Simulation User Manual

SteamVR™ Tracking

Introduction

High quality tracking depends on the shape of the tracked object and the configuration of sensors on its surface. Performance is degraded when sensors are occluded by other obstacles or the tracked object itself in some poses. Due to the complexity of the problem, an iterative process that allows designers to quickly test tracking performance and refine the object's shape and sensor placement is very important. To facilitate that process, Valve has created a suite of software tools that automatically generate sensor placement, simulate tracking performance, and display performance plots in two and three dimensions. The SteamVR™ Tracking HDK includes these tools for all licensees. Gaining proficiency with the simulation tools is a great way to reduce the time required to design objects and troubleshoot tracking problems.

System Requirements

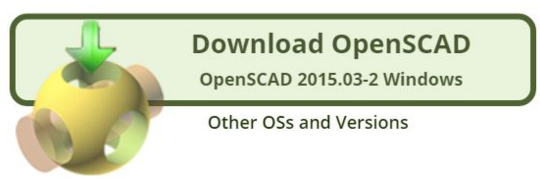
The simulation tool requires a computer with a 64-bit, multicore processor, running Windows 7, 8.1, or 10.

Installation

The simulation tools are distributed through Steam®. To gain access to the tools, you must install Steam®, create a Steam® account, and be a SteamVR™ Tracking licensee. Once Steam® is installed, the SteamVR™ Tracking HDK is available for installation.

1) Launch Steam®
2) Navigate to Library > Software
3) Click the INSTALL button and follow the prompts

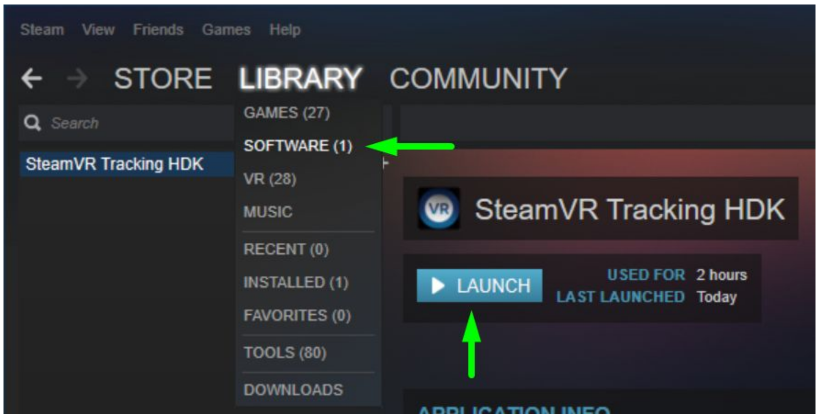
The SteamVR™ Tracking HDK uses OpenSCAD as a visualization tool. OpenSCAD is a free 3D modeling software that uses scripts to render 3D shapes. Download and install the latest version of OpenSCAD from www.openscad.org.



Once installed, run OpenSCAD and select View > Hide Editor to allocate the entire window to visualization. OpenSCAD may be edited in any text editor. If you find yourself working with OpenSCAD source often, consider using Notepad++ and installing the highlighter for OpenSCAD syntax.

Launching the Simulation Tool

Once the SteamVR™ Tracking HDK is installed, the INSTALL button becomes a LAUNCH button. Navigate to the SteamVR™ Tracking HDK and click LAUNCH to start the simulation tool.

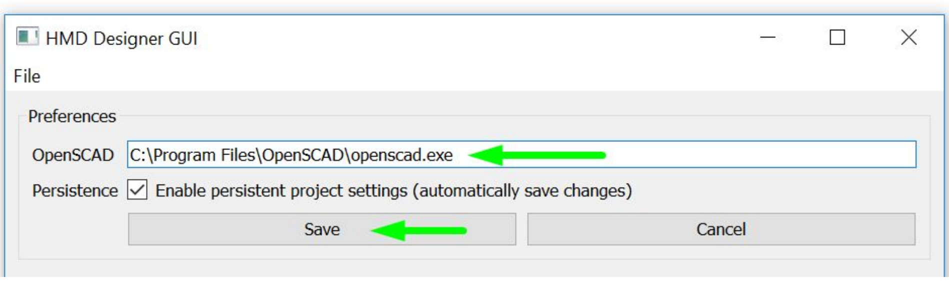


Setting Preferences

If you have installed OpenSCAD in a directory other than the default, you will need to set the path on the Preferences page.

1) Navigate to File > Preferences…

2) Set the path to your OpenSCAD installation directory and click Save.



Creating a New Project

A project contains the 3D model files (.STL or .SCAD), JSON files, simulation settings and simulation outputs for a tracked object. Generating sensor placement, simulating tracking performance, viewing simulation output, and visualizing JSON files are all features available within a project.

Create a new project by following these steps.

1) Navigate to File > New/Open.

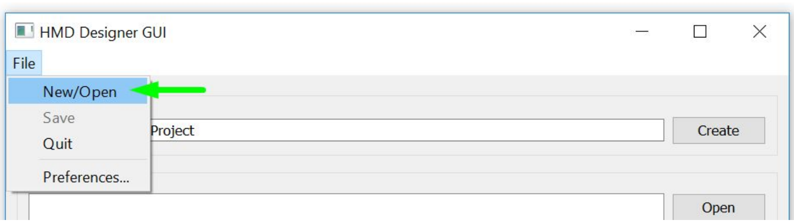
2) Give the new project a name and click Create.

After the project is created, its project screen is displayed for editing. At this point, you are ready to define the project settings depending on what you are trying to accomplish: Generating Sensor Placement, Simulating an Existing Model File, or Visualizing a Model File.

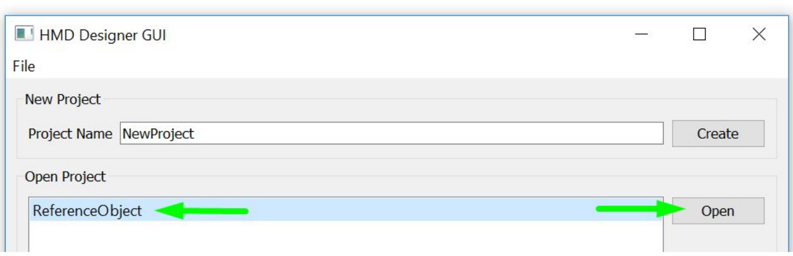
Opening an Existing Project

Open an existing project by following these steps.

1) Navigate to File > New/Open



2) Find your project in the list of existing projects
3) Double click the project in the list, or highlight the project and click Open



Generating Sensor Placement

The simulation tool allows designers to automatically place sensors on a given object shape. The shape is described in an STL or SCAD file. The simulation tool may be set to place from 5 to 32 sensors on the shape, simulate the results, and present the output as 2D and 3D plots. The tool also generates a SCAD file output to display the sensor locations on the shape. Generating sensor placement is a time consuming process. The simulation tool can take advantage of multicore processors by generating and simulating several sensor placement permutations simultaneously.

Preparing Input Files

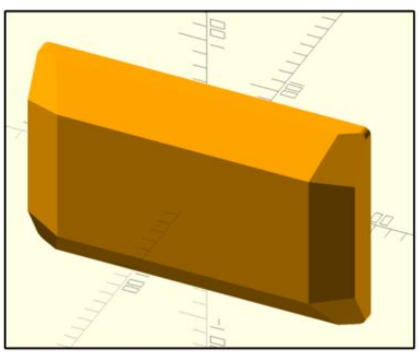
The simulation tool places sensors on the surface of STL or SCAD models. There are a couple rules you should follow when generating the STL or SCAD models to help the simulation tool perform the sensor placement efficiently.

1) Create solid shapes

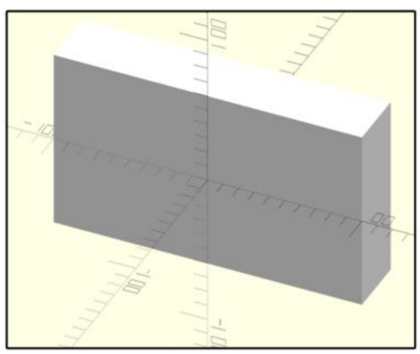
If the tool is presented with hollow shapes, it may spend time trying to place sensors on the internal surface of the model. The tool will place a sensor on an internal surface, move the position around trying to find a location where the sensor could receive a reference signal from a base station, ultimately fail, and move the sensor to the outer surface. Although the generation may result in an acceptable answer, time is wasted exploring failing sensor positions.

2) Mask surfaces that will not hold sensors

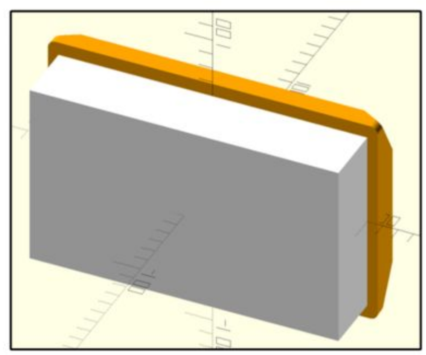
There are likely surfaces on a sensor object that are not valid for sensor placement. For example: surfaces where a handle may attach to the head of a controller, or where a binocular display would attach to an HMD. Creating separate STL or SCAD models that mask those surfaces of the sensor object, prevent the simulation tool from placing sensors on those invalid surfaces. Remember to export both the sensor and mask objects from the same coordinate system.



HMD Sensor Object



HMD Mask for Binocular Display



Mask prevents sensors placement where display and optics are attached

Tip: Orienting the sensor object STL so that the most prominent face of the object points in the positive Z direction ensures that the 2D and 3D output plots display the most critical data in the center of the plot.

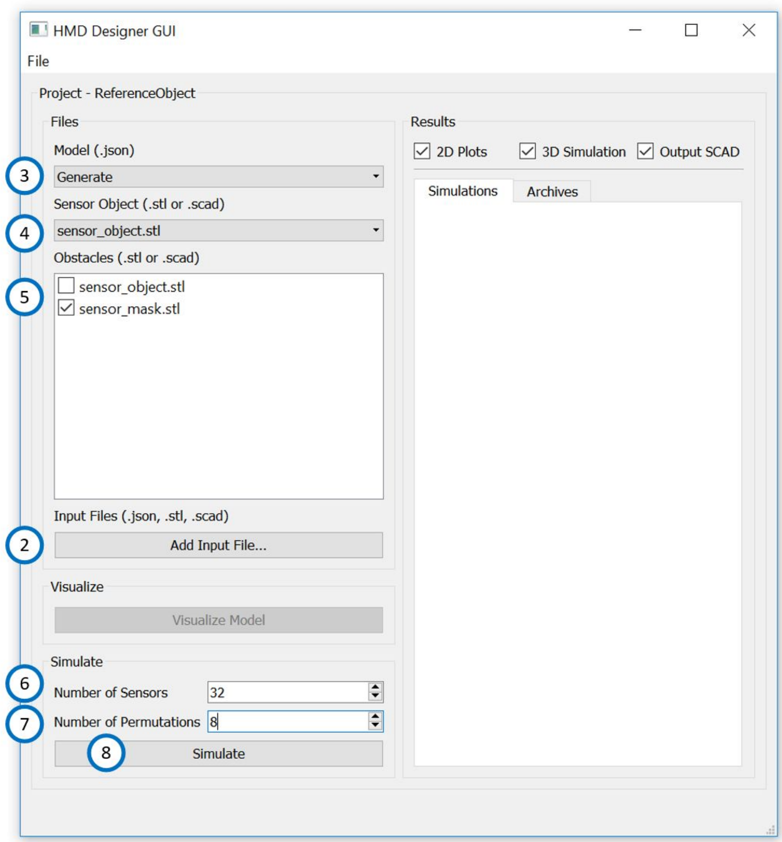
Configuring the Project

Configure the project by following these steps. Refer to the graphic below for control locations.

1) Create a new project or open an existing project.
2) Add STL or SCAD files of any sensor objects or obstacles by clicking the Add Input File… button
    a) Browse to the STL or SCAD files for the project and add them.
3) Leave the model file set to "Generate," which informs the simulation tool to generate the sensor placement before simulation.
4) Select the sensor object, which is the STL or SCAD model that holds the sensors.
5) Select STL or SCAD files to use as obstacles. Any mask models you created to constrain sensor placement are obstacles.
6) Select the number of sensors the tool should place.
7) Select the number of permutations to generate simultaneously.
8) Click Simulate to generate sensor placement and simulate tracking performance.

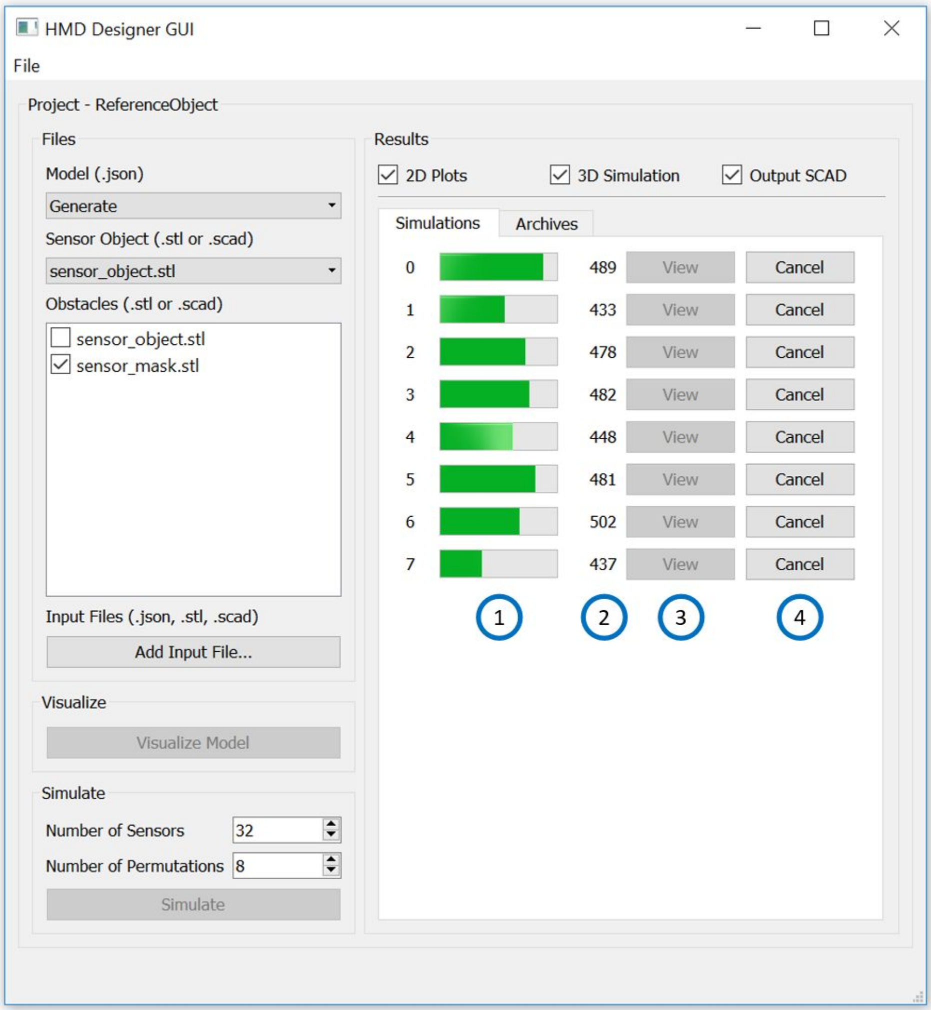
Tip: The time to generate sensor placement increases with the number of sensors, and each permutation is based on a random seed value. If you are taking the time to generate sensor placement, you can get more outputs in the same amount of time by using multiple CPU cores simultaneously. If you have an eight core CPU, try setting the number of permutations to eight before running the simulation.

Tip: If you are interested in quickly testing the generation process to verify the sensor and obstacle models, choose five sensors and one permutation. Using only five sensors and one permutation minimizes the simulation time. Increase these values once the 3D model files are verified.



When sensor placement is in progress, each permutation displays a progress bar (1) that wraps until simulation completes. To the right of the progress bar is a quality number (2). The View button (3) is disabled until the simulation process is complete. Click the Cancel button (4) to stop any permutation.

Note: As placement progresses, the quality number will drop from 1000 to a lower number. Lower numbers correspond to better tracking performance. However, the quality number is only useful for comparing the relative performance of different permutations. There is no threshold that indicates acceptable tracking performance. The only way to truly evaluate tracking performance is to interpret the simulation output plots, prototype the object and track it using SteamVR™.



Once the simulations complete, the progress bars display 100%, the View button is enabled, and the Cancel button becomes the Archive button. Now, you can focus on the permutations with the lowest quality score, view their 2D and 3D output plots, and visualize the sensor placement in OpenSCAD. See the section Viewing Results for more information.

Simulating an Existing Model

The simulation tool allows designers to simulate the tracking performance of a predefined sensor placement. This process is particularly useful once the sensor placement is defined by the mechanical design of the object. It is important to continue simulating the performance as the mechanical design matures.

Preparing Input Files

Simulating an existing model requires specifying the sensor placement by adding a JSON file that describes the position and orientation of each sensor. At a minimum, the JSON file must contain the “modelPoints” and “modelNormals” variables. Read more about defining sensor placement in **The JSON File**.

Although masking surfaces with obstacles is no longer required, it is useful to include obstacles that may occlude the sensors in certain poses. Including models for binocular display housings, controller handles, the user’s head or hand may help verify the sensor placement in real-world use cases.

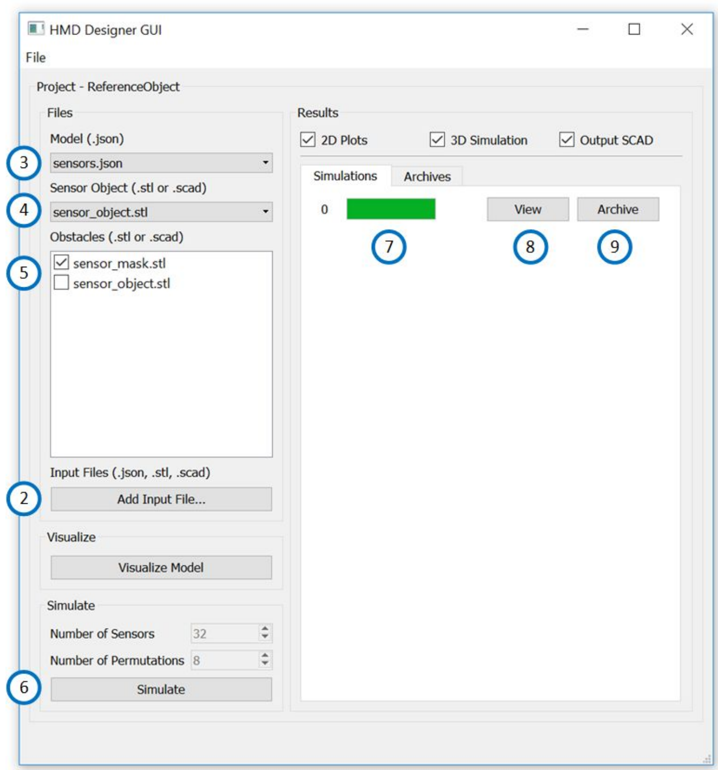
> **Tip:** Orienting the sensor object STL so that the most prominent face of the object points in the positive Z direction ensures that the 2D and 3D simulation output plots will display the most critical data in the center of the plot.

Configuring the Project

Configure the project by following these steps. Refer to the graphic below for control locations.

1) Create a new project or open an existing project.
2) Add the JSON file that defines the sensor placement, and the STL or SCAD files of any sensor objects or obstacles by clicking the Add Input File… button
    a) Browse to the STL or SCAD files for the project and add them.
3) Select the Model JSON file.
4) Select the Sensor Object, which is the STL or SCAD model that holds the sensors.
5) Select any STL or SCAD files to use as obstacles.
6) Click Simulate.

Simulating an existing model is much faster than generating sensor placement. After a short delay, the progress bar (7) displays 100%, and the View (8) and Archive (9) buttons are enabled. There is no quality score, because that number is an output of the generation process.



When the simulation completes, you can view the 2D and 3D output plots. See the section Viewing Results for more information. Output SCAD is not available using View button when a JSON file is specified. To visualize the JSON file using OpenSCAD, follow the process outlined in the section below, Visualizing an Existing Model File.

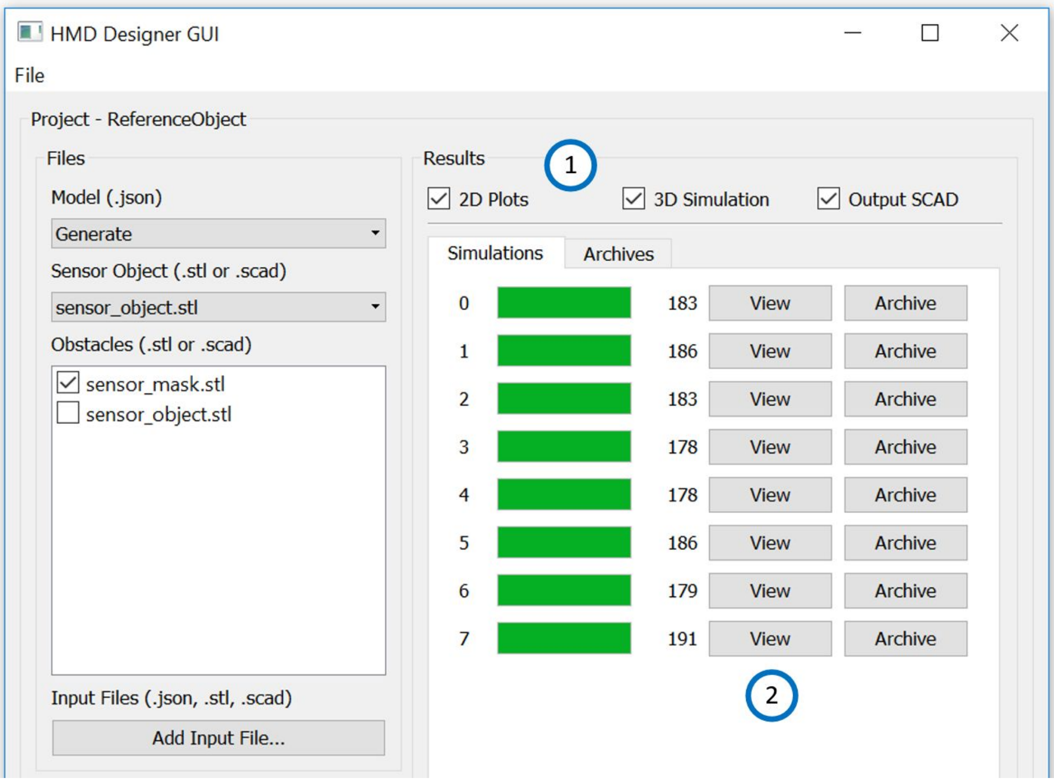
Viewing Results

After a simulation completes, the 2D and 3D plots of tracking performance may be displayed. Additionally, if the simulation tool generated sensor placement, you can also view the output SCAD file that shows the sensor placement. This section documents the mechanics of viewing simulation results using the simulation tool. For an in depth treatment of interpreting the simulation results and making design decisions to improve performance see the document **Interpreting Simulation Results**.

Launching the Viewers

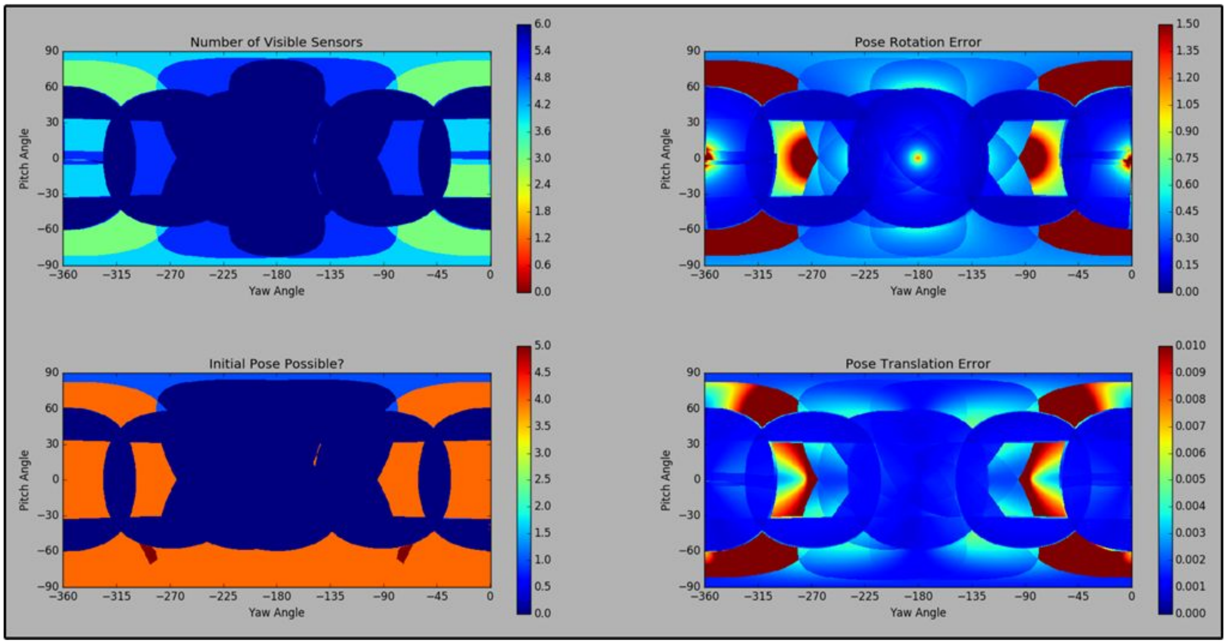
View output plots and SCAD models by following these steps.

1) Select the outputs you would like to view using the checkboxes in the Results section.
2) Click the View button beside the simulation you would like to view.

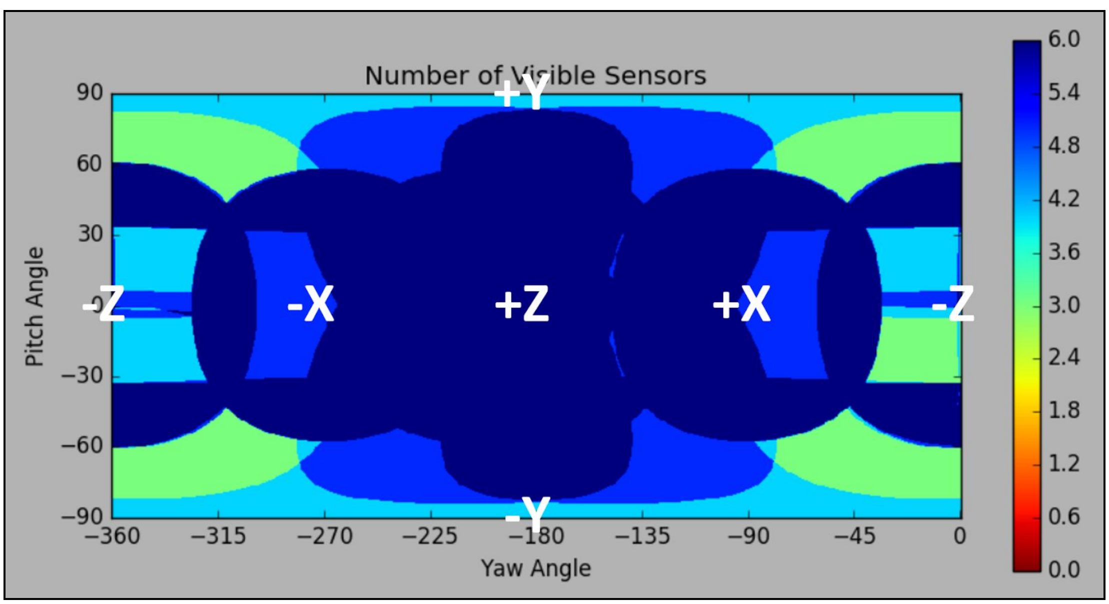


2D Plots

The 2D plots are very useful for comparing designs at a glance, sharing via email, and copying into documentation. They include output plots for the Number of Visible Sensors, Initial Pose Possible?, Rotation Error, and Translation Error. All poses, characterized by a sphere, are unrolled onto a two dimensional plot with Pitch and Yaw axes. Simulation values are represented in the color gradient on the plot.



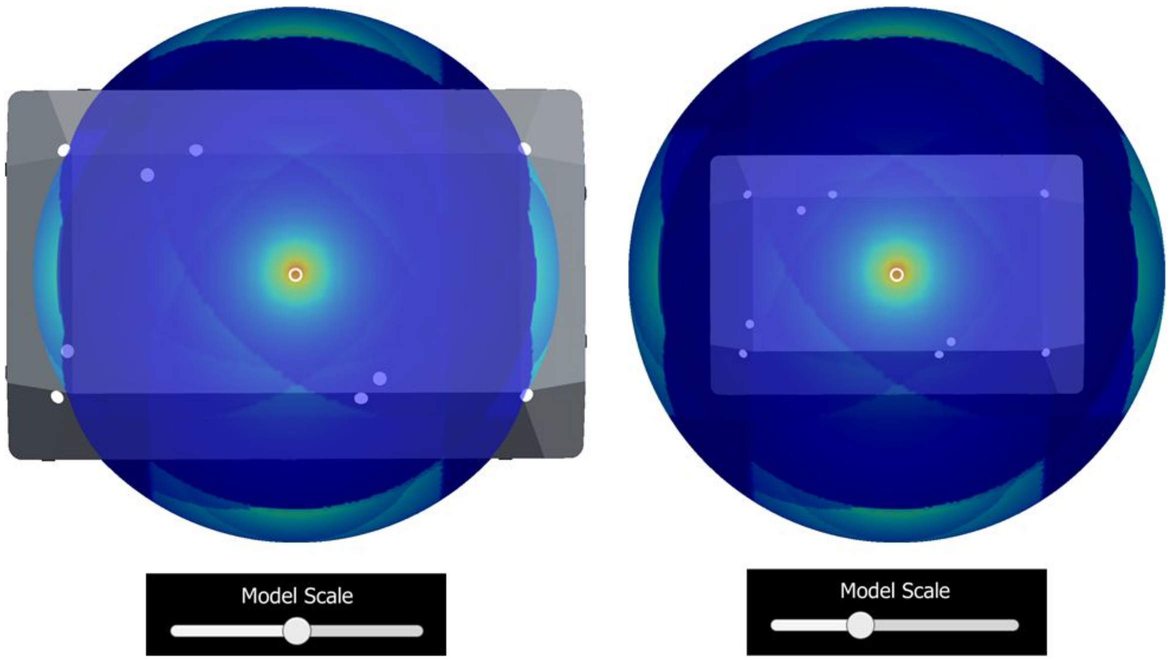
Understanding where the 3D axes are located on the 2D plots helps associate the plot to the actual object. However, for inspection of specific poses, the 3D plots are easier to navigate.



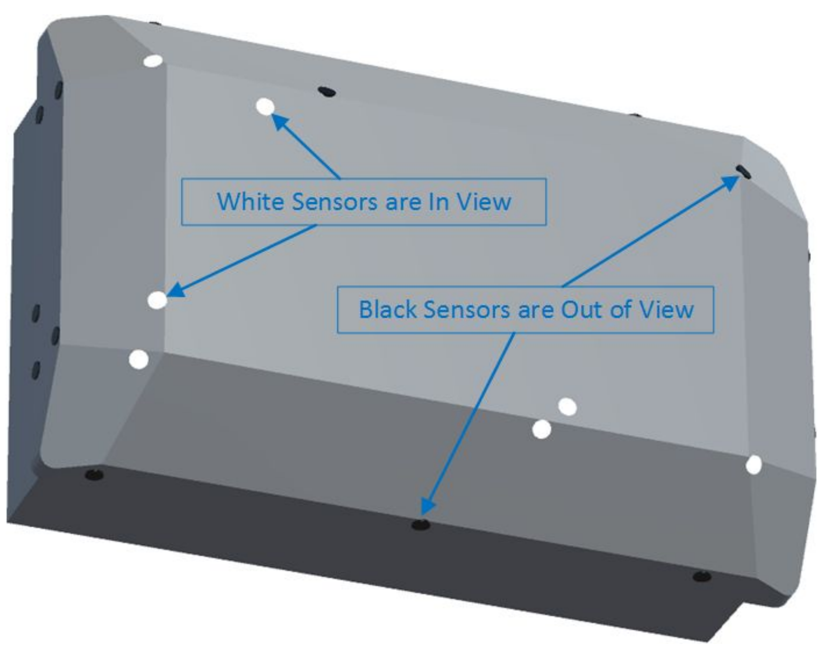
3D Plots

The 3D plots are very useful for pinpointing poses that exhibit low tracking performance. Hmd_designer_viewer displays the same four plots available in the 2D output: Number of Visible Sensors, Initial Pose Possible?, Rotation Error, and Translation Error. Use the number keys associated with a plot to turn it on or off.

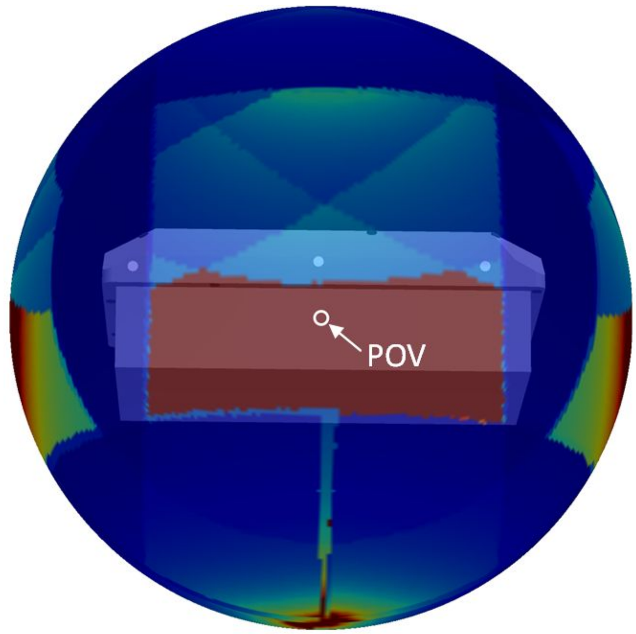
All these plots are displayed in a sphere around a 3D model of the object and obstruction. If the model is much larger than the bubble displaying the plot, use the Model Scale slider to shrink the model into the bubble.



Another useful feature of hmd_designer_viewer is its ability to highlight sensors when they are within ±60° of the point of view.



Rotating the model with the mouse, pointing the POV circle at areas of interest, and noting which sensors are active in a pose, makes it easy to see which sensors are contributing to the tracking performance in that orientation.

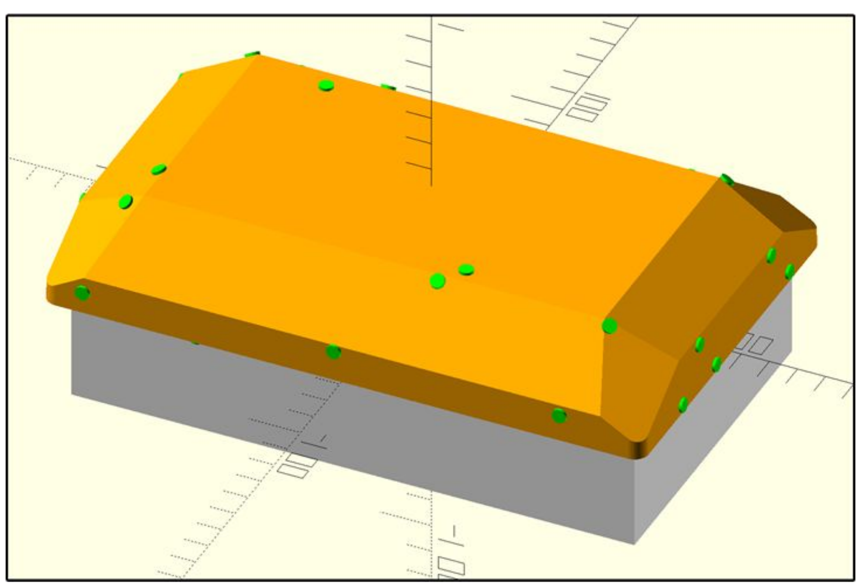


Rotation Error: Only three sensors are visible from this point of view, and there is only one axis with baseline.

Output SCAD

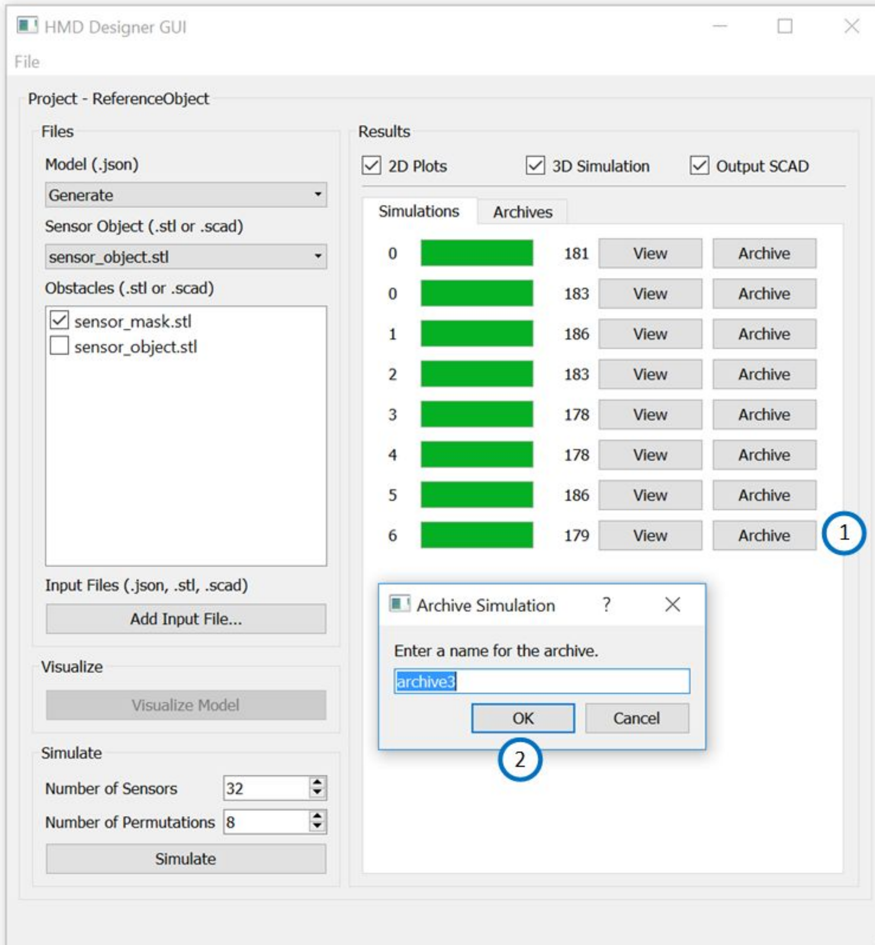
An output SCAD file is generated along with a JSON file when the simulation tool automatically places sensors on an object. Viewing the output SCAD file shows the locations that the simulation tool chose for sensor placement. This view is a starting point for refinements to the object shape, or integrating the sensor locations and orientations into the mechanical design.

The sensor object is colored orange. The obstacle solids are white, and the sensors are represented as green dots on the surface of the sensor object.

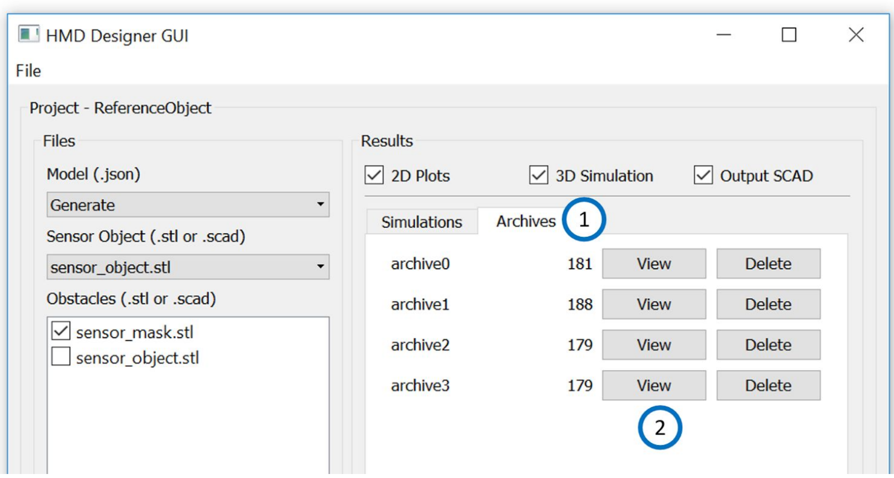


Archiving Results

Simulation results are overwritten with each new simulation. If the generation routine produced an output that you would like to save, or if you would like to store a model simulation to compare against the simulation of another model, you can archive the simulation results by clicking the Archive button. Give the archive a name and click OK to save the archive.



Viewing an archived simulation is the same as viewing simulation data. Simply switch to the Archive tab and click the View button next to the results you wish to view.



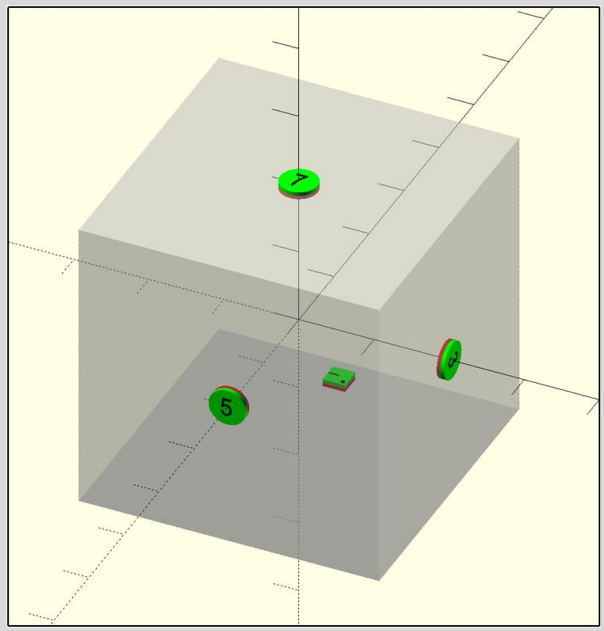
Visualizing an Existing Model

Although simulation is the best way to ensure an initial design is fit for prototyping, evaluating the actual object in SteamVR is the best way to truly understand the performance of the object. However, initial tracking problems are usually due to errors in the JSON file, not problems with the design of the shape. For SteamVR™ to correctly resolve the position of an object, the physical arrangement of the sensors and the IMU must correspond to the JSON file. It can be challenging to verify the values in the JSON file by the numbers. It is far easier if the JSON file is rendered in three dimensions for comparison to the physical object. The simulation tool provides a feature that does exactly that.

When a sensor STL or SCAD and a JSON file are specified, the simulation tool can generate a SCAD output file that displays the sensor locations, orientations, and channel numbers in addition to the IMU location and orientation.

Take this simplified JSON file for example. It specifies three sensors on the surface of a cube, with an IMU located inside the cube. The three sensors are centered on the faces of the cube, oriented in the +X, -Y, and +Z directions, and connected to channels 3, 5, and 7 respectively. The +X axis of the IMU is oriented in the model's -X direction, and its +Z axis matches the model's +Z axis. The IMU is offset one centimeter along +X and one centimeter along -Y.

```
{
   "channelMap" : [3, 5, 7],
   "modelNormals" : [
      [1, 0, 0],
      [0, -1, 0],
      [0, 0, 1]
   ],
   "modelPoints" : [
      [0.02, 0, 0],
      [0, -0.02, 0],
      [0, 0, 0.02]
   ],
   "imu" : {
      "acc_bias" : [ 0, 0, 0 ],
      "acc_scale" : [ 1, 1, 1 ],
      "gyro_bias" : [ 0, 0, 0 ],
      "gyro_scale" : [ 1, 1, 1 ],
      "plus_x" : [ -1, 0, 0 ],
      "plus_z" : [ 0, 0, 1 ],
      "position" : [ 0.010, -0.010, 0.0 ]
   }
}
```



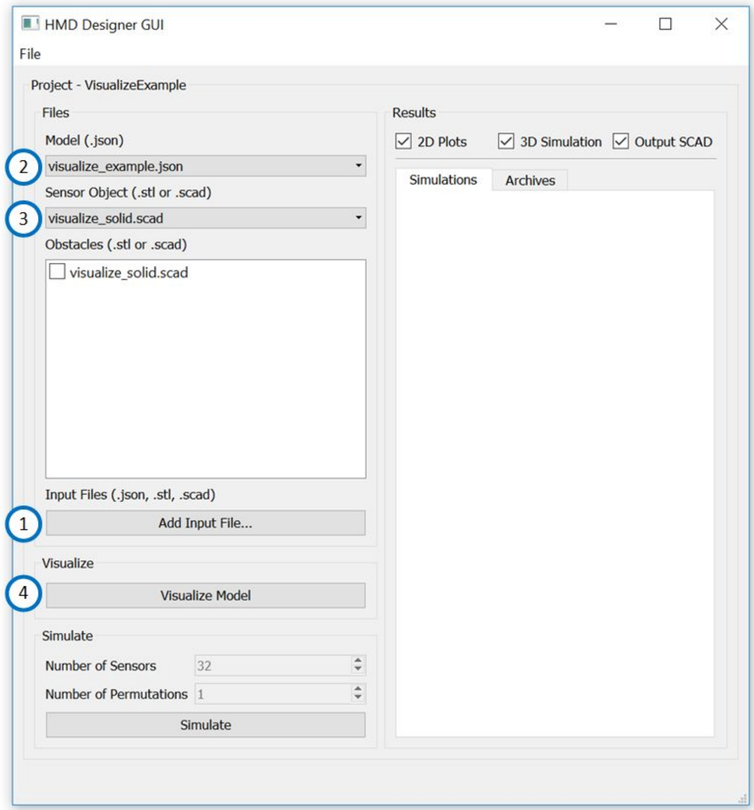
Preparing Input Files

Create a JSON file that includes "modelPoints" and "modelNormals." Including the "channelMap" variable is optional. If "channelMap" is missing, the tool will insert a "channelMap" numbered sequentially, starting at 0. The "imu" variable is also optional. However, if "imu" is included, be certain to specify the "position", "plus_x", and "plus_z" variables. For more information about how to specify these values see **The JSON File**.

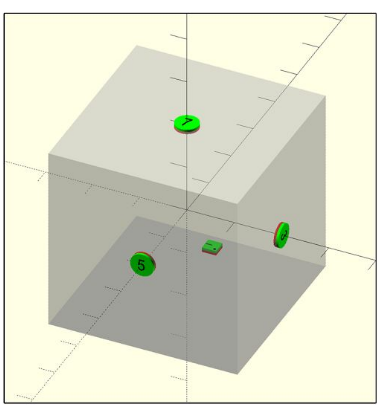
Configuring the Project

To visualize the JSON file.

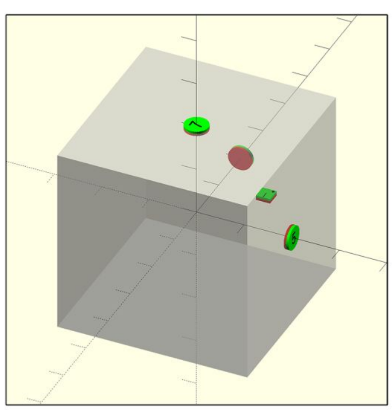
1) Add the JSON file and a sensor STL or SCAD file to the project.
2) Select the JSON file in the Model drop down list.
3) Select the sensor file in the drop down list.
4) Click Visualize Model.



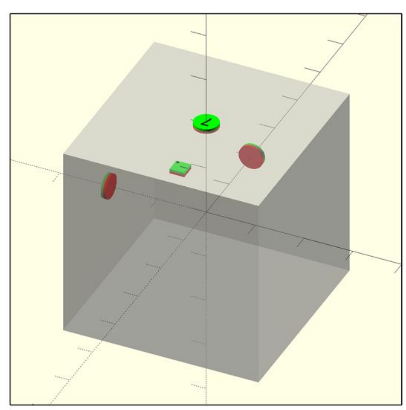
The SCAD output displays a transparent version of the sensor object, making the IMU within the object visible. The sensors are shown in their location and orientation. The front of the sensor is green and includes the channel number. The back of the sensor is red, making it easy to spot a sensor normal that is flipped 180°.



Rotated 0° about the Z axis



Rotated 90° about the Z axis



Rotated 180° about the Z axis