



HORUS

3D SCANNING FOR EVERYONE

USER MANUAL **ENGLISH**

Version 0.1.1

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1 Installing Horus

Installation on Linux: Ubuntu

Horus is installed on Linux using the apt-get command. Enter these keys to do this using the console. Administrator permissions are required.

```
sudo add-apt-repository ppa:bqopensource/opencv  
sudo add-apt-repository ppa:bqopensource/horus
```

Then update the system packets by entering these commands into the console:

```
sudo apt-get update  
sudo apt-get dist-upgrade
```

Once the update has finished, enter the following command to install the program:

```
sudo apt-get install horus
```

If you do not have permission to access the serial port, you will need to execute the following from console:

```
sudo usermod -a -G dialout $USER
```

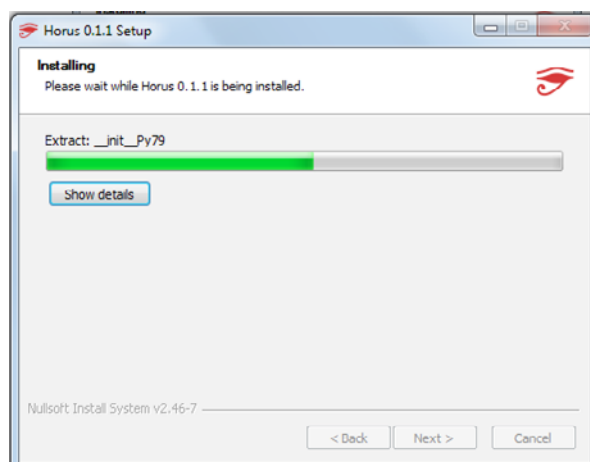
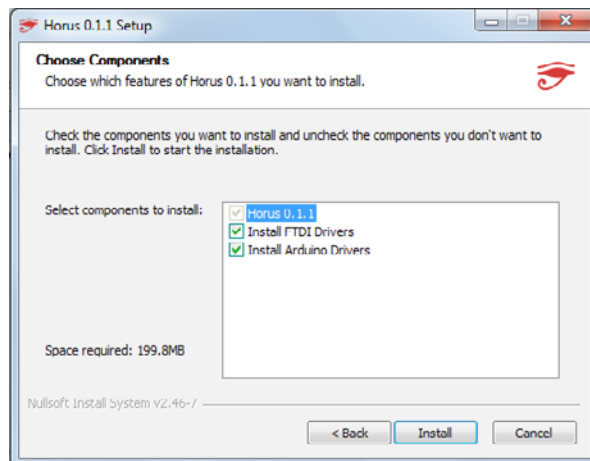
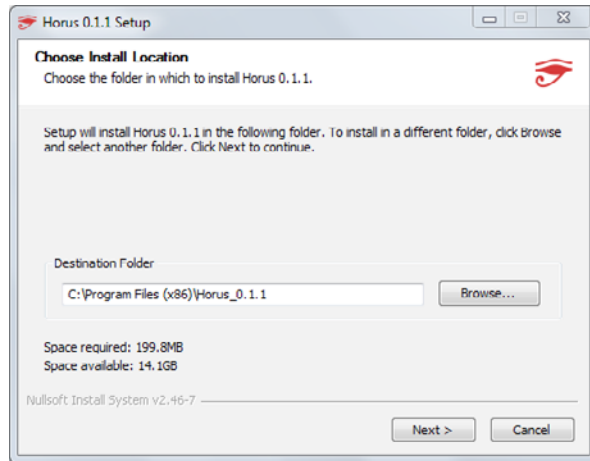
Lastly, you will need to reboot the system so that the changes are applied correctly. To uninstall the program, execute the following from console:

```
sudo apt-get remove horus
```

Installation on Windows

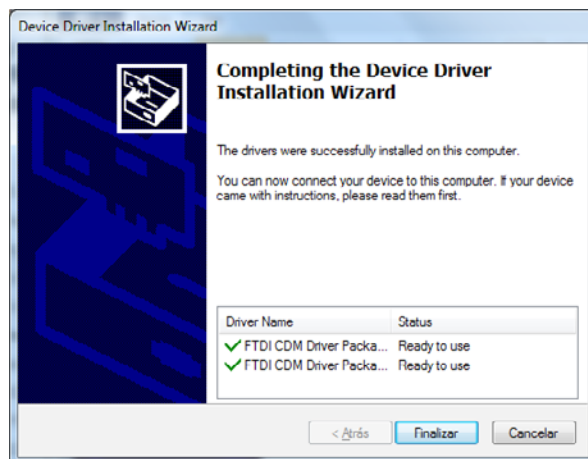
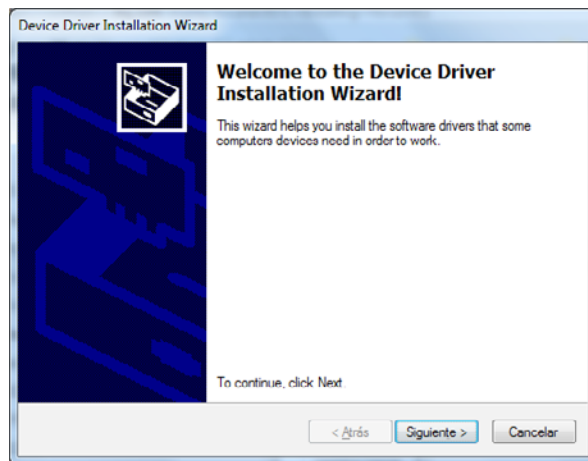
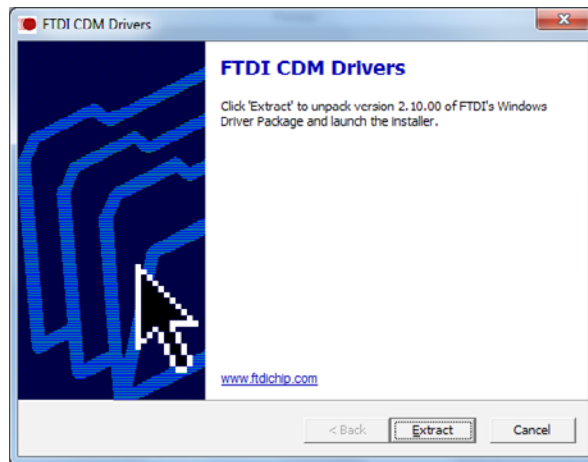
Horus is installed on Windows by executing the “.exe” file that you can find under the downloads section of www.bq.com/gb/products/ciclop.html. Administrator permissions are required.

Follow the steps of the installation wizard below:

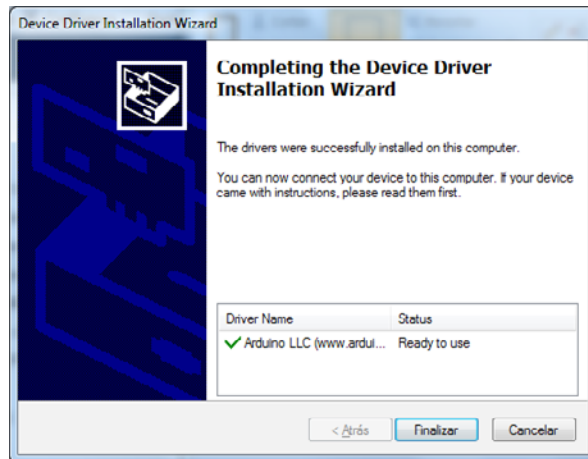


Installing Horus

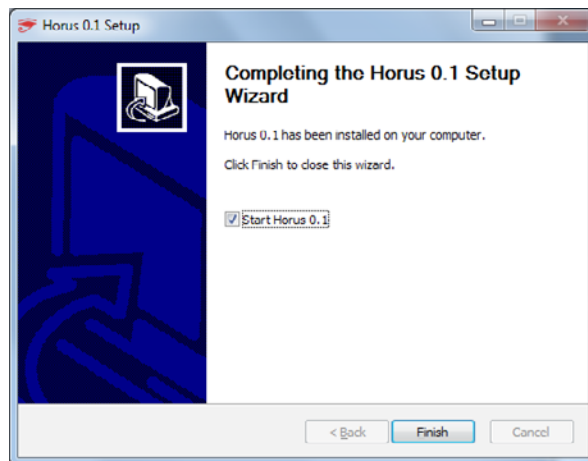
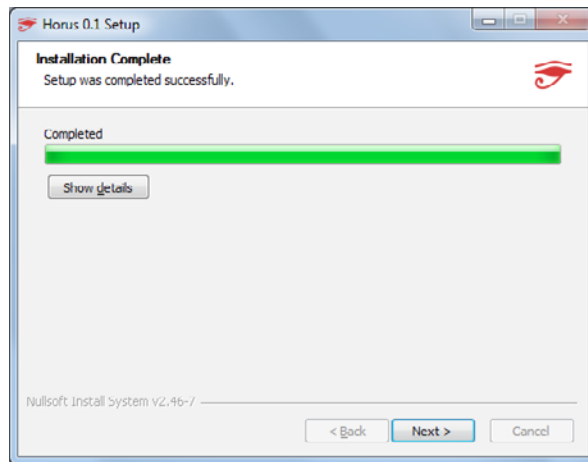
To communicate with the ZUM BT-328 board, install the FTDI drivers. You can also install them for Arduino Uno.



Installing Horus



Once the wizard has finished, the application will be correctly installed.

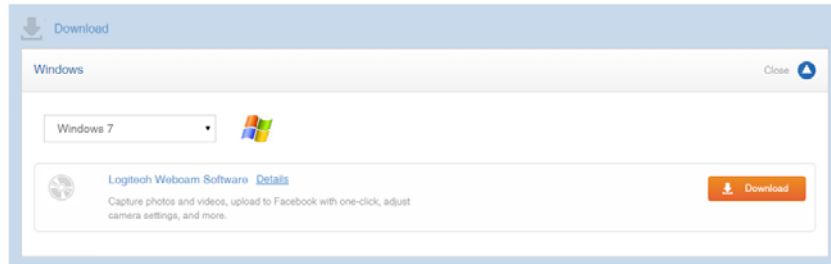


Camera drivers

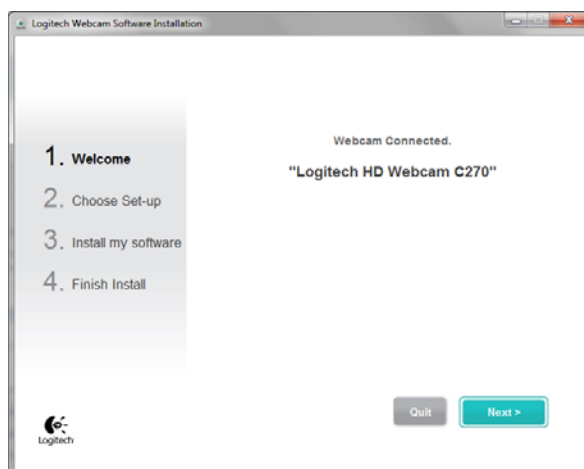
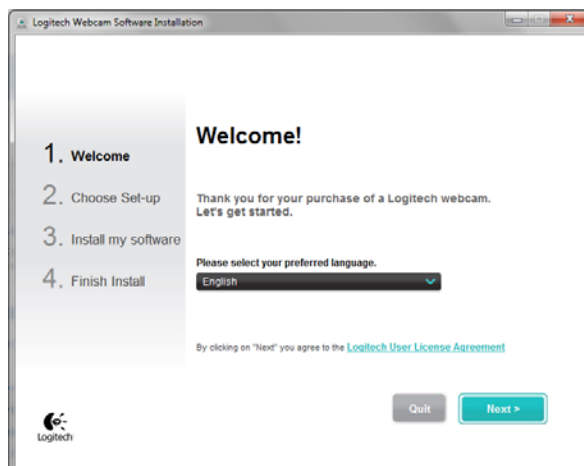
If the camera is not detected after you have installed Horus, you will need to install the camera drivers.

To do this, download the driver installation software from the manufacturer's website: http://support.logitech.com/en_us/product/hd-webcam-c270

Select your operating system and then click on **Download**.

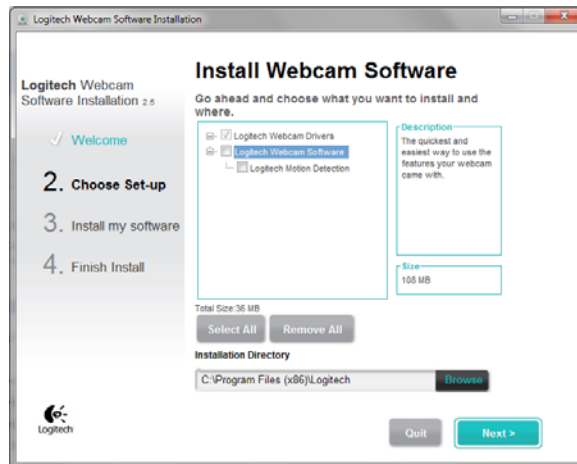


Once you have executed the driver installation file, follow the instructions as shown in the images below:

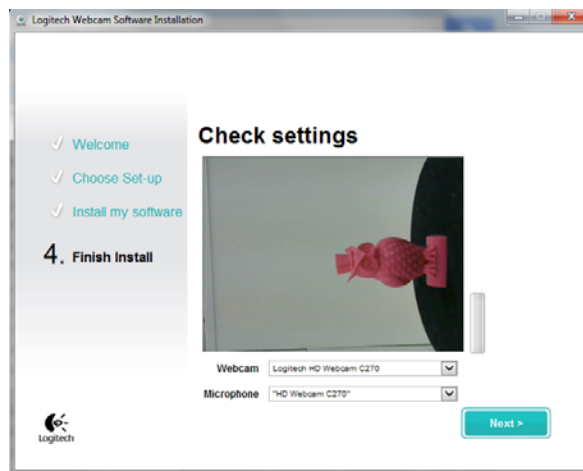


Installing Horus

You only need to install the Logitech Webcam Drivers, so make sure you untick the **Logitech Webcam Software** option.



Installing Horus



It is advisable to reboot everything after installing the camera drivers and then reinstall Horus so that it detects the camera correctly.

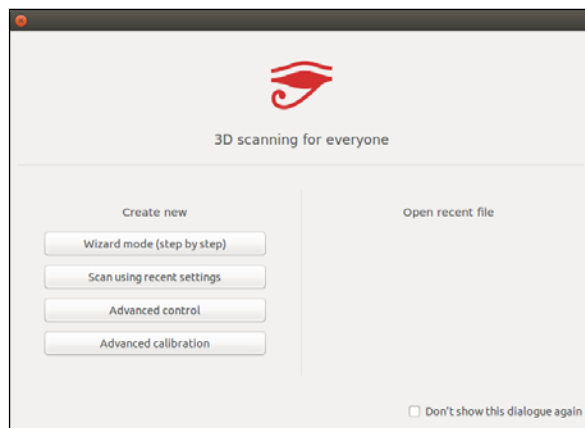
2 Running Horus for the first time

Welcome screen

This screen appears every time the program is launched or when you click on **Help > Welcome** in the main window.

It is divided into two columns: actions for scanning a new model (**New**) are listed on the left and files for recently scanned models are listed on the right. Click on the desired file to access a recently scanned model (**Open recent file**).

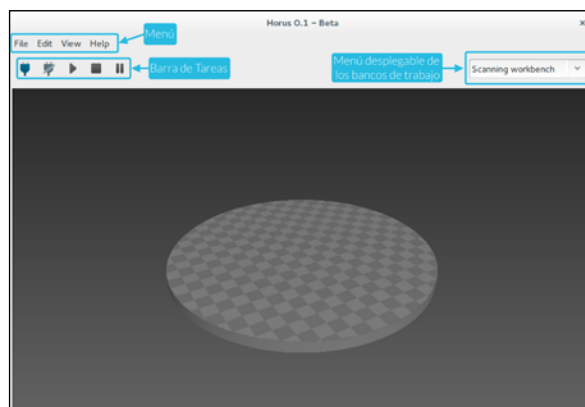
There is also a selection box which allows you to disable this window if you don't want it to appear every time you launch the program (Don't show this dialog box). This option is unticked by default.



Main window

The main window consists of a menu, a task bar and a drop-down menu. The menu contains these sub-menus: **File**, **Edit**, **View** and **Help**.

The task bar icons will vary according to the workbench selected.



Drop-down menu

You can choose from three workbenches in the drop-down menu.

- **Control workbench:** enables the scanner components to be controlled separately (Camera, Laser, LDR and Motor).
- **Calibration workbench:** allows the calibration processes to be carried out which determine the fundamental parameters of the scanner.
- **Scanning workbench:** enables the scanning to be carried out and the scan parameters to be edited.

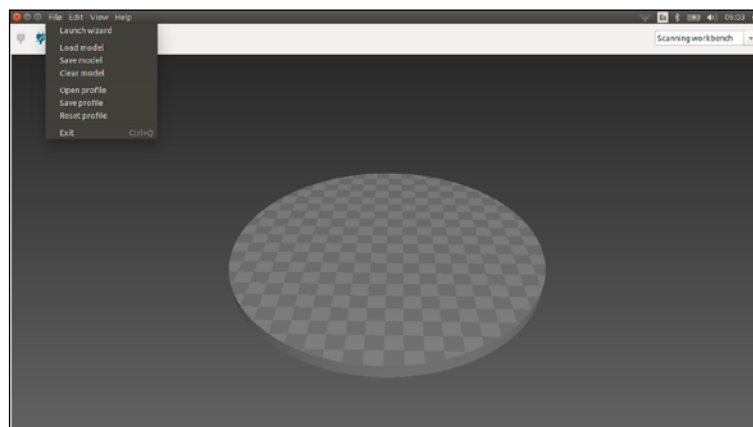
Menu

File

The **File** menu enables you to:

- *Run the wizard.*
- *Load, Save and Delete models.*
- *Open, Save and Reset profiles.* A profile is a file with a ".ini" extension, which contains all the parameters that the program uses.

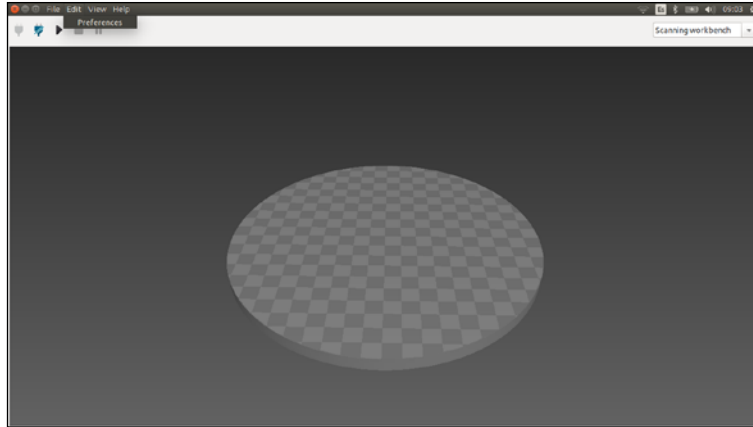
In the **Control** and **Calibration** workbenches, the actions on models are not available. A model is a 3D object. It could be a point cloud (.PLY) or a mesh of triangles (.STL).



Running Horus for the first time

Edit

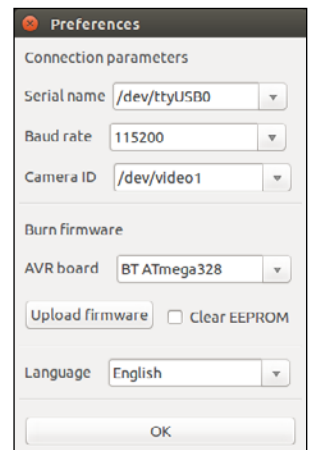
From the **Edit** menu you can access Preferences.



Preferences

The system preferences are:

- **Connection parameters:** Serial name, Baud rate and Camera ID. If several controller boards or cameras are connected, various elements will appear on the list. If no options appear, it means that the computer was unable to identify the board or the camera. The values selected will be stored in the profile.
- **Upload firmware:** enables the firmware to be uploaded to the controller. Select the corresponding board (Arduino Uno or BT ATmega328) and the **Clear EEPROM** option if you want to delete the data from the internal memory. Finally, click on **Upload Firmware**.
- **Language:** allows the language to be selected from the drop-down menu. It is currently available in English and Spanish.



The program configuration data is stored on the EEPROM memory. Clearing the EEPROM memory will restore the default configuration.

View

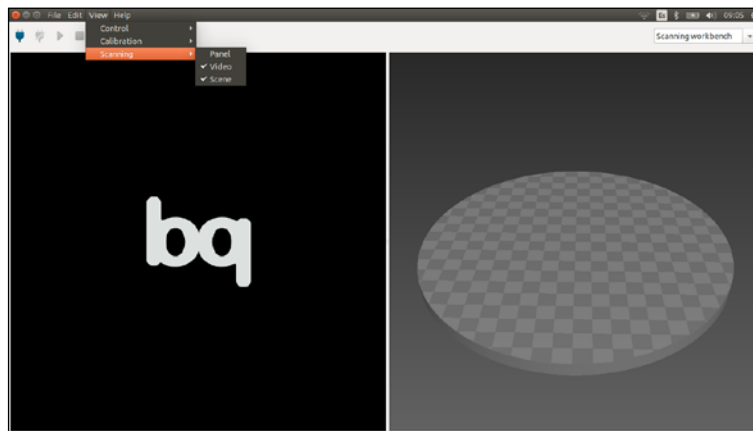
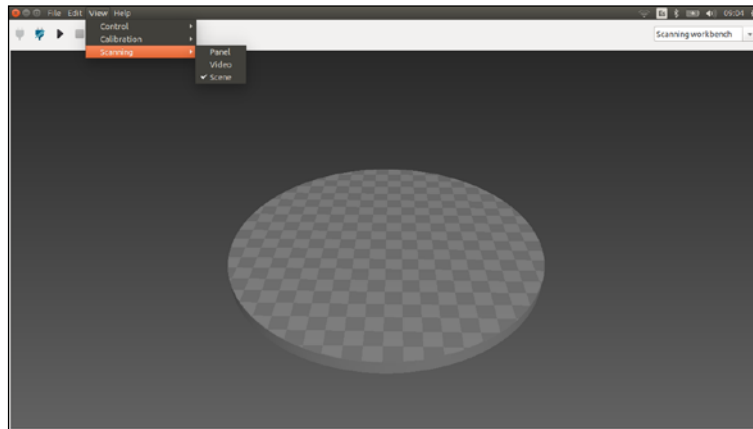
The View menu displays or hides the graphic elements of the different workbenches:

- **Panel:** displays the adjustable options and settings. If you move the cursor over some options and settings a brief description of them will appear.
- **Video:** displays the video captured by the camera.
- **Scene:** interactive 3D viewfinder, displays the scanned model in three dimensions.

HORUS

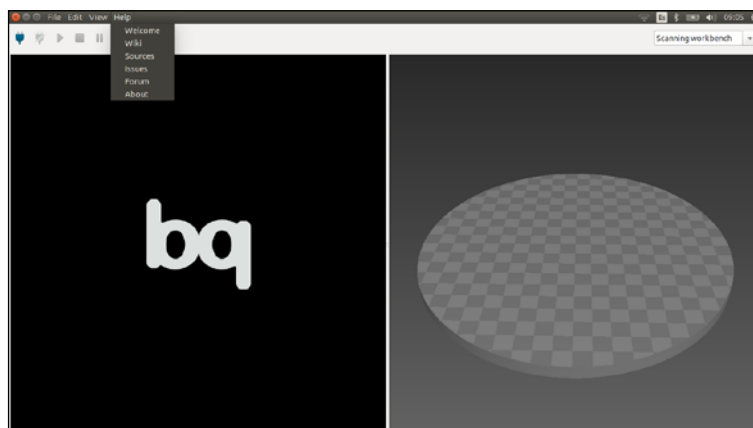
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Running Horus for the first time



Help

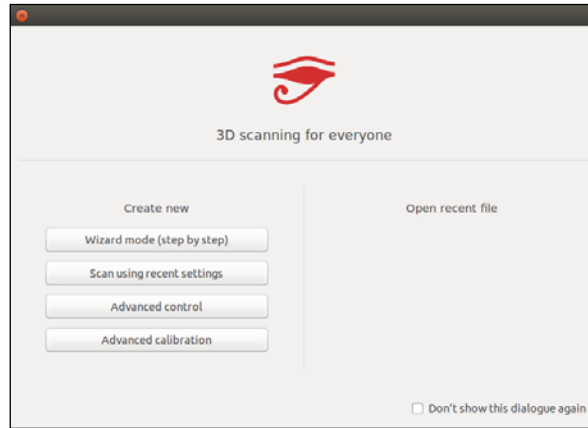
This menu provides Information on the application and access to the Welcome screen (*Welcome*).



3 Launching the wizard

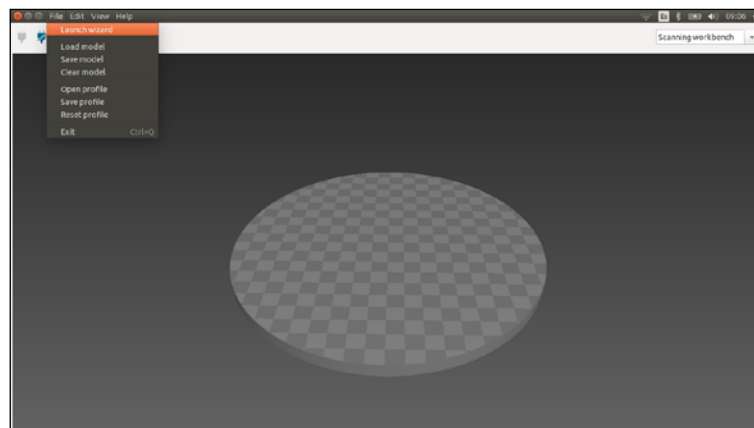
There are two ways of opening the wizard:

1. From the *Welcome* screen



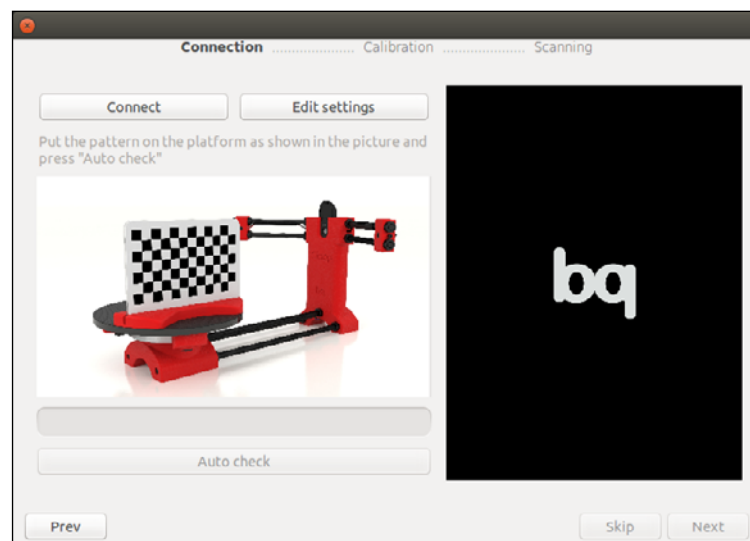
It can also be accessed via the *Help > Welcome* tab.

2. From the *File* menu

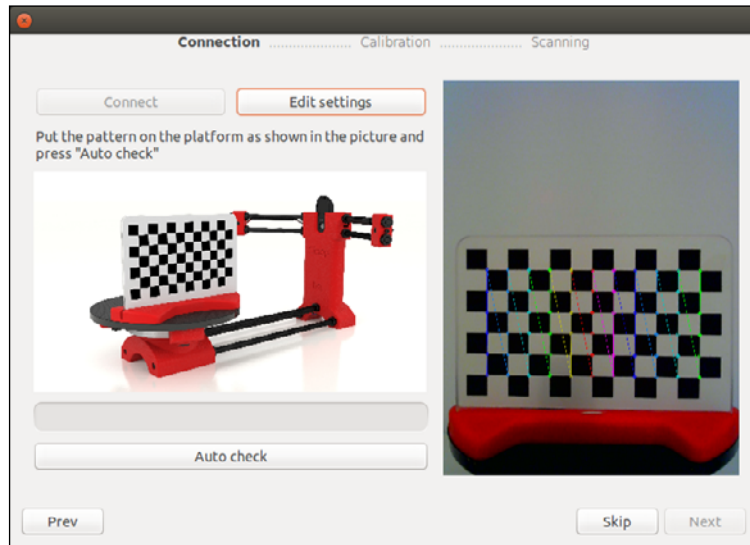


Connection

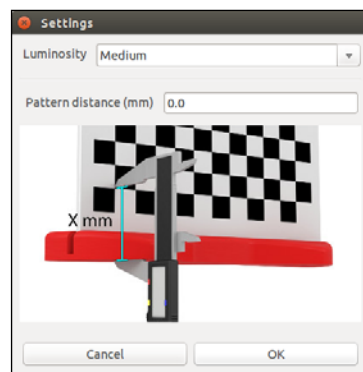
This screen will appear when the wizard is launched.



Hit the **Connect** button. If everything is connected and configured correctly, the video will appear in the box on the right.

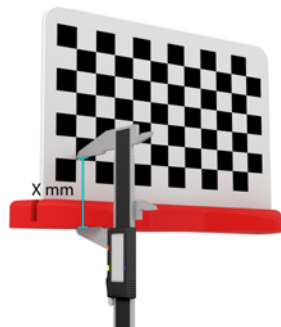


Next you will have the option to edit preferences. The following settings window will appear:



Here you can adjust the **Luminosity** type and the **Pattern distance**.

The pattern distance, which is measured vertically to the base in mm, from the top of the square on the bottom left part of the pattern, to the rotating platform of the scanner (as indicated by the X in the previous image). It should be as accurate as possible.

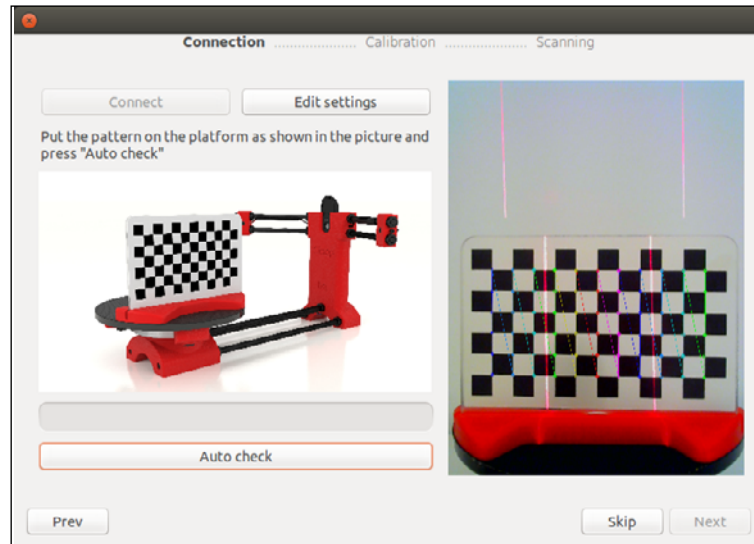


Launching the wizard

The luminosity selected for the wizard should be adequate for detecting the pattern correctly. The most suitable luminosity type will enable the pattern to be detected when the platform is rotating with the largest angle. To achieve this, return to the previous screen before entering the pattern distance, position the pattern as shown in the image and manually rotate the platform anti-clockwise. The luminosity type which enables the largest angle to be detected is adequate for the calibration. It is advisable to use the luminosity type that makes the image capture clearly visible, without being very light.

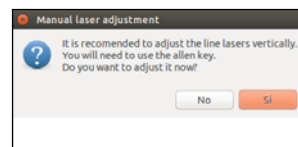


It is very important to position the pattern as shown in the image, making sure that the curve of the pattern coincides with the curve of the rotating platform.



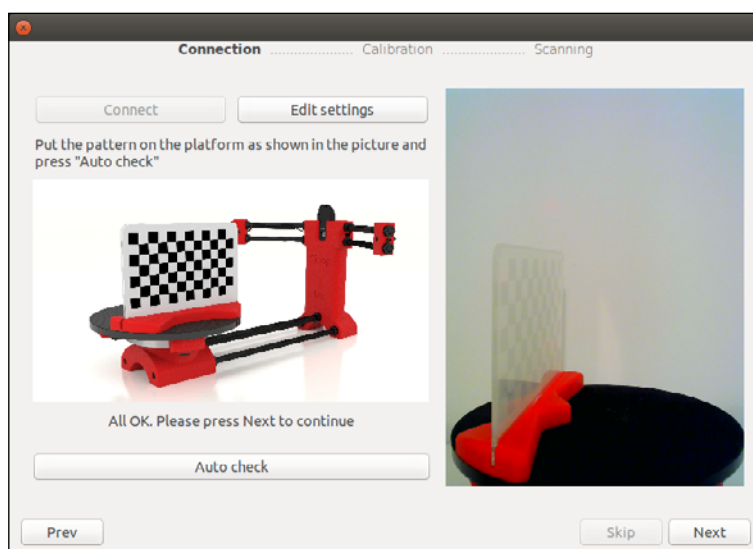
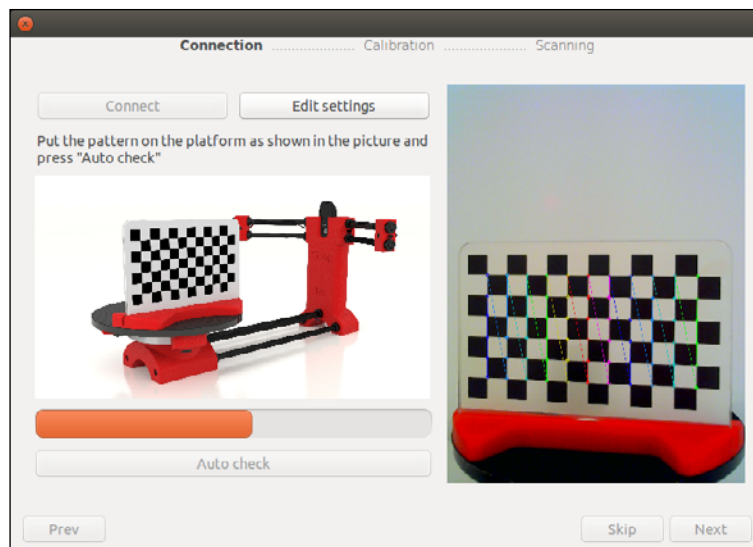
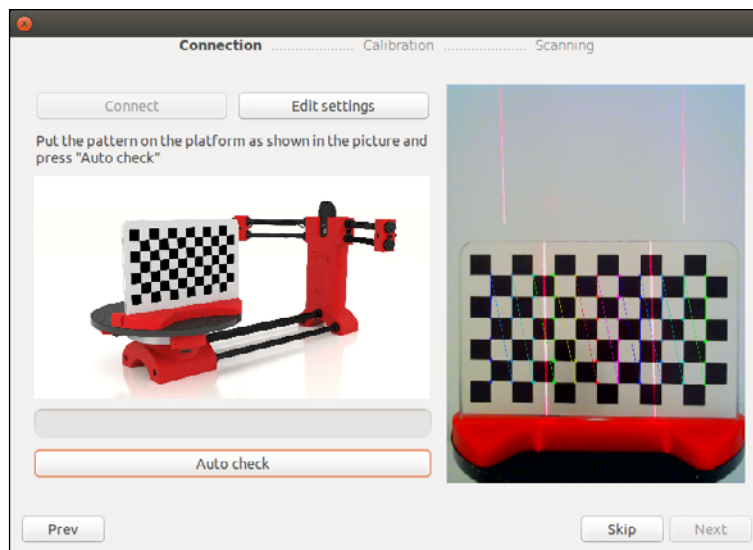
Then click on **Auto check**.

If you are configuring the scanner for the first time or you have reset the profile, the following window will appear advising you to manually adjust the lasers into a vertical position. This adjustment does not have to be 100% accurate as the lasers will be calibrated later by the software.



If you click on **Yes**, the two lasers will light up. Using a smooth surface (such as the calibration pattern) to assist you, position the lasers so that they both project a vertical line. Use the screws attached to the structure to adjust them.

Launching the wizard



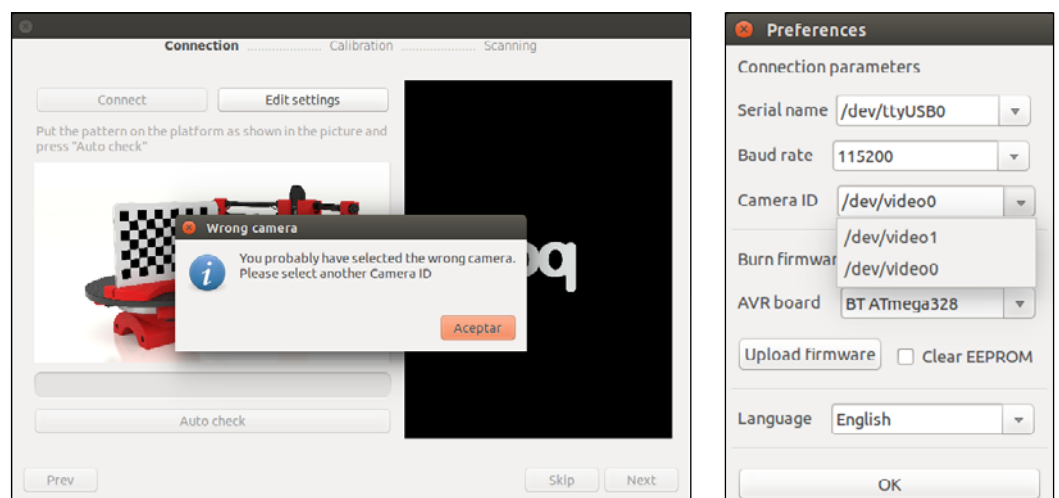
Launching the wizard

When the “All OK. Please press *Next* to continue” message appears, you can click through to the next step.

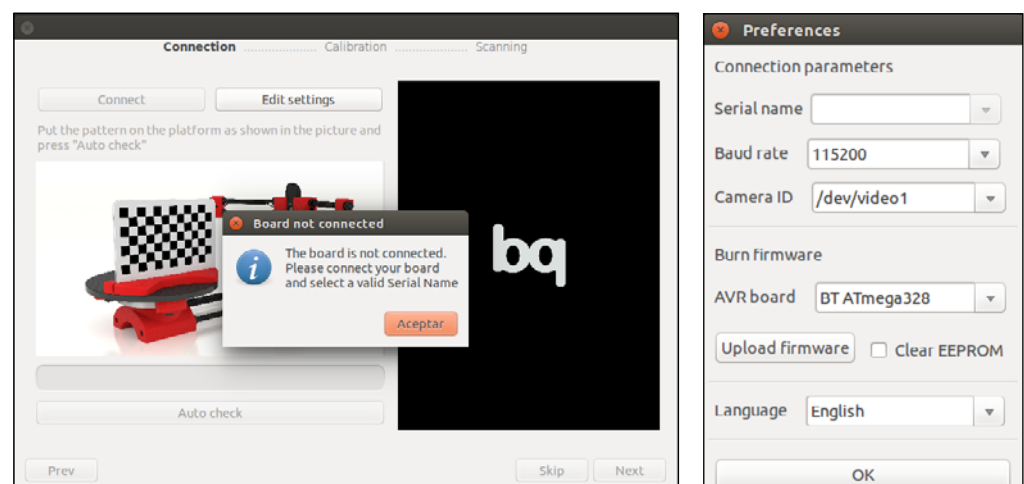
The first step is the calibration of the triangulation lasers, followed by the calibration of the platform extrinsics.

Potential error messages

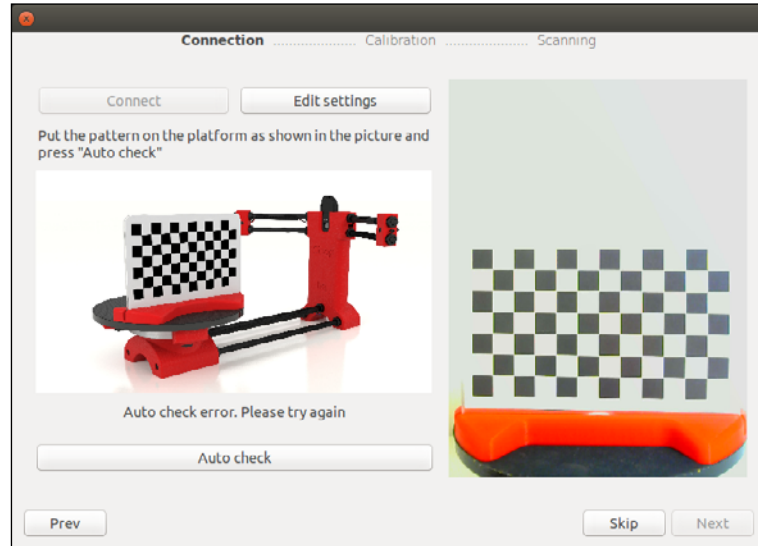
Wrong Camera: the program detects more than one camera and has selected the wrong one by default. Click on **OK** in the error message window and a preferences menu will appear enabling you to select the *Camera ID* of the scanner.



Board Not Connected: the controller board is not connected correctly to the computer or its ID has not been configured properly. Press the **OK** button and a preferences menu will appear enabling you to select the correct board. If nothing appears in the drop-down menu, check that the controller board is connected to the computer correctly and check the serial name access.

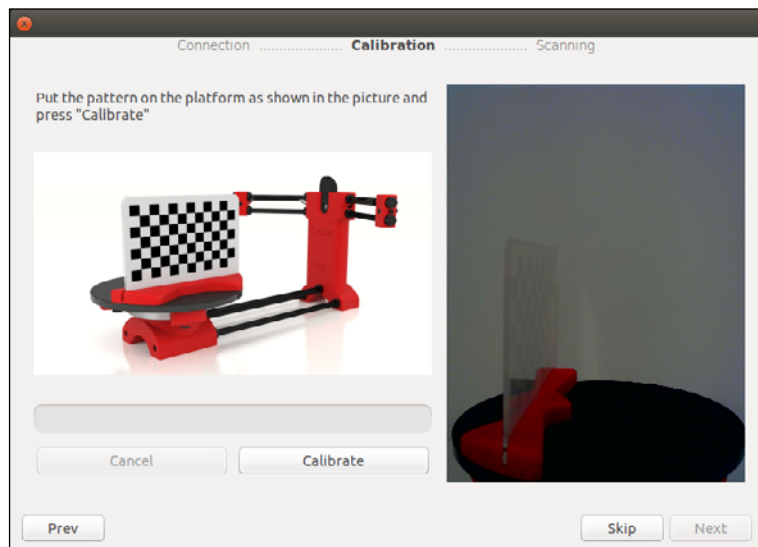


Auto check error, please try again: an error may occur on calibration due to selecting the wrong luminosity or positioning the pattern incorrectly. Make sure that the pattern has been detected and is in the correct position, then calibrate it again.



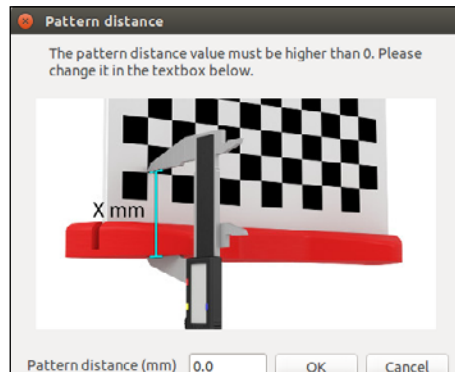
Calibration

The lasers of the scanner are calibrated during this step. The calibration pattern should have been put in place as shown in the diagram at the previous step. If not, place it manually into this position and then click on **Calibrate**.



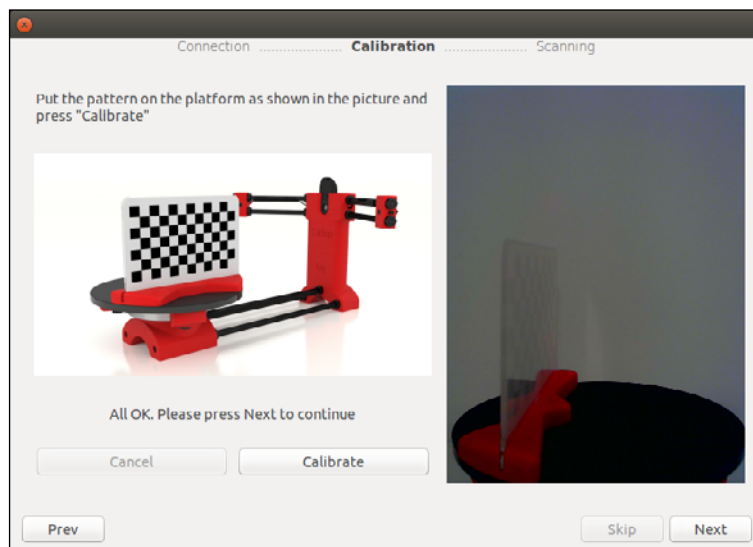
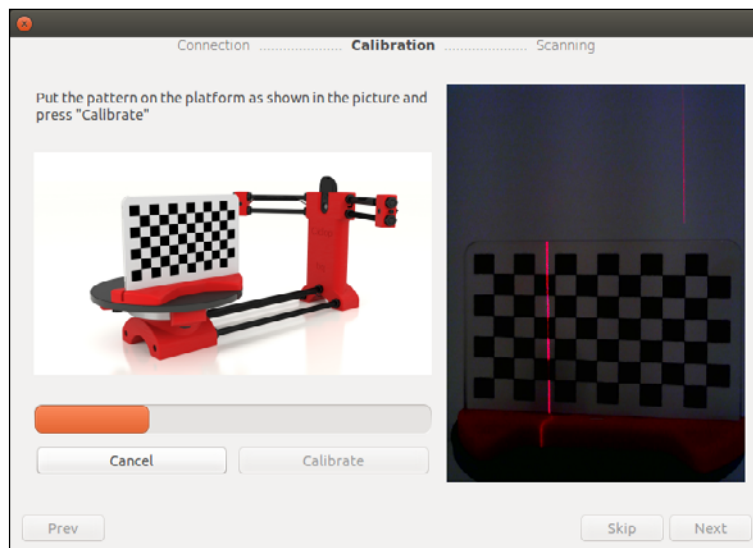
Launching the wizard

If you have not yet entered the pattern distance value, or you have reset the profile, it will appear in this pop-up window:



Enter the pattern distance. The image shows the pattern distance as distance X, which is measured in millimetres.

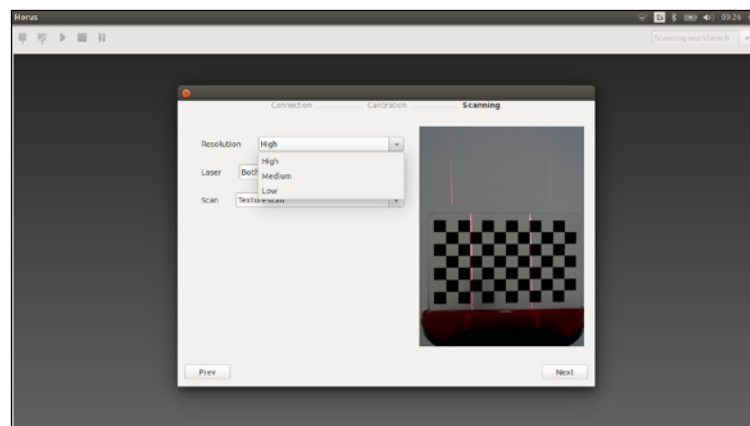
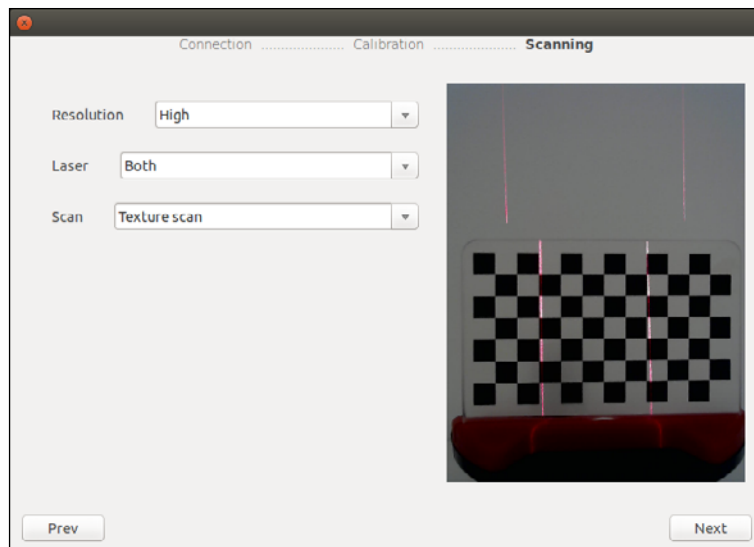
Click on **Calibrate** to start the process.

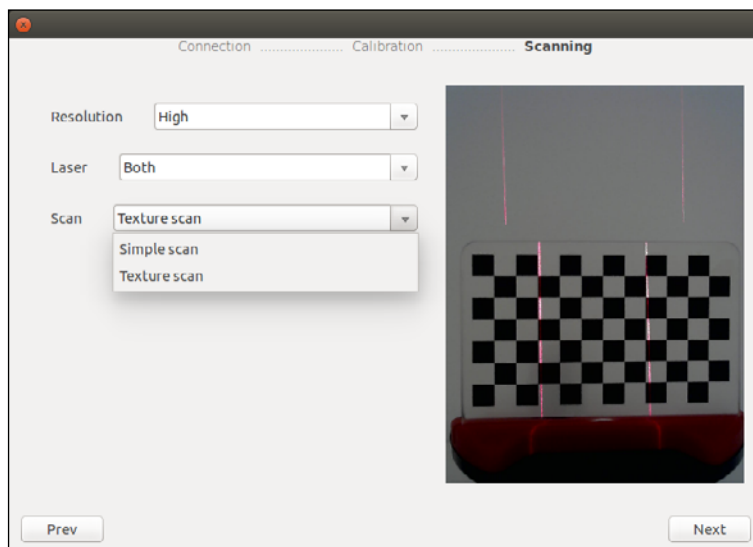
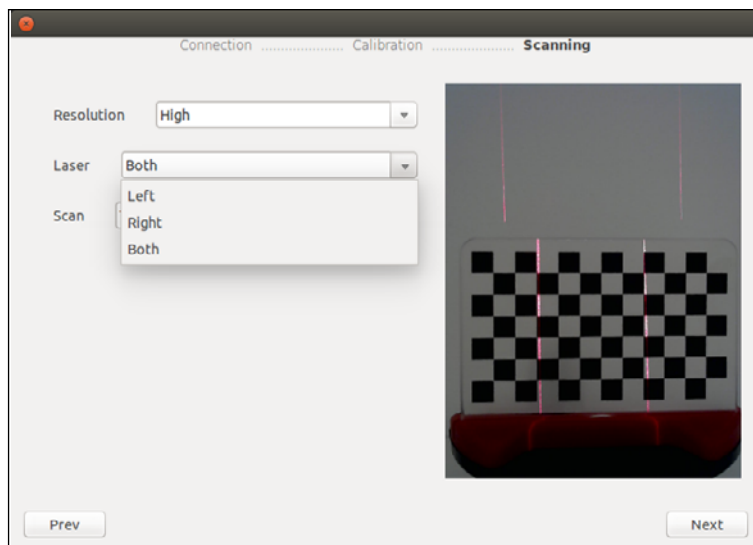


Scanning

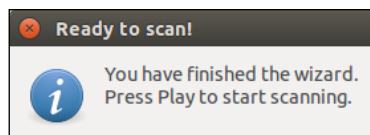
The last step of the setup wizard is to select the scanning preferences. You will see the following options:

- **Resolution:** you can select *High* resolution, *Medium* resolution or *Low* resolution. The higher the resolution, the longer the scanning time will be.
- **Laser:** you can select the *Left* laser, the *Right* laser or you can use *Both*. The scanning time will be longer if you use both lasers, but twice as many points will be scanned. Using both lasers is recommended as the scanning time will not be twice as long as with one laser under the same conditions.
- **Scan type:** you can select *Simple* or *Texture scan*. The simple scan uses one image per cycle to generate the point cloud and it does not capture the colour of the object. The texture scan uses two images to capture the laser and it also generates the point cloud using the actual colours of the object.





Once you have finished adjusting the scanning preferences, click on **Next** and the scanner is now ready to start working!



4 Control workbench



Any changes made in this workbench will not affect the other workbenches.

This workbench allows the scanner components to be controlled separately (camera, lasers, motor and LDR).

It includes:

- A task bar on the upper left for connecting and disconnecting the scanner.
- A control panel containing all the settings.
- A viewfinder for the camera video.

To connect to the scanner, simply click on **Connect**. If a problem occurs, such as a device not being connected, the **Preferences** window will open enabling you to select the correct device or to update the firmware, etc.

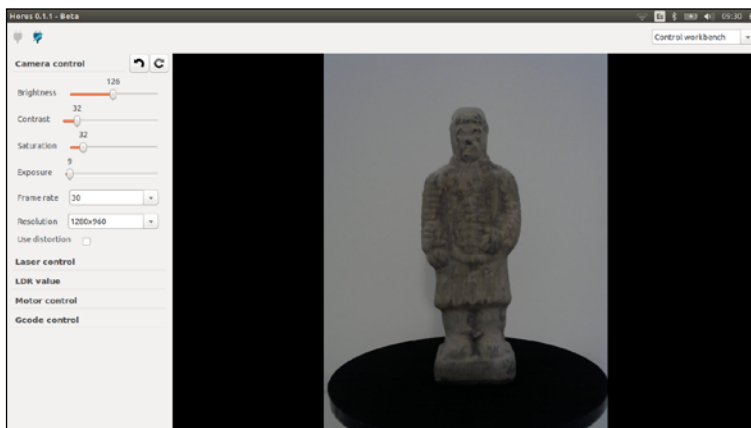


Once the connection to the scanner has been established, the **Control panel** will be enabled.

Camera control

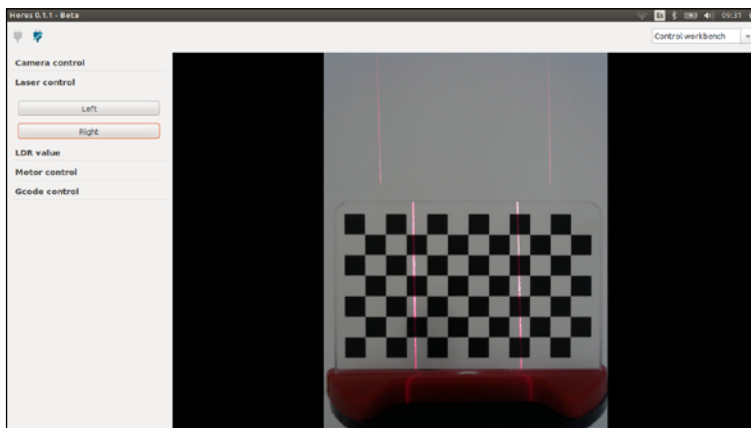
Under the camera control section you can adjust the following settings:

- **Brightness:** the luminosity of the image.
- **Contrast:** the relative difference in intensity.
- **Saturation:** the colour intensity of the image.
- **Exposure:** the aperture time of the lens in milliseconds.
- **Frame rate:** the images captured per second.
- **Resolution:** the size of the image. Always in a ratio of 4:3.
- **Distortion:** corrects the lens distortion according to the calibration.



Laser control

Under this section, the left and right lasers can be enabled or disabled. The verticality can also be adjusted using the pattern. The light beam projected by the lasers does not have to be totally vertical as the software will automatically calibrate the lasers later, although it is recommendable.

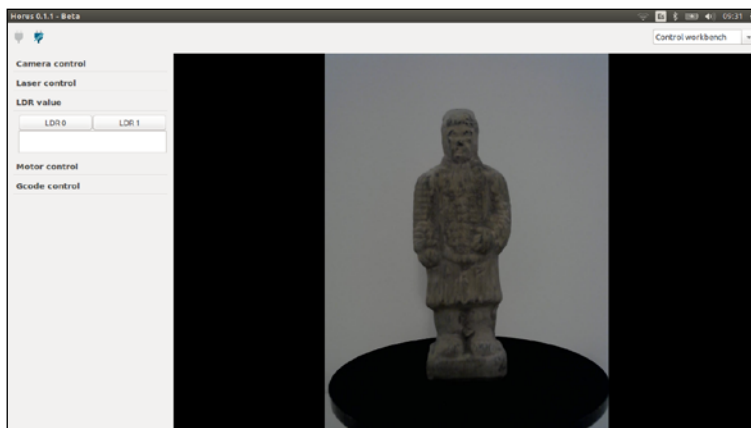


LDR value



We aim to include this type of sensor in later versions so that some of the camera settings can be automatically adjusted according to the LDR values given, making the user experience even simpler.

An LDR (Light-Dependent Resistor) or photoresistor is a light intensity sensor. If an LDR is connected to the controller board, click on the corresponding button (**LDR 0** or **LDR 1**) and the sensor value will appear in the dialogue box. The range of this sensor is between 0 and 1023, with 0 producing a very low light intensity and 1023 producing a very high intensity.

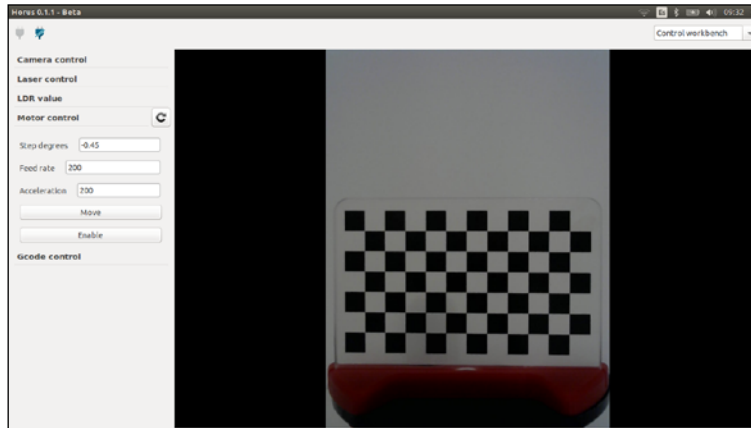


Motor control

Under this section you can *Enable / Disable* the motors. You can also move them, with options to adjust the angle of the step, the feed rate and the angle acceleration in degrees, degrees per second and per second squared, respectively.



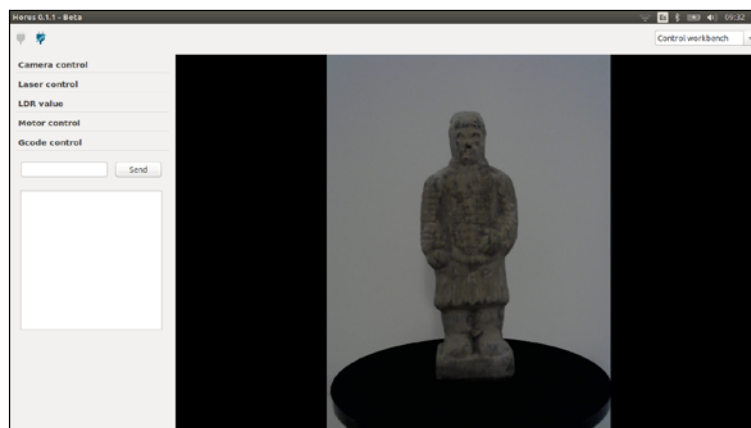
The motor consumes almost the same amount of electricity when simply enabled as when it is moving. Bear in mind that if the motor is left enabled for a long time, both the motor and the control driver will heat up.



Gcode control

The Gcode commands appear under this section, which are the commands used in order to communicate with the controller board. In concrete terms, the following list of commands is available, with "v" being a numerical value:

- To adjust the motor speed: G1 Fv
- To move the motor v degrees: G1 Xv
- To enable the motor: M17
- To disable the motor: M18
- To enable the laser: M71 Tv
- To disable the laser: M70 Tv
- \$\$ access to internal settings



5 Calibration workbench

The *Calibration* workbench enables the settings of the scanner components to be adjusted:

- **Camera settings:** to adjust the images captured by the camera.
- **Pattern settings:** to adjust the calibration pattern settings.
- **Laser settings:** to enable / disable the lasers and also to adjust the laser detection settings.

This workbench also enables you to carry out processes that determine the main calibration settings:

- **Camera intrinsics:** calibration of the camera sensor and the lens.
- **Laser triangulation:** calibration of the camera and the laser modules.
- **Platform extrinsics:** calibration of the camera and the rotating platform.

This workbench includes:

- A task bar on the upper left for connecting and disconnecting the scanner.
- A panel containing all the calibration settings.
- A viewfinder for the camera video or the different sections of the calibration processes.

Remember that due to the fact that the product is set up manually, the distances and positions of the elements of each scanner will be different. These specific settings are determined by carrying out calibration processes so that the results obtained from each scanning are the same, independently of the device.

The adjustment headings (*Camera settings*, *Pattern settings* and *Laser settings*) include:

- Name of heading.
- The **Undo** button to undo the last change made.
- The **Reset** button to restore the default settings.

The auto-calibration settings (*Camera intrinsics*, *Laser triangulation* and *Platform extrinsics*) include:

- Name of calibration.
- Calibration settings.
- The **Edit** button to edit the values manually.
- The **Default** button to restore the default settings.
- The **Start** button to launch the relevant calibration process.

Camera settings



In order to calibrate correctly, it is important to ensure that the pattern is properly detected in the light conditions of the scene and in different positions.

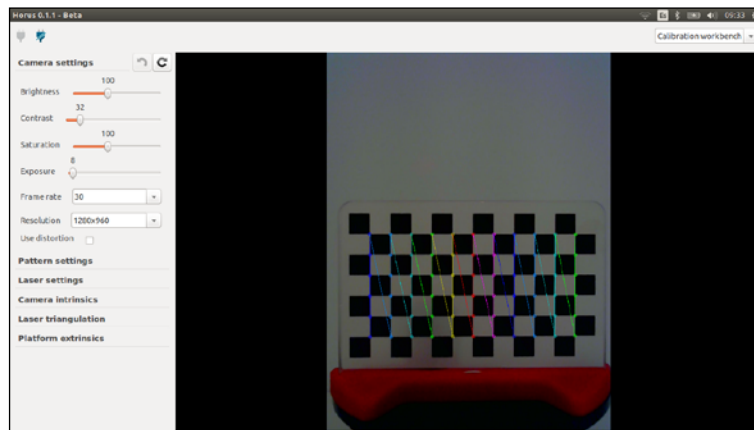
Calibration of the scanner consists of different stages, all of which use the same calibration pattern.

The calibration settings are the settings which can be adjusted on the camera: **Brightness**, **Contrast**, **Saturation**, **Exposure**, **Frame rate**, **Resolution** and **Distortion**.

If the pattern has been correctly detected, it will appear with the corners highlighted by coloured dots and joined by lines (as shown in the diagram). If no lines appear, it has not been detected properly and you will need to adjust the camera settings until it is detected.

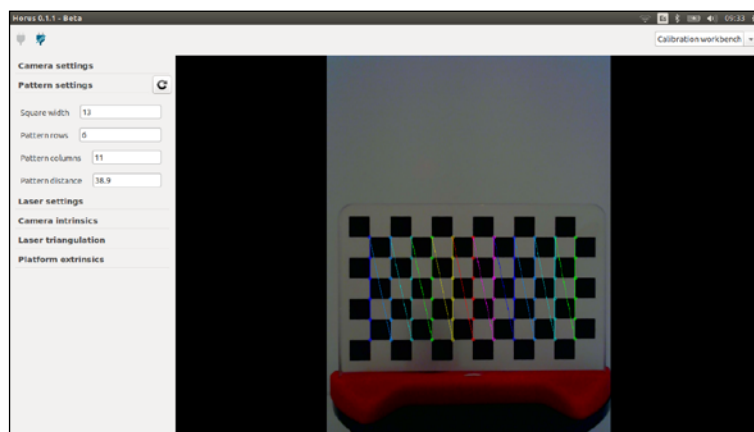


Configuring the camera for calibration is done to ensure that the pattern is detected correctly.

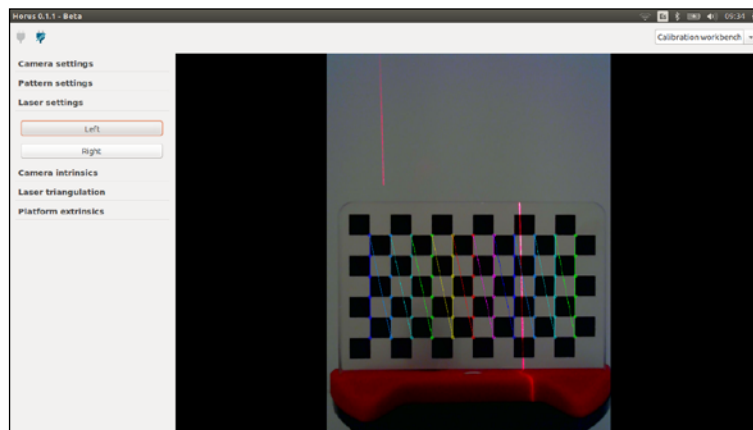


Pattern settings

The calibration pattern settings can be configured in this section.



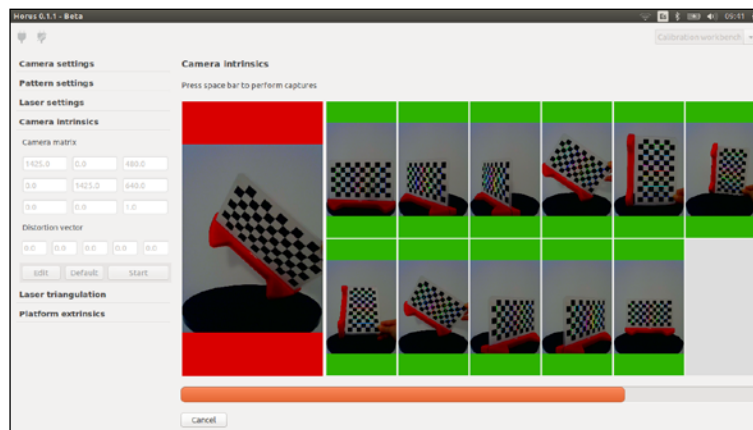
The pattern comes with black and white squares measuring 13 mm on each side as standard. The value of the rows and columns of the pattern does not correspond to the number of rows and columns of black and white squares on the existing pattern. The settings to be entered are the columns and rows formed by the corners of the internal squares. In the image below, the outlined columns and rows are shown in different colours.



The pattern distance refers to the distance, measured in mm, from the top of the square on the bottom left part of the pattern, to the rotating platform of the scanner (as indicated by the X in the image below).



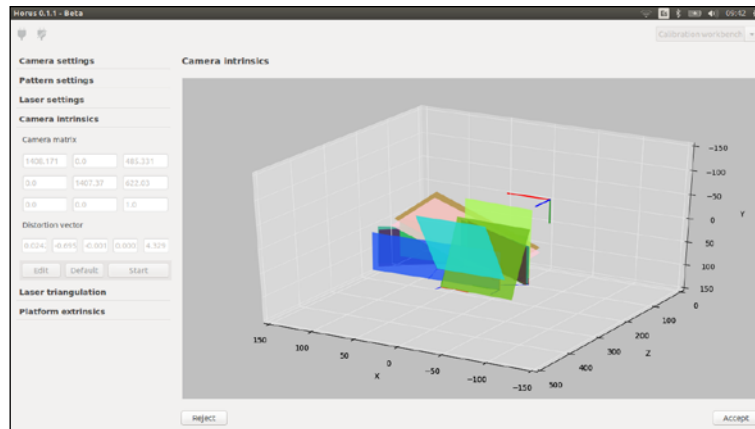
If you change any of the pattern values, you must calibrate the laser triangulation and the platform extrinsics again, or otherwise use the wizard.



All of these settings can be modified if you use a different pattern.

Laser settings

The buttons to enable the **Left** and **Right** lasers can be found in this section. You can adjust the verticality of the lasers using the pattern. The lasers do not have to be totally vertical to the camera, as the inclination will be automatically correction during calibration, but it is advisable to make them as perpendicular as possible.



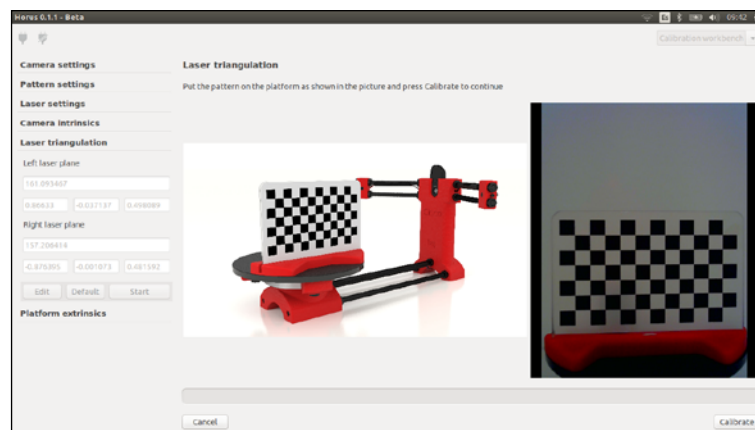
Camera intrinsics (calibration optional)

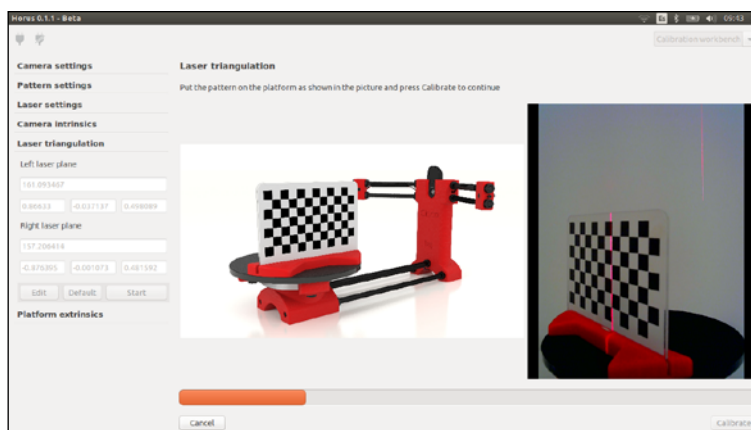
The internal camera settings are obtained from this calibration process. These include:

- Focal lengths (horizontal and vertical)
- Optical centre (horizontal and vertical)
- Lens distortion

This calibration depends on the resolution of the camera. In general, the higher the resolution, the greater the settings obtained from this calibration process.

This calibration process is optional, given that the cameras supplied are all practically identical and the experimental values are very close to the theoretical values. However, this option is reserved for advanced users.





The first window will proceed to capture the 12 valid patterns in different positions and inclinations. To do this, put the pattern in place and press the **Space** key.

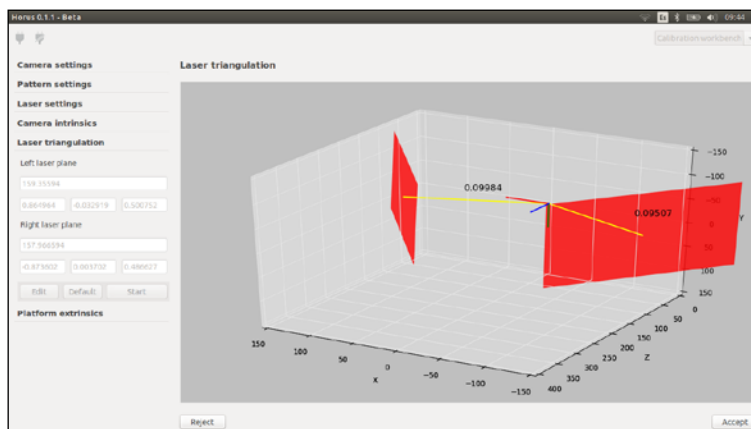
If you do not capture the pattern correctly, the image will appear in red and you will have to repeat the process, as shown in the last image.

Once you have obtained the images, you can proceed to calibrate automatically. The results of the calibration process will be displayed numerically and with a 3D graph, which shows the coordinate system of the camera and each coordinate system of the patterns captured previously.

At this point, you will have the option to accept or reject the results obtained from the calibration process.

Laser triangulation

During this calibration process, the inclination and distance of the intersection between the lasers and the central plane of the camera. It is one of the most important calibration processes.

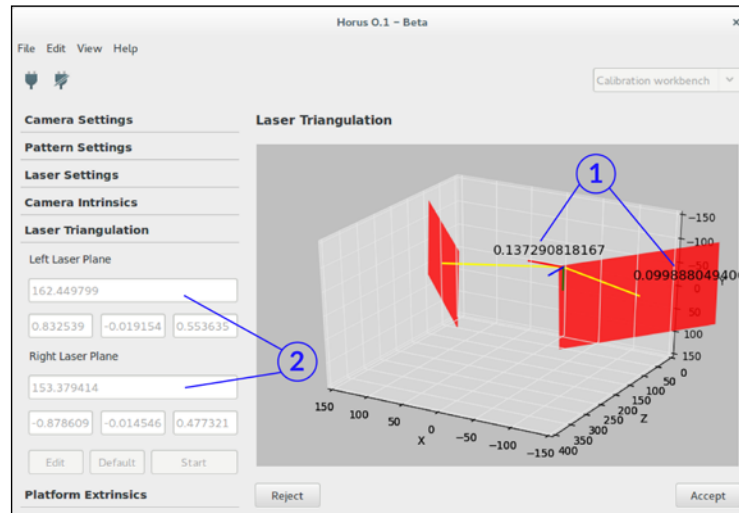


The **Start** button to launch the calibration process.

Put the pattern in place as shown in the image and press the **Calibrate** button. You will have the results within seconds.

The results are shown on a matrix which defines the inclination of the lasers in pixels and the depth of the pattern. The graph also displays the inclination of the lasers towards the camera.

You can use these parameters to determine whether a laser calibration is acceptable or not:

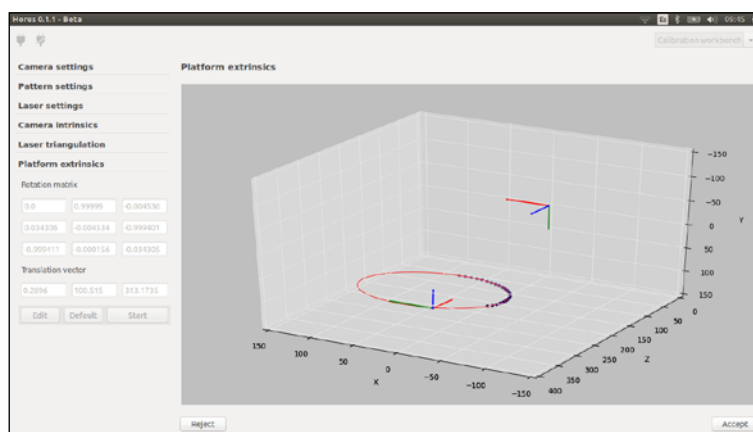
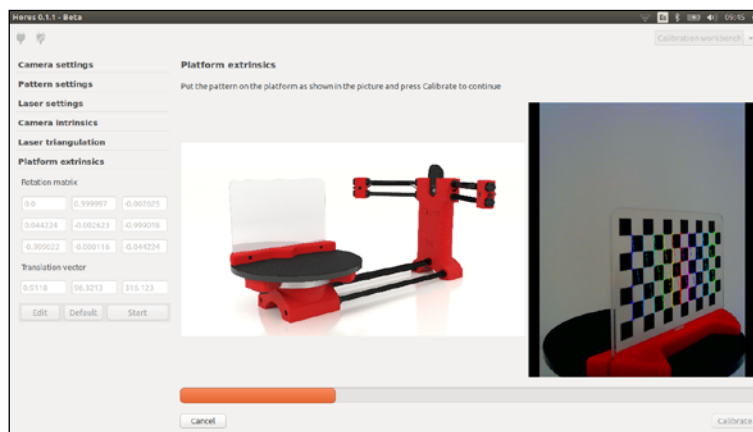


1. **The point spread of the plane in millimetres:** the spread of the distance at the plane of the points is obtained in order to calculate the plane. If it is 0, this means that all points belong to the plane. Values around 0.1 are adequate.
2. **The minimum distance from the original plane, measured in millimetres according to the camera coordinate system:** the difference between these values should not exceed 30 units.

As with the previous calibration process, you can accept or reject the results obtained.

Platform extrinsics

The homogeneous transformation matrix of the rotating disc in relation to the camera is obtained from the extrinsic calibration. In other words, the position and rotation of the disc. This calibration process is also very essential, along with the laser triangulation.



Put the pattern in place as shown in the diagram and then click on **Calibrate**.

Then disc will then move in small intervals until it has completed 180 degrees. The process will take around 20 seconds.

The results of the calibration process will be displayed on the next screen. A graph will also appear displaying the samples that have been captured, as well as the rotation centre of the disc.

As with the previous calibration processes, you can accept or reject the results obtained.

In the two essential calibration processes; the laser triangulation and the disc transformation, the intrinsic calibration values are used. If you are calibrating the camera, it is convenient to carry out the other two processes in order to generate coherent results.

6 Scanning workbench

This workbench includes:

- A task bar on the upper left for connecting and disconnecting the scanner, and starting, stopping or pausing the scanning process.
- A control panel displaying the scan parameters and options.
- A viewfinder for the camera video.
- A 3D viewfinder which displays the point cloud in real time as it is generated from the scanning process (Scene).

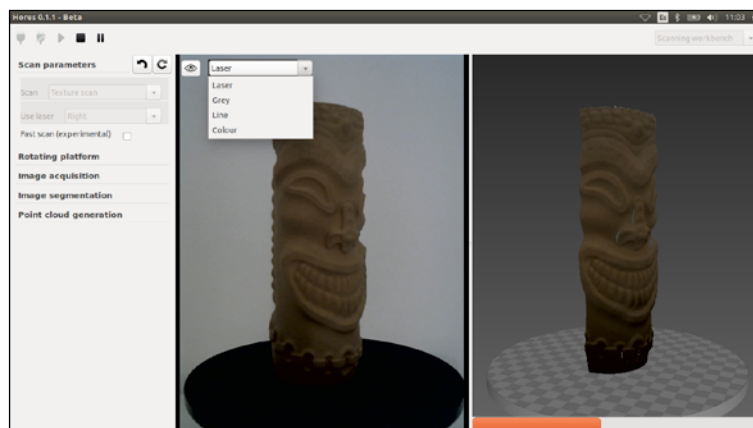
The *Panel*, *Video* and *Scene* windows can be enabled or disabled by going to **View > Scanning**.



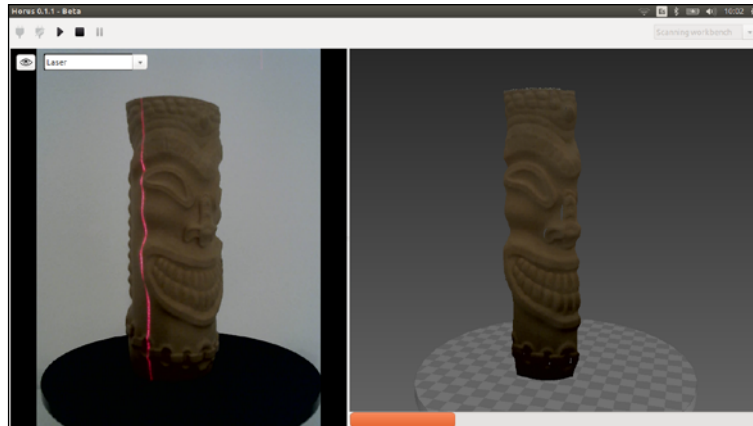
Video display window

This window shows the video captured by the camera in real time. It is possible that the scanning process will not be displayed in real time due to the image processing.

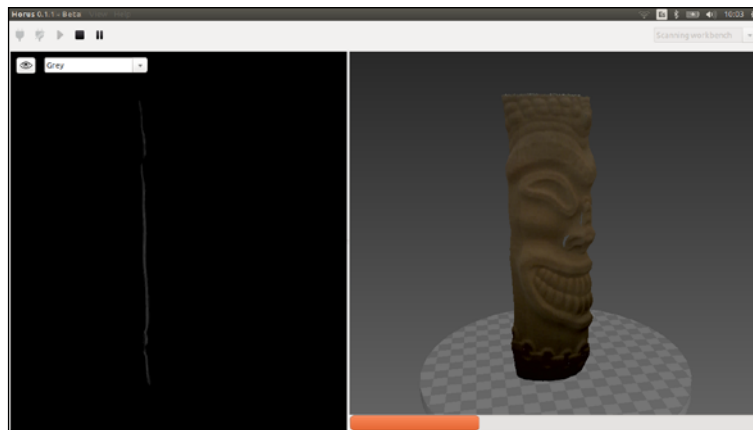
In this window you will see a button with the image of an eye. If you click on it during the scanning process, a drop-down menu will appear containing different viewing options.



· **Laser:** shows the images captured by the camera with the laser.



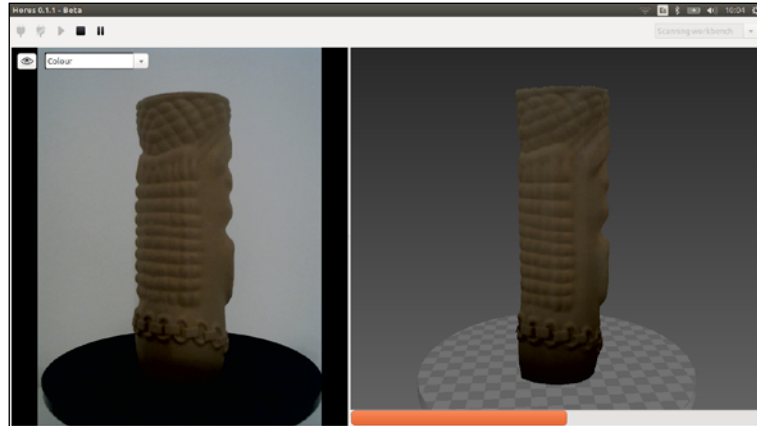
· **Grey:** shows the part of the model illuminated by the laser before being processed.



· **Line:** final line of points, resulting from the image processing obtained with the camera.



- **Colour:** shows the images captured by the camera, excluding the laser.



Control panel

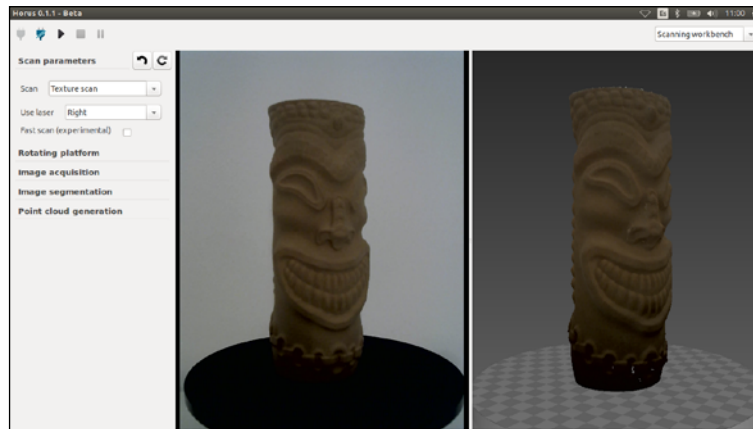
The scanning process has its own settings and adjustments for the camera, the lasers, the motor and the image processing algorithms and the point cloud.

The settings can be adjusted manually using this panel and they are divided into the following sections:

Scan parameters

The following settings can be modified in this section:

- **Scan type:** select from **Simple** scan or **Texture** scan. The simple scan uses one image per cycle to generate the point cloud and it does not capture the colour of the object. The texture scan uses two images to capture the laser and it also generates the point cloud using the actual colours of the object.
- **Use laser:** you can select the **Left** laser, the **Right** laser or **Both**. The scanning time will be longer if you use both lasers, but twice as many points will be scanned. Using both lasers is recommended as the scanning time will not twice as long as with one laser under the same conditions.
- **Fast scan:** an experimental option which is only available for the Linux version. It practically reduces the scanning time by half, without affecting the resolution. Being an experimental option, some errors might occur during the scanning process.



Rotating platform

In this section you can adjust the *Step degrees* moved by the platform, as well as the *Feed rate* and *Acceleration*.

As small step, for example of 0.45° , generates greater radial point density than a larger step (5°). Due to the electronics, the steps must be multiples of 0.1125° . A low feed rate and acceleration are recommended in order to prevent oscillations caused by inertia from appearing.



Image acquisition

The settings that affect the image acquisition can be adjusted in this section. These include:

- **Brightness:** the luminosity of the image.
- **Contrast:** the relative difference in intensity.
- **Saturation:** the colour intensity of the image.

- **Exposure:** the exposure of the laser is the time, measured in milliseconds, which the camera lens remains open in order to capture the light beam projected by the laser.
- **Resolution:** the size of the image. Always with a ratio of 4:3. It is very important that this value matches the resolution value entered during calibration, otherwise the results will not be coherent. You should always use the maximum resolution.
- **Distortion:** this settings allows the lens distortion to be corrected.

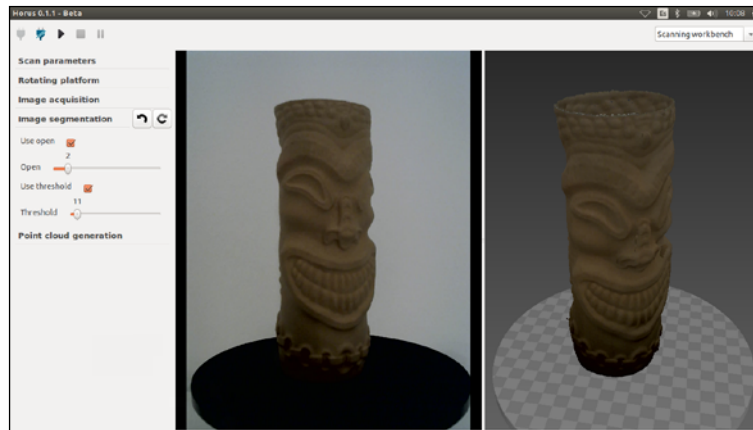


Image segmentation

Here you can modify the segmentation for the images captured by the camera. Bear in mind that there are different settings for *Simple scan* and *Texture scan*.

For the *Simple scan* you can have the option to use *Threshold*. If you enable it, you can change the value using the adjustment bar.

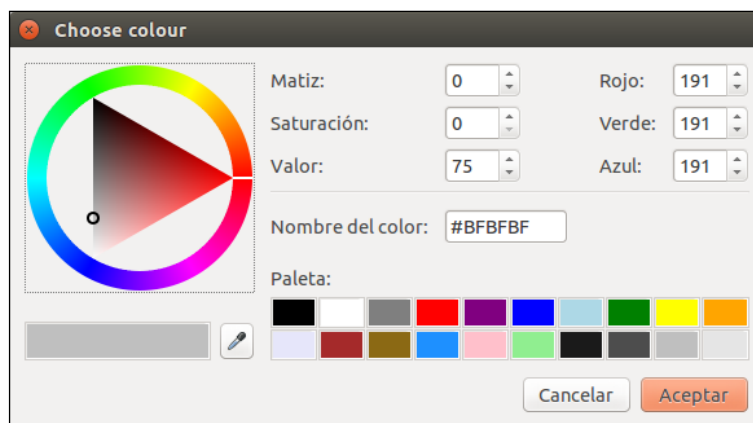
For the *Texture scan*, in addition to use *Threshold*, you also have the option to use *Open*. This option will apply the *Open* algorithm which, together with use *Threshold*, helps to reduce the noise during scanning. The higher the *Open* value, the lesser the noise during scanning and the lesser the detail on the final 3D model.



Point cloud generation

The settings that affect how the point cloud is generated can be adjusted in this section.

- **View ROI:** this element can be enabled or disabled. It displays the edges of the cylinder, which is the region of interest. By adjusting the region of interest of the object to be scanned and by changing the *Diameter* and *Height*, the chances of scanning undesired elements are minimised and noise is reduced. It also displays the centre of the rotating platform, which is useful for centring the object.
- **Choose point cloud colour:** this option allows you to select the colour of the point cloud for the *Simple scan*. The option is not available if you are using the *Texture scan*.



To verify that the ROI is centred on the platform, adjust the diameter to 200. If the base of the cylinder (blue) more or less coincides with the edges of the platform surface, the ROI can be considered to be centred.

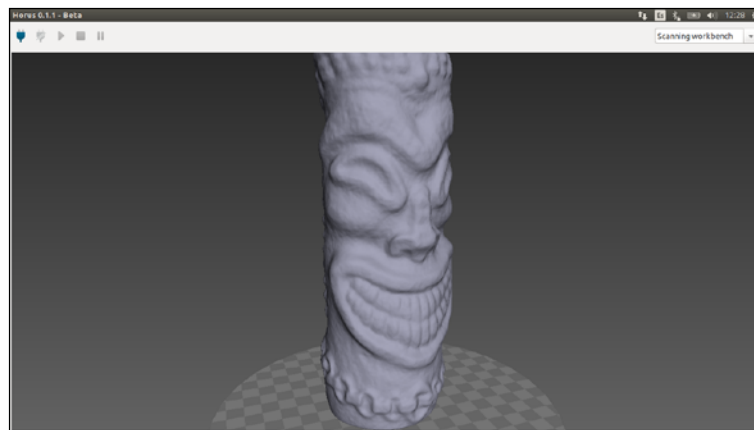
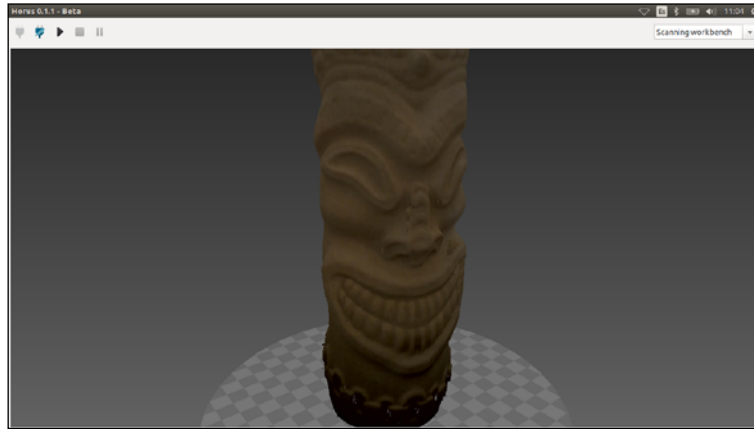
The ROI is off-centre if the cylinder that represents it is above or below the platform. This imbalance may be due to poor calibration of the platform and/or the pattern. To correctly locate the region of interest, check the pattern settings and calibrate the triangulation lasers and platform extrinsics, or alternatively, use the wizard.

The image on the left shows the ROI off-centre because it is above the platform.



3D viewfinder scene

The viewfinder scene shows the point cloud in real time as it is generated from the scanning process. It also enables viewing of complete point clouds and 3D models (.stl).



Shortcuts

These are the shortcuts for the Horus work environment:

Action	Shortcut 1	Shortcut 2
Default views	Home / PgUp / PgDn / End	
Rotate	Left click	Shift + Up/Down
Rotate horizontally	Up / Down	
Rotate vertically	Left / Right	
Vertical shift	Ctrl + Mouse wheel	Ctrl + Up / Down
Reset vertical shift	Double left click	
Translation	Shift + Left click	
Zoom	Mouse wheel	Shift + Up / Down
Delete object	Right click + Delete object	
Quit program	Ctrl + Q	



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