Wiest, Woodrow
2020-12-13

3D Scanning

Our Star Trek future

Introduction

What is 3D scanning? How does it work? What are the possibilities? Are all scanners the same? What does a 3D scanning workflow look like? What software is available? How do we make sure our scanned files are of high quality and accurately represent our design intent? All interesting questions, let's dive in!

What is 3D scanning

3D scanning is the process of collecting information from a three dimensional object or space in order to be reconstructed digitally. This information could be texture, dimensions, and even appearance.[1] In our case we are concerned about 3D scanning and its use for additive manufacturing but there are many other uses for 3D scanning.

Limitless possibilities

If we picture the Star Trek replicator materializing our needs in three dimensions we can begin to see how 3D scanning can play a huge role in our future. Arranging matter to create anything we want might be a far off future, but on a scale slightly larger than the atom and above, this is already happening with additive manufacturing in no small part thanks to 3D scanning.

The accurate 3D scan is a powerful tool. Having a database of the world around us can benefit many industries from the gaming world to microbiology and auto body shops to education. Scientists could scan life forms to understand growth patterns or use the shapes of nature to improve the structure of mechanical parts. Companies already utilize 3D scanning to streamline the design, prototype, and manufacture process using less time and less effort to produce parts. Some scan original components or mounting points to aid in the creation of new components.[2] 3D scanning can measure dimensions of parts and compare them to CAD models. It can measure space between, inside or around objects to allow a designer to model better fitting parts or retrofit a new part when an old

---

[1] 3D scanning - https://en.wikipedia.org/wiki/3D_scanning

[2] Reverse-engineering racing parts with Artec Eva - https://youtu.be/yjncPtVv0No

part no longer functions. Scanning can make old parts that are no longer available into digital models to later be printed on demand clearing out expensive storage space essentially creating a digital warehouse.

Proper scanning reduces the need for the physical act of measuring and imputing that data into a model. This smoothes the workflow freeing up time. Using tube bending for an exhaust system as an example we can see the improvement in workflow where traditionally the tube is bent and fitted in multiple steps mostly by eye and trial and error. With an accurate 3D scan of the chassis, the workflow is made more efficient from the 3D scan to a finished cad model in under an hour *(fig 1)*.[3] This model is ready to be created as a finished product. With an accurate cad model all of the difficult design and dimensioning work is now complete and can be reused on any vehicle of the same type in the future or the model could be sold to other exhaust shops.

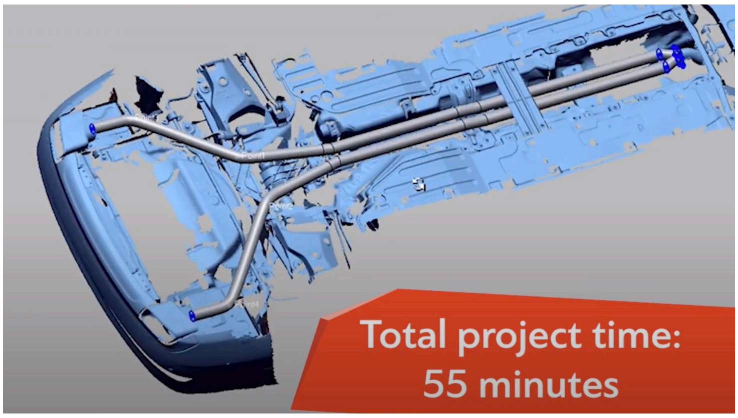

Fig 1[3]

These are but a small example of the possibilities inherent in 3D scanning. I am exited about the current and future uses of 3D scanning and could fill thousands of lines of text with many more potential use cases. Digitizing our world in three dimensions is one step closer to that future of the Star Trek replicator, and that is exciting.

How it works

3d scanners can utilize various forms of scanning technologies like laser range finding, photogrammetry, volumetric scans, modulated light or structured light, to produce a scan. While all of these techniques vary in approach, they tend to achieve the goal of

[3] Redesigning an exhaust system with Artec Leo, Artec Studio 14, and Design X in under one hour - https://youtu.be/uW3IegqxNLI

reproducing what exits in our world into a digital form. Many of the aforementioned techniques are outside of the scope of this essay so we will simply focus on structured light scanning.

The tech

Structured light technology is when the scanner projects patterns of light over the object to be scanned. That pattern is viewed from a slight angle distance from the projector and appears distorted as it hits the 3D object's surface. This distortion is calculated and the 3D object is built.[4] The blue light variant utilizes a more narrow band of the light spectrum which has the effect of filtering out ambient lighting, running cooler with less energy, and making the scanner more versatile than the white light variant.[5]

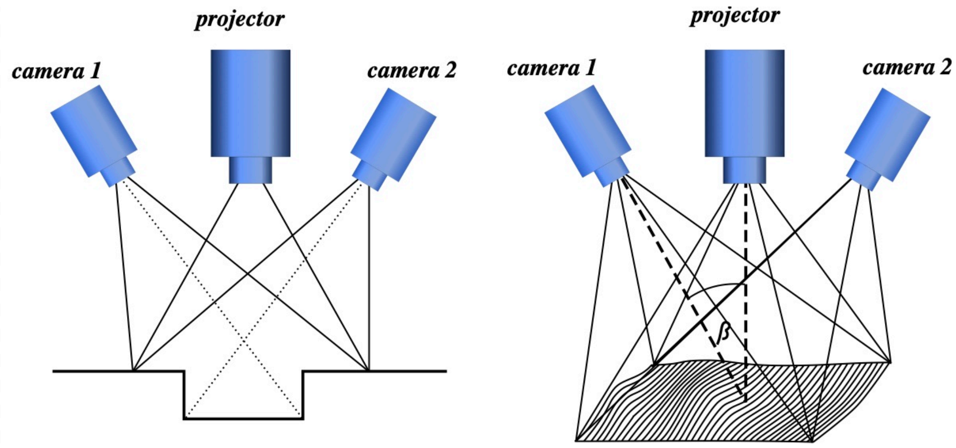

Fig 2
Fringe pattern recording system with 2 cameras (avoiding obstructions)[4]

3D scan to digital file

We want to scan something to create a digital copy of the original, or with the original parameters we are interested in to be intact. It is important for us to know what part of the object is most important to us. For example the dimensions and attachment points for a vehicle exhaust system *(fig 1)*, the inner details of an injection mould, or simply an overall idea of the shape of a person. With an idea of what we want to have scanned we can choose the type of scanner that will best suit our needs. (S*ee section 'Not all scanners are equal', below*)

[4] Structured-light 3D scanner - https://en.wikipedia.org/wiki/Structured-light_3D_scanner

[5] White Light vs Blue Light Scanning - https://www.capture3d.com/knowledge-center/blog/white-light-vs-blue-light-scanning

The actual operation of a 3D scanner is rather simple. With the 3D scanner in hand, started and the appropriate software ready if required, we begin by slowly and steadily moving the scanner around the object. It is important to pay close attention to the screen as it will show us the scan in real time and allow us to adjust our speed or gather more information if necessary. Different softwares have different ways of showing the quality of the scan so it will be important for us to be comfortable with how our scanning software displays this important feedback information. We will be sure to scan every face of the object that we require, turning it over or if necessary.

Not all scanning is easy however. Shiny surfaces, translucent objects, and poor lighting can all be factors making it more difficult to get a proper scan. There are at least a few tricks to get those objects to scan. One could apply a coating to surfaces giving it a slight texture or opaqueness, like chalk powder or special scanning sprays. Sometimes simply changing the lighting will improve a scan.

When the scanning is complete we move onto our preferred software for handling the scan data. There are many types of software one can use for the processing of 3D scanned files including but not limited to: XYZ scan handy or the open source Intel RealSense SDK for the XYZ scanner, GOM Inspect for the ATOS Core, and Artec studio for the Artec Leo.

In the software we have the goal of verifying the data integrity. We need to double check we have acquired all of the data we need, fill in any missing data like patching holes in the model, and take away any data that is not needed like platforms the object was standing on or background noise. Sometimes we have multiple scans and need to bring them all together. This can be a simple automated process by just hitting a button but can also be assisted by moving the images close to one another and selecting points to aid the software algorithms in joining the scans.

The final step is crating a useable 3D model. In this step we can work in whatever software is best for our situation and there are many to choose from. Some more common softwares are Meshmixer[6], MeshLab[7], SpaceClaim[8], and Artec Studio[9]. Here our goal is to ensure our model is accurate to the desired shape and watertight. At this point we may want to compare our finished model to some CAD data (*see: Quality control, below*).

When we are content with the watertight mesh we have completed its time to save and export the file to our desired file type. If we desire to have a texture overlay we can save the file as .obj, .ply, or other file type supporting more advanced 3D data, otherwise we can export the mesh as an .stl. With more data the file size can become very large very quickly. This may be important to consider when others may work on our files downstream.

Not all scanners are created equal

There is a vast array of scanners based on various scanning technologies and cost. It is possible to get usable three dimensional data cheaply from a series of photos taken from a simple digital camera, photogrammetry, but still there are scanners that cost more than several tens of thousands of dollars. Why is this and what is the difference between some of these scanners?

We have had access to three different scanners. The XYZ handy 3D scanner from XYZ printing, the Artec Leo *(fig 3)*, and the ATOS Core *(fig 4)*. The later two I have not yet tested first hand but will have the opportunity in January 2021. These scanners are a small representation of the quality range of scanning technologies currently available on the market.

The XYZ scanner is a budget 3d scanner with a market cost of around 2 000 SEK. The device is based on Intel RealSense Technology F200, an early generation technology originally designed as a front facing camera on laptops and other devices. It scans with infra-red structured light. The intent of this technology was for basic use with human

---

[6] Meshmixer - https://www.meshmixer.com

[7] MeshLab - https://www.meshlab.net

[8] Ansys SpaceClaim: A New Way of 3D Modeling - https://www.ansys.com/products/3d-design/ansys-spaceclaim

[9] Artec Studio 15 - https://www.artec3d.com/3d-software/artec-studio

gesture and recognition to convert to digital interaction and low resolution 3D scanning.[10] The XYZprinting website describes the scanner to have an approximate 1.0 to 2.5mm spacial resolution and scanning area from approximately 50 x 50 x 50 mm - 1000 x 1000 x 2000 mm, which makes it the lowest resolution of the three scanners.[11] Since this scanner is based on Intel RealSense hardware it might be possible to extract higher quality scanning data by using Intel's open source SDK software, but this is still limited when compared to the other scanners.[12] Compared to the other scanners here, the XYZ Scanner Pro is basically just a toy.

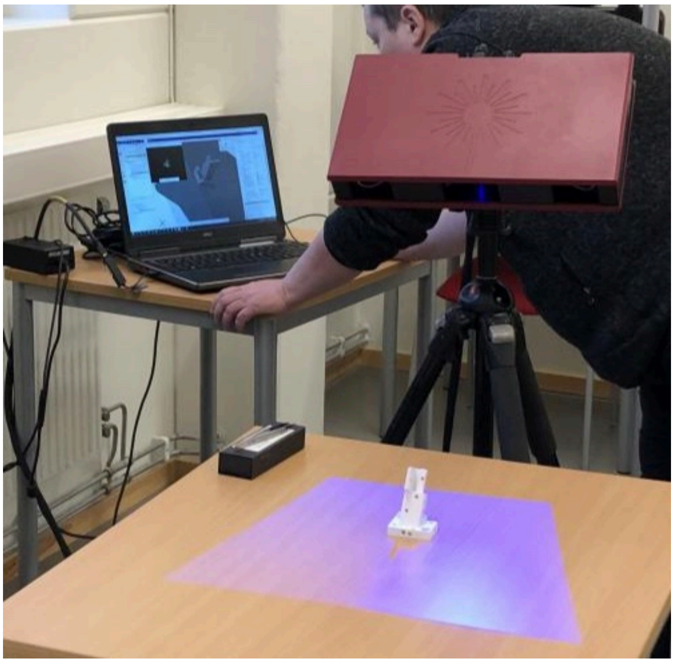

Fig 3
ATOS Core scanner in use during class.

The ATOS Core *(fig 3)* is a structured blue light scanner designed for micrometer accuracy and can cost over 300 000 SEK.[13] There are various sub-models of the ATOS Core but generally the resolution is 0.02 to 0.19mm with a scanning window of 45 x 30 mm to as much as 500 x 380 mm, making the ATOS Core a rather precise scanner for relatively

---

[10] Intel RealSense - https://en.wikipedia.org/wiki/Intel_RealSense

[11] 3D Scanner Pro - https://www.xyzprinting.com/en-US/product/3d-scanner-pro

[12] XYZPrinting 3d scanner (Intel RealSense F200) Review - https://3dscanexpert.com/xyz-3d-scanner-review/

[13] ATOS Core | Portable 3D Scanner - https://www.capture3d.com/3d-metrology-solutions/3d-scanners/atos-core

small objects. This scanner seems to be best accompanied with the GOM Inspect software and well suited to industrial applications.

The Artec 3D Leo *(fig 4)* is the most flexible of the three scanners. It is wireless with onboard processing and its own touchscreen to allow for a smooth wireless workflow. It scans with structured white light and processes images very fast, as much as 80 frames per second, with a 3D resolution up to 0.2 mm, and a linear field of view of 838 x 488 mm at a scanning distance of 1200 mm. On paper it is not quite as accurate as the ATOS Core, but very close and has much more capability. The Artec Leo has intelligent sensing and a powerful microcontroller so it can localize itself in space using onboard gyroscopes and a compass.[14] The cost for an Artec Leo is around 260 000 SEK.

Fig 4
Artec Leo in use during class

With the various scanners available one thing remains true, to achieve consistent high quality and resolution with an easy workflow is expensive. It seems that the hardware of these scanners is improving with time, but the cost remains quite high. It is not surprising knowing that these companies are aware that proper 3D scanning can save time and money for large industrial users[15] leading them to focus on industry as their main customer focus. However, I can imagine a scanner like the Artec Leo quickly having a

[14] Artec Leo - https://www.artec3d.com/portable-3d-scanners/artec-leo-v2

[15] Taking precision blue light 3D scanning to the next level - https://www.sme.org/technologies/articles/2017/may/taking-precision-blue-light-3d-scanning-to-the-next-level/

return on investment for someone with a desire for freelance scanning or a business Idea about scanning with the goal of 3D printing locally.

Quality control - GOM Inspect

Accuracy control is an important factor. If we want our parts to be useable and reproducible we need to have a way to compare our scanned data to the real life part or the design intent. There are various softwares available for measuring and comparing. In our case we have worked with GOM Inspect.

GOM Inspect is a powerful software that can compare a scanned object STL against a CAD file, and the following is a sample workflow explanation.

Import data. We will be comparing our scan against a CAD file so we will import that CAD file.

- Select **import** from the dropdown menu or **simply drag the file into the workspace**.

Next **import our scan**, the .stl file. GOM inspect can handle various different types of elements besides the mesh including point clouds and volumetric data.[16]

- Repeat the first step but with the .stl.

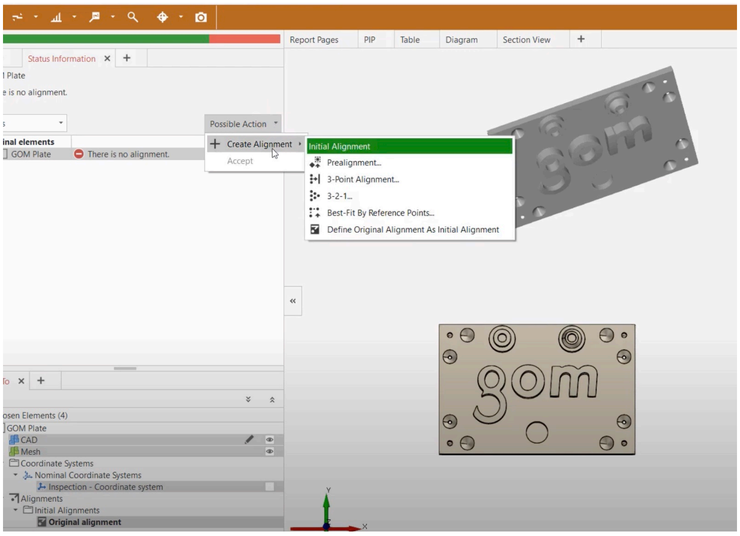

Fig 5
Initial misalignment of CAD and STL in GOM Inspect[16]

[16] How to Import Data in GOM Inspect - https://youtu.be/HJv4OKm-9H4

If needed **Align the part**. Often when the mesh is imported its alignment does not match the alignment of the CAD drawing.

- This is accomplished by clicking **Create alignment** and then click **Original alignment**. We find this under the “Possible actions” button on the left of the screen.

Compare the CAD to the mesh. This is where GOM Inspect really shines. Here the software compares the two surfaces together and gives a heat map of how far out of spec the mesh is to the CAD file.

- Click and drag the CAD file onto the workspace
- Click **surface comparison on CAD** in the top toolbar.
- Adjust the upper and lower limits by clicking the heat bar on the right. Red indicates out of spec above the cad surface and blue indicates out of spec below.
- Discrete deviations can be manually applied by **clicking the label tool** in the top toolbar, selecting **Deviation Labels**, and **ctrl + clicking** on the model at the desired locations. Hold ctrl and mouse over for a preview.
- If a local area is specifically out of alignment we can create a local best fit to inspect just that area.

Report our findings by creating a multipage report. GOM Inspect has a toolset which quickly and easily creates a custom report complete with images and text. There are multiple styles to choose from.

Conclusion

Duplicating our world in three dimensions will continue to benefit research, industry and improve our world. High quality scanners are expensive today with little indication of lowering in cost but there seems to be no limit to the horizon for 3D scanning technology to improve so keep an ear to the ground with this technology. With a very small amount of training this technology is quite simple to use and can be a very worthy investment for many industries in the near term and many more in the near future.