Enhancing Public Engagement in Sustainable Systems through Augmented Reality

Yu-Chen Lee, S.M.ASCE [1], Abdullah Alsuhaibani [2], Chih-Shen Cheng, Ph.D., M.ASCE [3], Fernanda Leite, Ph.D., P.E., F.ASCE [4]

[1] Ph.D. candidate, Sustainable Systems Program, Maseeh Dept. of Civil, Architectural and Environmental Engineering, The University of Texas at Austin, Austin, TX, USA.
[2] Ph.D. candidate, Civil Engineering and Project Management Program, Maseeh Dept. of Civil, Architectural and Environmental Engineering, The University of Texas at Austin, Austin, TX, USA.
[3] Postdoctoral Fellow, Civil Engineering and Project Management Program, Maseeh Dept. of Civil, Architectural and Environmental Engineering, The University of Texas at Austin, Austin, TX, USA.
[4] Associate Dean for Research, Cockrell School of Engineering, Joe J. King Professor in the Maseeh Dept. of Civil, Architectural and Environmental Engineering, The University of Texas at Austin, Austin, TX, USA.
yuchenlee@utexas.edu, alsuhaibani@utexas.edu, chihshen.cheng@utexas.edu, fernanda.leite@utexas.edu

Abstract –

The sustainability of building infrastructure has been a growing critical global concern. However, stakeholders often overlook the sustainability aspect of systems in their everyday lives. This paper presents an exploration of the potential of augmented reality (AR) technology as a tool for enhancing public engagement around sustainable systems in buildings. We introduce an innovative approach to address the challenge of gap between sustainable infrastructure and user awareness. Through data collection such as access counts, usage duration, and user feedback, we can evaluate the effectiveness of AR applications in improving awareness and engagement in sustainability. This study illustrates how AR technology can facilitate a deeper connection between the public and sustainable systems, thus paving the way for a more environmentally friendly society.

Keywords – Building Sustainability, Augmented Reality, Public Engagement

1 Introduction

According to the Intergovernmental Panel on Climate Change fifth assessment report, the global average temperature has significantly increased over the past century, with carbon dioxide concentrations identified as one of the most prominent drivers. Greenhouse gas emissions have risen globally by 70% from 1970 to 2004 [1]. Consequently, the care for the environment and sustaining the earth's resources have multiplied in recent years [2].

Sustainability, focused on using and conserving natural resources [3], has become a prevalent term in recent years. However, it is often seen as a complex concept with a lack of shared understanding among stakeholders about its effects, causes, roles, and strategies [4]. The lack of public awareness is commonly identified as a major barrier to implementing sustainability practices [5], [6], [7], [8]. This issue has led organizations such as UNESCO to advocate for sustainability education for several decades. For instance, in a UNESCO conference in 1999, the goal of environmental education was outlined as to "clearly show the economic, political and ecological interdependence of the modern world, in which decisions and actions by the different countries can have international repercussions. Environment should, in this regard, help to develop a sense of responsibility and solidarity among countries and regions" [9].

Furthermore, aging infrastructure and frequent climate-related disasters present an evident challenge for city-makers and communities across the U.S. Yet, the inaction of institutions, policymakers, and the public hinders significant progress toward climate-resilient infrastructure. We must convey the critical need for resilient infrastructure and allow these stakeholders to be more engaged in the process. In addition, in the built environment domain, with the increased focus on sustainable developments, recent buildings and infrastructures often contain sustainable systems, which are the integrated sustainable components in buildings or as Cabezas [10] defined them as systems that balance needs of human and the environment. However, many occupants are not aware of those sustainable systems, which may make some of them less efficient [11]. Moreover, it is worth mentioning that awareness, which

is knowledge about the sustainable system, is the first step to have the public engage with sustainable systems, which is the activities, decisions, and behaviours that promote sustainability.

Given the advancement of computing power, technologies such as augmented reality (AR), can make invisible, hard-to-imagine concepts visible to the public in meaningful ways. The use of AR has shown a positive impact on education, enhancing traditional learning methods and creating immersive and engaging experiences [12] Also, AR was found to attract those who are less interested in the topic [13]. To this end, this paper explored the potential of AR applications to help the public visualize, adapt, and engage in a conversation about the sustainable systems our community depends on to build resilience. Connecting scientific literacy, visceral experiences, and compelling storytelling provide a powerful pathway to motivate policymakers and the public to take the crucial next steps needed to prepare for the climate crisis.

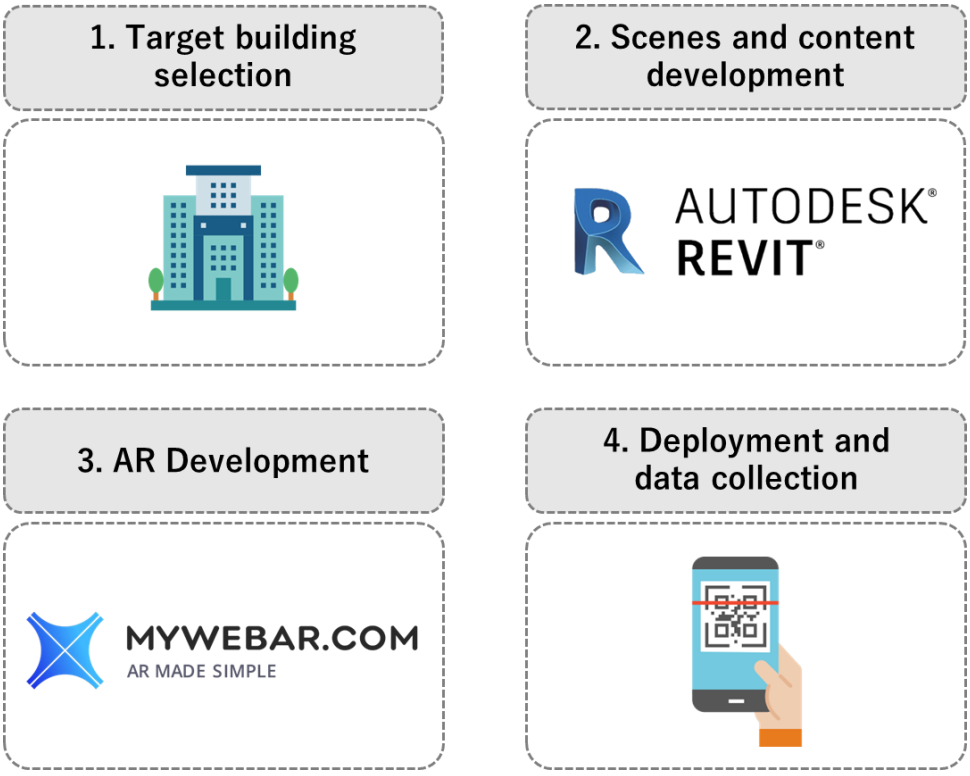

Figure 1. The proposed methodology

Additionally, to address the aforementioned challenges and better improve the awareness among building occupants regarding sustainable systems, this paper proposes a framework leveraging mobile AR to promote sustainability through increasing public awareness about sustainable systems in our daily lives. By scanning QR codes at specific locations within a building, community members and visitors can interact with the developed AR experience to learn about the building itself and sustainability principles.

2 Background

Despite an extensive body of research on sustainability, a notable gap exists in public awareness of sustainability concepts. Many studies that investigated challenges with implementing sustainability found low public awareness among the top barriers [14]. For instance, AlSanad [15] conducted a study to evaluate the obstacles to sustainable construction in Kuwait and found that lack of awareness was ranked as the top barrier, followed by cost. While many of the studies that investigated the barriers were focused locally on different countries such as Chile [16] and Ghana [17], the lack of awareness or similar terms is almost always among the top barriers [5].

To tackle the issue of limited sustainability awareness, various researchers have investigated the use of AR technologies. For example, Bekaroo et al. [18] examined AR for educating about sustainable electronic device usage by showing energy consumption. Moreover,

Strada et al. [19] introduced a collaborative AR serious game focusing on urban development sustainability. Similarly, Wang et al. [20] developed an AR game to educate about climate change. In the circular economy context, Katika et al. [21] tested an AR engagement tool in two Greek case studies, focusing on enhancing public understanding. Huh et al [13], who used AR to educate students about fine dust, mentioned that the use of AR triggers the students' interest and increases participation leading to improved learning activity. These examples demonstrated the positive impact of AR technologies in increasing sustainability awareness. This supports the findings of Alsaati et al. [22], who indicated that using AR in education can lead to environmental and economic benefits. Recently, Boncu et al. [23] thoroughly reviewed the use of mobile applications, including mobile AR, to improve public awareness. Their findings generally suggested that integrating these mobile technologies can be a highly effective approach for enhancing sustainability education.

While several studies leveraged AR to promote sustainability, existing literature focusing on sustainable building systems is still limited. Additionally, many of the solutions suggested in prior studies are not easily accessible to the public, as they often require specialized hardware or software that may not be readily available to everyone. Therefore, drawing inspiration from the success demonstrated by previous research that employed AR technologies, this paper proposed a framework for developing a web-based AR experience to enhance public engagement of sustainable systems.

3 Methodology

The framework for crafting a mobile AR experience focused on engaging the public in sustainability encompasses four steps: (1) Target building selection, (2) Scenes and content development, (3) AR development, and (4) Deployment and data collection. Figure 1 illustrates the proposed methodology of this study. Each step unfolds as follows:

1. Target building selection

The initial step involves targeting a building that incorporates sustainable building systems. For enhanced impact, it is recommended to select a building with high daily foot traffic. For example, campus buildings or public libraries tend to have high traffic, thus are appropriate for engaging the public given their high traffic. Upon selecting a facility, identifying sustainable design features within the building can be achieved by reviewing its Leadership in Energy and Environmental Design (LEED) documents or contacting the general contractor. It is crucial to opt for sustainable building systems that are easily accessible and situated in or near high-traffic areas of a building, such as hallways or gates. Additionally, selecting a wide variety of building systems can help the public acquire a broader spectrum of knowledge. In this study, the authors selected several building systems (such as daylighting and water systems) in a campus building, which received LEED Silver green building certification. A detailed example use case is presented subsequently.

2. Scenes and content development

With a list of selected systems and locations to be displayed, scenes and contents can be crafted based on this list. For each system, the scene should feature multi-media content such as audio, video, text, or a combination thereof to introduce that system. Incorporating 3D models or interactions can enhance the AR experience, making it more engaging. For example, Autodesk® Revit® can be employed to create 3D models of that building or specific components. In one of our use cases, the authors leveraged Autodesk® Revit® to create 3D models and simulation of daylighting, providing the user with precise insights into natural light distribution and sustainable design features within the spaces. In this phase, developers should also strategize for the deployment of this AR experience. Within the framework, the authors created QR codes for each system selected and placed them in designated locations within the selected facility. By scanning the QR codes, users can be directed to the AR experience, elucidating the sustainable feature present in that location, and facilitating knowledge acquisition.

3. AR development

In this research, the authors utilize MyWebAR (https://mywebar.com/), a web-based AR development platform, to construct an AR experience accessible effortlessly through scanning QR codes, eliminating the need app downloads. This way, we can ensure that all users can access the experience through any type of mobile device. Following the preparation of all requisite resources, the files are imported into MyWebAR for mobile AR experience development. The AR experience undergoes multiple pilot tests to confirm accessibility across all devices and proper display of all content.

4. Deployment and data collection

After finalizing the AR experience, the QR codes are printed and placed in designated locations. The authors suggest gathering information for future analysis, such as the kind of device a user uses, how much time they spend on each system, and how many people scan QR codes. With this data, developers can attain a better understanding of the AR experience. This insight allows for iterative refinements to enhance user engagement.

4 Use cases

This study develops four AR experiences in lighting, daylighting, water refilling, and heating, ventilation, and air-conditioning (HVAC) systems. Let's consider one of our AR experiences, where a water refilling machine is an example of sustainable infrastructure within a campus building. Typically, building occupants (e.g., faculty, students, staff, and visitors) encounter this machine, yet often without recognizing its important role as a sustainable feature designed to reduce the consumption of disposable plastic bottles. Moreover, users may not fully understand the machine's eco-conscious purpose, highlighting the need for our effective communications through AR to convey the sustainability message and engage users. To address the challenge, an AR experience of the water-refilling machine was developed, as visualized in Figure 2.

Figure 2. AR implementation: Introducing a water refilling station in a campus building.

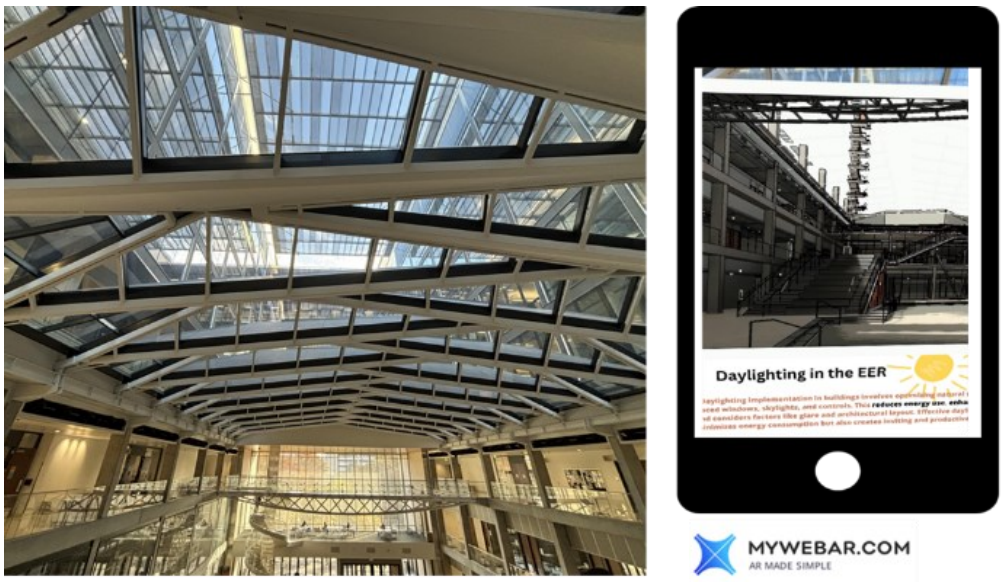

Figure 3. AR implementation: Introducing a daylighting system in a campus building.

The daylighting system is another example of a selected sustainable system in the same building, as shown in Figure 3. The roof structure design is an architectural feature that incorporates transparent materials to allow natural sunlight to penetrate interior spaces. These systems can provide multiple benefits, including energy savings through reduced reliance on artificial lighting, enhanced aesthetics, and improved occupant well-being by developing visually appealing indoor environments. By leveraging AR, users can immerse themselves into the developed AR environment and interactively gain a deeper insight into the sustainable benefits of daylighting systems. Overall, this AR-based approach enables users to actively engage with the concept of daylighting and its energy-saving potential.

In our future work, the authors plan to collect and analyze users' data, including tracking their usage frequency, accessed AR content (e.g., water refilling machine information), and engagement duration. Qualitative feedback will also be gathered through an online survey. Particularly, three types of data will be collected, including access counts, usage duration, and general feedback from users.

We will then use the data to evaluate the impact on public engagement in sustainable systems. Combining the quantitative or qualitative insights from the data, we will be able to evaluate the feasibility of AR in raising awareness and engagement regarding sustainability within the building. For example, access frequency and usage duration can be used to gauge user engagement levels while the user feedback provides qualitative insights into their experiences. Additionally, the general feedback from users provides qualitative insights into their experiences, offering strategies for improving the applications and identifying which elements are successful in enhancing public engagement in sustainability. Note that the metrics related to evaluating public awareness and engagement are crucial for measuring the effectiveness of our initiatives. The metrics will serve as important indicators for demonstrating effectiveness to engage the participants and to improve the awareness, which is also a potential direction of our future research.

5 Conclusions

This research explored the use of AR with an aim to improve the public engagement in sustainable systems. Existing literature has highlighted the need for raising awareness about sustainability as well as the challenge of communicating sustainability to the public despite the abundance of related technical publications. To address this issue, this manuscript proposed an AR-based framework to facilitate educating building occupants about sustainable systems. In this study, four sustainable systems were identified within an engineering building on campus, which included lighting, daylighting, and HVAC systems. Subsequently, corresponding AR experiences were developed for these systems.

The research team faced some challenges when building this framework that are present in almost all existing AR applications, including the compatibility between software systems used, and the accuracy of augmentation. Due to the inherent limitations of paper-based presentations, our use case demos were confined to 2D imagery. It is worth noting that our use cases also include the visualization of 3D objects in motion and auditory instructions. In our future work, we will collect user data and analyze these data to assess user engagement levels and gather feedback. The collected data is beneficial for us to refine the AR experiences, identifying successful elements and strategies for enhancing public engagement in sustainability. Beyond this, as we continuously enhance the AR experience and expand its coverage to include a broader range of sustainable systems (e.g., sustainable construction materials), this visualization technology could contribute towards a more sustainability-aware society.

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