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3D SCANNING FOR OPTIMIZED HISTORIC BUILDING RESTORATION

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Abstract. Heritage preservation represents a fertile ground for innovation, bridging engineering education, applied research, and territorial engagement. In this framework, the rural municipality of Mittainvilliers-Vérigny (Eure-et-Loir, France) became an experimental field for second-year engineering students from ESTP Orléans, within their research and innovation training module. The project aimed to engage future engineers with advanced methodologies and technological tools commonly used in both industry and research environments. Beyond technical learning, it provided an authentic opportunity to explore how cutting-edge digital technologies can contribute to the documentation, conservation, and valorization of local built heritage.

The restoration of historic buildings, at the crossroads of civil engineering, heritage conservation, and emerging digital construction technologies, represents a major challenge for both architects and engineers. Within this framework, the students focused their research on Saint-Rémy Church, a modest yet emblematic building of the local landscape, built from the 11th century with additions over the centuries, notably during the Renaissance. The existing documentation was limited to a few historical surveys carried out between 1852 and 1854, preserved in the departmental archives.

The scientific objectives of the project were twofold: first, to acquire new geometric and material data on the building; second, to explore the potential of cutting-edge digital tools in the context of built heritage conservation.

To address these challenges, the students deployed a combination of advanced surveying techniques: 3D laser scanning, photogrammetry, GPS and total station georeferencing, as well as multispectral imaging campaigns, enriching the available documentation. Beyond data acquisition, the digital approach implemented throughout the project opened new perspectives for heritage conservation: accurate 3D modelling of existing structures, early detection of structural disorders, simulation of intervention scenarios, and precise estimation of material quantities required for restoration works.

This project provided students with a concrete learning environment, confronting them with real, complex, and interdisciplinary situations. It also offered an opportunity to reflect on the evolving role of the engineer within territorial dynamics, as a technical expert, a cultural actor, and a partner in local development. This pedagogical experience demonstrates how even modest heritage assets can become powerful drivers of innovation, research, and education, while fostering meaningful connections between engineering schools and rural communities.

1 INTRODUCTION

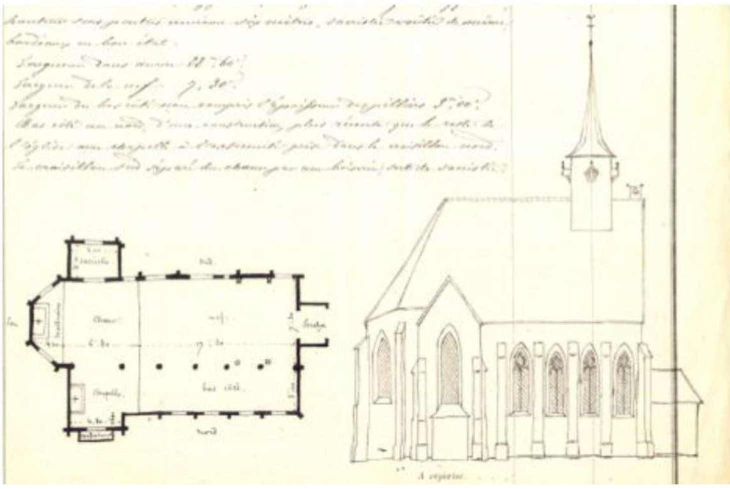
1.1 Learning through research

In the context of continuous transformation of engineering professions, it has become essential to train future engineers in rigorous scientific approaches, grounded in concrete and meaningful challenges. The project presented here is part of an innovative pedagogical engineering initiative aimed at introducing students to the world of research and development, whether academic or industrial. Departing from conventional exercises with purely didactic purposes, this framework adopts a constructivist learning approach: students are placed in real-world situations, often complex or uncertain, that require initiative, critical thinking, collaborative work, and the ability to overcome obstacles and setbacks.Guided by academic researchers and industry professionals, students manage their projects autonomously, starting from a defined set of requirements. In doing so, they learn to identify the problems to be addressed, to design a methodology (including literature review, experimental or analytical protocol, and feasibility analysis), to collect and interpret data, and to present their findings in accordance with scientific communication standards. Beyond technical skills, this type of project mobilizes transversal competencies such as literature review, project management, scientific integrity, written and oral communication, and teamwork.

1.2 3D surveying and modeling

First, the students carried out a state-of-the-art review on modeling methods and 3D surveying. From this, they identified several studies [1], [2] highlight the precision and speed of 3D scanning in capturing architectural details. Unlike traditional surveying, 3D scanning can record millions of points in a short time, producing a point cloud that can be converted into BIM (Building Information Models). This process integrates scan data with metdata about materials, structure and condition, enabling predictive analysis and simulation [3] .This supports decision-making in conservation strategies.

The municipality of Mittainvilliers-Vérigny (Eure-et-Loir), provided the students with historical documentation of the Saint-Rémi Church, as illustrated in Fig. 1. Examining these archival materials enables them to assess the limitations of past surveying and representation techniques, and to explore how these can be enhanced through the application of contemporary digital technologies. The project therefore concentrates on the digitization of the archival records and the comprehensive analysis of the church which was recently added to the French inventory of historic monuments.Fig.1a presents the only existing architectural drawings of the structure. Fig.1b and Fig.1c present views of the church’s exterior and interior, which will serve as the basis for initiating a 3D scanning process to help generate updated and accurate plans. The 3D documentation of the building through scanning technologies is a valuable tool for anticipating and supporting upcoming conservation efforts.



(a)

(b)

(c)

Figure 1: (a) Existing architectural drawings of the church; (b) exterior view and (c) interior view used as a basis for the 3D scanning process.

1.3 Methodologies and applied research

The 3D digitization project of the Saint-Rémi Church is structured around a systematic workflow consisting of successive technical stages, combining on-site data acquisition, digital processing, and geometric modeling. Building on the knowledge acquired in their topography courses, the students began developing a study plan outlining the protocol to be followed. This stage of the project allows students to move from theory to practice by applying their coursework knowledge to a real heritage site. It gives them hands-on experience with professional surveying tools and workflows, helping them develop practical skills while getting closer to the methods used in industry for conservation and construction.

The operation begins with site preparation and the establishment of geodetic reference points. A differential GPS is employed as shown in Fig.2a to mark multiple positions around the building, ensuring precise spatial alignment of the scan data. Signal stabilization is monitored at each station before recording the coordinates. The collected data includes planimetric, altimetric, and three-dimensional values, along with the GDOP (Geometric Dilution of Precision), a key metric indicating the spatial accuracy of the positioning using Leica CS20 as figured in Fig.2b. These coordinates are projected onto a base map to validate the spatial distribution of the stations and ensure adequate coverage of the aerial view of the Saint-Rémi Church and its surroundings as illustrated in Fig.2c.

(a) (b) (c)

Figure 2: (a) GNSS data acquisition using a Leica GPS antenna for georeferencing the survey area. (b) Leica CS20 field controller used to record and manage geospatial data during the survey and (c). Aerial view of the Saint-Rémi Church site and its surroundings, showing georeferenced points used for positioning and alignment.

The acquisition phase is conducted using a terrestrial laser scanner with a rotating beam, enabling the capture of dense 360° point clouds from each station. The average acquisition time per station is approximately 15 minutes. Station placement is determined based on accessibility, surface visibility, and the required overlap between scan scenes to ensure proper alignment. For example, some stations were positioned inside the nave on a moisture-affected floor, others near the choir in front of the altar, and additional stations were set up outside, in the cemetery adjacent to the church as shown in Fig.3a, Fig.3b and Fig.3c

The building’s interior is scanned in several sequences to address signal loss due to enclosed spaces and variable lighting conditions. Following the on-site acquisition using specialized sensors (laser scanner, GPS), the data undergo digital processing to generate a usable 3D model.

(a) (b) (c)

Figure 3: 3D laser scanning survey campaign inside and around the church.

2 RESULTS INTERPRETATION

2.1 Topographic processing

The students initially worked with surveying software, applying the knowledge they had acquired in previous school projects. Through this process, they carefully planned the subsequent steps of the workflow, considering how to structure the survey, manage the GPS data, and perform topographic referencing of the stations. Using Covadis software, they generated the baselines and developed a systematic approach for the survey.

As part of this process, a station network is established around the building to ensure consistent spatial referencing as shown in Fig.4. This network includes a main station (in green), an external georeferenced reference point (in yellow), and a set of secondary stations (in red), all interconnected by directional vectors. These connections represent the measured baselines used for aligning and georeferencing the scan data. This structured configuration guarantees the spatial coherence of the entire survey, allowing the point cloud to be precisely integrated into a global coordinate system.

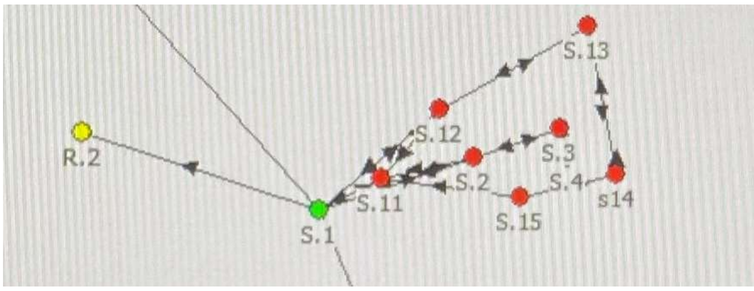
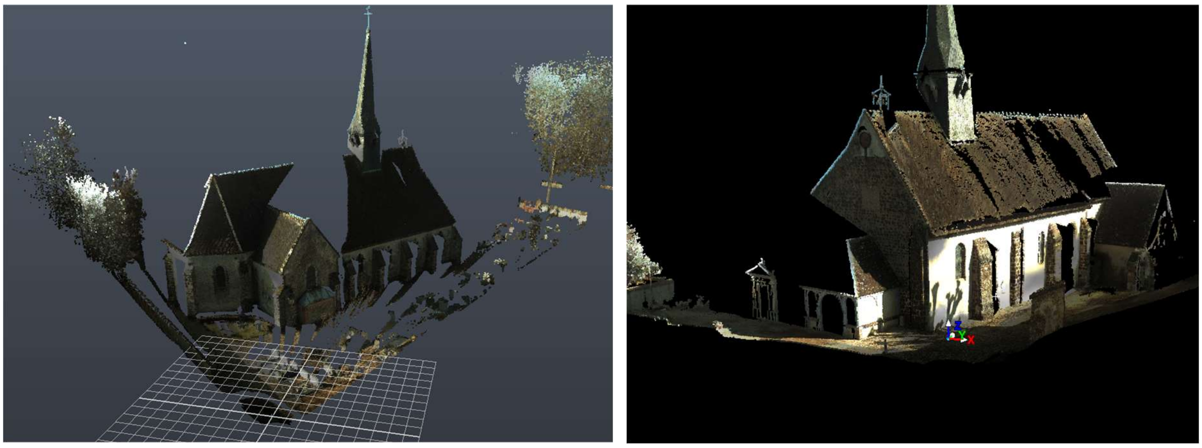


Figure 4: Station network used for georeferencing the 3D survey.

2.2 Post-processing and visualization

The post-processing and visualization of the 3D models allow students to apply digital modeling techniques, helping them connect theoretical knowledge with practical applications commonly used in professional projects. By importing the consolidated point cloud into AutoCAD, the students were able to further analyze the structure, assess geometric deformations, and explore digital modeling techniques

The resulting consolidated point cloud, as illustrated in Fig. 5, provides a detailed and metrically accurate representation of the Saint-Rémi Church. The model captures the full volumetry of the structure, including the roof geometry, openings, and architectural details, while preserving the integrity of scale and proportion. This digital model was subsequently imported into AutoCAD for further exploitation. It serves as a basis for analyzing geometric deformations. The entire processing workflow maintained a high level of precision, and data exports were performed within a national geodetic coordinate system, ensuring full interoperability with other GIS and CAD datasets.



(a) (b)

Figure 5: (a) Overall point cloud view of the church and its surrounding environment and (b) the southern façade of the church, highlighting architectural details

3 PEDAGOGICAL PERSPECTIVE

Engaging students in real industrial projects promotes a deeper understanding of the challenges and practices that engineers may encounter. This approach offers a dual benefit: it allows industry to address concrete problems requiring the expertise of future engineers, while providing students with practical training aligned with these needs. Furthermore, it enables students to strengthen social and collaborative skills by working with individuals of different ages and disciplines, to operate professional tools, experiment with new techniques, and face various operational challenges such as working under diverse weather conditions, managing complex software and licenses, processing and integrating large datasets, making timely decisions, coordinating within multidisciplinary teams, and adapting to strict time constraints.

The study of an actual heritage building allowed students to grasp the requirements for precision, accuracy, and geospatial data management in a professional context. While these concepts are thoroughly covered in coursework, they often remain abstract and disconnected from practical application. Participating in this project, however, allows students to directly apply what they have learned, experiencing firsthand the challenges of planning and executing a complete workflow from data acquisition to post-processing and visualization, thereby reinforcing and extending their classroom knowledge.

This hands-on approach also has a significant impact on their professional development: it fosters autonomous decision-making, critical thinking, and the maturation of technical skills. By directly engaging with real industrial challenges, students bridge the gap between academic learning and professional practice, enhancing their preparation for careers in engineering, digital modeling, and heritage documentation.

4 CONCLUSION

- This type of project is part of an experiential and professionally oriented educational approach, based on project-based learning and student immersion in situations closely resembling real-world professional contexts. It serves as an effective lever for the acquisition of technical skills such as 3D surveying, data processing, digital modeling, project management, and scientific reporting. This work places students at the heart of tangible challenges related to the documentation, analysis, and enhancement of built heritage, while also raising their awareness of contemporary issues in its conservation within a digital context. The adopted approach further encourages interdisciplinarity by integrating contributions from engineering sciences, architecture, and information technologies.
- The quality of the data acquisition, particularly in elevated areas, enabled a precise reconstruction of the interior volumes, especially the vaulted spaces.
- From a medium-term research perspective, the project aims to build a comprehensive BIM model of the building based on the collected data, in order to provide a coherent and dynamic framework for planning and managing potential restoration efforts. In parallel, it seeks to develop methods for the automated recognition of construction and restoration materials, leveraging advances in artificial intelligence. While these findings call for further structural analysis, they already provide valuable insights to inform future interventions. In the upcoming surveys, the integration of AI-based methods will make it possible to detect and assess whether any structural movements or changes have occurred over time.
- Combined, these directions aim to renew the tools and practices for the knowledge, management, and preservation of architectural heritage, relying on data interoperability, semantic modeling, and the advanced analytical capabilities enabled by digital technologies.
- Using 3D scanning not only improves accuracy but also reduces costs by minimizing site visits, avoiding destructive testing, and facilitating virtual assessments [4].Restoration teams can simulate restoration scenarios before implementation.Thus, this work constitutes a foundational step toward intelligent and actionable documentation of historic buildings, at the intersection of education, applied research, and heritage valorization.
- In this context, the resulting 3D model also opens the way for virtual reality experiences designed for the general public, offering new means of heritage

engagement and dissemination.

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