pst

Instruction Manual

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Safety Notices

LED radiation warning: The tracking system uses infrared LED flashes to illuminate the tracked volume. These flashes are generated with a frequency of up to 120 Hz with a duration of less than 4 ms.

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 (< 10 cm). If harmful use of the PST is possible, all people in the room need to be instructed of the risk.

Contents

1 Item check list

Check that all the following items have been included with your PST. If anything is missing, contact your dealer.

The PST Iris package contains:

- PST Iris unit
- One referencing device
- Power adapter
- Power cable
- USB cable
- A starter set of 10 mm retro-reflective markers
- PST solution disk (CD-ROM)

A multi PST Iris order comes with additional items:

- BNC cable (each unit)
- Registration device (per order)

The PST Base package contains:

- PST Base unit
- One referencing card
- Power adapter
- Power cable
- USB cable
- A starter set of 7 mm retro-reflective markers
- PST solutions disk (CDROM)

These items can also be purchased separately.

2 Safety precautions

2.1 Operating conditions

- Please use the PST in AC grounded power sockets:
  AC 100-240 V, 1.0A, 50-60Hz
- 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 cause damage to the system or inaccurate measurements.
- Never attempt to open the tracker's casing, remove any of its components, or disassemble the tracker. Opening the tracker’s casing 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 tracker malfunction.
- 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. A scratched or damaged front window may cause measurement inaccuracies. Clean only with a very soft perhaps lightly damp cloth.

3 Requirements

3.1 Software requirements

The PST is an integrated solution, and does not require a separate processing unit. The bundled software communicates with the tracker and provides mainly communication services between PST and other applications. Because of this the PST software does not require heavy system resources. The software runs on the Microsoft® operating systems Windows Vista®, Windows 7® and Windows 8®.

3.2 Hardware requirements

- 800Mhz x86 processor
- 512 MB of RAM
- One free USB 2.0 high speed port
- An OpenGL capable graphics card

4 System description

4.1 PST

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 devices within a specific measurement volume. The PST is an optical measurement system that allows you to transform any object into a 3D measurement device.

The PST is a complete measurement system and does not require the use of complicated calibration procedures or external processing units. It can be connected to your desktop computer or laptop directly using a free USB port, or through a USB hub. The PST brings 3D measurement to your computer without exhausting your own system's resources. A single system is intended for optical tracking in small environments of up to 7 meters from the tracking system. Multiple PST systems can be coupled together to extend the workspace or reduce issues due 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. Optics with a higher field of view result in a wider tracking area closer to the system, whereas a lower field of view gives a narrower but longer tracking area (see Section 5.2).

The PST uses tangible, wireless devices for 3D interaction and 3D measurement. The position and orientation (pose) of the devices are reconstructed with millimeter accuracy. The system is based on infrared lighting, reducing interference of visible light sources from the environment. This allows the PST to be used under normal office working conditions, without requiring controlled lighting. Objects can be tracked by applying retro-reflective markers. The PST uses these markers to recognize different devices and to reconstruct their poses. Basically, any kind of physical object can be used as a device, e.g. a pen, a thimble, a cube, or even a toy car. Antenna like devices, often used by other optical tracking systems, can also be used.

The PST is reconstructs the pose of tracking devices at an adjustable frequency with a maximum of 120 times per second. It 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 infrared flash and shutter glasses that are synchronized to a 3D monitor using an infrared signal.

4.2 Tracking Devices

Tracking devices are physical objects that can be recognized by the tracking system and of which the 3D position and orientation can be measured. Such devices can be used to measure the spatial coordinates of objects, or for instance to interact with virtual 3D objects in an application. Just as a mouse can be used to position a pointer in 2D, a tracking device is could be used to position an object in 3D with six degrees of freedom. The 3D position and orientation (pose) of a tracking device is optically tracked, ensuring wireless operation.

Figure 4.1. Example tracking devices.

4.3 Retro reflective markers

Retro-reflective markers are applied to objects to transform them into tracking devices. The tracking system uses these markers to recognize devices and to reconstruct each pose. In order for the PST to be able to determine the pose of a device, at least four markers need to be applied.

The size of the markers determines the optimal tracking distance. For a PST with 3.5mm lenses we recommend round markers or spheres with a minimum diameter of 7 mm. The PST supports flat retro-reflective markers for the construction of tracking devices that do not hamper manipulation, as well as spherical markers for optimal visibility from each viewing angle (see Figure 4.2).

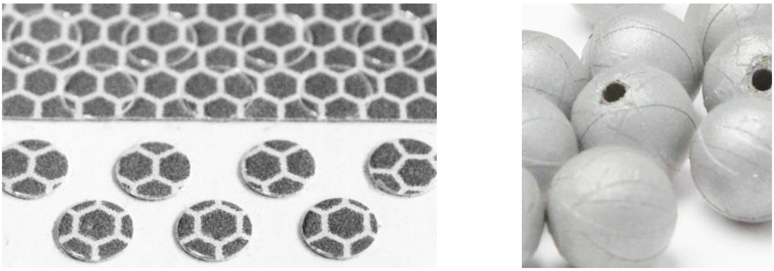


Figure 4.2. Retro-reflective markers. Both flat and spherical markers are supported.

4.4 Easy new device creation

New devices are easily created. Randomly add markers to a new device and use the PST software to train the device. After the system has captured the device it can be used in your application. This process is described in Section 6.4.

5 Setting up a PST

5.1 Mounting a PST

To ensure optimal accuracy it is recommended to mount the PST on a stable surface. If the tracker is moved slightly, this movement is immediately shown as a movement in the tracked volume and therefore should be avoided. Furthermore, care should be taken that the PST has sufficient room for air circulation around it when it is mounted. Please allow for at least 20 cm of free, ventilated air around the casing.

A PST can be mounted using the tripod mount. On the bottom of the system, a 1/4”-20 TPI mount hole is present. This allows the PST to be mounted on a standard tripod, see Figure 5.1.

Figure 5.1. A PST Iris mounted on a tripod

5.2 Positioning a PST

A PST has a certain measurement volume in which devices are tracked optimally: the measurement area or field of view (FOV). The FOV and distance to the tracker depends on the choice of lenses and the model of the PST. Position the PST such that it has a clear view of the volume that has to be tracked. Different versions of the PST and the corresponding working volume can be found on the PS-Tech website.

5.3 Reference coordinate system

A PST reports the 3D position and orientation of each input device it finds in a metric, right-handed Cartesian reference coordinate system. The location and orientation of this coordinate system is pre-defined relative to the tracking unit. Figure 5.2 shows how the reference coordinate system is defined with respect to the PST. The axes of the coordinate system are aligned with the tracker unit. If the PST is placed horizontally facing the user, the x-axis points to the right, the y-axis points up, and the z-axis points in the direction of the user. The origin of the coordinate system resides 100 cm in front of the center of the unit.

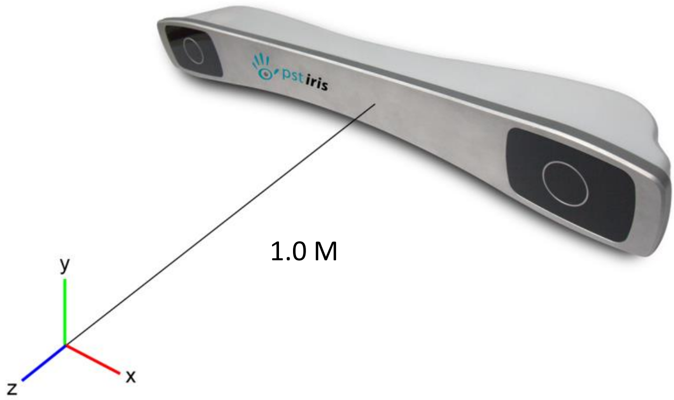


Figure 5.2. Default reference coordinate system

Many environments where 3D tracking systems are employed already have a coordinate system defined. In such cases, the PST software provides for an easy mechanism to change its reference coordinate system. A tracking device can be used to set a new reference coordinate system. This process is described in Section 6.8.

5.4 System illustration

Figure 5.3 illustrates the back panel of the PST. The panel consists of the following connectors in left to right order:

- *The USB connector*
  This port is used to connect the PST to your computer.
- *The power adapter connector*
- *Trigger Input*

The left BNC connector can be used to synchronize the optical tracking system 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 optical tracking system.

Figure 5.3. The PST back connector panel

5.5 Connecting a 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 connecting it to your computer's USB port

The PST client software provides an easy way to connect to the tracker. On startup, it automatically searches for connected PST systems and connects with them. To communicate with connected systems, the software used a system service named the "PST Interface Service". This service should not be removed or disabled.

Due to the real time communication between a user's computer and the tracker, it is strongly recommended to limit the amount of USB communications. For instance, copying data to an external USB hard drive may interfere with the tracking system's communication.

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

1. Before connecting A PST to the computer, make sure to install the software and USB drivers first. This ensures correct detection of the system. Turn on

the computer and insert the PST Solutions Disk. 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 such that it has a clear view of the volume 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. Connect the other end of the USB cable to the USB port in the PST.

6. Start the PST Software. See Chapter 6 for more details.

5.6 Turning off a PST

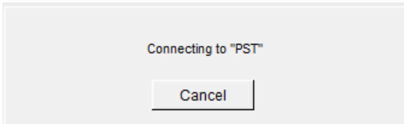
The PST automatically switches to a low power mode when the PST client software is not running. If the PST is not used for a longer time, it is recommended to turn it off completely. Unplug the USB and power cable and store the system at a cool, dry, well-ventilated location.

6 Basic Operation

6.1 Connecting to the PST

Plug in the PST (see section 5.5) and check that the status LED on the front turns on. 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 6.1 appears.



If you receive an error message following a connection attempt, close the error message and check all connections, the status LED of the PST, and that the “PST Interface Service” is installed. Next, reconnect. If the problem persists, refer to Chapter 8 for troubleshooting suggestions.

6.2 Camera images

After the connection is established, it is possible to view the camera images of the connected PST systems. This enables a user to verify the correct operation of the tracker and to accurately setup the system to cover a certain working area. The camera images can be viewed by opening the “view” menu and pressing “camera images”. A window as shown in Figure 6.2 is opened.

Figure 6.2. Viewing of camera images

Note that the viewing of the camera images is intended only for setup and verification purposes. Due to bandwidth limitations, the tracking sampling rate is reduced to 30 fps during camera image transfer. Therefore, in normal usage scenarios the camera image window should be closed.

6.3 Tracking

When the tracker is connected, the main window appears with the tracking page activated, as illustrated in Figure 6.3. The program opens on the tab page “Tracking options”.

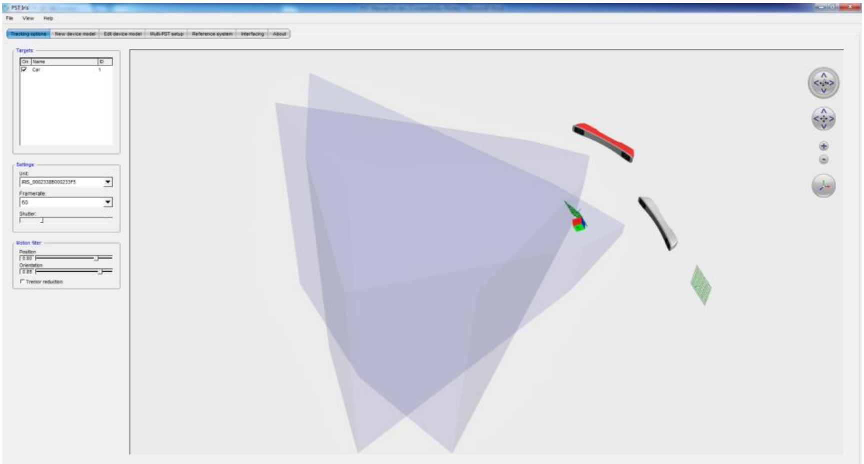


Figure 6.3. PST window in tracking mode

The main tracking window is divided into four parts: a device list, settings, viewing parameters, and a tracking live view.

Device list

The device list contains all tracking devices that are currently present in the model data base, and subsequently can be tracked by the PST systems (see Figure 6.4). The list includes the tracking devices included in the package.

The checkmarks in the list indicate whether the connected PST systems are tracking the given tracking device. Only tracking devices with a check-mark are tracked. The user can change which devices are to be tracked by clicking the checkmarks in front of the device names in the list. The PST is immediately updated when the list is changed.

In the last column of the device list a device identifier (ID) is displayed. This ID can be used by external tracking interfaces that cannot handle device names. This includes interfaces such as VRPN, WorldViz Vizard. The ID of each device can be changed on the fly. (see section 6.6)

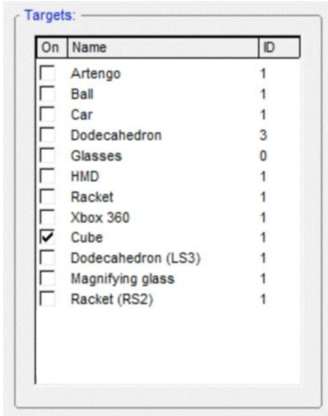


Figure 6.4. Device list

Settings

To change the settings of a unit (see Figure 6.5), first select the desired tracking unit by selecting it from the list of trackers or click on the tracker in the tracking live view. The following settings can be changed:

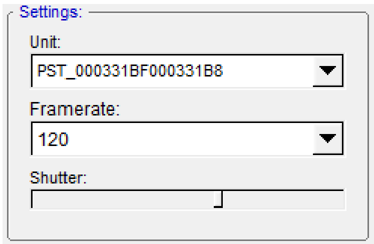


Figure 6.5. PST settings

- The frame rate. This sets the frequency at which the cameras takes a snapshot of the working environment and outputs tracking data. A higher frame rate requires slightly more computation time. When a lower frame rate is sufficient for the application and system resources are low (e.g. on older systems), the frame rate can be adjusted.
- 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 sensitivity to stray infrared light, but also generally results in darker images and less visibility of the markers. This option can be used to tune the tracker to a particular environment.

Motion filter

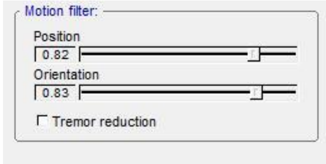


Figure 6.6. Motion filter

The PST is a measurement system with a certain precision. Small measurement inaccuracies may result in some visible jitter in the position and/or orientation of an input device. This effect gets stronger when moving further away from the PST. The pose of each reported device can be filtered using a motion filter. The strength of the position and orientation filtering can be adjusted by moving the slider, where 1 is maximum filtering and 0 is no filtering.

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

Tracking live view

The tracking live view (Figure 6.7) displays the 3D position and orientation of each of the tracking devices that are currently being tracked and identified by the connected systems. The devices are represented by cubes or coordinate systems. The data is updated at the same frequency as the update rate of the PST.

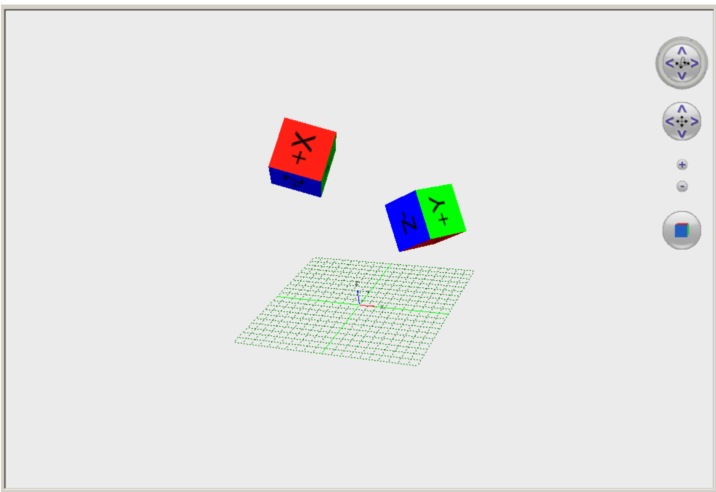


Figure 6.7 Tracking live view window

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 devices are tracked properly.

6.4 Training

Training refers to the process of “teaching” the system to recognize and use new objects as tracking devices. This is done by equipping an object with small circular markers and slowly moving the object in front of a PST. During this object motion, the PST internally constructs a model of the object, which is used to identify each tracking device. The training page is selected by pressing the “New device model” tab page in the main window (see Figure 6.8).

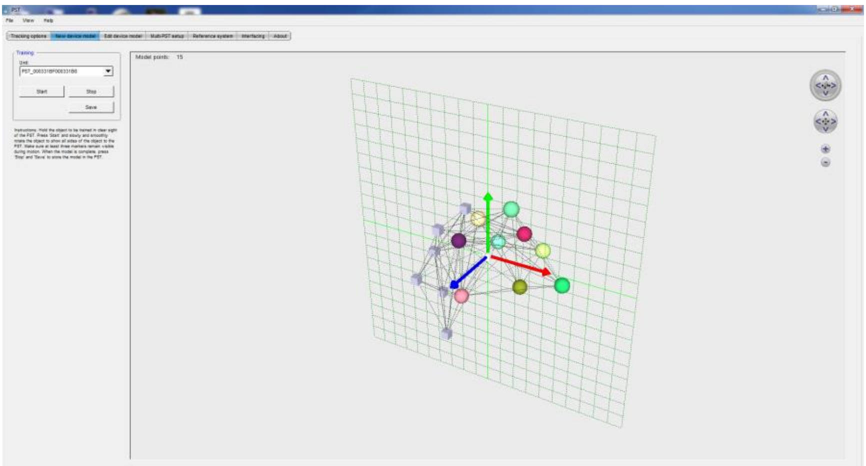


Figure 6.8. PST window in training mode

New devices can be trained as follows:

1. Attach four or more retro-reflective markers to the object. Refer to Section 6.5 for device construction guidelines. Place the object in the middle of the working volume of a PST, in clear sight. Remove any other

tracking devices and reflective materials from the working volume. Having more than one object visible during training can cause incorrect device models. The training procedure can train single objects containing up to 100 markers.

2. Select the tracking system 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 6.9. The colors encode the different markers in the device 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 6.3).

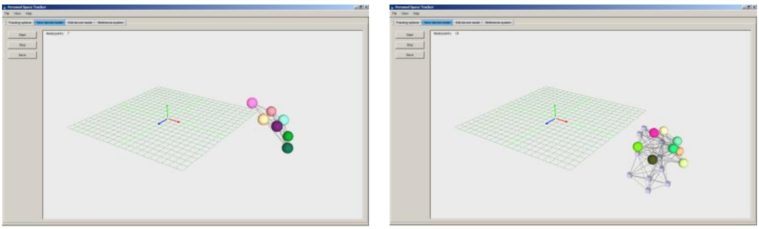


Figure 6.9. Training in progress

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 motion. In case not enough markers remain visible, training is aborted and the window as shown in Figure 6.10 appears. In this case, close the window and restart the training procedure. If the problem persists, check that the device has enough visible markers from each angle.

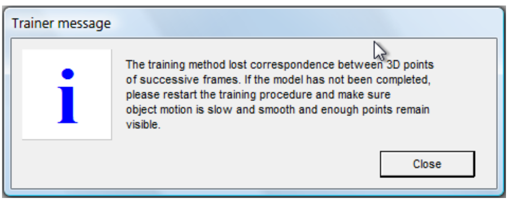


Figure 6.10. Correspondence lost

When the displayed number of tracking device 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 device model as obtained by the PST.

An example input device with the corresponding device model as obtained from the training procedure is illustrated in Figure 6.11.

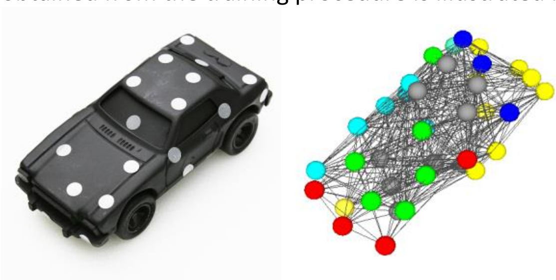


Figure 6.11. Example of an object with the trained model

4. If the device model is finished and the new tracking device is to be used in practice, press the "Save" button in order to store the model. A dialog as given in Figure 6.12 appears asking you to enter a model name and ID. Please enter a unique name, select a device ID, and press "Save".

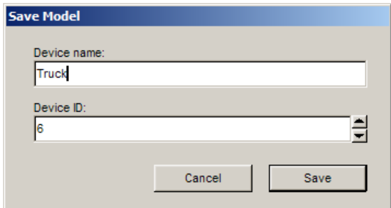


Figure 6.12. Saving a device model

5. Return to the tracking view and select the new tracking device. The device should immediately be visible in the tracking live view.

6. If necessary, the relation between the device model and its coordinate frame can be adjusted. See Section 6.6.

6.5 Device construction

New devices are easily constructed by applying a number of markers randomly onto the object. However, some care should be taken to ensure optimal performance of a device:

- For the tracker to identify and track an object, it should always have a clear sight of at least four markers on the object. So, make sure that for each viewing angle on an object at least four markers are visible.
- The pattern of the markers on the device 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 co-linear markers (markers on the same line) do not provide sufficient information for the tracker to determine a full 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 marker distance should be approximately 5 mm.

6.6 Model editing

The device models present in the device 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 device model" tab page in the main window (see Figure 6.13). The model editing view consists of two parts.

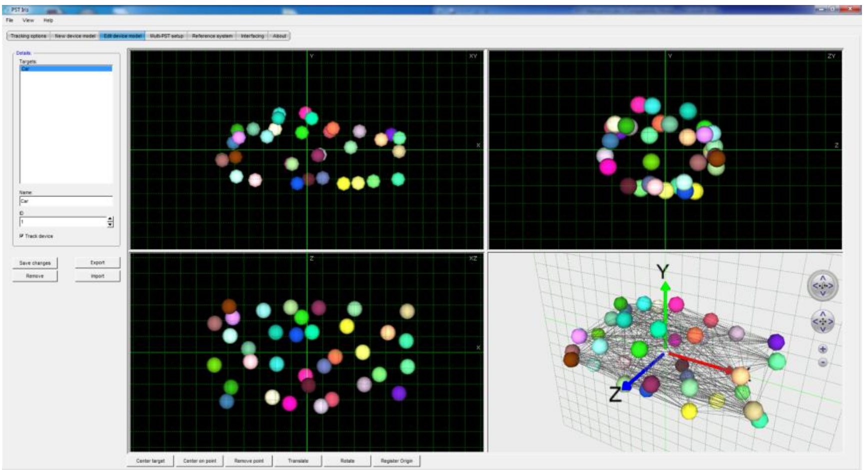


Figure 6.13. PST window in model editing mode

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

A tracking device can be erased by pressing “Remove”. Please take care using this function is permanent: once removed, a device will have to be retrained (as described in section 6.5) before it can be tracked again.

To change the Name of the device, Select the entry in the “Name” box and replace it with the new one. To change the “ID” of the device, Select the entry in the “ID” box and replace it with the new one, or change it with the arrow buttons.

Device models can be imported from and exported to a given file on the user’s computer with the buttons “Import” and “Export”. This feature is useful for backup purposes or for distributing existing device models to other systems.

On the right of the model editing view, the tracking device model is illustrated from different angles. The views subsequently show the projection of the device model onto the XY-plane, the ZY-plane, and the XZ-plane, as well as a full 3D view similar to the one in the tracking and training live view. The device model projections can be used to precisely orient and translate the device model with respect to the coordinate system that will be reported by the tracking system for this device. This is for instance needed in case a pointing device is created where the position reported by the PST should correspond to the tip of the pointer and the orientation should be aligned to the Z-axis. The grid drawn in the device model projections has a spacing of one centimeter.

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

- Left mouse button and drag left/right/up/down: change the orientation of the device model.
- Middle mouse button and drag left/right/up/down: change the position of the device 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 device 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 device using the "Register Origin" option. This option makes it possible to automatically determine the origin of a tracking device simply by pivoting the tracking device around the desired origin.

The procedure to establish a new object origin is as follows:

1. With the device model selected, click the "Register Origin" button. This will open a new dialog.
2. Position the tracking device in such a way that it is possible to pivot around the desired origin.
3. Press "Record" and pivot the tracking device calmly around the origin.
4. When approximately 200 samples have been recorded press the "Record" button again to stop the recording step.
5. The "Registrate" button will become active (see Figure 6.14). Press this button to calculate a new origin.
6. Press "Close" to close the dialog and set the origin to the currently selected device model.

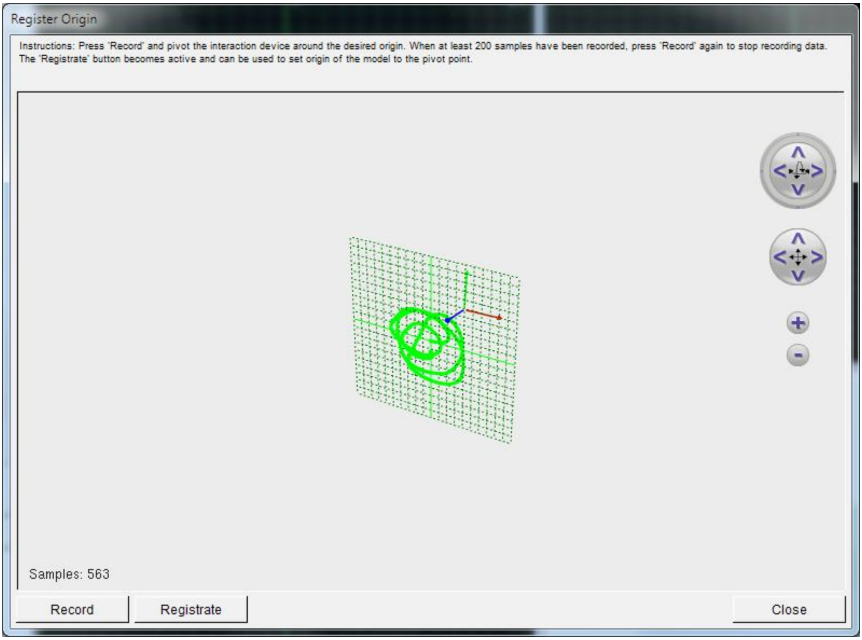


Figure 6.14. Register Origin Dialog

6.7 Multi-tracker 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 device is regularly not visible for a tracker, adding a second tracker from a different viewing position may improve the tracking quality.
- Extend the tracking volume. Multiple tracking units can be placed such that they view different parts of an area.

PST placement

Trackers should be placed such that each unit has an overlapping area with at least one other tracker. If the goal is to extend the tracking volume, the most efficient setup is to create a minimal overlap between tracking systems, such that each unit adds a maximum amount of tracked volume. The overlapping area only serves as a means to be able to determine the position and orientation of multiple PST systems with respect to each other.

An example setup is illustrated in Figure 6.15. Here, four PST systems are setup such that the angle of the overlapping area between units is about 10 degrees.

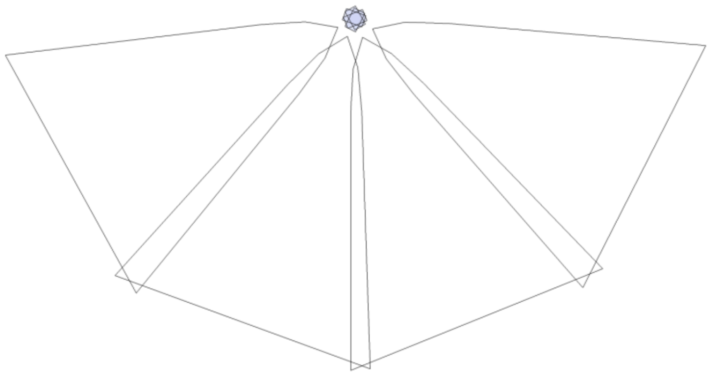


Figure 6.15. Possible setup of 4 PST systems where the tracking area is maximized.

Registration

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

The registration procedure proceeds as follows:

- Press the “Multi-PST setup” tab page in the main window to show the registration page.
- Press the record button and slowly wave the registration device (as illustrated in Figure 6.16) through the working volume.

Figure 6.16. Registration device used for setting up multiple PST systems

  Concentrate on the areas where tracking units have an overlapping field of view. Make sure that the device is clearly visible to the trackers and that motion is slow and smooth. During recording, the data is plotted as trajectories in different colors representing each tracker.
- When enough data has 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 tracking units. Note that at this time, the position and orientation of the trackers may still be incorrect. Check that all tracking systems have a set of 3D points, drawn in a different color for each tracker (see Figure 6.17).

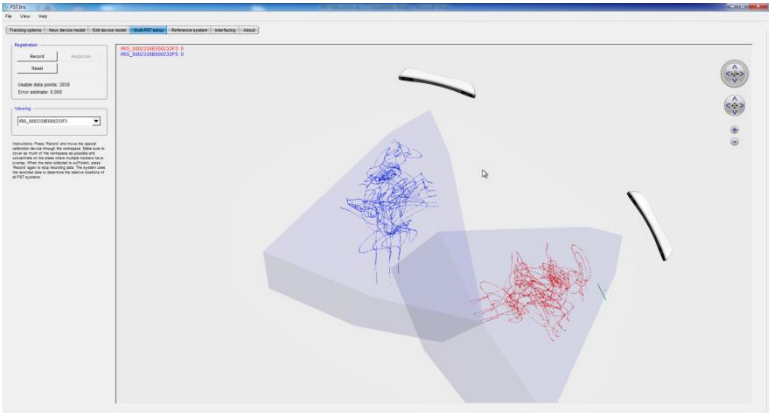


Figure 6.17. PST window in registration mode

- Press the “Registrate” button to execute the registration procedure. This can take from a few seconds to a couple of minutes, depending on the size of the data. Upon completion, the registration results are shown in the live view. The recorded point trajectories should be placed over each other (as illustrated in Figure 6.18), where the error estimate indicates the quality of the registration. A number below 0.5 is generally a good value.

In case a PST is not tracking objects well after registration, or if the recorded point trajectories are not neatly placed over each other, the factory default calibration of each PST can be restored by pressing “Reset”.

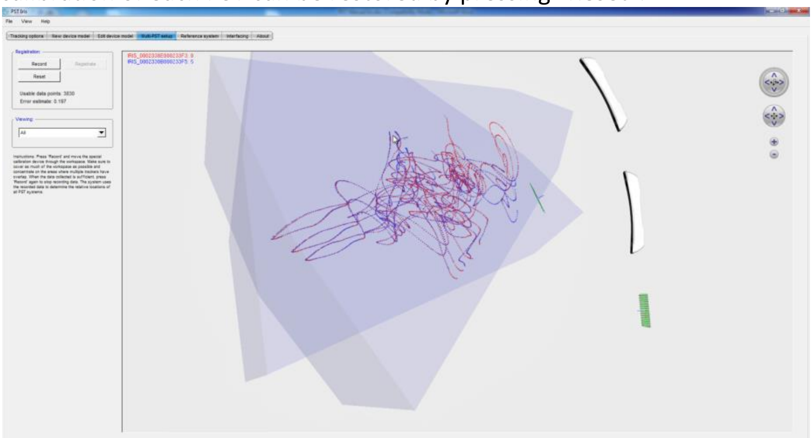


Figure 6.18. Registration results

6.8 Reference coordinate system editing

The reference coordinate system of the PST can be adjusted to the user's liking. Press the “Reference system” tab page in the main window to reveal the reference system editing page (see Figure 6.19).

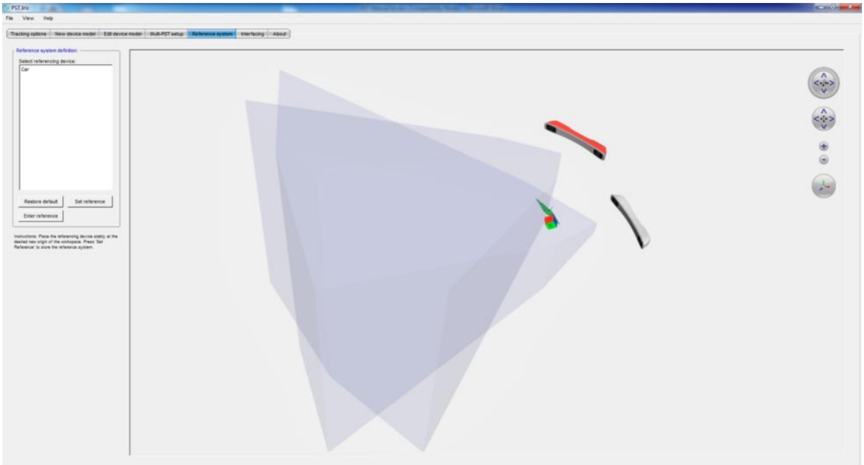


Figure 6.19. PST window in reference system editing mode

The reference coordinate system is defined relative to the PST systems. All reported tracking values from a tracker are with respect to the reference coordinate system (see Section 5.3). When integrating one or more PST systems into an existing environment, the reference coordinate system can be aligned to the coordinate system already defined by the environment.

To set a new reference coordinate system, first select the device that will be used to define the new coordinate system. It is recommended to use the special referencing device that is shipped with the system. This device has pre-defined axes and an origin as defined in Figure 6.20.

Figure 6.20. Device used for defining a reference coordinate system.

Note that any other device could also be used, as long as its axes are known. The selected device 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 device to the desired location within the tracking volume and align the displayed axes with the coordinate system used in the application. Once the coordinate system defined by the device and the coordinate system of the application are aligned, press “Set reference” to update the connected PST systems. 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 window appears as illustrated in Figure 6.21.

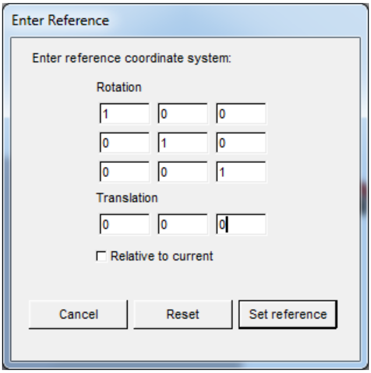


Figure 6.21. Manually changing the reference coordinate system

Enter a full orthonormal rotation matrix and a translation vector describing the reference coordinate system. Checking the “relative to current” defines a reference coordinate system relative to the one currently being used by the PST, whereas unchecking it simply replaced the coordinate system in use with the new one.

7 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 7.1.

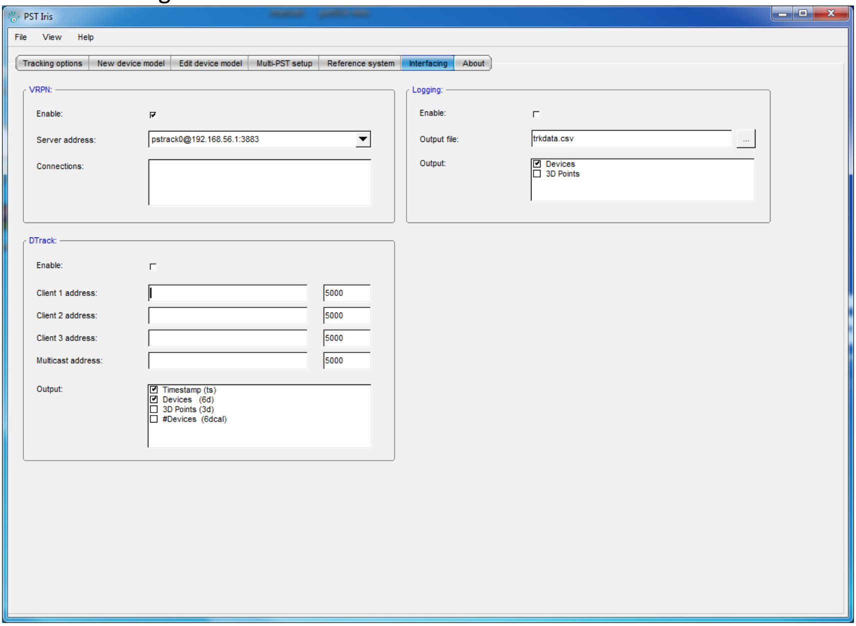


Figure 7.1. Interfacing options.

7.1 SDK

The Software Development Kit (SDK). The SDK and its documentation is located on the installation CD-ROM and allows for applications to directly communicate to the PST client software.

7.2 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 checking the “Enable” box. The VRPN server address is given in the box below. 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. When using multiple servers for other devices, make sure to configure other servers to run at a different port. Devices are identified in VRPN using the device IDs as specified in the tracking device list. For more information on VRPN, see http://www.cs.unc.edu/Research/vrpn/.

7.3 DTrack emulation

The DTrack emulation interface is a communication layer that enables users of A.R.T. tracking systems to interchange their old tracking systems with the 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 an UDP packet for each frame. A packet contain several ASCII string separated by CR/LF. Each line starts with an identifier, which specifies the type of data:

- fr <integer>
  The frame counter.
- Identifier 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 devices. The tracking data starts with an integer specifying the number of devices, followed by a list of device measurements defined by

  $$[\text{id qu}][p_x\ p_y\ p_z\ \alpha\ \beta\ \gamma][u_x\ u_y\ u_z\ v_x\ v_y\ v_z\ w_x\ w_y\ w_z]$$

where

- ○ id: Device identifier, corresponding with the selected ID in the tracking device list.
- ○ qu: Quality value (unused).
- ○ p_i: Device position (meters).
- ○ α, β, γ: Orientation of the device defined by Euler angles (degrees).
- ○ u_i, v_i, w_i: The basis vectors of the rotation matrix.

- 3d <marker data>

  Measurement data of all tracked additional markers, i.e. markers not part of a tracking device. The marker data starts with an integer specifying the number of markers, followed by a marker list defined by

  [id qu][p_x p_y p_z]

  Containing

  - ○ id: Marker identifier.
  - ○ qu: Quality value (qu, unused).
  - ○ p_i: Marker position (meters).

- 6dcal <integer>

  The number of tracked devices.

The convention for the Euler angles is:

$$R = R_x(\alpha) R_y(\beta) R_z(\gamma)$$

with:

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

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

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

7.4 Data logging

The PST client software features logging functionality that enables a user to log tracking data to .CSV (Comma Separated Values) file. These files can be conveniently loaded into Microsoft Excel for data analysis. Specify an output file and press "Enable" to start logging tracking data to the specified file. Data logging can be stopped by unchecking "Enable" again.

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 the Epoch.
- The number of devices found (integer)
- For each device found, the following data is reported:

  name p_x p_y p_z α β γ

  Where
  - name: An ASCII string containing the device name.
  - p_i: The position of the device (meters).
  - α, β, γ: Rotation of the device defined by Euler angles (degrees).
- The number of marker positions (integer)
- For each marker found, the following data is reported:

  id p_x p_y p_z

  Where
  - id: Marker identifier.
  - p_i: Marker position (meters).

The Euler angles use the same convention as defined in Section 7.3.

7.5 TrackD

The Trackd software provides a standard interface to receive data from tracker and input devices and make it available to applications via shared memory. In the PST software installation, subfolder trackd, the file "pst2trackd.dll" is a TrackD module is located to add support for the PST. The files pst2trackd.conf and pst2trackdserver.conf provide two example configurations.

The general configuration format for defining the PST device is:

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

The module connects to the PST and passes the first N consecutive sensors (PST devices with id's 0 to N-1) to Trackd. These sensors are then available in Trackd as sensors 1 to N. The maximum number of sensors is limited by Trackd to 32.

8 Troubleshooting

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

3. *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 services.msc and checking the service is enabled and running.

4. *Performance is slow, stuttering.*
   Possible cause: Too much other communication using other USB devices
   Remedy: Limit the other USB communications.
   Possible cause: Camera images are being viewed.
   Remedy: Close the camera images dialog for optimum performance.

5. *Devices move erratically*
   Possible cause: Disruptive elements present in the tracked 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.

9 Technical Specifications

technical data	
refresh rate	120 Hz
degrees of freedom (DOF)	6 (position and orientation)
Number of targets (120fps)	at least 15 independent 6DOF bodies
working distance	at least 0.4 – 7 m, depending marker size and tracker configuration
lighting	built-in IR flash
ambient conditions	normal indoor lighting conditions
Measurement area / field of view (FOV)	Depends on configuration. See PS-Tech website for information on available configurations.
precision[1]	< 0.5 mm RMSE
	< 1 deg RMSE
calibration	pre-calibrated unit
6DOF target creation	easy training of custom built targets
interface	USB 2.0 High Speed
output	x, y, z positional coordinates and orientation angles, rotation matrices

1 Precision measured using a grid of 10mm markers moved through the workspace up to a distance of 2.5m w.r.t. the tracking system (5.5mm optics configuration).

power supply	9V, 40 W (external power supply 100–240 V, 50–60 Hz)
power consumption	max. 12 W
size	PST Iris: 50.5 x 6 x 9.5 cm (W x H x D) PST Base: 31 x 6 x 15 cm(W x H x D)
weight	approx. 1.1 kg
minimum latency	approx. 9 ms
software support	standard interfacing to VRPN, TrackD, and most VR programs. Further extendible via simple SDK.