Game Engines for Urban Exploration: Bridging Science Narrative for Broader Participants

Verina Cristie and Matthias Berger

Abstract One aspect of playing is exploration. A playable city could therefore be regarded as an explorable city. In recent years, a growing number of urban exploration tools have been developed, empowered by the technology of game engines. Traditionally, game engines have been used to create virtual environments for entertainment and enable the user to explore. We seek to apply game engines in urban planning beyond the visualization of buildings, trees, traffic, or people in the city. It can become a tool for a multidisciplinary approach that involves engineers, scientists, architects, planners, and even the citizens themselves. Those kind of mixed stakeholders have quite diverse needs, which all can be addressed by game engines in an easy way. In this chapter, we look toward bridging the seen and unseen elements in a collaborative game environment. One of the less visible elements in urban environment involves the urban microclimate: heat emission, wind flows, and outdoor thermal comfort. These unseen scientific elements have become a narrative on their own on top of the urban exploration. If they are to be presented in the traditional way of scientific visualization, the connection to the built environment would be difficult to understand for many kinds of stakeholders, especially the nonscientists. Hence, we utilize the power of the Unity3D game engine to show the potential of collaborative and explorative virtual environments: a bottom-up citizen design science within the narrative of exploration and urban science data.

V. Cristie (✉)
Singapore University of Technology and Design SUTD, 8 Somapah Road,
Singapore 487372, Singapore
e-mail: verina_cristie@mymail.sutd.edu.sg

M. Berger
Department of Architecture, ETH Zurich, Building HIT, Wolfgang-Pauli-Str. 27,
8093 Zurich, Switzerland
e-mail: mberger@arch.ethz.ch

M. Berger
Future Cities Laboratory, Singapore-ETH Centre, 1 Create Way, #06-01 CREATE Tower,
Singapore 138602, Singapore

© Springer Science+Business Media Singapore 2017

A. Nijholt (ed.), *Playable Cities*, Gaming Media and Social Effects,
DOI 10.1007/978-981-10-1962-3_5

Keywords Citizen design science · Game engine · Unity3D · Urban microclimate · Urban planning · Visualization

1 Introduction

What is a playable city? By starting on what it is not one can determine which elements are conditional, which elements are enabling, and where the barriers are. In terms of urban planning a top-down planning approach might exclude citizens' participation and knowledge. It transforms citizens from agents or protagonists into patients, sufferers of their fate. 'Playable' incorporates a bottom-up approach of citizens engaging in an active, positive loop with their city. While we assume for citizens that a certain amount of interest and willingness exists to interact with [the] urban planning [authorities], there is a need to bridge the gap of data, information, and knowledge required to actually do so (Berger 2014). Furthermore, channels of communication between the stakeholders are essential to promote a functional discourse, and skills to use them require training as well. The traditional top-down approach in urban planning is being replaced by the new forms of mobile and cooperative labor.[1] Following Pierre Levy, it is important to have capabilities of collective intelligence (Lévy 1997); to compare, regulate, communicate, and reorganize one's activity. Our vision is that game engines can provide the key to enter the world of urban planning for citizens while reducing the need for previous knowledge and skills at the same time. With game engines citizens can even contribute to citizen design science,[2] give feedback to urban design and planning directly (Crowston and Prestopnik 2013).

Four out of five households in the U.S. own a device to play video games, reports *Essential Facts About Computer and Video Games Industry* published by the *Entertainment Software Association* in 2015 (ESA 2015). The big market for computer games together with Moore's law explains the constant need for progress in game engines: state of the art computer graphics namely the lighting, texturing, particle systems, physics, animation, and special effects, all blended in eye gratifying visuals.[3] As such, we can see game engine as a very powerful visualization tool for nongaming content as well. Furthermore, game engines are commonly made for license-free end-usage (even so programming requires a proprietary license) and are platform independent. The Unity3D engine, i.e., runs on Windows, OS X, Xbox 360, Xbox One, Wii U, New 3DS, PlayStation 3, PlayStation 4, PlayStation Vita, Windows Phone, iOS, Android, BlackBerry 10, Tizen,

[1]Paul Coulton (University of Lancaster, UK) notes that new policies in the UK require now all towns and cities to include participation.

[2]For a working definition of citizen design science see Wikipedia (2016).

[3]Countless examples could be given here. The work of Ulrike Wissen (Manyoky et al. 2014) is most comparable: simulating audio-visual landscapes with the CryEngine.

Unity Web Player, Windows Store, WebGL, Oculus Rift, Gear VR, Android TV, and Samsung Smart TV. Humanity is moving toward having more and more *digital natives*, a term connected to the name Marc Prensky; his team bridged a new CAD software learning experience by creating a game like tutorial (Prensky 2001).

In a similar manner, we believe that it is feasible to use game and play like behavior to bring urban science to a wider audience. This chapter will expand the role of game engine not only as a tool for urban exploration, but also as a tool to tell a narrative within the context of urban science.

1.1 Games as Narratives

Game design is often seen as an interplay between interactivity and narratives (Ampatzidou and Molenda 2014). However, not all games are telling stories, although many games have narrative aspirations (Meirelles 2013). We need to expand the concept of games beyond its definition as a system to win or following objectives, given that different elements interacting with each other in somehow limiting constraints (Abt 1987). Helpful might be the differentiation made by LeBlanc, which separates emergent narratives from embedded narratives (LeBlanc 2000). Emergent narratives are defined as storytelling that comes as a result of player actions and events within the game. The embedded narrative is the [background] storyline, content which has been pre-generated prior to the player's interaction with the game.

The creation of embedded narratives includes the creation of hypothetical, fictional worlds [or realms, levels], so a big portion of game design is level design, where worlds are designed and spaces are sculpted. If the context of the fictional world is a city, then the level design becomes similar to urban design, yet a simpler one—without having to consider the most realistic representation of buildings and their layout within the city. Since we want citizens to become players [who are supposed to walk through the spatial environments of the virtual representation of urban topologies], we need to look into emergent narratives of the urban planning environment and compare them with game narratives.

1.2 Citizen, Urban Design, and Science as a Narrative

The Chair of Information Architecture at the Swiss Federal Institute of Technology in Zurich (ETHZ) is dealing exactly with the interplay of *Citizen, Urban Design, and Science*, since it has been established around 2006: "We develop visual methods for the analysis, design and simulation of urban systems for a sustainable future" is the leitmotif of the research group. Citizens as well as urban planning authorities are equally seen as stakeholders. By the nature of the specific problem, often one stakeholder has or should have more power, i.e., for an airport superior interests of a larger region predominate and residents' NIMBY (not in my backyard) behavior would rather destructive than constructive, whereas the design of a local playground explicitly should consult the residents. While the discourse or dialog between citizens and authorities has to be direct, we can provide tools and means to enable, enhance, and democratize—by given equal access to data, information, and knowledge—the communication.

Here computer-aided tools come into play. Exploration tools allow users to play and incorporate naturally the concepts of [video or computer] games. Perspectives as first-person or birds-eye come into action as players walk through different places of the virtual environment (Zeng et al. 2014). Collaborative tools come in form of multiplayer games, or even as a person observing other people playing a game and voice out his/her opinion (Klein et al. 2014). Communication from virtual to real world is a feature here (Treyer et al. 2013). Not only the exchange of information and knowledge has to be taken into account, the requirements for the exchange of data from real world and scientific domain has to be included during design and implementation of a tool.

In this context, the data then becomes the narrative in or of the urban landscape. Will more trees in the city provide a better climate such that residents are more satisfied? How does putting a hospital at the city center correlates to the longer life expectancy in the city? What will happen if factories are being relocated to the other part of the city? As such, simulation tools in the urban modeling have provided a dynamic context to urban narratives (Guhathakurta 2002). Not only that it has created a method to construct 'stories' of the past and possible futures, but it is also able to create stories of the current time with multiple [design] alternatives.

2 Related Works

2.1 Game Engines for Urban Explorations

In *visualisation support for exploring urban space and place* (Pettit et al. 2012) a game engine is being categorized as visualization support tool together with GIS and cartography tools, digital globe (Google Earth, ArcGIS explorer), virtual simulation environments, and building information models (BIM). The development of game engines as urban visualization tools comes from the need to have a user perspective as well as navigational view. These views are understood to be more engaging as they contain more complex spatial information to be explored and learned (Clemenson and Stark 2015). Other than the purpose of engagement, having a 3D navigational view could also help user from missing out information that could have been understood or caught only if 3D navigational view was available. Such examples include the designing of rural roads in which many curves are needed in uneven topography and heights. By navigating through the road from the level of different vehicle's height, for example, critical blind sections that would cause accidents otherwise can be identified and minimized (Kühn and Jha 2006).

We noted that there are various game engines available in the market, of which better known to urban exploration are Unreal Engine and Unity3D. Both have been shown in many cases of serious gaming, as in various training and educational fields. Several applications have been made related to virtual urban environment navigation using Unity3D, such as Yaesu district, Tokyo (Indraprastha and Shinozaki 2008) and the 19th century town scale model of the Lorraine region, Paris (Humbert et al. 2011). Similarly, Boeykens also coupled the tool with 3D design software and a BIM to do historical reconstruction and to finally explore the environment (Boeykens 2011). Game engines provide additional benefits as adding a 'wow' factor in BIM presentations and visualizations (Slowey 2015). This trend in the industry is also boosted with the current launch of Autodesk's Stingray game engine. In additional, not only visual, but also sound representations in the public space could be explored and evaluated in the work done by Signorelli (2011).

The Unreal Engine has been used for urban scale visualization in the Paestum tourism area, Italy (Andreoli et al. 2006). In this work, the real position of user is to be reflected in the virtual environment by using location awareness technology through GPS and Wifi. The engine is also capable of visualizing indoor and outdoor elements (Fritsch and Kada 2004). Both engines have a powerful rendering pipeline as they are built for games; hence, an interactive frame rate is achievable. They could also run on multiple platforms of operating systems, and could be exported to mobile devices. By nature, 3D models are easily imported. Lighting system is available to provide vivid scenery. Special effects can be added to enhance visual esthetics of the visualization. For outdoor element, terrain and tree systems are available in abundance. Networking frameworks are built in the system, as the engines are able to support multiplayer or network gaming. In addition, basic physics engine that deal with gravitation, Newton's laws, particle systems, even fluid dynamics are available such that a scientific simulation could be performed. In Xu et al. (2013) computed a dynamic fire simulation to show how smoke propagates in high-rise building in case of fire. They built upon the existing game engine's particle system and improved it by adding a stack effect model and computing the coordinate system algorithm using Excel file. While both the engines are equally powerful, in our study cases, we used Unity3D as it has lower learning curve for our programmers who are more familiar with Unity3D with C# than Unreal with C++ (Unreal uses C++).

2.2 Scientific Visualization Tools

Some background is needed to emphasize the difference between scientific visualizations and [general] information visualizations. Information visualization in cities is usually related to abstract data representing the elements of a city to understand the larger concept of a city. Such data includes for example population data, infrastructure data, and economic data. The data that we will be looking at in our case studies is related to the [urban] science of climatology, such as heat [in temperature and humidity] and wind flow [as velocity and direction], where the geographic location is given [in our case study it will be Singapore] and simulations of the local microclimate are performed (Papadopoulou et al. 2015). In the most straightforward visualization manner, the process could start from data collection, continued with the 3D modeling of the data, and presentation (Kim and Bejleri 2005). Challenges are everywhere, as data collection deals with an accuracy issue, 3D modeling deals with a reality issue, and visualization with its representativeness (Wissen Hayek 2009).

We experienced that especially in the architectural world; there is a tendency for scientific visualizations to be separated from the design process. Visualizations are conventionally seen rather as the end product than as a part of designing itself, e.g., conducting wind flow studies for the purpose of obtaining scientific-looking evidence[4] rather than optimizing the design subject to wind.

2.3 Public Participatory Urban Planning Games

Participatory design is meant for an inclusive planning with all stakeholders. In this process, they are able to negotiate, to reach an agreement, allowing flexibility and the learning curve to progress over time for stakeholders of different backgrounds (Chen and Schnabel 2011). In a similar note, collaborative design is viewed as social action where instrumental, communicative, discursive, and strategic actions take place. Instrumental action includes drawing and producing prototype. Goal orientation is considered discursive, and negotiation is considered strategic (Vosinakis et al. 2008).

There have been several discussions on bringing the city planning exercise into game like environments where different stakeholders get to negotiate to reach a consensus. This could be done either in a physical or in a virtual space. While it is traditionally easier to communicate in physical space, there are so many avenues to communicate in digital space nowadays. One such digital/virtual example is *YouPlaceIt!* (Vemuri et al. 2014). It brings a serious game play approach and has to be differentiated from other city planning games whose purpose is solely for entertainment. In *YouPlaceIt!* each player will take a role in urban planning [like resident representatives, government, real estate agents, NGO, etc.], and discuss through multilingual text chats and icons about an objective in a study case in Dharavi in Mumbai, India. For each action done, the game engine will calculate the costs, all in all leading to a consensus. While we advise to relay on participatory processes in general, the timing is even more crucial: Including end user early on in the design process empowers richer design solutions (Bodker et al. 2004).

In *Nextcampus*, early public engagement through an online serious game was developed to find a new location for current university campus. Each player is a resident of the campus and he/she is given an initial amount of money to further do

[4]The Bahrain World Trade Center is here an example where environmental ambitions became a selling point, with three wind turbines integrated into the building, even so wind flow studied would have led to a different result: the turbines are facing the wrong direction.

the planning and observe the mood of the local population [= the campus' residents]. The goal is to find the best strategy of relocating that will ensure a good mood in population (Poplin 2012).

The playful element through game is deemed necessary as a potential solution because the public are in general rationally ignorant (Krek 2005) due to the high cost [e.g., time and difficulty] to be involved in the planning and also to learn about planning alternatives. Hence, through serious game, participant could be engaged in learning and participate in the planning unintendedly. Some other examples of serious game would also be usually deployed in the city museums where more audience could be reached. One of the examples is SingCity. It is a game installed at Singapore's city gallery that will invite up to eight participants to solve the needs of the residents in city planning (URA 2016).

Adapted from (Cecchini and Rizzi 2001), we then can compile the following list of requirements for an urban 'gaming' simulation for participatory urban planning, in contrary to pure video games with urban settings like the notorious Grand Theft Auto (GTA):

- Made for (and with feedback by) lay persons which are as well end-users
- Standardized interface to other software
- Providing control to the user, enable scenario-making and evaluation
- Not include 'give' knowledge or results, user has to come to own conclusions
- Interactivity to be based on suitable menus (software) and human–machine interfaces (hardware)
- No proprietary hardware required, better able to run on any device
- License-free, freeware, shareware, or General Public License (GNU).

2.4 Virtual Reality and Interaction Tools

The concept of virtual reality in architecture came in the early 1990s as proposed by Schmitt et al. (1995). Since then, exploration of space has been advancing in the virtual world using computers without the need of a physical 3D model representation or 2D drawing based on pen and paper.[5] Research on how to interact with the virtual world has also been progressing from Graphical User Interfaces (GUIs) to natural user interfaces. Tangible interfaces are now expected to bridge the gap between the real world and the virtual world. As such, an augmented reality on tangible interfaces could be used rather than a fully virtual reality (Müller Arisona et al. 2012). In urban design collaborative platforms, i.e., a pen-like 3D manipulator or direct manipulation of 3D blocks could be employed to modify the urban layout, which is then projected to a head-mounted display or display screen (Seichter 2007).

[5]This is one direction, coming from the real world into the digital domain. Vice versa, with augmented reality (AR) both domains could be merged with the physical domain in focus, e.g., https://vimeo.com/65130490.

'Play the City' uses a games physical environment as method for collaborative decision making by bottom-up stakeholders (Tan 2015). By having augmented environment, another dimension of city planning can be added: the unseen elements of traffic simulations or climate related studies. Such example includes 'Tangible 3D Urban Simulation' table by RMIT university to simulate urban wind using projection and fabricated urban 3D blocks (Salim 2014), or 'CityScope' by MIT Media Lab to simulate urban metrics like walkability, energy, daylighting, and trip upon changing the neighborhood block configurations using projection and Lego® blocks (Winder 2014).

Fig. 1 The context of the environment is shown with a multiscreen setup. Users are able to focus on different aspects of the environment and adjust the views according to what they need. The views on the screen build a cohesive understanding of a story the presenter wants to portray

Table 1 Interface and collaborative space options in physical, augmented, and virtual environments in architecture and urban planning

	Environment		
	Physical	Augmented	Virtual
Interface	Tangible interface: 3D model, pen, and paper	Tangible interface with head-mounted display/projectors (usually table-top-based)	Any display device or screen
Collaborative space	Same room		Could be same room (using a large screen) or via internet (multiple players, each with own screen)

For a fully immersive experience, large displays or projectors in a CAVE-like environment are still preferred for urban planning or visualizing project models. In addition to a big amount of information that can be displayed on the screen, such setting allows multiple participants to discuss and collaborate with each other over the screen's content. ETH's *ValueLab* exemplified an environment for collaborative environment: Five large screens with a total of 16 mega pixels and equipped with touch interface capabilities and three full-HD projectors as visualization and decision support tools in urban planning (Kunze et al. 2012). Figure 1 shows the latest multi-screen setup in the *ValueLab Asia*, where the projectors have been replaced by multi-touch screens. Alternatively, a head-mounted display is utilized for augmented reality projections. The cons, however, are that they are heavy and prolonged usage can cause discomfort. In the spirit of play and exploration, one also can look forward to the recent advancement of omnidirectional treadmill as developed by *Virtuix* and *Cyberith*. Just imagine roaming around in the virtual city with walking and even jumping. Another advantage with a fully immersive virtual environment is also that collaborative action does not need to happen in the same physical space. Game engines, especially, have the capability to provide Massive Multiplayer Online Role-Playing Game (MMORPG) experience. Some of famous multiplayer online city building game are *SimCity* and Sid Meier's *Civilization*. Table 1 summarizes the classification we use for the different kinds of environments according to interface and setup.

3 Data Driven Design Interfaces

3.1 Operations with Data

With the availability of open and big [urban] data through online Application Program Interfaces (APIs), various visualization tools have been developed for a collaborative urban planning of future. One of such is *OSCity* (van der Net 2013) in which we note its two key features: 'Urban Dash' to monitor spatial events and trends, and 'Spatial Search' to have semantic search within GIS analysis, both in real time. A semantic search capability is useful to transform natural language to GIS queries. As such, for example, one will be able to search supermarkets with certain names, or offices along the river. Major challenges in big data visualization are perceptual and interactive scalability (Liu et al. 2013). The number of data points visualized must be balanced such that it will not overwhelm user's perceptual and cognitive capabilities. This balancing is also important because we do not miss any interesting structure or outliers. The amount of data loaded furthermore will determine the latency of the tool, finally affecting the interactivity of the exploration.[6]

[6]The MATSim framework (http://www.matsim.org), for example is an excellent transport planning tool, but has never been designed for an interactive use in workshops. The whole simulation has been developed with the underlying assumption that the solver can take more time, yielding a better accuracy, and computing more complex and large cases.

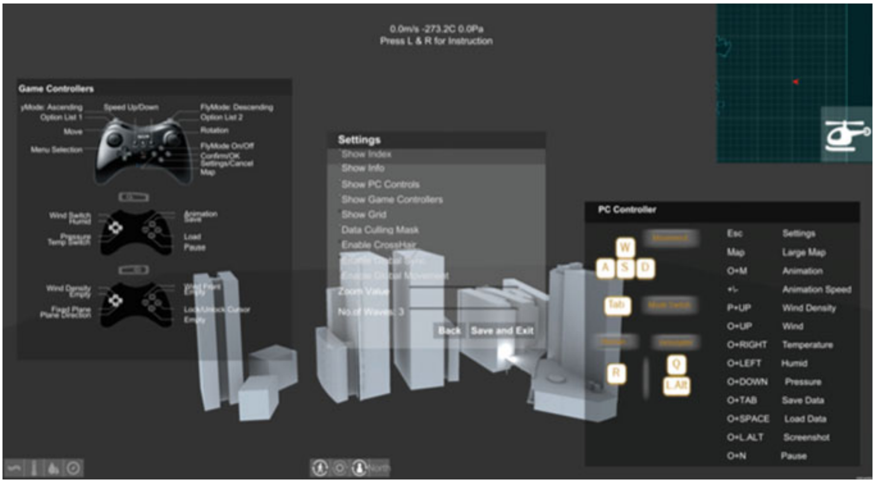

Fig. 2 There could be more than one set of navigation and control for 3D exploration. Here, keyboard controls and a joystick are allowed. For navigation, the mode is set to 'helicopter'—a virtual fly-through. The map view is located at the *top right* corner to easily find the current position

There are several guidelines in creating a user interface for an interactive environment exploration. It is important for user to be able to navigate around not only by an arbitrary or third-person camera view but also by walking on pedestrian level to simulate realism. Next, the user should be able to plan the views. For example, the user should be allowed to save the camera's position and create a fly-through view as in Fig. 2. Views can be saved as screenshots, and fly-through can be saved as video. This view will especially be helpful for presentation and discussion. Knowing current coordinates by using a map will also help user to navigate better: to put emphasis on the data [about the urban microclimate] in our tool, buildings are visualized as grayish, featureless blocks (as in Fig. 5); recognition of real world locations is hence limited. As such, like in first-person games a 2D map view can complement the 3D view. We also noted several optional interactions with the 3D model. Such as mentioned by Greenwood et al. are: importing the 3D model, transformation of model (scale, move, rotate), measurement of model, copy and delete, layering of models (to better organize the visibility of model), and editing of model's texture. In additional, the tool allows the user to analyze shadows and line of sight in the model (Greenwood et al. 2009). In Fig. 3 the menu for customization in our tool is shown.

Fig. 3 Camera presets and views are necessary elements in every exploration tool. The info panel helps users to know the context of data and model. Filter and color settings help further to understand the information shown better

3.2 Realism, Art, and Style

Architectural design is a visually evaluated process. Onur Yüce Gün stresses the importance of realism in the architectural process in his work on a very real walk-through using interactive real-time rendered stereoscopic animations (Gün 2013). Realism is described as the resemblance of the displayed image versus the reality. The degree of realism depends on its level of abstraction. Abstraction levels can go from very similar (reality) representation, to indexed, iconic, symbolic, and down to language writes Lars Bodum in Dykes et al. (2005). In Zanola et al. (2009), the authors created three different levels of realism in a 3D stereoscopic display of a spatial data, namely photorealistic, CAD-style, and sketch-style rendering. After the experiment where users were shown the representation on a video wall, they were asked of their confidence of the credibility of the spatial display. Photorealistic has higher confidence level than CAD-style, and CAD-style has higher confidence level to the sketch-style. Clearly the higher level the realism is, the higher the confidence level will be (Manyoky et al. 2014) (Fig. 4).

It is common understanding that the higher the realism is, the less interactive the tool will be. For example, a realistic model will result in bigger file size of geometry, which then can make the rendering slower. Game engines, however, deal with rendering quite well since an interactive frame rate is a must have in every game. It does this by optimized utilization of the GPU to process the rendering faster. Another level of detail and realism, adding vegetation is also understood to improve the quality of the environment and creates an esthetically more pleasant picture. Depending of the art and style that we aim for, we might

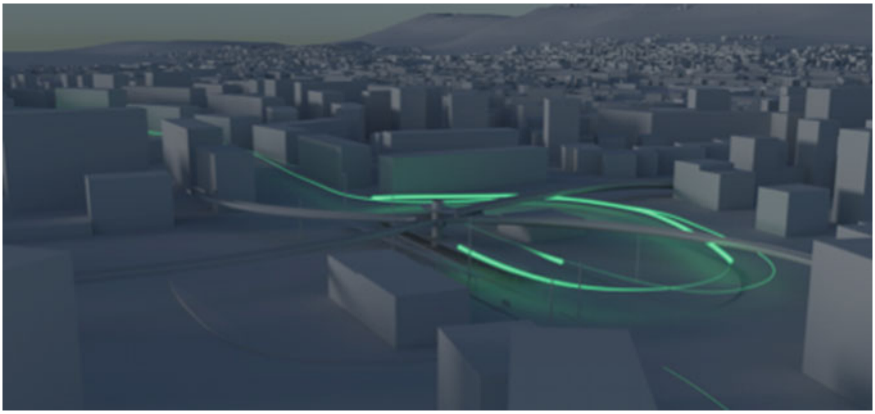

Fig. 4 Public transport data is visualized as animated *green lines* over nontextured building models (© Treyer 2014). This mock-up was highly acknowledged by visitors and became the foundation of our urban climate tool

or might not add texture. While adding texture will contribute richness to the exploration and a more realistic view, if we want to focus on data instead, we can opt for a clean look without the texture.

4 The Making of an Interactive Tool

Seeing the need of an interactive tool to explore engineering and or scientific simulation data and the environment in an urban participatory planning platform, we then develop a tool using the Unity3D game engine. We seek to make the process of designing in the virtual world as iterative and intuitive as it is in the real life to become accepted and utilized by different stakeholders. Design and visualization have been implemented as a loop around and including Unity3D as in Fig. 5, rather than a straight process involving various software elements. In the context of urban design, the urban science simulation result is then integrated as part of decision-making process (Berger et al. 2015). In additional, storytelling principles are integrated by injecting urban science data and walking exploration as the element of playful public participation (Krek 2005).

During the development phase, we cooperated with architects and researcher closely such that we can develop a suited tool for the exploration. It is also aimed that the tool can be used by a general public or lay audience and as such, we noted that there will be adjustment in the features of the tool: i.e., a general public does not need as much detail and information as researchers do. Menu bars and options also could be simplified to avoid confusion.

Fig. 5 Unity3D editor: The creator of the tool is able to import 3D models and change various parameters of the component (*right panel*). The components in the scene are listed on the *left panel*. The *bottom panel* shows the list of files that make up the project (textures, scripts, 3D model, images, audio, etc.)

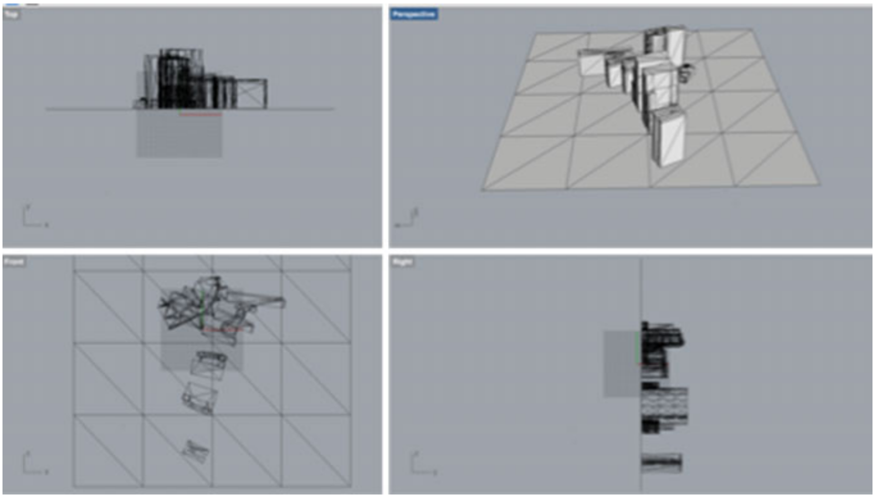

Fig. 6 The 3D model of the city can be imported from various 3D modeling software sources. We simplified the triangles to make the rendering jobs less heavy

To produce such a tool, we first imported the 3D geometry elements and engineering/scientific simulation results into the game engine, as in Fig. 6. The format of the geometry can be of *.obj, *.dae, *.fbx, or other proprietary 3D elements.

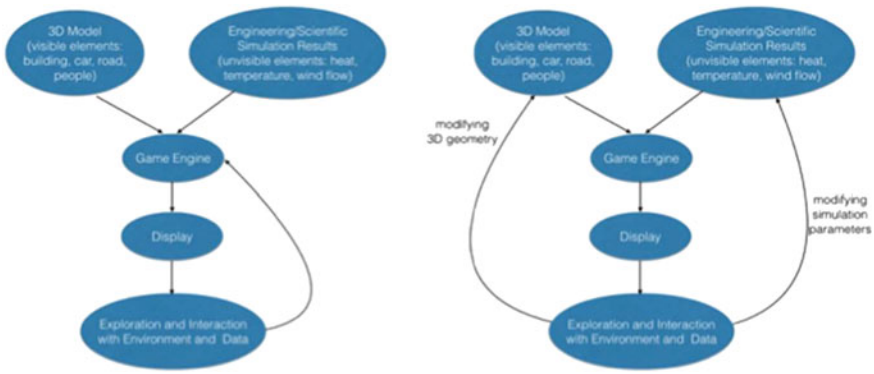

Fig. 7 Simulation–Visualization–Exploration as a flow on the left versus, Simulation–Visualization–Exploration as a design loop. Exploration results could affect the next iteration of the design process, which will then provide new input parameters to the simulation

Currently, the format of the simulation data is any text-based format like *.txt, *.csv. Loading data into RAM memory will provide a better frame rate for interactivity in case (a) sufficient RAM is provided and (b) a balance between visual details and scarcity of file size is kept. The game engine will then render the result and the user is free to explore in the environment using any input controllers that has been setup with the game engine. Several input controllers like mouse, keyboard, game controller (joystick), gesture-based input (Microsoft *Kinect*) have been tested, or even touch-based input and head-mounted input that can track eye/head movement could be used. With the recent advancement of virtual reality gaming, we can also include the treadmill as an input source for positioning.

There can be up to six degrees of freedom in the movement input. Three degrees are employed for positional (up–down, frontward–backward, left–right). Another three are used for orientation: yaw, pitch, and roll, each is rotation in x-, y-, and z-axis, respectively. To have a user perspective when he/she is walking between the buildings or on the road, we use the first-person perspective with five degrees of freedom—the user is allowed to tilt their heads to simulate rotation, and moving frontwards or backwards and left or right. We disabled up and down to simulate realism because the user is not assumed to fly. Elements of playfulness can be injected by allowing vertical movements to a certain extend such as jumping or squatting. Because the simulation mainly deals with outdoor data, we do not have cases such walking up and down the stairs indoor. We still allow another mode where the user freely roams in the 3D environment as if using a helicopter. We adjusted the travel speed to be faster in this exploration mode. The entire procedure is shown in a conceptual flow chart in Fig. 7.

4.1 Study Case: CFDtoUnity3D

In our first study case (Berger and Cristie 2015) we utilize Unity3D to visualize problems of computational fluid dynamics (CFD) to address outdoor thermal comfort (OTC) (Nikolopoulou 2011; Tapias and Schmitt 2014). Simulated are wind flow, temperature, and pressure around a complex of buildings in the University Town area, Singapore. Due to the humid tropical climate urban planning and design is more and more dealing with a loss in the quality of living, perceived as reduced OTC. We use ANSYS as the CFD simulation software. ANSYS divides the simulation space into polygonal elements of the 3D space, the so-called meshing. After numerical calculation of the fluid dynamic behavior, we have data of temperature and pressure within the volume. We import the results based on a rectangular grid with each block defined by its center's position and size.

Wind flow data is independent of blocks and represented in the format of streamlines or tube. For each streamline, we have information about the speed at each specific time step. We then can use this information to create an animation of wind flow by adjusting the wind speed to the frame rate of the interaction tool, from time = 0 s (beginning of animation) until the final time step. Seeing an animation is a bridge for the wider audience to understand more, compared static wind lines. When the wind is hitting the building, we can notice that the speed is going slower. We could also observe how the wind is dispersing, leaving some area to be windier, and some area to be less windy. The tool has been designed to run especially on large and high resolution devices, which is best suitable for workshops with many stakeholders involved. In test cases it runs for small scale on the 5 k resolution iMac, for large scale on our 4 × 4 full-HD screen with 33 megapixel on about 3 × 4 m in the Future City Lab's *ValueLab Asia* (Anwar et al. 2015). According to the large screen, up to 16 sub-screens [each full-HD] could be opened in parallel, however, four subscreens were regarded as optimal by the test audience. The site of the case study in Figs. 8 and 9 has been originally designed in a way to improve wind flow between buildings [by Perkins and Will architects]. Yet the design process was not public or open to shareholders.

4.2 Study Case: CityHeat

CityHeat is the second study case of a tool where we bring the context of [anthropogenic] heat produced by traffic in a stretch of the Ayer–Rajah Expressway, Singapore (Cristie et al. 2015; Wagner et al. 2015). Here, we would like to invite users to interact with resulting data from heat simulations. To display, we experimented with using a touch screen rather than the video wall. Users can have immediate feedback based on their gesture control on the screen. The interactions include the navigation in the 3D space and time, and also data visualization control (filtering, color settings, output styles).

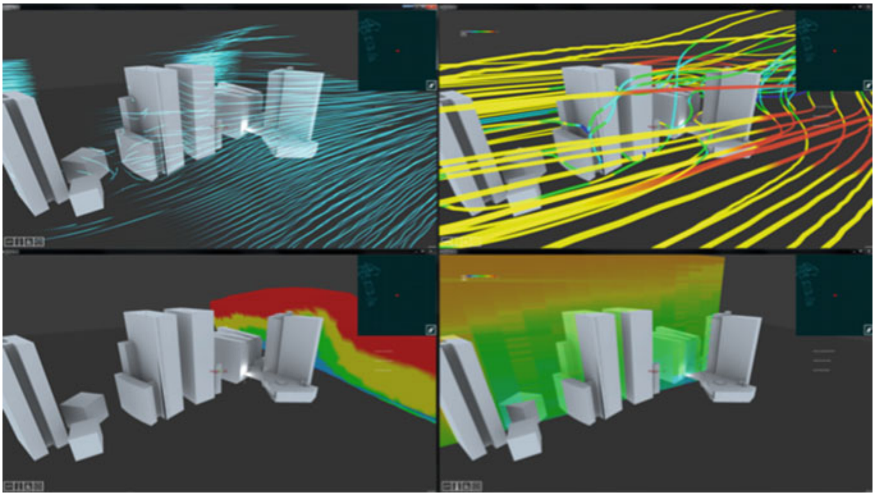

Fig. 8 Multiscreen implementation can also be used to show different representations of the same dataset. The wind flow visualization is shown by animation (*top-left*), static lines (*top-right*), and the wind's wave-front as a triangular surface (*bottom-left*). In additional, by showing the pressure visualization (*bottom-right*), we can see how wind flow and pressure correlates to each other over time

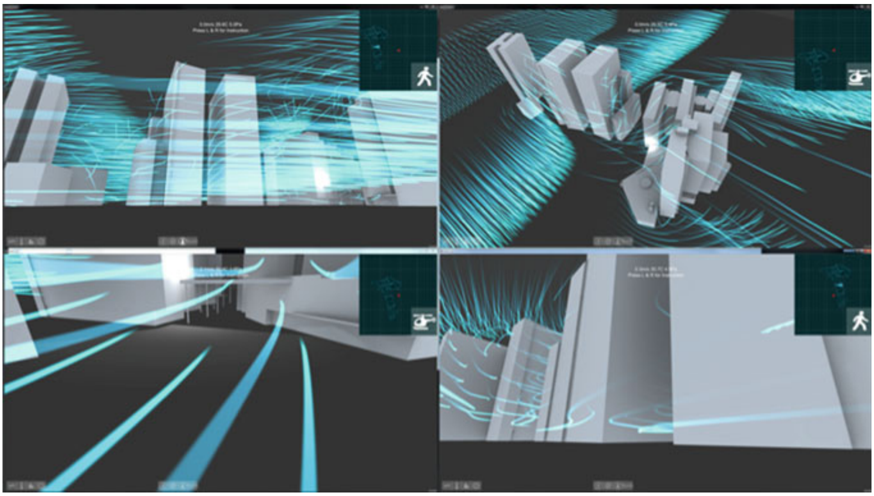

Fig. 9 In a different setup multiscreen implementations allows the user to observe wind flows from different angles to get a better holistic understanding of the scene

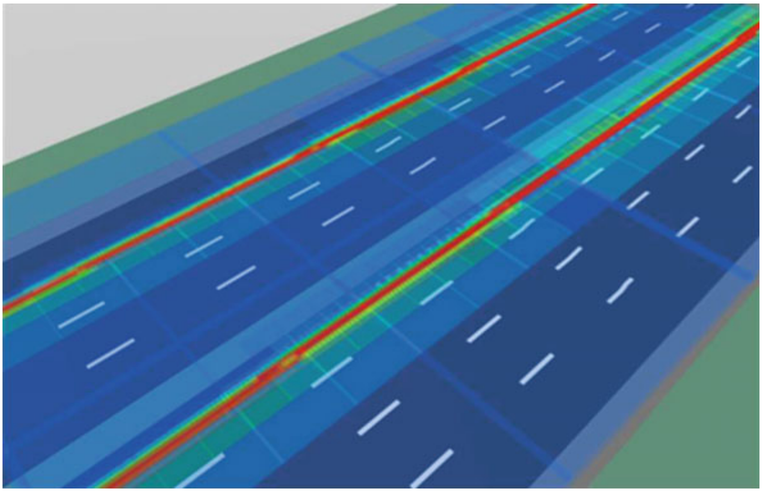

Fig. 10 Traffic heat visualization using cubes. More details are shown in the area near the engines of the vehicles. In the picture, *red* color is the cube with the highest temperature, and *blue* color is set as average air temperature

From an engineering point of view, similar to *CFDtoUnity3D*, we also employ animation to help the visualization show how heat is produced from vehicle's components (engine, exhaust, underbody, breaks, tires, and cooling) and its propagation over time. We added a timeline player that has a play and pause button so that the user can stop and move the time-slider to observe the heat propagation at a specific points in time. Additionally, we allow a dynamic color configuration for users to be able to differentiate temperature gradients better. In doing so, one could observe that the air area above the asphalt and below the vehicles will be hotter due to heat from the vehicle through radiation, convection, and friction. As we are using cubes within the 3D cellular automata to visualize the air temperature, we note that too many visible cubes will lead to distracted vision and inability to focus and get a meaning out of the data, as in Fig. 10. On the technical side, it is massively slowing down the rendering process. As such, we had filtering options where user can filter to only see certain cubes with certain range of temperature. We also set a cluster filter where the simulation area is divided into sectors and user can choose the area that they would like to zoom in. Furthermore, we allow users to customize the visibility of vehicles and trees. Disabling vehicles and or trees will allow user to really focus on the zoom in air cubes. On top, an octree algorithm aggregates [and disaggregates] cubes of similar [and different] temperature levels, in order to minimize the number of cubes as much as possible without losing information. This is done already in the scientific simulation level before the data transfer to Unity3D.

Perhaps, one of the most important features in Fig. 11 of this tool is the adjustability of level of details. When enabling automatic level of details, cubes will be less detailed from far, and more detailed as we go nearer to the road level. This is an

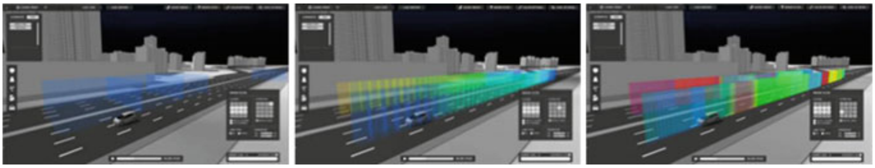

Fig. 11 Gradual level of details visualization. Bigger cubes can be used when viewing from far (*left*), and smaller cubes can be used when we are inspecting closer (*right*)

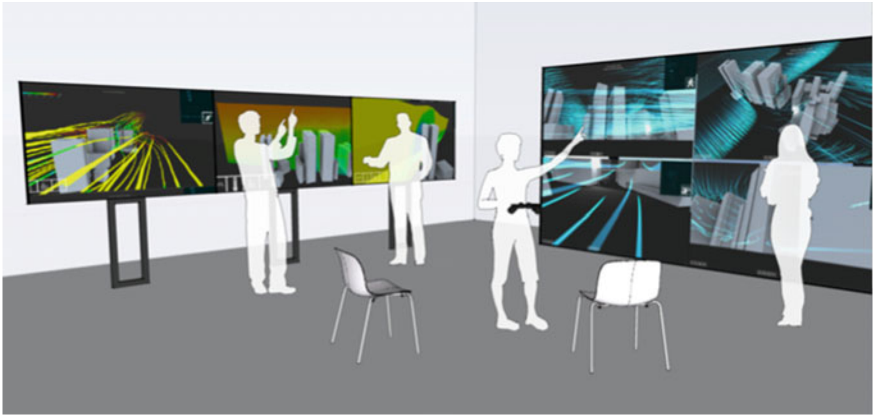

Fig. 12 A collaborative environment in urban planning that fosters exploration. Each participant/stakeholder discovers through playing and is enable to engage in further discussion

important timely feedback that will encourage discoverability. Currently, both *CFDtoUnity3D* and *CityHeat* are installed on a local machine due to the huge amount of data imported from the simulation. We could show that the tools are a necessary element in a collaborative environment such that all participants could be engaged in understanding the urban science better, as rendered in Fig. 12. Running seamlessly as normal executable program, the program and relevant data could then just be copied to similar discussion center across the city to get the citizen or other kinds of stakeholders talking. In addition, we could also foresee this tool to be put on a web platform where greater number of audiences could join and participate via remote connections.

5 Conclusions

We have demonstrated how game engines can be used to create exploration tools not only for buildings and for environments, but also introduced how they could act as a bridge to stakeholders who are otherwise not usually connected to urban science, because the data visualized is too complex otherwise. We see urban science as a narrative that emerges during a serious game approach as the data is being explored, in the embedded context of urban area we are exploring. By means of exploration of the 3D space and the data, the tools have introduced knowledge via discovery, be it through personal experience or collaborative exploration.

It is noted that urban planning is an interdisciplinary endeavor, which can be supported by related data about the urban environment. To navigate easily in potentially immense data sets, we have mentioned how data can be segregated according to user needs, and most importantly, we focused on showing enough level of detail to gain understanding without compromising visual or perceptual limitation by displaying too much information or data at once.

In both study cases, we have highlighted the importance of having a first-person perspective and discovery together with the flexibility of user-defined settings. Information panels are also deemed necessary to put visuals into its context.

While looking forward to more similar tools to be developed and easily deployed in the future (in fact, the web is a great platform), we also look to close the loop of design–simulation–visualization by allowing via game engines the user to modify the design and consecutive simulation parameters. In this light, not only everyone can get a scientific story of his or her city, but also everyone then can take part in his or her city planning process.

References

Abt, C.C.: Serious Games. University Press of America (1987)

Ampatzidou, C., Molenda, A.: Building Stories—The Architectural Design Process as Narrative. In: Paper Presented at the Digital Storytelling in Times of Crisis, Athens, Greece. http://www.cristina-ampatzidou.com/building-stories-the-architectural-design-process-as-narrative-conference-paper/ (2014)

Andreoli, R., De Chiara, R., Erra, U., Iannaccone, A., La Greca, F., Scarano, V.: Some Real Experiences in Developing Virtual Environments. In: Paper Presented at the Tenth International Conference on Information Visualization 2006, IV 2006 (2006)

Anwar, A., Klein, B., Berger, M., Müller Arisona, S.: Value Lab Asia: A Space for Physical and Virtual Interdisciplinary Research and Collaboration. In: Paper presented at the 19th International Conference on Information Visualisation (IV 2015) (2015)

Berger, M.: Augmenting science through art. J. Prof. Commun. **3**(2) (2014)

Berger, M., Cristie, V.: CFD post-processing in Unity3D. Procedia Comput. Sci. **51**, 2913–2922 (2015)

Berger, M., Buš, P., Cristie, V., Kumar, A.: CAD integrated workflow with urban simulation-design loop process. Sustain. City X **194**, 11 (2015)

Bodker, K., Kensing, F., Simonsen, J.: Participatory IT Design: Designing for Business and Workplace Realities. MIT Press, Cambridge, MA (2004)

Boeykens, S.: Using 3D Design Software, BIM and Game Engines for Architectural Historical Reconstruction. CAAD Futures, Liege, Belgium (2011)

Brown, T.: Design thinking. Harvard Bus. Rev. **86**(6), 84 (2008)

Cecchini, A., Rizzi, P.: Is urban gaming simulation useful? Simul. Gaming **32**(4), 507–521 (2001). doi:10.1177/104687810103200407

Chen, I.R., Schnabel, M.A.: Multi-Touch: The Future of Design Interaction. In: Paper Presented at the CAADFutures 2011, Designing Together, Liège (2011)
Clemenson, G.D., Stark, C.E.: Virtual environmental enrichment through video games improves hippocampal-associated memory. J. Neurosci. **35**(49), 16116–16125 (2015)
Cristie, V., Berger, M., Buš, P., Kumar, A., Klein, B.: CityHeat: Visualizing Cellular Automata-Based Traffic Heat in Unity3D. In: Paper Presented at the SIGGRAPH Asia 2015 Visualization in High Performance Computing (2015)
Crowston, K., Prestopnik, N.R.: Motivation and Data Quality in a Citizen Science Game: A Design Science Evaluation. In: Paper Presented at the 46th Hawaii International Conference on System Sciences (HICSS) 2013 (2013)
Dykes, J., MacEachren, A.M., Kraak, M.-J.: Exploring Geovisualization. Elsevier (2005)
ESA: Essential Facts About the Computer and Video Game Industry. Retrieved from http://www.theesa.com/wp-content/uploads/2015/04/ESA-Essential-Facts-2015.pdf (2015)
Fritsch, D., Kada, M.: Visualisation using game engines. Archiwum ISPRS **35**, B5 (2004)
Greenwood, P., Sago, J., Richmond, S., Chau, V.: Using Game Engine Technology to Create Real-Time Interactive Environments to Assist in Planning and Visual Assessment for Infrastructure. In: Paper Presented at the 18th World IMACS/MODSIM Congress, Cairns (2009)
Guhathakurta, S.: Urban modeling as storytelling: using simulation models as a narrative. Environ. Plan. **29**(6), 895–911 (2002)
Gün, O.Y.: Performing Realism: Interactive Real-Time-Rendered Stereoscopic Animations for Architectural Design Process. In: Paper Presented at the eCAADe 2013: Computation and Performance–Proceedings of the 31st International Conference on Education and Research in Computer Aided Architectural Design in Europe, Delft, The Netherlands, 18–20 Sept 2013
Humbert, P., Chevrier, C., Bur, D.: Use of a Real Time 3D Engine for the Visualization of a Town Scale Model Dating from the 19th Century. Retrieved from Prague (2011)
Indraprastha, A., Shinozaki, M.: *Constructing virtual urban environment using game technology*. Paper presented at the 26th eCAADe Conference: Architecture in Computro Antwerpen (2008)
Jenkins, H.: Game design as narrative architecture. Computer **44**(3), 118–130 (2004)
Kim, D.-H., Bejleri, I.: Using 3D GIS Simulation for Urban Design. In: Paper Presented at the ESRI Users conference (2005)
Klein, B., Treyer, L., Zünd, D., Müller Arisona, S.: Value Lab Asia. FCL Magazine **3**, 6–13 (2014)
Krek, A.: Rational Ignorance of the Citizens in Public Participatory Planning. In: Paper Presented at the 10th Symposium on Information-and Communication Technologies (ICT) in Urban Planning and Spatial Development and Impacts of ICT on Physical Space, CORP (2005)
Kühn, W., Jha, M.: Using Visualization for the Design Process of Rural Roads. In: Paper Presented at the 5th International Visualization in Transportation Symposium and Workshop (2006)
Kunze, A., Burkhard, R., Schmitt, G., Tuncer, B.: Visualization and decision support tools in urban planning. Digital Urban Modeling and Simulation, pp. 279–298. Springer (2012)
LeBlanc, M.: Formal Design Tools: Emergent Complexity, Emergent Narrative. In: Paper Presented at the Proceedings of the 2000 Game Developers Conference (2000)
Lévy, P.: Collective Intelligence. Plenum/Harper Collins (1997)
Liu, Z., Jiang, B., Heer, J.: imMens: Real-time Visual Querying of Big Data. In: Paper Presented at the Computer Graphics Forum (2013)
Manyoky, M., Wissen Hayek, U., Heutschi, K., Pieren, R., Grêt-Regamey, A.: Developing a GIS-based visual-acoustic 3D simulation for wind farm assessment. ISPRS Int. J. Geo-Information **3**(1), 29–48 (2014)
Meirelles, I.: Design for Information: An Introduction to the Histories, Theories, And Best Practices Behind Effective Information Visualizations. Rockport publishers (2013)
Müller Arisona, S., Aschwanden, G., Halatsch, J., Wonka, P.: Digital Urban Modeling and Simulation. Springer (2012)
Nikolopoulou, M.: Outdoor thermal comfort. Frontiers in Bioscience **3**, 1552–1568 (2011)
Papadopoulou, M., Raphael, B., Smith, I.F.C., Sekhar, C.: Optimal sensor placement for time-dependent systems: application to wind studies around buildings. J. Comput. Civil Eng. (under review) (2015)

Pettit, C., Widjaja, I., Russo, P., Sinnott, R., Stimson, R., Tomko, M.: Visualisation Support for Exploring Urban Space and Place. In: Paper Presented at the XXII ISPRS Congress, Melbourne (2012)
Poplin, A.: Playful public participation in urban planning: a case study for online serious games. Comput. Environ. Urban Syst. **36**(3), 195–206 (2012)
Prensky, M.: Digital natives, digital immigrants part 1. On the horizon **9**(5), 1–6 (2001)
Salim, F.: Tangible 3D Urban Simulation Table. In: Paper Presented at the Proceedings of the Symposium on Simulation for Architecture and Urban Design (2014)
Schmitt, G., Wenz, F., Kurmann, D., Mark, E.V.D.: Toward virtual reality in architecture: concepts and scenarios from the architectural space laboratory. Presence Teleoperators Virtual Environ. **4**(3), 267–285 (1995)
Seichter, H.: Augmented reality and tangible interfaces in collaborative urban design. Computer-Aided Architectural Design Futures (CAADFutures) 2007, pp. 3–16. Springer (2007)
Signorelli, V.: Game Engines in Urban Planning: Visual and Sound Representations in Public Space. In: Paper Presented at the International Conference Virtual City and Territory (7è: 2011: Lisboa) (2011)
Slowey, K.: New player: How gaming technology adds a 'wow factor' to BIM. Retrieved from http://www.constructiondive.com/news/new-player-how-gaming-technology-adds-a-wow-factor-to-bim/410956/ (2015)
Tan, E.: Play the city. Retrieved from http://playthecity.eu/ (2015)
Tapias, E., Schmitt, G.: Climate-sensitive urban growth: outdoor thermal comfort as an indicator for the design of urban spaces. WIT Trans. Ecol. Environ. **191**, 623–634 (2014)
Treyer, L., Müller Arisona, S., Schmitt, G.: architectural projections: changing the perception of architecture with light. Leonardo electronic almanac **19**(3), 148–163 (2013)
URA (Producer): SingCity. Retrieved from https://www.ura.gov.sg/uol/citygallery?p1=learn&p2=games (2016)
van der Net, M. (Producer): OSCity. Retrieved from http://www.oscity.eu/ (2013)
Vemuri, K., Poplin, A., Monachesi, P.: YouPlaceIt!: A Serious Digital Game for Achieving Consensus in Urban Planning. In: Paper Presented at the AGILE 2014 Castellón, Spain (2014)
Vosinakis, S., Koutsabasis, P., Stavrakis, M., Viorres, N., Darzentas, J.: Virtual environments for collaborative design: requirements and guidelines from a social action perspective. Co-Design **4**(3), 133–150 (2008)
Wagner, M., Viswanathan, V., Pelzer, D., Berger, M., Aydt, H.: Cellular automata-based anthropogenic heat simulation. Procedia Comput. Sci. **51**, 2107–2116 (2015)
Wikipedia: Citizen Design Science. Retrieved from https://en.wikipedia.org/wiki/Citizen_Design_Science (2016)
Winder, I.: CityScope. Retrieved from http://cp.media.mit.edu/city-simulation/ (2014)
Wissen Hayek, U.: Virtuelle Landschaften zur partizipativen Planung: Optimierung von 3D-Landschaftsvisualisierungen zur Informationsvermittlung. vol. 5. vdf Hochschulverlag AG (2009)
Xu, Y., Kim, E., Lee, K., Ki, J., Lee, B.: FDS simulation high rise building model for unity 3D game engine. Int. J. Smart Home **7**(5), 263–274 (2013)
Zanola, S., Fabrikant, S.I., Çöltekin, A.: The Effect of Realism on the Confidence in Spatial Data Quality in Stereoscopic 3D Displays. In: Paper Presented at the Proceedings of the 24th International Cartography Conference (ICC 2009), Santiago, Chile (2009)
Zeng, W., Fu, C.-W., Müller Arisona, S., Erath, A., Qu, H.: Visualizing mobility of public transportation system. Vis. Comput. Graph. IEEE Trans. **20**(12), 1833–1842 (2014)