TITLE OF THE RESEARCH PROJECT

Digital Stereotomy: from treatises to geometry for interventions

SUPERVISORS

	First name	LAST NAME	University	Research Unit
Supervisor	Paolo	Borin	University of Brescia	Department of Civil, Environmental, Architectural Engineering and Mathematics - DICATAM
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Fields of study

History and theory of representation, history of construction (SH5_11 Digital humanities; SH8_5 History of art and of architecture)

Requirements (academic background, languages...) needed to apply for this research topic

-Requested academic background: Master's degree in Architecture; Master's degree in Construction/Building Engineering-Architecture.
-Language (minimum requirement): English B2; Italian A2 or Spanish A2 or French A2.
-Expertise in 3D modeling with software as Rhinoceros, Blender, AutoCAD
-Knowledge of, or availability to learn, scripting language such as Python, scripting techniques in Visual Programming Languages environment (Grasshopper, Dynamo), BIM modeling (Revit, ArchiCAD), ontology creation (Protegé), digital survey techinques, basic analysis of stability of structures

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5 main KEYWORDS

Digital humanities; stereotomy; ontology; 3D modeling; architectural treatise

ABSTRACT *(250 words max.)*

This project addresses the challenge of making the knowledge of stereotomy, the art of cutting and assembling building stones, accessible. While fundamental to European architecture, this knowledge is documented in complex and often inaccessible treatises. The research aims to bridge this gap through an interdisciplinary approach that unites history, geometry, and digital technology. The treatises on stereotomy contain text accompanied by a series of coordinated representations. These representations are the result of a series of graphic operations needed to break down the main surface into its constituent elements (voissoirs), and the subsequent operations for cutting the stones and assembling them into a single, structurally stable system.

The study has a dual objective. First, it will create a digital knowledge base for historical treatises, developing a formal ontology and semantically transcribing portions of texts in French, Italian, or Spanish using the TEI-XML standard. This process will make the content searchable and accessible, allowing for the tracing of connections between drawings and texts, and between the texts themselves. Second, the project will apply scripting and 3D modeling techniques (Python and Grasshopper) to analyze and virtually reconstruct the complex geometries of masonry vaults, such as surfaces of revolution and rotation-translation, thus contributing to the advancement of geometric culture. The theoretical framework will be validated through practical case studies from diverse geographical regions, including France and Spain. The integration of digital surveys and 3D reconstructions with a specific semantics tool, within a unified platform will allow for a direct correlation between the principles described in historical treatises and their concrete architectural applications.

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Research aims and methodology

This project addresses the challenge of knowledge transfer in stereotomy, which, despite its foundational role in European architecture from Renassaince, is today documented in complex treatises. The research aims to bridge this knowledge gap through the integration of advanced digital methodologies. Thus, the primary aim of this research is to construct a comprehensive digital knowledge base for European stereotomy treatises. This objective extends beyond mere digitization; it seeks to create a semantically rich environment that allows for the tracing of connections, similarities, and lineages between theoretical texts and their graphical representations. This includes establishing a direct link between the intricate drawings of vaults and their corresponding textual descriptions, as well as cross-referencing concepts and techniques across different treatises. By doing so, the project will inform the network of knowledge transmission that underpinned architectural practice during the Renaissance and subsequent periods. A second key aim is to analyze the geometrical principles encoded within these treatises through 3D modeling. The research will systematically catalog the geometric operations and construction sequences required for vaulting, such as the generation of surfaces of revolution and rotation-translation. This investigation will seek to demonstrate how stereotomy was not merely a practical discipline but also a significant driver for the advancement of geometric culture in Europe. The formalization of these processes will reveal the sophisticated theoretical foundations that informed the practical application of the science. Finally, the research aims to provide a practical real-world verification of the theoretical rules of stereotomy through the analysis of selected case studies. This objective will involve a critical examination of historical constructions to determine the extent to which the theoretical principles outlined in the treatises were actually applied in practice. This will allow the research to evaluate whether European treatises were truly practical manuals for builders or, conversely, served primarily as intellectual exercises in theoretical or geometric development. The results of this analysis will contribute to a deeper understanding of the relationship between architectural theory and construction practice in historical contexts.

The research will employ a multi-faceted methodology to achieve its stated aims, integrating both traditional and advanced digital techniques. The foundational step is a critical bibliographic review. This will involve the systematic collection and analysis of a heterogeneous body of existing scientific literature, including primary sources (historical treatises) and secondary scholarly works. This phase is crucial for identifying key historical figures, theoretical concepts, and the existing gaps in the literature that this research will address.

The core of the digital methodology involves the semantic transcription of selected stereotomy treatises. These texts will be transcribed according to the TEI-XML (Text Encoding Initiative) standard, which will provide a robust framework for encoding textual and structural information, making the content machine-readable and semantically interoperable. This standardized approach will enable the creation of the digital knowledge base, facilitating complex queries and the establishment of links between texts.

For the geometric analysis, the research will utilize procedural modeling techniques. The geometric operations described in the treatises will be coded using textual scripting languages, such as Python, or visual scripting environments like Grasshopper within the Rhinoceros software platform. This method allows for the parametric reconstruction of complex vault forms and the systematic cataloging of their geometric properties. Rhinoceros and Grasshopper will also serve as the primary environments for the

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development of the case studies. The case studies will be selected from different geographical and chronological contexts to ensure a broad representation of European stereotomy. These real-world examples will be documented using advanced digital surveying techniques, including laser scanning and photogrammetry. These methods provide highly accurate 3D point clouds and mesh, which will then be used to generate precise digital versions of the historical structures. By overlaying the theoretical models derived from the treatises onto these digital surveys, the research will be able to perform a direct comparison, quantitatively and qualitatively, to verify the application of theoretical rules in historical constructions. This integrated approach, combining textual analysis, geometric modeling, and digital surveying, will provide a holistic and scientifically rigorous framework for the entire research.

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Relevance and added-value of the proposed research in relation to the current state of knowledge

While significant scholarly work on European stereotomy has been published in recent years, a critical gap persists: this knowledge is not yet represented in a coherent digital framework. The existing body of literature, though rich and insightful, is often fragmented across various publications and languages, making it difficult to access, compare, and apply systematically. The proposed research directly addresses this deficiency by creating a comprehensive digital pipeline. This project is not merely an act of digitization, but an endeavor to structure and semantically enrich a vast collection of information, from treatise to construction element. By cataloging and organizing the geometric rules and theoretical concepts of stereotomy in a digital format, this research will create an open-ended resource that can be continuously expanded and integrated over time. This initiative will enable the formation of a multilingual European catalog of treatises, constructed examples, with their specific techniques used.
The relevance of this digital framework extends directly to the field of architectural conservation. To correctly and sensitively intervene in the restoration and preservation of historical masonry artifacts, a deep understanding of their original geometric and structural logic is essential. By making the rules of stereotomy and the intentions of historical builders more accessible, the proposed research provides a vital tool for modern-day restorers and architects. It transforms static, difficult-to-interpret knowledge into a dynamic, queryable database, ensuring that the legacy of this geometric discipline remains active and applicable in contemporary practice.
A key added value of this research is its contribution of a novel methodological framework for analyzing historical treatises and architectural geometries. The project will provide a clear, reproducible model for other researchers to apply to a broader range of texts and monuments. By codifying geometric procedures through scripting and standardizing textual analysis using TEI-XML, this research will equip the academic community with a powerful set of tools for tackling similar historical and architectural questions. This approach moves beyond traditional qualitative analysis, offering a rigorous, quantitative method for understanding the intricacies of historical constructions. Furthermore, the in-depth analysis of at least two key treatises—selected from French, Italian, or German traditions based on the candidate's language ability—will allow for a critical, comparative study of two influential authors. By systematically comparing their respective geometric constructions and methodologies, the research will be able to establish a network of a priori knowledge. This process can unveil direct and indirect relationships, intellectual influences, and mutual references that are often not explicitly cited in 16th and 17th-century treatises. This ability to digitally trace the lineage of geometric ideas represents a significant leap forward in our understanding of intellectual history within architectural theory. The research will therefore not only fill a gap in the digital realm but also offer a paradigm shift in how we interpret and connect the theoretical works of the past.

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Interdisciplinary nature of the research together with the alignment with the CHORAL programme and complementarity expertise of the teams

This research project is inherently interdisciplinary, reflecting the dual nature of stereotomy as both science and art. On one hand, stereotomy is a rigorous science that contributed significantly to the development of modern geometry and representation. Its principles, much like astronomy's role in calculating orbits or cartography's in manipulating naval routes, provided a foundational framework for tackling complex spatial challenges. On the other hand, it is a practical art form, enabling the construction of intricate and previously unfeasible architectural works, such as the impressive ground-floor vault of the Hôtel de Ville in Arles.

Addressing this multifaceted subject requires a blend of diverse competencies, from art history to analytical geometry and digital modeling. The proposed project will leverage this mix of expertise; a fact reflected in the complementary backgrounds of the supervising team. This interdisciplinary approach is further strengthened by the candidate's access to the wider UNITA network. The project supervisors maintain close contact with researchers within this network, allowing the candidate to seek specialized advice on key multidisciplinary aspects of the research, including the development of ontologies, TEI-XML transcription, and database management.

The project is ambitious and perfectly aligned with the core mission of the CHORAL Programme to "encourage the development of interdisciplinary, international and inter-sectoral research that addresses any aspect of Cultural Heritage." This doctoral research directly contributes to two of the programme's key themes: Study and preservation of tangible Cultural Heritage and Enhancement and dissemination of cultural and natural heritage.

By creating a digital knowledge base of historical stereotomy treatises and verifying their principles through the analysis of built heritage, the project directly supports the study and preservation of tangible cultural heritage. The digital models and the structured database will provide invaluable tools for architects and restorers, enabling more informed and accurate interventions on historical buildings. Furthermore, the research's focus on making this knowledge accessible through a multilingual, organized platform directly addresses the enhancement and dissemination of cultural heritage. It ensures that the intricate art of stereotomy, often hidden in dusty archives, becomes a vibrant and accessible part of our collective cultural legacy. The project's international scope, involving the study of treatises and case studies from different European countries, further reinforces its alignment with the CHORAL Programme's international dimension. In essence, this research embodies the CHORAL ethos by integrating diverse disciplines and leveraging digital technology to preserve, study, and share our shared cultural past.

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Output plan including publication and dissemination activities

The publication and dissemination strategy for this research is designed to reach both the academic community and a wider audience of professionals and students. At the core of the academic plan is the production of peer-reviewed scientific articles. The goal is to publish at least one paper per year in a high-profile journal (i.e. Journal of Cultural Heritage) or in the proceedings of international conferences dedicated to the topic (i.e. Nexus conference). In the first year, the focus will be on a foundational article that outlines the project's methodology, aligning it with international standards. Subsequent publications will delve into the specific research outcomes, such as the development of the ontology, the analysis of the treatises, and the findings from the case studies.

Beyond formal publication, the project plans for broad dissemination to maximize its impact. For this, a dedicated website will be created to serve as a central archive for the research's key deliverables. The site will make multilingual transcriptions of historical treatises, the ontologies, the digital vault models openly accessible to everyone. This platform will not be a mere archive, but a living tool for researchers and professionals, making the knowledge of stereotomy directly and functionally available.

Finally, a crucial part of the dissemination will involve direct engagement with future professionals. The research findings and the advanced modeling techniques developed will be presented in seminars and workshops at university architecture and architectural restoration departments. This transfer of skills will ensure that the knowledge acquired during the PhD is not confined to academia, but becomes a practical tool for the next generation of architects and conservators, allowing them to use technology for a more informed and conscious management of our heritage.

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Estimated schedule

The first year of the program is dedicated to establishing a solid foundation for the research. This will involve the comprehensive collection of existing bibliography, as guided by both supervisors, along with the acquisition of all the necessary tools and resources to complete the project. A key initial activity will be to complete the foundational skills required for the work, which includes advanced three-dimensional modeling techniques and, if necessary, the study of specific computational languages or traditional languages like French or Spanish. To conclude the first year, the candidate is expected to attend a specialized summer school, such as the HIMASS summer school, to gain practical insights into the construction and stability of masonry structures. This will bridge the gap between theoretical knowledge and real-world architectural challenges. The methodological learning will be a continuous process throughout the initial 30 months of the program. Given the experimental nature of the methods employed, they will be continuously adapted and tuned to meet the evolving needs of the research. During the second year, the primary focus will shift to the in-depth study of the historical treatises, which will form the basis for constructing the initial ontology of terms. The candidate will critically analyze at least two key reference treatises, chosen based on their linguistic proficiency. One of these research activities will be conducted at the supervisor's host institution to facilitate close collaboration. Between the 18th and 30th month, the practical phase of the research will commence with the digital surveying of the selected case studies and their subsequent three-dimensional modeling. The final six months of the program are dedicated to the completion and finalization of the doctoral dissertation. This final document will be partially drafted during the preceding months, with the last six months allocated for its completion and refinement. The candidate's progress will be closely monitored through monthly meetings with both supervisors, conducted in person or in a hybrid format, to ensure continuous guidance and effective project management.

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