Visualizing Mackintosh's Alternative Design Proposal for Scotland Street School

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Abstract. This paper describes the process of creation of a set of visualizations (elevations, perspective views and a short animation) of C.R. Mackintosh's original but unrealized first design proposal for Scotland Street School (dated January 1904). Moreover, the piece of writing reflects upon some key aspects of the project such as how architectural historians were involved and how ambiguities due to the discrepancies between the drawings and missing details were resolved by studying multiple drawings and transferring clues from other Mackintosh's built works. The contributions of this research are important for several reasons: it proposes a methodology that can be applied to similar research projects; it explains the educational value of the development work, which can be defined as digitally handcrafted, behind the visualizations; it contributes to studies of buildings designed by C.R. Mackintosh by using digital technologies that open up new insights to aspects still overlooked of his architectural production.

Keywords: Digital handcrafted · Digital heritage ·
3D digital reconstruction · Visualization · Charles Rennie Mackintosh

1 Introduction

This paper describes the process of creation of a set of visualizations of C.R. Mackintosh's original but unrealized first design proposal for Scotland Street School (dated January 1904), and identifies and reflects upon some key aspects of the project such as how the architectural historians were involved in the process and how ambiguities due to the discrepancies between the drawings and missing details were resolved. Hence, the work goes beyond the sole creation of the visualizations of the building and considers aspects related to the interpretation of archival information and collaboration. Furthermore, the whole development process of the visualizations can be defined as digitally handcrafted because the CAD drawings, the investigation of the 3D shape and architectural details of the building, the making of the 3D model and the creation of the textures/materials have been time-consuming works that presented a level of care similar to a handcrafted work, with solutions personalised to this specific project.

Charles Rennie Mackintosh is one of the most important names in the history of architecture and a pioneer of modern movement [1]. However, despite another

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publication where digital technologies were used to investigate the narrative features of the Glasgow School of Art [2], there are no other known research publications that have explored other buildings designed by him through the use of digital tools and related methods.

Digital technologies have already been used in several projects that focused on architectural analysis and critique of existing, lost or unbuilt works. In each of these projects, digital tools supported by specific theoretical and methodological approaches allowed the development of a better understanding of several aspects of those projects and the discovery and dissemination of relevant information [3–5].

In all the previous projects, one of the constant elements that the scholars had to deal with was the scarcity of information available that, in most cases, also presented many inaccuracies and discrepancies. Considering the subcategory of unbuilt projects designed by famous architects, this lack of information was often overcome by interpreting the archival material and by studying the architect's life and the historical, cultural, social and economic context when he or she operated [4]. Also in this project, one of the main challenges was to manage missing, incomplete and inaccurate information presented in the original drawings by C.R. Mackintosh. This situation was handled by studying multiple drawings and transferring clues from other Mackintosh's built works, and by the support of architectural historians.

The lessons from this case study are multiple, starting with the proposal of a methodology that can be applied to similar research projects.

1.1 Main Aims of the Paper

The main objective of this paper is to describe the process of creation of a set of visualizations of C.R. Mackintosh's original but unrealized first design proposal for Scotland Street School and identify and reflect upon key aspects including:

- The educational values of the whole project;
- How and when the architectural historians were involved in the process;
- How ambiguities due to the discrepancies between the drawings and missing details were resolved;
- The methodology and the tools that were used.

The main aim of the set of rendered images (the four elevations and a few perspective views) and the animation was to communicate the different materials and the main architectural elements of Mackintosh's first design proposal which differs from the final design. The visualizations deepen the knowledge of the design of this remarkable building and allow further comparisons and reflections between Mackintosh's works.

2 Scotland Street School: Design Proposal and Built Version

Scotland Street School is one of the most relevant buildings designed and built by Charles Rennie Mackintosh in Glasgow [6–8], and today, after the tragic fire that recently destroyed the Glasgow School of Art [9], it can be considered as the main

existing educational building designed by him in the Scottish city. Nowadays it is used as a museum of education.

One of the most remarkable features of the building is constituted by the two glazed towers located on the North façade which is the main elevation of the building. These towers accommodated the two separated main entrances and staircases: one for girls and one for boys. The two towers represent a modern reinterpretation of traditional Scottish architecture, and it is evident the influence of Scottish castles, especially for the shape and the conical roofs, that Mackintosh studied and recorded in his notebooks when he travelled around Scotland [10]. Hence, these two towers have a strong link with the architectural heritage of his home country. As for other details of Mackintosh's architectural production, the big glazed surfaces and the interior staircase of the tower anticipated similar solutions adopted during the modern movement by Walter Gropius [11].

The first design is different from the built version for several small details, but mainly for the proposal of a different material. The existing building is made in red limestone (red Locharbriggs sandstone ashlar) while the proposed building was meant to be made with white Dullatur stone (Fig. 1). Hence, the color and the stonework were very different. Other differences encompassed architectural elements and decorations.

Fig. 1. (Left) Original drawing showing of the North Elevation (Source: © CSGCIC Glasgow Libraries Collection. All rights reserved); (Right) Photo of the actual building in Glasgow (Source: Personal archive of the author).

3 Methodology: How to Visualize Mackintosh's Alternative Design Proposal

The methodology was based on approaches developed during, and applied on, other digital heritage projects, such as [2] and [12].

The main aim of this research was to contribute to a significant project, titled "Mackintosh Architecture: Context, Making and Meaning" [13], by developing a set of elevations, a 3D model of Scotland Street Public School (1904–1906) and a short animation, for inclusion on the website of the project.[1] Hence, the work was also a contribution to a significant research project. The 3D digital reconstruction phase and the creation of the visualizations were supported by conversations with two architectural historians, including the principal investigator of the research project, Professor Pamela Robertson.

The following diagram (Fig. 2) shows the main steps that characterised the process by readapting the visual framework developed for 3D digital reconstructions of lost buildings and described in [14]. This visual framework supports the reading and classification of existing projects, the development of new works and foster sharing of information. To some extent, each step of the 'How' phase has aspects linked to content and interpretation on one side, and digital technologies and their applications on the other side.

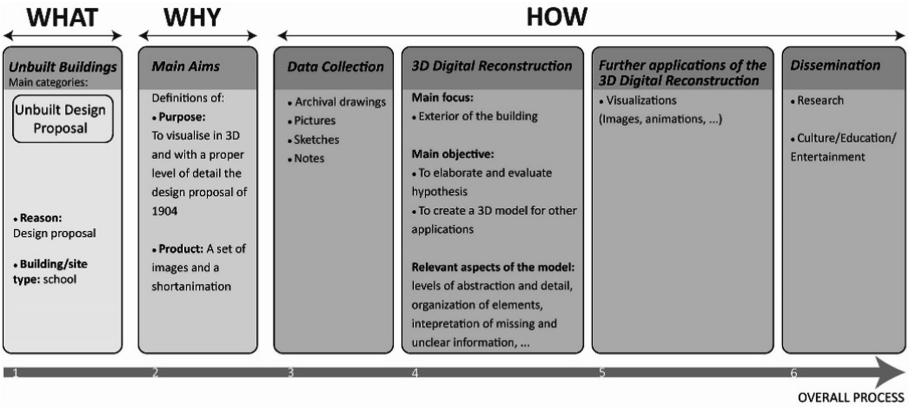

Fig. 2. Visual framework of the overall process and its main steps (Source: Personal archive of the author).

3.1 Collection, Analysis and Interpretation of the Available Information

The first step of the project was the collection of all the available archival information. The Hunterian Art Gallery provided a set of high-resolution scans of 9 original drawings that show the design proposal of January 1904. The drawings' set included: a

[1] "Mackintosh Architecture: Context, Making and Meaning" was funded by the Arts and Humanities Research Board of the U.K. and was based at the University of Glasgow. It aimed to provide the first authoritative catalogue raisonne of the architecture of Charles Rennie Mackintosh (1868–1928). Its major output was the website www.mackintosh-architecture.gla.ac.uk, which contains 350 projects, over 870,000 works, over 3,000 images, 380 biographies, contextual and analytical essays, and supporting features. More information can be found on the website: https://www.mackintosh-architecture.gla.ac.uk/.

block plan, the three plan views (ground-floor plan, first-floor plan and second-floor plan, the four elevations, two cross sections and one longitudinal section) (Fig. 3).

The analysis and interpretation of the drawings constituted an essential step. A first careful observation of the drawings showed several discrepancies that were confirmed and increased in number after the drawings were imported into AutoCAD.

Once the drawings were imported in the CAD environment, and placed in correspondence to each other based on the main vertical and horizontal axes and alignments, it was possible to compare them and identify other discrepancies accurately. Furthermore, the original drawings, being at a design stage, lacked information about various elements and decorations.

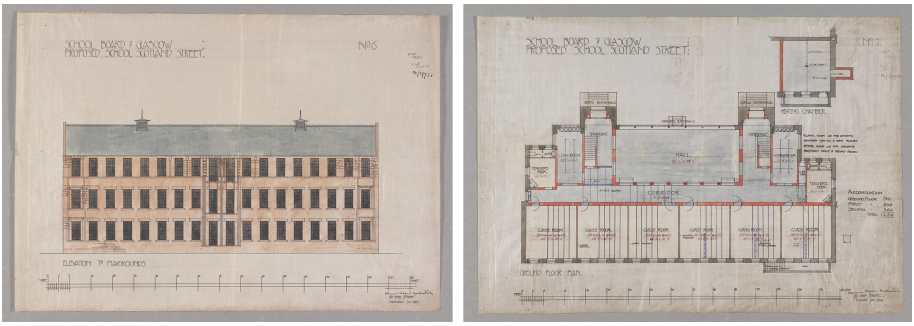

Fig. 3. Two of the original drawings of the first design proposal of January 1904 (Source: © CSGCIC Glasgow Libraries Collection. All rights reserved).

The following list summarises some of the main issues identified during a first analysis of the collected graphical documentation:

- The same elements (e.g. walls and windows) present slightly different dimensions on different drawings;
- Details or technical elements, such as chimneys, shown in one elevation are missing in another one;
- The W. and E. elevations do not present any details about the two towers; this makes complicated any interpretation of the carved mouldings and decorations;
- On the top of the long central windows of the north facade, Mackintosh did not indicate lintels; considering the presence of cast-iron internal columns noticeable on one of the two transverse sections, it has been assumed that the lintels appearance might look like those on the N. facade of the GSA building;
- In general, information about the dimensions of the reliefs of cornices, edges and other carved decorations, are missing because, as with other technical elements, they seem unresolved in the original drawings of this first design proposal.

3.2 Redrawing Process

The imported drawings in AutoCAD were carefully arranged, scaled, and aligned with each other. Then, each vector drawing was traced over the related original drawing and compared to the other orthographic projections in order to create an accurate and consistent set of CAD drawings (Fig. 4). Even if the final aim of the project was to produce visualizations of the exterior of the building, the redrawing process also involved the main interior elements which were used as further visual references. Once the basic 2D representations were completed, they were coloured in order to understand the different materials, edges and the projections of different volumes and elements (Fig. 10 - right).

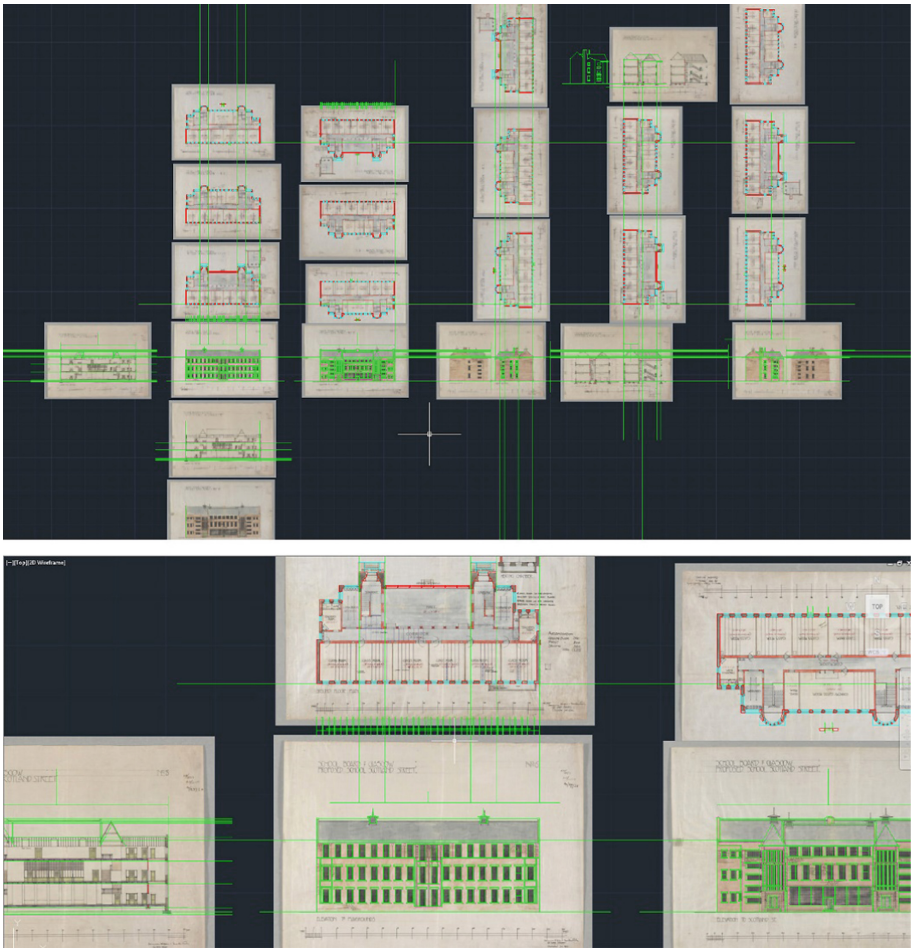

Fig. 4. The Redrawing process in AutoCAD: the original drawings were arranged and aligned in order to create a consistent set of vector drawings (Source: Personal archive of the author).

The 2D and 3D modelling processes were supported by hand sketches and notes which allowed to investigate and clarify details at several levels: from the shape, ridges and slopes of the pitched roof to the shape and measures of the windows' frames (Fig. 5)

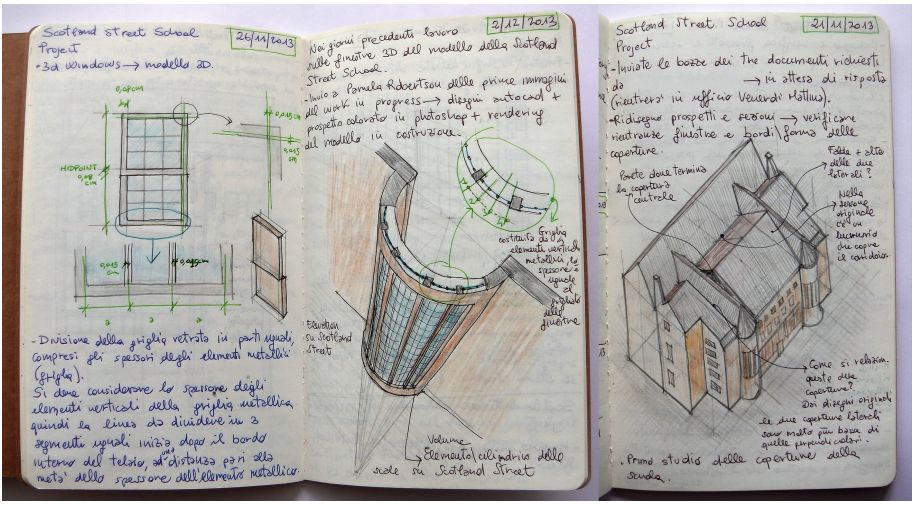

Fig. 5. Sketches and notes from a personal notebook to interpret the standard windows, the glazed surfaces of the towers, and the shape, ridges and slopes of the pitched roof (Source: Personal archive of the author).

3.3 3D Digital Reconstruction

The main challenge of the 3D digital reconstruction was to translate into 3D architectural and technical elements that were implied and unresolved in the original drawings of January 1904. This difficulty was tackled by looking at other projects designed by Mackintosh (and in particular the Glasgow School of Art) and by sharing hypothesis with the architectural historians and receiving their points of view.

At the beginning of the 3D Digital Reconstruction process, the CAD drawings produced in AutoCAD were imported into Rhinoceros v5.0 and used as a metrically accurate base to create the 3D model of the building. Hence, they were aligned in a way that supported the 3D modelling process (Fig. 6). However, other discrepancies were discovered during the translation of the 2D drawings into a 3D model, and this required a continuous check and update of the 2D drawings in AutoCAD and reimported them into Rhinoceros. This process was time-consuming. For this reason, and considering the improvement of Rhinoceros v5.0's 2D drafting tools, it was decided to undertake the whole work directly within this software package. This decision brought several benefits. One of the main ones was to have flexible and precision tools while exploring

the possible geometry of architectural elements in 2D and 3D. Like in a handcrafted work, the geometry of each architectural element was carefully evaluated, and each 3D object modelled.

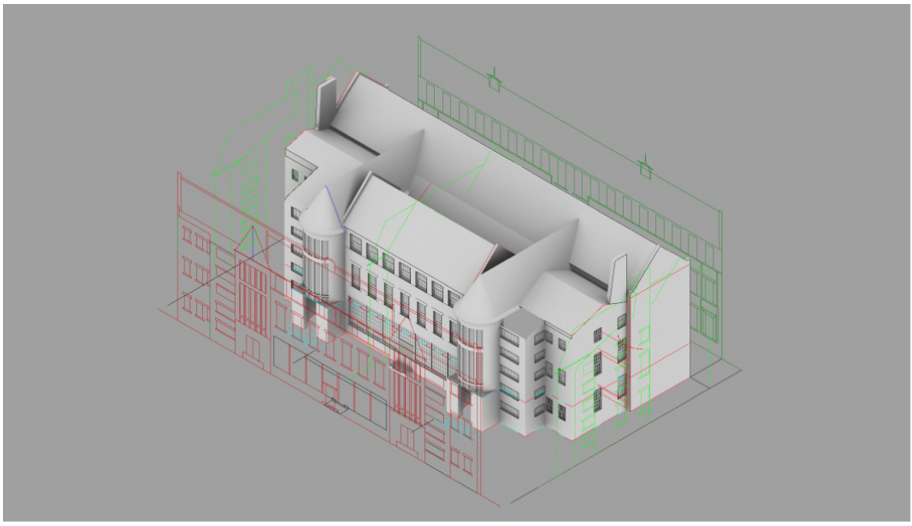

Fig. 6. During the 3D digital reconstruction phase, the vector drawings were arranged and aligned in order to support the 3D modelling process (Source: Personal archive of the author).

3.4 Study and Representation of the Materials

An essential step in the project was represented by the definition of the pattern and the color of the primary material, the snecked[2] pale yellow Dullatur sandstone selected by Mackintosh. The original drawings were the starting point to create a texture to convey the stonework. However, Mackintosh suggested the stonework in selected areas only. Hence, the plan was to try a schematic approach to convey the stonework following Mackintosh's draughtsmanship. The observation of the stonework of the Glasgow School of Art provided other vital information to define a stonework pattern for a wider wall surface (Fig. 7). Moreover, from an analysis of the selected windows of the Glasgow School of Art, it was noticed that the snecked sandstone was used for the overall stonework with the only exception of the areas around the windows (including lintels and sills) that were made with ashlar[3].

[2] Snecked describes small pieces of stone used to fill the gaps between larger stones in a wall. 'Snecked rubble' describes masonry that has a mixture of squared stones of different sizes.

[3] Ashlar: masonry in regular blocks with a smooth surface (These two definitions were provided by Professor Pamela Robertson).

Fig. 7. Photos of two windows of the East Façade of the Glasgow School of Art. Around the windows, it is possible to recognize the ashlar. The photos also show the variation of the stone color (Source: Personal archive of the author).

In order to avoid the annoying tiling effect caused by the repetition of the same texture, a basic set of textures was created (by tracing over Mackintosh's original drawings in AutoCAD and coloring them in Photoshop), and then they were stitched together and customized for each façade. In this way, the stonework of each façade looks different and more consistent.

For the colours different references were used, starting from the Orrock Johnston tombstone (the Dullatur stone there is now aged, however, as a reference it was selected an area where the stone looked fresh and relatively clean), also designed by Mackintosh, plus other buildings that used the same kind of stone, in this case one of the primary references was the Pearce Institute in Govan (Glasgow).

Observations of the facades of the Glasgow School of Art showed that the stonework presented some variations in the stone color (Fig. 7) which was replicated on the textures/materials of the digital model. The final images communicate the snecked sandstone, the ashlar and the masonry's joints.

The color of the slates of the roof matched the colour as built.

3.5 Lighting, Mood and Presentation of the Final Images and Animation

The four elevations were lit respecting the actual orientation of the building and a specific time to create a more dramatic visual effect. The images were rendered in 3ds Max using sunlight and a skylight for indirect illumination (scanline renderer).

The short animation used a path target and a camera target and focused on the North elevation. The main value of the animation is to provide better communication of the tridimensional qualities of the building (Fig. 8).

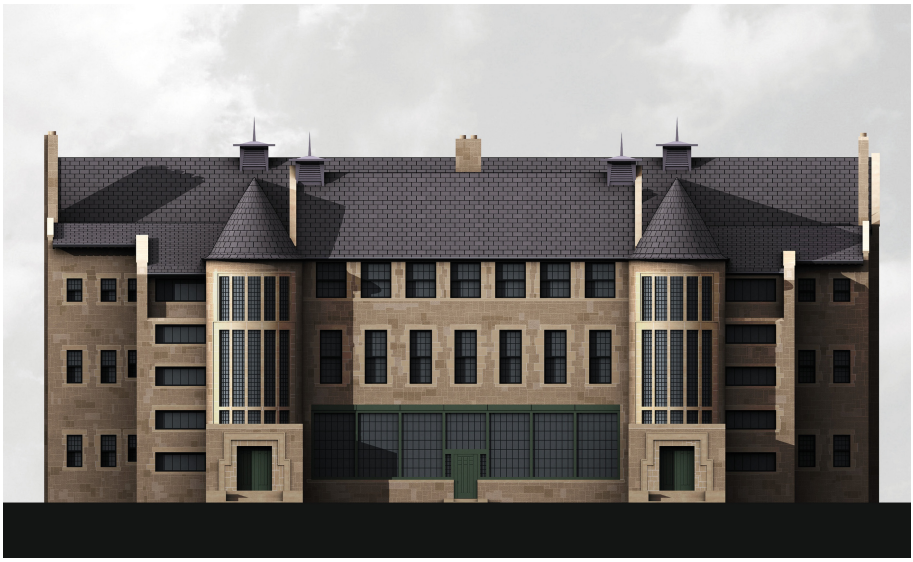

Fig. 8. N. elevation, rendering based on Mackintosh's earliest surviving drawings of January 1904 and showing his specification for pale yellow Dullatur sandstone © Mackintosh Architecture, University of Glasgow; CAD by Danilo Di Mascio (Source: www.mackintosh-architecture.gla.ac.uk).

4 Reflections on the Key Aspects of the Project and Their Values

4.1 The Visualization Process and the Communication with the Architectural Historians

One of the most relevant aspects of the project was related to the communication with the architectural historians who provided essential support along the whole process.

The whole work was carried out by a scholar with a background in architecture and research experiences in digital heritage. A background in architecture is useful in order to evaluate architectural and technical elements also during the analysis of the original drawings, and it is even more helpful during the 3D digital reconstruction. In fact, it is beneficial to understand shape, function, meaning and technological/material aspects of each architectural element while creating its 3D digital representation. Moreover, the knowledge of the scholar covered also aspects related to other buildings designed by Mackintosh in Glasgow.

The two architectural historians provided expert knowledge related to the whole of Mackintosh's architectural production, and the architecture of Glasgow during Mackintosh's period.

The communication with the architectural historians was undertaken on a quite regular basis. Updates were shared every time there was a doubt about missing information on the drawings or when the available data led to an uncertain result, such as the shape of a decoration.

The below diagram (Fig. 9) shows the main steps of the process and when updates were sent to the architectural historians in order to let them provide their comments and pieces of advice. In total, there had been 18 updates, with the last one about the delivery of the final visualizations. Each update or set of updates covered one or more aspects of the work in progress. For example, 4 updates covered the creation and application of the primary material/texture of the stonework. Some updates also covered more than one single aspect. As shown in the diagram, once the first draft of the 3D digital model was completed, the work was carried out on multiple levels simultaneously. Considering the visual nature of the project, the updates were constituted by drawings or rendered views of the work in progress or by images where some important element where highlighted (Fig. 10). All the visual information were accompanied by descriptive text, such as personal reflections and interpretations, and questions. The extensive use of visual material proved to be very effective and made the communication process straightforward and the comments always precise and useful.

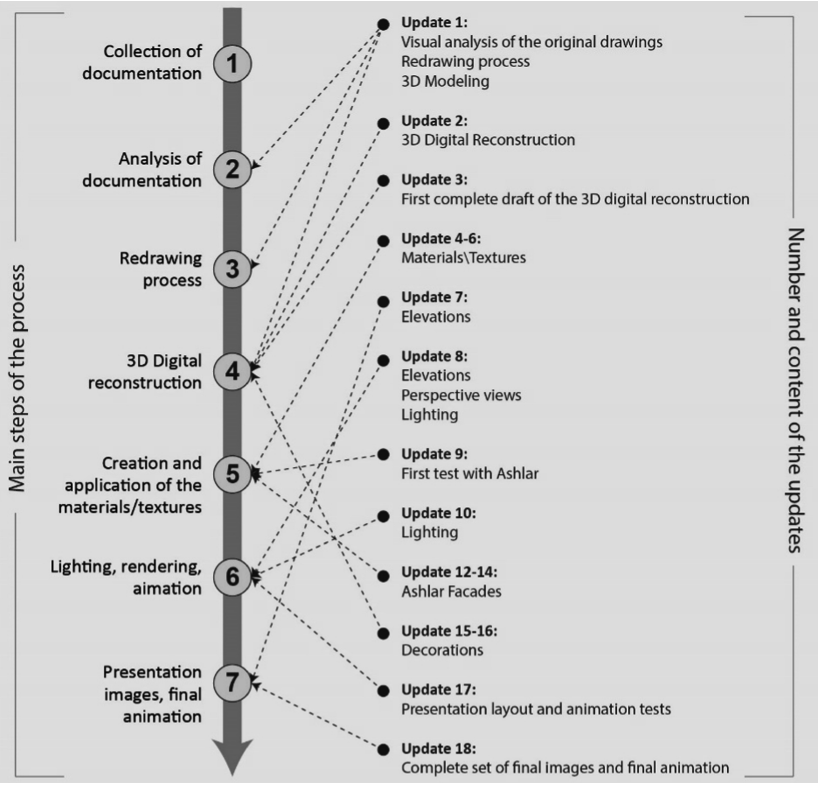

Fig. 9. Diagram that shows the main steps of the process and the number and content of the updates sent to the architectural historians (Source: Personal archive of the author).

Fig. 10. Examples of two drawings shared during one of the updates to the architectural historians (Source: Personal archive of the author).

4.2 Educational Aspects of the Development Process

Like in design works, both in practice and in an educational environment, the development process (in this case the set of visualizations, in a design work a final design proposal) has strong educational value. Firstly, the methodological process can be applied, adapted and expanded by other scholars in order to study other unbuilt works in any cultural context.

Secondly, all the information produced and recorded along the process can be useful to let other scholars, students and laypeople understand the amount and variety of work and tools involved in this kind of research projects. Usually, people that are not familiar with this kind of research projects may find it difficult to imagine how those visualizations were made.

Part of the information produced and recorded along the process is constituted by ca. 500 rendered images that document the 3D digital reconstruction process, including tests related to materials and lighting. A selection of these images can be disseminated in several ways, including during public exhibitions.

The process has been defined 'digitally handcrafted' because of, as mentioned in the introduction, the similarities with a handcrafted work. Studies of architectural heritage always require personalized approached and a modelling care similar to the creation of physical models and objects. The variety of architectural elements and shapes about different historical and cultural contexts do not allow using automated and standard approaches that are becoming more and more common in the design and construction of new building.

4.3 Digital Tools

The 2D redrawing and 3D digital reconstruction processes let also reflect upon the digital tools. Producing 2D drawings and 3D models within the same digital environment gives many benefits. Rhinoceros provides a wide range of precision and 2D drafting tools that are usually missing in pure 3D modelling software such as 3DS Max or Cinema 4D. At the same time, a powerful 2D drafting tools as AutoCAD does not offer the same range of 3D modelling tools and the flexibility provided by Rhinoceros.

Also, a BIM tool does not provide the same flexibility required in these kinds of research projects. In a BIM environment, the architectural elements are represented as 3D components. However, as in this case, there are situations when it is not necessary to create walls as 3D objects because it is not required by the project to represent the interior spaces. Hence, in this work, a 3D surface is the preferable solution.

In this kind of project, it is important to have a high level of control of the geometry of the architectural objects, in both 2D and 3D. In this regard, a software package as Rhinoceros may be more and more useful in architectural/digital heritage projects.

Texturing, rendering and animation were done in 3DS Max which offered powerful tools for UVW Unwrap. Improved and new tools within Rhino 6.0 will be explored in further projects.

5 Conclusions

This paper presented the process of creation of a set of visualizations and a short animation of Mackintosh's first design proposal for Scotland Street School.

Moreover, this piece of writing allowed to reflect on the work done and on key aspects that are usually overlooked such as the communication with the architectural historians and the educational aspects of the development process.

The digitally handcrafted quality of the work, which involves all the main phases of the process from the 2D drawings through the 3D digital modelling until the creation of the materials/textures, and its educational values have never been properly critically analyzed in other pieces of writing. A future paper will further explore this topic (together with the material produced during the development work) and its value, especially for architecture students.

This is the second piece of writing that investigates aspects of a building designed by Charles Rennie Mackintosh by using digital technologies. The research about the Glasgow School of Art presented in the previous paper [2] is still in progress, and new findings will be presented in future publications.

The application of this methodology to other historic buildings is also under consideration. Other case studies will allow exploring further and new functionalities of the used software packages and alternative digital tools.

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