Abstract—Villa lo Zerbino, built at the end of the 16th century, is an example of an Alessian villa in a suburban area of Genoa. During the centuries, the expanding city reached the villa, later incorporating it completely. As the surrounding urban landscape evolved, the garden was also modified, following the English landscape trends of the era. The main objective of the project discussed in this paper is the creation of a model for the virtual reconstruction of the historic garden of Villa lo Zerbino and its evolution over time. We describe the process that starts from a specific knowledge (based on documents, drawings and maps) and leads to a 3D model focusing on the vegetation elements. A second objective faces the difficulties of the visualization of the uncertainties related to the 16th century virtual garden. When using sources of different qualities and ages, the viewer might not distinguish the difference between the elements that were reconstructed based on documentary information and those that result from mere imagination. To give a transparent image of the credibility of the elements, their level of uncertainty has been evaluated and visualized in the virtual representation. The virtual reconstruction methodology has been applied to three areas of the garden. The digital product gives a general image of the 19th century villa. The second part of the paper focuses on the visualization of a 16th century virtual garden. When using sources of different qualities and ages, in particular in the 16th and 19th centuries, in order to analyze their evolution over time. Furthermore, the methodology of the virtualization of Villa lo Zerbino recognizes the importance of showing the reconstructed elements at different levels of credibility in the 3D model. This virtual representation requires further studies about the historical documentation on which the research is based, and also new ways of visualization.

The case study identified for the project of historical-virtual reconstruction, Villa Balbi Durazzo Gropallo allo Zerbino [1], is one of the most important examples of an Alessian villa built in the city of Genoa, in a suburban position, between 1599 and 1604. Over the centuries, the villa witnessed various changes. Along with the expansion of the city, which slowly reached and incorporated the villa, the landscape surrounding the villa complex. This allows us to enter the garden and have a full appreciation of how the landscape was part of the villa. The second part of the project, related to the 16th century villa, increases not only the information on the development of Villa lo Zerbino, but also proposes new perspectives on the visualization of additional historical circumstances, such as the study of the level of uncertainty associated to the reconstructed elements, or to the different layout proposed, thus increasing the perception of reliability of the 3D model.

The historical reconstruction of the Villa regards mainly two periods, the 16th and the 19th century. Thanks to the virtualization of the three areas of Villa lo Zerbino, it is now possible to study the evolution of the garden from the 19th century to nowadays, and to recreate also the views of the landscape surrounding the villa complex. This allows us to enter the garden and have a full appreciation of how the landscape was part of the villa. The second part of the project, related to the 16th century villa, increases not only the information on the development of Villa lo Zerbino, but also proposes new perspectives on the visualization of additional historical circumstances, such as the study of the level of uncertainty associated to the reconstructed elements, or to the different layout proposed, thus increasing the perception of reliability of the 3D model.

The project has reached a good stage of implementation, and, to date, the following components are completed: the virtual reconstruction of three sample areas at the 19th century
condition and the virtualization of the first area at the 16th century condition with the 3D models of possible layouts.

The paper is structured as follows: section 2 presents an overview of related projects; section 3 presents the methodology; section 4 shows and discuss the results and finally, section 6 proposes conclusive remarks.

II. RELATED PROJECTS

Virtually reconstructing an historic architecture is never simple and dealing with historic gardens further increases the complexity of the task, since vegetation is ephemeral by nature and usually poorly documented, also its organic shape requires an additional effort in the modeling phase. Furthermore, very few examples of virtual reconstruction of historic gardens are available in the literature [2] and, often, they focus on the virtualization of architectural elements within the gardens [3] or on very large areas such as landscapes [4]. It is therefore valuable to deepen the research in the field of virtual reconstruction of historic gardens, and their vegetation in particular, in order to study their evolution over time.

There are several examples for virtual reconstruction of heritage sites, which allow the viewer to compare the representation of "then and now" [5]. The authors of the reconstruction of historical sites make enormous efforts to develop high-resolution, realistic representation of past times, often without considering that the most realistic fact of its characteristics is the high level of uncertainty. This must not prevent any historic site of being virtually represented, but should encourage the development of digital visualizations and the deepening the research of documentation.

The virtual model related to the 16th century condition of the villa, for example, required further research in the literature. The more we go back in history, indeed, the less reliable information we have. This is related to the available documentation and to its representation, often artistic but not always realistic.

The paper of Nicolucci and Hermo [6] well underlines the importance of studying reliability in virtual reconstructions. However, the numeric approach used in this work results unsuitable for the virtual model of our case study and new approaches must be explored.

III. METHODOLOGY

Two main contributions characterize our approach to the virtual reconstruction of Villa Lo Zerbino: the integration of all elements of the complex (villa, garden, surroundings), based on a rich source of documentation (digital scans, maps, images, texts), and a visualization based on the level of uncertainty of the reconstructed elements.

A. Virtual reconstruction of the 19th and the 16th century complex

The virtualization project of the complex of Villa lo Zerbino entails a high level of complexity, mainly due to its extremely varied nature and to the scarcity of documentation regarding more distant historical periods. Looking at the reconstruction only from the point of view of the 3d modeller, the difficulty regards the very varied nature of the villa complex, which encompasses architectural elements, vegetation (both formal and free) and the surroundings. Each element brings with it different needs, different levels of detail and a diverse modelling approaches, which lead to a necessarily hybrid methodology. Furthermore, various and often incomplete sources raise the question of the reliability of the resulting model and invite to reflect on how to represent the diverse degrees of trustworthiness in the model itself.

As already stated, the aim of the project here discussed is to provide a highly realistic virtual reconstruction of the complex at different epochs, intended as a means to raise awareness of the historical importance of Villa lo Zerbino and of its transformations over time. In particular, an accurate architectural and botanical survey of the garden has been carried out to verify the completeness and reliability of the available sources and used as a basis for the modelling phase. Survey, modelling, texturing and reflection on reliability are the essential steps followed for the project that faced the complexity induced by a hybrid modelling approach.

Concerning the architectural part, the process followed the methodology elaborated and tested in previous projects [2,7,8], which implies the definition of different levels of geometric simplification for the architectural elements based on their formal complexity and semantic importance in the overall scene. Time consuming and expensive survey technologies such as laser scanning and photogrammetry has been avoided and texture mapping and bump maps have been employed to increase the level of realism keeping the total amount of polygons under control. By virtue of a consolidated methodology and of the experience gained in previous projects, we were able to create a model with a high level of realism in its architectural parts in a relatively short time and with a good control on the number of polygons. The vegetation elements have been divided into two groups, basically separated by the differences of the garden trends. On the one hand, the formal vegetation has a dominating presence in the layout of the 16th century. Shrubs and trees are shaped by *ars topiaria*, which consists in pruning the elements to give them a geometric form. On the other hand, the project realized by Andrea Tagliafichi follows the rules of the English landscape garden and results in a minor visibility of the human work on the vegetation.

The aforementioned reasons indicated the necessity to divide the vegetation into two groups in the modelling process. On one side, the formal garden elements have been modelled on the basis of procedures elaborated in a previous project [2] that addressed the same issue. Compared to that project, in this paper we faced a wider amount of formal vegetation. Also, we had to improve the procedure in order to preserve a high level of realism without weighing down the model. Thanks to a well-balanced use of polygons, photographic textures and techniques, such as the scattering, we managed to obtain realistic models of formal vegetation with a relatively small amount of polygons. The other group of the vegetation is comprised by existing polygonal models, which have been chosen after accurately studying the
botanical species in the garden. These models’ dimensions and colours were modified according to the requirements of the garden.

As mentioned, the surrounding landscape has a relevant role in the structure of the villa. It is not only a background, but a panorama, in which certain elements, such as the sea and the basilica of Santa Maria Assunta, have particular importance. Therefore, the basilica has been accurately modelled. By contrast, since the rest of the landscape has significance only as group of buildings, whose presence is understood in terms of the distribution of the urban structure and not as singular elements, they have been modelled using a simplified approach. The volumes of the buildings are based on the plan of Barbieri. [9]

**B. Visualization of the levels of uncertainty**

Even if the virtual models of 16th and 19th century were created following the same methodology, there is a fundamental difference between the two results: the sources they are based on are diverse from the point of view of the credibility. While in the case of the 19th century complex, not only the historical documentation but also the current structure of the vegetation indicated the original layout of the garden, the 16th century complex appears only in the book of Martin Pierre Gauthier in the 18th century. [10] Although the author of the collection never saw the villa in its 16th century form, his drawings represent what may have been the plan of the garden until the changes of the 19th century. Since this is the only known historical document regarding the 16th century appearance of Villa lo Zerbino, we considered it as the main basis for the virtual model. Inevitably, the result of the two digital models cannot be compared regarding the level of uncertainty, which stimulated an evolution of our work.

Making use of sources of different qualities, characterised by hidden uncertainties, risks to result in a model that seems to be the visualisation of facts, but does not allow the viewer to understand the difference between the elements that were realized based on documental information and the ones that may be the result of mere speculation. The aim of this part of the project was to give a visual evaluation on the elements of the villa complex from the point of view of the uncertainty and to replace the elements of low reliability with other possible components in a second and in a third virtual model. The levels of the uncertainty are defined thanks to a larger knowledge regarding the garden history and represented with both a chromatic language (fig. 2, left), which favours readability to realism, and a more realistic visualization based on a grey scale (fig. 2, right).

The elements of high level of credibility (yellow in the first representation) were certainly present in the 16th century as they appear in the original virtual reconstruction. The orange colour indicates a mostly probable fact in the digital model, while the red elements might be only the result of imagination. A crucial point of the evaluation is the orange element, which could be the basis for proposing further virtual models. In our case the orange rectangles sign that the structure of the vegetation was probably organised in a rectangular form in the 16th century. Consequently certain elements of the parallel digital models correspond with parts of the original virtual model, while the new elements were inspired by existing garden layouts of the same historical and cultural period.

Several tests have been conducted trying alternative methods for the visualization of uncertainty, some explored by previous projects, such as using different line styles [11] or transparency [12]. However, considering the complexity of the vegetation elements, we believe that the colored design is the most effective solution.

**IV. RESULTS AND DISCUSSION**

This project has been realized using a commercial software (Autodesk 3 Ds Max), starting from the polygonal modeling till the production of photorealistic renderings. Once the final representations were completed, it was possible to add the colors of the evaluation to the different elements using the software Adobe Photoshop.

The representation obtained with the aforementioned procedures realistically depicts three areas of the complex of Villa lo Zerbino at the 19th century condition and one area at the 16th century condition (Fig. 1, 2, 3). Considering the different level of reliability of the sources, there is a visual rendering of the level of uncertainty of the 16th century area (from yellow to red) and a realistic representation that incorporates the information of the evaluation. Figure 3 shows two other possible reconstructions of the 16th century area,
also based on the evaluation of the level of uncertainties and followed by an additional research on possible garden layouts.

As an early result of the project here described, we can also mention the definition of a methodology for the historical virtual reconstruction of a villa and of its garden, made of two main stages: the historical reconstruction through the research of documentation and the virtual reconstruction as a means to verify the hypotheses and to disseminate the results.

The methodology used for the visualization of the levels of uncertainty is composed of three stages: a deeper research work verifies the result of the virtual reconstruction, which is represented with different colours in a new digital model and finally the creation of parallel layouts helps the exploration of alternative possible structures of the evaluated area.

The virtual reconstruction of the 19th century condition resulted to be meaningful for the project's aim. The photorealistic renderings allow an easier comparison of the present condition with the 19th-century project, increasing the awareness of the past of the villa for non-experts and providing scholars and experts with new means to study the villa’s evolution over time and its changing relation with the landscape. The virtual reconstruction of the 16th century villa complex is a realistic 3D model, which enlarges successfully the timeline of the virtual representation of the history of Villa lo Zerbino. Analysing the results of the evaluation of the components of the garden from the point of view of the uncertainty, we can note the difference between the values of the architectural and vegetation elements.

In most cases, architectural elements have a high value of reliability, while the vegetation components are uncertain from the point of view of the composition, of the species or both. Therefore, the visualisation apparently suffers from the lack of information, but at the same time, in the analytical part, the researcher is encouraged to create further hypotheses on the image of the past. Multiplying the possibilities of the layout of the garden in the past centuries requires additional research effort, in order to visualize all these possibilities. This consideration adds further uncertainty to this type of virtual reconstructions, since many alternatives are possible and also credible.

V. Future work

The experience of the historical-virtual reconstruction of Villa lo Zerbino identifies several issues for future research directions, some defined at the beginning of the project but still not completed and others emerged during the project development.

Completing the virtualization of the entire complex at its 19th century condition, together with the aforementioned reconstruction of the 16th century state, are certainly the first aim to be accomplished in order to describe with completeness the evolution over time of such an important complex. This new experience could further assess the methodology here described, and make it available and reliable for other virtualization projects regarding historical villas and heritage as well.

Our work could also be the basis for restoration projects of historical sites, which require a detailed description of past situations: the virtual reconstruction provides indeed a likely visualisation of the past and can reveal hidden concepts (e.g. visual connections). A polygonal model, suitably adapted, can also allow real time navigation both on the web and in large screen virtual theatre, providing users with an inspiring navigation in the past.

Finally, visualizing the uncertainty in the 3D models could indeed extend the potential of many virtualization projects, by giving a clear image of the quality of the available sources, by adopting new methods of visualization (colours, transparencies, animations, etc.) and by providing several hypothetical representations of the past.

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References