TOWARDS IMMERSIVE URBAN DIGITAL TWINS

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Urban digital twins are virtual representations of physical systems, subsystems, and processes of a city. The construction of a three-dimensional geometric model of the city provides the basis for the development of an urban digital twin. On top of the 3D model, heterogeneous data describing or simulating one or more systems and subsystems can be embedded and visualized. In this context, we focus on the possibility to exploit Virtual Reality (VR) technologies to enhance the visualization of these 3D representations and to provide an innovative immersive approach to interact with urban digital twins. We describe a pipeline for the design of a 3D model of an urban area suitable for an immersive visualization and a natural interaction so that the users can have a sense of reality as if they are in the real world. Preliminary results are shown related to our case study in Matera, in Southern Italy.

Keywords: *virtual reality, 3D modeling, 3D visualization*

1. Introduction

In the context of creating an Urban Digital Twin, the geometric representation of the morphology and physical features (either built or natural) of the city, possibly annotated with additional contextual information, has a high potential in describing, monitoring and/or predicting urban processes [1, 2]. Focusing on smart tourism management, for instance, the geometric model can be useful to design a virtual visit to non-accessible sites (due to overcrowding, closing hours, or visitor disabilities) or to show a preview for the tourist to select the must-see spots in their day visit, simulate emergency egress, plan temporary events according to the capacity and morphology of the site, etc. Another example is represented by the public engagement, indeed an accessible 3D model of the city can foster citizen engagement and participation. People can virtually explore the city, understand proposed developed projects and provide constructive feedback. This creates a more inclusive and transparent decision-making process, which allows citizens to have an active voice in building their community.

Currently, urban digital representations are still visualized on 2D displays, providing a limited perception of the real tridimensionality of the environment. The availability of realistic 3D representations of real objects embedded with heterogeneous data (i.e. colors, normals, semantically relevant attributes) opens the doors to new visualization methodologies, conveying the 3D content and its associated information in an intuitive way. In this context, Virtual Reality (VR) technology has gained much interest in the last years, since it allows innovative and intuitive ways to explore and interact with 3D models [3].

In this contribution, we focus on the design and development of a virtual immersive visit of an urban area, starting from the data acquisition survey to the 3D model generation and its embedding into a Virtual Reality (VR) environment. Our pipeline seems promising in strengthening the visualization capabilities of digital twins and providing realistic experiences and natural interactions.

2. Methodology

Our main long-term objective is to immerse individuals in the city digital twin with a 1:1 scale, and thus allow the users to explore and learn about an urban environment by moving in it as if they are in the real city.

To this aim, the first step is generating a 3D surface representation of the city to be embedded in VR. Our 3D generation method assumes the input point cloud to represent the area of interest with a high level of details and associated colors. This is necessary in order to guarantee an authentic experience with realism. When such a representation is not available, data acquisition surveys are performed by exploiting proper technologies able to capture a wide area at fine geometric and appearance detail [4]. Since point clouds coming from LiDAR/laser scanning and photogrammetric technologies are often subjected to noise and other types of artifacts and defects, a pre-processing pipeline is often necessary to remove undesired elements. Acquisitions performed by these techniques return dense point clouds (i.e. resolution is often of one point per millimeter). To use these representations in VR, it is important to choose a good trade-off between the high level of detail and realism and the complexity of the model. The pre-processed point cloud is then given as an input to triangulation methods (such as the well-known marching cubes algorithm [5]). The result is a 3D model representing the morphology of the real world enriched with color attributes on vertices, where the color is an interpolation of neighbor points in the decimated point cloud.

Once the 3D digital model has been reconstructed, its exploration in VR arises two main challenges. On the one hand, the overcome of the issues associated with importing a georeferenced 3D model in a game engine (e.g. Unity) to correctly position and orient it, as well as give the model appropriate colors or textures to ensure realism. On the other hand, the development of natural and intuitive navigation techniques by which users can freely navigate in the reconstructed environment in a natural way. We addressed the former issues, specifically related to repositioning the 3D model into Unity world. Our solution takes into account the different coordinate system used in Unity, that is a left-handed, Y-Up coordinate system. Since Unity does not properly support geographic coordinates, the 3D model is rigidly translated so that the center of its bounding box is centered on the origin of the Unity coordinate system. Then, our approach tries to identify the terrain level in the model in order to properly set the camera position. Notice that, as for the appearance of the 3D model, when imported in Unity it is transparent by default. It is thus first necessary to assign the built-in material and set the occlusion properties.

3. Preliminary Results

As a preliminary result, we describe the development of a virtual replica of the main square (well-known as "Piazza Vittorio Veneto") in Matera together with the Hypogeum located underneath. The Hypogeum, including the main water reservoir (well-known as "Palombaro Lungo"), is only partially open to the public, due to some environmental issues, such as the cave environment, the steep steps, and the low illumination. This is to demonstrate the benefits of 3D urban Digital Twin for improving accessibility and better overall experience for visitors.

Figure 1 shows an example of the results in the pipeline on our use case, from the reality to the generated triangulation. In particular, in the proposed case study, the original point cloud has 256M points and it was decimated to 65M points after some cleaning. The final triangulation is made of 75K colored vertices.

Figure 1: Left: view of the Vittorio Veneto square (the hypogeum is underneath). Middle: Acquired points cloud. Right: Reconstructed triangle mesh.

The preliminary VR environment representing Piazza Vittorio Veneto in Matera and the Palombaro cistern is shown in Figure 2. It enables an immersive virtual exploration of these sites moving between the different underneath levels in a quite realistic way, also allowing the visit to the narrow, steep, or closed to the public areas. Preliminary visualization has been tested accessing the VR environment by wearing a Meta Quest 2 head-mounted

display (HMD).

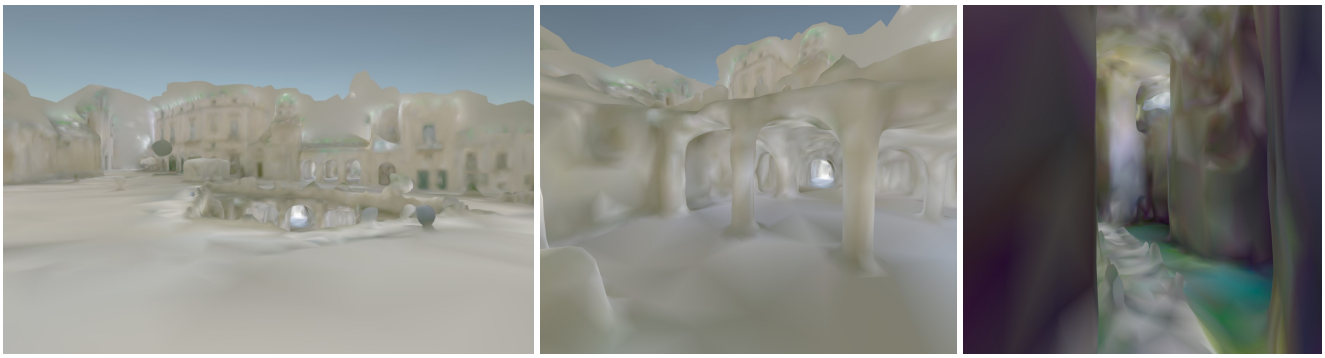

Figure 2: Different areas of the VR environment representing the Vittorio Veneto square, the Hypogeum access, and the Palombaro cistern (from left to right).

4. Discussion and Future Works

One of the primary objectives is to achieve a reconstruction by the 3D acquisition described previously that ensures an authentic and realistic experience balancing the level of details and the model size so that it does not affect the performance. To this aim, our approach generates a 3D model with a certain color associated for each vertex. However, some work should be done to improve realism, possibly by defining and using more specific textures.

As future work, we aim to study and develop interactive navigation techniques of the virtual 3D environment. For instance, users can freely navigate the city simply by teleporting them into different parts of the 3D reconstructed areas, or naturally walking around the urban area. In the last case, an analysis of the height variations of the floor and a camera adaptation has to be taken into account to improve the sense of realism.

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