Proceedings of International Structural Engineering and Construction, 9(1), 2022
State-of-the-art Materials and Techniques in Structural Engineering and Construction
Edited by Holschemacher, K., Quapp, U., Singh, A., and Yazdani, S.

ISSN: 2644-108X
www.doi.org/10.14455/ISEC.2022.9(1).Ref_ID

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

SIMONA ROGGERI[1], GIORGIO PAOLO MARIA VASSENA[1], LAVINIA CHIARA TAGLIABUE[2]

[1]*Department of Civil Environmental Architectural Engineering and Mathematics, University of Brescia, Brescia, Italy*
[2]*Department 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 various elements within a digital environment preserving all 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 algorithms runs and a 3D point cloud model is produced. The model is moved in the Gexcel Reconstructor® point cloud post processing software where several deliverables are obtained as orthophotos, blueprints and a filtered and optimized point cloud. In the proposed processing workflow, the data are moved to Autodesk ReCap®, where the model is 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 that an optimized data processing workflow allows to make the scan-to-BIM more automatic and economically sustainable.

Keywords: Scan-to-BIM, Existing Building digitalization, iMMS, Digital transition, Automation in modeling procedure.

1 GENERAL APPEARANCE

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

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 & Kim 2019, Rebolj et al. 2017). The aim of this paper is to present the result of a studied efficient approach to extract 3D models from high productive indoor Mobile Mapping Systems with a reliable and time saving process nevertheless advanced machine leaning procedures and techniques are now applied in this field (Lee et al. 2020, Bhadaniya et al. 2021, Perez-Perez et al. 2021).

2 METHODOLOGY

The scan-to-BIM procedure that has been used allows reconstructing various elements within a digital environment preserving all the features and reusing them in the development of the BIM project. In Figure 1 the research workflow is presented with the instruments and software included.

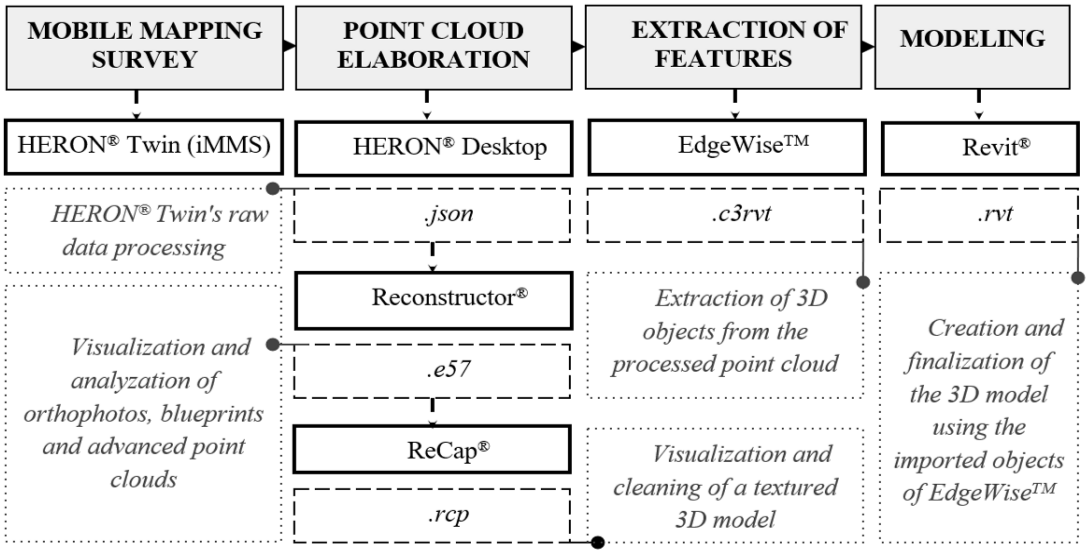

Figure 1: Surveying and data processing workflow.

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 moved in the Reconstructor® where the point cloud is georeferenced, filtered and some deliverables produced as orthophotos, blueprints and the final point cloud. The point cloud is moved to Autodesk ReCap®, where the point cloud is edited and textured 3D model exported. This step is very important to guarantee that the 3D point cloud model is in a correct .rcp format. EdgeWiseTM is used to run the scan-to-BIM process where and to export the 3D objects from the point cloud model. The results are moved to Autodesk Revit® where with Authoring tool the final 3D model of the surveyed building is obtained. Often 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.

3 CASE STUDY

The scan-to-BIM workflow applied in the present paper starts with the survey of a case study building using a double Lidar sensor portable mobile mapping system, namely HERON Twin® (Marotta et al. 2021). This SLAM-based scanner is easy to use and to transport and equipped with a light rugged backpack that can be used both for transportation and as capture head support during the mapping phases. HERON® allows viewing, in real time, directly displayed on the touch screen control unit, the mapping trajectory and 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 synthesized: Importation, Odometer, Create Maps, Global Optimization, Clean Data and Export. The final 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 interesting to highlight how a BIM model have been obtained using a mobile device instead of a TLS approach.

4.1.1 *HERON® Desktop*

The software HERON® Desktop extract the point cloud model from the raw data acquired on the field. This software merge LIDAR data and the 5K or full HD panoramic images and harvest reference points. The software uses a SLAM algorithm to extract the surveying trajectory minimizing the drift effects thanks to a "*3DVirtual Scan"* patented algorithm. As final result the final point cloud model, as shown in Figure 2.

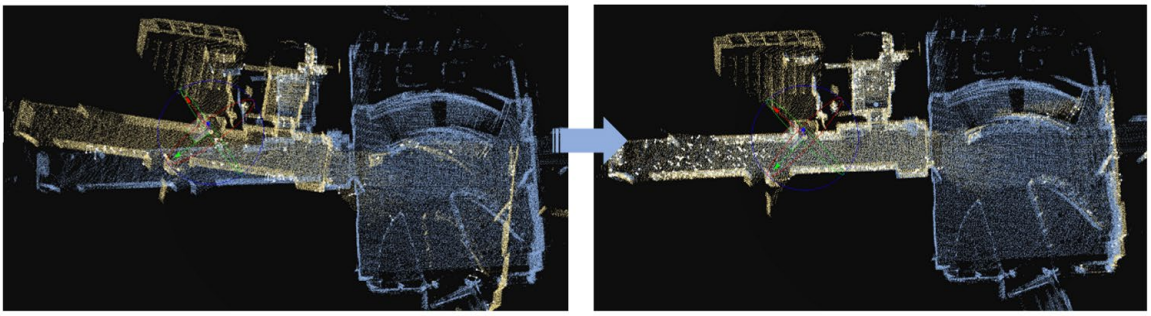

Figure 2: A phase of the HERON® Desktop Point clouds alignment.

4.1.2 *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 most various sensors, with different resolution and accuracy. An interesting output is the fly-through tool that can provide a walkthrough experience with distances and areas capabilities. In Reconstructor® cross sections

and isolines maps can be produced and volumes computed. From Reconstructor® the point cloud can be exported in the most common formats. In particular in this case study (the level zero of the Department DICATAM of the University of Brescia), a point cloud in the standard .e57 format has been exported.

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

4.1.3 *ReCap®*

The point cloud in the .e57 format are now moved in Autodesk ReCap® where the data are edited and several undesired part of the model removed, in order to create a clean and essential point cloud, shonw in Figure 4, that will be later used to create the final 3D BIM model. This phase is also very important to guarantee the perfect respect of the standard .rcp format on the final point cloud generation.

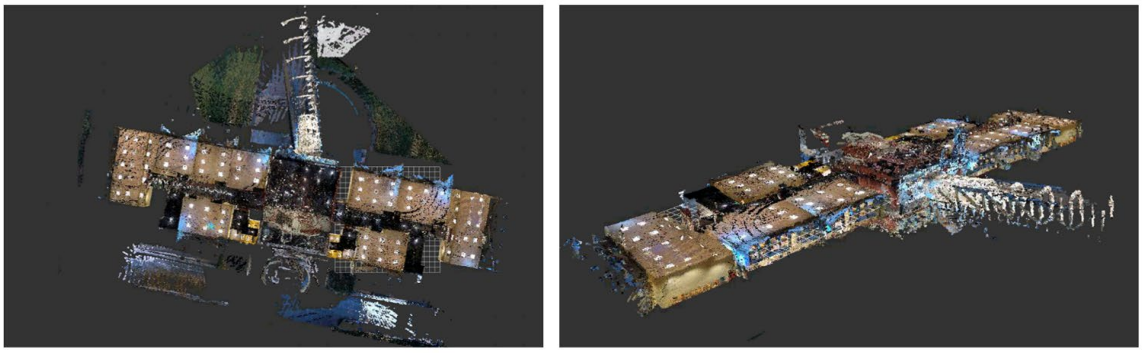

Figure 4: ReCap® Point cloud.

4.2 Data Extraction

As the final point cloud data is elaborated, it is possible to start the last step of the scan-to-BIM process: extraction of features from these data in order to create a 3D BIM model. The interesting result is that with the simple workflow described it is possible to extract an accurate model of the site starting from a mobile mapping instruments, characterized by local accuracy of 2 cm.

4.2.1 *EdgeWise™*

ClearEdge 3D EdgeWise™ is a 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 so obtain in the way to produce a BIM model. The results of the modelling phase can be easily verified and corrected; missing objects can be easily added, as in Figure 5.

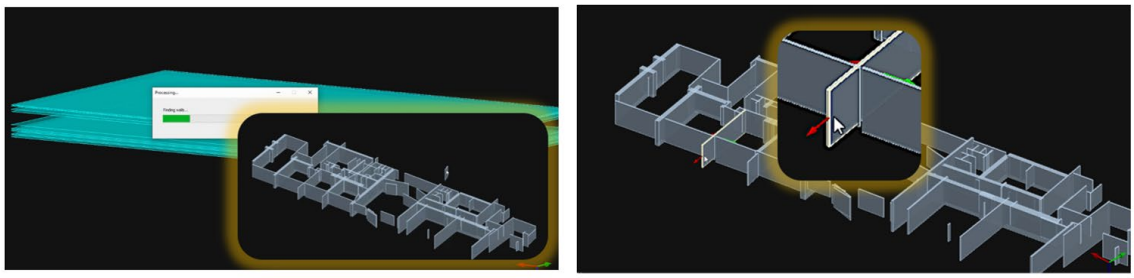

Figure 5: EdgeWise™ Level setting (left) and walls dimensions and position correction (right).

4.3 Data Modeling

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

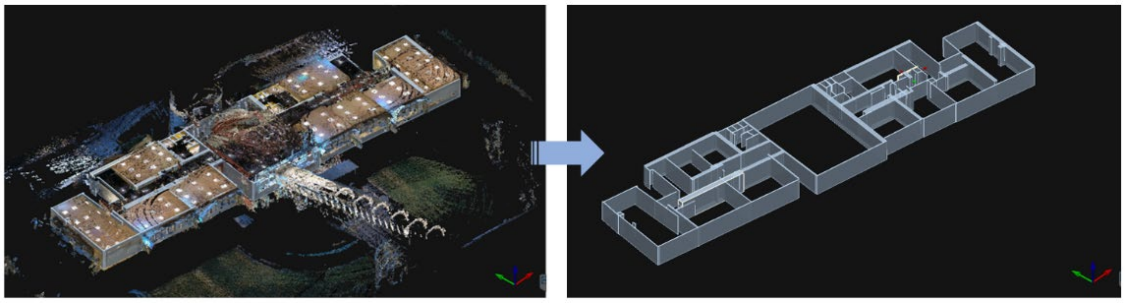

Figure 6: EdgeWise™ translation of the point cloud in a 3D model.

4.3.1 Autodesk Revit®

Autodesk Revit® is applied to create the final BIM model. 3D models, plans, sections, elevations, legends, and schedules are all interconnected, and automatically updated in the views and organized in a DB that can shared among multiple users. Revit® allows to support, in the same platform, multidisciplinary projects. The .c3rvt file exported from EdgeWise™ is moved in Revit® where it is possible to visualize and manage all the objects recognized in the previous phase. This process is immediate, as the mere manual process to perform is to insert levels connecting them to Revit ones, in order to recognize the walls properly.

5 DISCUSSION AND CONCLUSIONS

It is interesting to highlight how a BIM model have been obtained using a mobile device instead of a TLS approach. The possibility of using mobile LiDAR instrumentation to extract a BIM model of the building from the point cloud represents a first interesting level of efficiency. In fact the use of TLSs (Terrestrial Laser Scanners) is so time consuming that is generally not applicable except in particularly prestigious 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 the measurement of the three-dimensional model of the existing is indispensable. The indoor mobile mapping systems approach represents a valid alternative, not so much to the TLS one, which, due to costs and timing of data acquisition and processing, are often positioned out of the market, but rather to the traditional systems of limited accuracy as low cost portable laser distance meter. The so obtained plant view of the site 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 such as ClearEdge 3D EdgeWise™ can they can handle with great effect the operation of extracting the parametric model from the point clouds. To reach the results, of a reliable BIM model, all the post processing phases must me managed with 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. Particular attention is required, in the modeling procedure, for example, to the dimensions of some elements. In the analyzed structure (figure 7), for example, the thickness of the walls has been checked and imposed in the processing phase. The "supervised" approach, which contemplates a first automatic modeling process followed by a man driven model correction, appears to be able to reduce the timing of the process of more than 70%.

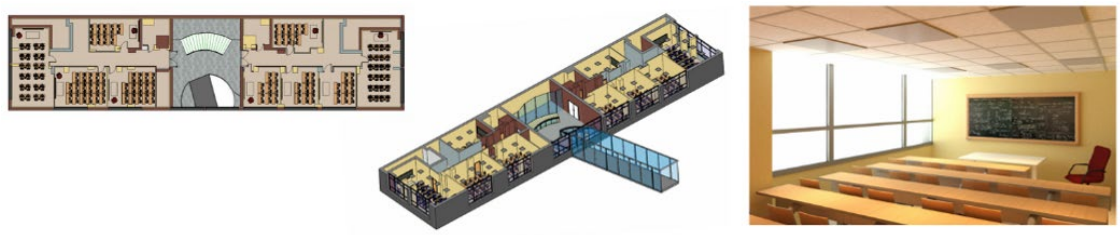

Figure 7: Autodesk Revit® 3D model and visualization.

A correct supervised, semi-automatic scan-to-BIM process, from mobile data, can be successfully implemented and is more productive and reliable of the often approach based on the 3D BIM model extraction from plant views. On the other hand, cannot be hidden away that efficiency problems still exist. In particular the process of correction and validation of the model created automatically by the software must be carried on by an operator having a good knowledge of the site. Therefore, at the moment it is strongly recommended that the technician who governs the scan-to-BIM process coincide with the one involved in the surveying work.

References

Bassier, M., Hadjidemetriou, G., Vergauwen, M., Van Roy, N., & Verstrynge, E. *Implementation of Scan-to-BIM and FEM for the documentation and analysis of heritage timber roof structures*. In Euro-mediterranean conference (pp. 79-90). Springer, Cham, 2016, October.

Bhadaniya, P., Reja, V. K., & Varghese, K. *Mixed Reality-Based Dataset Generation for Learning-Based Scan-to-BIM*. In International Conference on Pattern Recognition (pp. 389-403). Springer, Cham, 2021, January.

Esfahani, M. E., Rausch, C., Sharif, M. M., Chen, Q., Haas, C., & Adey, B. T. *Quantitative investigation on the accuracy and precision of Scan-to-BIM under different modelling scenarios*. Automation in Construction, 126, 103686, 2021.

Lee, J. H., Park, J. J., & Yoon, H. *Automatic bridge design parameter extraction for scan-to-BIM*. Applied Sciences, 10(20), 7346, 2020.

Perez-Perez, Y., Golparvar-Fard, M., & El-Rayes, K. *Scan2BIM-NET: Deep Learning Method for Segmentation of Point Clouds for Scan-to-BIM*. Journal of Construction Engineering and Management, 147(9), 04021107, 2021.

Marotta, F., Teruggi, S., Achille, C., Vassena, G.P.M., Fassi, F. Integrated Laser Scanner Techniques to Produce High-Resolution DTM of Vegetated Territory. Remote Sens. 13. https://doi.org/10.3390/rs13132504, 2021.

Rebolj, D., Pučko, Z., Babič, N. Č., Bizjak, M., & Mongus, D. *Point cloud quality requirements for Scan-vs-BIM based automated construction progress monitoring*. Automation in Construction, 84, 323-334, 2017.

Rocha, G., Mateus, L., Fernández, J., & Ferreira, V. *A scan-to-BIM methodology applied to heritage buildings*. Heritage, 3(1), 47-67, 2020.

Rocha, G., & Mateus, L. *A Survey of Scan-to-BIM Practices in the AEC Industry—A Quantitative Analysis*. ISPRS International Journal of Geo-Information, 10(8), 564, 2021.

Sanhudo, L., Ramos, N. M., Martins, J. P., Almeida, R. M., Barreira, E., Simões, M. L., & Cardoso, V. *A framework for in-situ geometric data acquisition using laser scanning for BIM modelling*. Journal of Building Engineering, 28, 101073, 2020.

Wang, Q., Guo, J., & Kim, M. K. *An application oriented scan-to-BIM framework*. Remote sensing, 11(3), 365, 2019.