CowTech Ciclop 3D Scanning Guide v1.1

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Introduction

This guide was written for use with the CowTech Ciclop 3D Scanner, which began as a Kickstarter project in February 2016. The aim of this guide is to show you how to get the highest quality scans possible, and is based off our own experience with using the scanner. It covers the physical act of scanning an object utilizing your Ciclop and a free accompanying program called Horus, and assumes that you already have a scanner built and ready to go. For help with assembling your CowTech Ciclop 3D Scanner, please see our assembly guides on the CowTech website: http://www.cowtechengineering.com/downloads

This guide is not comprehensive. Usually there is a significant amount of post-processing work to be done after a scan. Although we do offer some related tips, please refer to the links below for help with any kind of post-processing work (if for example you want to turn your raw scans into meshes usable with a 3D printer or other 3D software packages).

We also highly recommend taking a look at the following resources if you need troubleshooting help not covered in this document.

Post-processing and Scanning Guides:

- CowTech website's downloads section - http://www.cowtechengineering.com/downloads
- BQ's Ciclop and Horus Documentation Page - http://diwo.bq.com/en/documentation-ciclop-and-horus-2/
- Horus Github - https://github.com/bqlabs/horus

Troubleshooting Hardware and Electronics Related Issues:

- CowTech Ciclop Facebook Group - https://www.facebook.com/groups/564912093672675/
- CowTech Ciclop 3D Scanner Google Group – https://groups.google.com/a/cowtechengineering.com/forum/?hl=en#!forum/cowtech-ciclop-3d-scanner

Troubleshooting Software Related Issues

- BQ Ciclop 3D Scanner Google Group - https://groups.google.com/forum/#!forum/ciclop-3d-scanner
- Horus Github - https://github.com/bqlabs/horus

Things to Have Before Starting

There are a number of items you will want to have on hand before you begin scanning. If your kit has any damaged or missing parts, we are happy to send you replacements. Please email us at info@cowtechengineering.com.

Assembling the Hardware

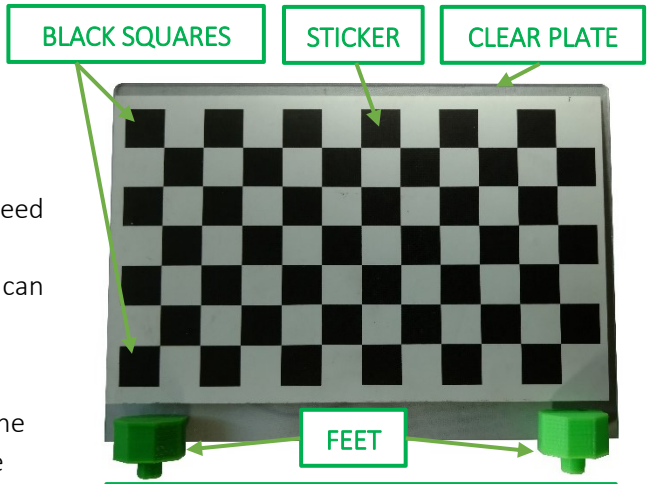
You will need a fully assembled Ciclop. If you haven't done so yet, please refer to the "downloads" section of the CowTech website for assembly instructions:

http://www.cowtechengineering.com/downloads

It is important to build the scanner in the order prescribed by the assembly instructions. Some parts in the assembly are press fit and cannot be taken apart again without risking damage. It pays to get it right the first time.

The Calibration Pattern

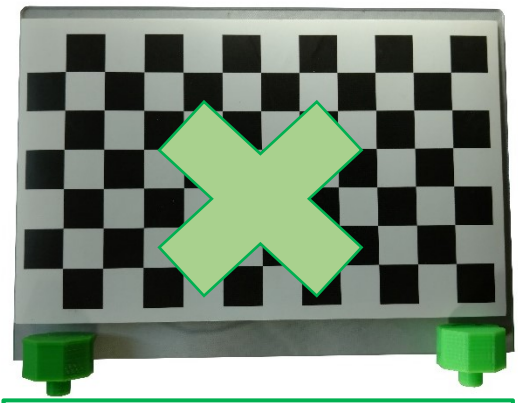
The calibration pattern is a grid of black and white squares that the camera uses to orient itself in 3D space. It is a critical piece of the scanner. You will need to use it to calibrate the scanner before every scanning session. A picture of a calibration pattern can be seen at right. It consists of two pattern holders ("feet"), a clear plate, and a sticker.



CORRECT: Black squares are in the left corners and white squares are in the right corners

To assemble the calibration pattern, simply press the feet into the slots of the clear plate. Then place the sticker centered on the clear plate. It is critical that the rows of boxes on the sticker are as parallel as possible to the edges of the clear plate. Try to be as careful as possible about parallelism when placing the calibration pattern. It is fine if the sticker is not perfectly centered as in the example at right.

The stickers must also be oriented correctly. See the pictures at right. You want to ensure that the left hand corners have black squares and the right hand corners have white squares.



INCORRECT: White squares are in the left corners and black squares are in the right corners

Your scanning kit should come with two stickers in case you make a mistake with the first one.

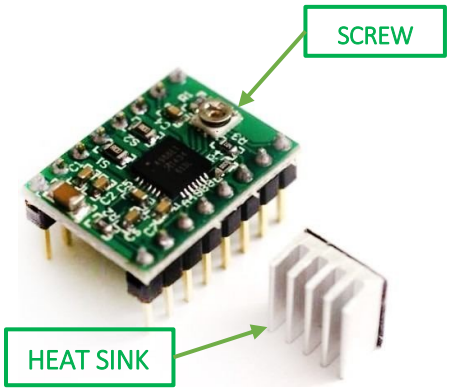
The calibration pattern is used only when calibrating. Never leave the calibration pattern on the table when scanning an object, as the scanner will include the calibration pattern in the scan.

Assembling the Electronics

The following sections will walk you through the process of putting the electronic components of the scanner together. This section is here so that you do not break any of your scanner's parts. Please follow it carefully.

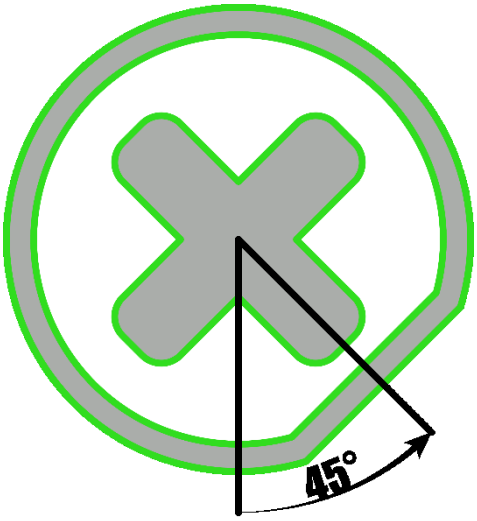
Calibrating the Stepper Motor Driver (the Easy Way)

At right is a picture of the Stepper Motor Driver. This component of the scanner should be handled with care. It can be shorted out and ruined with improper handling. Please carefully follow the instructions in this document to ensure that it works properly.



The screw shown in the picture at right controls how much electrical current is given to the Ciclop's stepper motor. This motor spins the scanning table, which allows the scanner to get a 360° view of an object. You want to ensure that this screw is adjusted to the right position. Too much electrical current, and the motor may eventually fail or the Stepper Motor Driver may overheat. Too little electrical current, and the motor will not turn properly and results in inaccurate scans.

Orient the Stepper Motor Driver such that the screw is on the bottom and the black square is above it. See the section below titled "Plugging in the Boards and Components" for a picture of this orientation. The screw has a flat side. The flat side of the screw is normally pointing straight down. Using a Phillip's head screwdriver, turn the screw 45° counterclockwise. This corresponds to the hour hand's position on a clock at 4:30. See the diagram at right.

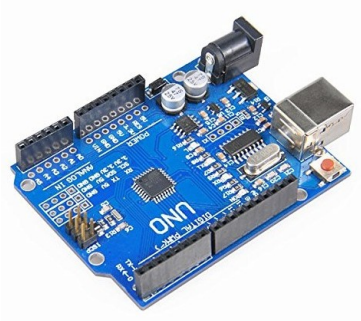


If your Stepper Motor Driver is having issues, we highly recommend consulting the more detailed calibration guide presented at the end of this document.

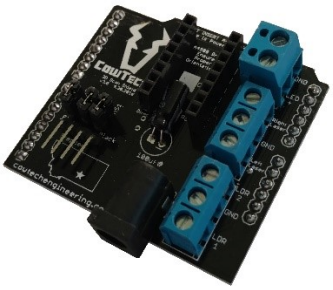
Stacking the Boards

WARNING: It is easy to short out and ruin the Stepper Motor Driver on your scanner. Please ensure that none of the boards are plugged in while you connect them to one another. If any of the boards are powered while doing so, you run the risk of ruining the Stepper Motor Driver.

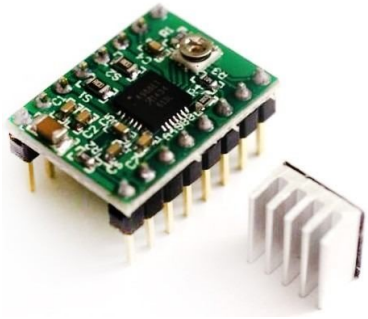
The three circuit boards included with the Ciclop are shown below.



Uno Clone



CT Board



Stepper Motor Driver

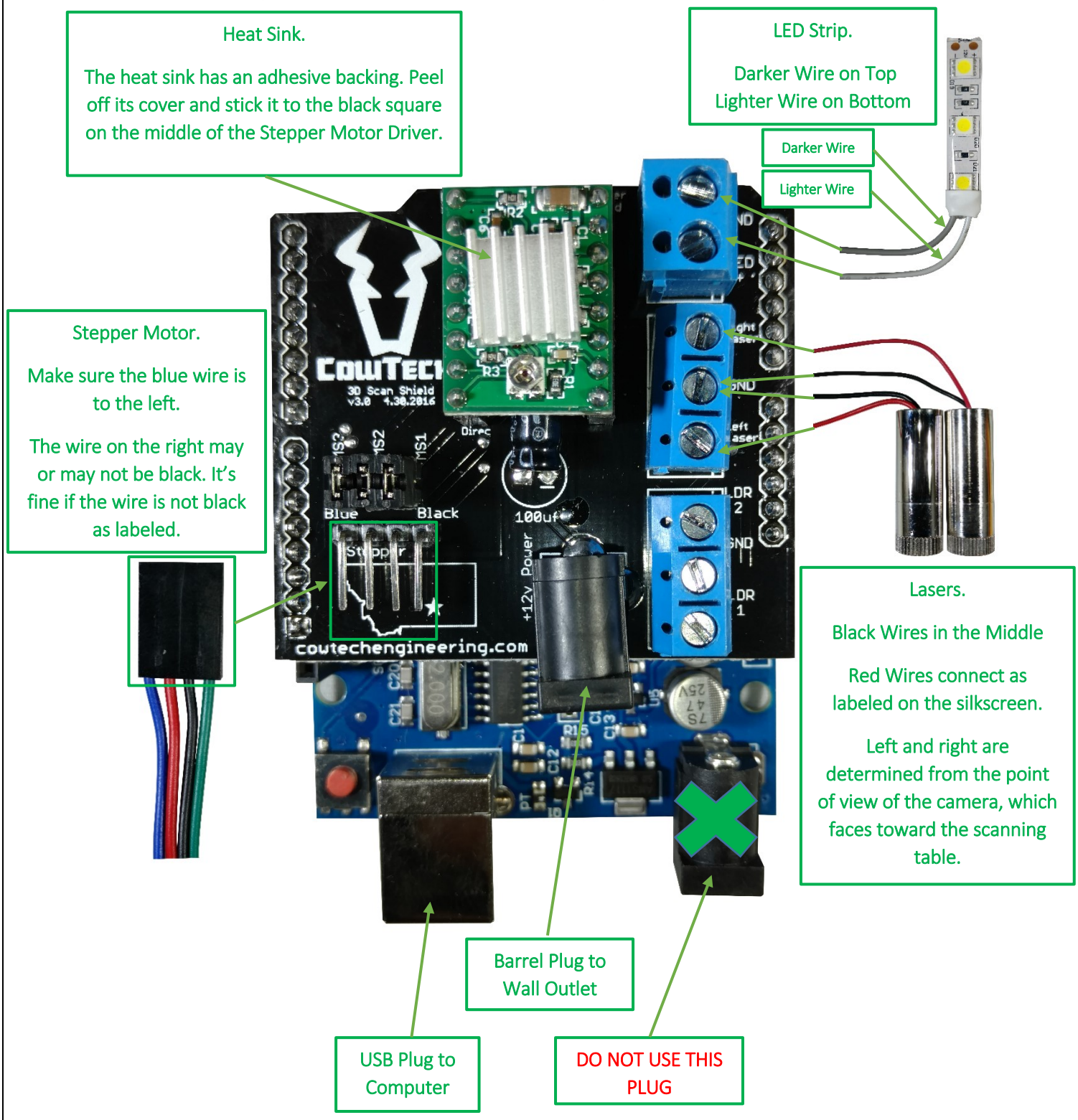
The boards all stack on top of one another. The Uno Clone sits at the bottom of the stack, the CT board is in the middle, and the Stepper Motor Driver is on top. It is essential to properly orient the boards.

- The CowTech logo on the CT Board should be oriented opposite from the USB and power plugs on the Uno Clone.
- The small screw on the Stepper Motor Driver should be oriented closer to the power plug on the CT Board. On the CT Board, there is also a silkscreen just under the pins for the Stepper Motor Driver that indicates the proper orientation.

A picture of all three boards correctly assembled can be found on the next page.

Plugging in the Boards and Components

Make sure to plug in the boards and components as shown in the picture below. It is possible to damage the Stepper Motor Driver if the boards are plugged in incorrectly. The blue connections on the right side of the board will require a flathead screwdriver to secure in place.



Installing the Software

Horus

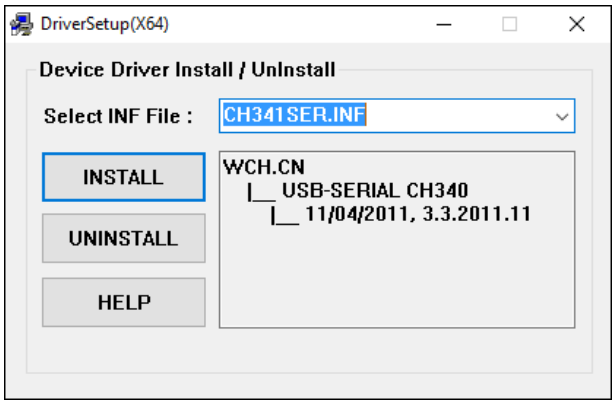
Horus is a software program on your computer that connects to the Ciclop scanner. This guide was written for use with Horus version 0.2rc1. You can download Windows, Mac, or Ubuntu versions of Horus for free at the link below. Run the installer and follow the onscreen instructions. The installer may give you the option to install "FTDI Drivers" or "Arduino Drivers." Neither are necessary to run the CowTech Ciclop 3D Scanner.

https://github.com/bqlabs/horus

After installation, it is recommended that you restart your computer before continuing.

Uno Clone Drivers

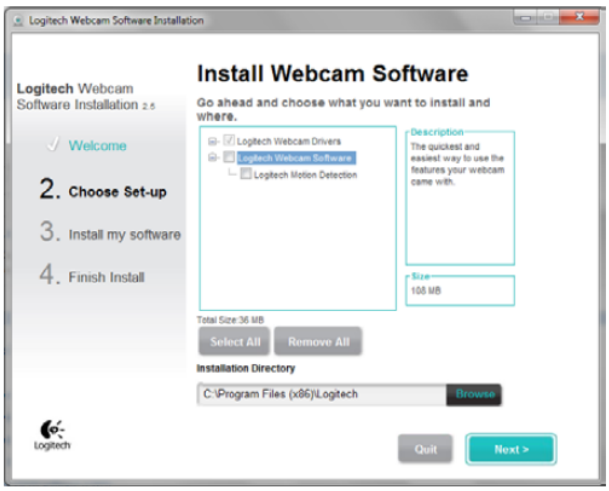
Horus interfaces with the components of the scanner via the Uno Clone. In order to enable your computer to recognize the Uno Clone when it's plugged in, you may have to download and install Uno Clone drivers. These drivers can be found on the CowTech website. Please see the link below. Unzip the file, run "SETUP.EXE," and then click "INSTALL."



http://www.cowtechengineering.com/downloads

Logitech C270 Webcam Drivers

The Ciclop uses a Logitech C270 Webcam to make scans. Although your computer may recognize the webcam if plugged in straight out of the box, Horus will not be able to. Horus requires a special set of webcam drivers, all of which can be obtained from the Logitech website below. Make sure that you download drivers that match your operating system. The installer will give you the option to install:



- "Logitech Webcam Drivers"
- "Logitech Webcam Software"
- "Logitech Motion Detection"

The last two options are not necessary to run the CowTech Ciclop 3D Scanner.

http://support.logitech.com/en_us/product/hd-webcam-c270

If you ever have trouble getting Horus to recognize the webcam, uninstall and then reinstall Horus. In some cases, Horus needs to be able to see the Logitech C270 drivers during installation in order to recognize

them properly. If your problem persists, see our troubleshooting guide at the end of this document for more help.

How the 3D Scanner Works

The CowTech Ciclop can generate scans with or without a texture. A scan with texture will be colored like the object is, while a scan without texture will be the object's geometry only. The Ciclop utilizes a camera, two lasers, and a spinning table to make scans.

When an object is placed on the spinning table, the lasers flash on and "paint" the object with vertical red lines. The camera takes an image and records the areas that show up as red on the object. If the scan is recording textures, the camera also records the colors visible at these areas. This happens just after the lasers flash off. The table then rotates at a very small angle (usually a fraction of a degree) and the process repeats until the table makes a full revolution.

The output of the scan is known as a "point cloud" and is saved as a .ply file. A point cloud is simply a collection of coordinates that represent points in 3D space. Calibrating the scanner ensures that Horus knows how much the table spins and the locations of the camera / lasers with respect to the object. It uses this information to coherently assemble these points in 3D space so that they resemble the scanned object. Smaller angles of rotation will take longer but result in higher resolution scans.

The quality of your scans will vary widely based on three important factors:

- Object – colors, finish, and features of the scanned object
- Lighting – ambient lighting in the room
- Calibration – brightness, contrast, saturation, and exposure of the camera

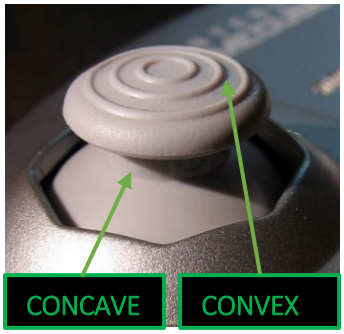
The remainder of this guide will walk you through our process for generating scans step by step.

Selecting an Object

Select an object suitable for scanning. The Ciclop uses red lasers to highlight sections of an object for the camera to record in 3D space. When selecting an object to 3D scan, it's important that the object makes it easy for the camera to see the red lasers. It's ultimately up to you to experiment with what works and what doesn't, but the following are good guidelines to follow for your first scan.

Shiny or reflective objects are difficult to scan. They reflect the lasers off their surface, making the object more difficult for the camera to detect. Additionally, a reflective surface will reflect different areas of its surroundings while it rotates around, meaning that the camera will not be able to capture its textures well.

Red, black, or darkly colored objects are difficult to scan. Red surfaces are difficult to tell apart from the red light from the lasers. Black surfaces tend to absorb of the laser's light, making it difficult for the camera to detect the object. Other colors like dark brown and dark purple are likewise hard to detect. If the object you would like to scan is red, black, or darkly colored in certain areas, it is likely that it will show up as blank spaces in the scan and require significant post-processing work to fix.



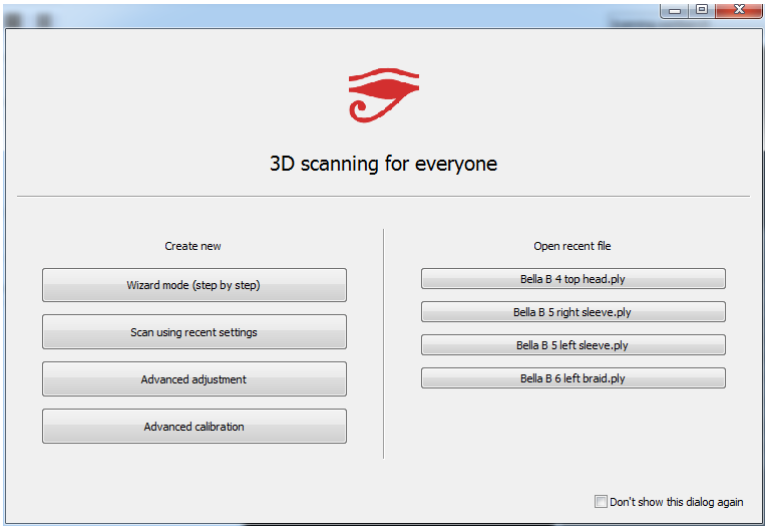
Concave or interior features are difficult to scan. Concave features are areas of an object that form pockets or overhangs. The lasers generally can't reach the inside of the pockets, and they'll show up as large holes in the model. Models with rounded, convex features generally result in better scans.

Significant detail on the top of bottom of an object may require multiple scans and post-processing work to properly capture. The lasers generally don't see the top or base of an object. If you'd like to capture these areas of an object, please see our supplementary post-processing tips at the end of this document.

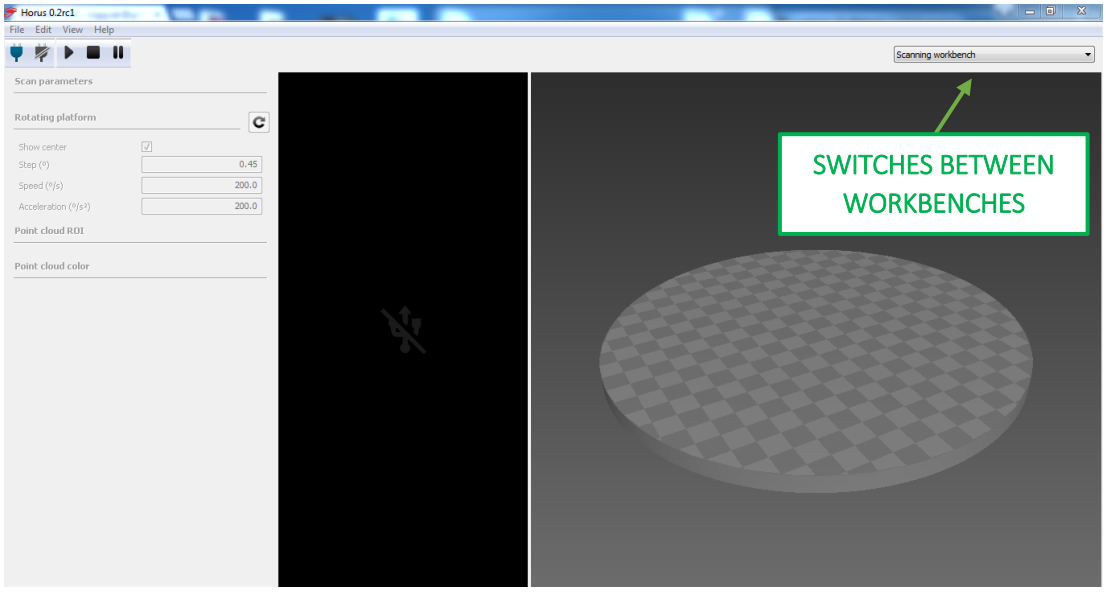
Calibration

Calibration is the difference between a good scan and a bad scan. Follow all of the steps below to ensure that you get a good one. If you come across any further tips and tricks, please do share them with us on our FaceBook page! https://www.facebook.com/groups/564912093672675/

When you first start up Horus, you'll be greeted by the window shown below. Close the window. The window prompts you to launch the "wizard," and in our experience the wizard generally does not make for very good calibrations. You can get much more accurate scans by calibrating manually.



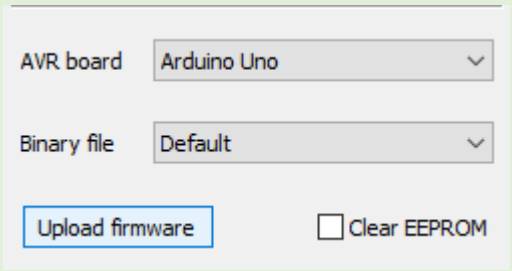
Horus' functionality is divided into four separate windows called "Workbenches." Each workbench is suited to a different step in the calibration process. You can cycle through the workbenches by clicking on the drop-down bar on the top right corner of the window. The default workbench is the Scanning Workbench, which is what you see below. You can stay on the Scanning Workbench for now.



Connecting the Camera

1 Ensure that there is power to the scanner. Plug in the camera and the Uno Clone to your computer.

2 Go to Edit -> Preferences and ensure that your settings match those shown at right. Also make sure that your baud rate is set to 115200.

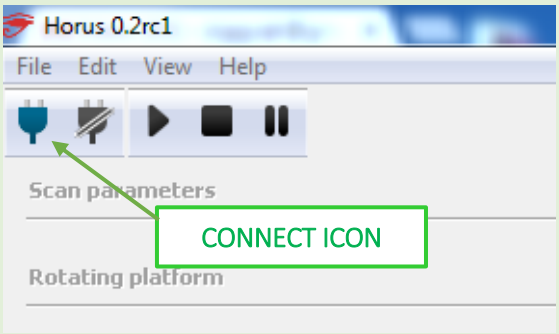


3 Press "Upload Firmware". If you are having issues uploading firmware, try changing the "COM" port selected under "Serial Name". It may also help to restart Horus after changing any settings. If this does not help, please see our troubleshooting tips at the end of this document.

4 Press the Connect Icon on the top left corner of the screen.

Failure to connect seems to be the most common issue the scanners have with Horus. Please see our troubleshooting tips at the end of this document if nothing seems to work, and please don't hesitate to consult the CT Google Group if your issue is not covered in this guide.
Remember: the CowTech team is here to help!

If all goes well, you will see live footage from the camera in the middle segment of the Scanning Workbench.



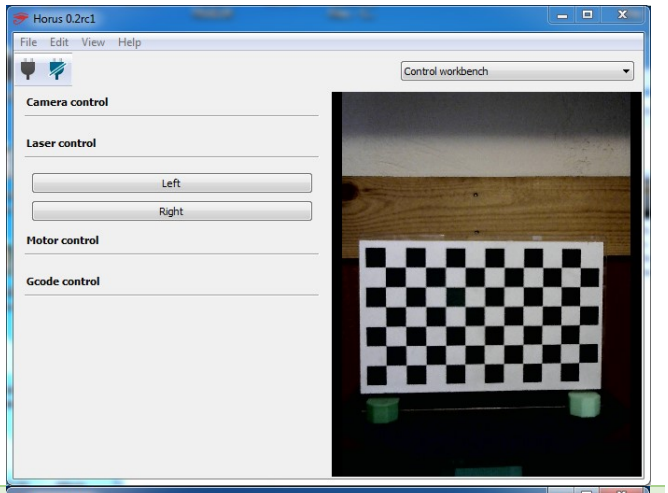
Using the Control Workbench

The Control Workbench helps you test the different components of the scanner. You can use it to troubleshoot any issues you may have with the motors, lasers, or camera. The button on the left side of the workbench can control all of these components.

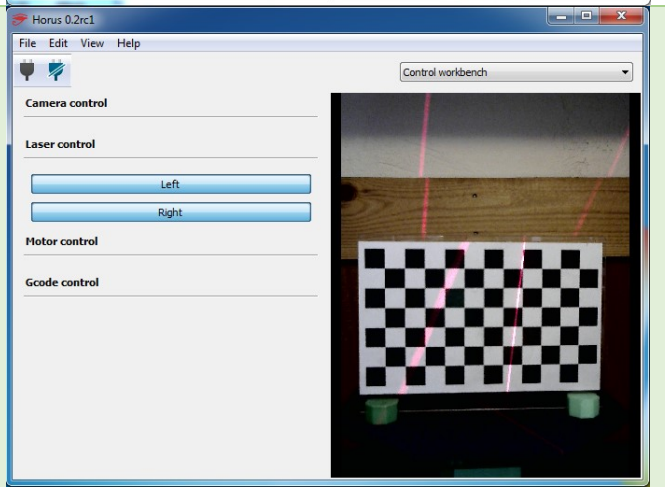
We'll use the Control Workbench to make sure that our lasers and object are in a good position to scan.

Vertically Align the Lasers

1 Place the calibration pattern on the table. The calibration pattern comes with your scanner, and it's fairly important. Don't lose it! Be sure that it is as perfectly perpendicular with the table as possible. If the calibration pattern is skewed, you may get some skewed scans after calibration.



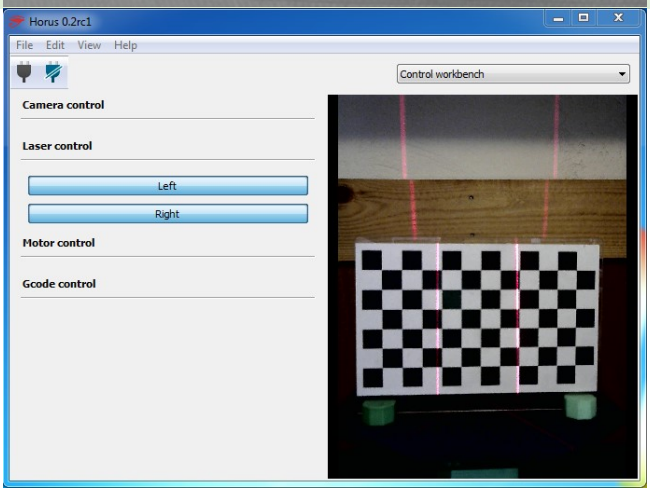
2 Turn on the left and right lasers. Use the buttons on the left side of the Scanning Workbench. In the picture at right, you can see that the left laser is much broader (and therefore dimmer) than the right laser. This needs to be fixed.



3 **Focus the lasers.** The lasers have a small plastic lens on the end that focuses the beam into a line. Rotate it to make the line as thin and bright as possible. A thin laser makes it easier to capture fine detail.

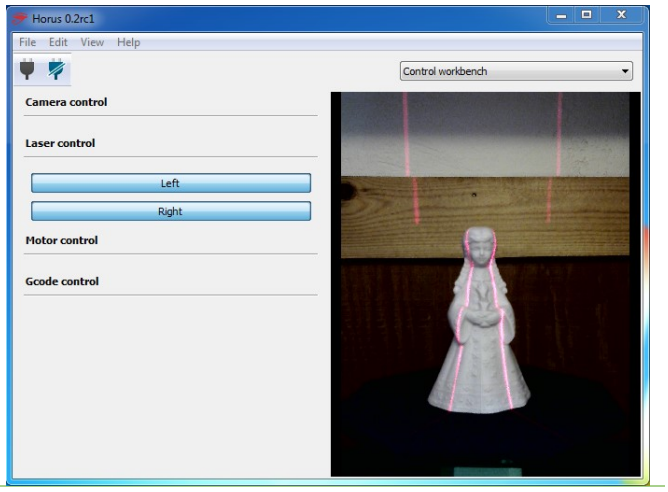
If you are having trouble with this step, please see the more detailed Laser Focusing Guide in the Supplemental Troubleshooting Guides section at the end of this document.

4 **Rotate the lasers so that they're vertical.** You can use the borders between the checkers to help align the lasers. They should be perfectly parallel.

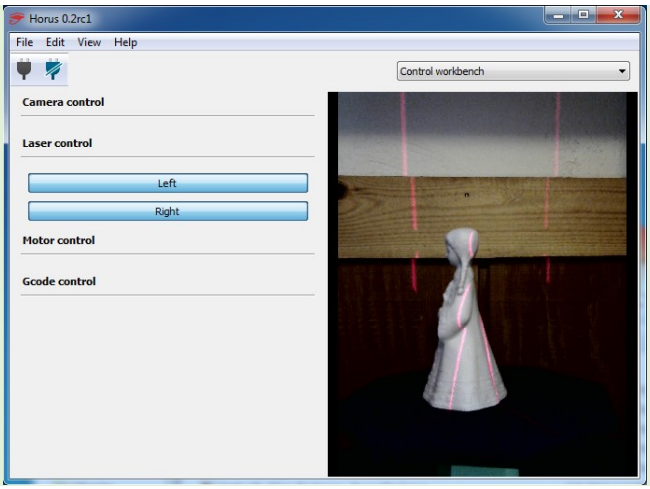


Ensure Good Laser Coverage

1 **Remove the calibration pattern and place your object on the table.** The calibration process will require a lot of switching back and forth between the two, so keep the calibration pattern handy.

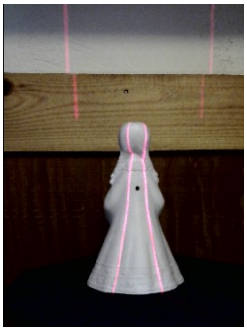


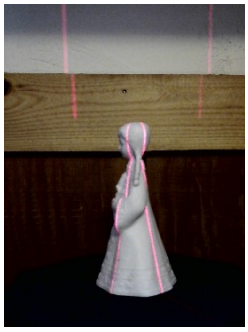
2 Rotate the table with your hands. You may notice that the lasers don't hit as much of the object at certain angles.



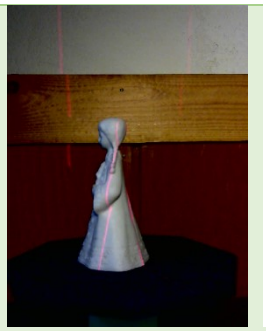
3 Adjust the position of the lasers or object to ensure good coverage. Good coverage means that the lasers are visible along the entire length of the object. Ensure that this is true for all angles of the table. It may take some guess and check work to get it right. Some examples of good and bad coverage are given at right.

GOOD





BAD



4 Mark object's position on the table. You will want to be able to replicate the objects current position later. A piece of tape works well to mark the boundaries of the base of the object. If you adjusted the position of the laser holders, it may also be worth it to make sure the lasers are still vertical and focused, as it's easy to accidentally skew them during this step.

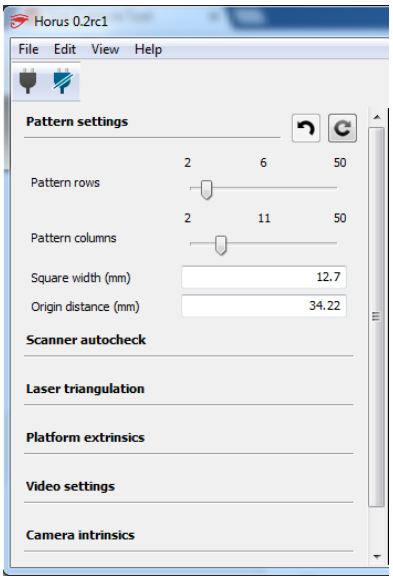
A Quick Detour to the Calibration Workbench

Before you begin using the Adjustment Workbench in the next section, it is helpful to quickly check some settings in the Calibration Workbench. Follow the steps below to ensure that your calibrations will work properly.

1

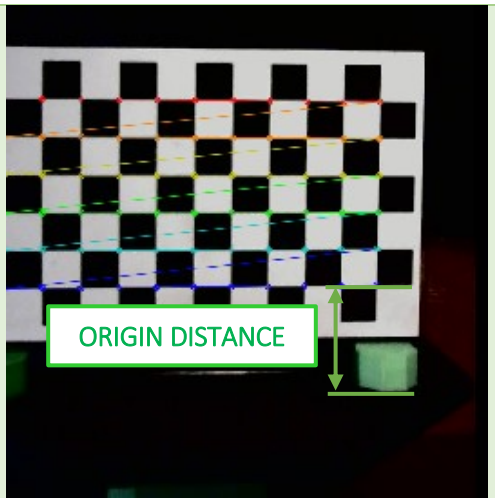
Go to Calibration Workbench -> Pattern Settings. Make sure that rows and columns are set at 6 and 11, respectively. If you look at the grid on the calibration pattern, you might notice that there are in actually 7 rows and 12 columns. Regardless, if you set these values to 7 and 12, your scanner will not be able to recognize the patterns. BQ (the makers of Horus) may change this at some point in future versions.

Also set the square width to 12.7 mm. You're free to measure this yourself, but this value has worked well for us and should be consistent across all CT Ciclop scanners. The more accurate you can get this value, the better your calibration will be. Better calibrations mean better scans!



2

Measure origin distance as accurately as possible. The origin distance is measured from the bottom edge of the feet of the calibration pattern to the top edge of the nearest square. We recommend using calipers if you have them. The more accurate you can get this value, the better your calibration will be. Better calibrations mean better scans! Input this measured distance into the appropriate field.



Using the Adjustment Workbench

The adjustment workbench is where you adjust the camera's settings. The camera's settings are crucial. When using the lasers, the camera relies on distinguishing red from other colors to differentiate the object's space from empty space. When calibrating, the camera relies on distinguishing white from black to detect the calibration pattern. The Adjustment Workbench lets you adjust the camera's settings separately for each task to maximize its ability to tell colors apart.

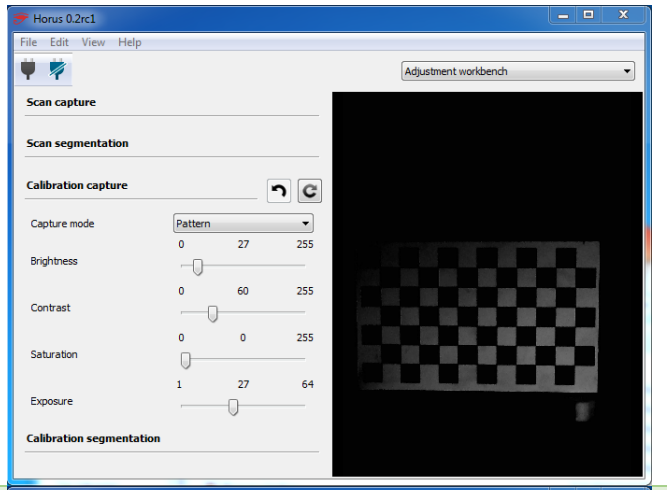
Success is dependent on the lighting of the room. Although we have some general tips about lighting, you may need to experiment with different kinds of light to get good results.

Calibration Capture

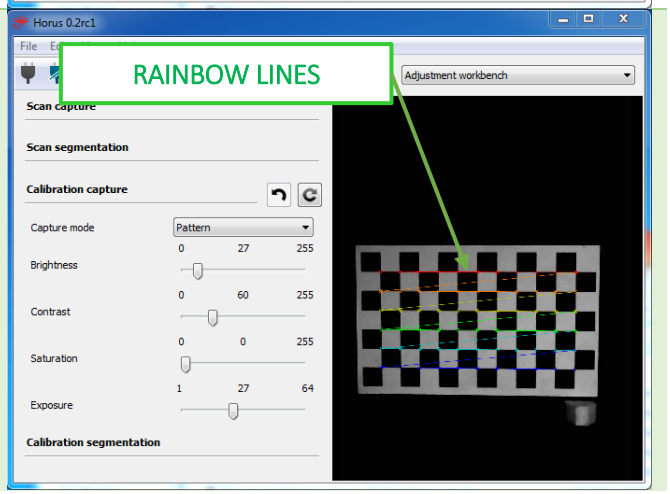
Calibration Capture covers all the settings that govern how the camera looks at the checker pattern during calibration. Horus tells you if the camera can detect the pattern by displaying a series of rainbow lines running between the squares on the camera's feed at the right side of the workbench.

The trick is to get Horus to display these rainbow lines for as wide a range of rotation as possible. Rotating the table away from the position where it directly faces the camera makes the pattern slanted from the camera's perspective. The more slanted the pattern can be while still displaying the rainbow lines, the better the calibration will be.

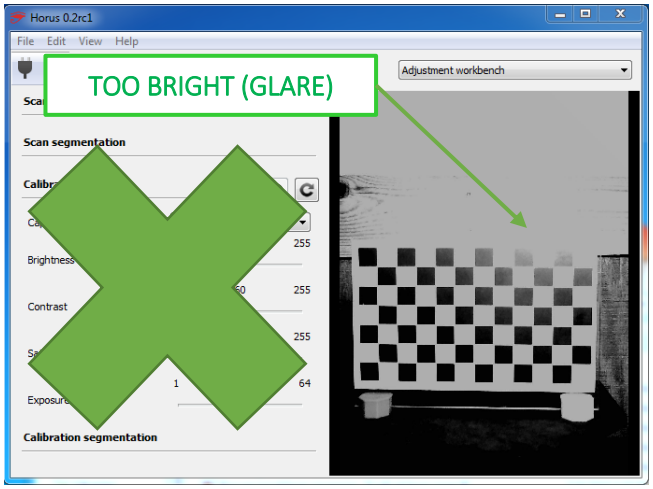
1 Place the calibration pattern on the table.



2 Adjust the light until you see the rainbow lines. The picture at right gives you an example of what the rainbow lines look like. Horus can get quite picky about recognizing the pattern, so be prepared to adjust the settings of the camera and experiment with a few different light sources.

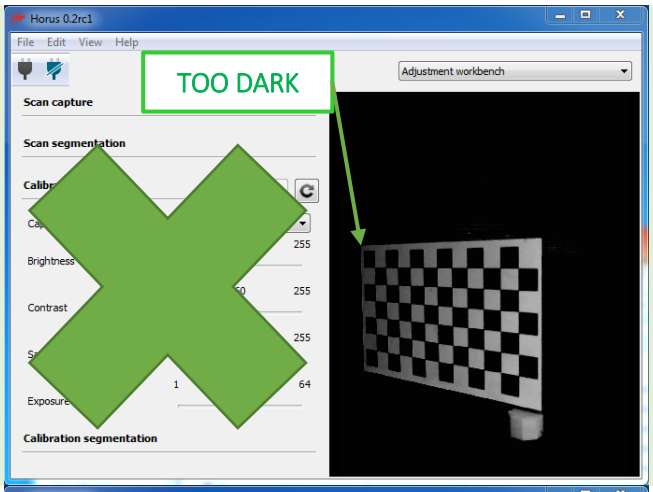


- The more indirect the light is, the better. Direct light can cause glare on the slightly reflective surface of the sticker, which makes the black squares in some areas indistinguishable from the white ones. The picture at right is an example of this. If even one square is obscured by too much glare, Horus will not recognize the pattern.

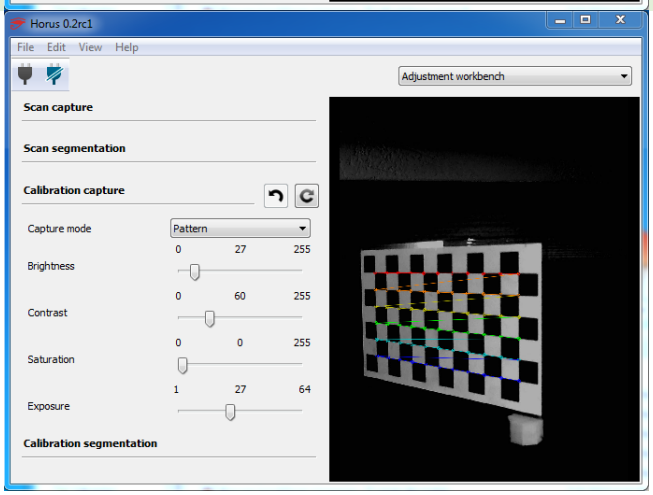


- To get more indirect light, try shining a lamp at a white surface near the scanner. The white surface will bounce a fair amount of indirect light onto the pattern without glare.

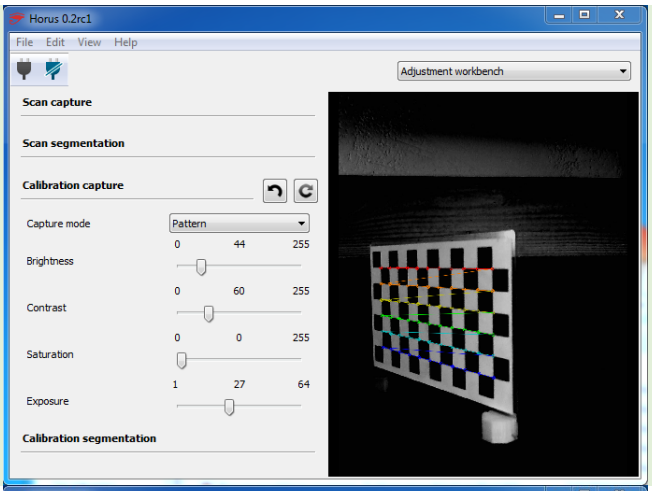
3. Rotate table to the left or right with your hand. Try to see how far you can rotate the table before the rainbow lines go away. They usually go away when one side of the pattern is exposed to less light and becomes darker. When the pattern's lighting becomes inconsistent like this, Horus will fail to recognize the pattern. The picture at right shows the angle at which Horus just begins to stop recognizing the pattern



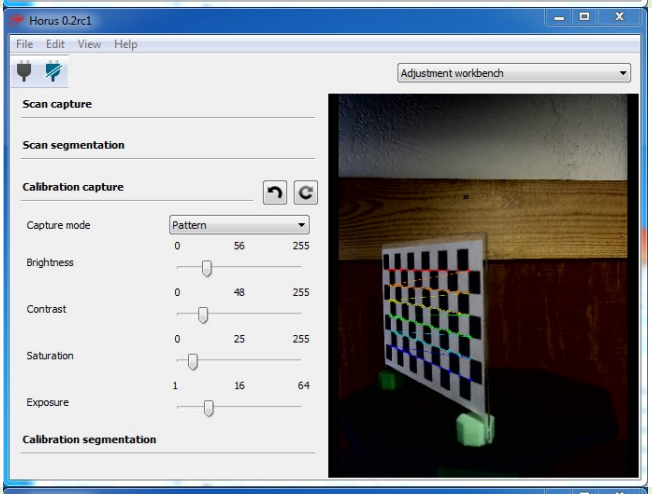
4. Add light sources to either side of the table. This increases the scanner's range of pattern detection. At right you can see how this allows Horus to detect the pattern at a steeper angle of rotation. Again, this may take some time to get right.



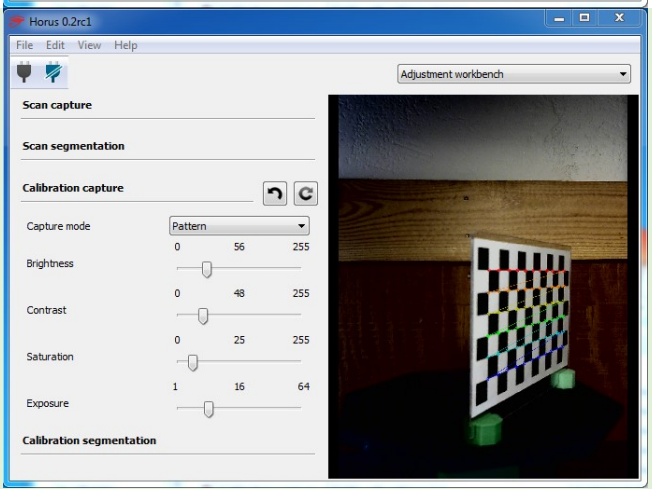
4 **Fiddle with settings to get Horus to detect the pattern at as steep angle as possible.** The picture at right is the result of modifying only the brightness, and gives a decent angle of detection. Generally, you want to be able to detect the pattern when displaced at least 45° from its initial position directly facing the camera. If you can do more, do it!



- **Be patient and experiment**. After adding more light and adjusting all the settings, we arrive at an angle that's roughly 65° from the initial table position. It may take a little patience and guess and check work to get it right.



6 **Maximize the range for the other side as well.** The picture at right is the result of adding some indirect light to the right side of the table.



7 **Check the pattern when facing the camera directly once again.** Slowly rotate the table with your hand all across the range where the pattern is detected. Sometimes adding more light on the sides will make the pattern too bright in the center, giving detection on the sides but not in the middle. Make sure that the rainbow lines are detected along the entire range of rotation from left to right.

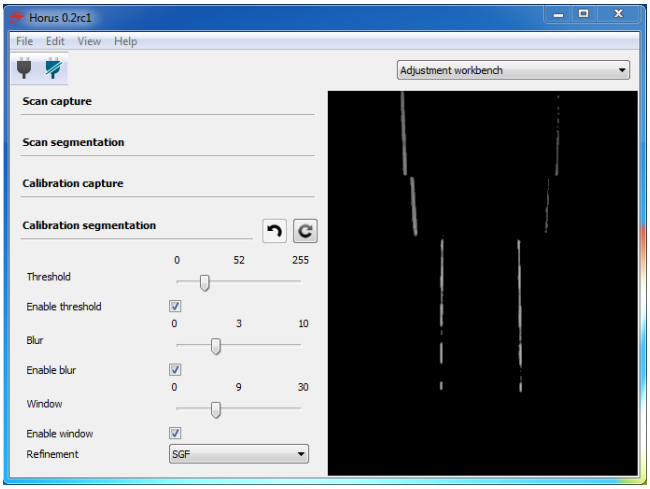
Calibration Segmentation

Calibration segmentation covers all the settings that govern how Horus tells red laser light from other colors. Horus will show you which areas register as laser light with white highlights, while leaving everything else black. This is important during calibration, when Horus uses light from the lasers shining on the calibration pattern to orient the lasers and table in relation to the camera.

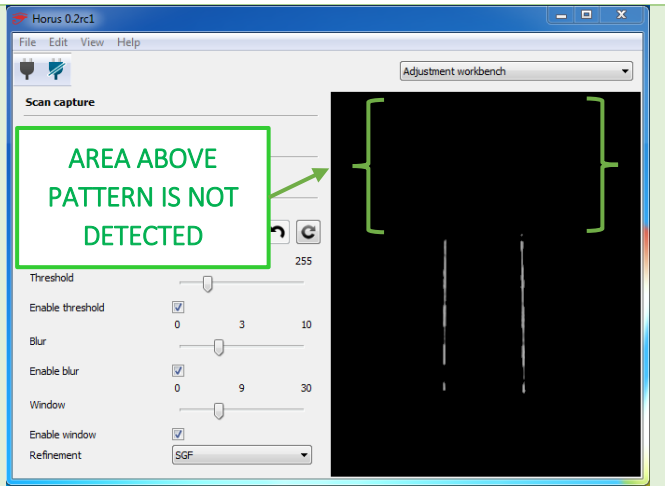
The goal is to get Horus to detect only the laser light that shines on the white squares. Ideally, the areas where the laser lines hit the black squares should not be detected. We also want to lines to be stable (not constantly shifting) and to be relatively crisp.

1 Turn off the lights. For this step, less ambient light will allow the red laser light to shine brighter and make it easier to detect. The lights will stay off when it's actually time to scan. We can do this because we are not capturing a texture.

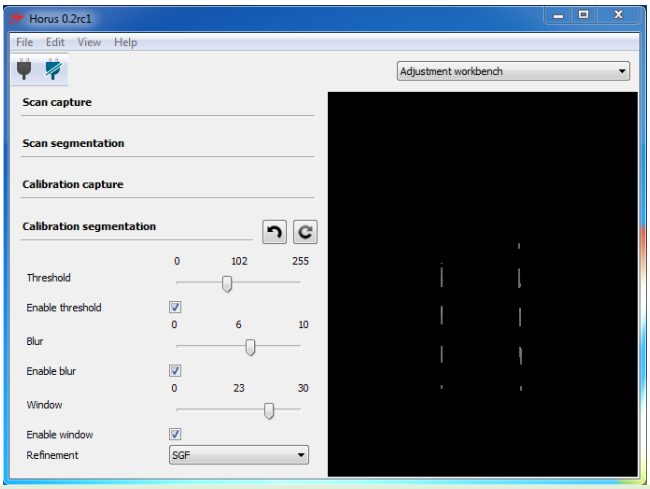
If we were capturing a texture, we would want to keep the lights on during scanning. Lights on means that you get an accurate depiction of the object's colors. Just be warned that texture scans may make calibration more difficult and possibly compromise the level of detail of the scan.



2 Make sure Horus does not detect the background. In the picture on the previous step, the top four lines are from the wall rather than from the calibration pattern. To remove them, hang a darkly colored sheet behind the table or move the table further away from the wall.

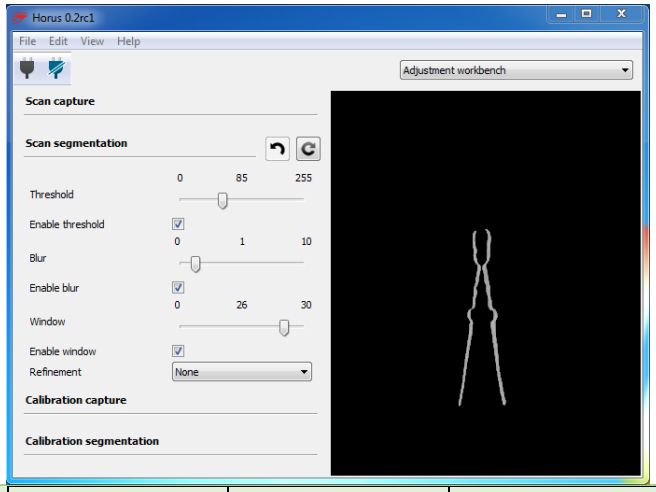


3 Fiddle with the settings until only white squares are detected. It can be difficult to make it so that all of them show up with equal thickness. It's fine if only two or three of the white squares show up on each laser. Experiment with the settings to see what works best. A brief description of each one is below.



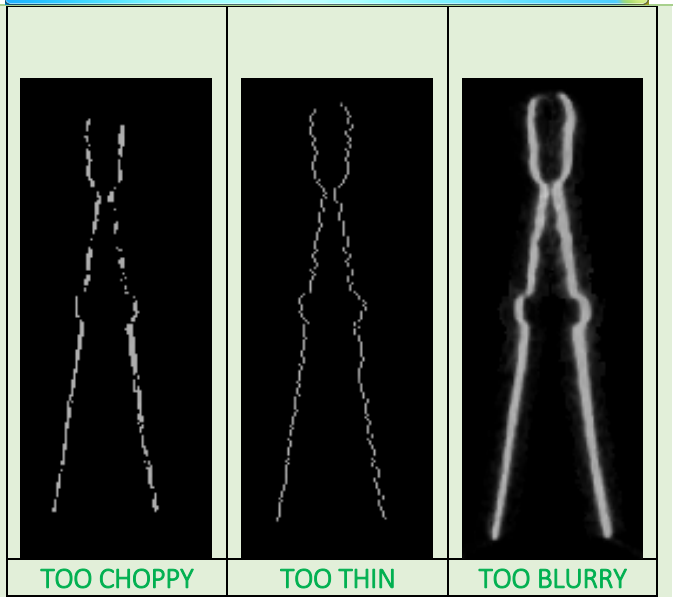
- Threshold – Changes the minimum intensity of light that counts as laser light. Any pixel that falls below this value is discarded. This is like the "brightness" setting on the camera.
- Blur – Draws a box around each pixel. That pixel's intensity will count only as the average of all pixels within the box. The value of Blur changes the size of the box drawn. This is similar to the "saturation" or "contrast" setting on the camera.
- Window – Discards pixels that fall outside a certain distance from the highest intensity pixels in the image. This is similar to the "exposure" setting on the camera.

Scan Segmentation



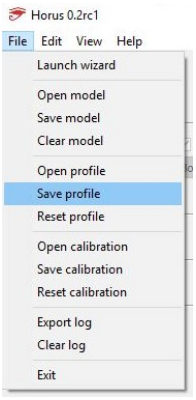
1 Put your object on the table. This step is just like Calibration Segmentation, except you use the object rather than the calibration pattern.

2 Fiddle with the settings. Depending on the color of your object, they might be slightly different from those from Calibration Segmentation. Examples of some bad settings are at right. Use the picture above these three as an example of good segmentation.



3 Rotate table to ensure good coverage. Double check that the lasers hit all the areas of your object that you want to scan.

Saving the Adjustment Profile



The settings you got from the previous steps can be saved and loaded for later. This is extremely useful as long as you have consistent lighting, as it saves you the trouble of fiddling with settings each time you'd like to scan. The files are saved with the .json file extension.

Using the Calibration Workbench

The calibration workbench is how the scanner figures out where its components are in 3D space. This is crucial for making the model geometrically accurate. Once the camera settings have been worked out in the Adjustment Workbench, the scanner accounts for distortions caused by the camera's lens and triangulates the positions of the lasers, and table.

Pattern Settings

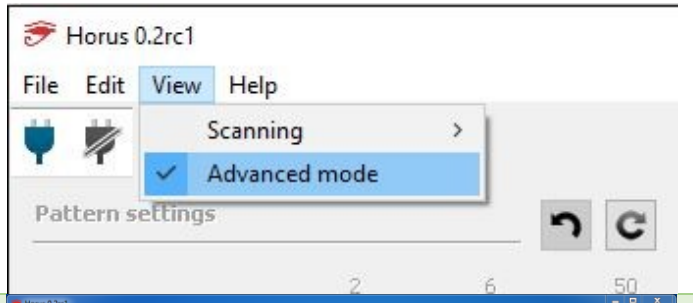
Ideally, you have already set the correct Pattern Settings earlier in this guide. Please see the section titled "A Quick Detour to the Calibration Workbench" page 14 for a walkthrough on what to do.

Scanner Autocheck

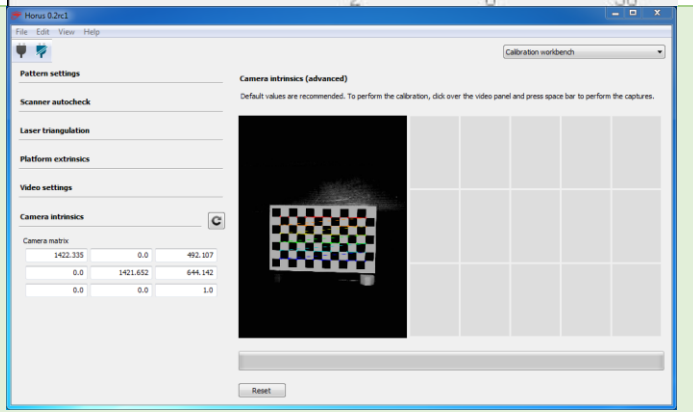
Skip this calibration. Scanner Autocheck simply turns on all of the components of the laser and confirms that they work. We recommend against using this, as occasionally it will cause the stepper motor to behave erratically. Regardless, by now it should be fairly obvious if something doesn't work on the scanner.

Camera Intrinsics

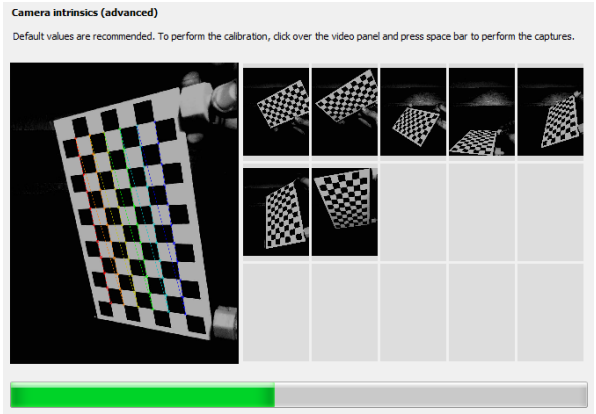
1. Go to View -> Advanced Mode. Make sure that Advanced Mode is enabled with a check mark. This is the only way that you will be able to access the Camera Intrinsics settings.



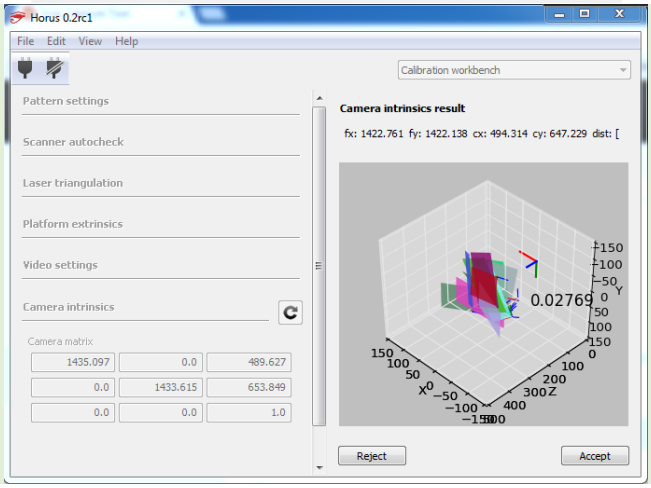
2. This step accounts for distortion in the camera's lens. It works by taking many pictures of the calibration pattern in as wide a range of positions as possible.



3 Use your hand the move the calibration pattern around as directed. Aim for as wide a range of positions and angles as the scanner will detect. You will know if the scanner is detecting the pattern via the rainbow lines. Press spacebar for each new position. Horus will take a snapshot of each one.

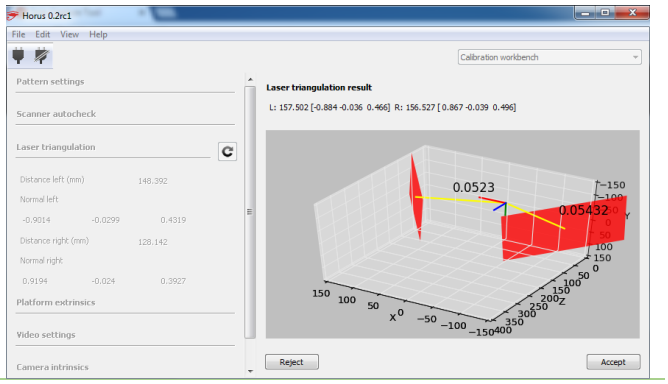


4 Click accept if the results seem reasonable. Each colored plane in the diagram represents a one of the nine orientations of the calibration pattern.

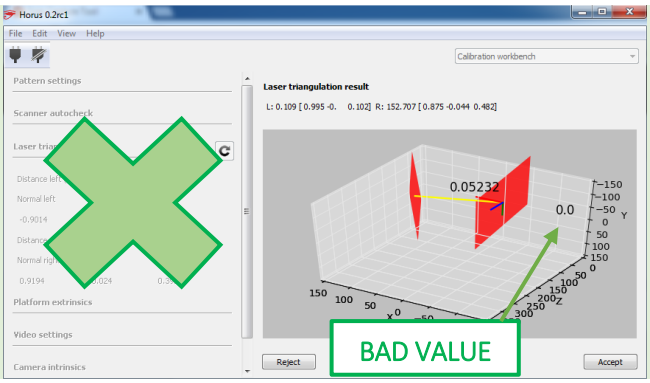


Laser Triangulation

1 Run the Laser Triangulation calibration. Make sure you have the pattern on the table when you do. The result should look similar to what is shown at right. The two numbers floating next to the red planes should be somewhere between 0.05 and 0.06.



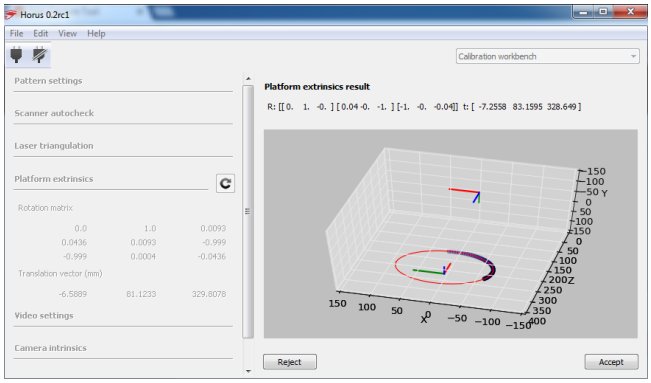
- If those numbers are off, the scanner isn't properly detecting the laser. Readjust your settings for Calibration Segmentation and try again. You can see an example of a bad triangulation on the right.



Platform Extrinsics

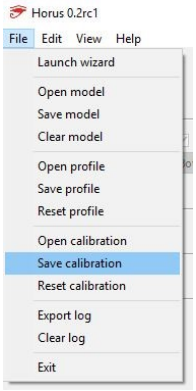
1. Run the Platform Extrinsics calibration. If Laser Triangulation worked without a problem, this should work fine as well. It will spin the table and record a number of frames at different angles.

- Make sure that your result is similar to the one at right. There should be many dark dots along the top right quarter of the circle inside the 3D graph. If there are fewer than shown at right, readjust your Calibration Capture settings and try again. You want to see as many as possible.



Saving the Calibration Profile

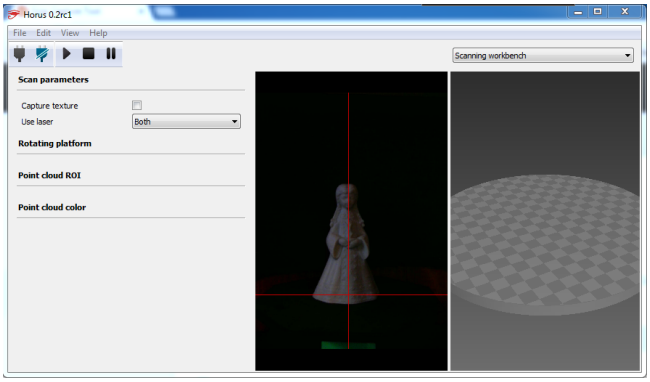
The calibrations you got from the previous steps can be saved and loaded for later. Just like adjustment profiles, these files are saved with the .json file extension. Please note that unlike adjustment profiles, we don't recommend reusing calibration profiles between scanning sessions. Even the slightest bump of the table can set the lasers or table slightly out of alignment and compromise scan quality. Adjustment profiles can be reliably reused as long as your lighting setup remains the same.



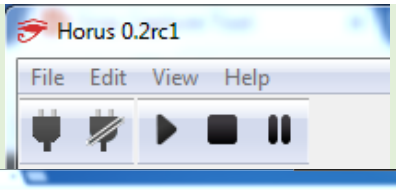
Using the Scanning Workbench

Congratulations, you are now almost ready to scan! The Scanning Workbench is where you specify whether or not to capture texture, determine the Range Of Interest (ROI), and set the display color of the points captured. The rightmost pane of the Scanning Workbench will display the 3D model as it is captured.

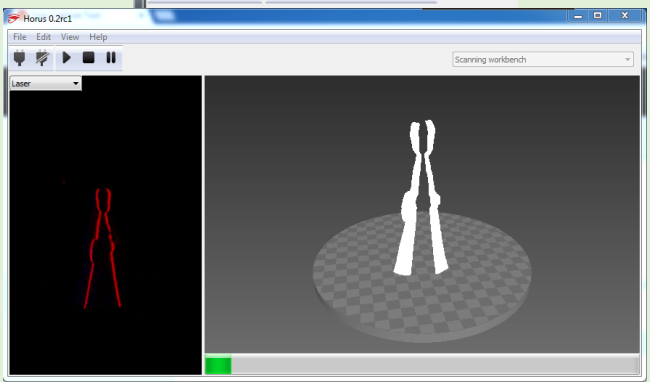
1. Put your object on the table. Make sure it's in the position you found earlier that provides good laser coverage.
2. Turn the lights off if you're not capturing texture. If you are capturing texture, skip this step.
3. Set your ROI to the minimum area that will encompass your object. The ROI ensures that the scanner will not pick up erroneous points that are far from your model but still within the camera's view.



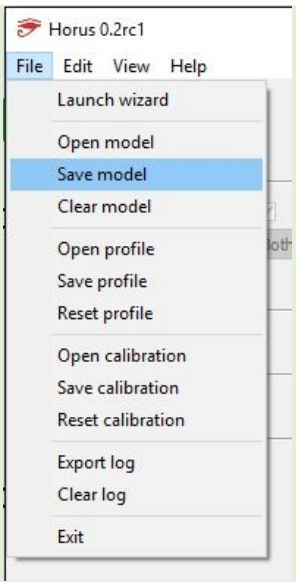
4. Press the play button on the top left corner. The scan will now begin!



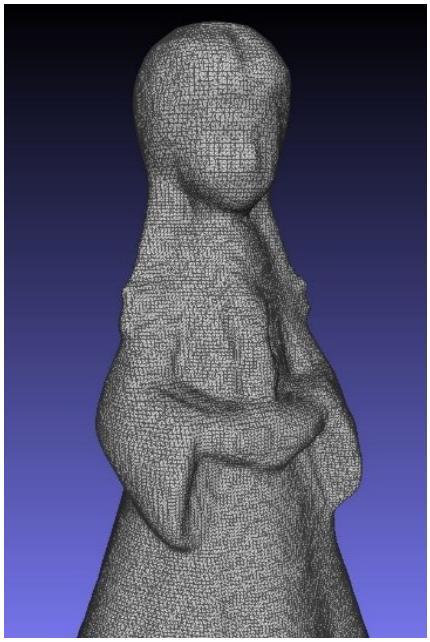
- The scan may take 10 to 20 minutes to complete. It may be hard to make out the details of your object at the moment, as the point cloud does not provide outlines for the object's features.



5 Save your model once the scan is complete. You are now ready to begin post-processing your model.



After post-processing, your 3D model is ready to print!



Post-Processing Tips

For help with post-processing your point cloud, please refer to the BQ guide on the page linked to below.

http://diwo.bq.com/en/documentation-ciclop-and-horus-2/

Although the bulk of the information that you need for post-processing can be found at the link above, we have a few supplemental tips included below. Note that the BQ guide gives you the option of using either MeshLab or CloudCompare to process your point clouds. Our tips are only applicable when using MeshLab, although you could likely find analogous operations in CloudCompare.

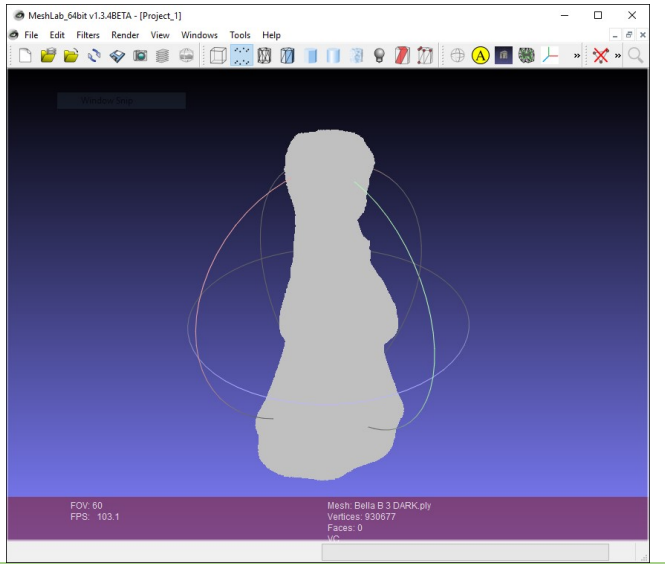
Don't forget to post pictures of your cool scans on our FaceBook page! Likewise, if you're stuck with an issue, we encourage you to reach out to the community for help on the CowTech Ciclop Google Group.

- CowTech Ciclop Facebook Group - https://www.facebook.com/groups/564912093672675/
- CowTech Ciclop 3D Scanner Google Group - https://groups.google.com/a/cowtechengineering.com/forum/?hl=en#!forum/cowtech-ciclop-3d-scanner

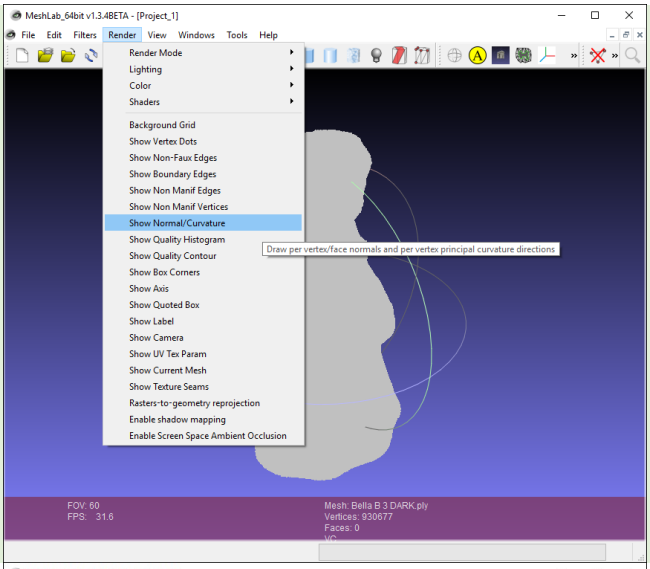
Inverting Normals Before Generating A Mesh

Before you can make a mesh from the point cloud, you must generate normals for the model. Ideally, the normals poke outward away from the model so that it looks fuzzy. But sometimes the normals are facing inward. This can cause lots of problems when it comes time to build a mesh. MeshLab offers tool to invert the normals associated with a mesh already, but it does not offer any tool to do so if the mesh hasn't been built yet. The following workaround allows you to invert the normals without a mesh.

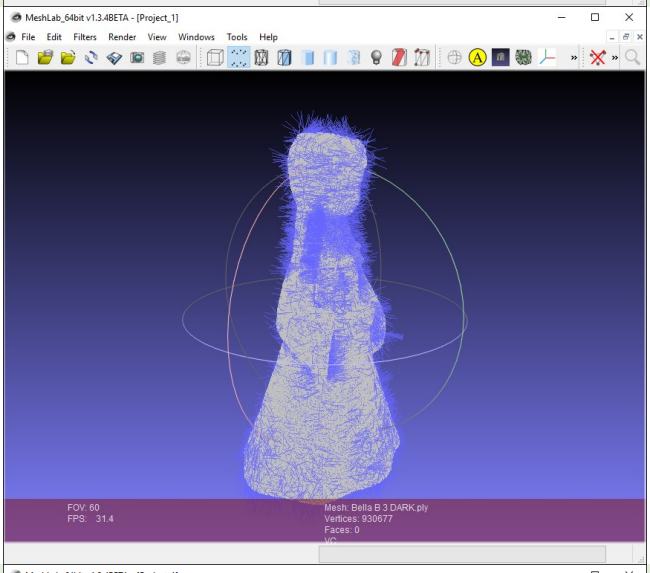
1 Open up your point cloud. At right you can see the object we scanned earlier.



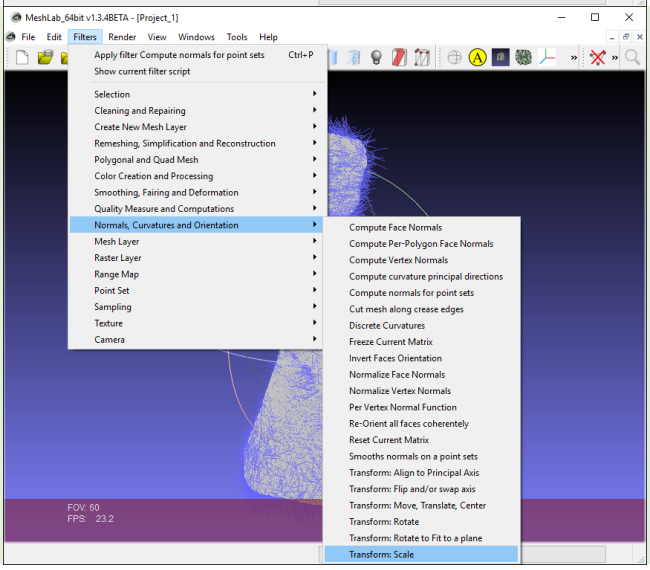
2 Display the normals. To do this, go to Render -> Show Normal/Curvature. (If you haven't yet generated the normals, please read the BQ guide linked to earlier in this document!)



3 At right is an example of a bad set of normals. Generally it is easy to tell if the normals are bad because the normals look like scraggly hairs instead of a rich coat of fur.



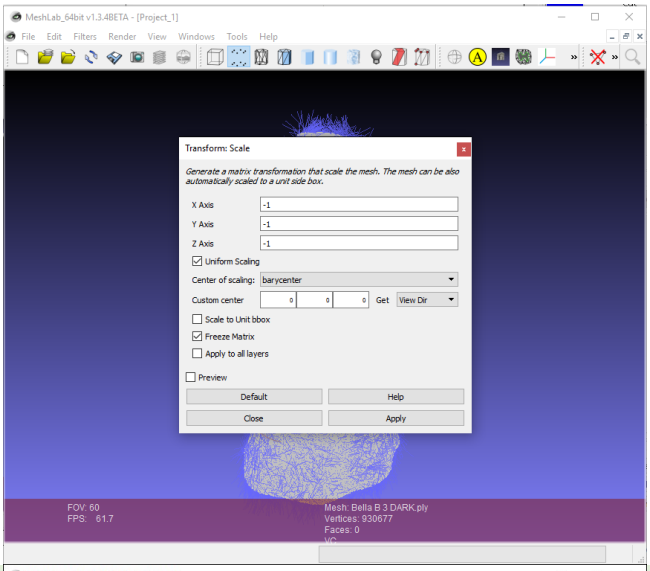
4 Go to Filters -> Normals, Curvatures and Orientation -> Transform: Scale.



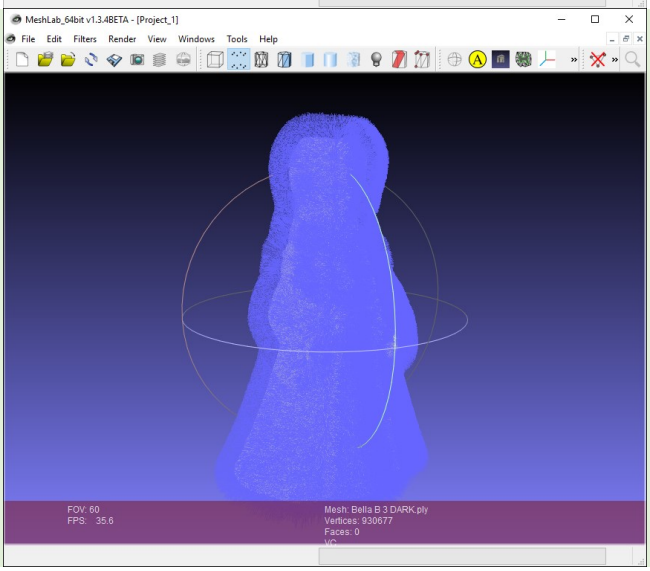
Set X, Y, and Z to -1.

5 Set the “Center of Scaling” to “barycenter.” Press the “Apply” button.

This will flip your model upside down, but it’s simple enough to reorient by clicking and dragging the left mouse button.



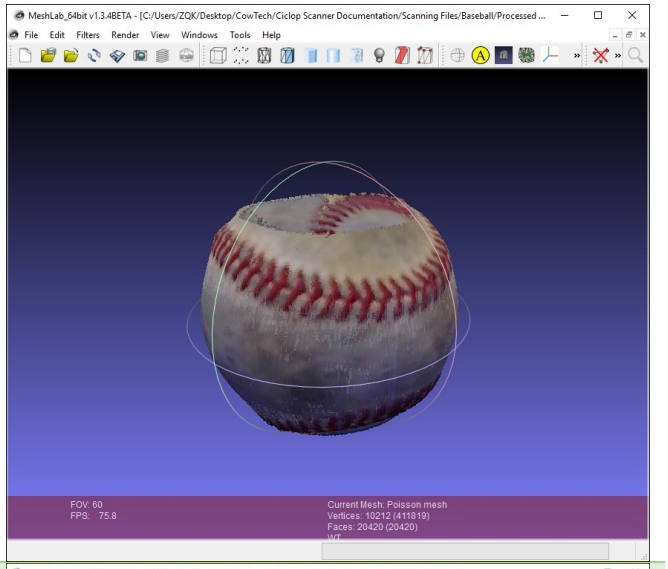
6 Recompute the normals and render them. The result should be much better! You are now ready to compute the mesh



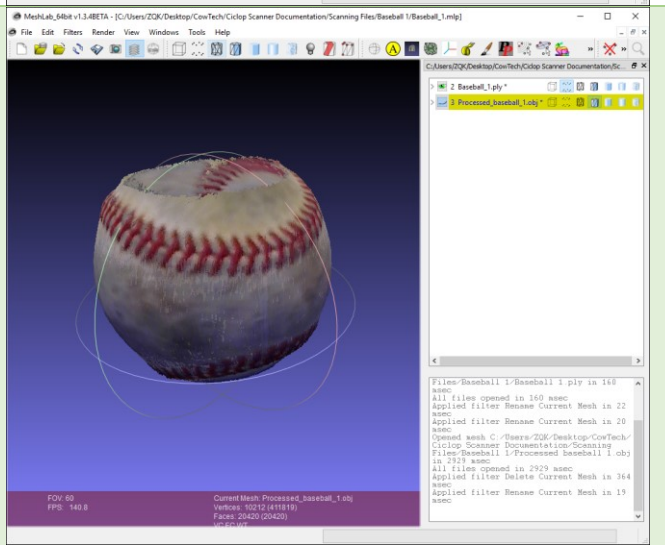
Exporting A Mesh With Texture in .OBJ Format

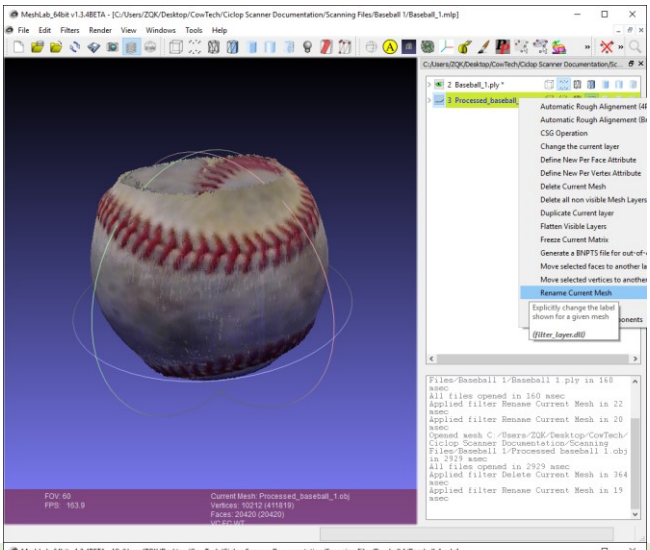
The following section assumes that you've already made your mesh and would now like to apply a texture to it. After adding the texture to it, it can be saved in the .obj file format. Normally, the .stl file format is used for 3D printing. Keep this in mind before beginning the following guide. Please ensure that the .obj file format is suited to your application.

1 Open up your mesh. Shown at right is a partially complete scan of a baseball. Ideally, this scan would be fused with another to cap off the top and bottom, but we will proceed with this scan alone for demonstration purposes.

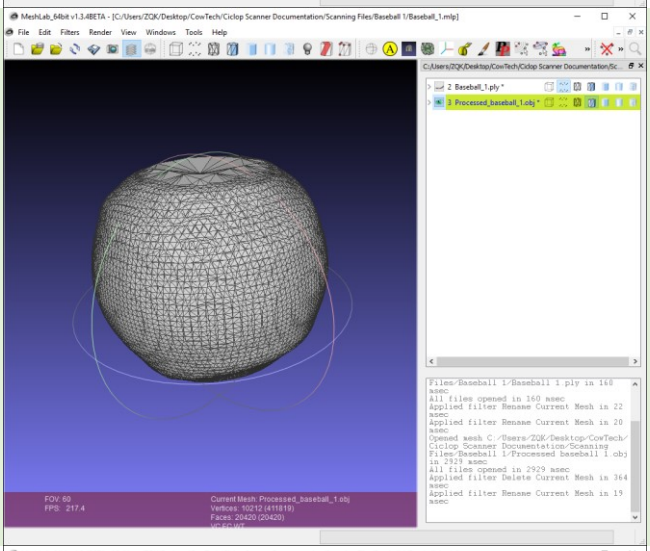


2 Press Ctrl + L to see all of the layers present in your project. "Baseball_1.ply" is the point cloud currently visible, and "Processed_baseball_1.obj" is the mesh generated from it.

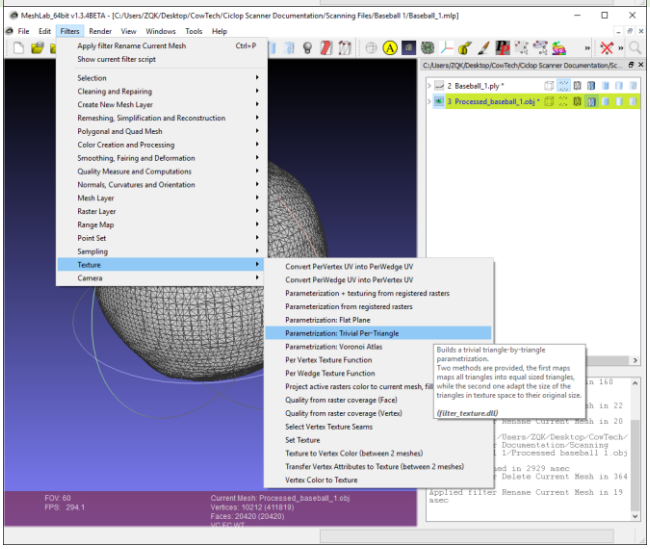




3 Rename both layers such that there are no spaces in them. MeshLab does not like spaces in file names. Don't forget this step, it will save you the hassle of redoing this entire process!

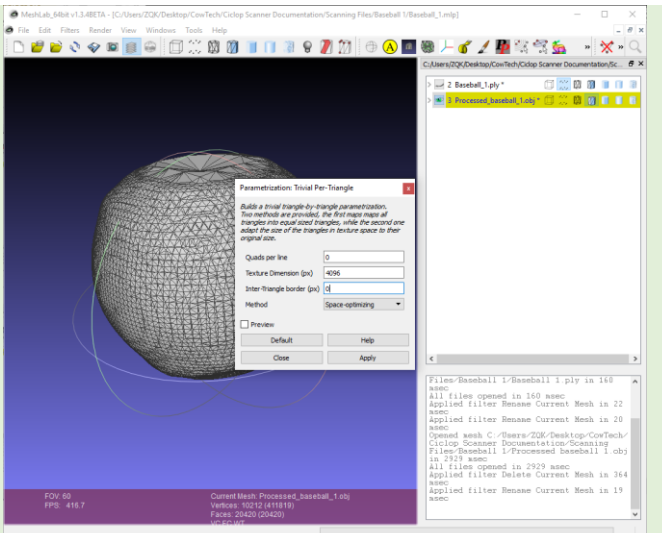


4 Select the mesh so that it's highlighted yellow and click the small eye icons next to each layer's name to toggle visibility. At right is the untextured mesh.

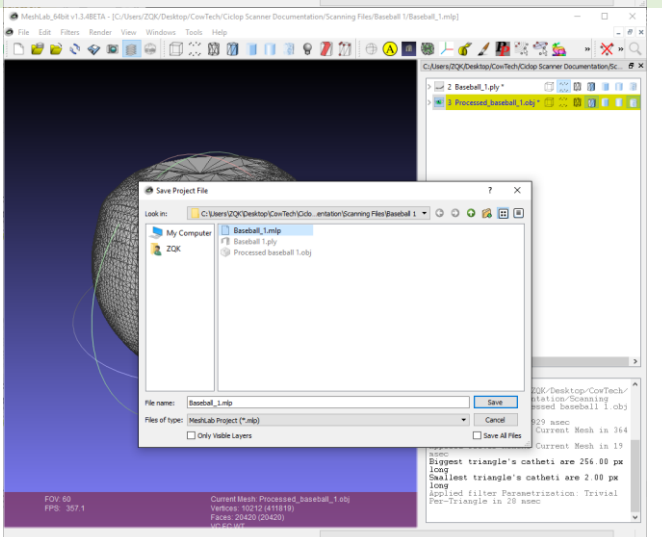


5 Go to Filters -> Texture -> Parametrization: Trivial Per-Triangle. This chops the point cloud colors into triangular bits that correspond to your mesh's triangles.

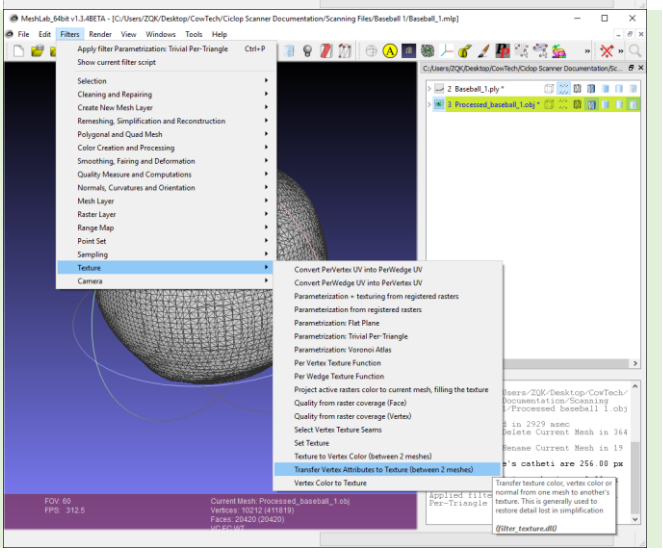
6 Change the “Texture Dimension (px)” field to 4096 and the “Inter-Triangle Border” field to 0. Do not check the preview box, this will often crash MeshLab. Hit “Apply” and then close the window.



7 Go to File -> Save Project. The steps after this may be destructive and reloading the file will be your way to revert back to square one. Again, make sure that there are no spaces in the name.



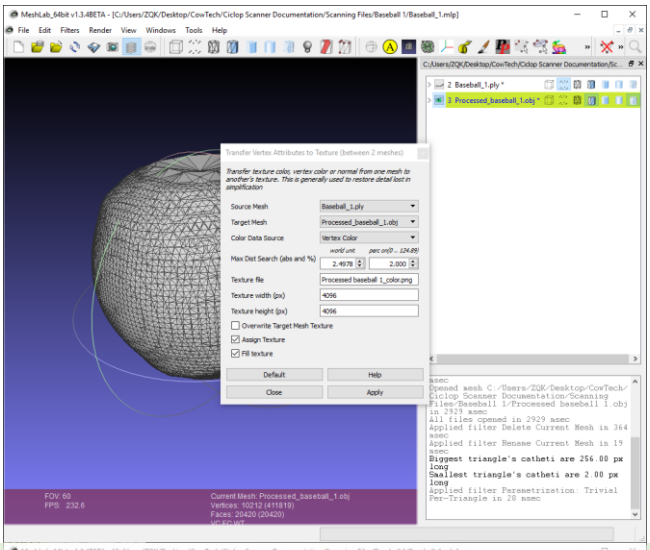
8 Go to Filters -> Texture -> Transfer Vertex Attributes to Texture (between 2 meshes). This transfers your texture data onto the mesh.



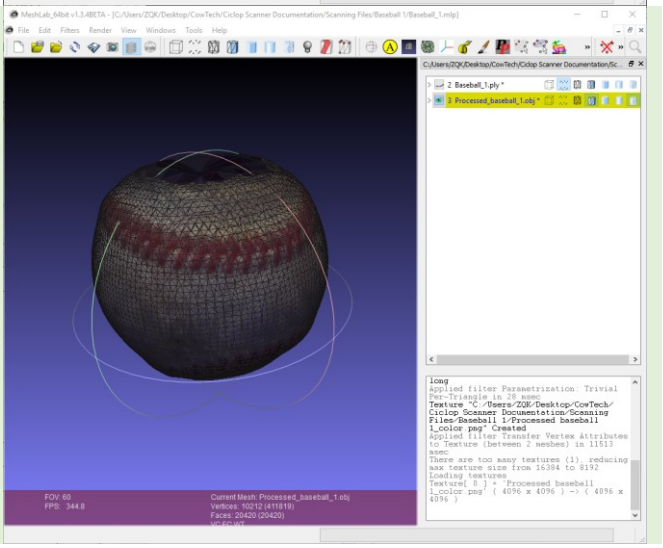
Change “Source Mesh” to be the name of your object’s point cloud. Leave “Target Mesh” the way it is.

9 Change both “Texture Width” and “Texture Height” to 4096.

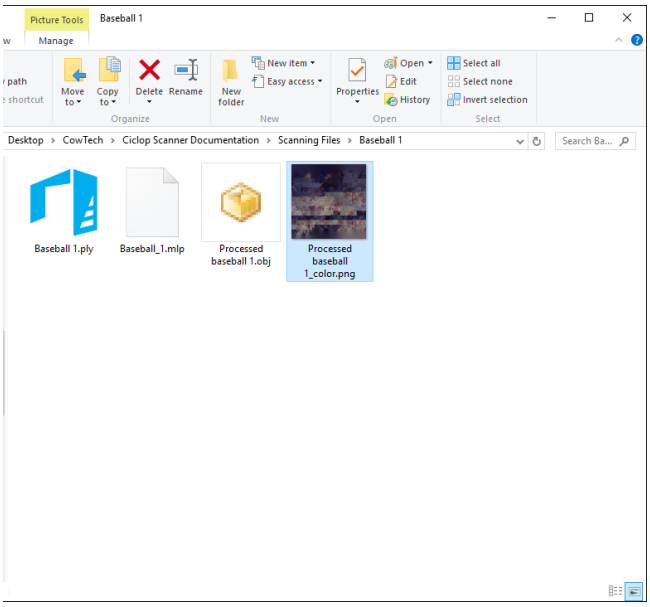
Check the boxes titled “Assign Texture” and “Fill Texture.” Leave the “Overwrite Target Mesh Texture” box unchecked.



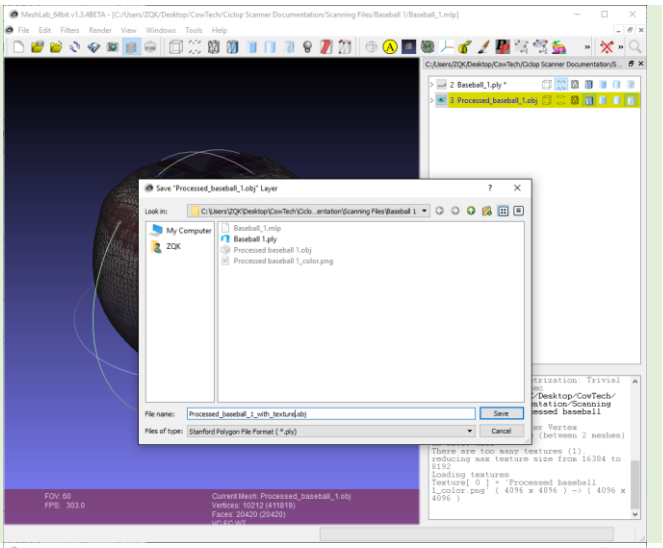
10 Click apply. It may take a while for MeshLab to generate the result. Close the parameter input window when MeshLab has completed the operation.



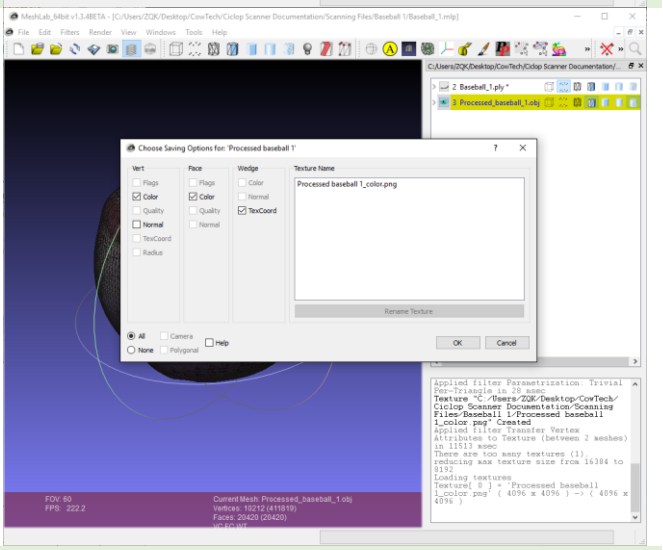
11 Open up the directory that your project is saved in. You should now see a .png file saved in the same directory as the .mlp file you saved earlier.



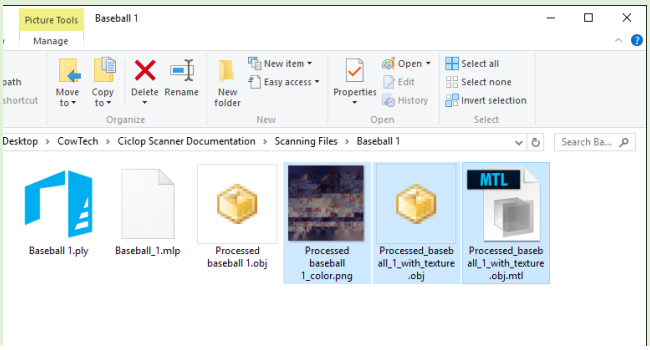
12 Go to File -> Export Mesh As. Save the file as an .obj file and name it however you please. Make sure that there are no spaces in the name! MeshLab does not like spaces in file names.



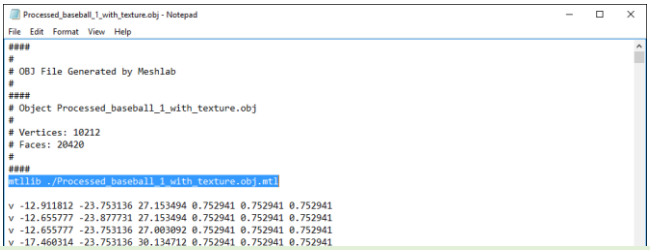
13 Make sure that the "Vert – Normal" box is unchecked and "Wedge – TexCoord" is checked. The picture at right has a problem – there are spaces in the name! Make sure you don't make that mistake.



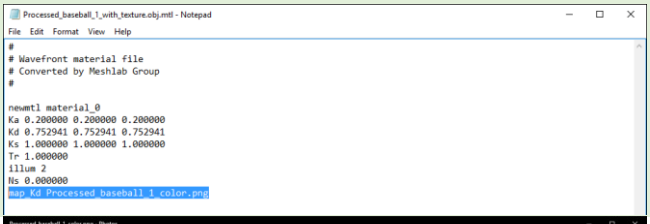
14 Go back to the directory where you have saved all your files. You now have three files of three different types: .obj, .mtl, and .png. They should all be in the same directory like they are at right. If they are not, move them so that they are.



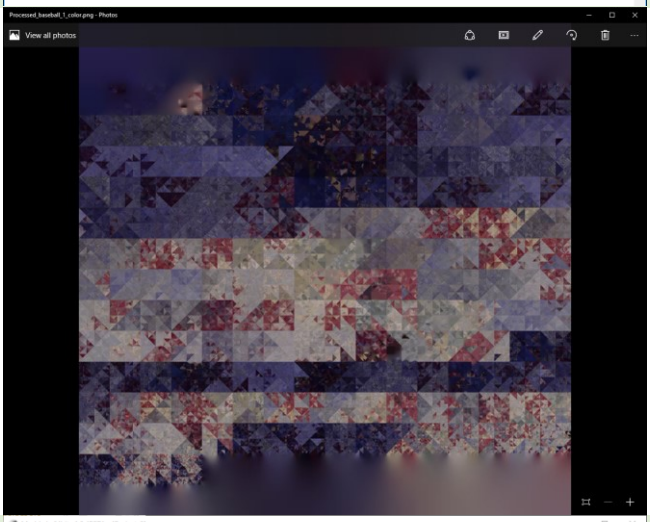
15 Open up the .obj file in Notepad or another text editor of choice. Notice that it references the .mtl file. The line that does this is highlighted in the picture at right.



16 Open up to .mtl file in Notepad as well. We see that this file in turn references the .png file.

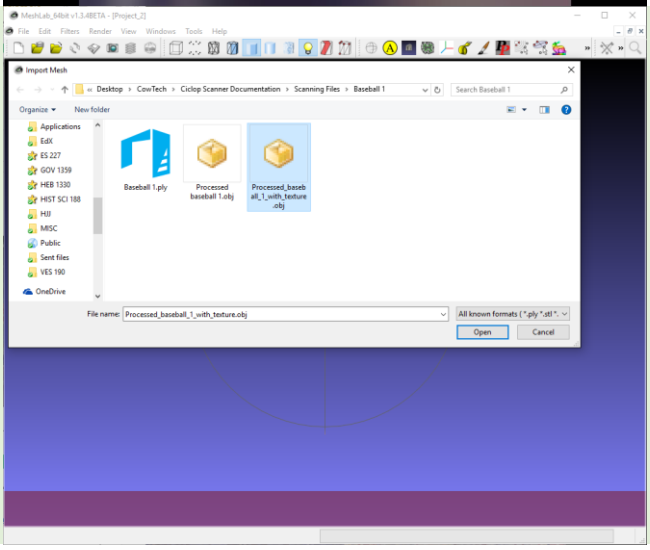


17 Open up the .png file. The .png file is a normal image file. As long as all three of these files stay in the same directory, you are good to go.

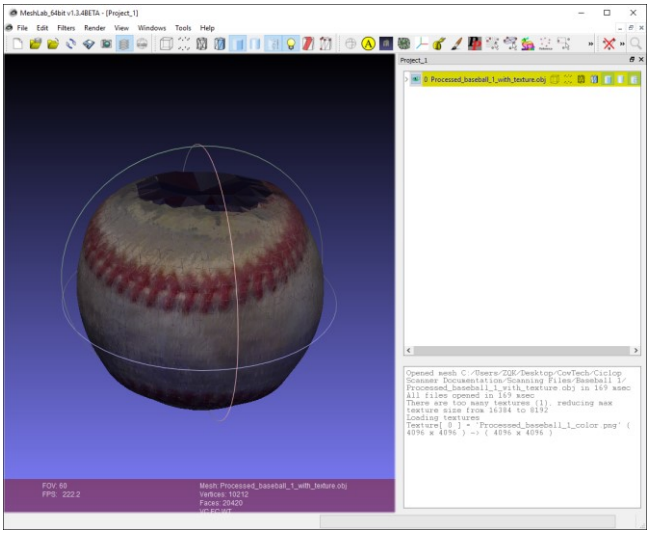


Open up a fresh new project in MeshLab and import the .obj you just made.

18 If MeshLab crashes, you probably had spaces in the name of one of those three files. Rename as needed, but make sure you edit the references in each one to account for the changes.



19 Congratulations, you're done! The .obj should open up with only a single mesh and the texture already on it.



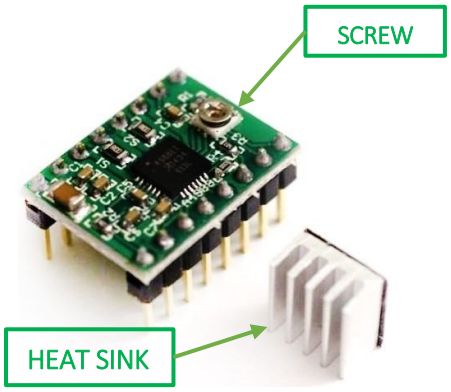
Supplemental Troubleshooting Guides

The following guides go into more detail about potential issues and how to solve them. If your problems persist, please reach out to the community at:

https://groups.google.com/a/cowtechengineering.com/forum/?hl=en#!forum/cowtech-ciclop-3d-scanner

Precisely Calibrating the Stepper Motor Driver

Earlier in this document, we give a ballpark method for calibrating the Stepper Motor Driver. If your stepper motor is experiencing erratic behavior, we recommend calibrating the Stepper Motor Driver more precisely with the following method.



Precisely adjusting the Stepper Motor Driver will require the following tools:

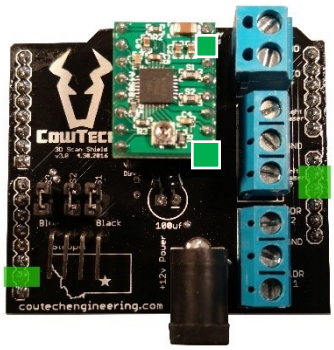
Multimeter

Small Phillips Head Screwdriver or Screwdriver Bit

Alligator Clips

- Plug in the Uno Clone to your computer via USB. This will power the board. You must use the USB, make sure you do not use the barrel plug. The CT Board must also remain unplugged.
- Prepare your multimeter. Put a probe on the black side of the multimeter and an alligator clip on the red side. Adjust it so that it can read voltage between 0V and 1V to at least 0.01V accuracy.
- Clamp the alligator clip to the Phillips head screwdriver. Ensure that there is a good electrical connection between the two.

WARNING: From this point on, it can be easy to accidentally short out the Stepper Motor Driver and render it useless. Please be very aware of what the probes are touching and make sure they are not making contact with any pins or exposed solder on the board.



- Measure the voltage between the Uno Clone's ground and the screw. Place the black probe at any of the locations indicated in green boxes on the picture at right. These green highlighted areas are all connected to the Uno Clone's ground. Place the screwdriver with

alligator clip attached on the small screw of the Stepper Motor Driver. The multimeter should be measuring a voltage somewhere between 0V and 1.2V

- Twist the screw until the multimeter reads 0.48V. It's ok to be a few hundredths of a volt off in either direction.
- Unplug the Uno Clone.
- Stick the heat sink to the Stepper Motor Driver. The heat sink has an adhesive backing protected by a layer of paper. Peel off the paper and stick the adhesive side of the heat sink to the black square in the center of the Stepper Motor Driver (known as the IC). The heat sink ensures that the driver does not overheat and burn out. Please make sure that the heat sink is not touching any exposed metal surfaces on the driver such as the pins to the left and right of it.
- Congratulations, you're done with calibrating the stepper!

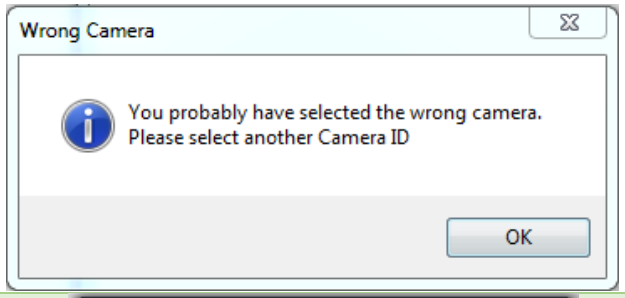
Troubleshooting Camera Connection Problems

The steps below are for the Windows OS. If you're using a different OS or if the steps below do not help, visit either of the following resources for troubleshooting help:

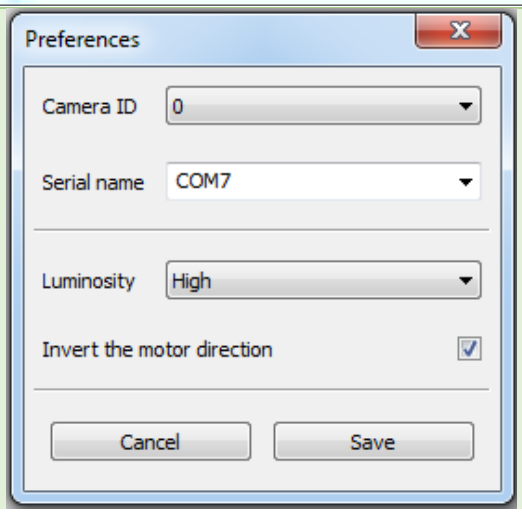
- BQ Ciclop Google Group - https://groups.google.com/forum/#!forum/ciclop-3d-scanner
- Horus Github - https://github.com/bqlabs/horus

Please remember that Horus is software created and maintained by BQ. While CowTech provides supplemental tips to help you get through potential issues with Horus, further troubleshooting and suggestions for improvement are best directed toward the BQ links above.

If Horus can't detect your Logitech C270 Webcam, it may bring up an error window similar to the one shown at right.



Usually Horus will bring up something similar to this menu after you hit "OK." Some of the values here might look different for you, and some fields may be missing.



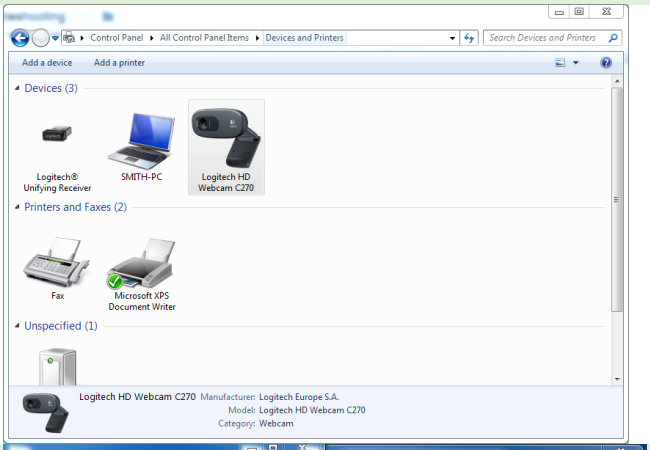
A Note on USB 2.0 vs USB 3.0: Some users report that the camera will not work with a USB 3.0 port. It may be helpful to try using a USB 2.0 port on your computer.

Blue colored ports are always USB 3.0 ports, while black colored ports are generally USB 2.0 ports. To more accurately determine what kind of USB ports your computer has, it may be easiest to look up your computer model's specifications or use a system information tool such as Speccy.

Second thing to try: Quit out of Horus, unplug the camera, and plug the camera back in. Open up Horus and give it a shot. Sometimes this will resolve the issue.

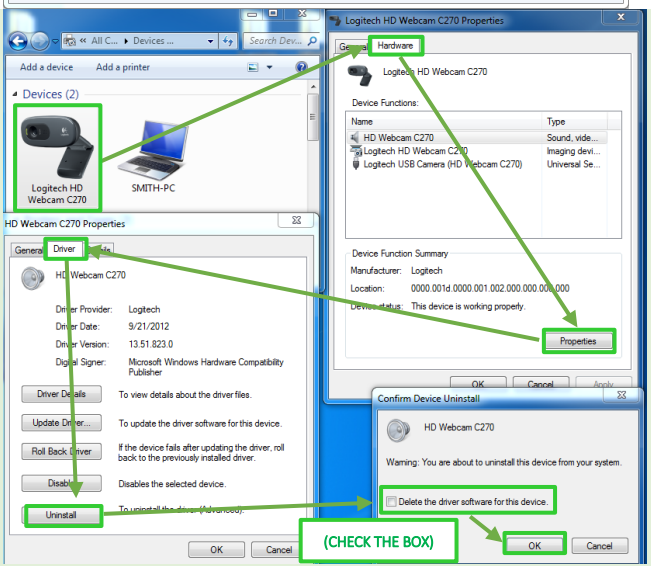
Third thing to try: Quit out of Horus. Plug in the camera. Click **Windows Icon -> Control Panel -> Devices and Printers**. Right click the icon labeled "Logitech HD Webcam C270."

If you don't see the icon, the issue is not with Horus but with the Logitech drivers. Check the Logitech website to troubleshoot: http://support.logitech.com/en_us/product/hd-webcam-c270



Click **Properties -> Hardware -> Properties -> Change Settings -> Driver -> Uninstall**. There may be a box asking if you want to delete the driver files, make sure it is checked and then click ok. The picture at right shows this series of clicks graphically.

Some users report that they must instead uninstall from **Control Panel -> Device Manager**. If this is the case, select the Logitech C270 Webcam and uninstall it from the Device Manager instead.



Now unplug the camera and plug it back in. Windows should begin automatically installing generic Windows webcam drivers. Once installation is complete, open up Horus and now the camera should be recognized when pressing the connect button. If not, try once again changing the values of "Camera ID" and "Serial Name" like you did earlier.

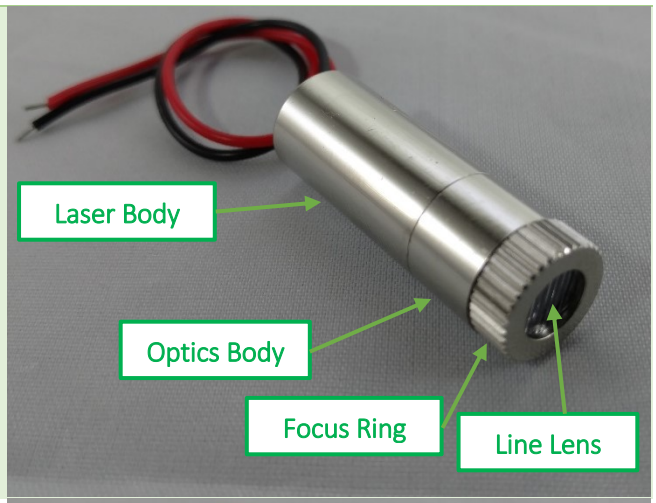
Fourth thing to try: Close Horus and uninstall the generic Windows drivers from the previous step. The steps to uninstall them should be the same as before. Reinstall the official Logitech drivers. They can be found at the link below:
http://support.logitech.com/en_us/product/hd-webcam-c270
Installing the official Logitech drivers will require Windows to restart.

Please reach out to us on the CowTech Google Group and the BQ links above if your issue persists.
Occasionally, the camera connectivity error window can be caused by connectivity issues to the Uno Clone board. Please see the section titled “Troubleshooting Uno Clone Connection Problems” at the end of this document for tips on how to solve this.

Troubleshooting Laser Focus Problems

Some users report that their lasers are unable to make thin, bright lines necessary for good scans. The following guide explains the origin of this issue and provides steps to fix it.

1 Make sure you have all the parts shown. Above is an exploded view of a laser. At right is a picture of the fully assembled laser. Note that the Beam Lens and Spring are not visible in a fully assembled laser.



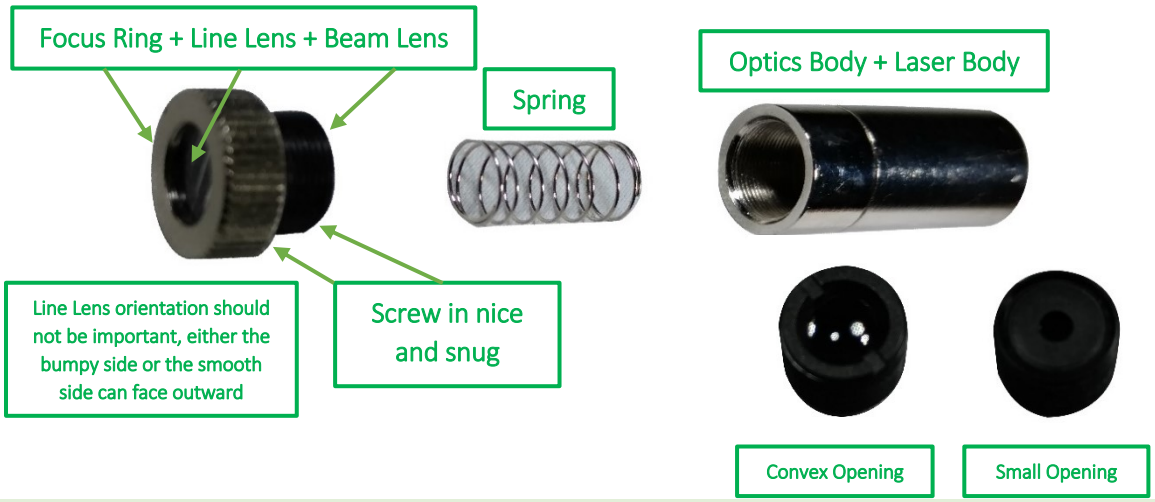
2 Begin by removing the laser from your scanner and fully unscrewing the Focus Ring.

Don't worry if the Line Lens comes out when you do this, just make sure you don't lose it.

3

Ensure that the Beam Lens is screwed all the way into the Focus Ring. See the picture below for an example of this. If you've been having laser focusing issues, usually this is because the Beam Lens is screwed too far into the Optics Body. This will reduce the possible range of focus for the laser. If this is the case, the Beam Lens will probably not unscrew out along with the Focus Ring. Instead it will stay inside the Optics Body.

If the Beam Lens does not come out along with the Focus Ring, unscrew it from the Optics Body and snugly screw it into the Focus Ring. The Line Lens should fit between the Focus Ring and the Beam Lens. Ideally, the Beam Lens should not spin freely off the Focus Ring. A diagram of what your laser should now look like is below.



-

The Beam Lens must be oriented properly. On one end it has a convex opening. On the other end it has a smaller opening. Ensure that the large convex opening is facing in the direction that the laser points. Above are pictures of both orientations.

The Line Lens does not need to be oriented one way or another. It has a smooth side and ridged side. Either side can face in either direction, its orientation will not affect your ability to focus the laser.

4

Screw the Focus Ring + Lens assembly into the Optics Body. Make sure that the spring sits between them.

Your laser is now ready to go. You can focus it by twisting the Focus Ring. A good focus is a red line on the object 1mm or less in thickness. Remember that the laser's focus is dependent on the distance between the laser and the surface it hits. You may need to readjust the focus when scanning objects of significantly varying size.

Troubleshooting Uno Clone Connection Problems

The following guide assumes that you've never worked with an Arduino / Arduino Clone microcontroller or the Arduino IDE. The steps below are for the Windows OS. If you're using a different OS or if the steps below do not help, visit either of the following resources for troubleshooting help:

- BQ Ciclop Google Group - https://groups.google.com/forum/#!forum/ciclop-3d-scanner
- Horus Github - https://github.com/bqlabs/horus

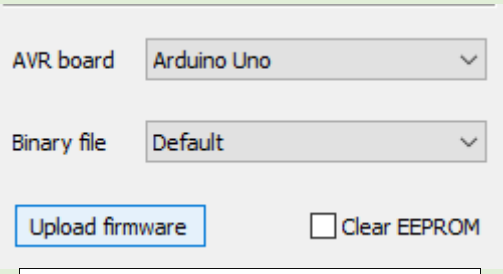
Please remember that Horus is software created and maintained by BQ. While CowTech provides supplemental tips to help you get through potential issues with Horus, further troubleshooting and suggestions for improvement are best directed toward the BQ links above.

1 If Horus cannot recognize the Uno Clone, it may give an error message saying so. Alternatively, Horus will sometimes give an error message related to the camera if it cannot detect the Uno Clone.

2 Power the scanner. Plug in the Uno Clone and the camera via USB to your computer.

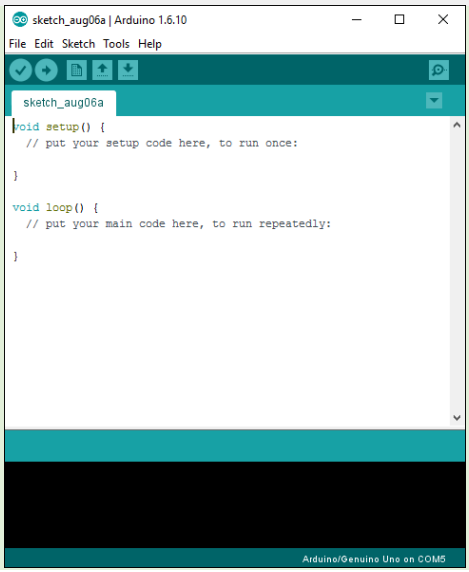
3 In Horus, go to Edit -> Preferences -> Upload firmware. Ensure that "Arduino Uno" is selected.

Restart Horus and try to connect once again.



4 If the board is still not recognized, it may be useful to determine if Horus is properly uploading code to the Uno Clone. To test this, download the Arduino IDE here: https://www.arduino.cc/en/Main/Software

The IDE is the place where you can load code from your computer onto your Uno Clone. Install the latest version of the IDE and open it. At right is a picture of what this might look like.

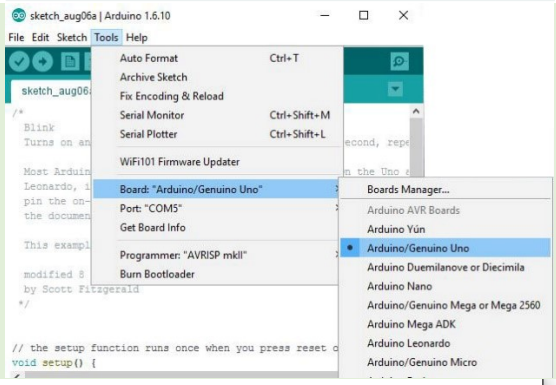


Delete the text that appears in the IDE window by default. Go to the following link and find the box of code that contains the “Blink” program: https://www.arduino.cc/en/Tutorial/Blink

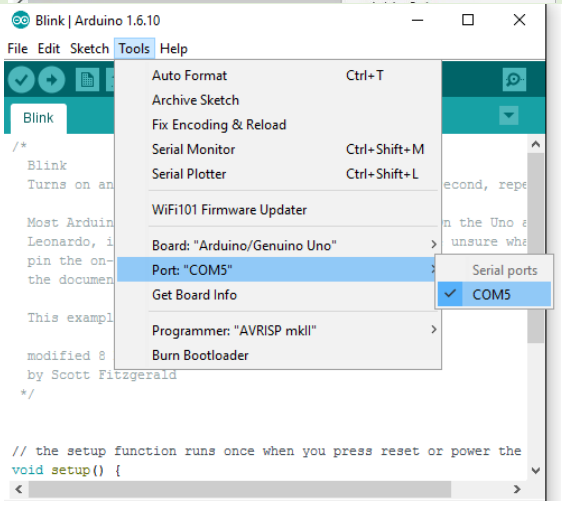
5 Copy and paste this code into the Arduino IDE. A screenshot of what this code looks like is presented at right. Blink is a common tool used to test and troubleshoot Arduinos. It simply flashes a small built-in LED on for one second and then off for one second.

```
/*
  Blink
  Turns on an LED on for one second, then off for one second, repeatedly.

  Most Arduinos have an on-board LED you can control. On the Uno and
  Leonardo, it is attached to digital pin 13. If you're unsure what
  pin the on-board LED is connected to on your Arduino model, check
  the documentation at http://www.arduino.cc

  This example code is in the public domain.

  modified 8 May 2014
  by Scott Fitzgerald
 */


// the setup function runs once when you press reset or power the board
void setup() {
  // initialize digital pin 13 as an output.
  pinMode(13, OUTPUT);
}

// the loop function runs over and over again forever
void loop() {
  digitalWrite(13, HIGH);   // turn the LED on (HIGH is the voltage
level)
  delay(1000);              // wait for a second
  digitalWrite(13, LOW);    // turn the LED off by making the voltage LOW
  delay(1000);              // wait for a second
}
```

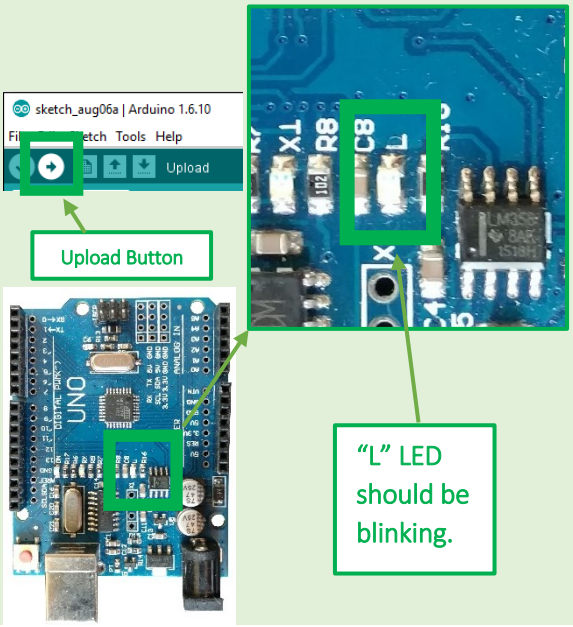
6 Go to Tools -> Board and select “Arduino/Geniuno Uno”.



7 Go to Tools -> Port and select one of the available options. It should read something like COMX, where X is a number. If the next step in this guide does not work, select a different port and retry.



8 Press the "Upload" button. Blink is now uploaded into your Uno Clone. You should see the small LED labeled "L" flashing on for one second and then off for another.



9 If you're having issues uploading Blink, then your computer is having a USB driver or port problem. Please see the Arduino webpage to help troubleshoot further: https://www.arduino.cc/en/Guide/Troubleshooting

As mentioned above, a common fix is to change your COM port. Please also ensure that you have the most recent version of the IDE and that you have properly installed the Uno Clone drivers provided on the CowTech website.

10 Close the Arduino IDE, unplug the Uno Clone, and start Horus. Plug the Uno Clone back in once Horus is open and try to connect. It should fail because the board has Blink loaded on it. Upload the firmware again the same way you did earlier in this section through Edit -> Preferences -> Upload Firmware.

11 If the "L" LED is still blinking after the previous step, then the issue is with Horus. Please post your issue to the BQ Horus google group here: https://groups.google.com/forum/#!forum/ciclop-3d-scanner