3D Laser Scanning in Technology Education

A hands-on experience with 3D scanning can enhance learning by captivating students' interest and empowering them with creative tools.

Introduction
It is ironic that as technology education has forcefully embraced the need to teach about design, high-tech design tools are often overlooked. Understandably, pencils are more economical than holographic hardware and software, yet the technology of design cannot be overlooked. This article looks at how one piece of high-tech design equipment, a three-dimensional laser scanner, can be used as a tool for design and problem solving in technology education. Students are bombarded with solid models and virtual realities in video games and animation; a hands-on experience with 3D scanning can enhance learning by captivating students' interest and empowering them with creative tools.

Among the technological tools modern product designers use is a three-dimensional digitizer or scanner. A contact digitizer allows a designer to place a pointer on a model or a part, and to read into a database the coordinates of the pointer. By taking readings at many different locations, it is possible to construct a database with enough points so that a wireframe representation of the object can be made.

A more advanced version of the digitizer does not even contact the part. Instead, a beam of laser light is aimed at the object's surface, and a photo sensor known as a Charged Coupling Device, or CCD, picks up its reflections. Non-contact laser digitizers are often much faster, but they do have limitations. The laser beam travels in a straight line to the object, but it reflects back toward the CCD in a different straight path. If either of these paths is obstructed, the digitizer will be unable to correctly digitize a surface. This happens frequently with items such as S-shaped tubing, the spaces behind a human ear, and undercut areas on a host of consumer products.

Still, the digitizer is very useful in transforming surface information from a physical object to a virtual environment. Once in a computer, the virtual part can be manipulated in many ways. It can be stretched or compressed, twisted or drilled, made any size, and duplicated as needed. The virtual part can have any spatial orientation, and a variety of surface textures can be applied. It can be put into a virtual scene, with realistic backgrounds, lights, and shadows. But how can this be used?
One example is provided by starting with a tiny clay model of a car. It is possible to digitize the model to get a wire-frame drawing; the virtual car can be processed by surface modeling and by altering its size and orientation to be included in a computer-generated animation for a television commercial. In another example, a part that caused an engine to fail could be scanned, and an animated computer simulation could be used to test subtle variations in an attempt to solve the problem. What if a company has an old part and needs a replacement, but there are no drawings? That part could be scanned and new drawings could be created from the part. The company could also attempt to trace back the production processes that produced the part; this is referred to as reverse engineering. Students interested in paleontology may wish to scan fossils, creating virtual images of bones and shells that can be surface textured, virtually assembled, and animated. Classroom teachers can also use 3D scanning to show off student work; after a student creates a small product, it could be scanned, and an animated GIF file could be uploaded to a class website.

There are many examples of 3D digitizing products; some of these are more artistic and some are more technical. Examples of scanned sculpture applications can be seen at the website of Miles and Genaris Studios (www.mgsstudios.com/modeling.htm). Wohlers (1995) discusses engineering applications of 3D digitizing, and Laser Design Inc. has examples of 3D scanning used in rapid inspection, quality control, reverse engineering, rapid prototyping, and CNC toolpath generation at http://laserdesign.com/applicat.htm. The manufacturers of laser scanners seem to try to showcase their products by highlighting a host of varied applications, as does Digibotics at www.digibotics.com/3Gallery.htm.

Hardware, Software, and Process
A 3D laser digitizer was recently purchased at Ball State University so that technology education majors and others could gain firsthand experience with this design tool. There are a number of manufacturers making 3D digitizers, and Ball State purchased one of the least costly of these: a small desktop model (M-15®) from Cyberware® (www.cyberware.com), which sells for $22,900. It included digitizing software, but a computer and 3D modeling software (3D Studio Max®) were additional purchases.

After about one hour of instruction, students are able to scan the surface geometry of small parts and models (Figure 1). Each model requires a series of straight-line passes, and the model rotates slightly between passes.

Figure 1. Nick Cames, a Ball State student, working on the 3D laser scanner.

These 8 to 36 passes are then cleaned of extraneous data and automatically assembled. However, this still results in many voids (such as on the top of an object where a lateral laser beam does not reflect.) The model is then reoriented on the scanning table, and another series of scans is made. It took one to three sets of these scans to capture the surface geometry of the models shown here.) These series are then automatically assembled, and the resulting virtual model can be edited and saved in a variety of formats.

3D Studio Max® is the modeling software used to reshape the model, apply surface textures and colors, resize the model, duplicate or mirror the model, and to place the model in a scene. Other modeling software is available from a variety of vendors. The scene may be virtually generated, or made using digitally photographed images. Camera angle, lighting, and special effects, such as fog, can be used to create more dramatic settings. Students can then render these scenes as still graphic images, which may be printed, used in documents, or uploaded to the Internet. Furthermore, they can animate these scenes, showing the full three-dimensional aspects of the models.

Sample Activity: A New Approach to Monument Design
One typical way for students to engage in technological design activities is to follow a design brief, which would outline a design task and steps to accomplish that task. There are many examples of this in the technology education literature; one particular design problem on monument design was developed by Richard Seymour (1997) and the Center for Implementing Technology Education (CITE). Students can use this informative, and eye-catching brochure to guide them through the process of designing and building a model of a new "monument on your school grounds that will honor an individual, team, or event" (p.4). Seymour specifies the following steps for students to engage in during this activity:
1. Identify the person or event.
2. Identify the site for the monument.
3. Gather information about the person or event.
4. Sketch a plan view of the site for the monument.
5. Sketch a pictorial view of the site for the monument.
6. Sketch three different monument designs.
7. List the advantages and disadvantages of each of these three designs.
8. Sketch a final design for the monument.
9. List the materials needed to build a model of the monument.
10. After the instructor approves the list, build the model.
11. Evaluate the solution.

Modifying Seymour's activity to take advantage of 3D laser scanning technology results in the following steps:
1. Identify the person or event.
2. Identify and take a digital photograph of the site for the monument.
3. Gather information about the person or event.
4. Using modeling clay, create a model for the monument, where the shape has a message. Multiple models may be created (Figures 2 & 3).
5. Use the 3D scanner to capture the surface geometry of the model (Figure 4).
6. Manipulate the virtual model's surface (Figure 5).
7. Create a virtual scene for the model with proper lighting, shadows, materials, and the site background (Figures 6 & 7). (Several may be created with different surface materials, monument sizes, etc.)
8. Render the scene(s), and print out a hard copy. (A variety of view angles can be rendered. Rendered still images can also be uploaded onto a web document.)
9. With the help of others, evaluate the design of the monument. This approach represents a near reversal in the typical approach taken in modeling design solutions. Whereas students might normally begin with orthographic and pictorial sketches, then proceed through more refined drawings, and finally arrive at a three-dimensional model, this approach begins with the three-dimensional model. If necessary, drawings can be derived from that model at a later date. Depending on the software used, students may be able to generate animated fly-throughs, showing how their designs would look to a person walking by, for example.

There are distinct advantages and disadvantages of this new approach. One of the biggest disadvantages is the expense and present unavailability of the hardware and software. Also, students must gain a certain level of familiarity with these tools in order to use them effectively. Students do not practice their sketching skills as much as
with a more traditional approach. Also, it may be time-consuming to scan models. Finally, some objects are not good candidates for scanning due to undercuts and surfaces where a laser beam might enter, but from which it cannot reflect back into the scanner.

However, this approach is undoubtedly more attractive to students, who are regularly bombarded with virtual worlds in video games. It gives them control over a virtual scene. It lets them experience a newer technology. It's cool. The modeling capabilities in a virtual world are vast and diverse, empowering the students to present their ideas in professional and realistic ways, or even in fantasies.

**Conclusion**

Three-dimensional scanning may be a technology that is too costly for most technology education programs. High schools that cannot afford this technology may be able to give students hands-on experiences by forming partnerships with universities, professional design firms, manufacturers, or companies involved in animation. As with other digital optical equipment, prices of 3D scanners are expected to decrease.

The three-dimensional scanner is a high-tech tool of the current technological world, and can be used to empower students, instilling in them a greater sense of their own design capabilities. It can help integrate technology, design, art, and science, while capturing students' interest.

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**References**


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