

Digital Twin System in Virtual Participation

Subjects: Geography | Architecture And Design | Green & Sustainable Science & Technology

Contributor: Junjie Luo, Pengyuan Liu, Lei Cao

Public participation is crucial in promoting built environment quality. Most studies on built environment participatory projects primarily use physical models (i.e., physical replicas) or 2D maps as tools to interact with the general public. The digital twin model and physical replicas have the common ground of simulating built environment changes and, therefore, assisting the decision-making process in environment optimization.

Keywords: public participation ; participatory design ; digital twin

1. Introduction

Urban parks are critical public spaces for physical and recreational activities ^{[1][2]}, and they are also one of the primary elements of urban ecosystems and urban landscapes ^{[3][4][5][6]}. Thanks to the growth of the urban population and its social need for public open green spaces, we have witnessed an increasing demand for more citizen-centric landscape design, environmental conservation, and facility management in parks ^{[7][8]}.

How to integrate human–environment interactions (e.g., feedback and sentiments) into environmental design or landscape renewal of urban parks is a problem being studied by various disciplines. Public participation is increasingly important in urban renewal practices as a result of urbanization, leading to a growing focus on creating a contemporary governance structure ^[9]. The concept of public involvement is emphasized in the participatory urban renewal strategy so that citizens can actively participate in environmental management operations ^{[10][11][12]}. Such a concept is based on communication, sharing, cooperation, and coordination, and it can give the general public the freedom to live their own lives and unleash their creative potential ^[13]. The early involvement of citizens in the participatory process is crucial to developing eye-level communication mechanisms between professionals and local residents, which alternates residents from the role that can only passively accept landscape changes to the active designer of the local environment ^[14]. The participatory workshop is the most common way for individuals to participate in such a participatory practice ^{[15][16]}. Through the joint participatory workshop of multiple subjects (e.g., residents, designers, and local governments), the communication between different urban governance parties in the area can be effectively improved ^[17].

Most studies on built environment participatory projects primarily use physical models (i.e., physical replicas) or 2D maps as tools to interact with the general public and simulate urban changes ^[18]. As important as these tools are, researchers have witnessed an increasing number of studies using digital equipment and models (e.g., virtual 3D models) for better communication and simulation ^[19]. Virtual models offer the participatory process the potential of remote evaluation and near real-world sensing and perception ^[19]. However, most of these 3D models adopted grey boxes (without texture information) which were distinct from the actual landscapes ^[20]; that is, this simplified virtual 3D grey box environment cannot capture the entire essence of the built environment. Therefore, whether such models can be considered a proper tool to evoke participants' perceptions of the actual environment is questionable.

Meanwhile, thanks to the fast development of the digital twin (a virtual representation that serves as the real-time digital counterpart of a physical object or process), studies on virtual perception based on such trending techniques are proliferating ^{[21][22]}. A digital twin takes a high-precision 3D virtual model as the digital base and integrates the attribute data (e.g., from physical sensors) of numerous objects in the physical space ^[23]. It can achieve near real-time data communication between a digital replica and the physical environment, which can support the decision-making process of environmental management for designers, residents, and the government ^[24]. For the participatory workshop in the context of the digital twin, high-precision replicas of the physical environment are key to encouraging public engagement and environmental scenario simulation ^{[24][25][26][27]}.

2. The Concept and Method of Participatory Design

The planning system, created by the British Urban and Rural Planning Act in 1947, was the forerunner to public participation in contemporary urban design and planning [28]. It encourages and enables the general public to voice their ideas and needs for urban development during the design process [29]. Participatory design, as an approach, is more democratic than the traditional 'top-down' design because it allows the public to shape places based on individual living experiences and redesign the local landscapes [30]. Presently, the ways of urban design, planning, and renewal in most Chinese cities are dominated by government guidance and policies [31][32]. The government-led design and planning often neglect the needs of residents, which can lead to unequal expression of interests in the local communities. Thus, social democracy is unavoidably overlooked [33][34]. In contrast, the 'bottom-up' concept rooted in the participatory approach offsets such a defect. Such participatory designs incorporate the views of professional planners, residents, governments, and other communities to cooperatively improve public spaces in the built environment and achieve the Sustainable Development Goals [35][36]. The consideration of 'people' is the core concept of the participatory approach, aiming to satisfy the needs of every 'person' in the design process [37]. Therefore, the participatory concept is essential to promoting social democracy. Although such a concept is still in its early stages, participatory design has gained increasing support from people with different backgrounds around the world [35][38].

A large body of research has demonstrated participatory workshops to be the primary method for urban design [39][40][41]. The workshop for a particular area is often an intense multi-day design process, during which a group of experts and residents jointly develop planning strategies, taking feedback and sentiments from the general public into account [42]. Collaborations that involve, for example, urban designers, residents, and local authorities can collect in-depth knowledge about the landscape under study [10]. The workshop often includes visualizations in the form of physical or digital replicas and brainstorming on the design plans. As such, the workshop offers practical ways to take big groups on board, promote more interactive collaboration, and actively collect feedback on every minor detail [17][19]. Design, analysis, and negotiation are the three interconnected elements of this collaborative workshop [29]. The participatory design workshop operation requires an environment where everyone can equally express opinions and actively contribute to the discussions. Previous studies have affirmed that such interactive discussions and collaborative designing activities benefit urban planning and preserve public coherence [43][44]. Therefore, the regeneration of urban areas through participatory workshops has become one of the key strategies for urban development [10][42].

3. Digital Twin System and Virtual Participation

Recent studies have increasingly placed their interests in the methodology development of digital visualization to encourage interactive communications, such as 3D visualization [41][45]. Compared with conventional visualization methods such as construction plans, sections, and perspectives, near real-world 3D digital models can provide a better visualization effect [19]. A digital twin is a digital replica of a physical object, and this concept was first introduced by the National Aeronautics and Space Administration (NASA) as a paradigm for future NASA and U.S. Air Force vehicles [46][47]. The digital twin concept is becoming popular thanks to the rapid development of technologies that render the two-way interaction between digital replicas and the physical environment possible [24][48][49]. The 3D model can visualize spatiotemporal information in space, which allows the pre-simulation of the urban planning initiatives to identify their strengths and weaknesses before changing the physical environment [24][50]. Those technologies open up opportunities for the human to sense urban places in the digital models, thus suggesting the potential to encourage participation from the general public in the urban planning process [20][51][52][53][54]. With the proliferation of digital twin studies, the oblique photography data that can be integrated into the models are increasingly scattered [55][56]. For example, a solid 3D city model based on geographic data and information, such as a digital elevation model (DEM) or a digital building model provided by regional authorities, serves as the foundation for the digital twin [57]. With unmanned aerial vehicle (UAV) oblique photography, a high-quality digital base plate for the digital twin model can also be created, yielding a fine three-dimensional genuine scene model [58][59]. The advancement of UAV oblique photography, as well as 3D laser modeling approaches, has aided in these multi-regional built environmental studies [60][61]. As a result, the UAV is now a crucial instrument for creating a digital twin city and is vital to investigating and modeling the environment [62].

References

1. Halkos, G.; Leonti, A.; Sardanou, E. Activities, motivations and satisfaction of urban parks visitors: A structural equation modeling analysis. *Econ. Anal. Policy* 2021, 70, 502–513.

2. Huai, S.; Van de Voorde, T. Which environmental features contribute to positive and negative perceptions of urban parks? A cross-cultural comparison using online reviews and Natural Language Processing methods. *Landsc. Urban Plan.* 2022, 218, 104307.
3. Kabisch, N.; Kraemer, R.; Masztalerz, O.; Hemmerling, J.; Püffel, C.; Haase, D. Impact of summer heat on urban park visitation, perceived health and ecosystem service appreciation. *Urban For. Urban Green.* 2021, 60, 127058.
4. Peng, J.; Dan, Y.; Qiao, R.; Liu, Y.; Dong, J.; Wu, J. How to quantify the cooling effect of urban parks? Linking maximum and accumulation perspectives. *Remote Sens. Environ.* 2021, 252, 112135.
5. Mäntymaa, E.; Jokinen, M.; Juutinen, A.; Lankia, T.; Louhi, P. Providing ecological, cultural and commercial services in an urban park: A travel cost–contingent behavior application in Finland. *Landsc. Urban Plan.* 2021, 209, 104042.
6. Silva, L.T.; Fonseca, F.; Pires, M.; Mendes, B. SAUS: A tool for preserving urban green areas from air pollution. *Urban For. Urban Green.* 2019, 46, 126440.
7. Han, D.; Zhang, C.; Wang, C.; She, J.; Sun, Z.; Zhao, D.; Bian, Q.; Han, W.; Yin, L.; Sun, R.; et al. Differences in response of butterfly diversity and species composition in urban parks to land cover and local habitat variables. *Forests* 2021, 12, 140.
8. Wang, P.; Zhou, B.; Han, L.; Mei, R. The motivation and factors influencing visits to small urban parks in Shanghai, China. *Urban For. Urban Green.* 2021, 60, 127086.
9. leBrasseur, R. Cultural Greenspaces: Synthesizing Knowledge and Experience in Nova Scotia's African-Canadian Communities through Participatory Research and SoftGIS. *Soc. Sci.* 2022, 11, 281.
10. Yang, J.; Yang, L.; Ma, H. Community Participation Strategy for Sustainable Urban Regeneration in Xiamen, China. *Land* 2022, 11, 600.
11. Głowczyński, M. Toward User-Generated Content as a Mechanism of Digital Placemaking—Place Experience Dimensions in Spatial Media. *ISPRS Int. J. Geo-Inf.* 2022, 11, 261.
12. Speller, G.; Ravenscroft, N. Facilitating and evaluating public participation in urban parks management. *Local Environ.* 2005, 10, 41–56.
13. Geekiyanage, D.; Fernando, T.; Keraminiyage, K. Mapping participatory methods in the urban development process: A systematic review and case-based evidence analysis. *Sustainability* 2021, 13, 8992.
14. McEvoy, S.; van de Ven, F.H.; Blind, M.W.; Slinger, J.H. Planning support tools and their effects in participatory urban adaptation workshops. *J. Environ. Manag.* 2018, 207, 319–333.
15. Street, P. Scenario workshops: A participatory approach to sustainable urban living? *Futures* 1997, 29, 139–158.
16. Chen, F.; Chen, Y. Urban Metabolism and Spontaneous Architectural Growth: A Sustainable Strategy Featuring Participatory Co-Construction by Multiple Stakeholders. *Buildings* 2022, 12, 352.
17. De Siqueira, G.; Malaj, S.; Hamdani, M. Digitalization, Participation and Interaction: Towards More Inclusive Tools in Urban Design—A Literature Review. *Sustainability* 2022, 14, 4514.
18. Pánek, J. Emotional maps: Participatory crowdsourcing of citizens perceptions of their urban environment. *Cartogr. Perspect.* 2018, 91, 17–29.
19. Postert, P.; Wolf, A.E.; Schiewe, J. Integrating Visualization and Interaction Tools for Enhancing Collaboration in Different Public Participation Settings. *ISPRS Int. J. Geo-Inf.* 2022, 11, 156.
20. Schrotter, G.; Hürzeler, C. The digital twin of the city of Zurich for urban planning. *PFG—J. Photogramm. Remote Sens. Geoinf. Sci.* 2020, 88, 99–112.
21. Scalas, A.; Cabiddu, D.; Mortara, M.; Spagnuolo, M. Potential of the Geometric Layer in Urban Digital Twins. *ISPRS Int. J. Geo-Inf.* 2022, 11, 343.
22. Tzachor, A.; Sabri, S.; Richards, C.E.; Rajabifard, A.; Acuto, M. Potential and limitations of digital twins to achieve the Sustainable Development Goals. *Nat. Sustain.* 2022, 1–8.
23. Redelinghuys, A.; Basson, A.H.; Kruger, K. A six-layer architecture for the digital twin: A manufacturing case study implementation. *J. Intell. Manuf.* 2020, 31, 1383–1402.
24. White, G.; Zink, A.; Codecá, L.; Clarke, S. A digital twin smart city for citizen feedback. *Cities* 2021, 110, 103064.
25. Shahat, E.; Hyun, C.T.; Yeom, C. City digital twin potentials: A review and research agenda. *Sustainability* 2021, 13, 3386.
26. Kikuchi, N.; Fukuda, T.; Yabuki, N. Landscape Visualization by Integrating Augmented Reality and Drones with Occlusion Handling to Link Real and Virtual Worlds-Towards city digital twin realization. In *Proceedings of the 39th eCAADe Conference*, Novi Sad, Serbia, 8–10 September 2021; pp. 521–528.

27. Ham, Y.; Kim, J. Participatory sensing and digital twin city: Updating virtual city models for enhanced risk-informed decision-making. *J. Manag. Eng.* 2020, 36, 04020005.
28. Taylor, N. *Urban Planning Theory Since 1945*; Sage: Thousand Oaks, CA, USA, 1998.
29. Li, X.; Zhang, F.; Hui, E.C.m.; Lang, W. Collaborative workshop and community participation: A new approach to urban regeneration in China. *Cities* 2020, 102, 102743.
30. Groulx, M.; Lemieux, C.; Freeman, S.; Cameron, J.; Wright, P.A.; Healy, T. Participatory planning for the future of accessible nature. *Local Environ.* 2021, 26, 808–824.
31. Enserink, B.; Koppenjan, J. Public participation in China: Sustainable urbanization and governance. *Manag. Environ. Qual.* 2007, 18, 459–474.
32. Li, Y.; Cheng, H.; Beeton, R.J.; Sigler, T.; Halog, A. Sustainability from a Chinese cultural perspective: The implications of harmonious development in environmental management. *Environ. Dev. Sustain.* 2016, 18, 679–696.
33. Semeraro, T.; Zaccarelli, N.; Lara, A.; Sergi Cucinelli, F.; Aretano, R. A bottom-up and top-down participatory approach to planning and designing local urban development: Evidence from an urban university center. *Land* 2020, 9, 98.
34. Sim, T.; Dominelli, L.; Lau, J. *A Pathway to Initiate Bottom-Up Community-Based Disaster Risk Reduction within a Top-Down System: The Case of China*; WIT Press: Southampton, UK, 2017.
35. El Asmar, J.P.; Ebohon, J.O.; Taki, A. Bottom-up approach to sustainable urban development in Lebanon: The case of Zouk Mosbeh. *Sustain. Cities Soc.* 2012, 2, 37–44.
36. Pettit, C.; Nelson, A.; Cartwright, W. Using on-line geographical visualisation tools to improve land use decision-making with a bottom-up community participatory approach. In *Recent Advances in Design and Decision Support Systems in Architecture and Urban Planning*; Springer: Berlin/Heidelberg, Germany, 2004; pp. 53–68.
37. Pogačar, K.; Žižek, A. Urban hackathon—alternative information based and participatory approach to urban development. *Procedia Eng.* 2016, 161, 1971–1976.
38. Li, Y.; Beeton, R.J.; Sigler, T.; Halog, A. Enhancing the adaptive capacity for urban sustainability: A bottom-up approach to understanding the urban social system in China. *J. Environ. Manag.* 2019, 235, 51–61.
39. Ortiz Escalante, S.; Gutiérrez Valdivia, B. Planning from below: Using feminist participatory methods to increase women's participation in urban planning. *Gend. Dev.* 2015, 23, 113–126.
40. Lawrence, D.; Christodoulou, N.; Whish, J. Designing better on-farm research in Australia using a participatory workshop process. *Field Crop. Res.* 2007, 104, 157–164.
41. Salter, J.D.; Campbell, C.; Journeay, M.; Sheppard, S.R. The digital workshop: Exploring the use of interactive and immersive visualisation tools in participatory planning. *J. Environ. Manag.* 2009, 90, 2090–2101.
42. Nikologianni, A.; Betta, A.; Gretter, A. Contribution of Conceptual-Drawing Methods to Raise Awareness on Landscape Connectivity: Socio-Environmental Analysis in the Regional Context of Trentino (Italy). *Sustainability* 2022, 14, 7975.
43. Akbar, A.; Flacke, J.; Martinez, J.; van Maarseveen, M.F. The Role of Participatory Village Maps in Strengthening Public Participation Practice. *ISPRS Int. J. Geo-Inf.* 2021, 10, 512.
44. Kenny, D.C.; Castilla-Rho, J. No Stakeholder Is an Island: Human Barriers and Enablers in Participatory Environmental Modelling. *Land* 2022, 11, 340.
45. Neuenschwander, N.; Hayek, U.W.; Grêt-Regamey, A. Integrating an urban green space typology into procedural 3D visualization for collaborative planning. *Comput. Environ. Urban Syst.* 2014, 48, 99–110.
46. El Saddik, A. Digital twins: The convergence of multimedia technologies. *IEEE Multimed.* 2018, 25, 87–92.
47. Glaessgen, E.; Stargel, D. The digital twin paradigm for future NASA and US Air Force vehicles. In *Proceedings of the 53rd AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference 20th AIAA/ASME/AHS Adaptive Structures Conference 14th AIAA*, Honolulu, HI, USA, 23–26 April 2012; p. 1818.
48. Tao, F.; Cheng, J.; Qi, Q.; Zhang, M.; Zhang, H.; Sui, F. Digital twin-driven product design, manufacturing and service with big data. *Int. J. Adv. Manuf. Technol.* 2018, 94, 3563–3576.
49. Mohammadi, N.; Taylor, J. Knowledge discovery in smart city digital twins. In *Proceedings of the 53rd Hawaii International Conference on System Sciences*, Maui, HI, USA, 7–10 January 2020.
50. Luo, W.; Hu, T.; Zhang, C.; Wei, Y. Digital twin for CNC machine tool: Modeling and using strategy. *J. Ambient. Intell. Humaniz. Comput.* 2019, 10, 1129–1140.
51. Havard, V.; Jeanne, B.; Lacomblez, M.; Baudry, D. Digital twin and virtual reality: A co-simulation environment for design and assessment of industrial workstations. *Prod. Manuf. Res.* 2019, 7, 472–489.

52. Kuts, V.; Otto, T.; Bondarenko, Y.; Yu, F. Digital twin: Collaborative virtual reality environment for multi-purpose industrial applications. In Proceedings of the ASME International Mechanical Engineering Congress and Exposition. American Society of Mechanical Engineers, Virtual, 16–19 November 2020; Volume 84492, p. V02BT02A010.
53. Singh, M.; Fuenmayor, E.; Hinchy, E.P.; Qiao, Y.; Murray, N.; Devine, D. Digital twin: Origin to future. *Appl. Syst. Innov.* 2021, 4, 36.
54. Dembski, F.; Wössner, U.; Letzgus, M.; Ruddat, M.; Yamu, C. Urban digital twins for smart cities and citizens: The case study of Herrenberg, Germany. *Sustainability* 2020, 12, 2307.
55. Ruohomäki, T.; Airaksinen, E.; Huuska, P.; Kesäniemi, O.; Martikka, M.; Suomisto, J. Smart city platform enabling digital twin. In Proceedings of the 2018 International Conference on Intelligent Systems (IS), Wroclaw, Poland, 17–18 September 2018; pp. 155–161.
56. Deng, T.; Zhang, K.; Shen, Z.J.M. A systematic review of a digital twin city: A new pattern of urban governance toward smart cities. *J. Manag. Sci. Eng.* 2021, 6, 125–134.
57. Shirowzhan, S.; Tan, W.; Sepasgozar, S.M. Digital twin and CyberGIS for improving connectivity and measuring the impact of infrastructure construction planning in smart cities. *ISPRS Int. J. Geo-Inf.* 2020, 9, 240.
58. Levine, N.M.; Spencer Jr, B.F. Post-earthquake building evaluation using UAVs: A BIM-based digital twin framework. *Sensors* 2022, 22, 873.
59. Lim, S.H.; Choi, K.M.; Cho, G.S. A study on 3D model building of drones-based urban digital twin. *J. Cadastre Land InformatiX* 2020, 50, 163–180.
60. Mohammadi, M.; Rashidi, M.; Mousavi, V.; Karami, A.; Yu, Y.; Samali, B. Case study on accuracy comparison of digital twins developed for a heritage bridge via UAV photogrammetry and terrestrial laser scanning. In Proceedings of the 10th International Conference on Structural Health Monitoring of Intelligent Infrastructure, Tokyo, Japan, 30 June–2 July 2021; Volume 10.
61. Mihoković, V.; Zalović, L.; Zalović, V. Establishing the utility charges spatial database using digital twin technology. In Proceedings of the 2020 43rd International Convention on Information, Communication and Electronic Technology (MIPRO), Opatija, Croatia, 28 September–2 October 2020; pp. 437–441.
62. Mohammadi, M.; Rashidi, M.; Mousavi, V.; Karami, A.; Yu, Y.; Samali, B. Quality evaluation of digital twins generated based on UAV photogrammetry and TLS: Bridge case study. *Remote Sens.* 2021, 13, 3499.

Retrieved from <https://encyclopedia.pub/entry/history/show/66107>