E-Learning and Serious Games

New Trends in Architectural and Urban Design Education

Francesc Valls[1(✉)], Ernest Redondo[1], and David Fonseca[2]

[1] Barcelona School of Architecture, UPC - BarcelonaTech, Barcelona, Spain
{francesc.valls,ernesto.redondo}@upc.edu
[2] Architecture School, La Salle Universitat Ramon Llull, Barcelona, Spain
fonsi@salle.url.edu

Abstract. The complexity of urban processes needs professionals trained in understanding and managing the design of its spaces and the implementation of urban policies. This paper discusses an educational methodology to complement the standard Project-Based Learning approach with an experience using serious games with gamification elements to stimulate critical thinking in urban planning and urban design students, to promote designing spaces more adaptable and usable for a wide range of users and situations of public life. The proposed methodology uses five "mini games" that place students in different situations: (1) finding an unknown landmark, (2) reaching goal avoiding obstacles, (3) navigating with artificial lighting, (4) simulating the point of view of a person with a disability, and (5) simulating group behaviour. As a secondary objective the experience will track the participants' behaviour to extract data to be incorporated into an agent-based model rule set.

Keywords: Serious games · Gamification · Simulation · E-Learning · Urban space

1 Introduction

As the total number of people living in cities increases, as well as the percentage of urban dwellers relative to people living in rural areas [1, p. 12], the necessity to improve the quality urban life becomes more important.

The formation of the city is unlike a manufacturing process; it is an artifact created by society, through the interactions between its inhabitants, consciously and unconsciously, with different levels of coordination, in a constant state of change, adapting itself over time.

Urban planning and urban design shape the complexity of the city, through building codes, housing policies or urban regulations; planners and designers establish the guidelines of what they think the city should be, but ultimately what the city will become depends on a number of factors: social, economic and historical. Urban planners and designers need to interpret the past of the city, know with precision its present state, and understand the nature of the factors that drive its processes to plan its future.

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Information about the past gives us valuable insight on the underlying mechanisms of the transformation of the city, usually in the form of historic maps that can be georeferenced to generate a timeline of its (physical) evolution. As we get closer to the present, historic data gets more rich and precise, especially since the generalization of digital storage technologies in the decade of 1980. Data about the present situation is vast and it is essential to filter, summarize and visualize them to be understood. Correctly interpreting the current state of the city allows planners to identify areas of improvement and anticipate future necessities, which is crucial considering the slow pace of urban transformation processes compared to the increasingly rapidly changing world.

Planning involves addressing the future challenges of the city. This requires the evaluation of multiple what-if scenarios, generally using informal mental models acquired by practitioners throughout their training, both academic and professional. However, the availability of (synthetic) formal models of urban phenomena, using knowledge of events in its past (to train or calibrate the model) applied to the information gathered about its current state, should be a valuable tool for urban management professionals; in their education, the use of models to explain urban phenomena should allow a deeper comprehension of the subject matter.

This paper explain an educational proposal using a serious games in a gamified educational environment to teach complex concepts regarding urban planning and design to architecture students. It is structured as follows: first the challenges of training professionals in urban planning and design are discussed, followed by an introduction to gamification and serious games, after which the proposed experience outline is discussed and the conclusions are presented.

2 Urban Planning and Urban Design Training

Cities are very complex, and it is precisely this complexity that makes them attractive and fascinates us. The morphology of the city is a multi-scale mosaic in which the architecture of buildings – which are themselves complex – interplay, articulating themselves through public spaces. This physical configuration of the built environment and its empty spaces not only affects the image of the city [2], but has implications on environmental factors such as the available solar radiation, the optimal mix of modes of transportation, the development of specific economic or residential activities in specific areas, the flow of energy, matter and information, as well as its safety.

Moreover, if grasping the complexity of the morphology of the city is a difficult task, understanding the myriad of events that take part simultaneously in the city and their interrelations is extremely difficult, even with today's technology.

In this scenario, education on topics related to urban planning (managing the development of the city) or urban design (shaping the elements of the city: buildings, streets and public spaces) needs to explain the concepts urban planners and designers handle in their professional practice. The educational strategy followed is usually Project-Based Learning (PBL), where students learn as they develop a – fictional but grounded on reality – project. This methodology allows the students to develop critical-thinking skills, which will be useful later in their career to tackle problems effectively.

In the standard PBL approach in urban space design training, where students make proposals which are discussed by the instructor as well as their fellow students, we propose the addition of two introductory activities before the PBL: (1) an analytical approximation to the attributes of the space in which the PBL will be developed, and (2) a gamified experience simulating different aspects of the urban environment.

This paper discusses this educational approach, to promote critical thinking in urban planning and urban design students in their project workflow using serious games in a gamified environment. The strategy is to place students in a virtual reality (VR) environment to simulate different scenarios, to bring up several issues seldom discussed in their training. In addition, the proposal also wants to give students the instruments to manage the complexity of urban data in three – not necessarily geometric – dimensions: (1) physical dimension, (2) data dimension, and (3) human behavior dimension.

3 Gamification and Serious Games as Learning Strategies

For the vast majority of students today, videogames are an integral part of their daily life, especially since the emergence of casual games on smartphones have broadened the audience of people playing games. Thus, it is not unreasonable to argue that incorporating game elements into their education can be beneficial.

A search using Google Trends comparing the trends of the searches "gamification" and "serious games" shows a sharp increase in the amount of queries of the term "gamification" since 2011, overtaking the term "serious games" just one year later and quadrupling the amount of queries as of today (February 2015), and revealing a slight decline in the interest on the term "serious games" over the last four years (Fig. 1).

Gamification is the use of game mechanics in non-game situations [3], taking advantage of some aspects of gaming that make them engaging, generally using a reward system to place the player in a positive reinforcement loop. Gamification can be used to promote a desire to improve using the competitive aspects of playing, and to make an experience more enjoyable and as a consequence reducing abandonment rates.

Serious games usually involve the simulation of real-world phenomena to practice specific skills, and have been traditionally used in areas where it is difficult to train effectively in the real word, such as life-threatening situations (e.g. military tactics, crisis management) or situations which are very rare, such as space exploration. Serious games can also be used in research to test hypotheses.

Both methodologies applied to learning are not mutually exclusive, and serious games can incorporate gamification elements to make the experience more engaging, such as using scoreboards to encourage the competitive spirit among participants, or use game elements to make the experience more entertaining, avoiding procrastination.

The benefits of using simulations cannot be neglected either [4]; as distilled abstractions that model reality, they can enlighten the comprehension of complex phenomena and help us interpret them. In addition, performing experiments though simulations ("in silico") is usually more cost-effective and sometimes allows conducting research that would otherwise be impossible in the real world.

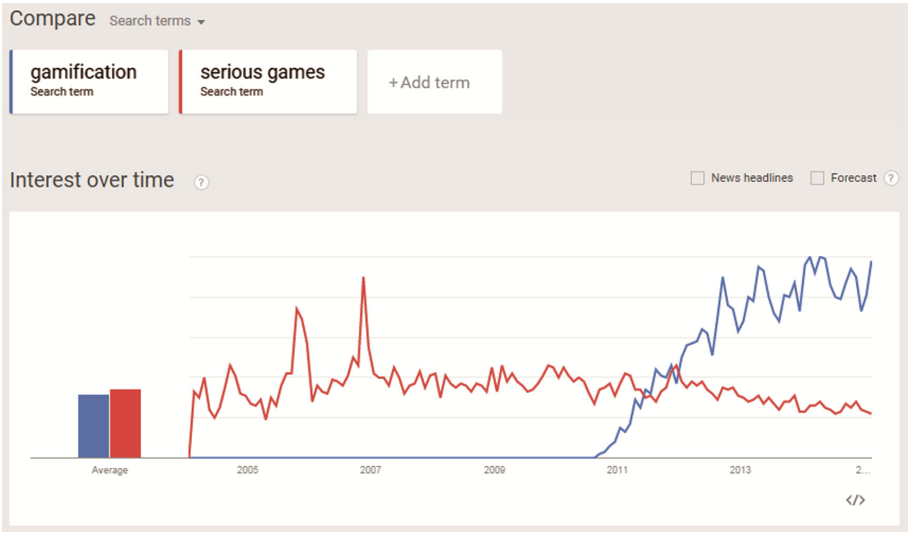

Fig. 1. Terms "gamification" and "serious games" on the Google Trends™ tool (screenshot retrieved on February 10th 2015).

The proposed experience uses elements from serious games mixed with gamification aspects to place learners in a simulated environment, with the objective of helping them reflect on the consequences of different design decisions on the usability of public spaces. As a secondary objective, their (virtual) actions will be tracked by the simulation software to gather data to research on the behavior of pedestrians in urban spaces.

4 Understanding the Multiple Facets of Urban Spaces

Approaching the many aspects of urban spaces may seem an easy task, after all, we are trying to understand the spaces of the human habitat that we experience every day. However, gaining a deep knowledge requires sharp observational skills [5], and many phenomena is not visible, at least not directly or without spending lengthy periods.

Prior to the main chunk of the training consisting on developing the design of an urban space using the standard and time-tested PBL method used in urban planning and design courses, the students will perform two introductory activities: (1) an introductory activity where the students will be asked to analyze the case of study – which will change with every edition of the course – using publicly available data, and (2) a serious game experience with gamified elements where they will be placed in different situations in a setting similar to the one where they will develop their proposal.

The analysis of the case of study is articulated in two sections – the geometry of the built environment and the compilation of the publicly available data on the site – that will use geolocation as their link, using a Geographic Information System (GIS) to integrate and analyze these heterogeneous data. This workflow is very similar to the approach urban planners and designers have traditionally used, but in this case assisted

using GIS tools to augment their analysis capabilities. All the information used is publicly available so the students are able to pursue their research autonomously.

Geometry of the Built Environment. This introductory part will focus on approaching the urban setting from its physical [6] form using different publicly available data:

- 2D and 2.5 cartography of the built environment, at different scales
- Urban elements (i.e. trees, pedestrian crossings, sidewalks, lighting)
- Administrative divisions (city limits, census tracts, districts)
- Remote sensed data (land use and aerial orthophotos)
- Utility and transportation networks
- Planning regulations, location of green spaces and public facilities
- Digital Elevation Models (DEM)
- Georeferenced data (historic maps, hand-drawn sketches)
- Environmental data (pollution, rainfall, geology)

Some of these data are not directly observable in the field, because either no longer exist (historical maps), are buried underground (utilities), exist only as legal regulations (administrative limits or planning regulations), are not visible from ground level (aerial or satellite imagery), or require extensive topographic surveying. The integration these cartographic data into the same environment should give the students a robust set of tools to approach the setting where their proposal will be developed. Special emphasis will be placed on analyzing the perceptual qualities of the physical environment from the pedestrians' point of view [7] and analyzing its visibility using space-syntax [8,9], although the usefulness of this technique is somewhat controversial [10,11].

Non-cartographic Data Sources. There is a plethora of publicly available urban data [12] from government open data initiatives, volunteered geographic information (VGI) [13,14] and geolocated social media.

The Spanish Cadastre offers information about the whole built stock in Spain with the same semantics, which allow comparing different regions, and allows obtaining information about their quality, types of uses, and year of construction, as well as identifying vacant lots.

In addition to Cadastral databases, other databases offer valuable information for urban planning as they provide information about population and economic activity such as census, transportation and other publicly available socio-economic data.

Finally, social media (i.e. Twitter, Flickr, Instagram) offers a treasure trove of information waiting to be explored, with some caveats considering that geolocated social media represents a fraction of what constitutes itself a biased sample [15] of all users, even though some studies have shown success in assigning location to data even without geotagging [16].

Human Behavior in the Public Space. Even though people are very diverse in their physical traits or thought processes, their aggregate behavior is known to follow some patterns. To be able to successfully design a space that fulfills the expectations of its users, an urban designer must be capable of understanding the behavior(s) of the people that will use his or her design, during a length of time which, considering the pace of

urban change, will most likely be measured in decades. The aspects that influence the behavior and perception of urban spaces are multiple, encompassing from the physical characteristics of the space itself (materials, shapes) to the physical traits of its users, their knowledgeability of the space, environmental factors, the presence of temporary elements, etc.

While the pedestrians' perception of the space depends on subjective aspects such as colors, materials or composition, it also depends on their visual field of view at eye-level, which can be conceptualized using space-syntax. However, this general built envelope is not immutable but is altered by temporary (outdoor markets, public performances, other pedestrians, vehicles, terraces) or permanent (furnishing, vegetation) obstacles.

The physical characteristics of people have implications on their walking speed, their capacity to climb or descend steep slopes or steps, and their capacity to detect and avoid obstacles, narrow passages, traverse uneven or slippery surfaces or walk long stretches without resting. Regarding their attitude, pedestrian behavior varies depending on multiple factors: whether they walk alone or in groups, their activity at any given time (i.e. jogging, working, shopping, cycling), their knowledgeability of the space (i.e. frequent users compared to tourists), etc.

To understand the flows in the public space, information about the uses of buildings at the ground floor facing the public space (e.g. restaurants, shops and kindergartens) is necessary, as well as other factors such as the location of public transport stops or pedestrian crossings, and the population and workplace density. Other environmental factors include nighttime/daytime cycles (related to security), weather conditions (capacity to provide shelter for rain or wind, or avoid slippery surfaces) or seasonal changes (which dictate preference for sun or shade).

Understanding the logic of the combination of these and other factors and the interaction of different people gives designers insight when proposing new public spaces that can fulfill the needs of their users and will endure the test of time.

5 Proposed Experience Outline

The introductory exploration of the site using cartographic and attribute data described in the previous section will be followed by the gamification experience. These two preliminary activities should lay the groundwork to develop the main part of the course – the development of an urban design proposal – successfully, allowing the student to easily integrate information about the site. The main objectives of the gamified experience are threefold: (1) promote critical thinking when designing urban spaces, (2) make the experience more engaging, and (3) gather experimental data about the behavior of students in a virtual environment.

5.1 Serious Game Proposal

The primary objective of the experience is to promote critical thinking [17] in the design process of urban spaces using serious games. The five proposed "mini games" are

designed to simulate a limited set of synthetic behaviors in a virtual environment, to stimulate the students to consider specific issues of public life, and compelling them to consider them when developing their designs:

1. Finding an unknown landmark in the least time possible
2. Reaching a known goal quickly, avoiding obstacles
3. Navigating the space with artificial lighting only
4. Simulating the perception of a person with a physical disability
5. Simulating group behavior

These "mini games" incorporate two different attitudes, one change in the environmental conditions and two different profiles of users, and share some common features:

- Each simulation should not be longer than five minutes
- The participants will be asked to participate at least twice in each simulation, to evaluate the effects of experience in repeated tests
- The games will be presented in random order for each participant, but will follow the same order in both runs
- After the compulsory two runs, the students will be allowed to repeat any game more times if they desire so, to find out which experience they find more engaging

Finding an Unknown Landmark in the Least Time Possible. The educational objective of this game is to motivate the students to reflect on the spatial understandability of the spaces for users without complete knowledge, as well as the visibility of landmarks [18,19]. Its research objective is to gather data on search patterns of pedestrians seeking an element they don't know the location of.

The environment of the simulation will be seeded with as set of elements with different physical attributes in different positions, and the participants will be asked to locate a specific – unique – landmark whose description will change every time they run the simulation:

- Relative position to another element (i.e. the element next to the bench)
- Element color, absolute (i.e. the red element) or relative (i.e. the darker element)
- Height of the element, absolute or relative to others
- Element shape

Therefore, the participants may be asked to find "the tall red cylinder next to a tree". This description will be displayed as a reminder on their screens, as well as a time counter that will stop once they have clicked the correct landmark and will increase in a specific amount of time every time they select an incorrect landmark. The final time score will be displayed on a scoreboard with the participant alias.

Reaching a Known Goal Quickly Avoiding Obstacles. In this case the simulation mimics the behavior at the rush hour. The educational objective of this game is to reflect on the physical and visual obstacles in urban spaces, while avoiding of an (artificial) crowd. The research objective is to track the trajectories of the participants and their strategies to achieve their goals.

- The participants will be placed in the flow of a virtual crowd.
- The space will contain static obstacles (i.e. trees, benches, vehicles), some of which will also be visual occlusions
- The avatars will have a finite acceleration and deceleration as well as a steering penalty. Each collision will stop the participant momentarily
- Some paving surfaces allow walking faster than others (pavement opposed to grass)

The participants will be displayed a countdown with the time they have left before the departure of a train, once the countdown reaches zero the simulation ends. The time spent in reaching the goal is displayed in a scoreboard.

Navigating the Space with Artificial Lighting Only. The educational objective of this game is to promote the students' reflection on the importance of adequate lighting [20, pp. 122–125]. The research objective is to compare the change in behavior of users in limited visibility conditions, as the settings will be the same ones described in Sects. 5.1.1 and 5.1.2 above:

- The scene is darker resulting from the light intensity falloff
- The color reproduction is poorer
- The participants will face an unspecified threat to simulate decreased safety

Using the same cases as in the "find a landmark" and "reach the goal quickly" should encourage the students to think about the different space perception depending on the day/night cycle, the seasonal changes or the weather conditions. The data gathered will allow to compare their behavior with and without reduced spatial awareness.

Simulating the Perception of a Person with a Disability. Its educational goal is to place the participants in the role of a person in a wheelchair, to internalize the difficulties that these users face if the urban design does not adapt to their necessities. Using the same environment and objectives described in Sects. 5.1.1 and 5.1.2 above but changing the user profile should raise awareness on the specific needs of people with disabilities. As a research objective, it will gather data on the changes in the participants' behavior when evaluating different itineraries with a time/effort tradeoff. The game will incorporate the following elements to emulate some aspects the experience of a person in a wheelchair:

- The participants have to press two opposite keys alternatively to steer and move their avatar, simulating pushing each wheel of the wheelchair with alternating hands
- Uphill slopes will reduce their speed and therefore increase their effort, forcing the participants to press the keys more quickly and hampering their maneuvers
- Downhill slopes increase their speed and will have to press simultaneously both keys at the same time, otherwise their trajectory gets jerkier and their speed higher
- Some obstacles cannot be avoided
- Their point of view is lower

Simulating Group Behavior. The educational objective is to show the participants that the public space can be understood differently when walking individually or in groups. As a research objective, it should allow to gather data about "flocking" behavior in

groups [21]. In this game the participants will be asked to reach a goal without colliding with other people or the environment, and avoid getting separated from the group:

- The environment and goal is the same as in Sect. 5.1.2, but in a group of 3 people (two computer-controlled and the participant avatar)
- The participants hear a conversation, which gets played with a lower volume as the avatar distance to the group increases, so they must be close enough to hear it
- Collision and steering speed reduction results in increased separation from the group
- At the end of the simulation, participants are asked a question about the conversation

5.2 Gamification Elements

The proposed educational experience uses serious games with gamification elements. These gamification elements have the objective of making the experience more engaging and natural –easier to use– for the students. Using a game engine for the simulation translates to indirectly incorporating some game elements familiar to the participants and associated with a play environment:

- User interface (on screen heads-up display, game menus)
- Controls (gamepad, keyboard, mouse)
- Visual language (geometry, shading)
- Use of a – subjective– first person perspective
- Audio cues
- Physical behavior of the elements in the virtual world and of the avatar
- Behavior of the computer-controlled AI (artificial intelligence), using navigation meshes and FSM (finite state machines) for NPC (non-player characters)

These metaphors, ingrained in the player attitude in their experience playing computer games, contribute to a greater acceptance of the limitations of the virtual world – stylized design, simplified behaviors, appearance of artificial actors– to avoid falling into the uncanny valley [22].

In addition some time-tested game mechanics are employed to improve the entertainment value of the experience, facilitating the incorporation of the educational content of the serious game:

- Providing scoreboards for each activity, where participants can compare their results with the results of other participants and compete to get the top score
- Incorporating challenging elements, where participants have to overcome some difficulties
- Introducing novel experiences, where the students are placed in situations outside their daily routine
- Using elements of tension, such as timed countdowns or hit counters

5.3 Participants' Behavior Data Collection

The educational experience will have a data collection counterpart, which will log the participants' behavior in order to gather data about their interactions in the virtual world

and investigate whether it can be extrapolated to pedestrians' behavior in the real world. This data collection in a virtual environment does not exclude gathering data in real settings, but can be a valuable complementary source of information due to the difficulties in collecting data in a public environment.

The objective of this data collection is to infer a set of rules to be fed into an agent-based model to simulate pedestrian behavior [23,24] in public spaces and will consist on tracking over time the following data over successive runs:

- Trajectory tracking
- Heatmap of participants' location in all runs
- View direction of the avatar (azimuth and altitude)
- Objects inside the users perspective

Finally, data about user satisfaction will also be collected [25–27] to compare the proposed methodology perceived advantages and disadvantages relative to traditional learning methodologies.

6 Conclusions and Future Work

The proposed educational methodology describes an experience using serious games with gamification elements to stimulate critical thinking in urban planning and urban design students, to promote designing spaces more adaptable and usable [28] for a wide range of users and situations of public life. To improve the proposal, some ideas will remain to be explored in future editions of the course:

- Simulating the perception of a visually impaired person [30], using audio cues and haptic technology using a force-feedback controller
- Generation of the geometry of the simulated urban environment using data acquired using a Terrestrial Laser Scanner (TLS) or procedurally from a set of rules
- Allowing students to visit each other proposals in a virtual environment
- Use an agent-based model to simulate the behavior of pedestrians in each of the students' designs
- Implementing remote participation in the games over the Internet

In addition to the educational experience, data gathered from the behavior of participants in the virtual world, along with tracking data of people's behavior in actual public spaces using infrared cameras or GPS, should be able to help develop a set of rules to be incorporated into an agent-based model to simulate pedestrian behavior, assuming that structure a the macro level arises from interactions at the micro level [29].

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