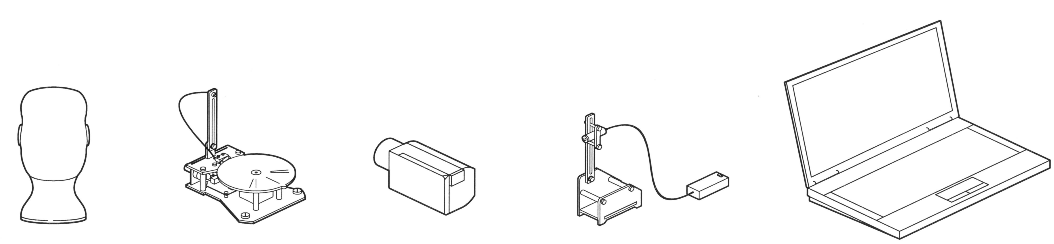
TriAngles™

3D Circumference Scanner

V1



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Tri Angles 3D Viewer Version 1 Release 2 SOFTWARE
Tri Angles 3D Builder Version 1 Release 2 SOFTWARE
Tri Angles 3D Circumference Scanner Version 1 Release 1 SOFTWARE
Tri Angles rsd Editor Version 1 Release 1 SOFTWARE
Tri Angles Turn Table, Laser Support Stand DESIGN
3D Circumference Scanner; Operations Manual Version 1 PUBLICATION

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Tri Angles 3D Circumference Scanner, Version 1 IntriCAD
Tri Angles; 3D Scanner, 3D Builder and 3D Viewer rsdEditor IntriCAD

DO NOT LOOK INTO LASER BEAM

3 Worlds
now exist; the real world as we know it, the world of our imagination and the world that we have created within our computers.

While each world offers almost endless possibilities their collective limitation resides in the ability to efficiently and effectively
***interact**.*

Introduction

Drawing a 3D cube in your favorite graphics program is an easy task by today's standard. But try drawing something more intricate like a face, a car a medallion or some other complicated shape. Chances are that this will be a difficult task to complete. Fortunately there are other ways to accomplish this. Probably one of the most impressive solutions is to use a 3D scanner.

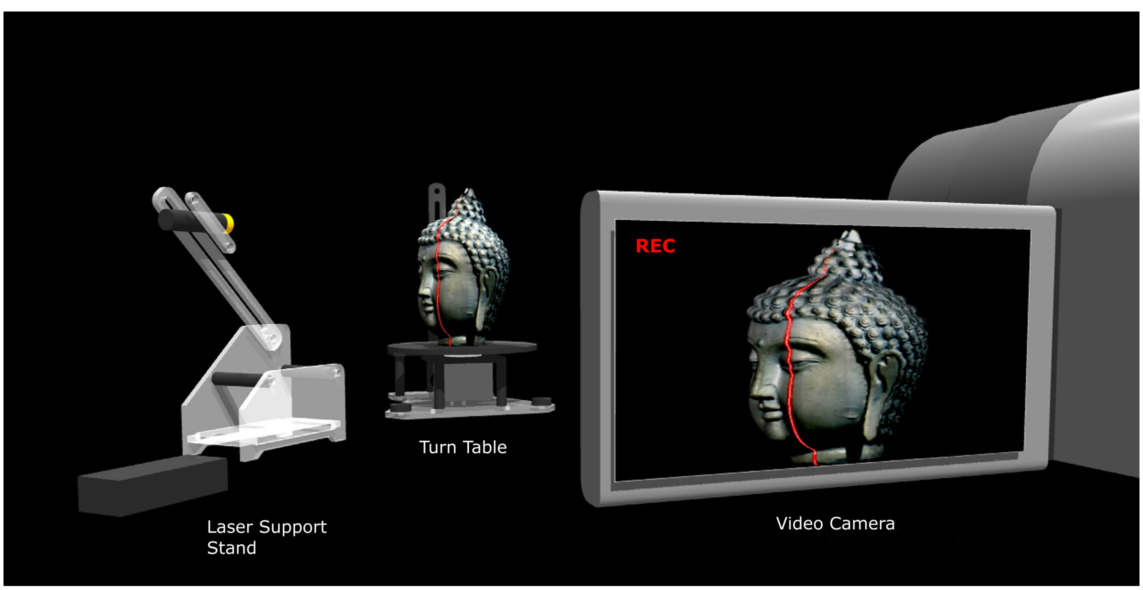
3D scanning offers the means to take a tangible object and automatically convert it into a 3D computer model through some or other technique. The basic idea would be to have an apparatus detect enough points of an object in 3 dimensions and convert this into information that would allow a computer to display the object as a 3D model. Once it's in the computer you can modify it in almost anyway.

However, unlike 2D scanning, entering the third dimension is somewhat of an art. 3D scanning is not a trivial task to perform as many factors contribute to the integrity of the scanning process. It is important to clearly understand how these factors can influence the scan process and how they should be adjusted accordingly in order to permit the best scanning conditions possible. This product provides the platform to get started. Naturally, your most important tools will be your attention and patience.

There are many kinds of 3D-scanner technologies in existence. The technology developed here includes a non-contact, circumference type 3D scanner. Non-contact meaning that the object is not touched during scanning as the scan technique is based on a visual acquisition process. Circumference means that it scans around an object. Apart from the supplied hardware, the basic setup requires things that must of us already have such as a video camera, tripod and a computer with a video interface.

The chosen design concept is based on various criteria. One of which is to bypass the economical constraints and electrical/mechanical complexities usually coupled with an apparatus of this type while providing high quality scanning capability. An added feature is that this scanner not only scans objects but also an object's texture. The result is a 3D-scanner package that can approach the accuracy of mid range scanners and will permit scans to be made with texture in less than 2 minutes! Better yet it does not cost thousands of Dollars. In fact this is probably one of the best cost to performance scanners on the market today.

IntriCAD Amsterdam 2007




TriAngles
3D Scanner
Object
Scan
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Export
DXF STL VRML OBJ
Texture
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Getting started

This section provides a quick overview of the basic set up and conditions required to making your first 3D scan. The next section titled "Maximizing the Scan Process" provides a more detailed overview of the process and technology.

3D scanning can be complex as many, seemingly trivial, factors can negatively influence the quality of a scan. While this section provides a quick way to get started it is important to read through the entire manual to get a complete overview. This will save time and lead to better scanning results.

1 Product Overview

The full TriAngles 3D Scanner package includes some sophisticated software programs and hardware.

1.1 The Software

- **3D Circumference Scanner**. Video interface and processing functions to acquire the object and texture scan.
- **RSD Editor**. Allows editing of the scan lines before building the 3D model.
- **3D Builder**. Processes Raw Scan Data from the scanner to create the 3D model and allows for export to popular 3D file formats like STL, VRML and OBJ.
- **3D Viewer**. Allows viewing of 3D scanned models in a compressed native file format as well as export to popular 3D file formats. Free to distribute (license applies).

1.2 The Hardware

- **Turn Table**. Precision rotating platform onto which object is positioned on for scanning a full 360 degrees.
- **Laser Support Stand**. Supports the positioning of the adjustable focus laser module which projects a scan line over the object to scanned.

1.3 What you Need to supply *

- **Camcorder**. Preferably DV type with FireWire connection, remote and picture stabilization. Requires manual iris control and manual focus.
- **Tripod**. To support the Camcorder.
- **PC**. High end system with OpenGL supported graphics card and FireWire connection
- **Halogen Lamp**. For texture scan of object.

*** Consult "Absolute Base Requirements" section for full details**

2. Process Overview

The TriAngles 3D scanner permits several ways to process a scan. One important features of the product is that it actually does not require a PC during scanning. You can simply record your scans and then process the video at a later time.

Explanations in this section will focus on the recommended method to capture a scan. Basically, we are going to record the scan on a camcorder and then process this video to eventually reveal the 3D model of the scanned object.

Room lighting is switch off or set to very low as ambient light will otherwise influence the scanning process. The object to be scanned is positioned onto the Turn Table and a vertical laser line is projected onto the object. The laser line remains stationary while the object turns. The object turns a full 360 on the Turn Table and the camcorder is used to capture this. In case the texture of the object is to be included then a second pass is made. The captured video is then processed by the 3D Scanner software which produces a raw scan file. This file is then further processed by TriAngles 3D Builder to produce the 3D model which is ready for export.

2.1 Calibration

1. The Laser is setup and aligned with the Turn Table. The camcorder is setup at and angle to the laser. An object to be scanned is positioned onto the Turn Table and is centered in the camera's field of view.
2. The object is then carefully removed and a calibration surface (O1) is placed onto the Turn Table. This is done to view the exact center of rotation of the Turn Table. The software will need to know this in order to build the 3D model. This is briefly recorded by the camcorder (10 seconds).

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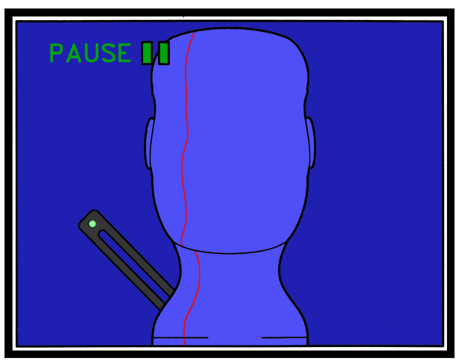

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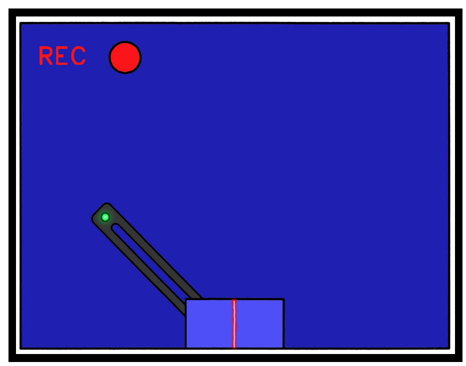

2.2 Object Scan

1. The calibrator is then replaced again by the object. The Turn Table is switched on to rotate the object.
2. The camcorder is set to record.
3. During turning, the indicator LED on the Turn Table will automatically switch OFF. This indicates the scan start position. The object continues to rotate.
4. The indicator LED will light up again after the object has made a complete 360 degree turn. This indicates the end of the object scan. Unless a subsequent texture scan is to be made the recording may be stopped.

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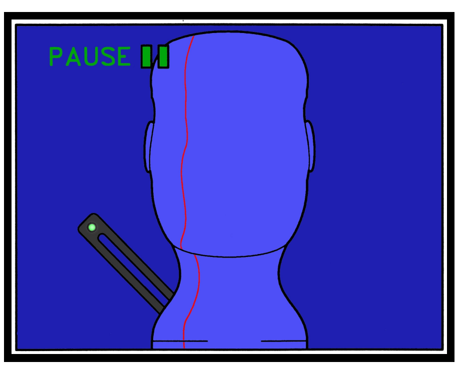

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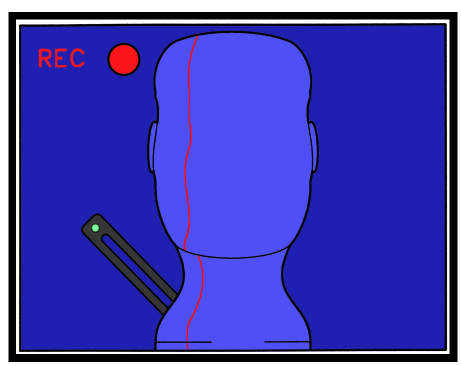

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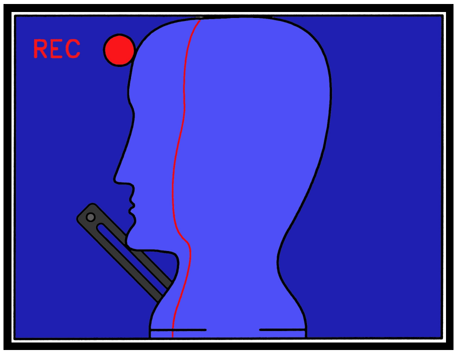

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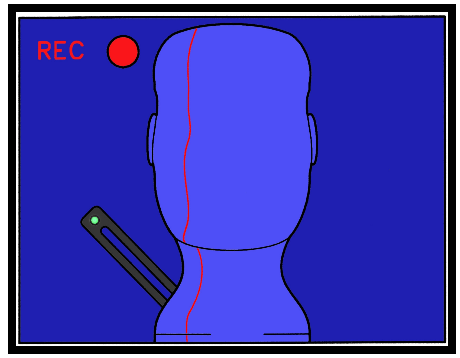
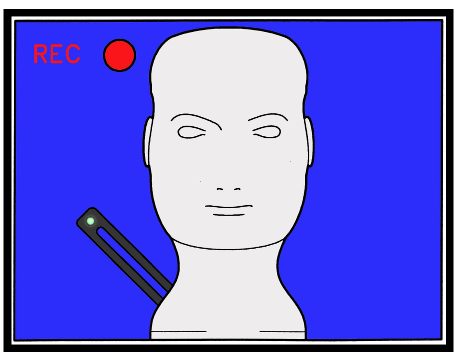


2.3 Texture Scan

1. While the object is still turning the ambient lighting is switched ON for texture scanning of the object. Usually room lighting and a halogen light is used for this. The laser is switch OFF.
2. The indicator LED switches OFF which marks the start of the texture scan.
3. The object continues to rotate while being recorded.
4. The LED indicator goes ON indicating that the full turn has been made. Recording can now stop. The captured video can now be processed.

1



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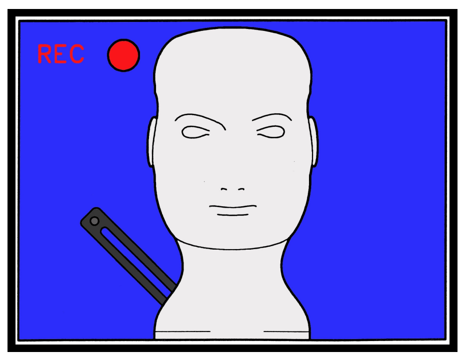

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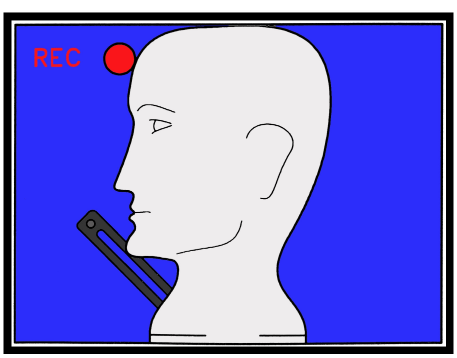

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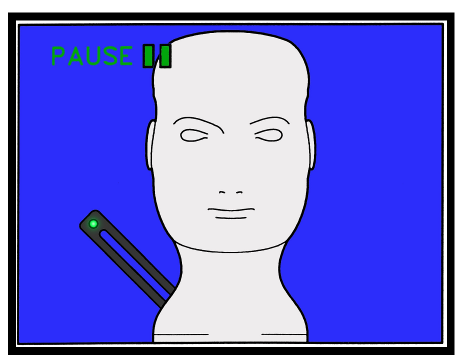
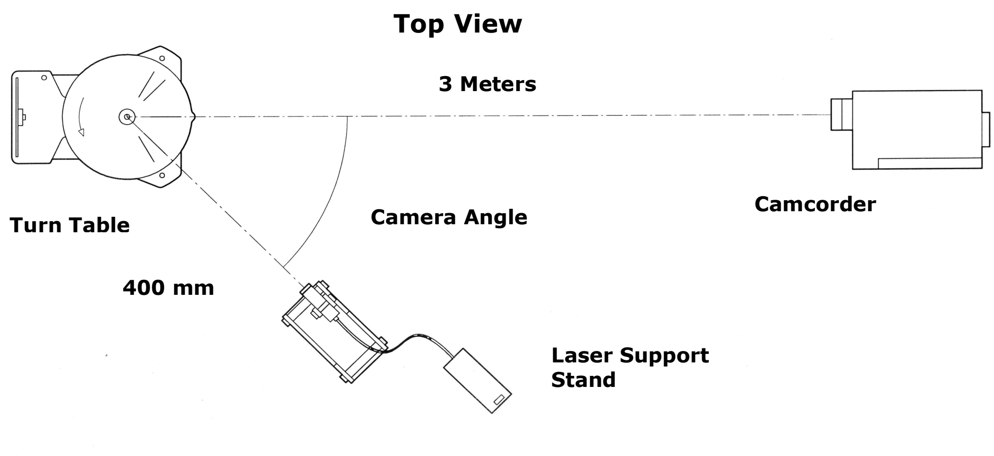


3. Scan Session Setup

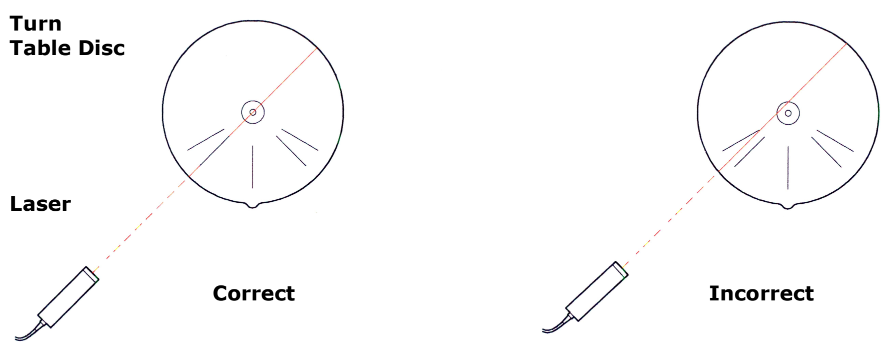
The following explanations presume that the Turn Table and Laser Support Stand have been assembled and tested. Low lighting conditions are required as ambient light affects the scan process. Choose a dark room to perform the scan. The setup should not be disturbed once positioning and settings of instruments and camera have been made. Unpredictable scans will result otherwise.

3.1 Positioning the Turn Table and Laser Support Stand

Place the Turn Table and Laser Support Stand on a flat leveled table. Position as depicted in the drawing below. Hook up the Turn Table to the power supply. The speed setting should be 45 seconds for a full turn. Switch the device OFF after setting the speed. Pay attention to the Turn Table disc turning direction. Turn the disc's engraved lines to orientate as depicted in drawing.



The angle between the camcorder and Laser Support Stand is 45 degrees. Place the Camera on a tripod at about the distance indicated in the drawing.

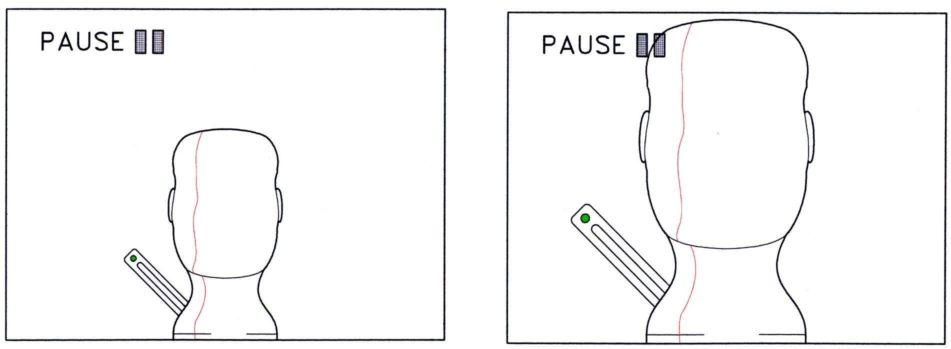


Make sure that the laser line shines exactly over the engraved line of the Turn Table disc as depicted in the above drawing.

3.2 Choosing the Object

As a circumference scanner, objects which are more or less circular in shape tend to make better scan models. The object to be scanned may not be transparent; it should have a mat or flat surface (not glossy) and, preferably, have light colors. Hold it in front of the laser to make sure the laser line projects a distinctive line over the objects surface. The line should not show up as a fuzzy or as a highly blurred line. The software will have trouble identifying it otherwise. Later on in the next main section of this manual you will learn more about how to get the most out of the objects that you want to scan with this type of 3D scanner.

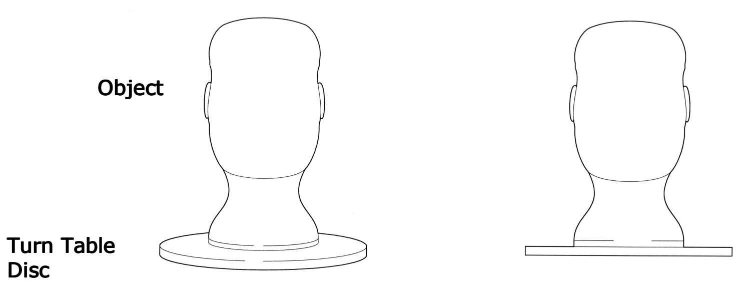
3.3 Setting Up the Camera



Incorrect **Correct**

As depicted in the previous drawing, the distance between the Turn Table and camcorder is about 3 meters (3 yards). Typically, this will require some degree of zooming. Zoom is important since the farther the camera is from the object the more zoom will be required the more **flat** the image will be. The flatter the image the better the shape accuracy of the resulting 3D model will be. At the same time the depth of focus range (DOF) will increase resulting in a better focused image of the object (do not use digital zoom this will only degrade the resolution of the resulting scan).

To take full advantage of the camcorders resolution, maximize the image of the object in the camcorders field of view. The above drawing displays this.



Incorrect **Correct**

The height of the camera must be set to permit the frontal image of the object to be viewed. This is depicted in the illustration above. The illustration on the left shows the image of the object too low in the cameras field of view. The right illustration shows the image that would be seen if the cameras lens center is at the same level as the objects center.

As mentioned in previous sections the camcorder must have a manual focus and iris or at least have the option to fix set these. Scans will fail in case the camcorder starts to auto focus or change its iris settings during scanning.

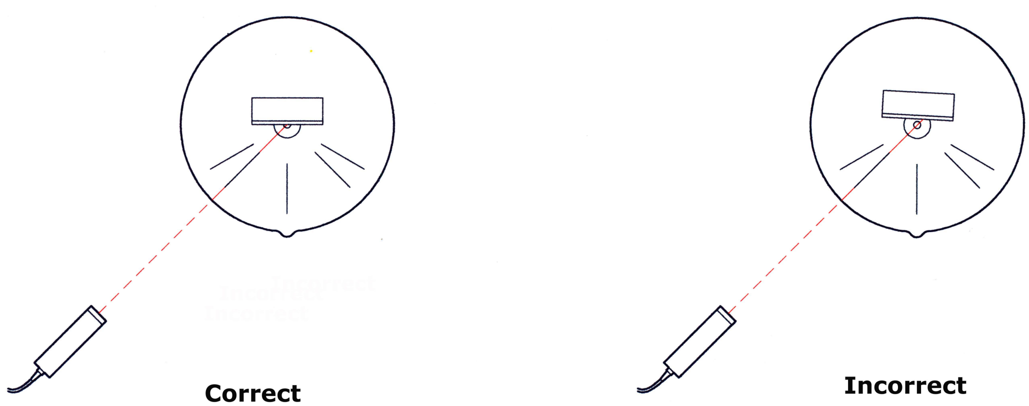
The camcorder should also have a remote. Upsetting the cameras set position during or in-between scanning can lead to shifts in the resulting object scan and/or texture scan. By using a remote the camera will not have any chance of being disturbed.

3.4 Setting the Texture Lighting

While the object scan is made in dark conditions, with only the laser lighting the object, the texture scan will require lights. Position a halogen lamp in front of the object without obstructing the view of the camera. Highlights and shadows on the object should be made minimal. Search for the best position to minimize this. Multiple lights may be required. Make sure that the camcorders iris is not set too much open (over-lighting).

4. Video Capturing a Scan

With the hardware set up its time to make a scan of an object. Turning the Turn Table disc is now permitted since the camera and other instruments have been set. However the Turn Table, Laser stand and Camera position should not be moved at all. Carefully remove the object off of the Turn Table and position the calibrator onto the Turn Table. The drawing below illustrates the correct positioning.



Video record for about 10 seconds the calibrator on the turn table. The laser line on the calibrator must be clearly visible. Replace the calibrator with the object.

In case the LED indicator is OFF, click the roller switch once to set it ON. Turn down/OFF the room lighting. Switch ON the Turn Table and directly afterwards also set the camcorder to record. At one point the roller switch will engage and the LED indicator will switch OFF.

After the Turn Table disc has made its full turn (LED indicator lights up again), switch ON the halogen light to begin the texture scan. The process is same as with the object scan. Stop the recording once the LED indicator has switched ON again after a full turn.

5. Processing the Captured Scan

The following explanations will require that a Camcorder-PC connection (FireWire IEEE 1394) is established and that an AVI file is made of the captured scan using TriAngles. After adjusting certain settings the AVI file containing the captured scan will be processed to create an RSD file. This is the Raw Scan Data which will be used to build the 3D model of the scanned object in TriAngles 3D Builder.

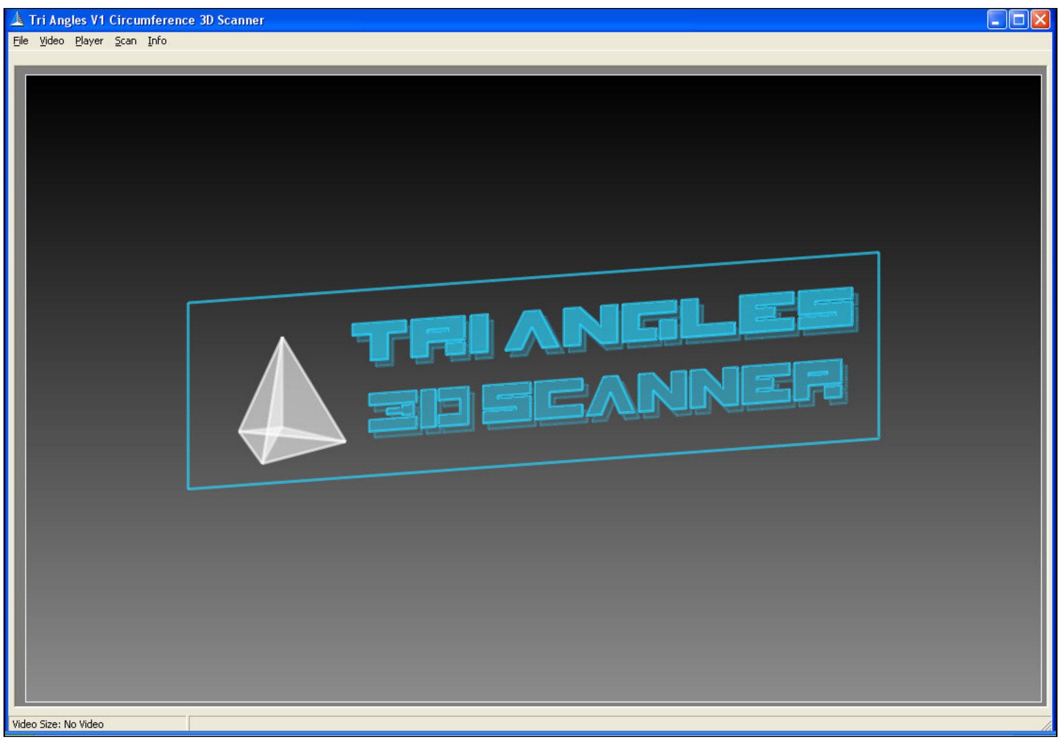
5. 1 Connecting the Capture Device to the PC

TriAngles offers several ways to interface with your camcorder (Video In, USB, etc). However the type that will be used here is a FireWire interface. FireWire offers the highest level of integrity and functionality available. In case you chose for another type of connection or not you must install the cameras supplied drivers and test your camera before proceeding. TriAngles will piggy back on the driver used and provide its functionality within the application.

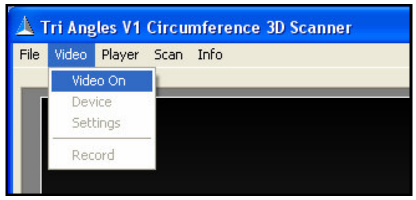
Turn the camcorder OFF. Establish a FireWire connection between camcorder and the PC. Switch ON the camcorder and set it to its playback position.

5.2 Creating an AVI file of the Captured Scan

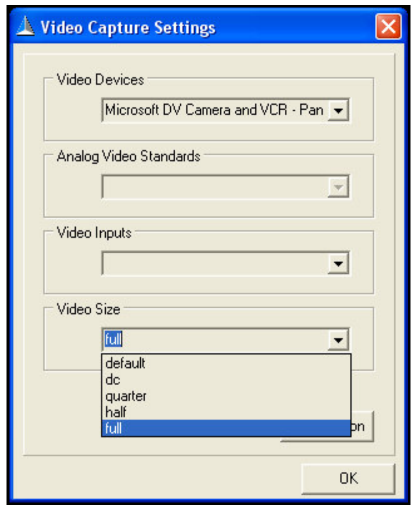
Run TriAngles 3D Circumference Scanner. At start up TriAngles shows a rotating log banner in its main window. This is a real time rendering that serves to benchmark the computer. In case the logo rotates in an erratic or jittered fashion or very slow then this may be an indication that the computer used does not posses the required performance to process the scan. This is important as the processing of the scan is time dependant. The following explanations presume that the PC used to process the scan meets specified requirements.



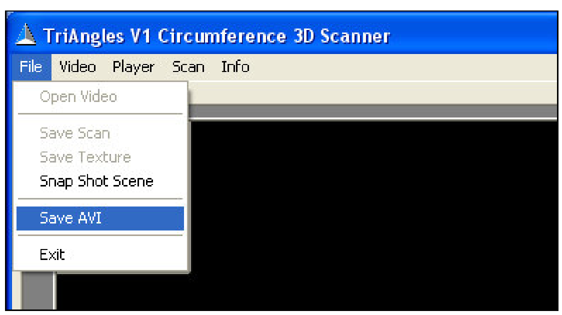
Click Video in the applications main menu and choose Video On. The camcorder should now be linked with the application.



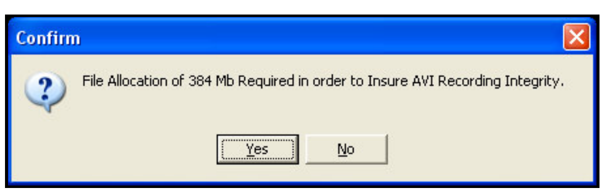
Click on Video again and choose Settings. Make sure that Video Size is set to Full in this menu. Setting to Full will set the camcorders video to its highest resolution.



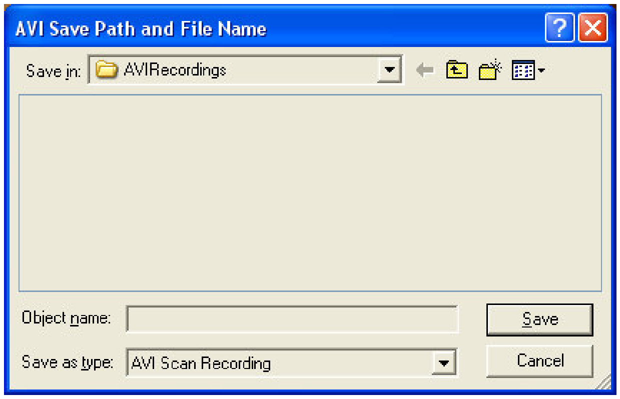
Click on File and choose Save AVI. This is a short procedure to pre allocate the file path for saving the recorded AVI file.



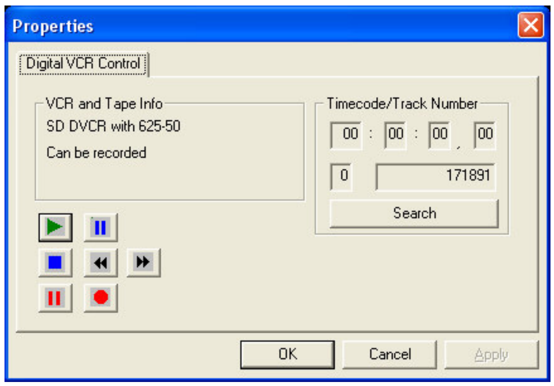
A message will appear requesting the allocation of disc space for recording. Press Yes. This process will only take a few moments to complete.



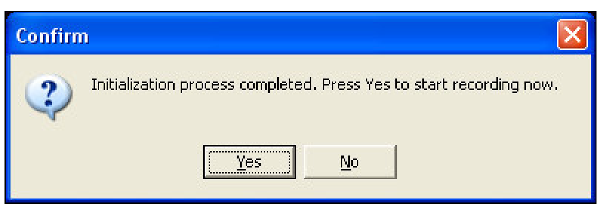
Once this is completed a Save Dialog Box will appear. Choose a file name and destination path and press Save.



Click on Video again and choose Device (a native dialog will appear that may differ from the screen shot presented in this manual). If your camera supports software remote control then TriAngles will be able to remotely control the camera using a dialog like this.

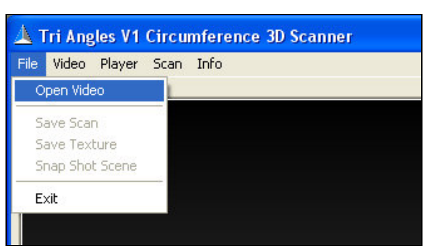


In the Device Properties menu rewind the recorded scan to at least 1 minute before the scan starts and press the Play symbol in Device dialog. Close the dialog, click Video and choose Record. A message will appear shortly after to start recording. Press Yes. Record the entire scan, including the recording of the calibrator scene. To stop recording, click Video and choose Stop.

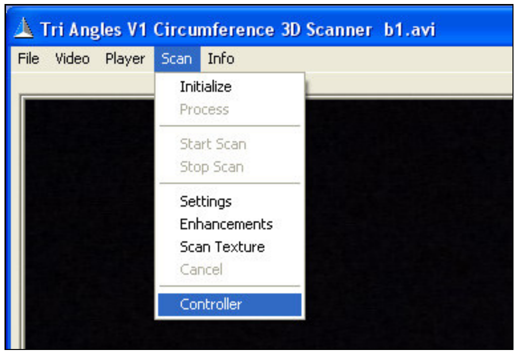


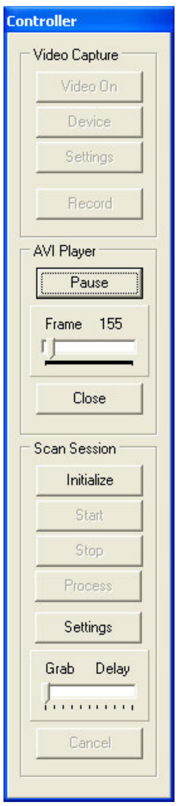
5.3 Allocating Memory for Processing of the Captured Scan

Now that an AVI of the captured scan is available click File, Open Video in the main menu of TriAngles. This will bring up the Open Video dialog. Open the captured scan AVI.



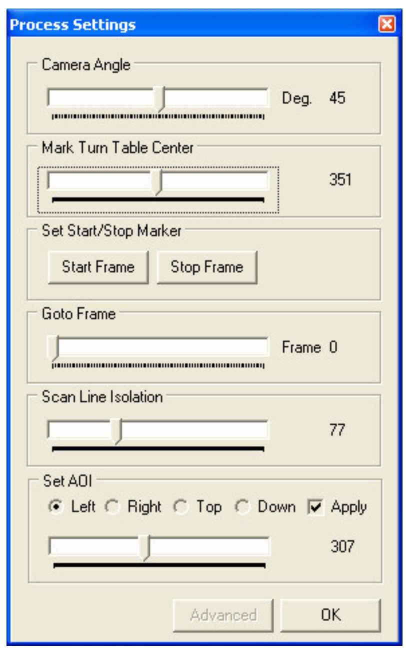
The AVI will play in the applications main window. Click Scan in the main menu and choose Controller.



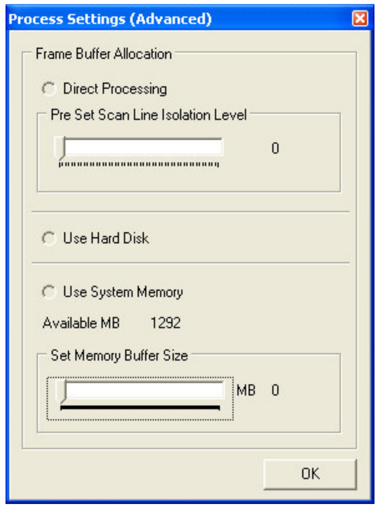


The Controller menu includes the main options and controls. It reflects the main menu controls with some additional options. The Video Capture group box includes items already acquainted with. The others will be discussed later.

Press the Settings button. This will present the Process Settings dialog.



Press the Advanced button on the Process Settings dialog.



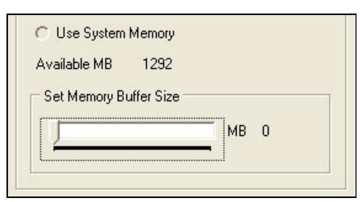
The Frame Buffer Allocation needs to be set. In order to process the AVI of the captured scan, separate frames will need to be grabbed of the scan. Many frames will be needed. These frames need to be temporarily stored somewhere prior to processing. There are three options to do this.

1. **Direct Processing.** This option primarily uses the CPU. The load on other system resources is minimal but it has the lowest level of scan process integrity.
2. **Use Hard Disc.** This uses the system's HDD (fast disc required) and results in medium level processing integrity of scans.
3. **Use System Memory.** Requires maximum system resources and results in the highest level of scan processing integrity.

Direct Processing uses the systems CPU and is very time dependant. The CPU should be at least 2GHz of faster or dual core. Storing grabbed frames on the hard drive includes a read/write penalty which can affect the quality of the resulting scan. This option should only be employed for high-end drives that run at speeds of 7200 and higher. The benefit of using the CPU or hard drive is that the system memory size does not have to be that large. Initialization is also almost immediate.

However the recommended choice is to use system memory which permits much faster reads/writes than a hard drive and leads to higher frame grabbing rates. The result is a scan that has a higher degree of quality. The penalty is the required memory size. A Typical scan will yield about 400-600 frames. That's about 750 mb of data that needs to be uploaded to memory at real time rates. You will need to have at least 1.5 GB of system memory available to do this.

To determine the max amount of memory you will be able to use simply slide the Frame Buffer Allocation slider to the right.

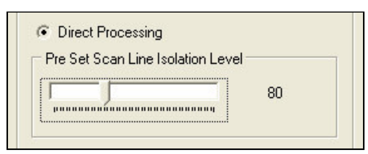


At one point the following message box will appear:

The amount of memory at your disposal should be at least 1 GB. If it is not, close any other applications running and check again. Press OK and then press OK to close the Process Settings dialog.

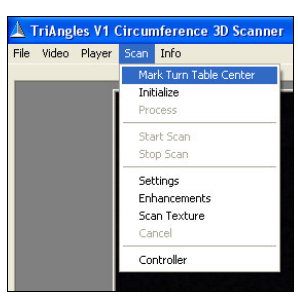
TriAngles also includes a way to reduce the dependency on memory by reducing the amount of frames grabbed. This will however also reduce the circumferential resolution of the scan. The way to set this can be found in the Scan Session group box of the Controller which includes a slider labeled Grab Delay. This slider controls the grab rate delay. Moving the slider to the right will increase the delay time between grabbed frames. Set this to 3 for now.

While your PC may be capable of processing the video using the system memory option it is probably best to first start using the Direct Processing. Direct Processing is the safest way to process a scan. Choose this for now and set the Pre Set Scan Line Isolation Level to about 80.

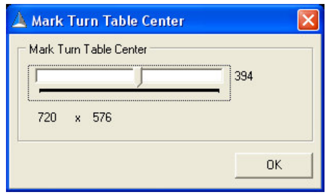


5.4 Marking the Rotation Axis Center

In the AVI Player group box of the Controller form slide the slider to the scene which includes the recording of the calibrator (this is the scene were the laser is seen on the angle piece that was centered on the turn table). Keep the scene Paused here. Click Scan on the main menu and choose Mark Turn Table Center.

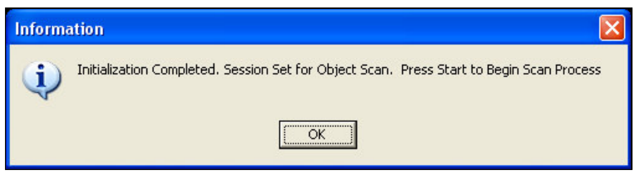


This will bring up the Mark Turn Table Center Menu which includes a slider. Move the slider to the right and a green vertical line will appear. In order to inform the software where the Turn Table center of rotation is move the vertical green line and position it exactly over the vertical laser line stripe on the calibrator and press OK. The alignment is now set.



5.5 Processing the Captured Object Scan

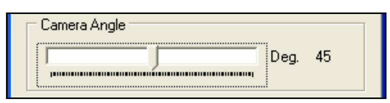
With the Frame Allocation set to "Use Hard Disc" or "Direct Processing" press the Initialize button in the Controller dialog Scan Session group box. The system resources will now be allocated to TriAngles. This will take a few seconds to complete and as much as minute in case "Use System Memory" is chosen. Once completed, the following message will appear.



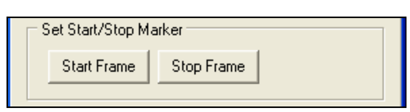
Make sure it reads **Session Set for Object Scan** (if not, Press Cancel, click Scan in the applications main menu, uncheck Scan Texture and the repeat the Initialization).

Slide the AVI Player slider to the start of the actual scan starting point. This is the point where the LED indicator switches Off for the first time. Read the frame number and slide the slider a few hundred frames back. Press the Play button. Press the Start button as soon as frame count is about 20 frames away from the point where the LED indicator switches Off. TriAngles will now start grabbing frames. The amount of frames grabbed can be read on the status bar located at the bottom of the application. At one point the LED indicator will switch ON again. When this happens press the Stop button. In case during the process the PC runs out of memory then a message box will appear stating that the maximum amount of grabbed frames has been attained. Should this occur then set the grab rate to a higher setting and start the object scan process again.

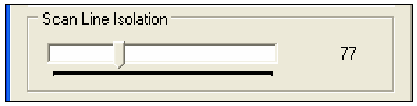
The Process Settings dialog will appear once the Stop button is pressed. Set the Camera Angle slider to 45 degrees.



Slide the Goto Frame slider to exactly one frame after the LED indicator switches OFF. Press the Start Frame button in the Set Start/Stop Marker group box. This tells TriAngles to mark this position as the rotation start position. Go to the end of the scan by sliding the Goto Frame slider to the right. Position one frame before the LED indicator switches ON and Press the Stop Frame button in the Set Start/Stop Marker group box. This set the end of rotation position of the scan.



The last group box in the Process Settings dialog contains the Scan Line Isolation slider. Slide this to left and then slowly to the right. Notice that groups of green pixels start to align with the scan line as you move the slider to the right. Adjust to a position that best aligns the green pixels with the laser scan line on the object. The setting should reside somewhere between 60 and 120. This setting adjusts the level of sensitivity that TriAngles will use to identify the laser line.



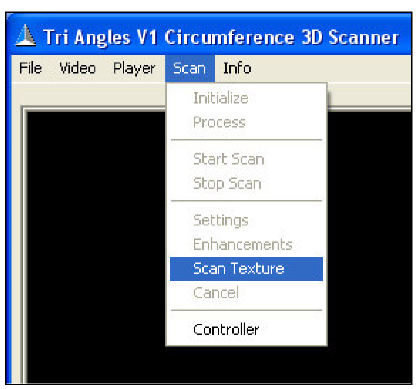
Setting the AOI Clipping Area allows you to restrict the processing of the scan to a defined area of the video. This will not only reduce scan processing time but will also reduce the chances of false registrations due to video noise and any light reflections of the laser on surrounding surfaces other than the object. It also allows you to clip areas that are not desired. It is always highly recommended to use this function in order to achieve the best possible scans.

To use this function simply check the Apply checkbox and choose which area you want clipped; Left, Right, Top or Bottom. Use the slider to position the white lines which define the clipping area. The area outside the clipping area (white box) will be ignored during processing.

Press OK on the Process Settings dialog. On the controller form press the Process button. The grabbed frames will now be processed one by one. The progress can be read on the status bar located at the bottom of the application. Once the process completes a Save dialog box will automatically appear. Choose a file name and destination and press Save. This will save as a raw scan data file.

5.6 Processing the Captured Texture Scan

The processing of the Texture scan is the same procedure as that of the object scan. But instead of an rsd file the texture scan will produce a bitmap of the objects texture. Set the Grab Rate to 0. Click Scan in the main menu and choose Scan Texture.



Press the Initialize button. Wait for the process to allocate the memory and press OK at the Initialization Completed message. Slide the AVI Player slider to the start of the actual texture scan starting point.

This is the point where the LED indicator switches Off for the first time. Read the frame number and slide the slider a few hundred frames back. Press the Play button. Press the Start button as soon as frame count is about 20 frames away from the scan start frame point. TriAngles will now start grabbing frames. The amount of frames grabbed can be read on the status bar located at the bottom of the application. At one point the LED indicator will switch ON again. When this happens press the Stop button. In case during the process the PC runs out of memory then a message box will appear stating that the maximum amount of grabbed frames has been attained. Should this occur then set the grab rate to a higher setting and start the texture scan process again.

The process Settings dialog will appear once the Stop button is pressed. Slide the Goto Frame slider to exactly one frame after the LED indicator switches OFF. Press the Start Frame button in the Set Start/Stop Marker group box. Go to the end of the scan by sliding the Goto Frame slider to the right. Position one frame before the LED indicator switches ON and Press the Stop Frame button in the Set Start/Stop Marker group box. Press OK on the Process Settings dialog.

On the controller form press the Process button. The grabbed frames will now be processed one by one. The progress can be read on the status bar located at the bottom of the application. Once the process completes a Save dialog box will automatically appear. Choose a file name and destination and press Save. This will save a bitmap of the texture that was captured.

5.7 Creating the 3D Model

The object (rsd file) and texture (bmp file) scans processing is now completed. The basic process should now be clear. The next step is having the data built into a 3D model. This is done in Tri Angles 3D builder (how to do this is included in a separate manual).

There is a good chance that the scan was a success. Still, there is a lot more to making good scans. The following section will take a closer look into what’s involved.

Maximizing the Scan Process

3D scan technology has been around for many years. Despite this, the technology has not been accessible for most of us. The 3 main reasons for this have to do with the level of complexity involved, the available computing power to process and display the data and, more over, the very high costs of the required instruments and product development. That changes with TriAngles.

Like any technology a 3D scanner is a tool that offers some impressive solutions. But it's important to keep in mind not only what 3D scan technology can do but what it can't do as well. Facilitating a better understanding of the technology will in turn allow you to better determine what can be expected from a scan or, more importantly, how to maximize the scan process to get the best possible results.

3D scanning can be complex as many factors contribute to the quality of a scan. In fact the technology can be considered somewhat of an art since there are so many different ways to scan an object. Also, most all 3D scanners rarely yield the finished product and more often than not require some degree or more of post processing.

The following chapters provide a more in depth overview of the technology than the preceding chapters. The incentive is to provide you with the basis to make better scans as well as make modifications to the hardware that may better suit your scanning needs.

6. What is a 3D Scanner?

A practical definition of 3D scanning technology is that it entails the process of converting the 3D geometric shape of a tangible object/scene/surface into a 3D-computer model representation. Actually there is a long line of different technologies that have been devised to accomplish this task. This is not that surprising when considering the fact that no single 3D scanning technology can scan the entire range of different objects around us. That being the case there are many different types of 3D scanners. Certain 3D scan technologies can scan large areas of land while others can scan something as small as large molecules. The idea is to choose the right scanner for the right application.

6.1 Contact 3D Scanners

While there are many ways to categorize the different scanning technologies the most popular division is based on Contact and Non-Contact type scanners.

Contact type scanners are very straightforward, purely mechanical registration scanners. All have some or other mechanical probe that touches the object in order to understand its geometric shape/surface. The probe is attached to some type of XYZ axis coordinate measurement system (automatic) or be user assisted (manual). Following a sequence, the probe moves over the object. Once a point on the object has been touched the 3D position is stored in computer memory. The more points registered the greater the resulting scan detail will be.

Contact scanners are known for their paramount accuracy and registration sensitivity, which can go all the way down to the sub micron or nanometer level for certain types. Contact scanners are also not easily fooled and thereby, theoretically, do not suffer from artifacts (spikes, stray points) normally found in non-contact scans.

Yet, usually, contact scanners entail a bulky apparatus, especially for scanning objects that are shoebox size and up. More importantly they are typically very slow scanners, unless the object being scanned is very very small. Scan times can sometimes be as long as hours and even days in some cases. They can also be very expensive due to the instruments required.

6.2 Non-Contact 3D Scanners

Non-contact scanners include a much wider range of types yet have typically yielded much lower accuracy. They also usually require more involvement from the user to set up correctly. But they have much higher scan rates (faster scanning). They are more easily modified to scan different objects. And, as the name implies they do not touch the object during scanning. These properties make them very popular. In addition, some of these scanners can actually scan within certain objects as well. For instance, the Magneto Resonance Imager (MRI) scanner can scan within an organism.

There are basically two kinds of Non-Contact scanners namely, Structured Light (Scan Line Deformation) and Time of Flight. SLD, Non-Contact type scanners find wide spread use and employ triangulation to determine the 3D points of an object. Typically some type of line scanning instrument is used that projects a straight line over the object to be scanned. The deformation of the line, when looked at an angle, as it follows the curvature of the object's surface functions as a cue that represents the changes in the surface's depth.

The laser scanner is probably the most nostalgic type known within this category. However there are other techniques that can sometimes offer more versatility than a laser scanner. Instead of a laser, a projection system can be used to project a structured image onto the object.

Both of these approaches can be used for this product. Each has some important benefits that will be explained in detail in subsequent sections of this manual.

Time of Flight type scanners work much like sonar or radar technology. A pulse of acoustic or electro magnetic energy (this can include light) is transmitted to the object that is being scanned. The energy is reflected back. The time it takes for the energy to reflect back is a cue for the distance (depth) of the object and the transmitted energy source. A 3D model can be built by repeating this for many different points on an object.

6.3 Hybrid 3D Scanners

A new breed of scanners is arising which combines the benefits of both Contact and Non-Contact type scan technologies. They are not as fast as conventional Non-Contact type scanners and require, relatively speaking, a lot of user input but they offer a level of versatility not available before. For instance, using a laser scanner combined with a Contact type scanner probe.

7. The TriAngles 3D Circumference Scanner

The type of 3D scanner described here pertains to a 3D non-contact, circumference scanner. As mentioned before, non-contact meaning that the object is not touched during scanning as the scan technique relies on a visual based process. Circumference meaning; that the scanner scans around an object.

The technique employed to acquire 3D information about an object's surface involves projecting a distinctive, thin line over the object called a scan line. A camera (sensor) views the scan line that is projected over the object at an angle. From the projector's or laser's point of view the projected image is a straight vertical line that is displayed onto the object. Yet viewing the object at an angle will reveal a deformed line as it follows the curvature of the object's surface. Using the known camera angle (angle between camera and scan line), the relative 3D position of each point of the line can be calculated through triangulation. The object is then rotated one increment and the procedure is repeated. Repeating the process over the entire object's surface creates a full 3D-model data set of the object. This data set contains points, each representing the 3D positions of the scanned object. The object is built by connecting these points to form a circumference, or surfaced, 3D-computer model representation.

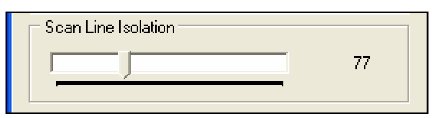
7.1 Scan Line Mechanics

It should be evident that scan line quality represents the foundation of this type of 3D scanner. Hence, the line quality, its position and how well the capture device is able to see it will have direct effect on scan accuracy and quality. Incorrect positioning of the scan line, for instance, will affect the size and shape of the resulting scanned object. Visual aspects, on the other hand, affect the integrity of the scanned data as well as the amount of authentic data acquired during scanning. Parameters that determine visual line quality include:

- **Reflection on object** (should be: low)
- **Line thickness** (should be: thin, accurate, consistent)
- **Line Intensity** (should be: high, consistent)
- **Line/object contrast** (should be: high)

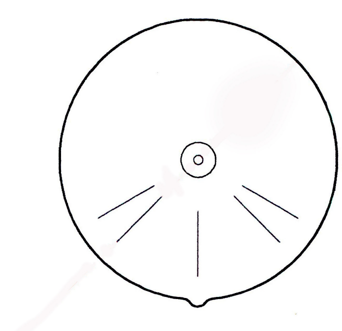
Approaching these values will allow the camera to view the scan line more clearly. Still, the camcorder itself has a very limited efficiency when it comes to the picture quality it produces. While most all of today's camcorders are digital this only pertains to the method of data storage. The imaging element (CCD) is still an analogue (non-digital) device which has a signal to noise ratio. Basically the image produced by the camera always contains some degree of noise. Noise (also sometimes refereed to as static) shows up as the pixels of the imaging element randomly changing in intensity. Noise can obstruct the process of detecting the actual scan line and it needs to be filtered out. Along side noise, glow and reflection that surround the scan line, which are generally attributed to the quality of the camcorders lens system, make it difficult to detect the actual scan line. These attributes can leads to unnecessary loss of detail and even artifacts such as spiking, which is frequently found on most scanners.

TriAngles includes a sophisticated algorithm to limit these affects. It also allows the user to choose the best level of scan line detection sensitivity. The Process Settings dialog includes the Scan Line Isolation slider. Basically, the lower the setting the higher detection sensitivity will be but with less noise compensation.



7.2 Occlusion and Shape Accuracy

The Turn Table disc includes 5 engraved lines. The middle line should be in alignment with the camcorders line of sight. Of the 4 remaining lines the 2 that are nearest to the middle line are each exactly 45 degrees from it. The remaining 2 lines are 60 degrees from the middle line. These angles represent the camera angle or, more specifically, the angle between the camera and the scan line.



The choice of camera angle has a direct influence on the quality of a scan. More specifically, the shape accuracy and occlusion probability of the resulting scanned object. It can mean the difference between smooth or bumpy scan lines.

Larger camera angles yield better shape accuracy since the camera is able to view a more pronounced curvature of the scan line. The curvature is more spread out over the camera pixels.

On the other hand the greater the camera angle the greater the chance is that certain parts of the object will not be seen by the camera. The scan line is obscured from camera view at larger angles, which leads to holes in the 3D data. To get a better idea on how this works, imagine scanning a head. While the head object tends to be circular in shape the nose on the face sticks out. As the object rotates on the Turn Table the scan line is clearly seen by the camera traveling over the nose. However at one point the scan line will reside behind the nose as the object continues to rotate but this area of the object is not yet visible here. The camera can not see this yet because one side of the nose is obscuring that view. The scan line will reside on other parts of the object by the time this area is visible for the camera.

The basic rule is to always strive for the largest camera angle but choose smaller camera angles when scanning objects that have extending shapes or protrusions.

Most objects will always have some degree of occluded areas. Fortunately Tri Angles 3D Builder includes a patching function to fill this. Also, the use of texture mapping can offer some solution to this problem (this will be described later).

A more common yet rigorous solution is to make 2 scans at opposite angles and then merge these in a 3D application.

It must be mentioned that every frame processed of a scan must include a scan line. If an entire line is obscured from view at any time during a scan then the scan will likely fail. In case this occurs, choose a smaller camera angle. Also, rotate the object a full turn on the Turn Table by hand and check to see that the scan line can always be seen by the camera.

7.3 Scan Resolution and Accuracy

Probably one of the most frequently asked questions is "what is the resolution or accuracy of the scanner?". The resolution is actually determined by the capture device. While HD type cameras are entering the market most all camcorders have a fixed resolution. For PAL this is 720H x 576V and for NTSC this is 720H x 480V. It should be evident that PAL type cameras are the better choice.

However, when it comes to the accuracy of the scanner it is a bit of a different story. For one thing since the resolution is fixed the size of an object relates to its detail. It should be obvious that scanning a face will unlikely reveal the hairs of an eyelash while scanning just an eye probably will.

Fortunately, it is possible to say something about the expected accuracy of a scan. The answer is divided between the vertical and horizontal accuracy.

With a PAL type camcorder the amount of vertical pixels is 576. If an object's height is 250mm and it uses all of the vertical pixels (the objects height is exactly set in the cameras view) then you could say that the vertical accuracy is 250mm/576p=0.43mm. Hence details smaller than 0.4 mm can not be seen by the scanner. This is of course under ideal conditions, which is only very rarely achieved. Scan line quality, the camera lens system and other aspects all contribute to determining the accuracy of the scan. In practice the resolution will reside more around 2.5 mm than 0.4 mm.

Practice reveals that the accuracy of the scanner using a PAL type camera is about 100-200 times less than the cameras viewable height of an object.

The horizontal accuracy on the other hand is related to the vertical accuracy, the diameter of the object and the amount of scan lines acquired. Smaller diameter sections of a scanned object will contain more detail than larger diameter sections. The scan lines acquired are more densely packed in these smaller diameter sections. Hence the more scan lines acquired the greater the detail the greater the accuracy. A typical object should yield about 450 scan lines but as many as a 1000 lines is not uncommon provided that sufficient system memory is available. However even with this many scan lines the horizontal resolution will only approach but not be greater than the vertical accuracy. Typically, the amount of scan lines would have to be substantially greater than the above mentioned to rise above the vertical accuracy level.

7.4 Scanable Objects

Probably the most important part of the 3D Scanner set up is actually the object that is to be scanned. All objects have certain visual properties which may make some better suited than others. Some of these properties include:

- Opaqueness
- Size
- Dimensional Proportion
- Shape
- Color
- Texture
- Detail

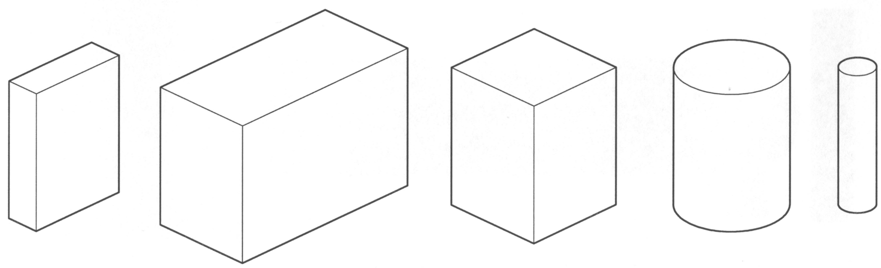
The properties of an object can have a direct effect how well it can be scanned or not. For instance, since the scanner relies on visual information it is obviously not possible to scan an object, which is transparent such as glass. It is however possible to powder/paint such an object in order to permit it to be scanned. A smooth mat white surface offers the ideal visual conditions for an object to be scanned.

Theoretically this type of scanner technology could scan something as large as the earth or as small as an ants head. This is obviously not very realistic but what it implies is that what ever object your camera can view, can rotate on a turn table and can project a laser line onto can usually be scanned.

As a Circumference scanner the types of objects best suited for scanning tend to be circular in shape and dimensional proportion. A bottle, for instance is an ideal shape to scan using this technology. Rectangular objects, such as a shoe, are usually suited but flat/thin objects such as a mobile phone will rarely yield the desired result. Simply stated; objects with significant difference in dimensional proportion are difficult to scan. This is due to the fact that the chances of entire scan lines being occluded from camera view increase. In addition the sudden change in object diameter leads to loss of detail as the scan line more rapidly moves across the objects surface.

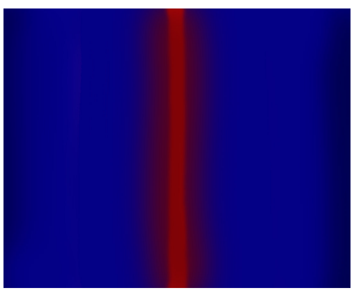
The basic rule is that objects tend to result in better scans when length is no more than 3 times width and height more than 5 times width or diameter.

Different Dimensionally Proportioned Objects

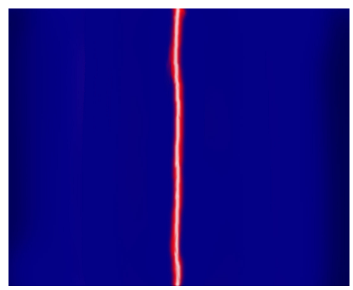


Difficult **Acceptable** **Good** **Ideal** **Good**

Object color and texture have bearing on the expected quality as well. Dark glossy surfaces or materials that diffuse the intensity of the scan line or have a fuzzy texture will have significant effect on the quality of the scan.



Diffused Scan Line



Sharp Scan Line

The diffused scan line lacks intensity and discreetness and will be difficult for the camera to see in relation to the sharp line. Materials such as marble and furry textures tend to result in diffused scan beam.

8. Alternative Scan Line Projection Methods

Up until now the type of scan line projection method employed was to use a laser. However there is another way to produce a scan line which offers certain benefits. Instead of a laser the scan line can also be projected onto an object using a slide projector. The Turn Table is supplied with 2 35mm slides to permit this option. Both slides contain a line pattern.

8.1 Laser Properties

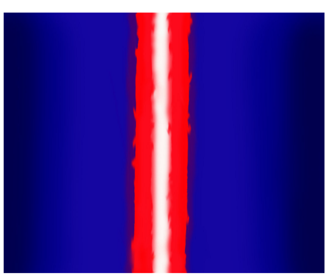
When it comes to surface color and range the laser can scan a wider variety of objects than the slide projected scan line. Lasers throw an intense coherent light which provides a distinctive scan line on an object at many different ranges and under many different color conditions. By this same token the laser can also cause severe reflections on certain material surfaces as well as cause certain surfaces profiles to light up. The intensity of the line can vary significantly as well and as show up as beading (high intensity areas). These attributes can all contribute to confusing the line detection function the software and thereby impairing its ability to identify the true scan line over the object. It also makes it more difficult to choose and appropriate Scan Line Isolation level.

8.2 Slide Projector Properties

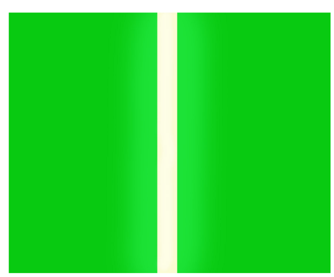
The slide projected scan line projects a more distributed and balanced intensity and suffers much less from the problems found when using a laser. It may not have as wide a range as the laser but it offers better peak performance under certain conditions. The projected line is much smoother and sharper than the laser. These contribute to more accurate and cleaner looking scans which include more detail and require somewhat less post processing.

However the slide projected method may require that the object be prepped since the intensity of the projected slide may not be sufficient otherwise. Prepping includes spray applying a washable layer of mat white paint to the object's surface. This will result in a more visible scan line.

Another aspect is the Depth Of Focus of the slide projected scan line. The DOF is the range that the object remains in focus if moved closer to or farther from its set focus point in front of the projector. To increase the depth of focus the projector will have to be moved farther away from the object. This, unfortunately, reduces the light intensity as well as makes the scan line wider.



Laser



Slide

9. Capture Options

Tri Angles includes 3 ways to acquire a scan from the capture device:

1. Directly from the live video feed of the camera (on the fly)
2. Playback a recorded scan made with the camera to the computer
3. Playback a recorded scan made with the camera or live video feed and record this on the computer's HDD

Each method offers certain benefits. The easiest and fastest way is to process the video stream directly from the camera during the scanning of the object. However it is also possible to have the camera record the scan and then play it back to the computer after the object has been scanned. This method offers more freedom to make more accurate adjustments so that a better scan can be produced. If you make wrong adjustments simply rewind and try again. It also has the benefit that a computer connection is not required during the object scanning. Hence, scanning can take place at a remote location without having to be directly dependent on a PC connection. The last method involves recording the playback or live video feed from the camera to hard disk as an AVI file. This method offers the highest degree of post scan adjustments to be made.

9.1 Using a WebCam

While it is possible to use a webcam as the capture device it is not recommended. Most webcams have CMOS type image arrays. Although this type of imager has come a long way, in terms of its technology and performance, the image it provides is only good under ideal conditions.

CCD type sensors have a much better signal to noise ratio and provide a much better picture, even in less than ideal conditions. Still webcam's, CCD or not, do not have very good optics, their maximum resolution is usually no more than 640 x 480 and they frequently include functions which disrupt the scan process.

Digital video camera's with picture stabilization and manual iris control or iris lock work best. These types of cameras typically have higher resolutions and have much better optics.

9.2 Tricks with Textures

2D Texturing mapping is simply the mapping of a photo onto the surface of a 3D model. Yet once a texture is wrapped around a 3D model it can add an almost magical realism. It can also offer important solutions with regard to shape accuracy, elevated detail and 3D model file size.

Texture maps affect the appearance of a 3D model and not the mesh data. Basically this means that you can display a model in two different ways; the model surface or the model with the texture.

Tri Angles creates 2D circumferential texture maps which can be used to enhance the level of detail of a 3D scanned model. More precisely, this gives the appearance of a much higher level of detail.

Circumferential Texture Map

As mentioned earlier it is sometimes necessary to choose a small camera angle for certain objects. The consequence is that the shape accuracy will suffer. Applying the scanned texture map of the same object can do a lot to compensate for this.

After you have made and saved a couple of scans it will be evident that the scanned models usually have very large file sizes. Typical file sizes can be as much as 70-180MB. This is huge in comparison to your regular 2D photo. Opening and closing files this large also involves a lot of processing time. Texture maps offer a trick to reduce file sizes without losing the detailed appearance of the scanned model. By setting the Grab Rate to a higher level during scanning the amount of scan lines acquired will be less. The resulting file size will also be less. This is at the cost of scan resolution and detail. Appling the texture map of the object onto the low resolution scan will still yield its high level of detail.

Colored Surface

Surface with Blended Texture and Shine

Surface with Blended Texture

10. Absolute Base Requirements

As mentioned throughout the manual, 3D scanning, as well as the post processing of the acquired data, sets a heavy load on a computers CPU, GPU and memory. Certain processes are also time dependant and will fail unless the employed PC offers the required performance. The following chart includes the absolute base requirements needed to run and use Tri Angles.

PC

Unit	Absolute Minimum	Advised
CPU	1 GHz	3 GHz
System Memory	1024 MB	4 GB
Hard Drive	35 GB (high speed)	160 GB (7200 RPM), SATA 2
Free Drive Space	3 GB	25 GB
Graphics Adapter	64 MB (not Shared), OpenGL Compliant	256 MB (not Shared), OpenGL Compliant
Operating System	Windows 2000, XP (Vista not Tested)	Same
Video Interface	USB, FireWire, Composite In	Same
Pointing Device	3-button, scroll-wheel mouse	Same
Other	DirectX 8 and Above	Same

Camcorder

Unit	Absolute Minimum	Advised
Focus	Auto/Manual	Auto/Manual
Iris	Auto	Auto/Manual
Picture Stabilization	-	Yes
Digital	Analog/Digital	Digital
Tape/HDD/DVD	Tape/Hard drive	Tape
Remote	-	Yes
FireWire	USB, FireWire, Composite Out	FireWire

Note: HD 1080i type camcorder resolutions have not been tested. However provided that the required codec's are available on the PC that is processing the video then this should permit the use of Tri Angles. High end PC will be required as the processing load will be 4 times greater than using standard video.

11. Tri Angles 3D Scanner Specifications

Scan Type	3D Non-Contact Circumference Scanner
Scan Technique	Point Triangulation
Scan Method	Deformation of projected pattern (stripe) over the 3D object/scene (laser, projection) to indicate depth points
Scan Sensor	CCD type visual array, video camera (recommended)
Scan Range	Depends on scan set up and optics
Scanning Speed	Typically less than 60 seconds at full video resolution per rotation pass
Scanner Accuracy	Factor 100-200 times less than height of object
Scanable Materials	Most opaque surfaces. (Mat white surfaces are best)
Texture Scanning	Yes
Hardware Footprint	Desk top
PC-less scanning	Yes
Hardware control	Manual (Motorized turn table)
Software Features	Auto interface to CCD video (Composite, USB, FireWire), AVI recorder, Pre scan filters and process control, device interface control, post process transformations (patching, smoothing etc.), hardware rendered graphics, export to popular formats: STL,DXF,RAW,PNT,VRML,OBJ and a compressed native format TXS