EXTENDED-ABSTRACT

Footprints of Travel: AIoT and AR Enhanced Tourist Gaming Experience in Unmanned Cultural Sites

SHIHYU LAI, National Cheng Kung University, Tainan, Taiwan

DAIEN LIU, National Cheng Kung University, Tainan, Taiwan

ZONG FAN YEH, National Cheng Kung University, Tainan, Taiwan

CHUNCHE HSU, National Cheng Kung University, Tainan, Taiwan

FUYAO CHANG, National Cheng Kung University, Tainan, Taiwan

MINGZHI TSAI, National Cheng Kung University, Tainan, Taiwan

View all

Open Access Support provided by:

National Cheng Kung University

Published: 11 May 2024

Citation in BibTeX format

CHI '24: CHI Conference on Human Factors in Computing Systems
May 11 - 16, 2024
HI, Honolulu, USA

Conference Sponsors:
SIGCHI

https://doi.org/10.1145/3613905.3648626
ISBN: 9798400703317

Footprints of Travel: AIoT and AR Enhanced Tourist Gaming Experience in Unmanned Cultural Sites

Shih-Yu, Lai*
National Cheng Kung University,
Tainan City, Taiwan
d84099084@gs.ncku.edu.tw

Dai-En, Liu*
National Cheng Kung University,
Tainan City, Taiwan
n76114031@gs.ncku.edu.tw

Zong-Fan, Yeh*
National Cheng Kung University,
Tainan City, Taiwan
n76114023@gs.ncku.edu.tw

Chun-Che, Hsu*
National Cheng Kung University,
Tainan City, Taiwan
n96124153@gs.ncku.edu.tw

Fu-Yao, Chang*
National Cheng Kung University,
Tainan City, Taiwan
n76091039@gs.ncku.edu.tw

Ming-Zhi, Tsai*
National Cheng Kung University,
Tainan City, Taiwan
e84109026@gs.ncku.edu.tw

Rui-Hong, Lin*
National Cheng Kung University,
Tainan City, Taiwan
n76104010@gs.ncku.edu.tw

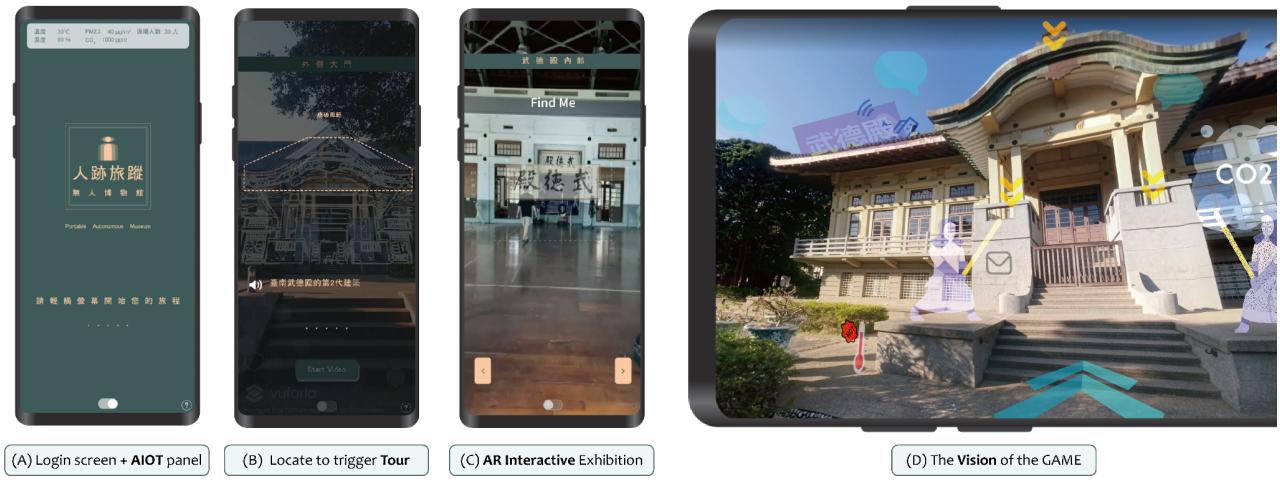

Figure 1: : *Footprints of Travel.*

ABSTRACT

Footprints of Travel is a game that enhances cultural attraction experiences for tourism and space management, utilizing Augmented Reality (AR) and the Artificial Intelligence of Things (AIoT). This "unmanned" approach diverges from traditional museum-focused models, creating personalized, city-wide cultural experiences with comprehensive information services. Our game is tailored for navigating cultural sites, recognizing crowds, and dynamically processing data within the context management framework. The application enhances safety and comfort through temperature control, smoke detection, automatic fans, and artifact protection. We aim to offer a sustainable, interactive exploration game of historical sites, benefiting visitors and site managers. This AR and AIoT game innovatively enhances the visitor experience and blends technology with cultural preservation.

*All authors contributed equally to this research.

CHI EA '24, May 11–16, 2024, Honolulu, HI, USA

ACM ISBN 979-8-4007-0331-7/24/05
https://doi.org/10.1145/3613905.3648626

CCS CONCEPTS

• **Human-centered computing**; • **User interface management systems**; • **Hardware**; • **Sensor applications and deployments**; • **Software and its engineering**; • **Interactive games**;

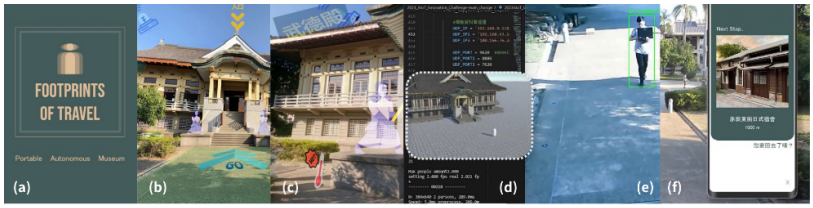

Figure 2: Game Contents with (a) Login Screen, (b) AR Navigation in Tour, (c) IoT with Sensors Data, (d) Model of Digital Twins, (e) Tourist Locating and Tracking, and (e) Recommending Attractions in Wude Hall, Tainan.

KEYWORDS

Augmented Reality, Artificial Intelligence, Cultural Attractions, Explorative Game

ACM Reference Format:
Shih-Yu, Lai, Dai-En, Liu, Zong-Fan, Yeh, Chun-Che, Hsu, Fu-Yao, Chang, Ming-Zhi, Tsai, and Rui-Hong, Lin. 2024. Footprints of Travel: AIoT and AR Enhanced Tourist Gaming Experience in Unmanned Cultural Sites. In *Extended Abstracts of the CHI Conference on Human Factors in Computing Systems (CHI EA '24), May 11–16, 2024, Honolulu, HI, USA.* ACM, New York, NY, USA, 6 pages. https://doi.org/10.1145/3613905.3648626

1 INTRODUCTION

Addressing world heritage management challenges, our Augmented Reality (AR) game, "*Footprints of Travel*," integrates top-tier technologies for an innovative cultural exploration experience (Figure 1). Central to the game is AR technology, enhancing visitor interaction with real-time virtual overlays. It incorporates crowd monitoring, precise location tracking, and data analytics to personalize the user experience by combining the Artificial Intelligence of Things (AIoT) with crowd recognition. Key features include interactive AR tours [1], effective crowd management [2], customizable paths, and tailored recommendations, all supported by multilingual services, enhanced by personalized voice-guided tours (Figure 2). "*Footprints of Travel*" offers an immersive game that blends historical and cultural insights with interactive learning, using AR to vividly represent inaccessible exhibits [3]. This game not only enriches the visitor experience but also aligns with UNESCO's objectives of resilience, humanity, and innovation in heritage management [4]. Applied to sites like Wude Hall in Tainan and Beihai Tunnel in Matsu, the game transforms traditional cultural spaces into engaging, modern experiences. It exemplifies the synergy of technology and culture, contributing to the evolution and development of Taiwan's cultural heritage sector. Through this game, AR technology is showcased as a powerful tool in reinterpreting historical sites with contemporary relevance, offering sustainable and interactive explorations for both visitors and site managers.

2 RELATED WORK

2.1 Crowd Counting and Management by Detection

The management of crowd dynamics in public spaces is a significant challenge [5]. Technologies like surveillance systems and remote monitoring are increasingly used to manage crowds efficiently. These systems enable real-time tracking and analysis of footfall, optimizing space layout and ensuring safety.

2.2 AR Games for Digital Twins

Augmented Reality (AR) games are being explored for their potential in cultural heritage sites. These games utilize digital twins [6], which are virtual replicas of real-world objects [7], to provide immersive experiences [8]. They are used for organizing related data, simulating behaviors of heritage assets, and setting up automatic responses based on interactions between the virtual and real worlds [9]. This approach is seen as an innovative method for studying, communicating, preserving, and exploiting cultural heritage [10].

3 INTERFACE INNOVATION

The "Unmanned Museum" initiative innovatively integrates AIoT and AR technologies into mobile game [11], revolutionizing the management and visitor experience of cultural heritage sites. This approach enhances smart management, offering immersive historical and cultural presentations through AR, and efficient remote monitoring of site resources by Digital Twins and AIoT in tourism (Figure 3a, 3b, 3c). Key features of the game include crowd management, smart navigation with personalized routes, and AR-driven interactive learning. This game project integrates real-world interactions with a digital twin model through innovative technology, creating an immersive player experience.

3.1 Game Concepts and Design

This study presents an AR cultural exploration game, offering novel representations of historical treasures in urban cultural heritage for on-site use (Figure 4). It focuses on two research sites: Tainan Wude Hall, a richly historic building in Tainan, Taiwan, and the Beihai Tunnel in Matsu, a unique military landscape repurposed for public access (Figure 5a, 5b). Moving away from traditional museum experiences, it offers personalized, city-wide exploration with AR technology [12]. The game provides dynamic site navigation, crowd management, and interactive historical content, accommodating global audiences through multilingual support. Integrating AR with real-time data and sensor-based tracking, it enhances visitor interaction and management of cultural spaces, offering a new paradigm for cultural heritage engagement.

3.2 Techniques and Details

Integrating YOLO v8 and Unity [13], our system leverages advanced crowd recognition and spatial data processing for precise indoor

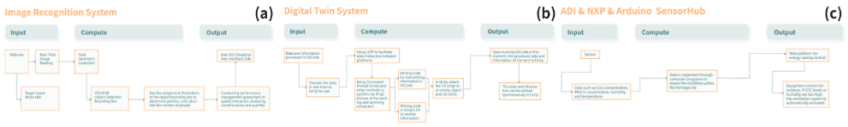

Figure 3: System Framework of (a) Crowd Recognition, (b) Digital Twins, (c) Sensor Hub.

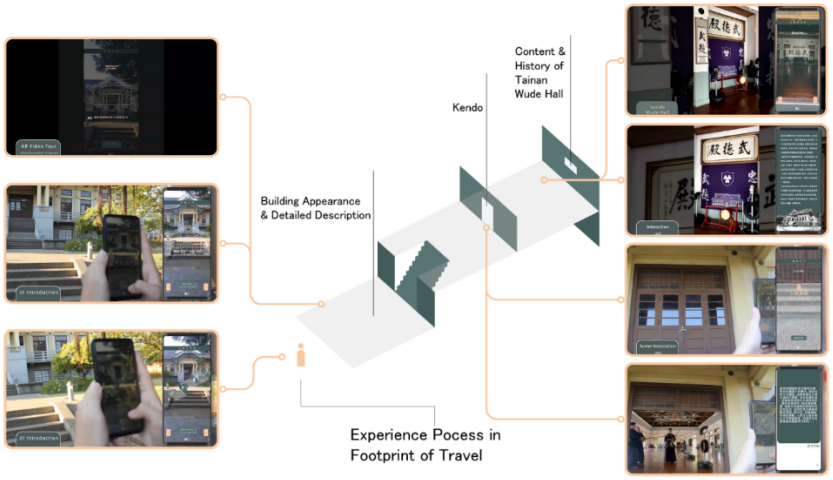

Figure 4: AR Tour and Interaction with Cultural Sites in the Game.

Figure 5: (a) Wude Hall in Tainan City, Taiwan and (b) Tunnels in Matsu Islands, Taiwan.

positioning. It assigns unique IDs for user tracking and integrates with Google Maps for customized recommendations, enhancing accuracy beyond traditional GPS, Bluetooth, and WiFi. A SensorHub, combining devices from Analog Devices Inc. and NXP Semiconductors with Arduino, facilitates sophisticated environmental monitoring. Sensors like DTH11, SCD40, and G5T PMS5003T accurately measure humidity, temperature, CO2 levels, and particulate matter, ensuring reliable environmental data collection for diverse applications (Table 1).

4 IMPLEMENTATION

"Footprints of Travel" is a groundbreaking game focused on cultural heritage, employing AR for historical exploration and AIoT for smart site management. The Cultural Heritage Game aspect immerses visitors in heritage through a mobile app, boosting engagement and conservation awareness. The AR Historical Game provides an interactive deep dive into sites like Wude Hall, where visitors uncover history through tasks and puzzles. The Smart Management System aspect efficiently oversees heritage sites, monitoring vital parameters for effective, unmanned museum operation. This triad of technology-driven solutions collectively enhances visitor experiences and optimizes heritage site management.

4.1 Hardware with Sensor Test

Our integrated system, utilizing sensors from ADI, NXP, and Arduino, offers sophisticated environmental monitoring and control. It automatically manages appliances like air conditioners and lighting in response to changes in temperature, humidity, and CO2

Table 1: Sensors and Specifications.

Sensor	Features	Measurement Range	Accuracy	Resolution
DTH11	Temperature	0-50℃	±2℃	1℃
	Humidity	20-90%	±5%	1% (Relative)
SCD40	Carbon Dioxide	400 - 2000 ppm	±50 ppm	NA
G5T PMS5003T	PM2.5 Particulate	0.3-1.0;1.0-2.5;2.5-10 μ m	Effective Range: 0-500 μg /m^3;Max Range: *≥1000 μg/m^3	1 μ g/m^3

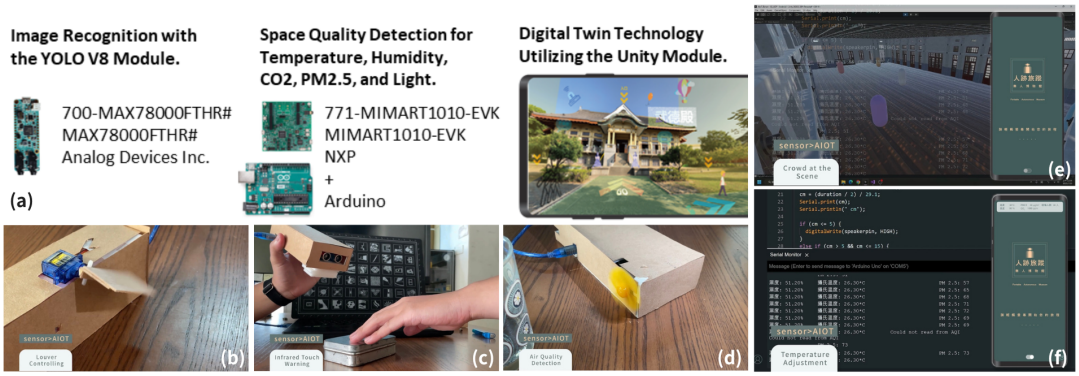

Figure 6: SensorHub: (a) Microcontrollers and Sensors, (b) Louver Controlling, (c) Infrared Touch Warning, (d) Air Quality Detection, (e) # of Crowds, and (f) Temperature Adjustment.

levels. This setup not only facilitates interactive guided tours based on players' movements and interest levels but also integrates environmental data (temperature, humidity, CO2 levels) gathered by sensors into the digital model for enhanced immersion. The system adapts to environmental and crowd dynamics, ensuring optimal conditions while preserving energy. Advanced data analysis supports trend observation and future pattern prediction, enhancing both visitor experience and exhibit preservation through responsive environmental adjustments (Figure 6).

4.2 Software in Evaluation

The software employs a modified YOLOv8 framework to integrate speed estimation and human tracking through crowd recognition, enabling efficient spatial data collection via CCTV without the need for wearable sensors. It facilitates real-time tracking and assigns unique IDs, making it adaptable to various architectural spaces. Image geometric correction is implemented to correct perspective coordinate errors (Figure 7a). These spatial coordinates are then transmitted to a Unity application via UDP, enabling real-time avatar updates within a virtual environment. The system uses environmental references for spatial analysis in Unity's digital twin 3D model, created by scanning with a Microsoft XBOX 360 Kinect Sensor and processed using Cloud Compare software (Figures 7b, 7c). It also integrates environmental sensor data for IoT control. Technical challenges associated with Vuforia and UDP data transmission have been addressed through AR Foundation and protocol enhancements (Figures 7d, 7e). Additionally, AR objects provide educational content and demonstrations, enhancing player engagement by merging physical interaction with digital exploration (Figure 8).

5 USER EXPERIENCE EVALUATION

5.1 Feasibility and Experience

Our questionnaire, focusing on users aged 20-30 with a balance in gender and a variety of professions, showed a strong inclination (83.3%) towards visiting cultural sites or heritages (9**a**). The gamefulness analysis revealed that certain features of AIoT applications significantly enhance cultural tourism experiences (Figure 9b, 9c). The regression model indicated that about 63% of the effectiveness in cultural tourism is explained by variables like 'Satisfaction with Conception and Implementation' and 'Interesting Level,' highlighting their significant impact on enhancing user experience (Figure 9d). This data underscores the importance of engaging content and effective implementation in AIoT applications to enrich cultural tourism experiences.

5.2 Evaluation and Improvement Directions

This work reveals that integrating voice features in cultural heritage games could boost convenience and engagement, but concerns about app size and accessibility suggest a need for a more user-friendly interface and offline functionality. Effective visitor flow management remains a challenge, especially with uneven app adoption. Simplification of the user interface and ensuring compatibility across platforms, including iOS, are crucial for improvement.

The study underscores the importance of balancing interactive elements with the intrinsic value of experiencing historical sites.

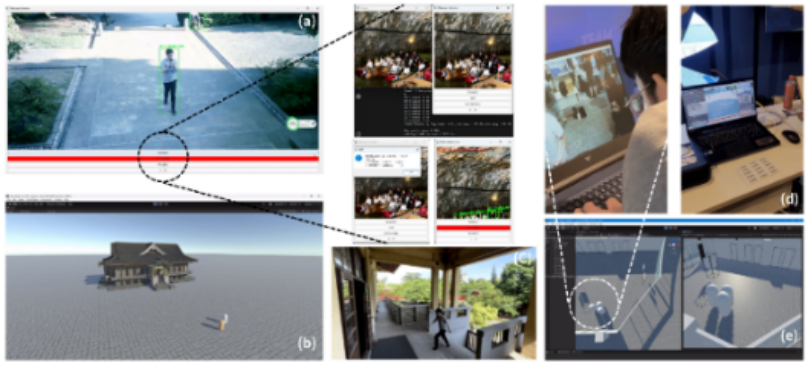

Figure 7: The Process of Spatial Geometric Correction, Digital Twins System with YOLOv8, Unity and Sensors.

Figure 8: The Details of Gameplay: (a) AR Interaction, (b) Exiting, (c) Tourist Locating, (d) Tracking, Recommended Attractions with (e) Google Map, and (f) Navigation.

Incorporating tangible interfaces, like in Nintendo Switch, might enhance the experience, but the game design should cater to all ages, including senior-friendly options. The focus should remain on visually appreciating artifacts and spaces, supplemented by auditory guidance for a well-rounded cultural experience.

6 DISCUSSION AND CONCLUSION

The "Footprints of Travel" game, leveraging AR and AIoT, revolutionizes the cultural site experience, diverging from traditional museum approaches. It offers personalized, interactive explorations, enhancing visitor engagement and site management. This innovative solution is applied to Tainan's Wude Hall and Matsu's Beihai Tunnel, providing immersive AR tours and efficient management. The game combines YOLO v8 for crowd recognition with Unity for spatial data processing and environmental sensors, creating a precise digital twin model. This integration enriches user interaction and ensures accurate monitoring for a more engaging cultural experience. Survey data indicate a strong preference among young adults for visiting cultural sites, highlighting the game's appeal. Key features identified from the study enhance the cultural tourism experience, guiding improvements in AIoT applications to better serve visitor needs and preferences, thereby marking a new era in heritage site management and engagement.

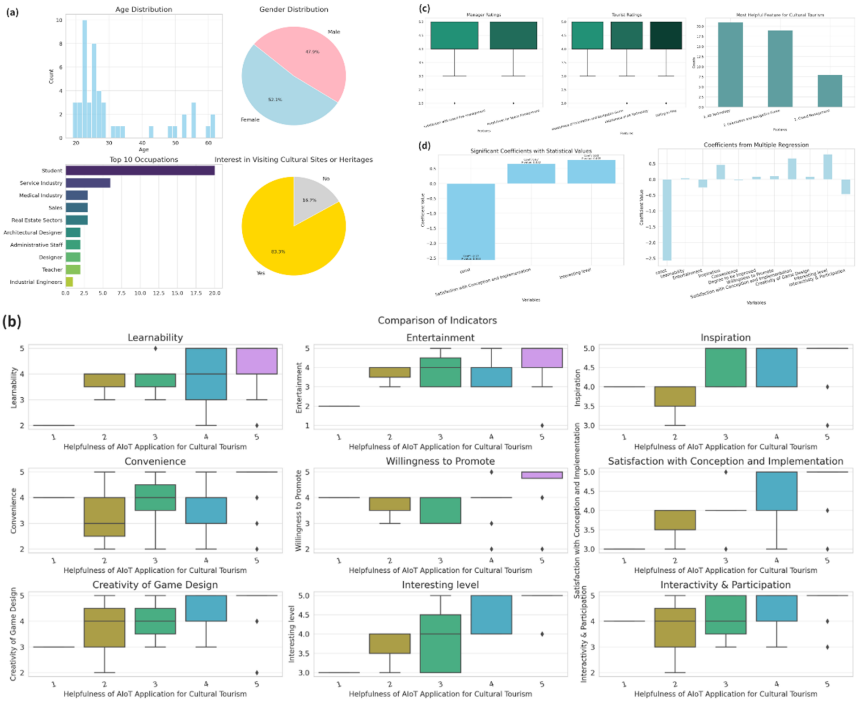

Figure 9: The Questionnaire Measuring (a) the Demographical Variables of the Users, Bar Charts and Boxplots for the (b) Experiences of the Users, (c)Satisfactions of Managers and Tourists, and (d) Multiple Regression Analysis.

REFERENCES

[1] Dieck, M. Claudia tom, and Timothy Hyungsoo Jung. 2017. Value of Augmented Reality at Cultural Heritage Sites: A Stakeholder Approach. *Journal of Destination Marketing & Management* 6, 2, 110–17. https://doi.org/10.1016/j.jdmm.2017.03.002.

[2] Sam, D. Babu, S. V. Peri, M. Narayanan Sundararaman, A. Kamath, and V. B. Radhakrishnan. 2020. Locate, Size and Count: Accurately Resolv-ing People in Dense Crowds via Detection. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 1–1. https://doi.org/10.1109/TPAMI.2020.2974830.

[3] Ariza-Colpas, Paola, Marlon Alberto Piñeres-Melo, Roberto César Morales-Ortega, Andres-Felipe Rodriguez-Bonilla, Shariq Aziz Butt, Sumera Naz, del Carmen, Maribel Romero-Mestre, and Ronald Alexander. 2023. Augmented Reality and Tourism: A Bibliometric Analysis of New Tech-nological Bets in the Post-COVID Era. *Sustainability* 15, 21, 15358–58. https://doi.org/10.3390/su152115358.

[4] Gann, George D., Tein McDonald, Bethanie Walder, James Aronson, Cara R. Nelson, Justin Jonson, James G. Hallett, *et al.* 2019. International Principles and Standards for the Practice of Ecological Restoration. Second Edition. *Restoration Ecology* 27, S1. https://doi.org/10.1111/rec.13035.

[5] Franke, Tobias, Paul Lukowicz, and Ulf Blanke. 2015. "Smart Crowds in Smart Cities: Real Life, City Scale Deployments of a Smartphone Based Participatory Crowd Management Platform." *Journal of Internet Services and Applications* 6, 1. https:// doi.org.10.1109/SSCI.2017.8285439.

[6] Mohammadi, Neda and John Eric Taylor. 2017. Smart city digital twins. In 2017 *IEEE Symposium Series on Computational Intelligence (SSCI '17)*, Nov.27 -Dec.01, 2017, Honolulu, Hawaii, USA. 1-5. https://doi.org.10.1145/567752.567774

[7] Dembski, Fabian, Uwe Wössner, Mike Letzgus, Michael Ruddat, and Claudia Yamu. 2020. Urban Digital Twins for Smart Cities and Citizens: The Case Study of Herrenberg, Germany. *Sustainability* 12 (6): 2307. https://doi.org/10.3390/su12062307.

[8] Jiang, Shan, Brent Moyle, Ryan Yung, Li Tao, and Noel Scott. 2022. Augmented Reality and the Enhancement of Memorable Tourism Experiences at Heritage Sites. *Current Issues in Tourism* 26, 2, 1–16. https://doi.org/10.1080/13683500.2022.2026303.

[9] Tai, Nan-Ching, Jia-Ling Wu, and Chih-Yi Yeh. 2022. Supplementary Physical Device for In-Depth Augmented Reality Touring of Architectural Heritage Sites. In 2022 *IEEE International Conference on Consumer Electronics-Taiwan (ICCE-TW '22)*, July.6-8, 2022, Taipei, Taiwan. IEEE, 53-54. https://doi.org/10.1109/icce-taiwan55306.2022.9869009.

[10] Vlachos, Apostolos, Maria Perifanou, and Anastasios A. Economides. 2022. Augmented Reality Applications for Urban Cultural Heritage Sites: An Overview. In *2022 International Conference on Advanced Learning Technologies (ICALT '22)*, July.1-4, 2022, Bucharest, Romania. IEEE, 322-324. https://doi.org/10.1109/icalt55010.2022.00102.

[11] Guzden Varinlioglu, and Suheyla Muge Halici. 2019. Gamification of Heritage through Augmented Reality. *Blucher Design Proceedings*, Decem-ber. https://doi.org/10.5151/proceedings-ecaadesigradi2019_168.

[12] Varinlioğlu, G., Vaez Afshar, S., Eshaghi, S., Balaban, Ö., & Nagakura, T. 2022. GIS-Based Educational Game Through Low-Cost Virtual Tour Experience- Khan Game. In *Proceedings of the 27th International Conference of the Association for Computer-Aided Architectural Design Research in Asia (CAADRIA '22)*, April. 12-14, 2022, Hong Kong, China. CAADRIA, 69-78.

[13] Lysakowski, M., Zywanowski, K., Banaszczyk, A., Nowicki, M.R., Skrzypczy'nski, P., & Tadeja, S.K. 2023. Real-Time Onboard Object Detection for Augmented Reality: Enhancing Head-Mounted Display with YOLOv8. In *2023 IEEE International Conference on Edge Computing and Com-munications (EDGE '23)*, JULY 2-8, 2023, Chicago, USA. IEEE, 364-371