



# PST

## Target Construction Manual





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# 1 Constructing tracking targets

## 1.1 Introduction

The PST uses tangible, wireless objects for 3D interaction and 3D measurement (in this manual referred to as “tracking targets”). 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. The 3D position and orientation (pose) of a tracking target is optically tracked with millimeter accuracy, ensuring wireless operation.



Figure 1.1: Example tracking targets.

The system is based on infrared (IR) lighting, reducing interference of visible light sources from the environment. Any object 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. Figure 1.1 shows some examples of tracking targets.

## 1.2 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 1.2).

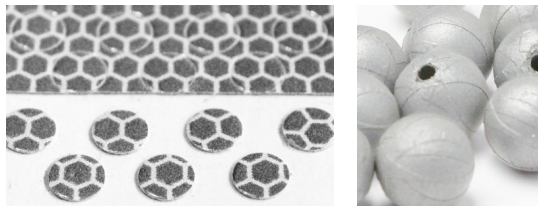


Figure 1.2: Retro-reflective markers. Flat and spherical markers are supported.

## 1.3 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.

## 1.4 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 2.

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  $90^\circ$ . Figure 1.3 shows two examples of well-performing general-purpose tracking devices.



Figure 1.3: 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. 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 1.4

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.

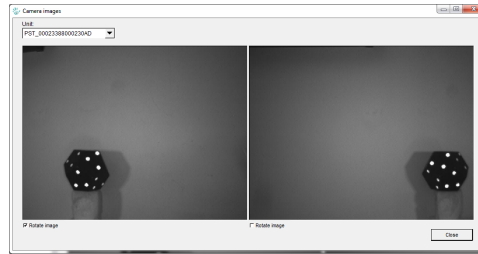


Figure 1.4: Tracker camera view showing optimal target image.

- 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)

## 2 Training tracking targets

After a new tracking target has been created it needs to be trained using the PST client application in order to be recognized by the PST. The training page is selected by pressing the “New target model” tab in the main window (see Figure 2.1). Training refers to the process of “teaching” the system to recognize and use new objects as tracking targets. This is done 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.

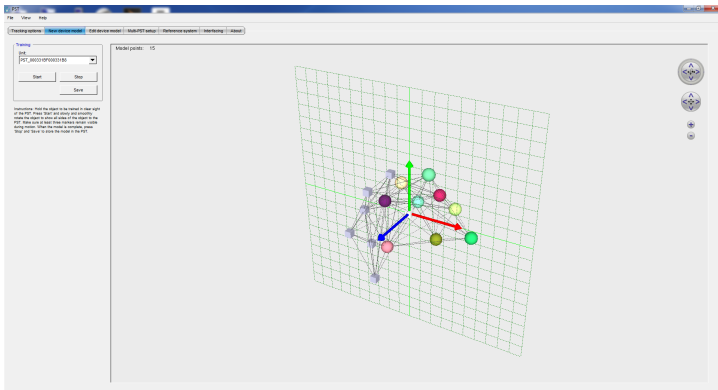


Figure 2.1: PST client in training mode

New tracking targets are trained as follows:

1. Attach four or more markers to the object. Refer to Chapter 1 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 tar-



- get 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 2.2. 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 viewpoint of the training live view can be manipulated using the mouse.

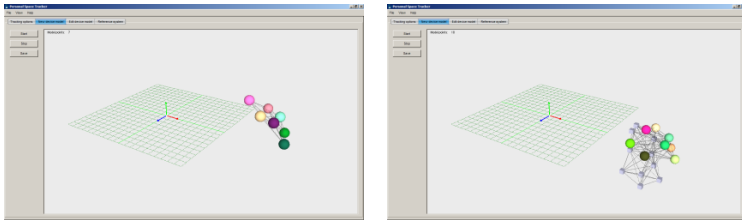


Figure 2.2: Training in progress

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 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.

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 2.3.

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.

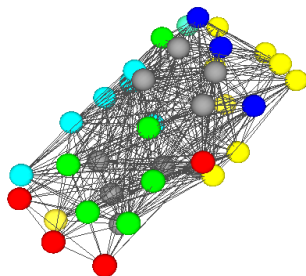


Figure 2.3: Example of an object and its trained model

6. If necessary, the relation between the target model and its coordinate frame can be adjusted. See Section 6.6 of the manual for instructions.

### 3 Manually creating targets

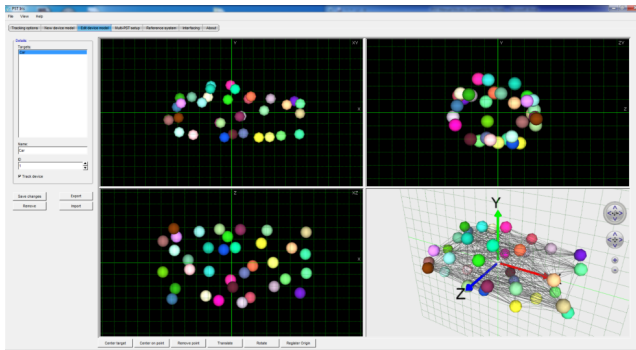


Figure 3.1: PST client device model editing tab

Besides using the training procedure to construct new tracking targets, tracking targets can be created and edited manually. From the “Edit device model” tab in the PST client application (shown in Figure 3.1), select any available tracking target and press the “Export” button. In the file export dialogue, select the JSON file format and choose a location and file name. This will create a JSON formatted file containing the full description of the tracking target. This file can be inspected and edited manually and imported into the PST client using the “Import” button on the “Edit device model” tab. Please refer to Appendix A of the PST Manual for a complete description of the JSON target model structure.

Besides inspecting and editing trained tracking target models, JSON file import enables manual definition of these models. When accurate real-world measurements on marker positions are known, e.g. from a CAD model of the tracking target, a JSON file following the structure described in Appendix A of the PST Manual can be created and imported. Please carefully follow the instructions in Appendix A of the PST Manual to create a custom tracking target model.