PST

Instruction Manual

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Rev. 7.0.0-0-gc6c5a57

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Contents

1 Item check list

Check that all of the following items have been included with your PST. If anything is missing, contact PS-Tech or your supplier.

The PST Iris (HD) package contains:

- PST Iris (HD) unit
- One coordinate reference card
- Power adapter
- Power cable (European)
- USB 2.0 cable (only for the standard PST)
- Set of 10 mm retro-reflective markers

The PST Base (HD) package contains:

- PST Base (HD) unit
- One coordinate reference card
- Power adapter
- Power cable (European)
- USB 2.0 cable (only for the standard PST)
- Set of 7 mm retro-reflective markers

A multi-PST order comes with additional items:

- BNC cable (one for each PST unit)
- Registration device (one per order)

A PST Pico package contains:

- PST Pico unit
- One coordinate reference card
- Power adapter (including 4 interchangeable AC plugs)
- Set of 10 mm retro-reflective markers

These items can also be purchased separately.

2 Operating and safety precautions

2.1 Operating conditions

- Use the PST in AC grounded power sockets:
  PST Iris and PST Base: 100-240 VAC, 1.0 A, 50-60 Hz
  PST Pico: 90-264 VAC, 0.5 A, 47-63 Hz
- Environmental conditions:
  +15 °C ~+35 °C, 20% ~80% RH

2.2 Handling precautions

- The PST is a precision instrument. Do not drop it or subject it to physical shock.
- The PST is not water resistant and cannot be used underwater or be exposed to moisture.
- Do not use or store the PST near heat sources such as ovens or direct sunlight. High temperatures can damage the system or cause inaccurate measurements.
- Never attempt to open the casing of the PST, remove any of its components, or disassemble the PST. Opening the PST can cause damage to the internal electronic circuitry and will void your warranty.
- Never use or store the tracker near anything having a strong magnetic field or emitting strong radio waves, such as magnets or antennas. Strong magnetic fields can cause measurement errors or malfunctions.
- To reduce tracking inaccuracies, avoid using the PST in a place that receives direct sunlight.
- If the PST is not used for a long time, unplug it and store it in a cool, dry, well-ventilated location.
- Do not scratch or otherwise damage the front windows of the PST Iris or Base. A scratched or damaged front window may cause measurement inaccuracies. Clean only with a very soft dry or lightly damp cloth.

- Do not scratch or otherwise damage the lenses or the front panel of the PST Pico. A scratched or damaged lens or front panel may cause measurement inaccuracies. Clean only with a very soft dry or lightly damp cloth.

2.3 Safety notice

LED radiation warning

The tracking system uses infrared LED flashes to illuminate the workspace. These flashes are generated with a frequency of up to 200 Hz with a duration of up to 4 milliseconds.

In general, light of high intensity might cause damage to the user's eyes. As infrared light is invisible for human beings, one might be exposed to a high intensity of light without knowledge. The American Conference of Government Industrial Hygienists (ACGIH) publish "Threshold Limit Values" (TLV). According to the ACGIH, the TLV for the irradiance of near infrared radiation of viewing longer than 16 minutes is 10 $mWcm^2$. LED manufacturer OSRAM recommends the IEC 62471 standard ("Photobiological safety of lamps and lamp systems") to be taken into account, which follows the ACGIH TLV.

The maximum radiant intensity of the tracking system in the PST stays well below the ACGIH TLV for viewing distances of over 10 cm from the tracking system. Nevertheless, PS-Tech recommends not to look directly into the tracking system, in particular at very close distances (less than 10 cm). If harmful use of the PST is possible, all people in the room need to be instructed of the risk.

3 Requirements

3.1 Software requirements

The PST software runs on the Microsoft® operating systems Windows 10® and Windows 11®. The PST HD software is also available for Linux®.

3.2 Hardware requirements

- Intel Core i3 processor or equivalent
- 1024 MB of RAM
- Free USB connections
    - For a PST HD or PST Pico: two free USB 3.0 SuperSpeed ports
    - For a standard PST: one free USB 2.0 Hi-Speed port
- An OpenGL capable graphics card

4 System description

This manual covers the operation of all available types of PST optical tracking systems: the PST Iris, PST Base, PST Iris HD, PST Base HD and PST Pico. Figure 4.1 shows the PST Iris HD tracking system as an example. The PST is an optical measurement/tracking system that measures the 3D positions of either active or passive markers affixed to physical objects. Using the spatial information derived from the markers the PST is able to determine the position and orientation of objects within a specific measurement volume.

Figure 4.1: The PST Iris HD, one of the available PST optical tracking systems.

The PST is a complete measurement system and does not require the use of calibration procedures. A single unit is intended for optical tracking in small environments of up to 7 meters from the tracking system. Multiple PST units can be linked together to extend the workspace or reduce issues with regard to the line-of-sight requirement of optical systems. The PST is available with different optics configurations, such that the tracking area can be adapted to the needs of the user. Optics with a greater field-of-view result in a wider tracking area closer to the system, whereas a smaller field-of-view gives a narrower but longer tracking area.

The PST uses tangible, wireless objects for 3D interaction and 3D measurement (in this manual referred to as "tracking targets"). The position and orientation (pose) of the tracking targets can be determined with millimeter accuracy. The system is based on infrared lighting, reducing interference of visible light sources from the environment. The PST can be used under normal office working conditions, without requiring controlled lighting. Any objects can be transformed into a tracking target by applying retro-reflective markers. It is also possible to use IR LEDs as markers, usually referred to as "active markers". The PST uses these markers to recognize targets and to reconstruct their pose. Basically, any kind of physical object can be used as a tracking target, e.g. a pen, a cube, or even a toy car. Antenna like targets, often used by other optical tracking systems, can also be used.

The PST reconstructs the pose of tracking targets at an adjustable frequency with a maximum of 200 Hz for the PST HD, 120 Hz for the standard PST and 55 Hz for the PST Pico.

The PST Iris and PST Base can be triggered externally, such that it can be synchronized to external clock sources. This can for instance be used to prevent interference between the internal infra-red flash and shutter glasses that are synchronized to a 3D monitor using an infra-red signal.

5 Setup

5.1 Setting up the PST

To ensure optimal performance and accuracy it is recommended to mount the PST on a stable surface. A slight movement of the PST will be directly visible in the reported target pose and should therefore be avoided. Furthermore, care should be taken that the PST has sufficient room for air circulation. Allow for at least 20 cm of free, ventilated air around the unit.

The PST can be mounted using the tripod mount (1/4"-20 UNC) that can be found on the underside of the unit. This allows the PST to be mounted on a standard tripod, see Figure 5.1.

Figure 5.1: A PST Base HD mounted on a tripod.

5.2 Positioning the PST

When positioning the PST, place it in such a way that it has a clear view of the workspace that has to be tracked. Keep in mind that every PST has a certain measurement volume in which targets are tracked optimally. This is generally referred to as the workspace or viewing cone. The field of view (FOV) and the maximum tracking distance depend on the choice of lenses and the model of the PST (details can be found on the PS-Tech website).

5.3 Default coordinate system

The PST reports the 3D position and orientation of each tracking target in a right-handed Cartesian coordinate system using metric units. The location and orientation of this coordinate system is defined relative to the PST unit. Figure 5.2 shows how the default reference coordinate system is defined with respect to the PST. If the PST is positioned horizontally, facing the user, the x-axis points to the right (red), the y-axis points up (green), and the z-axis points in the direction of the user (blue). The origin of the default coordinate system resides one meter in front of the center of the PST unit.

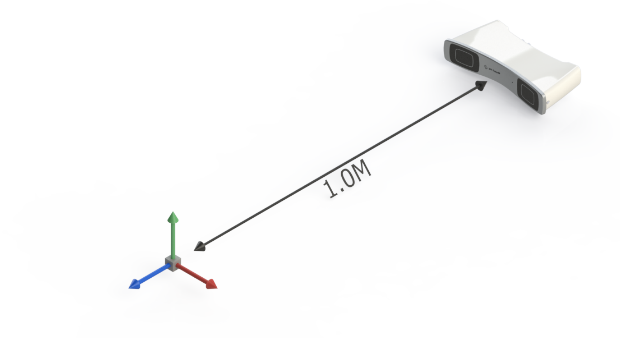

Figure 5.2: Default reference coordinate system.

Many environments where 3D tracking systems are deployed already have a coordinate system defined. In such cases, the PST software provides an easy mechanism to change the reference coordinate system. Any tracking target can be used to set a new reference coordinate system. This process is described in Section 7.8.

5.4 PST Iris and PST Base connections

Figure 5.3 illustrates the back panel of the standard PST and Figure 5.4 the back panel of the PST HD. The panels consists of the following connectors in left to right order:

- A USB connector for the PST or a USB cable for the PST HD
- The power adapter connector
- Trigger input
  The left BNC connector can be used to synchronize the PST to the trigger of an external source.

- Trigger output
  The right BNC connector can be used to synchronize an external system to the internal triggering of the PST.

Figure 5.3: The PST back panel.

Figure 5.4: The PST HD back panel.

5.5 PST Pico connections

Figure 5.5 illustrates the back panel of the PST Pico.
The back of the Pico has dual usb cable and a micro USB power connector.

5.6 Connecting the PST to your computer

The PST is connected to your computer using a USB connection. The tracker can be connected in two ways:

- Using a USB hub
- Directly to the USB port of the computer

Figure 5.5: The PST Pico back panel.

> **Note:**
>
> Using a USB hub in combination with the PST HD might prevent the PST HD from reaching the maximum 200 Hz frame rate.

The PST client software provides an easy way to connect to the PST. On start up, the software automatically searches for all connected PST units and connects with them. Different types of tracking units cannot be combined. If a standard PST and a PST HD or PST Pico are connected, the software will give connection priority to the PST HD or PST Pico. To communicate with the connected PST units, the software uses a system service called "PST Interface Service". This service should not be removed or disabled.

> **Note:**
>
> When the PST SDK has been installed together with the PST Software, the "PST Interface Service" will not be available due to potential conflicts. Instead of just starting the PST Client after connecting a PST, the PST Server has to be started manually from the start menu first.

Due to the real time communication between the computer and the PST, it is strongly recommended to limit the amount of USB communication with other external devices. For instance, copying data to an external USB hard drive may interfere with the communication of the PST.

To connect the PST to a computer, please follow the steps below. Refer to Figure 5.3 and Figure 5.4 for the tracker connections.

1. Before connecting a PST to the computer, make sure to install the soft-

ware and USB drivers first. This ensures correct detection of the system. Install the software following the instructions on the screen.

2. Secure the PST in a stable position by using, for instance, a tripod.
3. Position the PST in such a way that it has a clear view of the workspace that has to be tracked (see Section 5.2).
4. Plug in the power supply of the PST.
5. Connect one end of the USB cable to a free USB port in your computer or hub.
6. Connect the other end of the USB cable to the USB port in the PST (only for the standard PST).
7. Start the PST client software. See Chapter 7 for more details.

5.7 Turning off the PST

The PST automatically switches to a low power mode when the PST client software is not running. If the PST is not used for a longer time, it is recommended to turn it off completely. See Chapter 2 for more details.

6 Target construction

Tracking targets are physical objects that can be recognized by the PST and for which the 3D position and orientation can be determined. Just as a mouse can be used to position a pointer in 2D, a tracking target can be used to position an object in 3D with six degrees of freedom (6DOF). The 3D position and orientation (pose) of a tracking target is optically tracked, ensuring wireless operation. Figure 6.1 shows some examples of different tracking targets.

Figure 6.1: Example tracking targets

Any object can be transformed into a tracking target by applying retro-reflective or active markers to it and training it in front of the PST. This chapter will explain in detail how to create tracking targets that function optimally with the PST.

6.1 Retro-reflective markers

Retro-reflective markers are applied to objects to transform them into tracking targets. The PST uses these markers to recognize objects and to determine their pose. In order for the PST to be able to determine the pose of a target, at least four markers have to be applied.

The size of the markers determines the optimal tracking distance. For a PST with 3.5 mm lenses round markers or spheres with a minimum diameter of 7 mm are recommended. For the construction of tracking targets, the PST is able to use flat retro-reflective markers as well as spherical markers (see Figure 6.2).

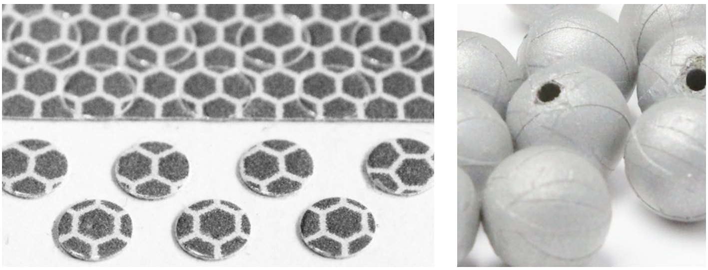

Figure 6.2: Retro-reflective markers. Flat and spherical markers are supported

6.2 Active markers

When adding electronics to a tracking target is not an issue, it is possible to use IR LEDs as active markers. This is particularly useful when targets are tracked at larger distances or when environment illumination conditions make retro-reflective markers hard to see. The specific combination of cameras and filter material used in the PST make it most sensitive to IR light with a wavelength of 850 nm. Therefore, the use of 850 nm LEDs is recommended. Depending on the required observation angles and possible rotation angles of the perceived tracking target, different LED viewing angles (the angle over which the LED emits light) can be optimal. In general, LEDs with a viewing angle of about 120° show good performance.

6.3 New target creation

New tracking targets can be easily created. The procedure below can be used for both retro-reflective markers as well as for active markers. However, when designing an active tracking target, take into account that active markers will require a power source and electronics. The procedure consists of randomly adding markers to a new object and use the PST client software to train the target. After the PST has learned about the target it can be used in your application. The process of training a target is described in Section 7.5.

The PST functions best when at least four markers are visible at all times. Therefore, convex objects are most suitable for tracking. Furthermore, to prevent self-occlusion of markers, the shape of a new tracking target should optimally be such that the angles between all neighboring sides are larger than 90°. Figure 6.3 shows two examples of well-performing general-purpose tracking devices.

Figure 6.3: Examples of two general-purpose tracking targets. Notice how multiple markers are clearly visible from a single viewing angle.

Since the PST uses IR LED panels to illuminate its environment, care should be taken that reflectivity of the tracking target is minimized. Metallic or glossy surfaces will result in poor tracking performance. Tracking performance is optimal when using mat-black objects. To verify that a target is suitable for tracking, open the “Camera Images” window in the “View” menu of the PST client application (Section 7.3). Put the target in front of the PST and check that the contrast between the markers and the target is high and that there are no reflections except for the markers. In the optimal case, the target should show up black while the markers are white. An example of a tracking target with optimal contrast as perceived by the PST is shown in Figure 7.4.

When applying markers to an object to convert it into a tracking target, some care should be taken to ensure optimal performance:

- For the PST to identify and track an object, it should always have a clear sight of at least four markers on the object. Therefore, it is important to ensure that at least four markers are visible from each viewing angle.
- The pattern of the markers on the target should be more or less random. In order to avoid ambiguities try to make sure no symmetric, regular, or similar patterns exist on the object.
- Note that multiple co-linear markers (markers on the same line) do not provide sufficient information for the PST to determine a full 6DOF pose of the object.
- Use circular or spherical markers only, as these provide the most accurate and consistent positional accuracy.
- Use markers with a minimum diameter of 7 mm. Larger markers may provide better accuracy, whereas smaller markers do not provide sufficient information for accurate tracking.
- The minimum edge-to-edge distance between two markers should be at least once the diameter of the marker-size used (e.g. 7 mm edge-to-edge distance for 7 mm markers).
- Try to avoid using more than 40 markers on a single tracking target. (There is a maximum of 100 markers per target)

7 Using the PST

7.1 Connecting to the PST

Connect the PST (see Section 5.6) and check that the status LED on the front turns on. When the PST SDK has been installed together with the PST Software, start the PST Server from the start menu. Then start the PST client software. The main window will appear.

The PST client software automatically detects the PST systems that are connected to the computer and connects to them. During this process the dialog in Figure 7.1 appears.

If you receive an error message following a connection attempt, close the error message and check all connections. Also check that the "PST Interface Service" is installed or that the PST Server application is running. If the problem persists, refer to Chapter 9 for troubleshooting suggestions.

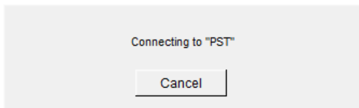

Figure 7.1: PST connection dialog

When the PST client is connected to a specific PST unit for the first time, unit-specific initialization information is required. The initialization dialog in Figure 7.2 will be shown offering four different options:

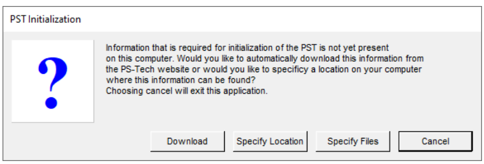

Figure 7.2: PST Initialization

- "Download": (recommended) initialization files are automatically downloaded from the internet.

- “Specify Location”: manually specify the directory where the required initialization files can be found.
- “Specify Files”: (advanced) manually specify the individual initialization files for the left and right PST camera.
- “Cancel”: cancel the initialization and close the PST client.

When no internet connection is available, choosing the “Download” option will result in an error message. This message will provide urls where the initialization files for the connected PST unit can be downloaded. Download the files manually from an internet connected device and copy the files to the machine running the PST client. In the initialization dialog, select the “Specify Location” option and specify the directory where the downloaded initialization files can be found.

After successful initialization, the PST unit can always be re-initialized by choosing the “Reinitialize PST” option from the “File” menu. This will show a dialog similar to the one in Figure 7.2 and provides the same initialization options.

When the PST client is started for the first time the “Select reference device” dialog (Figure 7.20) is shown. This dialog configures the reference device to be used with the system. For more information on the reference device, see Section 7.8.

7.2 Camera files verification

Note:

The configuration verification feature is not available for Multi-PST setups.

The registration process calculates the position and orientation of all PST units relative to each other, modifying the local files and causing them to mismatch when compared with the files on the server.

After the PST unit has successfully been initialized, the “Tracker Verification” dialog (see Figure 7.3) can be used to verify that the local initialization files (camera files) match the initialization files stored on-line. This dialog can be opened by selecting the “Verify cam files” option in the “File” menu.

Clicking the “Verify” button verifies whether the SHA1 signatures of the initialization files stored locally and on-line match. If these signatures do not match, the mismatching SHA1 signatures are highlighted in red. This can happen because the on-line initialization files have been updated after re-calibration, or because local files have been corrupted. Re-initializing the PST unit as explained in Section 7.1 will usually fix any verification issues.

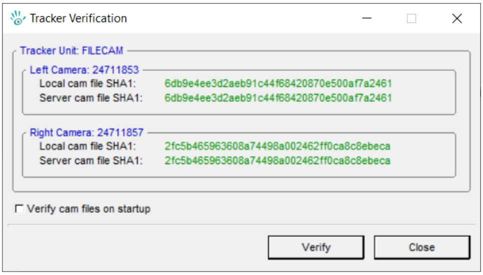

Figure 7.3: Tracker Verification Dialog

Enabling the "Verify cam files on startup" checkbox will trigger automatic verification of the initialization files each time the PST client is started. This will issue a notification if verification failed during startup of the PST client.

Note that automatic verification of the initialization files is not performed when using the PST SDK. Refer to the PST SDK documentation to learn how to obtain the SHA1 chacksums of the local and server calibration files.

7.3 Camera images

To verify if the PST unit is functioning operationally correct, the camera images of the connected unit can be viewed. This enables verifying the correct operation of the tracker and to accurately setup the system to cover a certain workspace. The camera images can be viewed by opening the "View" menu and selecting "Camera images". A window as shown in Figure 7.4 is opened.

Note that the viewing of the camera images is intended only for setup and verification purposes. Due to bandwidth limitations for the standard PST, the frame rate is reduced to 30 frames per second during camera image transfer. Therefore, in normal usage scenarios, the camera image window should be closed. The PST HD maintains its frame rate but frame rate selection is disabled while viewing the camera images.

When the option to "Show Detected Markers" is selected, reflective markers detected in the camera images will be shown as green and red dots. This information can be used to determine if the camera shutter is set correctly and the PST

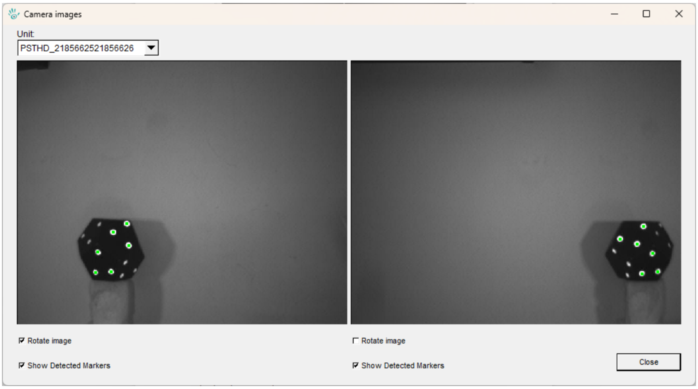

Figure 7.4: Camera images dialog

unit picks up as little noise as possible. On PST units that support configuring the detection region, markers in the "Optimal" tracking region will be shown in green while markers outside this region will show up in red.

7.4 Tracking

When starting the PST client software while a tracker is connected, the "Tracking options" page shown in Figure 7.5 is displayed. This page is divided into four sections: the target list, settings, viewing parameters, and the tracking live view.

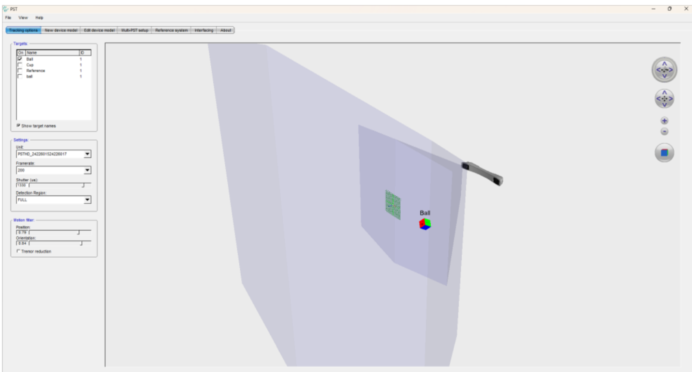

Figure 7.5: PST client in tracking mode

7.4.1 Target list

The target list contains all tracking targets that are currently present in the model database and subsequently can be tracked by the PST systems (see Figure 7.6).

The checkmarks in the list indicate whether the connected PST unit are tracking the given target. Only tracking targets with a checkmark will be tracked. The user can change which targets are tracked by clicking the checkmark in front of the target name. The PST is immediately updated when the list is changed.

In the last column of the target list a target identifier is displayed. This identifier can be used by external tracking interfaces that cannot handle target names. This includes interfaces such as VRPN and WorldViz Vizard. The identifier of each target can be changed by selecting the identifier in the target list and by specifying a new number.

When the option “Show target names” is checked, the names of the tracked targets in the tracking live view will be displayed hovering above them.

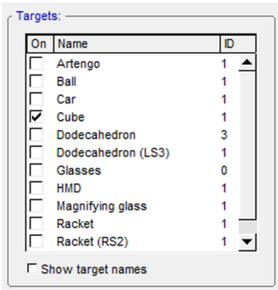

Figure 7.6: Target list

7.4.2 Settings

To change the settings of a PST unit (see Figure 7.7), first select the desired unit from the list of trackers in the “Unit” dropdown box or click on the unit in the tracking live view.

The following settings can be changed:

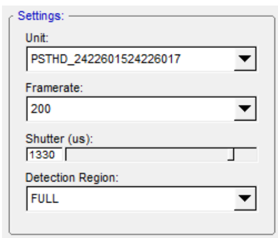

Figure 7.7: PST settings

- The frame rate. This sets the frequency at which the cameras takes snapshots of the workspace and output tracking data. A higher frame rate requires more computation time. When a lower frame rate is sufficient for the application and system resources are low (e.g. on older systems) it is recommended to select a lower frame rate.
- The shutter time. This sets the time the camera shutters are open to take a snapshot. A lower shutter time results in less motion blur and lower

sensitivity to stray infrared light, but in general results in darker images and less visibility of the markers. This option can be used to tune the tracker to a particular environment.

- The detection region. This option is available on supported PST units. It defines the workspace in which tracking is enabled. "Optimal" uses a reduced tracking region to ensure maximum positional accuracy for all detected targets. "Full" expands the tracking region to cover a larger area. However, targets detected outside the "Optimal" region may have reduced positional accuracy. The tracking live view shows the workspace matching this setting. On supported PST units, the detection region will be set to "Optimal" on startup by default.

7.4.3 Motion filter

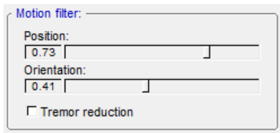

Figure 7.8: Motion filters

The PST is a high precision measurement system. Small measurement inaccuracies may result in visible jitter in the pose of a tracking target. This effect gets stronger when moving further away from the PST. To counter these effects the pose of each reported tracking target can be filtered using a motion filter. The strength of the position and orientation filtering can be adjusted by moving the slider between zero and one, where zero means no filtering and one means maximum filtering. Please note that while filtering will increase the smoothness of the tracking results it also increases latency.

When using the PST as an interaction tracker, natural hand shake can be filtered by checking the box for "Tremor reduction".

7.4.4 Tracking live view

The tracking live view (Figure 7.9) displays the 3D position and orientation of each of the tracking targets currently tracked and identified by the connected PST units. The targets are represented by cubes or coordinate axis. If the "Show Target Names" option is checked, the target names of the tracked and identified targets will be displayed. The data is updated at the same frequency as the frame rate of the PST.

When the detection region is set to "Full", the tracking live view will show both the boundaries of the "Full" working space of the PST as well as the boundaries of the "Optimal" working space. When the detection region is set to "Optimal", only the boundaries of the "Optimal" working space will be shown. When

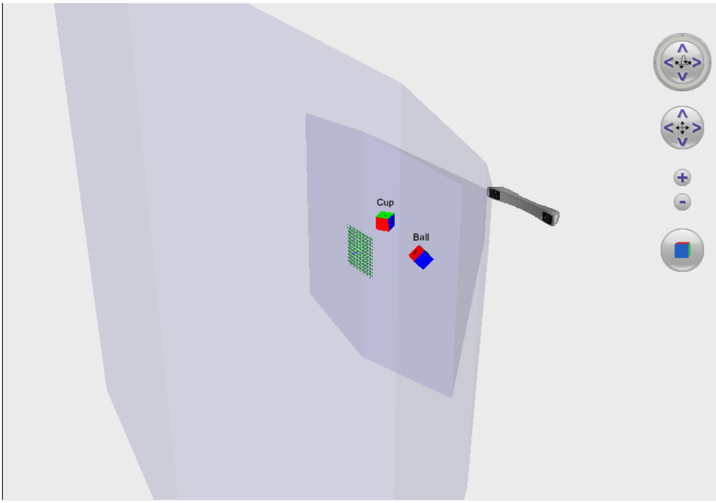

Figure 7.9: Tracking live view window

“3D points” is enabled from the “View” menu, enabling “Color points by detection region” will highlight detected markers in the “Optimal” detection region in green and markers outside that region in red.

The tracking live view can be manipulated using the buttons on the right side of the window. Alternatively, it can be manipulated with the mouse:

- Left mouse button and drag left/right/up/down: rotate the view.
- Middle mouse buttons and drag left/right/up/down: translate the view.
- Right mouse button and drag up/down: zoom in/out.

Note that the tracking view serves only as feedback to the user to check if targets are tracked properly.

7.5 Training

The training page is selected by pressing the “New target model” tab in the main window (see Figure 7.10). Training refers to the process of “teaching” the system to recognize and use new objects as tracking targets. This is done by equipping an object with retro-reflective markers and by slowly moving the object in front of the PST. During this object motion, the PST constructs a model of the object, which is used to identify each tracking target.

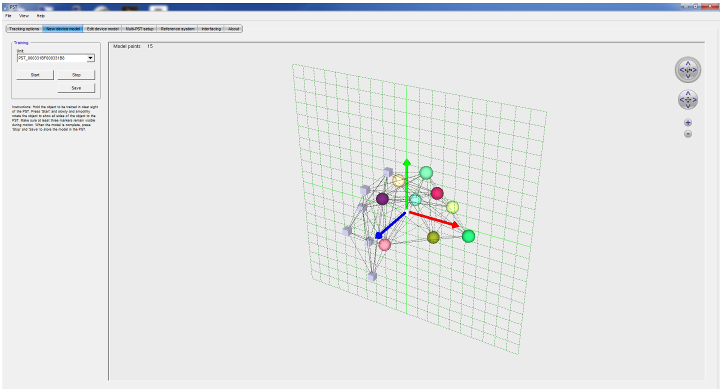

Figure 7.10: PST client in training mode

New targets can be trained as follows:

1. Attach four or more retro-reflective markers to the object. Refer to Chapter 6 for more details on target construction. Place the object in the middle of the working volume of a PST without occlusion from other objects. Remove any other tracking targets and reflective materials from the working volume. Having more than one object visible during training can cause incorrect target models. The training procedure can train single objects containing up to 100 markers.
2. Select the PST unit to use for training and press the “Start” button in the training window. The training live view is updated and displays the 3D points corresponding to the visible markers. An example training session is shown in Figure 7.11. The colors encode the different markers in the target model. Grey cubes indicate that a previously visible marker is occluded and its position is being predicted by the PST. The training live view can be manipulated in the same way as the tracking live view (see Section 7.4.4).
3. Slowly and smoothly move and rotate the object in front of the PST such that all markers will be shown to the system. Make sure that three or more markers always remain visible during training. In case not enough markers remain visible, training is aborted and an error dialog will be shown. In this case, close the error dialog and restart the training procedure. If the problem persists, check that the object has enough visible markers from every angle.

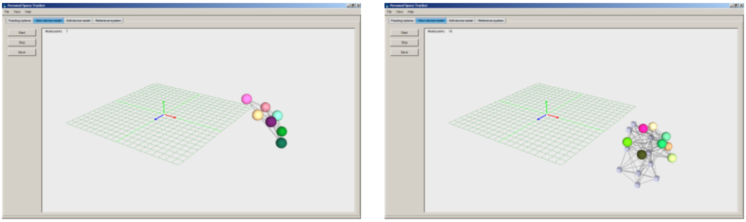

Figure 7.11: Training in progress

When the displayed number of tracking target markers reaches the actual number of markers on the object, press the “Stop” button. The training live view can now be used to view the target model as obtained during the training procedure.

An example tracking target with the corresponding target model obtained from the training procedure is illustrated in Figure 7.12.

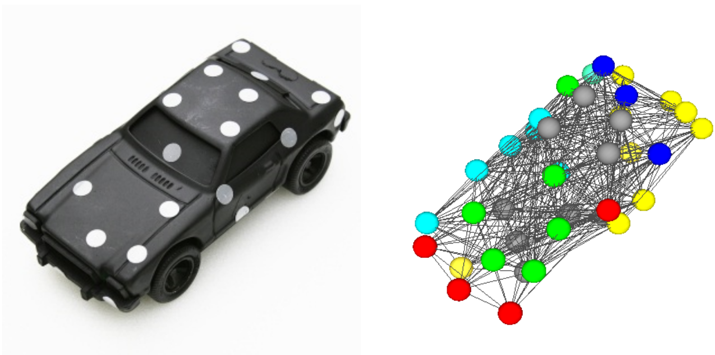

Figure 7.12: Example of an object and its trained model

4. If the target model is finished and the new tracking target is to be used in practice, press the “Save” button in order to store the model. A dialog appears asking you to enter a target name and target identifier. Enter a unique name, select an identifier, and press “Save”.
5. Return to the tracking view and select the new tracking target. The target should immediately be visible in the tracking live view.

6. If necessary, the relation between the target model and its coordinate frame can be adjusted. See Section 7.6.

7.6 Model editing

The target models present in the target list can be edited. The model editing page allows the user to alter properties of a model, such as its name and reference coordinate system location and orientation. The model editing page is selected by pressing the "Edit target model" tab page in the main window (see Figure 7.13). The model editing view consists of two parts.

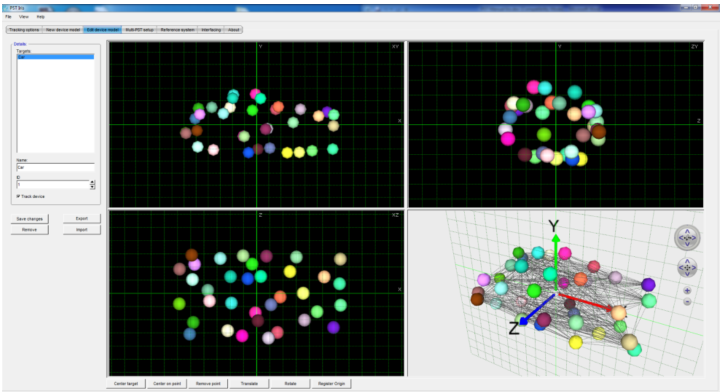

Figure 7.13: PST client in model editing mode

On the left side of the model editing page is a group of controls to select the tracking target to edit, along with its name, identifier, and a checkbox that indicates if the PST should track the target. Any changes to these parameters are not applied directly, but need to be committed by pressing "Save changes".

A tracking target can be erased by pressing "Remove". Please take care using this function is permanent: once removed, a target will have to be retrained (as described in section 7.5) before it can be tracked again.

To change the name of the target, select the entry in the "Name" box and replace it with a new name. To change the identifier of the target, select the entry in the "ID" box and replace it with the new one, or change it with the arrow buttons.

Target models can be exported to a file with the "Export" button and imported from a file using the "Import" button. Exporting and importing models can be done as a proprietary binary psm file or as a human readable JSON file. Using the JSON file it is possible to inspect and edit exported model files. JSON files can also be created by converting accurate real-world measurements of target model marker positions, such as those contained in a CAD model, into the JSON file specification defined in Appendix A.

The right section of the model editing view shows the tracking target model from different angles. From left to right, top to bottom, the views show the projection of the target model onto subsequently the XY-plane, the ZY-plane, the XZ-plane and a full 3D view similar to the one in the tracking and training live view. The target model projections can be used to accurately rotate and translate the target model with respect to the coordinate system that will be reported by the PST for this target. The grid drawn in the target model projections has a spacing of 10 mm.

The projection views of the target model can be operated as follows:

- Left mouse button and drag left/right/up/down: change the orientation of the target model.
- Middle mouse button and drag left/right/up/down: change the position of the target model.
- Right mouse button and drag up/down: zoom in/out.
- Ctrl+left mouse button and drag left/right/up/down: position the origin.

On the bottom of the model editing page is a collection of buttons to manipulate target models. This includes centering the model, centering the model on the selected model point and translating and rotating the model. Model points can be selected by pressing the left mouse button on a point in one of the projection views.

Additionally it is possible to register the origin of the tracking target using the "Register Origin" option. This option makes it possible to automatically determine the origin of a tracking target by pivoting the tracking target around the desired origin.

The procedure to establish a new target origin using the "Register Origin" option is as follows:

1. With the target model selected, click the "Register Origin" button. This will open a new dialog.
2. Position the tracking target in such a way that it is possible to pivot around the desired origin.
3. Press "Record" and pivot the tracking target calmly around its desired origin.

4. When approximately 200 samples have been recorded press the "Record" button again to stop the recording process.
5. The "Registrate" button will become active (see Figure 7.14). Press this button to calculate a new origin.
6. Press "Close" to close the dialog and set the origin to the currently selected target model.

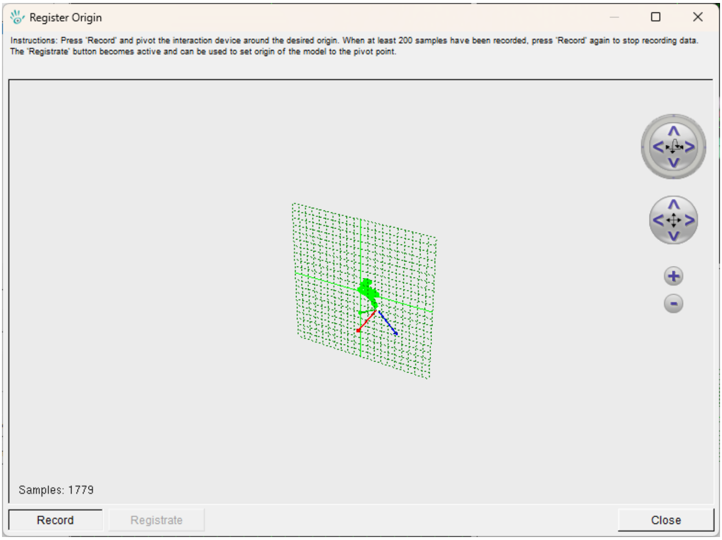

Figure 7.14: Register origin dialog

7.7 Multi-PST setup

Note:

The PST HD and PST Pico are not able to work in a Multi-PST setup.

Multiple PST systems may be connected and can work together in the same environment. This may serve two purposes:

- Reduce problems with occlusion, i.e. the line-of-sight requirement inherent in optical tracking. In case a target is not visible for a PST unit, adding a second unit from a different perspective may improve the tracking quality.

- Extend the tracking volume. Multiple PST units can be placed such that they extend the workspace.

7.7.1 Placement

In a PST setup with multiple units, units should be placed in such a way that each unit has overlap with at least one other unit. If the goal is to extend the workspace, the most efficient setup is to create a minimal overlap between units, such that each unit adds a maximum amount to the total workspace. The overlapping areas are used to determine the position and orientation of multiple PST units with respect to each other.

An example setup is illustrated in Figure 7.15. Here, four PST units are setup such that the angle of the overlapping area between units is about ten degrees.

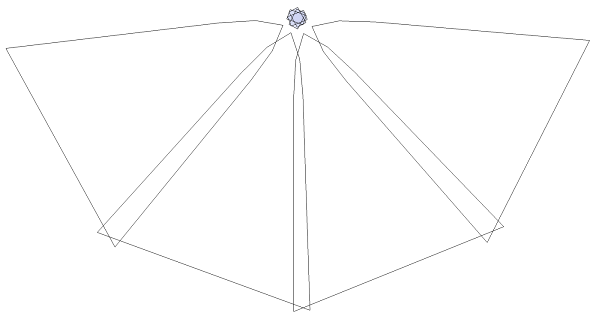

Figure 7.15: Possible setup with four PST units

7.7.2 Registration

To ensure that each PST reports its data in a common coordinate system, a registration procedure is required. During this procedure, the position and orientation of all PST units are related to each other.

The registration procedure proceeds as follows:

1. Press the "Multi-PST setup" tab page in the main window to show the registration page.

2. Press the record button and slowly wave the registration device (as illustrated in Figure 7.16) through the workspace. Concentrate on the areas where tracking units have an overlapping field of view. Make sure that the registration device is clearly visible to the trackers and that the motion is smooth. During recording, the data is plotted as trajectories in different colors representing each PST.

Figure 7.16: Registration device used for setting up multiple PST units

3. When approximately 500 points per PST unit have been collected, press the record button again to stop recording data. The registration window shows the recorded data points and the field of view of the PST units. Note that at this time, the position and orientation of the PST units may still be incorrect. Check that all PST units have a set of 3D points, drawn in a different color for each unit (see Figure 7.17).
4. Press the "Registrate" button to execute the registration procedure. This can take from a few seconds to a couple of minutes, depending on the number of the points collected during the registration procedure. Upon completion, the registration results are shown in the live view. The recorded point trajectories should be placed on top of each other (as illustrated in Figure 7.18), where the error estimate indicates the quality of the registration. An error below 0.5 can generally be considered a good value.

In case the PST is not tracking objects properly after registration, or if the recorded point trajectories are not neatly placed on top of each other, the fac-

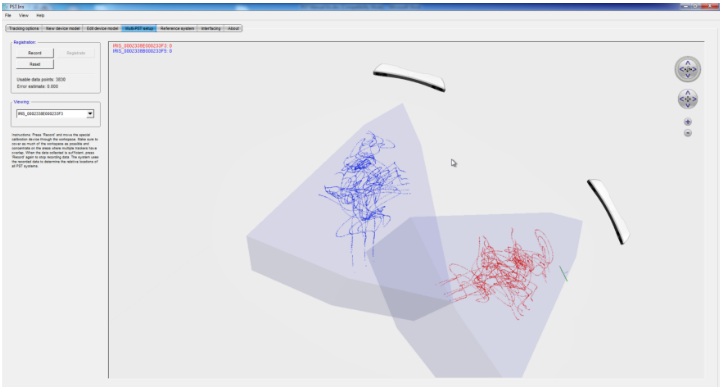

Figure 7.17: PST client in registration mode

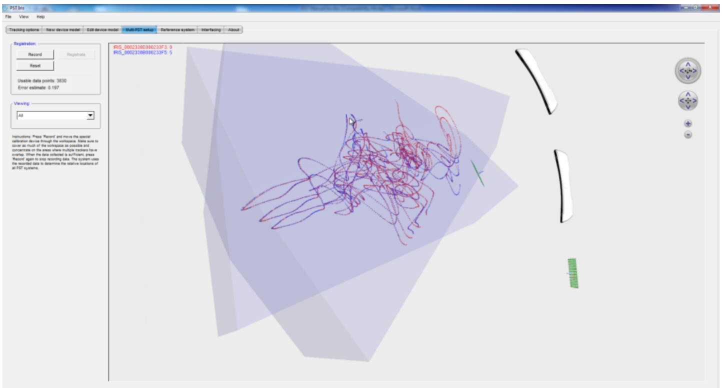

Figure 7.18: Registration results

tory default calibration of every currently connected PST can be restored by pressing "Reset".

7.8 Reference coordinate system

This reference coordinate system can be adjusted to a custom coordinate system in the "Reference system" tab page (see Figure 7.19).

The reference coordinate system is defined relative to the PST unit. All reported tracking values from a tracker are reported with respect to the default reference

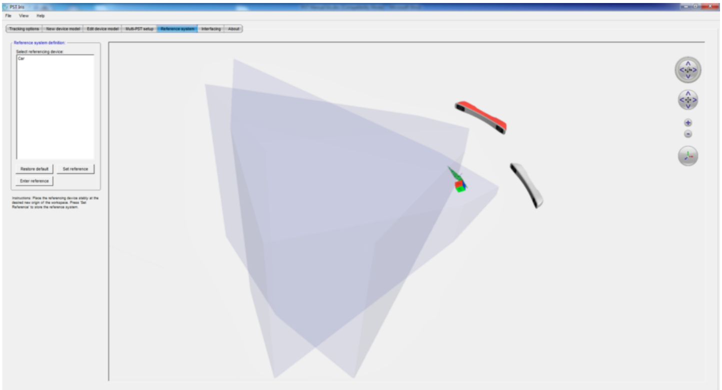

Figure 7.19: PST client in reference system mode

coordinate system (see Section 5.3). When integrating one or more PST units into an existing environment, the reference coordinate system can be aligned to the coordinate system already defined by the environment.

For ease of use a reference device is included with the PST unit in the form of a coordinate reference card or metal reference triangle. When the PST client is started for the first time, the dialog in Figure 7.20 will be shown asking for the type of reference device that was included with the PST unit. Please select the option matching the device included in the box.

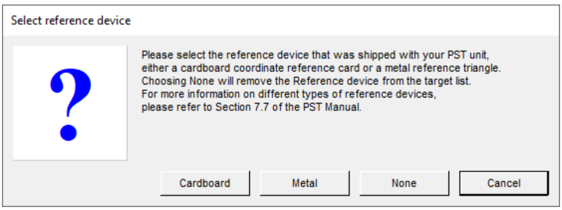

Figure 7.20: Select reference device dialog

For the cardboard reference card (Figure 7.21 (left)) please select “Cardboard”. For the metal reference triangle (Figure 7.21 (right)) please select “Metal”. When no reference device is available the option “None” can be selected. The selected reference device will show up in the target list as “Reference”.

The PST client requires one of the options to be selected at least once. If the “Reference” target needs to be reset/restored or switched to the other device,

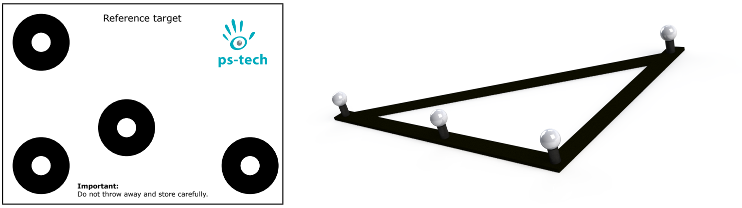

Figure 7.21: (left) Cardboard coordinate reference card. (right) Metal reference triangle.

select the “Tracking options” tab and select “Reset reference device” from the “File” menu. When required, the generated target can be removed from the target list by choosing the “None” option from the dialog.

To set a new reference coordinate system, first select the tracking target that will be used to define the new coordinate system. This can be the reference device included with the PST unit, but it can also be any other trained tracking target.

The selected target is shown in the live view as a Cartesian coordinate system. The x, y, and z-axes are encoded as follows:

- Red: x-axis
- Green: y-axis
- Blue: z-axis

The live view also shows a grid with the current reference coordinate system. The next step is to bring the target to the desired location within the workspace. Once the coordinate system defined by the target is positioned at the desired location, press “Set reference”. This will update the reference coordinate system of the PST unit to the coordinate system of the target. The live view is immediately updated to reflect the new reference coordinate system. To restore the factory default reference coordinate system, press the “Restore default” button.

The reference system can also be entered manually by pressing the “Enter reference” button. A dialog appears as illustrated in Figure 7.22.

Enter an orthonormal rotation matrix and translation vector describing the reference coordinate system. Checking the “relative to current” checkbox will define a reference coordinate system relative to the one currently being used by the PST, whereas unchecking it replaced the coordinate system with the defined one.

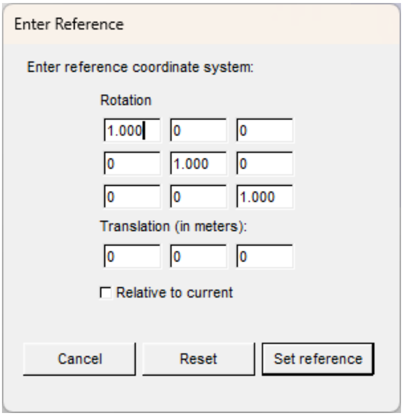

Figure 7.22: Manual reference coordinate system dialog

8 Communicating with other systems

The PST uses a proprietary interface to communicate its tracking data to the computer over the USB connection. An application that needs the tracking data can communicate with the client tracking software using different interfacing options. Various interfaces support networking, such that applications can even be executed on different machines or even operating systems as the computer connected to the PST.

These options are selected in the interfacing tab page as illustrated in Figure 8.1.

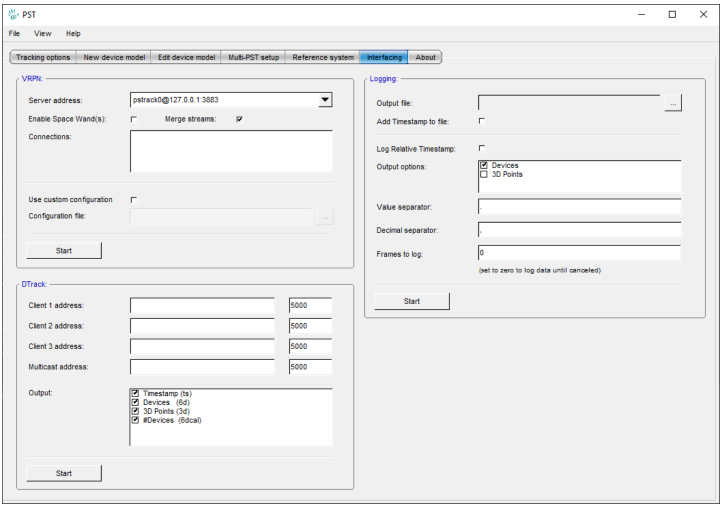

Figure 8.1: PST client in interfacing setup mode

8.1 SDK

The PST Software Development Kit (SDK) is installed by selecting the "PST SDK" component during installation. Installing the PST SDK creates a Development directory in the installation folder containing all the required files and documentation for using the PST SDK. Extensive documentation on the API and how to use the SDK can be found in the "PST SDK Manual" that can be accessed through the start menu. Note that when the PST SDK is installed, the "PST Interface Service" will not be added as a Windows service since it can conflict with the PST SDK. When the PST Client software needs to be used, the PST Server application needs to be started manually from the start menu.

For legacy reasons, the Classic SDK that communicates to the tracker through the PST Client is also available in the installer. It should be noted however that this Classic SDK is marked as legacy software and that the use of the PST SDK is recommended instead.

8.2 Data logging

The PST client software features logging functionality that enables logging of tracking data to Comma Separated Values (CSV) files. These files can be loaded into Microsoft Excel for data analysis. Specify an output file and press "Start" to start logging tracking data to the specified file. If the "Add Timestamp to file" option is selected, the filename specified in "Output file" box will be prefixed with a timestamp formatted "yyyymmdd_hhmmss". Data logging can be stopped by pressing "Stop".

Each line in the data file contains tracking data of a single time frame. A line contains the following data, separated by commas:

- The frame counter (integer)
- The timestamp (double), i.e. the time when the infrared flash of the cameras is fired. The timestamp uses the PC clock, given in seconds since system boot (Windows) or Epoch (Linux). If the "Log Relative Timestamp" option is selected the timestamp is given in seconds since data logging was started.
- The number of targets found (integer)
- For each target found, the following data is reported:

$$[n]\,[p_x, p_y, p_z]\,[\alpha, \beta, \gamma]$$

where:

- n: An ASCII string containing the target name.
- p_a: The position of the target (meters). With $a \in \{x, y, z\}$.
- α, β, γ: Rotation of the target defined in Euler angles (degrees).

- The number of marker positions (integer)
- For each marker found, the following data is reported:

$$[i]\ [p_x, p_y, p_z]$$

where:

- n: Marker identifier.
- p_a: The position of the marker (meters). With $a \in \{x, y, z\}$

The Euler angles use the same convention as defined in Equation 8.1.

8.3 VRPN

The Virtual-Reality Peripheral Network (VRPN) is a set of classes within a library and a set of servers that are designed to implement a network-transparent interface between application programs and the set of physical devices. The VRPN interface can be activated by clicking the "Start" button.

The VRPN server address is provided using the "Server address" dropdown box. If the computer has multiple active network interfaces, the interface on which the VRPN server should run can be selected here. The "Connections" list shows the currently connected VRPN clients. Note that the VRPN server runs on port 3883 by default. When using multiple servers for other devices, make sure to configure other servers to run on a different port.

Targets are identified in VRPN using the target identifiers as specified in the tracking target list. Target tracking data is transmitted using a VRPN device named *pstrack0*. When the checkbox "Enable Space Wand(s)" is checked, controls pressed on connected SpaceWands will be transmitted using a VRPN device named *SpaceWand0*. If preferred, it is possible to combine the SpaceWand control information with the tracking target data into the *pstrack0* VRPN device by checking the "Merge streams" checkbox.

A custom configuration file for the VRPN server can be provided through the "Use custom configuration" option. For more information on VRPN, see http://vrpn.org.

8.4 DTrack emulation

The DTrack emulation interface is a communication layer that enables users of A.R.T. tracking systems to transparently exchange their tracking system with a PST. The DTrack emulation interface can send tracking data to one or more clients. Up to three different client IP addresses and port numbers can be specified. Alternatively, a multicast address may be specified to send data to multiple clients simultaneously. After specifying the client addresses, DTrack emulation can be activated by pressing "Enable".

The DTrack emulation interface sends a UDP packet for each frame. A packet contain several ASCII string separated by CR/LF (carriage return/line feed). Each line starts with an identifier, which specifies the type of the data:

- `fr` <integer>
- `ts` <double>
  The timestamp, i.e. the time when the infrared flash of the cameras is fired. The timestamp uses the PC clock, given in seconds since the Epoch.
- `6d` <tracking data>
  Measurement data of all tracked targets. The tracking data starts with an integer specifying the number of targets, followed by a list of target measurements defined by:

  $$[i, q]\,[p_x, p_y, p_z]\,[\alpha, \beta, \gamma]\,[u_x, u_y, u_z, v_x, v_y, v_z, w_x, w_y, w_z]$$

  where:
  - i: Target identifier, corresponding with the selected identifier in the tracking target list.
  - q: Quality value (not used).
  - p_a: Target position (meters). With $a \in \{x, y, z\}$.
  - α, β, γ: Orientation of the target defined by Euler angles (degrees).
  - u_a, v_a, w_a: The vectors of the rotation matrix. With $a \in \{x, y, z\}$.
- `3d` <marker data>
  Measurement data of all tracked additional markers, i.e. markers not part of a tracking target. The marker data starts with an integer specifying the number of markers, followed by a marker list defined by:

  $$[i, q]\,[p_x, p_y, p_z]$$

  where:
  - i: Marker identifier.

  - q: Quality value (not used).
  - p_a: Marker position (meters). With $a \in \{x, y, z\}$
- `6dcal` <integer>
  The number of tracked targets.

The convention for the Euler angles is:

$$R = R_x(\alpha)R_y(\beta)R_z(\gamma) \tag{8.1}$$

with:

$$R_x(\alpha) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\alpha & -\sin\alpha \\ 0 & \sin\alpha & \cos\alpha \end{bmatrix}$$

$$R_y(\beta) = \begin{bmatrix} \cos\beta & 0 & \sin\beta \\ 0 & 1 & 0 \\ -\sin\beta & 0 & \cos\beta \end{bmatrix}$$

$$R_z(\gamma) = \begin{bmatrix} \cos\gamma & -\sin\gamma & 0 \\ \sin\gamma & \cos\gamma & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

8.5 trackd

The trackd software provides a standard interface for receiving data from trackers and input devices. In the PST software installation (directory “trackd”), the file pst2trackd.dll is located to add trackd support to the PST. The files pst2trackd.conf and pst2trackdserver.conf provide two example configurations.

The general configuration format for defining a PST is:

```
DefineDevice <device name> pst2trackd <# of target>
```

The module connects to the PST and passes the first N consecutive targets (PST targets with identifiers 0 to N-1) to trackd. These targets are then available in trackd as target 1 to N. The maximum number of targets is limited by trackd to 32.

9 Troubleshooting

1. **Problem:** Unable to turn on the PST.
   Possible cause: The power is not connected properly.
   Remedy: Connect the power adapter included with the PST to the power input of the PST unit and a suitable wall socket.

2. **Problem:** The status LED does not turn on.
   Possible cause: The power cable or USB cable is not connected properly.
   Remedy: Check that the power and USB cables are connected properly.

3. **Problem:** No tracking units found.
   Possible cause: No tracking units connected to a USB port of the computer.
   Remedy: Connect the tracking unit directly to the computer or using a connected USB hub.
   Possible cause: Disabled "PST Interface Service".
   Remedy: Make sure the "PST Interface Service" is enabled and running. This can be done by running the Windows "Services" application (services.msc) and checking that the service is enabled and running. Please note that the startup type of "PST Interface Service" should be set to "Automatic".
   Possible cause: The PST Server is not running.
   Remedy: When the "PST SDK" has been installed the "PST Interface Service" will not be available. Start the PST Server manually from the start menu before starting the PST Client.

4. **Problem:** "PST Interface Service" not found in the Windows "Services" application (services.msc).
   Possible cause: When the "PST SDK" is installed the "PST Interface Service" will not be available.

Remedy: Start the PST Server manually from the start menu before starting the PST Client.

5. **Problem:** Configuration information is not saved properly when using the PST REST server (e.g. frame rate, target status, reference system).
   Possible cause: File access rights to PST configuration files might not be set correctly while using a non-admin Windows account.
   Remedy: Run the PST REST server as administrator once and change the required settings. Alternatively, run the PST Server and use the PST Client to change the settings once.

6. **Problem:** Performance is slow or stuttering is observed.
   Possible cause: Too much other communication by other USB devices.
   Remedy: Limit the other USB communications.
   Possible cause: Camera images are being viewed.
   Remedy: Close the camera images dialogue for more optimal performance.
   Possible cause: The PST motion filter settings are set too high.
   Remedy: Turn down the PST motion filter settings.

7. **Problem:** Devices move erratically.
   Possible cause: Disruptive elements present in the workspace.
   Remedy: Make sure the view of the tracking system on the workspace is not disturbed by any objects or disruptive (reflective) materials or light sources.
   Possible cause: Damaged tracking devices or markers.
   Remedy: Check that all markers on the tracking device and the device itself are intact. Damaged or dirty markers may show degraded reflective performance.

8. **Problem:** The PST client keep asking for a reference device when started.
   Possible cause: The PST client needs a reference device to be selected at least once.
   Remedy: Select one of the available reference device options from the dialog. When no reference device was shipped with the PST unit or the device was lost, select the option “None” from the dialog. When a reference device is required at a later point in time, choose the “Reset reference device” menu option from the “File” menu to select the appropriate reference device.

A JSON Model Definition

In order to provide a human readable alternative for the binary psm target model files, models can be exported and imported as a JSON file. This enables inspecting and editing trained target models, as well as creating new target models manually from scratch. This appendix describes the structure of the JSON target model file.

The JSON attributes used to define a target model are as follows:

- A **ModelData** object containing all further target model data.
- A **name** string containing the tracking target name as it is shown in the target list in the PST client software.
- An **id** number identifying the target model in the VRPN interface, as shown in the target list in the PST client software.
- A **status** number specifying if the target is being tracked as shown by the checkmark in the target list in the PST client software.
- A **uuid** string uniquely identifying a tracking target.
- A **points** array containing all the marker points that make up the tracking target. Each point is an object containing the 3D homogeneous coordinates of the marker. These coordinates are represented using the number **w**, which is always one, and the numbers **x**, **y** and **z** that represent the X, Y and Z coordinates of the marker in meters.
- An **edges** array describing which markers are visible to the tracker at the same time. This array describes an $N \times N$ matrix (where N is the length of the **points** array) of the distances between all points in the order they appear in the **points** array. The distance between markers that are visible at the same time is set to their euclidean distance in meters. The distance between markers that are not visible at the same time as well as the distance of the marker to itself is set to -1.

> **Note:**
>
> When creating a custom target model, the **uuid** string should be removed. Furthermore, when it is not known which markers will be visible at the same time, the **edges** array can be removed as well. In that case, the PST client will assume all markers are potentially visible at the same time and create a fully connected visibility graph. While this could have a small impact on tracking performance for very large target models, in general this should not impact performance.

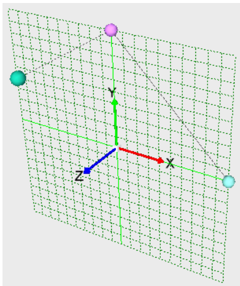

Figure A.1: Custom created three-point target model imported from a JSON file

Using these attributes, an exported JSON model file describing the three-point model shown in Figure A.1 looks as follows:

```
{
  "ModelData" : {
    "name" : "target_name",
    "id" : 0,
    "status" : 0,
    "uuid" : "xxxxxxxx-xxxx-xxxx-xxxx-xxxxxxxxxxxx",
    "points" : [
      {"w" : 1, "x" : 0.1, "y" : 0,   "z" : 0  },
      {"w" : 1, "x" : 0,   "y" : 0.1, "z" : 0  },
      {"w" : 1, "x" : 0,   "y" : 0.1, "z" : 0.1}
    ],
    "edges" : [
      [-1,      0.14142, -1 ],
      [0.14142, -1,      0.1],
      [-1,      0.1,     -1 ]
    ]
  }
}
```