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Technical control and monitoring of hydraulic sites using the 3D scanner laser

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Medjahed manal & Korichi imane

Dedication

I dedicate this work:

To my beloved mother Sellami Nadia who patiently tolerated all my misgivings with a smile and stood by me in times of despair. Her prayers, moral support and kind words were of great inspiration during my piece of research.

To my father Salim Medjahed to whom I forever remain indebted.

The fruit of this work would not be possible without your upbringing; you taught me to trust myself to achieve what I wish. I am proud to be your daughter. Thanks Dad.

To my future husband Hüseyin Bayraktar.

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To all my teachers who always push me to hold on and never to give up.

To all my friends and classmates.

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Abstract

The paper presents the practical aspects of hydraulic sites monitoring using terrestrial laser scanning.

Hydraulic sites Monitoring is an important aspect in ensuring their proper functioning.

Monitoring can be done on several levels with physical methods or geometric methods (geodetic measurements). Among geodetic measurement methods could be mentioned: the method of triangulation and trilateration, geometric leveling method, satellite measurements methods and terrestrial laser scanning the newest method to capture a physical object's exact size and shape into the computer world as a digital three dimensional representation (BIM).

This representation is accurate and rich in site information that helps us solve problems before they happen, especially those that occur during design and implementation. We can also avoid the wasted costs that result from bad planning and lack of a clear vision of the project (saving cost and time).

Key words: 3D scanner laser, hydraulic sites monitoring, dam monitoring, leica BLK360 scanner laser, scan to BIM, Terrestrial scanner laser.

الملخص

يعرض البحث الجوانب العملية لمراقبة المواقع الهيدروليكية باستخدام المسح الأرضي بالليزر حيث تعد مراقبة المواقع الهيدروليكية جانبًا مهمًا في ضمان عملها بشكل صحيح.

يمكن إجراء المراقبة على عدة مستويات بطرق فيزيائية أو طرق هندسية (القياسات الجيوديسية) من بينها: طريقة التثليث ، طريقة التسوية الهندسية ، طرق قياسات الأقمار الصناعية والمسح بالليزر الأرضي كأحدث طريقة لالتقاط الحجم والشكل الدقيق للكائن المادي و إنشاء بيانات ثلاثية الأبعاد لإدماجها في نمذجة معلومات البناء (BIM) حيث يمكننا خلق نموذج ذكي تخيلي دقيق غني بالمعلومات الخاصة بالموقع يساعدنا على حل المشاكل قبل حدوثها خصوصاً تلك التي تحدث أثناء التصميم و التنفيذ وتفادي التكلفة المهدورة نتيجة سوء التخطيط وعدم الرؤية الواضحة للمشروع (Cost & Time Saving).فتطبيق تكنولوجيا البيم يوفر علينا أخطاء جسيمة وواضحة يمكن أن نقع بها أثناء التنفيذ دون لفت الانتباه لذلك.

الكلمات المفتاحية: ماسح ضوئي ثلاثي الأبعاد ، مراقبة المواقع الهيدروليكية ، مراقبة السدود ، الماسح الضوئي لايكا BLK360 ، من المسح ضوئي إلى نمذجة معلومات البناء BIM ، ماسح ليزر أرضي.

Résumé

L'article présent les aspects pratiques de la surveillance des sites hydrauliques à l'aide du stationnaire scanner laser, La surveillance des sites hydrauliques est un aspect important pour assurer leur bon fonctionnement.

L'observation peut être réalisée à plusieurs niveaux par des méthodes physiques ou techniques (mesures géodésiques), Parmi eux figurent la méthode à trois voies, la méthode de nivellement géométrique, les méthodes de mesure par satellite et le balayage laser du sol en tant que méthode de pointe pour capturer la taille et la forme exactes d'un objet physique et générer des données 3D à intégrer dans la modélisation des informations du bâtiment (BIM),Où nous pouvons créer un modèle intelligent imaginatif précis riche en informations sur le site qui nous aide à résoudre les problèmes avant qu'ils ne surviennent, Surtout ceux qui se produisent lors de la conception et de la mise en œuvre et évitent le gaspillage des coûts en raison d'une mauvaise planification et d'un manque de vision claire du projet (économie de temps et d'argent).

L'application de la technologie BIM nous évite des erreurs graves et claires que nous pouvons commettre lors de la mise en œuvre sans attirer l'attention sur elle.

Les mots clés: Scanner 3D, surveillance de site hydraulique, surveillance de barrage, scanner Leica blk360, La numérisation vers BIM, stationnaire laser scanners.

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List of Abbreviations

LIDAR: Light Detection and Ranging.

INS: inertial navigation system.

GPS: Global Positioning System.

TLS: Terrestrial laser scanner.

IP/54:

- IP = Protection index.
- 5 = solid = Protected against dust and other microscopic residues.
- 4 = liquid = Protected against splashing water in all directions.

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General Introduction

If you are working in the construction industry, you have probably come across the term 'Scan to BIM' or 'Field to BIM' at some point.

Or, you may have noticed your construction partners using a 3D laser scanner on the building site. But what is scan to BIM exactly?

Let's start with the part you may not have already known: BIM

BIM is an acronym for Building Information Modeling. It is a highly collaborative process that allows multiple stakeholders and AEC (architecture, engineering, construction) professionals to collaborate on the planning, design, and construction of a building within one 3D model.

In a scan to BIM process, a laser scanner is used to capture an accurate 3D scan of the real world conditions on a project. The scan data is then imported into a 3D modeling environment to create either accurate as built models or to inform the design with the real world conditions.

The main objective of this project is to apply the building information modeling process to an example from reality while we will do a technical control and monitoring of a hydraulic site

(Oued ksob) using a terrestrial laser scanner.

This research consists of three chapters:

CHAPTER I: this chapter contains of two parts:

1. General review on 3D scanner laser and types of scanning techniques.
2. The role of the 3D scanner laser in hydraulic sites monitoring.

CHAPTER II: Collecting hydraulic site data with a 3D stationary scanner laser.

CHAPTER III: Point cloud registration and post processing.

CHAPTER IV: point cloud to BIM conversion.

CHAPTER I

GENERAL REVIEW ON 3D SCANNER LASER

Chapter I: General review on 3D scanner laser

General review on 3D scanner laser and types of scanning techniques

Introduction

3D Laser Scanners also known as LIDAR is an acronym for Light Detection and Ranging.

It is an optical remote sensing technology that can measure the distance to or other properties of a target by illuminating the target with light pulse to form a 3D representation of the scene often called a point cloud.

What is the point cloud?

Most 3D scanners output raw scanned data in point cloud format. Point clouds produced by 3D scanners and 3D imaging are visualized for the ease of measurement.

A point cloud is basically a set of data points in a 3D coordinate system, commonly defined by *x*, *y*, and *z* coordinates, they are used to represent the surface of an object and do not contain data of any internal features, color, materials, and so on.

However, many CAD applications employ parametric, direct, or mesh-based modeling.

Therefore, there is a need to convert the data from the point cloud into formats natively adaptable to CAD software in order to obtain geometric information of the scanned part.

History of the 3D scanning development

With the advent of computers, it was possible to build up a highly complex model, but the problem came with creating that model.
So in the eighties, the tool making industry developed a contact probe. At least this enabled a precise model to be created, but it was so slow. The thinking was, if only someone could create a system, which captured the same amount of detail but at higher speed, it will make application more effective.
Therefore, experts started developing optical technology. Using light was much faster than a physical probe. This also allowed scanning of soft objects, which would be threatened by prodding. At that time, three types of optical technology were available:

- Point, which is similar to a physical probe in that it uses a single point of reference, repeated many times. This was the slowest approach as it involved lots of physical movement by the sensor.
- Area, which is technically difficult. This is demonstrated by the lack of robust area systems on sale.
- Stripe, the third system - was soon found to be faster than point probing as it used a band of many points to pass over the object at once, which was accurate too. Therefore, it matched the twin demands for speed and precision.

So stripe was clearly the way forwards, but it soon became apparent that the challenge was one of software. To capture an object in three dimensions, the sensor would make several scans from different positions. The challenge was to join those scans together, remove the duplicated data and sift out the surplus that inevitably gathers when you collect several million points of data at once.
One of the first applications was capturing humans for the animation industry. By the mid nineties they had developed into a full body scanner.

In 1994, 3D Scanners launched REPLICA which allowed fast, highly accurate scanning of very detailed objects. Meanwhile Cyber ware were developing their own high detail scanners, some of which were able to capture object color too, but despite this progress, true three dimensional scanning with these degrees of speed and accuracy remained elusive.
One company Digibotics did introduce a 4 axis machine, which could provide a fully 3D model from a single scan, but this was based on laser point not laser stripe and was thus slow.

Neither did it have the six degrees of freedom necessary to cover the entire surface of an object, neither could it digitize color surface.
While these optical scanners were expensive, Immersion and Faro Technologies introduced low cost manually operated digitizers.

These could indeed produce complete models, but they were slow, particularly when the model was detailed. By this time, 3D modelers were united in their quest for a scanner, which was:

- accurate
- Fast
- truly three dimensional
- capable of capturing color surface
- Realistically priced.

In 1996, 3D Scanners took the key technologies of a manually operated arm and a stripe 3D scanner and combined them in Model Maker. This incredibly fast and flexible system is the world's first Reality Capture System. It produces complex models and it textures those models with color. Color 3D models can now be produced in minutes.

The main advantages of laser scanning

Speed

The rapid speed of data capture, from a 3D laser scanner, allows millions of data points to be recorded in seconds. This ensures that large environments can be surveyed in a short timescale and makes 3D surveying ideal for work on particularly time sensitive projects, when a quick turnaround is vital.

The rapid nature of the 3D measurement process greatly reduces man-hours required on site as well as any shutdown of facilities and overall disruption.

This innate speed and flexibility is of huge benefit to the measurement industry and it is one of the reasons that 3D laser scanning is become more and more widely utilized.

Accuracy

3D laser scanning shines with accuracy. At ±1mm, you can depend on the data for design work with no field fabrications needed.

More safety

The remote nature of documentation from the 3D scanner is ideal for hazardous or hard to reach areas. 3D scanners allow surveyors to capture environments without the need to physically access the area.

This reduces the requirement for costly and laborious health and safety measures and ensures the safety of 3D surveyors.

Detailed documentation

The 3D data captured through the scanning process is so comprehensive, that almost every detail is recorded. The chance of any omission is hugely reduced, with a very small risk of error.

This vast level of detail ordinarily eliminates entirely, the requirement to re-visit site on the basis that measurements we missed during the survey process.

The detailed documentation process also allows 3D surveyors (and indeed end clients) to visit sites virtually via point cloud walk through or interactive 360 image viewers.

This again helps to eliminate the need to "actually" visit site when virtual visits are so realistic and easy to facilitate.

Less assumptions

In traditional methods we have to include many assumptions to coordinate the survey points or regarding features on the ground. With the coming of laser technology, the advantage is that there needs to be very less assumptions.

Better coordination among various processes

With the scanned model, the architect, engineer and construction companies can make better collaboration and coordination. Once scanned data is helpful for all these professionals in doing their jobs related to the site.

Better visualization

The 3d models can be used for visualization and make the final output better by making tweaks as far as possible. Alternate visualization suggested or proposed can be evaluated, visualized and adopted.

Laser scanning limitations

- Given the optical nature of 3D laser scanning, it is impossible to measure any surface that is out of the scanner's line of sight. This means that hidden or internal geometry that is not visible to the scanner is unable to be measured.
- Scanners can't determine the material they are scanning
- Scanners can't successful scan transparent or reflective objects
- Some systems do not work in sun or rain.
- Large 3D data sets require post processing to produce a useable output.
- Difficulty in extracting the edges examples from indistinct data clouds.
- Output requires manipulation to achieve acceptable recording quality.
- No common data exchange formal currently in use.
- Difficult to stay up to date with developments.
- Hardware expensive and sophisticated software required to processes data.

Types of LIDAR

There are different scanning systems used for capturing different sized objects (from a small tool to a large building), with a wide range of scales (from few mm up to tens of hundreds of meters), and so can be divided into different scanning systems according to range:

- Airborne LIDAR.
- Terrestrial LIDAR.

Airborne LIDAR

With airborne LIDAR, the system is installed in either a fixed-wing aircraft or helicopter. The infrared laser light is emitted toward the ground and returned to the moving airborne LIDAR sensor.

There are two types of airborne sensors:

- Topographic LIDAR
- Bathymetric LIDAR

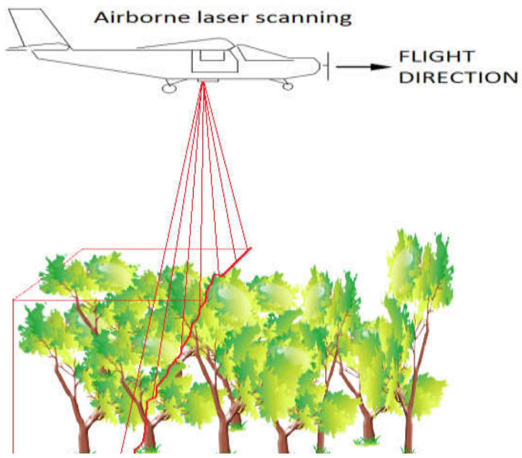


Figure 1 airborne laser scanning

Topographic LIDAR

Topographic LIDAR can be used to derive surface models for use in many applications, such as forestry, hydrology, geomorphology, urban planning, landscape ecology, coastal engineering, survey assessments, and volumetric calculations.

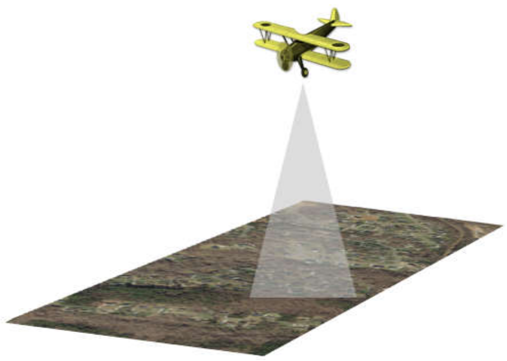


Figure 2 topographic LIDAR

Bathymetric LIDAR

Bathymetric LIDAR is a type of airborne acquisition that is water penetrating. Most bathymetric LIDAR systems collect elevation and water depth simultaneously, which provides an airborne LIDAR survey of the land water interface.

With a bathymetric LIDAR survey, the infrared light (traditional laser system) is reflected back to the aircraft from the land and water surface, while the additional green laser travels through the water column.

Analyses of the two distinct pulses are used to establish water depths and shoreline elevations. Bathymetric information is very important near coastlines, in harbors, and near shores and banks.

Bathymetric information is also used to locate objects on the ocean floor.

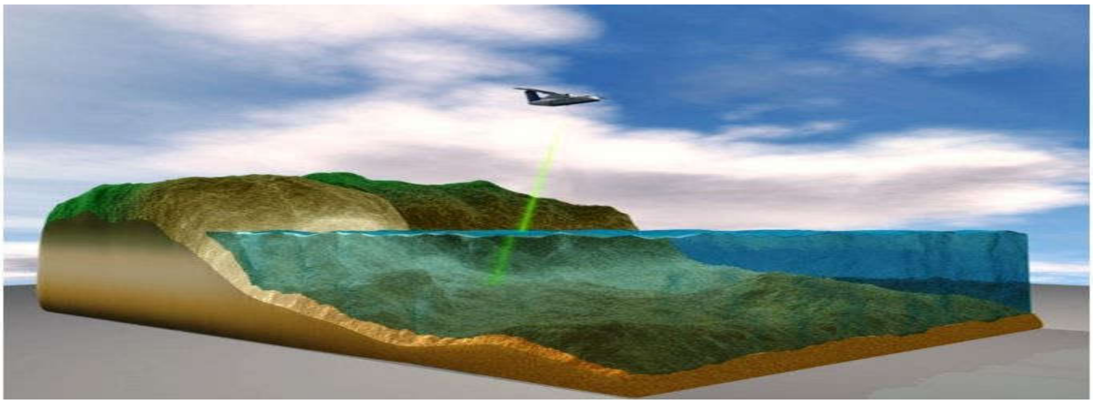


Figure 3 bathymetric LIDAR

Terrestrial LIDAR

Terrestrial Lidar collects very dense and highly accurate points, which allows precise identification of objects.
These dense point clouds can be used to manage facilities, conduct highway and rail surveys, and even create 3D city models for exterior and interior spaces, to name a few examples.

There are two main types of terrestrial LIDAR:

- Mobile LIDAR.
- Stationary LIDAR.

Mobile LIDAR

Mobile LIDAR is the collection of LIDAR point clouds from a moving platform. These systems can include any number of LIDAR sensors mounted on a moving vehicles such us, trains, and even boats.

Figure 6 car- borne mobile scanning system

Figure 5 small-vehicle-borne mobile scanning system

Figure 4 train-borne mobile scanning system

Mobile systems typically consist of a LIDAR sensor, cameras, GPS (Global Positioning System), and an INS (inertial navigation system), just as with airborne LIDAR systems.

Mobile LIDAR data can be used to analyze road infrastructure and locate encroaching overhead wires, light poles, and road signs near roadways or rail lines.

Stationary LIDAR

Stationary LIDAR is the collection of LIDAR point clouds from a static location.

Typically, the LIDAR sensor is mounted on a tripod mount and is a fully portable laser based ranging and imaging system.

These systems can collect LIDAR point clouds inside buildings as well as exteriors.

Common applications for this type of LIDAR are engineering, mining, surveying, and archaeology.

The following table shows the most of the static TLS scanners on the current market, and Figure 7 shows some pictures of them.

TLS scanner	Company	Date of introduction
DeltaSphere-3000IR	3rdTech	2005
Surphaser 25HSX	Basis Software	2006
Surphaser 25HS	Basis Software	2005
LS 420	Faro	2005
LS 480	Faro	2005
LS 880	Faro	2005
Imager 5006/HDS6000	Z+F/Leica	2006
Imager 5010/HDS7000	Z+F/Leica	2010
Faro Focus 3D	Faro	2010
CPW 8000	Callidus	2007
CP 3200	Callidus	1997/2006
4400-LR	I-Site	2006
4400-CR	I-Site	2006
Scan Station 2	Leica Geosystem	2007
ILRIS-3DER	Optech	2006
ILRIS-3D	Optech	2000
LMS-Z420i/LMS-Z390i	Riegl	2003/2007
LPM-321	Riegl	2007
GX	Trimble	2005
VX	Trimble	2007

Table 1 stationary laser scanners existing on the current market

Figure 7 examples of static TLS scanners on the current market

Leica 3D stationary laser scanners

Leica Geosystem (formerly known as Wild Heerbrugg or just Wild) based in eastern Switzerland produces products and systems for surveying and geographical measurement (geomatics).

Among what this company has produced is a set of three-dimensional ground scanners, which are as follows:

Leica BLK360 Laser Scanner

BLK360 captures the world around you with color panoramic images superimposed on a precision point cloud.

With a single button, Leica BLK360 is not only the smallest and lightest of its kind, but also offers a simple user experience.

Anyone who can operate an iPad can now capture the world around them with high resolution 3D panoramic images.

Figure 8 leica BLK360 laser scanner

BLK 360 Proprieties

- 0.6 up to 60m range.
- 6mm at 10m to 8mm at 20m 3D point accuracy.
- Weighs 1 kg / Size 165 mm tall x 100 mm diameter.
- Less than 3 minutes for full-dome scan (in standard resolution) and 150 MP spherical image generations.
- 360,000 laser scan set points per second.
- High-Dynamic Range (HDR) and thermal imaging.
- Ip54/ open mirror
- Equipped with one button.
- Self assembly.
- +5 to 40 C° operating temperature.

Leica RTC360 Laser Scanner

The Leica RTC360 3D reality capture solution empowers users to document and capture their environments in 3D, improving efficiency and productivity in the field and in the office through fast, simple-to-use, accurate, and portable hardware and software.

The RTC360 3D laser scanner is the solution for professionals to manage project complexities with accurate and reliable 3D representations and discover the possibilities of any site.

Figure 9 Leica RTC360 laser scanner

RTC 360 Proprieties

- 2,000,000 pts /sec.
- 0.5m to 130m range.
- 3mm at 10m 3D point accuracy.
- HDR imagery.
- Less than 1 min imagery speed.
- Ip54/ closed mirror.
- 5.35 Kg weight.
- Full automatic registration.
- -5 to +40C° temperature range.

Leica P-series

Leica ScanStation P-Series 3D laser scanners are the perfect partner when capturing 3D geometry of civil infrastructure, creating an as built representation of a large industry complex, reconstructing a crime scene or generating 3D data for integration into Building Information Modeling (BIM).

Figure 11 Leica ScanStation P50/P40/P30

Figure 10 Leica ScanStation P16

	P50	P40	P30	P16
Maximum range	> 1 km	270m	120m	80m

Table 2 Leica ScanStation proprieties

Maximum scan rate	1,000,000 pts/sec	1,000,000 pts/sec	1,000,000 pts/sec	1,000,000 pts/sec
Maximum Resolution at 10m	User definable	User definable	0.8 to 50 mm	1.6 to 50 mm
Imaging speed	<1min	<1min	<1min	<1min
HDR imagery	yes	yes	yes	yes
Weight / volume	12kg / 24cm × 35cm × 40cm	12kg / 24cm × 35cm × 40cm	12kg / 24cm × 35cm × 40cm	12kg / 24cm × 35cm × 40cm
Operating temperature	-20 to +50C°	-20 to +50C°	-20 to +50C°	-20 to +50C°
Solid particle / Liquid ingress protection	Ip54/closed mirror	Ip54/closed mirror	Ip54/closed mirror	Ip54/closed mirror

TLS Scanner laser applications

3D TLS laser scanner expands surveys to the following fields:

- Architecture and civil engineering: 3D survey of buildings, survey of facades with acquisition of georeferenced photos, establishment of plans to standards (architectural SIA) based on the laser survey, acquisitions and plans of all kinds of works.
- Construction sites: excavation control, validation of free spaces, calculation of cubature volumes, determination of outside profiles.
- Road applications: 3D surveys of tunnels, inspection and documentation of structures.
- Natural hazards: monitoring of cliff movements, determination of moving masses, landslides.
- Monitoring: monitoring deformation of surfaces, control of engineering structures (dams, bridges, walls of buildings, etc).

Among the multiple and unlimited uses of a 3D scanner, we are interested in using it in the field of hydraulic site monitoring and analysis to conduct surveying, then analyze data to extract specific useful information. This will be explained in detail in the second part of this chapter.

The role of the 3D scanner laser in hydraulic sites monitoring

Accurate and precise storage tank analysis

Laser scanning facilitates a comprehensive analysis of water storage tanks.

Scanning allows us to monitor the entire tank shell for deformation rather than by surveying a limited number of discrete points.

Traditionally, storage tank survey is carried out using a total station or a simple measuring tape. While these techniques provide the necessary position information, they are generally time intensive when multiple measurements are required.

When using a measuring tape, measurements are prone to errors.

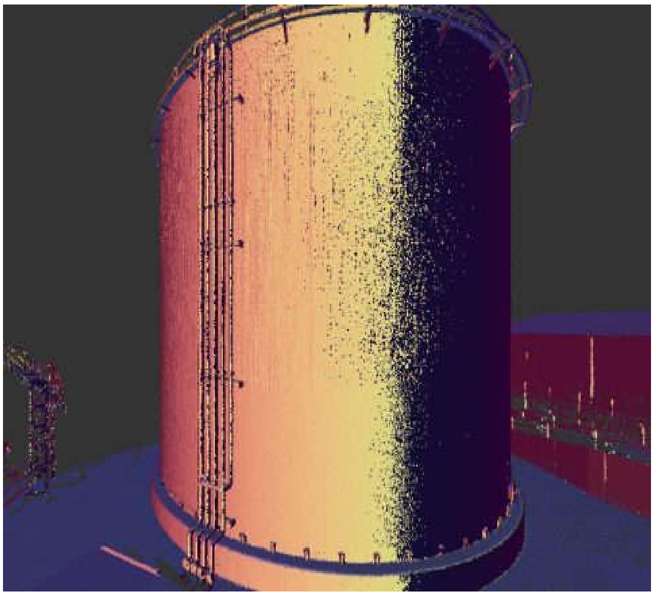


Figure 12 a 3D point cloud of the tank for analysis and monitoring

3D scanning removes these deficiencies by capturing thousands of points in the same time it takes to capture ten points with a total station.

From the scan data, we are able to provide:

- Difference maps that compare millions of points between scans to highlight areas where change has occurred.
- Radial displacement plots for every degree around the storage tank.
- Diametrical distance analysis so that engineers can understand the variation in verticality of the tank wall.
- Overall verticality analysis.
- Tilt/subsidence analysis.

We can also capture imagery on site, this visual information provides a record of areas surveyed and could be used for monitoring.

The exact roundness of a tank is determined; this ensures that roof fabrication or seal selections match the existing structure. Alternatively, the information can be used to identify areas to be corrected for roundness and to verify repairs before fabrication.

Comparisons of millions of points between two scans over an extended period can highlight areas where change has occurred.

Closer inspection or repairs could then be undertaken on the specific areas of concern to avoid costly failures and potential loss of assets.

Monitor and check the pipeline networks

For the oil and gas industry, corrosion is one of the leading causes of pipeline leaks, ruptures, spills, and explosions.

The oxidization of steel pipelines leads to gradual loss of wall thickness and a drop in pipe strength, which can result in leakage or rupture depending on the pressure stress in the pipeline.

Thanks to the 3D scanner, we can create a model that helps us to monitor the pipelines and to accurately detect any defects to avoid the pipeline leak which costing millions to clean it up.

The scanner can also detect a change in thickness of the material’s viscosity, typically a red flag for corrosion.

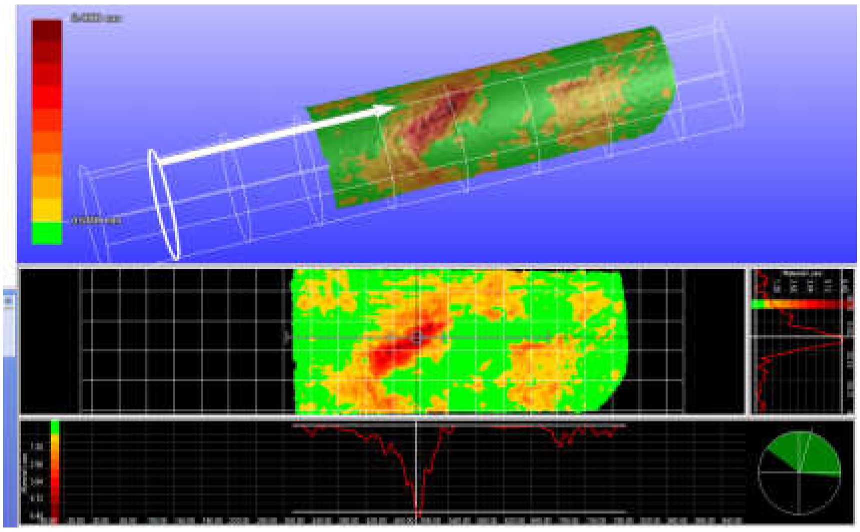


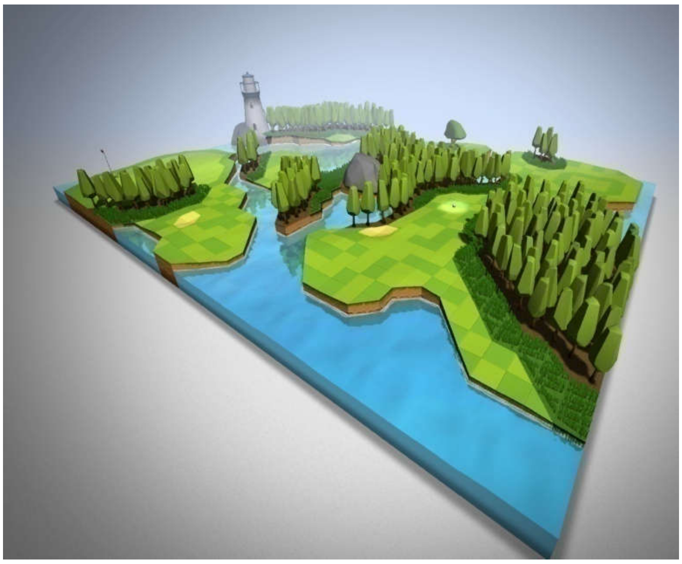
Figure 13 water pipe modeling and detection of damaged surfaces

Waterways control

We can draw three dimensional maps of surface waterways, which are a channel in which water runs continuously or intermittently, from a natural or anthropogenic source of human creation.

Surface waterways include rivers, streams, and canals that are monitored in order to precisely control the water course to reduce the risk of floods and store this water for irrigation or electrical energy production.

We can also determine the degree of surface water pollution, measure its temperature and speed of flow.



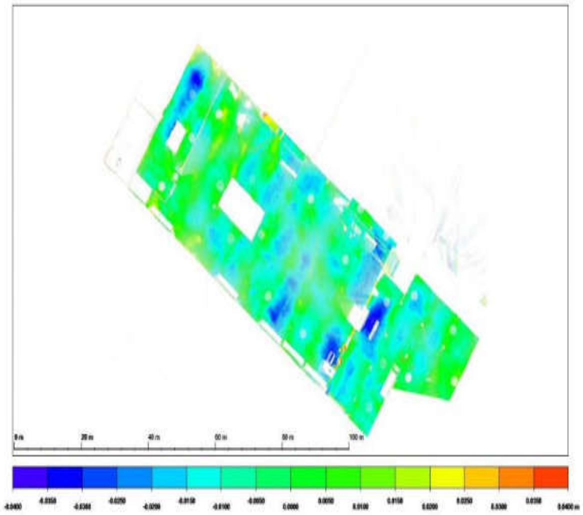


Figure 14 a 3D model of waterways

Dams monitoring

The difficulty in monitoring dams is to find a spatial control and measurement technique that includes many desirable properties, such as accuracy, reliability, low cost, and ease of use.

Some of these benefits can be seen in several ways, but it's really hard to find a way to cover them all.

In the following paragraphs some of the approaches developed in this context are reported (from classic techniques to new technologies):

- Classical topographic methods based on angles, distances and height variation measurements are very popular in the quantitative surveying field. The equipment used consists of accurate and appropriate the odolites or total stations. When the point that has to be determined is inaccessible, indirect methods are used, for example: single or multiple intersections. Furthermore, contact sensors can complete these measurements, such as: an inclinometer, a pendulum, dials gauges or extensometers. However, this contact nature prevents them from us eat the final stages of destructive load testing, and they can only acquire measurements in one dimension.
- The Global Positioning System (GPS) has been used in structural monitoring of large dams, as well as combined with other sensors such as accelerometers and inertial navigation systems. In spite of this, GPS has two significant limitations, as well. Firstly, as signals are received from satellites, coordinates cannot be measured indoors or through obstacles. The second limitation is that the current precision levels of GPS are limited to +/- 1cm horizontally, and +/- 2cm vertically.
- Digital close-range photogrammetric has been a low cost alternative, and is highly accurate. It also offers a quick, remote, three-dimensional data acquisition with images that provide a permanent visual recording of the test, but the compulsory use of targets might be disadvantageous in some circumstances; especially when the access to the object is risky or when it is inaccessible to operators. Due to the lack of scale definition in the photogrammetric process, measurements must be taken by using additional instrumentation (for example, reflector less total stations).
- Terrestrial Laser Scanning has become a new alternative to the monitoring of structures incorporating novelty approaches and computer methods. Although the approaches noted above present an accurate modeling strategy and have demonstrated their viability for structural monitoring, none of them has been tested yet over complex structures such as large dams. In this context, outlined some first results of a project aimed at monitoring deformations of large concrete dams by terrestrial laser scanning. The reported analysis focuses on two main problems: the first one is the accuracy and the stability of georeferencing, which is fundamental to make comparisons between different multi-temporal scans; the second one is the computation of deformation based on the acquired point clouds. Particularly, a comparison is performed using different surfaces types, such as: resembled point cloud, mesh and polynomial surface.

CHAPTER II: Collecting hydraulic site data with a 3D stationary LIDAR

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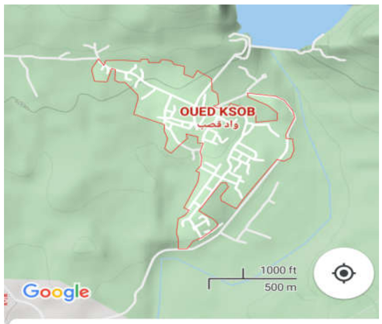

Figure 15 Oued ksob location

Introduction

Ksob dam is one of the oldest dams in Algeria and it is located in the village of Boukhemissa, 10 kilometer away from the city of M'sila on the road Borj bou arreridj at the southeast.

Its water is characterized by its sweetness and purity but due to neglect it is muddy.

It is used to irrigate 13,000 hectares of agricultural lands with a capacity of 50 million cubic meters of water but the dam currently only allows irrigation of a third of this area due to silt accumulation.

Geography	
country	Algeria
city	M'sila
village	Boukhemissa
waterway	Ksob
Objectives and impacts	
vocation	Irrigation
Starting date of construction	1933
Final completion of construction	1939
Activation date	1939
Dam	
Height	32m
Tank	
Volume	50 million m^3

Table 3 studied site informations

Equipment used for this mission

Figure 16 Leica BLK 360

Figure 18 GLK 312 battery charger

Figure 17 BLK360 tripod

Figure 20 BLK360 tripod adapter

Figure 19 BLK360 mission bag and transport hood

Figure 21 GEB212 lithium- Ion battery

Instrument setup

Battery setup

1. Open the battery compartment.
2. Remove the battery from the battery compartment.
3. Insert the new battery into the battery compartment. (Ensure that the battery contacts are facing inwards).
4. Close the battery compartment.

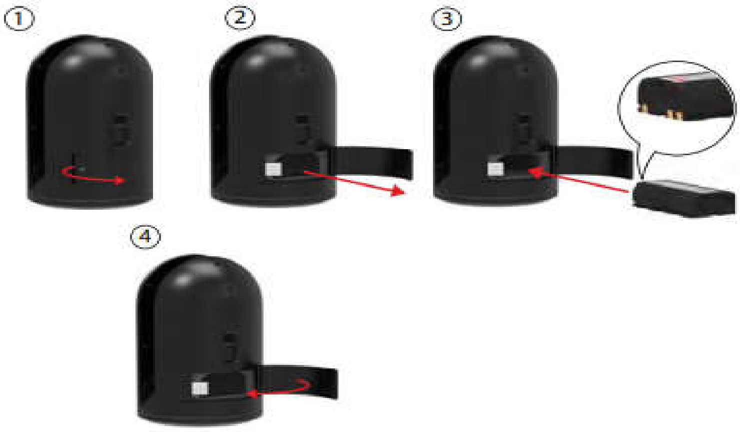

Figure 22 Battery preparation steps

Tripod Setup

1. Deploy the tripod and install the instrument.
2. Spread the tripod legs.
3. Adjust the height of the feet.
4. Insert the BLK by pressing the two press buttons on the tripod head in order to release the locking pins.
5. Once the BLK is pressed, release the buttons which will block the BLK on the tripod.
6. The instrument is ready to operate.

Note: the tripod should be placed approximately horizontally which is easy on flat ground, but less on sloping ground: adjust the feet so that the instrument appears the most vertical to the eye.

Figure 23 Tripod preparation steps

Connecting to a computing device

1. Start the BLK360 and wait until the LED is continuous green.
2. On the computing device select settings and tap Wi-Fi.
3. The BLK itself gives off its own Wi-Fi signal so you can connect to that with your device just like you would any other Wi-Fi network.
4. Select the network BLK360-35xxxxx in the Wi-Fi settings to be connected.

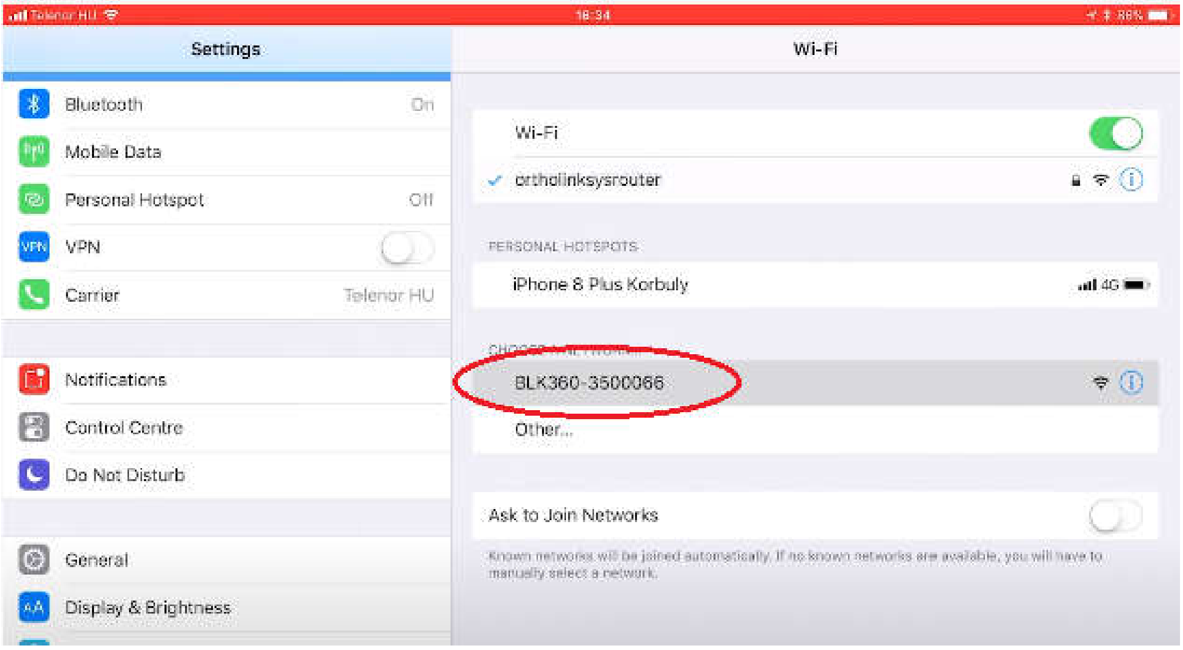

Figure 24 connecting to the computing device

→The number 35xxxxx is the serial number of the BLK360.

5. Enter the password.

→The instrument specific password is printed on the label in the battery compartment (e.g. COL-123-456-789).

Figure 25 the password is printed on the inside cover of the battery door

Scanning process

If we click on "start," The BLK 360 emits a rapidly pulsing or continuous laser beam as it emits the beam the scanner automatically rotates around its vertical axis and a rapidly spinning or oscillating mirror also moves the beam up and down, the result is a systematic sweeping of the beam over the area.

When the beam hits an object some of its energy bounces back to the scanner where if the returned energy signal is strong enough a sensor detects it and timer uses it to calculate the distance from the scanner to the object.

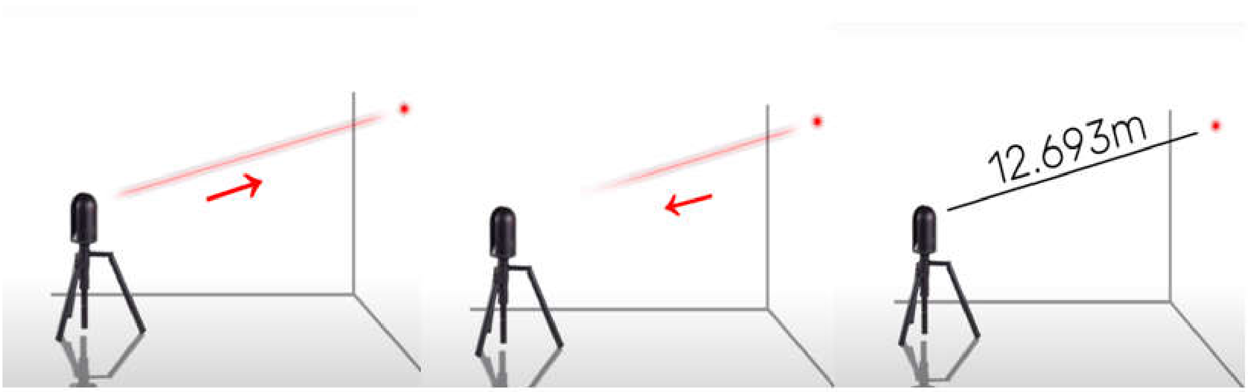

Figure 26 beam reflection and distance measurement from the scanner to the object

But there's more to 3d scanning than just measuring distances, it also knows exactly which angle the mirror was at when it sent out that pulse of light and which direction the BLK360 itself was facing.

By using all that information, it can calculate a 3d x y and z coordinate position for each point in relation to the device itself.

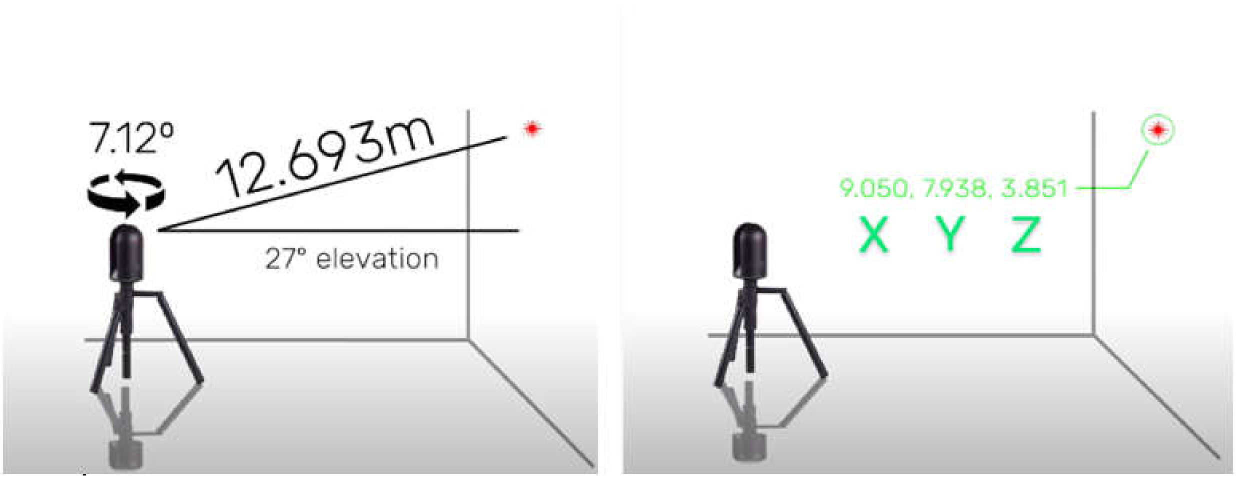

Figure 27 the scanner determines the coordinates of the first point in the space

Then the mirror rotates ever so slightly and it does this whole process again measuring a point just above the previous point that has been determined.

So the mirror spins all the way around and measuring anything that's in its line of sight.

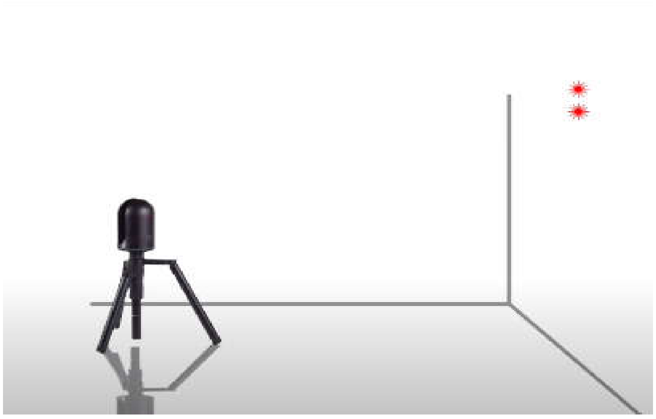

Figure 29 the scanner determines the second point just above the previous point that has been

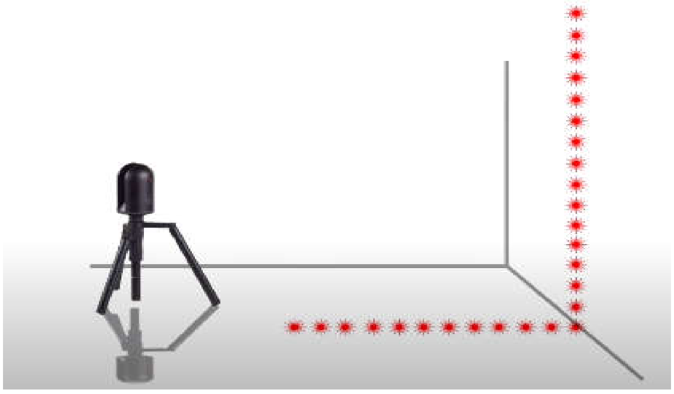

Figure 28 the mirror spins all the way around and measuring that's in its line of sight

During this whole process, the BLK360 itself is spinning. By the time the mirror gets all the way returns to where it has started the BLK spins and measures the second line of points right next to the first line.

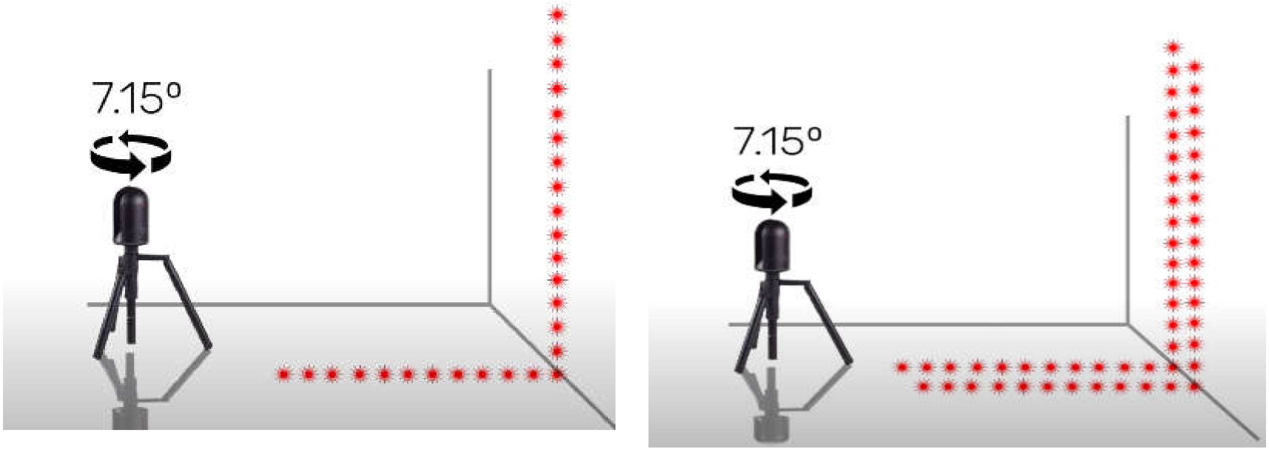

Figure 30 after the scanner finishes measuring the first line of points; it rotates slightly on its vertical axis and start measuring the second line

But in reality the mirror is spinning so fast we can hardly see it, and it's doing this whole process up to 360,000 times every second. It goes around, sweeps the entire room and taking measurements in every direction.

The resulting scan is a set of 3d coordinate measurements; it's a detailed 3d representation of the scene often called a point cloud.
The more points that we collect, the greater the accuracy of our scan a factor commonly referred to as a scan's "resolution".

There will be times when we need the highest possible scan resolution, but this is isn't always necessary and it comes back to determining what we want to use the scan data for, right from the outset.

Inside of the BLK360 There are three outward facing cameras which are used to take a panoramic image of the site, so we can actually colorize this point cloud with that panoramic image to create this true color realistic 3D environment.

Now what if we need to capture an entire scene where some views may be obstructed or if a site is so big that the scanner can't reach all of it with one scan? In those cases which are very typical, the scanner is moved to different vantage points for more scans then we can register these point clouds together to create a single cloud with no missing data.

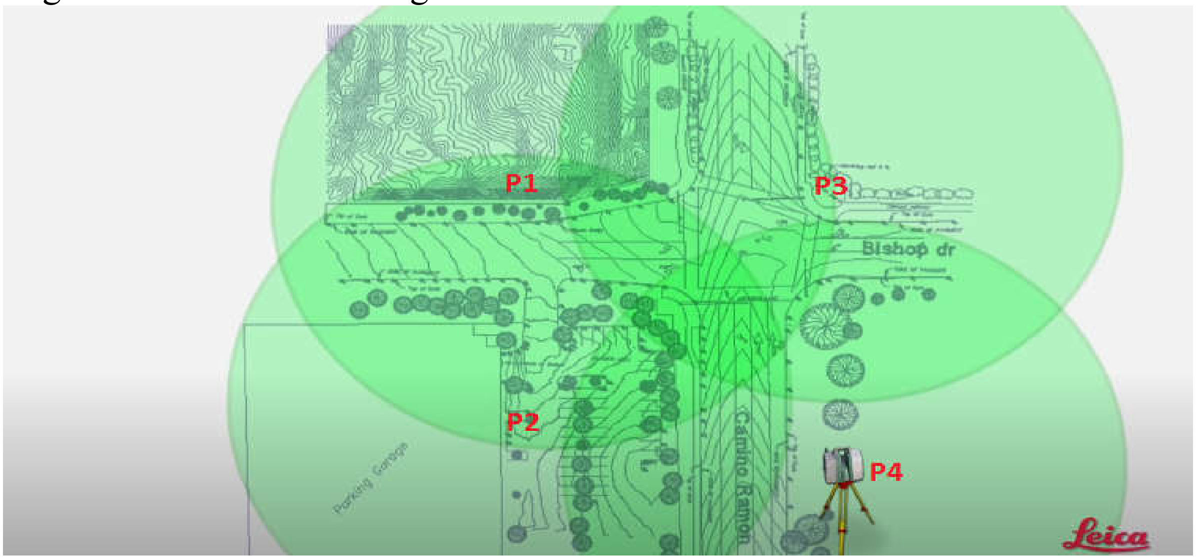

Figure 31 the scanner is moved to different vantage points for more scans

The registration step can be done directly during the scanning process otherwise we can do this later by post processing.

Chapter III: Point cloud registration and post processing

Chapter III: Point cloud registration and post processing

Introduction

As part of the Leica Geosystems 3D Reality Capture Solution, the Leica Cyclone FIELD 360 mobile-device app links the 3D data acquisition directly in the field with the BLK360 imaging laser scanner and the final data registration with Leica Cyclone REGISTER360 post processing office software.

Data link with Leica Cyclone Field 360

When we open up the cycle field first thing we need to do inside this app is to set up our project by pressing the little plus symbol, give it a name and click on safe.

We can also take a picture of our site as a thumbnail for this project.

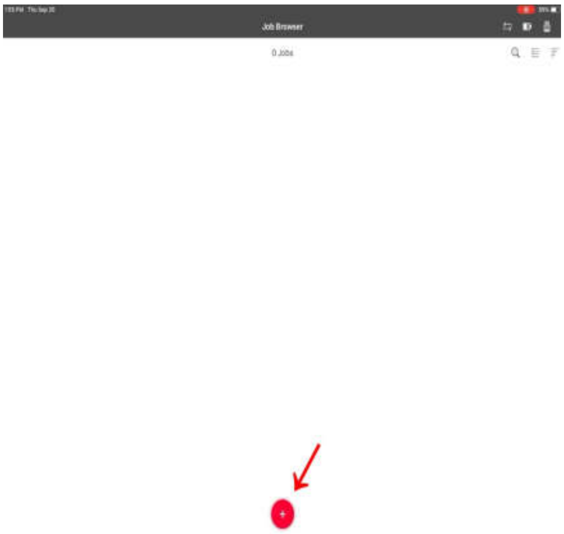

Figure 33 the little plus symbol

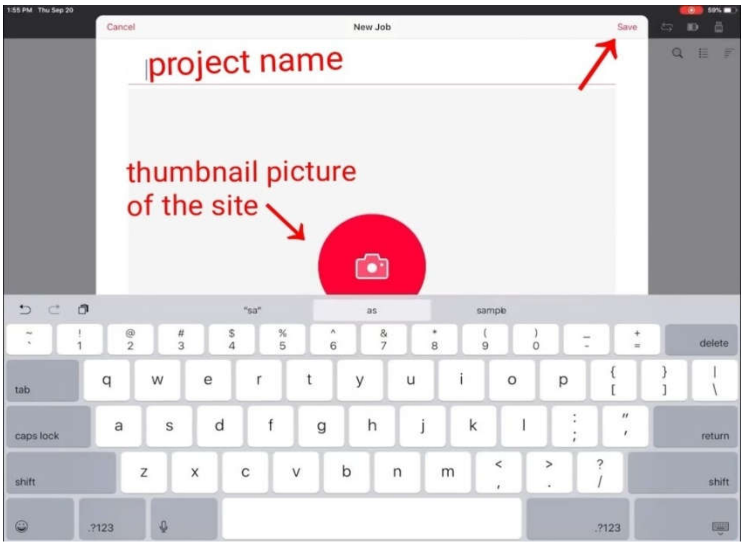

Figure 32 naming the project and saving it

Once the project is set up we get into it and open the first icon that we see is start scan.

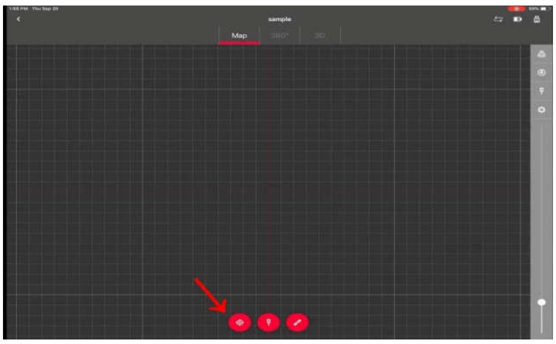

Figure 34 start scan icon

When we choose start scan we have the opportunity to set our settings .At the bottom there's four little buttons:

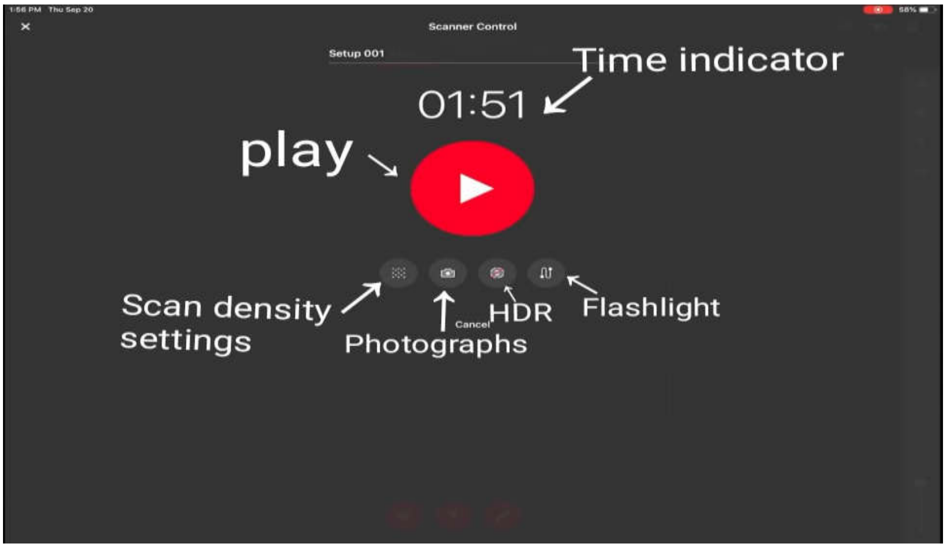

Figure 35 scanning settings

Scan density setting: we can choose between different scanning densities (low medium or high) and we can see a little time indicator that will show us how long the scan is going to take depending on these settings.

Photographs button: In order to add colour to the point cloud.we can turn imagery off completely if we don't need it and the point cloud won't be colorized but if we don't need it we can really cut down our scan time considerably by doing a 40 second scan ,for this project we definitely need imagery.

HDR button: To adjust the color gamut between bright and dark places, we can toggle HDR on or off depending on our conditions.

Visual tracking system: when HDR is toggled off we can turn on the automatic flash (on or off).

After adjusting the settings, we can press" play" to start the scanning process from the first point. When the scan is complete, we will notice the data appearing on the iPad screen.

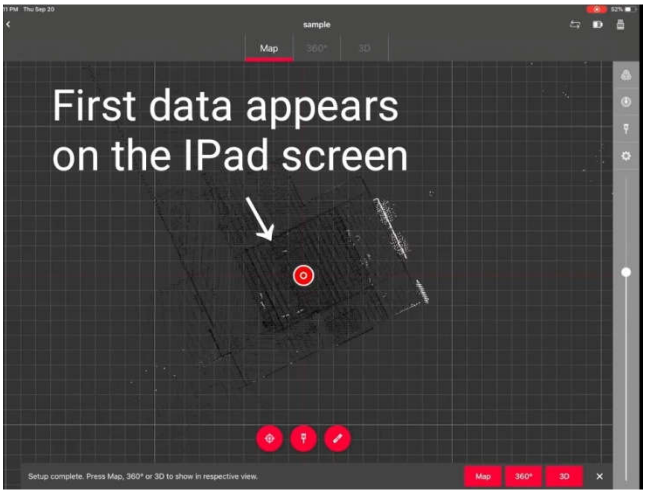

Figure 36 first data appears on the IPad screen

Once scans of the first area are complete, the tripod is moved to another location to scan from another angle or capture data from a new area by pressing" play" again, when the second scan ends we will have two different setups initially they will be dropped in the middle of our coordinate system at 0-0 but we can tap on one of them and drag them around.

In this step, we can link these two data together, we can do that simply by clicking on the" link" icon and it will ask us to choose the first one then the second.

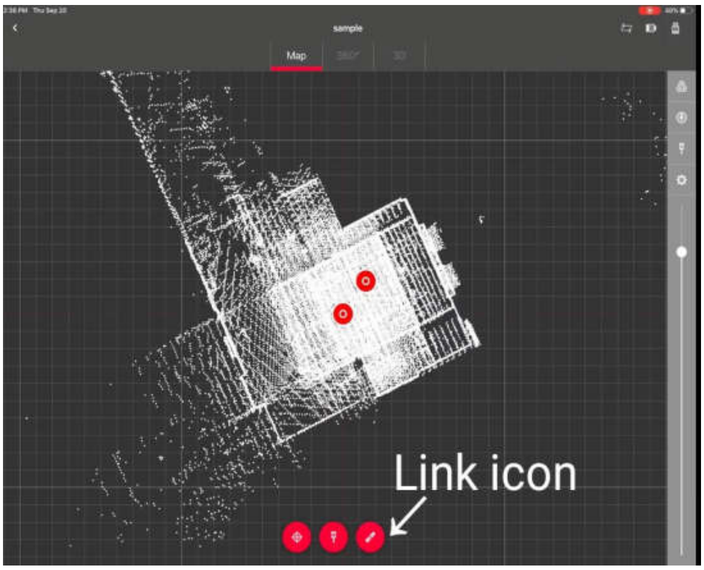

Figure 37 link icon

At the lower right hand corner we choose "start alignment" and we will notice that the data is already lined up; we will see one scan is orange and the other one is blue.

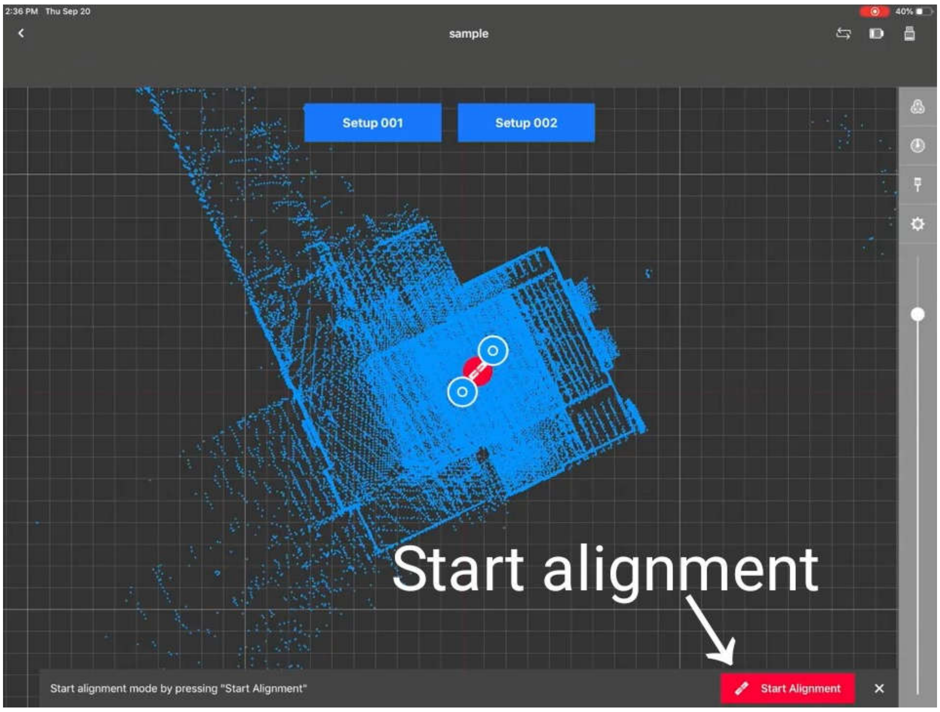

Figure 38 start alignment icon

After we make sure that they're pretty well lined up, we tap “optimize” to snap the scans together in the right orientation then we tap “create link” to lock them into one bundle.

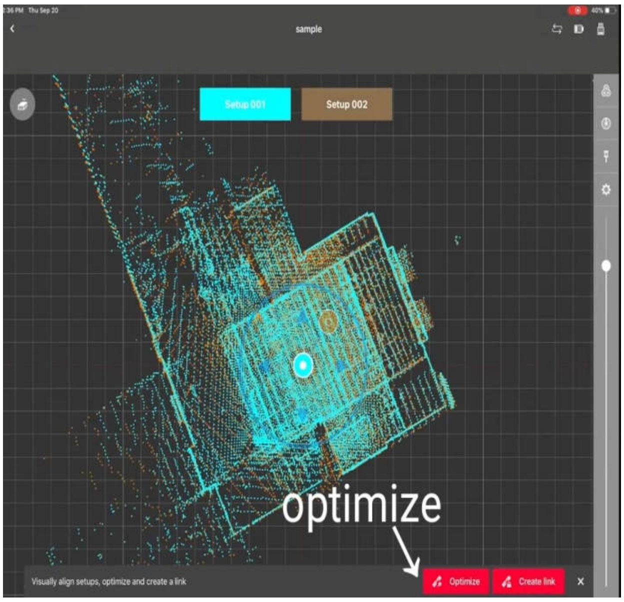

Figure 40 optimize icon

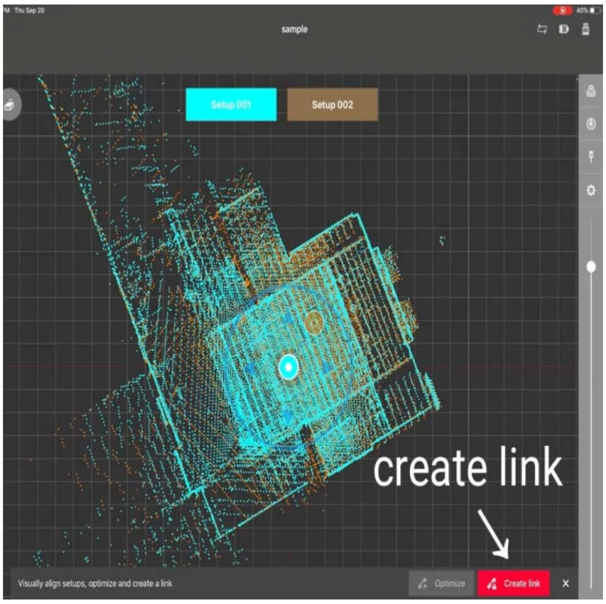

Figure 39 create link icon

Right off the bat there is kind of a bird's-eye view of the scan data, if we tap on the scan and choose "360" button we can see the panoramic image that the scanner captured .

Figure 41 360° view of the scene

Then if we tap on "3d" button we can see an initial rendering of the 3d scan data and navigate around it, we can also turn our point cloud color to true color which allows us to see that information in the actual point cloud.

Figure 42 3D view of the scene

Support for BLK360 data capture with Cyclone FIELD 360

Definition

Leica Cyclone REGISTER 360 3D laser scanning point cloud registration software is the latest upgrade to the number one point cloud registration, Cyclone REGISTER.

This new product built from the ground up brings with it all new capabilities from simple, guided workflows to automated registration.

REGISTER 360 empowers users of any skill level to work smarter, deliver results more accurately, visualize in more detail and collaborate more effectively.

Importing scans into Leica Register 360

1. After Cyclone FIELD 360 data collection, we click the info icon in the upper right corner of Cyclone FIELD 360 to open the Sync Server option dialog.
2. We check the Sync Server checkbox to active the server and provide the IP address.

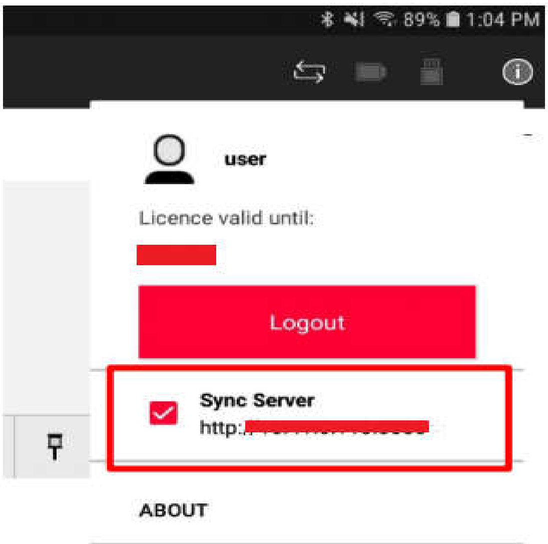

Figure 43 Sync server checkbox

3. Next, we open Cyclone REGISTER 360, create a new project and use the new command in the Import area: Import Cyclone FIELD 360 Project.

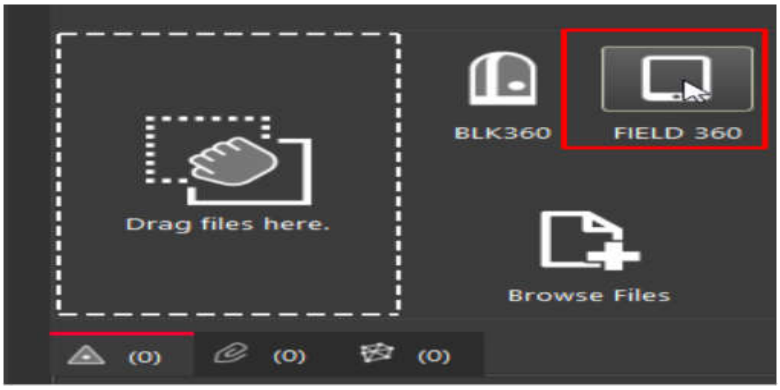

Figure 44 the import area in cyclone register 360

4. We enter the IP address from step 1 above and click the Test Connect button.

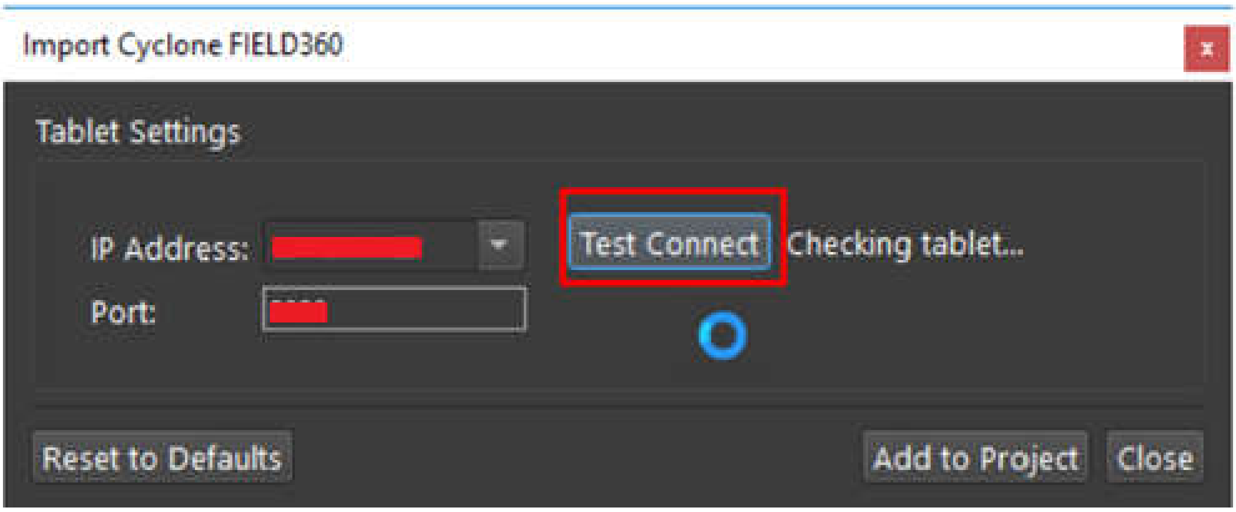

Figure 45 test connect button

5. After Cyclone REGISTER 360 and Cyclone FIELD 360 are connected, we click the Add to Project button and the setups will appear in the left side import panel, then in the center view area.

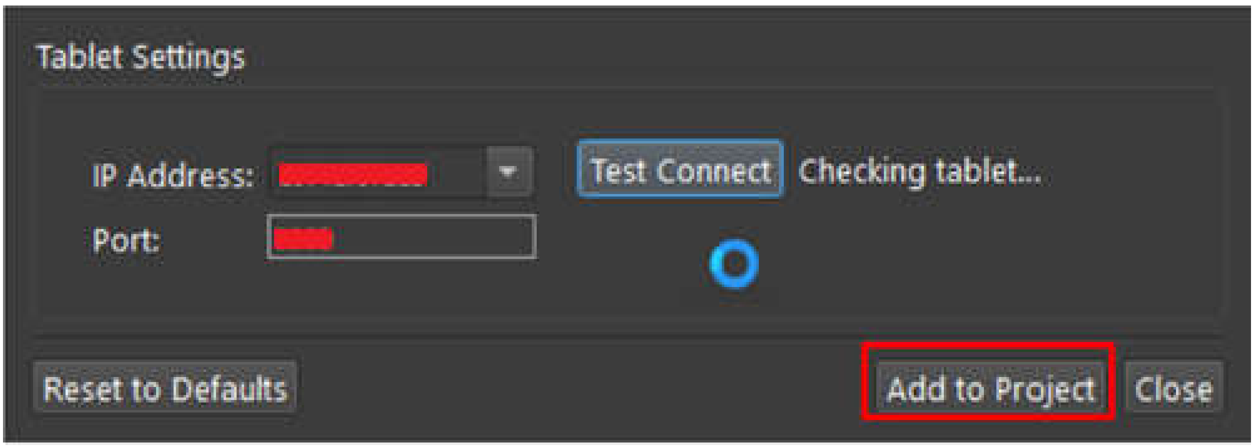

Figure 46 add to project button

6. So then it's going to bring in just a quick preview of each of the projects that we have on field 360 on the iPad.
7. We select the project that we want to import and deselect the ones we don't need.
8. And now we can click on “import” and it's going to import all that data to the computer.

We may view our project either as a “Sitemap” (2D, top-down) view or as 3D cloud by hovering over the icon in the lower right-hand corner of the workspace and selecting the appropriate viewing option.

Figure 47 viewing options

Point cloud cleanup

Data should contain high resolution scans only (and not be mixed with lower resolution scan data) to produce the best results.

So the next step involves filtering (removing) the points that do not belong to the study area to reduce the large file size.

Delete areas or fixed objects using fence tool

Checking Export cleaned will allow us to delete points, export the modified point cloud.

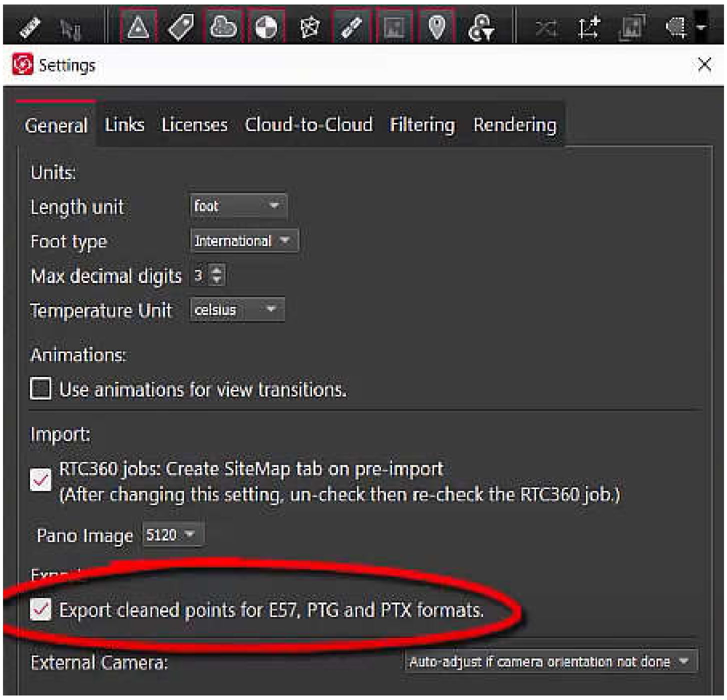

Figure 48 export cleaned option

In the bundle cloud view, fences are useful way for isolating or deleting points from the point cloud. There are 3 fence modes: Polygonal Fence, Rectangular Fence and Circular Fence.

If we draw a fence around an area of interest, the points will be highlighted.

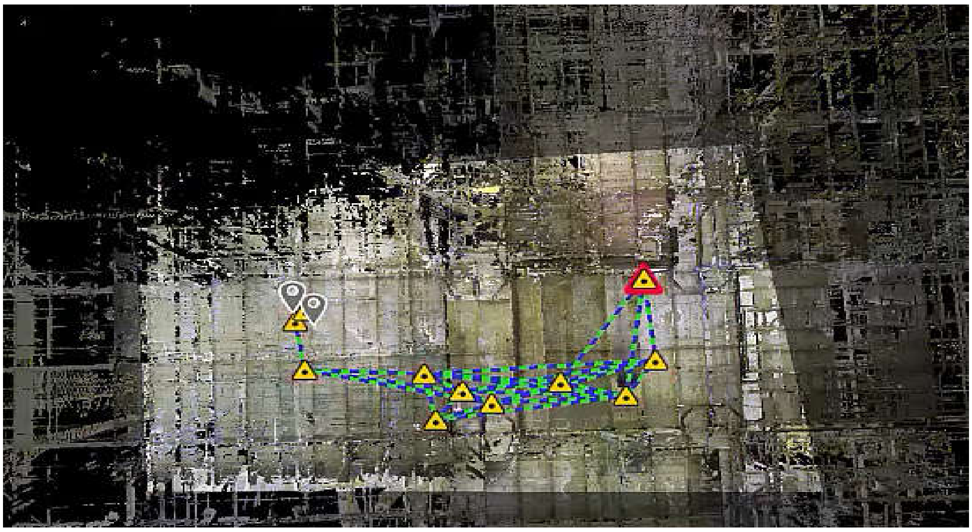

Figure 49 highlighted points

After selecting the area or the object we want to delete, we will have four options below:

1. Edit visual points: to delete the visual points out of the cloud and out of each setup.
2. Edit cloud-to-cloud points: If we want to edit the cloud-to-cloud points we can choose this option and this won't actually delete the points it will just disregard them for the cloud-to-cloud registration but then after the registration is done we would still have the points.
3. Delete in side: is used to clean the entire point cloud.
4. Delete outside: is use to remove extra data.

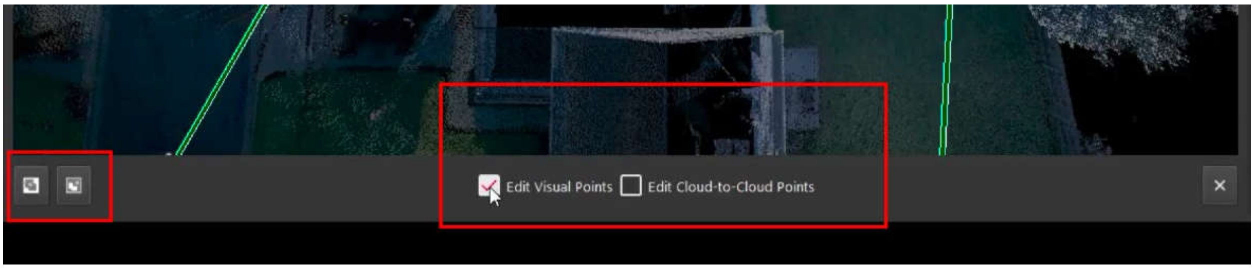

Figure 50 deletion options

Detect moving objects filter

This new tool in Cyclone REGISTER 360 works on a bundle to detect objects that have moved between setups. Moved points are marked in red after the filter has been run on a registration.

This filter works optimally when the scan positions surround the data being filtered and the scanner locations are less than 10 meters apart.

1. To run the filter, right-click on the bundle and execute the Detect Moving Objects command.

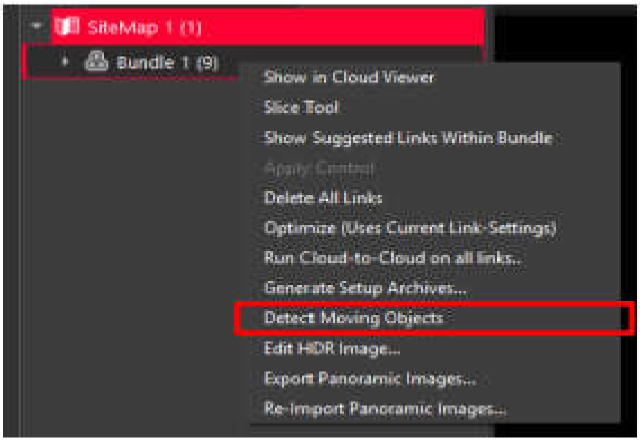

Figure 51 detect moving objects command

2. The filter automatically detects and marks the points that are associated with the objects that are moved between setups.
3. After the processing has finished, the points associated with moved objects are classified and highlighted in red. To show the moved points we click Show Moved Points.

Figure 52 Show Moved Points option

4. Once the marked points are shown, the following options are available:

- ✓ Delete all marked points.
- ✓ Delete all marked point inside or outside of a fence:
- We can use the fence tool in the upper tool bar to draw a fence around an area of interest.
- Then we use the Delete Inside or Delete Outside buttons.

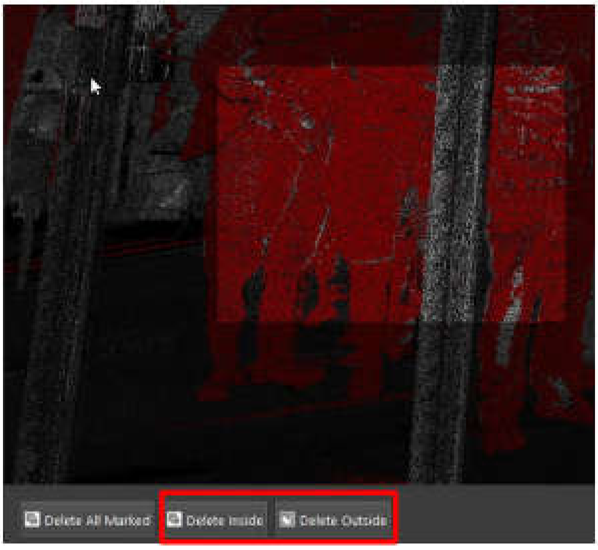

Figure 53 delete all marked points inside or outside of a fence

We can restore all the deleted points by using the Restore command for the entire bundle or individual setups.

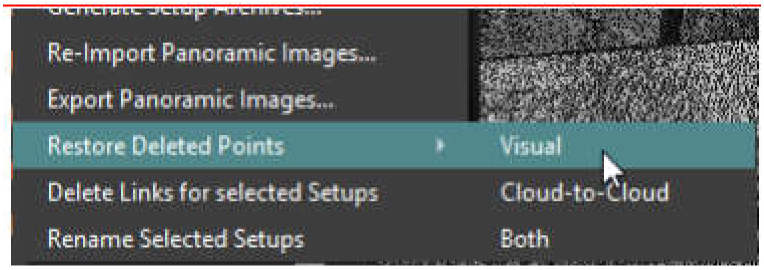

Figure 54 Restore Deleted points command

Limit Box Tools

With the release of Cyclone REGISTER 360, a new Limit Box tool has been added to aid users in cleaning and segmenting the cloud. This tool controls point cloud visualization by isolating a subset of points within the extents of the Limit Box and hiding those outside the box. Use of the Limit Box tool is limited to the Setup Cloud, Bundle Cloud, and TruSlicer view modes. Usage of the Limit Box tool is detailed below.

Create Limit Box

By clicking Create Limit Box a temporary clipping box is placed and shown that is vertically aligned to the z-axis and fits the setup/bundle extents.

If there is an active UCS then the Limit Box comes in aligned to the UCS.

The current box can be set to shown/hidden from the command in the Limit Box tools.

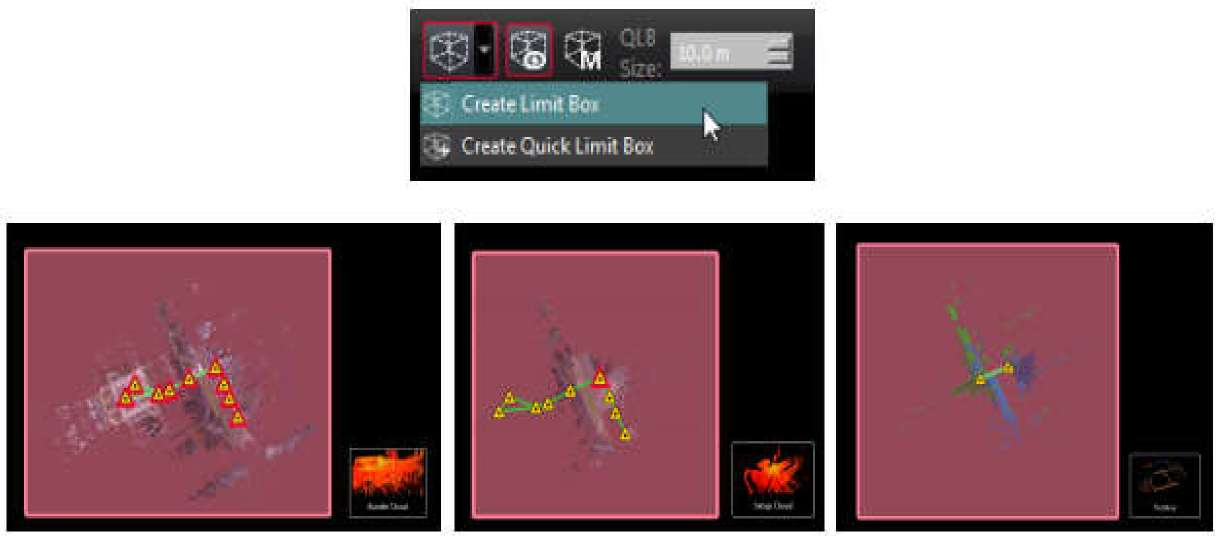

Figure 55 create limit box

Create Quick Limit Box

Using Create Quick Limit Box (QLB) a temporary clipping box is placed by user selection. The box is aligned to z-axis, centered at the pick point and extends to the size provided by the user.

The default QLB size is 10.0 m that can be adjusted by the user. If there is an active UCS then the Limit Box comes in aligned to the UCS.

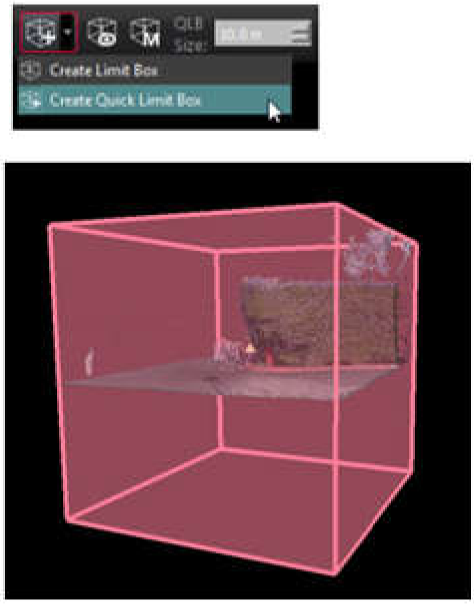

Figure 56 create quick limit box

Resizing Limit Boxes

To resize a limit box, hover over the box faces to highlight. The highlighted face can be moved using mouse in two directions.

We Hold SHIFT key for selecting the opposing faces.

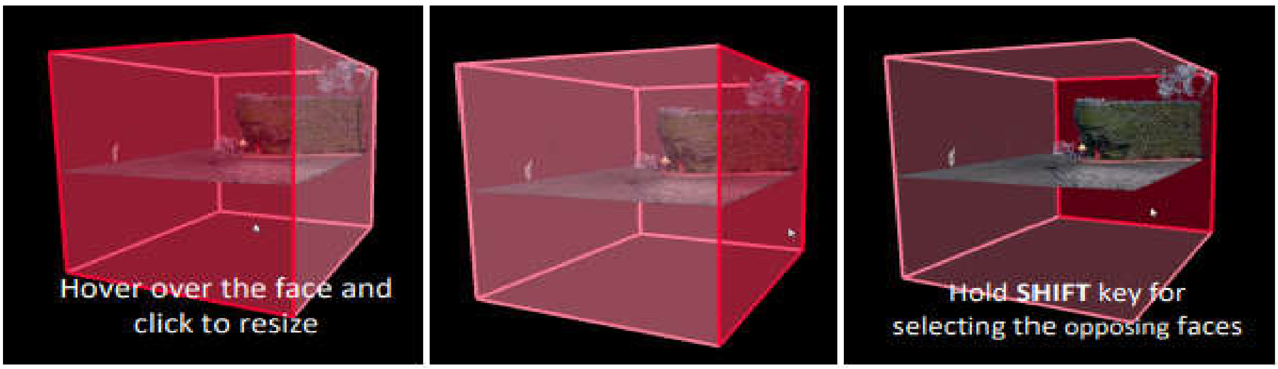

Figure 57 resizing limit boxes

Rotating Limit Boxes

To rotate a limit box, hover over an edge line while holding the ALT key to highlight the line. The highlighted edge will become a handle for rotation.

We hold ALT + SHIFT keys to select the opposing edges.

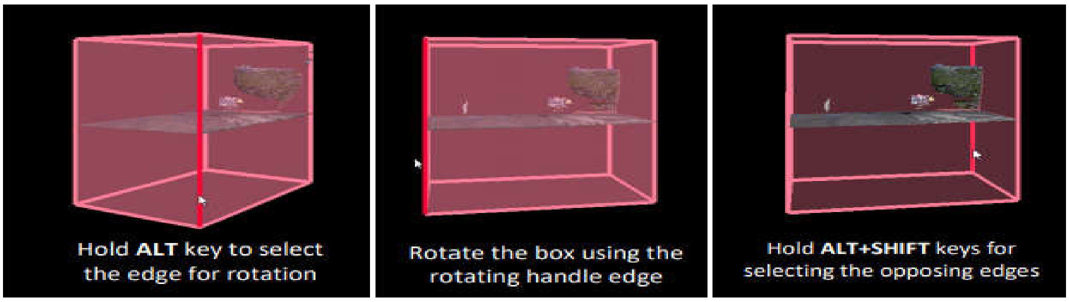

Figure 58 rotating limit boxes

Limit Box Manager

The Limit Box Manger is used to store the created Limited Boxes.

The created Limit Boxes are temporary and discarded when user switches to a different view mode, unless stored.

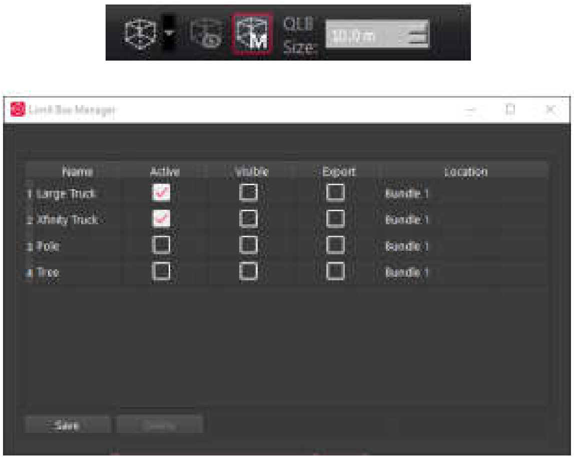

Figure 59 limit box manager

Using the Limit Box Manger, user can save newly created boxes, delete existing boxes, activate clipping functionality, set the visibility and export to options.

- Active: if checked, Limit Box affects point display.
- Visible: if checked, the Limit Box is visually rendered in Cyclone REGISTER 360.
- Export: If checked, the Limit Box gets published as a clip to JetStream Enterprise projects and LGS files. Appropriate licenses are required for publishing and/or JetStream Enterprise itself.

The result is a small point cloud file without impacting the quality of the data and easier to move and share.

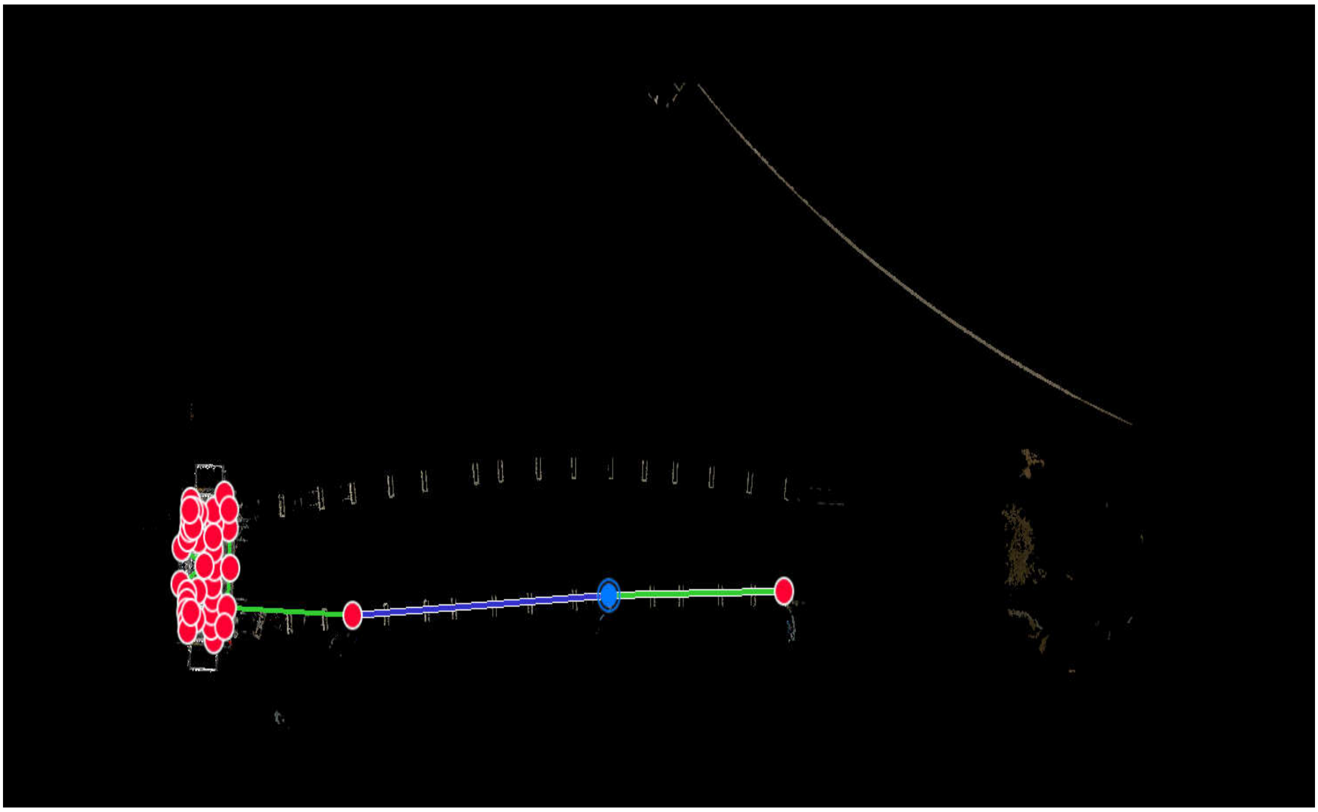

Figure 60 top view of the resulting model

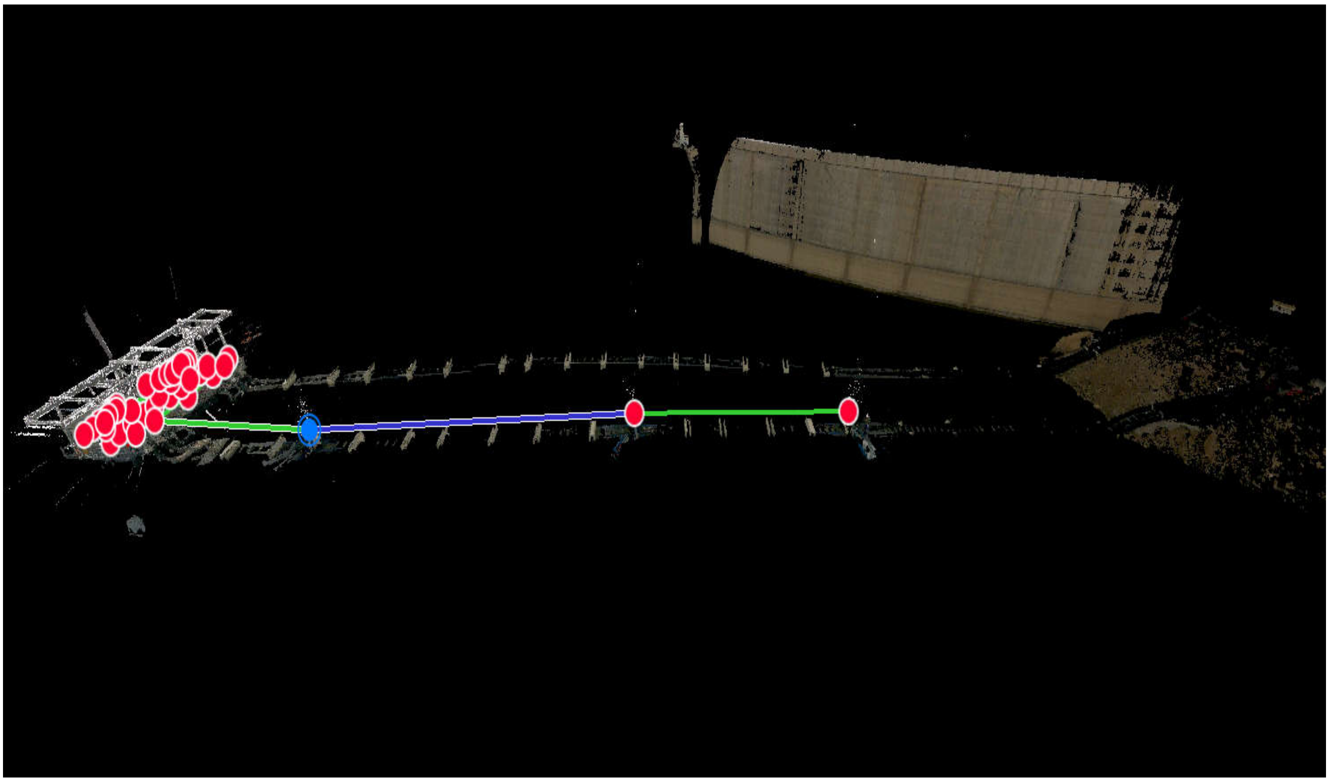

Figure 61 an over view of the final model

Photo Editing in Register 360

There are two ways we can think of to edit photos within a scan.

The first way requires us to right mouse click on the setup we would like to edit and choose "Edit HDR" Image.

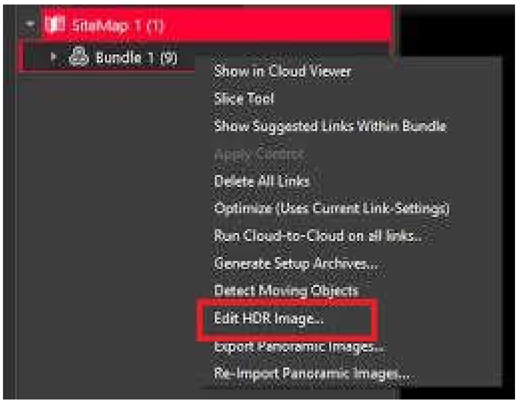

Figure 62 Edit HDR image option

The "Tone Map Editor" will open.

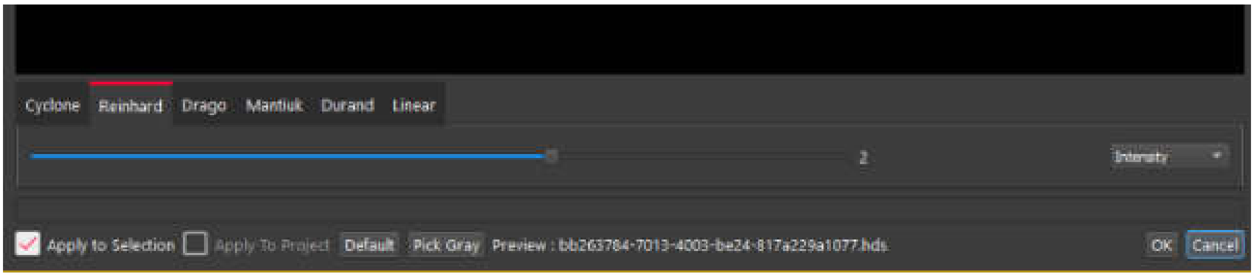

Figure 63 the tone map editor

Using the slide bar, we move the slider back to darken the photo and forward to brighten the photo.

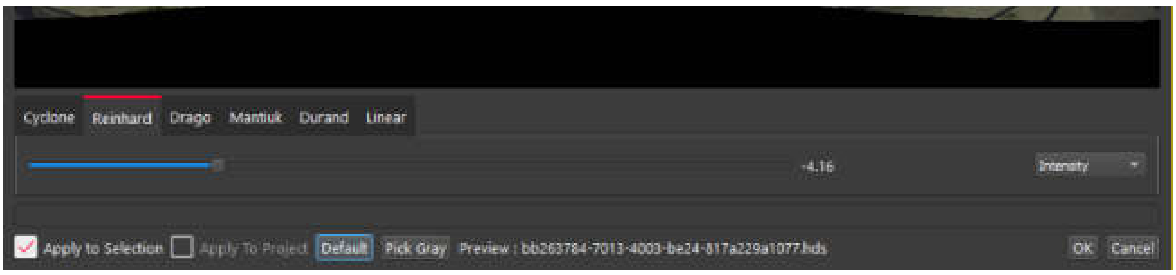

Figure 64 slide bar to edit the photo

Multiple photos can be edited at one using the "Shift Select "command and ticking the check box in the lower left corner next to "Apply to Selection".

Now maybe we wanted to actually edit the photos by adding or removing parts to the photo.

The good news is that feature is the second way of editing a photo. To accomplish this, we once again will need to right click on the setup of the photo we want to edit.

This time however, we will need to edit only one photo at a time.

Because Register 360 is point cloud software and not a photo editing software, we are going to use something else to edit the photo. So, how do we do that?

We are going to export the data out of Register 360. Right mouse click on the setup we would like to edit and choose "Export Panoramic Images".

Note: The image should be exported to an empty folder.

Once the image is exported, we can use our favorite editor to edit the jpg in any way we would like.

After the changes have been saved (using the same name as we exported to), we exit the photo editing software and go back to Register 360 and right mouse click on the same setup we exported from and choose "Re-Import Panoramic Images".

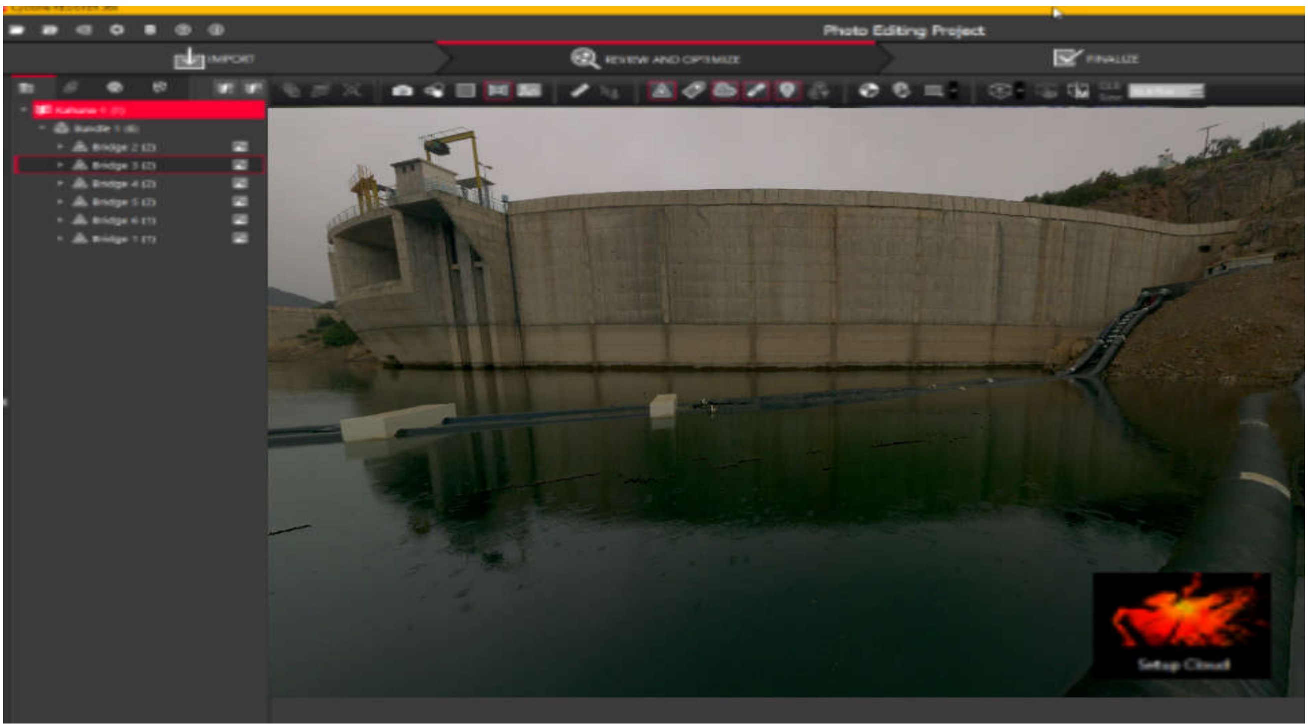

Figure 65 the Image is now edited and mapped back to the point cloud

Chapter IV: point cloud to BIM conversion

Chapter IV: point cloud to BIM conversion

Introduction

Point cloud scans or the point cloud mesh when are imported in BIM platforms like Revit, each object can be identified distinctly.

It is because when the photos are taken with high definition scanners, they give a true color for 3D point cloud so that every element can be differentiated and an intelligent BIM model can be created.

Revit as a BIM platform

Revit is software for BIM (building information modeling) with tools to create intelligent 3D models of spaces and objects, which can then be used to produce site or construction documentation.

There is still a major confusion between Building Information Modeling and Revit, where BIM is considered to be a piece of software such as Revit.

However the fact is that Revit is one of the BIM tools available and is widely used for the creation of the 3D digital BIM model.

Leica cyclone CloudWorx for Revit

Leica CloudWorx for Revit is a breakthrough plug in for efficiently using rich as built point cloud data, captured by laser scanners, directly within Revit for better BIM modeling of existing buildings.

This is useful for a wide range of BIM activities. It provides a virtual visit to the site within Revit with a complete view of the captured reality.

Exploit the final resulting models

The final results are geometric referencing of digital image data and 3D point clouds given by a terrestrial laser scanner which can be used for:

Discovering the physical properties of the dam wall

The walls of a dam are continuously exposed to moisture. Under high pressure, the water penetrates into cracks and pores and may contribute to the damage of the structure. Therefore, the 3D scanner provides accurate models that continuously discover the different physical properties of the dam wall.

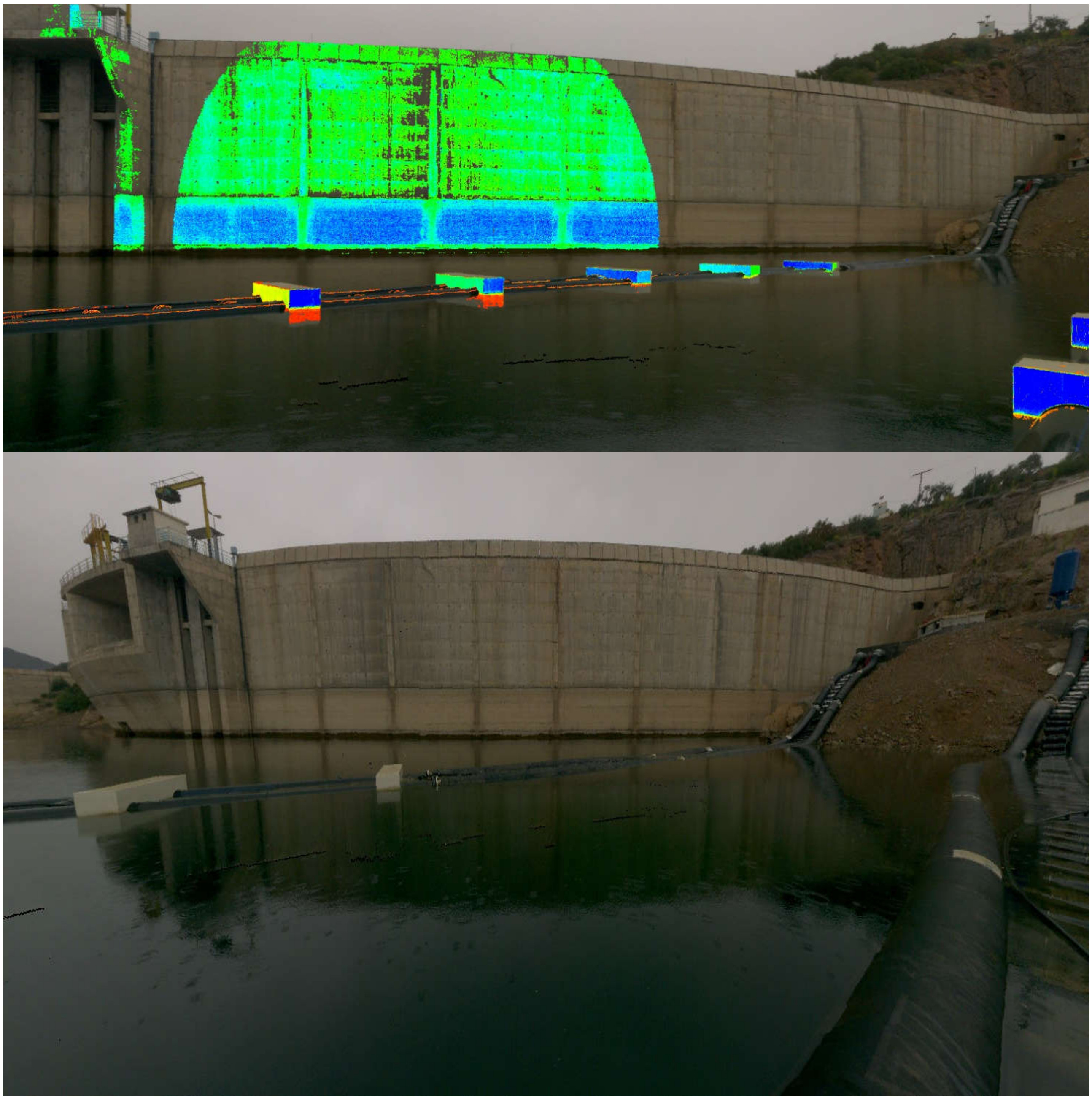

Figure 66 an accurate 3D model of the dam wall and its surroundings

Detecting potential floating pump station problems

These units are structures that allow the water to be taken from the water basin (river, dam or lake) and transported to the transmission lines. These structures are used in many places in the world for a multitude of purposes.

The aim here is: the ability to take water at any time, the quality and cleanness of the water received, the constant flow of water despite the changes that may occur (water rises or subsides in the basin).

Figure 67 a 3D model of the floating pump station at oued ksob dam wall

The pump station failure or malfunction can happen because of numerous equipment related problems.

To detect all the problems that may occur while trying to keep maintenance costs low, we can use the following accurate 3D models provided by the scanner:

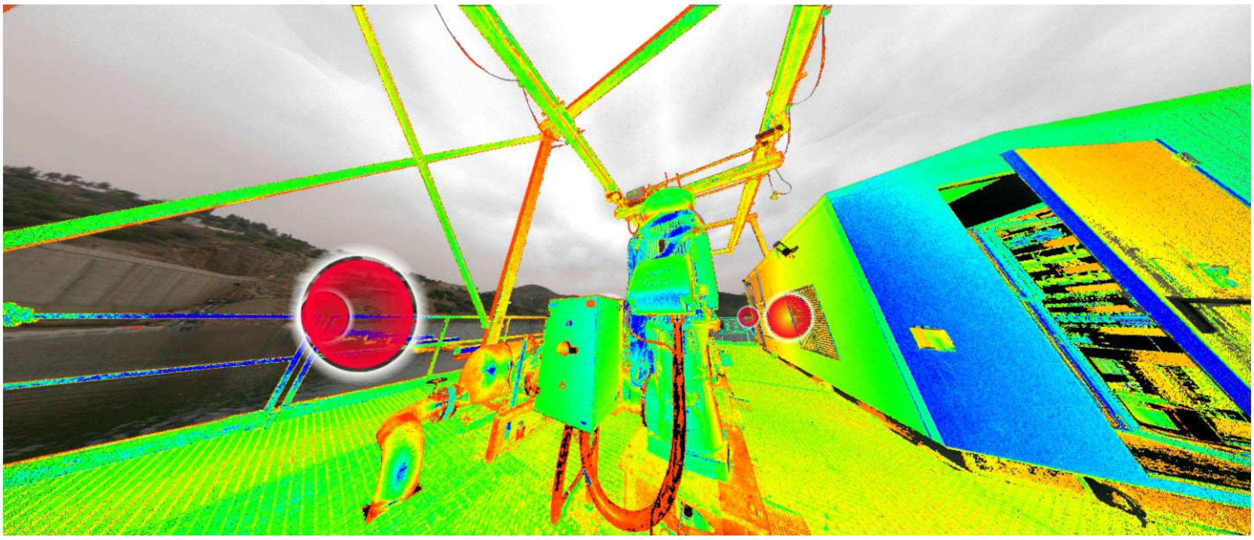

Figure 68 detecting any defect or malfunction in the structural

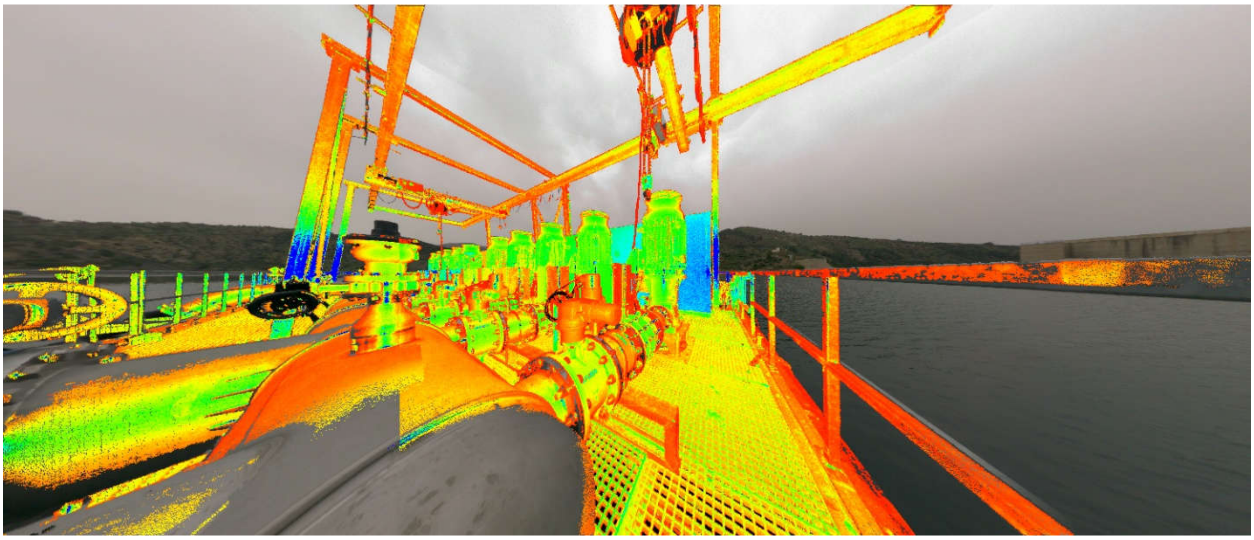

Figure 69 monitoring the pumps to ensure their proper functioning

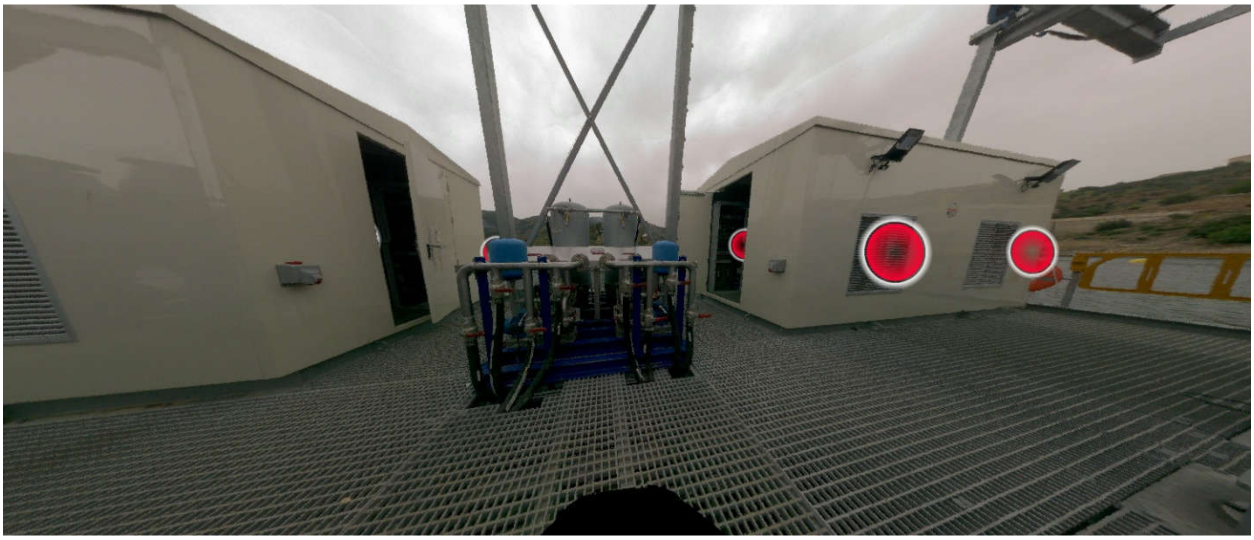

Figure 70 for accurate and smart BIM model, we applied true color to the point cloud.

Conclusion

3D laser scanning has significant advantages compared to other characterization old methods because it enables quick capture of an object in 3D with large coverage and high resolution without illumination.

The scanning data consist of different information, including geometrical, spatial, visible and physical information.

In particular, the data can be retrievable and reusable, which makes the 3D scanner the ideal tool in monitoring the most complex hydraulic sites, most notably dams.

The process of monitoring the dam through the 3D models provided by the scanner is an important aspect in ensuring its proper functioning and preparing the necessary information that enables us to assess its safety and monitor any phenomenon that indicates a defect in it.

The design of the dams can also be developed and reviewed thanks to the constant monitoring of the various risks and problems that the dam was exposed to, thus creating more sophisticated modern designs ready to resist any kind of similar future risks.

References

http://nordicpointclouds.net/files/InstallationMedia/Leica%20Cyclone%20REGISTER%20360%20QuickStartGuide%201.5_EN.pdf

http://www.befoonline.org/UserFiles/Archive/250/Rapport__114_NY_G5.pdf

http://www.blk360expert.com/

https://1sth.co.uk/advantages-3d-laser-scanning/ http://www.geodesis.ch/wp-content/uploads/2017/03/FICHE_LASER_SCAN_V1.pdf

https://3space.com/blog/advantages-disadvantages-of-3d-laser-scanning/

https://blogs.rand.com/civil/2020/02/photo-editing-in-register-360.html

https://en.wikipedia.org/wiki/Lidar

https://fr.wikipedia.org/wiki/Barrage_du_Ksob

https://knowledge.autodesk.com/support/revit-products/learn-explore/caas/CloudHelp/cloudhelp/2020/ENU/Revit-Model/files/GUID-875AD6F7-B9CC-4963-8526-D73C1B6A309E-htm.html

https://leica-geosystems.com/nl-be/about-us/news-room/news-overview/2017/04/2017-11-16-blk360

https://leica-geosystems.com/products/laser-scanners/scanners/blk360

https://new.certainty3d.com/blog/differences-between-mobile-laser-scanning-and-terrestrial-laser-scanning/

https://pdf.directindustry.com/pdf/leica-geosystems/leica-blk360-specification-sheet/14324-787071.html

https://pdf.directindustry.com/pdf/leica-geosystems/leica-scanstation-p50-data-sheet/14324-732608.html

https://storagetanksurveys.com/#home

https://surveyequipment.com/assets/index/download/id/983/

https://www.gefos-leica.cz/data/original/skenery/rtc/853811_leica_blk360_um_v2.0.0_en.pdf

https://www.hsbmarine.com/en/floating-water-intake-structures-and-floating-pump-station/

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3705536/

https://www.sccssurvey.co.uk/pdfs/HDS/Leica-ScanStation-Comparison-Chart.pdf https://www.sciencedirect.com/topics/engineering/point-cloud

https://www.slideshare.net/tejistha/lidar-47652814

https://www.water-aerator.com/en/water-treatment-equipment/dredging/pumping.html

https://www.youtube.com/watch?v=eNtdCY2uICA

https://www.youtube.com/watch?v=Fpr8iumcW28

https://www.youtube.com/watch?v=GQm3U4_MiNM

https://www.youtube.com/watch?v=tLGjxMQqxf8