

The use of 3D printing technologies in the restoration of architectural historical patrimony.

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Abstract. This article presents a literature review on the application of 3D printing technology in civil construction and the preservation of architectural heritage. The analyzed studies demonstrate that 3D printing has the potential to revolutionize the construction sector by offering greater efficiency, cost reduction, and sustainable practices. In the realm of historical preservation, the technology allows for the precise reproduction of architectural elements. However, significant challenges, such as the lack of regulation and the need for the development of new materials, still need to be overcome. The final discussion explores current limitations and future opportunities for the large-scale adoption of 3D printing.

Keywords. 3D printing, civil construction, patrimony preservation, digital technologies, architectural restoration.

1. Introduction

3D printing is an additive manufacturing technology that enables the creation of three-dimensional objects from a digital model. It supports fast prototyping, decreased production costs and exaggerated items personalization. 3D printing, On the other hand, has driven some of the most important advances in human history in fields like healthcare (think custom prosthetics and implants) and construction (we now build homes out of biodegradable materials). Its applications in the automotive and aeronautical industry contribute to faster, lighter, and stronger parts being fabricated, while educationally is used as one of this millennium best tools in teaching, allowing easy understanding of engineering (design) or even medicine. This high level of flexibility also makes possible the on-demand production of parts, reducing waste and promoting a more rational use.

Given the progress in technology within this domain and its impact on preserving historical structures original aesthetics and cultural significance through the use of 3 dimensional printing for ornament restoration in heritage sites as explored in various

publications; this research is grounded on Viollet Le Ducs principle advocating for a restoration process that upholds historical accuracy and cultural value, in building conservation efforts.

2. Metodology

The study approach in this project was divided into three phases; gathering materials sorting them into categories for analysis and conducting an in depth review of the literature. We searched through three databases. Google Scholar, IEEE and Web of Science. Using search terms like "concrete printing," "restoration with 2 printer " "historical buildings with 2 printers " and "mortar printing with 2." We examined articles that covered the use of 2, in construction well as those that focused on preserving historical landmarks.

The chosen articles were grouped into four categories; review of literature; implementation of 3d printing techniques; contrast between conventional construction and 3d printing; and

examination of the benefits and obstacles associated with this technology. While many studies discuss the application of 3d printers in construction or other fields this research centers, on the preservation of historic structures. The goal is to identify any information in existing literature and propose ways to enhance and continue utilizing 3d printing, for preserving historical heritage sites to guide future research efforts in this area.

3. Discussion

The findings reveal huge potential for 3D printing to revolutionize building construction and architectural cultural heritage conservation, but the technology is still facing numerous challenges. Reduced costs and construction time, as well as the ability to create more sustainable structures are some of the main advantages of 3D printing in the field of construction. Nevertheless, as Formiga & Carneiro [3] have suggested the technology continues to be hindered by a number of road blocks including a no specific legislation and yet limited alternative substance developments. As per Lopes (2022), 3D printing can offer architectural designs a wider freedom of form since it opens up all kinds of shapes previously impossible to achieve. Even still, the lack of codification along with how involved it is to certify these new modes of construction hold them back from 3D printing becoming a mainstream construction technique. Meanwhile, in the domain of historical heritage preservation, 3D printing technology is still at a nascent stage. On the one hand, technological feasibility for reconstructing ornamental details that are essential to conserving original fabric intact as has been outlined by Canuto, Moura and Salgado (2021) setting against such a promising scenario some doubts about the authenticity of restorations. In addition, the act of replacing historical artefacts with 3D-printed ones presents ethical dilemmas that will need to be discussed prior to any widespread use.

3.1 Literature Analysis

The literature on the application of 3D printing in architectural restoration and cultural heritage conservation presents a rich and complex panorama, involving theoretical concepts and contemporary practices. Filho (2021) discusses the protection of Brazilian cultural heritage in light of Viollet-le-Duc's theory, which advocates for the idealized recreation of buildings. The author suggests that this approach can be adapted to the Brazilian context, where cultural diversity requires reflection on authenticity. Rapke (2021)

complements this discussion by presenting prototyping as an innovative tool that, when integrated with 3D printing, enables the precise recreation of architectural elements, but also raises concerns about the authenticity of the interventions.

Porto (2016) and Lopes (2015) explore the advancements of 3D printing in the construction industry, highlighting its practical applications and ability to create complex shapes. Both acknowledge the challenges that this technology still faces, such as economic and logistical issues. Formiga and Carneiro (2021) conduct a critical review of the literature on 3D printing, discussing the ethical and practical benefits and challenges, such as the sustainability of materials and social acceptance.

Finally, Medeiros (2023) presents a case study on the conservation of hydraulic tiles in the Paço dos Açorianos in Porto Alegre, highlighting how 3D printing allowed for the preservation of historical elements. The work demonstrates the effectiveness of this technology in maintaining the aesthetic and historical integrity of heritage, showing that, when applied judiciously, 3D printing can be a valuable ally in cultural conservation.

In summary, the literature analyzes the intersections between theory and practice, proposing a dialogue between restoration traditions and technological innovations, expanding the possibilities for the preservation of cultural heritage.

3.2 Application of 3D Printing with Viollet-Le-Duc's Theory

It is an approach which can be argued bears a lot similarity to the theory of Eugène Viollet-le-Duc (1814-1879), namely, that heritage should include restoration of historical buildings so as to make them appear in their perfect original or near-original state, and in this way 3D-printing lays emphasis on that dichotomy. According to Viollet-le-Duc, restoration does not just seek to fix a building at the state of damage that it finds itself at but instead make it "complete" as conceived under an idealized view of how it might have been intended to be (Viollet-le-Duc 1854).

For this, 3D printing becomes a game-changer in allowing to manufacture ornaments, capitals or any other architectural feature as it should look like according to the theoretical vision of Viollet-le-Duc. The technology provides the capability to accurately replace worn or lost features of a listed building

within millimeters, mirroring the original façade. However, this application raises a debate about authenticity, as the use of new materials and modern techniques may contrast with historical materials and methods. The application of 3D printing based on Viollet-le-Duc's theory challenges restorers to find a balance between innovation and faithful preservation, maintaining the historical value of buildings while also integrating technological advances for long-term conservation.

3.3 Case Study: The use of 3D Printing on Hydraulic Tiles for a restoration in Porto Alegre.

The thesis of Arthur Thiago Thamay Medeiros, presented in the Graduate Program in Design at the Federal University of Rio Grande do Sul, investigates the application of 3D technologies in the conservation of heritage properties, specifically focusing on the hydraulic tiles in the entrance hall of the Paço dos Açorianos, an emblematic building located in Porto Alegre. The work begins with an analysis of the importance of hydraulic tiles as architectural elements that represent the cultural and historical identity of the city. Medeiros discusses the challenges faced in conserving these materials, which are often subject to deterioration due to the wear of time and inadequate interventions. In this context, the research proposes the use of three-dimensional digitization techniques to document, analyze, and preserve these decorative elements. The thesis is divided into several parts. In the first, the author explores the theoretical foundations of cultural heritage conservation, addressing concepts such as authenticity, integrity, and the importance of documentation in the restoration process. Next, a literature review on the use of 3D technologies in similar contexts is presented, highlighting successful cases and different technological approaches, such as photogrammetry and 3D modeling. In the methodological section, Medeiros details the digitization processes carried out at the Paço dos Açorianos, emphasizing the techniques used to capture the details of the hydraulic tiles. The research includes a comparative analysis between traditional and digital documentation, highlighting the advantages of the 3D approach, such as the possibility of creating interactive models and the ease of sharing information with the public and other professionals in the field. The results of the research demonstrate that 3D technologies not only allow for more accurate and accessible documentation but also offer new opportunities for raising awareness and education about cultural heritage. Furthermore, the thesis suggests that digitization can serve as a valuable tool for planning and executing conservation interventions, minimizing risks of damage to original elements. Ultimately, Medeiros concludes that the

integration of 3D technologies in the conservation of heritage assets, such as the hydraulic tiles of the Paço dos Açorianos, represents a significant advancement in the protection of cultural heritage, allowing future generations to appreciate and understand the historical and aesthetic richness of these elements. The research highlights the importance of a multidisciplinary approach that involves designers, architects, conservators, and the general public, promoting greater appreciation and preservation of cultural heritage.

4. Results

The literature review confirms the mechanical properties and functionality of 3D printing in construction are prone and can be verified for certain sectors. This technology, as per Formiga and Carneiro (2021), offers automation that could greatly decrease costs, construction time, and human errors. This point of view is supported by Porto (2021), who stresses the capacity of 3D printing to develop sustainable modular structure, mainly due to new materials such as concrete and its reinforced polymer forms.

Lopes, Loo (2022) takes this further by noting the design possibilities that can be unlocked with 3D printing. He says this technology opens the door for new architectural forms that were just not possible prior to these advances. Additionally, Lopes highlights the sustainability part of it; 3D printing is a tool that will allow you to use recyclable materials and reduce waste.

In his work on the preservation of heritage, Canuto; Moura and Salgado (2021) demonstrated how 3D printing can be a valid help in repairing architectural ornaments. This is 1 of the biggest points made, as it allows you to reproduce intricate ornamental styles with nearly perfect precision. The authors do warn of technical and ethical limitations involved, such as the replacement of artifacts with 3D-printed replicas in place of historical materials. However, the automation of 3D printing may save costs and construction time a little bit but to see how it remains limited in certain aspects: maintenance precision as right angles; Using 3D printers and concrete (or similar materials to the original construction in listed buildings) might not be the best way ahead for heritage restoration.

That said, the precision of 3D printing may serve as a valuable tool for recovering ornaments and interior attributes within historic buildings. One of the primary challenges in restoration has been a lack of labor skilled in developing these details over the years. Technologically, it is

possible to reproduce architectural elements with greater delicacy simulating from their original condition advancing the breed of restoration works as Viollet-le-Duc idealized.

5. Conclusion

According to previous studies, 3DP is anticipated to reshape both the preservation of architectural heritage and construction industry. These then summarize the efficiency of the technology in construction sector and its contribution to sustainability as well as cost being reduced, along with how it reminisces a step back on heritage preservation, by providing an accurate method for replacing complex ornamental rich details.

Still, there are challenges to be faced in both the field and preservation regarding regulations, new materials that must be elaborated from scratch or ethical implications in how we are replacing functional elements of History. This review unambiguously suggests that mass deployment of 3D printing in these domains is only a question of time as the technologies will acquire pull. But it is necessary that studies prioritize the creation of new materials and the elaboration of norms and standards to guarantee a certain purity in the works built or restored with the aid of this technology.

6. References

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