Error Assessment of Point Cloud and BIM Models to Actual Works

Sy Tien Do, Hiep Hoang, and Dat Ho Quang Che

Abstract 3D Laser Scanning technology is being widely applied in the construction industry 4.0 for promoting the digitalizing and BIM modeling procedure, also called Scan-to-BIM. Scan-to-BIM technology helps to capture the continuously existing condition of the project and construct a BIM model in just a short period of time, also, update and store the data of the project throughout construction stages. Scan-to-BIM technology could, however, entail many risks if the users cannot control the errors of the point cloud model and BIM model. Although point cloud collected by 3D laser scanners has high accuracy, there are mistakes during Scan-to-BIM process, which cause errors. Therefore, the 3D BIM model based on the point cloud contains errors of dimension, coordinate, position, and these errors could cause difficulties for construction project management engineers and make the BIM model meaningless. This paper presents the causes of the errors, also analyzes and evaluates the errors of Scan-to-BIM process by the methodology of comparing point cloud and BIM models with physical objects to control the errors and support the next step of using the VR, AR, and MR. The data used in the paper is obtained from a real project which applies Scan-to-BIM technology to verify the theory.

Keywords 3D laser scanning · BIM · Scan-to-BIM · Point cloud · Error assessment

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1 Introduction

Nowadays, 3D Laser Scanning technology obtained by laser scanners is becoming a common practice due to the demand for high accuracy in construction work, especially in project management. Documenting as-is conditions of sites and generating BIM model in just a short time conducted by Scan-to-BIM technology is an improvement in project management. Many sites all over the world are using this technology in quality control and quantity control. In Vietnam, Scan-to-BIM is also a potential technology, being adopted at several projects in recent years.

Nevertheless, there are inadvertent mistakes during Scan-to-BIM process, which cause errors. Hence, the 3D BIM model formed by the point cloud contains errors of dimension, coordinate, position, causing obstacles for construction project management engineers and make the BIM model unusable. One of the most important reasons for the deviation is the lack of a particular error assessment method to verify the completeness and accuracy of the data for each phase.

The following qualities should be spotted in a good quality-assessment (QA) method. To begin with, on the basis of project requirements, the method itself should enable the assessment of the accuracy and completeness of the statistics as well as the model. The compulsory level to which the model's details and accuracy should be might be determined by the end uses of the BIM. Moreover, receiving instant outcomes while the project is in progress can be advantageous. Early identification of potential mistakes can also allow such errors to be fixed. Figures, for instance, can be amassed again with different scanning devices, should there be a detection of a calibration error. Furthermore, it is necessary to trace the sources from which those errors appear to address the issue urgently. Finally, a QA procedure is deemed good when it is user-friendly and offers efficiency in time and resource requirements.

In this article, an error assessment process will be offered using both comparison algorithm in a computer program for Phase 1: Quality control for Point Cloud Data, Phase 2: Quality control for 3D BIM Model compare to Point Cloud Data, and physical measurement comparison for Phase 3: Quality control for 3D BIM Model compare to physical object. This paper also points out the causes of the errors, finds solutions, and gives some instructions in order to diminish the deviation as optimal as possible. This article will support further studies on the Error Assessment of Scan-to-BIM process in the future.

2 Literature Review

In recent years, there have been many suggestions for evaluating the quality of the Scan-to-BIM process. The physical measurement method is one of the simplest approaches to control the quality of 3D Laser Scanning process explored by Cheok and Franazsek for the QA of as-is 2D/3D building plans. Although this approach is effective in identifying modeling issues, assessing comprehensively the model's

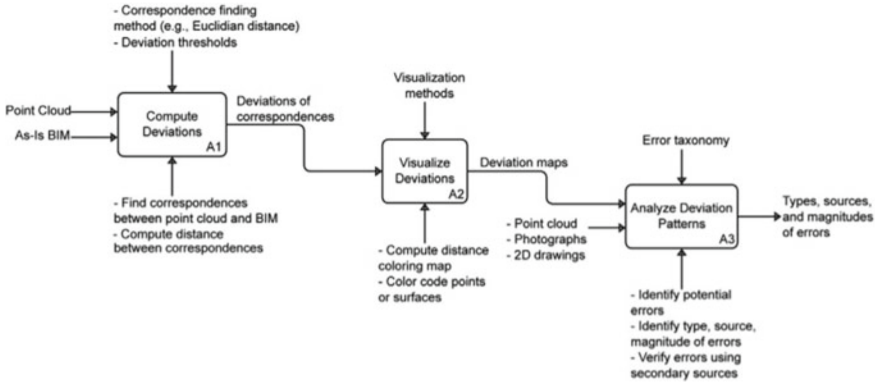


Fig. 1 The deviation analysis method of Engin Burak Anil et al. (2013)

quality is challenging and consuming an enormous of time because it will establish a direct comparison between the model and the physical measurements [1, 2]. Afterward, Tang et al. [3], and Anil et al. [4] introduced the deviation analysis method using correspondence finding method and visualization methods as a way of assessing the quality of as-is BIMs generated from the laser-scanned point cloud data (Fig. 1). The deviation analysis method is capable of recognizing almost six times more errors with more than 40% in time-saving compared to the physical measurement method in the analysis results. However, the current implementation of the deviation analysis method is limited in differentiating errors happening in the plane of the component surfaces [3, 4].

On the aspect of scanning method and quality control, the study of Thu et al. [6] had good potential to exploit scanning technology to civil engineering however they cannot clarify and solve the difference, deviation, and errors to actual work caused by the process [5, 6]. Quality control was also studied by Quang et al. [7] brought many advantages of laser scanning in construction supervising, but the accuracy of the process was not reliable. Based on the workflow for the Scan-to-BIM process suggested by Quang et al. [7], there are three phases needed to be focused on: Digital Terrain Modeling, Creating Model, and Creating BIM Model [7]. In our research, both the physical measurement method and the deviation analysis method will be applied to control the errors for each phase.

3 The Error Assessment Method

The given flowchart (Fig. 2) depicts information about assessing errors throughout three phases namely in Point Cloud Data, in 3D Model vs. Point Cloud Data, and 3D Model vs physical object.

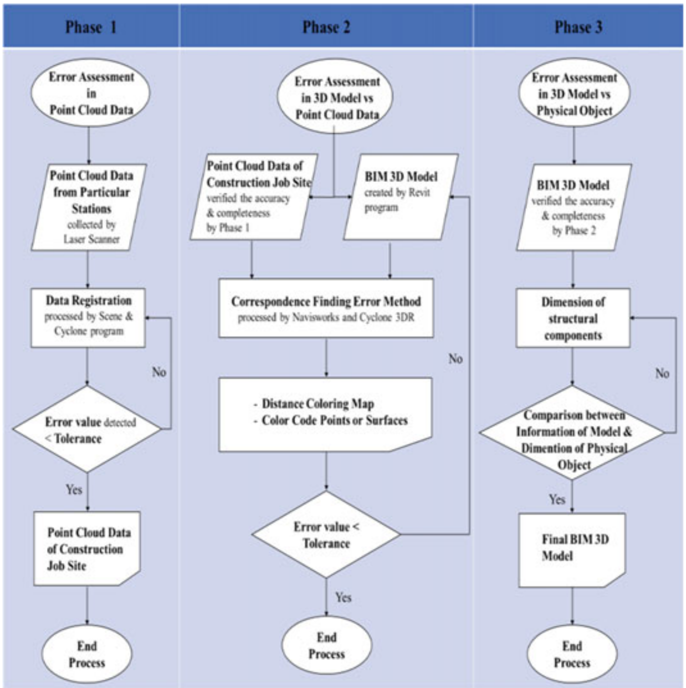


Fig. 2 Error Assessment suggested for Scan-to-BIM process

First and foremost, phase 1 presents the error assessment in Point Cloud data. To be more specific, Point Cloud Data from Particular Stations will conduct the evaluation with the aid of Laser Scanner in gathering the errors. Then, the Data Registration will be processed by the Scene and Cyclone program. At this point, if the Error value detected is not accepted, it will be processed again in the last step. However, if the error value is tolerated, it will be transferred to the Point Cloud Data of Construction Site which is also the end of this process.

In phase 2, the errors accumulated from phase 1 will be evaluated in either Point Cloud Data of Construction Site, which verified the accuracy and completion by phase 1, or BIM 3 M Model created by Revit. The data from both of the previously mentioned will experience a Correspondence Finding Error Method processed by Leica 3DR (Fig. 3), followed by an assessment of Distance Coloring Map and Color Code Points or Surfaces. Similar to phase 1, if the error value is acceptable, it will then be carried on in phase 3. Or else, those errors will go back to the first state of the ongoing phase.

Phase 3 illustrates how the output from phase 2 is evaluated in 3D Model vs. physical object. Once their accuracy and completeness have been verified, those errors will undergo the dimension of structural components. During the comparison between Information of Model and Dimension of physical object, unless those errors are qualified, they will be transferred back to the last period. Those successfully

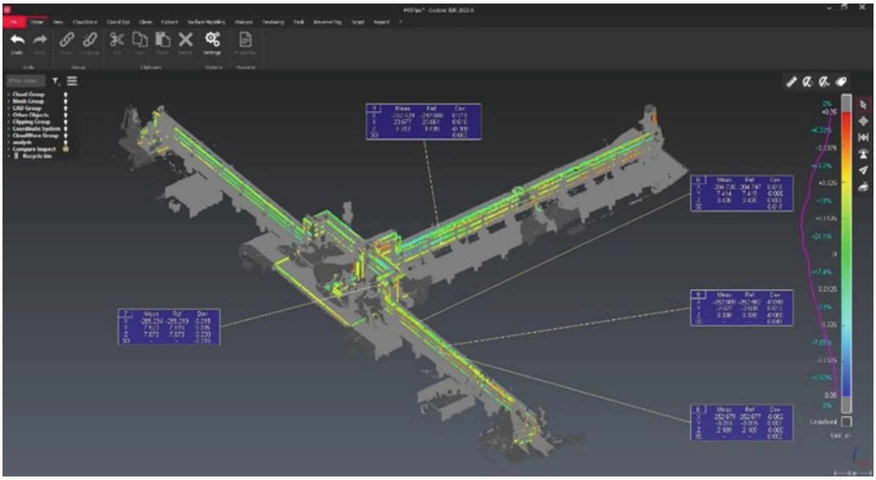


Fig. 3 Error assessment in Phase 2 conducted by 3DR program

passing processes will become the Final BIM 3D Model which is also the conclusive result (Fig. 4).

4 Error Category

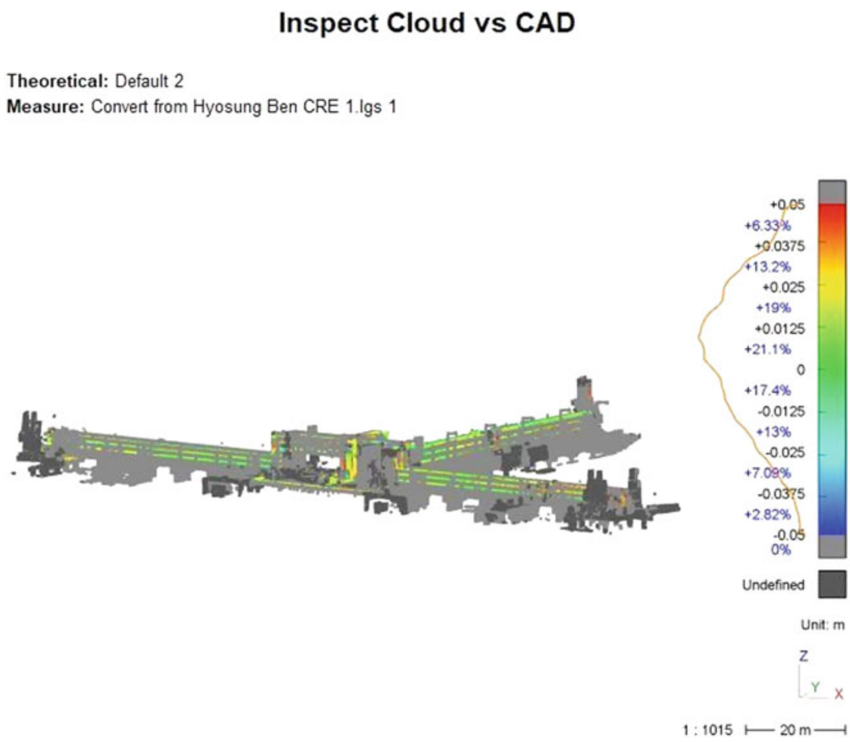
Categories and types of error are as shown in Table 1

Error of scanner (1). The first factor which affects the accuracy of the 3D scanning process is the specification of a scanner. The quality and density of the point cloud depend on the type of scanner, and user setting.

Out of field of view (2). When an object is out of a field of view of projector and camera, it is difficult to gather the point of scanning object's digital file [8]. So, it is clear that proper selection of camera and projector is essential for the field of view and scanning with accuracy.

Environment interference (3). The high temperature could affect the directional ray of the laser scan. Furthermore, during the scanning process, multiple moving or stand-still obstacles could intercept the scanning ray and cause an error in the process. The error of Scan to BIM process. From the point cloud, the modeling engineer creates models using Autodesk Revit. By drawing the model, there are errors, inevitable, existing during the process because of the level, skill of the engineer.

Software problem (4). When the scanning process is completed, the points are synchronized among different stations to create a finished point cloud. To optimize, the process is analyzed and linked automatically using algorithms and



id	name	Meas X (m)	Meas Y (m)	Meas Z (m)	Ref X (m)	Ref Y (m)	Ref Z (m)	Dev X (m)	Dev Y (m)	Dev Z (m)	Dev 3D (m)	Tol- (m
5	Label #5	-252.60924	-2.6267	3.33776	-252.56162	-2.63913	3.33802	-0.04762	0.01243	-0.00026	0.04922	-0.
6	Label #6	-252.67904	-3.01444	2.1093	-252.67707	-3.01504	2.10945	-0.00196	0.00059	-0.00014	0.00206	-0.
7	Label #7	-285.23441	7.62025	7.67273	-285.21898	7.61552	7.67274	-0.01544	0.00473	-0.00001	-0.01615	-0.
8	Label #8	-284.7281	7.41362	3.42582	-284.74667	7.41945	3.42579	0.01857	-0.00583	0.00003	0.01946	-0.
9	Label #9	-292.62863	23.6772	3.31155	-292.84807	23.06127	3.41989	0.21945	0.61593	-0.10834	0.66277	-0.

Fig. 4 Error Assessment in Phase 3 when comparing BIM Model to physical object conducted by 3DR program

applications. The error of the finished point cloud completely depends on the calculation of them. Therefore, developing algorithms and apps will determine the accuracy of the model [8].

Table 1 Categories and types of error

Phase	Category	Type	Error
Collecting point cloud	1. Error of scanner	Type of scanner	Point density and accuracy
		User setting	
	2. Out of field of view	Range of scanner	Point density and accuracy
	3. Environment interference	Heat	Inconsistent ray
		Fog and dust	Disturbed
		Black and shining object	Missing point
		Crystal object	Scattering
		Experience and skill	Missing point
Building model	4. Software problem	Software	Point cloud model accuracy
		Experience and skill	Model accuracy

5 Solutions and Discussions

5.1 Solution

Based on the problems and results gathered from the workflow interviewing some expert individuals, and on-field experiments, there are many solutions to control the error of the model. As the product specifications cannot be modified, the best way to downgrade the error is to focus on the improvement of the scanning procedure and limit the influence of the environment.

Error of scanner (1). The scanner has its specification: distance measurement, laser class, field on view, range, speed, resolution, and most importantly for this article is the accuracy. Therefore, choosing the appropriate scanner decide the quality and accuracy of the point cloud. Furthermore, the 3D scanner also required proper calibration to produce accurate results. By calibration, the process scanner provides more precise data using a standard calibration plate as the specification.
Out of field of view (2). Laser scanners have scan mode options that adapt to a variety of situations. Understanding the actual condition of the site and selecting the appropriate scan mode improves the quality of the point cloud model. For example, the Leica RTC360 scanner has 3 selectable settings (3/6/12 mm@10 m) with a range of up to 130 m and 2,000,000 pts/sec [10], depending on the type of construction.

Environment interference (3). Choosing the proper time to scan is important because the impact of environmental temperature could affect the error. The operating temperature should be from 18 °C to 30 °C [9] to avoid the scanning ray not being direct.

Software problem (4). For each 3D scanner, it is highly recommended using software and application developed by its own company because it is optimal and data synchronization. The software has its algorithm, and this could decide the precision of the point cloud and BIM model, by choosing the proper software could improve the accuracy of the model.

Besides, it also depends on the level and experience of the modeler. This leads to the required high-quality modeling engineer training.

5.2 Discussion

To the 3D Laser scanning and Scan to BIM process, it is highly required that the product, which is the digital 3D model, as the same as possible to the actual work, and with the development of 3D scanning technology, that requirement became possible.

With the development of technology and in a specific situation like the COVID-19 pandemic, using 3D scanning, scan to BIM the construction, work is helpful and easier in management, information storage.

Scanning for Point Cloud is a time-consuming operation and requires a high budget to have a proper, high-quality scanner. In milestone, this technology brings many benefits, effectiveness, and time-saving. Future research will improve technology more accurately, less time, and decrease cost. With the development of AI, the future scanner could optimize the process, disturbance handler, and saving time.

Creating as-built BIM from Point Cloud includes a serious manual process, which is subject to a personal flaw, thus raising the economical of processing. It also suffered a high cost because it takes a long period. Currently, commercially available BIM tools are not able to publish from the point cloud to the BIM model, this could lead to errors cause by human. Future research or development should focus on automatically create a BIM model.

No standard process is established to determine the proper process with a particular setting needed to meet the required level of detail for different environments and objects to be modeled. The current practice in the industry in this regard is driven by the client's requirements, the higher requirement the higher cost it takes. A worldwide set of standards or specification need to be researched to define the level of detail and required accuracy for the laser scanning operation. This is another crucial area that future research should focus on.

The finished product of this process is the BIM model. This product is applied for further technology like virtual reality (VR), augmented reality (AR), or mixed reality (MR) to create an easier way to the management and quality control. Therefore, error assessment among 3D scanning to Point cloud to BIM model and actual work is necessary. If the point cloud or BIM model contains too much error, the process is meaningless and these errors could cause many problems in practical application. Furthermore, this technology could help maintain, preserve ancient places or heritages with the highest accuracy.

6 Conclusion

Combining two methods and triple checks for the error assessment help to increase the reliability of the final BIM 3D Model. In addition, this suggested process will be conducted in a shorter time and give more comprehensive assessments for the deviation occurring in the Scan-to-BIM process. In other words, the combined method is more effective in the domain requirements of timely, detailed, and thorough quality assessment of the point cloud data and BIM model.

However, this process suggested in this paper has some limitations. This study clarifies some of the problems that 3D laser scanning and Scan to BIM usually suffer. We have studied, researched, and operated 3 different types of scanners, scanning an actual work, analyzing the preliminary point cloud, and build a model using applications. Although we have carried out many experiments, been trained, and studied from other research, we cannot carry out the solutions. Besides, we have given proof that it can improve the process and how much it is better by calculating, comparing it with the actual work. Despite the software and algorithms supporting the process, it still has many errors because of subjective causes during manual modification in some parts of the process. Furthermore, due to limited time, some of the information and documents are restricted this study was only conducted at the level of general processes.

The Error Assessment Method suggested in this paper can be enhanced in future research. We plan to conduct intensive research to prove the efficiency of this QA process comparing to other papers. Furthermore, these related aspects are also necessary to consider: recognizing more QA problems and evaluating the performance of the combined process; carrying out a more detailed assessment of the effectiveness of the technique, and building pattern recognition approaches for automated deviation pattern analysis.

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