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A Process for the 3D Scanning of COTS Parts for Use with Commercial CAD Software

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by

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Dedication

This project is dedicated to the team that I work with at The Boeing Company, and to everyone who has helped me get this far. Charge on!

Abstract

The purpose of this project is to develop a process using a 3D scanning app to speed up the modeling process for commercial-off-the-shelf parts (COTS parts). Modeling these parts, while important, can take time away from working on higher-priority projects. Using a 3D scan will allow for the collection of a mesh that would then be able to be converted to rough representative geometry, which could be used to speed up the modeling process. This process will be developed by testing different 3D scanner applications that are available on the Apple App Store, working with different groups and tools available at The Boeing Company, and evaluating different software options that could convert a mesh to the desired representative geometry. The software options that were ultimately chosen were Laan Consulting Corp's 3D Scanner App™ and PTC's Creo Student Edition 7.0.8.0. The ultimate goal of this project is to develop a process that not only shortens the amount of time required to model COTS parts, but also is efficient, easy to follow, and useful for other engineers in the future. By the end of this project, the full process that was developed took between six and ten minutes to complete on average, with most of that time spent in the processing in the app phase.

Introduction

This is a project to develop a process for scanning COTS parts and then convert that scan into a model that can be used in a larger and more detailed assembly with little additional work needed on the part. This is accomplished by using a free app on the Apple App Store called 3D Scanner App™ and PTC's Creo Parametric (Creo). The 3D Scanner App™ was used to collect the initial 3D scan of the COTS part and to edit the mesh that was generated from the collected point cloud. The mesh was then imported into Creo, inspected, shrink-wrapped, and converted into a part. The geometry of this part was then able to be touched up, and the part could be checked into a parts library or used to accelerate the modeling process of the object. This report outlines the process developed to collect this data, convert it to usable geometry, and speed up the overall modeling process, as well as provides a discussion on possible ways to improve the process and starting points for future work.

Discussion of the Problem to be Solved

Modeling COTS parts is important in designing and creating large assemblies with expansive capabilities. These parts tend to be designed to be easy to install and are intended to be used straight out of the box. Unfortunately, these parts, such as resistors, capacitors, gears, wires, fasteners, and so much more tend to be necessary but uninteresting and sometimes time-consuming to model. This project aims to develop an affordable process to collect a 3D scan of these parts and convert the mesh from that scan to geometry to massively speed up the process of modeling this type of part. One way to speed up modeling these parts is to use a model automatically created from a 3D scan as a comparison to use alongside the model in progress to improve the accuracy of hard-to-model features. In fact, in some cases, this companion model could be used as the actual COTS model itself.

Available Software and Software Selection Criteria

An important point to consider is the methods available for collecting the 3D scan of the COTS parts. For the highest level of detail to be collected, a physical 3D scanning system would be best. These systems tend to cost anywhere between less than $1,000 and up to $50,000 (Cherdo, 2022). A more affordable alternative would be to use a 3D scanning app that uses the depth-sensing camera in some smartphones. Apple's iPhone 12 has a TrueDepth camera, which is a 12 megapixels (MP) camera that has a $f/2.2$ aperture (*iPhone 12 - Technical Specifications*). "Aperture can add dimension to your photos by controlling depth of field" (Mansurov, 2022). Using an Apple iPhone instead of a physical scanner would allow engineers interested in quickly creating models for COTS parts to avoid investing in a physical scanner, as well as avoid the shipping time and effort needed to assemble the system.

Various 3D scanning apps on the Apple App Store were evaluated based on cost, compatibility, type of files exported, and accuracy of the initial scan. Ultimately, the app called 3D Scanner App™ by Laan Consulting Corp was chosen. Appendix A shows a table comparing this app and the other apps that were considered. This app can not only perform an accurate 3D scan promptly, but it also allows for editing the point cloud that is collected during the scanning process. It can export several file types such as OBJ, GLTF, GLB, STL, PTS, and XYZ. This app has more capabilities than are used in this project, but ultimately it fulfills the criteria that were necessary for the mesh to be collected.

CAD Software Selection Criteria

The CAD software chosen was Creo Parametric, which is used by The Boeing Company. Creo is a type of CAD software that has several diverse capabilities. It is a 3D CAD software suite that is used by many engineers commercially for mechanical design, analysis, tooling,

manufacturing, and more. It can perform geometry element analysis, handle computational flow analysis, analyze frameworks for buildings, simulate increasingly complex assemblies, and produce mechanical drawings for advanced engineering design and documentation (*Creo CAD Software: Enable the latest in design* 2023). This software will not only be used for converting the produced mesh into geometry, but also for creating the final model of the COTS part. Because of its diverse capabilities, Creo can import and export several file types, including STP, OBJ, PRT, ASM, STL, and IGS. This software is usable by teams in a commercial setting.

Initially, this process was going to use three different phases of software. The software phase that has not yet been discussed was the so-called middle-man software. This software would have been used to convert the mesh to a geometric solid, such as a STEP file, that could be imported into Creo as one body. Some of the software that was considered for this step were GeoMagic X, Blender, Autodesk Recap, and Autodesk 3Ds Max. Ultimately, Creo was used for the conversion step after experimenting with its shrinkwrap option.

The Process

The following sections explain each step of the process that was developed throughout the course of this project. This process was primarily developed through trial and error, which is an indication that there could be several areas of potential improvement in the future.

Setting Up to Scan

There are several possible methods to use the chosen app to scan COTS parts. The first step is to collect general measurements of the part, such as length, width, and thickness. These measurements can be collected using a ruler or calipers. Later in the process, these measurements will be used to determine the appropriate scaling for the model since the mesh tends to import

much smaller than the original object. This step is important to ensure the accuracy of the final companion model.

Methods of Scanning

The first method to easily scan the original part is to place the part on a low table, activate the scanning process by pressing the record button on the app, face the front camera toward the object, and slowly walk around the table while staying within three feet of the object at all times. Before ending the scan, it is important to make sure the app records the top of the object so that the mesh will not have holes on the top of the object. When the scan is complete, press the record button again to stop scanning.

The second method of scanning is to dangle the COTS part from a thin string so that data can be collected on all sides of the part. It works best to try to dangle the part at approximately chest height when using this method. The scanning process outlined in the earlier paragraph is followed for this scanning setup as well – the user presses record, aims the front camera, and slowly walks around the part. Datapoints must be collected for the maximum number of surfaces on the original part while keeping the camera a consistent distance away from the part.

There are both benefits and drawbacks to both scanning methods. The flat, stationary method allows for the collection of data points on nearly every side of the object – except the bottom. This leaves a relatively large hole in the mesh that transfers over onto the companion part. However, this method tends to be easier than the dangling method to complete when collecting the 3D scan. This method is easy to set up, tends to require fewer data points, and tends to have a higher quality mesh produced after processing. The dangling method, while allowing the collection of data points from every angle, has an issue with some undesirable movement of the object. Vibration makes the object difficult to accurately scan. The vibration in

the dangling system could be decreased by attaching a weight to the bottom of the item that the part is attached to but below the part; damping the vibration by increasing the mass of the system. While testing this setup, it was observed that additional weight did not completely resolve the vibration issue, however, it did greatly improve the accuracy of the scans when compared to the scans without any controller added to the system.

Processing Scan in the App

Once the scan is complete, it needs to be processed within the app. The HD processing option provides the most detailed result, and the max depth cutoff value can be adjusted to an appropriate value, which would help avoid having additional data points from the surroundings. The start button begins processing the data from the point cloud. The processing step is the step that takes the longest in this entire process.

After the scan has been processed, editing options within the app can be used to decrease the remainder of the surroundings in the point cloud. These options are accessed by selecting More, then Crop & Edit Scan. Renaming the scan is also possible from this menu. Inside the Tools menu in the Editor, there are also options to align and transform the scan. The Align to Centroid XZ option will center the scan on the X and Z axes. The Align to Ground option adjusts the scan to have its' bottom aligned to what the software perceives as the ground. The Align to Ground option does not always place the sketch where the user would prefer it, and a more reliable option to move the sketch is by using the Transform Sketch option. This option operates similarly to the various cropping options explained in the following paragraphs. It can translate, rotate, and scale the sketch based on the amount that the user rotates a wheel at the bottom of the screen. Similar to the following editing options, the word Done is selected when the user has

made all desired changes. It is important to note that the user should select Save when exiting the Editing menu to keep all changes made to their mesh.

The Crop with Box option is the first option in the Editor under the Tools icon. When selected, it allows users to select the face that they wish to translate. The face is selected by using the six colored icons in the menu at the bottom of the screen. The wheel underneath these icons is used to position the face the desired distance away from the object. The inside and outside options located above the face options are selected to tell the software to crop the mesh facing toward the scanned object or the mesh facing away from the scanned object. Once the desired position of the face is determined, the word Crop is selected to crop the mesh. This part of the editing process can be repeated until the scan has the user's desired boundaries. The Done button is selected to exit the Crop with Box option. This option is useful for a detailed and precise removal of parts of the mesh, such as removing the mesh of the solid surface that the object was sitting on while being scanned or for removing the thread that the object was dangling from.

The Crop with Plane option has a similar menu to the Crop with Box option. First, the plane is chosen by selecting the option that is labeled by the axis that is not included in that plane. For example, the XZ-plane is selected by choosing the Y - up option on the software. The location of the plane is moved along the axis that is stated in the software. Using the XZ plane as an example, moving the wheel will move that plane along the y-axis. The Below and Above options correspond to the direction of a yellow arrow. These options allow the user to determine the area above or below the plane to be cropped. Similar to the Crop with Box option, the mesh is cropped by selecting the word Crop, and the word Done is selected when the user is finished cropping the mesh. Analogous to Crop with Box, this option is useful for the detailed removal of parts of the mesh.

Crop with Sphere is also similar to the Crop with Box and Crop with Plane options. It allows the user to position and resize a sphere around the scan. Comparable to the Crop with Plane option, the axis button selected is the axis that the sphere is translated along. The sphere is resized by selecting the radius button and rotating the wheel until the sphere is at its desired size. Also, like Crop with Plane, the Inside and Outside options allow the user to choose if the inside of the sphere is removed or if everything outside of the sphere is removed. Similar to both of the previous options, the word Crop is selected to crop the mesh, and the word Done is selected when the user is finished. This option is useful for removing the surroundings initially from the total mesh.

Crop with Paint allows the user to “paint” over the mesh with their finger to select parts of the mesh to remove. The Select option allows the user to begin painting on the mesh, and the Deselect option works similarly to an eraser. The Camera option allows users to stop painting on the mesh, and to rotate it by dragging a finger along the screen the other options will do as well. The Paint option allows the user to resume painting on the mesh. The select all option will paint the entire mesh, and the select none option will deselect everything that had been painted. In the same way as every other option, the word Crop is selected to crop the mesh and the word Done is selected when the user has finished cropping. This option is especially useful for removing random parts of the mesh that are not connected to the main mesh, such as pieces of the surroundings that were meshed during the processing step.

The Bounding Box can allow users to easily see rough dimensions around either part of the mesh or the entire mesh. It can be adjusted by opening the Measuring Menu and selecting the Adjust Bounding Box option. The mesh is first positioned and oriented in the center of a wheel. Once placed to suit the user’s needs and the Next button is selected, a box similar to one that

appears around images in Microsoft Word appears around the mesh. The first box allows users to change the length and width of the box. After Next is selected again, the next box allows users to change the length and the height of the bounding box. The final review option allows users to see the new bounding box around the mesh. Changing the bounding box is not an alternative to cropping the mesh.

When the mesh is ready to export, the Share menu is opened. This menu displays different file types or different ways to export the mesh. The option recommended for export in this process is STL. This is a file type that is used for 3D printing and prototyping, among other things. These files record the surface geometry of the object, but not the color or other things that CAD software typically records. They can also be imported into most CAD software. In the Share menu, this option has a gray square and is labeled STL. When this option is selected, a new menu opens, showing apps that the mesh can be exported through. Emailing the STL file sends the file to the desired recipient, who can then download the file. Using email as a means to export the mesh allows users to quickly transfer their mesh from their phone to a computer. Once the file is downloaded from the email, it can be imported into Creo to Shrinkwrap the mesh and create rough geometry.

Creo Parametric

Creo was used to convert the mesh to a rough geometry, which can then be used as a guide for accurately modeling more complicated features on the original object. It was also used to check in the final part to the parts library. The check-in process is not explained in this paper. Creo can be purchased and downloaded from PTC.

After the download is complete, Creo can be launched by either selecting a window on the desktop or opening it through the start menu. First, the mesh was imported into Creo. This

was done by selecting Open at the top of the screen, changing the file type in the search menu to STL, and selecting the downloaded STL file. A menu for importing options opens, and the user should select Current Profile from the drop-down menu, Geometry as the import type, and it is up to the user if a log file should be generated. After these options are selected, the user can name the file. It is recommended that the user names the file something similar to the part number of the original object. Now that the mesh has been imported, select the Analysis tab at the top of the screen; then select Measure from the middle of the bar under the Analysis tab. Measure the mesh, and compare the measurement data that Creo supplies to the original general measurements. The equation below shows the equation for the scaling factor that can be used if the measurement data supplied by Creo does not match the original general measurements.

$$SF = \frac{Original\ Measurement}{Creo's\ Measurement}$$

This scaling factor is used in the Scale Model command, which is under the Operations menu at the far left of the screen under the Model tab. Once this command is selected, a prompt pops up in the center of the screen where the scaling factor (SF) is typed into the box. The model will then regenerate, and the steps described earlier to measure the mesh should be repeated to check that the model is the correct size.

After the mesh has been resized, the mesh can be shrink-wrapped, which will apply a very thin layer of geometry around the outside of the mesh. This geometry can be interacted with in the same way that all other features can be while modeling parts in Creo. To shrinkwrap the part, select the File tab then Save As. When the Save As menu opens, select the type dropdown and then select Shrinkwrap. A menu on the side of the screen will open and the following options should be selected. First, select Faceted Solid as the creation method. Then in the special handling section deselect ignore quilts. Next under the faceted solid options, select Part. Finally,

under quality insert a value ranging from one to ten, where one is the least detailed and ten is the most detailed. Note that at any time the preview button at the bottom of the menu can be selected to view the current shrinkwrap. After the user is satisfied with the preview of the shrinkwrap, select Ok, and Creo will create the geometry. This saves the shrink-wrapped part in a new file, which now is a PRT or part file. Part files have editable geometry and are primarily used in the commercial design of products. It is also notable that part files are the file type that is checked into the parts library.

Depending on the accuracy of the shrinkwrap and any holes in the mesh, the companion model might be able to be checked in as the COTS part, depending on if the inside of the part must be solid or if the mass of the model is critical to the 3D assembly that the part will be used in. Sometimes when using parts libraries, external containers can be used to represent the material, weight, and density of the part. This means that, in some cases, the denseness or the mass of the model might not be as important as the external dimensions since they are stored separately from the model. In these cases, the shrink-wrapped model could be checked into the parts library for use as that COTS part. However, it should be noted that the geometry of shrink-wrapped parts can be difficult to edit.

Suggestions for Improvement

As with any process, there is always the possibility that there is a better way to achieve the result. To improve the scanning process, a physical 3D scanner could be used to eliminate any problems that arose from unsteady hands or a varied camera velocity and distance while scanning the original object. A different scanning setup could also be used. Instead of either of the options that were explained earlier, a scan could be taken by using something that would steadily rotate around the object. It would be ideal if the possible new method would also include

some way to steadily raise the phone while it is rotating so that the top of the object can also be steadily recorded. It would also be ideal if there was an easy way to edit a shrink-wrapped file in Creo. Since the shrinkwrap keeps the sharp vertices from the mesh, no matter how detailed it is converted, it is difficult to use the faces of the part as references to make changes to the geometry such as extruding, sweeping, adding rounds, and cutting holes.

Suggestions for Future or Continued Work

Future work on this process could start in several areas of the process. A 3D scanning system could be used instead of the 3D Scanner App™ to collect the original mesh. Typically, these systems are compatible with different CAD software, which allows for the option that there exists software that would take the mesh and be able to swap it to a geometric solid with a built-in option. Another place to start future work would be to consider investing in GeoMagic X. This software is designed to reverse engineer parts from 3D meshes, which would have been an ideal software to experiment with during the development of this process. However, GeoMagic X is a hefty investment for one person, as it costs $21,002 for one license (*GeoMagic Design X: Scan to CAD Software for Reverse Engineering*). This software also has the possibility that it is only compatible with 3D scanners made by Artec, which could be potentially disappointing for individuals and companies that own other types of 3D scanners or wish to use an app on their phone to collect the initial scan. Another place in this process to consider for future or continued work would be experimenting more with the file types that can be shrink-wrapped in Creo. The STL file was used because it was easy to export from the 3D Scanner App™ and it was easy to import into Creo. This, however, does not necessarily mean it is the best or only way to get a shrink-wrapped model.

Conclusion

Throughout this project, a process was developed to collect 3D data from a COTS part and use that data to create models quicker than before. By first collecting general measurements, then scanning the object, meshing it, editing the mesh, exporting it to Creo to scale and shrinkwrap, and generating the final companion model, the general process for modeling COTS parts can not only be sped up but also it can become more accurate. The improved accuracy of these parts will help to eliminate small design errors and also will free up more time for focusing on creating assemblies, drawings, and custom parts. The developed process accomplishes the goal of this project: to affordably find a way to speed up the modeling process of COTS parts. There are several areas where the research and process development for this product can be continued, and this project has the potential to change the COTS modeling process that currently exists in the workplace for the better. Overall, the developed process typically takes between six to ten minutes to complete, depending on the time taken to set up the scan location, the time taken to process the scan, and the time taken to load the shrinkwrap in Creo.

Appendix A: Software Comparison Table

App	Cost	Phone Compatibility	File Type Exported	Accuracy of Initial Scan
3D Scanner App ™	Free – no subscription required.	iPhone 12 Compatible	OBJ, GLTF, GLB, DAE, STL, PTS, PCD, PLY, XYZ, LAS, DXF	Mostly accurate size when compared to the original object.
MagiScan	A monthly subscription is required.	iPhone 12 Compatible	OBJ, STL, FBX, PLY, USDZ, GLDB, GLTF	Not tested due to subscription.
Polycam	A monthly or yearly subscription is required.	iPhone 12 Compatible	DXF, SVG, PNG, OBJ, DAE, FBX, STL, DXF, PLY, LAS, XYZ, PTS, GLTF	Not tested due to subscription.
Scaniverse	Free – no subscription	iPhone 12 Compatible	OBJ, FBX, USDZ, LAS	Slightly inaccurate in size when compared to the original object. Limited cropping capabilities.
Scandy Pro: 3D	One free export per week. A subscription is required for all other features.	iPhone 12 Compatible	STL, PLY, OBJ, GLB, USDZ	Slightly inaccurate size for small objects. Can be hard to get a good mesh on smaller objects.
3D Scanner Tool	Weekly through yearly subscription required.	iPhone 12 Compatible	OBJ, PLY, STL, SCN, USDZ	Not tested due to needing a subscription to use the app.
Metascan	Pro requires a subscription. Exporting scans requires a Pro subscription.	Not iPhone 12 Compatible – requires iPhone 12 Pro		The photo option is inaccurate. Unable to test the LiDAR option.

Information in this table was found either on the Apple App Store or was determined when trying out various 3D scanning apps that were downloaded from the App Store.

Appendix B: Useful Software Resources

Help guides for Creo can be found at https://www.ptc.com/en/support/help/creo

The website for 3D Scanner App™ is https://3dscannerapp.com/

The website for Creo is https://www.ptc.com/en/products/creo

The website for GeoMagic X is https://www.artec3d.com/3d-software/geomagic-design-x#overview

Appendix C: Glossary

Assembly – a collection of parts that are connected to represent a final design.

CAD – Computer-Aided Design

Check in – To return a part to the parts library

Commercial-off-the-shelf parts – hardware that is available for sale commercially

Export – to send a file from one software to either another file or to another software

Geometry – features of a part, such as faces, edges, vertices, and rounds.

Import – to open a file from another software in a new software

Mesh – this is a set of finite elements, which are typically quadrilaterals or triangles, that are used to model or represent a 3D surface

Parts library – a server where parts, assemblies, and other related objects are stored for use across a company or program

Point cloud – a collection of spatial measurements as data points to represent a surface

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