DESIGN GLOBALLY, IMMERSE LOCALLY

A Synthetic Design Approach by Integrating Agent Based Modelling with Virtual Reality

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Abstract. The last three decades have witnessed the explosion of technology and its impact on the architecture discipline which has drastically changed the methods of design. New techniques such as Agent-based modeling (ABM) and Virtual Reality (VR) have been widely implemented in architectural and urban design domains, yet the potential integration between these two methods remains arguably unexploited. The investigation in this paper aims to probe the following questions: How can architects and urban designers be informed more comprehensively by melding ABM and VR techniques at the preliminary/conceptual design stage? Which platform is considered more appropriate to facilitate a user-friendly system and reduces the steep learning curve? And what are the potential benefits of this approach in architectural education, particularly for the design studio environment? With those questions, we proposed a prototype in Unity, a multi-platform development tool that originated from the game industry, to simulate and visualize pedestrian behaviors in urban environments with immersive design experience and tested it in a scenario-based case study. This approach has also been further tested in an architectural design studio, demonstrating its technical feasibility as well as the potential contributions to the pedagogy.

Keywords. Agent based modelling; Virtual Reality; Urban Design.

1. Introduction

From modeling to renderings, from conceptualization to visualization, digital applications are ubiquitous amongst architectural industries that now afford designers with the opportunity to access and analyze information with a complexity at an order of speed and depth that wasn’t conceived as being possible before. In urban design particularly, the growing complexity of cities requires new modeling techniques as traditional approaches are no longer adequate to describe complicated urban scenarios. (Batty 2007) In this case, agent-based modeling is...
considered one of the applicable methods and has been further developed to adopt different objectives, (Heppenstall, 2011) and has proved useful for design process by suggesting various forms of analytical and statistical evidence (Aschwanden 2011).

In most agent-based simulations, particularly in crowd simulation scenarios, the outputs we expected are usually a series of intricate 2D evaluation maps with corresponding figures and recorded animations. However, we argue that the classic post-simulation procedure which follows observation - analysis - design adaption (Aschwanden 2011) can be tuned and further enhanced in three aspects. Firstly, pattern observation and data analysis are commonly accomplished two-dimensionally that might overlook some crucial architectural properties from 3D. Secondly, rules of agents and system are frequently preset and calibrated globally from a ‘god perspective’ and neglects the engagements in local scale. Finally, a typical simulation offers a series of objective metrics but rarely well-correlated with subjective aspects like aesthetics, resulting revised models may not be properly integrated with design propositions.

To overcome those issues, we are proposing a new possibility that emerged from the available technologies by synthesizing ABM pedestrian simulation with the Virtual reality devices. Immersive environments become feasible during the simulation process where local awareness and factors are greatly emphasized and global design decisions are further informed.

2. Background

2.1. ABM IN ARCHITECTURAL AND URBAN DESIGN

Agent-based modeling is considered as an applicable method to inspect and test increasingly complex issues and emergent properties. (Macal and North 2007) In general, ABM is a system that models a collection of autonomous decision entities called agents and described from the perspective of its constituent parts. This idea can be tracking back to late 1940s yet, as the procedure of ABM is usually computationally intensive, it has not become widely employed until the 1990s. (Batty 2007)

The early agent-based modeling approaches in urban design were initiated on large scales research. In the 1990s, Benenson (1997) and Coates had proposed a series of planning ABM on GIS platform and soon, in precinct level, more rigorous pedestrian movement simulations were carried out by Batty (1998) based on space syntax theory. Since 2000, new techniques and skills have been widely employed. Turner and Penn (2001) crystalized visual graphical analysis (VGA) ABM which assumes pedestrians’ movement behaviors are dominated by destination selection and the field of views. In 2008, a synthetic methodology was implemented by Aschwanden (2011) where ABM is closely correlated with procedural modeling that both static and interactive behaviors can be described. To date, some design-based lightweight ABM methods have emerged. Pedcatch (Badland and White 2013), provides an accessible online platform to evaluate the accessibility from given nodes. Apart from cases mentioned above, many other techniques have also been proposed to simulate crowd and pedestrian behaviors, all of which
can be differentiated in three levels: 'strategical,' 'tactical' and 'operational.' (Hoogendoorn and Bovy 2005). 'Strategical' part creates activities that impact on people while 'tactical' level generate routes with location and order choices. The 'operational' stage produces instantaneous and unpredictable decisions like random 'wandering' or 'stop' behaviors. In most cases, the manipulations on these levels are mastered by professionals from a 'global viewport', whereas there is a shortcut today with VR we could lower the learning difficulty for designers (see section 5) and reduces misinterpretations that derived from the inadequate local engagement.

2.2. VIRTUAL REALITY AND EMERGING IMPLEMENTATIONS

For the designer in architecture and urban design, VR is a technology that improves the visualization of a built environment as well as the communication and innovation within projects via virtual environments. (Stouffs 2013) It’s also a technique that offers an immersive and interactive atmosphere and a possibility of exploration in the 3D digital model that is not available with the traditional form of representation (Burdea and Coiffet 2003). In last ten years, we’ve witnessed the growing enthusiasm on VR in both academia and industry due to the reduction in cost and availability of hardware that gradually reshape the conventional design paradigm. Amongst most of the VR methods, we can generally divide them into three clusters: 360 Panorama render & equirectangular projection which aims to mock-up a simplified spherical virtual environment that allows people to observe a space from the internal location; Simple VR representation which utilizes existing third-party plug-ins where virtual environments can be generated by importing or synchronizing data from traditional modeling tools to a well-packed software; Customized VR which requires developers/users to create specific VR spaces via game engines or other professional software and hence reaches a higher degree of flexibility and interaction.

3. Methodology

To test our proposal more operationally, a new design approach has been suggested. We have scanned the existing inventory of digital tools and selected a suitable platform from it, creating a user-friendly prototype that accommodate both ABM and VR. This prototype has been further experimented in a preliminary test and case studies.

3.1. SYSTEM DESIGN

As mentioned in Section 1, we typically scan evaluation maps and figures and analyze them with a global perspective, then accordingly adjust the design and ABM system settings. This process may be biased and deliver inadequate or inaccurate information with the absence of 3D data and local awareness. For instance, in both target finding and force driven methods, agents tend to follow the shortest route which might lead them to traverse through a very uninviting space where, however, detours are preferred in reality. This issue could be less properly realized by designers without offering an immersive environment. The
new system agenda we proposed aims to enhance whole procedure on different levels by utilizing VR techniques, which is particularly beneficial for preliminary design stage where flexible and agile design workflow is required. Following elaborates the correlation between the VR and the original ABM structure (Figure 1):

VR & Observation: revealing spatial details and concerns that are omitted before like building environments in 3D perspective and immersive walking experiences. Delivering multi-level information from not only visual discovery but also acoustic perception if needed.

VR & Analysis: verifying calibration in both global and local perspective and revise ABM system accordingly, e.g., wandering force could be more conveniently adjusted with the local viewport that we could therefore eliminate the ‘drunken agent’.

VR & Design Adaption: it amplifies the sense of scale as well as material, form, and aesthetics, allowing designers to comprehend and revise the built environment with a higher degree of profundity.

3.2. PREVAILING TOOLBOXES

At present, there are many commercial software for crowd simulations, such as Oasys and MASSIVE. However most of them offer neither moderate price that individual designer can afford nor the potential for further extensions which in our case, the VR device. On the other hand, for many research projects, open-sourced scripting platforms are extensively used for the free license and relatively unconstrained possibility they offer. Nevertheless, engaging with those platforms like Eclipse/Processing and Visual Studio/NetLogo still require back-end skills of programing which are not common for normal designers.

In this case, we consider game engine as a viable choice where most prevailing game development apps now contain built-in VR toolkits and modular scripting functions. Unity3D, Unreal Engine4 (UE4) and Autodesk Stingray are now
most predominant software in the market and offering enough flexibility to adopt different external devices, e.g., HTC Vive and Oculus. Compare with UE4 and Stingray, Unity3D might be less powerful regarding the visualization authenticity and suitability to specific software, yet we reckon it is overall more suitable for testing early-stage architectural and urban design scenarios due the accessible workflow, better correlation with ABM and the wider user communities. (Figure 2)

3.3. PROTOTYPE

The idea and the resulting paradigm we proposed are further tested and verified by establishing a digital apparatus in Unity3D which is considerably accessible and supports most of the VR gears. For the purpose of a better demonstration, we’ve divided our prototype setup into four stages, elaborating how the working environment is being initialized in detail:

1. Model import: Unlike well-defined models in the design development stage, VR environment favors meshes with simple definitions, as the rendering rate is around 90fps which require smooth computation. Therefore, in our case, we didn’t attempt to reach highly detailed representation of buildings at the conceptual design stage that in most areas only massing and simple texture maps applied while trees and other small amenities are inserted from external libraries afterward.

2. Basic environment settings: in this part, we are to set up primary attributes for the geometric environment, light system, and cameras. We assign static built environments and infrastructures as colliders that assure agents would obey the basic physics settings; For the lighting environment, baked GI has been selected since the sunlight movement is insignificant in our case and it offers a much higher computation efficiency; Cameras can be set freely according to various design objectives, including classic top/masterplan view and static local perspectives. Dynamic cameras are designated as child objects with 1.6 meters height under different agent (pedestrian) Prefabs, offering local visions when the simulation is
3. Pedestrian system: Unity3D has a powerful scripting compiler that allows most of the crowd simulations to be realized. The embedded NavMesh function makes the target finding method achievable within several clicks while the core mechanism of Force-driven and Trajectory-based methods are also easily achievable. What fascinates us more is that different methods and systems can coexist under the same umbrella where designers can shift from one algorithm to another by simply activating/deactivating several components. Spawning and vanishing area for agents are set as basic geometries which could move or omit smoothly, while other parameters like agent population and different force factors can be manipulated by dragging sliders in the inspector panel or customized UI if needed.

4. Gear Deployment: In our prototype, two assets (SteamVR and GoolgleVR) are used to empower PC and mobile devices respectively. An Android cellphone with GearVR can be linked with Unity console via USB protocol and allow people to immerse into the environment that an agent can perceive or, switch back to the static views for global observation. In the Vive environment, end-user is equipped with controller alongside with headset which makes it possible not only to observe but also interact with the surroundings.

3.4. PRELIMINARY TEST

In this test, we proposed a simple simulation in the Federation Square, Melbourne with adjacent urban massing models. Agents tend to follow the preset trajectories which are based on pavement positions, yet have the freedom to deviate since the VGA has also been applied that places with higher visual accessibility are preferred. In a typical post-simulation procedure, we interpret space popularity based on the pattern draw from two-dimensional agent trails and adapt design correspondingly. However, as the experience of passing in front of a 5 meters pavilion is different from walking by a highrise, describing 3D urban entities in traditional 2D ABM approaches are often challenging. With the VR environment that an agent’s camera offered, designers could receive far richer sources intuitively. In the initial test, the place indicated by the red dot on Figure 6 is less visited by agents due to the blocked view of its enclosed typology, whereas when zooming in with 3D perspective we find this space inviting and in fact attracts more people in reality. Nevertheless, we should not impute this issue to VGA method per se yet, at very least, this case demonstrates the significance of introducing stereo perceptions of the built environment that even 3D IsoVist algorithm cannot offer. By observing the space more properly, we can calibrate agent/NavMesh parameters or create new POI (points of interest) in a more accurate manner. (Figure 3)
4. Studio Experiments

As vehicles for examining the opportunities of this approach, two scenario-based case studies in an architectural design studio were offered, demonstrating its technical feasibility as well as the potential contributions to the pedagogy. In this studio, students were asked to deliver prompt speculative urban design and architectural proposals in a condensed schedule, and engage with multiple digital toolboxes including ABM and VR assessing the existing urban form and attempt to weave current urbanism into their own propositions.

4.1. VISUAL CONNECTIVITY

The first proposal emphasized visual connectivity as the design priority by explored the field of vision at certain points/routes on the site. The students intended to increase the permeability of the existing urban blocks in both physical and visual aspects while limit building height to maintain the view linkage towards various landmarks. A simple agent-based modeling and VR technique have been implemented in this project to facilitate their proposition. The pedestrians are designated to moving toward to different positions of interest via target finding method where both VGA and shortest walk algorithm were applied. This approach doesn’t require any long-term training since essential components are already packaged and the user interface is friendly enough that student can master it in a short period. In the simulation, agents are navigated by the NavMesh and can be observed from both global and local positions while resulting procedure could be mutually informed from both perspectives. The Vive and affiliated controllers provide a possibility to switch between different agents or even teleport to the designated area if necessary. During the test, multiple urban schemes were modeled and simulated in an iterative design process to optimize visual accessibility on different pedestrian paths, while other aspects of scale, form, and function were concurrently discovered and further balanced under the visual priority agenda. (Figure 4)
4.2. WALKABILITY AND MIXED LAND USE

Walkability is, in general, a measurement that describes how a natural or built environment is “friendly” to walking (Giles-Corti and Donovan 2002) and is becoming an important objective in many city planning schemes. This project particularly focused on one significant aspect that influences the pedestrian experience, the land use mix (LUM). To evaluate the pedestrian experience, one of the most widely-used methods is the walkability index (WI) which translates physical urban attributes into the readable cumulative indices. However, many argue that this method doesn’t involve all design elements (Ewing 2009) which may bias by simplistic numerical accumulations. Therefore, the students started their proposal with the assessment of WI and reshaped the design (mainly land use mix) with suggested information and executed crowd simulation with virtual scenarios to inspect and discover potential misconceptions. In the experiment, several areas and routes that with high WI have been selected. Crowds were generated in these places and students were able to ‘walk’ along the street they designed then fine-tuning streetscapes, as some places might not as good as indicated on the WI map yet favored by optimized route. This time the VR environment was powered by Gear VR SDK that could not only applied as a testbed on PC but also used as portable demonstrations strategy by exporting the scenarios into mobile devices. (Figure 5)
In this studio, the students presented an in-depth cluster of pedestrian-oriented urban design proposals with the assistance of different ABM-VR approaches. The apparatus built in Unity3D has proved feasible for many participants and abovementioned two projects have articulate that VR technology is a valid supplement for ABM, suggesting the potential to provide 3D information, offer local perception and bridge design speculation with the simulation. In addition, the fundamental ideas of the platform can be utilized by students with proper learning references while the system manipulation could be achieved without obtaining a high level of expertise. The participants showed high enthusiasm when engaged with those new techniques and were beneficial by the information suggested during the preliminary stage that we believe this design approach could further contribute to broader design pedagogies. (Figure 6)

5. Discussion and Conclusion

Compared with the conventional agent-based modeling, this paper investigated a novel design approach by melding VR and ABM technologies, facilitating
pedestrian-oriented design positively with the reciprocity between local immersion and global design perception, where an agent-based simulation can be better informed than possible in the past. Technical viability today affords architects and urban designers equipped with powerful toolsets with a convenient workflow, which enables this design approach by utilizing multiple professional platforms and game engines. In this research, particularly, the Unity3D shows substantial potential to engage with pedestrian simulation, disrupting traditional ABM modules of observation and analysis by feeding additional information from the virtual environment and therefore enhancing the design-adaption process.

In addition, the advent of the ABM-VR strategy appears to raise promising opportunities for the design studio. It changes the ordinary way we teach the ABM where complicated operations are demanded. Students could now engage more efficiently with those digital techniques with preset templates and master basic manipulations with less effort. This allows people to concentrate more on the essence of architectural design - the space and reveals more opportunities at the conceptual stage which wasn’t being conceived if ABM is solely applied. However, due to the time limitation, this approach is currently lack of experiment samples and quantitative comparisons, and we are now proposing more tests and analysis in the further studies. With this approach, we could envision with optimism a design shift in the near future that builds more effective bridges between objective modeling/analysis and subjective design speculations, guiding radical shifts in architectural simulation during the next decades.

References