NavVis VLX 2 and 3 in an Open Urban Environment

Avenue de la Médecine

Université Laval - Québec

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Summary of the Study

The report provides a comparative study of NavVis's mobile mapping systems, VLX 2 and VLX 3, conducted in an open urban environment. The results demonstrate that both systems deliver surveying performance with high precision, resolution, and efficiency, maintaining reliability even under variable conditions.

One of the key advantages of VLX systems lies in their ability to significantly reduce fieldwork time compared to conventional surveying methods. This efficiency not only enhances productivity but also technician safety by minimizing risks associated with data collection in potentially hazardous environments. Furthermore, comprehensive project coverage minimizes the need for returns to the field.

The ease of sharing collected data through the Ivion platform promotes collaboration with clients and stakeholders, simplifying communication and decision-making. This feature also enhances operational efficiency by eliminating the need for physical travel to on-site meetings.

It is important to note that while VLX systems offer numerous advantages, they may not be suitable for all situations, especially for highly detailed or flatness or verticality analysis. However, in the context of overall structural analysis, they prove to be effective tools.

In conclusion, this study confirms that NavVis's mobile mapping systems, the VLX, are high-performing tools that provide a fast and efficient alternative to traditional surveying methods. Their appropriate use maximizes the benefits of these systems in various mapping and topographic survey applications, while promoting a more efficient and secure approach to urban planning and construction projects.

Introduction

A common challenge with the NavVis VLX relates to spaces with remote or even non-existent geometry or structure. We are pleased to present this report detailing the results of our study on the performance of NavVis mobile mapping systems VLX 2 and VLX 3. The study took place in July in a specifically chosen urban environment known for its spaciousness, with buildings distanced from each other, typically more than a hundred meters apart. Data collection was carried out on a segment of approximately 500 meters along Avenue de la Médecine on the Université Laval campus in Quebec.

The primary objective of this study was to observe the behavior and mapping capabilities of these two systems comparatively and to produce a topographic-style deliverable from the collected point cloud.

Please note that the figures and results presented in this report are specifically related to this specific study and may vary from one project to another or depending on the environment in which they are applied.

Data collection

Figure 1 : Ground Control Point 27 with checkerboard

The data collection was carried out by Simon Gingras-Gagnon, cpi, and Jules Suzineau, a.-g. The project began with a conventional survey using a Trimble S7 total station from two geodetic points located on the main axis of Université Laval. They were then used as control points in the traverse adjustment performed with Trimble Business Center software. This survey mainly involved recording the coordinates of control points (22 points), which were later used to georeference the point clouds collected with the VLX systems in the platform Ivion[1]. Verification points (14 points) were also surveyed using checkerboards placed on walls, as well as physical objects in the environment such as window corners.

Subsequently, data collection was performed using NavVis products. The process was initiated from the center of our study area, and then successively from one side to the other, following the manufacturer's usage recommendations. The entire operation was completed in just under six hours.

[1] Ivion : Point cloud data processing, visualization, and management platform produced by NavVis.

Data processing

Data processing was conducted in three stages: first, traverse adjustment in TBC[2], followed by point cloud processing in Ivion, and finally, classification and data extraction in TBC. In the Ivion platform, control point coordinates were used to georeference our point clouds. The processing tasks were configured to achieve a 5 mm resolution.

Once the point cloud processing was completed, the data was exported in e.57 format. This data was then subject to a classification in TBC version 5.90, which benefits from deep learning for improved point cloud classification. Subsequently, automatic extraction of various elements was carried out in the same software to extract items such as trees, poles, traffic signs, pavement edges, etc. These elements were automatically extracted and simply required verification.

Figure 2 : Point cloud after classification into 11 classes by TBC

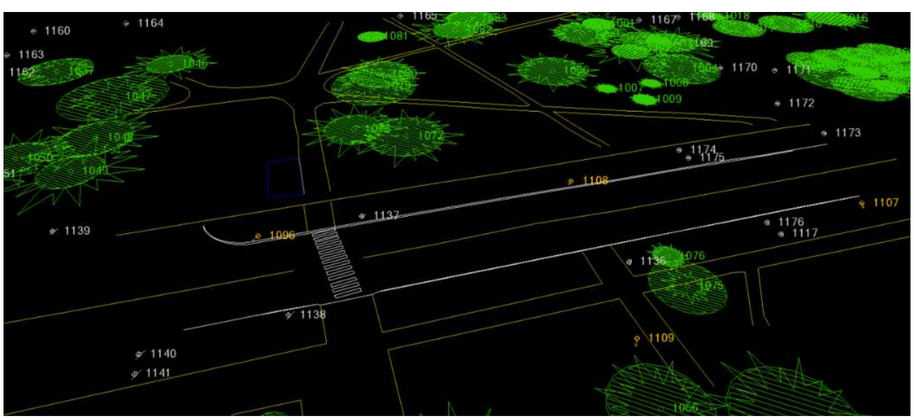

Figure 3 : Brief linear, geometric, and point extractions

[2] **TBC : Trimble Business Center**

Temporal Analysis

In terms of time, there are two important aspects to consider: time spent in the field and time spent in the office. In the field, as mentioned earlier, the time spent on-site was just under 6 hours. A conventional survey of this magnitude would take approximately 3 days for a standard technician. Furthermore, even in 3 days of work, the technician would not be able to collect as much data as a LiDAR scanner.

Next, it takes about 17 hours for data downloading and processing. The good news is that this time is not included in the fieldwork process because it occurs on a remote AWS[3] computer provided with your Ivion package. You can focus on other tasks during this period. Indeed, this type of processing happens in parallel to your work, without your intervention. Moreover, Ivion offers you the best possible computer performance, meaning you no longer need to worry about using a high-performance workstation solely for point cloud processing. As for data extraction from the point cloud, it depends on the drafter's experience. With data of this type, it's fair to say that the office steps can be longer at the beginning because you need to learn how to manipulate this point cloud and become familiar with the most suitable tools. So, for drafting, you should budget around ten hours for a standard novice technician.

Now, when comparing the two VLX devices, there is no significant difference between them. Two hours for the VLX 2 and one and a half hours for the VLX 3. This can be explained by the range, which is greater with the VLX 3 and therefore covers more area quickly. It also greatly depends on the operator's trajectory and hence, their experience.

TIME			
	Tasks	NavVis (hrs)	Conventional (hrs)
FEILD	**Field survey**	**5,4**	**24**
	Conventional survey	3,5	24
	NavVis survey	1,9	
OFFICE	**NavVis IVION**	**17**	
	Download	2	
	Processing	15	
	Post-processing	9,66	5,16
	Path adjustment	0,16	0,16
	Extraction	0,5	
	Drafting	9	5
TOTAL		**15,06**	**29,16**

[3] **AWS : Amazon Web Services, is a company specializing in cloud computing.**

Analyzing the results, we can see a global time saving of approximately fifteen hours on this project. To put this time saved into perspective compared to current conventional methods, such as using a total station, several surveying firms provided estimates of the time required for a project of this scale. It was concluded that a 3-days field survey would have been necessary, along with a minimum of 5 hours of office work by an experienced technician. In other words, there was a reduction in time by half compared to conventional methods for this project. It's important to note that the time estimates for the conventional survey are approximate, and no such survey was conducted for the purposes of this report.

Accuracy and Resolution Analysis

One of the most common concerns in mobile mapping is accuracy. SLAM is known to be less accurate than terrestrial LiDAR scanners. This is where NavVis has succeeded where others have failed; they have designed the VLX to act as a hybrid system. Within a five-meter radius of the trajectory, the VLX behaves like a normal terrestrial LiDAR scanner, with accuracy down to half a centimeter. From five to fifteen meters, there will be a gradual degradation of accuracy and resolution. Beyond fifteen meters, the VLX will behave like a typical SLAM system, with accuracy ranging from two to three centimeters.

Regarding the project, as mentioned in previous paragraphs, the team collected 24 control and verification points, in addition to the stations, to allow for the comparison and analysis of the accuracy of the two VLX units. Some of these points were captured at ground level using checkerboards, while others were captured at height using targets or individual corners of structures.

Residuals between conventional points vs. point cloud (meters)								
ID	VLX 2				VLX 3			
Targets on the wall	ΔH	ΔV	Δ3D	Dist. to trajectory	ΔH	ΔV	Δ3D	Dist. to trajectory
1	0,023	-0,010	0,025	6,6	0,007	0,009	0,011	6,4
4	0,020	0,000	0,020	5,8	0,010	-0,007	0,012	6,4
6	0,017	-0,001	0,017	6,8	0,004	-0,01	0,011	3,8
20	0,010	-0,008	0,013	1,8	0,005	0,000	0,005	2,6
23	0,021	-0,007	0,022	5,5	0,015	0,005	0,016	3,1
Average	**0,018**	**-0,005**	**0,019**		**0,008**	**-0,001**	**0,011**	
Point on building								
200	0,030	0,001	0,030	3,2	0,022	0,004	0,022	25,5
201	0,013	0,013	0,018	2,2	0,021	-0,008	0,022	3,2
202	0,013	-0,020	0,024	17,6	0,009	0,001	0,009	19,0
203	0,069	-0,033	0,076	22,5	0,031	0,011	0,033	22,0
204	0,011	-0,002	0,011	9,2	0,008	0,000	0,008	14,0
205	0,029	0,059	0,066	40,6	0,005	0,011	0,012	17,5
206	0,019	0,007	0,020	4,5	0,015	-0,001	0,015	4,2
207	0,030	0,020	0,036	12,5	0,009	-0,006	0,011	13,2
208	0,019	-0,001	0,019	17,9	0,018	0,009	0,020	18,0
Average	**0,026**	**0,005**	**0,033**		**0,015**	**0,002**	**0,017**	

A similarity in accuracy can be observed between the two VLX units at ground-level checkerboards, which served as control points for processing. In fact, Ivion distinguishes the VLX 2 and the VLX 3 in some of the processing parts, but not for the georeferencing part, as it applies the same parameters to both point clouds.

Regarding the wall targets placed at human height, their precision is quite different. Since the processing was not based on these points, they serve as verification for accuracy. Here, a much better accuracy is noted for the VLX 3 for the targets as well as for the points taken on the buildings. To assess the accuracy quality, it was preferable to add the distance between the targeted point and the operator's trajectory. As mentioned earlier, with NavVis, like with all LiDAR scanners, quality deteriorates with distance. It can be seen by looking at errors as a function of distance that below 10 meters, they are approximately 1 to 2 cm. Above 10 meters, the error is more in the range of 2 to 3 cm.

It is important to note that the points on the buildings were collected at height to test the accuracy of the VLX based on the laser's angle of incidence. Therefore, it is normal to observe larger deviations for these points.

As for resolution, both NavVis products were compared. The decision was made to assess the point cloud density in a one-meter by one-meter square. For this purpose, the team relied on TBC and obtained some figures. This operation was carried out both horizontally and vertically. The extracted figures reveal that VLX 3 has a density of approximately twice that of VLX 2. These results fully correspond to NavVis' claims about their new product. Improved density, of course, translates into a more accurate interpretation of the data and ultimately, an extraction that best reflects reality.

Number of points per square meter		
	VLX 2	**VLX 3**
Horizontal	8 303	20 117
Vertical	11 656	22 733

For meaningful comparative analysis, it was chosen to conduct this experiment with points located within 10 meters of the trajectory.

This increased density in the point clouds of VLX 3 is even visible to the naked eye when navigating within the point cloud.

Figure 4 : Density of VLX 2 (visualized in Ivion)

Figure 5 : Density of VLX 3 (visualized in Ivion)

The difference in resolution between the two images is clearly visible. Upon closer inspection, one can also clearly distinguish the Cansel logo and even see the distinct shadow of the truck on the ground. The sidewalk's imperfections are also visible in the image on the right compared to the VLX 2 image.

SLAM and Control Points Analysis

To assess the robustness of the SLAM algorithm for NavVis VLX 2 and 3, two datasets located north of the avenue were reprocessed using a minimal number of control points. Only 3 points were kept, which corresponds to the minimum recommended by the manufacturer for georeferencing the point cloud. The selected points are points 18, 27, and 100, which are located at the ends of the trajectory.

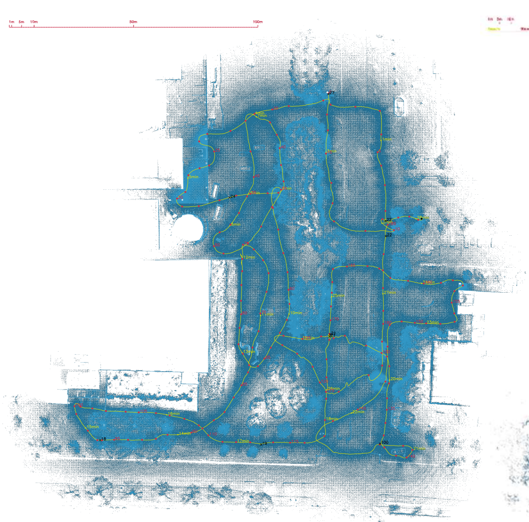

Figure 6 : QualityMap before processing

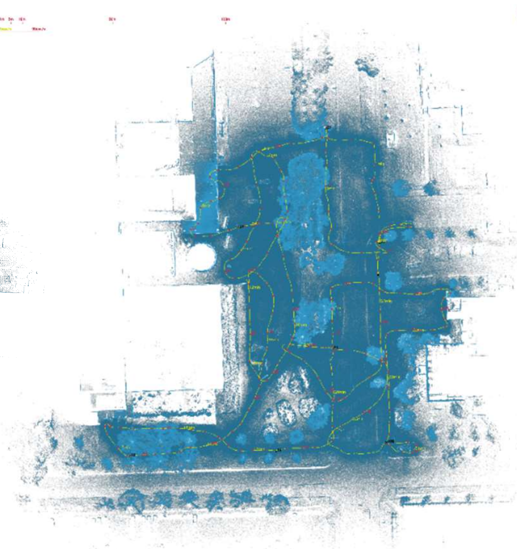

Figure 7 : QualityMap after processing With all points

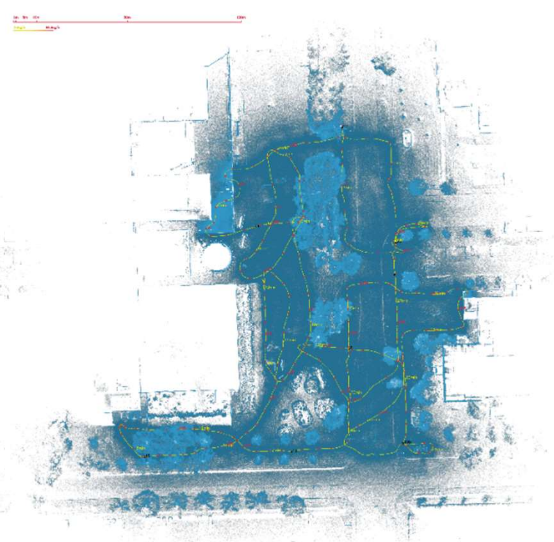

Figure 8 : QualityMap after processing with 3 points

VLX 2

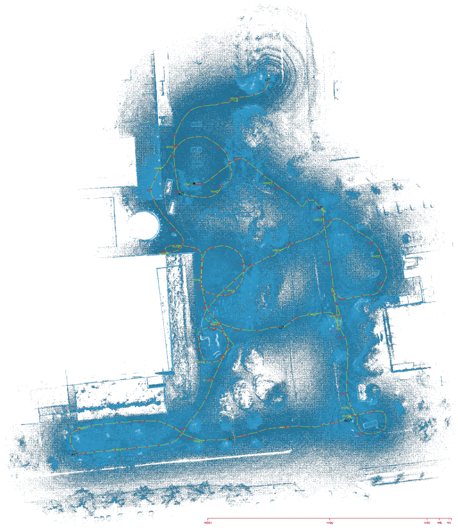

Figure 9 : QualityMap before processing

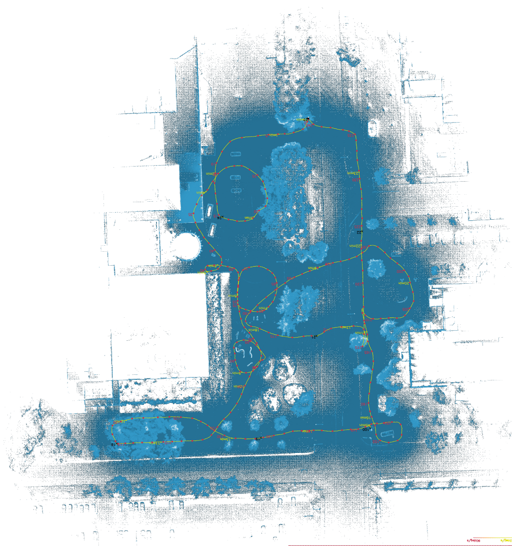

Figure 10 : QualityMap after processing With all points

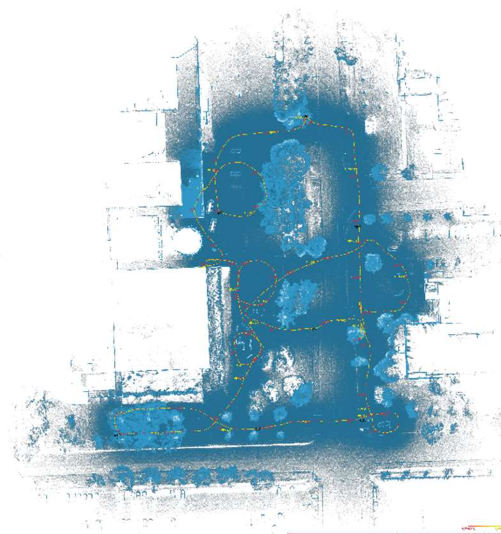

Figure 11 : QualityMap after processing with 3 points

VLX 3

First and foremost, it is important to highlight the remarkable efficiency of the processing performed by Ivion. This efficiency is particularly evident when examining the raw data from the VLX 3. The mapping accomplished by the SLAM is impressive, especially when considering the initial state of the QualityMap before processing. It is crucial to note that this processing greatly benefits from the capture of numerous control points. However, to justify this approach, it was imperative to quantify these benefits through concrete data. Thus, measurements of the coordinates of targets at points 19, 21, and 22 within the resulting point cloud were undertaken. Subsequently, these data were compared with the coordinates of the same points obtained using the total station. This approach allowed for the assessment of the SLAM accuracy using a minimal number of control points. The results of this evaluation are presented in the table below.

Residuals of control points VLX 2 (meters)						
ID	With all the points			With points 18, 27, and 100		
Checkerboard	ΔH	ΔV	Δ3D	ΔH	ΔV	Δ3D
18	0,005	0,002	**0,005**	0,004	0,001	**0,004**
19	0,007	0,002	**0,007**	0,044	-0,002	**0,044**
21	0,005	-0,005	**0,007**	0,001	-0,007	**0,007**
22	0,005	0,005	**0,007**	0,023	-0,001	**0,023**
27	0,003	-0,005	**0,006**	0,006	0,003	**0,007**
100	0,009	0,001	**0,009**	0,007	0,002	**0,007**
Residuals of control points VLX 3 (meters)						
18	0,006	-0,001	**0,006**	0,006	0,000	**0,006**
19	0,005	-0,007	**0,009**	0,023	-0,013	**0,026**
21	0,004	-0,005	**0,006**	0,035	0,009	**0,036**
22	0,014	-0,007	**0,016**	0,051	-0,004	**0,051**
27	0,003	0,010	**0,010**	0,002	-0,009	**0,009**
100	0,003	-0,001	**0,003**	0,003	-0,002	**0,004**

Upon examining the data, it is evident that the accuracy of the control points used twice in the processing shows no significant difference. However, it is interesting to note that the residuals of the verification points exhibit variations, especially in the case of the VLX 3 data. This variation is largely attributed to the initially poor quality of VLX 3's QualityMap. This finding suggests that challenges were encountered during the survey phase, likely due to heavy traffic on this street, a key criteria for selecting the study location.

At the end of the survey, an abnormal trajectory was observed traced by the VLX 3. Faced with this situation, the decision was made not to repeat the survey and to conduct the Ivion test under these conditions. It would have been desirable to carry out the same test with the VLX 2; however, intentionally generating such an error proved to be complex. Fortunately, for NavVis product users, it is difficult to make such errors deliberately.

To further expand the experiment and assess Ivion's capabilities, processing was carried out without control points to solely evaluate the quality of SLAM.

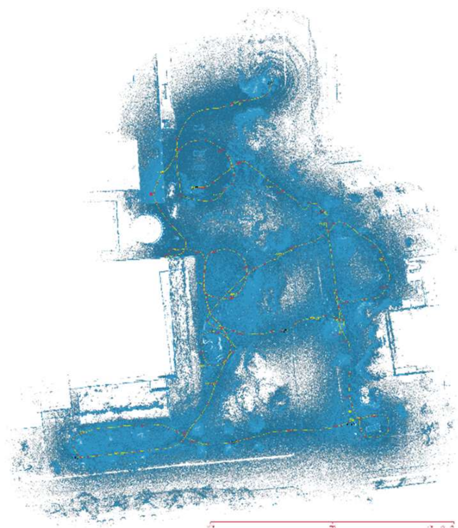

Figure 12 : before processing

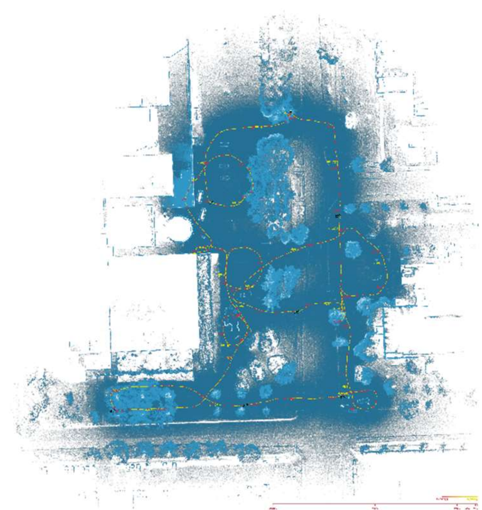

Figure 13 : after processing without control point

This demonstrates Ivion's capability to recreate a point cloud even from a survey of lower quality. It can also be inferred that control points come into play towards the end of the processing, serving solely for georeferencing and aiding in aligning the point cloud with strategic points to disperse residuals.

In conclusion, it appears that three control points are adequate for processing; however, the use of more points provides a better distribution of error. No significant difference was observed in this regard between VLX 2 and 3, which is good news and suggests that Ivion processes the data consistently.

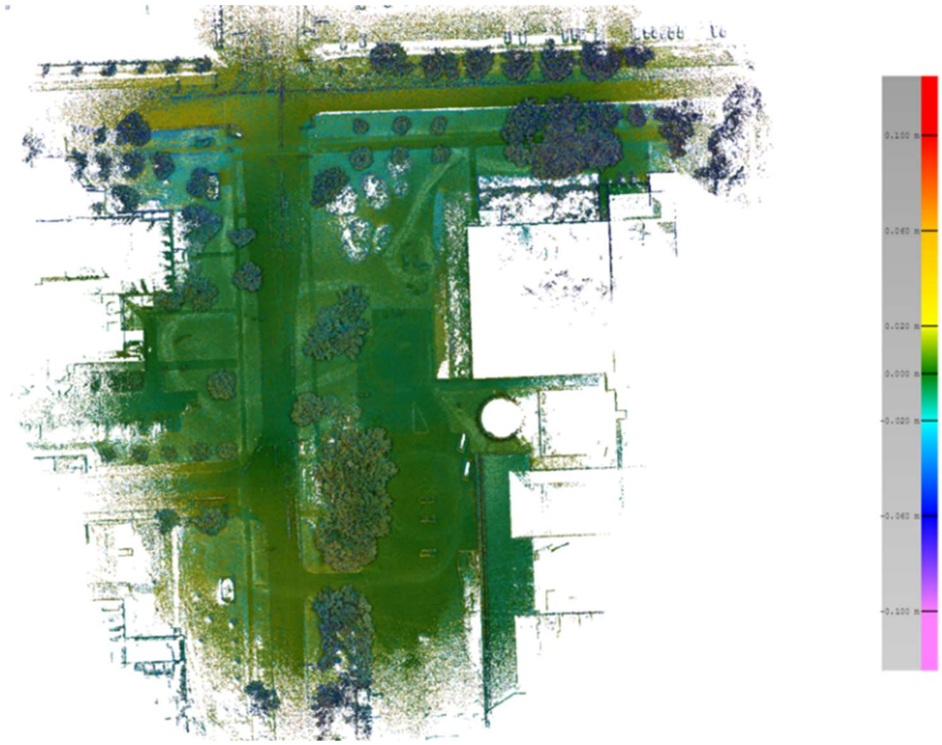

Figure 14 : Comparison of VLX 3 Point Clouds
(Cloud with All Control Points as Reference vs. Cloud without Control Points)

Range analysis

The two VLX devices exhibit both similarities and notable differences. However, what sets the VLX 3 apart is its exceptional range and ability to easily move away from structures such as buildings while maintaining precise positioning in space. This new version of the VLX can indeed capture data at much greater distances, enriching the SLAM process by providing a larger number of reference surfaces. As a result, the risks of corrupted data due to drift or tracking errors are significantly reduced.

Although the traced trajectories are not perfectly superimposable, the images below clearly highlight the difference in range between the two VLX devices. Data from the VLX 2 is represented in blue, while data from the VLX 3 is in red. It can be observed that the entire outline of the point cloud is marked in red, indicating a predominance of VLX 3 data in the distant periphery of the cloud. This disparity can be explained by the use of the latest NavVis model equipped with a LiDAR sensor from Hesai, featuring 32 laser layers, compared to the 16 of the VLX 2, with a range of up to 300 meters.

It is also possible to notice the difference in point density mentioned in a previous paragraph. Figure 8 indeed represents all the data from both VLX devices, where red clearly predominates over blue, illustrating the significantly greater contribution of points from the VLX 3.

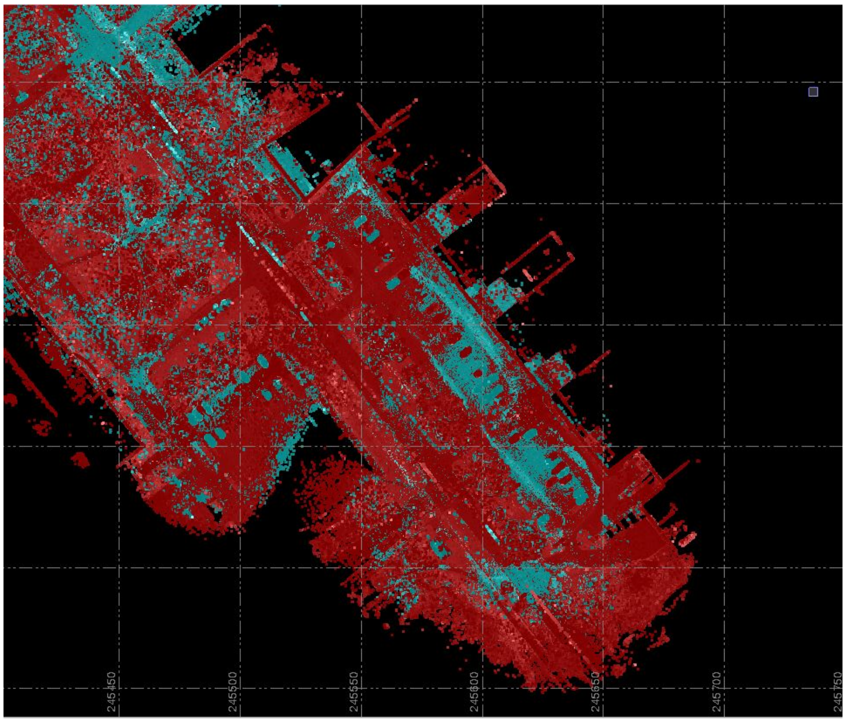

Figure 15 : Range Difference VLX 2 (Blue) vs. VLX 3 (Red)

The VLX and Sustainability

By providing an accurate and detailed view of structures and the environment, the VLX enables better planning and management of construction and urban development projects. This optimization helps avoid costly errors and rework, thus reducing the overall carbon footprint of projects.

Furthermore, the ability to share captured data with clients or stakeholders via the Ivion platform allows for improved collaboration and communication among different parties, reducing the need for physical travel and meetings, and promoting remote work. This can lead to further reductions in emissions associated with professional travel.

Lastly, thanks to the accuracy and high density data collected by the VLX, professionals can optimize project design by accurately accounting for existing conditions, which can prevent unnecessary destruction of vegetation or natural areas. This promotes a more environmentally friendly approach and contributes to the preservation of local ecosystems.

In conclusion, the use of NavVis' VLX mobile mapping system aligns with sustainable development by enabling faster and more efficient surveys, better project planning and management, enhanced collaboration, and a more environmentally conscious approach. These advantages help reduce the environmental impact of mapping and construction activities, while facilitating a more responsible and sustainable approach to urban and territorial development.

Processing Cost

Regarding processing costs, there will be a significant difference between the VLX 2 and the VLX 3. Processing data from the VLX 3 will cost approximately two and a half times the price of processing data captured with the VLX 2. However, due to the increased range and higher density of the newer model, a less extensive trajectory will be required. This will help mitigate the impact of the new pricing structure. For a project like this, the processing cost for the VLX 2 is about $850, and for the VLX 3, it's about $1900.

The various advantages and limitations.

There are several notable advantages to using the VLX. One of the first advantages that comes to mind is the significant reduction in time spent in the field. This time savings can be seen as a financial benefit, but it also has a positive impact on the safety of technicians in the field. Surveying near roads can be hazardous and comes with its share of risks, but with this type of scanner, the time spent alongside buses, semi-trucks, and reckless drivers is significantly reduced, thereby decreasing risks to personnel.

Another advantage is the elimination of numerous return trips to the field. Returns for missed measurements, unrecorded utility covers, or uncollected electrical wire heights are now a thing of the past. By covering the essential project elements, the user can be confident that everything else will also be covered.

Additionally, some clients may want access to the captured data. Thanks to the Ivion platform, it is now possible to share access to this data with specific users. They can viewpoints of interest, measurements, and even integrate DXF files on the visualization platform.

However, it is important to note that despite these many advantages, the VLX is not suitable for all situations. For example, it is not designed for vertical analysis or measuring the width of a bolt on a structure. Its primary purpose is to analyze the structure as a whole.

Return on Investment

The most obvious benefit of using a NavVis VLX is a time-saving advantage. As mentioned earlier, a conventional survey of this area would have taken 24 hours of field time and approximately 5 hours of drafting compared to 5 hours of field time for the NavVis (including setting up control points) and 10 hours of office drawing. Therefore, there is a 14-hour gain with the NavVis VLX. Given the current labor shortage issue, the VLX allows for completing twice as many projects with the same resources.

Figure 16 : Simulation of a survey with a tripod-mounted scanner. Each red point represents a station.

The Ivion Cloud processing platform also helps save costs on the acquisition of a processing computer. If the survey had been conducted with a tripod-mounted laser scanner, more than 260 stations would have been required to cover the area to be surveyed (see Figure 11, where each red point represents a station). For such a project, the user responsible for processing the data in the office would take approximately 4 hours to perform the registration if they use a high-performance processing computer. In contrast, NavVis' cloud processing saves human time.

This platform also enables various collaborators on a project to track its progress over time based on the different scans conducted. An engineer, an architect, and a general contractor can therefore monitor the project's developments without the need for software to read point clouds and can make notes on certain elements they observe in the scan or photos. Users of this platform are thus taking a step towards the BIM (Building Information Modeling) method, which aims to promote collaboration among the stakeholders involved in a project.

Personal words

From a personal perspective, the VLX is undoubtedly one of my favorite measuring tools. It's very user-friendly, easy to grasp, and has a slightly futuristic style that, I admit, may not appeal to everyone. One feature I particularly appreciate is the real-time visualization of captured data on the screen, which provides a sense of accomplishment and productivity. It also allows for quickly identifying any potential errors during the survey, making immediate corrections if necessary. – Jules Suzineau, a.-g.

Conclusion

In conclusion, the comparative study of NavVis' mobile mapping systems, VLX 2 and VLX 3, has yielded promising and intriguing results in a spacious urban environment. Both systems have demonstrated distinct performances in terms of accuracy and resolution, yet they have consistently produced high-quality results in terms of residuals. Moreover, they have exhibited notable reliability even in an environment exposed to numerous independent variables beyond the operator's control.

The efficiency of the VLX has been highlighted by the significant reduction in field data collection time. Compared to traditional surveying methods, the VLX enables data collection in just a few hours, whereas a standard technician would require several days to achieve a similar task.

In summary, the study has shown that NavVis' VLX mobile mapping systems are high-performing tools, offering an efficient and rapid alternative to conventional surveys. Their appropriate utilization, considering their advantages and limitations, will maximize their benefits in various mapping and topographic survey applications.