Experimenting with 3D Scanning: Faro Arm and Recap

ME 557 - Additive Manufacturing
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Introduction:

3D scanning opens the door to limitless possibilities in a variety of industries including additive manufacturing by enabling 3D capture, measurement and analysis of just about any industrial object/geometry. 3D scanning technology allows for inspection of a part or component and can maximize efficiencies across the design and manufacturing process. The hope is that this technology will allow engineers to scan an object and create that object using the virtual files created from the scan. This report will be an investigation of how close the technology this goal in reality.

Goal:

The purpose of this experiment was to compare the 3D scanning capabilities of two technologies for reverse engineering and 3D modelling purposes. The two technologies that will be discussed in this report are the Faro Arm laser scanner and the Autodesk Recap software. Two objects were chosen as representative geometries to be 3D scanned: a reamer and an allen-wrench. The objects were chosen because both had broad simple features, such as the reamer shank and the flat surfaces of the allen wrench, and also had more nuanced features like the reamer blades and allen wrench radius. We assessed the scanning technologies based on their ease of use, dimensional accuracy, and overall process efficiency.

Figure I: Reamer

Figure II: Allen Wrench

Technology 1: FARO ARM

Procedure

1. Mount object in an orientation to be scanned.
2. Scan using the Faro Arm laser until enough of the object surfaces have been captured
3. Create sketch geometry based on resulting surface mesh.
4. Created sketches into CAD software for final geometry creation/manipulation

Detailed Process

The Faro Arm scanner was used in unison with the GeoMagic Design X software to scan the physical gemetries of both the reamer and the allen-wrench. As the laser scanner is passed over the object, points are captured and then immediately plotted in the Geomagic software interface in real time. Rendering each pass of the scan and aligning it with any previous scans was computationally intensive. It was in our best interest for both objects to scan half of the geometry, in order to reduce the number of scans and the amount of processing required by the Geomagic software. The reamer was fixed in a vice and scanned upright, while the allen-wrench was scanned laying flat on its side as can be seen in Figure III and Figure IV below.

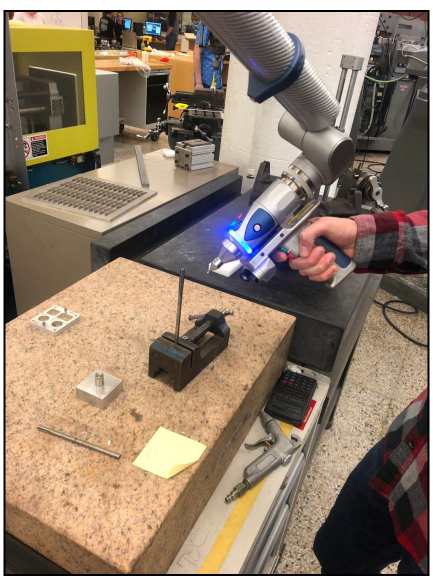

Figure III: Reamer experimental setup

Figure IV: Allen-wrench experimental setup

Due to the less than perfect nature of the surfaces created in the software, as seen in Figure V and Figure IX, it was hard to get a consistent surface. It ended up being inefficient to load the completely scanned object into solidworks because the file was too large for the software to process. Instead, we used the surfaces generated to recreate the geometries using more conventional CAD techniques. For example using the surface we created from scanning the allen wrench we were able to create an outline of the hexagon section of the allen wrench, seen in Figure X as well as the L-shaped outline of the allen wrench, we imported those two cross sections and their planes into solidworks and then swept the hexagon to recreate a complete solid model of the tool. A similar process was performed on the reamer. We used the software to make the shaft cross section and the bladed cross section and then used it to find the length of each and extruded those in solidworks.

Results: Reamer

Figure V below shows the resulting mesh geometry from the Faro Arm laser scan in Geomagic. This mesh only shows a fraction of the entire surface area of the part as capturing more resulted in the computer crashing during processing. As part of the scanning process the mesh also contained a significant amount of background such as the table and machines behind the scanning area. These background surfaces had to be edited out manually using tools in Geomagic before the mesh could be used.

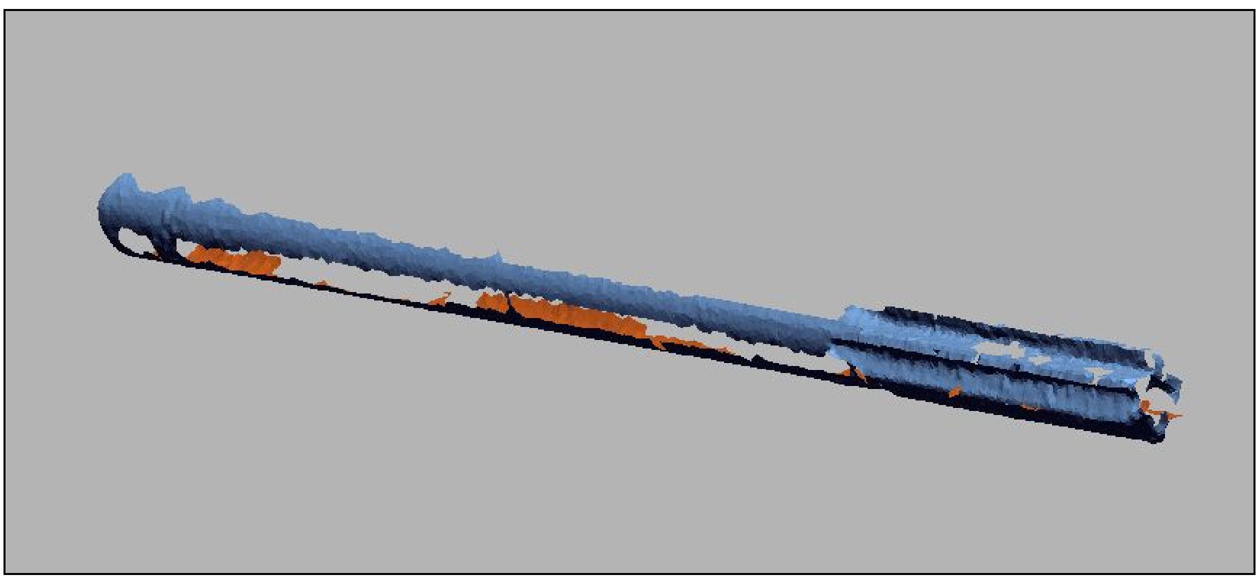

Figure V. Mesh result from reamer scan

Although this mesh is incomplete, enough information is present to model the reamer using a CAD software in conjunction with the Faro arm software. Geomagic itself has embedded translators for a number of different CAD software we chose to use

Solidworks. A sketch of the cylindrical geometry and reamer profile were able to be produced from the laser scan as seen in Figure VI.

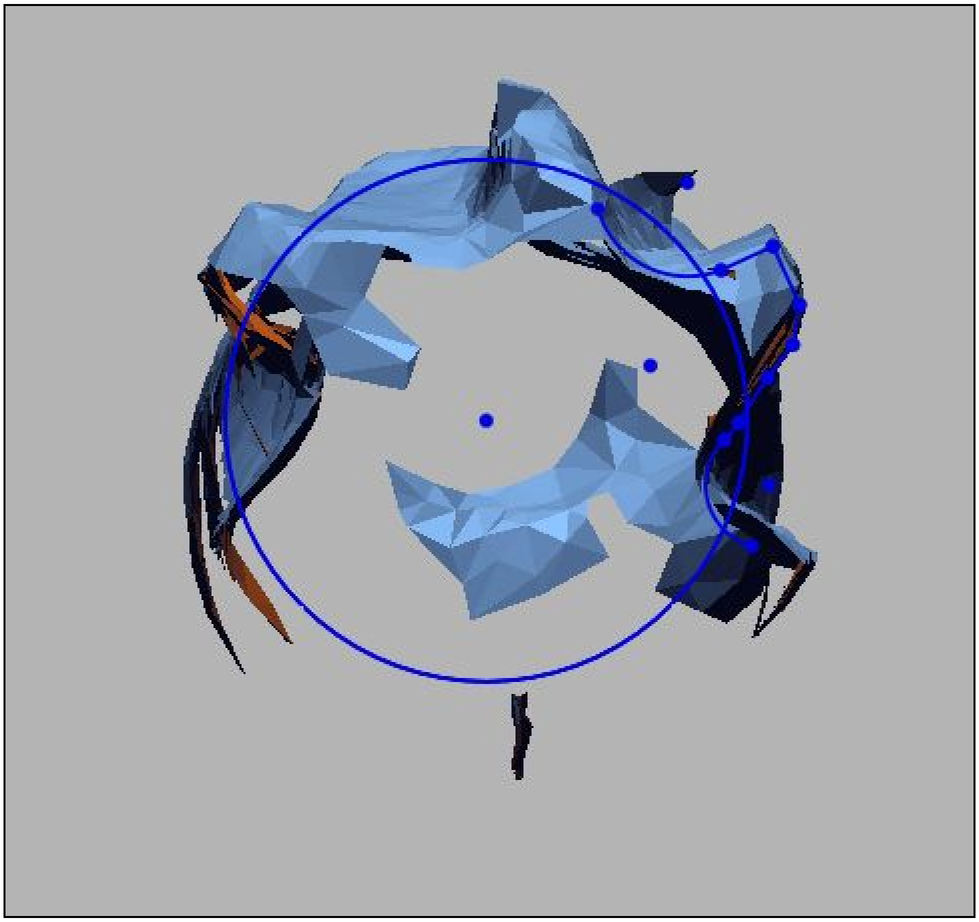

Figure VI. Cross section of mesh from reamer scan

The sketch above was then imported into Solidworks to create the full 3D model of the object. The length of the reamer, as captured by the 3D scan in Geomagic, was recorded and used for the model reproduction in Solidworks. The circular sketch was extruded as a cylinder to represent the cylindrical geometry of the reamer, while the ridge was patterned and then extruded. The resulting 3D CAD model can be seen in Figure VII below and the part drawing with dimensions can be seen in Figure VIII.

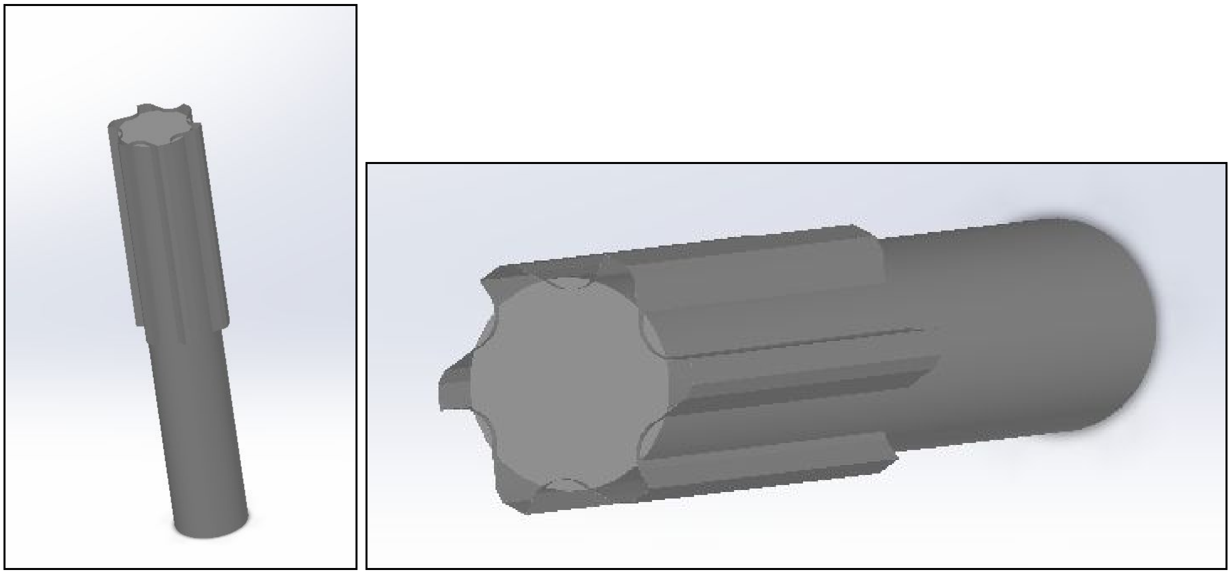

Figure VII. Reamer CAD model constructed from mesh dimensions

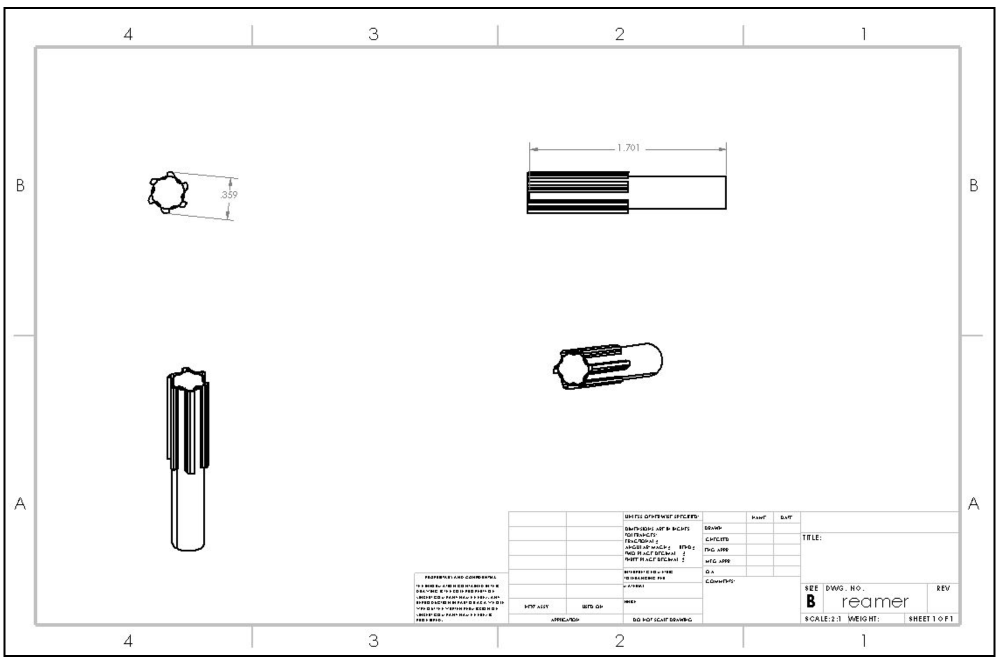

Figure VIII. Reamer CAD drawing

The mesh proved to be dimensionally accurate for the reamer diameter, while being over 1” off in length. The discrepancy in length can be attributed to the scanner thinking the bottom part of the vice was also part of the reamer (see Table I below for dimensional comparison). The scanned mesh was also able to provide a reasonable outline of the reamer blade geometry. However, a realistic model of the reamer was only obtained after extensive manipulation of the original mesh, and manual extrusion of part geometries.

Feature	Object True Dimension	Resulting Scan Dimension
Diameter	23/64” = 0.359375”	0.359”
Length	5.75”	6.967”

Table I: Comparison of actual and scanned reamer dimensions

Results: Allen-Wrench

After scanning the reamer multiple times, our ability to produce more complete meshes improved. The allen-wrench was scanned while lying flat on the scanning surface. This allowed us to obtain a very clear image of more than half of the symmetrical wrench. Figures IX and X show multiple angles of this mesh, as well as the cross sectional geometry.

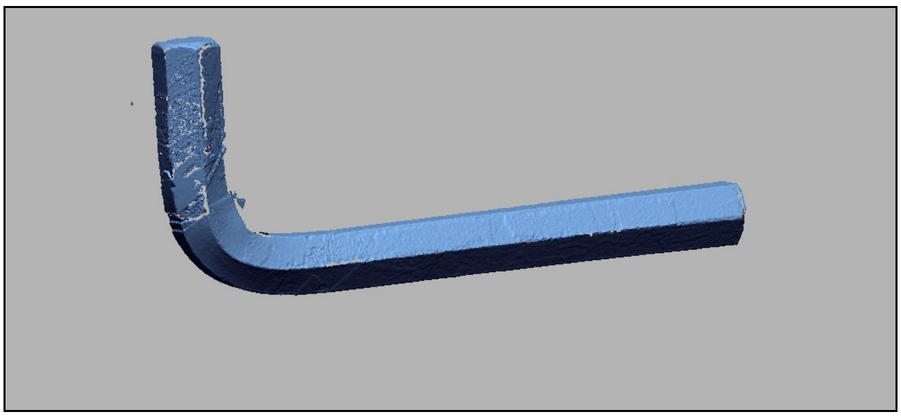

Figure IX. Mesh result from allen-wrench scan

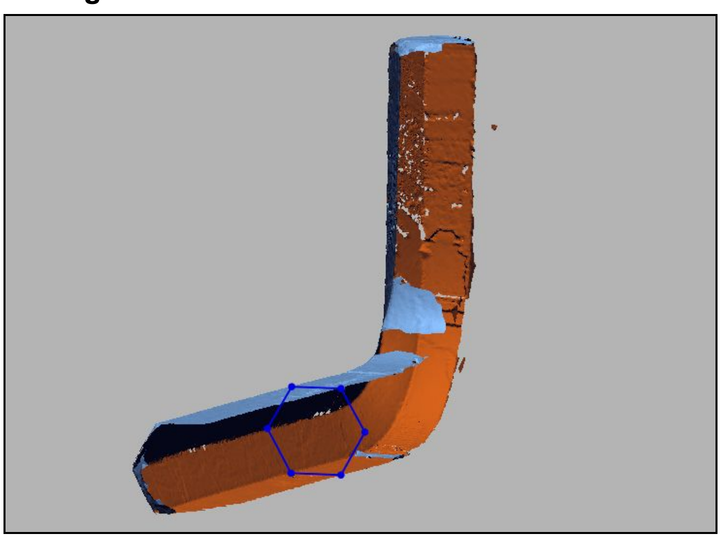

Figure X. Cross section of mesh from allen-wrench scan

The mesh is not complete, however it is significantly easier to manipulate when compared to the mesh used to model the reamer. The mesh originally contained very little background, other than the scanning surface. The scanning surface mesh was easily removed using the Faro arm software, as it existed only in one plane. The cross sectional geometry as well as the curvature, length, and width given by the mesh were used to construct a dimensionally accurate model of the allen-wrench. This model is shown in figures VII-VIII.

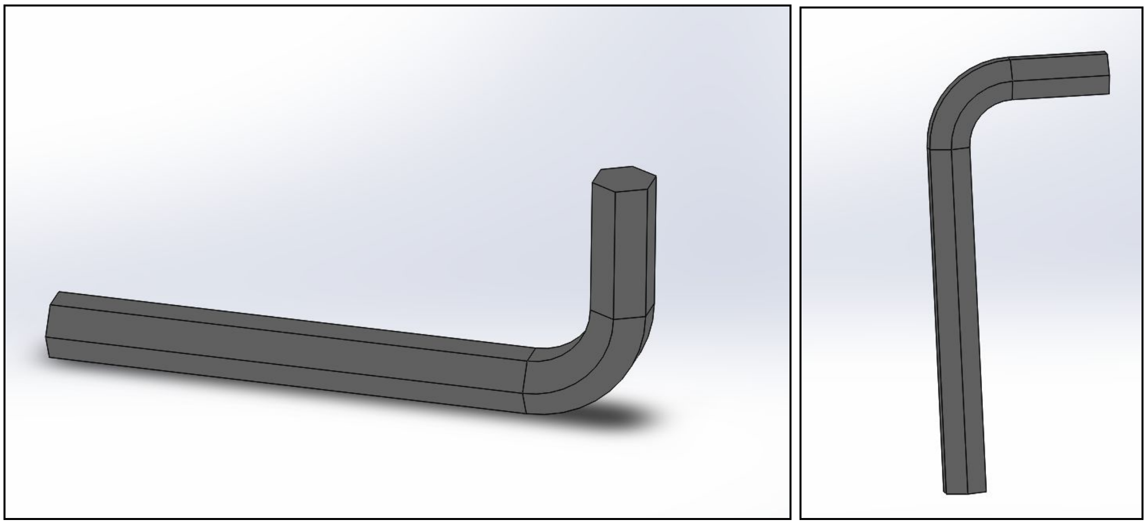

Figure XI. Allen-wrench CAD model constructed from mesh dimensions

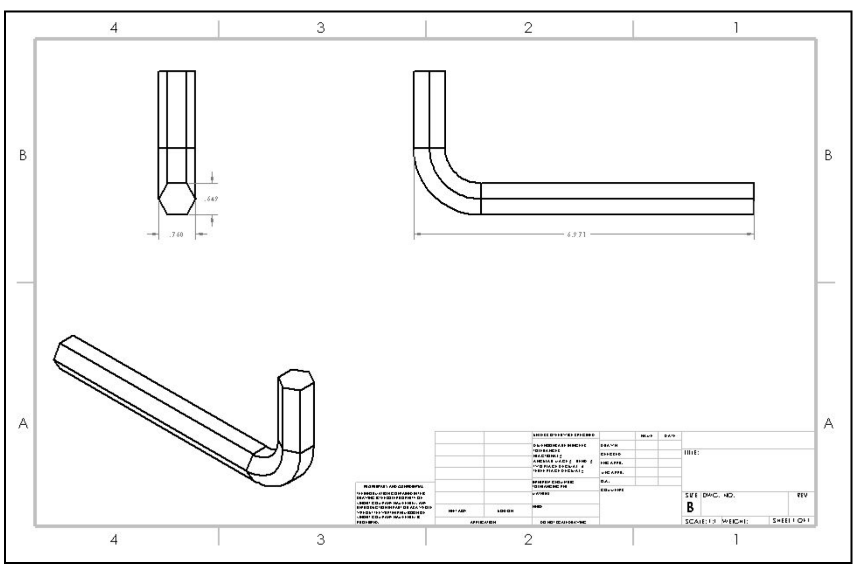

Figure XII. Allen-wrench CAD drawing

The mesh also proved to be decently dimensionally accurate for the allen-wrench, however it must be noted that the entire hex geometry of the part was based off of a single cross section derived from the mesh. The dimension comparison is summarized in *Table II* below.

Feature	**Object Dimension**	**Scan Dimension**
Hex Diameter	0.664”	0.649”
Length	7”	6.971”

Table II: Comparison of actual and scanned allen-wrench dimensions

<u>Faro Arm Discussion:</u>

In a raw scanned state the Faro arm was relatively dimensionally accurate, it just depended on what level of post processing you wanted to do. We were finding ocasional inconsistencies between the scans that prevent them from lining up well, maybe one scan surface of the same face didn't end up entering into the program completely parallel to the other one, or there might be a bunch of scattered noise in the software with little bits of surface floating around. To combat this however it was possible to delete the bad parts of the scans or only use the scans to find the basic geometries of the object. Then using the basic geometries you could recreate the object from that instead of directly from the raw scan results, this way the model produced had great dimensional accuracy even for objects with slightly complex geometry. The program was very hard to use and was not intuitive, there were many steps and if someone were proficient in the program then I think they would be able to model things even better than we did. When we created the cross sections for the tools it was very hard to create a plane to make the sketch on that was perfectly perpendicular to the part so the cross section we made ended up being slightly skewed so we had to use our best judgment to fix the skewed geometry.

<u>Technology 2: Autodesk RECAP</u>

<u>Procedure:</u>

1. Place the two objects upright with a noisy background.
2. The picture taker will make their way around the objects taking a series of photos to extensively encapsulate the full object in a 360 degree manner. The more pictures taken, the better.
3. Use the same technique but now taking photos along the vertical direction around the object, making sure to be thorough capturing all angles.

4. Upload the photos to a computer and send to AutoDesk to be processed (suggested minimum pictures: 100)

Results:

After following the above procedure, Recap returned our submission has an extensive 3D environment as shown in Figure XX. This environment not only included the objects in question, but also pieced together elements of their surroundings. The table the objects were resting on was almost completely rendered, as were sections of the room.

Figure XIII. 3D environment rendered using Recap

Figure XIV. 3D capture of reamer and allen wrench

After studying the environment, there were a few things to note. The first was the dimensional accuracy of the image. The allen wrench we used had a diameter of 17 mm. However, in Recap, this diameter was measured to be 0.7 m. Since the diameter was known, the whole environment could be scaled down, but without that known variable, it would be very difficult to use Recap for dimensional accuracy.

Additionally, Recap did not process small features very well. The model of the reamer is barely recognizable. Even with images from all angles, the fine details of the reamer were not picked up by Recap.The relatively large features of the allen wrench had significant error as well. Very few of the flat surfaces came out smooth, and the underside of the wrench is especially jagged. While the underside of the wrench may have not had enough pictures for Recap to successfully render, the other angles had plenty, and there was still error with the finer details.

While there were many shortcomings of Recap, the software is great for larger features, as well as picking up the color of the environment. The table in which the objects were resting on looked just like wood, and many of the structural details were captured as well.

Post-Process:

The goal of this scan was to have a 3D file that could be edited, 3D printed, or otherwise studied. Recap has many tools in order to fix, crop, or export your file. For this experiment, the wrench and reamer were the only thing of interest, not the rest of the room. Recap's selection tools made it easy to crop the 3D environment. The wanted section was then easily exported as a STLfile.

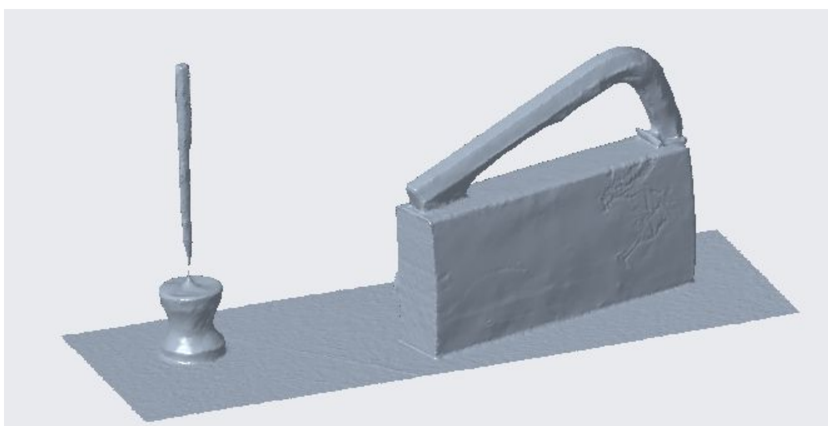

Figure XV. STL export of 3D scan

However, since the exported file is an STL file, it is only a surface. Recap does not interpolate from it's scan to form actual 3D objects, nor does it include tools for the user to easily create objects from the scan.

Comparison:

The main goal of the project was to find out the dimensional and geometrical accuracies of the two modeling methods. Neither of them worked out the way that we had hoped/thought they would however, were able to create workable CAD models.

The Faro arm had varying levels of dimensional accuracy depending on what level of post processing you wanted to do. The raw results had a large amount of noise and random surfaces imperfections that messed up the dimensions. Once these unnecessary surfaces were deleted the object itself was represented well. To create the most dimensionally accurate part from the Faro arm it was necessary to use the geometries as a guide and create the rest of the part in CAD. Using this method dimensional error was negligible. Though the dimensional accuracy of this scanning method was quite good, the process was far from efficient requiring long processing time and troubleshooting through the extra CAD process.

With Recap there was very low dimensional accuracy, however it did have the capability to produce great models. It had trouble with small complex objects, such as the reamer, but the models we ended up creating showed that it was capable of creating reasonably accurate models of much larger scope. Where Remap struggled with accuracy it made up for in process efficiency. The overall process of Recap was very painless requiring only a simple up load of 100 pictures and a day to wait for processing from Autocad. The only hardship is ensuring that your background remains stationary during the all of the photos taken.

Conclusion:

In conclusion neither method represents the complete scan to manufacturable part that is the ideal goal of 3D scanning. Both methods have pros and cons to them in terms of accuracy and process efficiency. The Fero arm was more useful for producing models of 3D objects with low dimensional error averaging only about ~.1inches and was able to capture very small features with reasonable accuracy. This performance came at the cost of lengthy computation and post processing. Recap on the other hand created a models that ended up being 1meter long opposed to the actual dimension of 7inches in length and was unable to create clean geometries of the smaller dimensions of the reamer and the allen wrench.

If the goal is to just create a 3D model of something and not to produce a physical part or to use it to represent a physical part with all its dimensional geometries then Recap with its very low post or pre processing would be best to use. This means that Recap would be most appropriately used in a more investigative manner as opposed to detailed design. However, despite the extra time needed the Faro Arm is able to be used in a more direct design context and create CAD files that can be used to create actual parts.