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Comparative Assessment of Point Cloud Annotation Workflows for Applications in Architectural and Spatial Studies

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Abstract

Manual annotation of 3D point clouds is essential for creating high-quality datasets used in training machine learning models for semantic classification. Despite the development of various annotation tools (ranging from research prototypes to commercial platforms) their usability, functionality, and availability vary greatly depending on users’ technical expertise and the intended application. This study presents a comparative evaluation of manual point cloud annotation tools, focusing on their effectiveness for users with limited Geomatics experience, such as architecture and urban planning professionals. The research encompasses both literature-based and market-driven analyses to identify prevalent tools, including open-source, commercial, and web-based solutions. Eight selected platforms (CloudCompare, QGIS, ArcGIS Pro, Autodesk ReCap Pro, Leica Cyclone 3DReshaper, GreenValley LiDAR360, TerraScan, and Pointly) were tested on two case studies: an indoor university office and an outdoor urban area in Mantova, Italy. Tools were assessed considering usability, interface design, supported formats, classification capabilities, and required user expertise. Results highlight differences in usability and performance. The study concludes that tool selection should align with user expertise, project scale, and environmental complexity. Findings aim to support informed software choices for professionals in built heritage, architecture, and urban studies requiring reliable manual point cloud annotation solutions.

1. Introduction

Manual annotation of point clouds (i.e. manually assigning semantic labels to each point in a given point cloud dataset) plays a crucial role in generating high-quality datasets for training Machine Learning (ML) models in semantic classification tasks. However, the variety of tools available, their technical specificities, as well as the needs and skills of operators, make the choice of the most suitable solution complex.

In literature there are several annotation techniques and tools, which can be categorized as: well-designed user interfaces that enhance usability and collaboration, tools using technologies like sensor fusion and VR, and machine learning tools with varying levels of human supervision to speed up labeling (Mahony et al., 2019). In addition to what can be found in the scientific literature, there are many commercial and open-source software solutions that have been created to manage point clouds and that, among other things, allow manual annotation of points. The existing tools, both research-side or commercial, and paid or free of charge or open-source, then, can be more or less user-friendly, depending also on the capabilities and needs of the users who use them.

Within this context, the study presented here provides a systematic review of existing literature and market solutions to identify available options for manual point cloud annotation, with a particular focus on their availability, usability, and efficiency. This research categorizes these solutions based on their type, application domain, user interface, and required level of expertise. The goal is to determine which software platforms can be effectively used by domain experts in architectural and spatial studies, such as architects and urban planners, who may not necessarily have advanced technical skills in Geomatics but require reliable tools for manual annotation.

The paper is organized as follows: section 2 “state of the art” presents a systematic literature review, providing a list of existing methods and tools for point cloud data annotation; Section 3 “Test and comparison of manual annotation solution ” presents the results of the manual annotation on a test dataset performed by authors; Section 4 “discussion and conclusions” critically discusses the usability of software tested and the results of the comparison and draws out conclusions.

2. State of the Art

The annotation of 3D point clouds has evolved significantly in recent years, driven by advances in machine learning and sensor technologies. Manual point cloud classification employs several key methodologies to ensure accurate labeling of 3D data. One of the most fundamental approaches is point selection and labeling, where users manually assign class categories (e.g., buildings, trees) to individual points or clusters (Roynard et al. 2018).

Despite significant advances in automated approaches, traditional manual annotation continues to play a vital role in precision-critical point cloud processing applications. In indoor mapping scenarios, Parent et al. (2021) demonstrated the ongoing necessity of manual methods through their development of ArcGIS-based workflows that successfully classified 29 distinct safety features in building interiors, though this process demanded substantial time investment of 20-40 hours per 14,000 m² facility. Similarly, in heritage documentation, Pellis et al. (2021) presented their manually labeled datasets (point clouds and images) of historic buildings, while simultaneously emphasizing the considerable time requirements of such processes. Comparably, Matrone et al. (2020) demonstrated the value of annotated real-world data through their ArCH dataset, showing how manually labeled heritage building elements can effectively support the training of segmentation models in cultural heritage applications. Even in industrial contexts where synthetic data has made significant strides, Noichl et al. (2024) observed that manual verification remains indispensable for ensuring annotation quality in complex environments.

Despite its precision, manual classification presents notable challenges. The process is time-consuming, particularly for large-scale datasets, and requires substantial human effort, which limits scalability in applications such as point cloud semantic segmentation (Noichl et al. 2024). Furthermore, the dependency on user expertise complicates the classification of ambiguous features, necessitating rigorous training and quality control (Weidner et al. 2019).

To bridge the gap between fully manual and automated approaches, semi-automated tools like CloudCompare's CANUPO (Moyano et al. 2021) have emerged as practical solutions, particularly for handling intricate geometries. These hybrid systems combine algorithmic processing with human expertise, allowing for more efficient annotation while maintaining the precision required for specialized applications. The continued relevance of manual and semi-automated methods underscores their importance in scenarios where absolute accuracy takes precedence over processing speed, serving as a foundation against which newer automated techniques are often benchmarked.

Beyond traditional tools, there is a growing adoption of web-based platforms for point cloud annotation, like Pointly or SanE (Arief et al., 2020), which incorporate AI-assisted manual correction, providing preliminary segmentation that users can refine, reducing manual workload while maintaining accuracy. Recent research has also explored the potential of virtual reality for visualizing and annotating 3D point clouds (Fol et al. 2024) in an attempt to expedite the manual labelling of large point clouds. These tools facilitate three-dimensional interactions, enabling efficient visualization, selection, and annotation of points through consumer-grade VR controllers (Lin et al. 2024).

To overcome the persistent challenges of manual annotation, researchers proposed techniques to generate synthetic data to be used as a training dataset. In infrastructure applications, Rahman and Hoskere (2025) developed an advanced synthetic data pipeline that models bridge elements including occlusions, that are used to train models which achieve high accuracies when applied to real-world point clouds. Similarly, Noichl et al. (2024) proposed an automatic generation of realistic and semantically enriched ground truth data using surface-based sampling methods and laser scan simulation on industry-standard 3D models. While these synthetic approaches significantly reduce dependence on manual annotations, they also introduce new research challenges, particularly in ensuring the adaptation between synthetic training data and real-world deployment scenarios.

Another approach in point cloud annotation involves cross-modal transfer techniques that leverage existing 2D data to generate 3D annotations. Researchers have developed several implementations of this concept across different domains. In urban environments, Lertniphonphan et al. (2018) exploited a method to propagate labels from the KITTI object dataset to 3D point clouds through 2D-3D alignment. For post-disaster damage assessment scenarios, Kallas and Napolitano (2025) manually annotated images exploiting the Computer Vision annotation Tool (CVAT), an open source tool developed by Intel. The annotated images were used to train a Mask-R-CNN-based segmentation model, then the proposed 2D-to-3D segmentation process transfers image-based segmentation masks onto 3D point clouds. These cross-modal approaches prove especially valuable in situations where obtaining comprehensive 3D ground truth data is challenging, but substantial 2D annotated datasets already exist.

3. Test and comparison of manual annotation solution

Several software solutions could be used for manual point cloud annotation, ranging from open-source tools developed by communities or research groups to commercial products from major software companies. These tools may be designed for general point cloud processing and include classification features which are often automated but with manual editing options, or may be built specifically for classification tasks. They span various application domains, including GIS, industrial, and architectural contexts, each with its own requirements and user expertise levels. Some are desktop-based, while others are web-based, offering increased accessibility and collaboration for users with diverse technical backgrounds.

Based on a comprehensive literature review, where articles related to manual classification of point clouds were read and the software programs used in each article were listed, we identified a range of commonly employed software and tools for point cloud annotation. By integrating these findings with a market analysis, and including the software in-use by our university, we selected a representative set of solutions for testing and comparative evaluation. Commercial software solution selected for our tests included Leica 3DReshaper (www.leica-geosystem.com), Autodesk ReCap Pro (www.autodesk.com), as well as TerraScan from TerraSolid (www.terrasolid.com) and GreenValley LiDAR360 (www.greenvalleyintl.com/LiDAR360), which were mentioned by Fernandez et al. (2008). According to the bibliographical research performed, the most used software appear to be the open-source CloudCompare (www.cloudcompare.org), being used by Weidner et.al.,(2019), Nardinocchi and Esposito (2025), Bruno et. al.,(2018), and Roynard et. al.,(2018). A significant volume of software remained to be assessed, requiring a selection of a final set from among those previously found. This selection was undertaken to ascertain which commercial and web-based software offered trials, balancing the number of software types across both categories. The other software selected were QGIS (www.qgis.org) with dedicated plugins, ArcGIS Pro (www.esri.com), and a web-based platform: Pointly (www.pointly.ai).

Identified solutions were then studied according to a taxonomy that considers several criteria: (i) Type of software (open-source, commercial, web-based); (ii) Main sector of use (e.g., cartography, environmental engineering, architecture); (iii) User interface and availability (e.g., standalone, plug-in, cloud-based, web-based, level of interactivity, ease of use); (iv) Supported files format (e.g., file format to import the point clouds); (v) Available features (e.g., class implementation, manipulation capabilities, additional tools); (vi) Maximum point cloud size; (vii) Level of expertise required (e.g., need for Geomatics or informatics specific skills or intuitive use for domain experts such as architects or town planners); (viii) Export options (e.g., file format, separate classes, etc). The result of the tests are reported by Table 2.

The purpose of this comparison is to identify the most appropriate tool or software solution for a specific situation: the manual annotation of point clouds by users who are not necessarily experts in Geomatics, and, in this specific case, the work has been carried out with the help of thesis students who have done their work in the UNESCO Research lab of Politecnico di Milano university. The process involved the use of two distinct case studies: an indoor and an outdoor scenario. The two case studies were acquired using a mobile laser scanning system (MLS) (Stonex X70 GO) in Mantova, Italy. As illustrated in Figure 1, the outdoor scene was a portion of the city centre, while the indoor scene represents one room in the university building's office complex.

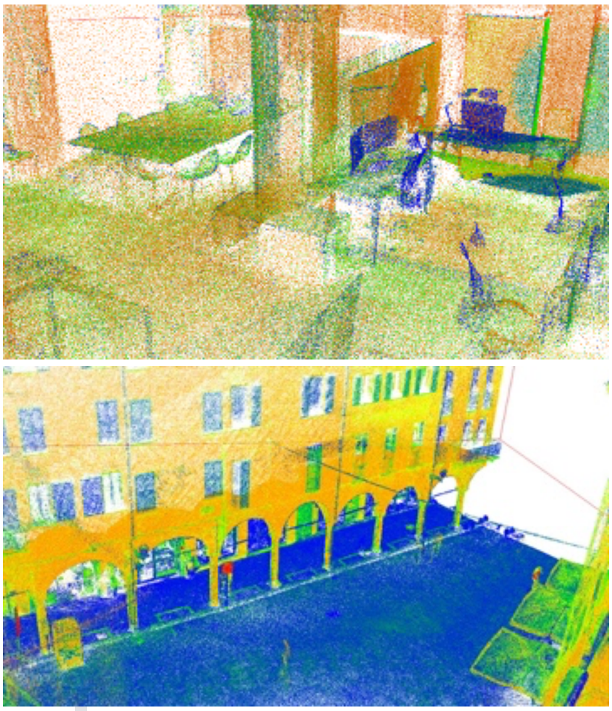

Figure 1 - Indoor scene (top, coloured as intensity, office rooms in the university building), and an outdoor scene (bottom, coloured as intensity, a portion of Mantova city centre).

To test the software, we manually classified both the scenes using distinct classes derived from the Standard LiDAR Point Classes defined by the American Society for Photogrammetry and Remote Sensing (ASPRS), which reserves classes 0 to 63 for official use, while values from 64 to 255 are available for user-defined purposes, as shown in Table 1. Each software was evaluated over a period sufficient to assess its performance and understand the basic functions, averaging 6 to 10 hours per scene, per software. However, it is possible that certain tools have been inadvertently omitted from the study, resulting in the findings being based on a limited number of hours of utilization with each software application.

Outdoor Scene	Code	Indoor Scene	Code
Unclassified	1	Unclassified	1
Building	6	Floor	64
Road surface	11	Walls and pillars	65
Sidewalk	64	Ceiling	66
Traffic signs	65	Windows and doors	67
Urban furniture	66	Furniture	68
Pedestrian	67	Electrical system	69

Table 1 - Classification categories for the case studies

3.1 Autodesk Recap Pro

ReCap Pro is a commercial standalone software normally used in the fields of architecture, engineering, and construction. The system is relatively intuitive, but it may require a period of adjustment to acclimate to its functionalities. When starting a new project users can define settings such as coordinate systems, up axis and point spacing. ReCap supports a wide range of formats (e.g. LAS, E57, RCS). According to the official website there is no limit for the file size, or the number of scans imported. It includes tools for transformation selection, visualization adjustment (e.g. RGB, intensity, elevation, normal and classification), and basic classification editing. Even though, the classification numbers are predefined, class names can be customized, just need to double click on the name. The incorporation of features such as limit boxes, the "Ctrl+Z" shortcut, and the "Unclip Last" function serves to enhance the overall usability of the software. The software demonstrates a capacity to manage substantial point clouds, making it accessible even to users with introductory proficiency. After classifying, it is simple to visualize the table with the respective classes, as shown in Figure 2.

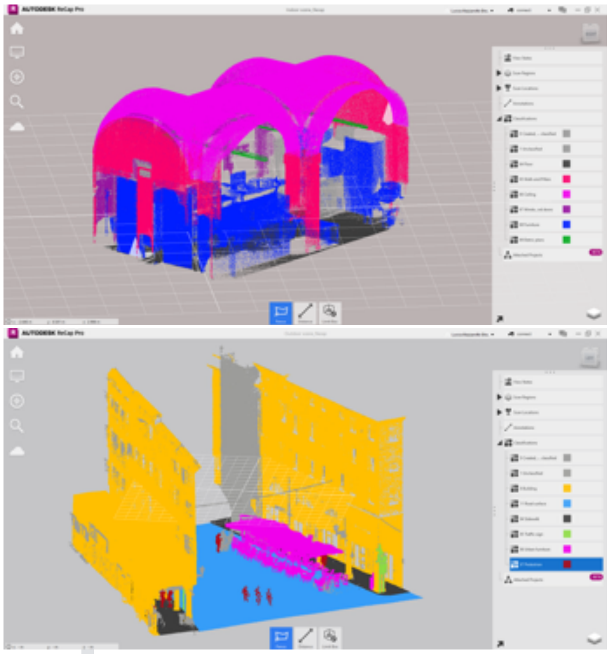

Figure 2 - Final classification in Autodesk ReCap Pro and its categories, on the left the indoor scene and on the right the outdoor one.

3.2 GreenValleey LiDAR360

GreenValley LiDAR360 is a commercial standalone software, normally used in architecture, engineering, topographic mapping, forestry survey and mine safety fields. This software supports LiData (proprietary format), LAS, ASCII, PLY, E57, and PCD files. According to the official website it is recommended to have a maximum individual LAS file size of 250 MB to optimize performance and functionality. During initial use of the Lidar360 software, it was noted that the start page presents a list of features, each linked to a video tutorial, which facilitates onboarding for users with no prior experience. Lidar360 provides advanced automatic classification tools, particularly through machine learning and deep learning algorithms. However, manual classification can sometimes be constrained and less intuitive for users.

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Software	Type of software	Sector of use	User interface and accessibility	Supported import file formats	Available features	Maximum point cloud size	Level of expertise required	Supported export file formats
Autodeks Recap Pro	Commercial	Architecture, Engineering, Construction	Standalone; Intuitive interface.	CL3, LAS, RDS, E57, PTG, PTS, XYZ, TXT, ZFS, etc.	Basic editing: rotate, visualize, classify, switch views, Undo, and "unclip last", Classification editable by renaming predefined classes.	No limit on number of scans or total size	Beginner (basic users can operate)	E57, PTS, RCP/RCS
Lidar360	Commercial	Surveying, Mapping, Forestry, Engineering	Standalone, Startup is easy, but classification tools are challenging.	LiData, LAS/LAZ, ASCII (.txt, .xyz, .csv, etc.), PLY, E57, PCD	Robust ML/DL classification options; Manual classification is limited.	Max LAS file recommended: 250MB	Beginner to intermediate	LiData, LAS/LAZ, ASCII (.txt, .xyz, .csv, etc.), PLY, E57, PCD
TerraSolid	Commercial	Geospatial, Engineering, City Modeling	Plugin-based (SPATIX or MicroStation), challenging to be used.	LAS, LAZ, FASTBINARY, SCAN8/16TOPEYE, EARTHDATA, GeoTIFF,	Manual classification using "clipper by polygon" and "classify inside fence." Color classes editable via hidden menu. Hard to isolate small details .	No official limit stated	Advanced users only	LAS, LAZ, ASCII, FASTBINARY, etc.
Cloud Compare	Open Source	Architecture R&D, Industry, Urban Planning	Standalone, Lacks autosave and undo. Limited hiding clipping box tools.	LAS, E57, STL, OBJ, PLY, FBX, SHP, DXF, Photoscan,	Classification via "Add Constant SF" and manual segmentation, Requires creating and naming DB Tree groups, Color-coded views need merging clouds.	Theoretical limit ~2 billion points per cloud	Beginner to intermediate	LAS, LAZ, E57, BIN, STL, OBJ, FBX, PCD, SHP, etc.
Leica 3D Reshaper	Commercial	Surveying, AEC, Tank Inspection	Standalone, Smooth workflow once learned, UI gets intuitive with use.	ASCII (.xyz, .csv), PTS, PTX, STL, LAS, LAZ, DXF, ZFS, E57, etc.	Manual and automatic classification, "Explode by class", UCS creation.	Handles several billion points	Beginner to intermediate	ASCII, NSD, LAS/LAZ, DXF, IGES, E57, etc.
Pointly	Online Platform	Urban Planning, Autonomous Vehicles, Construction	Standalone, dependent on internet connection quality. Simple intuitive UI	LAS, LAZ	Automatic segmentation, 3D bounding box, Easy to customize classification labels	15 million points for free account. Unlimited for paid account.	Basic level	LAS, LAZ
QGIS (from version 3.42)	Open Source	Land Management Environmental Sciences, Agriculture, Transportation	Standalone, Challenging, UI for non experts	Shapefiles, GeoJSON, KML, GeoPackage, DXF, PostgreSQLPostGIS, SQLite/SpatiaLite, MySQL, GeoTIFF, PNG, JPEG, DEM LAS/LAZ	Easy to customize classification labels, Polygon selection tool. LAS files are converted to COPC to work	No official limit stated	Intermediate to Advanced	LAS/LAZ, GPKG, SHP, DXF, CSV, GeoTIFF, etc
ArcGIS Pro	Commercial	Land Management Environmental Sciences, Agriculture, Transportation	Standalone, Understandable UI with enough practice	LAS, LAZ	Automatic ground and building classification, Multiple selection tools, Profile Views	Not oficial limit, but there is a display limit for clouds above 4M points	Advanced	LAS, LAZ, ASCII

Table 2. List of all the software solutions tested for the presented study. The Table also present for each software the various comments for each criteria used within the comparison.

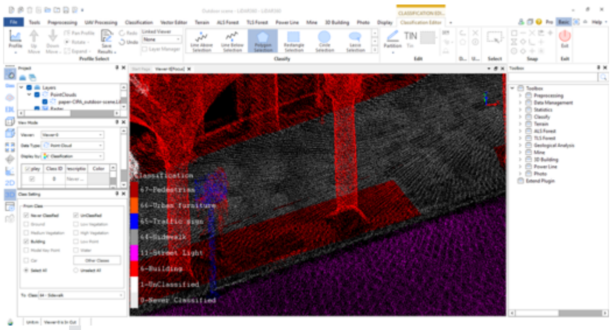

Figure 3 - Lidar360 interface and use of the tool “Classification Editor” to improve the classification.

The recommended workflow entails the initial utilization of the "Classify ground by selected" function, followed by the refinement of errors through the "Classification Editor”, as demonstrate in Figure 3. However, it remains challenging to conceal components of the point cloud, and the software often selects all underlying points, including those that are not visible, indicating a primary design for aerial data that lacks support for layered structures (such as the tested indoor scene). The absence of features such as "undo" and the constrained class ID editing capabilities, beginning at 39, contribute to diminished precision in meticulous manual tasks could influence the level of precision in careful manual tasks.

3.3 TerraScan

TerraScan from TerraSolid is a commercial software, the classification task could be performed by a plugin that runs within Spatix (www.spatix.com), which is free, or with Bentley MicroStation (www.bentley.com/software/microstation), which is a commercial software. TerraSolid sector of uses are surveying, engineering and geospatial industries. TerraScan has its own file type called FASTBINARY, but also allows users to import other files (e.g. SCAN8, SCAN16, TOPEYE, EARTHDATA, LAS). This software presents challenges for less experienced users. The configuration process necessitates additional installations, and the Spatix interface could be difficult to navigate. Manual classification requires a series of steps, including the establishment of a clipper polygon in Spatix and the subsequent application of classification through the "inside fence" tool in TerraScan. This process could be enhanced by tools such as clipping boxes or other straightforward methods for concealing portions of the point cloud. While the software allows for selective reclassification using “from-to” parameters, providing useful control over category-specific edits, as shown in Figure 4, it has limited abilities to isolate or navigate into the interior of the point cloud structure, making precise point selection in complex or occluded regions very challenging. As with Lidar360, the software selects points across all layers, including hidden ones, which further limits precision in detailed editing. The reason behind this issue could be linked to the primary usage of this software with aerial data. Although class categories can be edited via a hidden menu, the workflow could be very challenging for not-expert users. A benefit of this software is its capacity to adjust selections while performing zoom and pan operations. Nevertheless, since isolating specific areas can be challenging, manual classification tends to take more time and may be more susceptible to occasional errors.

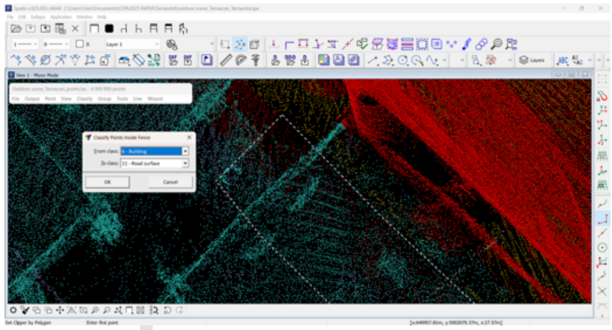

Figure 4 - TerraScan running on Spatix software. Demonstration of the reclassification of a portion of the point cloud using the tool “Classify Points Inside Fence”.

3.4 CloudCompare

CloudCompare (Figure 5) emerged from the bibliographic analysis as one of the most used open-source software. Its main sectors of use are architecture, engineering, urban planning and industrial automation. The supported formats allowed in this software is similar to others, permitting -among the others- files as LAS and E57. There is no limit for file size, but the maximum number of points per point cloud is two billion. The classification process tested required the segmentation of the point cloud followed by an incorporation of a constant scalar field equal to class value. This procedure then must be executed with consistency throughout the classification process. The segmentation phase directly modifies the point cloud itself, and the organization of different classes requires the manual creation of groups in the DB Tree (database tree) and the subsequent dragging of segmented point clouds into these groups. The software does not provide the functionality of an active clipping box for the purpose of concealing portions of the cloud, making more complex the execution of precise selections. However, users can adjust the rotation pivot point at will, facilitating navigation during the classification process. Furthermore, the visualization of distinct classes in colour may require the user to consolidate of all segmented clouds. Furthermore, since edits apply to whichever point cloud is currently selected (and in the process you may have many segments) it requires constant attention to selection. Although there is some flexibility, these factors may make achieving precision and fluidity in complex classification tasks more challenging

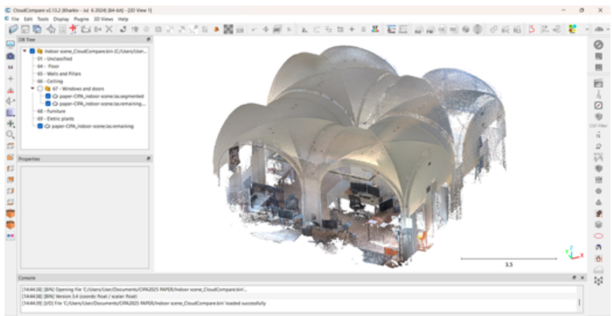

Figure 5 - CloudCompare interface; an initial classification procedure an be seen in the DB Tree on the left.

3.5 Leica Cyclone 3D Reshaper

The commercial standalone software Leica Cyclone 3D Reshaper is normally used in architecture, engineering and construction (AEC) sector. It presents a relatively user-friendly interface with both manual and automatic classification options accessible via the "Clean" tab. When initiating a project, users can immediately adjust point cloud density and measurement units, improving manageability. A notable feature is the "explode by class" function, which allows users to isolate and visualize individual categories after classification, facilitating refinement. It allows to visualize the point cloud in perspective view and adjust selection areas by expanding, editing nodes, and refining boundaries, as demonstrated in Figure 6, and after a portion of the point cloud is selected it is possible to rotate all of it and edit the size of the selection in any direction. Some challenges are related to custom clipping, as slices are initially aligned with the default view rather than architectural elements, and although users can define a custom coordinate system (UCS) using tools like "floor + wall" or "wall + wall," slice orientation cannot be freely rotated. For complex scenes, especially indoors, visibility is hindered without creating a clipping volume. The best workaround is to define a "limit box" within the "Clipping Group" panel, which can be edited side by side to better control the classification scope. During manual classification, users can also edit selections before finalizing them, allowing for more detailed and precise point choices. While the platform becomes moderately intuitive with use, certain features which may affect visual efficiency during classification may be implemented. On a positive note, the ability to move the view during selection supports smoother navigation during manual editing, offering an advantage over some other tested tools.

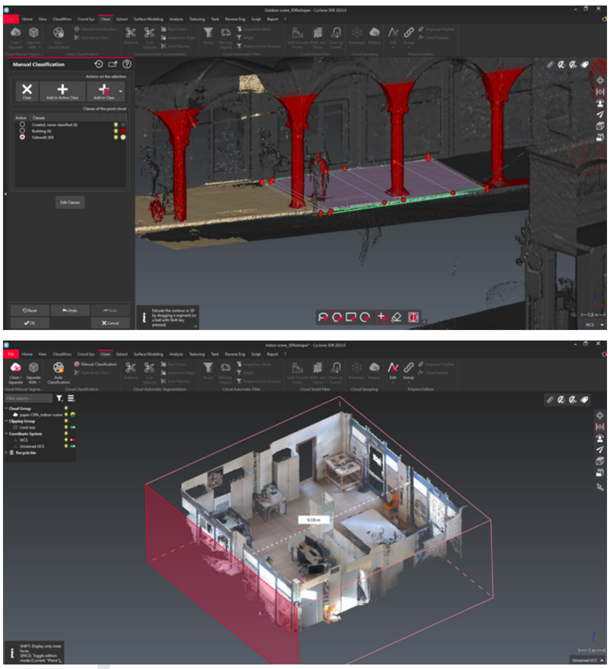

Figure 6 - Cyclone 3DR interface and modification of the selection before finalizing it (left); editing the limit box (right).

3.6 Pointly

Pointly is a cloud-based software designed for automated point cloud classification and 3D data processing. It is used in fields such as urban planning, autonomous vehicles, and construction, offering an intuitive interface supported by short video tutorials for each step. Users begin by creating a catalogue with predefined or custom classification labels before uploading the files (it supports LAS and LAZ formats, with a free tier limit of 15 million points). Since the platform operates online, processing speed depends on internet connectivity. The software includes essential tools for rotation, selection, visualization adjustment, and basic classification editing, along with user-friendly features like limited visualization boxes and undo shortcut, which improves workflow efficiency. Focused exclusively on point cloud classification, Pointly has interesting tools, particularly with its pre-segmentation feature, which significantly accelerates the labelling process (Figure 8). However, since it specializes in classification rather than broader point cloud manipulation, users may require additional software for advanced editing or analysis tasks. The platform's cloud-based nature ensures accessibility but also means performance varies with internet speed.

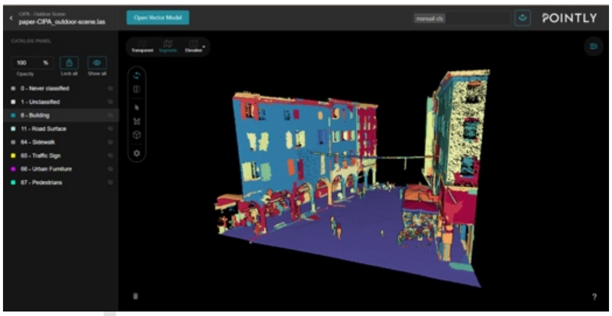

Figure 8 - Pointly interface and automatic segmentation.

3.7 QGIS

QGIS, a free and open-source Geographic Information System (GIS) software, also allow for the manual classification and editing of point clouds since version 3.42. It is used, among other sectors, for land management, environmental sciences, agriculture and transportation. The process in this software presents several challenges. First, the user interface (in specific, the 3D map view) can be intricate for new users, requiring a more advanced level of expertise to navigate effectively. Additionally, the software necessitates converting .las files to .copc format, adding an extra step to the workflow. The selection tool offers limited options, which not only interferes with precision but also complicates the selection of individual points. Furthermore, users may encounter difficulties when attempting to "enter" the point cloud, making the classification of interior scenes particularly challenging. The absence of other manipulation tools, such as clipping boxes, further restricts functionality and efficiency. These operational boundaries collectively hinder the software's usability, particularly for those without extensive experience in point cloud processing.

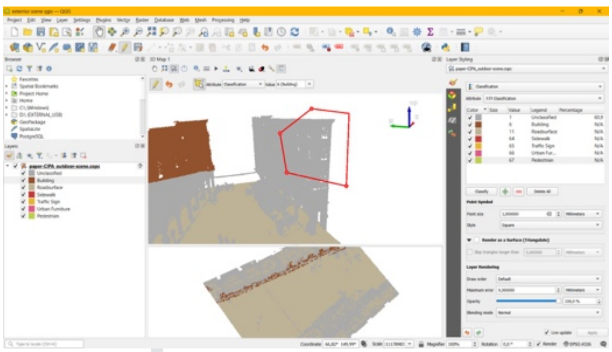

Figure 9 - QGIS workspace and selection tool

3.8 ArcGIS Pro

ArcGIS Pro is a commercial GIS platform. Within our tests it presented challenges when processing 3D point clouds, particularly in complex indoor environments. A first complication is the difficulty in manipulating the view, which complicates navigation and precise adjustments, especially in occluded or confined spaces. While users can create profile views, as seen in Figure 10, which helps with occlusions, their controls are sometimes not immediately clear or user-friendly. Additionally, the software’s interface poses navigational challenges, and the available online resources may be insufficient for users with limited prior experience. Another significant complication is the rendering delay that occurs each time a new classification is applied to a selection. While this delay may be minor in simple scenes, it accumulates in more intricate environments requiring extensive segmentation time, ultimately slowing workflow efficiency. To compensate, users could try to use their automatic ground and building classification and refine the errors but, for example, in our tests there was trouble getting the software to correctly identify the buildings in the outdoor scene. Additionally, some stability issues were noted during indoor scene processing, where the software occasionally crashed, resulting in longer task completion times. The automatic recovery feature in ArcGIS was especially helpful in preserving data; however, the frequency of these interruptions may warrant further attention.

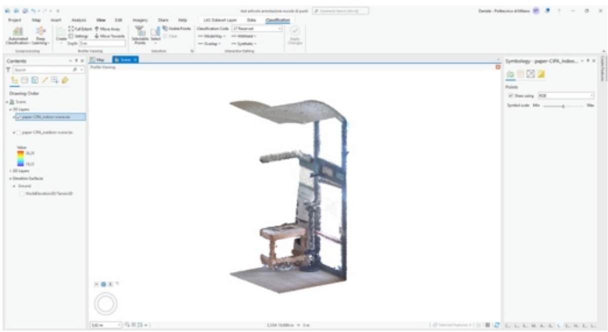

Figure 10. ArcGIS profile viewing tool

4. Discussion and conclusions

This study systematically evaluated multiple point cloud classification software solutions, categorizing them according to a defined taxonomy that considered software type, sector of use, user interface, supported file formats, available features, scalability, required expertise, and export capabilities. The selection methodology prioritized solutions with strong academic citations (e.g., CloudCompare appearing in 5+ significant studies) alongside tools actively used in the market, ensuring the evaluation balanced theoretical relevance with practical applicability. The evaluation was conducted using two distinct case studies - an indoor office environment and an urban outdoor setting - captured via mobile laser scanning (Stonex X70 GO).

Among commercial solutions, Autodesk ReCap Pro demonstrated large dataset management, supporting unlimited point counts while maintaining stable performance. GreenValley LiDAR360 showed good results in automated classification but revealed significant challenges in manual refinement workflows. On the other hand, other software, such as TerraScan, QGIS, and ArcGIS Pro, showed similarities in the use of manual classification tools, with some challenges related to the type of scene expected (probably aerial LiDAR data), where advanced 3D navigation of the data and very precise selections are not extremely necessary. Leica Cyclone 3DReshaper offered interesting visualization tools, including its "explode by class" feature, though its slice-based clipping system proved less intuitive for complex structures. The open-source software CloudCompare confirmed its academic popularity through extensive customization options and format support, though its technical interface presented a complicated learning curve for non-specialists. The cloud-based Pointly platform was notable with its pre-segmentation feature reducing manual effort. However, its web-based nature introduced latency issues with the datasets especially with low performance internet connections, and the absence of advanced editing tools requires the use of other software if the operations to be performed go beyond simple data classification.

This comparative analysis highlights the inherent trade-offs between automation and precision across the evaluated tools. Commercial packages, often optimized for productivity, tended to limit high specific control, whereas open-source alternatives offered more flexibility at the cost of operational efficiency. A consistent limitation observed was the lack of standardized occlusion handling; in fact, most tools struggled to accurately isolate interior structures, particularly within the indoor case study.

User expertise emerged as a decisive factor in tool usability. Some software environments demanded advanced, domain-specific knowledge, while others were more approachable for users with moderate experience. As the tester of this study were architecture students engaged in master’s thesis work, they encountered varying degrees of usability: some platforms posed significant challenges, while others proved more accommodating. These disparities are reflected in each software’s individual description previously presented.

Ultimately, this analysis underscores the importance of aligning software choice with project scale, user expertise, and environmental complexity. Such alignment is essential for optimizing outcomes and provides a valuable foundation for informed tool selection in both academic and professional settings. Annotation tools, in particular, remain central to spatial analysis workflows and must be selected with careful attention to user needs and project demands.

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