DAVID 4 MANUAL

- 3D Viewer

INTRODUCTION

Documentation for DAVID 4

↑ | Introduction

Welcome

Welcome to the DAVID 3D Scanner 4 documentation. DAVID 4 is a complete solution for generating a watertight 3D surface model of a real world object.

Videos

Before further reading you should watch our tutorial videos first:

1. SLS-2 Tutorial 1 Installation
2. SLS-2 Tutorial 2 Setup
3. SLS-2 Tutorial 3 Calibration
4. SLS-2 Tutorial 4 Scanning Texturing

INSTALLATION

Installing software and drivers

↑ | Installation

Before you connect any DAVID device to the PC, please install the DAVID software and drivers:

1. Connect the USB flash drive to your PC, then select "Browse" or Explorer / My Computer.
2. Start "DAVID_Setup_xxx.exe" (administrator rights required).
3. Choose "Full installation" as profile.
4. Follow the instructions on the screen.

You can download a trial / current version under Downloads.

SETUP

Setup of hardware and software

↑ | Setup

After successfully connecting all devices, you typically walk through the following steps:

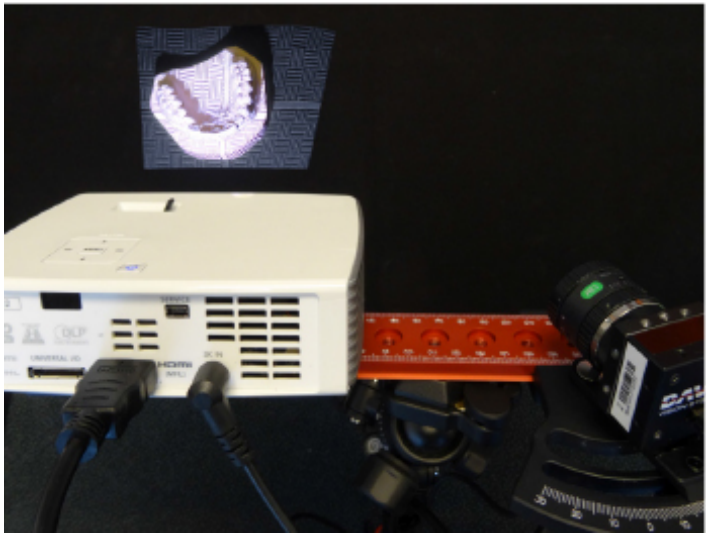
1. Main setting

Select `DAVID SLS-X` as "Setup Type".

2. Screen ID

Here you can select on which display device the stripe pattern is shown. Set the `Screen ID` so that the pattern is projected from the projector.

3. Working distance



Setup of the object and arrangement of the projector and camera

Place the scanner in front of the object to be scanned and aim the projector so that it illuminates the surface to be scanned - not less, but also not much more.

4. Projector focus

Adjust the focus of the projector with the focus lever, so that the stripes are perfectly focused on the object surface.

5. Selection of camera

Under "Camera Setup", select your camera (e.g. DAVID-CAM-3.1-M). The live image from the camera is displayed. If necessary, set the mechanical aperture and focus so that you get a picture.

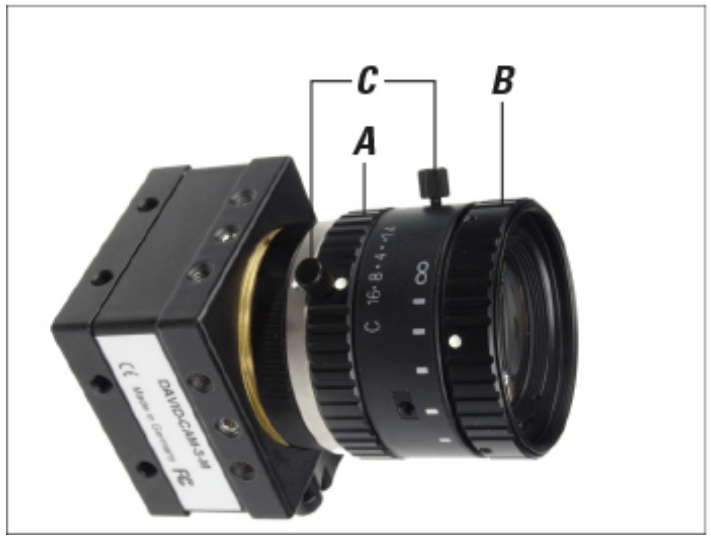
6. Position of the camera

Move the camera slide by loosening the thumbscrew so that the camera is aimed on projected pattern on the object. Then fix the camera slide. If the viewing range of the projector and / or camera contains much more than the surface to be scanned, you should reduce the working distance of the scanner (step 3).

7. Exposure time

The `Exposure` should be set to the same value as the frame rate of the projector (usually 1/60s), otherwise the camera image will flicker / pulsate when looking at the projection. In this case adjust the exposure time.

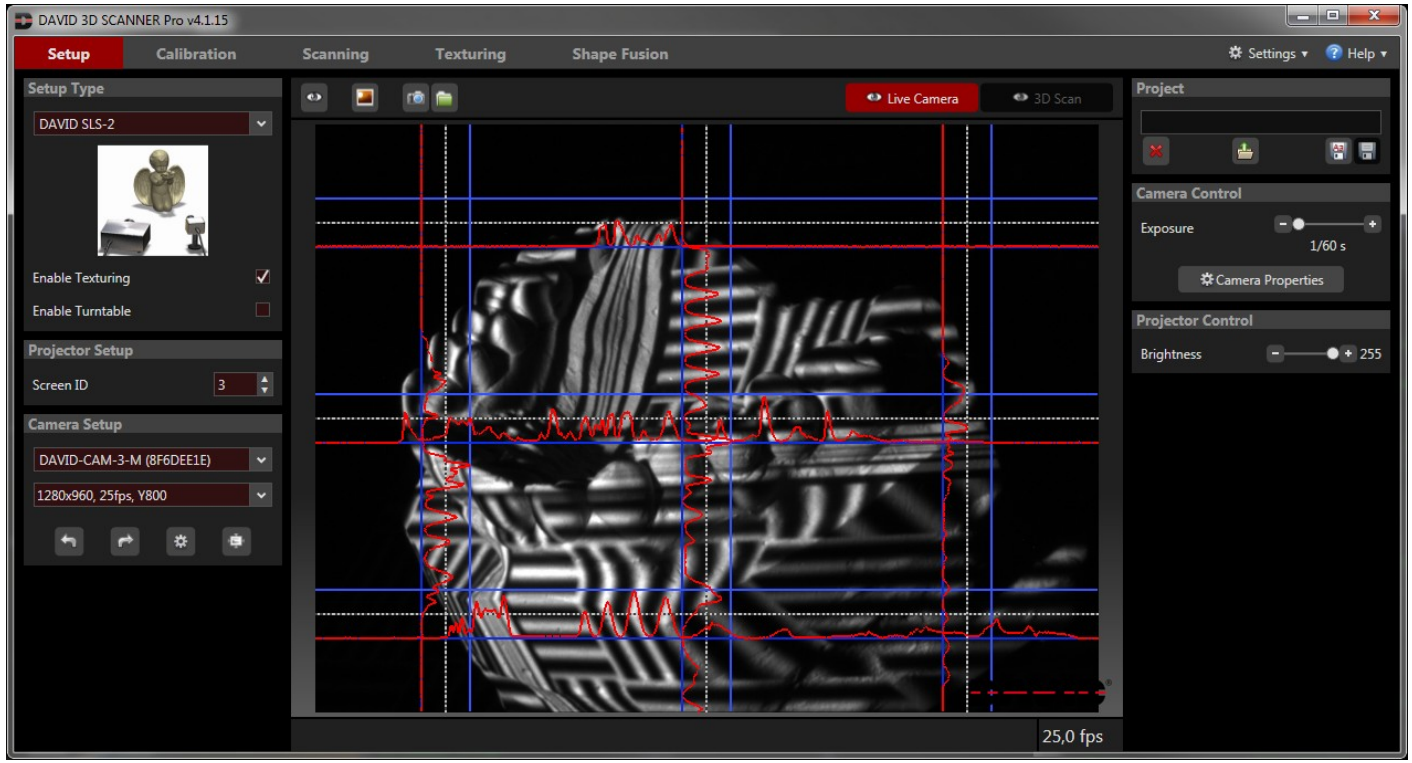
8. Camera focus



Adjusting rings (A) aperture and (B) focus, (C) fixing screws

Adjust the aperture of the camera (dial A) so that you will get a rather bright picture. Look at the camera image and watch the sharpness of the object and the sharpness of the projected black and white stripes (cross). Adjust the focus of the camera (dial B) so that the object is depicted as sharp as possible.

9. Camera brightness / aperture

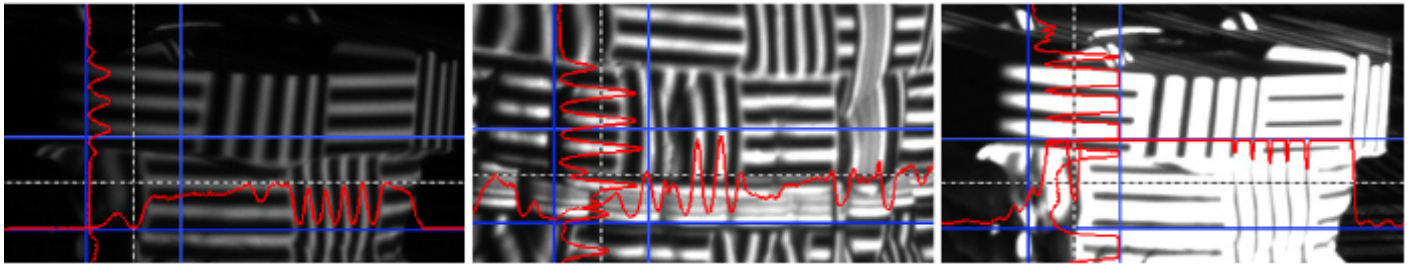


Typical live image with good setup and settings

The `Projector Brightness` slider in the software should be set to maximum. You should only reduce it if a clean modulation is not possible in the following. Adjust the mechanical aperture (dial A). Consider only those areas in the camera image which show the regular waves! The displayed intensity curves (red) must be sinusoidal and may neither be undersaturated nor oversaturated, i.e. the red sine curve (see figures) should not be cropped at the blue lines.

If the curves are strongly flattened in the dark area (bottom or left) without being close to the lower blue lines, the ambient light may be too strong. In this case please darken the room.

> The aperture dial (A) on the camera has a scale (f-stop from 16 to 1.4). Even for very bright conditions (small objects), please avoid setting f-stop higher than 16, otherwise you will lose sharpness. If necessary, better reduce the value `Projector Brightness` in the software.



Left: Too dark → open aperture further; Middle: Well-controlled sine wave almost reaching the blue borders; Right: Too bright, sine is cut-off (overdriven) → close the aperture somewhat

10. Fasten screws

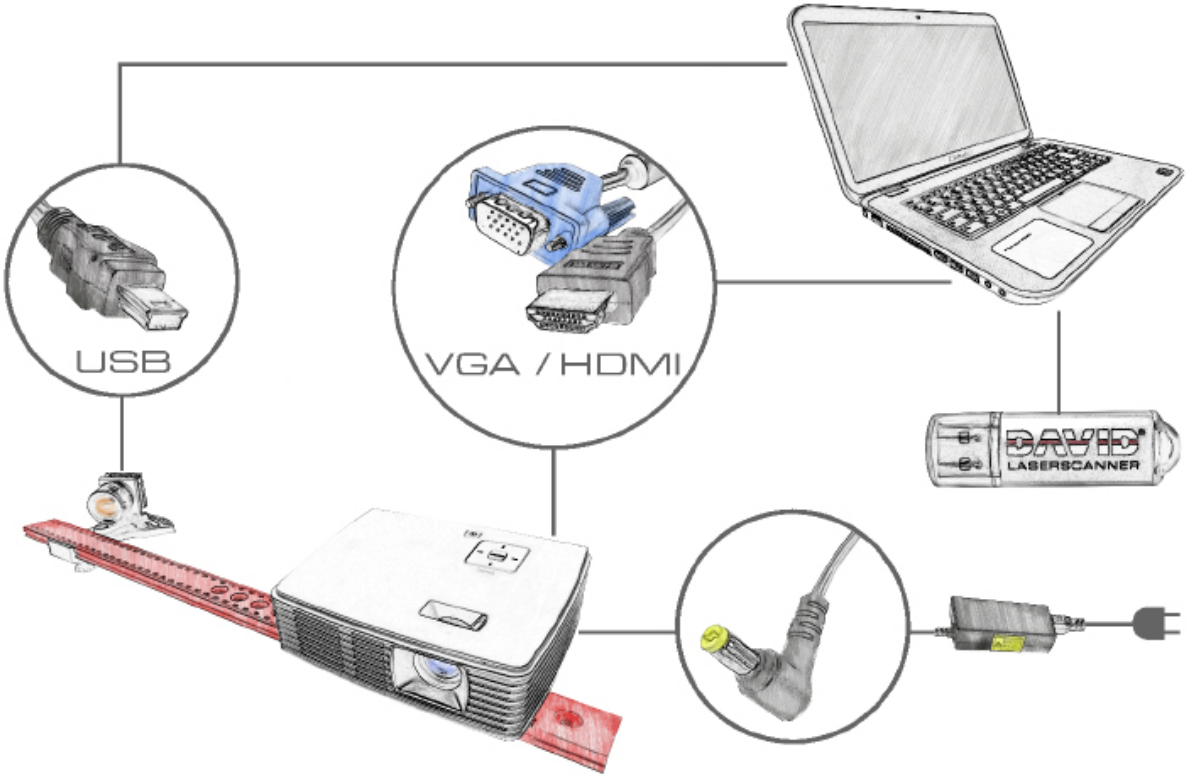
Fasten all screws (projector, camera and camera slide), so that nothing can be displaced from now on. The camera lens dials can be fixed with their locking screws (C). The scanner is now optimized for your object (size of the scanning area, working distance, brightness of the object) and must be calibrated like this.

Connections

Connect DAVID SLS hardware components to PC

↑ | Setup | Connections

Connect the camera, the projector and the DAVID USB flash drive according to the wiring diagram to your computer. To connect the projector to your computer, you can use HDMI (recommended) or VGA.



Connection diagram

If you want to change the video source (e.g. HDMI to VGA), follow these instructions:

1. Press `Source` key (↑ key) on projector.
2. Select desired video source using ↑ and ↓ keys.
3. Press → key to confirm selection.

Camera Positioning

Setup position and rotation of camera

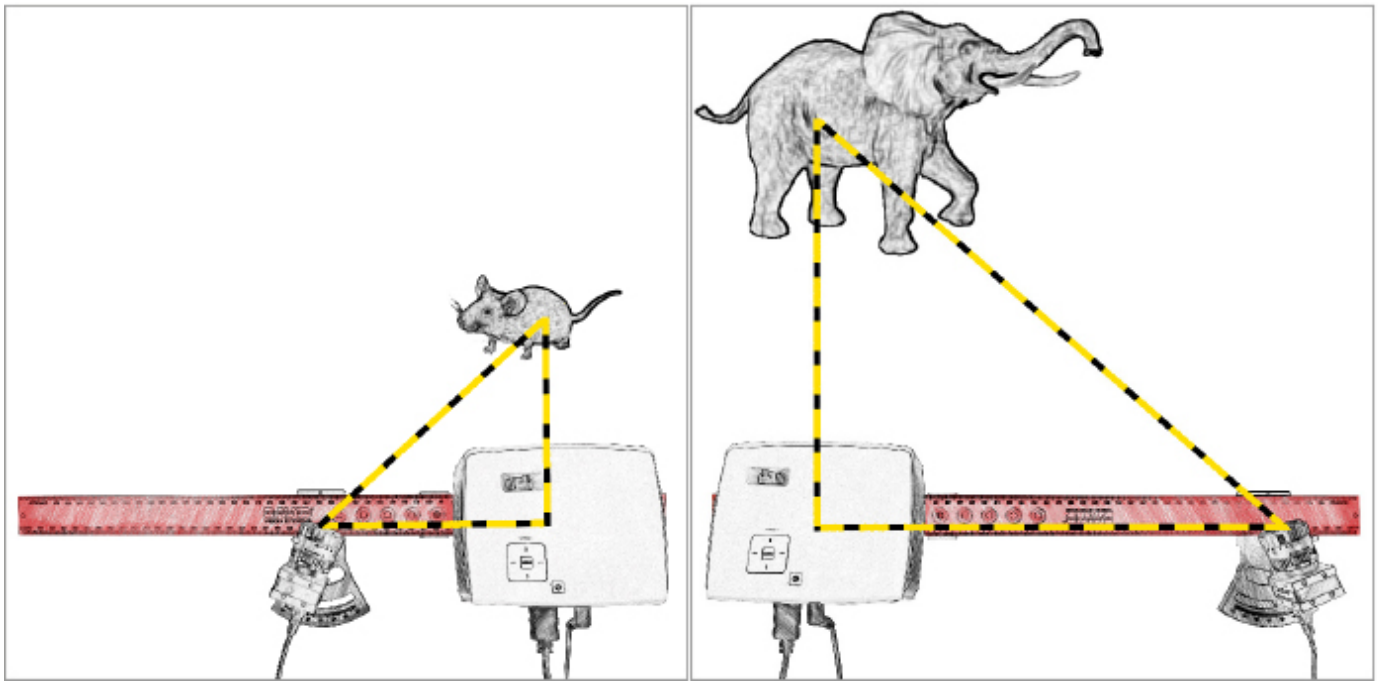
↑ | Setup | Camera Positioning

Position of the camera

The camera can be mounted on the right or left side of the projector:

Size of the scan object / scan area	Position of the camera (seen from rear)
up to 110 mm	to the left of the projector
110 to 350 mm	optional, better to the left
from 350 mm	to the right of the projector

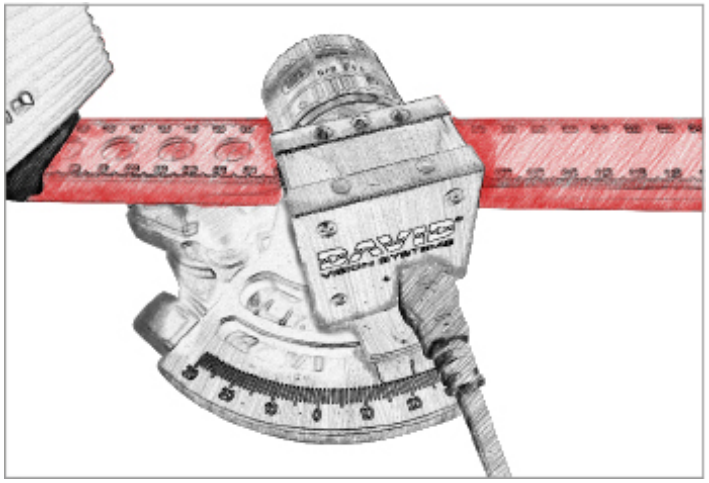
If necessary, mount the camera slide to the corresponding side. The exact position of the slide (distance from the projector) is set later in operation. The distance between the camera and projector optics will be similar to the size of the object / region to be scanned.



Left: Small object → short distances; Right: Large object → greater distances

Rotation of the camera

Rotate the camera by about 22° such that it aims at the projection area. To do this, loosen the thumbscrew under the camera. Set the rotation angle by means of the degree scale on the camera slide, then fix the thumbscrew.



Setting the camera angle

For very large objects, or objects with deep cavities, a smaller camera angle may be necessary. Angles less than 20° result in reduced scan quality (noise, inaccuracies). A very large camera angle (> 30°), may improve the scan quality a little, but is only suitable for very flat objects. Large camera angles are usually impractical and reduce the depth of the measurement range.

Camera Setup

Setup of camera

↑ | Setup | Camera Setup

Select your camera under "Setup / Camera Setup". This automatically sets recommended values for important properties (e.g. "Gain"). See also topic Camera Control.

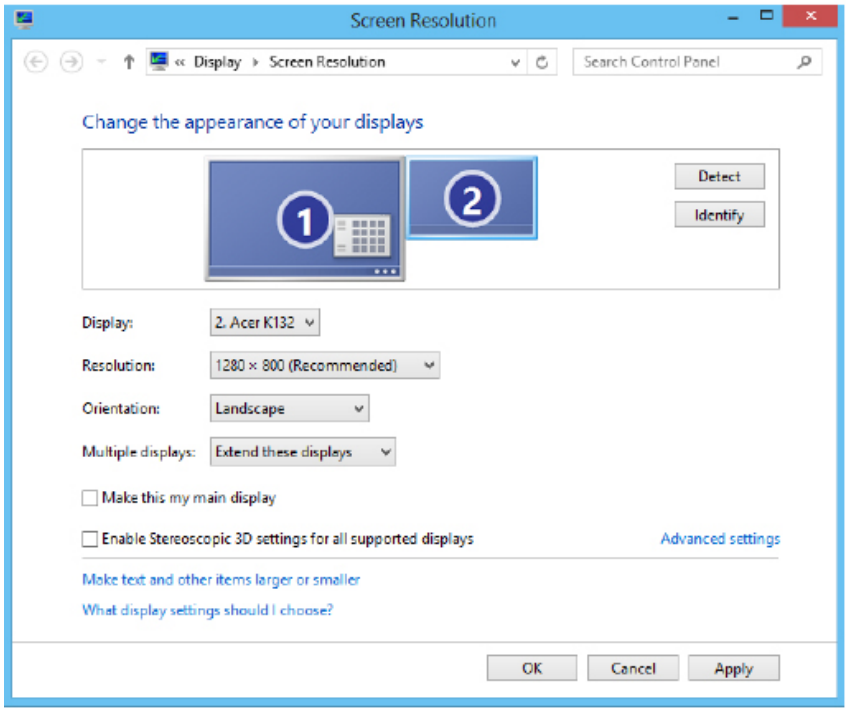
Projector Setup

Setup projector in Windows and DAVID

↑ | Setup | Projector Setup

Setting up the projector as Extended Desktop in Windows

Click the right mouse button on a blank area of your Windows desktop, select "Screen resolution" or "Properties" (depending on your Windows version).



In this window you can separately configure your two "Displays", the monitor and the projector. (Image may vary)

Your screen should be set as "primary monitor". Make sure the projector is set as extended desktop ("Extend these displays"). This is necessary so that DAVID can project the stripe patterns, while the user interface is displayed on your screen.

The resolution of the projector must be set to its native value. Furthermore, you should make sure the projector is set to its native refresh rate. Choose the Projector and click "Advanced", here you should set the refresh rate in the "Monitor" tab.

When these settings are correct, your monitor and projector will show the same desktop wallpaper, but otherwise different contents. You can move your mouse pointer sideways between the monitor and the projector image. The Windows Start menu and most of the desktop icons are only displayed on the monitor. Any window can be moved between monitor and projector back and forth.

So in case the main DAVID window is displayed on the projector, please grab its title bar with the mouse and drag it sideways onto the monitor.

	Projector name	Native resolution	Native refresh rate
DAVID SLS-1	Acer K11	800 x 600	60Hz
DAVID SLS-2	Acer K132	1280 x 800	60Hz
DAVID SLS-3	Acer K132	1280 x 800	60Hz

Select Screen ID

Set the `Screen ID` so that the pattern is projected from the projector. This selects on which display device the stripe pattern is shown.

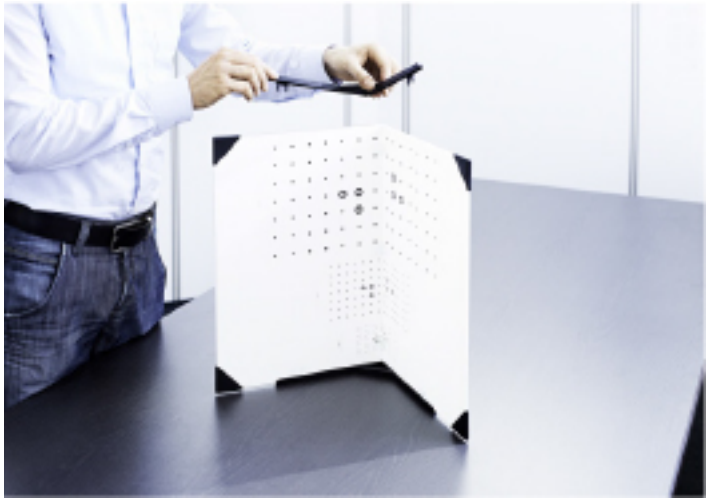
CALIBRATION

Calibration of camera and projector

↑ | Calibration

An advantage of the modular design of the DAVID 4 scanners is that it can be adjusted to scan a wide range of objects sizes. Therefore, a calibration (measurement of the scanner hardware in the software) is necessary so that the software can then obtain precise and undistorted 3D data at the correct scale. For this purpose, a 90° pair of glass calibration panels is used as a reference object, whose dimensions are precisely known.

1. Setup calibration panel

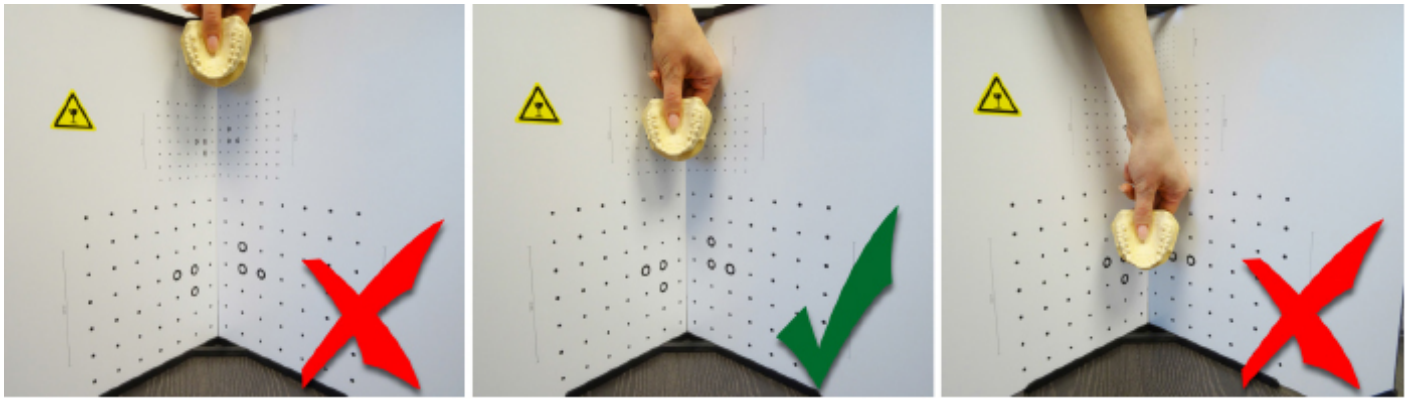


Setting up the glass calibration panels

Set up the calibration corner. You will need both 90° fixing brackets and the glass calibration panels. Put one fixing bracket flat on the used surface (e.g. a table). Insert the glass calibration panels in the fixing bracket. Finally, attach the second fixing bracket on the glass calibration panels.

> For starters, the pattern should be folded inwards. Advanced users can avoid undesired reflections with an outwardly folded pattern if necessary. Fix the glass calibration panels using the two fixing brackets to exactly 90°.

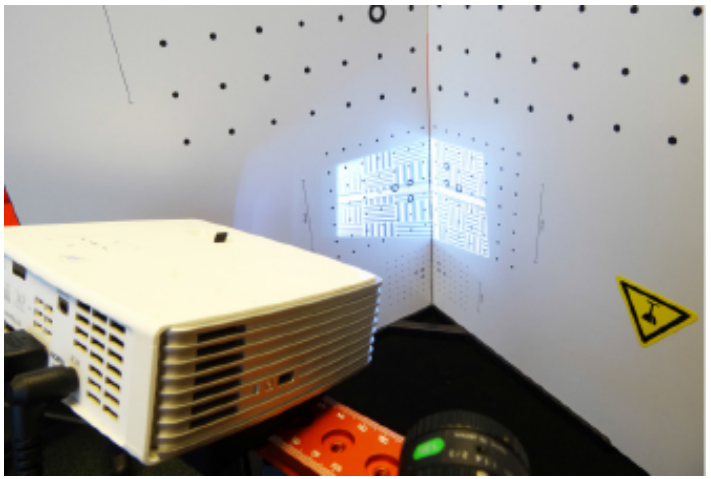
2. Select pattern scale



Calibration pattern too small; Suitable calibration pattern; Calibration pattern too large

Choose the calibration pattern whose size fits to the scanned object. The pattern should be slightly larger than the object / region to be scanned. For object sizes above ca. 200 mm, use the large 240-mm pattern on the back.

3. Move scanner in position

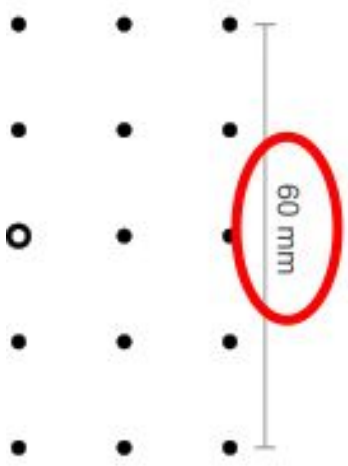


Typical setup for calibration

Remove the object and set up the glass calibration panels and the scanner in front of each other, about the same distance as the object previously, so that the projection and camera image are sharp. Camera and

projector should not look at a too flat angle at the calibration panels. The camera image should show the projected pattern as large as possible. In addition, the 6-rings and several other points of the calibration pattern must be visible. The entire camera image should be filled with about 15 to 70 calibration markers, the camera should not be able to look aside the glass calibration panels. You can achieve this by moving the scanner and tilting or adjusting the tripod, but you should not change anything above the red base rail.

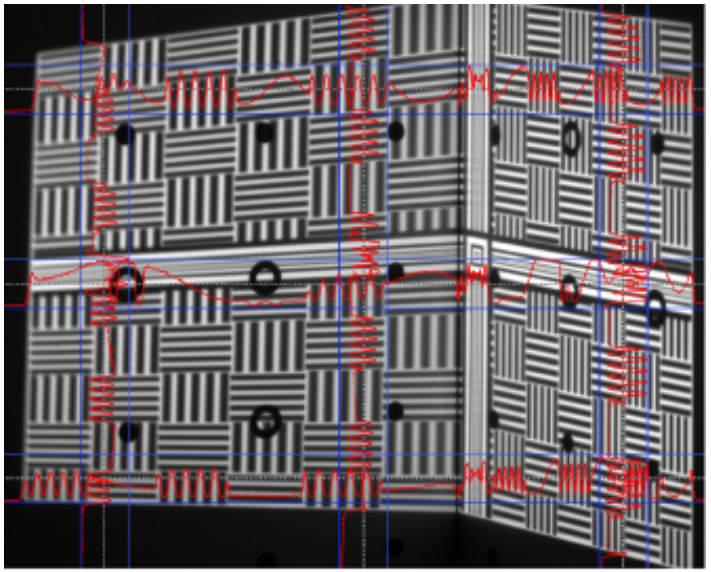
4. Enter correct scale



Typical setup for calibration

Enter the correct scale length in the `Calibration Scale [mm]` field. You can find it on the edge of the selected calibration pattern. (30, 60, 120, or 240)

5. Check camera image



Ideal live camera image for calibration

Check the camera image: In the areas where the waves are visible, the red intensity curves must not reach the blue lines. If the object to be scanned is considerably darker than the white glass calibration panels, the sine waves will now be overdriven. Correct this by temporarily reducing the `Projector Brightness` slider in the software. The camera image for calibration should look similar like shown in figure obove.

6. Calibrate

Click `Calibrate` to calibrate the entire scanner. In this step, the software first measures the position, orientation, focal length and distortion characteristics of the camera. Then, a pattern sequence is projected in order to measure the same optical characteristics of the projector. If texturing is not turned off, finally a white balance is performed. After successful calibration, a checkerboard pattern is projected, the corners of which should fall exactly into the calibration points.

The scanner is now calibrated. This refers to the position and rotation of camera and projector according to each other, as well as focusing and brightness settings. You can move, tilt and rotate the scanner as a whole, and you can close the DAVID software and restart it without losing the calibration. You can also change the value of `Projector Brightness` to adjust the brightness (red sine curves) to the respective

object to be scanned. However, if you rotate or move camera and projector separately or adjust the focus (for example for scanning significantly larger or smaller objects), the entire calibration process must be repeated.

SCANNING

Overview of Structured Light Scanning

↑ | Scanning

- Introduction
- Installation
- Setup
- Calibration
- **Scanning**
  - Turntable Control
  - Camera Control
  - Projector Control
  - Pattern Parameters
  - SL Scanning
  - Result Filtering
  - Result Transfer
- Texturing
- Shape Fusion
- 3D Viewer

The "Scanning" menu provides functions to setup scan parameters, capture new scans including texture, filtering, exporting, and sending them to "Shape Fusion". In the following, the most basic workflow is presented that can be altered by various options:

1. Place scanner

Place the scanner and the object in front of each other, at the same distance as during setup and calibration. With a wrong working distance, the camera image and projected stripes would be blurred. If necessary, correct the distance between object and scanner, but by no means change the focus of camera or projector.

> Before each scan please check that the red sine curves are not cropped / overdriven (relevant only in the areas where the wave pattern is visible). If adjustment is necessary, adjust the `Projector Brightness` in the software.

2. Select pattern parameter profile

Select the pattern parameter profile `Quality`, `Default` (recommended) or `Speed`. This setting affects scan quality and scan time. See also Pattern Parameters.

3. Click "Start"

With each click on `Start` a new scan is generated. A sequence of patterns is successively projected and recorded. This can take between settings 2-4 seconds or longer. See also SL Scanning for scan options.

Using the mouse, you can change the 3D view onto the object (see 3D Viewer for details). With the `Live Camera` button in the top toolbar you can return to live video feed.

To assure that multiple scans of the same object can be well combined later, they must overlap sufficiently. You usually will need about 6-8 scans all around the object, maybe plus some angular views of top and bottom. Textures can help later when aligning multiple scans.

4. Filter result

Modify parameters of "Result Filtering" to your need. You will see the filtering result immediately in the `3D Scan` view. See also Result Filtering.

5. Transfer result

Export scan or send it for further processing to "Shape Fusion". See also Result Transfer.

Turntable Control

Setup and control of turntable

↑ | Scanning | Turntable Control

Check `Enable Turntable` under "Turntable Control" to activate a DAVID turntable (Pro Edition) or your own turntable via plugin interface (Enterprise Edition). The initialization may take a few seconds.

You can set the `Number of Scans` that are automatically executed when you click on `Start` under "Scanning". When you have activated `Auto Align to List` and `Auto Align to Previous`, every new scan will be automatically aligned to the last scan of the sequence using the known rotation angle of the turntable.

Camera Control

Adjusting camera properties

↑ | Scanning | Camera Control

For most cases you setup the camera properties once and do not change it for every new scan object. If you want to change or check them, click on `Camera Properties`.

Deactivate all filters that might be active in your camera or camera driver (e.g. no smoothing and no extra sharpness). Prefer "raw" images.

Be careful with "gain", since this introduces noise to the scans. For many cameras and situations the lowest (or 0 db) gain value works best.

The `Exposure` should be set to the same value as the frame rate of the projector (usually 1/60s), otherwise the camera image will flicker / pulsate when looking at the projection. Increase exposure in multiple of projector frame rate (e.g. to 1/30) only in cases when your object is too dark.

Camera properties are handled and stored for scanning and texturing separately.

Projector Control

Adjusting projector brightness to scan object

↑ | Scanning | Projector Control

With `Projector Brightness` you can reduce the maximum projector brightness digitally. The default value is the maximum value of 255.

Depending on the used projector, drastic decreases of projector brightness (e.g. from 255 to 20) can have a significant impact on scan quality. Not only noise will increase, but in some cases you will also notice waves in your scans.

Pattern Parameters

Setup method and parameters for scanning

↑ | Scanning | Pattern Parameters

The amount and type of projected pattern influence the quality of a scan. On rule thumb is that with more scan time you get better scan results.

The following presets are available:

- `Speed`: Minimum scan time. Should only be used when speed is very important.
- `Default`: Medium scan time. Good compromise between speed and quality.
- `Quality`: Maximum scan time. Robustnesss and accuracy is improved.

There is also a `Custom` mode that let's you set the scan parameters to your requirements.

SL Scanning

Taking new scans with Structured Light Scanning

↑ | Scanning | SL Scanning

Click on button `Start` to make a new single scan or multiple scans in case of activated turntable. There are some options that get automatically executed when they are checked:

`Auto Grab Texture`
: Automatically grabs a color texture when scan sequence is finished.

`Auto Add to List`

Automatically adds the new scan (after result filtering was applied) to the List of Scans.

`Auto Align to Previous`

Automatically aligns the new scan to the previous one. If possible, the alignment mode currently set in 'Shape Fusion / Alignment' is used. This mode is only available, if `Auto Add to List` is checked.

Result Filtering

Post processing of new scans

↑ | Scanning | Result Filtering

Smoothing

With the smoothing filters under "Result Filtering" you can smooth the 3D scan result manually. However, we recommend not to do this (set filters to 0). If your scans are noisy or wavy, you should rather optimize the scanning conditions (brightness settings, room conditions). More smoothing options are available in the "Shape Fusion" menu later on.

Quality Check

The filter `Quality Check` removes scan data that are likely to be inaccurate. This is possibly on the edge of the scan or at transitions between light and dark areas. You can change the filter value and see the effect immediately on the scan. The recommended value is 0.5.

Background Removal

You can automatically remove an undesired background from your scene. First, run `Scan Background`. Second, ensure that `Background Removal` is activated. This procedure needs to be repeated whenever the

background changes relative to the scanner.

Please keep in mind that you get best results when you use a deep black background.

Result Transfer

Transfering new scans to "Shape Fusion"

↑ | Scanning | Result Transfer

Export each successful scan for example as an OBJ file (`Export`) and / or add it to the scan list (button `Add to List`). After each click on `Add to List` , you can align the new scan immediately to the previous scans ("Shape Fusion" menu, see next chapter). Alternatively, you can first create further scans in the "Scanning" menu, collect them in the list, and align them all later.

If the settings are optimized, and you do a lot of scans in a row, you can accelerate the workflow with the `Auto Add to List` and / or `Auto Align to Previous` scan options. This is recommended only for experienced users.

TEXTURING

Texture capturing and white balancing

↑ | Texturing

- Introduction
- Installation
- Setup

With the `Grab Texture` button, the current scan is provided with a new texture. You can toggle the visibility of the texture in the 3D view using `Show Textures` button in the top toolbar.

Settings here are stored separately. For the following scans, you will not have to go to the menu "Texturing" each time, instead you can activate the `Auto Grab Texture` option in the "Scanning" menu.

White Balancing

Global adjustment of the intensities of the colors

↑ | Texturing | White Balancing

Whenever you change the texture settings, you should re-perform the white balancing. That means DAVID calibrates color transmission characteristics of the entire system (projector, camera), in order to be able to measure the colors of the object correctly.

> For white balancing, the camera image must show exclusively a large white object (such as the glass calibration panels or a white wall). Then click `Adjust White Balance`

SHAPE FUSION

Overview of Shape Fusion in DAVID 4

↑ | Shape Fusion

The "Shape Fusion" menu provides functions to clean, align, fuse / merge several scans into a single 360° model, compare scans, and measure distances. The fused object subsequently can be exported to various formats, to be used e.g. for 3D printing.

Project

Saving and loading projects

↑ | Shape Fusion | Project

Use buttons `Save Project As...` and `Save Project` under "Project" to save all relevant data (like scans, fusion result, and measurements) within a single a project file. `Load Project` discards the current project and loads an existing one into DAVID4.

> Using projects should be the preferred method to save your data in DAVID 4. It is much faster and easier than using multiple OBJ files.

List of Scans

Add, remove, and manage scans

↑ | Shape Fusion | List of Scans

In general, the individual scans are collected via the `Add to List` button during scanning. You can import more scans into the "List of Scans" - either by drag and drop from the Explorer, or using the `+` icon below the list.

In the list individual scans can be made **visible / invisible** by click on  .

Supported file formats for **import / export**:

DAVIDMESH	Proprietary DAVID file format. All mesh data is saved. Default for projects.	Import /

		Export
OBJ	3D object file format from Wavefront Technologies. Some meta data is lost in export.	Import / Export
STL	STereoLithography file format. Only geometry is imported and exported.	Import / Export
PLY	Polygon file format. Only geometry is exported.	Export

`Right Mouse Button` on selected scans shows up a **context menu** with various options.

Use button `Scan Properties` on selected scans to get **additional information** like triangle count, vertex count, pose, surface area, volume, and more.

Cleaning

Removing unwanted parts from scans

↑ | Shape Fusion | Cleaning

Scans may contain some surface parts that you want to remove. You can do this by the following procedure:

1. Select parts of the surface with the `Select Triangles` tool.
2. You can invert your selection by clicking on `Invert Selection`.
3. A click on `Delete Triangles` will remove all selected triangles. Be careful: This can not be undone, at the moment.

Alignment

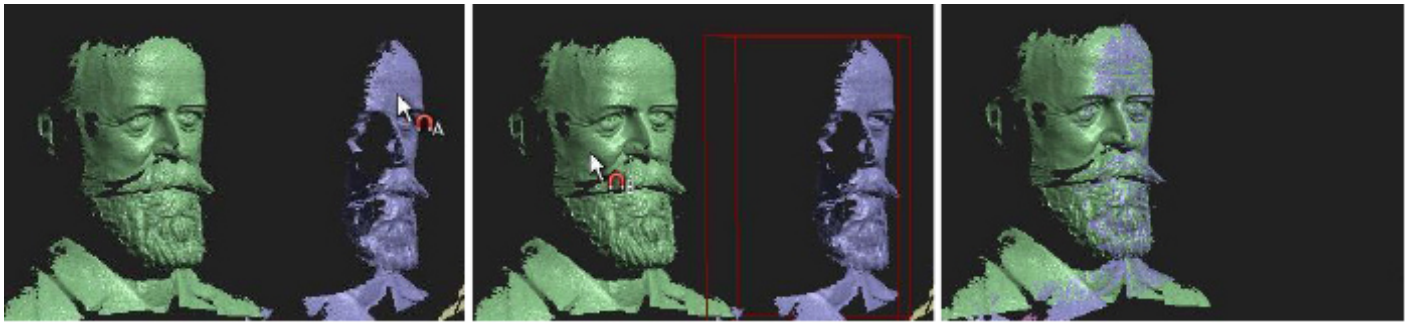
Alignment of scans

↑ | Shape Fusion | Alignment

Single scans prior to alignment, arbitrarily arranged

Using the buttons `Arrange 1D` and `Arrange 2D` under "Alignment" you can arrange all scans side by side, to get a good overview.

DAVID offers several alignment modes. First, start with the alignment mode `Free`, which allows you to align arbitrarily positioned scans one-on-one. In order for the automatic mode to align two scans successfully, the two scans must have a unique region of overlap in common, which must not be too small.



Automatic alignment with two mouse clicks

With `Align Scans` start the alignment. In the 3D view, first click on the object A to be aligned. Then click on the object B, to which A should be aligned. Successively align more scans to the already aligned scans. Always choose pairs that have as much overlap (common areas) as possible. In the above example, the next step would be to align the yellow to the blue scan: click on the yellow, then the blue scan, etc.

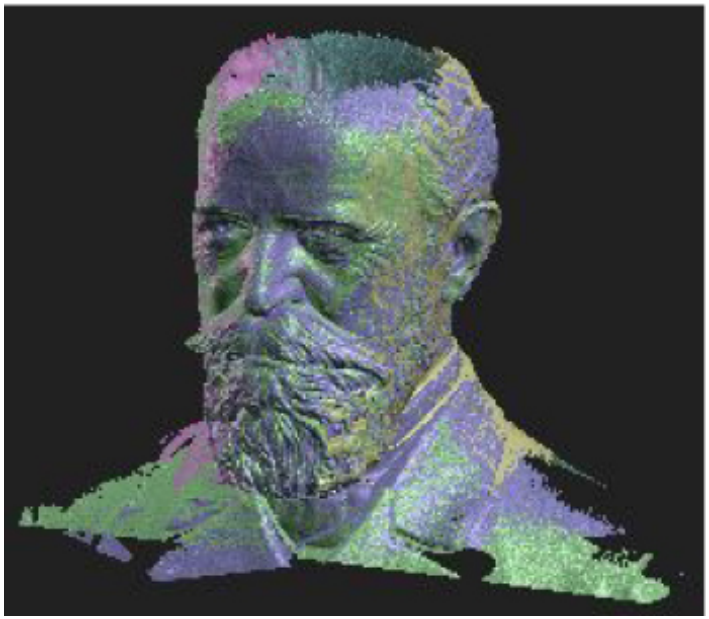
When all scans are aligned, a run of `Global Fine Registration` is recommended. Choose that mode instead of `Free`, then click `Align Scans`.

All movements can be individually made undone by the `Undo` button.

If the automatic alignment finds false solutions, you should activate `Contact Pair Selection` . Then you can help DAVID by clicking on distinctive points that are to be aligned with each other (e.g., tip of the nose). Relevant here is the area within the red circle at the mouse pointer. If you would like to define the contact pair points very precisely, zoom up close with the mouse wheel before you click. If you want to mark the contact area only roughly, zoom out before you click.

After a few registration steps, it may be helpful to group two or more aligned scans temporarily. Simply select two or more scans in the List of Scans (check the checkboxes of the respective scans), click with the right mouse button and select `Combine selected scans`. This allows you to group scans (temporarily) and use them as if they were a single scan. In our example we could combine scans 1 and 4 just before the alignment of the 5th. In this way, the 5th scan will be aligned simultaneously to both, which can lead to

more overlap and thus better results. To un-group, click with the right mouse button on the entry in the list and select `Uncombine scans`.



Scans after alignment

Fusion

Fusion of multiple scans into one 3D model

↑ | Shape Fusion | Fusion

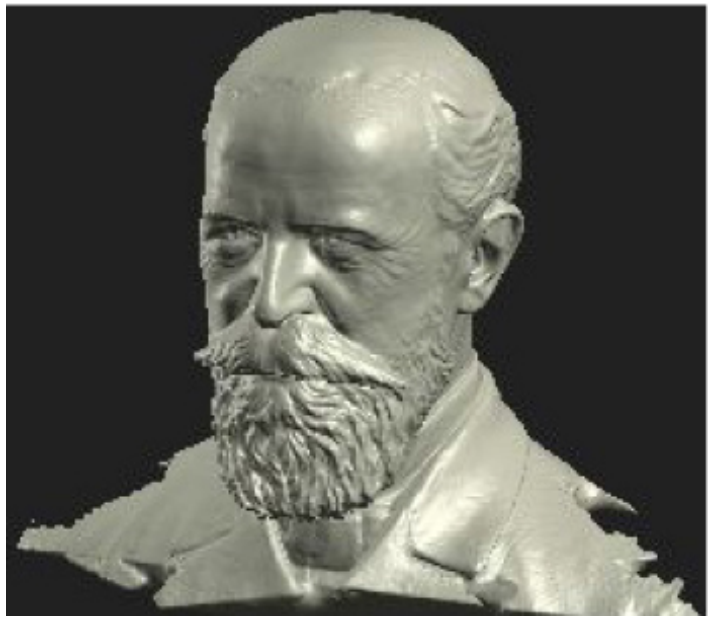
Make all scans visible, which you want to fuse. Invisible scans will not be included in the fusion.

First, try a small `Resolution` value. High values cause to very long computing time and higher memory usage.

With `Sharpness` you can influence how tight the fused surface is fitted to the 3D scan points (default value is 1). Greater values will make noise more visible. Negative values will smooth your fusion result. Feel free to try it, depending on the object.

Click on `Fuse` to start the fusion process. This is a computationally intensive process and will take a few seconds to several minutes. The visible scans are merged to form a closed triangle mesh, holes are (optionally) closed, smaller artifacts are removed, and if the scans have textures, a common texture is generated.

Finally, you can export your fused 3D object into an OBJ, STL or PLY file by using the `Export` button.



Fusion result (with "close holes" option)

A-B Distances

Measuring distances between two surface points

↑ | Shape Fusion | A-B Distances

"A-B Distances" allows to measure distance values between two surface points:

1. Click on `Add Distance` (`+`) under "A-B Distances".
2. Click with left mouse button on any surface within 3D window for point A.
3. Click with left mouse button on any surface within 3D window for point B.

Comparison

Comparing surfaces

↑ | Shape Fusion | Comparison

"Comparison" allows to measure signed distances between two surfaces:

1. Select a scan and set it as `Test Object`.
2. Select a scan and set it as `Reference Object`.
3. Enter the desired `Tolerance [mm]`.
4. Click on `Compare`.
5. Add data tips on the reference scan with `Add Reference Marker` (`+`).

3D VIEWER

3D navigation and object selection

↑ | 3D Viewer

3D Navigation

You can move around your scans in 3D by mouse:

`Left Mouse Button Down + Mouse Move`

The virtual camera is translated orthogonal to the viewing direction. The amount of translation is proportional to the distance between the virtual camera and the "Orbit Center".

`Mouse Wheel`

Translation of the virtual camera along the viewing direction. The amount of translation is proportional to the distance between the virtual camera and the "Orbit Center".

`Right Mouse Button Down + Mouse Move`

- *Inside white circle:* The virtual camera is rotated in an orbit around the "Orbit Center".
- *Outside white circle:* The virtual camera is rotated around the viewing axis.

`Right Mouse Button Click`

- *Point on object surface was clicked:* This point will be set as the new "Orbit Center".
- *Background was clicked:* Nothing happens.

`A`

Auto adjust camera view to all objects or selected objects. The "Orbit Center" is set to the center of the enclosing bounding box.

Select Objects

Just click with `Left Mouse Button` on the object you want to select. For multi selection hold `Ctrl` down. To deselect all objects click on the background.

Move Selected Object

Just select a scan, then keep the `Shift` key pressed. The manipulation is similar to the 3D navigation with the left and right mouse button:

`Shift + Left Mouse Button`

Move (translate) scan under mouse pointer.

`Shift + Right Mouse Button`

- *Inside white circle:* Rotate the scan around vertical and horizontal axis.
- *Outside white circle:* Rotate the scan around view direction.

Shortcuts

Key	Shortcut
`A`	Auto adjust camera view to all objects or selected objects.
`C`	Show coordinate systems on/off.

`E`	Show triangle edges on/off.
`P`	Toggle polygon mode between `Solid`, `Lines`, or `Points`.
`T`	Show textures on/off.
`N`	Show vertex normals on/off.

These are the shortcuts for the 3D viewer only. There are other function specific shortcuts which are displayed in the tooltips.