

SCAN-TO-BIM EFFICIENT APPROACH TO EXTRACT BIM MODELS FROM HIGH PRODUCTIVE INDOOR MOBILE MAPPING SURVEY

SIMONA ROGGERI¹, GIORGIO PAOLO MARIA VASSENA¹, LAVINIA CHIARA
TAGLIABUE²

¹*Dept of Civil Environmental Architectural Engineering and Mathematics, University of
Brescia, Brescia, Italy*

²*Dept of Computer Science, University of Turin, Turin, Italy*

Building Information Modeling represents one of the most interesting developments in construction fields in the last 20 years. BIM process supports the creation of intelligent data that can be used throughout the life cycle of a construction project. Where a project involves a pre-existing structure, reality capture can provide the most critical information. The purpose of this paper is to describe an efficient approach to extract 3D models using high productive indoor Mobile Mapping Systems (iMMS) and an optimized scan-to-BIM workflow. The scan-to-BIM procedure allows reconstructing several elements within a digital environment preserving the features and reusing them in the development of the BIM project. The elaboration of the raw data acquired from the iMMS starts with the software HERON[®] Desktop where a SLAM algorithm runs and a 3D point cloud model is produced. The model is translated in the Gexcel Reconstructor[®] point cloud post processing software where a number of deliverables as orthophotos, blueprints and a filtered and optimized point cloud are obtained. In the proposed processing workflow, the data are introduced to Autodesk ReCap[®], where the model can be edited and the final texturized point cloud model extracted. The identification and modeling of the 3D objects that compose the BIM model is realized in ClearEdge3D EdgeWise[™] and optimized in Autodesk Revit[®]. The data elaboration workflow implemented shows how an optimized data processing workflow allows making the scan-to-BIM procedure automatic and economically sustainable.

Keywords: Existing building digitalization, iMMS, Digital transition, Automation in modeling procedure.

1 GENERAL APPEARANCE

Survey represents the first and most important step in the investigation process of an existing building. Nowadays, new technologies and tools are replacing traditional topographic surveys, which allow an accurate analysis and measurement of the geometry of the buildings (Rocha and Mateus 2021). The level of accuracy of these new techniques guarantees the achievement of detailed information related to the existing building and components, which can be exploited through the Building Information Modeling (BIM) methodology (Rocha and Mateus 2020, Bassier *et al.* 2016). BIM enables a quick and connected workflow through all the phases, optimizing design and business processes with multiple benefits (Sanhudo *et al.* 2020, Esfahani *et*

al. 2021). Therefore, BIM optimizes project planning by combining reality capture and real-world data to generate contextual models of the existing built and natural environment (Wang and Kim 2019, Rebolj *et al.* 2017). The paper aims at presenting the result of a tested efficient approach to extract 3D models from high productive indoor Mobile Mapping Systems with a reliable and time saving process that can be replicable in different application use cases where the process is required and a geometrical recognition is concerned.

2 METHODOLOGY

The adopted scan-to-BIM procedure allows reconstructing various elements within a digital environment preserving the main features and enabling the reuse for the development of a complete BIM model. In Figure 1, the research workflow is presented with the instruments and software adopted for supporting such procedure.

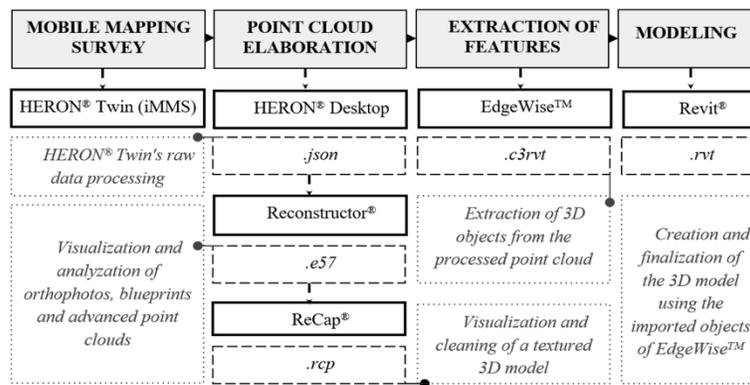


Figure 1. Surveying and data processing workflow.

The post-processing of the raw data acquired from the iMMS is performed with the software HERON® Desktop and then exported in Reconstructor®. In HERON® Desktop the raw data coming from the Lidar sensors, from the IMU and from the camera are managed using an advanced SLAM (Simultaneous Localization and Mapping) algorithm to produce a 3D point cloud. The point cloud is then translated in the Reconstructor® virtual environment where the point cloud is georeferenced, filtered and deliverables such as orthophotos, blueprints and the final point cloud are produced. Autodesk ReCap® is used to edit the point cloud and subsequently the textured 3D model is exported. This step is crucial to guarantee that the 3D point cloud model is in a correct .rcp format. The following step is the exploitation of EdgeWise™ to run the scan-to-BIM process and to export the 3D objects from the point cloud model. The results are imported into Autodesk Revit® where with the BIM authoring tool the 3D model of the surveyed building is finally obtained. Frequently due to the costs and timing of the rigorous 3D scan-to-BIM procedure, the 3D model is obtained by extruding elements from the orthophotos, obtained during the data processing missing a precise survey recognition and modelling process.

3 CASE STUDY

The scan-to-BIM workflow proposed in figure 1 has been applied to the survey of a case study, the level zero of the Department of Civil Engineering Environment Territory Architecture and Mathematics (DICATAM) building of the University of Brescia, using a double Lidar sensor portable mobile mapping system, namely HERON Twin® (HERON® Desktop Software 2021,

Marotta *et al.* 2021). This SLAM-based scanner is easy to use and to transport, it is equipped with a light rugged backpack that allows the transportation, and it can be used as capture head support during the mapping phases. HERON[®] enables a real time viewing, directly displayed on the touch-screen control unit, of the mapping trajectory and of the measured 3D point cloud. The panorama RGB images are acquired automatically at 15Hz in Full Resolution and on surveyor's request at 5K.

4 RESULTS

4.1 Data Elaboration

The process that transforms the raw data into a point cloud is composed by six different phases, which are here listed: a) Importation, b) Odometer, c) Create Maps, d) Global Optimization, e) Clean Data and f) Export. The result is a 3D point cloud model, characterized by a local accuracy and resolution of 2 cm and a global accuracy, if control points are used, of 3 – 4 cm. It is worthy to note how a BIM model have been obtained using a mobile device instead of a more commonly adopted TLS (Terrestrial Laser Scanner) approach. With this method, a dynamic procedure can be empowered and a quick survey of the geometry can be imported as point cloud information.

4.1.1 Point cloud creation through HERON[®] Desktop

The software HERON[®] Desktop extracts the point cloud model from the raw data acquired on the field. This software merges LIDAR data and the 5K or full HD panoramic images and harvests reference points. The software uses a SLAM algorithm to extract the surveying trajectory minimizing the drift effects using a “3D Virtual Scan” patented algorithm. As result it is possible to define the final point cloud model, as shown in Figure 2.

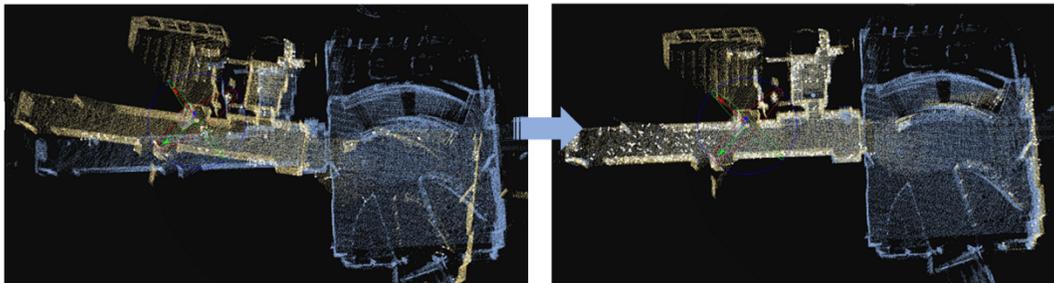


Figure 2. A phase of the HERON[®] Desktop Point clouds alignment.

4.1.2 Post processing of the point cloud with Reconstructor[®]

Reconstructor[®] is a point cloud post processing software, fully compatible with HERON Desktop[®] and used to filter, visualize, resampling, editing and colorized the point cloud model produced by HERON Desktop[®]. In Reconstructor[®] several products are extracted, as Orthophotos, Blueprints, represented in Figure 3, and the point cloud model from HERON can be combined and aligned with point clouds and scans coming from the various sensors, with different resolution and accuracy. A remarkable output is the fly-through tool that can provide a walkthrough experience with distances and areas definition capabilities. In Reconstructor[®] cross sections and isolines maps can be produced and volumes computed; moreover, the point cloud can be exported in the most common file formats. In the present case study, a point cloud in the

standard .e57 format has been exported in order to create the model of one floor of the department building where lecture rooms, teaching laboratories and the library are located.



Figure 3. Reconstructor® Blueprint on the left; Walkthrough navigator tool on the right.

4.1.3 Data cleaning of the point cloud in ReCap®

The point cloud in the .e57 format has been then translated into Autodesk ReCap® where the data has been edited and undesired parts of the model removed, in order to create a clean and essential point cloud, as shown in Figure 4, that will be later used to generate the final 3D BIM model. This phase of data cleaning is essential to guarantee the faultless compliance of the standard format .rcp on the final point cloud generation.

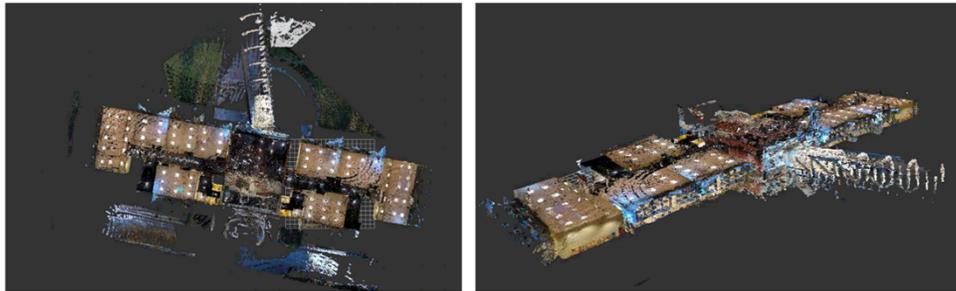


Figure 4. ReCap® Point cloud.

4.2 Data Extraction

As the final point cloud data is elaborated, it is possible to perform the last step of the scan-to-BIM process, namely the features extraction from the data in order to deploy the 3D BIM model. The key result of this process is that throughout the described workflow it is possible to extract an accurate model of the surveyed site directly starting from the survey developed by mobile mapping tool, characterized by a detailed local accuracy of 2 cm.

4.2.1 Automatic information and objects extraction through EdgeWise™

ClearEdge 3D EdgeWise™ is a sophisticated software, running on Autodesk Navisworks, designed to automatically extract proper information and objects from point clouds. After importing the .rcp file exported from ReCap®, it is possible to automatically recognize objects, organize the data thus obtaining the BIM model. The results of the modelling phase can be straightforwardly verified and corrected; missing objects can be effortlessly added, as shown in Figure 5.

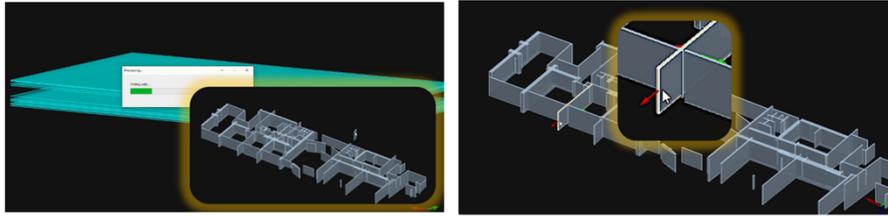


Figure 5. EdgeWise™ Level setting (left) and walls dimensions and correction of the position (right).

4.3 Data Modeling

As soon as all the manual adjustments have been implemented into the model, it is possible to find out discrepancies between model and point cloud, by comparing the point cloud geometry with the walls extraction. In Figure 6 the result obtained for the zero level is shown. The model is finally exported as .c3rvt file format.

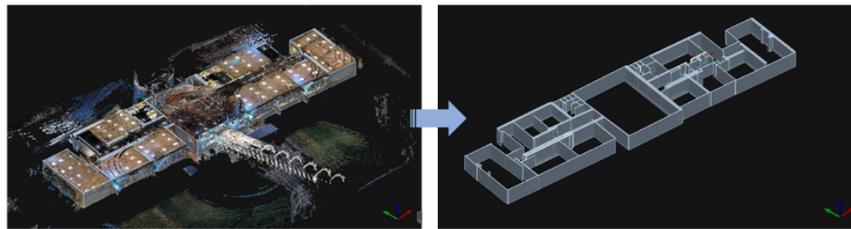


Figure 6. EdgeWise™ translation of the point cloud in a 3D model.

4.3.1 BIM modelling by authoring tool Autodesk Revit®

Autodesk Revit® is adopted to define the final BIM model. Hence, the 3D models, plans, sections, elevations, legends, and schedules are interconnected, automatically updated in the views and organized in a shareable among multiple users database (DB). Revit® allows supporting, in the same platform, multidisciplinary projects. The .c3rvt file exported from EdgeWise™ is translated in Revit® where it is possible to visualize and manage all the objects recognized in the previous phase. This process is direct, as the mere manual process to perform is to define the levels and connecting them to the Revit ones, in order to recognize properly the walls.

5 DISCUSSION AND CONCLUSIONS

In the described procedure the BIM model have been obtained using a mobile device instead of a traditional TLS approach. The possibility of using mobile LiDAR instrumentation to extract a BIM model represents a primary remarkable level of efficiency. In fact, the use of TLSs (Terrestrial Laser Scanners) is time consuming and thus it is generally not applicable except in particularly important applications. The scan-to-BIM approach is currently applied in the construction and real estate sector, mainly in building renovation projects, where to develop a project with a 3D BIM approach and the measurement of the existing three-dimensional model is central. The indoor mobile mapping systems approach represents an effective alternative, not specifically to the TLS method, which is, due to costs and long timing of data acquisition and processing, frequently positioned out of the market, nevertheless rather to the traditional systems as low-cost portable laser distance meter which have the drawback of low accuracy. In that case,

the obtained plant view is the starting point for a process of manual extraction of the 3D model in a CAD environment. The field test also demonstrated how the use of advanced software tools can handle with great effect the operation of extracting the parametric model from the point clouds. In order to reach the result of a reliable BIM model, all the post processing phases must be managed with specific attention. In particular, the automatic scan-to-BIM process, if correctly supervised, can produce the needed results with respect of time and sustainable costs of the modelling procedure. Exact consideration is required, in the modeling procedure, for example, to the dimensions of specific elements: in the analyzed structure (Figure 7) the thickness of the walls has been checked and imposed in the processing phase. The supervised approach appears to be able to reduce the timing of the process of more than 70% with a evident and dramatic improvement in the process efficiency.



Figure 7. Autodesk Revit® 3D model and visualization.

A correct supervised, semi-automatic Scan-to-BIM process, from mobile data, can be successfully implemented and it is more productive and reliable of the frequently adopted approach based on the 3D BIM model extraction from plant views. On the other hand, some limitations of efficiency still exist. In particular, the process of the correction and validation of the model created automatically by the software must be carried on by an expert operator with a good knowledge of the surveyed site. Therefore, now it is strongly recommended that the operator who manages the Scan-to-BIM process coincide with the operator or the surveyor.

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