Digital & Documentation

V5

From virtual space to information database

edited by
Francesca Picchio

PROSPETTIVE MULTIPLE
STUDI DI INGEGNERIA ARCHITETTURA E ARTE

PAVIA UNIVERSITY PRESS

Francesca Picchio

edited by

Digital & Documentation

Vol. 5

From Virtual space to Information database

PaviaUniversityPress

Digital & Documentation. From Virtual space to Information database / Francesca Picchio (edited by) - Pavia: Pavia University Press, 2023. - 240 p. : ill. ; 21 cm.

(Prospettive multiple: studi di ingegneria, architettura e arte)

ISBN 978-88-6952-175-1 (brossura)

ISBN 978-88-6952-176-8 (Open Access)

The present publication is part of the series "Prospettive multiple: studi di ingegneria, architettura e arte", which has an international referee panel. "Digital & Documentation: From Virtual space to Information database" is a scientific text evaluated and approved by the Editorial Scientific Committee of Edizioni Pavia University Press of University of Pavia.

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Printed by
DigitalAndCopy S.A.S., Segrate (MI)

ISBN 978-88-6952-175-1 (brossura)

On cover: Graphic photocollage by F. Picchio

The volume consists of a collection of contributions from the seminar "Digital & Documentation: From Virtual space to Information database", realized at the University of Pavia on the day of September 19th, 2022. The event, organized by the experimental laboratory of research and didactics DAda Lab. of DICAr - Department of Civil Engineering and Architecture of University of Pavia, promotes the themes of digital modeling and virtual environments applied to the documentation of architectural scenarios and the implementation of museum complexes through communication programs of immersive fruition. The fifth Digital and documentation conference was also the inaugural event of the first Pavia DigiWeek, held from 19 to 23 September 2022 in Pavia.
The event has provide the contribution of external experts and lecturers in the field of digital documentation for Cultural Heritage. The scientific responsible for the organization of the event is Prof. Francesca Picchio, University of Pavia.

This publication is made with the contribution of DICAr, Department of Civil Engineering and Architecture of University of Pavia, through the joint research of the experimental laboratories DAda Lab - Drawing Architecture Document Action and PLAY - Photography and 3D Laser for virtual Architecture LaboratorY.

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DIPARTIMENTO INGEGNERIA CIVILE ARCHITETTURA

DAda Lab - Drawing and Architecture DocumentAction

PLAY - Photography and 3D Laser for virtual Architecture laboratorY

The event "Digital & Documentation, V.5" has seen the participation of professors, researchers and scholars from University of Pavia, Politecnico di Torino, University of Rome "La Sapienza", University of Palermo, University of Catania, Politecnico di Milano, University of Ferrara, University of Florence, University of Basilicata, University of L'Aquila, University of Salerno, Gdańsk University of Technology (Poland), Nanyang Technological University (Singapore), Universitat Politècnica de València (Spain), University of Salerno, University of L'Aquila, Lublin University of Technology (Poland), Cracow University of technology (Poland), University of Cordoba (Argentina).

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PART 1 - PERCEPTION: VIRTUAL SPACES, SIMULATIONS AND INTERACTIONS

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Panelists

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10 DATA MANAGEMENT, EFFICIENT USE, AND SMART ACCESS TO REALITY CAPTURE DATA VIA WEB PLATFORMS

Abstract

Sharing the output data of a digital survey with other stakeholders can increase its professional and widespread use. How a non-surveying specialist can visualize, interrogate and measure the reality-based models in the three-dimensional space -and not only- without sector-specific software is, for most instances, a significantly challenging problem. The possibility to upload digital survey data on web platforms would allow for greater dissemination and greater exploitation of the capabilities of reality capture technology. The point cloud can be displayed and investigated directly on the web and accessible on any device (laptop, desktop, tablet, or smartphone). The tools for measuring, cropping, annotating, and downloading data are usually included as standard features. Moreover, the different commercial proposals provide many innovative functions: VR interaction, BIM interoperability, automatic scan alignment, and 3D point cloud automatic segmentation and classification. The web-based system solution represents a real revolution in digital data sharing among experts, technicians, and professionals, who can dispose of all the survey data directly on their devices anytime, anywhere, preventing data loss and enhancing user sharing.

This paper aimed to present the characteristics and the potential of some online platforms for direct sharing and management of the point clouds derived from image- or range-based techniques. This preliminary research is presented to underline the pros and cons and identify future developments in this new way of exploiting digital survey data. This approach can be advantageous in the Cultural Heritage field, especially when CAD or HBIM 3D modelling is unnecessary because it is not the final aim. The solution can be to skip the whole complex and time-consuming modelling phase and directly use the point cloud as the 3D geometric base and as a reference for the information repository.

Problem Statement

Several sectors relating to the natural environment, civil engineering, infrastructure, architecture, heritage, and art are involved in the 3D digitization process (Fig. 1) with different aims and purposes [Daniotti et al. 2022; Miceli et al., 2020; Parrinello 2021; Poux et al. 2020, Russo et al. 2023].
In the infrastructural and architectural field, the last hardware and software developments have simplified and speeded up the data acquisition and processing phases, even in the case of complex measurements (surveys with lots of scans, buildings with several floors and complex plan layouts, narrow environments and so on).
Laser scanner equipment types are becoming smaller, lighter, and quicker in field operations, making instrument transportation more flexible, faster, and suitable for different environments. Thanks to on-board real-time elaboration, the data capture phase is becoming quicker and more efficient. Moreover, laser scanners are now commonly equipped with additional sensors (GNSS systems, IMU platforms, tracking systems etc.) that allow users to run a raw pre-registration of the various range scans on-site in real-time while the survey is going on. This aspect primarily ensures that the detected surfaces are under control and that it is easier to determine if the 3D measurement is complete and if it includes all the involved areas. The on-site raw pre-alignment, therefore, simplifies the practical survey activity and drastically reduces the time required for the optimized registration of the scans in-office, optimizing and enhancing the scan-to-pointcloud pipeline. However, the scan-to-HBIM workflow is still a hard-working process even though it is becoming a reference standard in architectural heritage [Semina et al., 2022].
Even in the field of image-based methods, software development related to computer vision techniques has revolutionized the times and flexibility of the photogrammetric data processing workflow. The phases of image orientation and dense machining have been significantly accelerated, simplified, and optimized.
Despite the technological advancements that have

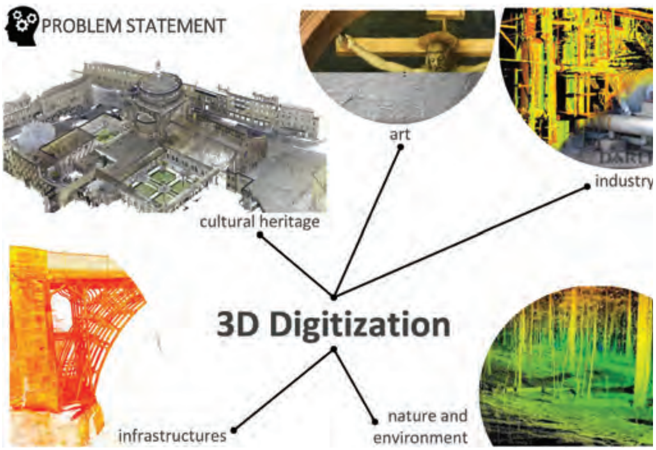

Fig. 1 – Possible fields of interest and applications of the 3D digitization process.

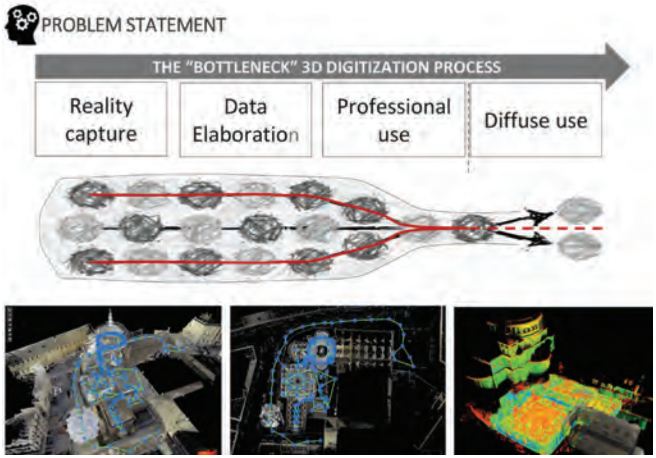

Fig. 2 – The "bottleneck" of the digitization process: diffuse use of reality capture data by users without professional-level hardware and expertise.

improved and accelerated the data acquisition and the processing phase in both image and range-based workflows, the use and management of output data by technical professionals who are not surveyors or 3D experts are still uncommon.

Nowadays, conducting a digital survey is usually simpler than utilizing its results and outcomes. The bottleneck is the practical, efficient, and immediate employment of the reality capture data (Fig. 2).

Indeed, observing the digital survey workflow, the more time-consuming step is the output elaboration, whether a 2D or 3D representation (Fig. 3). Whether using active or passive sensors, the final outcome is a point cloud model that takes a long time and effort to be transformed into a technical 2D drawing or a CAD or BIM model.

The discussion aims to present the characteristics and the potential of some of the web platforms available on the market for direct sharing and management of point clouds from image- or range-based surveys. Indeed, these solutions could facilitate the direct and professional utilization of point cloud models by various specialists (Fig. 4).

The main open issues that seem to hinder the widespread use of digital survey outputs are the following: i) digital data sharing and use require specific software; ii) these types of software are typically not user-friendly for professionals in other fields, and the acquired datasets are usually very huge; iii) the eventually subsequent geometrical CAD or BIM modeling is very time-consuming (above all for built heritage); iv) the 3D modelling implies many open issues about geometrical deviation among metric data and the reconstructed models.

A web-based platform approach can address these problematic aspects because: i) digital data can be shared and used directly through a web browser; ii) no specific software or plug-ins are required; iii) visualization and interaction also with massive data are quick and easy; iv) point clouds can be directly used as geometric and informative reference v) the point model is real scale, and any metric data can be extracted from the point cloud depending on the aim and graphic representation scale. In this context, the web-based platforms for online point cloud management can fill the gap between the digital survey and the widespread use of its outcomes.

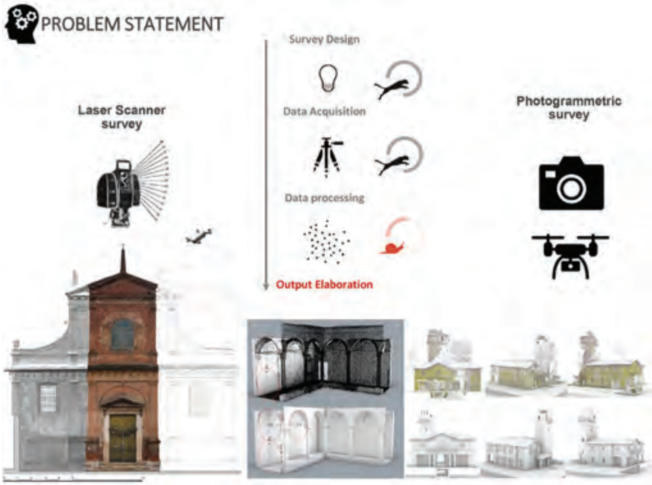

Fig. 3 – Digital survey pipeline.

Fig. 4 – Reality capture data use and sharing: problem statement.

State of Art

The significant increase experienced in the latest years in the use of reality capture outputs stresses urgently the need for suitable and easy tools for managing and broadly sharing this kind of data. The web platforms for point cloud data sharing are nowadays the most promising option to address this increasing need.
A web platform for point cloud management is a tool embedded in a website that provides users instruments to view and interact with point cloud data already present in the system, or that can be uploaded by the user. The user can interact with the point cloud by taking annotations, measuring distances, areas, and volumes, cutting cross-sections, and consulting information through databases related to point cloud objects. Whereas generally, for all the web platforms, the module for visualization is performative and achieves a smooth user experience, the "amount of interaction" that is possible with the point cloud depends on the purposes and goals of the platform. This latter aspect is a keystone in the future development of web platforms that promise to evolve from data-displaying tools to fully cloud-based elaboration software, as described later in this paragraph.

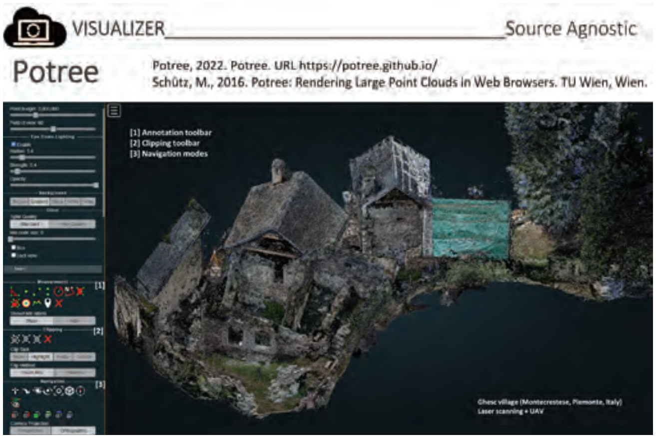

Fig. 5 – The interface of Potree visualizer and the main tools available.

The visualizer is the main core of the system and is the module in charge of delivering, through rendering and visualization, the 3D data stored in the system. It handles the most resource-consuming operations as point clouds are massive and require to be rendered fast in order to provide usability and a satisfying user experience.
The research on point cloud visualization systems has been focused, since its early stages [Axaridou et al., 2014], on finding more effective ways to index massive point clouds for out-of-core rendering [Bormann and Krämer, 2020] also adapting to the typology of data with semantic-dependent techniques [Discher et al., 2018], in order to get satisfying performances on most of the devices. The main focus of these efforts is directed towards point clouds at a territorial scale, especially massive, country-size ones derived from LiDAR surveys [Martinez-Rubi et al., 2015], which with the actual average hardware resources, represent a real challenge for in-core rendering.
One of the most diffused point cloud visualizer is Potree (Potree, 2022; Schütz, 2016) which originated from the SCANOPY Project [SCANOPY, 2009] and is still under development. Potree is an open-source converter and visualizer based on WebGL that can be used both as a standalone desktop application as well as an embedded tool in websites. The use of Potree for web applications is a common choice both for case studies that involve data at a territorial scale and for experiences at an architectural scale. Potree integrates some basic annotation tools that allow users to take measurements on the point cloud, put point labels with textual descriptions and attachments, and cut sections of the cloud (Fig. 5). Some case studies are useful to focus on possible uses of Potree, as an environment to display architectural reconstructions through point clouds of existing buildings and mesh models of artworks [Bent et al., 2022] and can be used as a renderer in more extended platforms for point cloud management that may also integrate WebGIS visualizers [Quintilla-Castán and Hernández, 2022]. The use of open-

source code can offer several possibilities in terms of adaptability and customization, allowing users to use point clouds as a geometrical basis for various purposes, such as the representation of acoustic features of space [Bergerot et al., 2022].
Aside from the open-source world, several companies are developing web platforms devoted to point clouds as a complementary service to their other products or as their core business. In the first category can be mentioned services such as Leica TruView Cloud [Leica Geosystems AG, 2022] and FARO WebShare [FARO, 2022], offered as additional services to the already established survey instruments and software, in order to enhance the possibilities of data sharing and diffusion by their clients [Fig. 6]. The second category comprehends platforms that propose data elaboration and analysis services based on cloud computing, sometimes starting directly from the data captured on-field. Cintoo [Cintoo, 2022] proposes tools for fully-operational data elaboration oriented to terrestrial laser scanning surveys in a perspective of digital twinning and built asset management. Vercator [Correvate Ltd, 2022] integrates alignment algorithms, automatic

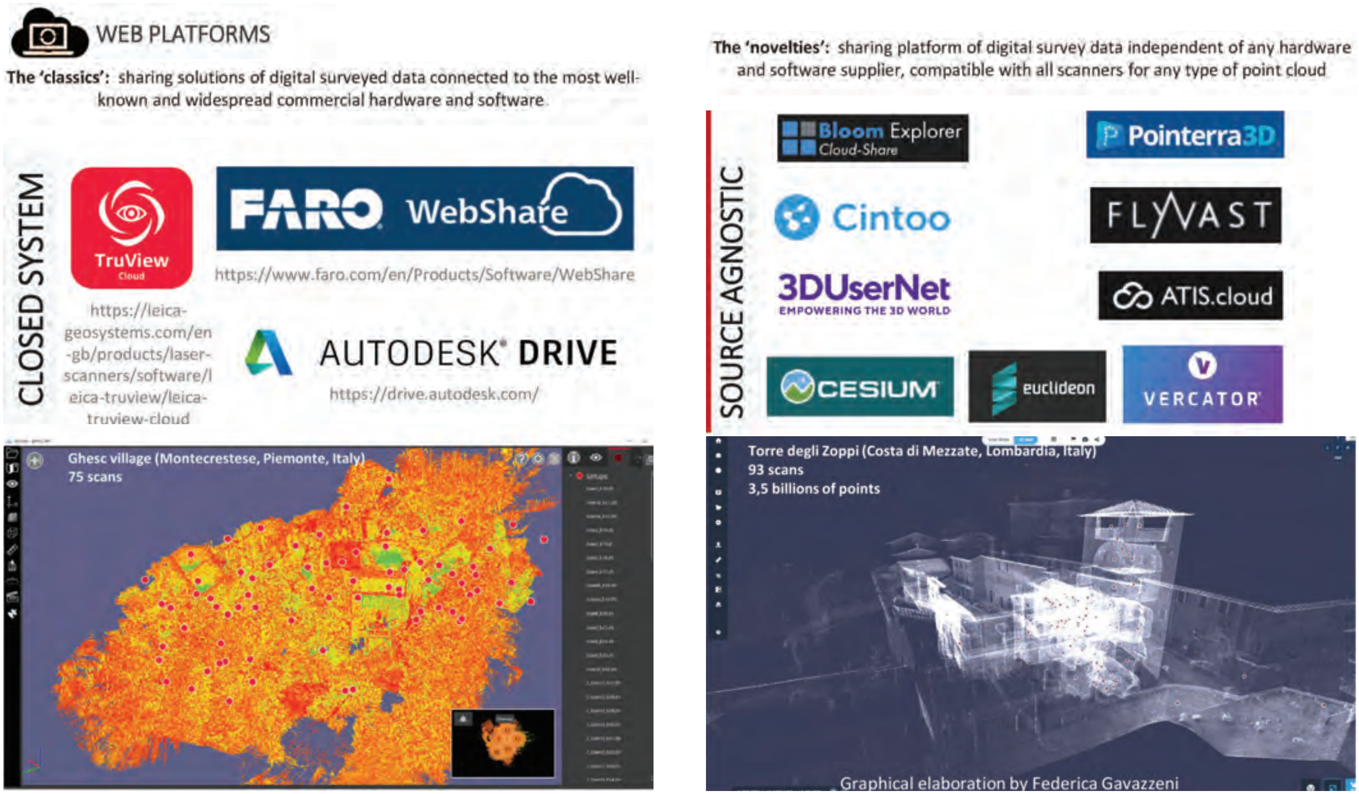

Fig. 6 – Web platforms for point cloud visualization and management can be categorized according to the data origin: specific instruments and software (closed systems) or virtually any possible data (source agnostic).

segmentation objects, and features recognition tools [Selviah, 2018]. FlyVast [Geovast 3D, 2022] is a platform based on the Potree visualizer that was developed to offer Artificial Intelligence (AI) support for geometry recognition [Poux et al., 2022]. NavVis IVION [NavVis, 2023] aims to provide elaboration tools from the beginning of the survey process, aligning cloud-to-cloud the laser scans, sharing the point cloud, and creating deliverables; the platform is integrated and optimized to work with the mobile mapping device [NavVis VLX] developed by the same company. Pointerra3D [Pointerra, 2023] is oriented towards using reality capture data for digital twinning and analysis and simulation based on geometry, offering three different modules with specific features according to the user's needs. Bloom Cloud Engine [Bloom Technologies, 2023] processes a broad amount of point cloud data and offers visualization and annotation tools; it embeds a plug-in to export point clouds to Autodesk products. udCloud [Euclideon, 2023a] is the web platform based on the udStream application [Euclideon, 2023b] which has the main feature to handle massive point clouds, providing basic measurement and annotation tools. ATIS.cloud [ATIS.cloud, 2023] supports a great variety of scanning projects, from terrestrial, aerial and mobile devices, for delivery and visualization of point clouds, including some annotation and slicing tools. Cesium ion [Cesium GS, 2022]

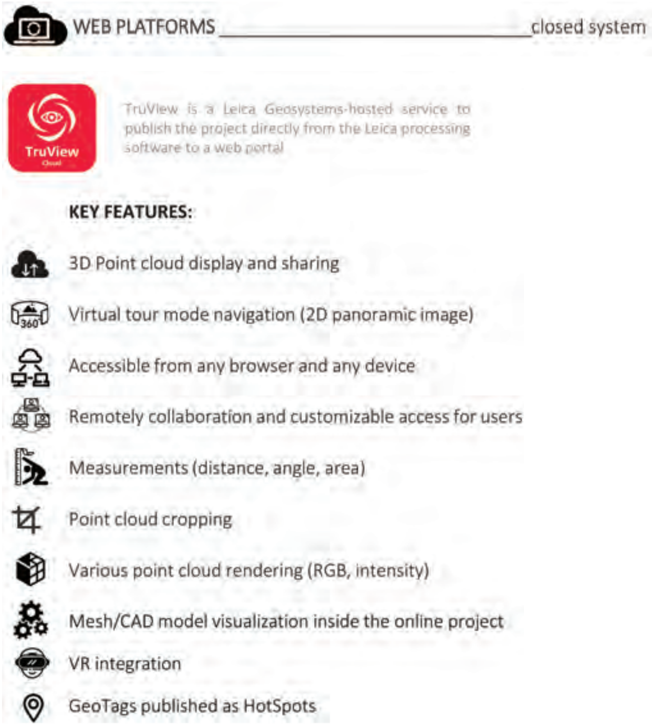

Fig. 7 – Features of the Leica TruView Cloud platform.

is a platform generally devoted to the representation of huge geodata, as point clouds and mesh, but can be used also with georeferenced clouds at the architectural scale. Cesium provides a series of embedded world-scale map and building databases from various sources to be used as standalone or with the 3D data provided by the user.
Web platforms for point cloud visualization and management are nowadays spreading and developing as fast as the request for reality capture increases, leaning towards the possibility of offering data elaboration features, automatized segmentation tools, and enhancing sharing possibilities in order to cover all the needs of professional and non-professional users.

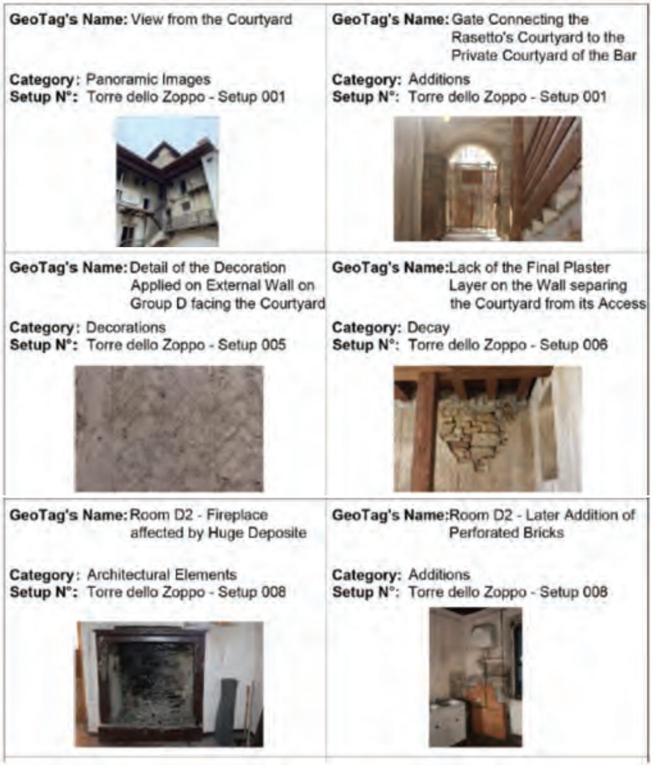

Fig. 8 – An example of the annotation possibilities offered by the Leica TruView Cloud platform.

Experimental case studies

As already specified, two main categories can be distinguished by studying the types of web platforms currently available. There are closed systems of sharing solutions for digital surveys connected to the most well-known and widespread commercial hardware and software. On the other hand, there are agnostic sharing platforms independent of any hardware and software supplier, compatible with all scanners and for any type of point cloud.
In order to test the functionality of both cloud-based platforms for reality data sharing, two sorts of datasets were used. The first dataset consists of data coming only from the laser scanner survey of the *Torre degli Zoppi*. The data were acquired with a single laser scanner instrument during the same survey campaign. The XII-century tower is located in Costa di Mezzate, near Bergamo (Lombardy, Italy). It was surveyed in 2020 using the Lecia RTC360 laser scanner, resulting in a point cloud of 3,5 billion points, composed of 93 scans [Gavazzeni, 2021].
On the other hand, a second dataset is a mixed set-up of data from image and range-based acquisitions collected over the years during the surveys developed in the village of Ghesc. The datasets refer to different years and are related to active and passive sensors. The historical village is located in the Ossola Valley (Piedmont, Italy), and it is characterized by the local stone peculiar architecture. From 2011 to 2017, the village was surveyed with various techniques during recurrent summer schools [Achille et al., 2018; Bolognesi and Fiorillo, 2023]. The final dataset used in this paper is composed of a laser point cloud of 75 scans and a UAV point cloud of roofs and the surrounding terrain [Achille et al., 2017].
Standard and common features among the different platforms are related to: i) 3D Point cloud display and sharing; ii) virtual tour mode navigation using a 2D panoramic image; iii) access from any browser and any device; iv) remote collaboration and customizable access for users; v) direct measurements (distance, angle, area) on the point model; vi) point cloud

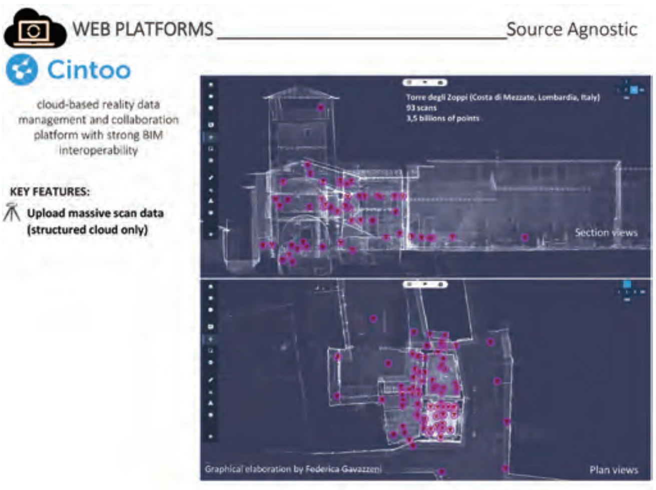

Fig. 9 – Cintoo web platform interface.

cropping or selection; vii) cross-sections extraction; viii) various point cloud rendering (RGB, intensity, elevation); ix) creation of annotations as GeoTags or HotSpots.
This last utility is essential to developing an informative structure that graphically represents information as a link on the point cloud with a specific icon.
Since the *Torre degli Zoppi* digital survey was carried out and managed entirely within the Leica Geosystems hardware and software environment, the acquired dataset was published using Leica True View (Figg. 7-8). True View is a closed system that allows sharing the project directly from the Leica processing software to a web portal. The platform provides an interesting feature related to the mesh or CAD model visualization inside the online project. Moreover, the more innovative resource is the possibility to integrate immersive exploration using Virtual Reality devices.

Fig. 10 – Features of the Cintoo web platform.

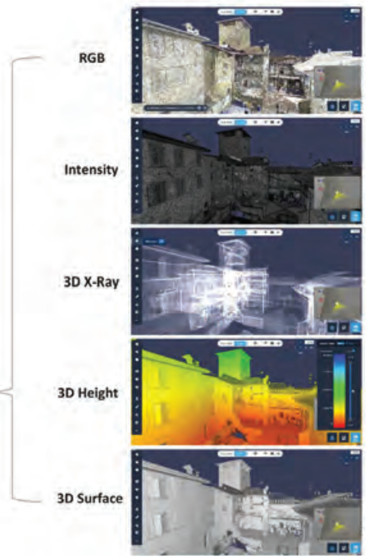

Fig. 11 – Cintoo rendering modes of the point cloud.

The same dataset was also uploaded on the Cintoo platform, characterized by strong BIM interoperability (Figg. 9-11). The cloud-based management and collaboration platform ensure the upload of massive scan data (structured clouds only). Furthermore, a repository of under-study building documentation (technical documentation and bibliographic research) can also be structured (Fig. 12).
Flyvast and Vercator adhere to the same principle and organizational structure as Cintoo: independently process, manage, publish, and share 3D data. In addition, both ensure the uploading of unstructured clouds, such as those generated by photogrammetric surveys.
These last two platforms share a strong spirit of research by proposing innovative AI-based tools for point cloud segmentation. Innovative and constantly under-development tools for semantic segmentation, automatic classification, and point cloud labeling characterize Flyvast (Figg. 13-14). Instead, as a novelty, Vercator (Fig 15) offers the option to implement an automatic targetless scan alignment.

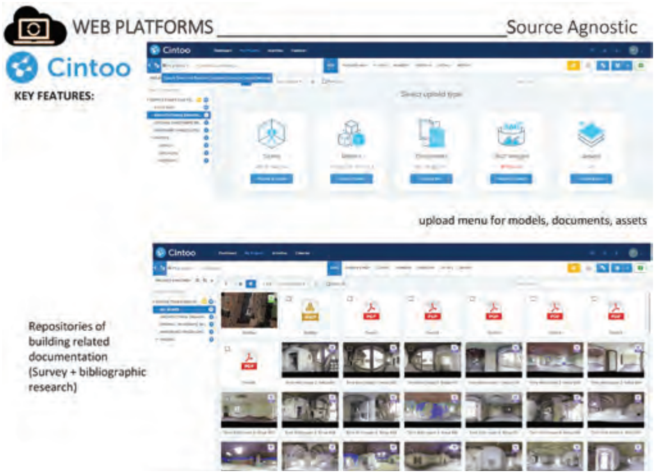

Fig. 12 – Cintoo data management interface.

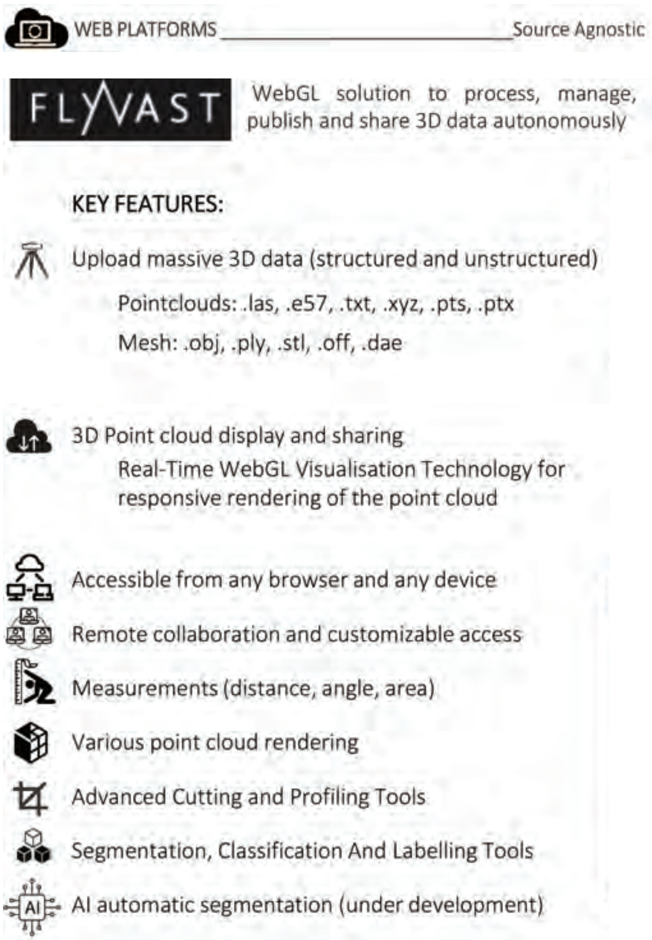

Fig. 13 – Features of the Flyvast web platform.

WEB PLATFORMS ______________________________ Source Agnostic

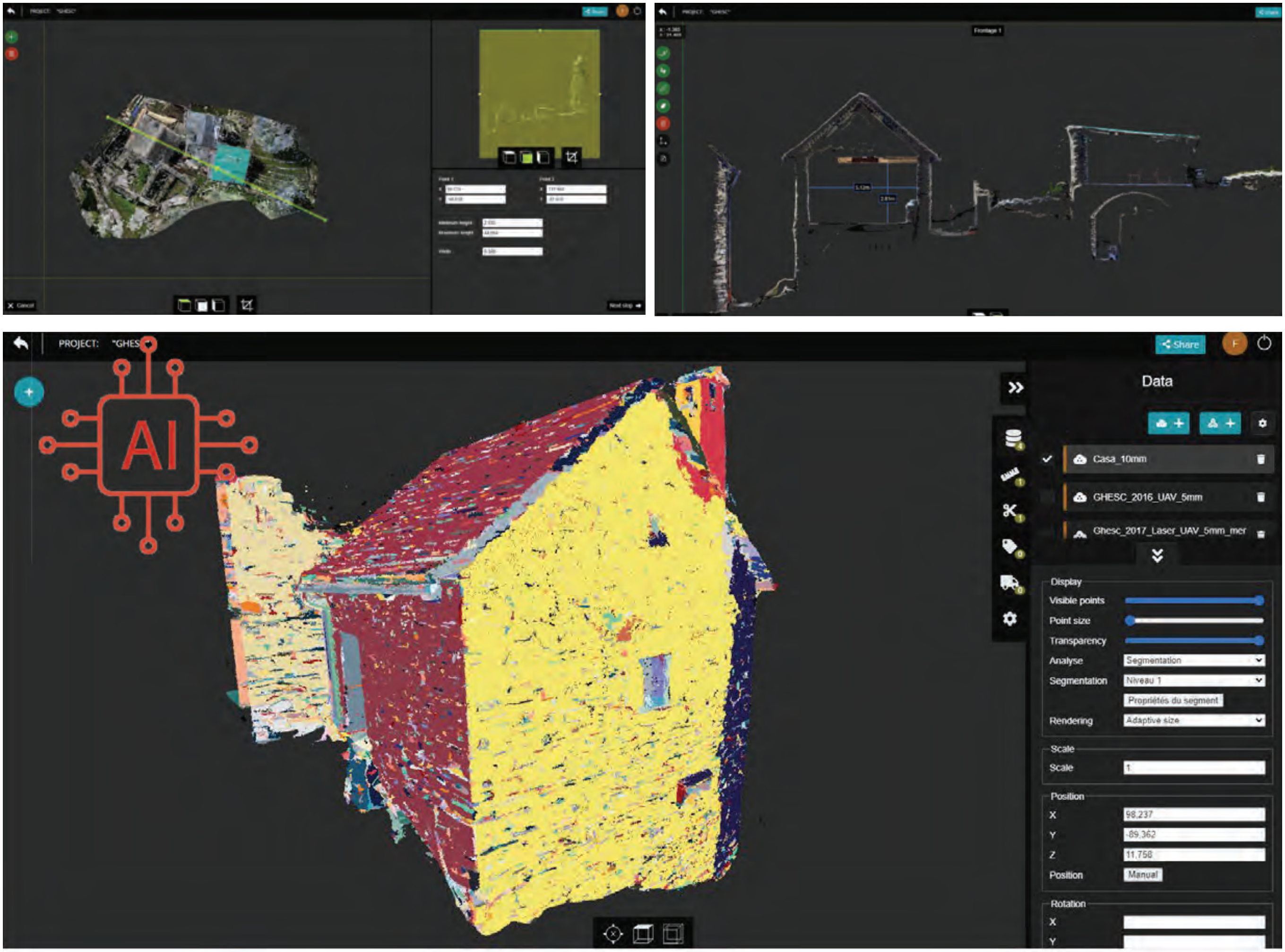

Fig. 14 – Flyvast point cloud sectioning tool and, below, flyvast automatic segmentation tool.

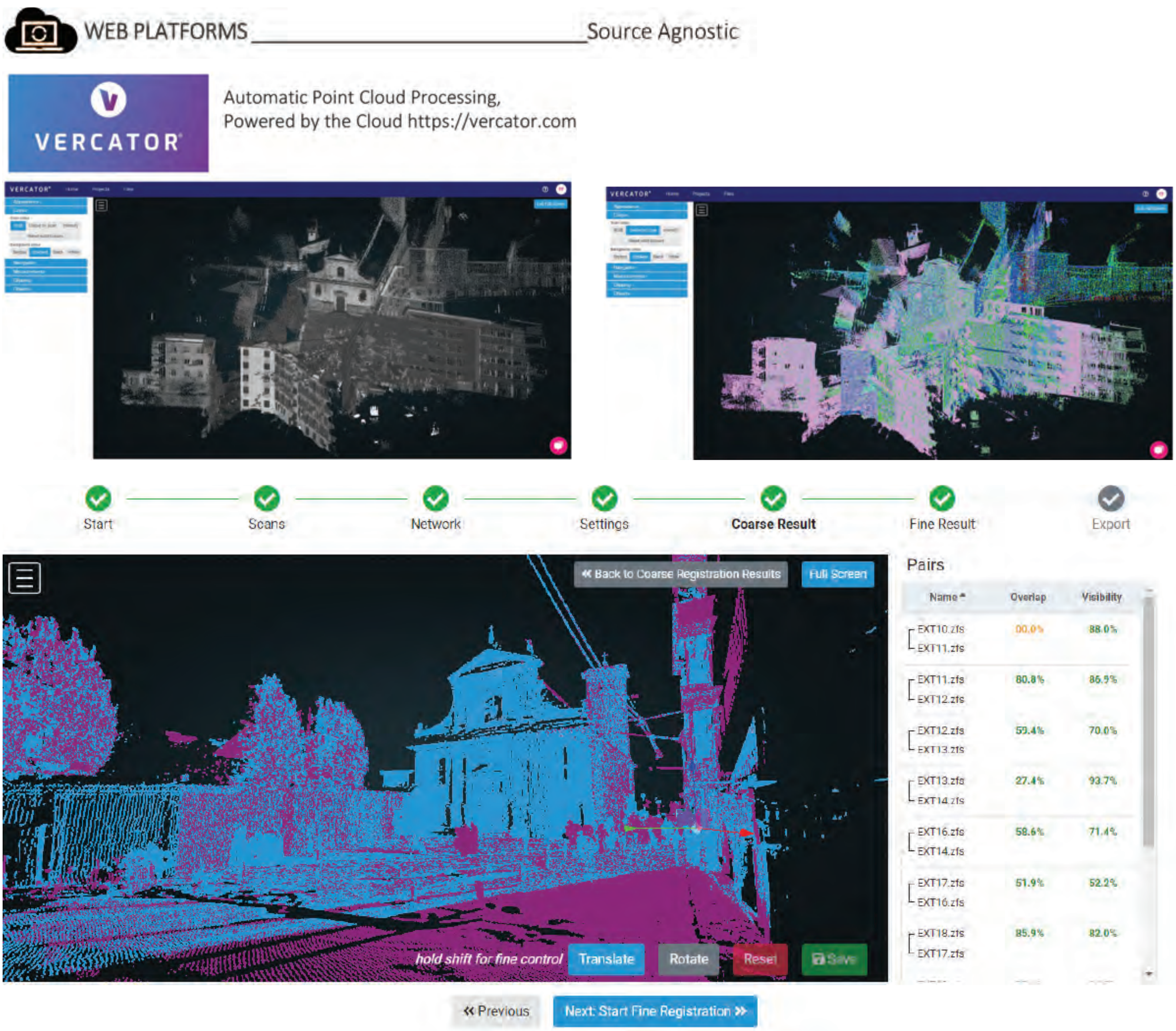

Fig. 15 – Features of the Vercator web platform.

Fig. 16 – Summary and highlights of the paper.

Conclusions

The presented critical analysis is configured as a preliminary report regarding the cloud-based platform for reality data sharing and management, revealing the following benefits (Fig. 17). The web-based approach allows workflow improvement from the digital survey to the use of its outputs collaboratively, without specific software, anywhere, anytime, and on any device.
The point cloud can be employed as a geometrical reference for attaching different forms of technical data, information, and additional analyses about the under-studied object using hotspots, annotations, and labels. This approach can be advantageous in the cultural heritage field, especially when CAD or HBIM model is unnecessary because it is not the final aim. The solution can be to skip the complex and time-consuming modeling phase altogether and use the point cloud directly as a 3D geometric base for the information repository. This strategy cannot replace geometric analysis and architectural interpretation phases but can support them and other types of structural preservation and restoration investigations.
At last, this approach offers innovative advanced tools for experiments aimed at automating specific processes (e.g., cloud registration, point cloud segmentation, classification, and change detection) by exploiting machine learning algorithms and AI strategies.

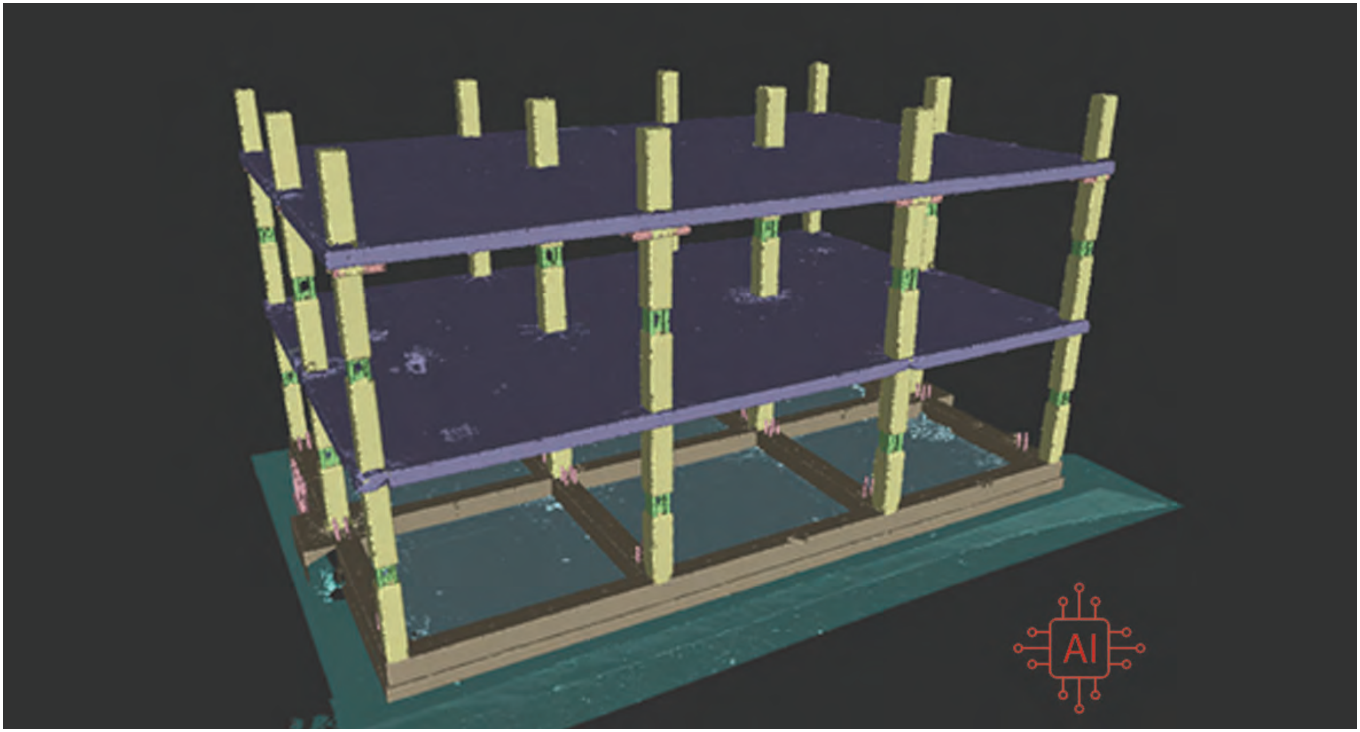

Fig. 17 – Point cloud classification.

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