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CHANGE DETECTION AND CONVERGENCE MONITORING USING EMESENT AURA

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Using this manual

Hovermap is a powerful system that can be used as a Lidar mapping payload but also as an advanced autopilot for drones. It is therefore recommended to read the user manual thoroughly to make use of all its capabilities in a safe and productive way.

Disclaimer and safety guidelines

This product is not a toy and must not be used by any person under the age of 18. It must be operated with caution, common sense, and in accordance with the instructions in the user manual. Failure to operate it in a safe and responsible manner could result in product loss or injury.

By using this product, you hereby agree that you are solely responsible for your own conduct while using it, and for any consequences thereof. You also agree to use this product only for purposes that are in accordance with all applicable laws, rules and regulations.

The use of Remotely Piloted Aircraft Systems (RPAS) may result in serious injury, death, or property damage if operated without proper training and due care. Before using an RPAS, you must ensure that you are suitably qualified, have received all necessary training, and read all relevant instructions, including the user manual. When using an RPAS, you must adopt safe practices and procedures at all times.

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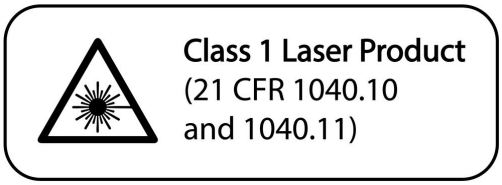
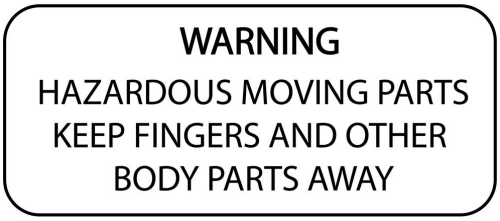
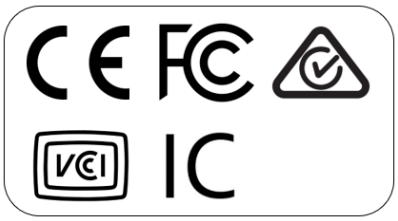
- Always be aware of moving objects that may cause serious injury, such as spinning propellers or other components. *Never* approach a drone while the propellers are spinning or attempt to catch an airborne drone.







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1. Overview

Emesent Aura's Change Detection and Convergence Monitoring solution integrates the rapid data capture capabilities of the Hovermap with Aura's intuitive processing and analysis to help you manage and monitor your excavation projects. Tailored for underground environments and enclosed spaces, our solution enables you to swiftly capture current excavation profiles with the Hovermap and seamlessly process, align, and visualize changes in Aura.

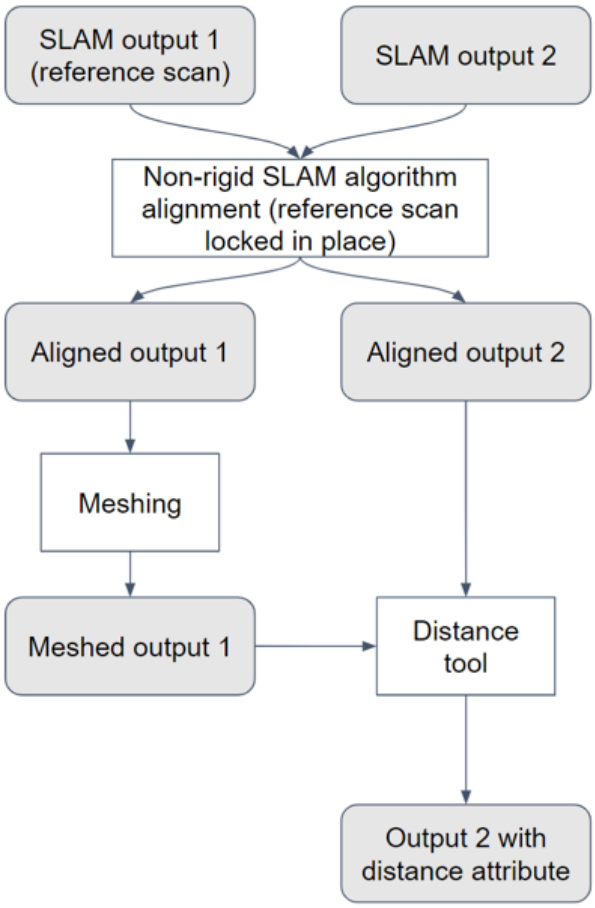
2. Prerequisites

- **Operating System:** Windows 10
- **Emesent Aura:** Version 1.6.1 or higher
- **Entitlement:** A valid SLAM and Convergence Monitoring license
- **Point cloud data:** 2 Hovermap scans of the same area

> **Note**
>
> - This solution is designed and optimized for use in underground mining (drives and tunnels) and other internal enclosed spaces. It may not be suitable for other environments.
> - Scans could be captured by walking, driving, or flying.
> - The original bag files are required for both scans.
> - Before going through the Convergence Monitoring workflow, it is necessary to process both scans using SLAM.

3. Convergence Monitoring Workflow

The basic process for change detection and convergence monitoring involves taking the user's reference scan, creating a mesh of that reference scan, and then measuring the distance from the points in the user's second scan (of the same area) to the mesh.

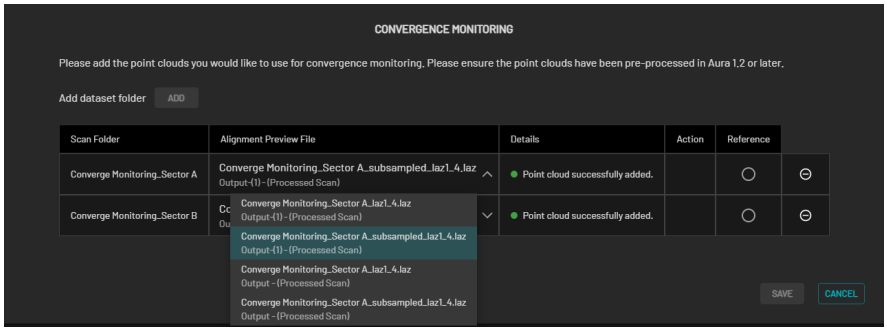


3.1 Step 1: Configure your convergence monitoring job

1. Open Emesent Aura. Make sure you have an active **SLAM** and **Convergence monitoring** license.
2. In the **Process** tab, click **Process Scan**.
3. In the **Configure New Scan Job** panel, select the **Convergence monitoring** workflow.
4. Click **Add Datasets**.
5. In the dialog box that displays, click **Add** then browse for the the point clouds to use.

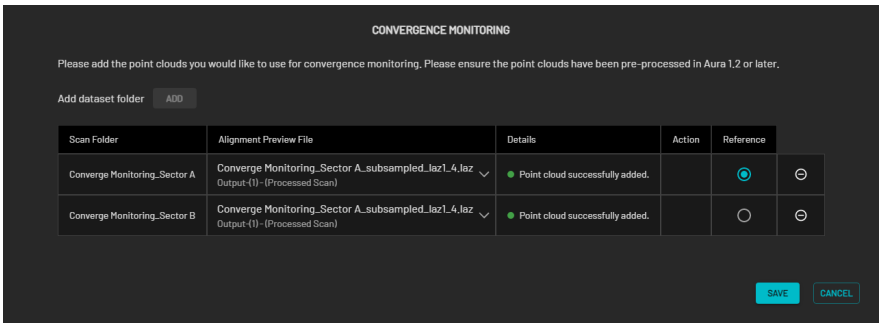
> **Reminder:** Make sure the point clouds have been pre-processed in Aura 1.2 or later.

6. In the **Alignment Preview File** column, select the scan file to use for alignment.

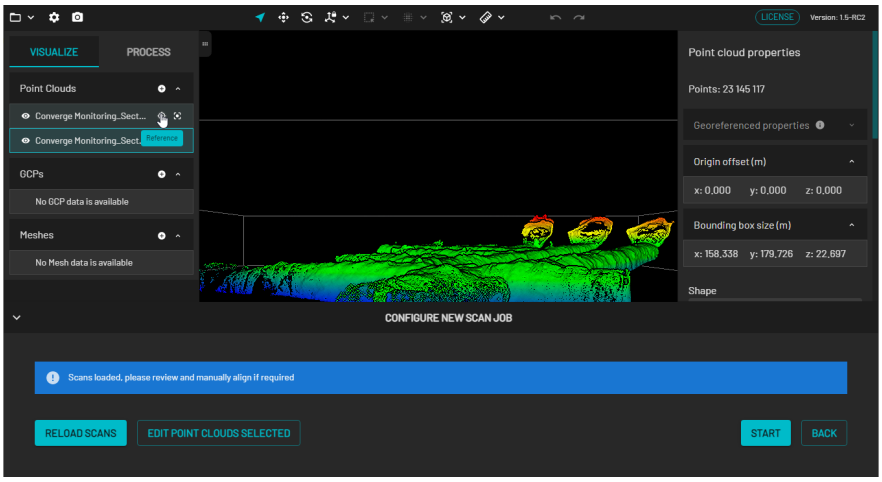


> **Tip:** Converge Monitoring is done on the full point cloud regardless of the selected **Alignment Preview File**. To make the alignment process more practical, it is recommended to use only the subsampled files to lower the computational resources needed, especially for large datasets. In addition, the reduced set of points on a subsampled file allows you to focus on key features or points of interest, which can facilitate more accurate alignment, leading to higher-quality merged point clouds.

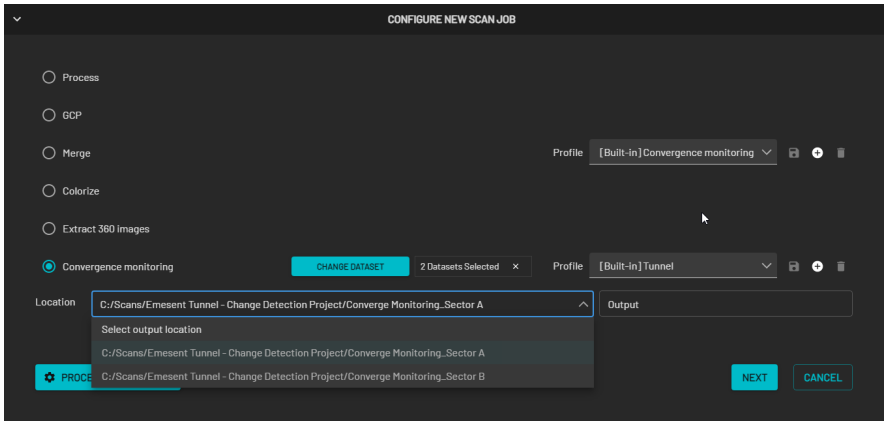
7. Select the reference scan file. The reference scan file provides a fixed frame of reference for aligning the other point cloud. Selecting a reference scan establishes a coordinate system that other scans can be transformed into, ensuring proper alignment between them.



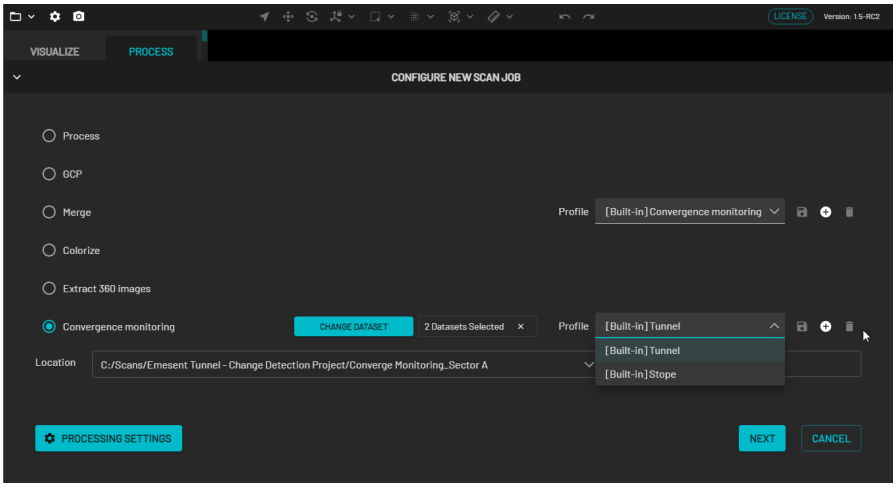
A target icon beside the point cloud file in the **Visualize** tab indicates a referenced scan file.



8. Once you have added the point clouds and selected the reference scan, click **Save**.
9. In the **Location** field, enter the preferred name for the output folder. Also, select the output folder location.



10. Select the profile to use.



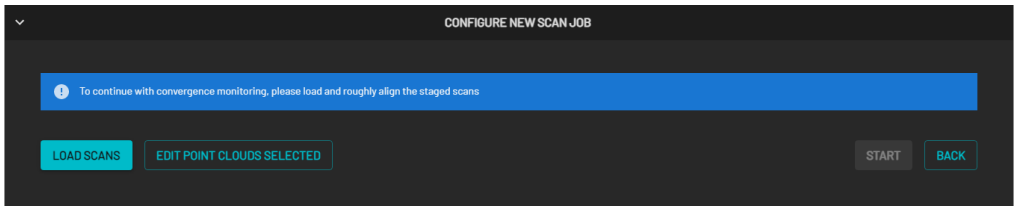
10. Click **Processing Settings** to configure the convergence parameters. Refer to the Processing Settings section for detailed information.

> **Note:** You can skip this step if you want to process using the default settings.

11. Click **Next**.

3.2 Step 2: Review and manually align your datasets

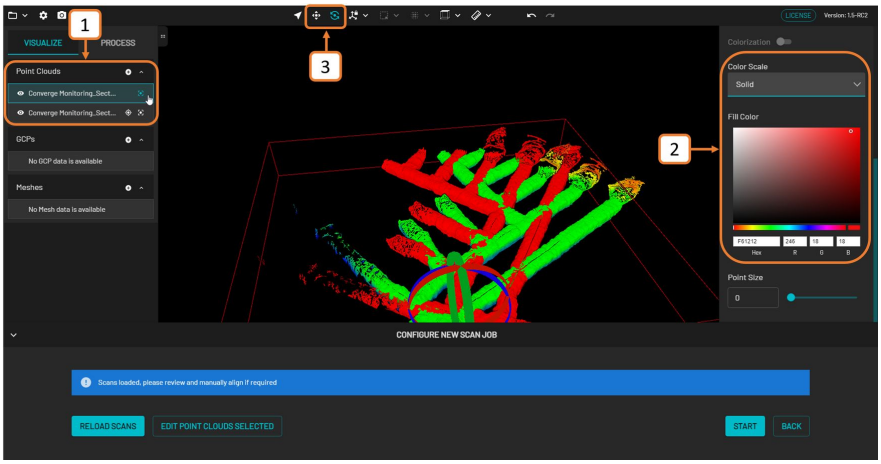
1. Click **Load Scans** to start your review. All scans will load at the same time.



> **Note:** If you have selected the incorrect dataset, click **Edit Point Clouds Selected** to load the correct ones.

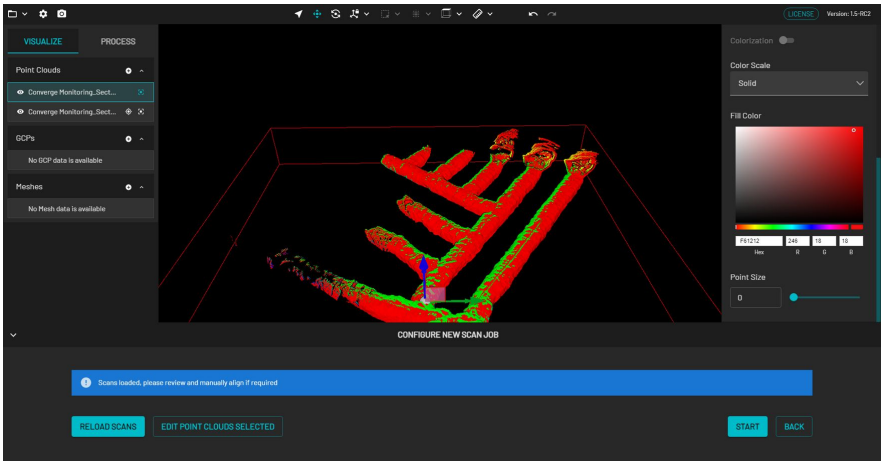
2. Follow these guidelines to roughly align your second scan with the reference scan:

(1) Ensure you have selected the second scan in the **Visualize** tab under the **Point Clouds** menu.
(2) Change the second scan to a **Solid** color using the **Color Scale** to help make alignment easier.
(3) Use the **Transform** and **Rotate** tools to align the point clouds.



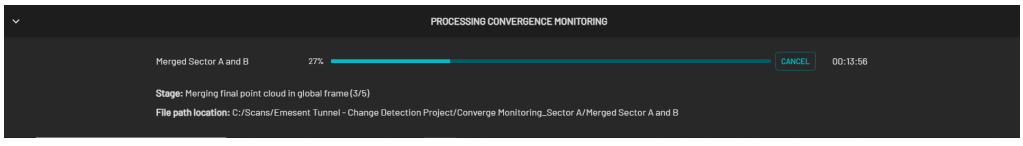
> **Tip:** As an option when using the **Rotate** tool, you can use the following shortcut keys to change the pivot point of the rotation:
>
> - **CTRL+Shift+C**: Changes the origin point to the newly selected point. Click on an area on the second scan to select a new origin point.
> - **Ctrl+Shift+Z:** Resets the origin point back to the point cloud's origin.

3. Once the scans have been roughly aligned, click **Start**.



3.3 Step 3: Start processing

1. Once you click **Start**, a progress bar shows how far along you are in your processing job. In addition to the progress bar, the elapsed time of the processing job is shown to the right. The directory file path below the progress bar provides a way to identify the dataset source. This is useful if simultaneously processing multiple jobs with the same output folder name. Copying the file path and pasting it on your computer's file explorer allows you to access the completed files without waiting for the processing job to be completed.



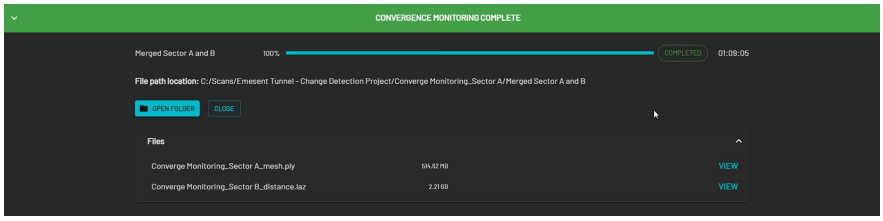
> **Note:** The **Retry** button becomes available when a failure occurs during processing. Click to attempt to process the current job from the last successful stage.

3.4 Step 4: Inspect your final output

Once the processing is completed, the following two outputs will be generated:

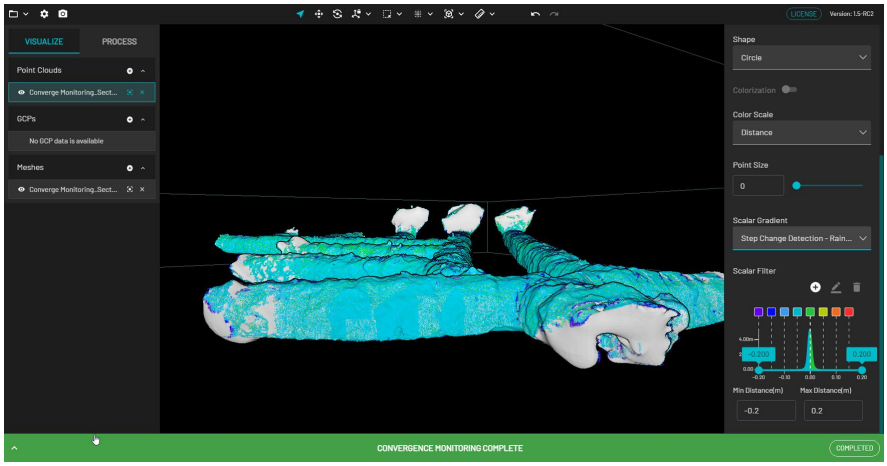
Output	Description
.LAZ	Point cloud with (point to mesh) distance attributes
.PLY	Mesh file created from the reference scan

1. Click **View** to display the generated **.LAZ** file in the Viewport.



> **Note:** Currently, aside from viewing the **.PLY** file, there are no options to interact with a Mesh file.

2. In the Context Panel on the right, click **Color Scale** then select **Distance** from the drop-down menu. The **Step Change Detection - Rainbow** color gradient should also be automatically selected.

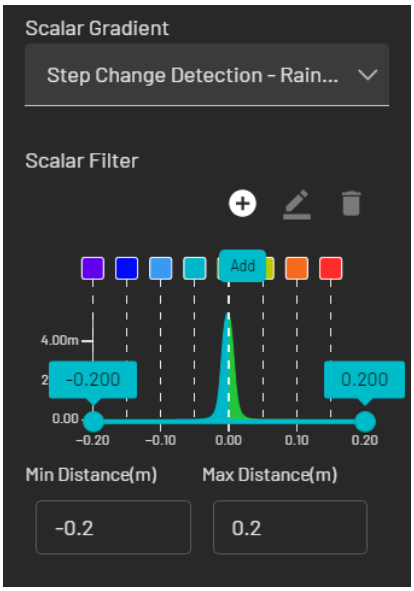


You can edit the colors and distance values within the Scalar Filter. It is also possible to adjust the distance points that should be included in the final output file (**.LAZ**), according to your requirements.

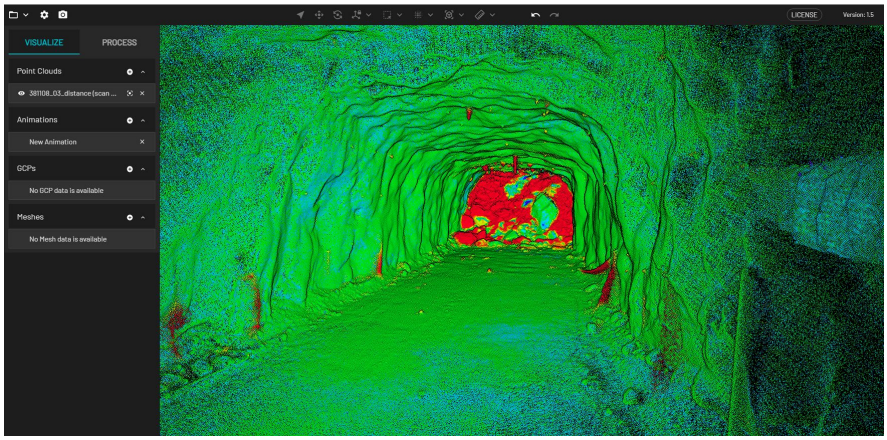
ADD: Click the **+** icon then select a color and specify the **Location** in meters.

EDIT: Click the square color box then click the **Pencil** icon.

DELETE: Click the square color box then click the **Trash** icon.



3. Use the near clip plane (by holding the **ALT** key while using the mouse scroll wheel in Perspective mode) to view and navigate inside the tunnel as shown in the screenshot below.



Note: Pieces of infrastructure (like pipes, rock bolts, fans, etc.) may show changes (as shown below in red) due to how the meshing removes and smooths out those features on the reference scan. These changes would typically be ignored.

4. Processing Settings

Alignment settings can be changed via the **Merge** and **Meshes** tabs in **Processing Settings**.

> **Note:** When you update the settings on a built-in processing profile in Emesent Aura, a temporary "**Custom**" profile is created, which can be used in any of the workflows for the current session. You can save this custom profile to save time in setting up processing jobs for common or known environments. Once saved, it becomes available for selection in the Profiles dropdown list.
> If you choose not to save the custom profile, it is automatically removed when the application is closed.

4.1 Merge Tab

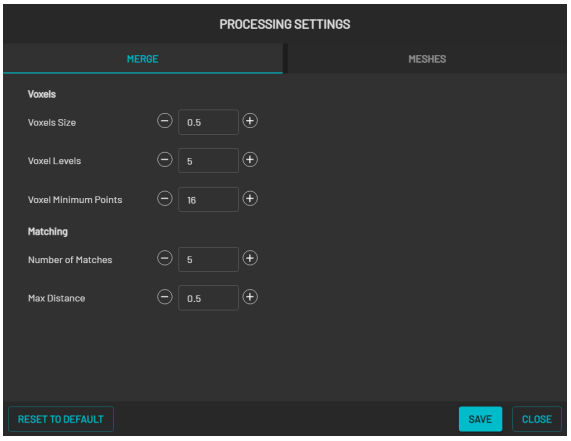


Table 1 Processing Settings - Merge Tab

Field	Data
Voxels	• **Voxels Size:** The lowest size of voxel used to generate surfels in SLAM. Use this inside smooth tunnels/bores, as most of the information within the points will be in the subtle variations in the surface direction that occur in relatively small dimensions. Increasing this number can significantly increase the processing time. *Default setting: 0.4 m* • **Voxel Levels:** The number of levels used to generate surfels in SLAM. Each level is twice the size of the previous level. Use this inside tunnels/bores, as most of the information within the points will be in subtle variations in the surface direction that occur in relatively small dimensions. *Default setting: 5* • **Voxel Minimum Points:** The minimum number of points in a voxel to use for SLAM. Use this to reduce the impact of noisy data on SLAM, or to ensure that features with a low number of points are included in environments with few geometric features. *Default setting: 8*
Matching	• **Number of Matches:** Number of surfels to look for matches during SLAM. • **Max Distance:** Maximum distance (in voxels) to search for surfel matches.

4.2 Meshes Tab

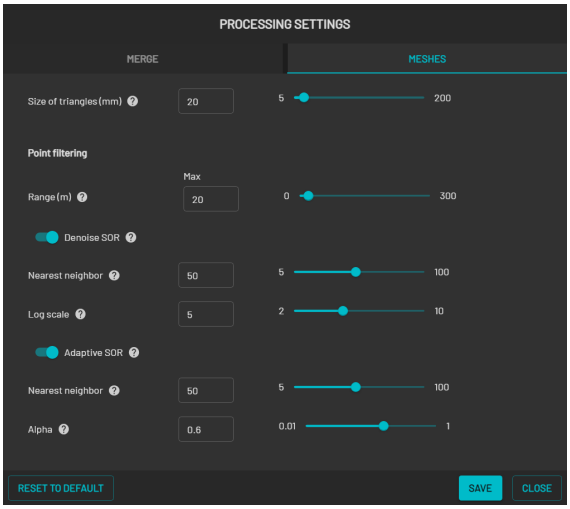


Table 2 Processing Settings - Merge Tab

Field	Data
Size of triangles (mm)	The level of detail that makes up the 3D mesh. A smaller triangle size results in a more detailed mesh.

Field	Data
Point filtering (m)	• **Range:** Filters the points outside the specified range from the scanner. • **Denoise SOR:** Removes outlier points that are less likely to be real. ◦ **Nearest neighbor:** The number of point neighbors used for data analysis. A smaller value results in quicker processing and less statistical certainty. ◦ **Log scale:** The threshold for filtering. A smaller value results in a more aggressive filtering. *8 = conservative; 6 = default; 4 = aggressive* • **Adaptive SOR:** Removes the points that seem fuzzier than nearby points. ◦ **Nearest neighbor:** The number of point neighbors used for data analysis. A smaller value results in quicker processing and less statistical certainty. ◦ **Alpha:** The threshold for filtering. A larger value results in a more aggressive filtering. *0.05 = conservative; 0.10 = default; 0.50 = aggressive*

5. Frequently Asked Questions

- **Are the Hovermap 100, ST, and ST-X all supported?**

  Yes. Note that using more accurate Hovermap products will improve the accuracy of the convergence monitoring result.

- **Why are the original bag files required?**

  The bag files are required for reference and second scans as part of the alignment process.

- **How close does the user need to roughly align the two scans for the convergence monitoring workflow to be successful?**

  The Aura alignment algorithm will search for matching features between scans within the **Max Distance** parameter, defaulting to 0.5m. Ensuring the rough alignment of scans is as close as possible improves the likelihood of a good final alignment.

- **Does convergence monitoring work with GCP?**

  No. GCP is not supported in this release.

- **If I don't use GCP, will a long scan matter if the two scans have drift? Can they still be aligned and be usable for convergence monitoring?**

  The Aura alignment algorithm will fix the reference scan in place, and align the second scan to the reference scan. This has the benefit of reducing drift in scans aligned for Convergence Monitoring.

- **What is the impact of noise like clutter, people, and dust in the scan?**

  False changes will be detected if objects or people are in one scan and not in the other.

- **What is the expected level of accuracy?**

  Measurements in a small controlled environment showed an average error of approximately 12mm. Accuracy will vary depending on factors such as the size of the scanned area, features in the scan, speed of the scan, and density of scanned areas.

- **How will changes in the drive that are unrelated to convergence monitoring impact our solution? For example, the vent bag is inflated on one scan and not on the other, changes on the drive floor, or changes created by vehicles knocking out chunks of the wall.**

  The alignment of the scans and the resulting distance values may be affected in areas with limited matching features. Small changes such as missing chunks in the wall typically will not largely impact the alignment of the scans.

- **Can I use non-Hovermap scans for convergence monitoring?**

  No. Only Hovermap scans are supported.

- **If two or more scans are merged to capture a longer tunnel, can that merged scan be used for convergence monitoring?**

  No. Currently, convergence monitoring only supports comparing between two Hovermap scans.

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