FARO

SCENECT

SCENECT 5.2 MANUAL
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1. Introduction

The SCENE software family is a comprehensive 3D point cloud processing and managing software for the professional user. It is specially designed for the viewing, administration, and working with extensive 3D scan data obtained from high resolution 3D laser scanners like the FARO Focus^{3D}. THE SCENE software family consists of SCENE and SCENE LT.

While SCENE offers the the complete functionality to view, administrate, process, register and analyze laser scans, SCENE LT is a free point cloud viewing software that mainly enables the user to view and analyze the laser scans. It also offers some basic functionality to process the laser scans and to export them into different file formats.

SCENECT covers all the functions of SCENE LT and, additionally, enables anyone with the Microsoft® Kinect™ for Windows, the Microsoft Kinect for Xbox® or the ASUS® Xtion Pro Live[1] to capture objects and environments in 3D in real-time. Along with the functions of SCENE LT you are then able to view, process and analyze the recordings obtained from these two devices as well as to export them into different file formats for further use in third party applications, like CAD programs. Due to the sensors being designed as a gaming hardware, not too much accuracy should be expected, although the results can already be impressive.

Please note that SCENECT is a technology preview. It is provided to you "as is" at no charge and without warranty of any kind. It should be regarded as a testing ground for new services and products and is therefore still in testing phase. It has not been released for sale and will be referred to as beta software from here on and should not be used on sensitive and/or valuable data. In no event will the licenser be liable for damages arising out of the use or inability to use the software. SCENECT is not supported by FARO Customer Service. For more information, see Software License Agreement on page i.

This manual will give you an overview of the functions that are necessary to record and process data obtained from the two supported sensor devices. It will guide you through the steps of capturing objects and environments with the Kinect or the Xtion and of postprocessing the resulting 3D point clouds. Functions that are part of SCENE LT and that are mainly required for processing and analyzing the recorded point clouds will be roughly described in this document. Detailed information may be found in the online help of SCENECT (under **Help ▸ Contents**) or in the SCENE manual (available in the Start Menu of Windows after installing SCENECT).

Watch tutorial videos on YouTube to learn more about recording and processing data with SCENECT: SCENECT Tutorials

[1] Reference to any ASUS products, services, processes, or other information and/or use of ASUS Trademarks does not constitute or imply endorsement, sponsorship, or recommendation thereof by ASUS.

1.1. System Requirements

Sensor specific hardware and software requirements:

	Asus Xtion Pro Live (with RGB and depth sensor)	**Microsoft Kinect for Windows or XBOX**
Power Supply	No extra power supply needed	Kinect Power Supply adapter (included with the Microsoft Kinect for Windows, not included with the Microsoft Kinect for XBOX) This adapter consists of a dedicated power plug and USB cord and splits the connection into separate USB and power connections thus providing power to the sensor and connectivity to your computer.
Drivers	▪ OpenNI 1.5.4 ▪ SensorPrimesense driver (version 5.1.2.1)	▪ OpenNI 1.5.4 ▪ SensorKinect driver (version 5.1.2.1)
	If these drivers are not available on your system, they will automatically be installed when installing SCENECT (if enabled during installation). For more information, see chapter 1.3.	

Computer specific hardware requirements:

	Minimal Specifications	**Recommended Specifications**
Processor	Double-Core 64-bit *(x64)* with at least 2-gigahertz (GHz)	Quad-core x64
Graphics Card (It is recommended to update the drivers of your graphics card to the latest version)	• Must support OpenGL 2.0 or higher • At least 256 MB memory.	• Dedicated graphics card • At least 512 MB memory • OpenGL 2.0 support
Main Memory	At least 4 GB	At least 8 GB
Hard Disk	Standard	Solid state for maximum performance.
Operating System	Windows XP, Vista or 7 (64bit versions)	64-bit Windows 7
Misc.	• Mouse with 2 buttons and a scroll wheel • Network card as it is required for licensing SCENECT	

1.2. Sensor Fundamentals

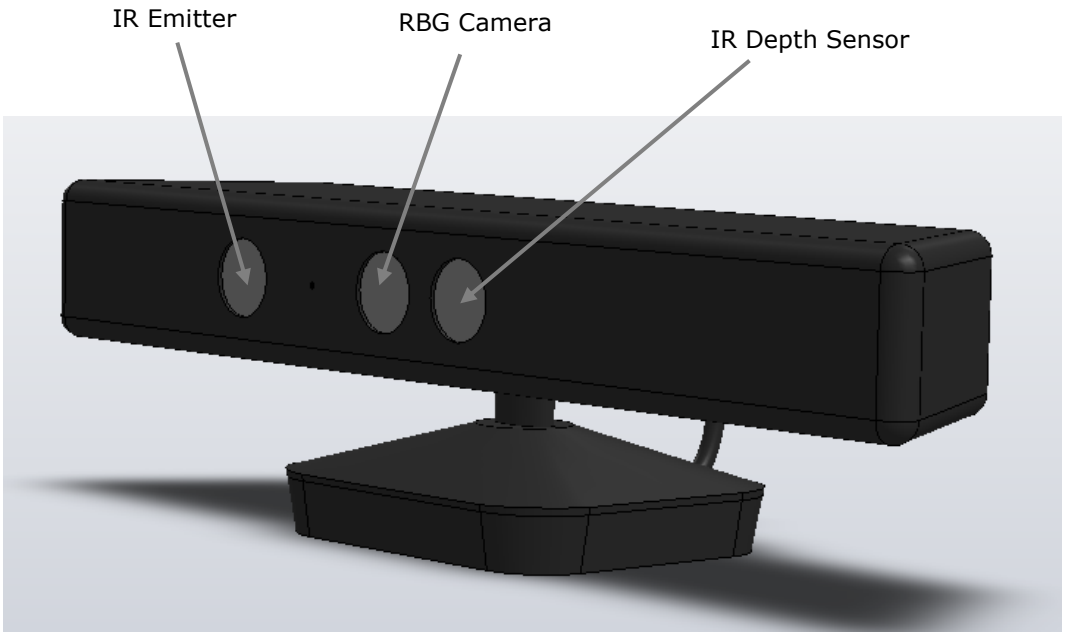

Figure 1-1: Sensor Description

The Kinect and the Xtion feature an RGB camera and a depth sensor.

The depth sensor consists of an infrared laser projector combined with a monochrome CMOS sensor, which captures video data in 3D by means of triangulation of coded light. As structured light is used for depth measurement, bright ambient light might reduce the measurement range.

Both devices feature microphones and the Kinect a motorized pivot. They are not used by SCENECT.

1.3. Installing the Software

You need administrator rights in order to install the software.

1. Unplug the sensor device from your computer.
2. Start the SCENECT setup file.
3. Follow the instructions on the screen.
4. On the **Select Additional Tasks** screen, make sure to enable **Install Kinect and Xtion drivers** if the required versions of the OpenNI library and the sensor drivers are not installed on your system. See chapter 1.1 for more information on the required driver versions.

Previous driver versions will be replaced by the SCENECT setup. If later versions are installed, uninstall them first and re-install the drivers with the SCENECT setup.

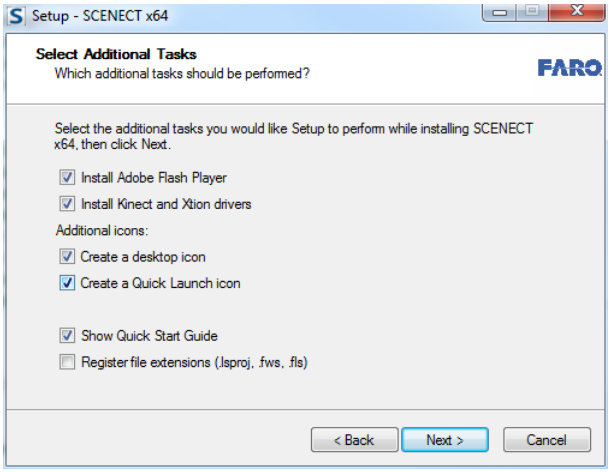

Figure 1-2: Installation – Select Additional Tasks

5. When installling the drivers, a security note from Windows might appear. Please confirm it.
6. Reboot your system after installation.
7. Connect the sensor device to the computer:
   - **Kinect**:
     1. Plug the cable from the Kinect sensor into the connector of the power supply adapter.
     2. Plug the AC adapter end of the power supply adapter into a wall outlet.
     3. Plug the USB cable of the power supply adapter into the USB port of your computer.
   - **Xtion**: Plug the USB cable of the XTION into the USB port of your computer.

The setup will also install demo data (raw data video files) into your personal documents folder under C:\Users\YOUR_USER_NAME\Documents\FARO\. See chapter 2.5 for more information on how to use them.

1.4. Licensing the Software

Once SCENECT has been installed, you may use it for 30 days without a license key. After this trial period, you need a license key to further use the software. ***This license is free of charge***. To license the software follow the steps below:

1. Request the free license key from FARO with the license manager (available in the main menu under **Help ▸ Licensing)**.

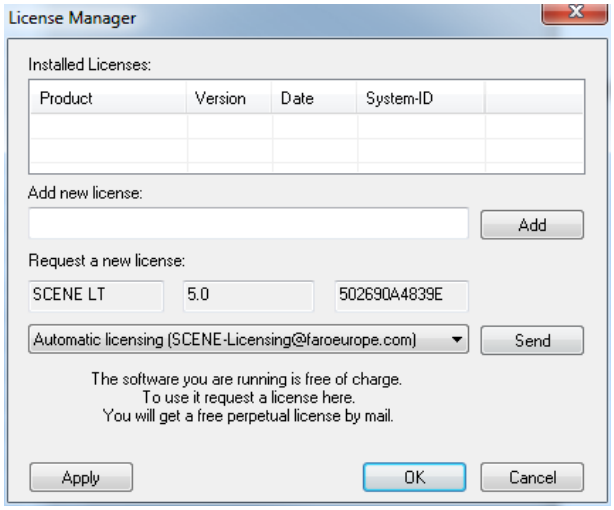

Figure 1-3: License manager

2. In the license manager, press the Send button to generate a license request file (this file does not contain any private data, it only contains the product name and your system ID generated from the MAC address of your network adapter).
   - If an E-Mail client is properly installed on your system an automatically generated E-Mail with the license request file attached will be opened. Send this E-Mail to the provided address.
   - In case an E-Mail client is not installed, manually send the generated license request file to FARO. Find this file in your local user folder under C:\Users\YOUR_USER_NAME\AppData\Local\FARO\SCENE\Data\Licensing. It is the file with the extension .lr. Attach it to an E-Mail and send it to: SCENE-Licensing@faroeurope.com
3. Once the mail with the license request file has been sent to FARO, you will receive an automatic reply with a valid license key. Copy this key to the **Add new license** field in the license manager, press the **Add** button, and then **OK** or **Apply**. SCENECT should then be licensed for your system and its license should appear in the list. It is valid for one year and must be renewed when it has expired.

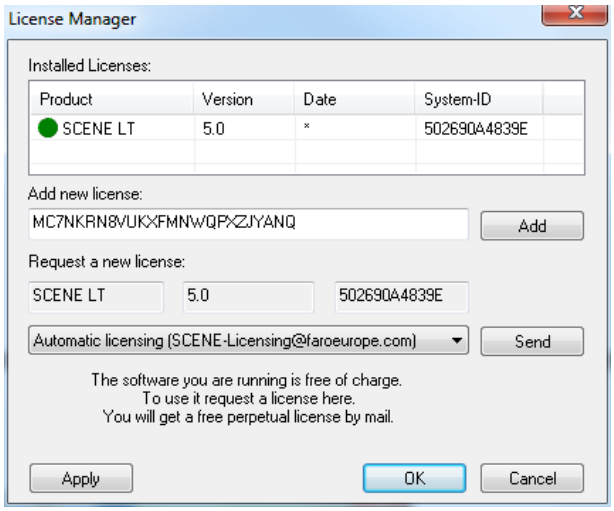

Figure 1-4: SCENECT License

Please note: If you change your hardware or if you want to use SCENECT on a different computer, you will need a new license, as the license is bound to a system ID.

2. Recording

2.1. Starting SCENECT

On the first program start, SCENECT asks you to set up a default project folder. Afterwards, SCENECT starts with the *Project Selector* window by default which presents all the scan projects known to SCENECT at that time.

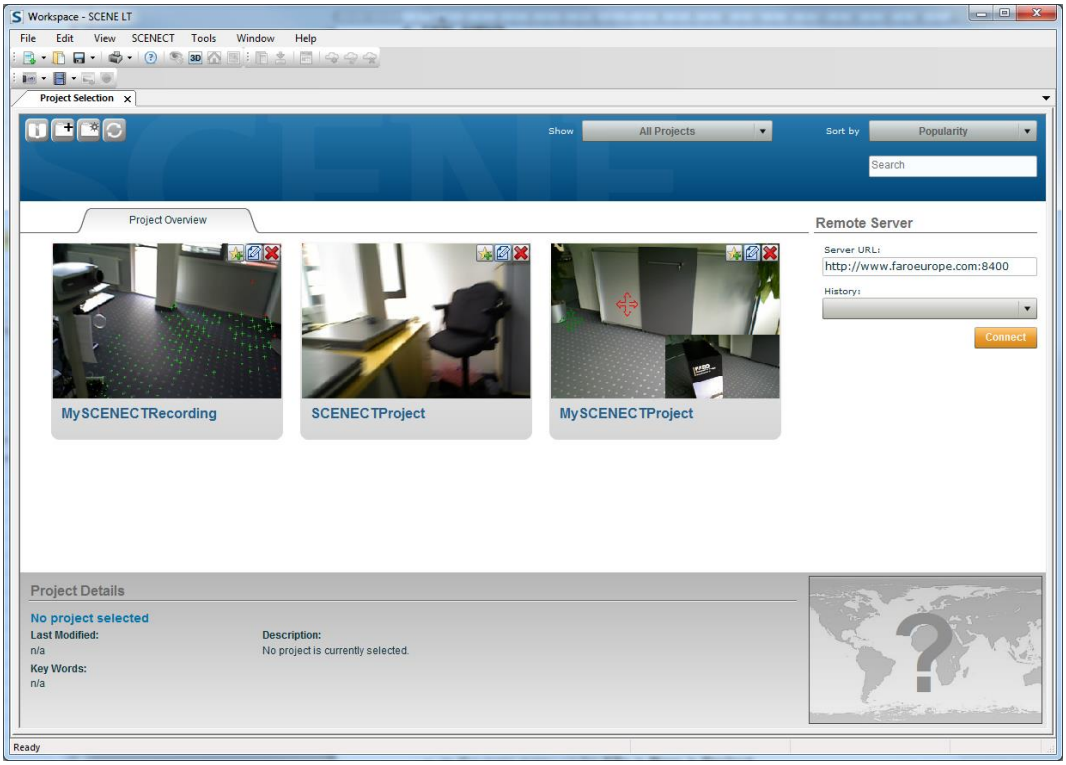

Figure 2-1: Project Selector Window

For more information on the Project Selector, see chapter "Working with the Project Selector" in the SCENE manual or in the online help. The SCENE manual was installed with SCENECT and is available from the Start Menu of Windows. The online help is available in SCENECT under **Help ▸ Contents**.

2.2. Opening a Scan Project

SCENECT needs to know where to save your recorded scan files before recording: Open an already existing scan project or create a new scan project.

Create a new project

- with the project button in the standard toolbar,
- in the main menu under **File ▸ New ▸ Project**,
- or with the **New Project button** in the Project Selector.

For more information on working with scan projects, please see chapter "Working with Scan Projects" in the SCENE manual or online help.

Once a scan project is opened, the typical SCENECT window appears. This window is made up of the following areas:

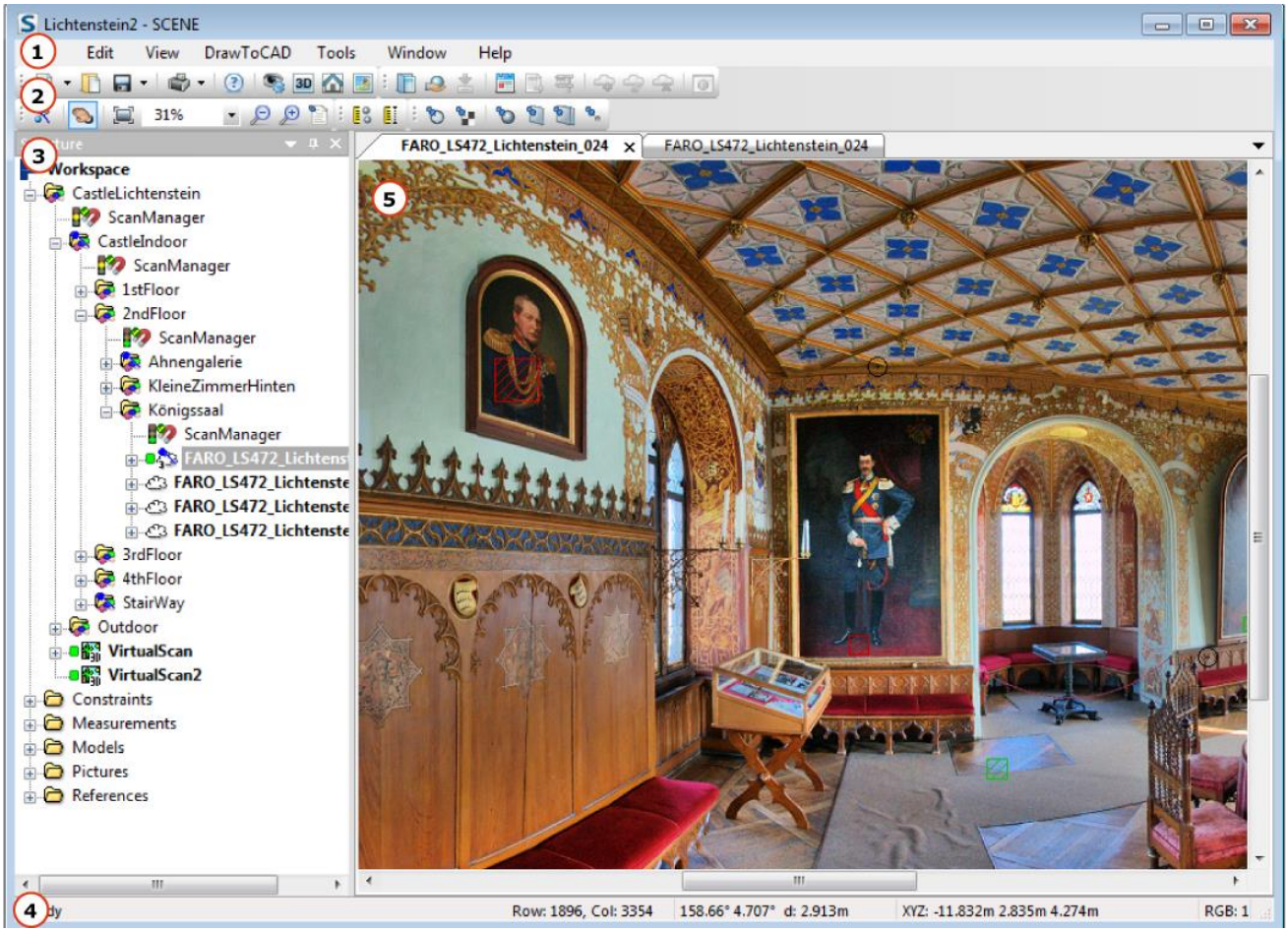

Figure 2-2: Composition of the SCENECT Window

1. **Main menu** – contains all the menus with commands for general operation.
2. **Toolbars** –provides common menu features.
3. **Structure view** – displays the structure of the project workspace, including all folders, recorded sequences, recorded frames and other objects.
4. **Status bar** – displays command and scan point data details.
5. **Scan and object views** – the visual presentation of the recorded scan data and other objects. Scans and objects can either be displayed in a quick view, a detailed planar view or in 3D view. The views can be displayed in *tabbed* or *unanchored* windows. Tabbed windows are the standard display option and allow maneuvering between multiple windows by clicking at the tabs on top of this area. Change this under **View ▸ Tabbed Documents**.

2.3. The SCENECT Toolbar and Menu

The SCENECT toolbar should be visible by default. In case not, toggle its visibility in the main menu under **View ▸ Toolbars**

Figure 2-3: SCENECT Toolbar

Live Tracking Button **-** Immediately starts the recording from the connected sensor device. If a scan project is not open yet, you will be prompted to create one first. For more information, see chapter 2.2. Clicking the arrow on the right will bring up this drop down menu with further options:

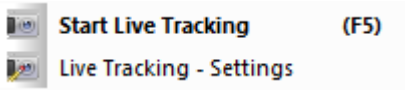

Figure 2-4: Drop Down Menu Live Tracking

Start Live Tracking – Same functionality as clicking on the button above.

Live Tracking - Settings – Opens the settings dialog for the live tracking. For more information, see chapter 2.4.1.

Tracking from File - Starts tracking of frames from a raw data video file (video that contains depth and color information) of a previous recording. For more information, see chapter 2.5. The arrow brings up this drop down menu with further options:

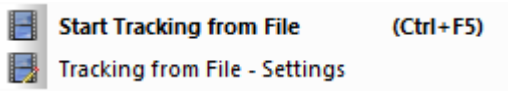

Figure 2-5: Drop Down Menu Tracking from File

Start Tracking from File– Same functionality as clicking on the button above.

Tracking from File - Settings – Opens the settings dialog for the file tracking. For more information, please see chapter 2.5.

Make Snapshot **-** Only available during live tracking or tracking from raw data video files. It enables you to create a snapshot frame from your recording whenever you want.

Stop Tracking - Stops live tracking or tracking from a video file.

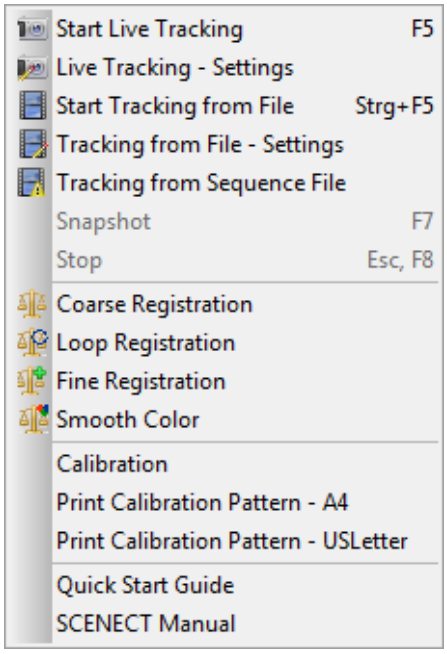

Figure 2-6: SCENECT Menu

The SCENECT menu covers the functionality of the toolbar plus additional functions:

Tracking from Sequence File - Track frames from the raw data video of the sequence that is currently selected in the structure view. For more information, see chapter 2.5.

Coarse Registration – Applies coarse registration to the frames of the sequence that is currently selected in the structure view. For more information, see chapters 2.4.1 and 3.2.

Loop Registration - – Applies loop registration to the frames of the sequence that is currently selected in the structure view. For more information, see chapters 2.4.1 and 3.2.

Fine Registration - Applies additional registration steps to the frames of the sequence that is currently selected in the structure view. For more information, see chapters 2.4.1 and 3.2.

Smooth Color – Smoothens the color scan points in overlapping areas within the selected sequence. For more information, see chapter 2.4.1 and 3.3.

Calibration – Start calibration of your sensor. For more information, see chapter 4.

Print Calibration Pattern – A4 / Print Calibration Pattern USLetter – Print a calibration pattern (in DINA4 or USLetter format). One of these patterns is needed for sensor calibration.

You should calibrate your sensor at least once before starting to use it with SCENECT. Calibration might increase tracking quality and color accuracy of you sensor device.

Quick Start Guide – Opens the SCENECT quick start guide.

SCENECT Manual – Opens this document.

2.4. Live Tracking

As described in chapter 1.2 the Microsoft Kinect and the ASUS Xtion consist of two sensors, a standard RGB camera and a depth sensor. The data obtained from these sensors is used to track the motion of the device and to create the colored 3D point clouds of objects and environments.

While recording the data, the sensor device has to be moved along or around the object of interest. While it is moved, the device's motion is tracked by means of distinctive features dynamically identified in the recorded data; the pose of each recorded frame is estimated by registration against its previous frame (frame-to-frame tracking). The pixels or points of the recorded frames which contain depth information from the depth sensor and color information from the RGB camera are used to build up the colored 3D model of the captured object(s). To reduce data size, only key frames which are selected by certain criteria are picked from the data stream and used for the 3D model.

You should calibrate your sensor at least once before starting to use it with SCENECT. Calibration might increase tracking quality and color accuracy. For more information, see chapter 4.

2.4.1. Settings

Before starting live recording, you may change the settings used for recording and processing of the captured data.

Open the settings dialog via **Live Tracking – Settings** from the SCENECT main menu or from the drop down menu of the **Live Tracking** button in the toolbar.

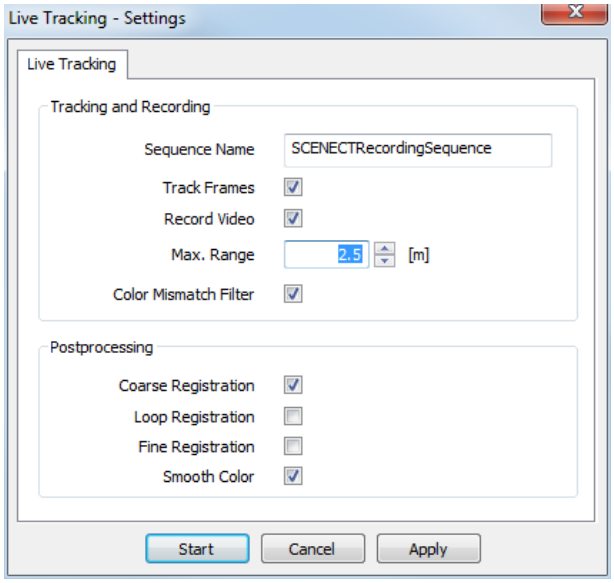

Figure 2-7: Live Tracking - Settings

Sequence Name – A sequence contains all the data of one single recording. It contains key frames, snapshots, the recorded raw data video and the device's trajectory as well as a sequence protocol. A sequence is organized as a folder in the project's workspace. This folder will be named according to the name provided in this dialog.

Sequence names may not contain special characters or blanks.

Track Frames – Enable to capture key frames in real-time while recording. You can also track frames offline at a later time from a recorded raw data video (see below for more information).

Record Video – Enable to save the raw data video for later offline capturing of the frames. This raw data video contains all the depth and color information obtained from the device's sensors. For more information, see chapter 2.5.

Tracking frames in real-time has increased system requirements. If you are tracking frames in real-time on a system with lower performance (e.g. tablet), frame-to-frame tracking might be less accurate. In this case, you may record the raw data video only and track the frames from the video later. See chapter 2.5 for more information.

But as tracking frames in real-time has the advantage of enabling you to recognize whether tracking gets lost and whether all objects are captured, it is recommended to enable it, even on systems with lower performance. In this case, it is recommended to record the video too and re-track the frames from the video later. This might improve the accuracy of the frame-to-frame tracking.

Max. Range – Limit the maximum recording range. Objects within this range will be captured; objects that are farther away won't be part of the resulting 3D point cloud.

The minimum depth sensor range of the ASUS Xtion and the Kinect is 0.8m, it depends on ambient illumination whether closer objects are recognized. The specified maximum range of the depth sensor of the devices is 4 meters. You might get depth data from objects that are farther away, but quality and accuracy may decrease noticeably at distances beyond this limit.

Color Mismatch Filter – If there is an object in the foreground which differs from the background color there might be some mismatch between the color of the background and foreground and the 3D model points at the edges of that object. This mismatching comes from

accuracy limitations of the Kinect and Xtion devices. The edge of the foreground object is smeared with the background color and vice versa. This filter attempts to detect such situations and removes the critical points from the model.

Figure 2-8: Left: No color mismatch filter applied, right: Color mismatch filter applied

Coarse Registration – Applies a global bundle adjustment to the recorded sequence and tries to distribute alignment errors evenly across the frames of the sequence to minimize major inconsistencies. Coarse registration will automatically be applied if loop registration is enabled. Select this option, if you want to apply coarse registration to the frames of the recorded sequence without loop registration.

Loop Registration – Applies loop registration, and afterwards coarse registration (see above) to the frames of the recorded sequence. Loop registration is an additional registration step which aligns non-consecutive frames to each other if they have overlapping areas. This is, for example, very useful if you are planning to record in a loop (e.g. around an object) where first and last frames have overlapping areas. Note: only overlapping areas of frames with the sensor pointing to the same direction will be taken into account; overlapping areas between frames resulting from opposite viewing directions (e.g. from the right and the left side of an object) will not be taken into account.

Fine Registration – As the initial registration by means of pairwise pose estimates between frames (frame-to-frame tracking) might be prone to a rapid accumulation of errors, a bundle adjustment is simultaneously applied to the captured key frames to improve their alignment. These registration steps are done on the basis of recognized features. However, you may apply fine registration afterwards which tries to further improve the registration from frame to frame on the basis of the scan points. This additional registration step is called fine registration. Enable this option if you want to apply fine registration immediately after the recording. Note that fine registration might take some time depending on the number of captured key frames.

Unlike the registration that is done during recording, fine registration attempts to refine the initial placement of the frames by analyzing the 3D scan points between successive frames. The placement is done on the basis of the 3D data only, color values are not taken into consideration. Fine registration might take some time depending on the number of frames.

If the recorded scene does not have sufficient 3D structures or the 3D points are significantly inaccurate, fine registration might not lead to satisfying results. Thus, it is recommended to limit the scan range to a maximum of 2.5 meters, scan points beyond that range might worsen the registration results. In all cases it is recommended to save your project before applying fine registration. You may then return to the saved state of your project if fine registration did not bring the expected results.

It is recommended not to apply fine registration immediately after recording as it does not always improve registration. You should apply fine registration later, and then

verify its results. If they are not satisfactory you will be able to discard the changes made by the fine registration.

The above mentioned registration steps can also be applied later. For more information, see chapter 3.2.

Smooth Color – Applies a color averaging algorithm to the scan points of overlapping areas between frames of the completed sequence. In most cases, this will remove differences in brightness between overlapping areas and improve the overall color impression of the point cloud. Color smoothing can also be applied later. For more information, see chapter 3.3.

Start – Save your settings and start live tracking.

Cancel – Discard unsaved changes and close the settings dialog.

Apply – Save your changes. To close the settings dialog without starting live tracking, press cancel afterwards.

2.4.2. Tracking

To get best results, take care of the following before and while you are recording:

- Make sure your device is connected to your computer and – if you are using the Microsoft Kinect – that it is connected to the power supply.
- When tracking frames in real-time, power management of your system should be set to maximum performance (with Windows 7: Control Panel > Hardware and Sound > Power Options: select "High Performance").
- Make sure that the object of interest is within the specified maximum range and that it is not closer than the minimum range of the sensor (see 2.4.1 for more information).
- Stable tracking requires objects and environments that have enough color structure. Avoid having only plain-colored surfaces in the device's field of view.
- Move the device slowly and constantly, avoid jerky movements. Fast and jerky movements may lead to inaccurate data or lost tracking.
- Objects should not move while they are captured.
- Ambient light conditions: In scenes with too bright illumination (close to lights or outdoors), the sensor will produce no 3D data or only data with a limited distance range.
- Keep an eye on the quality indicator of the progress dialog (more information below).
- If the number of features gets critical, try to move the device's field of vision to areas with more structures.
- If you want to record more than one sequence and if you want to put them in a spatial relationship (this step is called registration), make sure that the two sequences taken immediately before and after the current sequence have enough overlap. For more information, see chapter 3.1.

2.4.2.1. Starting Tracking

Start live tracking with

- the **Live Tracking** button in the toolbar,
- the **Start** button in the **live tracking – settings** dialog
- or with **F5** on your keyboard.

If the ASUS Xtion and Microsoft Kinect drivers have been installed properly and the device is connected to your computer, tracking should start immediately; the sequence folder will be added to the workspace and a split window will show up with the point cloud of your recording on the left and the video picture on the right as well as the progress dialog.

2.4.2.2. During Tracking

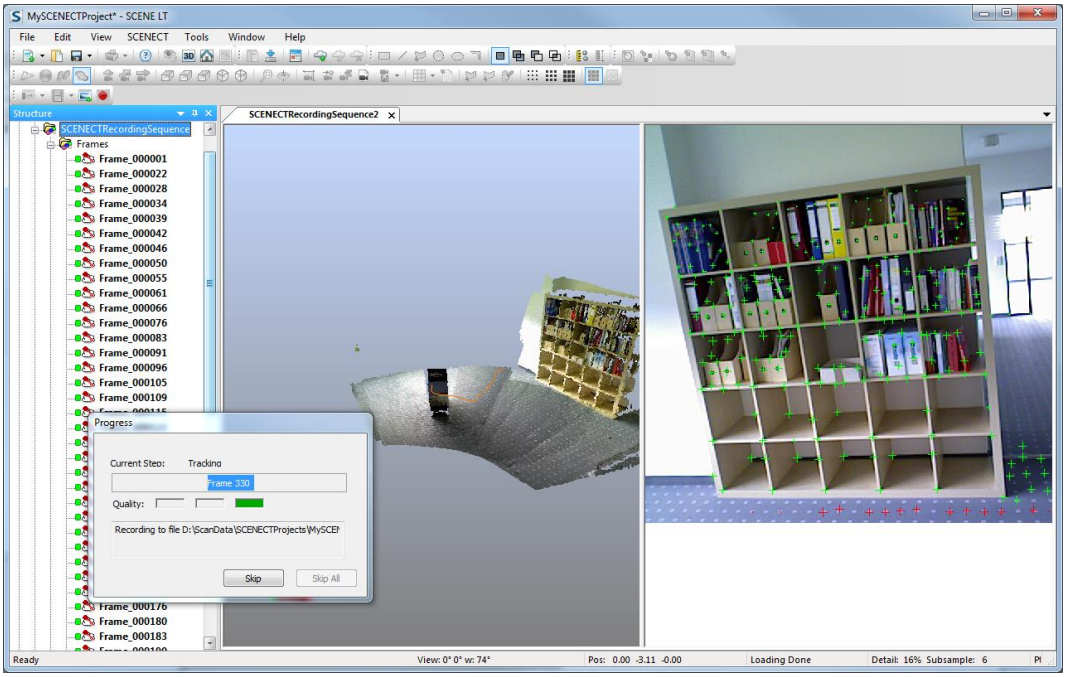

Figure 2-9: Live tracking – Split screen

The **video screen** on the right shows the RGB camera's field of view. The green, yellow and red crosses in this view symbolize recognized features used for tracking. Their quality is indicated by their color:

Cyan: New recognized features.

Green: Good features used for tracking.

Yellow: Recognized features that are not yet used but are good candidates for tracking.

Red: Features recognized but not good enough for tracking.

If the number of features gets below a certain threshold tracking is not possible anymore and gets lost. Please make sure to have enough features in the field of view.

The **3D view** on the left shows the point cloud of your captured area. It will build up in real-time. You are able to navigate in the point cloud during tracking.

The **progress dialog** shows the number of frames, some status messages and the overall quality of the tracking:

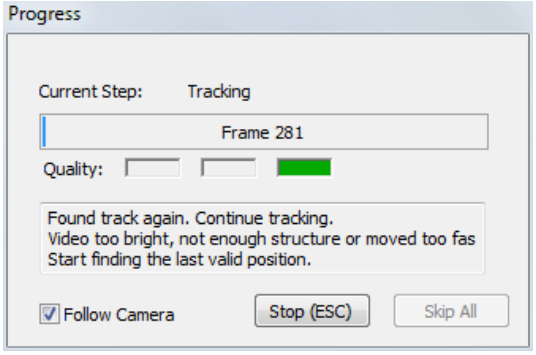

Figure 2-10: Progress dialog

Quality- Indicator for the tracking quality:

Green: both quality criteria are within the limits: there are enough structures available and the movement of the device is not too fast.

Yellow: at least one of both quality criteria is below a certain threshold. You should keep an eye on the number of recognized features and the movement of the device.

Red: at least one of both quality criteria is critical and tracking is on the verge of getting lost.

Status – Shows current and past status messages (general info and warnings).

Follow Camera – Enable to update the camera position in the 3D view according to the current sensor position. If you want to navigate in the 3D view while recording you should disable this feature.

2.4.2.3. Stop Tracking

Stop tracking at any time with the

- **ESC** key on your keyboard
- or with the **Stop** button in the SCENECT toolbar or in the progress dialog.

2.4.2.4. Resume Tracking

If tracking gets lost (e.g. by too fast movement or not enough recognized features), you may **resume** it.

If tracking got lost, the video screen will change according to the screenshot below.

Figure 2-11: Resume tracking

On the bottom right you will see the last video frame before tracking got lost. Try to align the sensor so that the current field of view approximately matches the last frame. The red and green crosses in the live video picture help you to get the correct alignment. Try to move the sensor so that both crosses match, tracking should then resume automatically.

If you are not able to resume tracking, you may start from the beginning or continue from the position where tracking got lost by starting a new sequence. Be aware that the new and the previous sequences are initially not linked to each other and that they have to be put in a spatial relationship in order to get a comprehensive point cloud. Therefore, make sure that there is enough overlap between them. For more information, see chapter 3.5.

2.5. Tracking Frames from Recorded Video Files

2.5.1. Settings

Before starting with tracking frames from a raw data video file, you may change the settings. Select **Tracking from File – Settings** from the drop down menu of the **Tracking from File** button in the SCENECT toolbar. The settings dialog will show up:

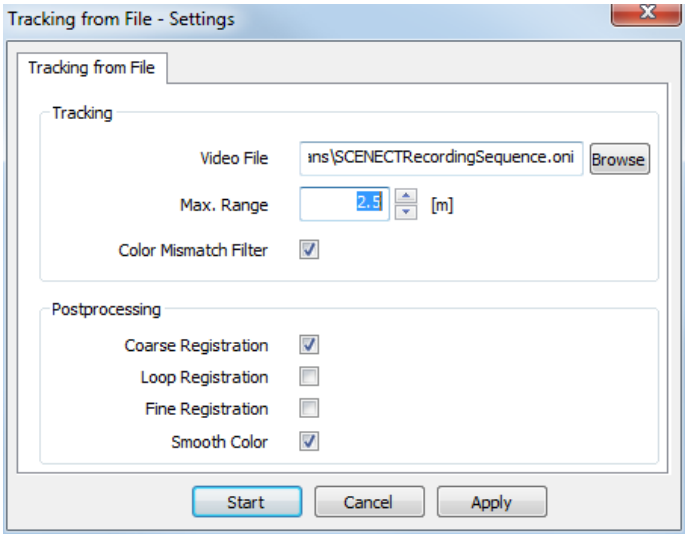

Figure 2-12: Tracking from file - Settings

Video File - Select the raw data video file that you would like to use for tracking the frames. SCENECT raw data video files have the file extension .oni and can usually be found in the *scans* folder of your scan project.

Max. Range / Color Mismatch Filter / Post processing Settings – same settings as for the live tracking. See chapter 2.4.1 for more information.

Start – Save your settings and start tracking from the selected file.

Cancel – Discard unsaved changes and close the settings dialog.

Apply – Save your changes. To close the settings dialog without starting tracking, press cancel afterwards.

2.5.2. Tracking from File

Start tracking from a video file with

- the **Tracking from File** button in the toolbar. You will be prompted to select a video file from your hard disk.
- the **Start** button in the **Tracking from File – Settings** dialog
- with **Operations ▸ Tracking from Sequence File** from the context menu of a sequence folder in the structure view (this will create a new sequence; the already available sequence will not be changed).

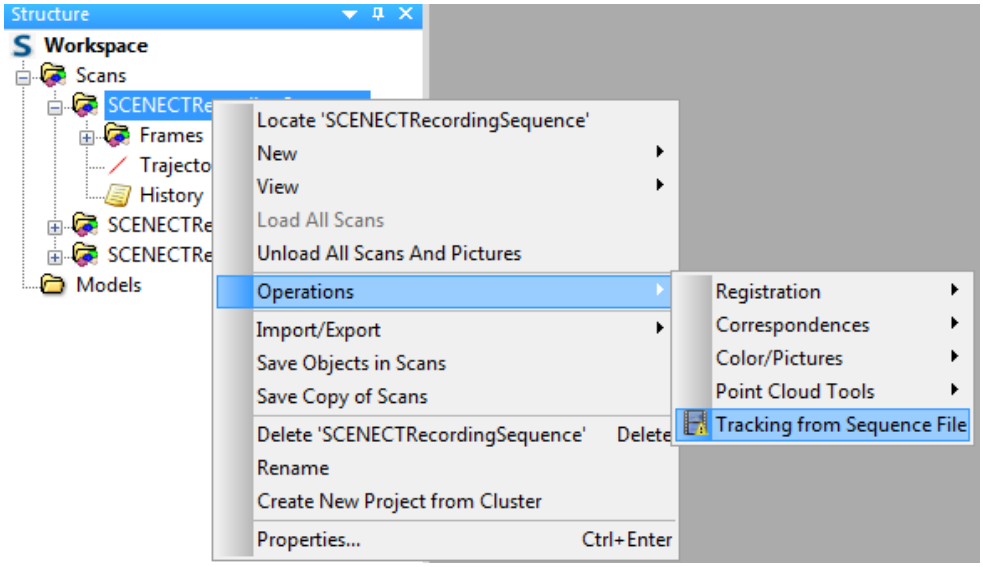

Figure 2-13: Tracking from file of an already available sequence

A new sequence with the name of the video file will be added to the workspace and the split window will show up with the point cloud on the left and the video picture on the right (see chapter 2.4.2 for more information). The video will be play backed on the screen and the frames will be tracked without user interaction.

You may test tracking from the demo video file which was installed with SCENECT and which is available under **C:\Users\YOUR_USER_NAME\Documents\FARO**. When tracking from the demo video file, you should set the maximum range to 1.8m.

2.6. Workspace Structure

Once the recording of a sequence is complete you will get the following structure in the project's workspace:

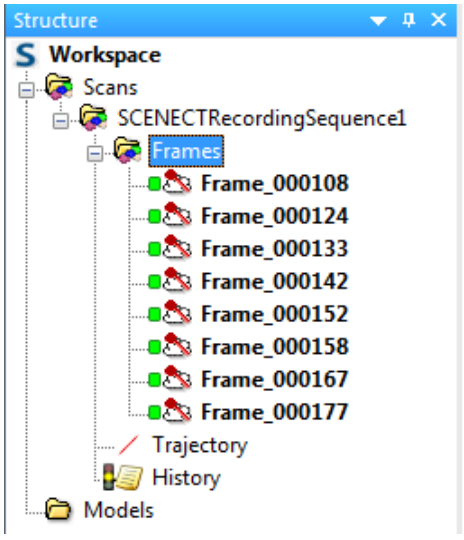

Figure 2-14: Workspace structure

Folder **Scans**: Contains all recorded sequences.

Sequence folder (here "SCENECTRecordingSequence1"): Contains all the frames, snapshots and other objects of a single sequence.

Folder **Frames**: contains all the captured key frames.

Folder **Snapshots**: Contains the snapshots.

Object **Trajectory**: represents the path of the recording device.

Documentation object **History**: Provides information about the sequence (for example, the recording duration, the number of key frames and recognized features, or the applied registration steps). A yellow traffic light indicates that frame-to-frame tracking might have been inaccurate during live tracking (mostly because of a low performance system used for recording). In this case it is recommended to re-track the frames from the recorded video file.

3. Post Processing

3.1. Viewing the Recorded Results

There are three view types to display the recorded data:

- **planar view**,
- **quick view**
- **3D view**.

While the planar view and the quick view are the views to examine single frames only, the 3D view is not limited to display the scan points of a single frame. It enables combined viewing of all the frames and objects in your project.

You may change the behavior and the look of the views in the visibility setting that are available by right-clicking into the view and selecting **Visibility Settings** from the context menu.

For more information on the available view types and their visibility settings, see chapter "Exploring Scan Data and Objects" in the SCENE manual or in the online help under **Help ▸ Contents**.

3.1.1. Viewing Frames with the Planar View and the Quick View

Single frames are best viewed and analyzed in the planar view but can also be displayed in the quick view or the 3D view.

To open the **planar view** of a frame, right-click it in the structure view and select **View ▸ Planar View** in the context menu.

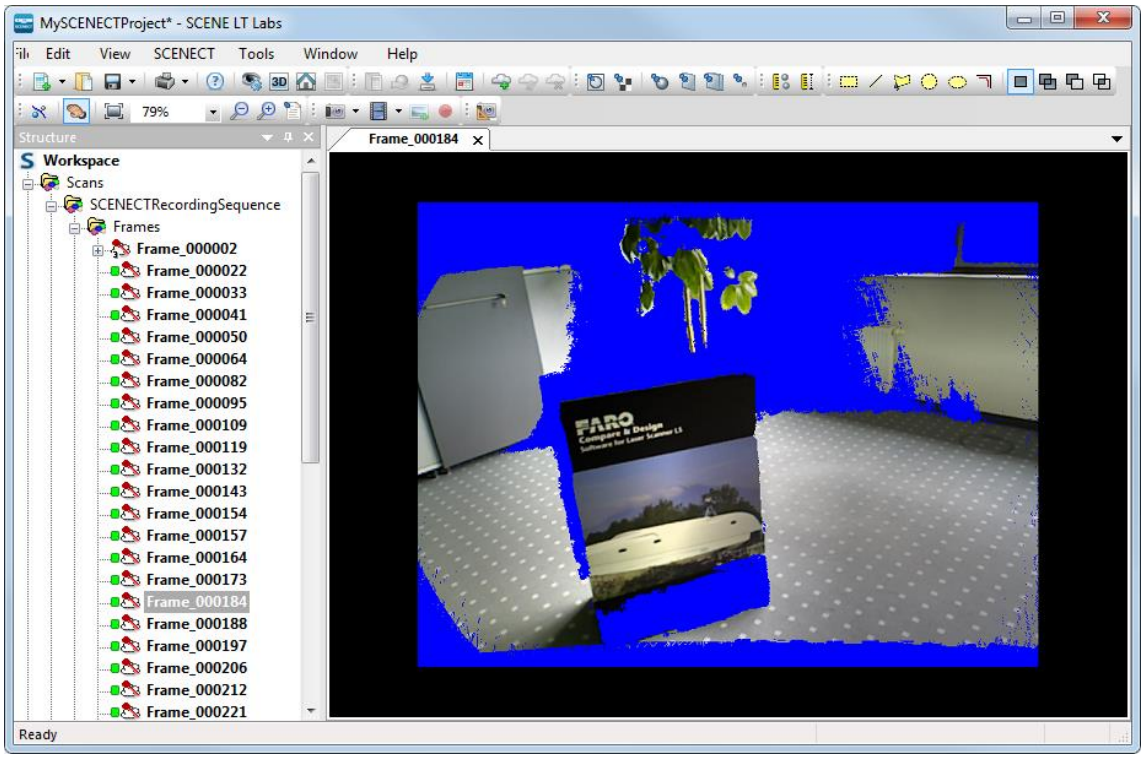

Figure 3-1: Planar view of a frame

Blue colored areas symbolize areas without scan points (areas where scan points have been removed by filters or areas without scan points due to limited range).

The planar view is mainly used to create reference objects. Reference objects are needed for the registration of two or more sequences. For more information, see chapter 3.5.

3.1.2. Viewing Scan Points with the 3D View

The 3D view is not only limited to display scan points of a single frame. It provides combined viewing of scan points of more than one frame, of an entire sequence or the entire workspace.

In the 3D view two types of scan points can be displayed:

- The scan points of the frames as they were recorded. They are organized in a row column order. Frames have to be explicitly loaded to the memory in order to be displayed in the 3D view.
- The scan points of so called scan point clouds which are an alternative representation of the scans and have to be created from the single scans. Scan point clouds are organized in a spatial data structure that facilitates fast visualization of scan points and automated point loading based on point visibility. The points of a scan point cloud do not have to be explicitly loaded into the memory in order to be displayed in the 3D view.

For visualization purposes it is recommended to create scan point clouds from the frames with **Operations ▸ Point Cloud Tools ▸ Create Scan Point Cloud(s)** from the context menu of a frame or a frames folder.

For more information on working with scan point clouds, see chapter "Working with Scan Point Clouds" in the SCENE manual or in the online help under **Help ▸ Contents.**

In the 3D view, the original points of the frames have priority over the points of scan point clouds, i.e. the points of **loaded** frames will be displayed instead of the points of the related scan point clouds. If you want to display and work with the points of the scan point clouds you must unload the frames first and if you want to display and work with the points of the frames you must load them into the memory.

Load frames into the memory with the command **Load all scans** in the context menu of the sequence folder or the frames folder. You may load / unload single frames by enabling / disabling the **Loaded** option in the context menu of the frames. Frames that are loaded into the memory have a green square in their icon in the structure view  .

Open the 3D view of a frame, sequence or the workspace with **View ▸ 3D View** in their context menu.

The 3D view is used just like the other views. In addition, in the 3D view you can position yourself at arbitrary positions in space and have a look at the scan points and CAD models. The mouse is used to define the turning movements you want to perform, and with the keyboard you define the actual movement in space. When you have selected the fly mode of the observer-based navigation  the cursor keys left, right, up, and down move you to the left, the right, forward, and downwards. The keys page-up and page-down move you up and down. In addition, you can press the shift key to accelerate movements. The walk mode of the observer-based navigation  is similar to the fly mode but the z-value cannot be changed by walking forward. The walk mode is e.g. very useful to limit movement to a level of a building.

When you have selected object-based navigation  , the cursor keys define how the objects move, whereas it appears you stand still. You can adjust the speed of the movement and the behavior of the mouse wheel under **Tools ▸ Options ▸ Navigation**. By default the rotation of the 3D view is stabilized by a locked Z-axis. Turn this behavior off under **Tools ▸ Options ▸ Tab Navigation ▸ Snap to Z-axis**. This results in an unlocked Z-axis and thus in a completely free rotation of the 3D view.

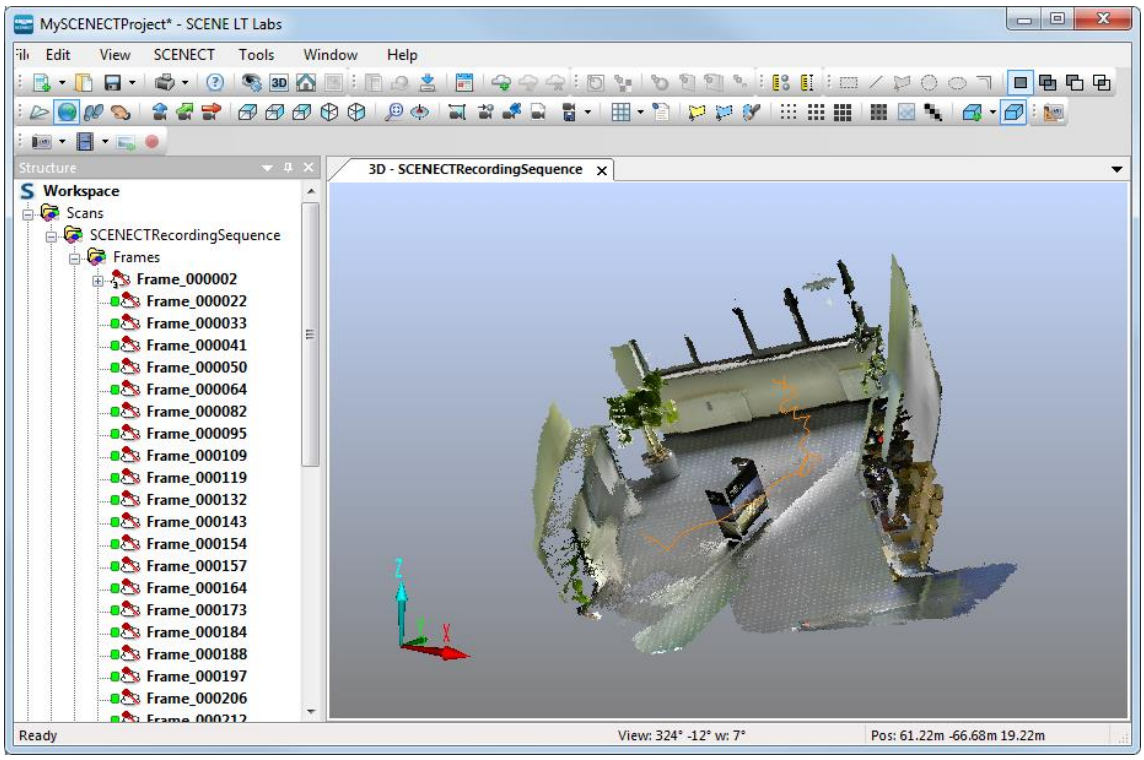

Figure 3-2: 3D view of a sequence

The orange line symbolizes the camera path (trajectory).

Recommended 3D view settings for displaying Kinect or Xtion scan points:

- Set the rotation point near the center of the captured scene: select from the 3D toolbar and click on a point in the 3D view to set the rotation point.
- SCENECT point clouds are best viewed with the object based navigation mode: Select in the 3D View toolbar.
- Use the smallest displayed scan point size: select in the 3D toolbar.
- Disable **gap filling**: deselect in the 3D toolbar.
- Hide the symbols for the sensor positions: right click in the 3D view and select **Visibility Settings** from the context menu. On tab **Extra** disable **Scan positions**.
- If the 3D view looks distorted switch to the orthographic view: right click in the 3D view and select **Camera ▸ Orthographic** from the context menu.
- •Disable **Snap to Z-Axis** under **Tools ▸ Options ▸ Navigation**.

For more information on navigating in the views and the available visibility settings, see chapter "Exploring Scan Data and Objects" in the SCENE manual or in the online help under **Help ▸ Contents**.

3.2. Applying Additional Registration Steps to the Frames of a Sequence

Coarse Registration, Loop Registration and Fine Registration have already been described in chapter 2.4.1. If they were not enabled in the tracking settings and thus not automatically applied after recording of a sequence you may apply them to the frames of the sequence at any time later. Apply them

- by selecting the sequence folder and executing the appropriate commands from the SCENECT menu
- or with **Operations ▸ Registration ▸ Coarse Registration / Loop Registration / Fine Registration** from the context menu of the sequence folder.

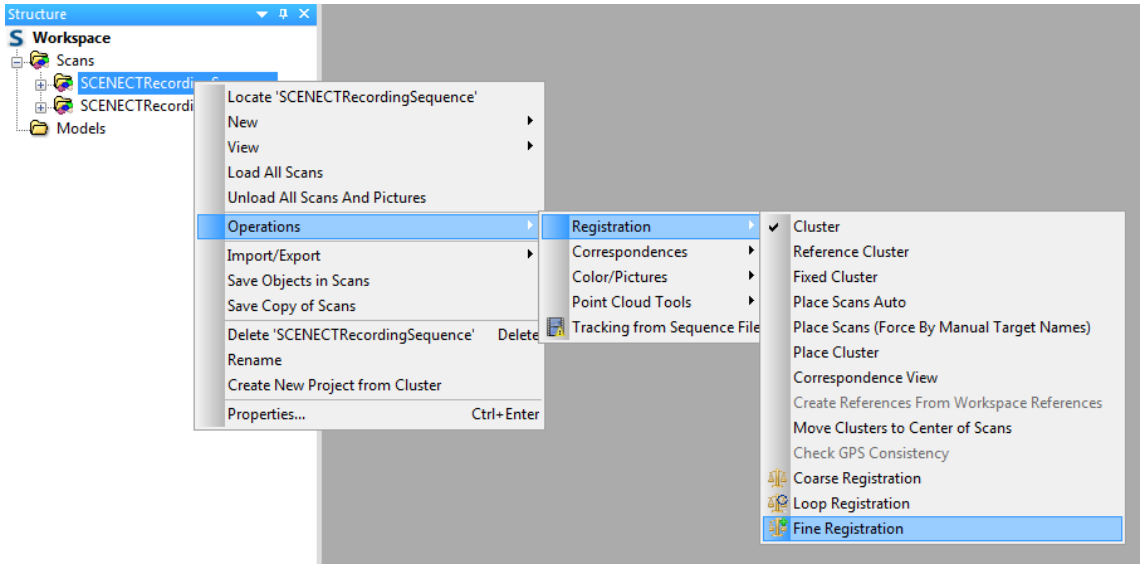

Figure 3-3: Apply additional registration steps

- Note: Fine registration should be applied to the sequence after coarse registration and loop registration.
- Fine registration does not always improve the registration of the frames. It is recommended to save your project before applying fine registration. If the results are not satisfactory you will then be able to discard the changes made by the fine registration.

3.3. Color Smoothing

Color Smoothing has already been described in chapter 2.4.1. If it was not enabled in the tracking settings and thus not automatically applied after recording of a sequence you may apply it to the frames of the sequence at any time later.

Apply color smoothing

- by selecting the sequence folder in the structure view and executing the appropriate command from the SCENECT menu
- or with **Operations ▸ Color / Pictures ▸ Smooth Color** from the context menu of the sequence folder.

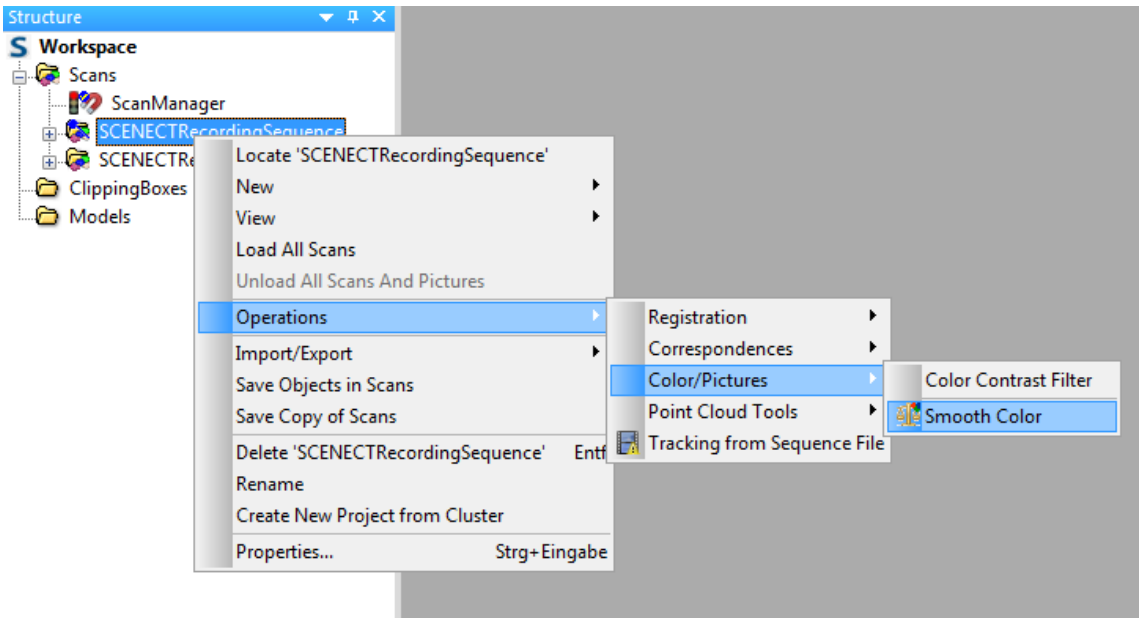

Figure 3-4: Apply color smoothing

Note: Color Smoothing should be applied to the sequence after coarse or loop registration.

3.4. Deleting Scan Points

You can modify scan points of your scan project by manually deleting unwanted scan points.

To delete the scan points open the 3D view of a sequence or the workspace and select the area to be deleted. Depending on the selection tool, you can select the points of the frames or the points of the scan point clouds (if available).

If you have used the polygonal selection tool to select the scan points from the frames ( ), right-click the point selection and select one of the available delete operations.

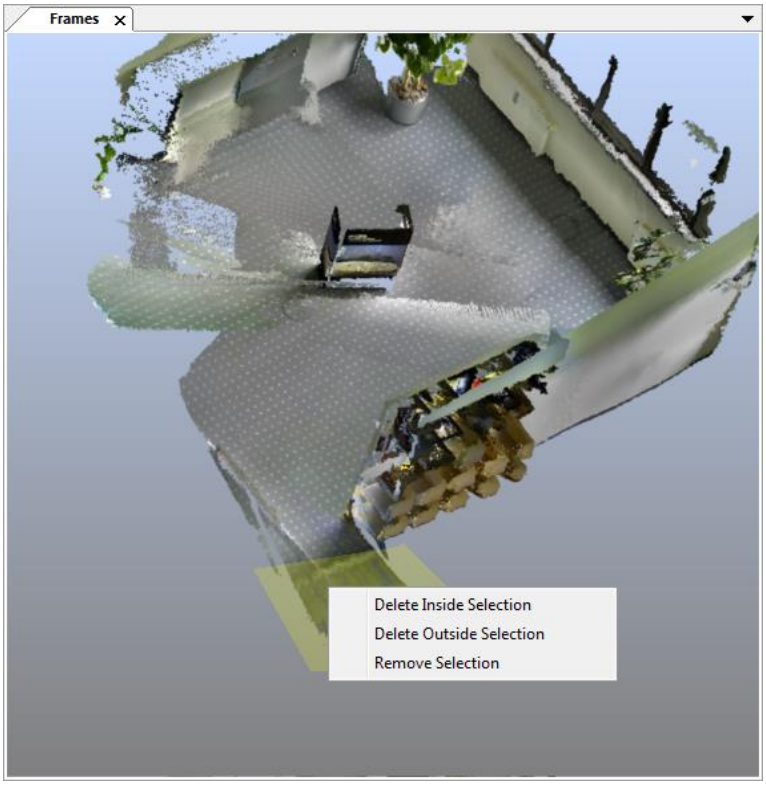

Figure 3-5: Delete operations on scan points of frames

If you used one of the selection tools to select points from the scan point clouds (or), right click the selection and use **Current Selection ▸ Delete** from the context menu.

Frames and scan point clouds are closely related to each other. Certain changes to the related frames will also have an effect on the scan point clouds and vice versa:

- The deletion of points in a scan point cloud will also be applied to the associated scan.
- When points are deleted or otherwise modified in the scan, the scan point cloud of this scan will be removed. If the scan point cloud is part of the shared data of a scan project, it will be automatically recreated after the next sharing (when working on a local workspace) or saving (when working on the scan project). To apply point modifications in a scan to the scan point cloud without sharing, when working on a local workspace, recreate the scan point cloud manually.

Please note that frames have to be loaded in order to apply delete commands to their points and they have to be unloaded in order to apply delete commands to the points of the corresponding scan point clouds. For more information, see chapter 3.1.2 or the online help under **Help ▸ Contents**

Delete operations can also be applied to the points of the project point cloud (if available). For more information, please see chapter 3.6.

3.5. Registering Sequences

The key frames within a sequence are aligned to each other when they are recorded, which means that the spatial relationship between them is initially known.

If you have several sequences in your workspace, the spatial relationship between these sequences is initially unknown; every sequence only knows its own coordinate system. By registering two or more sequences the spatial relationship between them will be determined and they will be merged into a single coordinate system. Each sequence (and their key frames) is placed in a correct spatial relationship with the other sequences.

Registering may be done manually with the correspondence view or automatically by means of reference objects like planes or distinctive points that are common in the different sequences. These reference objects have to be created from the data of selected key frames in each sequence. Given that there is enough overlap and that there are enough corresponding targets in the sequences which you would like to register, registration should be possible.

If you open a 3D view of your workspace (select **View ▸ 3D View** from the context menu of the workspace in the structure view) you will see that the position of the recorded sequences does not initially match.

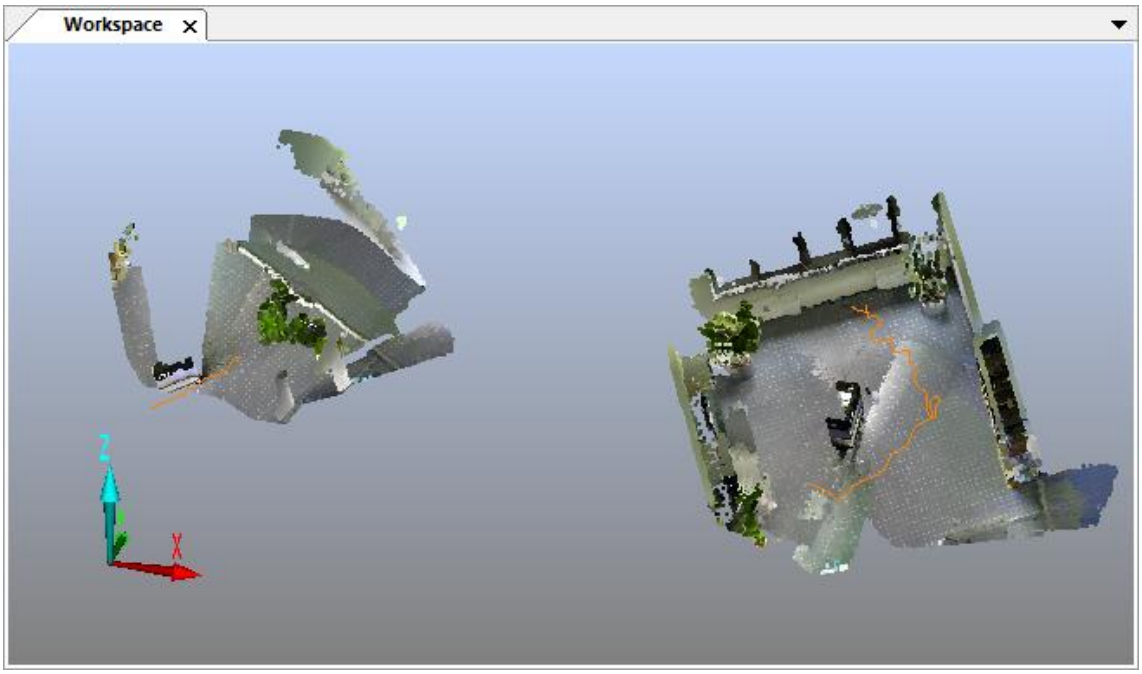

Figure 3-6: Not registered sequences in 3D view

This manual will not describe registration in detail. It will describe the standard way of registering sequences recorded with the Kinect or the Xtion. For detailed information about registration you should have a look at chapter "Registering Scans" in the SCENE manual.

3.5.1. Registration with Reference Objects

As already mentioned, you need reference objects (also called references or reference objects) that are common in the two sequences which you would like to register. These reference objects have to be manually extracted from the point data of the recorded key frames. If there are at least 3 corresponding reference objects between the two sequences you would like to register, it is mathematically sufficient to calculate their spatial relationship; 3 is the mathematical minimum but a greater number may improve registration results.

Reference object types which can be used to register sequences recorded with the Kinect or the ASUS Xtion are natural references, such as planes, slabs, pipes, corner points or other distinctive points.

Natural references should meet the following requirements:

- They should be easily and clearly visible in the frames.
- Do not use references with symmetric positions or on a plane (vary elevation).
- Avoid a linear reference alignment.
- References must be included in more than one sequence. A reference which is only available in one sequence is useless for registration.
- The distance between references should not be smaller than 1m.
- The distance between reference and sensor should not be too large.
- Generally, point references are more reliable than planes, slabs or pipes.

To create reference objects follow the steps below:

1. In case there are sequences in the **Scans** folder that should not be registered with the other sequences, remove them from the Scans folder, e.g. by moving them into another folder that is not a child of the Scans folder.
2. Pick key frames (frames recorded from the overlapping area of the two sequences) with common reference objects from each sequence.

- The 3D view of each sequence (open it with **View ▸ 3D View** in the context menu of the sequence folder) is a good tool to find key frames with overlapping areas. Selecting a key frame in the structure view will highlight its points in the corresponding 3D view and might help to identify key frames with overlapping areas in the different sequences.
- Select key frames with small distances between reference object and sensor.

3. Open the planar view or the quick view of the selected key frames: select **View ▸ Planar View** or **View ▸ Quick View** from the context menu of the frame (objects cannot be created in the 3D view).
4. The reference objects must be extracted from the data by selecting the relevant points in the view and performing an object fit. To do this, identify and mark the area in the key frame that contains the selected reference object and determine the object type to be created. There are two ways to mark the relevant scan points and create reference objects: with the object marker tool or from a selection of scan points:

- With the **object marker**:
  - First select the object type you want to create from the object marker tool bar:

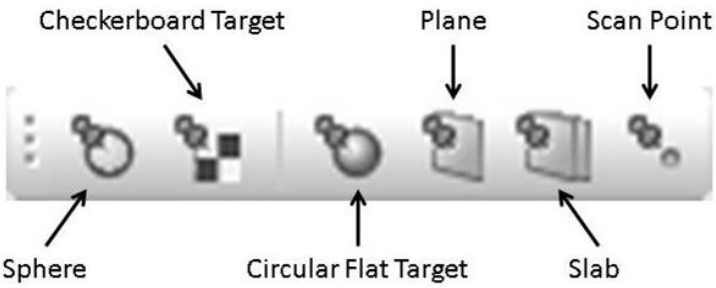

Figure 3-7: Object marker tool bar

  - For recordings made with SCENECT, recommended object types are natural targets like planes, slabs or points. Spheres, checkerboard or circular flat targets are artificial targets manually placed into the scan environment. They are commonly used in scan projects done with high resolution scanners.

- Once the object type is selected, click on the apropriate point(s) in the planar or quick view of the frame. The object will then be automatically extracted from the point data.

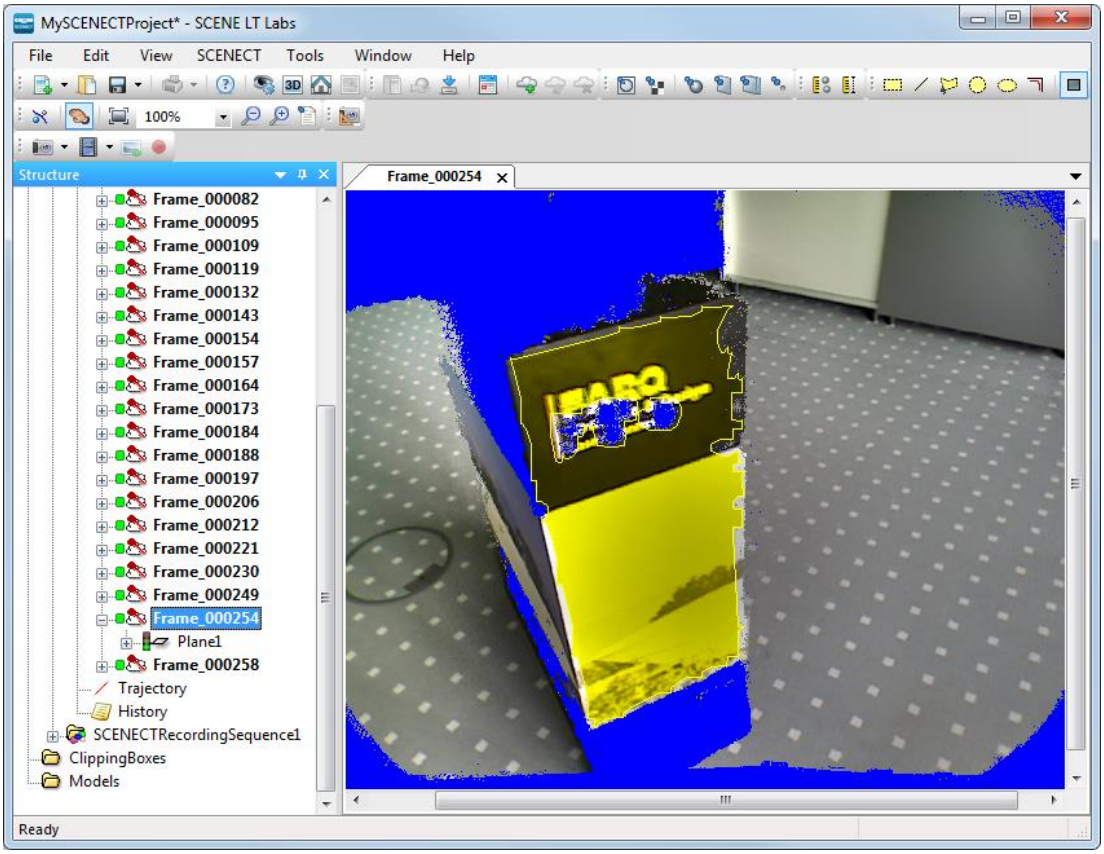

Figure 3-8: Plane fitted with the object marker tool

- From a **selection of scan points**:
  - First select a selection tool from the selection tool bar:

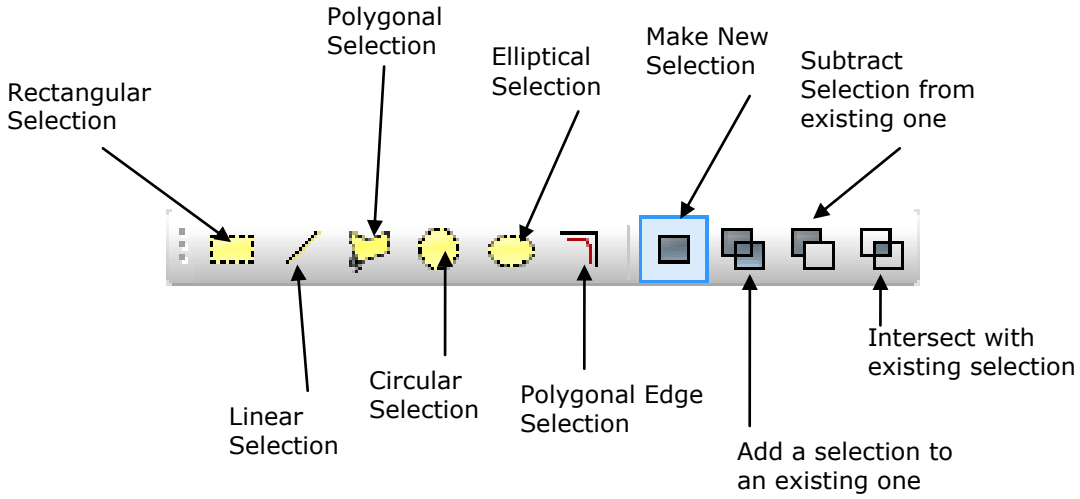

Figure 3-9: Selection Tool Bar

- Once the selection tool is selected, mark the points of interest in the planar or quick view.

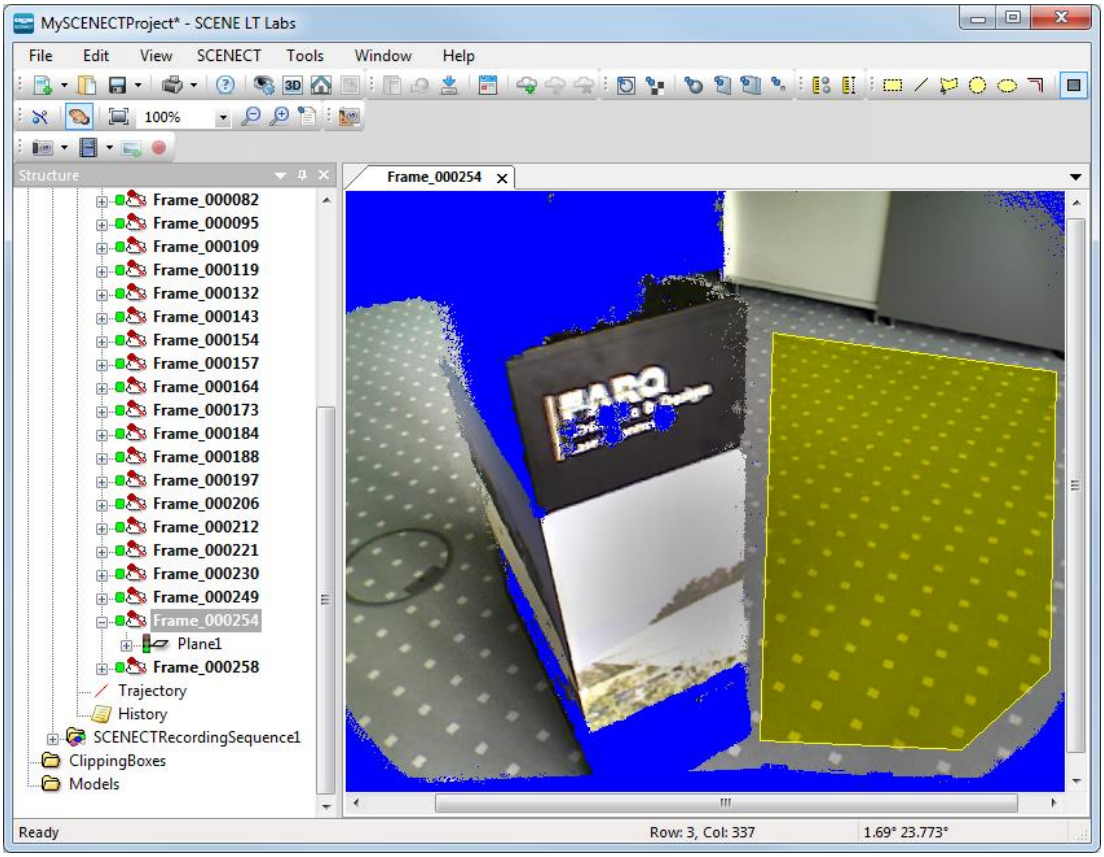

Figure 3-10: Polygon selection made to fit a plane on the floor

- Then let SCENECT fit the object from the point selection: Right click on the selection in the view, select **Create Objects** from the context menu and the object type you want to create.

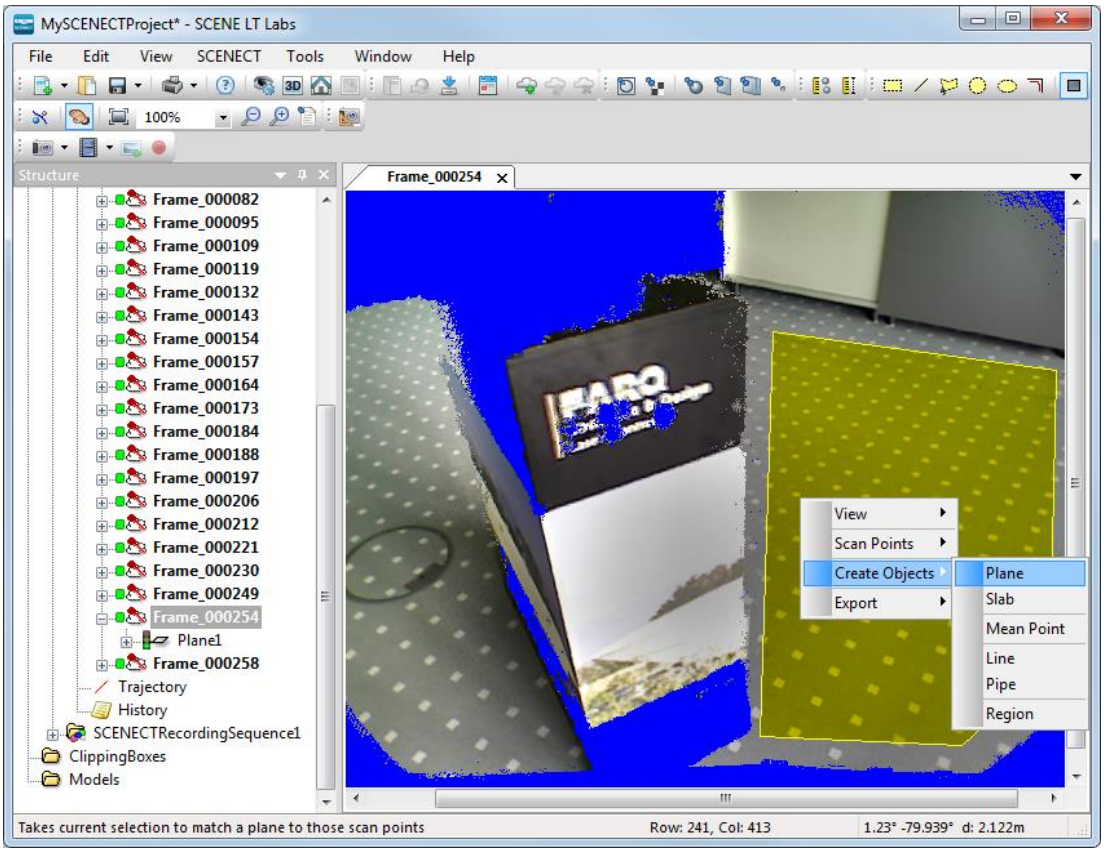

Figure 3-11: Create a plane from the selection

- Repeat this step for other objects until you have enough corresponding reference objects in the sequences.

5. The created reference objects will be added to the workspace. They are available as a child of the corresponding frame:

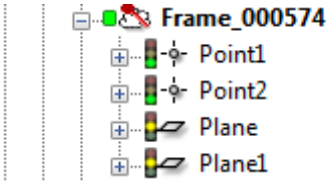

Figure 3-12: fit objects in structure view

The quality of the object fit is symbolized by the traffic light. Green means that all the quality criteria are met. The Amber shows that at least one quality criterion is somewhat compromised and red means that at least one criterion is seriously compromised. If the fit of your objects shows a red traffic light you may try the following:

- Delete the object and try another fit with a new point selection.
- Try to find the same reference object in another frame of the same sequence and try to create it in this frame. Maybe there are frames with smaller object to sensor distances.
- Try to find other reference objects and use them for registration instead.

6. Once enough reference objects have been fitted in all the sequences to be registered, you can start the registration process: Right-click the *Scans* folder and select **Operations ▸ Registration ▸ Place Scans Auto** from the context menu.

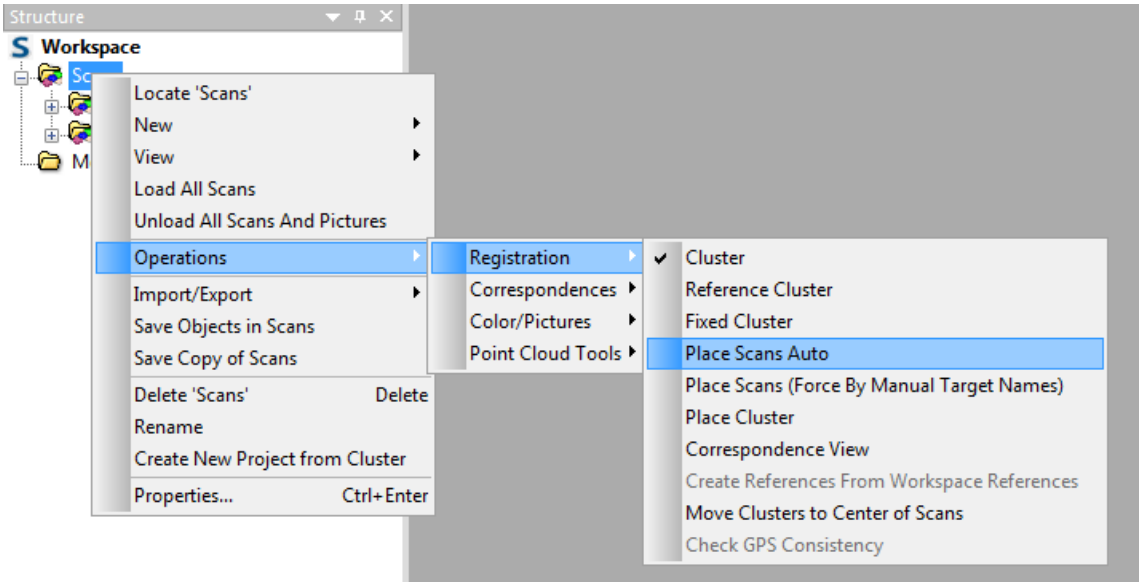

Figure 3-13: Place scans auto

7. After a short computation, registration should be complete. The quality of the registration results may be checked in

- the scan manager that is now available in the workspace under the scans folder
- the 3D view of the workspace or the scans folder.

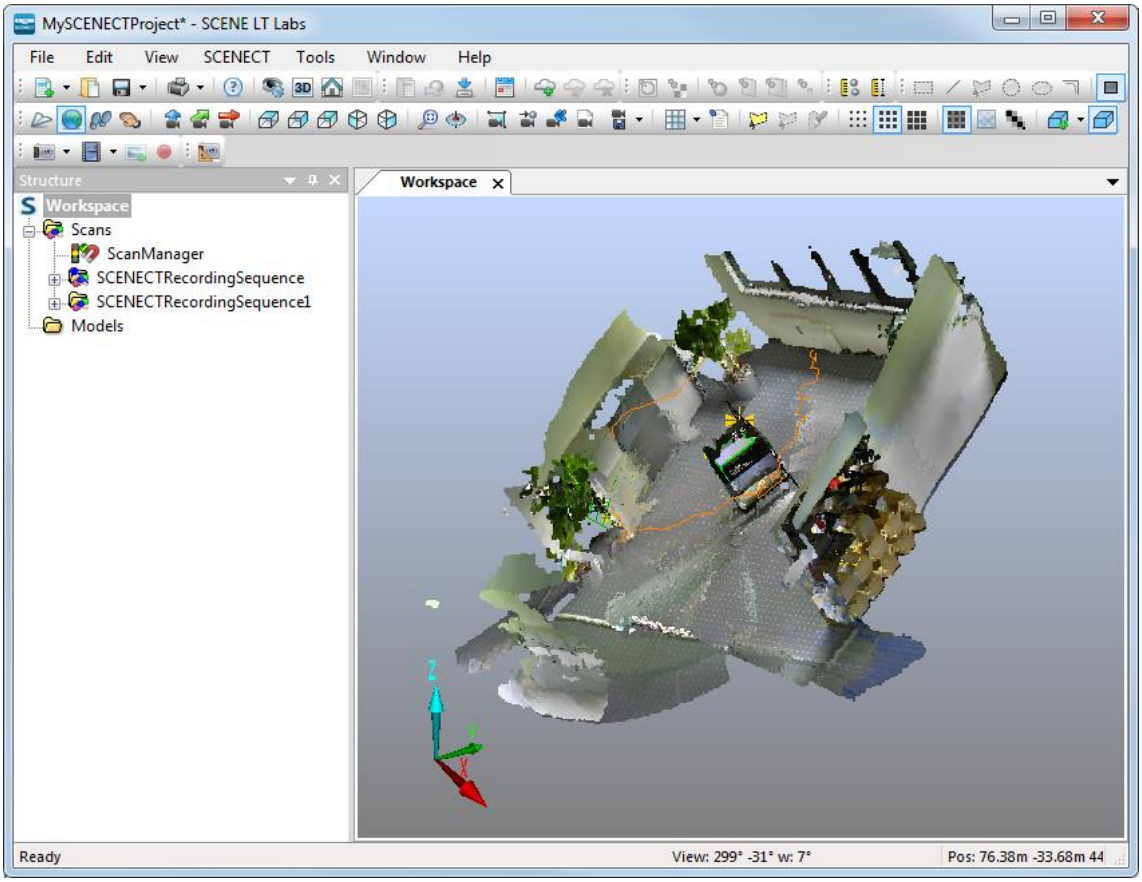

Figure 3-14: Registered sequences in 3D view

If registration is not good enough or failed you may try the following:

- Check and improve the fit quality of your objects as described above.
- Check whether sufficient reference objects have been found as corresponding in the different sequences. Reference objects with correspondence relationships to other references are marked with a C in their icon in the structure view. E.g. .
- You should have at least four or five corresponding reference objects between sequences. A higher number may improve the results.
- Generally, correspondences between point references are more reliable than between planes, slabs or pipes.
- You might have to decrease the quality criteria for the detection of corresponding reference pairs. Go to **Tools ▸ Options ▸ Matching ▸ Place Scans Settings** and move the slider in the dialog to the left. Apply registration again afterwards.

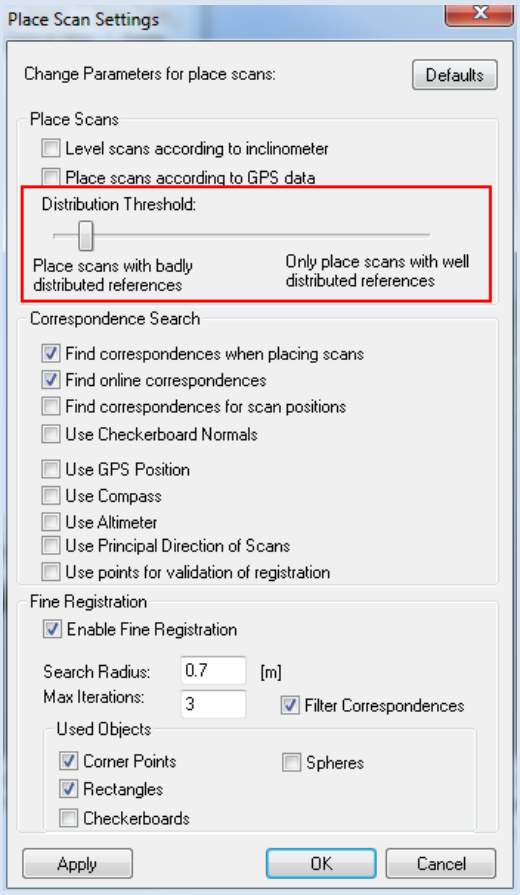

Figure 3-15: Place scans settings

- Make sure that **Find correspondences when placing scans** is enabled in the place scans settings (see screenshot above).
- If correspondences between reference objects are not automatically found you may try to manually create (or force) correspondences between the reference objects. Basically, there are two ways to manually create a correspondence between references:
  - Manually name the reference objects in a sequence according to their counterparts in the other sequences. You can rename objects in their properties dialog on tab **General** (open the properties dialog by selecting **Properties** in the context menu of the object). This forces correspondences between identical named reference objects. Then use the registration command **Operations ▸ Registration ▸ Place Scans (Force by Manual Target Names)** in the context menu of the scan folder which forces correspondences by name.
  - Arrange the sequence in the correspondence view, so that its references are positioned next to their counterparts in the other sequences. Then update the correspondences. This will create correspondences between the neighboring references. For more information, see chapter 3.5.2.
- To identify problematic target pairs you may have a look at the Scan Manager or the Correspondence View.
- If two objects are found to be corresponding, but in reality they aren't, you may mark their correspondence relationship as wrong in the Scan Manager. Correspondences marked as wrong are named "anti-correspondence".
- If you have applied one or more of the above mentioned improvements , you can reapply registration with **Operations ▸ Registration ▸ Place Scans Auto**.

- If automatic registration failed or did not deliver satisfying results you may also try to manually place the sequences with the correspondence view. For more information, see chapter 3.5.2.

For more information on the correspondence view, please see chapter "Registering Scans" in the SCENE manual.

3.5.2. Correspondence View

The correspondence view is a tool that enables manual placement and registration of sequences in an easy way if automatic registration fails. In the correspondence view you can manually move and rotate sequences so that they are correctly aligned to each other.

Open the correspondence view with **View ▸ Correspondence View** in the context menu of the *Scans* folder that contains the sequences you would like to register.

In the correspondence view, the scan points of a sequence are displayed in unique colors to distinguish between the different sequences.

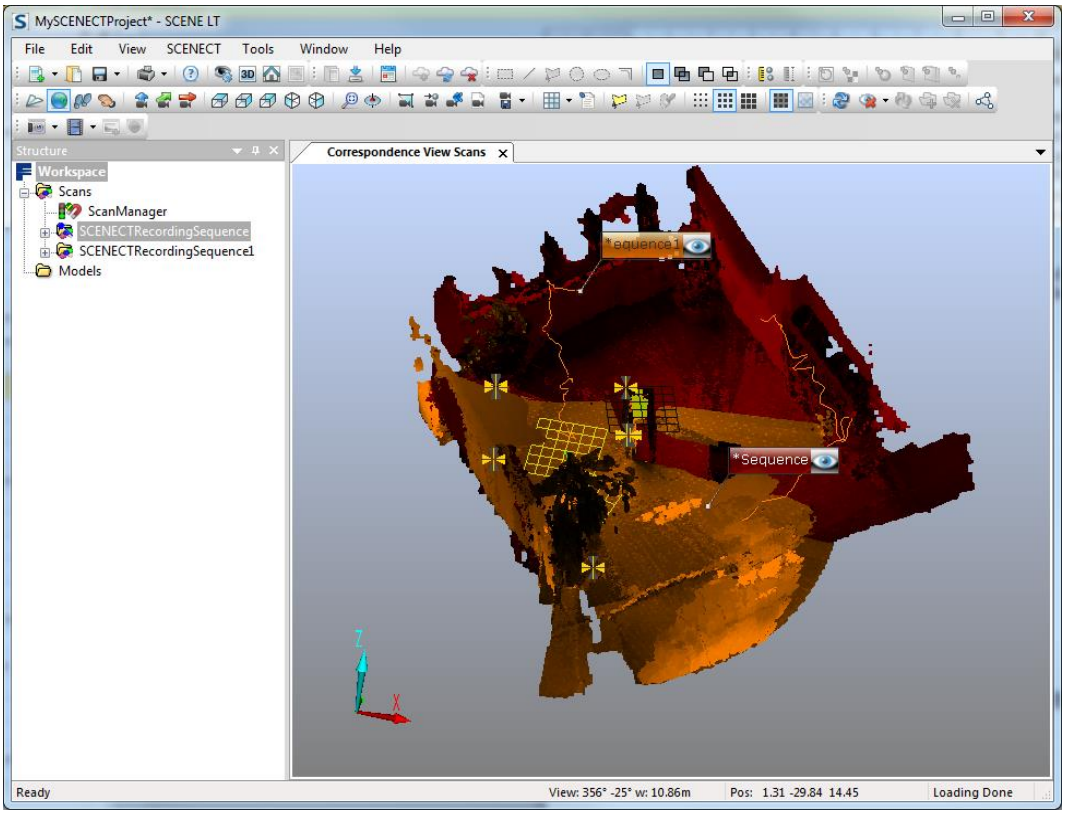

Figure 3-16: Correspondence view

Labels allow easy identification of individual sequences. Clicking the label will select the related sequence. When clicking the symbol on the right of the label, the sequence gets excluded (invisible) or included (visible).

To move or rotate a sequence, select it in the structure view or click on its label. The manipulator tool which allows moving and rotating the sequence will show up.

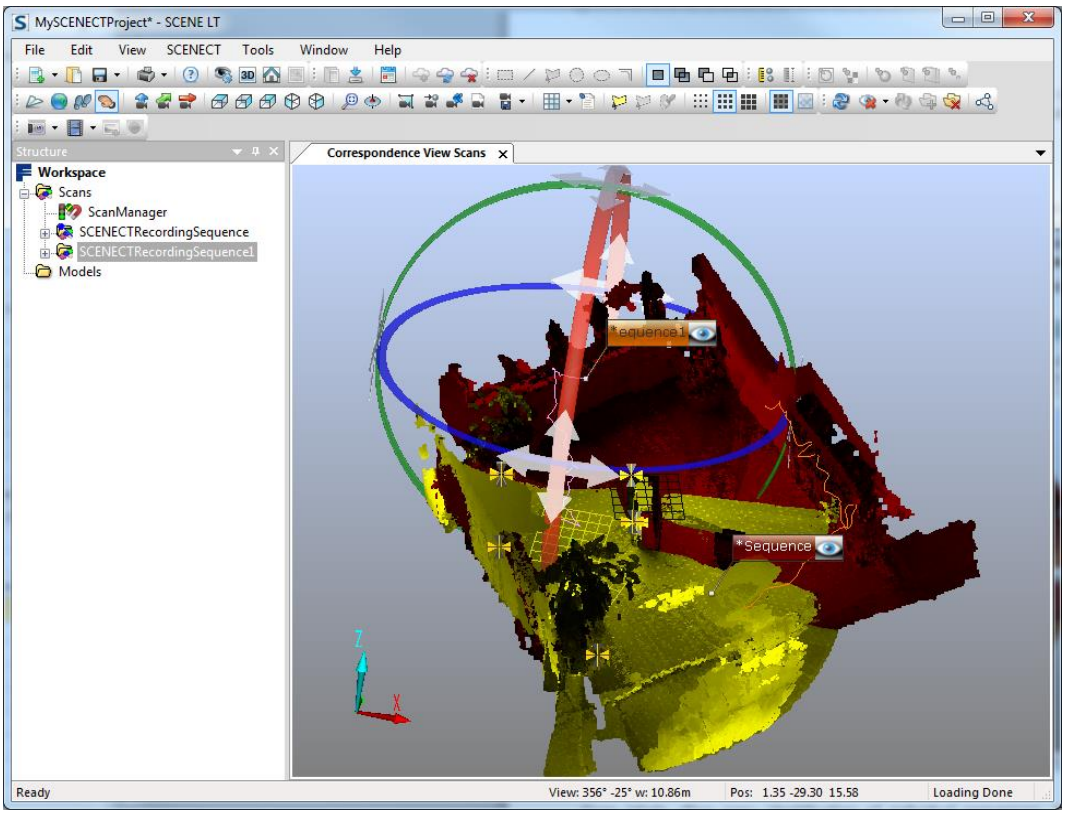

Figure 3-17: Correspondence view with manipulator

The manipulator tool consists of move- and rotate-handles. Clicking on a move handle (white arrows) and dragging it will move the sequence within two dimensions. The two dimensions depend on which move handle was clicked. Clicking and dragging a rotate-handle (red, green or blue circle lines) will rotate the sequence around the corresponding axis.

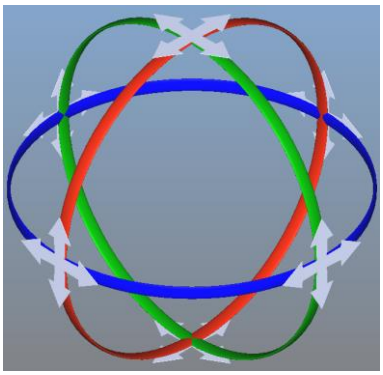

Figure 3-18: A manipulator with rotate handles (red, green, blue) and move-handles (white)

There are three buttons that allow correction of wrong manipulations:

- The button **restore previous transformation** can be used to move the sequence back to the previous location.
- The button **reapply transformation change** is used to reapply a transformation, which was reverted.
- The button **restore initial transformation** finally restores the initial transformation the sequence had when the manipulator was created.

These buttons are available in the correspondence view toolbar and also in a flying toolbar that appears after every manipulation.

- Manipulators can be resized via the "+" and "-" keys on your keyboard or the and buttons of the correspondence view toolbar.
- It is easier to use the manipulators while looking at the scene from the top, right or back, using the buttons in the 3D View toolbar.
- Don't forget to manipulate the level of the sequence, too. This is done best when looking on the scene from the side.
- Please note that deselecting a sequence will cause the manipulator to disappear and clear all previous transformations.

In the correspondence view all corresponding objects are connected by colored lines. To visualize these correspondences you can drag a sequence away from the others using the manipulator. To move the sequence back in place, simply use the **restore previous transformation** button.

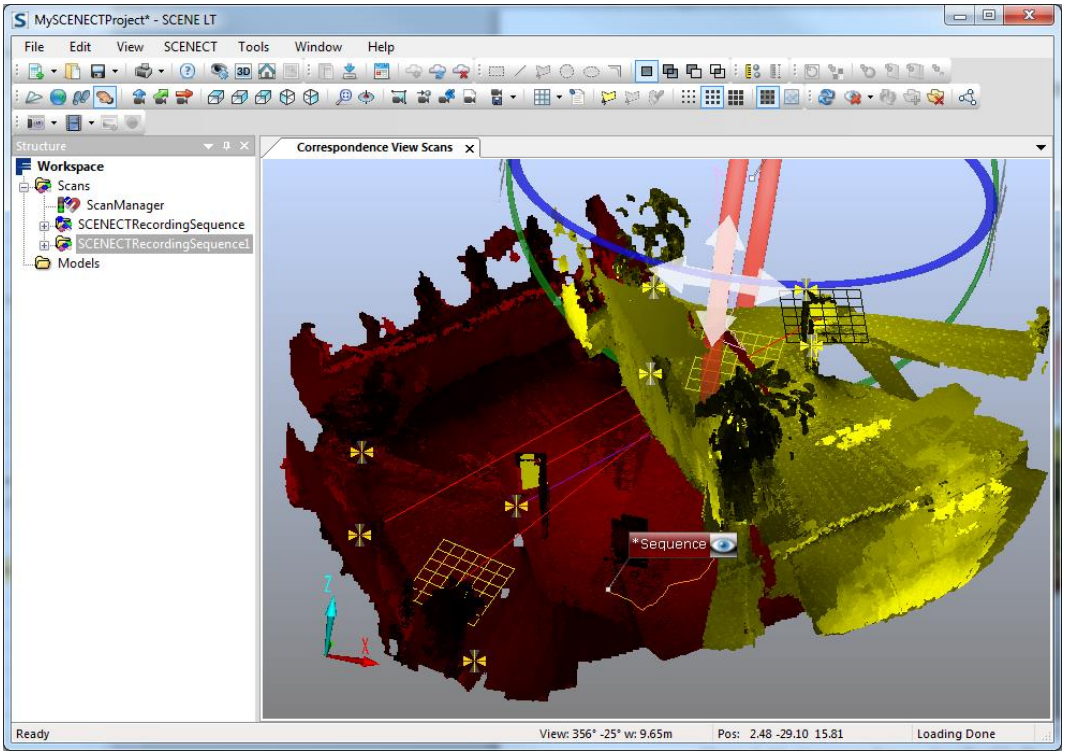

Figure 3-19: Correspondences visualized by lines.

If you think that the sequences are in their right place, you may confirm their placement with the **Update** button . Confirming the placement will start a special correspondence search between near references. All of the sequence's old correspondences will be removed in this step. The newly detected correspondences will get forced afterwards. Please note that the update button only confirms the correspondences to near references, not the placement of the sequence itself.

The update button will search correspondences for all selected sequences. Using update with no sequence selected will use all included (visible) sequences for correspondence search. Excluded (invisible) sequences are always ignored in this type of correspondence search.

When using the update button to evaluate correspondences, verify the results afterwards by checking the correspondence lines. The number of found correspondences is also displayed in the status bar after clicking the update button.

If no or not enough correspondences are found, check these common errors:

- Sequences aren't placed properly by level. This can be checked by using a viewpoint from the side.
- Sequence placement wasn't precise enough. Try placing the sequences more precisely.
- Sequences don't have enough references in the overlapping area. Open a planar or a quick view and identify additional references.
- Sequences don't have an overlapping area. Use additional sequences to fill the missing gaps between them.

When the sequences are placed in their right position and the correspondences have been updated, apply registration with the button in the correspondence toolbar or with **Operations ▸ Registration ▸ Place Scan(s)** in the context menu of the scan folder.

It is **strongly recommended** to use the update button before starting registration to confirm and force correspondences with the current placement. Without using update, the registration will completely ignore the current positions of the sequences and may mix up their manual placement.

When closing the correspondence view after at least one registration was performed, a message box may appear and ask whether to force all correspondences. Answer with Yes if the result of the registration was satisfying to fix the correspondences.

For more information on the correspondence view, please see chapter "Registering Scans" in the SCENE manual.

3.6. Creating a Project Point Cloud

The project point cloud consists of the 3D points of all the sequences within your workspace and can be seen as a comprehensive 3D point cloud of your complete scan project. The project point cloud is typically created from all the single frames in your project after they have been processed and the sequences have been registered.

The project point cloud is optimized for fast visualization of large amounts of scan points in the 3D view and is organized in a spatial data structure that facilitates fast visualization of the scan points. The amount of points in a project point cloud can be enormous. Unlike single frames, such large amounts of points cannot always be loaded into physical memory at once. Therefore, the points of the project point cloud are automatically loaded and visualized on demand based on the camera position and point visibility.

Create the project point cloud with the button in the project toolbar or under **File ▸ Scan Project ▸ Create Project Point Cloud**. This settings dialog will show up:

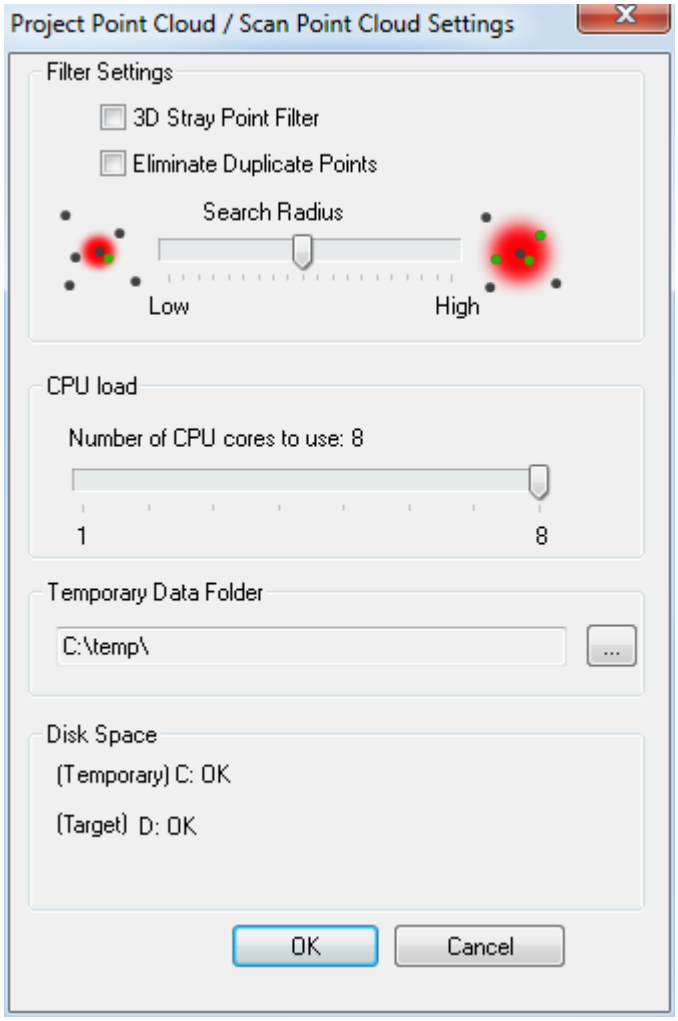

Figure 3-20: Create project point cloud

For the creation of the project point cloud two point filters are available. Each of these filters will reduce the overall point count by eliminating different types of unwanted points.

3D Stray Point Filter - The 3D stray point filter removes stray points from the project point cloud, creating a cleaner overall look.

Eliminate Duplicate Points - The filter removes duplicate points that exist in overlapping areas between the frames. These overlapping areas can be optimized by removing some of the duplicate points. This filter can improve the visual quality of your project point cloud significantly while reducing overall point count and therefore improving interactivity and loading times of the point cloud. With the search radius slider you can adjust the distance threshold for point elimination. The default setting should be sufficient for almost all scenarios. Adjust the search radius slider to the right to enlarge the search radius and increase the number of eliminated points. This may help to reduce point count when your registration is not very accurate. Adjust the search radius slider to the left to reduce the number of eliminated points. This can be useful if too many points have been deleted by this filter in previous point cloud iterations.

CPU Load - The slider allows adjusting the number of (logical) CPU cores used for parallel computation throughout certain steps of the point cloud creation process. The more cores are used, the sooner the point cloud creation may be finished. Please note that less performance is available for other programs running on the machine when increasing the number of CPU cores.

Temporary Data Folder – While point cloud creation all frames in the project will be loaded successively; their point data will be processed and transformed into a temporary representation. This temporary data will be stored inside the temporary data folder. Please do not delete, move or copy any of these files during point cloud creation or the process might fail. The temporary data will be deleted automatically once the process is complete.

Click **OK** to start the creation. Depending on the size of your project, this might take up some time.

Once the point cloud has been created, you can view it by opening the 3D view of the workspace (**View ▸ 3D View** in context menu of the workspace or by clicking the 3D button in the standard toolbar).

For more information on the project point cloud, please see chapter "Working with the Project Point Cloud" in the SCENE manual.

3.7. Analyzing the Scanning Results

There are several possibilities to analyze the scanned reality in SCENECT:

- You can use the 3D view to compare the scanned reality with existing CAD models.
- You can measure distances between objects and points.
- You can visualize distances and scales in the 3D view.

For more information, please see chapter "Analyzing Scan Points" in the SCENE manual or in the online help under **Help ▸ Contents**.

3.8. Exporting

You may export the recorded points from the sequences into different file formats in order to use them in other applications such as CAD systems. The following formats are available: E57, VRML, DXF, XYZ text, XYZ binary, IGES, PTS, PTX, PTC and POD (Pointools).

To export the points of a sequence right click on the sequence folder or on the Scans folder and select **Import / Export ▸ Export Scan Points** from the context menu. A dialog will show up to select the target file format.

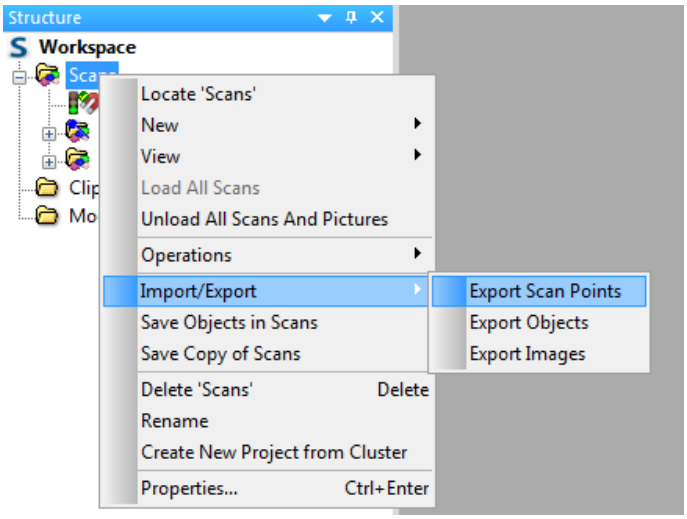

Figure 3-21: Export scan points

For more information on exporting scan points and the available file formats, please see chapter "Exporting Scan Points" in the SCENE manual or in the online help under **Help ▸ Contents**.

4. Calibrating the Sensor

It is recommended to calibrate your sensor device at least once before using it with SCENECT. Calibration might increase tracking quality and color accuracy of you sensor device. SCENECT calibrates the color camera of the sensor device.

Follow the steps below to calibrateyour sensor:

1. Attach the sensor to the USB port of your computer.
2. Open SCENECT
3. Open a project
4. Print the calibration pattern needed for the sensor calibration:

   Open it in the SCENECT menu under **Calibration ▸ Print Pattern A4 / Print Pattern USLetter**. Choose one of the two available formats. Make sure not to scale the pattern when printing (in the Adobe Reader settings set **Page Scale** to **none**).
5. Put the printed pattern on a flat surface, e.g. the desk, and fix it with adhesive tape.
6. Take your sensor and start calibration with **Calibration ▸ Start** from the SCENECT menu. A window with the video picture of the sensor and a progress dialog will show up.
7. Take 30 images of the pattern from different positions: **It is important to take pictures from the pattern from different distances, orientations and positions. Vary as much as possible**. Whenever the video picture is shown in color and colored lines are visible, the pattern is detected and SCENECT is ready to take an image.

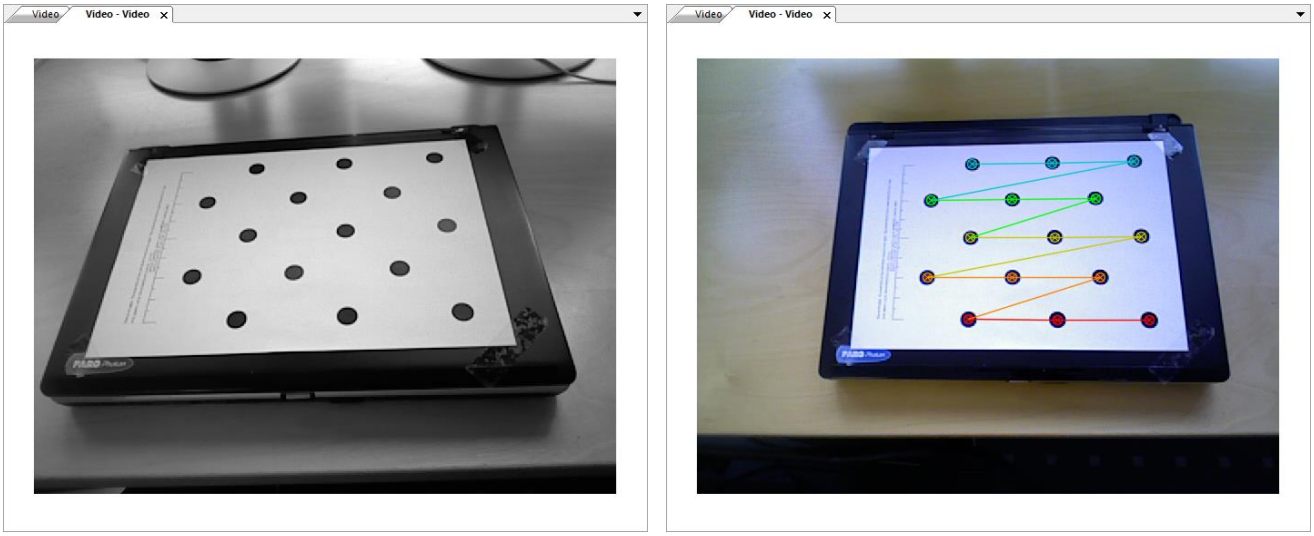

Figure 4-1: Left: pattern not detected. Right: pattern detected, ready to take an image

8. Press **F7** to take an image. Try not to move the sensor while taking the image.
9. After the last image, calibration will be calculated.

If you have more than one sensor device, calibrate each device. When recording, SCENECT will recognize the connected sensor and apply the appropriate calibration.

5. Hints & Tips

- After plugging in the Xtion or Kinect wait until the computer has detected the device. If scanning starts too early, initialization of the device may fail.
- If the drivers for the Kinect or the ASUS were already installed on your system and the devices are not recognized by SCENECT, you should uninstall the drivers and re-install them by executing the SCENECT setup.
- The Microsoft Kinect and the ASUS Xtion might not work on some USB 3.0 ports. If the device is not recognized by your system when plugging into a USB 3.0 port, plug it into a USB 2.0 port of your computer. USB 3.0 ports can be identified by their blue connector.
- When using a notebook in battery mode: Set the power management of your system to maximum performance.
- If you have many sequences in the workspace, unload some of them to reduce memory consumption.

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Apache

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