PARTICIPATORY AR

A Parametric Design Instrument

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Abstract. CAAD research has frequently investigated the realm of public participation in large scale urban design re-development. Yet, the recurring problem lies with the lay-person often not being able to read 2d and 3d graphic information effectively, and hence be able to participate in the process of design development proactively. To date, much-existing research focuses on developing designs for urban settings using contemporary interaction devices such as the /Hololens/; such devices, with custom interfaces, require a significant level of expertise, or an experienced 'guide', to help navigate or create within these environments. Our paper presents a novel alternative based on real-time-virtual-engines, XR, and a parametric back-end system. The paper discusses the advantages that the resulting tangible user interface (TUI) can play in the lay-person's engagement in the design process. In the paper, we describe how the integration of interaction design (IxD) and augmented reality (AR) offer new opportunities due to the increasing availability of barrier-free technologies that can better include lay-persons as active participants in the design development process.

Keywords. Augmented Reality (AR / XR); Participatory Design; Urban Design; Tangible User Interface (TUI); Parametric.

1. Introduction

Within the realm of urban design, and design and architecture in general, both client and architect should strive to strengthen their shared relationship, and develop a common core language. With a strong foundation such as this, communication between the layperson and the expert becomes less confusing and ambiguous and is therefore holistic, and common ground is found (Brown and Berridge, 2001). It has been reported for many years that there exists an apparent disconnect between the public/client (layperson), and the designer/architect (expert) (Healey, 1997). Urban design poses many of these disconnects, emphasising and focusing on clearly communicating design options while understanding that the layperson has not undergone the same

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rigorous training a designer who has developed strong spatial organisation and relationships skills. Some of these disconnects within urban design include the sun's effect on the orientation of buildings; appropriate positioning of a building on a section ("Location and orientation for passive heating and cooling" 2019); understanding of spatial arrangements (Seichter and Schnabel 2005) and understanding the translation from 2D to 3D representation (Hornyanszky-Dalholm and Rydberg-Mitchel, 1992). These issues have typically led to the designer taking control of these issues whilst failing to effectively interpret the layperson's intentions (Norouzi et al., 2015). The disconnect lies here.

There are some exceptions, such as 'Benchworks' by Seichter (2004), Schnabel and Chen's 'Multi-touch Table' (2011), and 'Laypeople's Collaborative Immersive Virtual Reality Design Discourse in Neighborhood Design' by Chowdhury and Schnabel (2019). Their research reports how design interaction instruments need to be increasingly accessible and have to be explicitly designed for the lay-person to provide a fair and equitable opportunity for participation and communication.

To address the defined problems above, this research's scope focuses on the preliminary design stage of the architectural design process. However, this focus is not on the design itself, but on the participatory methods developed to reach a design outcome.

1.1. FOUR FIELDS

We have found the project to sit at the intersection of four primary areas of design. These four fields are augmented reality (AR), urban design, serious games and interaction design (IxD). The first two fields that will be discussed being AR and serious games have modern connotations seen as a result of their gained traction over recent years. We believe that the advancement of technology in these fields offer insight into the direction they will lead in the future. Thus, the solutions being developed in modern-day AR and serious games, whether it be ARToolKit or similar products, show great potential when addressing the problems outlined at the beginning of the project (Kato et al., 2000, Seichter, 2004). Within the context of the project, the degree of availability and social applicability of AR allows for effective communication of the solutions with the layperson, and, consequently, provide an opportunity for them to be key stakeholders in the design process. Serious games, being games created for a primary purpose other than entertainment, provide a method of engaging laypeople in the design process. Researchers like Ben Sawyer pathing the way for better education through serious gaming (Sawyer, 2003). Through this method, new and more user-friendly systems have emerged to facilitate engagement in areas that may otherwise not interest the general user. It encourages youth engagement in these systems, promoting early education in ways that aim to entertain and educate the user simultaneously.

Although having its roots deep within all cultures of the world, the field of urban design is still not seen as an individual profession. Instead, it is seen as an activity involving the disciplines of architecture, landscape architecture, and planning (Schurch, 1999). Its disjointed history and adoption as a field give insight into its ever-developing and shifting nature. With the simultaneous advancement of modern technology, a natural progression forward in urban design is to adopt these technologies and begin developing novel methods of practising urban design.

Interaction design, one of the project's fundamental drivers, is described by Preece et al. (2003) as developing interactive products that are easy, effective, and pleasurable to use - from the user' perspective. With this in mind, a designer must pay very close attention to the user's needs, limitations and context, and allow for a customisable output to suit precise demands in that specific context. Interaction design is one aspect that makes up the realm of UX design (Cooper et al., 2007). Ben Schneiderman's eight golden rules of interface design (1987) provide a potentially crucial set of criteria for assessing and critiquing an interactive, participatory tool. With the adoption of these into the design process, the development of the necessary interface will have a robust backing in the literature that has been adopted by many of the world's leading interface designers.

2. System of Analysis

The analysis system looks to establish a set of criteria against which a participatory, low-tech AR environment can be evaluated (Figure 1). It divides the tool into two critical phases which focus is individually placed. First, we have the interaction design (IxD) phase, where Ben Schneiderman's (1987) and Jakob Nielson's (2012) established criteria provide a robust base for evaluating the effectiveness of a user interface. Secondly, a set of criteria for assessing the participatory function of the tool is established. The complete set of criteria emphasises communication, co-design, intuitive use and facilitation of design. After each design phase, these criteria are used to assess the interactive AR environment's effectiveness. Through the assessment method, an outcome can be found as to whether the tool is effective as a user interface and a participatory design environment.

With the adoption of a low-tech tangible user interfaces (TUI) AR method, particular criteria relevant in high-tech AR, become irrelevant. The culling resulted from personal analysis of criteria that either would not function in a TUI user interface or would have such minimal input that it would become impractical to place focus on it. Seen in the table above, relevant criteria have been marked with the letter Y, while irrelevant criteria have been marked with the letter N.

	Phase	Criteria found	Relevance in TUI
1	IxD	Strive for consistency in aspects such as terminology, icons, colours and menu hierarchy be identical throughout the whole interface	Y
2	IxD	Enable frequent users to use shortcuts to reduce the number of interactions and to increase the pace of interaction.	N
3	IxD	For every operator action, offer informative feedback.	Y
4	IxD	Offer simple design dialogue to yield closure at the completion of a group of actions	Y
5	IxD	Offer simple error handling if an aspect of the system cannot be designed to prevent serious errors from occurring.	N
6	IxD	Permit easy reversal of actions so that the user knows that errors can be undone, encouraging exploration of unfamiliar options.	Y
7	IxD	Give the operator the sense that they are in charge of the system and that the system responds to their actions.	Y
8	IxD	Reduce short-term memory load in the system.	Y
9	Participatory	Communication is enabled among design participants (layperson - layperson)	Y
10	Participatory	Emphasize co-research and co-design among designers and users (layperson - designer)	Y
11	Participatory	Allow for intuitive layperson interaction with the environment	Y
12	Participatory	*Facilitate* design rather than *dictate* design	Y

Figure 1. Defined system of analysis with outlining of relevant criteria.

3. Technology

The technology adopted in the project was the *Vuforia Augmented Reality SDK*. Vuforia is an AR software development kit for mobile devices that uses computer vision technology to recognise and track images and 3D objects in real-time. When utilised in collaboration with *Unity3D*, the user can design trackers and import them into the Vuforia target manager. The Vuforia target manager assesses the quality of the target, as well as finding tracking point locations. The user is then able to download their trackers and import them for use in a Unity3D project.

The current workflow for Vuforia requires only a base level of knowledge in augmented reality and 3D modelling. The process begins with the digital modelling of the object in any programme with the functionality to export as an OBJ file type. While these objects are modelled, image trackers must also be designed and imported into the Vuforia Target Manager. As mentioned previously, the target manager is where Vuforia determines the image trackers' quality and collates them into a database that can be used in Unity3D. The target manager requires the designer to set the overall width of the tracker and have requirements for them to be PNG or JPG file format, RGB or grayscale colour space and being under 2MB.

Once imported into Unity3D, the process of making one's desired model and target database appear and function in augmented reality is very intuitive. The designer simply creates an image-based target through the Vuforia Unity plugin and then makes the model a child of the image target. For testing the AR scene within Unity3D, a webcam is the most accessible camera to use. The scene must be built and then imported to the device to see the augmented scene functioning on a smartphone or tablet. The process can be very time-consuming if other designers need to test small changes in the AR scene repeatedly.

The most significant advantage of Vuforia is that it allows multiple different trackers in one scene, allowing the tracking of various building types in one AR environment. The image-based targets are also customisable and can be any high contrast image or drawing that the designer would like to use. One of the setbacks is the buildings' customizability once they are in AR, and the need for the 3D model to be generated externally from Unity3D. Once the buildings have been imported into Unity3D and placed in an AR scene, they are no longer customisable. The workflow that has been developed allows for the arrangement of buildings concerning one another but not the design of the buildings themselves. Despite these setbacks, we have still found Vuforia to be the tool that resonates the best with this research. Although it doesn't allow for complete customisation of individual buildings, it facilitates a very intuitive interface that merges very nicely with Unity3D, allowing for easy testing and building of these AR scenes as an application that can be used on smartphones or tablets.

4. Exploration

4.1. THE HOUSE AND THE MARKET

Before any further exploration was conducted, a pilot study using a base set of designs was developed to test the capabilities of Vuforia further. In the spirit of functionality and ease, tools existing within Vuforia itself were applied to a simple house+market typology. The typology consists of a simple house with a food market out the front, with possible combinations of the two to test the project's parametric aspects. These combinations are based on four functions: expand house up, expand house out, add a small market and add a large market. With these combinations, a total of 12 typologies can be created. A further reason for choosing the house+market typology is its shared characteristics across different regions, allowing for simpler testing of Vuforia's capabilities in a setting that is not constrained by local conditions, vernacular or complex design.

4.2. IMAGE-BASED TARGETS

Image-based targets in Vuforia have specific requirements for them to be effective. According to the Vuforia website, to have the highest chance of tracking effectively, the targets must fulfil the following criteria: i) be rich in detail, ii) have a high amount of contrast, iii) Not have any repetitive patterns. These requirements mean that images with sharp edges work very well as an image-based target, but a hatched grid, for example, does not.

Within Unity3D, the various simple house+market typologies are assigned to image-based targets so that when the camera reads them, the associated buildings are generated. The workflow provides a unique advantage within the realm of urban design. If the designer assigns typologies to different targets, the user can begin to arrange them in any manner that they wish. A significant limitation of these image-based targets is that a unique target must be designed for each building. This means that if a user wants two of the same typology in an urban arrangement, the underlying targets must be different even though they are the same design.

If utilised by a layperson, these image-based targets may pose some issues if not appropriately communicated. It would need to be very clear how each target functions and what building type it is generating. If only utilising the image-based targets, with no additional information, it may be challenging to understand the spatiality and arrangement of individual buildings and the function of that building.

Figure 2. Developing urban arrangements using simple image-based targets.

4.3. VIRTUAL BUTTONS

Virtual buttons in Vuforia provide a method for making image-based targets parametrically interactive. The functionality of virtual buttons relies heavily on the quality of the target with which the virtual button is associated. By covering a certain number of defined tracking points on an image-based target, events are triggered using Vuforia's OnButtonPressed and OnButtonReleased events.

The dependence on the quality of the underlying image-based target means that the virtual button's size and placement must be considered carefully, concerning both the user experience and the function of the image-based target. Several factors must be taken into account when designing virtual buttons for use in augmented reality; these factors are:

- Size: Virtual buttons should take up about 10% of the image target's size. When defining this, the length and width of the button are considered.
- Shape: If the virtual button is too skinny in one dimension it will not track easily. They should also be easily identifiable to stand out from the rest of the image.
- Texture or contrast: Virtual buttons should be defined in high contrast areas of the targets. The underlying target area needs to have sufficient features that

tracking points can be applied to. Choose a button design different in texture from the object that hides the tracking points, causing the button to activate.

- The arrangement on the target: Arrange buttons around the target's borders with enough space from the edge to avoid losing image tracking when the user "presses" a button.

Within the project context, these virtual buttons can change between different typologies parametrically and add additional components to existing buildings. Through testing their capabilities in Unity3D, the virtual buttons can be very effective in this regard. Starting with a simple house component, by covering or 'pressing' the virtual button, a small market place is added to the house's front, transforming it from a simple dwelling into a 'house+market' typology. With this single virtual button, the individual target now has the capabilities of harbouring the two unique typologies: the house and the house+market

Further looking into these virtual buttons' capabilities brought the realisation that by having multiple virtual buttons in a single target, the number of typologies able to be created expands exponentially. With the creation of a new target, four virtual buttons are planted, and with this, twelve unique typologies can be parametrically generated. These additional virtual buttons give an inexperienced user the ability to define what they would like their building to look like, and the freedom to explore options while simultaneously allowing the experienced design to retain a bulk of the design work.

When first visualised in AR, the image-based target centre is a small house (Figure 3 left). The house provides a base point that all of the variations are based off. The designer can then place a virtual button covers over the four buttons to the central target's side to trigger the building of the various typologies (Figure 3 right).

The process behind the events that happen when these virtual buttons are covered relies on a small amount of *C-sharp* scripting using the 'OnButtonPressed' and 'OnButtonReleased' events. The event triggered for OnButtonPressed is a simple animation, causing the associated model to scale from 0 to 1. The scaling happens for all virtual buttons, so, for example, if the 'expand up' virtual button is covered, the second story of the house is scaled from 0 to 1. The OnButtonReleased event causes the opposite of the OnButtonPressed event, simply scaling the model from 1 to 0.

Figure 3. Image-based target, with two virtual buttons on either side of the central tracker. Covering the 'expand up' and 'expand out' virtual buttons causes a new typology to be created.

4.4. CREATING URBAN ARRAGEMENTS

With the introduction of additional C-sharp scripting, the user can build typologies out to an XYZ-axis through the press of the spacebar. The creation of buildings gives the user the chance to create entire communities of these buildings based on their personal preferences.

By building multiple house types in one scene, the user can see how structures relate to one another at a 3D scale, rather than the standard model of representation with two-dimensional drawings. It also gives the user the chance to see how one building relates to another and how entire streets of buildings can be arranged concerning adjacent streets. A designer could consider problems like adding a market to the front of an existing building earlier in the design process, avoiding the market infringing on the road and being seen as "bad design. The structure may be built further back from the street to allow for potential later development in early design stages.

4.5. REAL-TIME LIGHTING

The lighting method in the project involved a graphical user interface (GUI) slider in simulating real-time lighting within the AR environment. A slider can be built through a combination of Unity3D's existing UI functionality and a small amount of C-sharp coding, which angled a directional light as if to follow the sun direction from 6:00 a.m. at the left of the slider, to 6:00 p.m. at the right. The UI lets the user know with certainty what time of the day is correlated with certain sun conditions, and, unlike previously explored methods, gives better insight into the way that real-world sun paths cast shadows on buildings.

The on-screen GUI used in this method requires user engagement with both a GUI and a TUI simultaneously. While these are both forms of user-interface, their interaction is vastly different (Ullmer & Ishii, 2000). In a GUI, we see interaction occurring with a mouse on a screen instead of a TUI where the user interface is a tangible element set in front of the user. For the slider lighting system to work one of two things must occur: i)The user would have to transition between GUI and TUI in a way that they do not lose touch with their initial design goal or ii) the

GUI and TUI would next to be designed as if occurring within one unified user interface.

5. Conclusion

The paper explores the role of an appropriately low-tech AR environment in the engagement of laypeople in urban design. It employed the Vuforia SDK, and exploited the software's capabilities as a method of creating tangible user interfaces to facilitate intuitive interaction within an AR environment. Our novel application is based on real-time-virtual-engines and XR that are connected to a parametric system that allows urban design proposals to be communicated with ease in real-time to laypeople and expert. Thus allowing for a novel and more equitable design interaction.

Within the realm of urban design and architecture, there is a disconnect between the public/client (layperson) and the designer/architect (expert). The disconnect is often found in the communication of design options and implications. In the past, these issues have been addressed by the designer commanding control of them and failing to communicate design options with the client effectively. The project sought to explore AR's role, and specifically, illustrates an effective system developed to show how appropriate tangible user interfaces can play a significant role in bridging this divide.The ease of gaining familiarity with the system is one essential ingredient; easily interpreted instant system feedback is the other.

The project outcomes are an intuitive solution for layperson engagement in urban design and a system of analysis for such a tool grounded in the existing literature. A low-tech TUI was an effective design tool, as it allows for a shallow learning curve due to the tangible aspect being something that the layperson is more familiar with. Facilitation of design was also found to occur at multiple scales. The small was the individual configurator and the large being building configurations out to the XYZ axis and developing an urban arrangement. These contributions offer a significant step into an area of research that does not focus primarily on experienced users and high-tech methods of interactions, hence being more democratic. Future research within this field could greatly expand upon the developed interactions, providing even more opportunity for layperson engagement in the process of urban design.

References

"Location and orientation for passive heating and cooling" : 2019. Available from <http://www.level.org.nz/passive-design/location-orientation-and-layout/> (accessed 15th May 2020).

Bai, N., Ye, W., Li, J., Ding, H., Pienaru, M. and Bunschoten, R.: 2018, Customised Collaborative Urban Design: A Collective User-based Urban Information System through Gaming, *Proceedings of eCAADe 2018*, Lodz, 419-428.

Broschart, D., Zeile, P. and Streich, B.: 2013, Augmented Reality as a Communication Tool in Urban Design Processes, *Proceedings of RealCORP 2013*, Rome, 119-126.

Brown, A. and Berridge, P. 2001, Games One:Two:Three: A triangle of virtual game scenarios for architectural collaboration, *in* M. Stellingwerff and J. Verbeke (eds.), *Accolade - Architecture, Collaboration, Design*, Delft University Press, 95-120.

Chowdhury, S. and Schnabel, M.A.: 2019, Laypeople's Collaborative Immersive Virtual Reality Design Discourse in Neighborhood Design, *Frontiers In Robotics And AI*, **6**, 97.

Cooper, A., Reimann, R. and Cronin, D.: 2007, *About Face 3:The Essentials of Interaction Design*, Wiley.

Healey, P.: 1997, *Collaborative Planning: Shaping Places in Fragmented Societies*, UBC Press.

Hornyanszky-Dalholm, E. and Rydberg-Mitchel, B.: 1992, Communicating with Laypeople, *Proceedings of European Full-Scale Modelling Conference 1992*, Lausanne, 25-32.

Kato, H., Billinghurst, M., Poupyrev, I. and Imamoto, I.: 2000, Virtual object manipulation on a table-top AR environment, *Proceedings of IEEE and ACM International Symposium on Augmented Reality 2000*, Munich.

Lo, T.T., Schnabel, M.A. and Moleta, T.: 2018, Social Media Design: Using VR to Empower Homebuyers to Design their Living Space Collaboratively, *Virtual + Actual: Process and Product of Design, Design Communication Associations (DCA) Conference*, Ithaca, 138-146.

Nielson, J.: 2012, "Usability 101: Introduction to Usability" . Available from <https://www.nngroup.com/articles/usability-101-introduction-to-usability/> (accessed 13th May 2020).

Nourizi, N., Shabak, M., Embi, M. and Khan, T.: 2015, A New Insight into Design Approach with Focus to Architect-Client Relationship, *Asian Social Science*, **11**, 108-120.

Preece, J., Rogers, Y. and Sharp, H.: 2002, *Interaction design: Beyond Human-Computer Interaction*, Wiley.

Sawyer, B.: 2002, *Serious Games: Improving Public Policy Through Game-Based Learning and Simulation*, Woodrow Wilson International Center for Scholars.

Schnabel, M.A. and Chen, R.I. 2011, Design Interaction via Multi-touch, *in* Y. Luo (ed.), *Cooperative Design Visualisation & Engineering, CDVE, Lecture Notes in Computer Science*, Springer, Berlin, Vol 6874, 14-21.

Schneiderman, B.: 1987, *Designing the User Interface: Strategies for Effective Human-Computer Interaction*, Pearson.

Schurch, T.: 1999, Reconsidering urban design: Thoughts about its definition and status as a field or profession, *Journal of Urban Design*, **4**, 5-28.

Seichter, H.: 2004, Benchworks - Augmented Reality Urban Design, *Ninth Computer Aided Architectural Design Research in Asia (CAADRIA)*, Seoul, 937-946.

Seichter, H. and Schnabel, M.A.: 2005, Digital and Tangible Sensation: An Augmented Reality Urban Design Studio, *Tenth International Conference on Computer Aided Architectural Design Research in Asia (CAADRIA)*, New Delhi, 193-202.

Spinuzzi, C.: 2005, The Methodology of Participatory Design, *Technical Communication*, **52**, 163-174.