Extending the Concurrent Engineering Design Graphics Paradigm to 3D Scanning

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Abstract

Our group at the University of Texas currently stresses the concepts of solid modeling in the Freshmen Engineering Graphics courses. In addition to sketching practices and learning measuring techniques, our students use SolidWorks to turn solid models into 3D printed models. A major portion of our graphics curriculum is the reverse engineering project. During this process students take a product, disassemble it, measure each piece with a caliper, replicate those pieces in SolidWorks, make adjustments to the original design to enhance its function in some way, and finally get to hold the new product in their hands after 3D printing. We believe this "art to part" concept is very beneficial in mechanical engineering. With 3D scanning, the reverse engineering projects will receive additional benefits. In conventional modeling with regular geometric processes it is difficult, if not impossible, to replicate irregular surfaces. Examples of this would be tool handles, kitchen utensils, and difficult intersections of geometric shapes such as water valves, (Figure 1), etc. Scanning these types of objects allow precise generation of the models. This paper will discuss the developments of affordable 3D scanning machines and the integration of such into the Concurrent Engineering Wheel (Figure 2), the Engineering Design Graphics curriculum and the upper level design courses.

Figure 1 – Water Valve

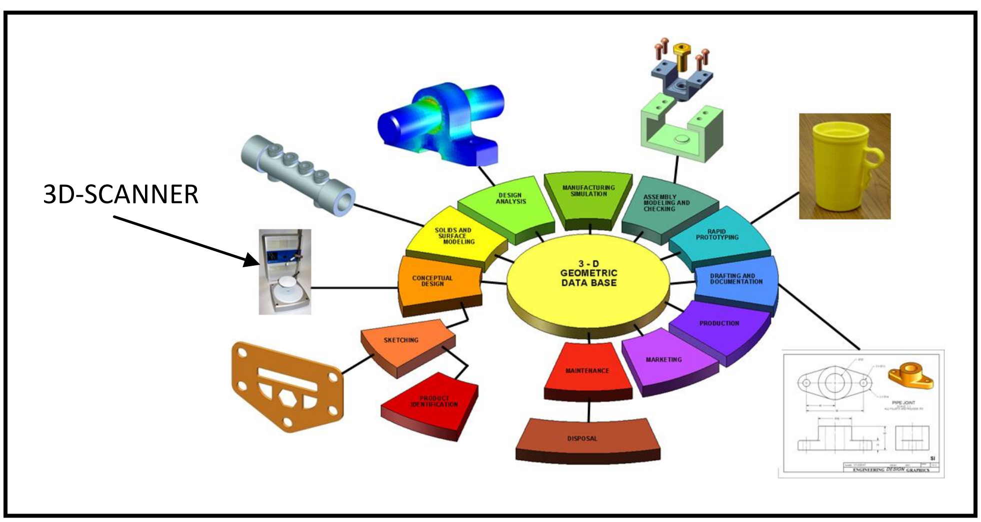

Figure 2 – How the 3D Scanner would be Applied in the Concurrent Engineering Wheel

Introduction

The 3D scanners displayed at past conferences have been costing upwards of $150K. Although impressive, these machines were out of any school's price range. In the past few years, economical 3D scanners have been developed which produce accurate solid models for a reasonable cost. This has allowed The University of Texas' Mechanical Engineering Department to purchase multiple NextEngine Scanners (with software) for under $10K.

Scanning Technology

Solid modeling software may be able to create regular shapes using lofts and sweeps along with blends and fillets. However, with the 3D scanner the user may sculpt an object or use an existing feature to scan. Irregular curves and unusual features are scanned using a series of lasers that produce a "point cloud" which is then converted into a surface model using ScanStudio. ScanStudio will then take the surface model and turn it into an STL file. There is accompanying software called RapidWorks, which is designed to take the surface model from ScanStudio and convert it into a solid model which can be opened, altered and manipulated in SolidWorks.

Scanning Process

A series of lasers are used to generate the data in the scanning process. Since black surfaces absorb light and transparent and shiny surfaces disburse the light, those surfaces must be treated in some way to make them scan-able. Objects with dark, transparent or shiny surfaces must be prepared using tools such as paint pens or talc powder (Figure 3) for the images to be adequately picked up by the scanner. When surfaces are homogeneous, it is difficult to zip scans together unless there are identifiable points that are visible in the adjacent scans. Placing target points on the object (Figure 4) makes it easier to place registration pins during the aligning process. After the object is properly prepared, it can be situated on the stage (Figure 5) to begin the scanning process.

Figure 3 – Paint Pens and Talc Powder

Figure 4 – Knife Handle with Target Points

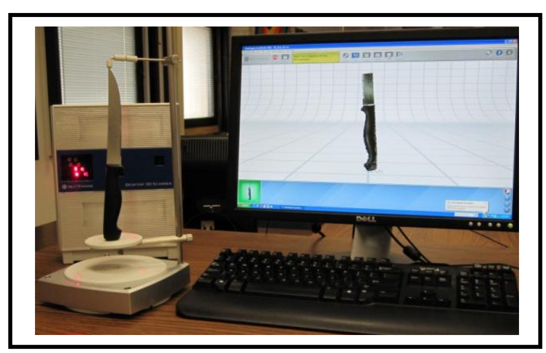

Figure 5 – Scanner, Stage and Monitor

The scanner can be set up to scan large objects (shoe box size) in the wide setting and small objects in macro setting. Scans can be taken as a single panel, a bracket of panels, or 360° for a full object scan. Choosing the number of divisions allows for different degrees of accuracy and coverage (Figure 6). Scan time varies depending on the number of scan panels and the quality setting chosen. For example, the completion of an HD quality 360° scan of 9 divisions takes about 15-17 minutes. Each scan can generate a point cloud that may exceed over 1MB.

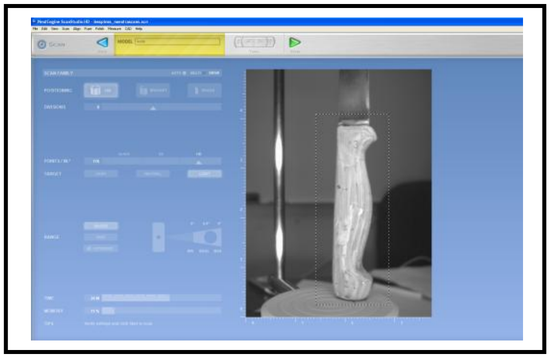

Figure 6 – Scan Settings Window

When scans appear on the screen, there is often unnecessary overlapping or portions that have been scanned inside of more than one scan panel. The trim feature allows these unwanted sections of a scan, such as parts of the stage or auto-positioner, to be eliminated from the scan data. This can be done at any point in ScanStudio, whether it is in the middle of a scan on individual panels, at the completion of the process before alignment, or at any other time after alignment.

Once a series of scans has been completed, the scans join together into what ScanStudio calls a family. The scans inside a family can be aligned by either using the auto-alignment feature or manually by placing pins on corresponding positions between scan panels (Figure 7). There are times that positioning of the object does not allow the scanning of the top and bottom of the object. In these cases, the object can be repositioned to capture those surfaces. Each complete set of scans is classified as a family. It is also possible to align families together from different scan processes, which is useful when obtaining scan data that was missed during the original scan.

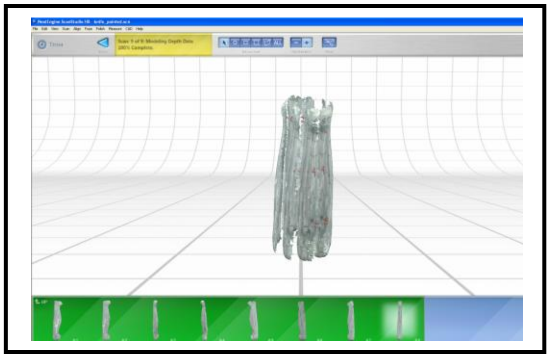

Figure 7 – The Merging of Scans

After alignment, there are many tools to perfect the new object. In the polish and fuse toolbars, you can fill holes, buff , re-mesh, regenerate, clean defects, smooth, volume or surface merge, and change the texture quality and simplification.

Now that the object has been reproduced on the computer, there are many options for outputting it for reverse engineering, replication, and 3D printing. If the purpose is to produce a 3D print directly from scanning, the object can be saved as an STL in ScanStudio and printed from there. To create a solid model, an object saved as SCN, IGES or STEP can be opened in RapidWorks. Once in RapidWorks, the object can be auto-surfaced and solidified as is, or rebuilt using segment, datum, sketch, and solidify tools. The object can then be opened in SolidWorks for further alteration, if desired, and printed as a 3D prototype.

Educational Application of 3D Scanning Technology

The availability of the 3D Scanners is useful to a range of applications. In the ME302 and ME210 Freshmen Engineering Design Graphics courses, the students might use the scanners to aid in their reverse engineering projects. Students often select several irregularly shaped objects such as tool handles, pump or valve bodies, and injection molded body parts. The scanner will aid them in producing accurate solid models of these parts.

Three additional courses receive substantial benefit from the availability of the scanners. The first is ME330 Fluid Mechanics, were students will use the 3D Scanners to create a project teaching stream flow aerodynamics. Model vehicles will be scanned so that students may alter their design and then test the aerodynamics in wind tunnels.

Next is ME366J Mechanical Engineering Design Methodology. This is a junior level course structured for designing mechanical systems. The students develop reverse engineering and redesign projects while focusing on conceptual design. Many of the design projects will benefit from the redesign software available with the 3D scanners.

The final course required for graduation is the senior capstone course, ME226K Mechanical Engineering Design Project. This course involves team projects emphasizing creative design, analysis, selections, development, and fabrication of engineering components and systems. One of the past ME226K projects is shown below where students scanned a cheetah (Figure 8 & 9) and an elephant (Figure 10) to produce STL files from which physical models were prototyped.

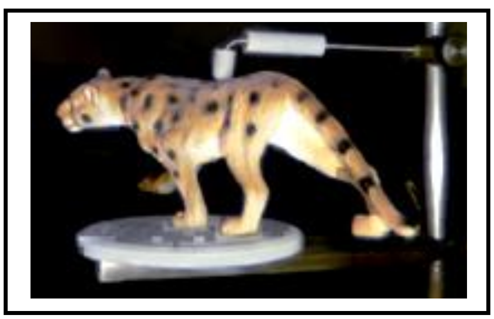

Figure 8 – The Toy Cheetah Ready To Be Scanned

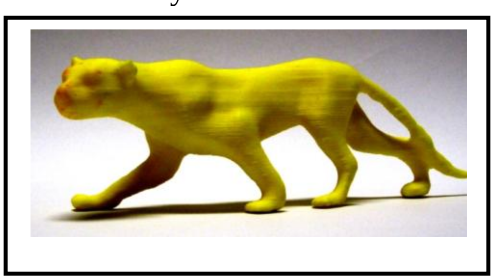

Figure 9 – The Prototyped Cheetah

Figure 10 – The Prototyped Elephant

Conclusion

3D scanners are obviously not the solution for all of solid modeling. They are, however, a valuable tool when it comes to complex and irregular surfaces. In addition to the scanning technology, the scanners also have the capability to find exact surface area and volume measurements as well as finding point-to-point coordinate distances on the object. When comparing the measurements of the original to the prototype, we found less than 1/3 millimeter discrepancy in dimensions (the 3D printing process might have contributed to this discrepancy).

There is a rather steep learning curve for mastering the software, and success in using this technology does not come easily. However, the technology can be very useful once you master the software and uniqueness of data manipulation.

Biographical Sketches

Dr. Thomas J. Krueger

Dr. Krueger is a Senior Lecturer in the Mechanical Engineering Department at the University of Texas at Austin, where he has taught since 1994. He received his B. S. from Concordia Teachers College in 1966 and his M. Ed and Ph.D. from Texas A&M University in 1971 and 1975 respectively. Before coming to the University of Texas at Austin, Krueger taught at Texas A&M University, Brazosport College, and Southwest Texas State University.

Kendall S. Berns

Kendall is a junior level undergraduate student in the Mechanical Engineering Department at the University of Texas at Austin. She has spent the past three months learning how to use our 3D desktop scanners and developing ways to make them useful for other engineering students. Kendall continues to pursue her interest in her chosen technical area of Design and Manufacturing at UT with an intended graduation date of May 2012.