



What is Ciclop?

- First DIY 3D Scanner
- Fully customizable

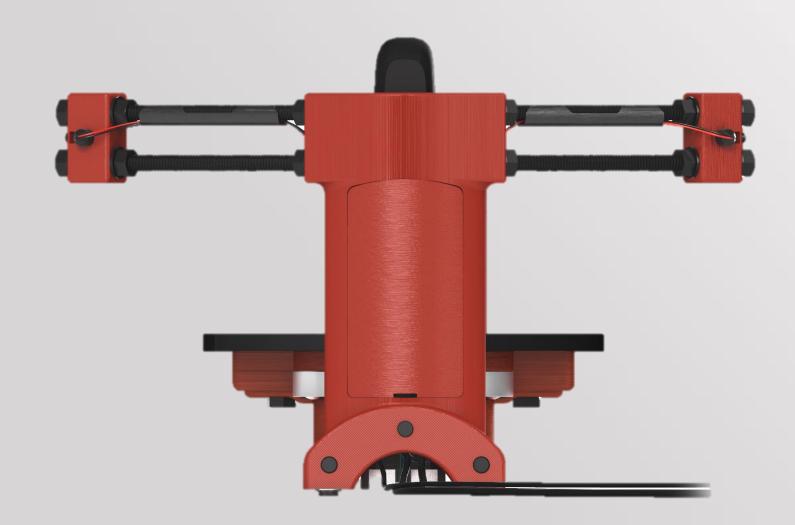
- 30 minutes assembling
- Open-Source



What is Ciclop?

- Scanning volume: 20 cm (diameter) x 20 cm (height)
- Accuracy around 0,5mm (according to calibration)

- BQ ZUM BT-328 & ZUM Scan
- Ready to connect 2 motors, 4 lasers, or one LDR.



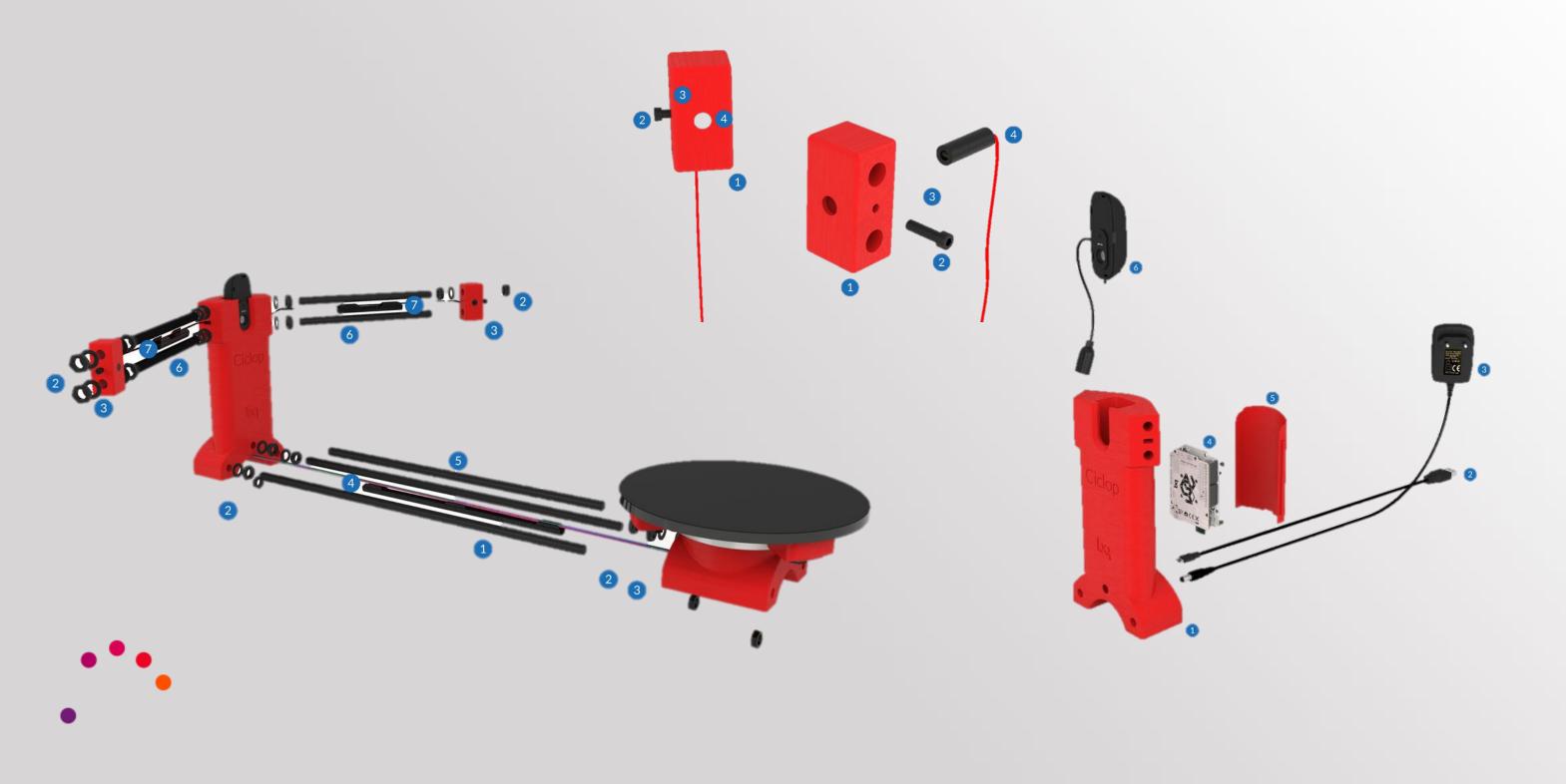
Hardware: Easy to build and open to improve







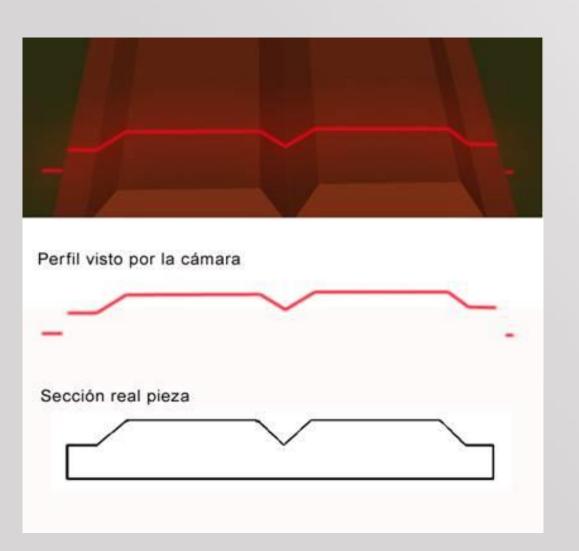
The technology: Laser triangulation





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The technology: Laser triangulation



Lasers impact on the rotating piece

The camera collects the surface information, analyzes and recreates the figure

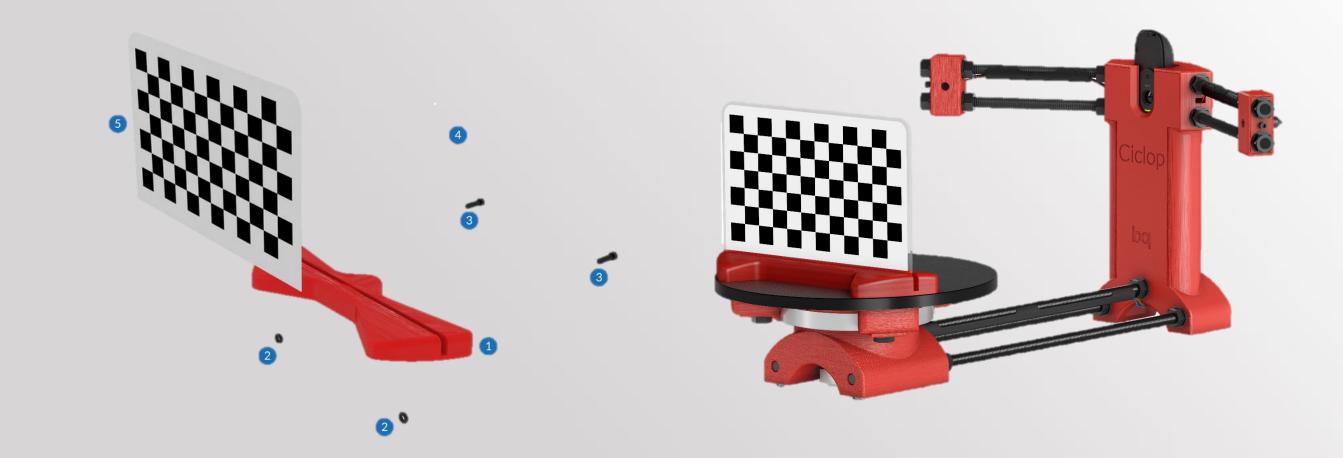








Auto-calibration: A differential value







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Software: Open to the future

HORU • S

• Camera Drivers





Meshlab





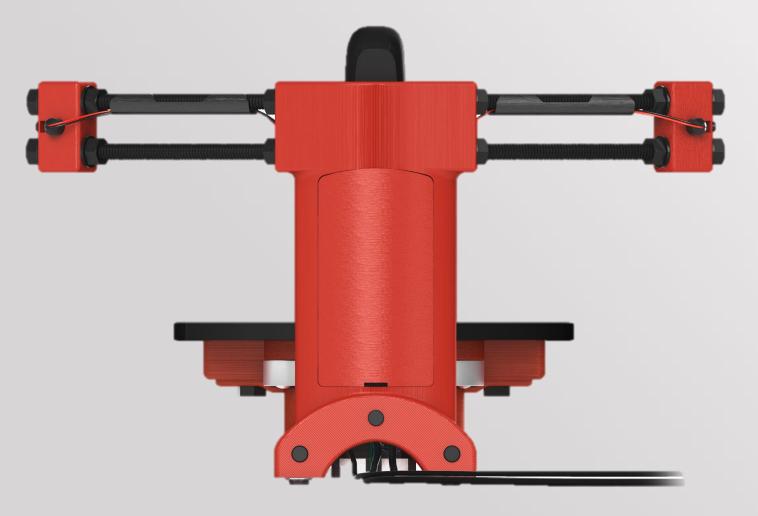
• Reconstructi on software



CloudCompa re

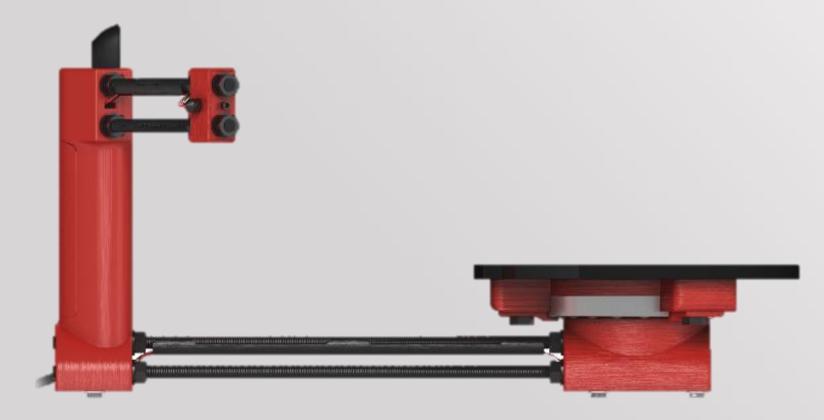
How can I obtain a good scanning?

Many factors are involved in the process: Lighting, color of the piece, brightness...Here we will learn how to control them



Ambient Lighting

Lighting should be uniform, indirect and medium intensity. Thus, the appearance of reflections and shadows are avoided.





Ambient Lighting

A commendable idea is to set a direct light from the back, with some dispersion and not concentrated



Objects with glossy finishes are difficult to scan because they can produce glare. But that does not mean it is not possible





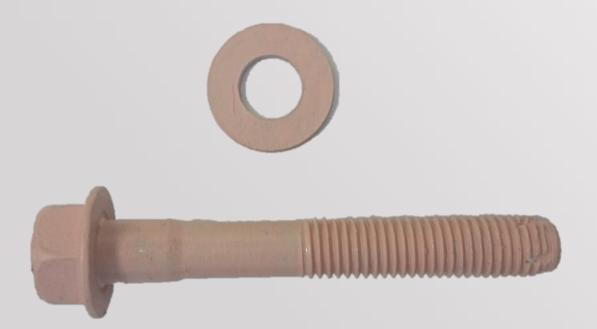
The next piece is a metal screw. It may seems impossible to scan





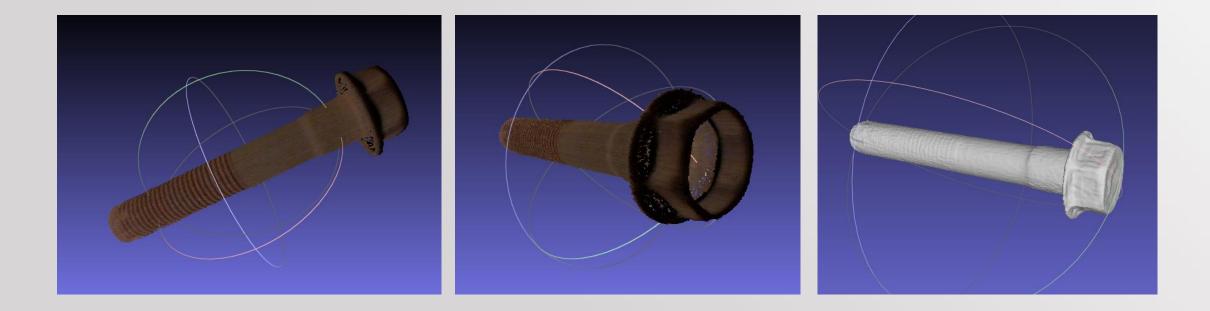


But there is the possibility of applying a watercolor or acrylic paint water-soluble covering the piece and remove all metallic sheen, making it matte





The result of scanning once this part is as follows:





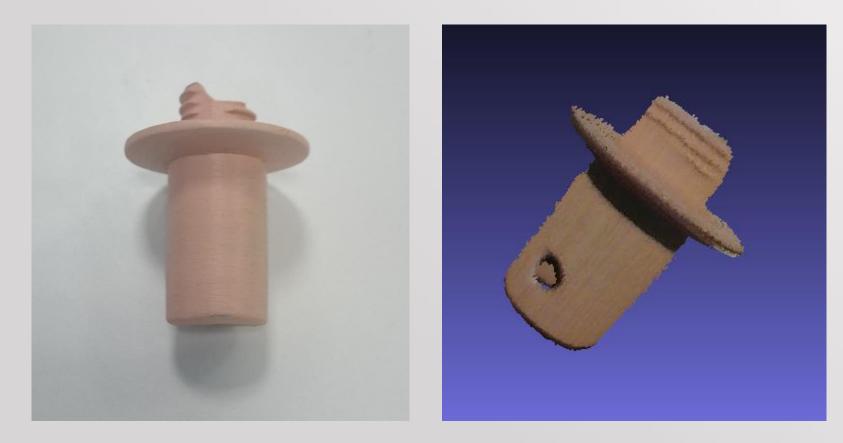
Object material

A next step would be the possible re-design of the piece (applying a smoothing with a 3D software for example)





Another metallic example, which was painted and then scanned:





Object color

The laser beam is red, so that color objects can cause problems when it comes to recognition.







Light-colored objects can cause problems, especially in high brightness environments. In these cases it is recommended to decrease the brightness



Uncorrected brightness



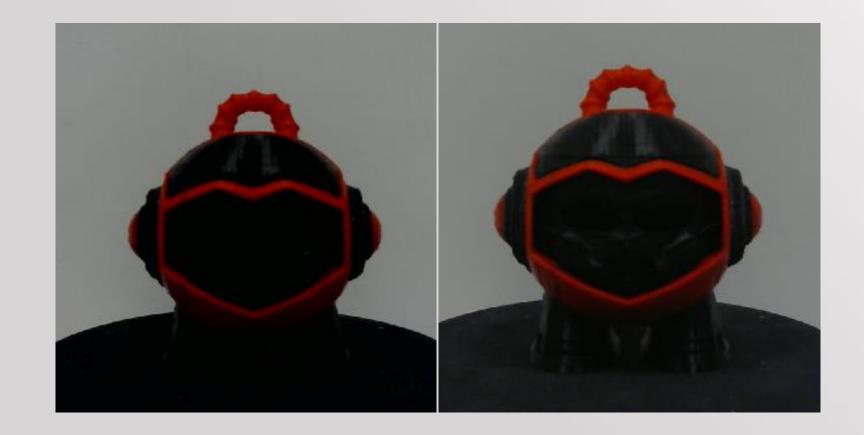
bq

Brightness diminished



In the same way that dark objects, the results can be inaccurate, especially in environments with little light

Uncorrected



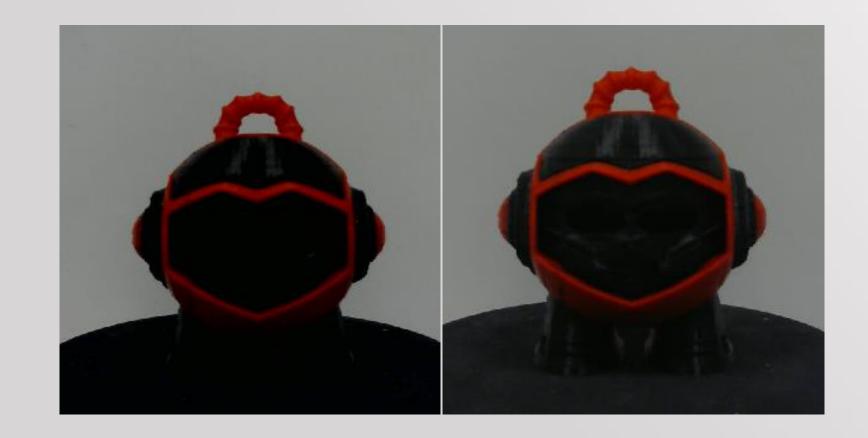


Corrected



It is recommended to decrease the contrast and exposure increase a little, in addition to lowering the threshold

Uncorrected



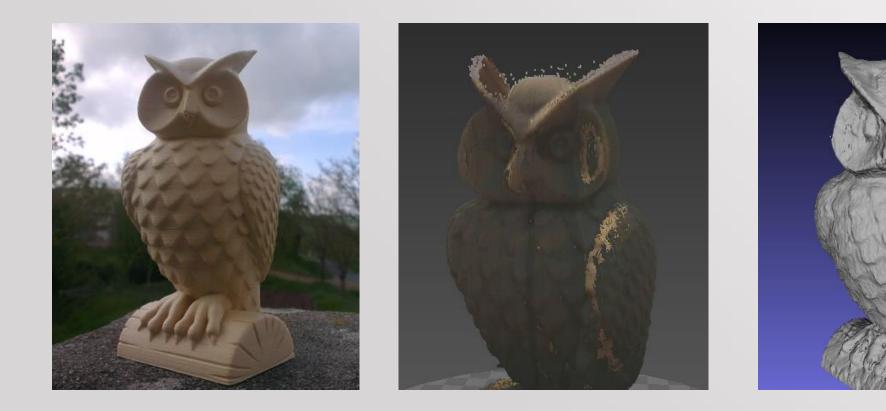


bq

Corrected

Object color

The ideal would be a non- aggressive or very intense color, matte and dull







A beginning and an end



Meshlab



Real piece



.PLY



bq



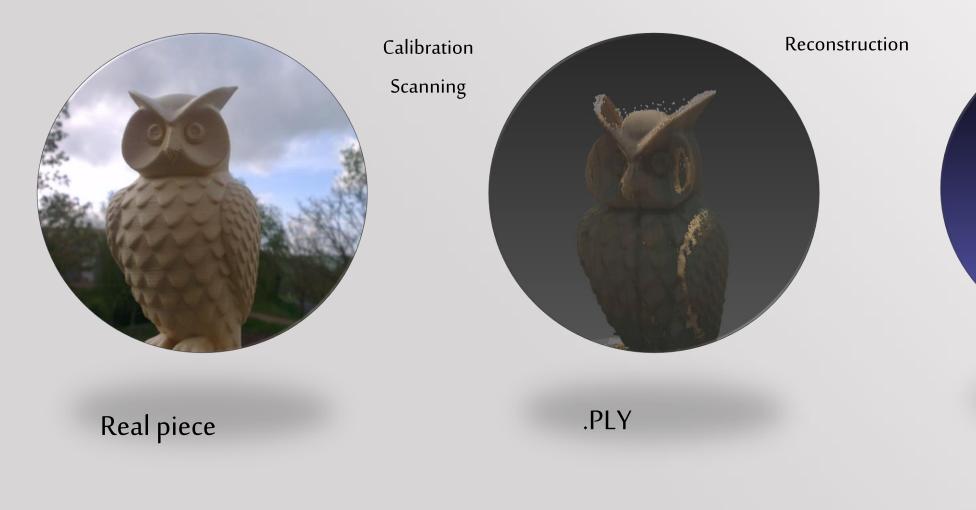


.STL

A beginning and an end



Meshlab



bq



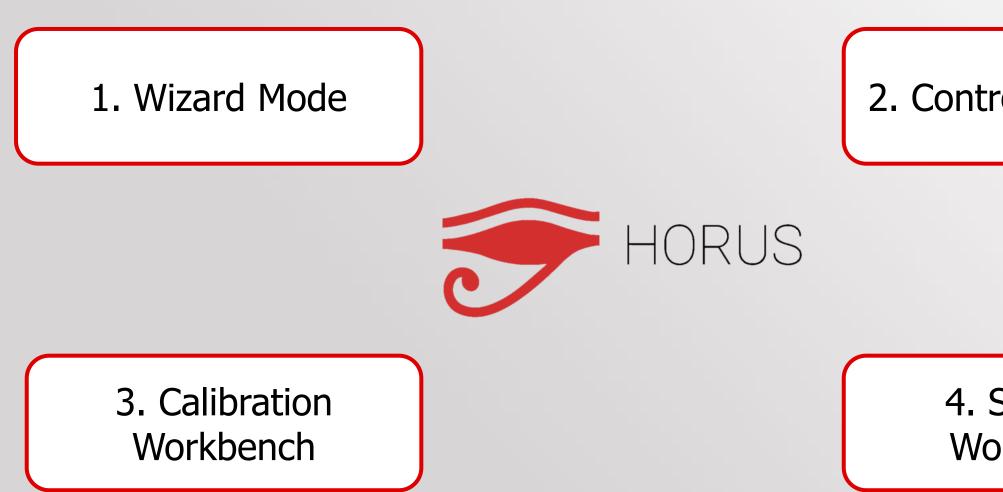


.STL



First step: Calibrating and Obtaining a point cloud





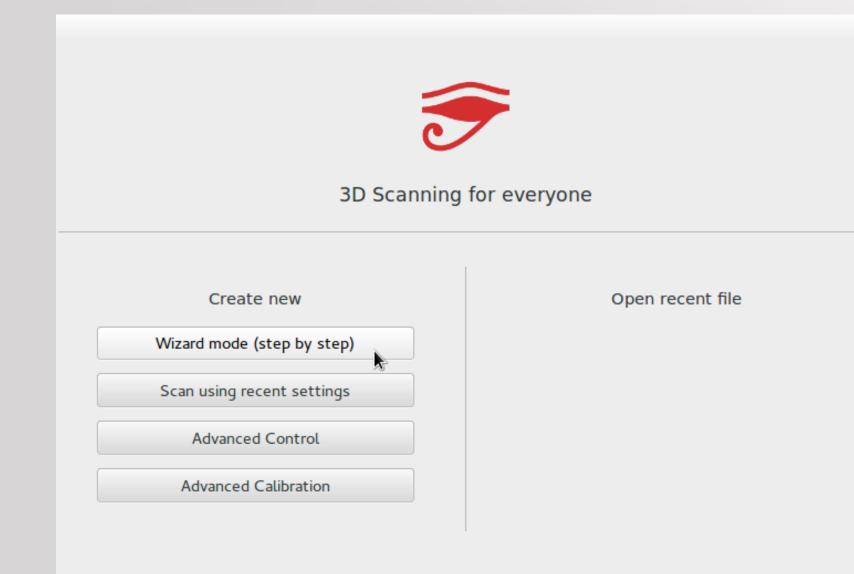


bq

2. Control Workbench

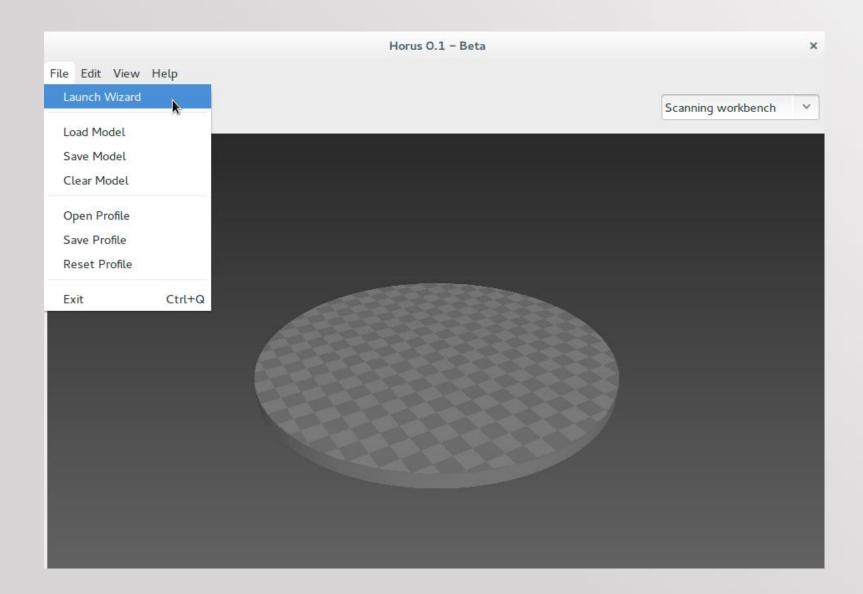
4. Scanning Workbench

Horus has a way of using "step by step" for users with no experience in 3D scanning



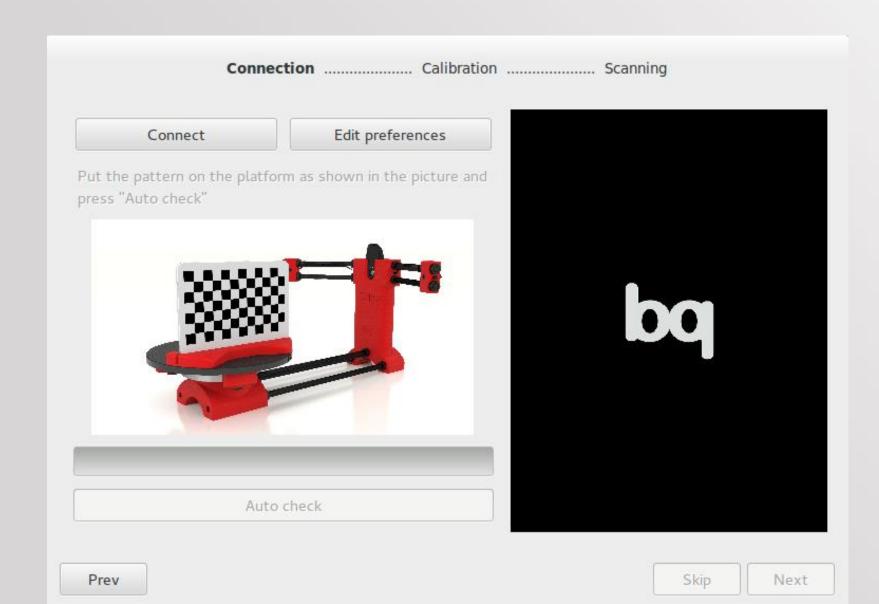


It opens every time the program is started, or from the File menu



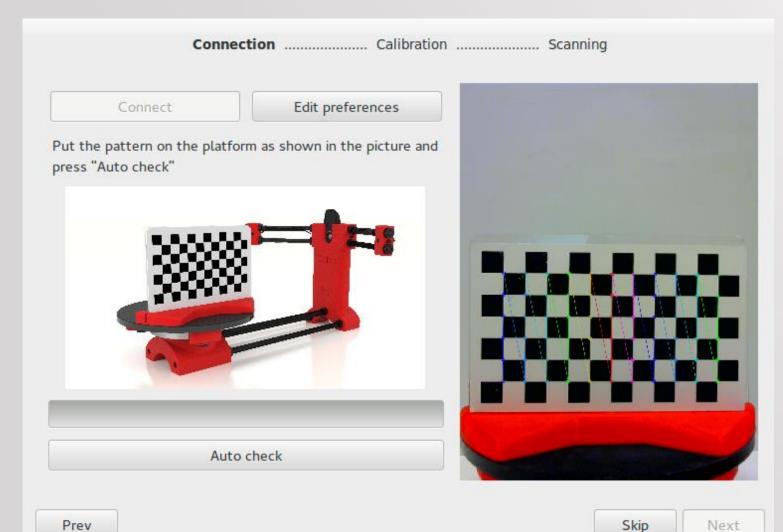


When you start the Wizard, this is the screen displayed





The first step is to press the Connect button. If everything is properly connected and configured, the video is displayed on the right side





Skip

Next is to edit the preferences. The following configuration window appears

	Sett	ings	
Luminosity	Medium		~
Pattern dis	ance (mm) 0.0		
Xr	nm		
		~~~~~	
Cancel		OK	

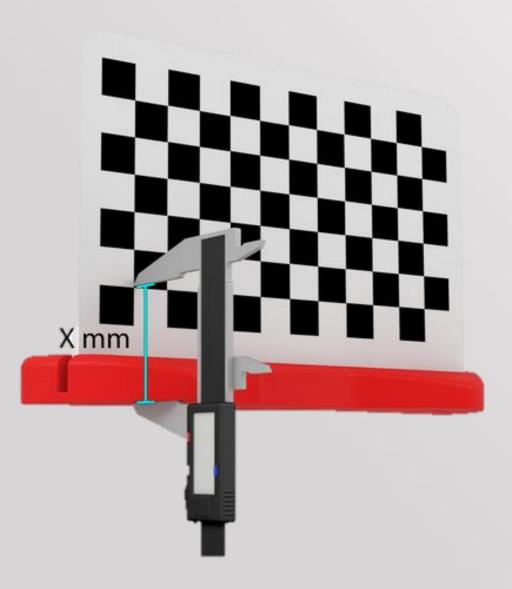


#### It may be modified brightness and distance of the pattern.

	Settings
Luminosity Medium	~
Pattern distance (mm)	0.0
Xmm	
Cancel	ок

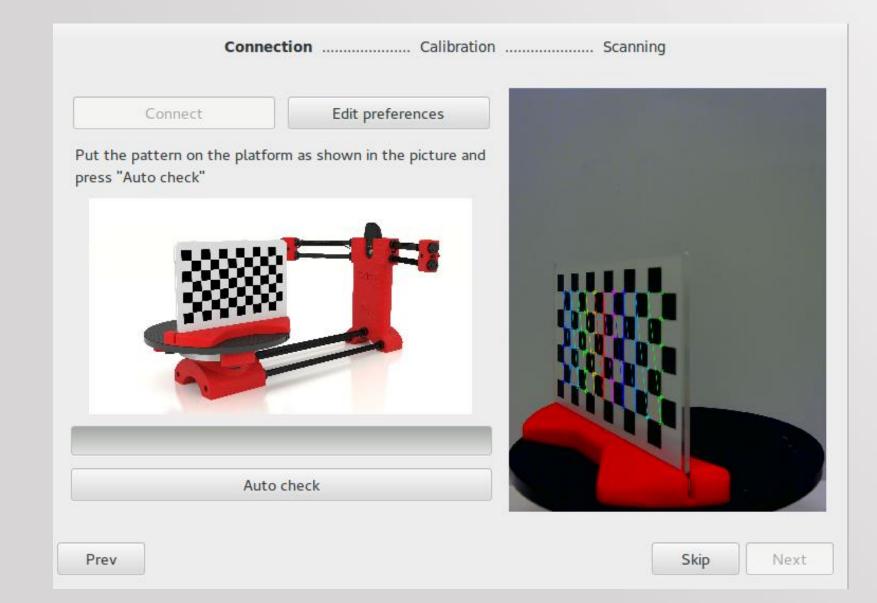


Pattern is the distance in mm, from the upper side of the square in the lower left part of the pattern to the rotating platform of the scanner



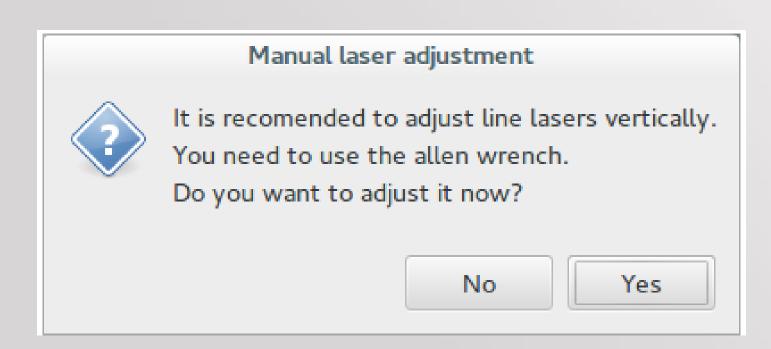


#### It is very important to place the pattern as indicated in Figure. Then select Auto-Check



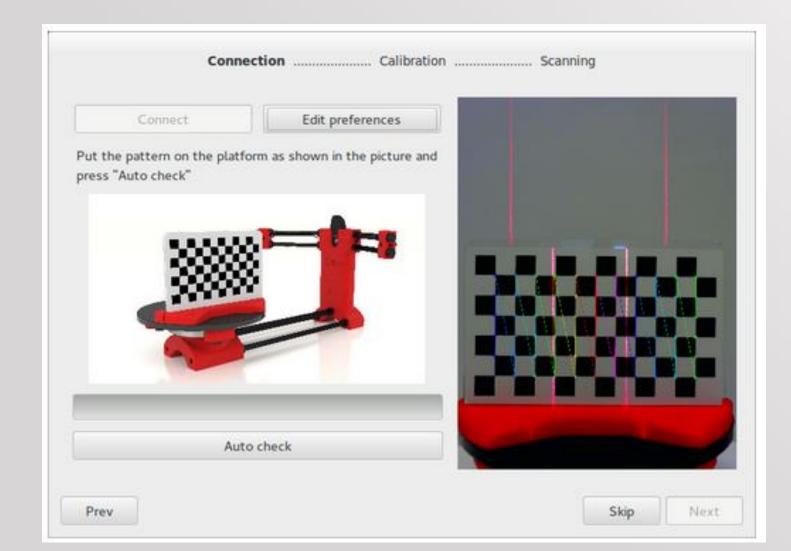


If this is the first time the scanner is configured, the following window will appear. This dialogue lasers recommend setting manually to get a vertical position.



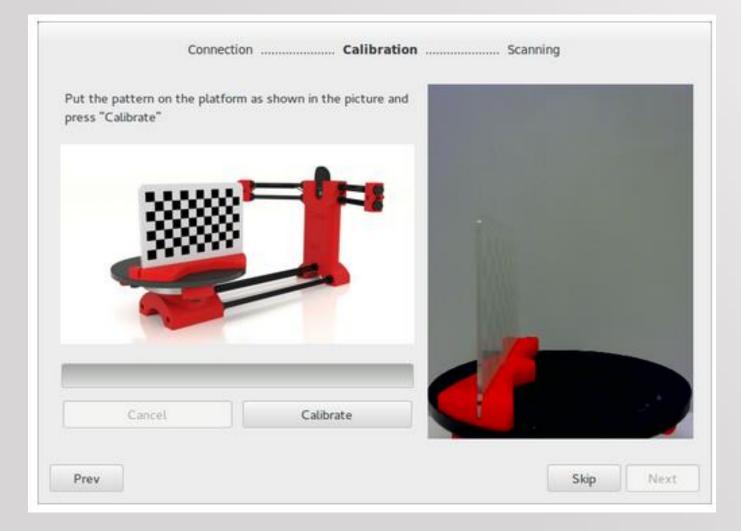


If the button YES is pressed both lasers will light. Using the calibration pattern, lasers will be placed vertically. To make this adjustment we will use the screws



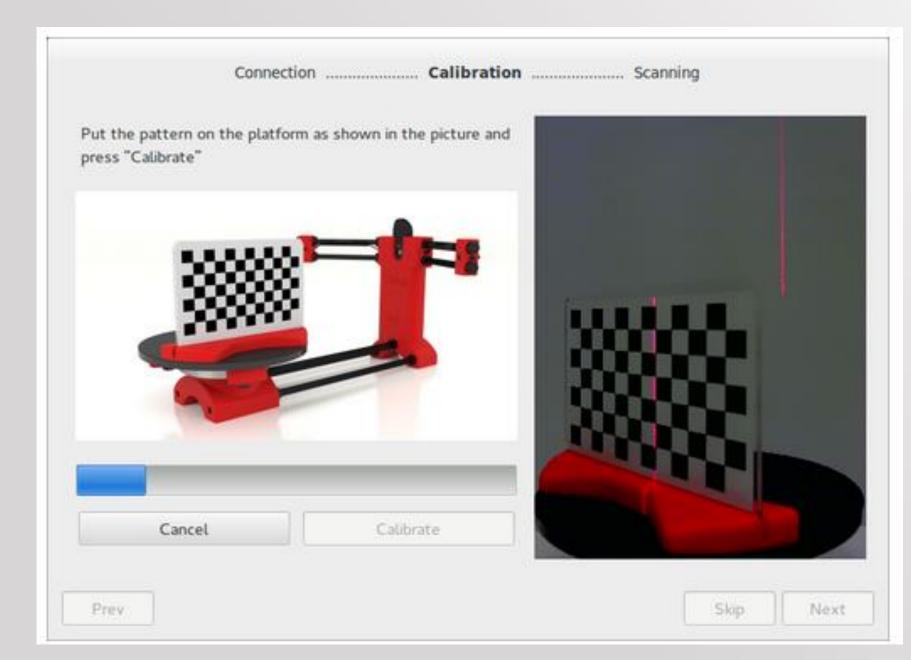


#### After clicking Next, we turn to the calibration. We place the pattern as the figure and click Calibrate



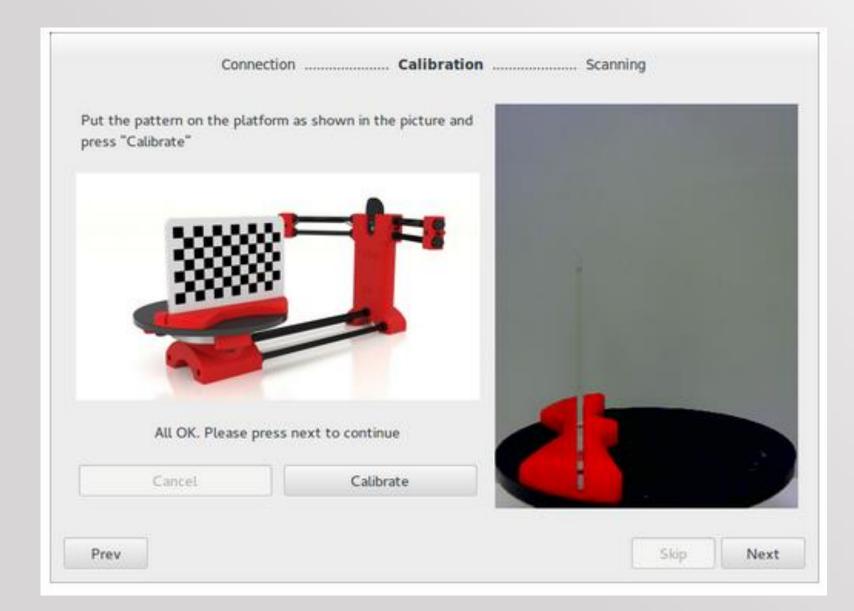


#### After pressing Calibrate, start the process





#### Once finished, if everything is correct, the message "All OK" is displayed





The last step of the Wizard will set the scan preferences. This screen shows the available options



Resolution: High resolution, Medium resolution, Low resolution. The higher it is, the higher the scan time



Laser: It can be used the left laser, right laser, or both. If we use both, the amount of scanned points will be higher, so our piece will be more detailed

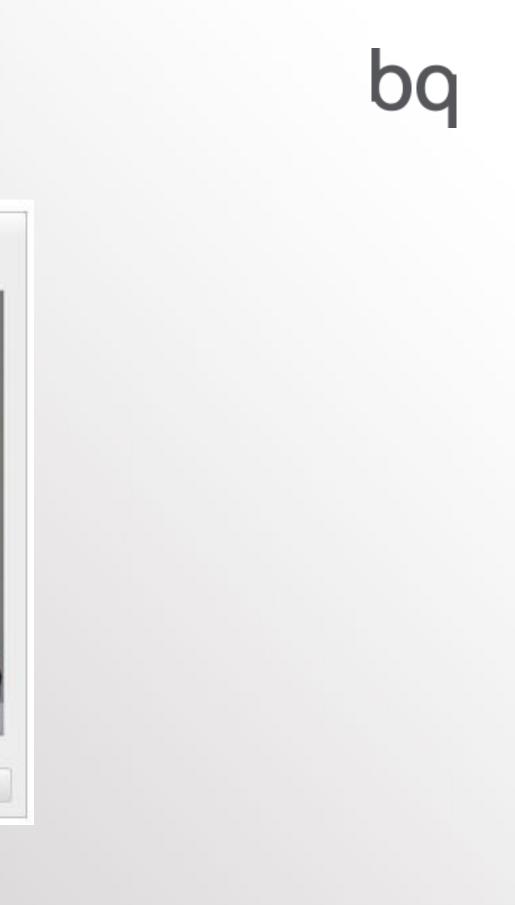


Scanning Type: It can be used Simple scanning or With Texture. The simple scanning doesn't catch the object color. The scanning with texture uses 2 Images to catch the laser, generating the mesh of points with the real colors of the object

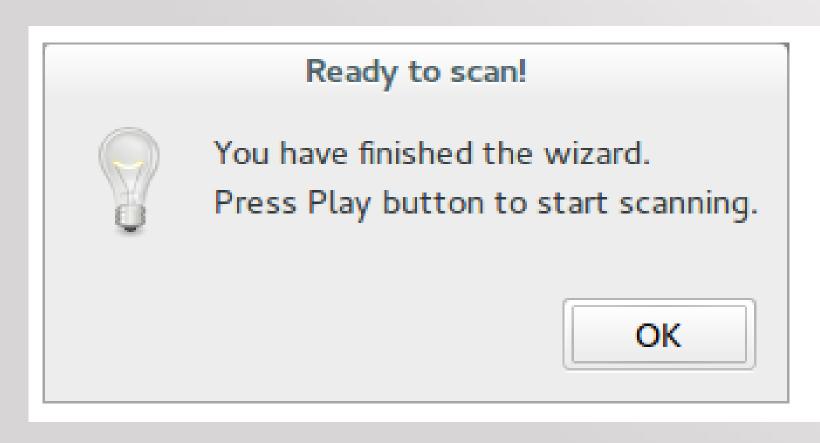


Resoluti	on	High	~	
Laser	Rig	ht	~	
Scan Tyj	e e	Texture Scan	~	
				Contraction of the local division of the loc





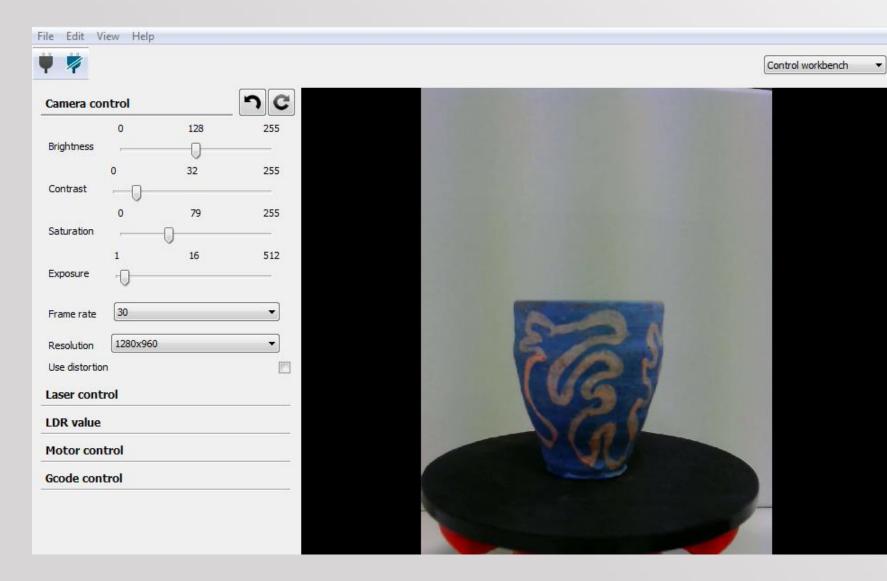
Once the Preference Scanning Settings are finished, we press Next, and the scanner will be ready to start working





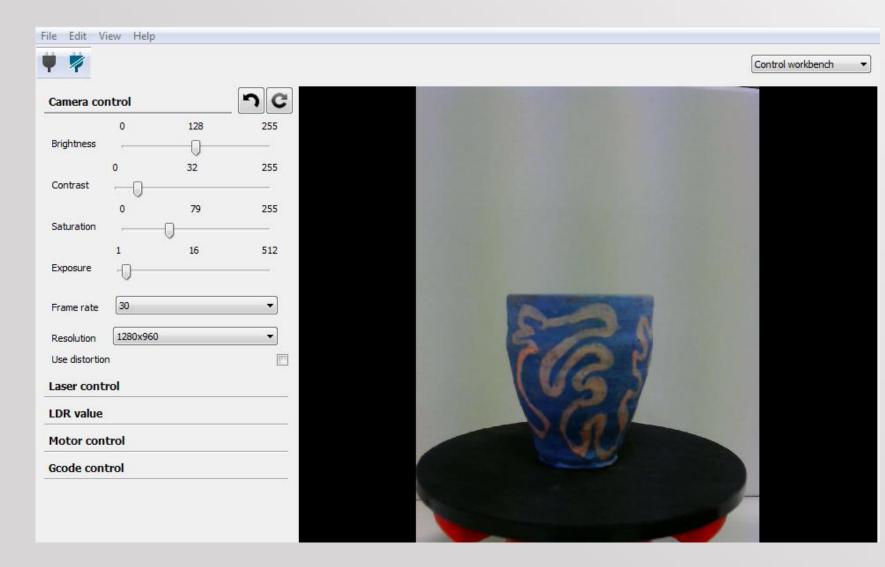
### 2. Control Workbench

Control of the parameters one by one

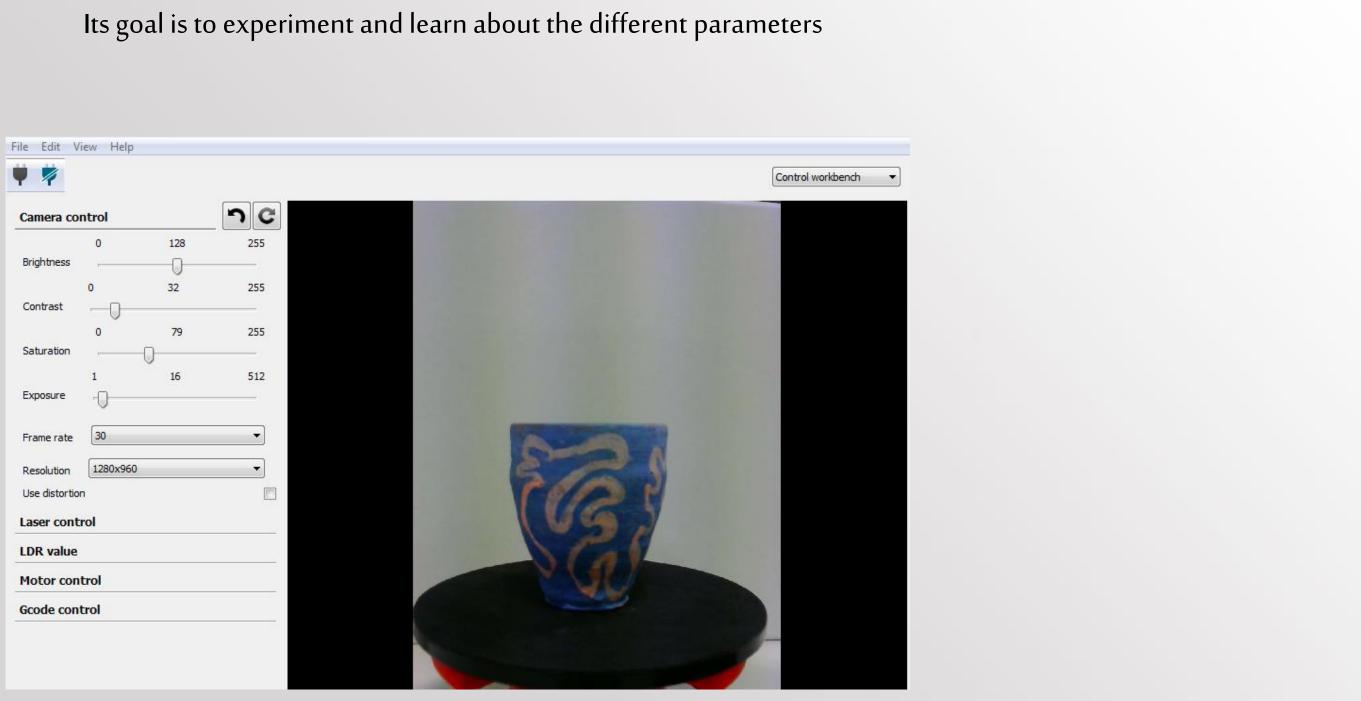


### 2. Control Workbench

The changes made into the workbench do not affect to the others

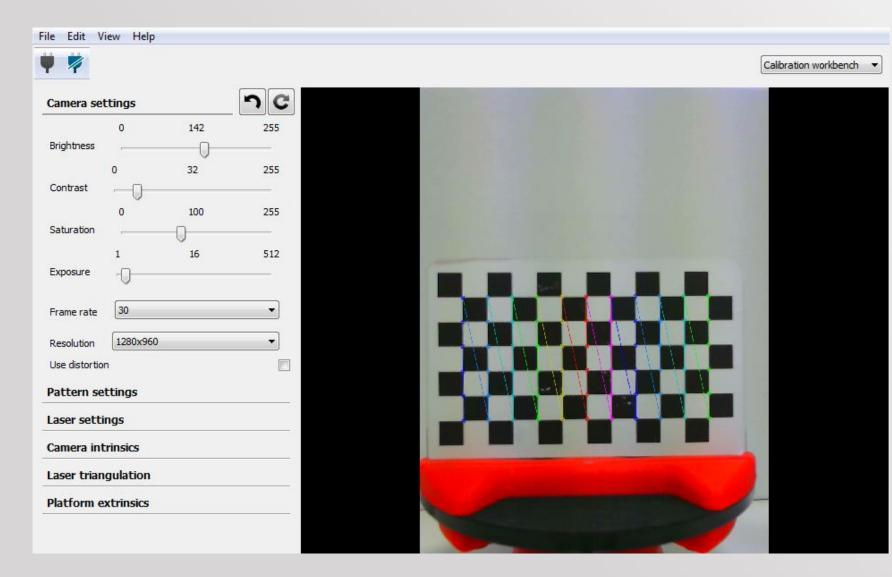


### 2. Control Workbench



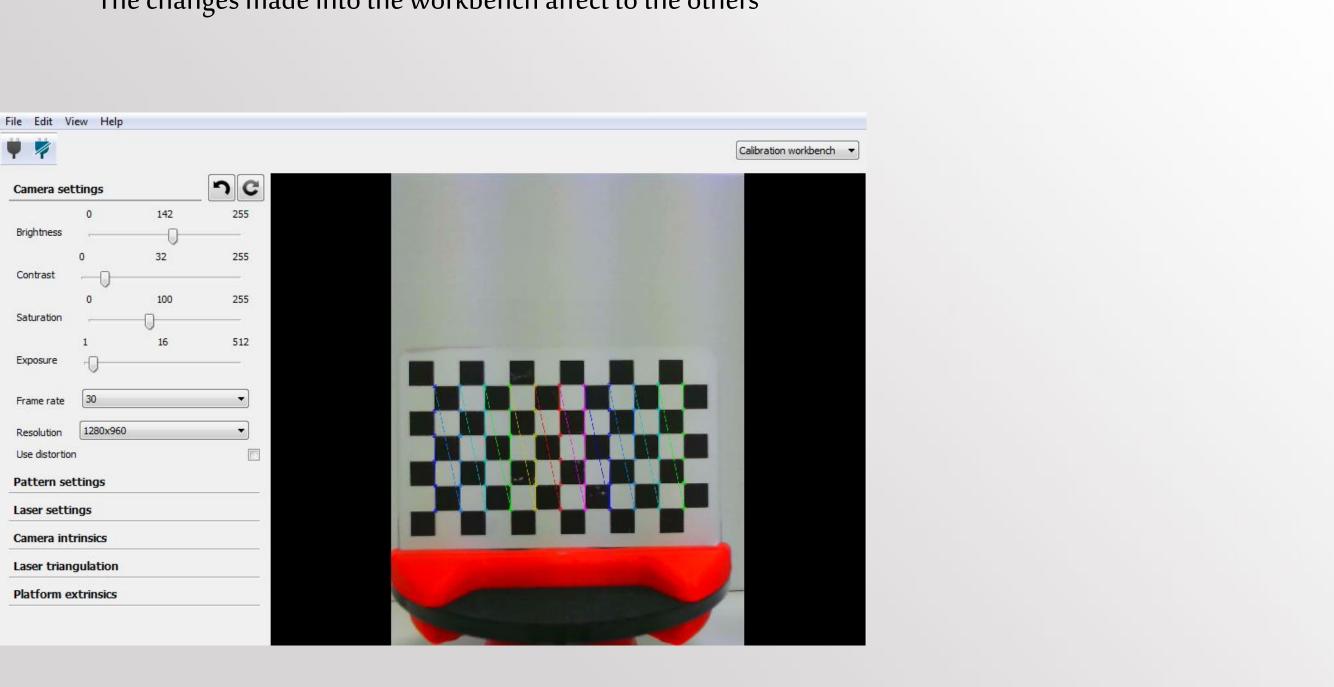


Calibration of the different components of the laser



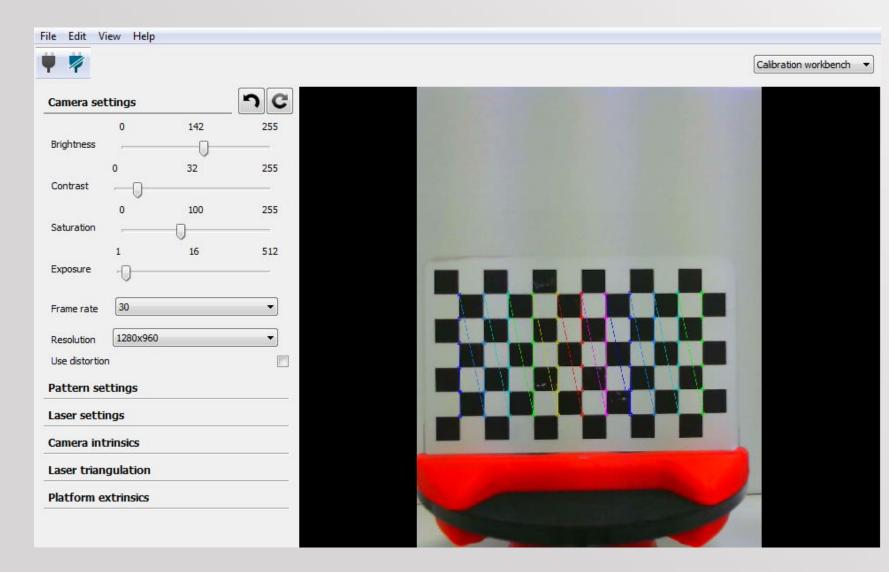


The changes made into the workbench affect to the others





This process will be essential to obtain a good result



It will consist of:

- Camara settings ullet
- Patern settings lacksquare
- Laser settings ullet

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- Intrinsics calibration  $\bullet$
- Laser triangulation Extrinsics calibration
- •

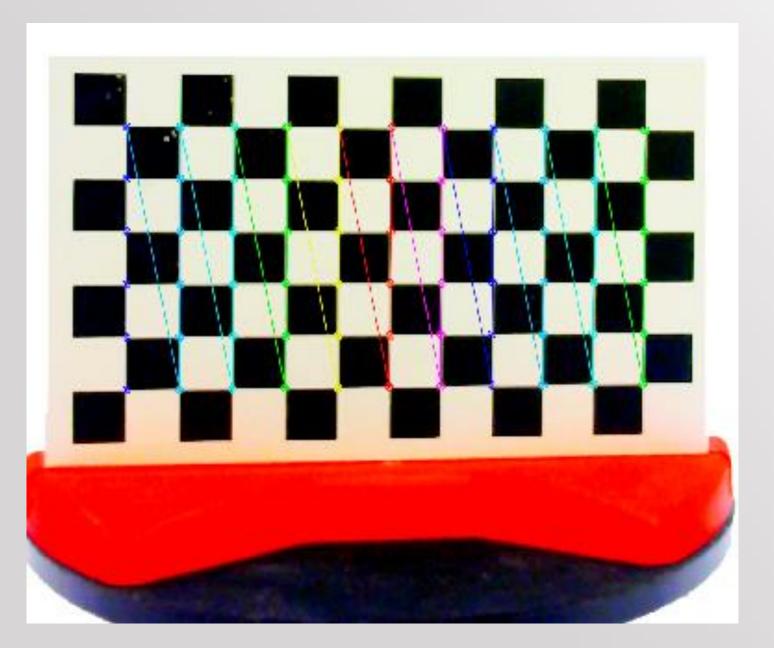


Camera Settings:

The camera settings aims to ensure that the pattern is detected correctly, in different positions Camera Settings and lighting conditions of the scene.



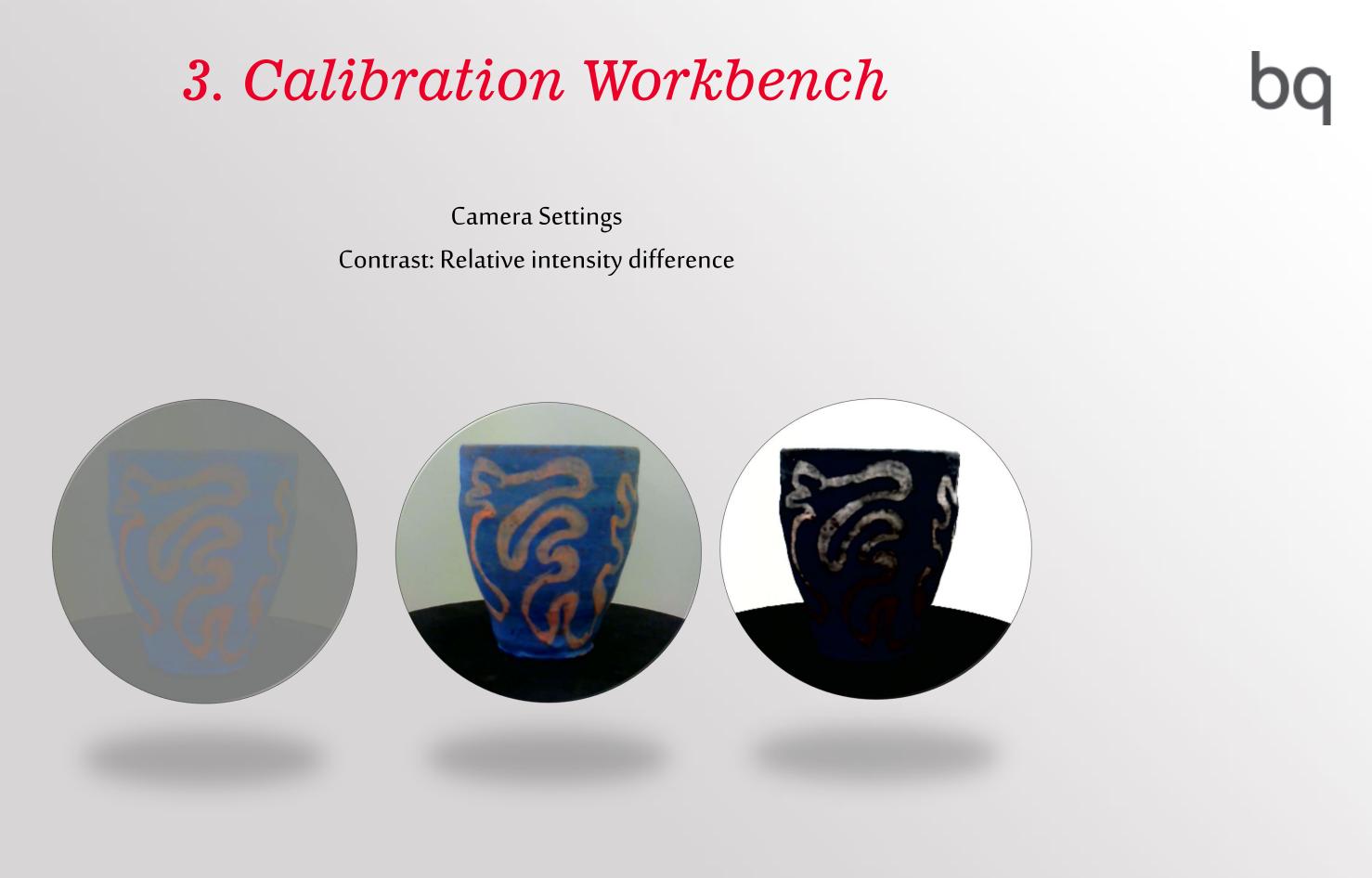
Camera Settings



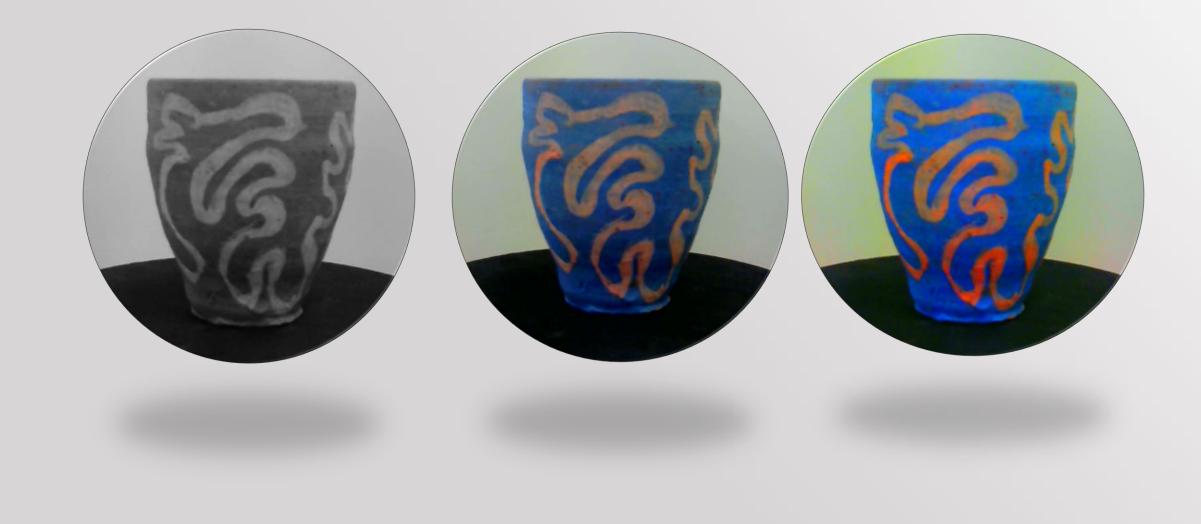


Camera Settings Brightness: Brightness of the image

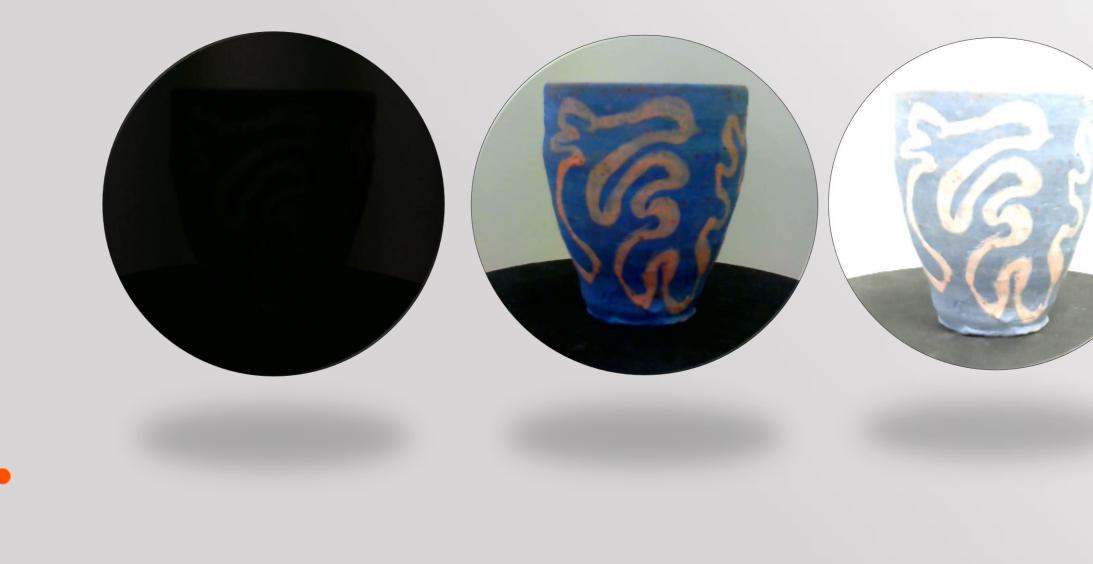




Camera Settings Saturation: Intensity of color image



Camera Settings Exposure Time lens aperture (milliseconds)



Camera Settings

Framerate: Images captured per second

Resolution: Image size. 4:3

Distortion: Distortion correction lens according to the calibration



Patern Settings: Calibration is done by a pattern





Patern Settings:

By default comes configured according to the one it comes with Ciclop

		500
Square width	3	
Pattern rows 6		
Pattern columns	11	
Pattern distance	37.5	







Patern Settings:

The distance set will be the one shown in Figure

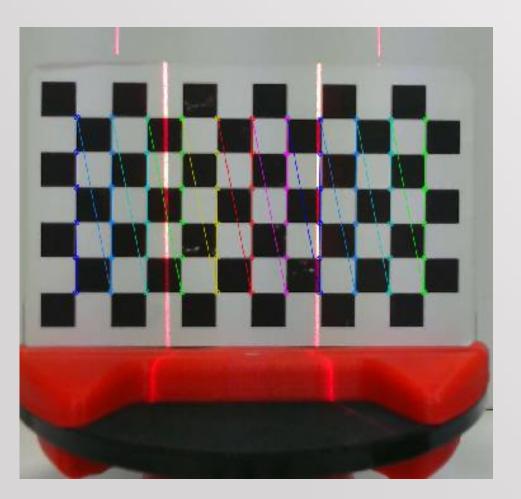
Square width 13	
Pattern rows 6	
Pattern columns 11	Xmm
Pattern distance 37.5	





Laser Settings:

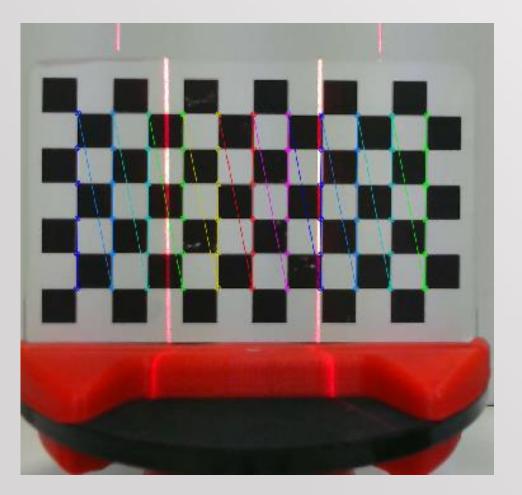
Option Enable / Disable right, left Laser, or both





Laser Settings:

They should be adjusted to be completely vertical relative to the platform





Intrinsics Calibration:

The aim is to calculate:

- Focal lengths
- Optical center
- Lens distorsion



#### Intrinsics Calibration:

			H	lorus 0.1 - Beta					>
ile Edit <mark>V</mark> iev	v Help								
₩ #						Calil	oration work	bench	~
Camera Set	ttings		Camera Intr	insics					
Pattern Set	tings		Press space bar t	o perform capures					
Laser Setti	ngs		-						
Camera Int	rinsics		_			4			
Camera matr	ix				888				Ş
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Edit	Default	Start							
Laser Trian	gulation								
Platform Ex	trinsics		Cancel						

different positions.

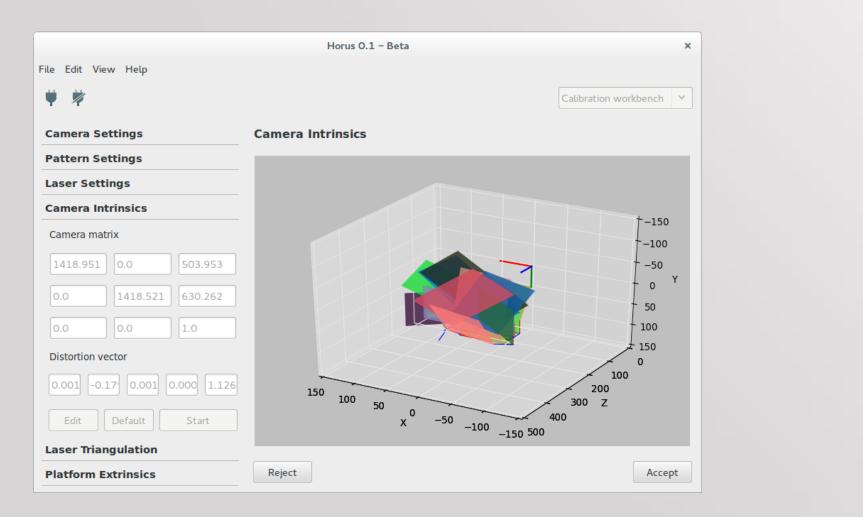
If the frame is green, the image is valid.

It is advised that the positions are as different as possible.



### We capture 12 pattern images in

#### **Intrinsics** Calibration:



The result is displayed numerically and graphically.

At this point, we can accept or reject the calibration.

Laser Triangulation:

The aim is to calculate:

• Lasers tilt and distance from the camera to its intersection



#### Laser Triangulation:

	Horus 0.1 - Beta ×	
File Edit View Help	Calibration workbench 💙	It is the second
Camera Settings	Laser Triangulation	
Pattern Settings	Put the pattern on the platform and press Calibrate to continue	
Laser Settings		
Camera Intrinsics		
Laser Triangulation         Left Laser Plane         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0		We position th example
0.0 0.0 0.0 Edit Default Start		We press on C
Platform Extrinsics	Cancel	



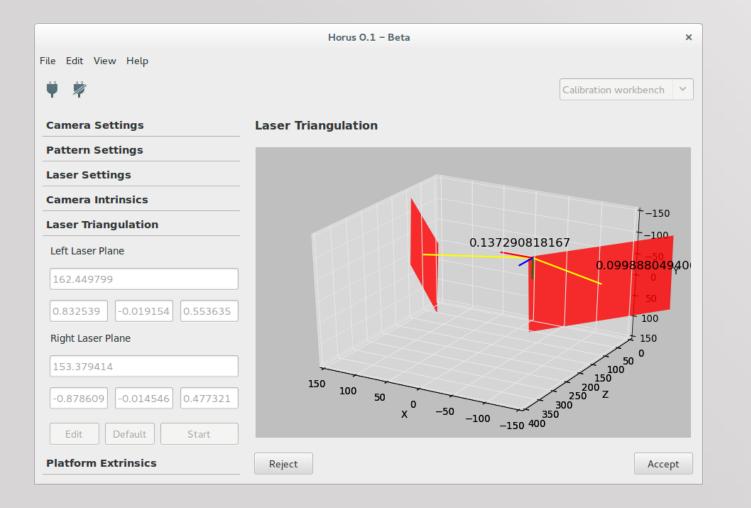
## bq

d calibration process

he pattern as in the

Calibrate

#### Laser Triangulation:



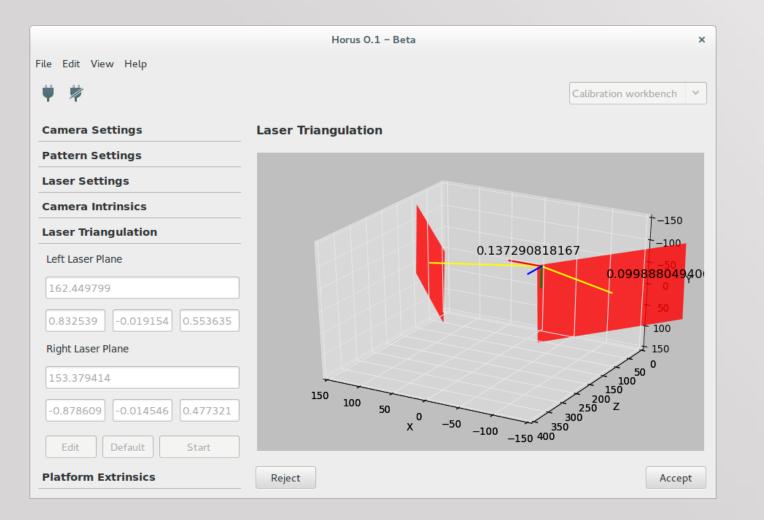
The result is displayed numerically and graphically.

At this point, to will discuss:

## bq

At this point, to see if it is acceptable, we

#### Laser Triangulation:



1- Dispersion of points: Both numbers should be as close to 0.1.

2- Minimum distance from the plane to the origin: The difference should be less than 30

Extrinsic Calibration:

The aim is to calculate:

• The position, and rotation of the disk center or platform



### 3. Calibration Workbench

Extrinsic Calibration:

			Horus 0.1 - Beta	×	
File Edit	View Help		G	alibration workbench 👻	last
Camera	Settings		Platform Extrinsics		
Pattern	Settings		Put the pattern on the platform and press Calibrate to continue		
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	iangulation n Extrinsics			example	
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# bq

calibration

ne pattern as in the

alibrate

### 3. Calibration Workbench

Extrinsic Calibration:

				Horus 0.1	- Beta				×
File Edit Vie	w Help								
Ÿ \$								Calibration w	orkbench 💙
Camera Se	ttings		Platform	Extrinsics	;				
Pattern Se	ttings								
Laser Sett	ings								
Camera Int	trinsics								†-150
Laser Triar	gulation								-100
Platform E	xtrinsics					•			-50
Rotation ma	trix								t o Y
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0.009802	-0.005142	-0.999939							150
-0.999952	-5e-05	-0.009802			A			100 150 250 Z 300 0	50 )
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-1.6726	78.7002	314.1144			x	50 -100 _	35 150 400	D	
Edit	Default	Start	Reject						Accept

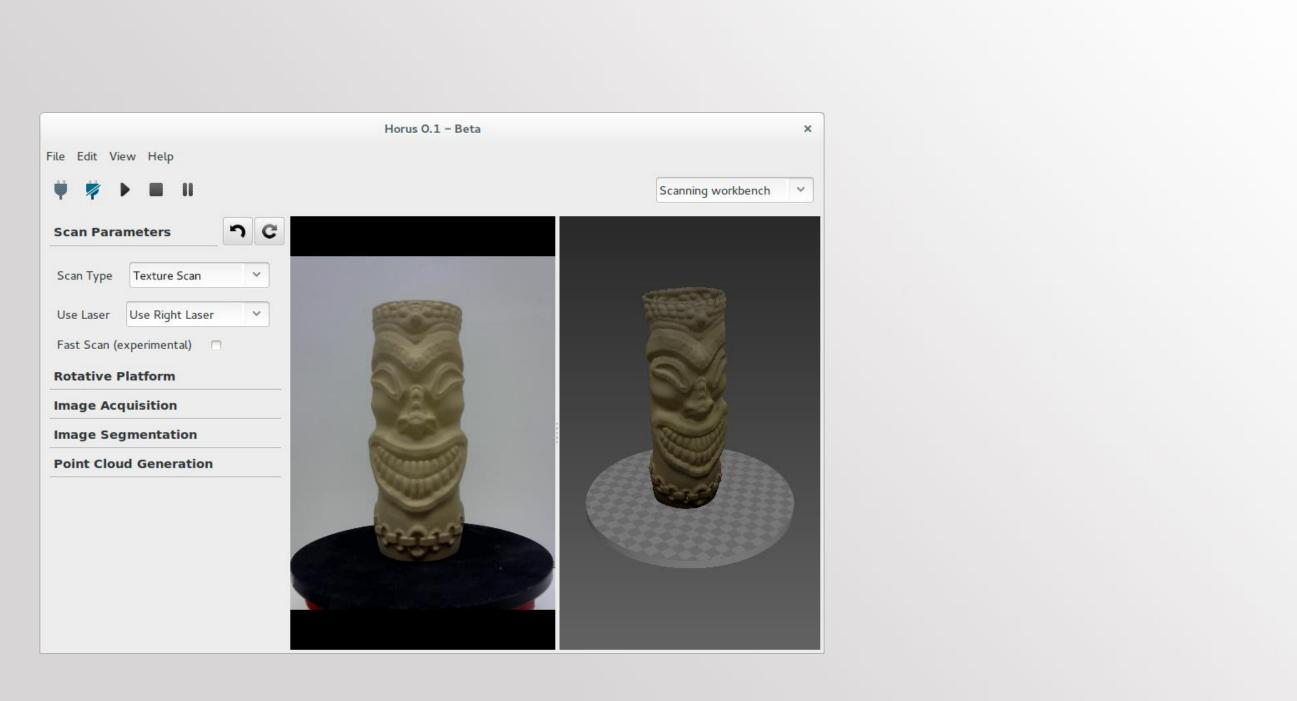
The result is displa graphically.

At this point, we can accept or reject the calibration.

## bq

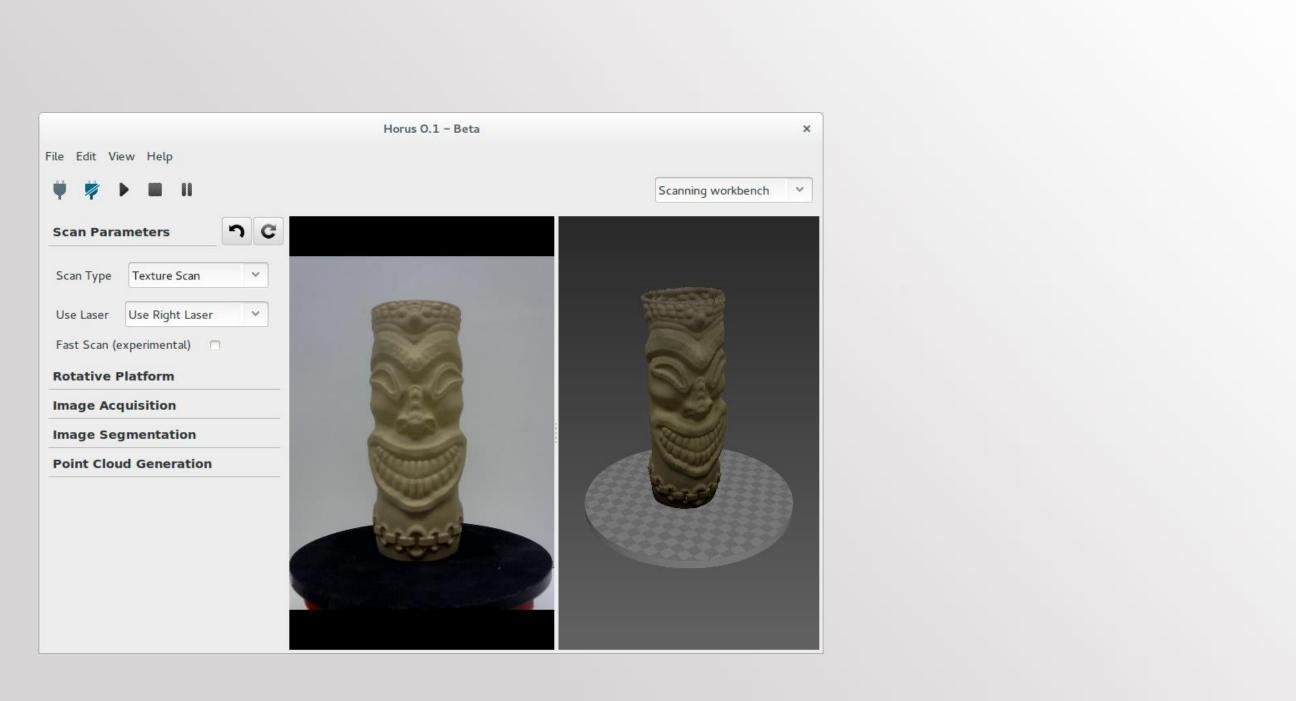
#### The result is displayed numerically and

Scanning and obtaining the points cloud





Configure the scanning options and you get the points cloud

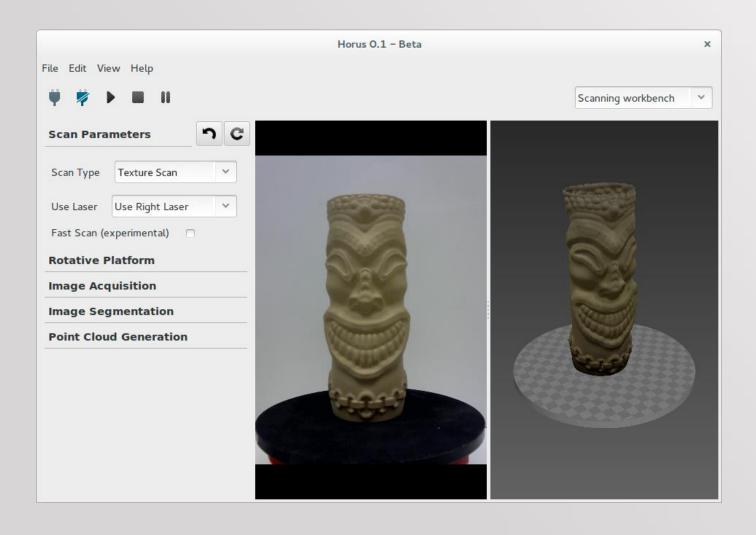




Settings panel

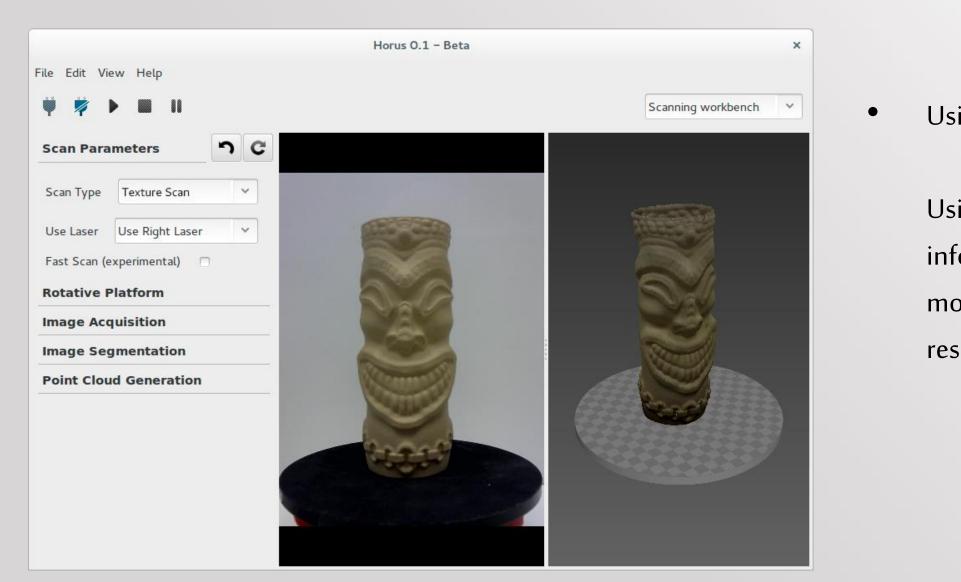
#### Scan Type: Without Texture / With Texture. In the second case, the real color of the piece is

captured





#### Settings panel



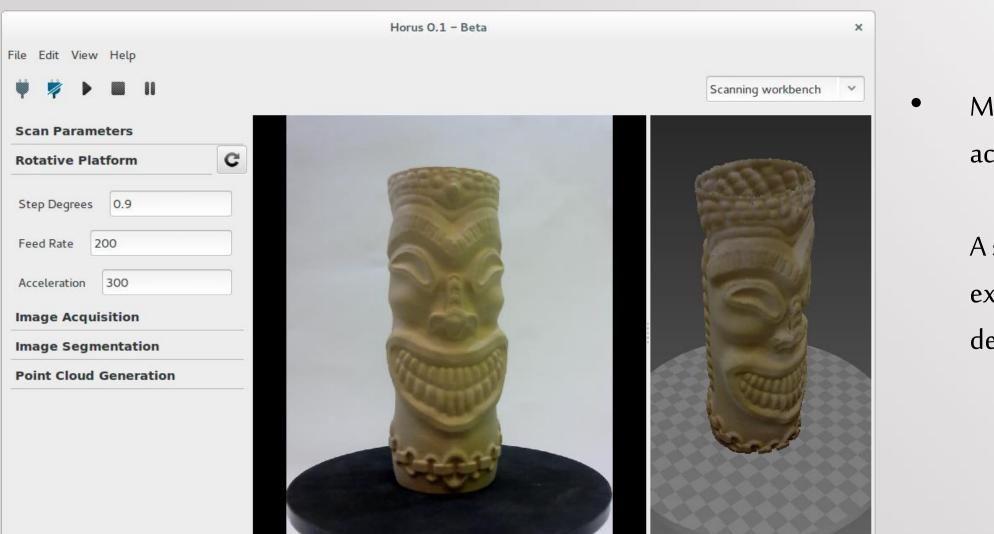


## bq

Using laser: Left, right, or both.

Using both, you'll get more information, but should make a more accurate calibration for better results.

#### Settings panel



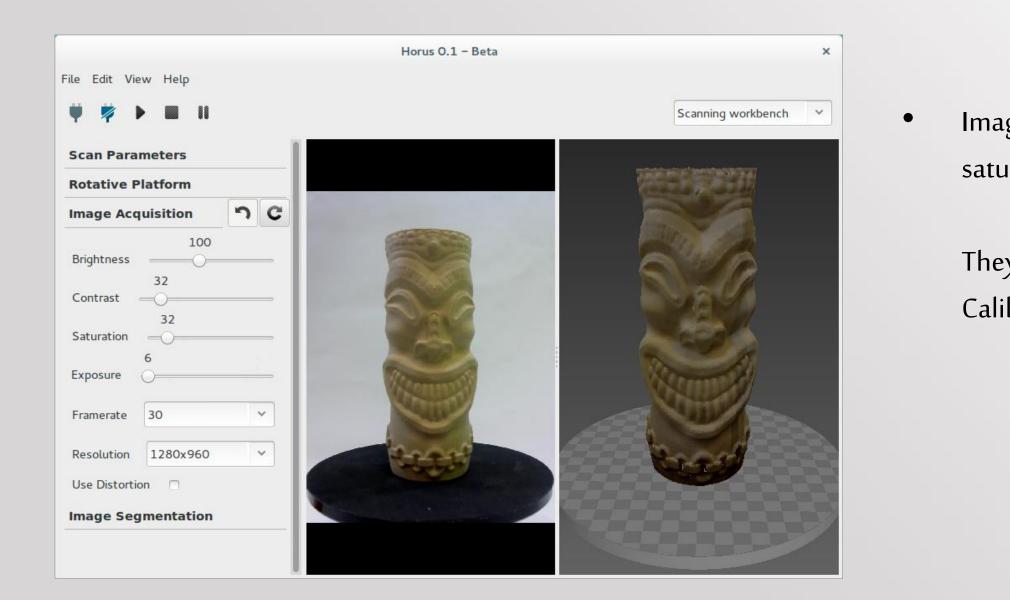


## bq

Motor parameters, speed and acceleration.

A small or minimum step, 0,45° for example, generates higher points density.

Settings panel



# bq

Image acquisition: Brightness, contrast, saturation, exposure...

They are the same parameters as in the Calibration Workbench.

#### Settings panel

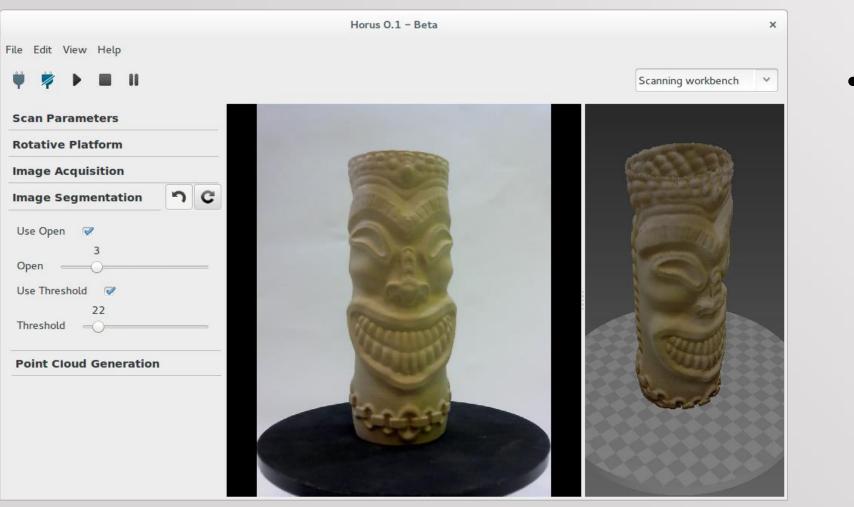
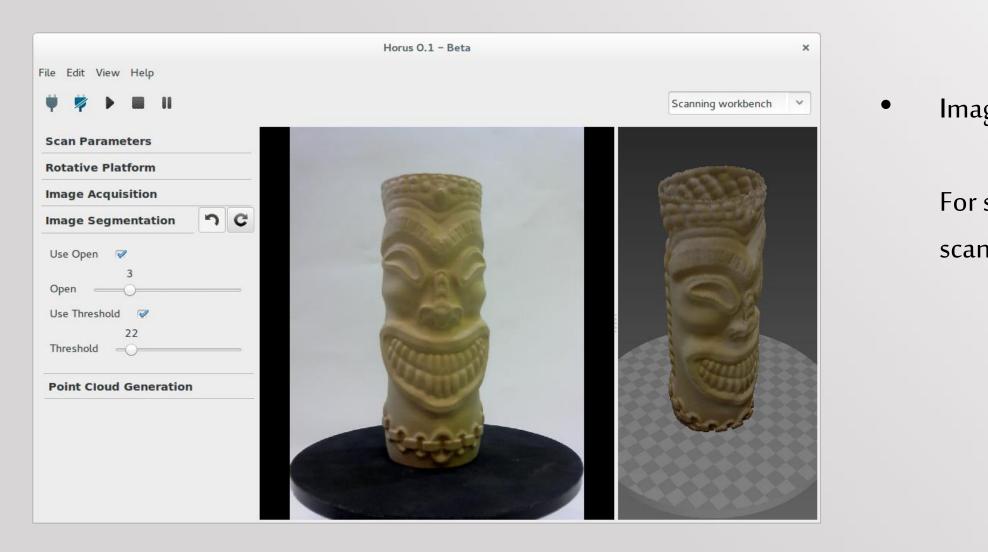


Image segmentation.

Applying a filter. Noise is removed above the desired value (threshold), but the cloud will have less detail.

#### Settings panel

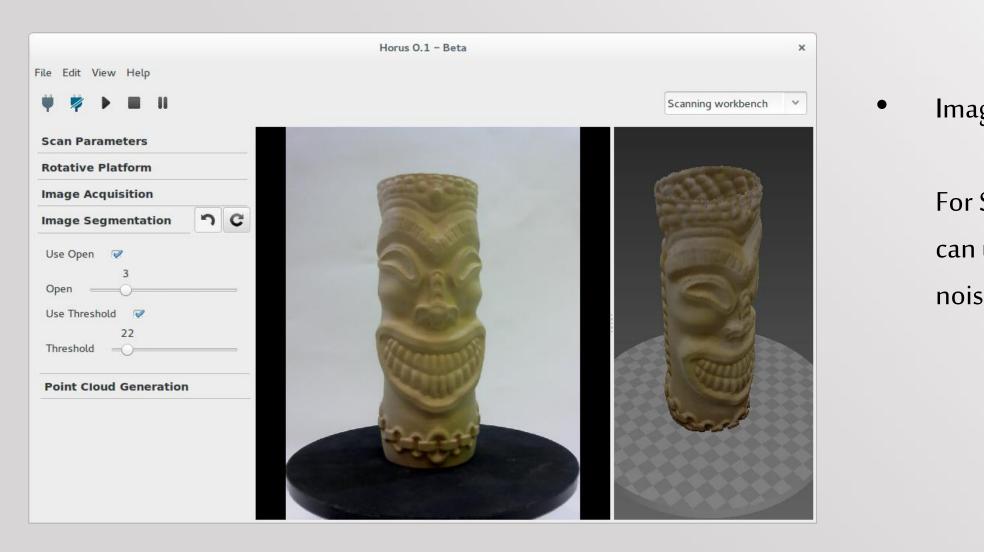


# bq

Image segmentation.

For simple texture or without scanning, can be used threshold.

#### Settings panel

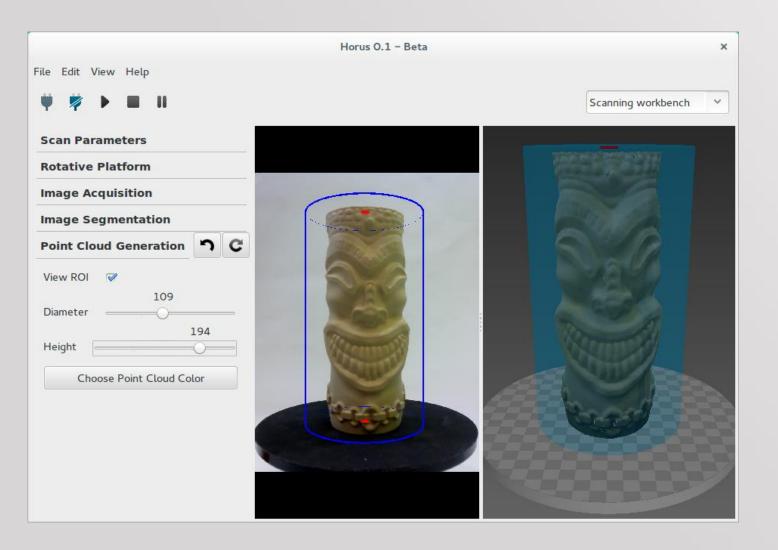


# bq

Image segmentation.

For Scanning with texture, you also can use Open, and the removing noise intensifies.

#### Settings panel



ROI: Creating an area of interest.

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It will be scanned only within the cylinder, avoiding obtaining noise from outer areas.



Settings panel

To scan, press in the PLAY icon

Once finished, to save the point cloud will click on File > Save Model

The output format will be .PLY









3. Poisson Reconstruction



5. Smoothing the .STL (optional)



#### 2. Calculation of normal vectors

#### 4. Joining clouds (optional)

Cloud cleaning is use to remove those points that do not want, because they are noise, or do not interest us

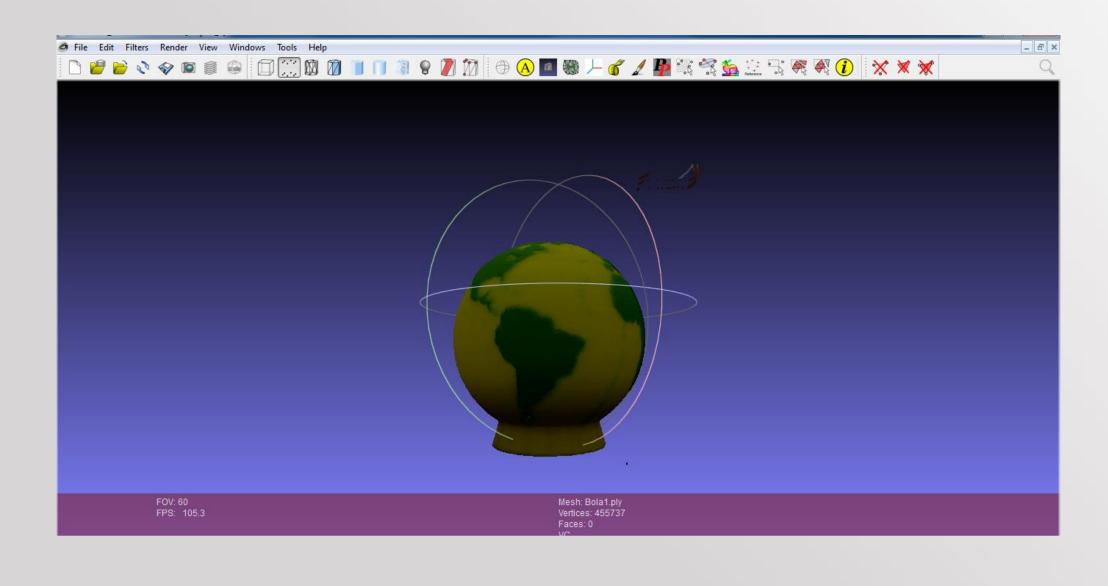


To do this, we open the point cloud format .PLY

File > Import mesh



We must open the point cloud in .PLY format

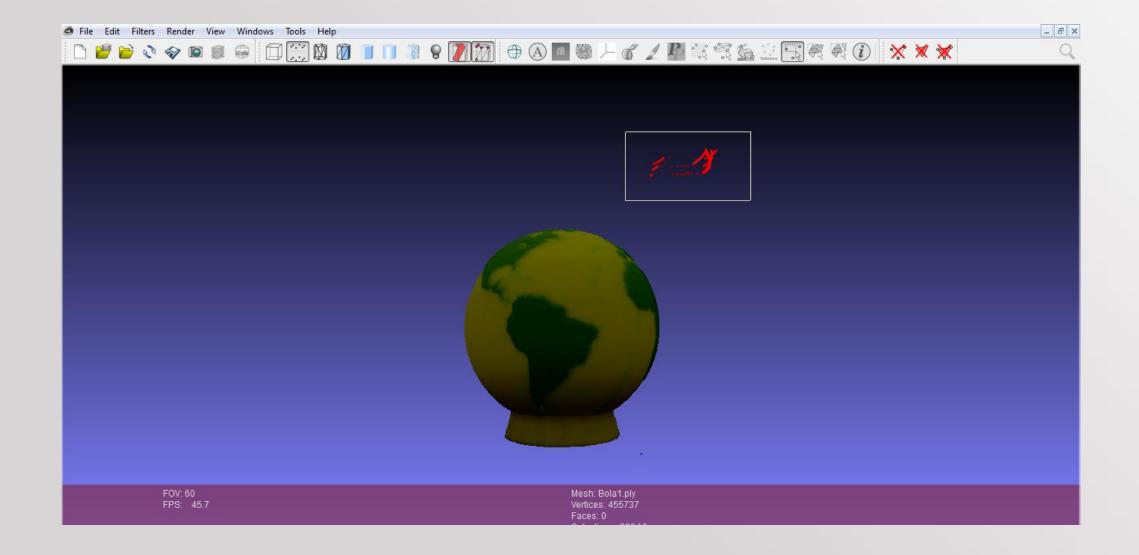




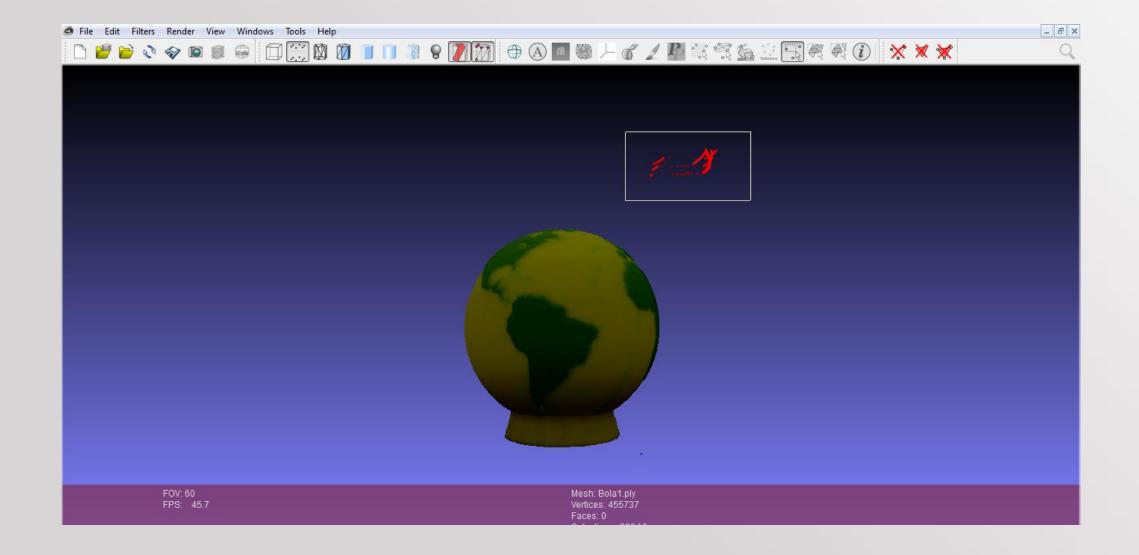
To delete points, select the Vertex Select tool

Then we choose the unwanted points. They are displayed in red











Then select the option *Delete selected vertices* of the toolbar



Delete the current set of selected vertices; faces that share one of the deleted vertexes are deleted too.

(filter_select.dll)

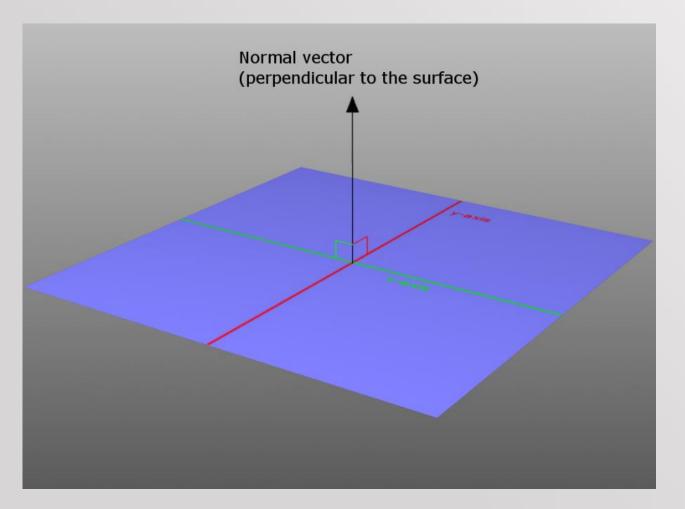




A cleaned cloud points will be very important to obtain a good result



A normal is a perpendicular vector to a plane

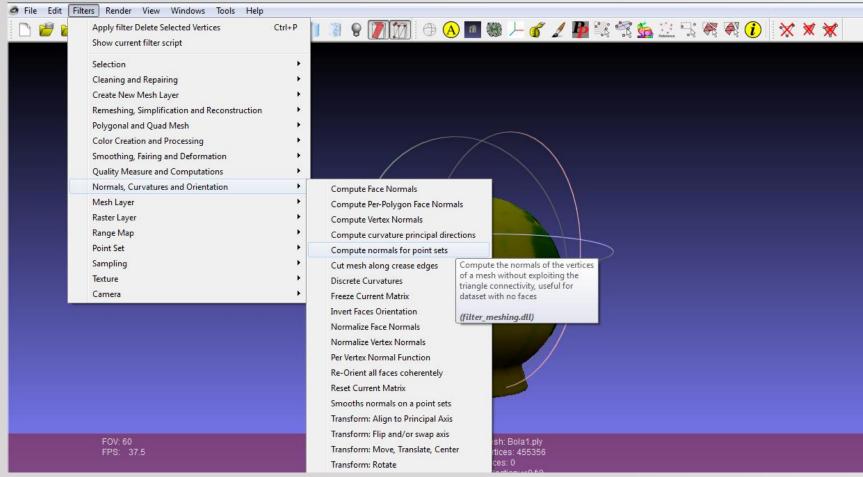




In this step, we will calculate the normal of the points cloud.

To do this, we group a number of points to form a plane, and finally the average is calculated.











Now we calculate the number of neighbors. Determines the amount of points needed to create a vector.

It is recommended to start with a value of 10. The other values will be left by default. Then, we apply it.





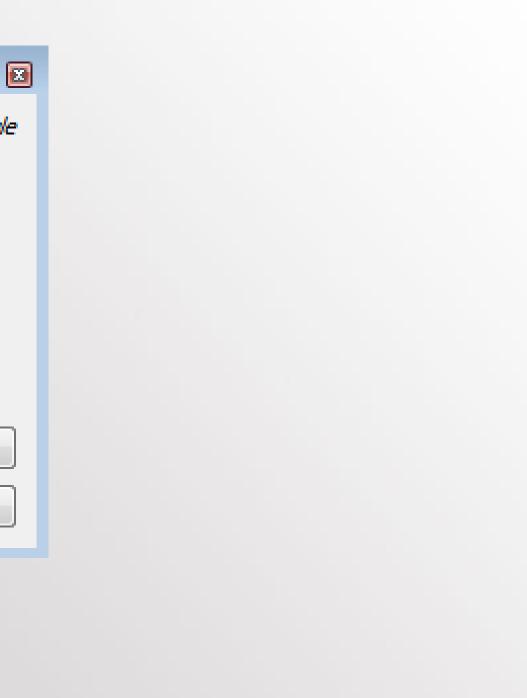
#### Compute normals for point sets

Compute the normals of the vertices of a mesh without exploiting the triangle connectivity, useful for dataset with no faces

Neighbour num	10				
Smooth Iteration	0				
Flip normals w.	r.t. viewpoint				
Viewpoint Pos.	0	0	0 Get	View Dir 🔻	
Defa		Help			
Clos		Apply			





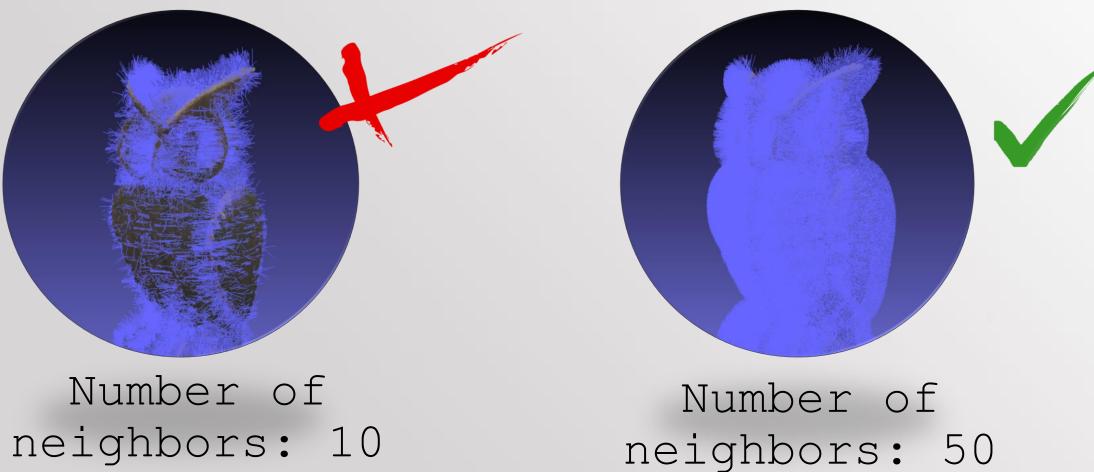


We show normal. The best reconstructions are when the direction of the vectors are oriented away from the object.

If the normal vectors are not directed outwards, we repeat the step changing the number of neighbors to 50; if repeated, 100.











For the reconstruction, we convert from .PLY to .STL

It is a critical step, because depending on the previously established normal and reconstruction values, the STL may vary.

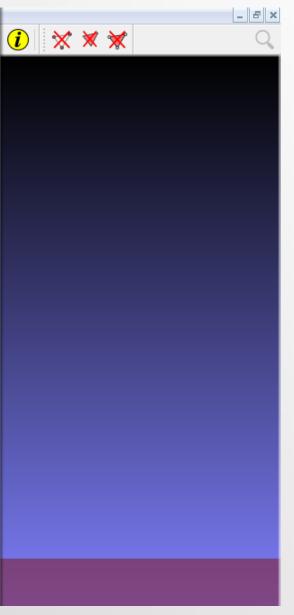


To do this, we choose the option *Poisson Reconstruction* 



D 🖻 🛛	Apply filter Compute normals for point sets	Ctrl+P	Close Holes		
	Show current filter script		Clustering decimation Convex Hull Crease Marking with NonFaux Edges Curvature flipping optimization Cut mesh along crease edges Delaunay Triangulation Marching Cubes (APSS) Marching Cubes (RIMLS) Mesh aging and chipping simulation Planar flipping optimization Points Cloud Movement Quadric Edge Collapse Decimation (with texture)		
	Selection         Cleaning and Repairing         Create New Mesh Layer         Remeshing, Simplification and Reconstruction         Polygonal and Quad Mesh         Color Creation and Processing         Smoothing, Fairing and Deformation         Quality Measure and Computations	•			
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		•	Subdivision Surfaces: Butterfly Subdivision Subdivision Surfaces: Catmull-Clark		
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			Surface Reconstruction: Ball Pivoting		
			Surface Reconstruction: Poisson		
			Surface Reconstruction: VCG Tri to Quad by 4-8 Subdivision Tri to Quad by smart triangle pairi		
	FOV: 60	Turn into Quad-Dominant mesh ( <i>filter_poisson.dll</i> ) Turn into a Pure-Triangular mesh			
	FPS: 48.1		Uniform Mesh Resampling		
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In this window you can modify two values:

- Octree Depth
- Solver Divide



The recommended values of both parameters are between 6 and 11.

With a higher the value, the reconstruction is more accurate, but it takes longer to make the process.



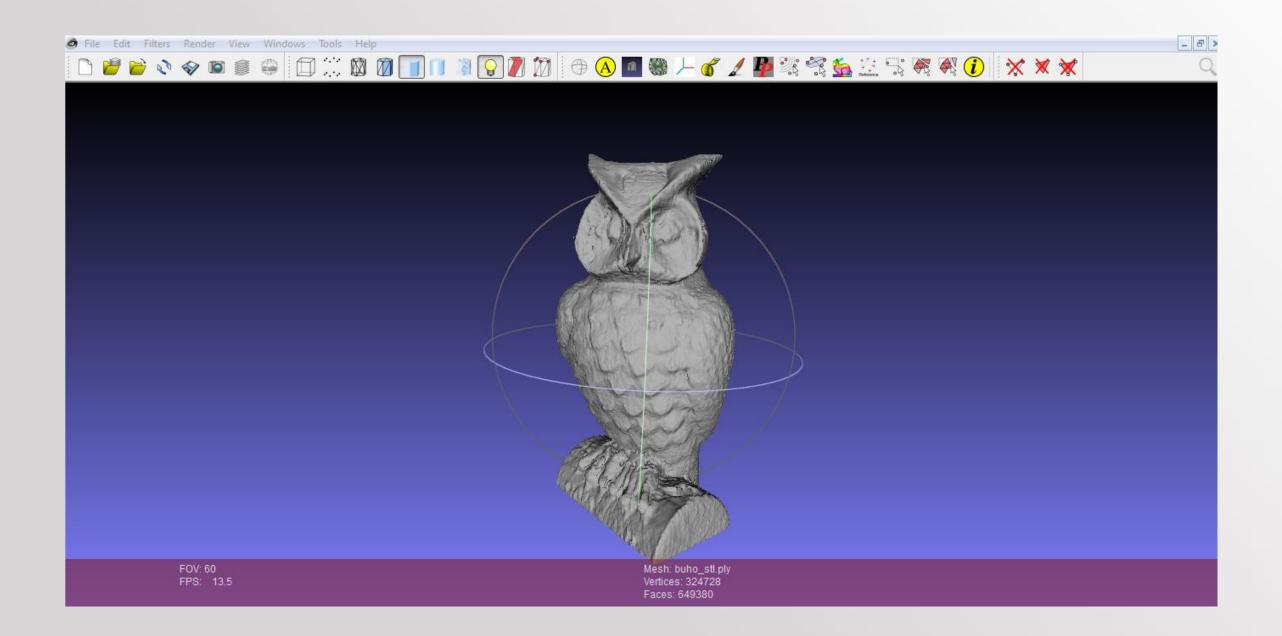
Surface Reconstruction: Poisson					
Use the points and normal to build a surface using the Poisson Surface reconstruction approach.					
Octree Depth	8				
Solver Divide	8				
Samples per Node	1				
Surface offsetting	1				
Default	Help				
Close	Apply				



To view reconstruction:

*View > Show Layer Dialog* 







To save the reconstruction (STL):

*File > Export Mesh...* 



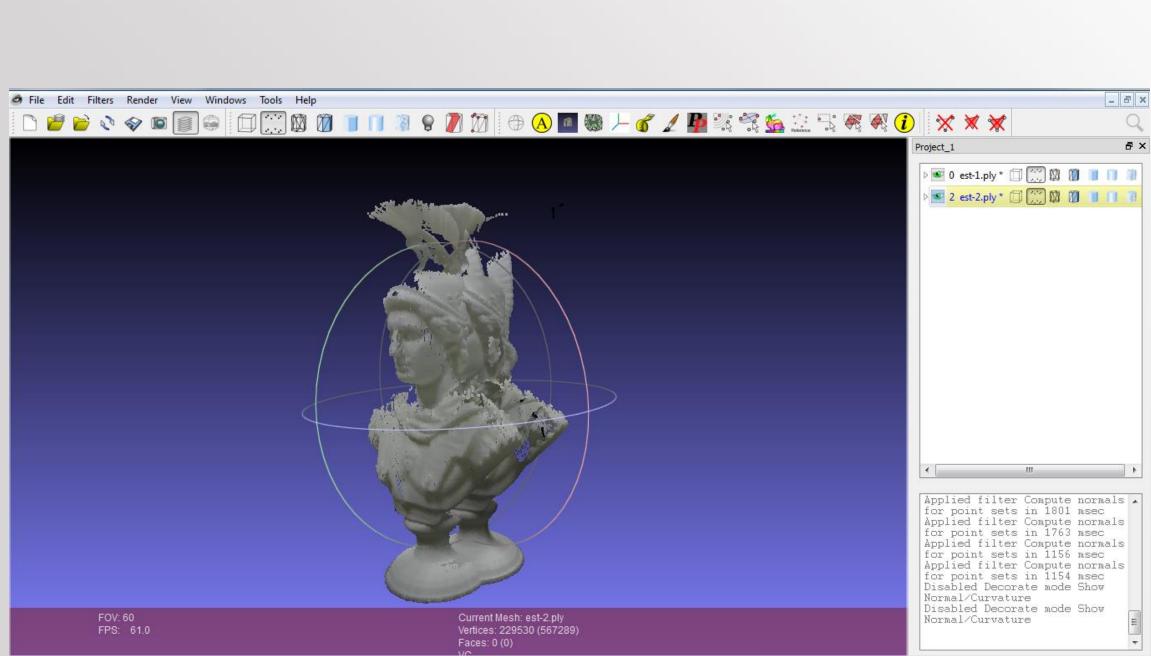
Sometimes due to the geometry of the piece, the cloud of points are incomplete.

To fix this, you can re-scan the piece in another position or by using another laser, and then join the different clouds.



To do this, we will open the various .PLY in MeshLab







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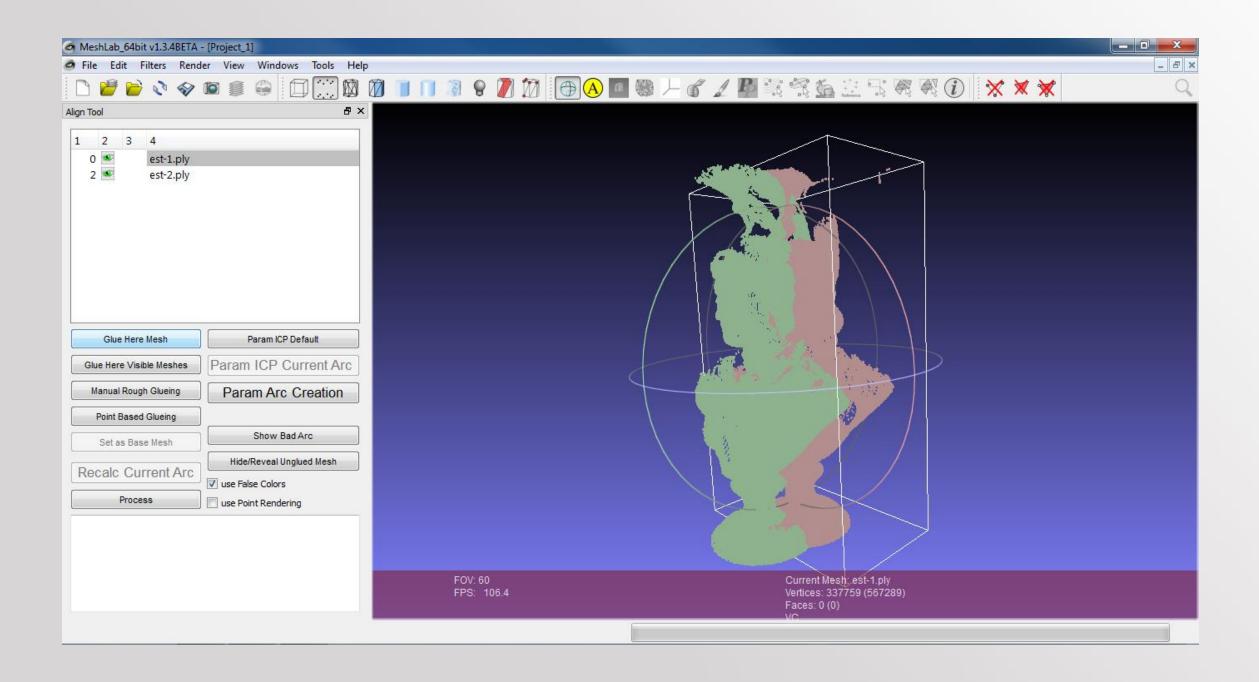
In the *Layer Dialog*, we calculate each normal point cloud, as described above.

Once done, we click on the *Align* tool







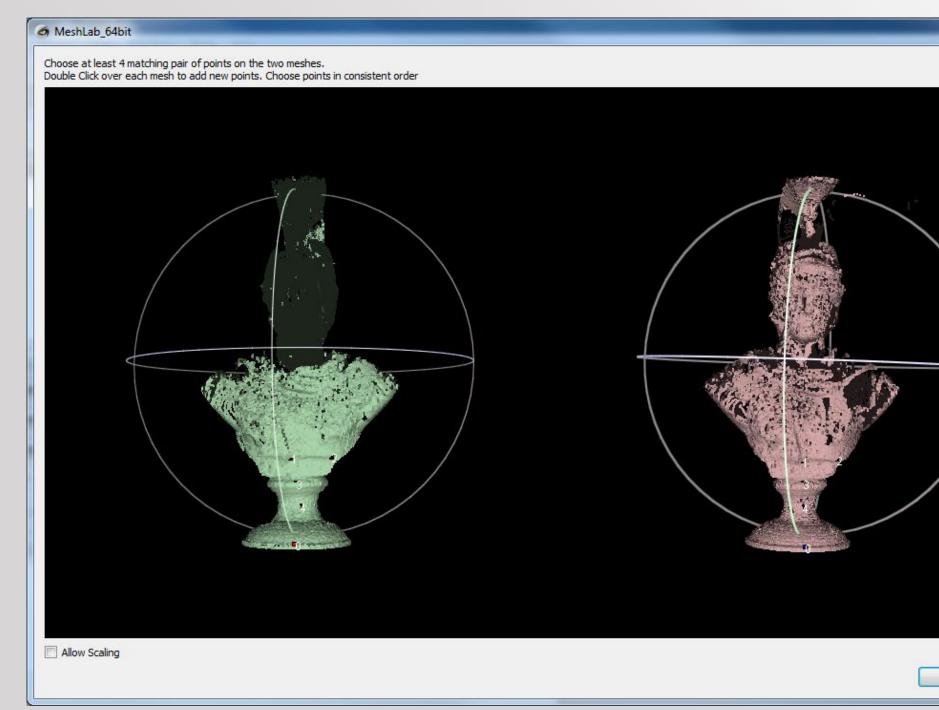




In the *Tool panel*, we click on the first layer, and we glue it at the space (*Glue Here Mesh*)

Then, we select the second mesh, and click on *Point Based glueing*.







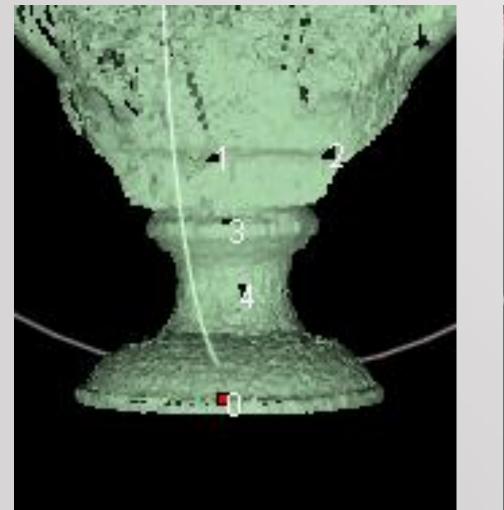


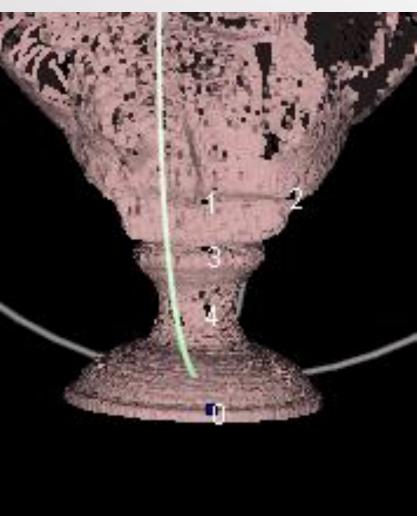
In this window you have to select at least 3 points in common of both clouds.

Example: First a point cloud 1, and then the same point in the 2nd.

The choice does not have to be exact, can be approximated.









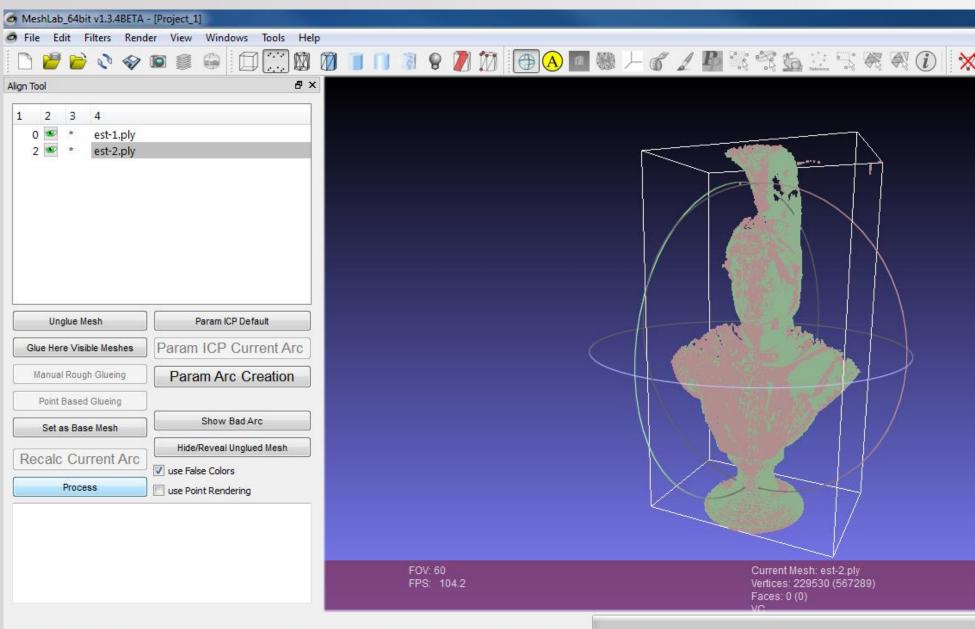


The numbered points appear. If you select an invalid point you must cancel and repeat the process.

Once the points are selected, click on OK.









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To join the aliened clouds:

*Filters > Mesh Layer > Flatten Visible Layers* 



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Flatten Visible Layers	8			
Flatten all or only the visible layers into a single new mesh. Transformations are preserved. Existing layers can be optionally deleted				
Merge Only Visible Layers				
Delete Layers				
Merge duplicate vertices				
Keep unreferenced vertices				
Default Help				
Close Apply				

All other values will be left by default.



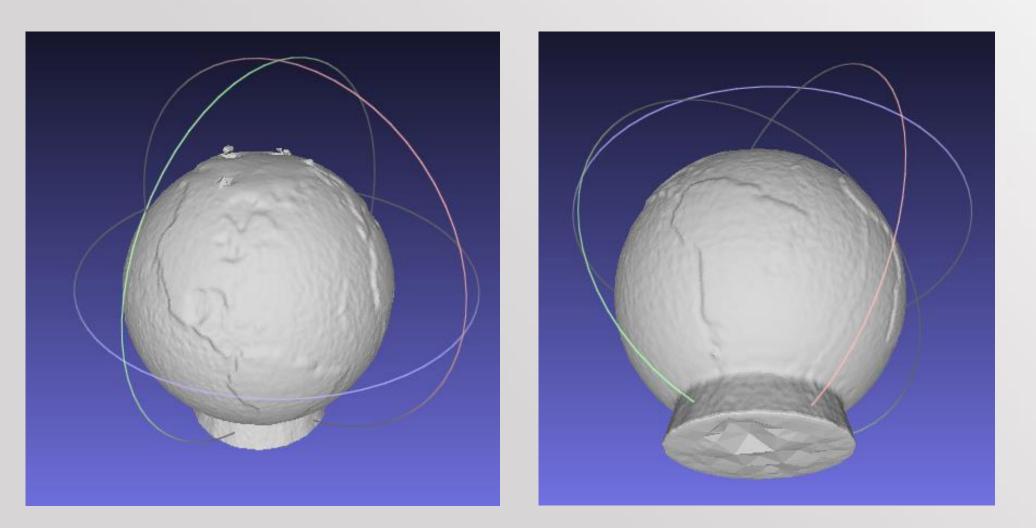
### In this window we select Keep Unreferenced Vertices option

Although it is a process that can be performed with a different software, MeshLab gives the opportunity to smooth the STL reconstructed.





Our goal is to smooth the jagged faces

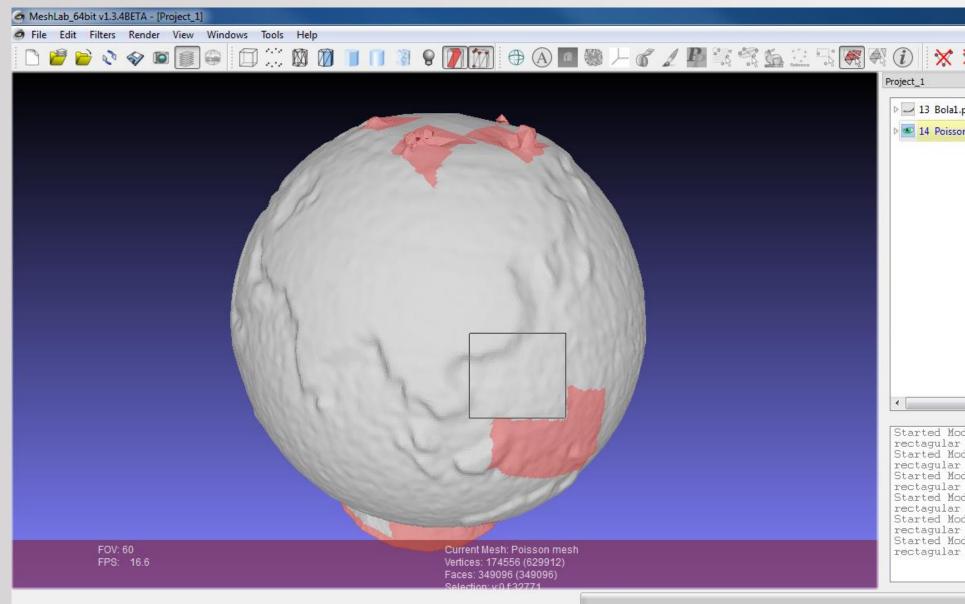




With the *Selection tool* faces, we select the faces that we choose to smooth, and then choose Smooth Taubin.











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Mesh Layer	•	Fractal Displacement	
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Range Map	•	Geometric Function	
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The result is the following:

