

FJDynamics P1- SLAM- Lidar test

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Objective and background information

A Lidar point cloud from an object (laser imaging, detection, and ranging) ¹ is an increasingly popular way to determine the dimensions and location of objects. This test was intended to investigate the performance of a small Lidar / SLAM (Simultaneous Localization and Mapping) ² when used in a combination of a Lidar and a RTK receiver in measuring a point cloud tied to a coordinate system. The advantage of such a combination compared to, for example, a single RTK device or a rotating LIDAR standing on a tripod is that the combination described in this test can be carried out quickly, in minutes, to capture a point cloud depicting even a moderately large building and its surroundings, consisting of millions of individual points. An RTK receiver with a measurement pole can measure only individual points, and a Lidar on a tripod typically ³ provides accurate results, but its use is significantly slower, because the tripod must always be moved to a new point and capturing one location typically takes the same amount of time as circling the building in this test with a SLAM / Lidar . The SLAM / Lidar -based equipment is compact, after starting up it continuously measures its position with RTK accuracy (1-2 cm) and it can be deployed quickly, typically within 1-2 minutes. The coordinates of all points stored in the point cloud can be checked later with a Trion Model software running in a PC computer. The purpose of this test was to determine:

- 1) What are the practical requirements when measuring outdoors in winter time with a lightweight RTK Lidar / SLAM device that measures the point cloud directly in the desired coordinate system?
- 2) What kind of accuracy can be achieved with a point cloud, absolutely and relatively?
- 3) can Lidar measure a challenging target?

Test object

The test site for the measurement was the Kiinteistö Oy Herukan Talliosake building located in Oulu at Varsikuja 7 (Photo 1). The measurement was carried out in cooperation with Talliosake Oy ⁴. The site is a relatively demanding site when measuring directly from the surfaces of the exterior walls with a laser, because the surface is quite shiny in places and the ends and corners are not flat surfaces but wavy. Based on the aerial photograph, the length of the building is 56.4 m and the width is 18 m. During the test, the weather was dry and the temperature was - 2 - 4 C.



Photo 1. The building of Herukan Talliosake Oy at Varsikuja 7. The facade faces Varsikuja.

Tested equipment and test method

The measurement used the P1-SLAM-Lidar manufactured⁵ by FJDynamics, which weighs approx. 1.4 kg (Figure 2). The device measures 200,000 points per second. The active surface is the hemisphere on the front wall, inside which the beam rotates in a full circle so that the emitting beam is 59 degrees wide (Image 3). The maximum measurement distance depends on the reflectance of the target: with an 80% reflectance (light target) the maximum distance is 70 m and with a 10% reflectance (very dark target) 40 meters. For example. The reflectance of white paper is 80-85% and that of red brick is 10-15%⁶. A typical measurement accuracy of P1 Lidar is 2 cm and when combined with an RTK satellite locator, such as the FJDynamics V10i (Figure 2), the combination is promised a positioning accuracy of 5 cm for the points in the desired coordinate system. The wavelength of the beam is 905 nm, i.e. infrared, so it is invisible to the eye. The device is in Class 1 safety class, i.e. completely eye-safe. When measuring with the shoulder support, the P1 is tilted slightly backwards so that the antenna on top of the RTK receiver is completely horizontal, which means that the Lidar P1's beam rotates more horizontally than when it is on a tripod (as shown in the picture). The P1 device is equipped with an Insta360 X3 video camera, which records 5.7k video using two 180-degree, i.e. semi-circular cameras. After scanning, the video image is utilized with the FJD Trion Model program running on a Windows computer, and the scan result can be "colored" based on the video image (Figure 5). FJDynamics recommends that this type of building measurement is done by walking around the building so that the horizontal front direction of the P1 device is at an angle of approximately 45 degrees to the wall being scanned (Figure 4). In this case, the direction of the

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device is also at an angle of 45 degrees to the direction of travel, because the travel is parallel to the wall (Figure 6). Scanning the entire building took approximately 6 minutes. Before scanning, the RTK device V10i was started and a short time was waited for the RTK device to find enough satellites in the sky to enter RTK FIX mode. FJDynamics RTK devices are controlled via Bluetooth using the Trion Survey program running on an Android device, which has a special mode for transferring results directly to the P1 lidar via a USB cable during scanning. The P1 lidar is controlled using the Trion Scan program running on either an Android or IOS device via a Wifi connection. In this test, both the Trion Survey and Trion Scan programs ran on the same device, the FJDynamics E600 (Android) controller. During scanning, the Trion Scan program creates a “raw” version of the point cloud on the screen, from which you can see how the scanning is progressing. The status of the RTK device is also displayed on the screen. Therefore, to control the scanning, it is sufficient that only the Trion Scan program is on the screen of the phone / controller in use during scanning, because the operation of both devices can be monitored from it. One person is enough for scanning.



Figure 2. FJDynamics P1- Lidar with shoulder support and V10i- RTK device.

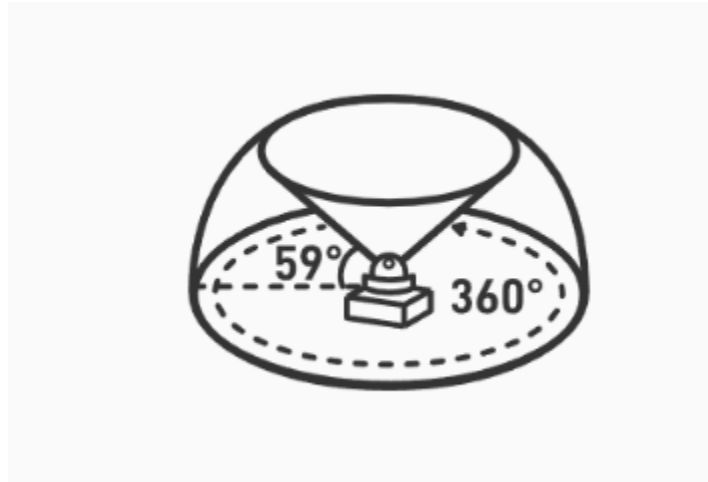


Image 3. P1-SLAM-Lidar scanning angle.



Figure 4. Scanning the end of the target in progress.



Figure 5. The back side of the stable share shown as a colored point cloud in Trion Model .

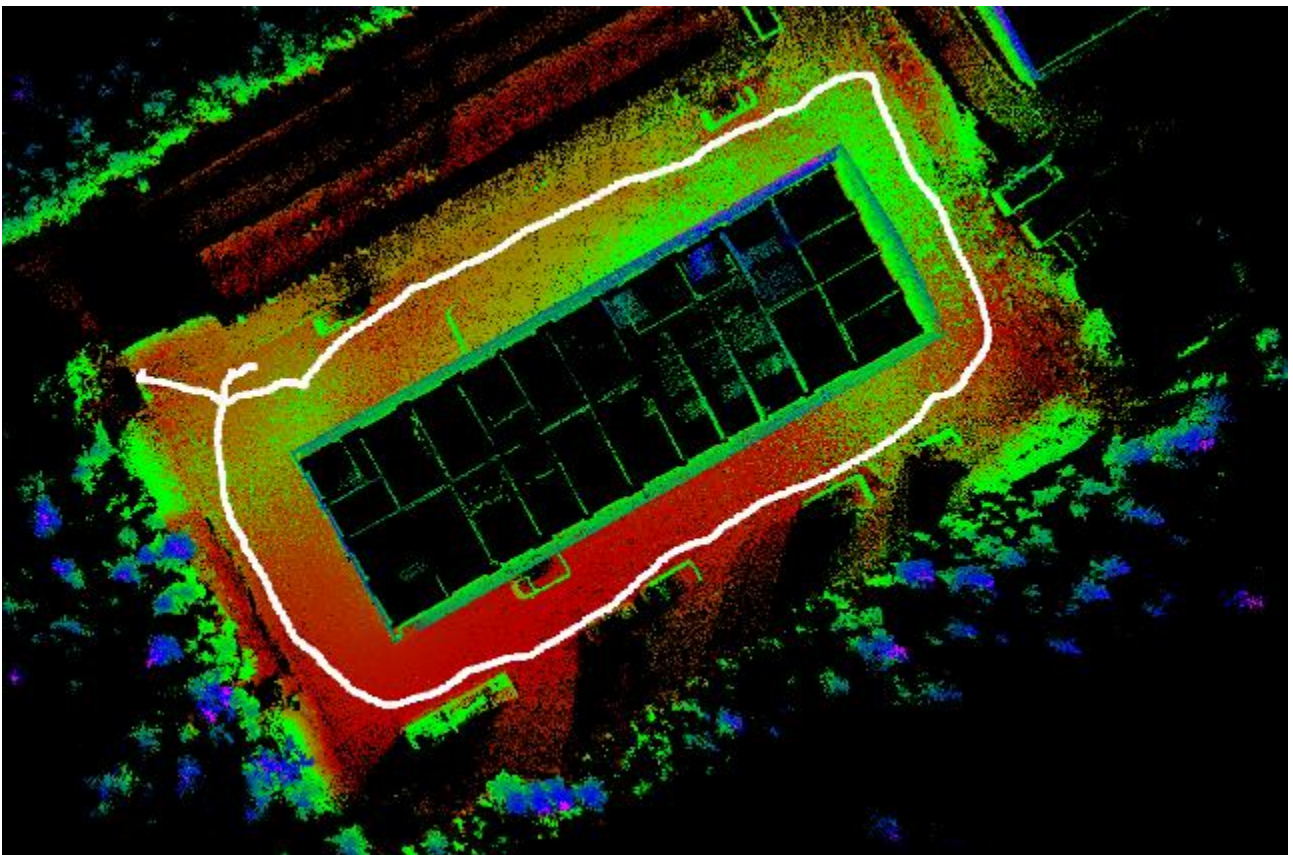


Figure 6. Stable share building in Varsikuja, point cloud viewed from above, with scan path (in white).

Comparison method

One of the purposes of this study was to determine the accuracy of the point cloud in the GK26 coordinate system and secondly, how closely the building dimensions correspond to reality, i.e. what is the accuracy within the coordinate system in question. The corners of the building were chosen as measurement targets from the facade at a height of approximately 1.3 meters above the ground. To determine these, Figure 7, Figure 8 10^{-6} D in distance measurement. The distance to both corners was approximately 33 meters, from which it can be estimated that the angular measurement accuracy corresponds to a measurement in the lateral direction of approximately 0.23 mm at a distance of 33 meters and a measurement accuracy of 2 mm in the depth / distance direction. Using the worse of these values, it can be estimated that the accuracy of the total station measurement was in the order of 2 mm. This accuracy allows us to measure all points that can be measured with this positioning in a rectangular coordinate system, where, for example, the coordinates of the left front corner of the building on the ground are 0,0,0 ⁷. The absolute position in the GK26 coordinate system was obtained by placing tripods in two places along Varsikuja street, approximately at the ends of Talliosake building, but on the other side of Varsikuja (like a total station), to which a South G4-RTK GNSS device was first attached and the positions of the tripods were measured with this device (Figure 8 Leica GMP104-type prisms were installed on the tripods and the total station was positioned in the coordinate system with the “ resection ” function using the coordinates given by the RTK measurement. The absolute position of the total station in the GK26 coordinate system is then determined by the accuracy of the South G4-RTK device. The average of 50 individual measurements was used to measure the positions at both locations. Based on previous measurements, it can be estimated that both prism positions used to position the total station were probably obtained with an accuracy of approximately +/-1 cm ⁸, since the location is almost open in terms of satellite visibility and there were no reflective objects, such as a house wall, too close.

GMP104-type prisms were also installed in the corners of the facade of the stable building (Figure 9 corner strips in the corners , the outer surface of which was approximately 10 mm from the surface of the corrugated sheet metal. The prism offset, i.e. the difference in position in relation to the angle of the wall sheets, has been taken into account in the post-calculation by drawing the facade of the building in a rectangular coordinate system using a CAD program so that the left corner of the facade corresponds to the origin of the coordinate system. Using the CAD program as an aid, the prism positioning offset was measured and taken into account when calculating measurement errors using the Excel program. The foundation material of the building was concrete and the location of its corner points were determined computationally in relation to the positions of the corner prisms by measuring with a meter stick how deep the foundation was in relation to the wall sheets.

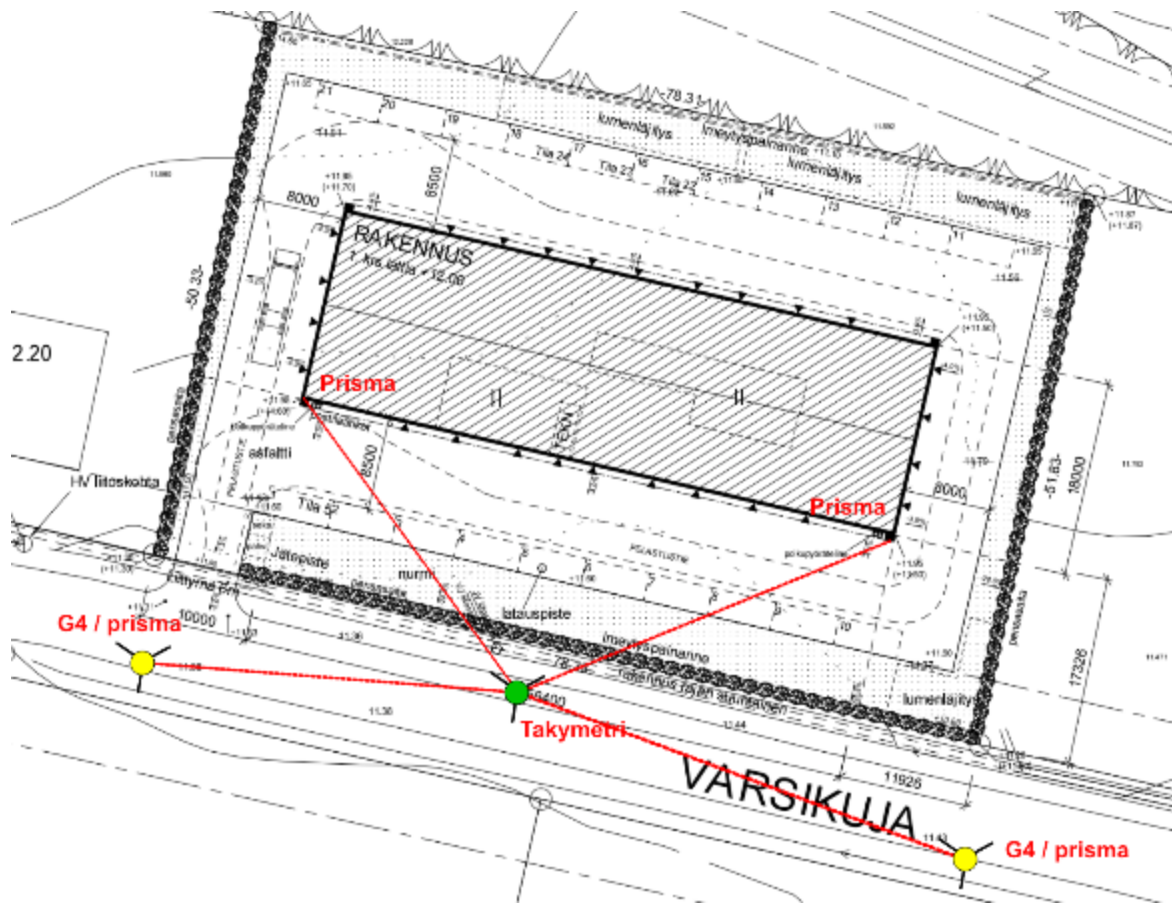


Figure 7. Station plan view of the building at Varsikuja 7.



Figure 8. Alpha Ti total station used in a total station measurement on a Leica tripod and in the background a GMP104 prism on a similar tripod.



Figure 9. A GMP104 type prism used in a total station measurement and its magnetic attachment. The image also shows a metal corner strip.

Post-processing of measurements

The scanning results were transferred from the P1 lidar to a PC (Lenovo Legion , i7-14700KF, 32 Gb RAM, Geforce RTX 4070 Ti Super / 16 Gb) via Wifi . The Wifi connection during scanning works so that the phone / controller creates a Wifi hotspot for the P1, but the other way around during file transfer. The Wifi hotspot status is changed with one quick and one long press of the P1 power switch and it is visible as a color change on the power switch. The PC had FJDynamics' Trion Model program installed for point cloud processing, which is included with the P1 package. When using the RTK configuration, at least fjdslam and fjdrtk files , as well as insv (video, 2 pcs.) files , are downloaded to the computer from the P1. The latter are first combined into one mp4 file using the Insta360Studio program. During file transfer, the camcorder must be connected to the P1 and both must be turned on.

In the Trion Model program you first give the project a name and then create a “Point Cloud” Mapping”, where the Trion Model program creates a point cloud, which in turn can be saved in the . las file format. If desired, a coordinate system - fjdrtk - is also attached to the point cloud using the help of a file and the point cloud can be "colored" using an mp4 video file (Figure 5). Natural colors are not really useful when examining the coordinates of a point cloud, and more useful point cloud coloring formats include Elevation , Intensity , RGB and Time. Of these, for example, Intensity shows the intensity of the received laser beam and Time organizes the point cloud according to when it was scanned starting from the start of the scan. Elevation shows the

relative height of the point cloud in color (blue for the lowest, red for the highest, Figure 10). Height is always a relative value relative to the height range in the image area.

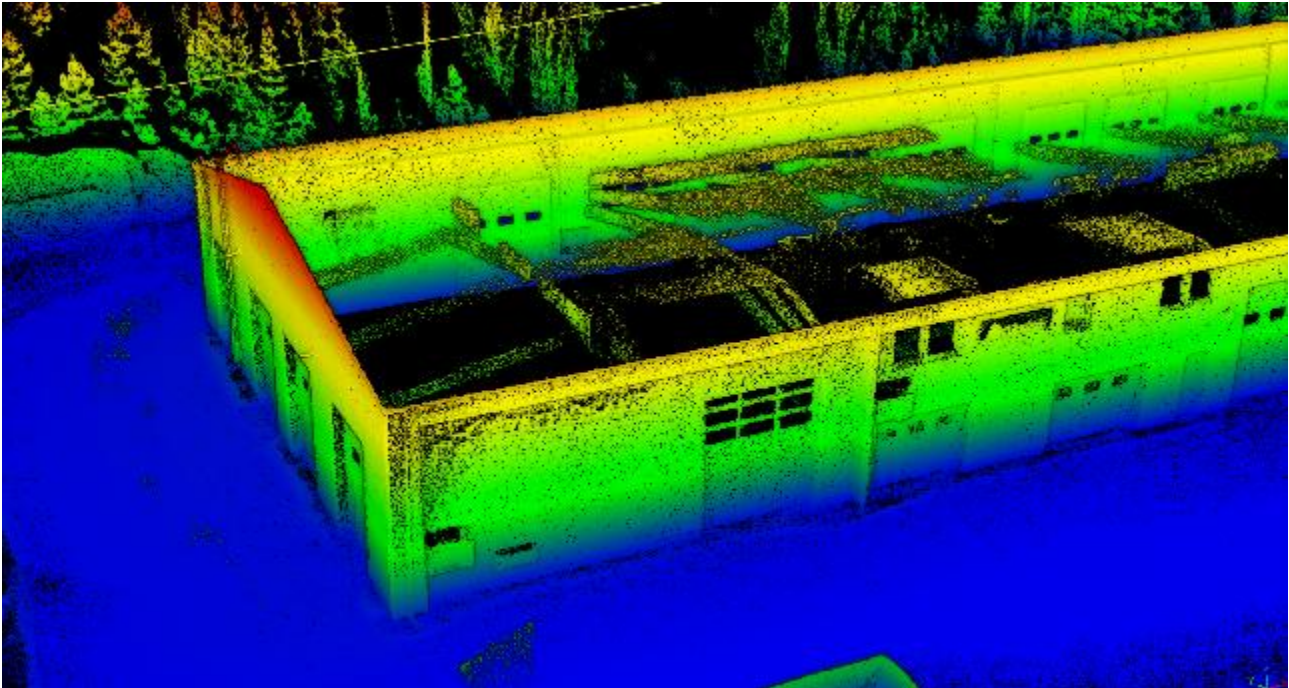


Figure 10. The scan result of the Talliosake building presented in the Trion Model program in Elevation mode.

When the corner of the sheet metal on the exterior walls of a building is determined from the point cloud describing the corner of the building, it is worth defining a “slice” of the walls in the height direction using the so-called Clipping Box method, which could be very narrow, centimeters, but since in this case the wall sheets were wavy, the thickness of the slice was about 30 cm (to ensure that the outermost point of the sheet metal is included) and from this the intersection points of the surfaces of the exterior walls were measured so that the corner was about 10 mm inside the location of the outermost points of both walls. Figure 11 shows the right-hand corner of the facade and Figure 12 shows the same corner as a slice image. The metal corner strip visible in the wall sheet metal is also clearly visible in the point cloud, where its shape is different from reality.

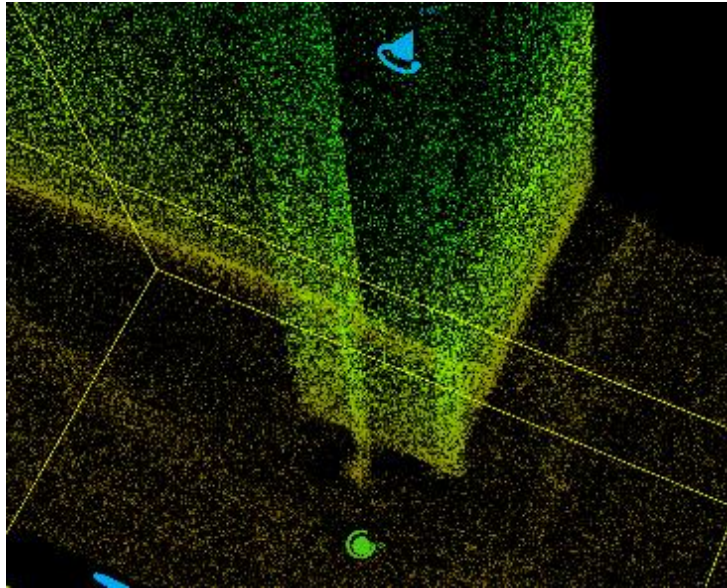


Figure 11 only partially visible.

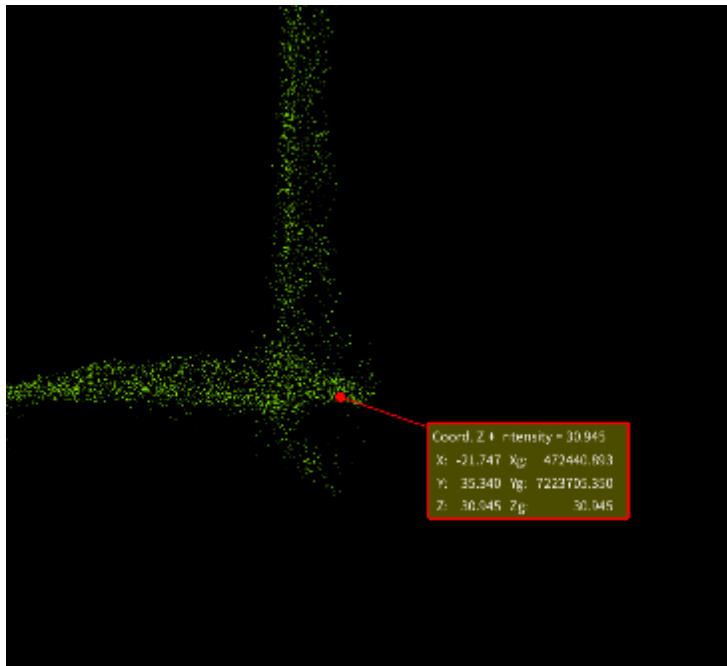


Figure 12. Right-side corner panels in a slice view.

Figure 13 shows a slice of the point cloud of the corner plates on the left side. The locations of the building foundation were determined from the point cloud in the same way as the locations of the wall plates, with the difference that there was no corner strip in the foundation. These are shown in Figure 14 and Figure 15. It should be noted that the coordinates are so-called short coordinates, i.e. the value 26 is missing from the beginning of the east coordinate. The height in the images is in accordance with the WGS-84 system, i.e. it was not calibrated to the N2000 system.

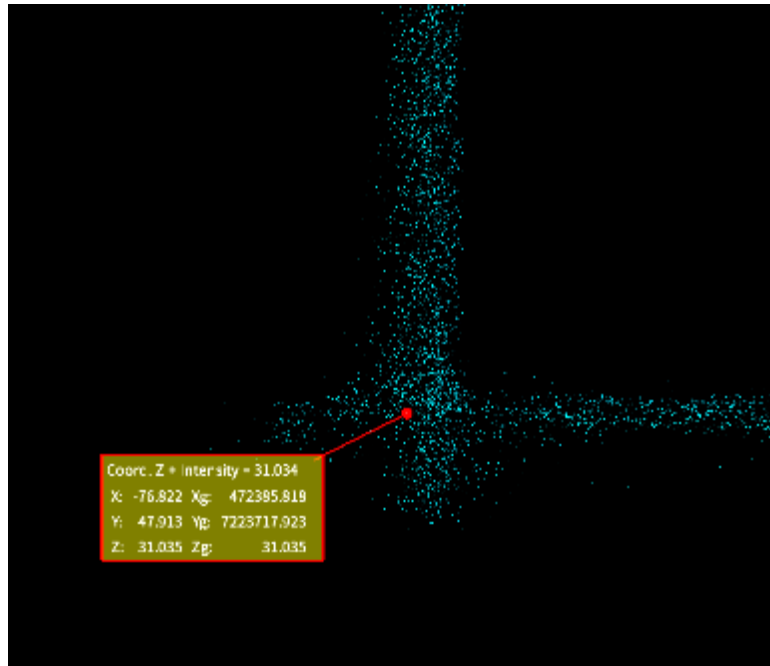


Figure 13. Left side corner panels in a slice view.

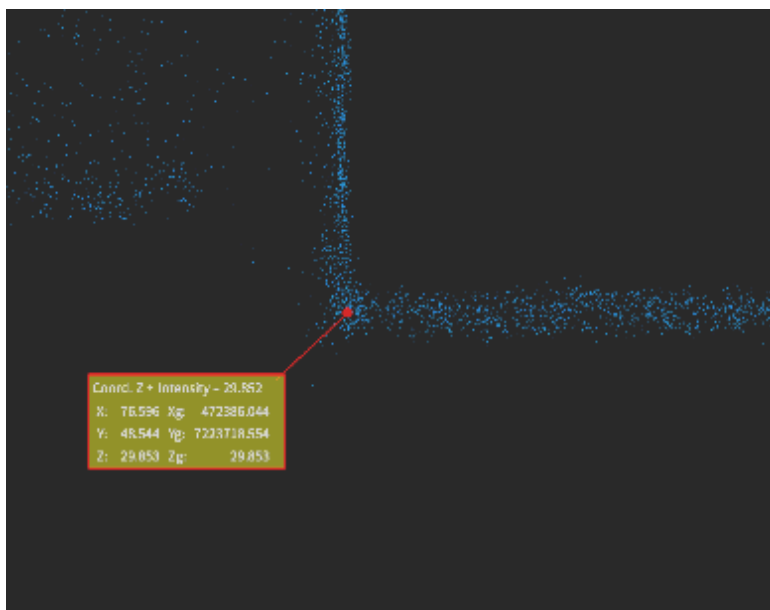


Figure 14. The left corner of the foundation as a point cloud image.

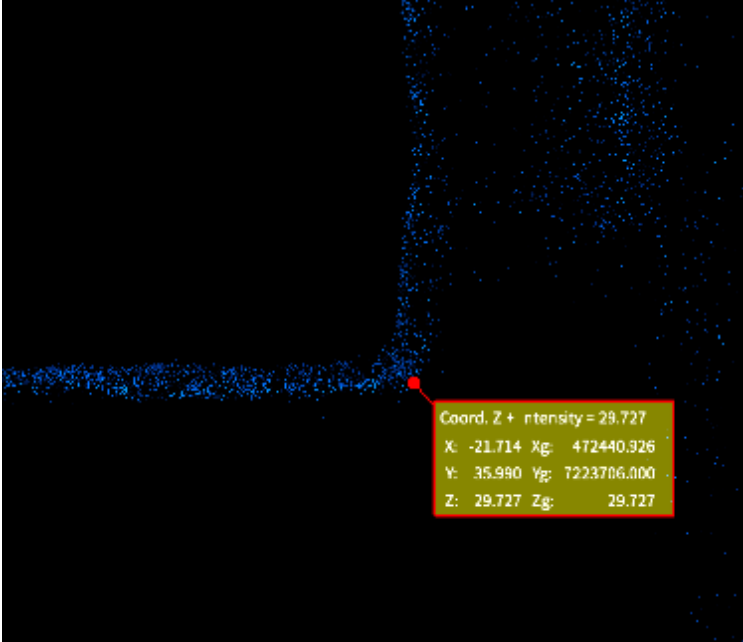


Figure 15. Right corner of the foundation as a point cloud image.

Score

The test results are presented below in Table 1. The figures in the table (yellow lines) have been obtained by subtracting the coordinates measured from the scanning point cloud from the coordinates of the reference measurement. In the measurement of the corner of the wall sheets, the differences were 5.1 cm in the right corner and 3.2 cm in the left, and in the measurement of the corner of the foundation, the differences were 3.7 cm in the right corner and 4.8 cm in the left. The average of these is 4.2 cm, which is the amount by which the positions of the scanned points on average differ from the positions of the reference measurement. The value is well in line with the 5 cm value promised for the P1 / V10i combination.

According to the scan, the length of the building measured from the wall sheets was 56.460 m and from the foundation was 56.281 m. The difference in the length of the building between the scanned result and the reference measurement (total station result) was -1.9 cm (wall sheets) and -0.7 cm (foundation). These values are also in accordance with the promised accuracy (2 cm) for the P1 device.

Location difference in GK26 coordinates -> (N/E)	Wall panels, right corner	Wall panels, left corner
	0.032 -0.041	-0.008 -0.030
	Difference to total station result [m] 0.051	Difference to total station result [m] 0.032
Location difference in GK26 coordinates -> (N/E)	Foundation, right corner	Foundation, left corner
	0.016 -0.034	0.006 -0.047
	Difference to total station result [m] 0.037	Difference to total station result [m] 0.048
	Building length from external walls, P1 result minus total station result [m] -0.019	Building length from foundation, P1 result minus total station result [m] -0.007

Table 1. Differences between point cloud and reference measurement.

¹<https://en.wikipedia.org/wiki/Lidar#Terrestrial>

²https://en.wikipedia.org/wiki/Simultaneous_localization_and_mapping

³<https://dimense.fi/mittalaitteet-ja-anturit/south-acutelas-spl-3d-laserskanneri/>

⁴<https://talliosake.fi/>

⁵<https://www.fjdynamics.com/product/fjd-trion-p1-lidar-scanner>

⁶https://www.engineeringtoolbox.com/light-material-reflecting-factor-d_1842.html

⁷https://en.wikipedia.org/wiki/Cartesian_coordinate_system

⁸https://dimense.fi/site/assets/files/2194/9_rtk_gnss_device_comparison.pdf