The David 3D scanning software and camera assembly is used to take three dimensional images of potentially any object 240mm tall or smaller. The final product can be imported into popular CAD software or, if the scans are complete enough, the David software can export .stl files that are ready to print in the Mojo 3D printers.

In this tutorial you will learn the following:

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1. Getting Started

On a PC, click
Start > All Programs > David4_64bit
> Right Click run as Administrator

![Figure 1: Start Menu]

2. Setup

Setting up your scan correctly is important. You want your object that is to be scanned to be visible, and must adjust the brightness and exposure accordingly. In this step, simply try to make your object look in the Live Camera as similar to the elephant as possible. That means you must adjust the focus and aperture on the David camera, as well as the brightness and focus of the projector so that everything is as crisp as possible.

*Remember* the camera only scans what it can see. If your brightness is too low, much of the object won’t be scanned.

![Figure 2: Setup Window]
Figure 3: David Camera

Figure 4: Projector
**Initial Setup Menu**

**Setup Type**
This current system is a **Structured Light Setup (SLS)**. To scan properly, one of the SLS options must be chosen (**DAVID SLS-3**).

**Textures**
If you want color and textures to be included in your scans, make sure the Enable Texturing box is checked. This will also add the Texturing tab in the Navigation Bar at the top of your screen.

**Turntable**
When scanning small objects it is best to set them on the turntable. To enable this feature, check the Enable Turntable box found in the Initial Setup Menu.

**Screen ID**
Having the Screen ID set to 2 will guarantee that the projected pattern used to scan the object will come out of the projector and not the monitor.

**Camera Setup**
There is only one camera available at the moment (**DAVID-CAM-4-M**). Make sure the Frame Rate (fps) of the camera is set to High. This will produce the best scan results.

**Navigation Menu**
Clicking on each one of the tabs will direct you to different menu options related to each selection. There are: Setup, Calibration, Scanning, Texturing, and Shape Fusion.

**Camera**

**Focus**
The Focus Adjustment Wheel is located at the tip of the camera. Turn it to adjust the focus/depth of field. Once finished, lock the focus/depth of field in place by tightening the Locking Screw located just behind the Adjustment Wheel.

**Aperture**
The Locking Screw and Adjustment Wheel for the aperture of the camera are one piece. Adjust the aperture to the desired position by turning the Adjustment Wheel and secure it using the Locking Screw.

**Camera Position**
The camera can be positioned anywhere along the length of the Ruler. It should be placed in whatever position required to fit the whole scan object within its field of view. In order to produce the most accurate scans, the Camera Angle should be adjusted so that it is between 22° and 25° from the projector.
**Projector**

**Focus Dial**
The **Focus Dial** is what adjusts the focal range of the projector. In order to get an accurate scan, the projected pattern must be crisply displayed upon the scan object. Refer to the image below for an example of the projected pattern.

**Menu and Selection Buttons**
It is unlikely that the **Menu and Selection Buttons** will be needed in the 3D scanning process. However, they are located on the top, rear of the device next to the **Power On/Off** button if needed.

![Figure 5: Scanning Pattern](image-url)
3. Calibration

After you perform the light setup by adjusting the focal length and aperture of the David camera, you will initialize the in-program Calibration Setup. What this does is tell the David4_64bit software that the object within the focal range of the camera is going to be around a certain size (in this case we're choosing 120mm). This allows the software to then create scans that are accurate to the size of the object as well as allow the software to accurately measure the distance between any two points within its field of view.

It is possible that when you select the Calibration tab there will already be presaved calibration parameters. This is shown in the image below by the green X’s.

![Image of Calibration Setup](image)

The green X’s are mapped points on a grid that are a set distance apart. Because we want to scan a smaller object, we must create new calibration parameters.

To make an accurate calibration you will need the Calibration Board.

When properly put together, two boards with matching dots and 6 black rings will form a right angle. This can be seen in the first image on the following page.

On the left side of your computer screen in the Calibration Options box you will see a number that represents the height of the grid on the Calibration Board. In this example the grid is 120mm tall, therefore we type “120” into the Calibration Scale section on the left side of the screen.
Now remove the object you used to set up the brightness and focal length and place the the same distance away. An example of this is shown in the image below.

![Figure 7: Calibration Board](image1)

It is **OK** to adjust the angle, height, projector brightness, and exposure to get the proper environment to make a good calibration. It is **NOT OK** to adjust the focal length of the camera or the aperture of the camera.

![Figure 8: Calibration Board and Camera Setup](image2)
After the Calibration Board is in its proper place and the live camera image shows all six black rings, click the Calibrate button found on the left side of your screen.

The projector will now flash a series of images onto the Calibration Board. Once the program has finished, a new window will appear demonstrating that new calibration parameters have been set.

In the Live Camera view you should see all of the dots and rings connected by a black and white checkerboard pattern.

This means that the calibration is complete and you may remove the Calibration Board and return your scan object and the camera/projector back into their original positions.

**REMEMBER:** The scan object must be placed within the original focal range of the camera, otherwise the new calibration will be inaccurate and the David software will improperly scan the object.
4. Texturing

If you want to scan the texture and color of your scan object as well as the size and shape, skip ahead to the Texturing tab located in the navigation menu at the top of your screen.

Grabbing the texture is mostly automatic. However, it is important that the **White Balance** is calibrated so that the colors are accurate to your scan object.

To calibrate the White Balance:

1. Hold a piece of *blank white paper* in front of the camera about the same distance away as the scan object.

2. Click the button that reads *Adjust White Bal*. located near the top, left of the window.

3. The program will display a series of patterns. After this, the white balance will be calibrated.

![Texturing Window](image.png)
5. Scanning

Navigate to the **Scanning** menu using the icons at the top of your screen.

To work best, the scan object must be contrasted from the background and the closest side of the object will be in the focus range of the **camera** and **projector**.

Scanning the object is extremely simple as long as you have performed the prior steps properly.

The menu on the left side of your screen are different scanning options. For this scan we’ve checked the box that says **Enable Turntable**. This will allow the turntable to spin the scan object 360 degrees more accurately than we can do ourselves.

Examine closely the image below:

Make sure that the light levels aren’t too high or too low. The readings marked inside of the **green rectangle** in the image above show how these light levels work.

**NOTE:** Objects that are too bright will over expose the camera and potentially cause the camera to misread information, such as height or surface texture. Objects that are too dark will not be scanned at all.

The final box that needs to be checked is the **Add to List** selection. This will guarantee that each scan you make will be temporarily saved within the David software to be aligned later after the scanning process is complete.
Pattern Parameters

Profile
Leave this at **Default**.

Number of Patterns
This setting will reflect the **Default** setting of the **Profile** option.

**Turntable Control**

Enable Turntable
For small objects, the **Turntable** is the best method to scan all sides accurately. Check the **Enable Turntable** box and allow the turntable to initialize.

Total Scan Angle
To scan a complete object, leave this setting at **360°**.

Number of Scans
For simpler shapes, fewer scans are acceptable. For more complex shapes, **15 Scans** will likely be the minimum required amount.

Rotation Between Scans
This value will directly reflect the options chosen in the **Total Scan Angle** and **Number of Scans** options.

**Scanning**

Add to List
This option should default to be selected. Make sure this option is checked because the **List** is what will be used in the next section when **Aligning Scans**.

Auto Align to Previous
This function lets the David software attempt to auto align the scans in the **List** to each other as they are scanned. Use at your own risk, it is not often effective.

**Result Filtering**

Smooth Average
Leave this option at its **default** value.

Quality Check
Leave this option at its **default** value.

Outlier Removal
Most likely this option will be left at its default value. If there is too much excess at the **edges** of your scans, you may increase this value **slightly**.
6. Shape Fusion: Shaping Tools

Look closely at the image below. Marked in white are the general tool bars that hold the most important tools that you will use when aligning and cleaning your scans.

The **Editing Toolbar** on the left holds all of the active tools—the tools that will align, crop, or undo an action.

The menu on the right is your **List of Scans**. Every scan listed in this area were scans that were taken while the **Add to List** box had been checked. Located just above this is the **Save Menu**.

The bar at the top changes your viewing options and give you the opportunity to take screenshots.

Hover the mouse over any of these icons to see what they can do.

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**Background Removal**
Checking this box allows you to scan the area *surrounding* the scan object to be *auto removed*. This is a useful feature when next to a wall or using the turntable. Remove the scan object from the Field of View before scanning.

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**Figure 13: Shape Fusion Window**
The Following will be a detailed breakdown of the Editing Toolbar found in Figure 13.

Cleaning

Crop Tool
The drop-down menu will list three options: Rectangle Selection, Polygon Selection, and Connected Components Selection. Each of these are different methods to selecting parts of the scans to be highlighted and then removed. For the Polygon Selection tool, a left click will create a point, while a right click will complete the shape.

Invert Selection
The Invert Selection toggle is located to the right of the crop tool. This will take any selection made by the crop tool and reverse the effected area.

Delete Triangles
The Delete Triangles or DEL tool is the red X located to the right of the Invert Selection toggle. This will delete and highlighted areas by the crop tool.

Alignment

Arrangement
The Arrange 2D and Arrange 1D icons are the first two buttons in the Alignment section. Clicking each button will change the layout of the scans visible in the workspace.

Alignment Drop-Down Menu
In this menu there will be four choices available to you: Free, Around Y-Axis, Pairwise Fine Registration, Global Fine Registration.

<table>
<thead>
<tr>
<th>Alignment Mode</th>
<th>Rotation Axes</th>
<th>Movements</th>
<th>Affects</th>
<th>Coarse</th>
<th>Fine</th>
<th>Typical application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pairwise Fine</td>
<td>X, Y, Z</td>
<td>X, Y, Z</td>
<td>The selected &quot;Scan A&quot;</td>
<td>X</td>
<td></td>
<td>Fine alignment of one scan to another.</td>
</tr>
<tr>
<td>Global Fine</td>
<td>X, Y, Z</td>
<td>X, Y, Z</td>
<td>All visible scans</td>
<td></td>
<td>X</td>
<td>Fine alignment of all scans to all others. Last step before fusion.</td>
</tr>
<tr>
<td>Manually by mouse</td>
<td>X, Y, Z</td>
<td>X, Y, Z</td>
<td>The selected scan</td>
<td></td>
<td>X</td>
<td>Manual movement of scans when automatic alignment fails.</td>
</tr>
</tbody>
</table>

Rotation Angle
This option restricts scan movement along a specific rotation angle. This works best with the Around Y-Axis function. Check this box and insert the rotation angle between each scan. When using the turntable, the degrees between each scan are listed in the Scanning tab.
Contact Pair Selection
Automatic alignment often fails when the scanned object does not have distinctive shapes or there is too little overlapping. In Free and Around Y-Axis modes use the Contact Pair Selection to select a point on each scan that should be connected.

Use Texture
The Use Texture feature allows the software to use the texture of the scans to auto align themselves. This is used best in the Free and Global Fine Registration options. The higher the value (1-100) the more strict the parameters will be.

Align Scans Button
This button must be clicked to align any scans. It will turn red when active. For Free, Around Y-Axis, and Pairwise Fine Registration you will then use the mouse cursor to select which scans you want to be affected.

Step Forward/Backward
For any mistakes or bad scan alignments, use the Step Forward/Backward buttons to undo or redo any alignments.

The Following will be a detailed breakdown of the List of Scans found in Figure 13.

List of Scans

Scans/Fusion
At the top of the list of scans there will be two buttons: Scans and Fusion. To view the list of scans, click the Scans button. To view the current list of fusion results, click Fusion. The selected option will be highlighted in red.

View All Toggle
This button looks like an eye and, when visible, means that all scans are visible in the workspace. When it is invisible or when there is a small circle, none of the scans will be visible in the workspace.

List of Scans
Here you will find all of the scans that were made while the Add Scan to List option was selected in the Scanning menu.
The name of each scan is listed to the right.

Clicking the name will highlight the scan.

The color of the scan is shown to the left of the name.

Clicking the box will select the scan.

The visibility of the scan is shown by the eye to the left of the color.

Clicking the eye icon will toggle the visibility of the scan in the workspace.

Add/Remove Scans
To add a scan, click the plus (+) sign located at the bottom of the list. To remove a scan, highlight or select the desired scan and then click the minus (−) sign.
7. Shape Fusion: Aligning Scans

Once you have familiarized yourself with the basic functions of the Shape Fusion tools, you may begin to align your scans.

It is very important to remove any excess or unneeded portions within the scan that may interfere with the automatic alignment process. This could include scanned portions of the wall, the front of the turntable, and any other non-scan object information that is present in the scan.

Rotate the scans to a position where there is nothing behind the areas that you wish to delete. Then, select the **Crop Tool**. Using the left mouse button, click around the areas that you wish to select.

When ready, click the right mouse button to approve the selection. Any affected areas will turn red. If everything is correct, you may then click the red **X** button next to the **Crop Tool**. The selected areas will be removed.

![Figure 14: Removing Excess](image)

When your **List of Scans** have been entirely cleaned, you may then begin aligning them to each other.
There are a multitude of constraints to align you scans, but the *Around Y-Axis* option or the *Free* option will most likely be the most useful.

The *Around Y-Axis* option restricts most movement that does not rotate around the Y axis. This is extremely useful if you use the turntable, and all of your scans are viewed from the same angle.

The *Free* option allows minor movement along X and Z axis as well as major rotation movement along the Y axis. This is very useful when scanning an object that is not consistent or is too large for the turntable.

**TIP:** The *Free* option works great when scanning people’s faces or objects that you rotate yourself.

In this tutorial, we will be aligning *Scan_01* to *Scan_02* and continuing from there. What this means is that we will consider *Scan_01* as our reference scan—the scan to which we want all of our other scans to match.

![Figure 15: Two Visible Scans](image)

With just two scans visible your screen should look something similar to this. From here, click the *Align Scans* button in your editing tool bar.

Look closely at *Figure 16* on the following page.
When aligning your scans, **Scan A** will be the first object you select while **Scan B** will always be the second, using the **Left Mouse Button** to make the selection.

**REMEMBER:** Scan A moves to the position of Scan B.

We must stair-step our way to combining all of our scans so that they line up properly.

For our first step, we will align **Scan_02 (Scan A)** to the position of **Scan_01 (Scan B)/also our base/reference scan**.

For our next step, we will select **Scan_03** as our **Scan A**, and then select **Scan_02** as our **Scan B**. If done properly, the 3 scans should be aligned to form a smooth surface.

In this tutorial we are alternating between the **Free** alignment option and the **maximum texture control (99/100)**, and the **Around Y-axis** alignment option with the maximum texture control.

Each project is different, and all of the tools in the **Alignment Toolbar** may be require to adjust your scans.

**IMPORTANT:** If you have improperly calibrated the software, or improperly set up the camera and projector, it may be much more difficult to align your scans properly.

**TIP:** At any point in time you can go back to the **Scanning** window at the top of your screen and add additional scans into your **List of Scans**.
There may be times when, after you go through the entire List of Scans, there are some problem areas or sections within your project that refuse to align properly.

To fix this, find the problematic scans and try a different method of aligning them to the same scan. If that doesn’t work, try and align the problem scan to a completely different scan than the one you’ve been doing so far.

The following figures display tips on fixing problem areas in your project:

Using the Contact Pair alignment option.
Removing Excess or the problem areas on the individual scan:

Familiarize yourself with the **Shape Fusion** layout and tool functions.

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Figure 18: Troublesome Excess

Figure 19: Shape Fusion Window
After the scans have been aligned to create a smooth mesh, they must then be fused into one object. This is done using the fuse options located at the bottom of your Editing Toolbar.

This process is straightforward and the quality of your fused scan will be determined by how well you have aligned your scans during the previous steps.

**Fusion**

**Resolution**
The Resolution determines the space between the individual vertexes in the mesh. Typically, more than 1000 resolution would be too large. You should expect to use 500-1000.

**Sharpness**
The Sharpness setting determines how strict the final fused object will adhere to the texture and placement of the scans. If your scans aligned well, then a higher sharpness would work. If not, then lowering the sharpness will help hide any imperfections that you can’t seem to fix.

**Close Holes**
The Close Holes option dictates whether or not the David software will automatically fill in empty spaces in your object with a mesh.

The following figures show examples of different sharpness renderings:
Figure 20: Maximum sharpness

Figure 21: Sharpness level 1
After your object has been fused, you may still go in and remove any imperfections NOT connected to the fused object.

If there are any problem areas in the final fused object that can’t be removed post-fusion, you must go back to your original List of Scans and fix the issue there.
9. Exporting

After you have successfully fused your scans and created an object with which you are satisfied, you may want to export the fused object so that you may edit it in a 3D rendering software or so that it can be printed in one of the STAC’s 3D printers.

Type in the name of the project in the field that reads Fusion Result. Then, hover your pointer over the right-most icon that looks like a floppy-disk. This is your save/export button.

A menu will pop up much like the image shown directly below:

![Figure 23: Exporting Popup](image1)

Make sure the name of your object transferred over to this window.

For printing and editing this object later, a .STL file extension is recommended. However, 3D rendering programs are able to work with .obj and other 3D file types.

When you are finished, click Save.

Congratulations! You have successfully 3D scanned an object.