting public interest in architectural design. Assuming that the unprecedented capabilities of AR techniques are facilitating the understanding of the displayed models and providing various ways of expressing opinions and participation in design. Furthermore, the interactive interfaces of augmented applications provide users with the ability to directly modify the properties of these models.

2. Literature review (Theoretical framework)

2.1 The concept of augmented reality

Augmented reality can be defined based on several institutions [9, 10]. The elements can include images, texts, sounds, videos, and 2D or 3D models. AR emerged in the 1990s as an evolution of virtual technologies, and there is often confusion between the two concepts, they may seem the same to the average person. The difference between them is that AR is created technologically by overlying virtual objects onto the real image of something, while VR is limited to creating fully virtual environments that only simulate reality [11]. Also, AR devices allow the user to interact with reality as well as virtual environments, facilitating movement during the interaction, unlike VR, which poses mobility risks [12]. That is, VR separates the user from his real environment, while AR leaves him with the ability and full awareness to interact with it. Within the limits of visual perception and its use in architecture, augmented techniques are classified into two types. 1- spatial augmented reality (SAR), which is the first to use for enhancing the architectural environment with virtual elements and includes various activities, the most important of which are light projection technologies (static, dynamic, interactive, and holographic). It does not require devices or equipment from the recipient, but it does not allow him to choose the time and place as well as the nature of the content, as all of this is determined by the specialized teams. 2- mobile augmented reality (MAR), which is represented by all applications that use handheld devices (smartphones, tablets), that facilitate the user's movement, transition and conducting experiments in the open air and in the actual place and time, and some of them use head-mounted displays HMDs. The use of HMDs can be considered part of (SAR) when restricted to specific environments, enhancing the user's surroundings and increasing interaction within those limits. Initially, AR faced technical, economic and usability challenges, as content creation requires advanced 3D modeling and programming skills, in addition to expensive computers to provide high data processing capacity [13].Also, there were concerns about its commercial motivations, cultural alienation, and potential social impacts [14].Therefore, the spread of AR apps in recent years is due to technical reasons represented by what the huge digitization provided in terms of large repositories of usable 2D/3D data, and the unprecedented leaps in devices and software. And for social reasons represented by the growing desire among individuals to access digital information and interact with it in all fields [3]. As well as economic reasons, as all requirements for using AR are now available on most mobile devices, making it easier and less expensive for general use compared to other devices. These requirements are limited to (a camera to capture live scenes, sufficient storage for virtual models, a powerful processor for integration and display, and a screen for user interaction) [15]. Hence, these advancements have enhanced the popularity, efficiency, and usability of MAR in fields like architecture, where AR facilitates on-site design development and aids designers, decision-makers, and the public in engaging with architectural designs.

2.2 Augmented reality in architecture

The focus in recent literature on the subject can be categorized into three main aspects: (potential scenarios for AR applications in architecture, integrating AR with other modern technologies, and enhancing participation by improving the user experience). These aspects are addressed in several contexts, such as architectural education, heritage preservation, and the construction industry, and others. One study [16] presented five scenarios for potential use: (the timeline scenario concerned with photographing lost historical contents and archiving them in apps, the sensing scenario, concerned with collecting environmental data through user experience, 2D information scenario related to displaying invisible features in AR screens using GPS, 3D scenario concerned with representing new buildings integrated with urban contexts, and the participation scenario concerned with enabling the user to submit proposals through some bidirectional apps). Another study [17] presented five possible uses: (placing buildings in their vacant lots, displaying building service details via BIM, modifying 2D maps and displaying results in 3D models, reconstructing missing historical structures, and finally full-scale 3D model visualization). The aspects of integration with other technologies and enhancing participation were addressed in different ways in the three contexts. In architectural education, several studies [18, 19] indicated the importance of incorporating AR in architectural curricula, aiming to enhance the traditional studio environment by making it interactive and simulating real-world training scenarios. This is due to AR's unique capabilities in visualizing design models, which enhances understanding, communication and interaction between students and instructors, all contribute to fostering collaborative design and support architectural critique activities. Other studies highlight AR techniques as a suitable context for education in terms of parametric design methods, generative design methodologies, and digital modeling, offering participation and interaction with displayed models and their transformations based on algorithmic parameters [20, 21]. Some [22], presented a vision to enrich the learning experience based on virtual environments by combining advanced virtual simulation tools with AR techniques. Overall, studies demonstrate the significant potential of AR to improve educational experience at several levels compared to traditional methods. Most of them indicated the possibility of applying their experiences in architecture beyond just education. In heritage preservation context, AR is considered as a vital tool for digitizing and preserving architectural heritage, as it contributes to solving the problem of restoring architectural history by re-modeling it virtually according to the historical description and integrating virtual models with real-world sites by projecting them onto the remaining artifacts, integrated with its real assets and enhanced with historical information displayed in different ways [23, 24]. Studies often combine AR with GPS to create sustainable cultural tourism experiences through which the cultural history of each site that represents a point of interest for the user can be viewed [25]. Additionally, enriching AR applications by integration with innovative technologies, such as linking them to semantic web services and real-time data updates [26]. Also, AR paired with 3D printing allows for physical models of historical structures, offering detailed, enhanced visual experiences [27]. In general, studies focused on providing texts and archival images, along with 3D models, to enrich residents' sense of belonging and improve the tourist experience for visitors. In the construction industry, studies [28, 29] have shown that AR's role in the Architecture, Engineering, and Construction (AEC) industry is to improve communication, share ideas, reduce project delays, and increase construction quality e, especially when integrated with BIM technologies, which allows for virtual interaction with building models across project stages. Some [30] have also shown AR's role in improving maintenance guidelines and reducing errors. As in infrastructure project maintenance and facilitating the precise detection of pipe locations and paths with high accuracy by integrating AR, photogrammetry, and BIM technologies. However, one of the main challenges facing AR in this context is the absence of comprehensive 3D models for building service systems [31]. Studies recognize AR's capacity to enhance visual communication, collaboration, progress tracking, and safety training in construction, but also acknowledge the emerging nature of AR research and the difficulty practitioners face in content creation.

2.3 Public participation in architectural design using AR

Participation in design is expressed by the term (user's participation), defined as an interest in developing a project of personal significance [32]. Users in architecture are classified as temporary visitors, continuous occupants, and owners [33]. In this sense, the term (public participation) is often used, especially in projects with urban dimensions, public impacts, and multiple interests. Users' participation during the design phase of any product achieves high quality by addressing user's requirements, eliminating unwanted features, increasing acceptance, and ensuring satisfaction [34] .This requires direct communication between the design team and potential users at different levels (an informational level for data exchange, a consultative level where users are consulted whenever necessary, and a participatory level, where users are given higher participation powers to influence decisions related to the entire process [35]. There are several ways to involve users, typically by two main methods: user-centered design and participatory design. In a user-centered approach, users' requirements are met by focusing on collecting qualitative and quantitative data, interpreting them into general design principles. In participatory design, users have a greater role by expressing themselves and directly engaging in design, also ongoing frequent dialogue with designers [36]. Architecture structures aim to meet human needs, which are translated, in design phase, into drawings and specifications, that reflect critical decisions affecting the building's performance. Therefore, it is necessary to adopt systematic methodological approaches to involve users, understand their needs, and grasp their cultural background, to anticipate the future use of buildings [37]. This comprehend and implement users' decisions, avoiding disputes and reducing changes later. Consequently, many studies have focused on involving users in the early design stages. The user-centered approach has been employed in some studies [38, 39] showing that designers gain a better understanding of user needs, validating design decisions effectively and producing ideas aligned with user expectations. However, participatory design is more commonly used in building design, which utilizes various tools and techniques, such as brainstorming sessions, sketching design ideas, developing 2D CAD drawings, and creating 3D models [40]. Numerous studies [41–43] highlight the importance of this approach, as it significantly influences the final building outcomes. Nevertheless, these traditional tools often pose a challenge for non-expert users who may not fully understand the design language, thereby limiting their participation. As a result, there is a pressing need for strategies that improve communication between users and designers, allowing users to express their preferences more effectively. AR has proven to be an effective platform for overcoming participation barriers and enhancing user experience for various purposes: evaluation, learning, and discussion initiatives. AR techniques address the challenge of public contribution in design through interaction and immersion in engaging experiences. Accessible devices allow individuals to visualize designs integrated within real environments, considering factors like sky, wind, light, and making the design appear closer to its final form upon completion. Architectural studies have increasingly explored AR as an innovative tool for collaborative design on multiple levels. For instance, one study [44]. developed an interactive interior design system using AR, incorporating participatory design concepts. This system significantly aided understanding and information presentation during discussions, enabling users to furnish their homes easily through realistic displays of furniture in terms of shape, color, lighting, and real scale. At the architectural design level, another study [45]. applied participatory design to redesign an existing building, comparing traditional tools with a specially developed MAR app. Results showed positive impacts of MAR on user participation, enhancing understanding and interaction while allowing users to engage flexibly with designs and express ideas effortlessly. In urban design, a significant study [46] highlighted AR's role in facilitating public participation in urban decision-making. AR can present urban design indicators interactively through a 3D virtual model, which can be adjusted by users according to specific buttons within the application interface, observing real-time urban changes, related to. The study indicated that AR enhances user understanding of urban indicators used by designers, as well as understanding of design, positively impacting urban decision-making through bottom-up feedback alongside traditional top-down approaches. AR offers numerous advantages for architectural projects, primarily by making them more comprehensible to users without requiring technical design knowledge, as it allows users to perceive 3D models in a realistic perspective, automatically understood without needing to mentally translate 2D into 3D [20]. Also, it enables the frequent replacement and modification of designs, allowing for evaluation by all stakeholders without impacting the real environment prior to execution. Moreover, AR enhances communication among the different teams involved in design and construction, improving understanding and reducing the possibility of false [47]. All facilitate time and effort savings in the design updates and testing various ideas before actual implementation. Thus, MAR apps contribute to a higher understanding of concepts, fostering collaborative design by encouraging user feedback with easy project evaluation and modification, directly from their smartphones [24] Most MAR studies focus on assessing user attitudes and behaviors toward applications, often employing surveys and other methods [16]. Some studies [2] advocate for reducing obstacles for users to engage with AR content rather than merely accessing it.

2.4 Requirements for developing MAR applications

To develop any MAR application, it is essential to identify the expected devices to be used, and select a compatible development environment, as there are many game engines used in developing AR apps such as Unity, Unreal Engine, and CryEngine, as well as many software development kits SDK, like AR Core and ARKit. The commonly used devices rely on two operating systems, iOS and Android. For Apple's iOS, ARKit features are used and require a phone or tablet equipped with an A9 processor or newer and iOS 11.0 or above. While AR Core features are used for Android devices and require at least API 24 version 7.0. [48]. In terms of game engines, Unity 3D is the most popular because it allows development across most platforms, including Android and iOS, and provides great flexibility in customizing user interfaces, in addition, it offers free licenses for personal use. C# is the preferred programming language for Unity because of its ease of use and its modern and powerful features suitable for AR development. There are also several SDKs like Unity's AR Foundation and Vuforia enable the creation of AR applications, leveraging both AR Core and ARKit capabilities. SDKs are responsible for the app's form and functions, determining ease of use and user interaction, as it allows the creation and integration of virtual objects with reality, and provides many other functions such as 3D objects tracking and image recognition [49]. Geometric recognition of the physical environment and the presentation of virtual content are two interlinked functions, allowing the device's camera to identify real-world elements and display virtual objects accurately by estimating the user's position and orientation, and linking the coordinates of the virtual and physical environment together to create a seamless interactive experience [50]. SDKs offer various tracking methods and support a variety of 2D and 3D targets such as image, model, layer or object recognition. These tracking methods operate through three modes. The first determines geographically through programs that convert real coordinates via the device's GPS into navigation coordinates specific to the app. The second is marker-based tracking, where visible targets are recognized by the device camera. While the third form is called feature-based tracking (marker-less tracking) using SLAM technology, originally developed for robotics, to simultaneously map the environment and calculate camera position in unfamiliar spaces [17]. From a functional perspective, translating ideas from virtual to the real world requires coherent emotional expression to enhance user interaction with them. This is achieved through high image quality, minimal distortion, interactive presentation methods, and a broad visual field that enhances perception and allows for movement instead of stability. Moreover, proper organization of the app is vital for gaining social credibility [31]. Thus, Azuma identified four basic characteristics AR to be complete in the field of architecture, which are: merging the real architectural environment with virtual objects in a shared visualization on a device, real-time synchronization between virtual and real environments, allowing for participation on a large scale and not being limited to specific points of view, and enabling movement within and around the architectural space with complete freedom.

3. Methodology and material

The research methodology in its practical aspect was built based on what was reviewed in the theoretical framework regarding the capabilities, characteristics, and applications of augmented reality. The practical work can be summarized as follows: - A 3D virtual model was created as a proposed hypothetical building for the Petroleum Engineering Department at the College of Engineering. An MAR app -named BUMAR- was developed to import the model and showcase it on-site. The app was shared within communication groups of students, faculty, and staff, enabling them to download and run it on their devices prior to the experiment. The experiment was conducted over several days, with users responding to a questionnaire within the app. Lastly, the survey results were collected, analyzed, and discussed to reach conclusions. The initiative was achieved through self-driven efforts, with assistance from some architecture students who have modeling and programming skills. Resources were identified using available free tools and software that align with the expertise of specialists in architecture. The steps, processes, and materials or resources used in the research can be illustrated as shown in Fig. 1, each of which will be detailed in its respective sections.

3.1 The model

A hypothetical building -for the proposed Department of Petroleum Engineering - was designed as a three-story structure with an overall height of 12 meters and a nearly square footprint of about 900 square meters (30 x 30). The virtual design model was created using Revit. The architectural features of the model, including its overall shape and facade details, differ from the surrounding college buildings while sharing some finishing materials Fig. 2. The proposed site was identified within the college complex.

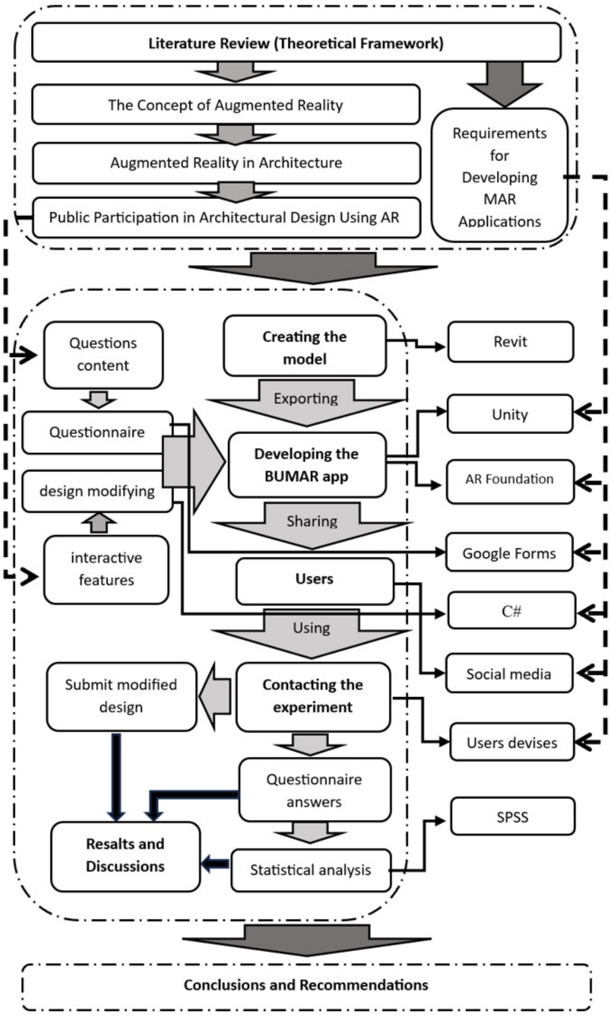


Figure 1. Research structure and methodology.

Figure 2. The model in the Revit environment.

3.2 The application

The BUMAR app was developed as the first MAR app at the University of Basrah, thus, its name was derived from the initials of (Basrah University Mobile Augmented Reality). It consists of three main sections as in Fig. 3. The first section, called information, was prepared to provide general information about the displayed models according to the purpose of their use. It may be textual, audio, visual information or video clips, but for this initial trial, it was limited to providing a video explaining how to conduct the experiment, create the model, use the app interface, and send the final data. The second one is 3D models, which display and create 3D models based on predefined markers. This section can import 3D models from various modeling software, but this feature is currently not accessible to users on their devices and requires intervention from the app development team. The third section is the survey, that is used to create questionnaires and collect opinions from users, as well as reactions and comments.

Figure 3. BUMAR Sections.

Currently, it is limited to a link of a Google Form questionnaire with three sections. Technically, BUMAR was developed using Unity and AR Foundation, using AR Core and ARKit features to be compatible with Android and iOS devices. However, it was limited to build the app using Android SDK only, because iOS apps require App Store submission, a complex process needing sufficient time after final developments in the future. The tracking method was achieved through markers, by directing the camera and recognizing a specific target. To adjust the model's true scale, a special method was adopted, using the building's ground floor plan, printed at a scale of 1: 100, as a reference marker. The model was imported into Unity as a Prefab to save the modifications made to it, creating two copies, one at a real scale of 1:1 and another at 1:100. When AR is created by overlaying the 1:100 model on the printed plan, the other one will appear at actual scale of 1:1. For positioning the actual scall model in its real location, it is defined relative to the 1:100 model in the Unity environment based on virtual coordinates that simulate the actual dimensions of reality between the marker's location and the intended site. The location of the small model -where the experience starts- is the virtual point (0,0,0), while the large model's coordinates reflect the real distances and directions between the small model's location and the proposed site. C# was adopted to write many codes for the app, alongside AR Foundation features and Unity tools for multiple requirements. Including a special code used with AR Foundation features for recognizing reference images and displaying models on them. Several codes were also created to help provide interactive features, enabling users to control the properties of displayed models and not just view them. Through the app interface- explained in the experiment section- the user can control a few model properties and modify them according to his vision within upper and lower values that can also be controlled. For example, moving the model to 5 meters within the site in four directions. And orienting the model as desired to the right or left, using a mirror-like feature achieved by combining a negative scaling value with rotation through specific code, as Unity Lake does. The height can also be increased or decreased by 10 percent. Unity's Collider features were utilized to provide the ability to change the finishing materials for some predefined surfaces in the model, as well as the ability to modify the lighting of the model and reposition its coordinates. These interactive features necessitate the collection of values decided by users. The user can submit their choices by pressing a submit button and this is accompanied by an automatic screenshot. This information is collected as inputs through a dedicated code that sends it to Google Forms using the Google API for developers. By adding Google API library, specifically the Google Forms API, authentication is set up using the credential file downloaded from the Google Cloud Console. Another code is used to send the data to the app's Google Form. The required information is not limited to numeric values; there are also images captured automatically during submission. Thus, the Imgur API is used to upload images via code, then a public link to it is obtained and attached to the Google Forms as part of the previous inputs.

3.3 Application experience and user interface

The experiment was conducted over several days in July 2024 at the College of Engineering, University of Basra Fig. 4 and one day -under the same assumptions- at the College of Engineering, University of Maysan. Dozens of faculties, students, and staff participated; however, some did not complete it due to the high temperatures in Iraq during July. Consequently, sessions were limited to early mornings. Most participants downloaded the app and completed the experiment, while some could not be due to device compatibility issues. They used team devices to participate but answered the questionnaire on their own devices. The experiment starts by directing the camera at a horizontal plan image on a table at the architectural department's back entrance. A small model is created over this plan, and then the camera is aimed at the proposed building site, revealing the large model at real-scale Fig. 5. Users can move freely towards the model, and the interface appears as the model created Fig. 6.

Figure 4. Conducting the Experiment on-site.

Figure 5. The steps of creating AR models in BUMAR.

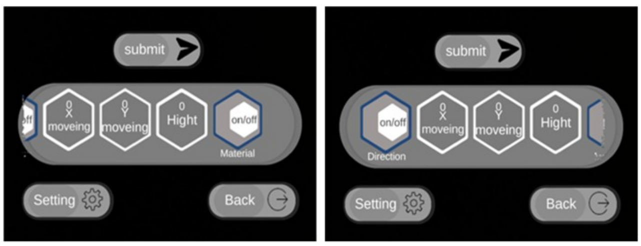


Figure 6. BUMAR app interface.

BUMAR interface contains many buttons for design control. It features a sliding button menu, allowing the addition of necessary buttons according to requirements of each experiment. This experiment focused on five primary indicators to control the model properties, suiting a wide range of models for the initial use of BUMAR. When any indicator is touched, it becomes activated and turns blue. The first is (Direction), which controls the model's orientation, allowing users to set the front facade to left or right while keeping the model corner in the same position, using blue arrows Fig. 7.

(a) Model 01

(b) Model 02

Figure 7. Controlling the model orientation, by the blue arrows.

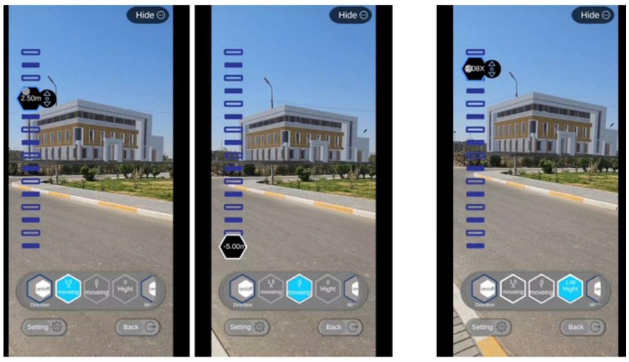


Figure 8. Controlling the model position in the site (X&Y moving) and the model height.

The second and third indicators, (X moving, Y moving), enable users to adjust the model's position within the site, allowing movement in four directions up to five meters by a slider that appears at left of the screen, snapping every half meter Fig. 8.The fourth, (Height), allows users to control model's height, increasing or decreasing it by up to 10% of the origin, using a similar method to the previous two. The fifth indicator, (Material), is for replacing finishing materials on certain parts of the model's facade. Users can select materials by tapping on the surface they wish to change, which turns yellow, and a list of available materials appears on right side of the screen to choose from Fig. 9. The interface also includes a Settings button located in the lower left corner of the screen, which offers advanced settings with two options. The first option is for resetting the model's position, allowing users to adjust the coordinates of the large model based on its reference point, which is defined by the small model's location at the start of the experiment. This feature enables users to control the model's position if they wish to use a custom model and can also be beneficial for resetting the model's coordinates during the experiment if an error occurs. The second option allows users to control the model's lighting through two choices: the first is based on GPS included in the device, and the second is manual lighting control through three adjustable indicators Fig. 10. After completing the control operations and adjusting the model to the user's satisfaction, the user can click the Submit button. This action sends all data to an integrated Google Form within the app, along with an image, which is provided as a link that can be accessed by clicking on it.

Figure 9. Controlling the finished materials.

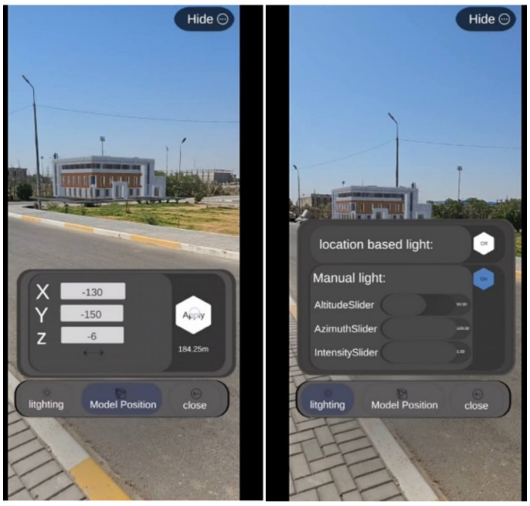
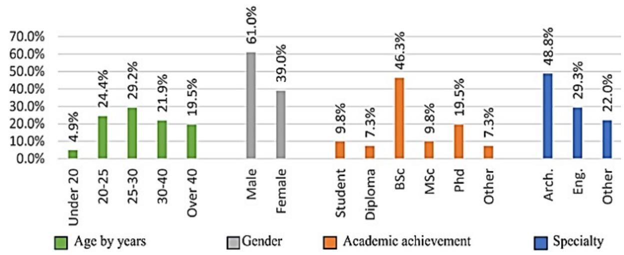


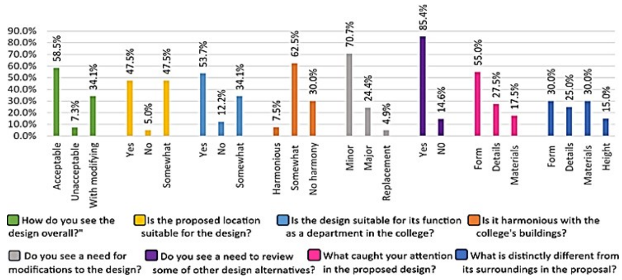
Figure 10. Settings options, position, and lighting.

4. Resalts and discussions

The research obtained the results through two methods: the questionnaire in the third part of the app and the integrated Google Form within the user experience of the app. Both reflect users' participation in design; the questionnaire focuses on a user-centered approach, enabling designers to address user needs, while the integrated form represents a collaborative or participatory design, allowing direct user modifications on design. The questionnaire received 41 responses, with some missing answers, resulting in 40 responses for some questions. The integrated form gathered 32 responses, some repeated by the same user, intentionally or unintentionally. This was expected, as the form requires an internet connection during the experience, while the questionnaire can be answered later. In the questionnaire's first section, general information about users was collected, Fig. 11a, showing a diverse range of participants in terms of age, gender, education, and specialization, indicating significant interest in this new experiment. It also included questions about their familiarity with AR techniques. Notably, 37.5% of users reported they had not heard of AR before this experiment, and only 19.5% were aware of AR applications. However, 92.5% indicated that BUMAR increased their knowledge of AR, and 73.2% remembered general applications they had used that involved AR without realizing it. Interestingly, 29.3% claimed to have previously participated in an AR experiment, which somewhat contradicted previous findings. The team followed up with these participants to clarify their responses. Most indicated they were referring to this experience, which they experienced before answering. Only one participant had developed a specific augmented application for his office, showcasing 3D models on horizontal surfaces for explaining designs to clients, but it was at a small scale and not intended for real-scale display in actual locations. The second section included a series of questions about the displayed virtual building, focusing on its general design acceptance, its suitability for its proposed function as an academic department in the College of Engineering, the appropriateness of the proposed site, and the degree of harmony with the surrounding college buildings. Also, there was a section for comments where users could express their thoughts freely Fig. 11b.



(a) The first section of the questionnaire



(b) The second section of the questionnaire

Figure 11. The first and second sections of the questionnaire.

This simulation activity was not intended to obtain true model evaluation but was included to make the experience closer to an actual evaluation of real projects, as the displayed project was hypothetical. Nevertheless, user responses were documented, showing their reactions to the model, acceptance, and rejection of various aspects. Also, this contributes to clarifying the distinction between evaluating the building's design and assessing the application or augmented techniques used to present it, which was the focus of the third section. Key feedback of provided comments highlighted a desire for greater freedom in modifying design features and requests for alternative design models and options to provide more choices. This was expected, given the engineering background of many participants. The third section represents the main part of the questionnaire, forming the basis for the research results, application evaluation, and the success of the experiment. It included fifteen questions: the first ten focused on evaluating the application and experience regarding usability, model clarity, understanding, interaction level, and willingness for future participation. The last five addressed user opinions on AR technique and its potential benefits, such as enhancing communication and public participation. Each question had five answer options based on a five-point Likert scale, with scores assigned as follows: (Strongly Agree = 5, Agree = 4, Neutral = 3, Disagree = 2, Strongly Disagree = 1). Statistical analysis was conducted using SPSS to calculate mean, percentage, sample direction, and standard deviation. Results in Table 1 listed an overall acceptance of BUMAR at 85.3%. Detailed analysis showed high acceptance rates for all questions, ranging from acceptance to strong acceptance, with percentages between 83-87%, closely aligning with the overall acceptance rate. The values also showed a logical connection between the answers of questions with each other, especially when explained based on the nature of the sample participating. in the experiment. Some questions had notably higher percentages, with Q10 showing a willingness to participate in future experiments at 89.3%, followed by Q9 regarding app development at 88.8%. This suggests that: the strong readiness to use BUMAR and participate in future augmented experiments is conditioned by a very strong desire to improve it Also, Q14 received 88.8%, indicating that participants believe AR significantly enhances communication, while Q13 showed 86.8%, reflecting their belief in AR's role in promoting public participation in design, the same percentage was achieved to Q5, indicated real interaction with the model during the experience. Conversely, Q7 had the lowest acceptance at 78%, reflecting user satisfaction with the app's capabilities for modifying the model. This was followed by Q11 at 81%, comparing AR to traditional techniques in design model presentation, then Q4 regarding model detail clarity at 82.9%. Similar objective justifications apply to these lower percentage questions, as the predominantly engineering and architectural background of participants likely led to their demand for greater freedom in modifying design features. Also, their prior knowledge of other design presentation techniques, which have capabilities for detail clarity, contributed to their partial disagreement regarding the model's clarity through the application, which had to consider device capabilities. The standard deviation values were minimal, indicating no statistical significance in the differences between answers. Also, a t-test showed no statistically significant differences in answers across questions despite some questions showing higher values than their appropriate degrees of freedom, as they were not far from zero values.

Table 1. Statistical analysis results using SPSS.

No.	Questions	Answers						Descriptive statistics				T-test		
		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Total	Mean	Standard Deviation	(%)	Sample direction	T-value	df	Sig. 2-tailed
1	**Ease of use:** BUMAR was easy to use, did not require high skills	17	19	4	0	0	40	4.325	0.656	86.5	Str. Ag.	41.708	39	00.00
2	**User interface:** Its interface was clear and understandable	18	17	6	0	0	41	4.293	0.716	85.9	Str. Ag.	36.812	40	00.00
3	**Enhanced understanding:** It greatly helped in understanding the model	16	20	4	0	0	40	4.300	0.648	86.0	Str. Ag.	39.257	39	00.00
4	**Clarity of details:** There was sufficient clarity in the presented model	12	24	4	1	0	41	4.146	0.691	82.9	Agree	38.399	40	00.00
5	**Interactive and realistic: there was a state of sensory interaction with the model on the ground**	17	21	3	0	0	41	4.341	0.617	86.8	Str. Ag.	45.067	40	00.00
6	**Fun and exciting:** The AR experience was fun and exciting	17	20	3	1	0	41	4.293	0.716	85.9	Str. Ag.	38.406	40	00.00
7	**Ability of modifying:** The app provides good capabilities for modifying the design features and expressing the user's desire	9	22	7	3	0	41	3.902	0.831	78.0	Agree	30.076	40	00.00
8	**Expressing opinions:** The experience provided a great opportunity to express opinions easily and conveniently	14	21	5	1	0	41	4.171	0.738	83.4	Agree	36.171	40	00.00
9	**Desire to develop:** I want to develop BUMAR, adopting it in other purpose.	23	14	3	1	0	41	4.439	0.743	88.8	Str. Ag.	38.242	40	00.00
10	**Willingness to participate:** I am willing to participate in new experiments for the purpose of evaluating designs	25	11	4	1	0	41	4.463	0.778	89.3	Str. Ag.	36.747	40	00.00
11	**Comparison:** There is an advantage in displaying designs using AR over other display methods and techniques	14	15	10	1	0	40	4.050	0.846	81.0	Agree	30.284	39	00.00
12	**Raising awareness:** AR can contribute to increasing public awareness of the importance of architectural design	15	22	2	1	0	40	4.275	0.679	85.5	Str. Ag.	39.826	39	00.00
13	**Enhancing participation:** AR can help increase public participation in design decisions if used widely in the city	17	22	1	1	0	41	4.341	0.656	86.8	Str. Ag.	43.568	40	00.00
14	**communication:** AR techniques can help improve communication between the designers and clients in private projects	24	13	2	2	0	41	4.439	0.808	88.8	Str. Ag.	48.722	40	00.00
15	**Sense of belonging:** AR techniques can contribute to enhancing the user's sense of belonging to the place and increasing interest in future development projects	14	21	5	1	0	41	4.171	0.738	83.4	Agree	36.171	40	00.00
	Total	—	—	—	—	—	—	4.263	0.724	85.3	Str. Ag.	38.630	40	00.00

1	Timestamp	X moving	Y moving	Hight	image link
2	02/07/2024 10:32:57	3	-1	1.06	https://i.imgur.com/zzXmiba.png
3	02/07/2024 10:34:18	-4	3.5	0.92	https://i.imgur.com/Xh9UVbi.png
4	02/07/2024 10:34:59	-5	4	1.08	https://i.imgur.com/pqKljXC.png
5	02/07/2024 10:35:09	-5	4	1.08	https://i.imgur.com/jDh3tJ0.png
6	02/07/2024 10:35:12	-5	4	1.08	https://i.imgur.com/5U4lJgH.png
7	02/07/2024 10:35:46	-5	4	1.08	https://i.imgur.com/NChJrry.png
8	02/07/2024 10:36:28	5	-4.5	1.08	https://i.imgur.com/CS9RK4J.png
9	02/07/2024 10:37:25	2	-5	1.08	https://i.imgur.com/VdY2UXV.png
10	02/07/2024 10:37:29	2	-5	1.08	https://i.imgur.com/ophXmcB.png
11	02/07/2024 10:37:41	2	-5	1.08	https://i.imgur.com/NKF0MQI.png
12	02/07/2024 11:05:18	5	-0.5	0	https://i.imgur.com/AJpHNuR.jpeg
13	03/07/2024 08:46:09	0	0	0	https://i.imgur.com/u9LZDdY.jpeg
14	03/07/2024 11:50:56	1	1	1	https://i.imgur.com/KNcHx1X.png

Figure 12. The integrated form within BUMAR.

Figure 13**.** As election of images submitted by participants.

This supports the assumption of strong application acceptance at the indicated rate of 85%. Regarding the integrated form within the application, values were received as shown in Fig. 12, which display the time and date of submission, along with numerical values for moving in the X and Y directions, represented with positive or negative values indicating the distance moved in meters and the direction along the axis, left or right. The form also shows values for the scaling factors related to the building's height. The final field contains links to images submitted by users, collected as in Fig. 13, which provide insights into the chosen finishing materials and the optimal orientation of the building entrance between north and west. These values are suitable for statistical analysis; however, in this experiment, they were not the primary focus for analysis but were used instead as a preliminary experiment to simulate real-world scenarios related to actual projects. What has been mentioned clearly demonstrates the potential of using the BUMAR app in various architectural fields, as well as achieving public participation in design. The application facilitates communication between the architect and the various stakeholders, allowing for the exchange of opinions either through questions and answers via a customizable questionnaire tailored to each experience or through interactive features that can be added or removed based on the nature of the presented model. In other words, the designer can understand differing perspectives on the design either through dialogue or through active participation by interacting with and modifying the model. In other words, the application can be used to showcase models of lost architectural and urban heritage in their actual locations and to record feedback on those presentations. It can also be utilized to display engineering service elements of a building before implementation and to gather opinions from experts prior to execution. Additionally, it can document these elements through modeling for the purpose of showcasing them and identifying hidden locations for maintenance. Furthermore, it can be employed to present design models created by students and facilitate interactive communication between students and instructors during architectural critique activities, among other possible uses due to the application's development potential

5. Conclusions and Recommendations

Augmented technique is an innovative tool that offers unique capabilities for displaying architectural models, making it suitable for various architectural fields and purposes. Its strength lies in the ability to display architectural designs as comprehensive three-dimensional models integrated with their real environments on a true scale. This capability provides objective perceptions that are easily understandable by both professionals and the public, establishing a common language for communication and interaction among diverse stakeholders, closely resembling real-world experiences. This characteristic plays a crucial role in enhancing public participation in design, from collaboration among architects to the involvement of decision-makers, owners, and executors, and ultimately engaging building users— whether workers in the building, beneficiaries of its services, or those interested in it as part of their urban environment. It also fosters educational and architectural critique between students and professors. Moreover, AR techniques compatibility with various digital tools, such as GIS, BIM, and 3D printing, further reinforces its effectiveness in presenting contemporary design outputs, particularly parametric designs and their complex dynamic forms, which are challenging to grasp through traditional presentation methods. Additionally, it facilitates the process of participation, opinion sharing, and feedback collection through accompanying questionnaires within AR apps. Its growing popularity is attributed to the fact that it no longer requires specialized equipment; instead, it can be accessed via widely available smart devices like smartphones and tablets. In practical terms, the experiment has demonstrated the potential for user participation, whether through approaches focused on user requirements via surveys or through participatory design that utilizes interactive features of the user interface to modify the model, translating user desires or modifications into quantifiable values for statistical analysis. BUMAR successfully achieved a good level of acceptance among participants and effectively clarified the augmented techniques potential for users, it created expectations and aspirations for AR capabilities that exceed what it provided. The results showed that users were more interested in interactive aspects and the ability to modify designs, as well as the demand for design alternatives to choose from, rather than merely displaying designs integrated with surroundings, although they referred the significant features in receiving, understanding, interacting with, and perceiving the model in realty. Participants expressed high confidence in augmented technique in general for presenting and understanding design proposals, indicating a willingness to participate in future experiments, especially if the application is developed and used in evaluations of real projects. They showed significant interest in assessing the model, despite knowing that it was not real, and the process was merely a simulation. It was observed in the experiment that the use of MAR apps on users' devices is negatively affected by weather conditions, particularly temperature and sunlight intensity. These factors cause the devices to overheat and reduce screen visibility due to sunlight. Therefore, this research recommends selecting an appropriate time from a climatic perspective for conducting augmented reality experiments, as unsuitable conditions may reduce participation rates since these experiments take place outdoors. Additionally, adverse weather can limit the user's ability to interact with the models displayed on their device screen. Additionally, it was noted that repeated trials by some users improved their interaction with the model. Therefore, it is preferable to make a simulation test of an app before using it in evaluations of real projects. This would enable users to be proficient in its use and distinguish their interest in the app as a new technique for displaying from their interest in the displayed designs as the main subject of evaluation.

Authors' contribution

All authors contributed equally to the preparation of this article.

Declaration of competing interest

The authors declare no conflicts of interest.

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Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

REFERENCES

[1] S. Mystakidis, "Metaverse," *Encyclopedia*, vol. 2, no. 1, pp. 486–497, 2022. [Online]. Available: https://doi.org/10.3390/encyclopedia2010031

[2] V. Nguyen and C. Nguyen, "A systematic review of structural equation modeling in augmented reality applications," *J Electr Eng Comput Sci*, vol. 28, no. 1, p. 328–38, 2022. [Online]. Available: http://doi.org/10.11591/ijeecs.v28.i1.pp328-338

[3] M. Russo, "Ar in the architecture domain: State of the art," *Applied Sci*, vol. 11, no. 15, p. 6800, 2021. [Online]. Available: https://doi.org/10.3390/app11156800

[4] A. Hajirasouli and S. Banihashemi, "Augmented reality in architecture, construction and engineering education," *Int J Educ Technol High Educ.*, 2022.

[5] G. Schall, J. Döllner, and D. Schmalstieg, “Augmented reality in architecture and design: potentials and challenges for application,” *In: Proceedings of the European Conference on Computer Graphics*, 2018. [Online]. Available: https://doi.org/10.1260/147807709788921985

[6] R. Azuma, “A survey of augmented reality,” *Presence: Teleoperators and Virtual Environments*, vol. 8, p. 355–85, 1997. [Online]. Available: https://doi.org/10.1162/pres.1997.6.4.355

[7] R. Fenjan, H. Alsamer, and N. Almansor, “The virtual documentation role in reformulating the heritage of basra city,” *Architecture and Engineering .J*, vol. 9, no. 4, p. 5–17, 2024. [Online]. Available: https://doi.org/10.23968/2500-0055-2024-9-4-3-3-18

[8] R. AbdulRahman and I. Al-Alaf, “Interactive modelling of lost landmarks – qishla of mosul: A case study,” *Diyala J Eng Sci*, vol. 15, no. 4, p. 72–86, 2022. [Online]. Available: https://doi.org/10.24237/djes.2022.15407

[9] M. Jafar, “Apple developer. augmented reality.” [Online]. Available: https://developer.apple.com/augmented-reality.

[10] “Google developers. augmented reality,” no. 1. [Online]. Available: https://developers.google.com/ar.

[11] S. Hemanth Kumar and T. Chetan, “Enhancing consumer engagement and product experience through augmented reality,” *Int J Creative Research Thoughts (IJCRT)*, vol. 9, no. 1, pp. 139–156, 2021. [Online]. Available: https://doi.org/10.5281/zenodo.4649637

[12] J. Amorim, C. Matos, A. Cuperschmid, P. Gustavsson, and C. Pozzer, “Augmented reality and mixed reality technologies: Enhancing training and mission preparation with simulations,” *STO-MP-MSG-9*, vol. 247, no. 1-3, pp. 180–189, 2013. [Online]. Available: http://doi.org/10.13140/2.1.1891.6642

[13] C. Rossi, M. Lima, A. Santos, and I. Winkler, “A participatory content authoring workflow for augmented reality at industrial maintenance,” *In: Advances in Virtual Reality. Intech Open*, vol. 57, no. 2, pp. 1–9, 2023. [Online]. Available: https://doi.org/doi:10.5772/intechopen.109727

[14] M. Tritthart, “Animated urban surfaces: Spatial augmented reality in public discourse,” *Int J Film Media Arts*, vol. 6, no. 2, p. 75–94, 2021. [Online]. Available: https://doi.org/10.24140/ijfma.v6.n2.05

[15] M. Bower, C. Howe, N. McCredie, A. Robinson, and D. Grover, “Augmented reality in education – cases, places and potentials,” *Educ Media Int*, vol. 51, no. 1, p. 1–15, July 2014. [Online]. Available: https://doi.org/10.1080/09523987.2014.885286

[16] B. Allbach, M. Memmel, P. Zeile, and B. Streich, “Mobile augmented city: New methods for urban analysis and urban design processes using mobile augmented reality services. in: 16th international conference on urban development, regional planning and information society; rome, italy; 2011. p. 333–4.” *in Artificial Neural Networks for Renewable Energy Systems and Real-World Applications*, pp. 159–187, 2022. [Online]. Available: https://doi.org/10.1016/B978-0-12-820793-2.00010-0

[17] E. Kaimakamis, “Comparison between augmented reality techniques in virtual-pilot. diploma thesis, technical university of thessaloniki, greece; 2020.” *Journal of membrane science*, vol. 368, no. 1-2, pp. 202–214, 2011. [Online]. Available: https://doi.org/10.1016/j.memsci.2010.11.030

[18] G. Goepel, J. Ho, and A. Fingrut, “Augmenting the exposure of extended reality (xr) technologies for architectural graduate and undergraduate students in hong kong: On teaching initiatives for virtual-, augmented-, and mixed reality (vr/ar/mr),” *Asian J Sch Teach Learn*, vol. 13, no. 1, p. 24–46, 2023.

[19] S. Malysheva, “Use of augmented reality information and communication technologies in urban historical environment,” *IOP Conf Ser: Mater.Sci Eng*, vol. 775, p. 012069, 2020. [Online]. Available: http://10.1088/1757-899X/775/1/012069

[20] Z. Shaghaghian, H. Burte, D. Song, and W. Yan, “Learning geometric transformations for parametric design: An augmented reality (ar)-powered approach,” *In: CAAD Futures 2021 Conference Proceedings;*, vol. 2, p. 1–14, Sep 2021. [Online]. Available: https://doi.org/10.48550/arXiv.2109.10899

[21] P. Jimenez Vicario, M. Ródenas López, M. Serrano Martínez, M. García Córdoba, M. Mestre Martí, and D. Ros MacDonell, “Augmented reality and generative design: A tour through print media for designing and representing architecture,” *In: 8th International Conference on Education and New Learning Technologies . https://doi.org/10.21125/edulearn*, vol. 13, p. 4769–77, 2016. [Online]. Available: https://doi.org/10.21125/edulearn.2016.2143

[22] I. Kishor, I. Kumar, P. Chaudhary, and P. Bansal, “Visualization of computer labs using augmented reality.” *JIRT*, vol. 10, no. 1, p. 707–9, 2023. [Online]. Available: http://doi.org/10.13140/RG.2.2.24101.88804

[23] D. Szekely, S. Vert, O. Rotaru, and D. Andone, “Usability evaluation with eye tracking: The case of a mobile augmented reality application with historical images for urban cultural heritage,” *Heritage*, vol. 6, no. 3, p. 3256–3270, 2023. [Online]. Available: https://doi.org/10.3390/heritage6030172

[24] J. Milovanovic, G. Moreau, D. Siret, and F. Miguet, “Virtual and augmented reality in architectural design and education: An immersive multimodal platform to support architectural pedagogy,” *Journal of American science Futures*, vol. 17, no. 1, p. 513–32., 2017. [Online]. Available: https://hal.science/hal-01586746v1

[25] D. Salgado, D. Benitez, A. Morales, M. Gonzalez, and N. Huertas, “Use of augmented reality technology and gps to encourage tourism in the sucre department1154-1201,” *IOP Conf Ser: Mater Sci Eng*, vol. 1154, no. 1, p. 012017, 2021. [Online]. Available: https://doi.org/10.1088/1757-899X/1154/1/012017

[26] G. Lampropoulos, E. Keramopoulos, and K. Diamantaras, “Semantically enriched augmented reality applications: A proposed system architecture and a case study,” . *Int J Recent Contributions Eng Sci IT (iJES)*, vol. 10, no. 01, p. 29–46, 2022. [Online]. Available: https://doi.org/10.3991/ijes.v10i01.27463

[27] F. Avella, M. Cannella, and F. Lanza, “3d printing and augmented reality: The project for the second competition for the italian parliament by ernesto basile,” *Int Arch Photogramm Remote Sens Spatial Inf Sci*, vol. XLVIII-M-2-2023, p. 129–37, 2023. [Online]. Available: https://doi.org/10.5194/isprs-archives-XLVIII-M-2-2023-129-2023

[28] O. D. Onososen, A., “Evolution in the intellectual structure of virtual reality and augmented reality research in the aec sector,” *Preprints*, vol. 2023030235, 2023. [Online]. Available: https://www.preprints.org/manuscript/202303.0235/v1

[29] K. Purushottam, K. Chandramouli, J. Naga Chaitanya, and B. Gowreswari, “A review on virtual reality and augmented reality in architecture, engineering and construction industry,” *Int J Modern Trends in Sci Technololgy*, vol. 7, no. 0708007, p. 29–33, 2021. [Online]. Available: https://doi.org/10.46501/IJMTST0708007

[30] A. Revoltia, P. Dallasega, F. Schulze, and A. Walder, “Augmented reality to support the maintenance of urban-line infrastructures: A case study,” *Procedia Computer Science*, vol. 217, p. 746–755, 2023. [Online]. Available: https://doi.org/10.1016/j.procs.2022.12.271

[31] X. Wang, “Augmented reality in architecture and design: Potentials and challenges for application,” *Int J Architectural Comput*, vol. 7, no. 2, p. 309–326, 2009. [Online]. Available: https://doi.org/10.1260/147807709788921985

[32] L. Kappelman and E. McLean, “The respective roles of user participation and user involvement in information system implementation success,” *In: Proceedings of the International Conference on Information Systems.*, vol. III, no. 1, pp. 1–12, 1991.

[33] A. Othman, B. Shouman, and M. Marzouk, “Enhancing users’ involvement in architectural design using mobile augmented reality,” *Eng Construct and Archit Manag*, vol. 29, no. 6, p. 2514–2534, 2022. [Online]. Available: https://doi.org/10.1108/ECAM-02-2021-0124

[34] S. Kaya, “Relating building attributes to end user’s needs: The owners-designers-end users’ equation,” *Facilities*, vol. 22, no. 10, p. 247–52, 2004. [Online]. Available: https://doi.org/10.1108/02632770410555968

[35] M. Caixeta, J. Bross, P. Tzortzopoulos, and M. Fabricio, “Value generation through user involvement in healthcare design,” *In: 21st Annual Conference of the International Group for Lean Construction IGLC*, p. 288–308, 2013.

[36] B. Fischer, A. Peine, and B. Ostlund, “The importance of user involvement: A systematic review of involving older users in technology design60(7):. https://doi.org/10.1093/geront/gnx054.” *Gerontologist*, vol. 60, no. 7, p. 513–23, 2019. [Online]. Available: https://doi.org/10.1093/geront/gnz163

[37] P. Christiansson, K. Svidt, K. Pedersen, and U. Dybro, “User participation in the building process,” *J Inf Technol Constr*, vol. 16, no. 1, p. 309–35, 2011. [Online]. Available: http://www.itcon.org/data/works/att/2011_20.content.00616.pdf

[38] J. Lai, T. Honda, and M. Yang, “A study of the role of user-centered design methods in design team projects.” *Artif Intell Eng Des Anal*

Manufacturing, vol. 24, no. 3, p. 303–316, 2010. [Online]. Available: https://doi.org/doi:10.1017/S0890060410000211

[39] N. Fumagalli, E. Fermani, G. Senes, M. Boffi, L. Pola, and P. Inghilleri, "Sustainable co-design with older people: The case of a public restorative garden in milan (italy)," *Sustainability*, vol. 12, no. 8, p. 3166, 2020. [Online]. Available: https://doi.org/10.3390/su12083166

[40] F. Visser, P. Stappers, R. Lugt, and E. Sanders, "Context mapping: Experiences from practice," *I nt J Cocreation Design Arts*, vol. 1, no. 2, p. 119–49, 2005. [Online]. Available: https://doi.org/10.1080/15710880500135987

[41] N. Norouzi, M. Shabak, M. Bin Embi, and T. Khan, "A new insight into design approach with focus on the architect-client relationship," *Asian Soc Science*, vol. 11, no. 5, p. 108–120, 2015. [Online]. Available: https://doi.org/10.5539/ass.v11n5p108

[42] P. Tzortzopoulos, R. Codinhoto, M. Kagioglou, J. Rooke, and L. Koskela, "The gaps between healthcare service and building design: A state of the art review," *Ambiente Construído*, vol. 9, no. 2, p. 47–55, 2009. [Online]. Available: https://seer.ufrgs.br/ambienteconstruido/article/view/7552/5489

[43] M. Kassem, T. Brogden, and N. Dawood, "Bim and 4d planning: A holistic study of the barriers and drivers to widespread adoption," *J Constr Eng Project Manag ,Korea Institute of Construction Engineering and Management*, vol. 2, no. 4, pp. 1– 10, 2012. [Online]. Available: https://doi.org/10.6106/JCEPM.2012.2.4.001

[44] T. Kymäläinen and S. Siltanen, "Co-designing novel interior design services that utilise augmented reality: A case study," *Adv Res Trends New Technol Softw Hum-Computer Interact Communicability*, pp. 269–279, 2014. [Online]. Available: https://doi.org/10.4018/978-1-4666-4490-8.ch025

[45] S. Bassam, A. E. O. Ayman, and M. Mohamed, "Enhancing users' involvement in architectural design using mobile augmented reality," *Eng., Construct and Archit Manag.*, vol. 29, no. 6, p. 2514–2534, 2022. [Online]. Available: https://doi.org/10.1108/ECAM-02-2021-0124

[46] Y. Wang and Y.-S. Lin, "Public participation in urban design with augmented reality technology based on indicator evaluation," *Front. Virtual Reality*, vol. 4, no. 16, 2023. [Online]. Available: https://doi.org/10.3389/frvir.2023.1071355

[47] T. Alazzawi and H. Alsamer, "The impact of augmented reality techniques on improving urban design effectiveness," *HBRC J*, vol. 20, no. 1, pp. 799–828, 2024. [Online]. Available: https://doi.org/10.1080/16874048.2024.2378657

[48] S. Janset and M. Narmeen, "Visions for a greener future at sail oman: Augmented reality as a tool for urban design," *Int J Archit Art Design*, vol. 10, no. 8, p. 220–229, 2020.

[49] Z. Seidametova, Z. Abduramanov, and G. Seydametov, "Using augmented reality for architecture artifacts visualizations," *Digital Library NAES of Ukraine .In: AR Edu 2021: 4th International Workshop on Augmented Reality in Education*, vol. 2898, p. 131–146, 2021. [Online]. Available: https://lib.iitta.gov.ua/id/eprint/727262

[50] B. Furht, "Handbook of augmented reality," *Springer Science Business Media*, 2011. [Online]. Available: https://doi.org/10.1007/978-1-4614-0064-6

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