Bachelor's thesis

Bachelor of Information and Communications Technology
2021

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SCAN TO 3D MODEL AND PARAMETRIC DATA SYSTEM IMPLEMENTATION

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BACHELOR’S THESIS | ABSTRACT

TURKU UNIVERSITY OF APPLIED SCIENCES

Bachelor of Information and Communications Techonology

(2021) | 30 pages

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The main purpose of this research is to provide the welding and 3D scanning field, new perspectives about the usage of 3D scanners in the context of ship building and the advantages it can bring. The research compared three different 3D scanners, the analysis was based on their performance and the workflow that each of them required, and the conclusion and recommendations were formulated on quantitative and qualitative examinations.

The commissioner of the thesis is Pemamek Oy, a welding and automation provider, who is interested in introducing the usage of 3D scanners in their current methods of welding. The main objectives of this thesis were to find out how impactful would be the differences between all the scanners in their results, what workflow is the most suitable for Pemamek and ultimately, which scanning option is the most appropiate.

This thesis shows the necessary steps that is needed to obtain a 3D model from the selected scanners and explain their differences. It was concluded that the available options can not provide a result up to the standards required by Pemamek, the proposed workflows take too much time, but one scanner seems to be the most promising. The main recommendation is that the company needs to look for scanners with a fast scanning process, capable to access difficult areas and provide an automatic system that produces a high quality mesh.

KEYWORDS:

Scan, scanner, 3D, point clouds, welding, mesh, model, engineering, robotics

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LIST OF ABBREVIATIONS (OR) SYMBOLS

3D = Three dimensional

PC = Personal computer

2D = Two dimensional

SDK = Software development kit

1 INTRODUCTION

The welding industry began improving with their technology since the 19th century with the introduction of the continuous electric arc, and since then, they have been looking for new ways to innovate. Due to the capabilities of 3D scanning, many industries have started to make use of that technology. One of the main reasons is that it allows the digitalization of any object, it also allows for the mofication of measurements of the scanned object inside a 3D modelling software; in that manner, companies would be able to visualize any potential change that could be done in a short period of time. Another possibility would be that, if there is a need for a replica of a certain piece, 3D printing is an option; it allows the reproduction of the said piece in a small scale. The welding industry has seen use of this technology. From spotting individuals in non-safe areas, to the detection of imperfections in a given surface. But there seems to be more potential in the initiative of reproducing digitally, pieces to be weld.

Pemamek Oy, a welding and automation provider, commissioned this study. Their current welding system depends heavily on obtaining a digital version of the piece that needs to be weld. It is a lengthy segment in their production, and they would like to increase their efficiency. They have made an initial study about new technologies that could be of use to them, and concluded that 3D scanning has potential in the field.

The main purpose of this research is to provide the welding and 3D scanning field, new perspectives about the usage of 3D scanners in the context of ship building and the advantages it can bring. The way to achieve this, is by finding the most suitable scanner among all the ones provided by the comissioner, which will be explained in great detail later on; on the other hand, to provide documentation with not only the accurate process but also finding out if the scanners could be implemented in the company mentioned above. Finally, the format of the result of the scan should be suitable with the Pemamek's requirements.

The personal motivation for this research is to enhance the knowledge in the scanning technology, to find versatile ways to use it and to learn about its usage in different contexts. The hypothesis is that the scanning method proposed will be beneficial, giving the company a new process that will make their current welding procedure far more productive compared to the current one. Some of the proposed questions are based on the results that will be achieved from this research. How impactful would be the differences between all the scanners in their results? Between Pemamek's previous method and the proposed one, which process takes less time? Which scanning option is the best?

This thesis initiates with an introduction that contains background information of the topic, presents the commissioner, and the objectives of this research. Chapter two, three and four explains the main concepts that will be explored throughout the next chapter. Chapter five, shows the hardware and software utilized in this research. Chapter six gives details towards the current system from the commissioner and the ones that are being proposed. Then it proceeds to show the results of each implementation and concludes with the respective analysis of the methods and recommendations.

2 WELDING

2.1 History of welding

There is evidence that welding started around 2000 years ago with the Egyptians using charcoal to produce fire and heat that could turn iron ore into solid metal iron; they made swords, spearheads and large cooking pots (Crom Weld, 2016). In the middle ages, in order to join two pieces of metal together, blacksmiths would hammer out imperfections while applying different levels of heat to the iron. What is considered conventional welding appeared in 1880, with the research of arc heat to join metal plates for batteries (FairLawn Tool, 2018).

2.2 What is welding?

It is a process in which pieces of material are combined in order to form one piece, and this occurs when they are heated to a temperature high enough to cause softening or melting and flow together. Welding is used in shipbuilding due how water resistant it is compared to other methods (Tojsat, 2011).

2.3 Robotics in the welding industry

The automative industry is the major applicant of robotics for welding, but it has also taken attention from others, such as the shipbuilding industry. This techonology implements arc welding, a procedure that consists of an electric arc joining materials together by using its concentrated heat (Tayler Studwelding, 2016). With robotics, it has a high improvement in speed and quality, it is safer and more cost-effective (Tojsat, 2011).

3 SCANNING TECHNOLOGY

3.1 History of 3D scanning

During the 1960s, 3D scanning technology was developed with the aim to recreate surfaces of various objects. The first iterations were limited, due to the scanning time and the amount of effort the operation required. In 1985, scanners started to use white light, lasers and shadowing (Modena, 2018). One of the first implementations of this technology came with head scanning for the animation industry (Acta Simulatio, 2018).

3.2 What is 3D scanning?

3D scanning is a procedure that captures information from the surface of a physical object and converts it as data points. These data points are used to replicate the scanned object digitally or for an analysis of its dimensions. Some 3D scanners that gather data from a specific subject, not only acquire shape but also shading information (Capture 3D, 2019).

3.3 Types of 3D scanning

In this section, there will be a brief explanation of the type of scanning technology present during this study and also, other ones that are deemed worth mentioning.

3.3.1 Laser Scanning

Laser scanning generally tends to involve two devices, one is responsible for pointing a surface with a laser beam, and the other records the exact location in which the object intersects with the beam. Through triangulation, it is possible to determine the angle of reflection and the distance between the scanner and the surface (NeoMetrix, 2017).

3.3.2 Structure Light Scanning

This technology uses a projection of structured patterns of light onto a surface, like parallel lines or simple geometric patterns. Evidently, the patterns will deform due to the shape of the object. By analyzing these deformations through a camera, it is possible to reconstruct the scanned surface through the distinction of edges and identifying the distance between scanner and object (Bitfab, 2020).

3.3.3 Time of Flight

It calculates the amount of time it takes for a laser or infrared beam to reflect back to a sensor, after emitting it onto a surface. This technology is highly subsceptible to temperature and humidity, requiring multiple scans to replicate an object. Moreover, the precision provided in these type of scanning, ranges in centimeters (NeoMetrix, 2017).

3.3.4 Photogrammetry

Photogrammetry uses triangulation, by intersecting specific points within two dimensional pictures, due to the available angles of said points. It depends highly on the quality of the images, how many of them are, and the size of the object to form an acceptable 3D model (3D Insider, 2019).

4 3D DATA

4.1 What is a mesh?

A mesh is a 3D shape that contains vertices, edges and faces that use common polygons to represent them (Autodesk, 2015). Faces can be composed of triangles, regular quadrilaterals or any other simple geometry. Acquiring a mesh comparable to the one shared by the company (see chapter 7.1 Pemamek's system mesh), by using the proposed systems, is one the main objectives of this research.

4.2 What are point clouds?

Point clouds are datasets that represent objects in space and they constitute the geometric coordinates of a sampled surface. Some of the additional data that point clouds can storage are color or luminance values (FME, 2020). In the case of a laser scanner, each point represents a single laser scan measurement (TOPS, 2020). The higher the amount of point clouds the scan possess, the denser the set of data becomes. This means that, there would be more detail and more properties within the structure. The main difference between a point cloud and a mesh is that the former is a collection of points, while the latter is a collection of polygons.

4.3 Noise points, normals and coordinate systems

Noise points are not part or at the border of a dense region of points, they are usually isolated (Medium. 2019). It is important to define them, since scans tend to produce these types of points, due to factors such as how reflective a material is, or the amount of light around the scan area. Normals are vectors that are perpendicular to a surface and they allow the points to have a correct reference in regards to the direction where the subject was scanned (Treehouse, 2015). Without them, the 3D model would not be able to show sharp edges. A coordinate system determines the location of a point in space and it is based on three mutually perpendicular axes: x, y and z; these intersect on a point called the origin (Math Insight, 2016). 3D models posses a coordinate system, with the origin at their center.

4.4 Point Cloud Data Handling

In the scanning process, it is inevitable to obtain some errors that deviate from the scanned subject; hence the point clouds need modification. One of the necessary processes is alignment, it consists in aligning 2 points in a determined set, to produce a model that has the right coordinate system. Removing the acquired noise points from the scan session. Relocation of the point cloud data, this will display the point clouds with the best positions for the coordinates. And the normals need to be added, in the cases that require them.

5 HARDWARE AND SOFTWARE UTILIZED IN THE RESEARCH

5.1 Hardware used in the research

These are the scanners that were available for studying, it is important to note that there are more scanners in the market but it was decided to test just the following three.

5.1.1 Phoxi 3D Scanner

A scanner meant for static scenes, it utilizes a structure light projection to reconstruct the geometry of a 3D surface of an inspected object (Photoneo, 2020). Phoxi 3D Scanner projects a series a of light patterns onto the scene, captures data and then process it by calculating all visible points on the surface and finally transfers it to the user via Ethernet connection.

5.1.2 MotionCam-3D

A scanner meant for large work areas that can be in motion, it utilizes a parallel structured light projection develop by the manufacturer Photoneo. The difference between the parallel and standard structure light projection is that in the former, a sensor performs the acquisition of data in one snapshot and the latter requires a sequential scanning (Photoneo, 2020). Ultimately, what this means is that this scanner provides a high level of detail on sudden unpredictable movements.

5.1.3 Leica BLK360 Imaging Laser Scanner

A 3D scanner with integrated spherical imaging system and thermography panorama sensor system, designed for indoor and outdoor use. It utilizes time of flight for capture and then streams the images and point clouds to a mobile device that possesses Leica Cyclone Field 360, the manufacturer’s app, via Wi-Fi (Leica Geosystems, 2020).

5.2 Comparison chart between scanners

The manufacturer of Phoxi 3D Scanner and MotionCam-3D is called Photoneo, and as such, both scanners share most of their main features. As for the BLK360 scanner, the manufacturer is Leica Geosystems, and the product have very distinctive features, as well as its ecosystem of applications necessary for the handling of the capture data. The scanners are compared in Table 1, highlighting only what is considered the core characteristics.

Table 1. Scanners comparison chart.

	Scanning Technology	Communication	Horizontal projection angle
Phoxi 3D Scanner	Structured light projection	Ethernet cable	47.5°
MotionCam 3D	Parallel structured light	Ethernet cable	47.5°
Leica BLK360	Time of flight	Wi-Fi	360°

5.3 Software used in this research

5.3.1 Phoxi Control

It is an application that allows users to control Phoxi 3D scanner and MotionCam-3D via a computer program. It allows to set up the device parameters, to trigger and visualize a scan or to facilitate the access of custom applications for the devices (Photoneo, 2020). The software allows for 2 methods of scanning: Record and Trigger Scan. Record is a method in which every certain amount of time, the scanner takes a snapshot automatically. Trigger Scan on the other hand, needs an operator to manually press the scan button.

5.3.2 Cloud Compare

A 3D point cloud and triangular mesh processing software, designed to compare and process point cloud data with advance algorithms (CloudCompare, 2016), some of which will be mention in the practical section. It provides a reorientation tool that gives more options in comparison to MeshLab.

5.3.3 MeshLab

An open source system that process triangular meshes and raw data produced by devices capable of capturing 3D data such as scanners, and prepare models for 3D printing (MeshLab, 2020). MeshLab was chosen due to its advances algorithms when creating a mesh from point clouds.

5.3.4 3DS Max

3DS Max is a 3D graphics program used for design visualization that allows modeling and rendering (Autodesk, 2020). It is used for the final steps of combining the different meshes, it was selected for its visualization and data handling range of options.

5.3.5 Leica Cyclone FIELD 360

It is a mobile device app that is used for the acquisition of data by the respective manufacturer’s scanner and process it to Leica Cyclone REGISTER 360. It controlls the capture settings of the scanner, it allows for the examination of the scan and image data, and it contains features such as tagging measurements, text or voice files (Leica Geosystems, 2020).

5.3.6 Leica Cyclone REGISTER 360

As the desktop solution for point cloud handling, Cyclone REGISTER 360 is the software that receives the point cloud data collected in the mobile app. It is able to manage projects with hundreds of scans without affecting performance and contains features such as automatic alignment and measurement (Leica Geosystems, 2020).

5.3.7 Leica Cyclone 3DR

Cyclone 3DR is a PC (personal computer) software capable of point cloud management, automatic point cloud analysis and meshing (Leica Geosystems, 2020). As part of the Cyclone ecosystem, its user interface is friendly to not only experts in the design industry but also for individuals in need of experimenting with a variety of features.

6 ANALYTICAL METHODOLOGY

6.1 Pemamek's system

Depending on the size of the panel that needs to be weld, a certain type of crane that is affixed to a pair of rails is used. This possesses: a camera mounted in the top part that takes photos of the piece and helps in the measurement process, and a robotic arm that takes responsibility for the welding.

If the client does not provide a 3D model of the panel, Pemamek makes a model of it. To obtain the overall look of said panel, the camera that is looking down to it, takes multiple photos. Then the operator combines these photos to form a 2D (two dimensional) representation of the panel. This figure merely works as a reference when the operator starts the modelling process. Finally, when the 3D model is created, this is taken to the company's own software: PEMA WeldControl 200. This software communicates with their robot-based welding system, and helps to locate important spots such as corners.

6.2 Proposed System # 1

Both Phoxi 3D Scanner and MotionCam-3D are tested with the following system.

6.2.1 Scan

Phoxi 3D Scanner and MotionCam-3D were allocated in the base of the robotic arm previously mentioned. The main reason for this decision is that, the arm allows for the recording of every movement that it performs.

PEMA WeldControl 200 allows very precise motions of the arm, which means that when using the scanner, it is possible to take scans using distance intervals with millimeters of margin of error. It is also capable of setting scanning locations as points in space, allowing the arm to move to those specific points. At the end, the information of each translation made by the arm can be annotated and the relative distance between each scan can be retrieved, this data is later used as a reference when the different scans need to be combined.

For this research, 6 points in space were chosen, these values are represented in millimeters. The scanner was positioned in 2 angles: one looking downwards and the other slightly upward (45 degrees relative to the ground), as seen in Figure 1. This method was utilized for both Phoxi 3D and MotionCam-3D, due to their similar dimensions.

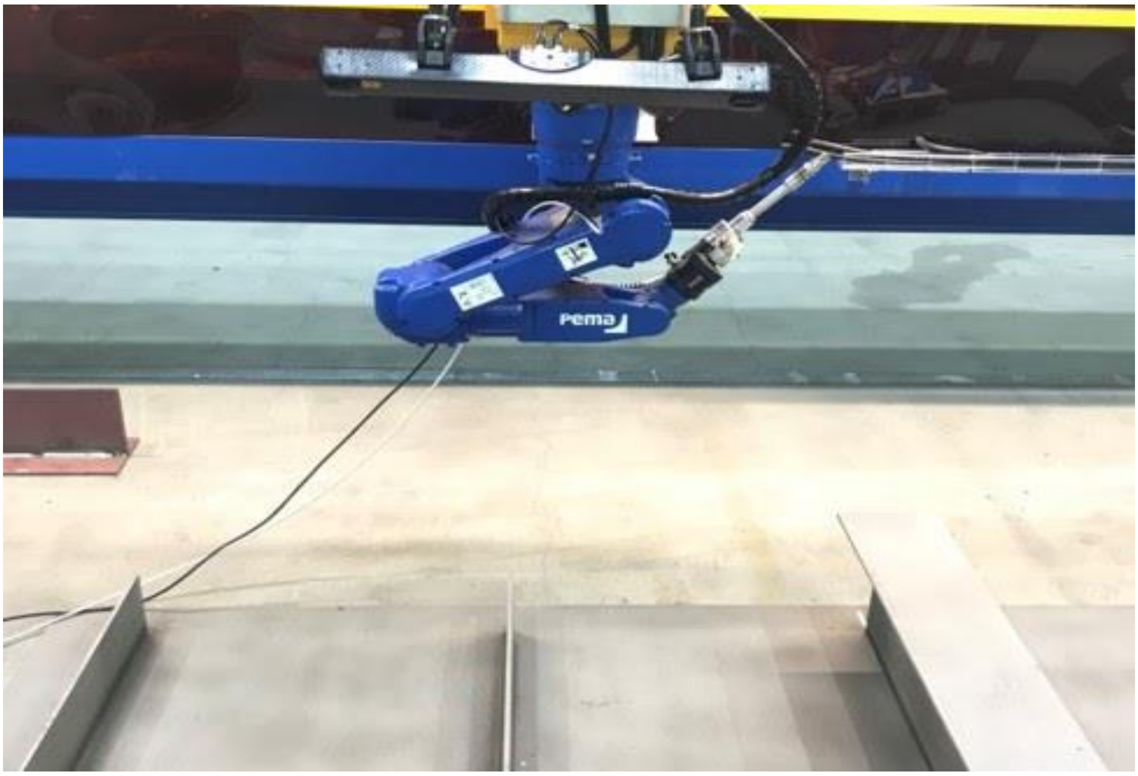

Figure 1. Scanner at 45 degrees relative to the ground

In Phoxi Control, it was decided to implement Trigger Scan as the sole method for the tests. The reason being that when using the Record method with Phoxi 3D, the point clouds from the scan were not consistent; the scanner was taking snapshots while the robotic arm was being moved continuously, this resulted in a set of points that did not resemble the piece. MotionCam-3D is described as capable of capturing scenes in motion, this would mean that the Record method could be of use in this scanner allowing for a continuos scan throughout the welding piece and reducing waiting times. But it was decided to test only Trigger Scan, as the researcher of this study was unaware of such capabilities at the time of testing.

6.2.2 Reorientation and adding normals

After making a scan, the data is saved and taken to Cloud Compare. The first step is to create a clone of the imported set of point clouds, this is done in such manner that the original scan file is not modified and remains as it was captured. Secondly is reorientation, the orientation of the point clouds taken with the Phoxi 3D scanner needs to be aligned in relation to the floor in which the panel was resting. One of the benefits of the reorientation process is that it facilitates combining one scan with others, these will share the same coordinate system orientation and it will be easier to allocate them in a 3D space. Inside Cloud Compare, the mesh level tool is selected; it requires 3 points from the point clouds: the first being the center of rotation; the second, aligned with the first, defines the x axis; and the third, defines the plane. With a redefined orientation, the scan is exported and taken to MeshLab. This software will handle all the necessary steps that will reconstruct the point clouds as a mesh.

In MeshLab, it is imperative to start by computing normals, an option that can be found as Compute normals for point sets under the Filters Tab and Normals, Curvatures and Orientation; as shown in Figure 2. The subsequent parameters that this filter provides, Neighbour num and Smooth Iteration, will remain with their default values, 10 and 0 respectively.

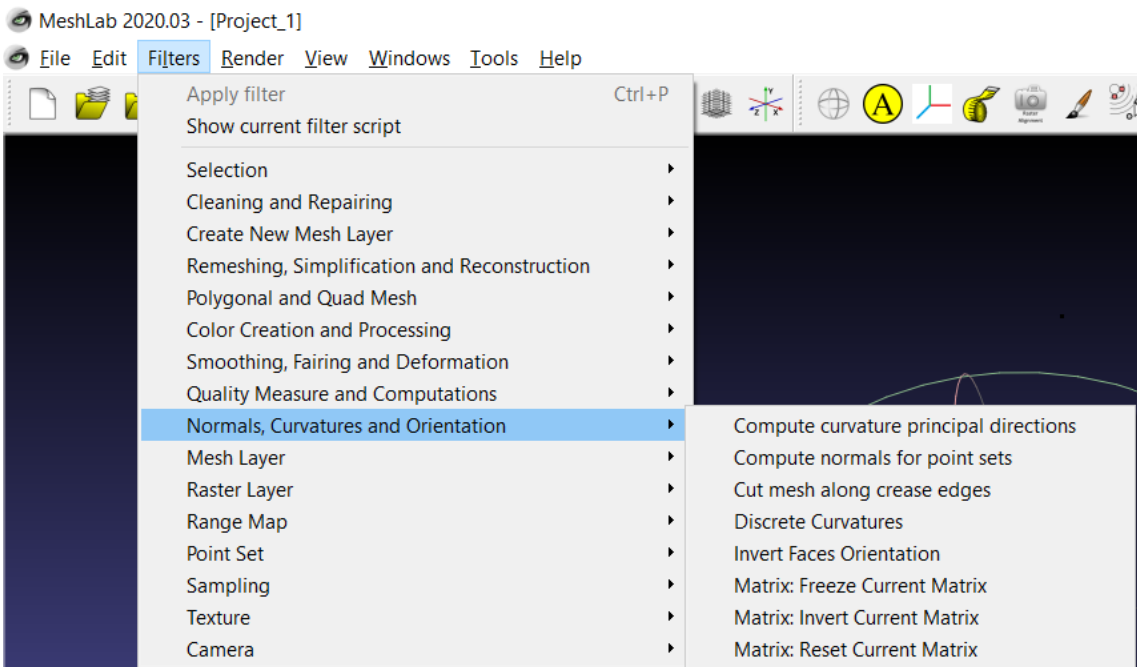

Figure 2. Available filters in MeshLab

6.2.3 Reconstruction

After these have been applied, the next filter is Surface Reconstruction: Screened Poisson. It can be found in the Filters tab, under Remeshing, Simplification and Reconstruction. This tool is a surface reconstruction algorithm, it creates a mesh from the available point clouds. The parameters keep their default values for the exception of Reconstruction Depth, this option represents the amount of detail the mesh will have. Any value above 14 is not recommended, since any improvement on the detail will be unnoticeable. The value used for this research is 12. Before applying this filter, MeshLab will ask to save the progress done, to prevent any data loss. The reconstruction method not only creates a mesh where the points were located, but also tries to fill holes between them. The difference between the point clouds and the new mesh can be seen in Figure 3.

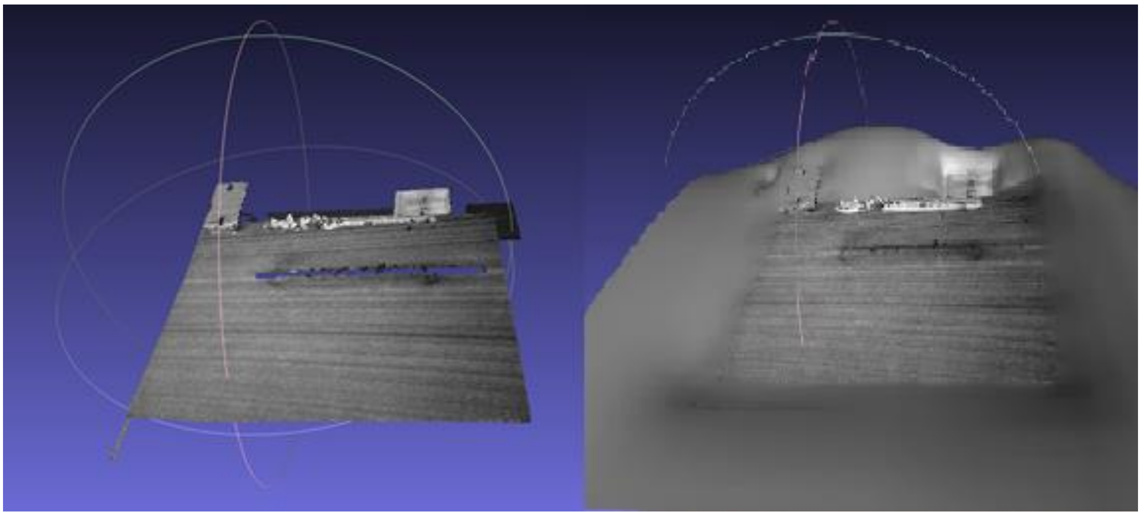

Figure 3. Comparison between point clouds and their reconstruction as a mesh

6.2.4 Selection, deletion of unnecessary faces and decimation

The next step is to use: Select Faces with Edges Longer Than, located under the Selection Filter. This option will select all triangles having an edge with length greater or equal than a given threshold, therefore it is used to select the excess created in the reconstruction and deletes it. The only available parameter for this option is Edge Threshold, and it is inversely proportional to the level of detail that the mesh possesses. This means that the higher the value in Reconstruction Depth, the lower it is for Edge

Threshold. In the case of this study, 1 was the most appropriate number for the selection filter, since it enclosed the unnecessary faces while preserving the details from the scan. After applying it, it is necessary to press the delete button from the keyboard.

The last step inside MeshLab is, the reduction of poligonal faces. Under Remeshing, Simplification and Reconstruction, the Simplification: Quadric Edge Collapse Decimation filter is selected. This tool helps in simplifying the mesh by reducing the number of faces and in turn, providing a more manageable file size. The default values presented are sufficient, it will reduce the amount of faces by half.

6.2.5 Preserving only the details of the panel

3DS Max is used at this point in order to merge the different scans, now as meshes. If the intention is to only use the surfaces from the panel, then anything that was captured during the scanning process that is not the working piece, needs to be deleted. After importing a mesh into the software, the unnecessary sections of the scan need to be selected. This can be done with Element Selection, found in the Command Panel tabs, under the Modify Panel, with the only available modifier in the Modifier List. The selected portion of the mesh is highlighted in red, as shown in Figure 4, and the delete button from the keyboard is pressed.

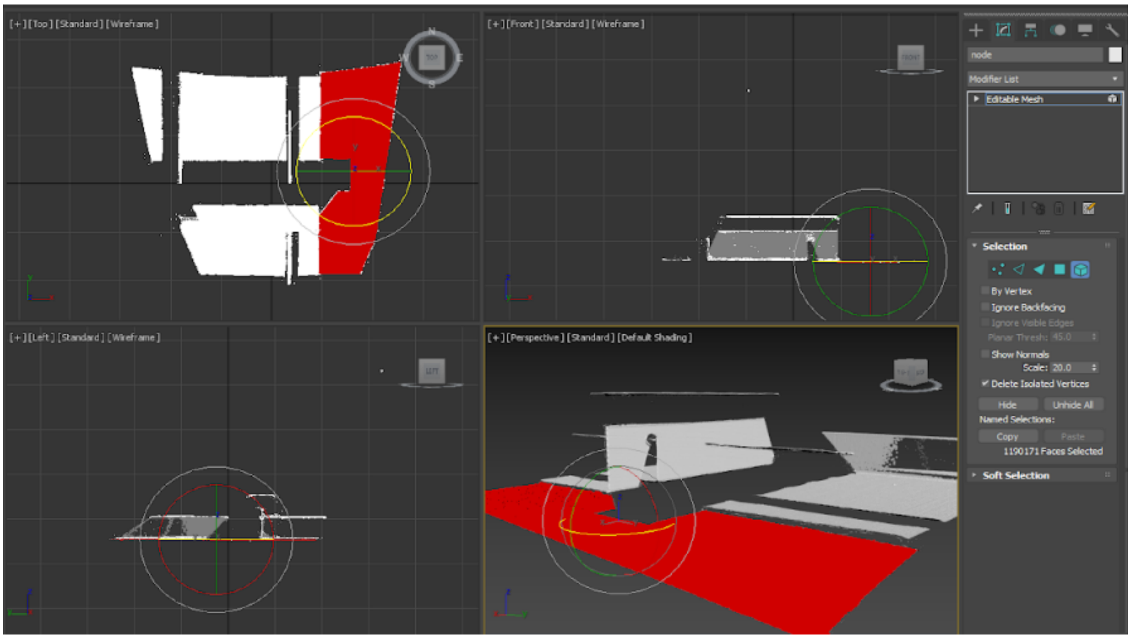

Figure 4. Unnecessary element in mesh and selection tool

6.2.6 Positioning of the mesh relatively to the space

Each mesh represents a portion of the whole panel, thus in order to merge them, they need to be allocated in a very specific location in space. It was stated in 3.2.1 that PEMA WeldControl 200 allowed to register each translation that the arm does and that each scan had a point in space, these recorded motions can be seen in Figure 5; those records are used in this step as a reference when positioning the meshes. Each position had a value on the lateral, longitudinal and vertical axes.

```
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//NAME MIGUEL
//POS
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///TOOL 0
///POSTYPE ROBOT
///RECTAN
///RCONF 1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
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C00001=-113.755,474.452,132.299,-43.7432,-4.6567,-3.4165
C00002=-113.755,474.452,132.299,-43.7432,-4.6567,-3.4165
C00003=-113.763,474.495,132.241,-43.7501,-4.6596,-3.4172
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BC00002=1313.740,3182.943,-528.564
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BC00005=1888.168,1870.107,-528.564
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///GROUP1 RB1,BS1
NOP
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MOVJ C00001 BC00001 VJ=10.00
MOVJ C00002 BC00002 VJ=10.00
MOVJ C00003 BC00003 VJ=10.00
MOVJ C00004 BC00004 VJ=10.00
MOVJ C00005 BC00005 VJ=10.00
```

Figure 5. Translations of the robotic arm recorded by PEMA WeldControl 200

The first scan had a location of: x = 1,313.740 [mm], y = 1,865.306 [mm], z = -528.564 [mm]; while the second scan had a location of: x = 1,313.740 [mm], y = 2,456.102 [mm], z = -528.64 [mm]. The course of action taken was to consider the very first scan as a start position, meaning the center of the mesh will be allocated in the origin of the workspace in 3ds Max, in other words as: x = 0, y = 0, z = 0. Subsequently, the location values from the other meshes will be subtracted to the first mesh, and the result will be their new position inside the 3D software. Thus, the location of the second mesh in 3ds Max is: x = 0 [mm], y = -590.796 [mm], z = 0 [mm]. These calculations are done to the other 4 meshes, providing them with their respective location; hence a 3D model of the welding piece starts to take form. After allocating all the meshes, the result is exported and sent to Pemamek for their approval or in this case, their feedback.

6.3 Proposed System # 2

This system solely utilizes one specific scanner: Leica BLK360 Imaging Laser Scanner. This method could be extrapolated to other scanners, but they would have to belong to the same Leica scanners franchise.

6.3.1 Scan

The shape of the Leica scanner utilized for this test, did not allow for it to be hanged without risking fall damage. Which is why it was decided to allocate it with the respective tripod that comes with the scanner as seen in Figure 6.

Figure 6. Scanning positioning of BLK360

The Leica BLK360 captures panoramic images overlaid on point clouds; which means that the scans will possess a 360 degrees view, considering the scanner as the center of rotation. It was decided to have 24 specific locations around the welding piece, as this allowed it to capture the most of the whole panel. The scanner is controlled through Leica Cyclone Field 360, it allows for 3 levels of point cloud density: low, medium and high; as well as setting the quality of the 360 images. It is important to note that the higher the quality of the point clouds and images, the lengthier is the execution of the scans. 1 minute and 50 seconds is the time needed for the BLK360 to gather medium level point clouds and no pictures. After setting the scanner through the app, the play button is pressed to initiate one scanning.

6.3.2 Mobile and desktop alignment

The app permits the alignment of the scans, even when the scanner is still working. In Field 360, the scans can be seen as blue points in a top view of the working site; it is possible to rearrange these points in relation to the distance with the others and the position in space where they were allocated. Each scan can be linked, but it needs a visual alignment between them; the app provides a front and side view to do it, the scans can be moved until their point clouds match. The Optimize button assures that the alignment is precise. When it has been confirmed that the pair of scans are in position, the Create Link button is pressed. This process can be visualized in Figure 7.

After creating the link between all the scans, the bundle is transferred to a computer wirelessly. In order for a computer to receive the aligned scans from the scanner, Cyclone Field 360 needs to connect with Cyclone Register 360, a desktop software. There is an option on both apps that allows their synchronization by sharing the same IP address and Port. In this study, the transferral of the 24 scans took 20 minutes.

On the other hand, Register 360 allows for a more automatic approach to the alignment process. The only requirement is to provide the software with a top view from the pan; it takes an estimate of 20 minutes to finish this process.

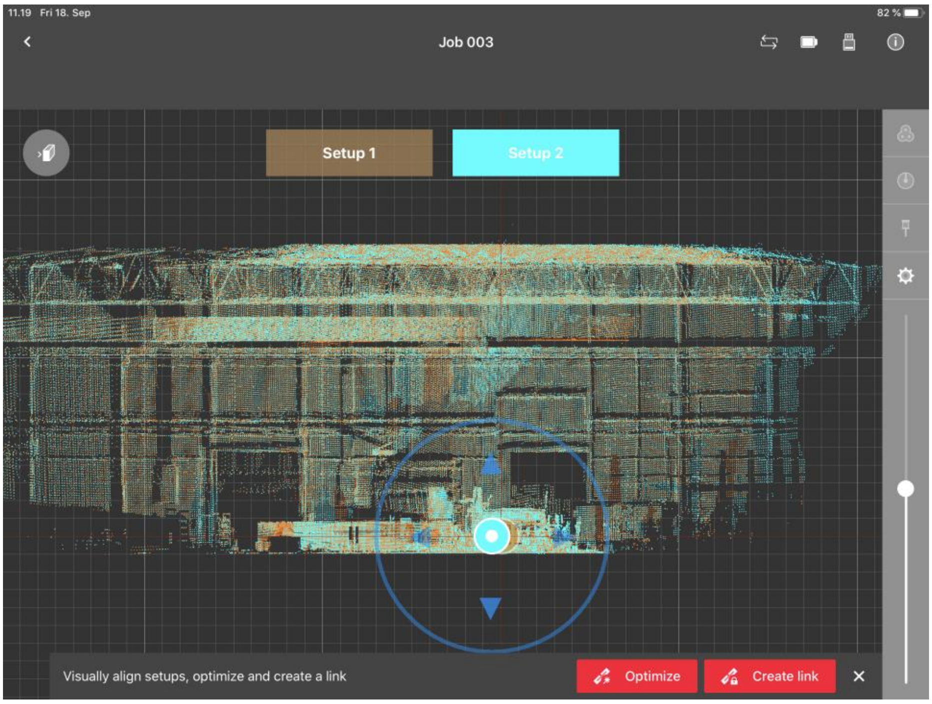

Figure 7. Alignment process inside Cyclone Field 360

6.3.3 Deletion of the environment and optimization of bundle

At this stage the scans are already aligned and linked. The bundle is highlighted with the Selection tool located in the upper left corner of the software, then the Delete Outside button is pressed to clear out the environment around the scanned panel. In the lower right corner there is an option to Optimize the bundle, this reduces the amount of overlap that exists in the linked scans. To export the bundle the software takes an estimate of 5 minutes.

6.3.4 Cleanup

The bundle is then taken to Cyclone 3DR. To delete the noise in the point clouds, the Clean Tab possesses a Noise filter option. After selecting it, a toggle bar appears on the left side, this represents the intensity of the filter. An intensity of 78 counts 8,996 noisy points, nearly 1 percent of a total of 873,700 points that the bundle possesses.

6.3.5 Mesh creation

In the Surface Modelling tab, there is a tool called 3D Mesh, it presents several options such as: Noise Reduction, Meshing parameters, Hole management and Meshing properties. After some tests, it was concluded that the best approach was to leave them with their default properties. After pressing the OK button, the process of mesh creations takes an estimate of 4 minutes. The final mesh can be exported in any format that Pemamek requires.

7 RESULTS

This section shows the final meshes produced by their respective system.

7.1 Pemamek's system mesh

Figure 8 shows the quality of a mesh that the company is capable of obtaining and it resembles the most to the real piece. It was shared by Pemamek and it was used as a point of reference when comparing the other three results. According to one of their employees, it takes less than an hour for most of the surfaces to get the desired 3D model.

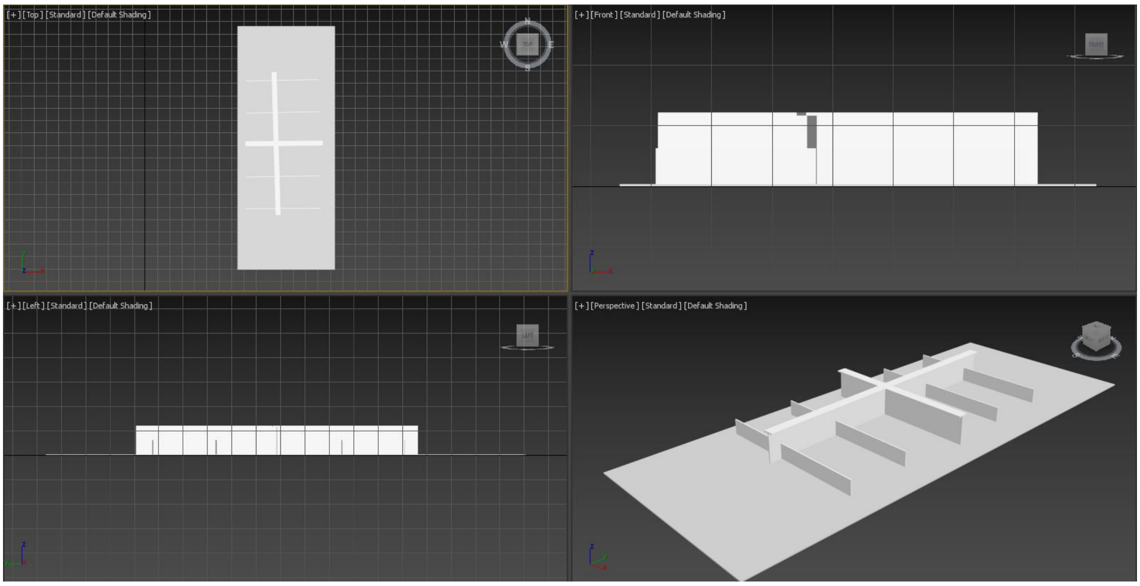

Figure 8. Pemamek's system mesh

7.2 Proposed system # 1 Phoxi 3D Scanner mesh

One of the problems encountered during the mesh conversion with this system, was that the acquired scans did not possess a correct orientation in relation to the ground. This explains the necessity of the reorientation step, otherwise it would be difficult to handle the data and visualize it. The final mesh shows holes or spaces where there is no data available as seen in Figure 9, that is due to the scanner not being able to reach those areas from its scanning position. The first reason for its inability of reaching is, that it has a size that does not allow it to move close to narrow spaces. The second being that the robotic arm that holds the scanner is unable to go too close to the ground and thus, there are no scannings under certain surfaces. And the third reason is, that the movements with the robotic arm are limited. The shape and size of he scanner did not allow for it to be attached to the lower part of the arm, but instead it had to be on its base for better stability. In this position, the scanner can not rotate for better scanning locations. To obtain the final mesh, the entire process took an approximate of 110 minutes.

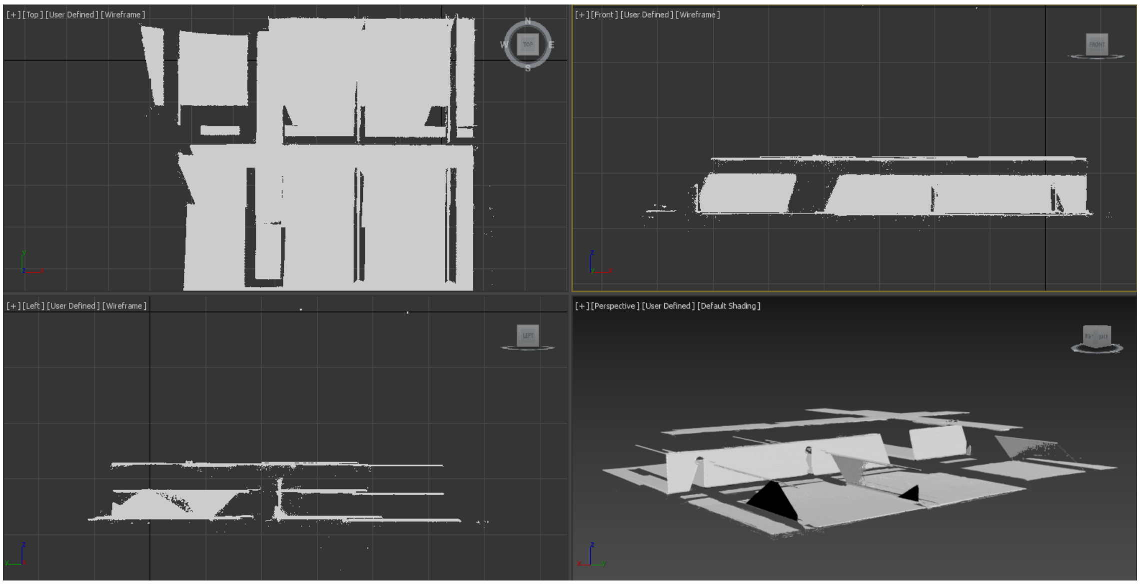

Figure 9. Propose system # 1 Phoxi 3D scanner mesh

7.3 Proposed sytem # 1 MotionCam-3D mesh

The same results pointed out previously on Phoxi 3D Scanner, can be said on MotionCam-3D. As describe before, this scanner could reduce scanning times thanks to the Record method in Phoxi Control. Even if the previously mentioned method, were to be used, the allocation of the scanner and its size would still affect the scanning process and show the same results in the quality of the final product. The mesh can bee seen in Figure 10, and it also took an approximate of 110 minutes to be created.

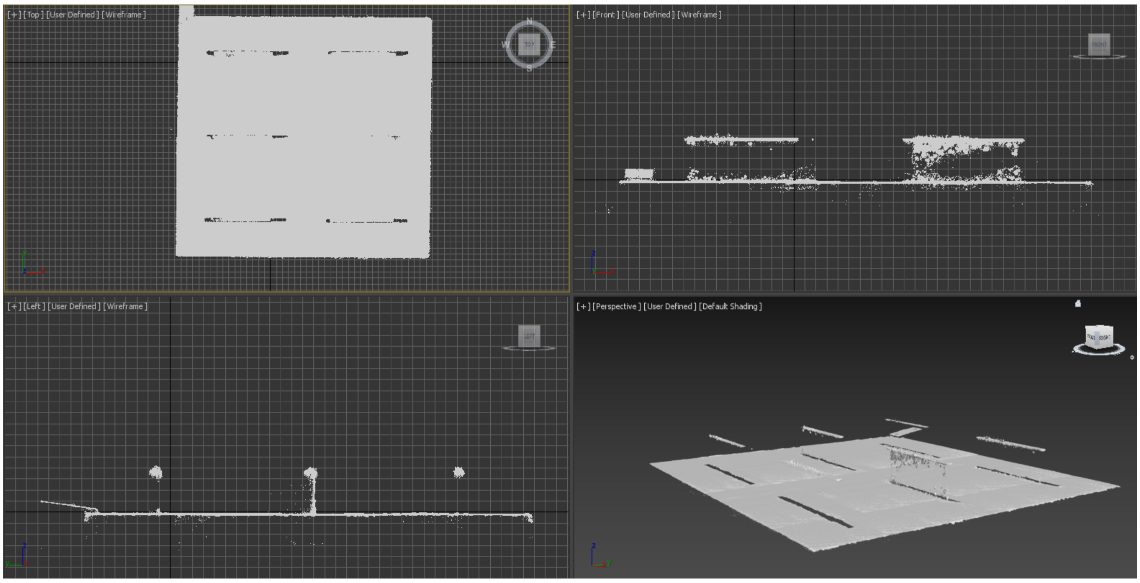

Figure 10. Proposed system # 1 MotionCam-3D mesh

7.4 Proposed system # 2 Leica BLK360 mesh

The whole process for this specific system was effortless; the only downside is, even with less steps in comparison to the previous system, it takes almost the same time: 100 minutes. The reason is, a combination of long scanning times, with the transfer of data only by Wi-Fi and the waiting time for the processing of said data. The final mesh resembles the most to the one presented by Pemamek and their system. But as seen in Figure 11, it still has some small holes that need to be filled and bumps to be flattened.

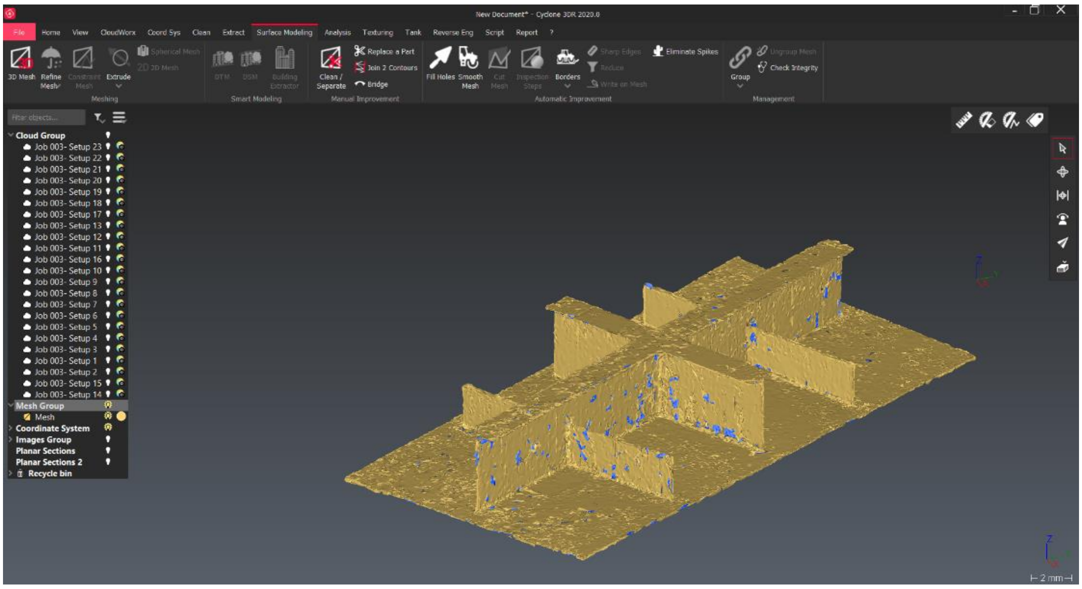

Figure 11. Proposed system # 2 Leica BLK360 mesh

8 CONCLUSION

Both Phoxi 3D Scanner and MotionCam-3D need different scanning angles in the same spot because of their limited scanning range. Leica BLK360 only requires one scan in the same spot, due to its ability to capture the environment in a 360 degrees view. This scanner also has the advantage that the whole process can be done within its own ecosystem of apps, while the other two require third party softwares to do anything besides manouvering them. For BLK360, the main procedures are nearly automatic, but at a cost of long waiting times. As for Phoxi 3D and MotionCam-3D, the handling of the point clouds and the necessary conversion to a mesh is the most laborious.

After analyzing the time required for each system, it was determined that the current implementation from Pemamek takes less time than the proposed ones. On the other hand, the quality of the final product from each of the proposed systems can not be utilized by the company. All of them possess holes in their mesh and their measurements are incorrect in comparison to their real counterpart. Adding more scanning locations by using the tested scanners, could reduce the amount of holes in their produced 3D model.

Conversely, with a familiar ecosystem of softwares, a friendly user interface and a more automatic approach for most of the required processes, Leica BLK 360 is the strongest contender between the proposed systems. A key element to take in to account is that the holes and bumps that the mesh from this system has, can be address with a third party software that could be capable of filling holes automatically and another with the ability to smooth the surfaces. But as mentioned before, waiting time is one of its biggest drawbacks.

An inquiry was made to the manufacturer of the BLK360 for some information about the scanner adaptability, and it was mentioned that one of their latest models: RTC360 3D Laser Scanner, reduced considerably the scanning time; and the connection between the scanner and PC is through cable, making the transfer of data, a faster process. The price of this scanner is around € 70,000, while BLK360 costs about € 10,000. This individual also assured that the processing of point clouds and scanning can be more automatic by using their SDK (software development kit), but it is not available for BLK360.

It is important to point out that both Phoxi 3D and MotionCam-3D are scanners that are mostly used for the inspection of objects and bin picking. In the case of Leica BLK360, it is a scanner meant for capturing large areas, the 360 view benefits greatly for that type of situation. Pemamek needs a scanner that posses a fast scanning process, capable to access difficult areas and provide an automatic system that produces a high quality mesh, up to the standards of the company. These are the qualifications that were concluded after this research.

The recommendation for Pemamek is to seek out scanners with those type of qualifications. In the market there are various products that fit those categories. One example is Artec Leo from Artec3D, with a price of € 26,700, a handheld scanner capable of capturing continuously and it has its own ecosystem of software for the processing of data. Leica has a possible option too, with their Absolute Scanner LAS-XL, another handheld with a wider scanning range and with a price above € 50,000. These types of scanners would be beneficial, specially when there are welding pieces with complex shapes.

This research was a rich experience, in terms of getting to know part of the welding industry from the inside and understanding the most influential technology there is for a variety of industries, 3D scans. With the possibility of revising new scanners with the recommended features, the researcher from this study, would be more efficient with the necessary tests. The welding industry can benefit greatly from the scanning technology, but in order to do so, it needs to be tailored specifically to the interested company.

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