Journal of Al-Azhar University Engineering Sector

Vol. 18, No. 67, April 2023, 396-412

3D DATA REGISTRATION EVALUATION OF INDOOR LASER SCANNER BASED ON VARIOUS TECHNIQUES

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Citation:

N. Saba, and K. M. Abdel Aziz, "3D data registration evaluation of indoor laser scanner based on various techniques", Journal of Al-Azhar University Engineering Sector, vol. 18, pp. 397-413, 2023.

Received: 14 February 2023

Accepted: 6 April 2023

ABSTRACT

In recent years, there has been a notable growth in the recording and modeling of building processes due to the advent of construction information modeling (BIM). A BIM promotes better information exchange and encourages teamwork. The best way to swiftly gather buildings for BIM geometry is with laser scanning technology as opposed to the traditional measured method with a total station. The point cloud generated by laser scanners is heavily utilized by the BIM applications Autodesk Revit and Recaps. In this experiment, A 1350 square meter building at October University was scanned using a BLK 360 interior laser scanner to produce a 3D point cloud. The entire scanned area had 26 4-inch-diameter black and white circular targets. Leica Cyclone 7.3 was utilized throughout the procedure to process the data collected. Different registration methods were used to create 3D models. (1) Auto Targets registration - (2) Cloud-to-cloud registration and (3) Manual registration. For each case, the accuracy evaluation is done using the control points by the total station instrument. Based on the results, the horizontal and vertical accuracy of the point cloud model from the registration methods were reasonably comparable.

KEYWORDS: Registration, Accuracy, Comparison, cloud to cloud, target, Modelling, Building, Laser scanning.

تقييم الدقة الافقية والرأسية لطرق النمذجة المتعلقة بالسحابة النقطية الناتجة من المسح بأجهزة الليزر سكانر

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الملخص

في السنوات الأخيرة، كان هناك نمو ملحوظ في تسجيل ونمذجة عمليات البناء مما كان له الأثر الجيد في تعزيز عملية النمذجة بشكل أفضل وأسهل وكذلك تشجيع العمل الجماعي. الجدير بالذكر ان أفضل طريقة لأعداد نموذج ثلاثي الابعاد بشكل أسرع ومستوفي البيانات هي باستخدام تقنية المسح بالليزر بدلاً من الطريقة التقليدية المستخدم فيها اجهزة المحطة الشاملة. تستخدم السحابة النقطية المنتجة بواسطة الأجهزة المساحية التي تعمل بتلك التقنية بشكل كبير بواسطة تطبيقات الاوتوديسك مما عزز الاستفادة القصوى من تلك البيانات وتطبيقاتها المختلفة. يهتم البحث بدراسة تأثير الطرق المختلفة لربط وتجميع البيانات المقاسة بجهاز الليزر (موديل ليكا) المستخدم داخليا في رسم المباني حيث يتم ربط وتجميع السحابات النقطية الناتجة من القياسات المرصودة من عدة وقفات للجهاز معا بثلاث طرق مختلفة وذلك لإنتاج نموذج ثلاثي الابعاد للمنشأ. الطرق المستخدمة هي: اولا: الربط باستخدام اهداف تم تثبيتها ورصدها على ان تكون ظاهرة في السحابة النقطية وكذلك رصدها بجهاز المحطة الشاملة لتحديد احداثياتها ومن ثم استخدامها لتجميع النموذج. ثانيا: الربط الالي او الأتوماتيكي للسحابة النقطية للوقفات المختلفة وثالثا: الربط اليدوي من قبل المستخدم. قورنت الدقة الافقية والرأسية من الثلاث طرق لتحديد الأفضل والاسرع وذلك داخل المبني الرئيسي لكلية الهندسة بجامعة 6 أكتوبر. اعطت النتائج تباين معقول في الدقة المتحصل عليها من الطرق المستخدمة.

الكلمات المفتاحية : السحابة النقطية، نمذجة، ليزر سكانر، تقييم الدقة.

1. INTRODUCTION

Today, due to the quick development of technology, there are several methods to capture 3D data. Among these technologies are an image-based technic, a point cloud-based technic, and an integrated technic [1]. These technologies offer potent tools for 3D scene visualization and modeling. Engineering, architecture, indoor emergency evacuation, urban planning, transportation planning, and management are just a few of the many fields where 3D visualization is very important. As a result, numerous 3D activities have been carried out and are very useful for such applications. In this paper, the registration of 3D data collected by indoor laser scanning as a point cloud approach was discussed and evaluated based on different techniques. A brief introduction followed by a review of 3D data acquisition approaches for 3D modeling is discussed in the next section. The study area, instruments, tools used, and data processing are covered next. The results, discussions, and suggestions are discussed in the last section.

2. 3D DATA ACQUISITION METHOD

According to the most recent technological advances, several data-gathering techniques, including aerial and close-range photogrammetry, airborne or ground-based laser scanning, mobile mapping, and GPS surveying have significantly improved the resolution and accuracy of 3D data[2-5]. Engineering projects as built and the reconstruction of three-dimensional (3D) objects have recently been the subject of much research employing a variety of methods for obtaining the necessary 3D data. Methods for data accusations for 3D modeling are point cloud-based, image-based methods, and integrated methods. A brief discussion of these methods is in the next section.

2.1. Image-Based Method

A common technique for acquiring 3D data using stereo-image pairs is the image-based approach. The measurement of objects in two- or three-dimensions using photographs is known as photogrammetry. Using a series of overlapping photos, stereo photogrammetry is a common method for 3D mapping and object reconstruction. It is now possible to use digital cameras to take up-close pictures of objects like buildings and then recreate them to development of close-range photogrammetry. Triangulation is a technique used in close-range photogrammetry. A collection of photographs orientated to a coordinate system is used in close-range photogrammetry for the measurement of 3D points. Prior to the evaluation, the positions of the pictures (x, y, and z) and their (ω, ϕ, κ) rotation angles must be established [6]. The advancement of digital image technology has led to the close-range photogrammetry process improved in its time and cost-effectiveness. Close-range photogrammetry visible objects. These laser scanners are available in several variants and categorized into three primary categories based on the longest distances they can scan: close-range scanners (2 to 3 meters), medium-range scanners (500 to 1000 meters), and long-range scanners (up to several kilometers). Accuracy expected from 3D modeling by photogrammetry is decimeters and sometimes meters in high altitudes while from close-range photogrammetry is centimeters.

2.2. Point Clouds-Based Method

Laser scanning technology can produce 3D point cloud data. By using non-contact laser pulses to measure an object's surface profile, laser scanning technology provides a quick and precise method for gathering 3D data [7]. Since a few years ago, laser scanners have become the most widely used technique for creating 3D data because they are quick and effective in gathering surface data to produce highly accurate measurements. These scanners are often best suited for a specified range and item size. The laser scanner is capable of millimeter-level accuracy in digitizing all the 3D data related to real-world objects including buildings, trees, and terrain. Previously pricey, these scanners are now becoming more accessible as usage increases. Laser scanners can be used to collect data both inside and outside doors. The foundation for surface reconstruction or modeling can be a collection of point clouds and true color 360 images created by a laser scanner. The point clouds also included details about the size, shape, location, and surface features of actual-world objects. The information gleaned from point clouds can then be used to model various objects.

2.3. Integrated Approach

Now, gathering 3D data is commonplace. The integrated approach combines the point cloud approach and the image approach. This technology concurrently takes point clouds and images by connecting a digital camera to a laser scanner [8]. With the help of this technique, it is possible to reconstruct geometric shapes from point clouds, and images of the objects are used to determine their color and texture. Combining point clouds with photos makes it feasible to depict actual objects and visualize the real world. Models that were built utilizing the high-accuracy point cloud and picture texture are advantageous and useful, and they can be interacted with and analyzed. because of the automated acquisition. The mechanism of the laser scanning system will consider everything surrounding it. A large collection of dense point clouds supports an interactive visualization. In addition to being quantifiable, 3D models are regarded as useful tools for managing and documenting structures and facilities. The point cloud can also be modified once it has been created using modeling software such as AutoCAD, 3Ds Max, Revit Architecture, and SketchUp. 3D data can be fully utilized by this platform for 3D data integration.

3. STUDY AREA AND USED DATA

At the Faculty of Engineering, October 6 University, a section of a building with a floor space of about 1350 square meters was selected as a study area. After Fixing 26 targets to the walls of the entire building, scanning was done using the indoor laser scanner BLK360 model from Leica. Most of the rooms are corridors with a floor height of 3 meters and a width of 2 to 10 meters. Figure 1-a displays the data displays gathered as a point cloud, and Figure 1-b displays the dimensions of the research area's extension drawing from the point cloud using AutoCAD software. Cyclone Register program performs georeferencing using three methods. As control points for the evaluation procedure, circular targets were used. The targets had a 4-inch radius and were printed on A4 paper. The laser scanner program Cyclone Registered 360 was designed to recognize the black-and-white targets when inputting data.

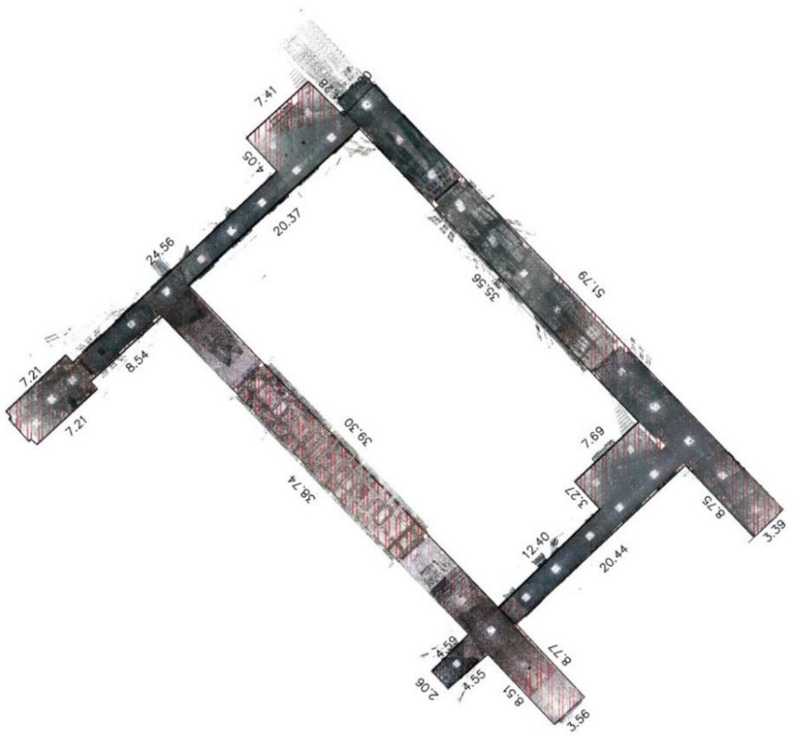

Figure 1-a: Study area extension as a point cloud data

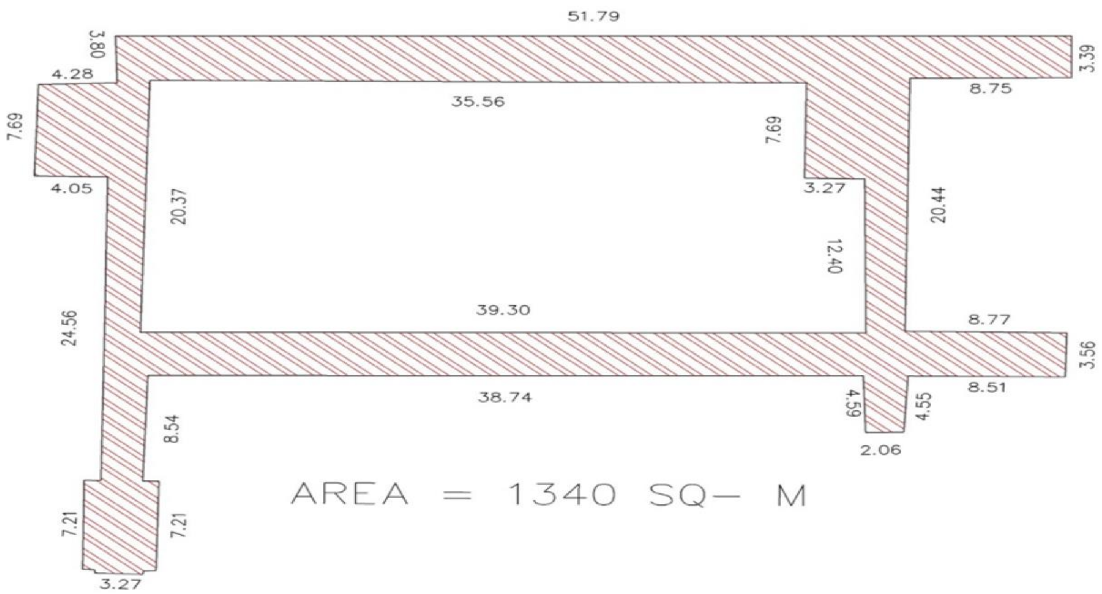

Figure 1-b: The Study area using AutoCAD software.

The program can be configured for the field-used sphere size, and the targets' sizes can vary from less than 4 inches to more than that. In the gathered configurations, Auto Sphere Target will automatically look for and extract sphere targets. Extracted targets are then used to build a registration bundle or as benchmarks for the correctness of the bundle. A target that was used is shown in Figure 2. The distribution criteria for the 26 targets are that at least two targets must be visible in each arrangement. After setup registration, links, and bundles will be created using these targets as checkpoints (control points). The locations of the used targets are shown by red dots, in Figure 3.

Figure 2: Example of targets used in fieldwork.

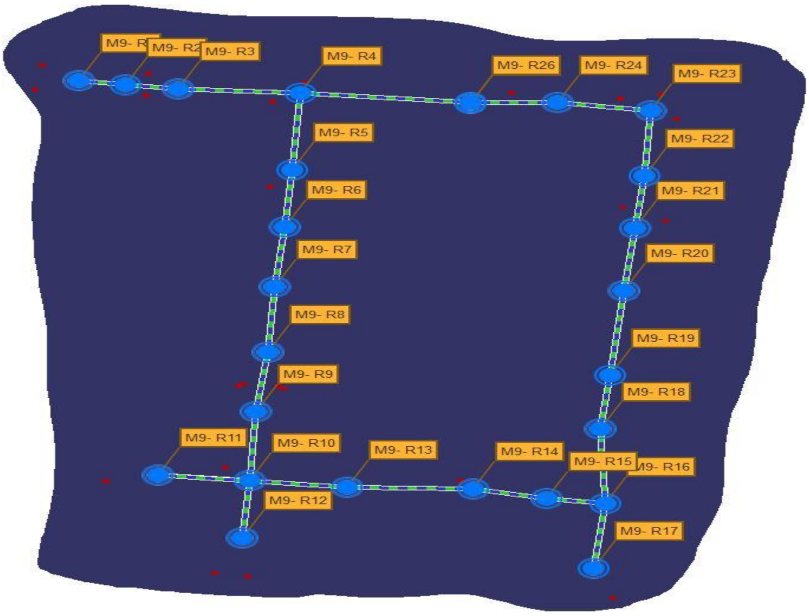

Figure 3: Links, inside the study area, and red dots represent the target location.

Four tools were used, (1) Black and white targets with a 4-inch diameter were employed as control points in this experiment. Targets are positioned on walls and dispersed around the entire room. Target areas are chosen to be clear, and visible, and to encompass all scanned regions. (2) Leica TS03 total station instrument with a distance accuracy of 1mm ± 1.5ppm and precision of 3 seconds. Using a single laser beam reflector option and no prism, the total station instruments were utilized to measure the XYZ coordinates for the black and white targets as a control point. (3) Leica BLK 360 indoor laser scanner, which is used to scan and measure all building elements. Figure 4 shows the laser scanner model. (4) Leica

Cyclone REGISTER 360 software, one of the Leica Cyclone products, is a commercial program that can import data from a laser scanner and perform data registration and optimization. Cyclone REGISTER 360, which includes automated registration and cleaning tools, reliable QA, and extensive publish functionalities, is designed specifically for the BLK Reality Capture family. Additionally, the software can export 3D capture point clouds to a variety of extensions. such as Autodesk Recap and Rivet AutoCAD.

Figure 4: LeicaBLK laser scanner.

4. METHODS

The entire building was scanned in static mode by the indoor laser scanner BLK 360. Twenty six 26 setups worth of 360-degree images and 3D point clouds was gathered. All elements around the scanner were gathered for each setup (instrument position) in the form of cloud points and 360-degree 3D images. A connection is created by connecting two setups. After linking to one another, links form a bundle. Figure 5 depicts the 26 setups , which represented the scanner's positions during data collection. Figure 6 shows how the locations of the instrument are connected to the form of links, which are then connected to make bundles.

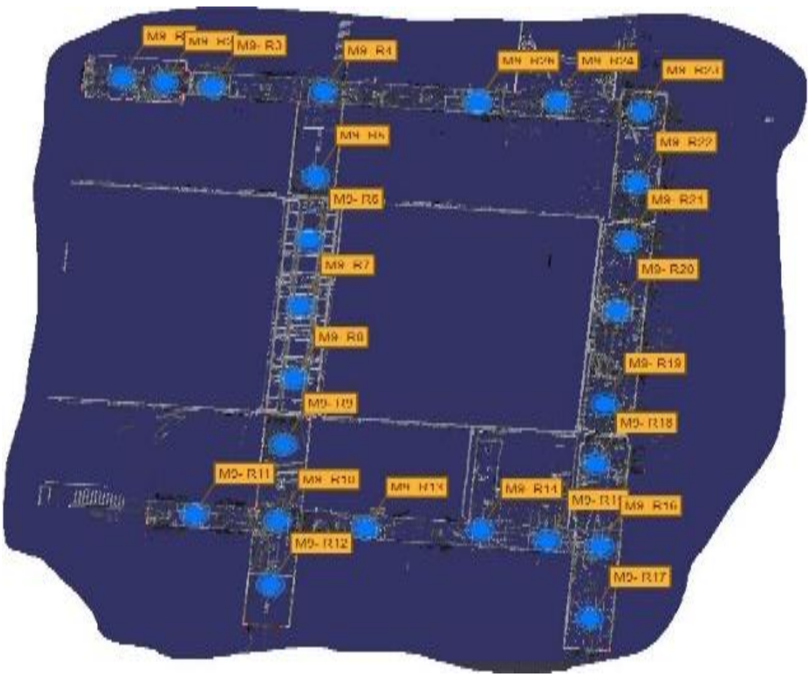

Figure 5: Laser scanner locations, from R1 to R26.

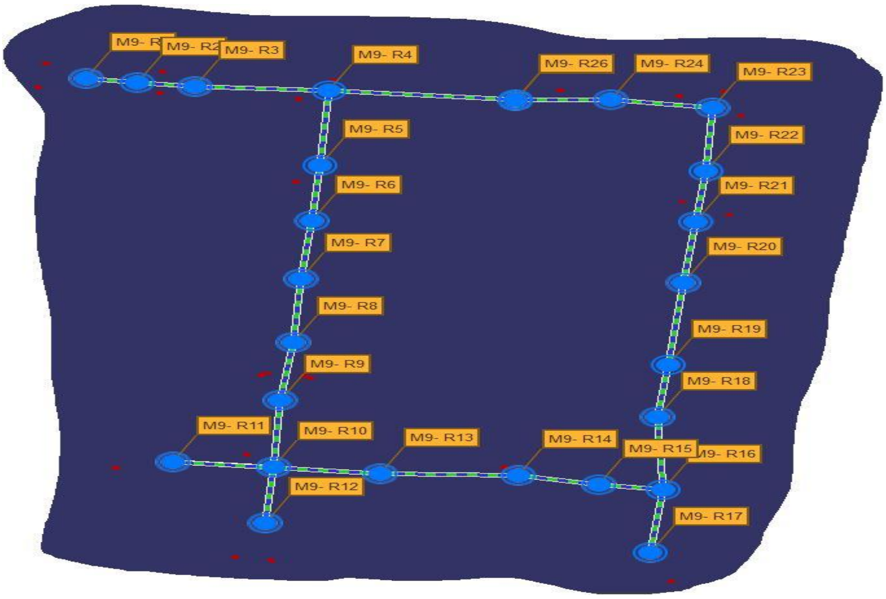

Figure 6: Links between locations of the instrument, dotted lines represent the links R1 to R26.

In this research, three methods of registering methods based on the point clouds-based included in cyclone registered software are introduced. (1) The auto-sphere target, (2) the cloud-to-cloud optimization, and (3) the manual optimization. The three approaches using cyclone-registered 360 BLK were used to import and register data from the laser scanning equipment. The 26 Control Points (CP) (targets on walls) are used to verify the accuracy of the bundle. The resulting model after optimization is compared to the relevant 3D location (XYZ) coordinates from the Total station instrument. In the sections that follow, results for the three optimization techniques are given and contrasted. Setups are connected to form links then, links are tied to form bundles, and setups are related to the links.

The 26 CP (targets on walls) are used to verify the accuracy of the bundle. Targets' 3D location (XYZ) coordinates from the Total station instrument are compared with the equivalent coordinates from the optimized model. The next sections provide results for the three optimization techniques and a comparison of the obtained results. The 26 Control Points (CP) (targets on walls) are used to verify the accuracy of the bundle. Where the resulting models from the three optimization methods are compared to the coordinates of targets (XYZ) obtained by using the total station instrument. The locations of instruments are connected to form links, links are tied to form a bundle, Figure 6.

4.1.Registration by Targets

One setup typically isn't enough to measure an entire object. So, the operator must perform several scans, each in a different setup position. Several scan clouds are produced as a result, each referencing a distinct coordinate system. A single coordinate system is necessary for scanning clouds. Establishing a set of corresponding points from two data sets can be employed in the absence of tie points [9]. All scans must overlap throughout the scanning phase. The registration of each scan is reduced to the computation of a 3D conformal transformation which is 3 translations and 3 rotations (6 parameters), figure 7, given that the scale factor between all the scans is not substantial, by employing homologous points, either manufactured targets or natural objects.

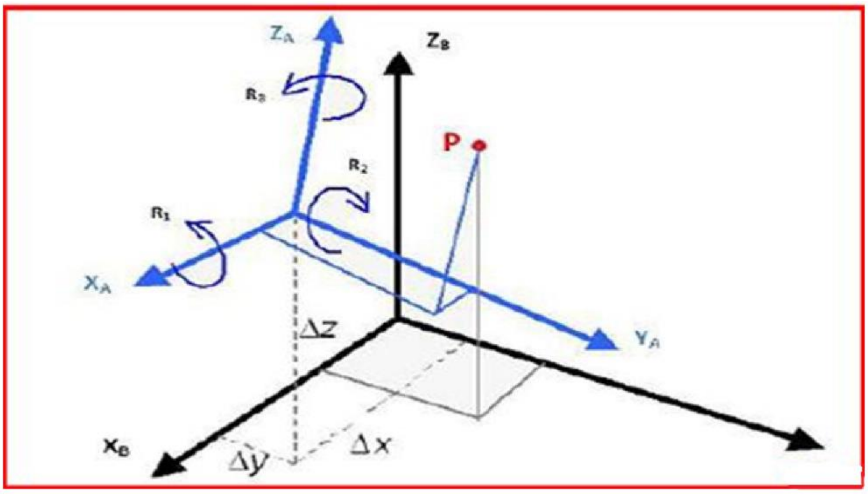

Figure. 7: Transformation parameters used in the registration process.

To compute the orientation to the object system or the registration between two adjacent scans, a minimum of three targets black and white or sphere targets are needed. A technique built on Hamilton Quaternions [10]. provides approximations for the transformation parameters and requires at least three points to be used by both reference systems. A least squares solution is used to further the approximate values for the transformation parameter; see [11] and for more information [12]. The distance between the scanner and the target, the laser beam's divergence, and the angular step width all affect the needed sphere target diameter for data registration purposes. To calculate how many cloud points will intersect a sphere's surface, apply the two equations below.

$$\tan^{-1}\frac{\theta}{2} = \frac{r}{range} \qquad (1)$$

$$n = \frac{\theta}{stepwidth} \qquad (2)$$

where

r = sphere radius.

θ = space angle at scanner head between two tangent lines for sphere diameter.

n = the number of cloud points in one direction which covers the sphere radius.

In this context, cyclone-registered software will recognize and automatically extract Black & White targets from the imported setups. A registration bundle will be made using the targets that were extracted. Automatic registration is performed by looking for and extracting sphere targets in each setup, and then registration is performed using those targets' coordinates. The Auto Sphere size item in the Cyclone Register 360 software adds a size hint to aid the extraction, but it does not replace the fitting size; rather, it only aids the process. The value "0" indicates that no size is specified. If all the project's spheres are the same size, setting a size can be useful. 22 sphere targets were found in this research out of all the employed targets. Critical requirements for the auto-spherical spherical target approach include the identification and detection of at least three targets in each setup. Targets in several settings in this experiment were not identified, thus parts of the entire model are automatically registered using targets that were found and detected. Cloud-to-cloud registration is used to match and connect the remaining setups. Therefore, 22 control points will be used in the verification. There are 26 links because of data collection, each of which has global and local errors affecting all links as well as cloud-to-cloud errors, which indicate the error between every two setups.

4.2.Auto Cloud registration

The registration technique is either cloud-based or target-based. When using Auto Cloud, also known as "targetless" registration, setup locations are automatically aligned and matched based on the geometry of the scene or setup contents. All links made during data import and all links formed in the review and optimization area have Cloud-to-Cloud functionality added by the CYCLON REGISTER 360 software. As a result, the software will take a long-time search target when utilizing the Auto Cloud option to find the same cloud geometry. When the software is successful in aligning the setups, all setups will be joined automatically. The application will not be able to connect the two chosen setups if there is insufficient overlap between the two sets. Accuracy decreases as overlapping gets smaller. Auto cloud-to-cloud registration was activated to make real-time matching for the setups when importing data from the laser scanner to the program (cyclone registered 360). The automatic cloud-to-cloud registration will not work if the overlap between the two setups is insufficient. The registration results will display the global and local setup and linkage errors based on the errors between each pair of setups.

4.3.Pre-registered or manual method

In the manual or pre-registered process, two setups are registered manually by the user in E, N, and Z coordinates using visual align tools in cyclone-registered software. Using the pre-registered, import option will import every setup without ever relocating or registering the data. Using this option WILL NOT affect the setup positions. The links generated are only intended to display to the user any links that include errors that have already occurred after import. To be included in the same package on REGISTER 360, all setups must be connected. The Minimum Spanning Tree (MST), or minimum weight spanning tree which is a subset of the edges of a connected, edge-weighted undirected graph that connects all the vertices together, without any cycles and with the minimum possible total edge weight. often MST known as REGISTER 360, joins all the setups imported with the fewest possible links. These links are unrelated to the registration details in the installations.

In the three registered used methods, there was no problem with cloud overlap, thus a blue link was made to show that the error couldn't be calculated. In this experiment, all gathered links are accepted without any problems. A group of installations that have been pre-registered is those that have been registered collectively using a registration tool. A user has visually inspected the registration to confirm any problems. This serves as the registration verification. Or the user accepts the setup's position as indicated by the scan data. When the project has already been registered/aligned, the pre-Registered option is used. Then, Cyclone REGISTER 360 will make use of this registration to build links that will enable the user to evaluate and enhance the current registration. There is no pre-registration for Cyclone FIELD360 connections. The pre-Registered option must be selected to import and display the control coordinate system for Cyclone FIELD 360 projects in REGISTER 360 after they have been registered to control. The Pre-Registered option is required to view the registration results for scan data file types (such as PTX, PTG, and e57) that permit numerous setups in a single file.

5. RESULTS AND DISCUSSION

Registration for indoor laser scanner data was evaluated using. (1) registration by targets (2) cloud–to–cloud registration and (3) manual registration. In target registration, 22 target points were used directly to match setups with each other in links and produced one bundle. In the cloud-to-cloud process, the connections between setups are done based on the geometry of the scene or setup contents, setup locations are automatically aligned and matched. In this research, the CYCLON REGISTER program has incorporated Cloud-to-Cloud capabilities to every link created during data import and every link created in the review and optimization area. Manual optimizations are done manually by users between two setups individually using the visual align tool. The local and global errors are immediately provided by the cyclone program when two setups are matched to one another. The difference between the local and global errors is how each employed setup interacts with the other and with each other. The strength of the model figure emerging from the registration procedure is shown by local and global errors. The local and global errors are immediately provided by the cyclone program when two setups are matched to one another. The produced bundle after using the registration process was assessed using 22 control points. The 3D coordinates of the equivalent points of 22 targets appearing on the 3 models are compared with the control point's coordinates produced from the total station instrument. So, for each model, the E, N, and Z differences between total station coordinates and the model coordinates were calculated to verify the models' accuracies. The root means square error, RMSE was used to evaluate the quality of the 3 models produced from the three registration methods; it is the most widely used statistic as a measure of accuracy.

Tables 1 and 2 show the accuracies of setups matching in global and local processes, while table 3 shows the total local and global error accuracies of bundles.
The target method had the best register statistics. The global and local errors are millimeter-level using this technique. The second most accurate method is cloud-to-cloud, while manual registration is the least accurate. It's logical that the local error would be prioritized above the global one, as shown in the obtained results. The local error demonstrates the connection between two setups, whereas the global error represents the average errors of all setups at one time. 0.005, 0.014, and 0.029 m were the meaning of the local errors of three methods, registration by targets, cloud to cloud, and manual registration respectively. While the global errors were, 0.004, 0.035, and 0.027 m by using the three methods respectively, see Table 3.

Table 1: Local errors of links

	Target registration	Cloud-to-Cloud	Manual optimization
Link 1	0.004	0.025	0.026
Link 2	0.006	0.006	0.006
Link 3	0.009	0.009	0.009
Link 4	0.01	0.011	0.019
Link 5	0.008	0.012	0.017
Link 6	0.006	0.014	0.018
Link 7	0.004	0.015	0.017
Link 8	0.005	0.024	0.027
Link 9	0.007	0.025	0.028
Link 10	0.006	0.012	0.016
Link 11	0.006	0.014	0.017
Link 12	0.007	0.017	0.027
Link 13	0.004	0.007	0.047
Link 14	0.005	0.008	0.028
Link 15	0.004	0.009	0.019
Link 16	0.006	0.006	0.056
Link 17	0.004	0.005	0.035
Link 18	0.006	0.006	0.056
Link 19	0.005	0.005	0.025
Link 20	0.006	0.005	0.045
Link 21	0.006	0.006	0.036
Link 22	0.009	0.005	0.025
Link 23	0.007	0.007	0.017
Link 24	0.001	0.008	0.018
Link 25	0.006	0.1	0.1
Link 26	0.005	0.017	0.027
average	0.005	0.014	0.029

Table 2: Global errors of links

	Target registration	Cloud-to-Cloud	Manual optimization
Link 1	0.004	0.035	0.027
Link 2	0.006	0.034	0.036
Link 3	0.003	0.023	0.033
Link 4	0.016	0.016	0.018
Link 5	0.035	0.054	0.045
Link 6	0.012	0.089	0.012
Link 7	0.008	0.087	0.099
Link 8	0.002	0.035	0.039
Link 9	0.003	0.024	0.029
Link 10	0.001	0.045	0.057
Link 11	0.005	0.018	0.04
Link 12	0.003	0.01	0.029
Link 13	0.002	0.039	0.047
Link 14	0.016	0.008	0.016
Link 15	0.002	0.045	0.058
Link 16	0	0.019	0.072
Link 17	0.001	0.005	0.018
Link 18	0.001	0	0.042
Link 19	0.001	0.003	0.077
Link 20	0.004	0.003	0.017
Link 21	0.002	0.002	0.016
Link 22	0.023	0	0.042
Link 23	0.027	0.012	0.016
Link 24	0.004	0.043	0.078
Link 25	0.019	0.019	0.054
Link 26	0.001	0.031	0.066
Average	0.004	0.035	0.027

Table 3: Mean Local and global errors of bundles.

Item	Auto Sphere Target	Cloud-to-Cloud	Manual optimization
Local errors	0.005	0.014	0.029
Global errors	0.004	0.035	0.027

RMSE can be given by,

$$\text{RMSE} = \sqrt{\frac{1}{n}\sum_{k=1}^{n}(V_k)^2} \qquad (3)$$

$$V_k = H_k - H'_k \qquad (4)$$

Where,
n is the number of checkpoints,
H_k is the known E or N or H of the used control points,
H'_k is the extracted E or N or H of point k in each model.

As a result, the three study area models created using the three methodologies were assessed, with the results shown in Tables 4, 5, and 6. The accuracy of the model created by the target technique is displayed in Table 4. Table 5 displays the auto cloud accuracy. Whereas table 6 illustrates the data of the model generated by the human registration process. 26 setups for the laser scanner throughout the entire research area, as shown in Tables 4, 5, and 6. Twenty-two control points are utilized, and the residuals are calculated using the coordinates of the model and the control points. 2.0 cm is the total error (RMSE) for the model produced using the target registration method, table 4. While using cloud-to-cloud and manual registration methods, the model accuracy was 3.2 cm and 6 cm respectively, as shown in tables 5 and 6. By using targets as control points, a good accuracy of up to 1 cm on the registered model is attained. However, we must not disregard the time, cost, and effort put forth in selecting the targets' ideal locations and distributing them along the study area's limitation. Additionally, some of them will be missing if the software is unable to recognize them. This experiment revealed that not all targets were detected by the laser scanner equipment.

The software needs three target locations to be able to calculate the six register parameters to successfully complete the registration process. Additionally, it should be highlighted that utilizing such a strategy has some disadvantages because it takes a long time for the BLK software to locate the target places and provide them with the codes needed for registration. Min-max and mean errors in coordinates given in Table 7 indicate small values. The cloud-to-cloud approach meets most requirements, precision and time were moderate. Every two successive setups were selected together by using this method, and the software takes some time to find the common geometries and similar points among the content of the setup that has been collected before aligning them one to the other to finish the matching process. The software will only achieve full success if there are enough overlap areas between every two setups to gain the best accuracy of the link.

The overlapping between most of the input setups was at a minimum of 60% this gives accuracy and use short searching time. Manual registration is interesting and enjoyable. Despite having a stressful appearance, manual matching is a fun process that the performer enjoys. The operator is the controller of this, and he or she can prevent precision from being either optimal or useless. In manual registration, the visual alignment, translation, and search for common sections are like the first two techniques but done manually by the operator. To get the best accuracy and the chance that the matching process would work effectively and completely, the setups needed to have the most overlap possible. The BLK program can be forced to manually match between setups with less overlap, which is achievable, but would reduce the accuracy of the results. The min, max and mean errors in Table 7 (cloud-to-cloud and manual registration) indicate converging readings for both registration procedures. Few setups have errors within twenty centimeters because there is less overlap across setups, which means the figure's strength is weaker and more inaccurate.

Table 4: bundle errors using the target registration method.

No	bundle errors		
	N	E	H
1	0.01	0.001	0.001
2	0.009	-0.001	-0.001
3	0.012	-0.002	-0.001
4	0.01	0.002	-0.004
5	0.011	-0.01	0.002
6	0.018	-0.014	0.002
7	-0.005	-0.004	0.002
8	-0.011	-0.004	0.001
9	-0.002	-0.009	-0.004
10	-0.002	-0.009	-0.006
11	-0.005	-0.002	-0.006
12	-0.008	-0.011	-0.005
13	-0.01	-0.015	0.061
14	-0.011	-0.016	-0.022
15	-0.011	-0.015	-0.004
16	-0.015	-0.017	-0.005
17	-0.016	-0.018	-0.006
18	-0.018	-0.021	0.002
19	-0.013	-0.02	0.005
20	-0.195	-0.042	-0.032
21	-0.039	-0.021	0.005
22	-0.045	-0.025	0.006
Total error	0.032		

Table 5: bundle errors using Cloud-to- Cloud method.

No	bundle errors		
	N	E	H
1	0.001	0.003	-0.002
2	-0.001	0.004	-0.003
3	-0.001	0.009	-0.003
4	-0.004	0.009	0.002
5	0.002	0.012	-0.009
6	0.002	0.021	-0.012
7	0.002	0	-0.001
8	0.001	-0.004	0
9	-0.004	0.007	-0.004
10	-0.006	0.009	-0.003
11	-0.006	0.008	0.005
12	-0.005	0.007	-0.003
13	0.061	0.007	-0.006
14	-0.022	0.008	-0.006
15	-0.004	0.01	-0.004
16	-0.005	0.008	-0.005
17	-0.006	0.009	-0.005
18	0.002	0.009	-0.007
19	0.005	0.016	-0.005
20	-0.032	-0.094	-0.026
21	0.005	-0.006	-0.004
22	0.006	-0.01	-0.007
Total error	0.02		

Table 6: bundle errors using Manual registration method.

No	bundle errors		
	N	**E**	**H**
1	**0.004**	**-0.002**	**0**
2	-0.002	0.001	0
3	**-0.002**	**0**	**-0.001**
4	0.004	0.003	-0.004
5	**0.008**	**0**	**-0.003**
6	0.016	-0.004	0.002
7	**0.014**	**0.021**	**-0.011**
8	0.01	0.019	0.008
9	**-0.264**	**-0.12**	**0.036**
10	0.158	0.059	0.019
11	**-0.177**	**0.101**	**-0.097**
12	0.168	-0.053	0.033
13	**0.081**	**-0.015**	**0.077**
14	0.028	-0.026	-0.014
15	**-0.001**	**0.003**	**-0.028**
16	-0.001	-0.015	-0.005
17	**0.008**	**0.005**	**-0.006**
18	-0.004	0.005	-0.003
19	**0.027**	**-0.012**	**0.016**
20	-0.104	0.059	-0.026
21	**0.013**	**-0.016**	**0.006**
22	0.014	-0.012	0.003
Total error	**0.060**		

Table 7: Min, max, and mean errors of the registration methods

item	Max	Min	Mean
		Target registration method	
N	0.01	-0.03	0.01
E	0.02	-0.09	0.00
Z	0.06	-0.03	0.02
		Cloud–to–cloud registration method	
N	-0.01	-0.02	0.01
E	-0.04	-0.20	-0.01
Z	0.00	0.02	0.08
		Manual registration method	
N	0.00	0.00	0.00
E	-0.12	-0.26	-0.10
Z	0.10	0.17	0.08

Figures 8 and 9 show the local and global errors conducted with the three registration methods. Figures 10,11 and 12 show the 3D accuracy of each mode using the three registration methods. Figure 13 shows 3D components accuracy of all used methods.

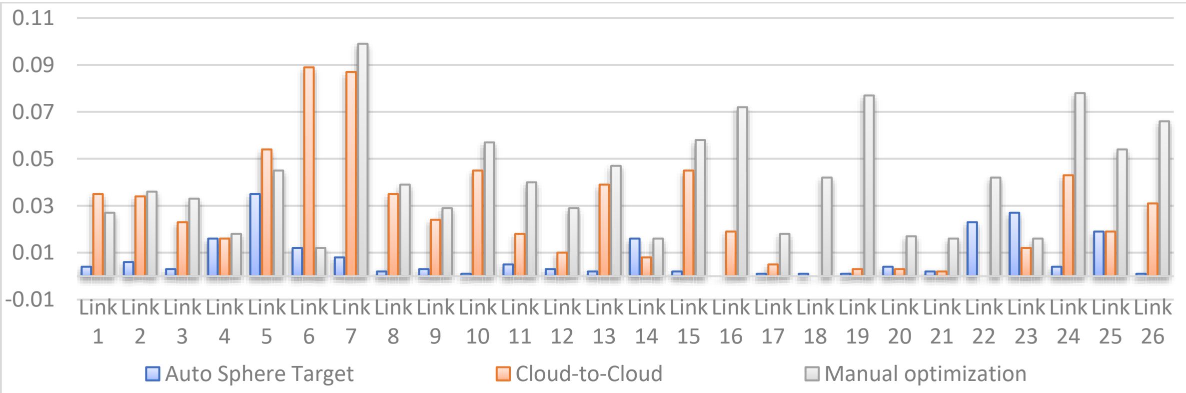

Figure. 8: Global error for registration methods.

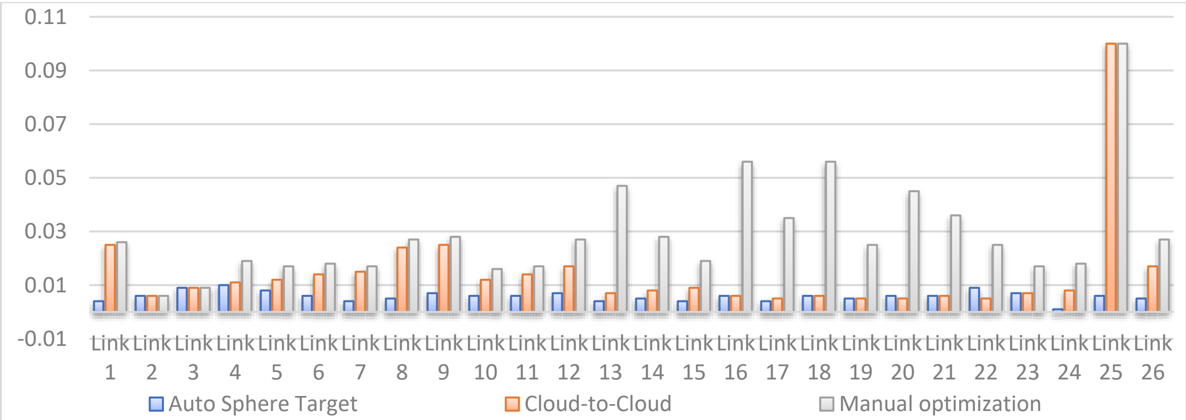

Figure 9: Local error for registration methods.

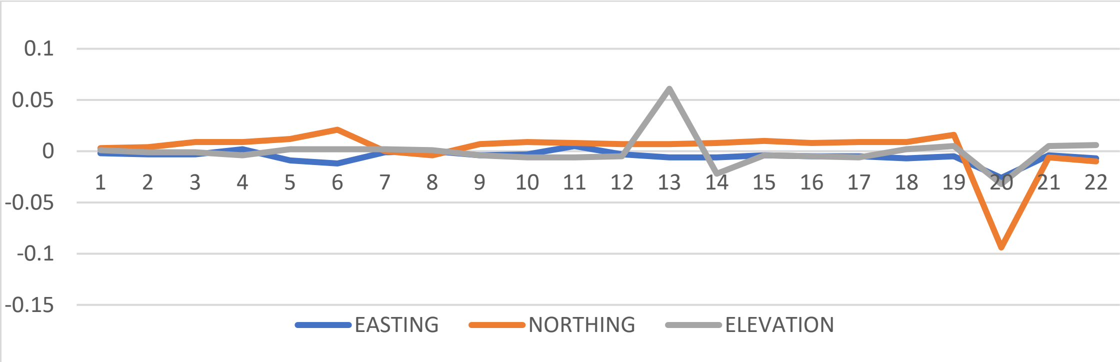

Figure 10: 3D accuracy for the target's registration method

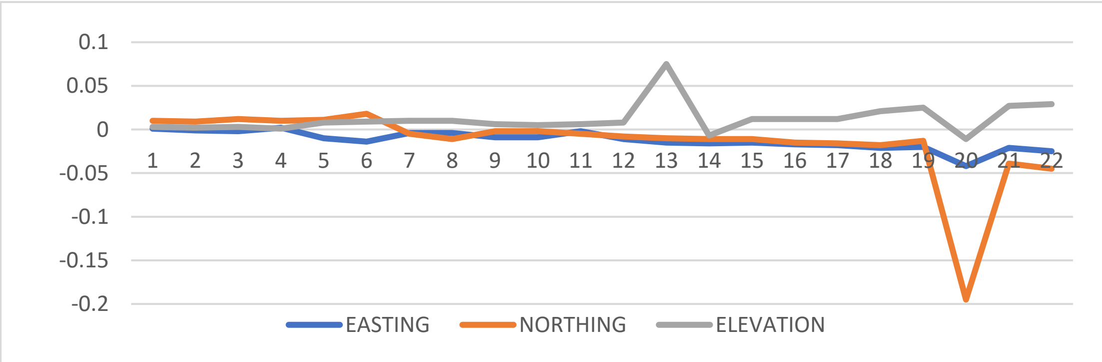

Figure 11: 3D accuracy for cloud registration method.

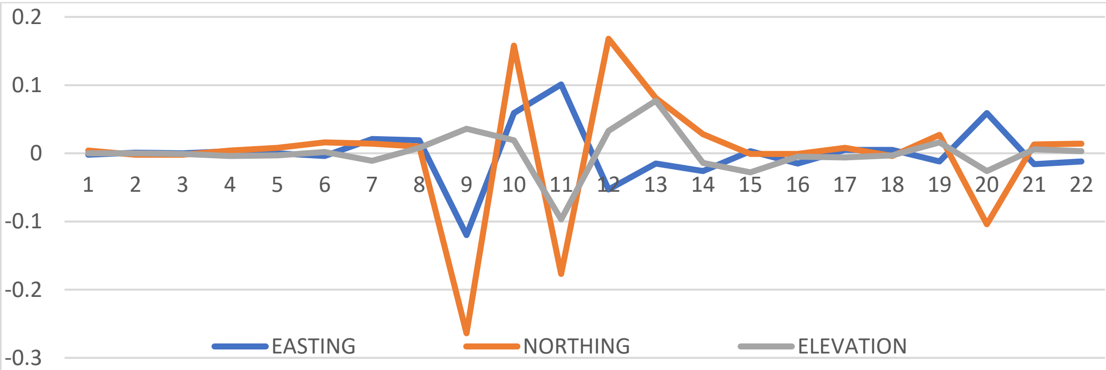

Figure 12: 3D accuracy for manual registration method.

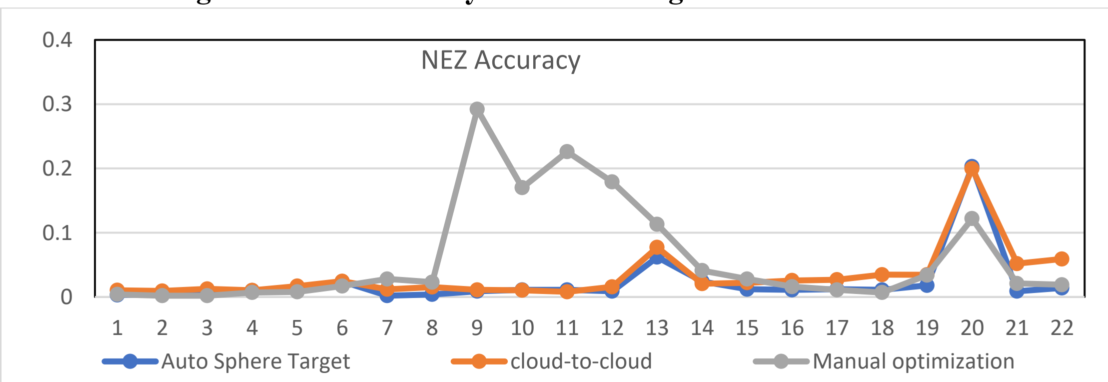

Figure 13: 3D components accuracy of all used methods.

6. CONCLUSION

Using targets, the global and local errors for the matching setups were high. Cloud-to-cloud and manual registration methods were to some extent acceptable for local and global errors; the resulting model errors were a few centimeters. Some applications call for exceedingly accurate target matching, while others just need short-duration work. For each approach to achieve the desired accuracy, the overlap between each setup must be a certain amount. In cloud-to-cloud and manual registration methods to achieve the desired accuracy, the overlap between the two setups is needed. It takes additional work on the site to select the ideal locations for the laser equipment to achieve sufficient overlap between the setups. The accuracy of the three methods ranges from 1 cm to 6 cm. The user can expect the accuracy of the final product and determine in which way it will work. Each method has its advantages and disadvantages, and the user must decide to what extent the method will be effective for his project. Finally, the results obtained from this study are results that are limited only to the study area and should not be generalized to all. They are only indicative to help for the evaluation of the available methods of registration. This analysis helps to inform the accuracy of point cloud models created with a laser scanner, which benefits the user by allowing them to recognize the strengths and weaknesses of each technique.

Extracting horizontal plans and vertical facades using accurate models for getting measurements and quantities and so on, which are required by various engineering projects, will come successively after the evaluation and enhancement are done, and this will have a great impact on the accuracy of such works and projects. The paper tested three registration methods for producing an accurate point cloud model from laser scanner data collection. Data was collected and tests were conducted on a selected study area indoors of the university and buildings. The obtained results indicate the suitability of the three methods for most of the engineering projects, with slight differences in accuracy for each method over the other. Also, the advantages and disadvantages of each method were discussed.

7. REFERENCES

[1] Zhang, J., & Lin, X. (2017). Advances in the fusion of optical imagery and LiDAR point cloud applied to photogrammetry and remote sensing. International Journal of Image and Data Fusion, 8(1), 1-31.

[2] Tao, C. V., & Li, J. (Eds.). (2007). Advances in mobile mapping technology (Vol. 4). CRC Press.

[3] Mitka, E., & Mouroutsos, S. G. (2017). Classification of drones. Am J Eng Res, 6(7), 36-41.

[4] Sebbane, Y. B. (2018). Intelligent autonomy of UAVs: advanced missions and future use. CRC Press.

[5] Kasvi, E., Hooke, J., Kurkela, M., Vaaja, M. T., Virtanen, J. P., Hyyppä, H., & Alho, P. (2017). Modern empirical and modeling study approaches in fluvial geomorphology to elucidate sub-bend-scale meander dynamics. Progress in Physical Geography, 41(5), 533-569.

[6] Koch, M., & Kaehler, M. (2009, March). Combining 3D laser-Scanning and close-range Photogrammetry-An approach to Exploit the Strength of Both methods. In Making History Interactive. Computer Applications and Quantitative Methods in Archeology Conference (pp. 22-26). VA, March: Williamsburg.

[7] Dongzhen, J., Khoon, T. Y., Zheng, Z., & Qi, Z. (2009). Indoor 3D modeling and visualization with a 3D terrestrial laser scanner. In 3D Geo-Information Sciences (pp. 247-255). Springer, Berlin, Heidelberg.
[8] Poux, F., Neuville, R., Van Wersch, L., Nys, G. A., & Billen, R. (2017). 3D point clouds in archaeology: Advances in acquisition, processing and knowledge integration applied to quasi-planar objects. Geosciences, 7(4), 96.
[9] Amano, K., Lou, E. C., & Edwards, R. (2019). Integration of point cloud data and hyperspectral imaging as a data gathering methodology for refurbishment projects using building information modeling (BIM). Journal of Facilities Management, 17(1), 57-75.
[10] Akca, D. (2003). Full automatic registration of laser scanner point clouds. ETH Zurich.
[11] Monserrat, O., & Crosetto, M. (2008). Deformation measurement using terrestrial laser scanning data and least squares 3D surface matching. ISPRS Journal of Photogrammetry and Remote Sensing, 63(1), 142-154.
[12] Elkhrachy, I., & Niemeier, W. (2006, March). Fitting sphere targets and their impact on data registration accuracy for Terrestrial laser scanner. In Fifth International Symposium "Turkish-German Joint Geodetic Days". March (pp. 29-31).