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Differentiation of 3D scanners and their positioning method when applied to pipeline integrity.

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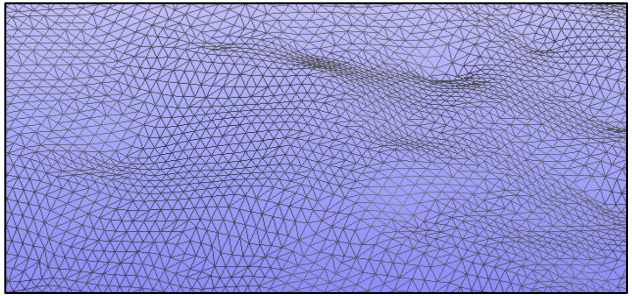
Introduction

- This paper aims at helping service providers and asset owners select the most suitable 3D scanner solution for their inspection needs.
- 3D scanners are differentiated according to the positioning method they use.
- The measuring arm, the tracked 3D scanner, the structured light, and the portable 3D scanner categories will be investigated.
- Each scanner category has been tested for corrosion assessment on a pipeline.

1 - BRIDGING PHYSICAL AND DIGITAL WORLDS

How 3D scanning works

- There are two major categories of scanners based on the way they capture data:
  - White-light and structured-light systems that take single snapshots/scans
  - Scan arms and portable handheld scanners that capture multiple images continuously
- 3D scan files can be a point cloud or a triangle mesh
- Scan alignment or registration can be performed during the scan itself, called dynamic referencing, or as a post-processing step.



3D Mesh File

Measuring arms, portable CMM scanners

- CMM (coordinate measuring machines) and measuring arms can be equipped with probing or 3D scanning heads.
- CMM with portable arms are positioned using the mechanical encoders integrated in the arm ➡ Lack flexibility
- Portable CMM need to be fixed on a surface and use a physical link (arm) as their positioning method ➡ Vibrations can affect accuracy

Tracked 3D scanners

- Optical tracking devices can track various types of measurement tools, including the positioning of a 3D scanner.
- These scanners use an external optical tracking device for positioning.
- Tracked 3D scanners provide very good accuracy and excellent precision throughout the measurement volume.
- The tracker must always have a clear and direct line of sight to the 3D scanner.
- Trackers often have a limited working volume.

Structured-light 3D scanners

- Project a pattern of light on a part and process how the pattern is distorted when light hits the object.
- Either an LCD projector or a scanned or diffracted laser beam projects the light pattern.
- One, two, or sometimes more sensors record the projected pattern.
- White-light scanners can acquire large quantities of data in one scan but overall project speed is not always improved by this methodology.

Portable 3D scanners

- Laser scanners project one or many laser lines on an object while white-light devices project a light and shade pattern. Both will analyze the resulting deformed projections to extract the 3D data.

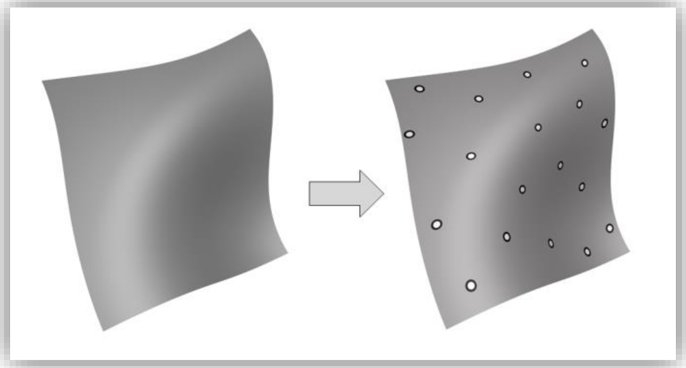
- The most advanced technologies can acquire more than half-a-million points per second and rebuild the 3D triangle mesh live during the scanning process.

- Handheld scanners do not require a mechanical link or a direct line of sight with a tracker. This enables them to reach narrow and enclosed areas.

2 – POSITIONING METHODS FOR PORTABLE 3D SCANNERS

Positioning through targets

- Positioning targets applied before scanning on the object or around its immediate surroundings.
- Targets enable users to register all the different camera frames for the 3D data sets acquired by the scanner.
- Targets are specifically designed for easy detection by the 3D scanner's optical components.
- A minimum of three targets is used to position the scanning frame.
- Positioning through targets is the only method delivering metrology-grade quality



Positioning by geometry with natural features

- This method uses the object's shape and texture to record object positioning.
- As data is acquired, the scanner will detect some shapes and textures on the scanned area and register them for future use.
- Unlike positioning targets, natural features vary from one object to another.
- The resulting precision and accuracy can be greatly affected by the type of objects being scanned.
- Cylindrical shapes usually don't offer enough geometry to lock all 6 degrees of freedom.

Hybrid positioning

- It is possible to combine target and natural positioning into a hybrid positioning mode.
- Users can compensate for the lack of natural features in a given object or specific areas by adding positioning targets.
- Although hybrid positioning would appear to be the best of both worlds, it will not generate metrology-grade results.

3 – MATCHING 3D SCANNING NEEDS TO POSITIONING METHODS

What's the right 3D scanner for my needs?

- If main goal is speed and simplicity, 3D scanner using **natural features positioning method** is the best option.
  - ➢ Trade-offs: lower accuracy and possible lack of natural features on the scan object which can increase modeling and correction time.
- If application requires flexibility, but not high accuracy or metrology-grade resolution, the **hybrid positioning method** is the best solution.
  - ➢ 3D scanners suited for scanning applications such as industrial product development, where absolute precision is not required.
- If application requires a level of precision or resolution (details) that scanners with hybrid positioning cannot match. Using a high-range portable scanner with **positioning targets** is recommended.

What's the right 3D scanner for my needs?

- The following table presents a simplified comparison:

Main Goal	Positioning Methods	Main Limitation(s)
Speed, Simplicity	Geometry (Natural Features)	Precision, features and performance depend on the object
Flexibility	Geometry + Targets (Hybrid)	Compromise on accuracy
Reliability, precision	Targets	Affixing targets on the object

4 – CASE STUDY: ANALYSING PIPELINE EXTERNAL CORROSION

Equipment used

- This section presents the results for external corrosion assessment for portable scanners using the following positioning methods:

  1. **Natural features**
  2. **Hybrid positioning**
  3. **Using targets**

- In parallel, the impact of not having any positioning method will be studied.

- The equipment used for this experimentation was two different structured-light scanners and a laser-based scanner.

- All gathered data were compared the results acquired from Mitutoyo Crysta-ApexS CMM mounted with a Kreon KZ50 optical head.

- The positioning of the CMM has an uncertainty of 0.0127 mm (0.0005 in) and the KZ50 specifies between 0.0127mm (0.0005 in) and 0.0254 mm (0.001 in). To insure the best correlation between results extracted from all scanners positioning methods, the same software platform was used to analyze all data.

Phase 1: Positioning Methods Comparison

- Maximum depth measurements using different positioning methods

	Positioning Methods					
	CMM	**Natural Features**	**Hybrid**	**Targets**	**None**	**Pit Gauge**
Feature 1	**8.146**	8.094	8.201	**8.147**	8.572	8.15
Feature 2	**2.916**	2.903	2.922	**2.926**	3.656	2.89
Feature 3	**4.203**	4.232	4.162	**4.241**	5.890	4.23
Feature 4	**3.607**	3.565	3.546	**3.626**	4.025	3.61
Feature 5	**4.590**	4.554	4.521	**4.602**	5.052	4.62
Feature 6	**5.588**	5.500	5.510	**5.623**	6.094	5.61

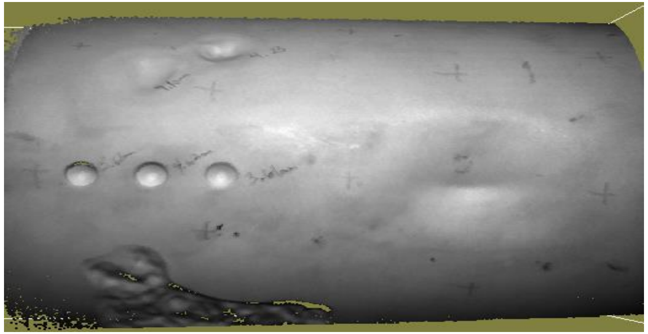
Phase 1: Positioning Methods Comparison

- Comparison between natural features positioning method and Hybrid positioning system
- Comparison shows that using targets as positioning method for portable scanners is the only way of getting metrology-grade results.
- The differences between the laser-based system and the CMM are all within 0.035 mm (0.0015 in).
- Natural features method seems to deliver an interesting level of accuracy compared to not having any positioning method.

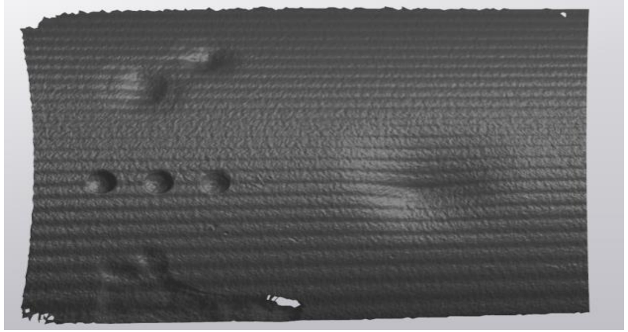
	Positioning Methods				
	CMM	**Natural Features**	**CMM vs NF**	**Hybrid**	**CMM vs Hybrid**
Feature 1	**8.146**	8.094	0.052	8.201	-0.055
Feature 2	**2.916**	2.903	0.013	2.922	-0.006
Feature 3	**4.203**	4.232	-0.029	4.162	0.041
Feature 4	**3.607**	3.565	0.042	3.546	0.061
Feature 5	**4.590**	4.554	0.036	4.521	0.069
Feature 6	**5.588**	5.500	0.088	5.510	0.078

Phase 2: Texture Projection vs Raw Point Cloud

- Structured-light scanner without positioning method projects the texture (color) on the acquired point cloud.
- Although the 3D picture looked good, the raw point cloud was noisy and once processed in the analysis software, found to be inaccurate (as demonstrated above).
- Such noise in raw data point cloud can be explained either by a system wrongly calibrated or the incapacity to compensate for vibrations during data acquisition.



Point cloud with texture projection



Raw point cloud

Phase 3: Impact of Pictures Registration

- To simulate a real inspection case, we took multiple pictures in different orientation to cover all angles.
- The registration of these pictures was not done automatically since the native acquisition software did not allow it.
- We were required to manually align the pictures based on natural features.
- Large variations were found between results got from the first picture and the ones gathered after the manual alignment. Merging operations were painful and time consuming.

	CMM	Picture 1	Pictures 1-2-3 Merged
Feature 1	**8.146**	8.572	9.035
Feature 2	**2.916**	3.656	3.368
Feature 3	**4.203**	5.890	5.371
Feature 4	**3.607**	4.025	4.299
Feature 5	**4.590**	5.052	5.419
Feature 6	**5.588**	6.094	5.887

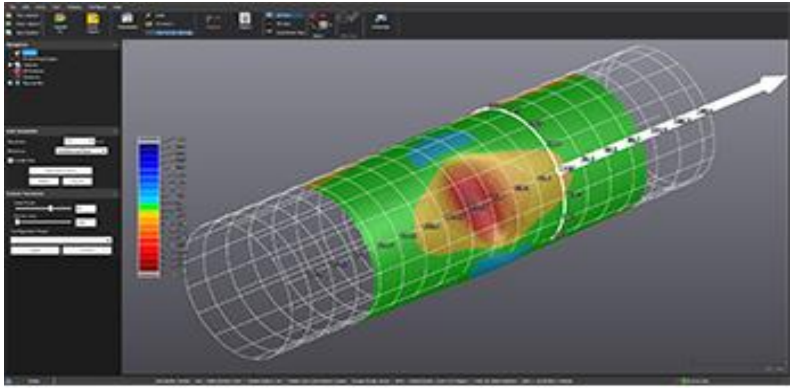
5 – CONCLUSION AND APPLICATION EXAMPLES

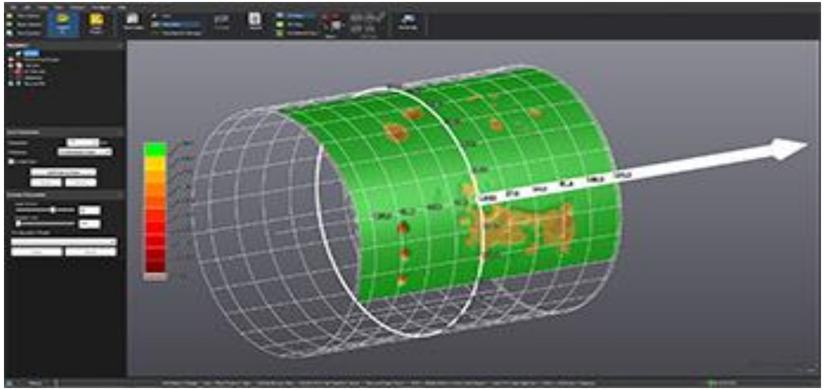
Conclusion

- Using positioning targets is the best method to delivers accurate results.
- One of the structured-light and the laser-based systems used during this study offered different positioning method for different results.
- They both had real time registration of the data which made the analysis faster and easier.

Application Examples

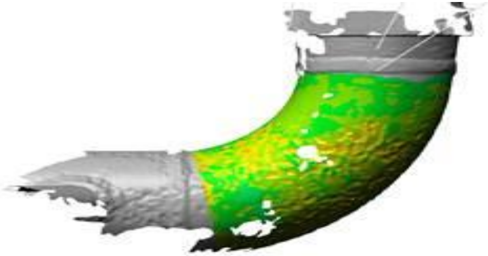
- Pipeline / Pressure Vessel Inspection
  - Mechanical Damage Assessment
  - External Corrosion Inspection

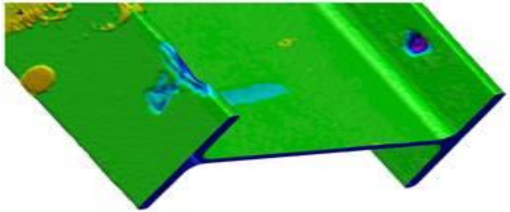


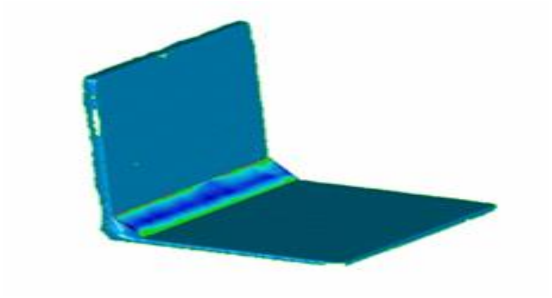


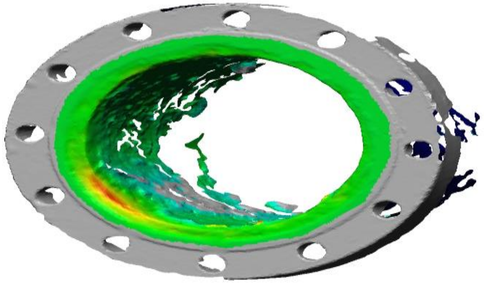
Application Examples

- Complex shapes (Elbows, I-Beams, Welds, Flanges…)



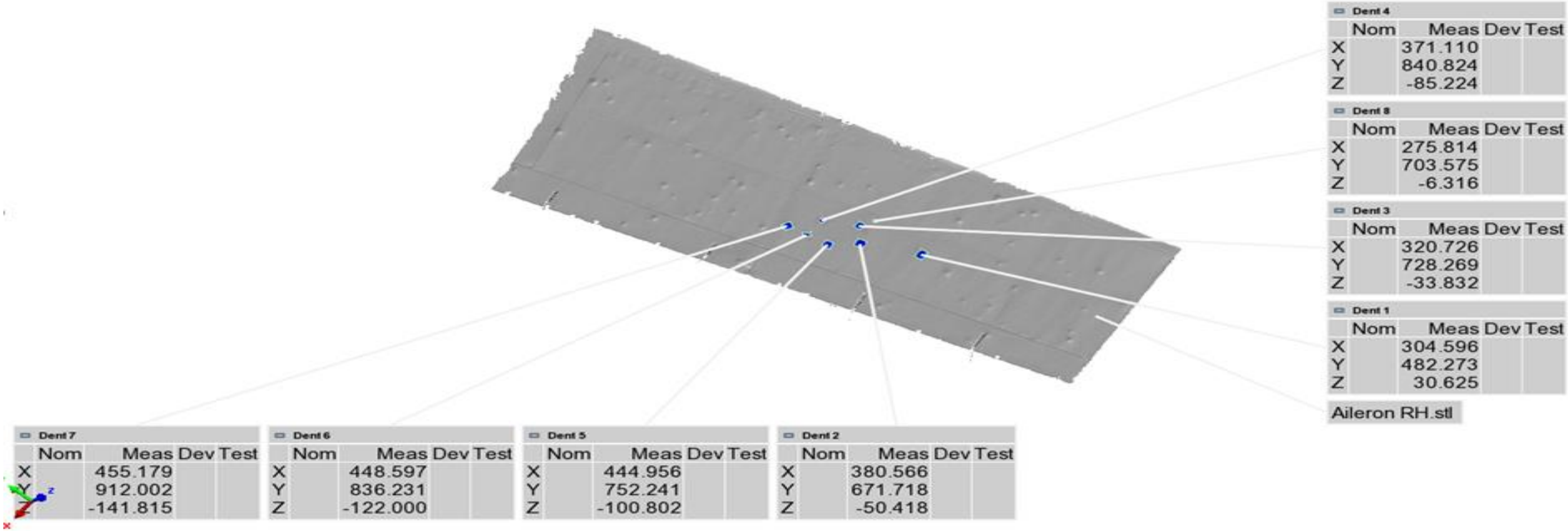






APPLICATION EXAMPLES

- Aerospace maintenance – Hail Damage



THANK YOU FOR YOUR ATTENTION

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