A Collaborative Augmented Reality Decision Support System for Crowdsourcing Urban Designs

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Abstract: Globally, cities and their infrastructures, people, and ecology systems are experiencing unprecedented changes due to environmental change and anthropogenic pressures. To create the most sustainable approaches for mitigating and adapting to environmental changes, urban designs require a radical rethink that accounts for the needs of local citizens and stakeholders. Decision support systems (DSS) can be utilized to engage with members of the public to elicit their opinions on proposed designs. To better engage citizens, DSSs have started to include the use of virtual reality and augmented reality to demonstrate designs, however, these systems are often only applied to smaller stakeholder engagement events. Here, we created a theory-informed augmented reality application for collaborative crowdsourcing of urban designs. The designed system allows users to manipulate a two-dimensional map with targets representing different objects (e. g., trees, lakes, infrastructure). The changes made to the 2D map are then visualized through a mobile application that displays a 3D AR visualization of the changes the user makes in real time. The resulting application can be used to engage a diversity of participants in a range of urban and environmental planning contexts.

Keywords: Augment reality, decision support system, crowdsourcing

1 Introduction

Urban areas are facing new challenges due to climate change, including, adaptation to new climate regimes, damage to infrastructure and health, well-being impacts from extreme weather events, and increased demand for housing for climate migrants (HUNT & WATKISS 2011, BAI et al. 2018, HOBBIE & GRIMM 2020). However, globally, there are no "one size fits all" solutions for increasing urban resilience as each city or region faces unique challenges due to its environmental conditions and varying capacities to respond to climate stressors. Practitioners have pursued a range of interventions to increase urban resilience with varying success, including green infrastructure and building social capital. Failure of such interventions is often related to inadequately addressing social equity issues (MEEROW et al. 2019), and there are increased calls for tools that chart just and equitable approaches to planning for climate change (VAN BERKEL et al. 2022).

Urban design and planning are traditionally expert-driven and top-down, which may not consider the needs and desires of local communities and stakeholders. This is particularly problematic as climate change hazards disproportionately impact low-income and minority communities, whose voices are often under-represented in the planning process (MEEROW et al. 2019). Numerous studies have tested approaches for more inclusive design and planning, examining the efficacy of stakeholder workshops (KUSTER et al. 2020), as well as digital participatory platforms or decision support tools (HASLER et al. 2017). Their result indicates that decision support systems (DSSs) that involve stakeholders in the planning and design

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processes can result in more just and equitable outcomes (CAMPBELL-ARVAI & LINDQUIST 2021, LINDQUIST & CAMPBELL-ARVAI 2021, VAN BERKEL et al. 2022).

DSSs are tools used to enable meaningful citizen participation in landscape and urban planning. DSSs include a range of media or "boundary objects" (WHITE et al. 2010) that help structure discussions around a topic. In the case of urban planning, they can include photomontages of proposed developments, participatory GIS, or highly immersive experiences using 3D videogame (FOX et al. 2022a). While less technologically advanced approaches using descriptive narratives or 2D designs are effective for engaging citizens in planning scenarios, providing DSSs with high levels of realism may be more beneficial for long-term engagement (GNAT et al. 2016). For example, providing players with a realistic 3D model of the proposed designs may increase spatial awareness and orientation for legitimacy and accuracy of discussion, as well as a sense of place and connection to depicted locations (GNAT et al. 2016). This sense of connection is likely related to the credibility of depicted experience, and legitimacy often requires realism and applicability to real-world scenarios (FOX et al. 2022a).

Augmented reality (AR) is an interactive experience that integrates real-world visualizations with computer-generated content, for example, overlaying textual descriptions and icons on a mobile phone camera's live feed. AR can allow for real-world visualization of in situ changes to urban areas in real-time (IMOTTESJO & KAIN 2018), e. g. to visualize flooding on a real site (HAYNES et al. 2018) and provide an additional layer of immersion and realism (CIRULIS & BRIGMANIS 2013), and may affect feelings of connectedness to the site related to its perceived realism (GNAT et al. 2016, OLSZEWSKI et al. 2017). However, DSSs are often built as stand-alone software, applicable to a single context, and unable to be easily updated to incorporate any changes to the environment (FOX et al. 2022b). Here, we aim to provide a flexible DSS that can harness real-world geographic information system (GIS) data to generate an interactive AR DSS for landscape and urban environments.

2 Application Creation

2.1 Application Design

To ensure that our application aligns with the most innovative approaches to engage citizens in urban planning we designed our game to follow the framework for gamified DSSs introduced by FOX et al. (2022a). The framework for gamified DSSs provides guidance on the three dimensions needed for success: engagement, education, and application. First, the use of innovative game technologies such as 3D models displayed in VR and AR provides more immersive experiences for users than games using text, or 2D models (GNAT et al. 2016, VAN LEEUWEN et al. 2018). Furthermore, static DSSs that do not allow users to interact in a meaningful manner does not provide an engaging experience for users to provide feedback (FOX et al. 2022a). We, therefore, designed our game to provide users with interactable 3D models displayed in AR to provide the most immersive experience. Second, without an educational element, the long-term engagement of citizens may be limited (DEVISCH et al. 2016, FOX et al. 2022a). We have therefore designed the application to provide feedback about the environmental and economic impacts of their choices. Third, for a DSSs to be successful, the outcomes of the engagement process should provide real-world benefits for local people. As a DSSs, should be grounded in a real-world context, we, therefore, built out DSSs to be flexible with the location displayed.

2.2 Augmented Reality Development

The AR DSS application was developed using unity3D, with a module of Vuforia Engine Library SDK as a main component of the architecture. We include image targets as tracking features for this project. This specific module allows us to add advanced computer vision functionality to our DSS, to create an AR experience that users can realistically interact with objects in the environment to provide opinions on a proposed design. Vuforia supports the majority of phones, tablets, and eyewear. The software makes it possible to create augment realistic 3D model from the use case by pointing the camera of the device over a main target (paper map) on any of these devices. Once the environment is displayed, the user can overlay other small targets over the 3D model in order to add corresponding elements to the environment. The DSS records the decision, of each user of the session and send this data to Firebase, recording the objects selected and its location, and the use case. Currently, the application does not allow user to 3D elements, and add them to the map (i. e., all paper cut-outs are predefined). The models that we are using for this use case are manually loaded into the application by the developer.

2.3 Application Development

3D models for AR urban areas can be created manually by human designers or through computer-aided designs (CAD) methods, however, these methods are often time-intensive and expensive (GNAT et al. 2016). 3D model data for the augmented reality model can be generated using a range of GIS data sources, including pretended buildings available from GIS software such as ArcPro, or generated through LiDAR point cloud data (FOX et al. 2022B). However, automatically generated models do not offer the same levels of realism as manually created 3D models (ZHANG & MOORE 2014). Therefore, the choice of data for developing the 3D worlds is context dependent. Here, we utilize 'RenderDoc' to automatically generate models from Google Maps of the case study area. For the additional elements added via the AR app (e. g., tress and ponds), these models can be found through existing libraries such as 'Speedtree' or the asset store on 'Unity', or manually created for specific use cases. In the current beta version of the application we are using fixed locations that we have designed. For future releases policy makers will be able to upload their own study sites to 'Unity' via 'SketchUp' to push them to the application.

3 Description of Application

Our AR mobile application DSS displays interactive 3D models of real-world locations and has been developed to work in conjunction with paper maps (Figure 1). The AR application interprets the paper map as a target and then displays a pre-made augmented environment on the phone screen at the location of the paper map. This enables users interacting with a map of a proposed site to view additional information on their phone such as 3D models of the buildings present in the map through their devices. Viewing 3D models of the environment within the study site (e. g. models of buildings and trees) enhances the user's experience by providing additional information about the proposed design. Multiple participants can be engaged in augmented reality as the application works simultaneously across multiple mobile devices. This also allows users to take different perspectives of the same augmented environment at the same time.

Fig. 1: Augmented reality DSS paper maps and marker

The AR mobile application also allows users to interact with and change the AR visualization in real time. The AR application recognizes multiple targets and is able to display them concurrently in the augmented environment. The additional targets are provided to users in the form of paper cut-outs that the users can place on the map. These paper cut-outs can be used to represent different natural and artificial features (e. g. trees, ponds, buildings, and benches) that are then displayed as 3D models in the augmented environment at the location of the paper cut-out. To demonstrate this application Figure 2 shows Heilman Park in Detroit, Michigan, USA as an augmented reality environment with additional 3D models of trees and a pond dictated by the locations of paper cut-outs.

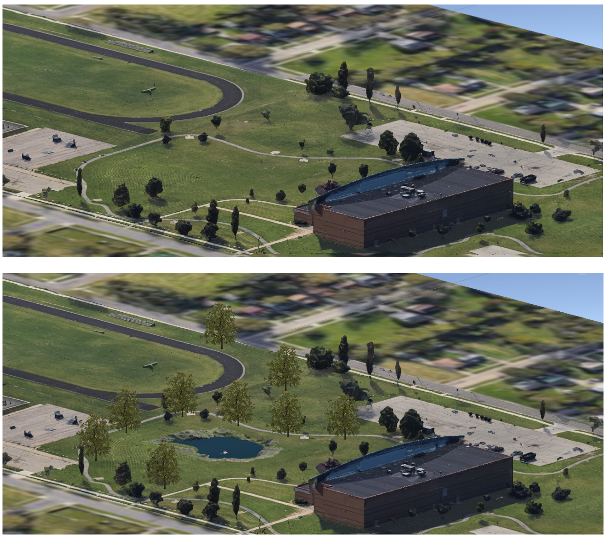

Fig. 2: Augmented reality version of Heilman Park. Top: 3D models using existing GIS data. Bottom: park with the additional 3D models representing trees and a pond.

We replicated the functionality of the paper maps on the touch table (Figure 3) for demonstration purposes. This allows for a higher level of interactivity with users able to easily zoom in and out of the map, while the AR 3D models scale with the movement.

Fig. 3: Augmented reality version of Heilman Park on a touch table with the additional 3D models representing a tree and a pond provided by the paper targets

4 Discussion

The resulting system offers different levels of complexity with both 2D and 3D depictions providing an easy-to-use interactive experience allowing for the real-time visualization of design and planning decisions. This flexible AR DSS allows policymakers to send paper maps and plans to stakeholders so they can develop their own scenarios remotely. This has the potential to catalyze inclusive planning processes from start to finish, by reducing barriers to use. First, policymakers can send unedited maps to citizens and stakeholders to crowdsource potential ideas. The AR application provides functionality for participants to screenshot their designs and return them to the policymakers. Second, we envisage that these crowdsourced designs could be hosted in a virtual gallery open to the public to assess and provide additional comments. Third, policymakers can use these crowdsource designs in their development planning. These final design proposals can then be distributed to participants who can then view these models in augmented reality and provide additional feedback. By allowing for citizens to engage at a time and location that is convenient for them, this methodology allows for policy makers to better engage with wider audiences than traditional DSS (Figure 4).

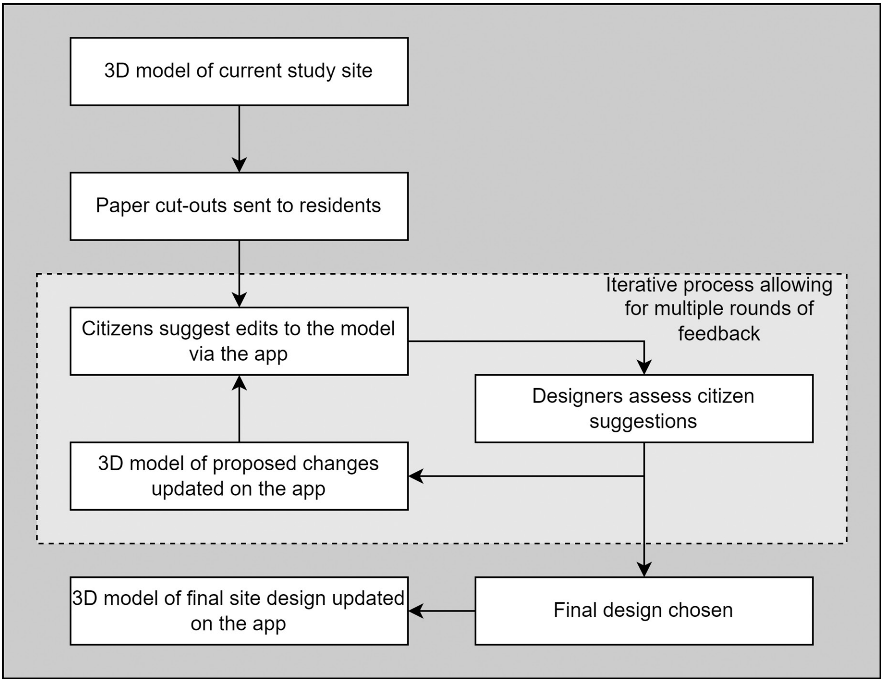

Fig. 4: Hypothetical crowdsourcing scheme for engaging participates with the tool

The AR app will be distributed to users using a downloadable application for mobile phones, while the physical maps and targets can be sent to citizens in the mail. However, we acknowledge that not all residents may have access to a mobile smartphone capable of supporting the AR required to partake in the design process. We also developed the application to be used with maps displayed on a digital touch table or interactive screen. Though this method does not allow participants to create designs remotely, it provides the ability for policymakers to hold interactive stakeholder engagement sessions that allow interactive citizen feedback. During these stakeholder sessions, the planners can provide participants with mobile devices already set up with the application allowing users to easily engage with creating urban designs. Furthermore, where stakeholder engagement teams do not have access to touchscreen technology, they can still host successful interactive and engaging feedback sessions using large print out maps.

We have also designed the application to include additional functionality so that the system provides real-time performance metrics of decisions made e. g. the impact on air quality or stormwater management. Adding new trees that trigger the visualization of sustainability measures would bring a greater understanding of the local environmental impacts of their choice (FOX et al. 2022a). While the beta version of the tool only has rudimentary functionality for editing, in the future we envisage a wide range of modifiable elements that will serve in diverse spatial planning applications. For example, modification of the height or features of a building via the interface could be reflected in real-time to those viewing in augmented reality for understanding shadows and site impact.

5 Conclusion and Outlook

Realistic AR DSS provides an engaging and immersive method for residents to participate in urban planning decisions. Though AR has previously been implemented into planning DSSs, they are often only used to engage with smaller audiences. Our mobile application design provides the advantage of allowing planners to collaboratively crowdsource designs. By being able to send paper maps and targets to all residents and stakeholders, our method allows for wider audiences to be reached compared to traditional AR DSS methods. Furthermore, by developing a method that is accessible to audiences via remotely asynchronous engagement as well as focused workshop events, our DSS can both reduce barriers to participation and is applicable to a wide range of planning and engagement contexts.

References

BAI, X., DAWSON, R. J., ÜRGE-VORSATZ, D., DELGADO, G. C., SALISU BARAU, A., DHAKAL, S., DODMAN, D., LEONARDSEN, L., MASSON-DELMOTTE, V., ROBERTS, D. C. & SCHULTZ, S. (2018), Six Research Priorities for Cities and Climate Change. Nature, 555 (7694), 23-25. https://doi.org/ 10.1038/d41586-018-02409-z.

CAMPBELL-ARVAI, V. & LINDQUIST, M. (2021), From the Ground Up: Using Structured Community Engagement to Identify Objectives for Urban Green Infrastructure Planning. Urban Forestry & Urban Greening, 59, Article 127013. https://doi.org/10.1016/j.ufug.2021.127013.

CIRULIS, A. & BRIGMANIS, K. B. (2013), 3D Outdoor Augmented Reality for Architecture and Urban Planning. Procedia Computer Science, 25, 71-79. https://doi.org/10.1016/j.procs.2013.11.009.

FOX, N., CAMPBELL-ARVAI, V., LINDQUIST, M., VAN BERKEL, D. & SERRANO-VERGEL, R. (2022a), Gamifying Decision Support Systems to Promote Inclusive and Engaged Urban Resilience Planning. Urban Planning, 7 (2).

FOX, N., SERRANO-VERGEL, R., VAN BERKEL, D. & LINDQUIST, M. (2022b), Towards Gamified Decision Support Systems: In-game 3D Representation of Real-word Landscapes from GIS Datasets. Journal of Digital Landscape Architecture, 356-364.

GNAT, M., LESZEK, K. & OLSZEWSKI, R. (2016), The Use of Geoinformation Technology, Augmented Reality and Gamification in the Urban Modeling Process. In: GERVASI, O., MURGANTE, B., MISRA, S., ROCHA, A. M. A. C., TORRE, C. M., TANIAR, D., APDUHAN, B. O., STANKOVA, E. & WANG, S. (Eds.), Computational science and its applications – ICCSA 2016. Springer, Berlin, 484-496. https://doi.org/10.1007/978-3-319-42108-7_37.

HASLER, S., CHENAL, J. & SOUTTER, M. (2017), Digital Tools as a Means to Foster Inclusive, Data-informed Urban Planning. Civil Engineering and Architecture, 5 (6), 230-239.

HAYNES, P., HEHL-LANGE, S. & LANGE, E. (2018), Mobile augmented reality for flood visualisation. Environmental Modelling & Software, 109, 380-389.

HOBBIE, S. E. & GRIMM, N. B. (2020), Nature-based Approaches to Managing Climate Change Impacts in Cities. Philosophical Transactions of the Royal Society B: Biological Sciences, 375 (1794), Article 20190124. https://doi.org/10.1098/rstb.2019.0124.

HUNT, A. & WATKISS, P. (2011), Climate Change Impacts and Adaptation in Cities: A Review of the Literature. Climatic Change, 104 (1), 13-49. https://doi.org/ 10.1007/s10584-010-9975-6.

IMOTTESJO, H. & KAIN, J. H. (2018), The Urban CoBuilder – A mobile augmented reality tool for crowd-sourced simulation of emergent urban development patterns: Requirements, prototyping and assessment. Computers, Environment and Urban Systems, 71, 120-130.

KUSTERS, K., DE GRAAF, M., BUCK, L., GALIDO, K., MAINDO, A., MENDOZA, H. & ZAGT, R. (2020), Inclusive Landscape Governance for Sustainable Development: Assessment Methodology and Lessons for Civil Society Organizations. Land, 9 (4), 128.

LINDQUIST, M. & CAMPBELL-ARVAI, V. (2021), Co-Designing Vacant Lots Using Interactive 3D Visualizations – Development and Application of the Land. Info DSS. Landscape and Urban Planning, 210, Article 104082. https://doi.org/10.1016/j.landurbplan.2021.104082.

MEEROW, S., PAJOUHESH, P. & MILLER, T. R. (2019), Social Equity in Urban Resilience Planning. Local Environment, 24 (9), 793-808.

OLSZEWSKI, R., GNAT, M., TROJANOWSKA, H., TUREK, A. & WIELADEK, A. (2017), Towards Social Fuzzy Geoparticipation Stimulated by Gamification and Augmented Reality, 1363-1370. In: LIU, Y., ZHAO, L., CAI, G., XIAO, G., LI, K. & WANG, L. (Eds.), 13th International Conference on Natural Computation, Fuzzy Systems and Knowledge Discovery (ICNC-FSKD). IEEE. https://doi.org/10.1109/FSKD.2017.8392965.

WHITE, D. D., WUTICH, A., LARSON, K. L., GOBER, P., LANT, T. & SENNEVILLE, C. (2010), Credibility, Salience, and Legitimacy of Boundary Objects: Water Managers' Assessment of a Simulation Model in an Immersive Decision Theater. Science and Public Policy, 37 (3), 219-232.

ZHANG, S. V. & MOORE, A. B. (2014), The Usability of Online Geographic Virtual Reality for Urban Planning, 225-242. In: ISIKDAG, U. (Ed.), Innovations in 3D Geo-Information Sciences, Lecture Notes in Geoinformation and Cartography. Springer International Publishing, Cham. https://doi.org/10.1007/978-3-319-00515-7_14.