COMPACT 3D PRINTED TURNTABLE DESIGN FOR INDUSTRIAL 3D SCANNING APPLICATIONS

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ABSTRACT

This research introduces a method for creating a medium sized turntable that is especially suited for industrial 3D scanning uses. A 500mm diameter turntable was designed to maximize scalability and minimize production costs, while also enabling smooth integration into current scanning settings. This was achieved by leveraging the limitations of a common 220mmx220mmx220mm 3D printer. The availability of turntables in this size range is very limited. The design achieves the ideal balance between functionality and efficiency by carefully considering industrial engineering principles, such as material selection, structural integrity, and manufacturability. The turntable's modest footprint guarantees compatibility with a variety of industrial applications, and its modular design facilitates simple assembly and maintenance. This breakthrough emphasizes the promise of industrial engineering approaches in expanding additive manufacturing solutions for practical applications, especially around high-precision 3D scanning, while accepting the constraints of traditional 3D printing technology.

Keywords: 3D Scanning, Turntable, Design, Artec EVA

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1 INTRODUCTION

The primary function of 3D scanning technology is to generate point cloud geometric samples of an object that is then transformed into surfaces that reconstruct the object scanned. With 3D scanning being an integral part of the modern-day technology boom in the industry, 3D scanning has been part of the world since the 1960s[1]. As 3D scanning was initially used it involved the use of lights together with cameras and projectors to obtain the surfaces of the object scanned. Since the 1960s, the technology and process of 3D scanning have improved, and labour-intensive processes used in the 1960s were left behind[2]. White lights, lasers, and shadowing technologies are used to capture more accurate surfaces of various objects. During the 1990s full body scanners hit the market and the advancement in the 3D scanning technologies greatly improved. Currently there is a continuing improvement in the field of 3D scanning as there are multiple companies that span multiple industries that use 3D scanning for various applications, such as in the additive manufacturing and medical industries, thus leading into further research in the field of technology[2].

In the construction and civil engineering industries, 3D scanners are used to verify as-built drawings, documentation of historical sites, site modelling, and establish benchmark parameters for existing structures. Moreover, the technology is used to reverse engineer objects by scanning these objects and generating a digital version which can then be modified and manufactured. Within the medical field, the 3D scanning process is used to scan a disabled patient's affected area and then model and produce possible prostheses around the digital model to save on manufacturing time and manufacturing costs. The 3D scanning technology is also used in law enforcement as the scanner which can help document crime scenes and help recreate or reconstruct an accident scene[2].

For objects of small to medium-sized nature, it is necessary to have more stability and accuracy in terms of the scanning procedure to minimize scanning errors and background 3D noise. Therefore, to minimize the errors picked up by a 3D scanner, a turntable where the object can be placed and rotated can be introduced while the 3D scanner can be placed in a stationary position. As there is to be less external noise and motion deviation from the scanning procedure, less error or background noise will be captured. Various turntables are available to be purchased, but the size restriction and the affordability of these tables make the purchasing of the items very difficult. Thus, a 500mm diameter turntable is designed and 3D printed, and all the parts are designed to fit on any basic 220mmx220mm 3D printer for ease of manufacturing and assembly. The turntable is also used to compare the two different scanning procedures of a manual handheld scanning versus a stationary structured scanning method.

2 DESIGN AND MANUFACTURING OF TURNTABLE

The turntable is designed with a diameter of 500mm to address the size constraint of a general 3D printer with a print base of 220mm by 220mm. By keeping the print base size constraint in mind, the modular design of all the parts makes it easy for the parts to be printed individually as well as makes it easy to do troubleshooting on individual printed parts. Thus, when a misprint or printing error occurs, only a single part has to be reprinted and not the whole table itself. Together with the modular printing process, the design enables the turntable to be easily assembled, disassembled, and also transported. This design makes access to a turntable a lot more accessible to individuals and to industry-relevant individuals or companies without having to spend a large amount of time or money on the accusation of a medium-sized turntable.

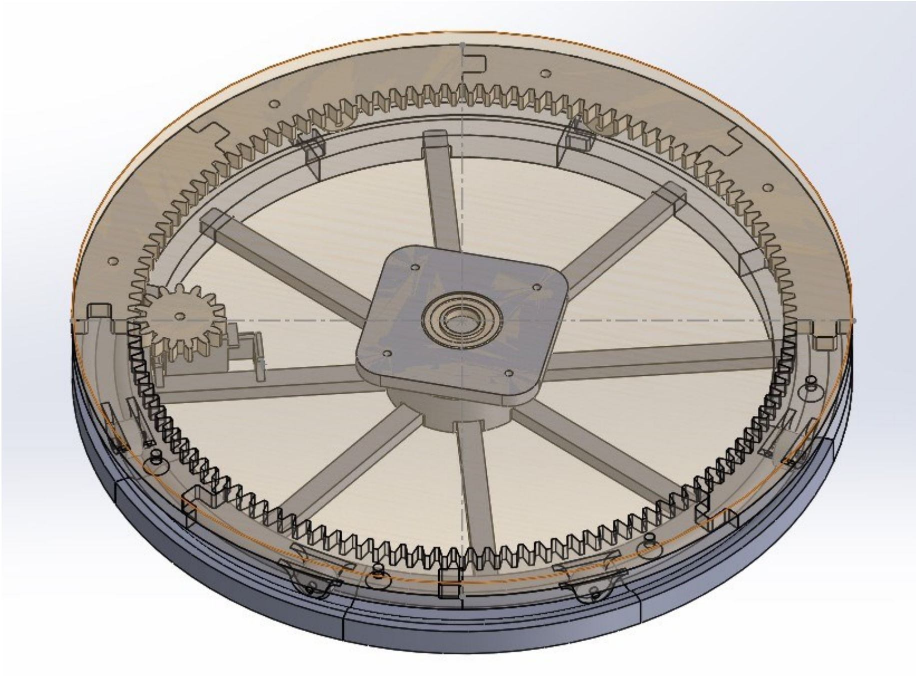

Figure 1: Fully Assembled Turntable

The manufacturing of the 3D printed 500mm diameter turntable was done on a Creality Ender 5 3D printer. A fully assembled Computer Aided Design (CAD) model can be seen in Figure 1 to illustrate the complexity of the turntable and its parts. The selection criteria for the material used in the printing process was based on that the material needs to be widely available, cheap, and strong enough for the intended use of the printed parts. Two types of printing materials are the onset primary materials, which are Acrylonitrile butadiene styrene (ABS) and Polylactic Acid (PLA). According to Ultimaker.com, PLA is a good material with good quality in terms of engineering properties, but ABS is the material to be used if a lot more physical work is to be done with the printed components. Both of the materials cost around the same at R300 for a 1kg spool of plastic. Any other material can be used to print the turntable as the function of the turntable in terms of the weight of parts and changes in part sizes.

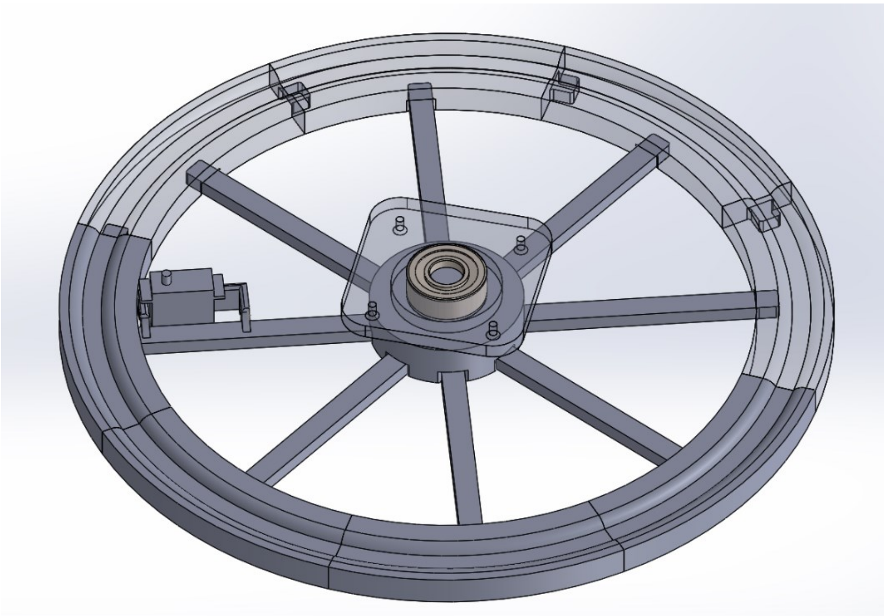

Figure 2: Base Rail assembly.

In Figure 2 and Figure 3, two sub-assemblies for the Base Rail assembly and Top & Gear set assembly show the two separated halves of the turntable. The top and gear set are supported in the middle of the structure with a tapered bearing and on the outer rim of the base by small rubber-lined roller bearings for maximum weight distribution to the bottom rail assembly.

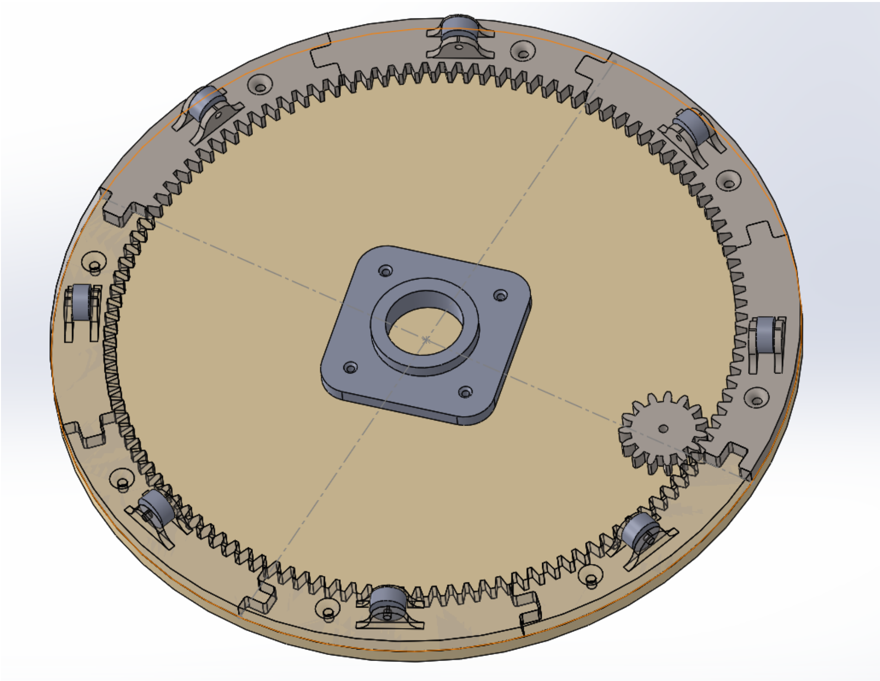

Figure 3: Top & Gear set assembly.

Ultimaker Cura 5.5 is the slicing program that is used to slice the imported 3D CAD models of the different parts printed into layers so that the 3D printer can be instructed to print the parts with selected parameters. For each turntable application, the parameters will vary for the slicing and printing software. For the current test unit, the parameters used are shown in Table 1. Ultimately, the plastic part of the turntable is printed, then post-printing cleaning is needed to clean up the parts so that each part fits together easily.

Table 1: Slicing/Printing Parameters

Parameter	**Unit**
Filament Thickness	4 mm
Nozzle Size	0.4 mm
Layer Height	0.2 mm
Wall Thickness	1.2 mm
Top/Bottom Thickness	0.8 mm
Infill Density	20 %
Infill Pattern	Cubic
Nozzle Printing Temperature	220 °C
Built Plate Temperature	60 °C
Print Speed	80 mm/s
Travel Speed	200 mm/s
Built Plate Adhesion	Brim
Brim Width	8 mm
Print Cooling	Enabled

With the turntable assembled with all the printed plastic parts and support bearings, the top base and gear set is turned by a Tower Pro MG 996R servo motor with a stall torque of 15kg·cm when supplied with a 6-volt power supply. The servo is driven by a coded Arduino Uno board that activates the servo, by the push of a button for 1 second and stops for 2 seconds on repeat until the stop button is pressed when a certain scanning process is complete.

3 ARTEC EVA 3D SCANNER & SOFTWARE

The 3D scanner used is the Artec Eva handheld 3D Scanner, produced by Artec 3D, and the company headquarters is based in Luxembourg. The Artec Eva scanner is designed and manufactured to generate 3D scanned models in a relatively short time. Meanwhile, the complexity of the model also plays a role since the scanner has set limits. The specification of the Artec Eva 3D scanner is displayed in Table 2 [3]. This Artec EVA is a structured light type of scanner and it has been used in multiple additional studies for producing customized orthoses[4].

Table 2: Artec EVA Specifications

Spec	**Measurement**
3D point accuracy, up to	0.1 mm
3D resolution, up to	0.2 mm
3D accuracy over distance, up to	0.1 mm, 0.3 mm/m
Working distance	0.4 – 1 m
Volume capture zone	61,000 cm^3
Texture resolution	1.3 mp
3D reconstruction rate for real-time fusion, up to	16 fps
Data acquisition speed, up to	18 mln points/s
3D light source	Flashbulb
3D mesh	OBJ, PLY, WRL, STL, AOP, ASC, PTX, E57, XYZRGB
CAD	STEP, IGES, X_T
Minimum computer requirements	Intel Core i7 or i9, 32 GB RAM, NVIDIA GPU with CUDA 6.0+ and at least 2 GB VRAM

As the minimum requirements are known, a HP Z440 workstation with a Xeon E5-1650 processor, 32GB RAM and a NVIDIA GeForce GTX 1060 6GB GPU is used in this study. The processing power of the setup used for the scanning process is more than adequate. For the capturing of the raw data from the 3D scanner and to do the post-processing procedures of the 3D scanned model, Artec Studio 17 is used.

4 3D SCAN AND EXPORT PROCESS

A rectangular box is used as an example of the scanning procedures and to compare the scanning methods with each other. The rectangular box is shown in Figure 4. The first scanning method is to put the test unit on the turntable and secure the 3D scanner to a stationary position. As the turntable rotates, with the object placed on it, the scanner will be placed in a stationary position to implement the scanning process. The second method entails that the test unit or object is placed on a stationary flat surface, and the 3D scanner is to be held by hand. The scanning process is initiated while the person moves around the object to complete the scanning process.

Figure 4: Test example (Rectangular box)

There are three individual scans done per scan test as the object is to be placed right up, turned upside down, and placed flat on its back. Each method will include three separate scan tests to compare the two scanning methods. As the Artec EVA has a High-Definition (HD) scanning option to include in scans, one test scan will be without the HD option enabled, and two scan sets with the HD option enabled.

Scanning can begin as the object is placed in the correct location and orientation. With the Artec EVA 3D scanner, the optimum distance from the scanner to the object is between 640mm and 740mm; as the object is within the optimum range, the scanning can begin. As the scanning progresses, it is necessary to let the scanning process continue until a full 360-degree rotation is done before a scan is stopped. The orientation is changed, and the scanning procedure is continued and repeated until all scanning iterations are completed. Each scan iteration is accompanied by an error factor that illustrates the quality of the frames captured. To get good results from frames captured from the Artec EVA scanner, the error factor can be between 0 – 0.3 and moderate results between 0.4-0.9. When the error factor exceeds 0.9, the frames are not acceptable[5]. The error factor illustrates the quality of the frame captured, thus the quality of the surface capture and possibly interference from background noise (objects) that is not relevant to the object scanned.

After all the necessary scanning procedures have been followed, the post-scanning procedures can begin. The post-scan processing is done the same way throughout the study to get the best overall results over all the scans. The post-processing procedure used is listed below:

1. Base Remove
    - Remove the base the object is placed on, as the base is irrelevant to the end product.
2. Remove Background noise.
    - Remove all additional small or big objects (Noise) that can be recorded during the scanning process and are irrelevant to the end product.
3. Align all three cleaned-up scan data sets.
    - Automatic alignment is done by aligning Geometry and Texture points recorded from the scans of the object.
4. Global registration.
    - All the one-frame surfaces of the aligned data is converted to a single coordinate system.
5. Outlier remove.
    - Remove additional outlier data missed in previous steps.
    - Level 2 3D noise level
    - 3D resolution 0.5 mm
6. Fusion (Sharp).
    - Combining all captured and processed frames together to create a polygonal 3D model.
    - 3D resolution 0.5 mm
    - Exclude frame with an error factor of 0.8 and above.
7. Remove small objects.
    - Remove possible small objects that are missed from previous removal processes.
8. Smoothing.
    - Smoothing evens out noisy areas in the 3D model.
    - 10 steps
9. Mesh Simplification.
    - To reduce the polygon mesh density to reduce memory used.
    - Shape deviation to a resolution of 0.05 mmm
    - Maximum allowable deviation from the original scan
10. Export Mesh
    - Export the mesh to any of the allowed file types.

With the scanning process and post-scan processing completed and a mesh file exported, the mesh file can be imported to a CAD program. Within this study, the mesh file is imported into Solid Works as a solid body so that the interaction between polygons is possible and to take distance measurements.

5 RESULTS

The rectangular box object that is used as an example for the 3D scanning was measured in 6 locations, three locations that related to measurements from side to side at the top, middle, and bottom of the object. Additionally, the other three measurements are taken front to back at the top, middle, and bottom of the object. In Figure 4, the green lines are a representation of the location where the measurements were taken. The measurements taken are the length between two points and is displayed below:

1. Side to Side
    - Top = 100.6 mm
    - Middle = 100.8 mm
    - Bottom = 100.6 mm
2. Front to Back
    - Top 100.5 mm

- Middle = 100.5 mm
- Bottom = 100.5 mm

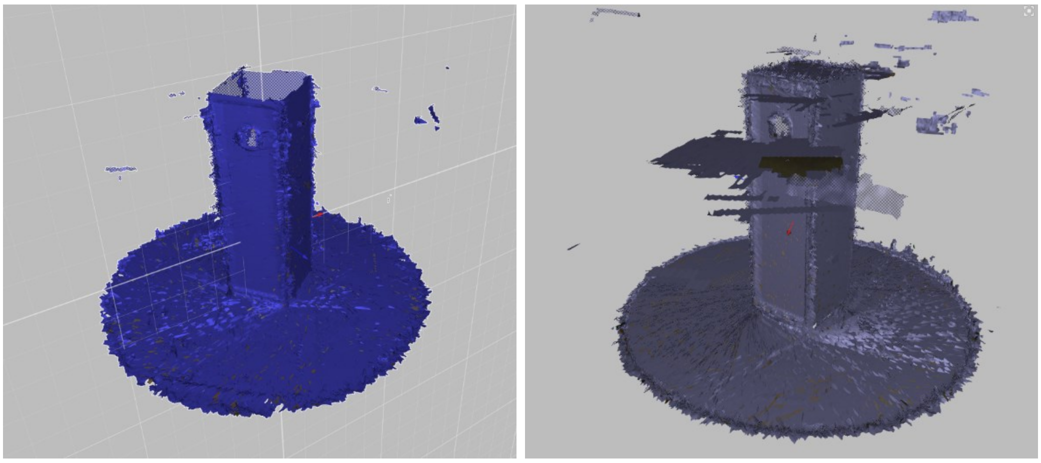

Figure 5; (a) Stationary Turntable Scan; (b) Handheld 3D Scan

Before any post-processing is done and any measurement data is extracted, it can be seen that with a comparison shown in Figure 5(a) and Figure 5(b) there is a lot more background noise related in the handheld 3D scan than the stationary turntable scans. From Figure 6 (a) the lowest minimum error factor from frames scanned and rendered comes from the scans done by the use of the turntable and stationery Artec Eva scanner. Thus, it can be said that the maximum error factor as it is captured comes from the handheld scan procedures, as seen in Figure 6 (b).

Figure 6; (a)Min error factor; (b) Max error factor; (c)Measurement difference; (d)# Frames captured

With the combination of data from Figure 6 (c) and Table 3, it can be seen that the difference in measurements from the physical rectangular box to the 3D Scanned meshed object imported to a CAD program the difference percentage is less than 1%. As previous studies and general academic studies show that when the difference in measurements is equal or less than 5%, the results are acceptable [6].

Table 3: Physical vs 3D Measurement differences (mm)

	Top sides	Middle sides	Bottom sides	Top Front	Middle front	Bottom front
Turn table scan 1	0.2391	0.1467	0.2361	0.0092	0.2674	0.2165
Turn table scan 2	0.3124	0.2697	0.2657	0.0629	0.0811	0.2570
Turn table scan 2 HD	0.0540	0.1921	0.0057	0.2814	0.1987	0.1915
Turn table scan 3	0.4844	0.3488	0.3588	0.1184	0.0716	0.0412
Turn table scan 3 HD	0.0632	0.0327	0.0500	0.2033	0.1866	0.1391
Handheld scan 1	0.1598	0.1247	0.1963	0.1440	0.1610	0.0059
Handheld scan 2	0.0750	0.1168	0.2371	0.0658	0.1464	0.0772
Handheld scan 2 HD	0.1544	0.1213	0.0388	0.2347	0.1593	0.1463
Handheld scan 3	0.1473	0.0741	0.0657	0.3564	0.0705	0.1781
Handheld scan 3 HD	0.1597	0.0416	0.0927	1.1081	0.0767	0.0084

6 CONCLUSION

With the photographic difference between the pre-processing scans of the turntable and handheld scanning, together with the minimum and maximum error factors, it can be seen that a turntable makes the processing process, noise extraction etc., of the 3D scans a lot more convenient, easy and less time-consuming. As can be seen from the results shown in Figure 6 (b) as more error and noise relate to more time spent on post scan processing. Even if the difference in measurements of the two scanning methods is not significant, there is still the need for a medium-sized turntable that is easily accessible or manufacturable, as there are not a lot of affordable medium-sized turntables on the market. Thus, the turntable can be manufactured with a basic 3D printer using affordable materials. This turntable can be used in a hobbyist environment as well as in an industrial environment. The manufacturing parameters can be varied and applied as the use for the turntable is known. Future research may include the use of a robotic arm with distance-measuring sensors to keep the 3D scanner at an exact distance from an object's surface while the object is rotating on the turntable. This will be to see if further errors or background noise can be filtered before any processing takes place.

7 REFERENCES

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