Laser scanning best practices

How to scan for the highest quality Digital Twins

WHITE PAPER

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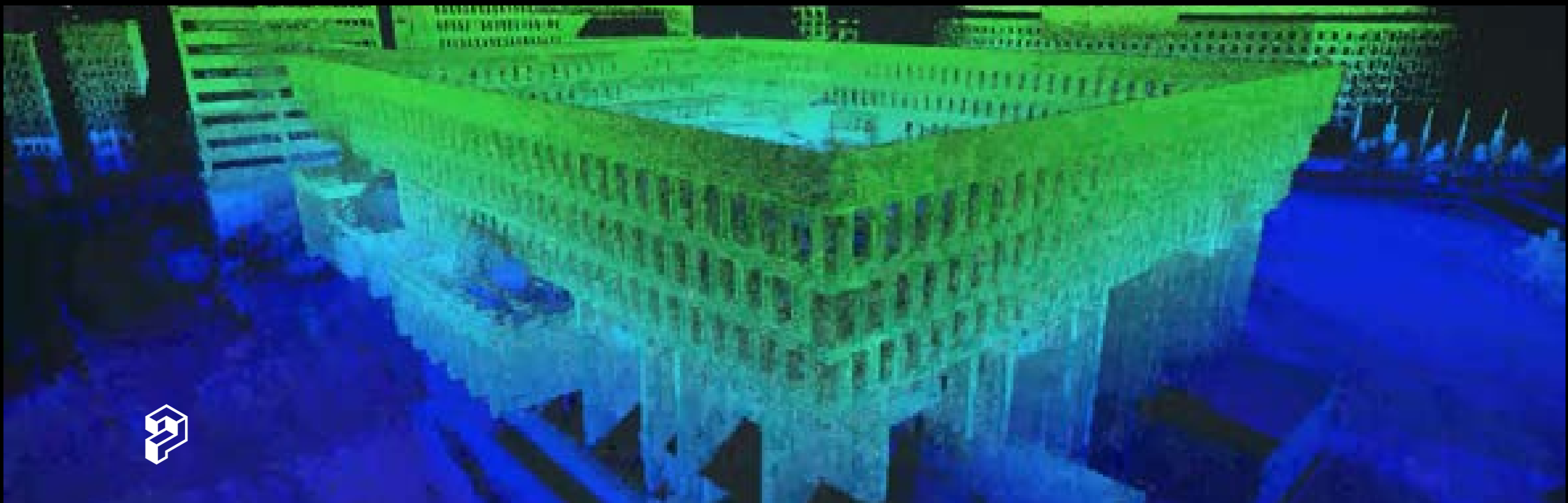


Executive Summary

While 3D scanning has been around for several years, creating photorealistic meshes for digital twins is still in its infancy. This white paper covers the best practice to scan for mesh results.

BIMstream has been providing some of the best product demo datasets for Prevu3D.

This white paper contains some of our tips and tricks to achieve optimal results for creating digital twins.

Peter Garran
BIMstream Founder

The field of reality capture is filled with a range of technologies that offer distinct capabilities and uses for engineers, project managers, and operations professionals, with even greater potential for various industries as these tools continue to advance.

Reality capture coupled with digital twin software provides several benefits to industrial sectors. In AEC industries, it reduces costs, saves time, provides accurate as-built documentation, and improves team collaboration. Digital twin technology can simulate and predict outcomes, enhancing manufacturing design quality and minimizing project risks.

For real estate, digital twin platforms enable remote property viewing, improving customer experience and accelerating sales.

In critical infrastructure sectors like power plants and oil rigs, digital twins can monitor and optimize operations in real time, preventing costly downtime and reducing safety risks.

Reality capture and digital twin technology empower companies to unlock actionable insights and make data-driven decisions, leading to improved productivity, efficiency, and sustainability.

Planning the reality capture process

Planning a reality capture process involves several steps to ensure the successful implementation of the technology. Key steps to consider:

1. **Define project goals and objectives:**
Clearly define the purpose of the reality capture process.

2. **Select the appropriate reality capture method:**
Choose the most suitable method for capturing the required data.

3. **Determine the equipment and software requirements:**
Identify the hardware and software tools needed to carry out the reality capture process effectively.

4. **Conduct a site assessment:**
Evaluate the site and identify any potential challenges or limitations that may affect the reality capture process.

5. **Plan the scanning positions:**
Determine the strategic locations for the scans to achieve comprehensive coverage of the site or assets.

Exploring scanning techniques

The two main reality capture techniques are Terrestrial and Mobile Laser Scanning. We'll introduce them both and present common applications before diving deeper into these technologies and their pros and cons.

Terrestrial Laser Scanning

The industry standard for laser scanning usually requires tripod-based terrestrial laser scanners capable of achieving 2mm accuracy—Leica RTC360 of choice. While the data obtained from a terrestrial laser scan is of the highest quality that can be achieved through Prevu3D, the capture time and effort involved are much higher than that of a mobile LiDAR scanner.

Mobile SLAM Laser Scanning

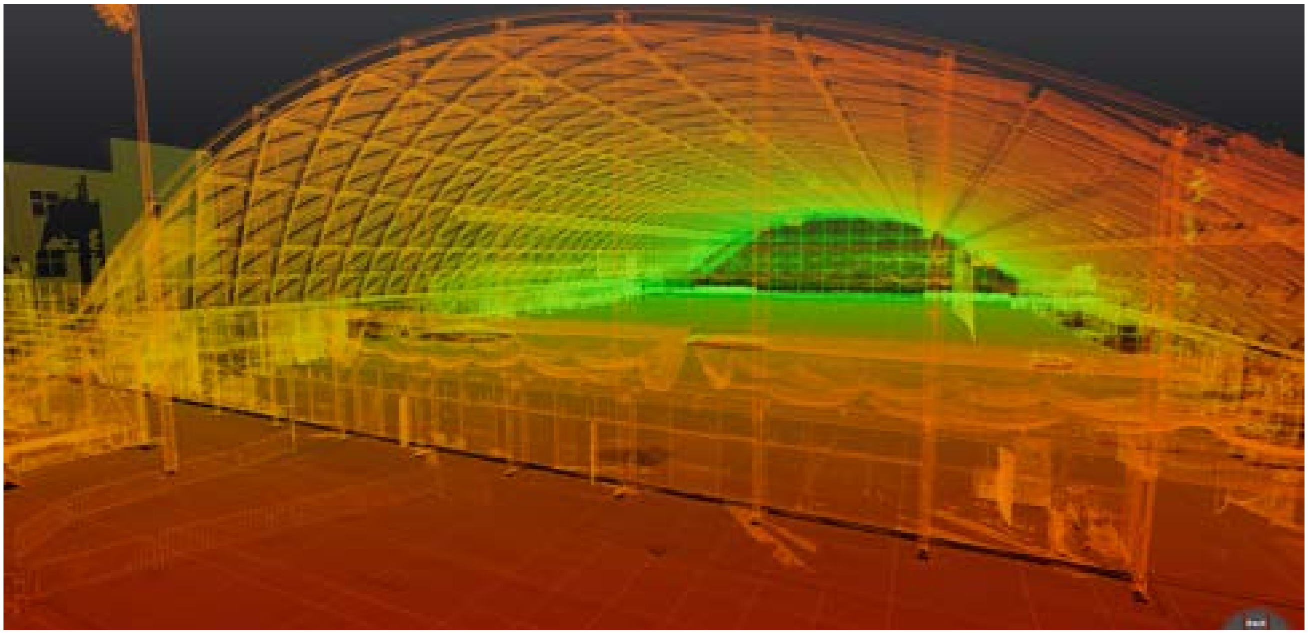
Providers use mobile Simultaneous Localization And Mapping (SLAM) laser scanners for an accelerated capture process. Mobile SLAM scanners continuously add data into one large scan as the operator moves throughout a space. This allows surveyors to capture large amounts of building space in hours rather than days, as terrestrial laser scanning often requires. While capturing with a mobile laser scanner is much quicker, some finer assets and features in certain spaces are captured with less fidelity than in a terrestrial scan.

Depending on the application and intended use of the 3D model, certain customers may opt for the slower, more detailed terrestrial scan, while others may prefer the quicker mobile scan capture. This choice could be due to various reasons such as budget, impact on operations associated with reality capture, intended use and accuracy requirements.

One example of a quicker mobile scan being a more effective solution is in the refit/reconfiguration of a manufacturing space. In this application, the client may prioritize the overall dimensions of machinery or production lines over intricate details. Using Digital Twin software like Prevu3D, the client can crop out, move, or delete machinery to find the most efficient configuration. Prevu3D also allows for the import of new equipment models for configuration and clash detection assessments.

IIn this situation, where overall dimensions are the primary concern, faster mobile laser scan capture is highly effective.

Another example where the slower but more detailed terrestrial scan is required would be in a training application. In environments like ECP and manufacturing plants, operating intricate machinery without prior training can be dangerous or expensive. In these instances, the highest detail possible is necessary when using Prevu3D software as a training tool.



Laser Scanner Point Cloud: image sourced from BIMstream's Prevu3D dataset.

In some cases, there may be mixed requirements between various spaces. In these instances, combining terrestrial and mobile laser scanning may be the most effective solution. An example of this could be a large factory with attached offices or warehouse spaces that do not require the highest detail but attached to them are manufacturing/production lines where more detail is needed. In many of these scenarios, the higher detail requirement might only cover 25% of the space. To efficiently capture this type of space, in terms of both time and cost, we would employ a combination of our Leica RTC360 to cover the areas with a higher detail requirement and our NavVis VLX 3 to capture the balance.

Terrestrial Laser Scanning (TLS)

Technology explanation

Terrestrial scanning, also known as terrestrial laser scanning (TLS) or ground-based LiDAR scanning, is a technology used to capture highly detailed and accurate three-dimensional (3D) data of objects or environments. It's commonly employed in various fields, including surveying, engineering, architecture, construction, archaeology, geology, and forestry. Terrestrial scanning relies on laser technology to create a precise point cloud, a collection of millions or even billions of 3D points in space.

Here's how terrestrial scanning typically works:

1. **Laser Emission**
Terrestrial laser scanners emit laser beams from a fixed or rotating instrument in various directions. These beams are directed towards the object or scene being scanned.

2. **Laser Reflection**
When the laser beams encounter surfaces, they bounce back to the scanner's sensors. The time it takes for the laser beam to return to the scanner is measured, allowing the device to calculate the distance to the object's surface.

3. **Point Cloud Generation**
The collected distance measurements are converted into 3D coordinates (x, y, z) to create a point cloud. Each point in the point cloud represents a scanned location on the object or surface.

4. **Multiple Scans**
To create a comprehensive 3D model, the scanner captures data from different positions and angles. This may involve setting up the scanner in various locations or using a rotating head to cover a wide field of view.

5. **Data Processing**
The point cloud data is processed and registered to create a unified 3D model of the scanned area or object. This processing may include tasks such as noise elimination, alignment of overlapping scans, and color information application if the scanner has a built-in camera.

Pros

Terrestrial scanning efficiently captures detailed 3D data over large areas or complex structures. It's particularly valuable in situations where precision and accuracy are critical.

High Accuracy and Detail:
Terrestrial laser scanners are known for their high accuracy and ability to capture intricate details. They emit laser beams that measure distances to objects in the environment with exceptional precision. By combining multiple scans from different positions, a comprehensive and highly accurate 3D representation can be created.

Large Scanning Range:
Terrestrial laser scanners have a large scanning range, allowing them to capture data from both nearby and distant objects. The range is typically several tens of meters, making them suitable for scanning large-scale environments, such as buildings, construction sites, or archaeological sites.

Cons

Fixed Position:
Terrestrial laser scanners remain stationary during the scanning process. They are set up at a fixed location, and the scanner's laser beams sweep across the environment to capture data from multiple viewpoints. Terrestrial scanners require a direct line of sight to the objects being scanned.

Obstacles such as vegetation, buildings, or other structures can block the scanner's view and limit its effectiveness. This often leads to some occluded areas if not enough scans are taken.

Cost

Terrestrial scanners can be expensive to purchase and operate. The initial investment includes the cost of the scanner hardware, software, and sometimes additional accessories like tripods or targets. Maintenance and calibration can also incur ongoing expenses. The operators will require training as well.

The price typically ranges from **20k USD to 100k USD**.

The high-end scanners are the ones providing the best results. The most popular one is the Leica RTC360. Its price is around 75K USD. A license to their registration software is also required.

SLAM Scanning

Technology explanation

SLAM, which stands for Simultaneous Localization and Mapping, is a technology used in robotics and computer vision to enable a device, such as a robot or a camera, to map its environment while simultaneously determining its position. In essence, SLAM allows a device to create a map of an unknown environment and keep track of its location within that map in real time.

SLAM uses various sensors, such as cameras, LiDAR (Light Detection and Ranging), and IMU (Inertial Measurement Unit), to collect data about the surroundings. The device then processes this data to build a map of the environment and estimate its pose (position and orientation) within that map. This is a complex computational task that involves solving a set of equations to reconcile the incoming sensor data with the existing map and the device's movement.

Here's how SLAM scanning typically works:

1. **Gathering Data**
The SLAM scanner starts by using its sensors, such as cameras and laser scanners, to collect information about the world around it. This includes tasks like measuring distances to objects and capturing images.

2. **Identifying Features**
If it's a visual SLAM system, it looks for unique points in the images that can be used as reference points.

3. **Getting Started**
Initially, the system tries to determine its location and gain an understanding of the surroundings. It may have a rough estimate of its position.

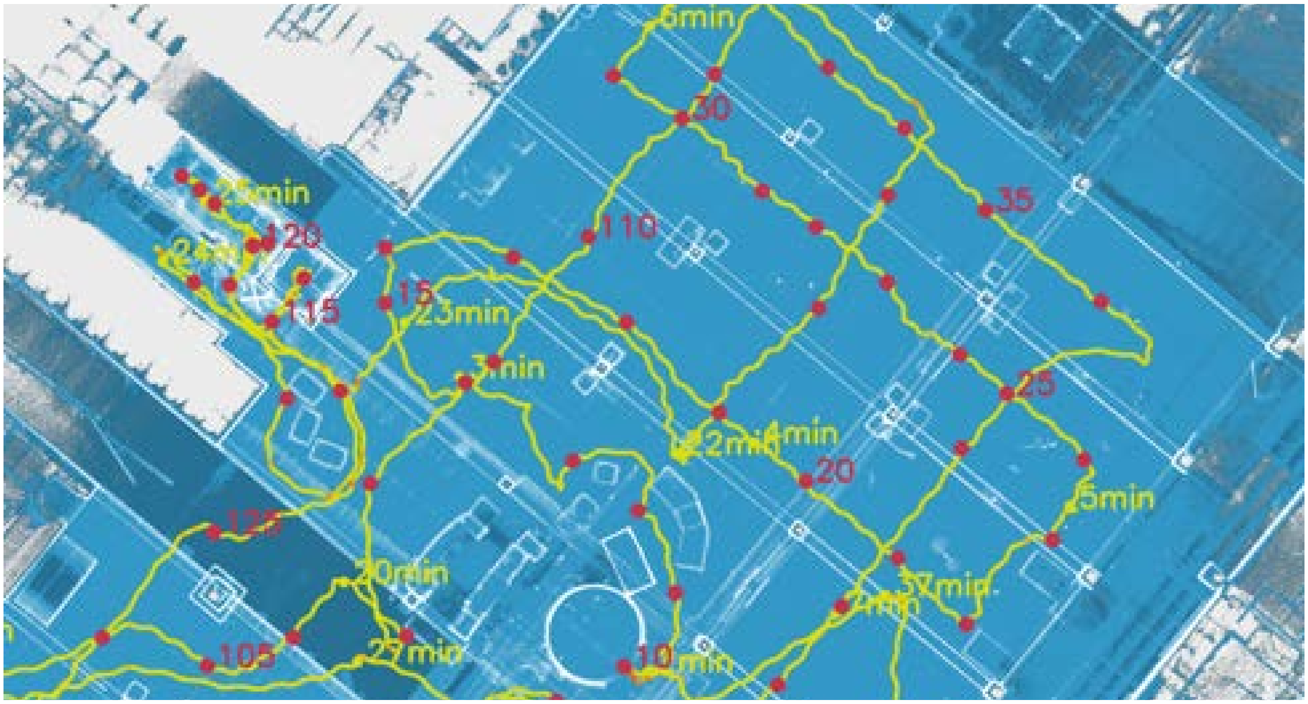
4. **Guessing Movements**
The scanner estimates how it has moved since the last check. This involves measuring turns or distances traveled.

5. **Matching Data**
It tries to determine which parts of the currently collected data match what it already knows from before.

6. **Creating a Map**
As it collects new data and finds matches, it builds a map of the environment. This map can be in the form of a collection of points or a grid.

7. **Loop Closure (Recommended)**
This is usually crucial during a scan. Over time, the device may experience some drift and accumulate errors. Loop closure involves revisiting the same location to mitigate these errors.

Here's an example of a scanning path including loop closure



Above, we can see the yellow line describing the device's position. The scanning provider did well by creating those "box" patterns and overlapping the trajectory. Those loops will help the algorithm tie the model back together and reduce the drift.

Usually, all the processes described above are a black box and proprietary to the device constructor. It's more user-friendly to capture data using a SLAM device like the NavVis VLX because the complexity is hidden from the user.

Pros

SLAM scanning is highly efficient for capturing large areas. It's particularly valuable when a good overview is required or access is time-limited on site.

Mobility:
SLAM scanners are typically mobile and can be mounted on robots, drones, or handheld devices. They move through the environment to capture data in real -time while simultaneously estimating their position.

Speed:
\Those devices are usually quite fast to capture a space. While scanning, reducing the environmental changes as much as possible is important. Time-limited access can be the main challenge in some cases.

User-Friendly:
These hardware devices are recent on the market and we can clearly see the different approach to the user experience compared to traditional terrestrial scanners. They are easier to control, but you still need a good experience to get the desired results.

Cons

Accuracy:
Those devices might be fast, but there's a small cost on the quality of the point cloud. Since the device is actively moving, it has less "occluded area," but there's a bit more noise in the data overall.

Drift:
Since the device tracks its position using anchor points in the space, it tends to accumulate errors over time. If you have a space with few assets or a similar pattern, the devices can also lose their tracking position—for instance, a rooftop without mechanical equipment, a long white hallway, or a cedar hedge.

Cost

The SLAM devices' price range is similar to the terrestrial scanner; the hardware typically costs between 20k USD and 80k USD.

For example, the NavVis VLX 3 is roughly **80k USD**, but you must also get their cloud processing instance (minimum price is 8k-10k USD).

Reality capture the foundational data layer of Prevu3D Digital Twins

By collecting data about the physical world using sensors like laser scanners, we can gather measurements, images, coordinates, and other sensory information that accurately represent the real-world environment. This data is often stored in point cloud files, which can be challenging to work with and require expertise to clean up and manage. However, once processed into 3D mesh models, the datasets become more accessible and provide a visually immersive experience.

By transforming reality capture datasets into mesh models, we can create virtual replicas known as digital twins. These digital twins are dynamic and real-time representations of physical assets, systems, and environments. They integrate data from various sources like CAD and BIM to provide a comprehensive and accurate digital replica of the physical entity.

Prevu3D software connects real-world assets, data and people

Prevu3D software automatically converts massive point clouds into 3D mesh models for visualization and data analysis. The user-friendly platform enables easy access and management of reality capture data, accelerating engineering workflows. Engineers can quickly design, edit, and share layouts, speeding up decision-making and project delivery.

Prevu3D software is compatible with industry-leading scanning devices

NavVis Leica Geosystems FARO RIEGL

emesent Matterport™

Prevu3D: the next generation of engineering concept design workflows

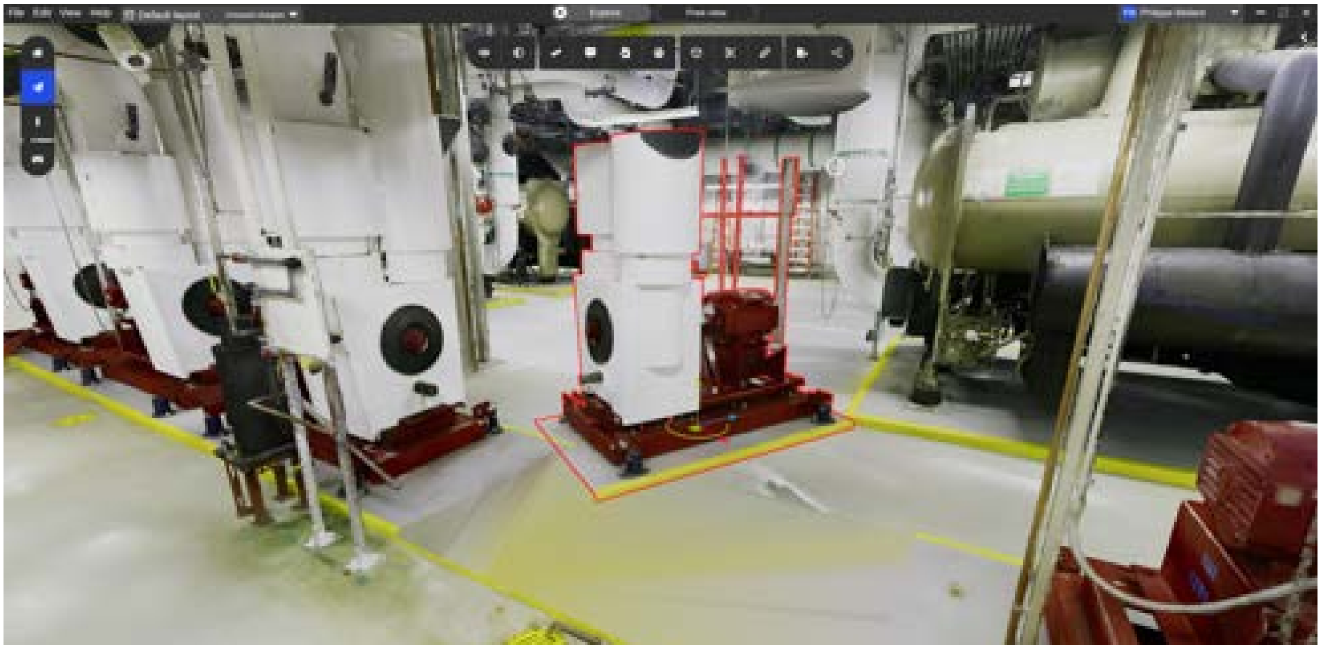
Through cloud processing, gaming technology, and AI, Prevu3D generates high-resolution, quality-textured 3D mesh models of real-world assets and environments. These environments are an editable and shareable visualization platform for all project stakeholders.

Organize virtual assets

- Easily cut meshes to define and organize virtual assets
- Combine meshed assets with CAD metadata
- Use segmentation tools for quick asset identification

Design and edit layouts

- Rapidly design, edit and share layouts
- Animate assets to visualize movement and test trajectory
- Access real-time data and measurement



Navigate and explore

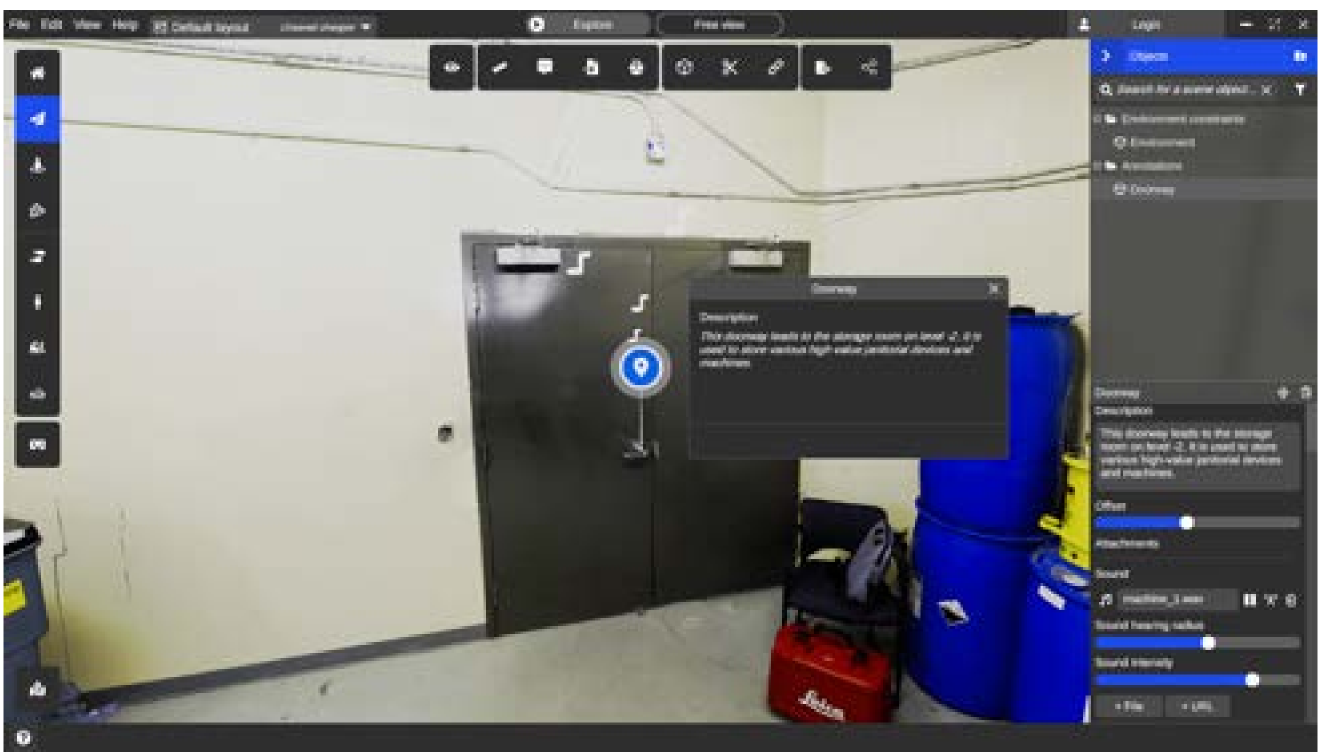
- Navigate through different modes for seamless exploration
- Zoom in to examine every detail and gain rich visual context
- Enhance analysis by evaluating circulation using avatars and vehicles

Reality capture for the industries of the future

Looking to the future of the industrial sector, it becomes evident that digital twins are gaining significant traction across all industries. The advantages of working in 3D are extensive, ranging from improved project visualization and efficient design engineering to streamlined collaboration and cost savings.

Prevu3D software provides a comprehensive platform that empowers companies to fully harness the potential of reality capture. It connects real-world assets, data, and people for top operational efficiency.

Embracing reality-capture technology means embracing its transformative potential.
For more information about Prevu3D's turnkey solutions, visit [the website](#).



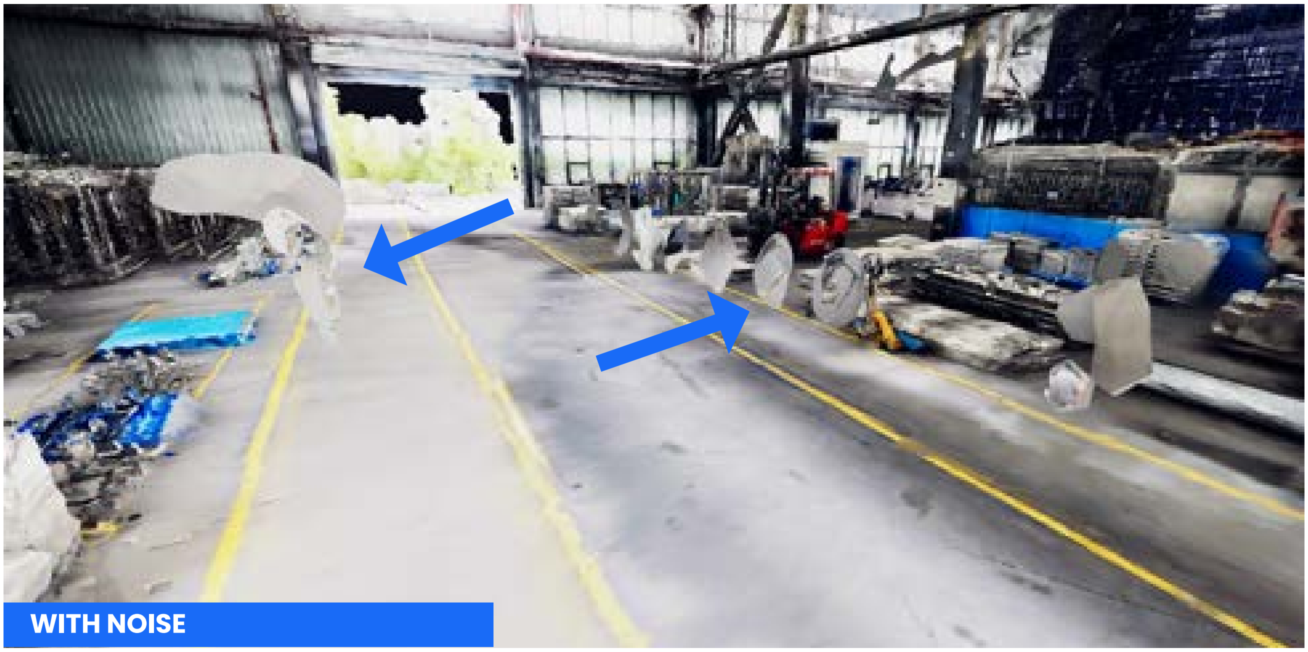
Scanning for highest level quality of meshes

Achieving the highest quality Prevu3D dataset starts with a meticulous laser scan. Prevu3D performs best when there are no gaps or missing data. While LiDAR scanners are highly effective, they can only scan what they can visually perceive using light pulses. Therefore, capturing objects from various angles becomes crucial to ensure comprehensive coverage. This often entails capturing scans from multiple heights and closely located positions. At times, specialized equipment may be necessary to access hard-to-reach areas, or the scanner may need to be placed on the ground to scan otherwise overlooked areas when using a SLAM or terrestrial scanner on a tripod. Over the years, the geospatial community has developed numerous techniques and tools to ensure accurate results. In addition to thorough capturing, lighting and movement can impact the dataset's quality.

Proper lighting is crucial for producing high-quality datasets, as many scanners use JPG imagery for colorizing the data. While some LiDAR scanners can capture intensity values in grayscale, only a few can capture RGB values directly.

Instead, these scanners typically acquire data in two passes: the first pass captures LiDAR points, and the second pass captures a JPG image. The scanner then combines these two datasets to assign colors to each collected point. If the environment is too dark, the points may appear black or very dark in the dataset. The Prevu3D software offers powerful color, lighting, and scene environment correction tools. However, the most effective way to ensure a quality dataset and avoid revisiting the site is to use additional lighting when necessary.

The Prevu3D software incorporates numerous advanced processing algorithms that effectively remove 'noise' and mitigate movement in a scan. 'Noise' can stem from factors like reflections, smoke, or moving objects present during the scanning process. While much of this 'noise' can be eliminated during post-processing, it is advisable to minimize movement as much as possible during the scan itself. This can be achieved by utilizing features like the 'Double Pass' option on the Leica RTC 360 or scheduling the scan for a time when the subject area is less congested. Although the software can compensate for movement, if the same area is consistently obstructed by movement in every scan, it will not be adequately captured and represented in the resulting data.



WITH NOISE

NOISE REMOVED

Scanning guidelines

Zone type	Average distance	Scannable surface per day	Number of scans with color per day*
Very crowded area	<2 ft	1,000 - 4,000 sq ft / day	100-200
Crowded zone	2-5 ft	4,000 to 8,000 sq ft / day	100-200
Normal zone	5 ft	8,000 to 18,000 sq ft / day	100-200
Empty area	5 ft	18,000 to 30,000 sq ft / day	100-200

Zone type examples


VERY CROWDED AREA


CROWDED AREA


NORMAL AREA


EMPTY AREA

*The number of scans with color per day is very job-specific, and the conditions can vary depending on job sites.

Contributor

Peter Garran
Founder and CEO BIMstream

BIMstream is a family of architects, engineers, and creative technologists who combine bleeding-edge technology with world-class artistry to solve your toughest challenges. They've scanned, modeled, and delivered tens of millions of sq ft of accurate 3D data, designed robots to survey hazardous sites, rendered photo-realistic VR spaces, and more.

For more information, visit:
https://bimstream.com/

BIMstream

Connect real-world assets, data and people through 3D software solutions

Prevu3D provides an end-to-end platform that empowers industries to harness the full potential of 3D technology. The software automates the conversion of extensive point clouds into detailed, textured meshes, allowing for the visualization of high-quality scan data using a web browser and standard hardware. By consolidating and overseeing reality capture data, Prevu3D facilitates swift design, editing, and sharing layouts with project stakeholders, ultimately enhancing operational efficiency.

Talk to a Prevu3D expert

PREVU3D