Sixdof Space

ULTRA FAST OPTICAL TRACKING

Sixdof Falcon Development Kit User Guide

Version 4

Abstract

Welcome to the Sixdof Falcon Development Kit User Guide. This manual is designed to provide documentation for people who will use the Sixdof sensor, beacons, and Sixdof Falcon software. It contains instructions for effortlessly setting up the sensor and verifying its functionality, along with essential reference materials needed to operate the system.

For technical support, please contact Sixdof Space by email support@sixdofspace.com

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1 Introduction

1.1 The Sixdof Falcon Development Kit

This development kit allows you to quickly create a test setup to demonstrate the operation of the Sixdof sensor with the Sixdof Falcon software, and help you plan the implementation of its use.

The Sixdof Falcon Development Kit is a blend of software, optics, electronics and algorithms that together provide a comprehensive understanding of object movements. By using the Sixdof sensor attached to an object, you can accurately track the position of that object during its motion. Additionally, the integration of multiple sensors across various objects enables simultaneous tracking of each object's movement. To get you started, this guide outlines a quick setup process to configure the sensor, enabling you to immediately visualize the real-time flow of 6dof positional data.

1.2 Content Overview

The Sixdof Falcon Development Kit contains the following components:

Sixdof Sensor: The heart of the system is the Sixdof sensor device comprised of three optical sensing units housed with a processing board.

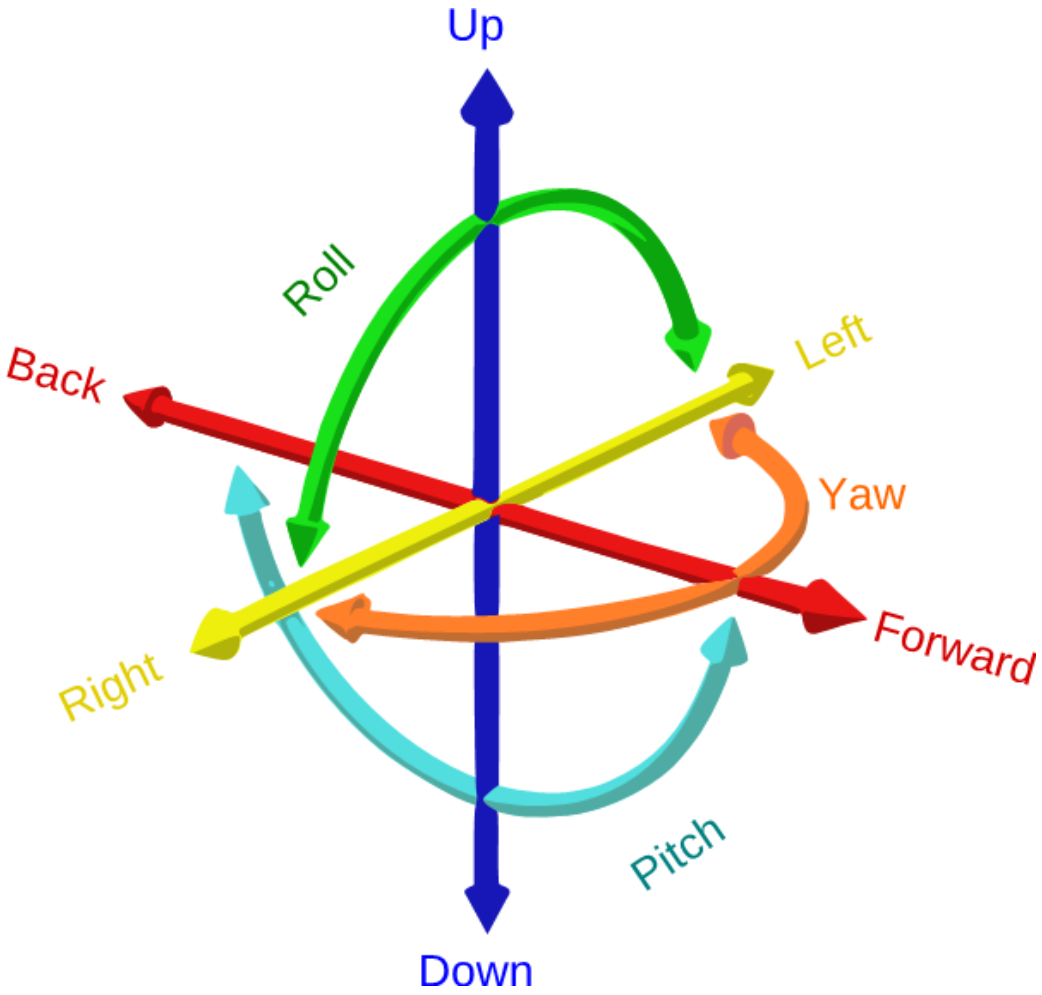
Sixdof Basalt IR Beacons: Every kit contains 1 Basalt to drive 4 or 6 lower powered LED's and 1 higher powered LED (the configuration is customized based on the use case).

Cabling, accessories: 90W - 20V power supply for the Basalt Beacons, 3-meter RJ-45 Ethernet cable, USB to RJ-45 adapter and 3-meter USB power cable.

Software download link: To download the Sixdof Falcon software.

1.3 What Sixdof Space Does

When describing the position of a rigid body, six parameters represent the directions in which the body is free to move. This is known as “6DOF” (Six Degrees of Freedom) - the full position and orientation (pose) of an object (see image below). Many systems require live, precise measurements and ongoing reporting of these six parameters in order to function. We provide those parameters in real-time with low latency. This means that the object’s absolute position and orientation are tracked and rapidly communicated to the system that needs them.



Whether embedded in drones, VR/AR headsets, robots, warehouse vehicles, medical devices or dozens of other applications, the key ingredients for such a system to be successful are speed, accuracy and low latency. The approach of the Sixdof Optical Sensor offers breakthroughs in all of these factors. The approach combines optics, algorithms and electronics in a single package for deployment in a variety of products, in multiple industries. The patented technology is used together with coded, infra-red LEDs that serve as location beacons. By embedding the Sixdof sensor in your existing hardware, the system will independently report accurate position to your host system at very high speed. Communications with your host computer are provided by an Ethernet interface and the Sixdof Falcon software that includes a suite of tools to control system operation, a host processing SDK and visualization tools.

1.4 Safety Notes

1.4.1 IR Safety

WARNING: The beacons emit infrared light. When powered on, do not look directly at the beacon from a very short distance with the naked eye.[1] **NOTE:** Many front-facing cameras on smart-phones are able to see infrared and will be able to see an emitting IR Beacon. If you have such a camera, you can use it to look at each beacon board to confirm that the IR emitters at the center of the board are lit up. It remains the responsibility of those installing infra-red emitters to check for themselves that the appropriate safety guidelines are followed.

1.4.2 Operation

- The hardware contents of the package are NOT waterproof and are not designed for operation in a wet environment.
- The system is currently evaluated for operation between 0℃ and 45℃.
- The kit is for demonstration, development and training purposes.

1.5 Support

The Sixdof Falcon Development Kit allows testing, evaluation, and prototyping with Sixdof's high-speed optical 6dof sensor.

With every kit, Sixdof also provides up to 10 hours of technical support to help you integrate the Sixdof sensor's optical tracking with your specific applications. We are here to help you get your application up and running as quickly as possible.

To schedule a consultation with the Development Team, contact Sixdof at support@sixdofspace.com.

[1] The emitted radiation is a wide beam of 850nm IR light (non-laser, over 120° × 120°, with average optical power of around 400mW, and peak optical power of around 4.8 Watts.

2 Quick Start

To get started, we highly recommend launching Sixdof Falcon Studio, an intuitive tool designed to guide you through the setup process. Here's a simplified breakdown of the steps:

- **Launch Sixdof Falcon Studio:** Navigate to the `bin` folder and then to the folder that corresponds to your platform's name, and run the Sixdof Falcon Studio application.
- **Connect the Sensor:** Follow the on-screen instructions to connect your sensor.
- **Tracking Mode Selection:** Choose between three distinct options:
  - **6DOF:** Position and orientation of the sensor relative to the map. Operating range 0-6m.
  - **Relative Beacon:** Position of a beacon relative to the sensor. Operating range 0-2m.
  - **Relative Angle:** Angle of a beacon relative to the sensor. Operating range 0-100m, depending on beacon availability.
- **Set Up Beacons (Optional):** If 6DOF mode is chosen, configure the beacons as per your requirements. Sixdof Falcon Studio provides easy-to-follow steps for this process.
- **Visualize Tracking Data:** Once the sensor is connected and, if applicable, beacons are set up, you can visualize the sensor in action with real-time visualizations of data flow.

You are now ready to dive into the SdsFalcon SDK code. To familiarize yourself with the SDK functions, we suggest exploring the provided build examples.

- **Examples Location:** The build examples can be found in the `examples` folder.
- **Review the Code:** Take a thorough look at the code. Remember to input your sensor's ID and network name in the appropriate locations, and to update the map if applicable.
- **Build and Run:** Work with one example at a time: build it and then execute it. You will find that each example yields distinct data outputs. Refer to the `Build Examples.pdf` in the `docs` folder for comprehensive instructions.

By following these steps, you will efficiently acquaint yourself with the system, paving the way for a smooth and productive exploration of its capabilities.

3 Sixdof Falcon Software Overview

3.1 Sixdof Falcon Studio

Sixdof Falcon Studio is a program that provides a graphical user interface for the Sixdof Falcon tracking system. The goal of Sixdof Falcon Studio is to provide users with a convenient way to test the system without the need of writing any code. It includes a step by step process for configuring the system, as well as various visualizations of the tracking data. Additionally, every feature provided in Sixdof Falcon Studio reflects a feature in the SdsFalcon SDK, therefore using Sixdof Falcon Studio is the best way to learn about the features of the SDK.

Sixdof Falcon Studio is available on the following platforms:

- Windows
- Linux Ubuntu

The files for running Sixdof Falcon Studio can be found in the folder that corresponds to your platform's name in the `bin` folder.

On Windows, when initially launching Sixdof Falcon Studio, you will encounter a popup requesting administrator permissions, click "Allow". These permissions are necessary because the program conducts network discovery of the sensor by adding the sensor to the ARP table. It is how the sensor obtains its own IP Address. On Linux, Sixdof Falcon Studio should be launched with administrator permissions by using the sudo command.

3.2 SdsFalcon SDK

SdsFalcon SDK is a shared library that provides a C++ interface to the Sixdof Falcon tracking system. The SDK comes with full documentation, stand alone examples, and is available on the following platforms:

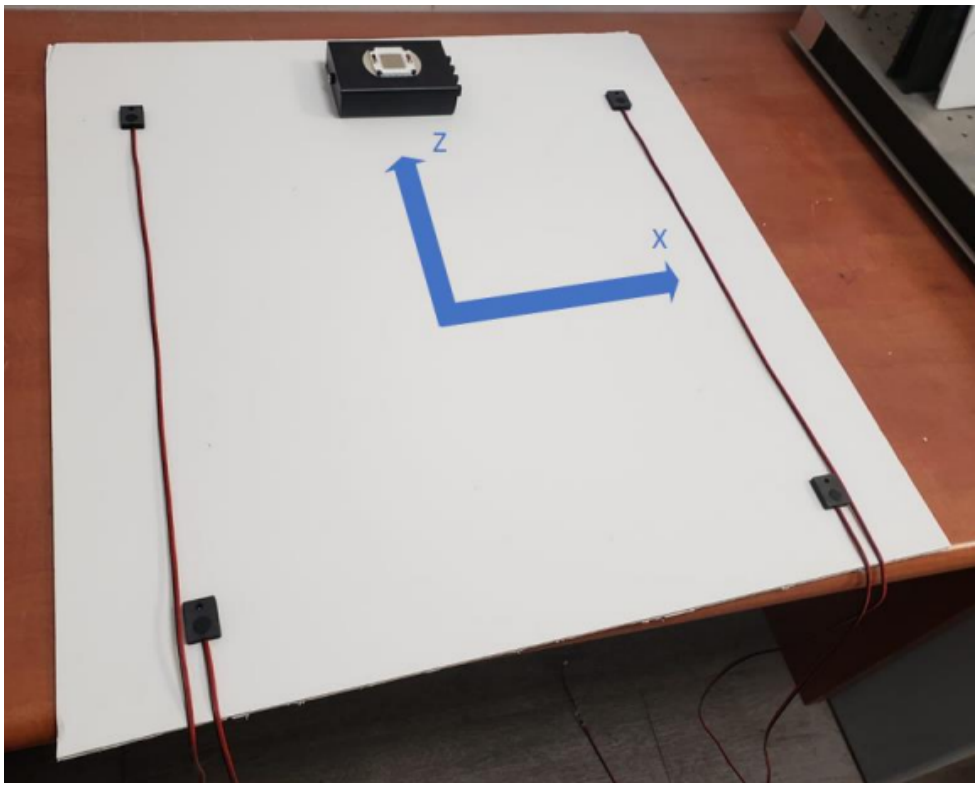
- Windows
- Linux Ubuntu
- Linux Raspberry Pi OS (32 bit)
- Linux Raspberry Pi OS (64 bit)
- Nvidia Jetson

The SDK shared library can be found in the `bin` folder of this software release. Use the library from the folder that corresponds to your platform's name to ensure compatibility. The SDK header file can be found in the `include` folder. See the `examples` folder for build-able examples that can get you started. The full API documentation "SdsFalcon API.pdf" can be found in the `docs` folder.

4 Hardware Setup - Creating a Map

In 6DOF tracking mode, the position and orientation of the sensor is tracked relative to a defined map of IR beacons. To create the map:

1. Choose a rigid surface, ideally about 1 meter square. Note that all measurements should be in meters.
2. Establish a right-hand coordinate system by selecting an origin point (typically the center of the surface) and defining two perpendicular axes (e.g., the x-axis points to the right from the origin, and the z-axis points up). It is recommended to mark these on the surface for easy reference.
3. Attach all the beacons to the rigid surface. Two criteria must be kept in mind when placing beacons:
   - By spreading out the beacons to the corners of the surface, you can achieve better geometry and therefore tracking accuracy.
   - 6DOF localization requires 3 beacons to be seen, the field of view of the sensor is a 120 degrees cone, therefore to localize when close to the map, ensure that at least 3 beacons will be positioned in the field of view.



4. Each beacon is labeled with a unique id.
5. Once the physical map is set up, determine the coordinates of each beacon, in meters, and record it with the corresponding id. If using a high powered beacon, do not include it in the map.

5 General Sixdof Technology Use Cases

The sensor has a large field of view, low data bandwidth and gives minimal disruption to your work site as it delivers accurate 6dof data. It gives you the ability to flexibly integrate this positioning technology into your product. Below are some recurring use cases:

5.1 Drone Landing

Sixdof Space has created an optical tracking solution offering precision landing with cm level accuracy both indoors and outdoors in direct sunlight. Our patented technology leverages infrared lighting to serve as location beacons. Our sensor unit, connected to your drone, can see the beacons on the ground at up to 100 meters. Our algorithms will report the 6dof positional data to the drone, to direct an autonomous landing.

5.2 Warehouse Logistics

Warehouses and manufacturing plants rely on robots, forklifts and other indoor vehicles. The sensor offers an optimized solution for using infrared coded beacons for autonomous navigation or independent location tracking.

5.3 AR in Industry

AR/VR is being used today for maintenance, manufacturing and simulators. The problem: if the head is not tracked accurately and at a very fast speed, the experience is underwhelming and often adopted with resistance. The Sixdof technology is accurate and very fast – we are tracking at speeds of up to 1000 times per second.

5.4 AR/VR Accurate Head Positioning on a Moving Platform

Most camera-based trackers rely on an IMU – the device in a smart-phone that lets it know that it is tilting or moving. Camera-based SLAM systems all rely on the IMU. But if you are using a headset in an active vehicle (a bus, a car, a tank or even an airplane) – the IMU cannot function properly because the vehicle is moving. The Sixdof sensor does not rely on an IMU and is thus ideally suited for applications in moving vehicles.

5.5 Drone Cluster Positioning

Some use cases require drones to fly in fast-moving swarms. With little distance between the drones, GPS does not offer the precision that operators need to keep the drones traveling safely in formation. The Sixdof tracking solution provides more precise tracking information, mapping the position of drones with unmatched accuracy.

5.6 Robotic Indoor Navigation

In a large facility or tunnel, the mounted Sixdof tracking solution can navigate a tractor or robot using beacons built in to lights. Positional data is sent back to a host computer over local-area wireless communication, or even uploaded to the cloud using 5G cellular service. A unified map of the facility or tunnel can be shared by all tracking units.

5.7 “Follow-Me”

A vehicle can follow another vehicle in its group by the Sixdof sensor and beacons on the front and back of the vehicle. This technology allows each moving vehicle to “see” the vehicle in front and behind, and to easily follow it.

5.8 Construction

By installing the Sixdof tracking unit as part of the helmet, workers can be tracked in a construction zone using installed infrared coded beacons.The Sixdof technology can significantly add to site safety, either for locating workers or to ensure that a worker does not accidentally go into a dangerous area. Sixdof sensors mounted on equipment enables you to precisely track that equipment, for example, preventing it from exceeding operating boundary limits or colliding with other equipment or objects.

A Troubleshooting and Technical Support

A.1 Firewall

If a popup is displayed asking about the firewall permissions, click "Allow". Make sure to check off and allow for both private and public networks.

A.2 Network Issues

In this section, we will discuss how to diagnose and solve issues relating to computer networking that can arise in Sixdof Falcon Studio or from the SdsFalcon SDK. When any of the following messages are displayed, the connection to the sensor was not established.

A.2.1 Ping Failed

The "Ping failed" message can be displayed when incorrect sensor ID was entered. Check the sensor ID label on the sensor and make sure that the correct ID is entered.

A.2.2 Network Not Found

The "Network not found" message is displayed when an incorrect network name is selected. Use the "Discover" button in Sixdof Falcon Studio to ensure that the network that the sensor is attached to is selected.

A.2.3 Algo Address Already in Use

The "Algo address already in use" message is displayed when the connection to the sensor cannot be established. This is most likely due to having one program that utilizes the sensor and then opening another, or rerunning the program immediately after previously closing it. Wait a few seconds and then reestablish the connection to the sensor.

A.2.4 ARP Entry Not Found

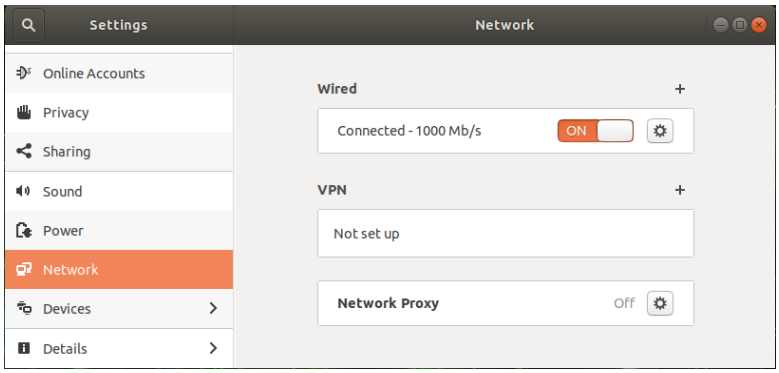
The "ARP entry not found" message is displayed when an incorrect sensor ID or IP address is entered. Check the sensor ID label on the sensor and make sure that the correct ID is entered, and check that the IP address entered corresponds to the address that you have entered in the ARP table.

A.2.5 Invalid IP Address

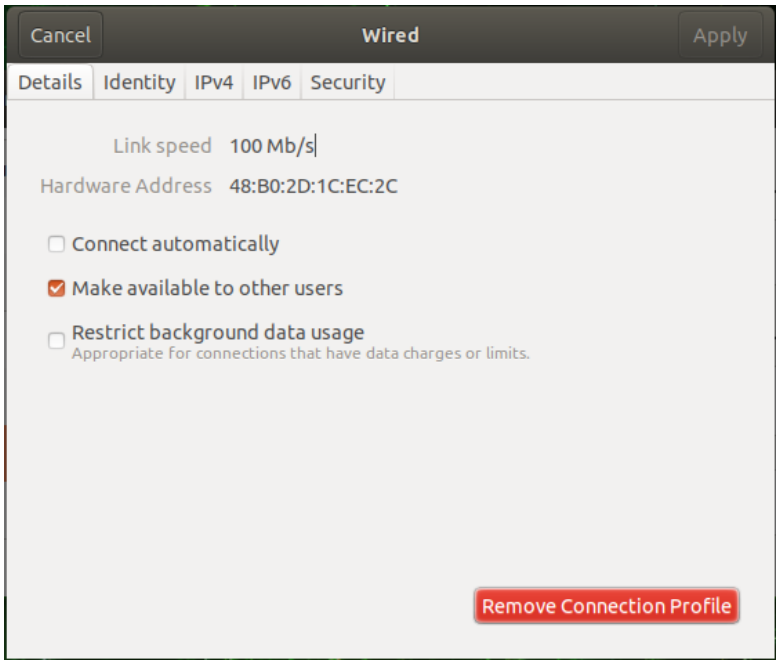
The "Invalid IP address" message is displayed when an invalid IP address is entered. Check that the IP address entered corresponds to the address that you have entered in the ARP table, and that it is a valid IP address.

A.3 Linux Network Setup

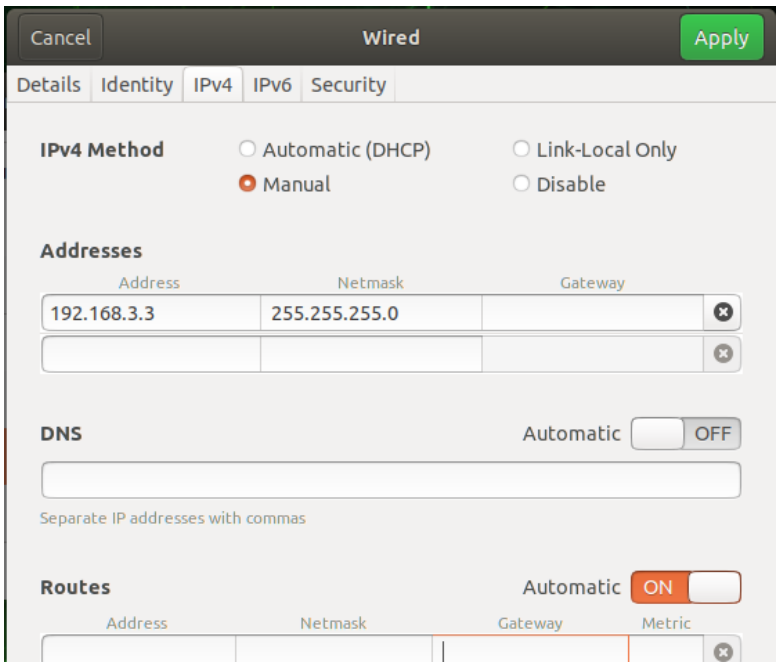
To connect the sensor to the host computer, first connect the sensor's micro-USB to a 5V power source. Next connect the RJ45 port to a network port on the host computer, or via a USB to Ethernet dongle. On Linux based computers, you must set up the network before operation of the sensor. Additionally, to achieve best performance on Linux platforms, Wifi should be turned off during operation. The net-tools package is required to connect to the sensor. You can test if you have the net-tools package by typing "ifconfig" into the command line, if the response says "command not found" please install the net-tools package via the command: "sudo apt install net-tools". The following instructions are for Ubuntu based distributions, the Raspberry Pi 3b instructions are shown below. First navigate to the Network Settings and ensure the "Wired" connection is set to "ON":



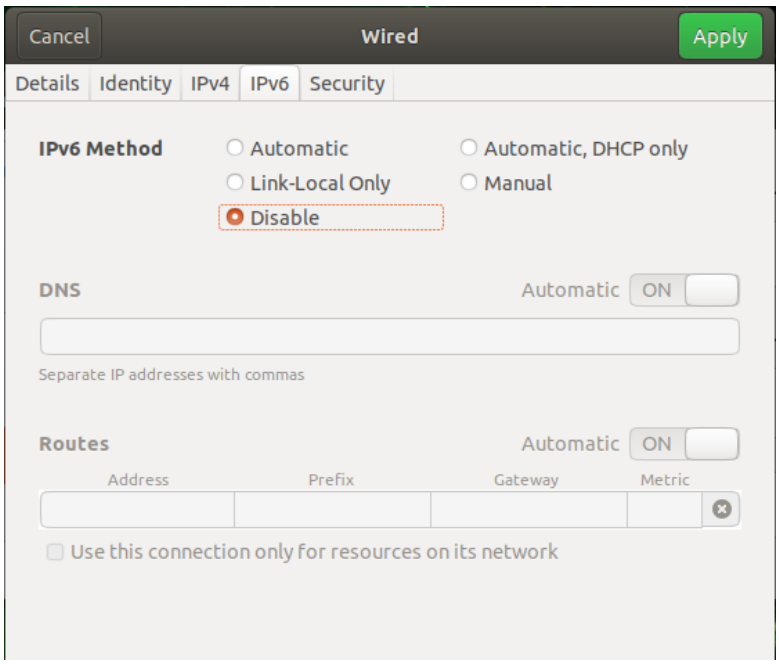
If you are using a USB dongle there will be another row labeled "USB Ethernet", set that to "ON". Next click the gear button to go to the advanced settings:



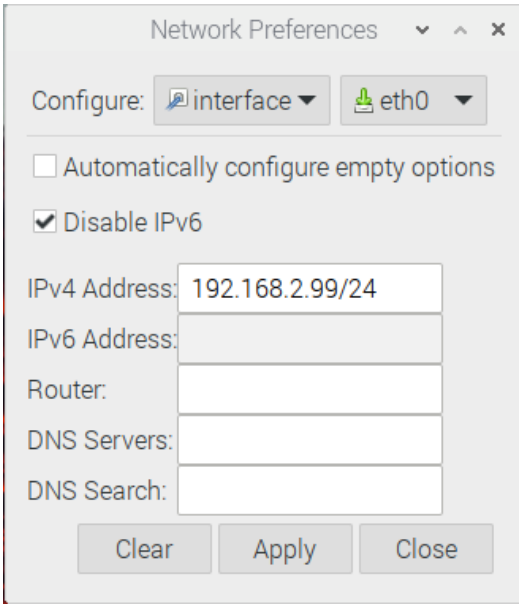
In the "Details" tab, deselect the checkbox that says "Connect automatically". Next navigate to the IPv4 tab and set the "IPv4 Method" to "Manual" and set the "Address" and "Netmask". The Address can be any IP address that you choose, however it should not clash with any other networks on the host computer. To avoid IP address clashes as much as possible you can set the Netmask to 255.255.255.0. Additionally, set the "DNS Automatic" to "OFF" as shown below:



Finally, navigate to the IPv6 tab and for the "IPv6 Method" select "Disable":



On Raspberry Pi 3b, navigate to the "Network Preferences" menu, next to "Configure" leave the first drop down on the "interface" option, and on the second drop down select the network that you are connected to, typically "eth0". If you are using a USB dongle the network may have a different name. Deselect the options that says "Automatically configure empty options", and select "Disable IPv6". Next fill in an IP Address that you selected and put "/24" at the end to indicate that you want a submask of 255.255.255.0. An example is shown below:



A.4 Network Configuration on Raspberry Pi

A connection to the sensor can only be established on a Raspberry Pi after its network is configured correctly. To configure the network, run the following three commands in a terminal:

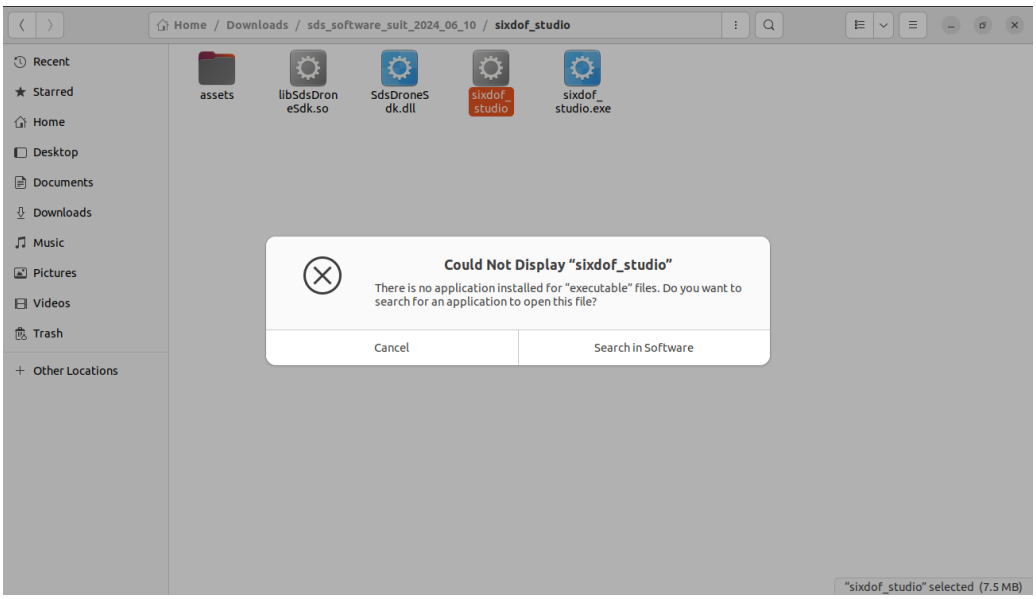
```
sudo ip address add 192.168.2.1/24 brd + dev eth0
sudo ifconfig eth0 192.168.2.1
sudo systemctl restart networking
```

Notes on the above commands:

- The IP address specified is the IP address that you want your computer to have, not the sensor.
- The /24 indicates the subnet mask.
- The Ethernet interface being configured is eth0. This is typically the name of the Ethernet port directly on the Raspberry Pi. If you are using a network adapter dongle, make sure to use the corresponding Ethernet name.
- The last command restarts the networking service to apply the changes.

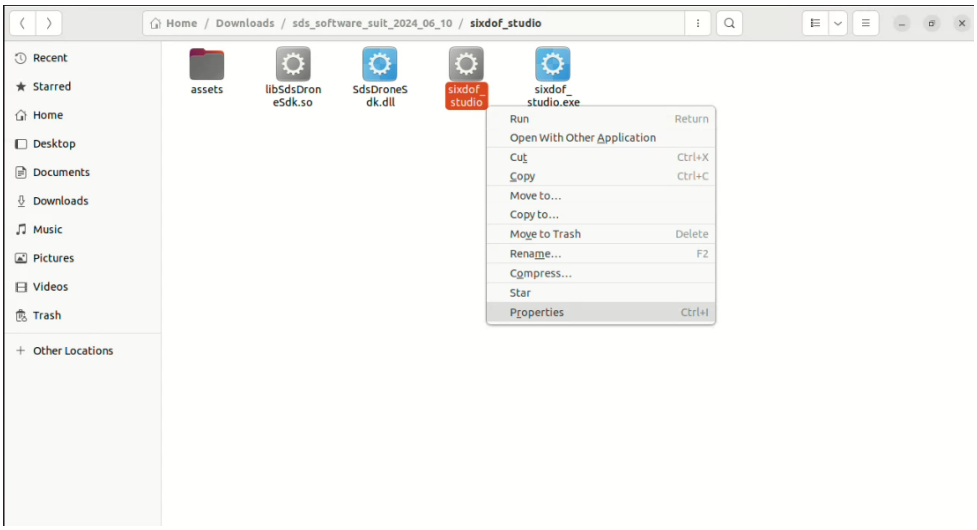
A.5 Running on Linux

If you are running Sixdof Falcon Studio from a Linux computer, it might need to be given executable permissions. If the program does not already have executable permissions and you are running the program from the terminal, you will get the error "command not found." If you are clicking on the file icon, you will see the following pop-up:

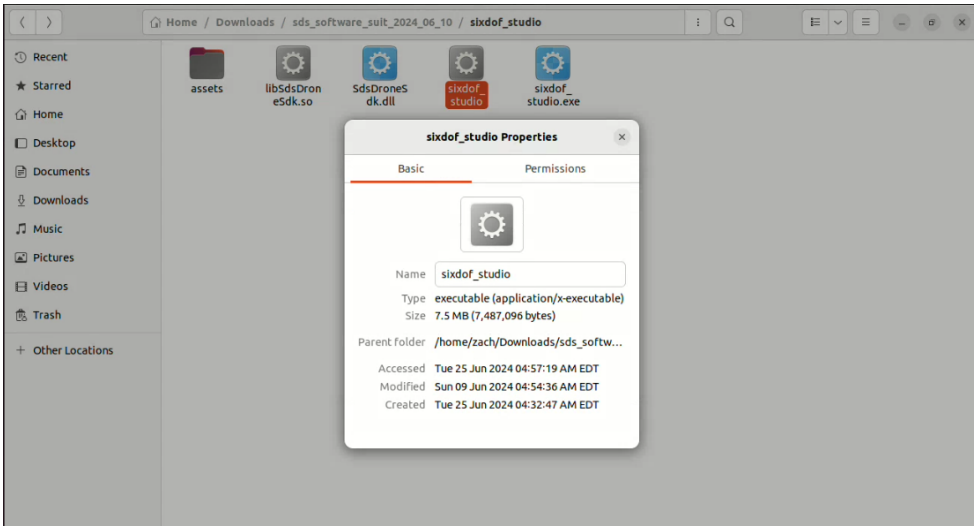


To give the program executable permissions, follow these steps:

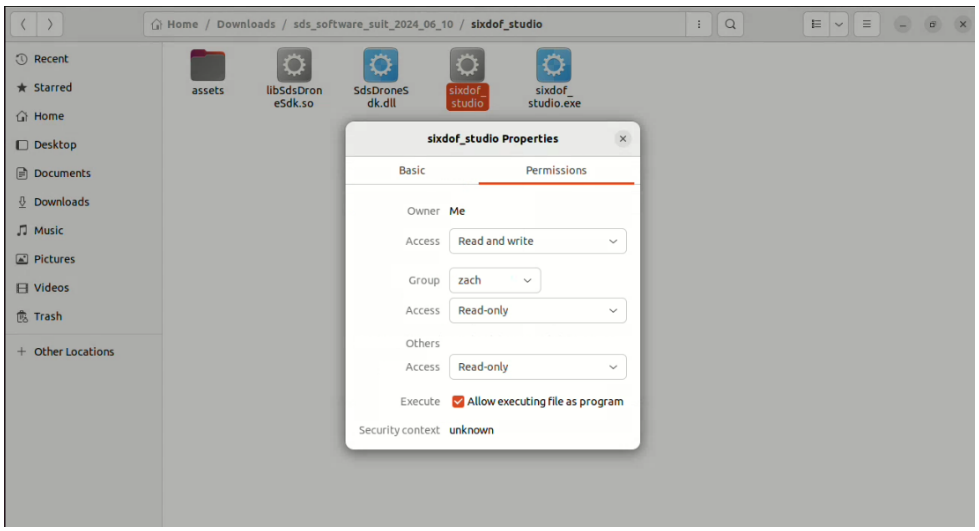
- Right-click on `sixdof_falcon_studio` and the following menu will appear. Select "Properties".



- The following window will appear. Select the "Permissions" tab.



- Under "Execute," select the checkbox to mark it.



Now you can run the program by clicking on the file icon or running it from the terminal. It is recommended to run the program from the terminal with sudo for the first time.

A.6 Sixdof Falcon Studio does not open on Windows

Sixdof Falcon Studio requires OpenGL version 3.3 or higher. If Sixdof Falcon Studio does not open correctly, and you are using an older Windows computer, it is likely that your computer does not have the graphics card necessary to run Sixdof Falcon Studio. If this is the case there is a solution, please contact the Sixdof team for more information.

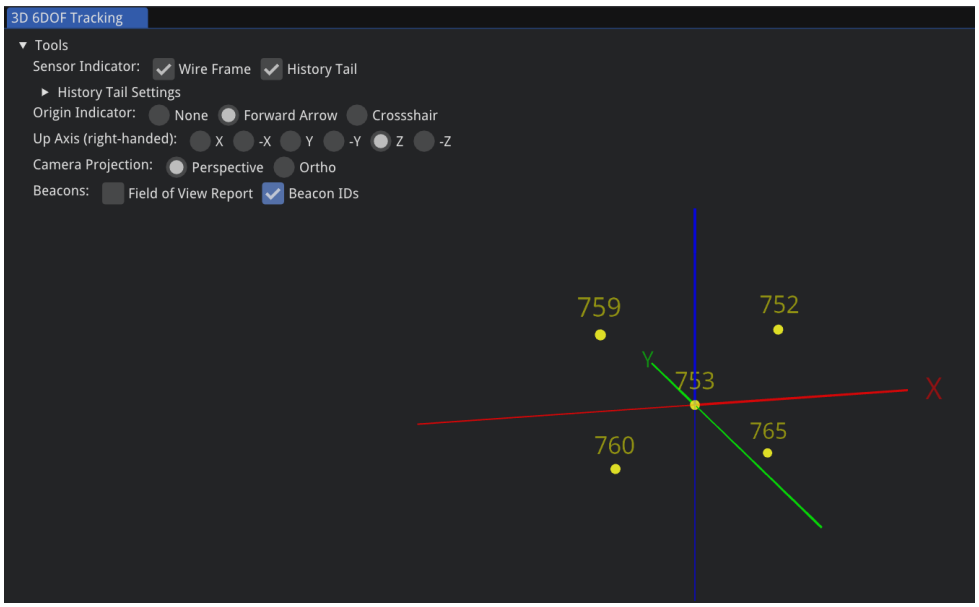
A.7 Magnet Placement Guidelines

A magnet cannot be placed near the back of the sensor. Ensure that you follow these guidelines for magnet placement around the board.

A.8 Localization Issues

The following could be reasons why the sensor is experiencing localization issues:

- There is a mirror or reflective material in the vicinity.
- The high-powered beacon is included in the 6DOF map (only applicable when using 6DOF mode).
- Ensure that the beacon positions are correct in the 3D 6DOF Tracking widget (only applicable when using 6DOF mode). By the top of the widget, click on the drop-down "Tools" menu and select the checkbox labeled "Beacon IDs". Now the IDs of each beacon will appear next to its corresponding yellow sphere. If the placements are incorrect, return to the configuration window (where you filled in the map) and load a map file instead of typing it in manually.



A.9 Language Issues

If your computer system language is not set to English, you may encounter issues while running Sixdof Falcon Studio and the SdsFalcon SDK. To ensure compatibility, please adjust your language settings to English. Follow these instructions to change the language on a Windows computer:

- Navigate to Language Settings.
- Download the English language pack and set it as the Windows display language.

After adjusting the language to English, the programs should run smoothly. However, please note that in Sixdof Falcon Studio, network names in the drop-down menu may display random characters. Use the Discover option to select the correct network connection.

If the program still does not work, the issue may be related to the name of the Ethernet connection. To resolve this on a Windows computer, follow these steps to rename the Ethernet connection:

- Navigate to View Network Connections in Settings.
- Right-click on the Ethernet connection you want to rename.
- Rename the Ethernet connection using ASCII characters only.

A.10 Sending Data to Sixdof for Debugging

Should you encounter an unresolvable scenario with the data flow, you may be asked to send data to Sixdof Space so that we can analyze and resolve the problem. Please follow this procedure to obtain the data for analysis.

A.10.1 How to prepare the data file

Generate a dump file as follows:

- Ensure that the system is connected, the IR Beacons are powered on, the sensor is connected to a USB power supply and also connected via the Ethernet cable to the computer running the Sixdof Falcon software.
- Open Sixdof Falcon Studio and follow the setup steps.
- In the mode configuration, open the "Additional Settings" tab. Next to "Dump Path" enter `C:\sixdof\data_from_companyname.bin`
  Please replace "companyname" with the name of your company.
- Click the "Start" button to continue and begin recording data.
- Once all the data is recorded, close Sixdof Falcon Studio.
- At this point, the data dump file **data_from_companyname.bin** will be automatically generated and will be located in the `sixdof` folder on your computer.

A.10.2 Send the data to Sixdof Space

Please e-mail the bin file to support@sixdofspace.com
Please include the following:

- The contact name and information for the person working with the Sixdof system.
- The serial numbers of the sensor and Basalt boards.

A.11 Contact Technical Support

At Sixdof, we value your feedback and questions. Please report issues by sending an email to support@sixdofspace.com
The guidelines below may prove helpful:

- Please choose a subject line that clearly reflects the issue. For example "Feature Request: Would like to be able to see magic lights" or "Bug Report: Sensor won't lock when UFO is present."
- In the body of the mail:
  - If it is not clear from your email address (e.g. you are using a Gmail address), please include your name and the company you work for
  - Please list the Sixdof sensor serial number you are using
  - Please describe the other equipment you are using (host computer, etc)
  - Please provide some details regarding the application or use case
  - For feature requests
    - Please describe the additional features that you feel would be beneficial
  - For bug reports
    - Please describe what you were doing at the time of the problem
    - Please describe what happened when the problem occurred
    - Please describe whether the problem happens all the time, occasionally, or rarely
    - Please describe if you were able to work-around the problem (for example by using a previous version of software or changing your behavior)
  - Indicate how important this matter is to you (high/medium/low priority)
  - Feel free to leave more contact information such as phone numbers, colleagues' email addresses, etc.

You should receive an automated response to your email that notifies you that your request has been received. Please check your SPAM filters and if necessary, notify us by other means. Additional contact details can be found at www.sixdofspace.com/contact .

B Licensing Notes

B.1 Open Source Code

Many of the Sixdof applications use open source software. You can find the licensing information for each program in the **SixdofSoftwareLicense.pdf** file.