Effectiveness of Open-Source Solutions for Limited Scale Interventions Planning

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Abstract. In this work we investigate how combining open-source game engines and graphic-related software can support planning and interventions in multiple scales, starting from something as small as a room. The proposed methodology allows the creation of a high fidelity 3D mesh representation of reality, using a small dataset, together with photogrammetric and topographic techniques. The 3D mesh can be imported to a game engine and be used during planning. The case study deals with the creation of a storage furniture setup, inside a small room, following a number of manufacturing restrictions. The storage space is designed using proposed tools. Manufactured items required minor to none changes, during assembly.

Keywords: renovation · gaming tools · game engine · free and open-source · simulated game · metaverse · virtual reality · augmented reality

1 Introduction

In the recent years, computer graphics have been dramatically improved [7], followed by the creation of realistic looking video games. There are several games in the market, which referred to real places, such us cities. Other games use virtual realistic environments, such us houses, with realistic and interactive playing mechanisms. Additionally, the introduction of the virtual reality [4], augmented reality [11] and metaverse [6, 9] in the industry, creates new opportunities for using this technology on other fields than gaming.

Video games and gaming tools can, also, be used for city planning, architectural design, or renovation [2]. This is an important study field, because this technology, can be used as a quick low cost solution to test and compare different approaches on any planning project. In addition, the creation of an interactive playing mechanism enriches more the experience of the planner, which can lead on improved and efficient solutions.

This work proposes a gamified alternative approach for a visualized renovation solution. This is achieved by creating a prototype of a simulation game, where the player can choose features and props, from a predefined list, to add in a realistic copied 3D base mesh of an actual predefined area of interest. The production of the 3D mesh is out of the scope of this manuscript, thus only the needed information will be presented. In this manuscript, are presented the basic steps for the creation of the simulated game. Furthermore, a real example is included as a case study, where the problem to be solved, was the creation of a storage furniture in a newly renovated warehouse, following some restrictions from the manufacturer.

Our contribution, in this research field, is that we propose a free and open-source alternative approach for creating and visualizing urban planning through gaming software tools. Our methodology can be used from a small scale renovations to a whole city scale.

The rest of this manuscript is organized as follows: (a) Section 2 provides details related to Urban Planning methodologies; (b) Section 3 displays the adopted steps, softwares and tools needed. (c) Section 4 presents the experimental results of this work. (d) Section 5 concludes this work.

2 Related Work

Urban planning, architectural design and renovation have been used widely in video games. Indicative examples, includes the work of Luke Caspar Pearson [10], where he studies the uniqueness of videogame spaces and their construction, which can be utilised by architects. De Carvalho et all [3] describes ECity, which is a European initiative to motivate students on following an engineering career by giving them a basic understanding of engineering problems and tasks through a city-simulator video-game.

In the work of Aguilar et al [1], a serious game, named Metropolis, is used for smart city planning and for promoting e-participation [14] within the context of city planning. John et al [8] examined the effectiveness of a simulation game, named SimCity™4, in undergraduate and postgraduate educational level. In both works the result was, that an urban planning simulation game can benefit the urban planners and in general the public opinion, because the problem becomes more understandable, as well as, the benefits and restrictions of the suggested solutions.

3 Proposed Methodology

The main goal of this work is to demonstrate a gamified solution, which can be used in urban planning, architectural design and renovation cases. The solution includes the usage of free and open-source 3D graphic softwares and tools, such as Blender and Unreal Engine 5. The proposed methodology is a three step process. The first step is the creation of the 3D models and props, needed for the solution, such as the building of the furniture. The second step, includes

the creation of the base simulated game, using an already existing game engine. The third step is the actual planning solution, by playing the game and interacting with the environment for providing urban planning innovations and extra environmental characteristics. These innovations through the 3D visualization can be reproduced and evaluated from end users and third parties directly, as their presentation and parameters as lighting, space occupation, obstacles, free space in the area, visitors' applicability, etc can be measured and parameterized according to the social life needs.

3.1 Dependencies

For the causes of this work, the needed equipment summarized to a simple mobile camera and a tool for distance measuring. For data processing a photogrammetric software is needed, for creating a rough model [5] and exporting it as FBX file format. The final 3D mesh produced, using Blender [12], which is a free and open-source 3D computer graphics software tool-set, which can be used for creating animated films, visual effects, art, 3D printed models, motion graphics, interactive 3D applications, virtual reality, and computer games. The simulated game developed inside Unreal Engine 5, which is a free game engine, supported by Epic Games company [13], and provides high level rendering and realistic graphic optimization.

3.2 Data Collection and Model Creation

Fig. 1. Preview of the place, where the methodology was tested.

The existed environment can be modeled using traditional topographic (geodesy) and photogrammetric approaches [15]. For the purpose of this work, as test area was selected an easy accessible place. Figure 1 depicts the selected area, where the experiment took place. This is a newly renovated warehouse, approximated $20m^2$, which needs furniture. For this purpose a 3D model of the inside of the storage and the garden outside, in a 1:1 scale created. The dataset included a set of 20 images, captured using a mobile camera, as well as distance measurements of the inside and the outside of the warehouse, used for scaling the produced 3D mesh.

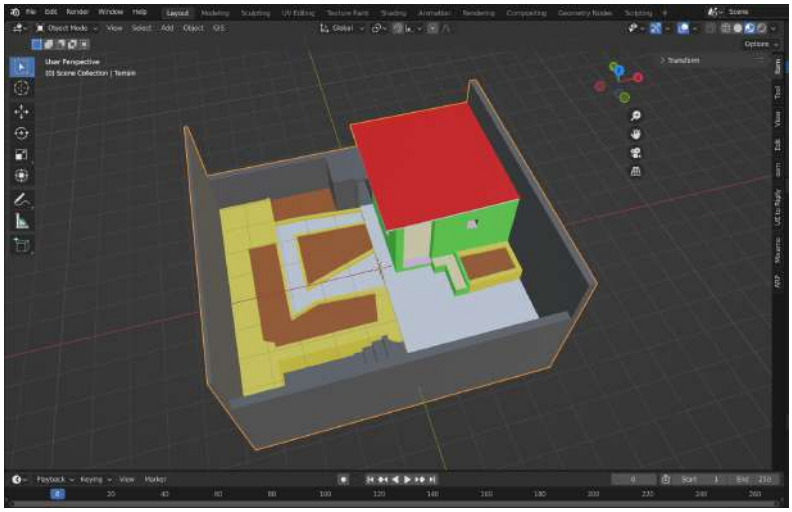

Fig. 2. Reproduction of the test area in blender

Using the 20 images dataset and appropriated photogrammetic softwares, a rough 3D mesh was created and exported as FBX file format. The FBX file imported into Blender and scaled according to the measured distances. Using the 3D mesh as base model and the geodetic data as references, in less than 24 hours a better approximated and realistic mesh of the area reproduced. The final mesh is presented in Figure 2. Using the measuring system of Blender, the estimated accuracy of the model is $\pm 2.5cm$.

3.3 Create Game Simulation

The actual game creation process is achieved inside Unreal Engine 5. This stage is divided into the code development and level design steps. The code development step includes all needed key-bindings for the game to be playable and interactive and developed only once. In our case study, the player needs to open an inventory list with the available objects for architecture renovation, select the appropriate

object from the list and finally place the object at the correct transformation, inside the world. The level design step includes the addition of objects in the scenes, such as trees, to enrich the base mesh (Figure 2) and make it more realistic (Figure 3).

Fig. 3. An overview of the level design viewport inside Unreal Engine 5.

Fig. 4. The left side of the garden as shown inside the game.

Fig. 5. The right side of the garden as shown inside the game.

Figures 4 and 5 depict the environment visualization through the game engine. Figure 4 visualizes the left (from the point of view) side of the garden as captured by playing the game, while Figure 5 visualizes the right (from the point of view) side of the garden. By comparing these visualization with Figure 1, its clear that the base characteristics (walls, flower beds, paths etc) have been optimized accurately.

3.4 Build Solution

The final step of the processing is to build the renovated solution inside the game. For this purpose, the game currently supports a simple prop selection mode, where the player can see with green color where it is possible to place a prop and selects the orientation (Figure 6). After the player decides, where he wants to place the prop, he presses the left mouse click to spawn the object into the level (Figure 7).

Fig. 6. A visualization of a possible valid area to place a prop.

Fig. 7. A visualization of the object after placed.

4 Case Study & Experimental Results

4.1 Description of the problem

The subject of this work is to estimate how easy is to design a renovated solution inside a simulated game environment, such us a furniture, which can be manufactured in reality. In this case, the problem is the creation of a wooden storage furniture in "L" shape, which covers the front and right (from the standpoint of the door) walls. The manufactured restrictions of this work are the following: (a) the constructive floor cabinet features are standardized in dimensions ($width \times depth \times height$) ($30cm \times 60cm \times 87cm$), ($60cm \times 60cm \times 87cm$), ($80cm \times 60cm \times 87cm$) and ($120cm \times 60cm \times 87cm$); (b) the wall hanging cabinets are standardized in dimensions ($40cm \times 60cm \times 40cm$) and ($60cm \times 60cm \times 80cm$); (c) the storage furniture needs to support cabinets from floor to ceiling; (d) the storage furniture use is the storing of books and different size and weights working tools. Another challenge of this work was the cabinet design in the corner of the walls.

4.2 Solution of the problem

Figures 8 and 10 depict the proposed solution using the simulated game from different perspective angles, door and outside the window respectively. The storage furniture on the front wall is divided into $4 \times (60cm \times 60cm \times 87cm)$ cabinets and a $1 \times (120cm \times 60cm \times 87cm)$ cabinet in the corner with a $5cm$ height

workbench on the top. In the corner on the right wall, the corner cabinet and workbench are extended with a $1 \times (30cm \times 60cm \times 87cm)$ cabinet and 5cm height workbench. Then follows a, $(width \times height)$, $1 \times (30cm \times 60cm)$ cabinet and $3 \times (60cm \times 60cm)$ cabinets from floor to ceiling. Finally, in the in game design the furniture closes into a $1 \times (120cm \times 60cm \times 87cm)$ cabinet with a $5cm$ workbench and a $(120cm \times 60cm \times 80cm)$ wall hanging cabinet, which is not in the standardized dimension, but in reality refers into design $6 \times (40cm \times 60cm \times 40cm)$. The above described design serves, also, the restriction of the different size and weights of working tools, as long as the cabinets from floor to ceiling can be used as bookshelves. Cabinet doors have not yet designed, thus it was unable to be added in this prototyping version.

Fig. 8. The proposed renovated solution captured from the door.

Fig. 9. The manufactured renovated solution captured from the door.

Figures 9 and 11 depict the manufactured solution from different perspective angles, door and outside the window respectively. The storage furniture on the front wall is divided into $1 \times (30cm \times 60cm \times 87cm)$ cabinet, $4 \times (60cm \times 60cm \times 87cm)$ cabinets and a $1 \times (90cm \times 60cm \times 87cm)$ cabinet in the corner (a special manufacture size, only for corner cabinets) with a $5cm$ height workbench on the top. In the corner on the right wall, the corner cabinet and workbench are extended with a $1 \times (30cm \times 60cm \times 87cm)$ cabinet and 5cm height workbench. Then follows a, $(width \times height)$, $1 \times (30cm \times 60cm)$ cabinet and $3 \times (60cm \times 60cm)$ cabinets from floor to ceiling. Finally, in the in the manufactured design the furniture closes into a $2 \times (60cm \times 60cm \times 87cm)$ cabinets with a $5cm$ workbench and a $6 \times (40cm \times 60cm \times 40cm)$ wall hanging cabinets. It's clearly, that the real manufactured is a little different than the in game design, however the base design and the final result are the same.

Fig. 10. The proposed renovated solution captured from the window.

Fig. 11. The manufactured renovated solution captured from the door.

5 Conclusions

To summarize, this research presents a gamified approach, which can be used in renovation. Currently, this approach is at a prototype stage, which means that there is a big range of development. In this research, using the proposed methodology, a simple simulation game was developed, with only the utmost necessary features and proposed a simple solution, which fulfilled the manufacturer restrictions. The real result was similar to the in game proposed. The necessary differences took place by the manufacturer.

Further development of the game is needed. The necessary additions on the game include more props and feature, such us cabinet doors. Furthermore, the game mechanism can be improved further, in an interactive way, where the player could interact with the environment (e.g. open/close doors or windows, touch items, move items, etc). Last but not least, the game can be further expanded to a virtual reality game, where the player could "feel" the interactive experience.

The manuscript presented a free and open-source way to create and visualize urban planning through a gaming software tools. The methodology steps can be used in a more complicated environments and case studies that can cover from a house area (as this manuscript case study) to a whole city, by inserting and working in its visualization in 3D. Further research on this topic will be continued through the European Research project euPOLIS.

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