SenseGlove Unity SDK

Documentation and troubleshooting

This guide is meant to help developers understand the SenseGlove SDK and how to work with it. Please note that the SenseGlove SDK is still in an early stage, and that you will be working with prototypes. We may not be able to guarantee that everything works 100% of the time, but we can 100% guarantee you that we will do your best to help you in any way we can!

Contents

Getting Started

The SenseGlove SDK works without any 3rd party plugins. Note that most of its features are still in an experimental stage until we reach version 1.0.

Please run through the following steps to ensure your SenseGlove is working:

1. Clone or download the latest version of the SenseGlove SDK, available from https://github.com/Adjuvo/SenseGlove-Unity
2. Import the unitypackage into your Unity project.
3. Ensure your SenseGlove is connected to and recognized by your computer.
    a. It should show up in the Device Manager under “Ports (COM & LPT)”, as “Teensy USB Serial”.
4. Open any of the example scenes and press play. Verify that your SenseGlove is working and that the glove’s orientations match that of your own. You might want to calibrate the wrist or fingers to get the most out of your glove. More on that in the Calibration section.

If you would like to add a SenseGlove Prefab to your existing Scene, follow steps 1-4 to ensure your glove is working, then continue with the following steps:

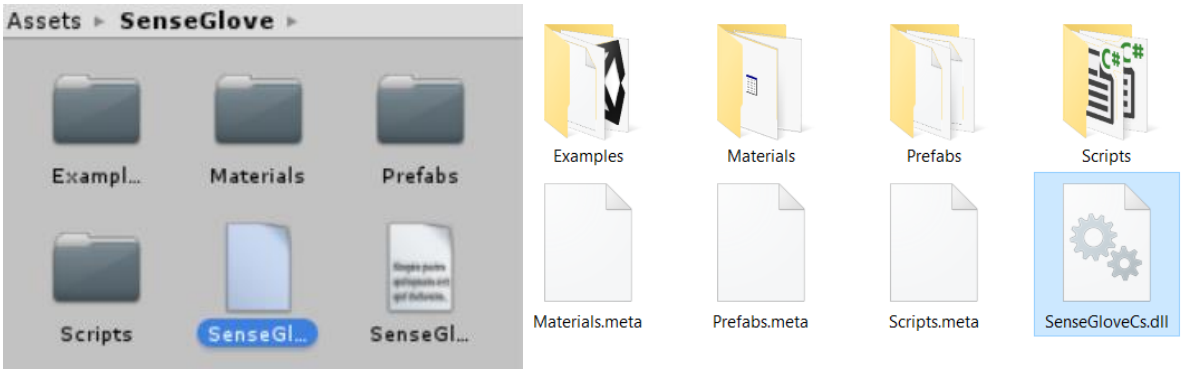
5. Drag one of the wireframes from the Prefab folder into your scene.
6. That’s it! Your SenseGlove should now be moving in your scene!

If you wish to link your SenseGlove to a GameObject under your control (An HTC Vive controller, for example), you need to assign this GameObject to the trackedObject property of the SenseGlove_Wireframe using the inspector.

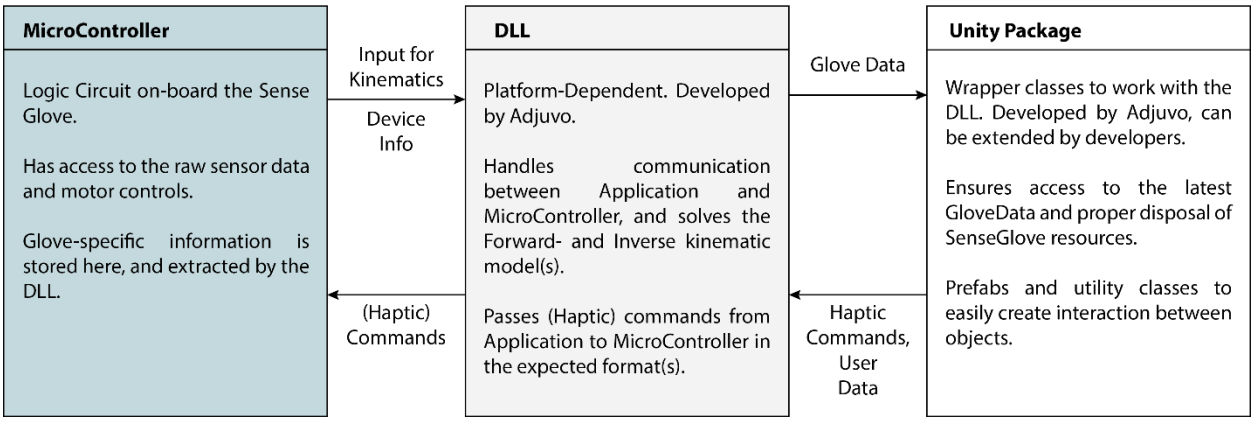
The Wireframe model copies its relative position to the trackedObject on StartUp(), so perhaps some adjustments are required to get the wrist and/or lower arm to align correctly.

The SDK

Before we get into greater detail, let's talk about the core of the SenseGlove SDK: The SenseGloveCs library, which can be found in the root folder of the SenseGlove unitypackage.



This Dynamic Linked Library (DLL) contains a variety of classes and methods that facilitate the communication between the SenseGlove and the PC, as well as the mathematics used to calculate joint angles. The figure below should give you an idea of its role in the SDK.

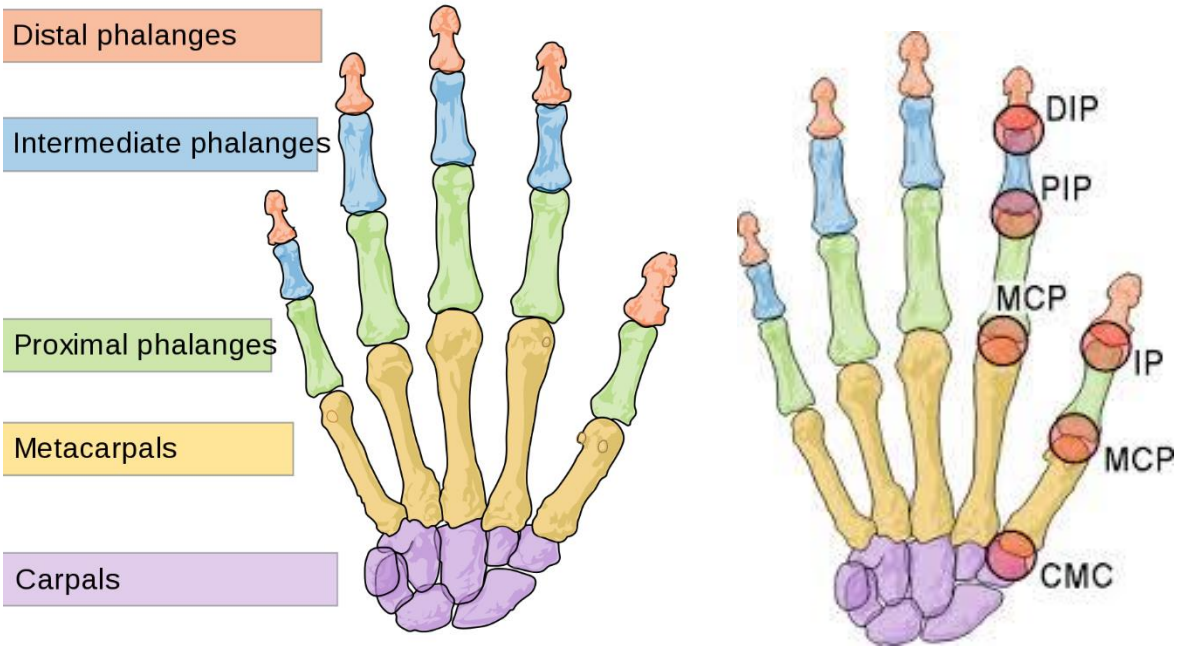


On its own, this DLL can be used by any .NET application (version 3.5+ and up) to work with the SenseGlove. In the Unity SDK, it is used almost exclusively by the *SenseGlove_Object* script. Most Unity developers will only deal with one class from this library; *GloveData*.

The DLL is accompanied by an XML file of the same name, which contains documentation generated by Visual Studio to provide tooltips for each of the classes and methods within.

Anatomy of the Hand

The SenseGlove was initially developed for orthopedic rehabilitation, and thus uses a number of anatomical terms. We encourage you to read this quick introduction so you know what some of the more obscure abbreviations stand for.



Jargon

Phalanges – The finger bones

Proximal– Closer to the body.

Medial – In the middle of.

Distal – Further away from the body.

Abbreviations

CMC Joint – Carpo-Metacarpal Joint

MCP Joint – MetaCarpal-Phalangeal Joint

PIP Joint – Proximal Interphalangeal Joint

DIP Joint – Distal Interphalangeal Joint

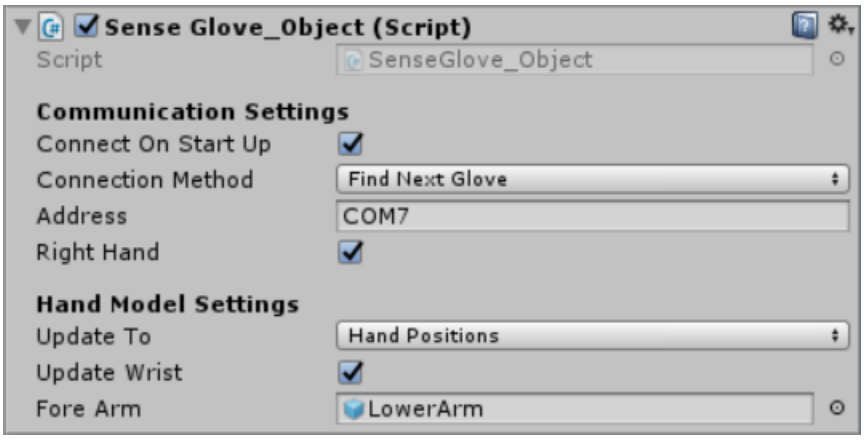
Unity Integration

Without touching any code, we will show you how to make the most out of the SenseGlove via the Inspector.

SenseGlove_Object

The *SenseGlove_Object* script uses several classes within the DLL access the data from a SenseGlove. No matter your application, you will most likely use this script.

Drag this script into your scene, and you can access a single SenseGlove's data: Every *Update()*, this class retrieves the latest data, such as joint angles or battery level. It also ensures that all resources and connections are properly disposed of when the program shuts down again.



Communication Settings

The communication settings determine *how* Unity will establish a connection with the glove via the *connectionMethod* variable.

connectOnStartUp

Set this Boolean to true if you wish to look for SenseGloves once the application starts. If you wish to manually decide when the *SenseGlove_Object* connects, set this Boolean to false and use the *RetryConnection()* method instead.

connectionMethod

This enumerator determines how the connection is established. Its default value is *FindNextGlove*, which will have the *SenseGlove_Object* connect to the first unconnected glove, if any are available. *FindNextRightGlove* and *FindNextLeftGlove* work the same way, but will specifically connect to a left or right handed glove. Finally, the *HardCoded* connection method has the script connect to the port listed in the address variable.

address

The address that the SenseGlove is connected to, or will connect to in case the *connectionMethod* is set to *HardCoded*.

rightHand

Shows if the glove connected to this *SenseGlove_Object* is a left or right hand.

HandModel Settings

These settings apply to the kinematic model of the hand that is used by the SenseGlove. By changing them, you can decrease the amount of calculations required by the DLL, and use only the data relevant for your project.

updateTo

You can change the level of kinematic calculations using the *UpdateTo* variable. Most calculations, such as the Hand Angles, require that we have access to the latest Glove Positions first.

Updating to the *GlovePositions* will give you enough to create a model of the SenseGlove, while updating to the *HandAngles* will give you access to the joint angles in Euler angles [roll, pitch, yaw, in radians]. Finally, updating all the way to *HandPositions* will give you the location of each joint in the hand [x,y,z, in mm], relative to the common origin.

updateWrist

Using the *updateWrist*, you can determine if the SenseGlove's wrist model is also updated. This can be done 'on the fly'. Note that this option is disabled automatically when the *SenseGlove_Object* is tracked by a *SenseGlove_WireFrame* that is attached to the wrist.

foreArm

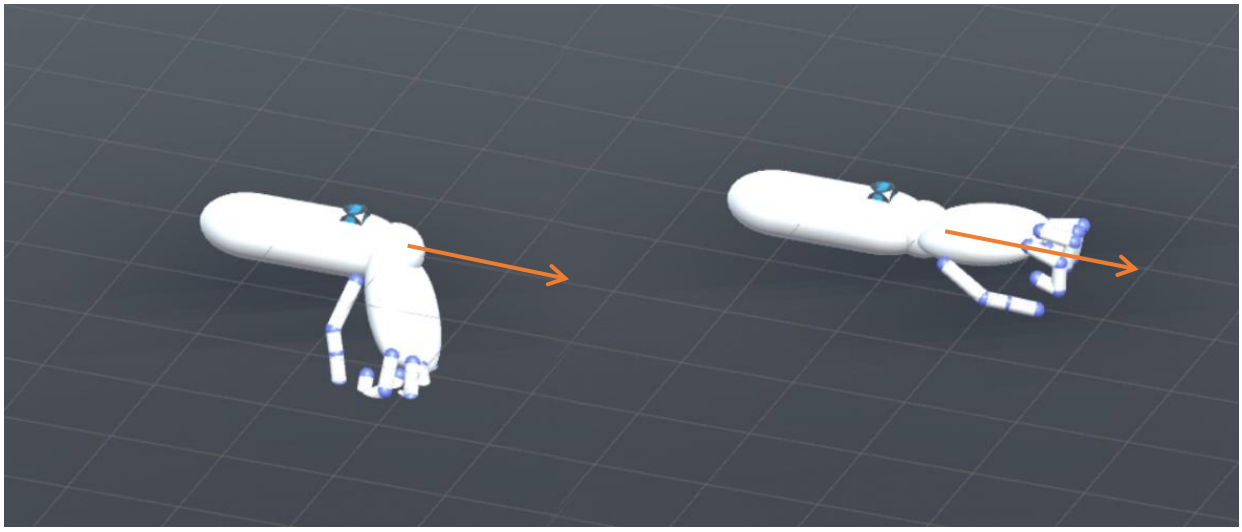
By entering a GameObject into the *foreArm* property of the *SenseGlove_Object*, that object is treated as the 'lower arm' for its wrist model. This GameObject's orientation will become the 'base' position for the hand. If you are not using the lower arm functionality of the SenseGlove, you may ignore this setting.

Calibration

To get the most out of your SenseGlove, you calibrate its mathematical model to use your finger lengths and joint positions.

Wrist

The Inertial Measurement Unit inside the SenseGlove knows nothing about the virtual world. The wrist model calibration tells the SenseGlove where its forearm is. After calibration, all wrist movement is performed relative to this forearm.



The wrist calibration can be called via the *SenseGlove_Object.CalibrateWrist()* function. This function automatically uses the orientation of the *SenseGlove_Object's* foreArm, if available. You can also pass a Quaternion rotation to use as a forearm instead.

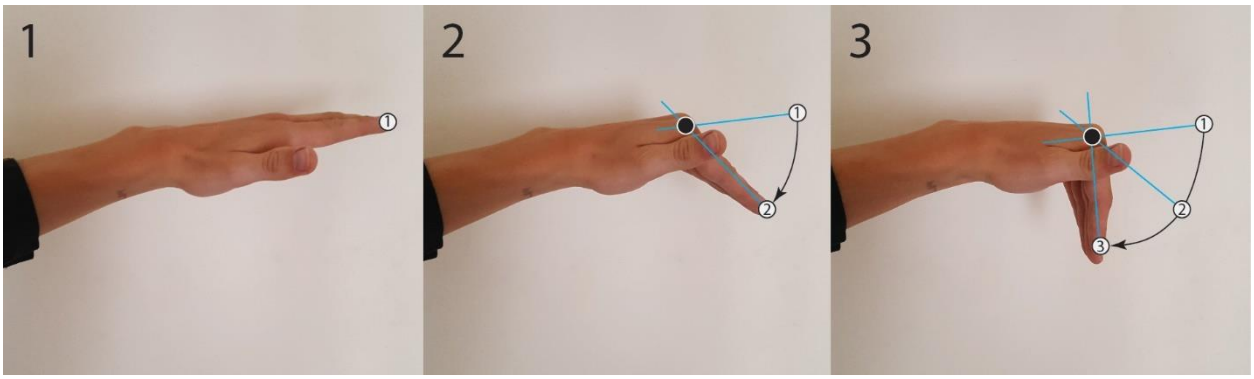
This calibration is called automatically when connecting to a SenseGlove. Of course, if you are not using the wrist model, or you have a tracker mounted directly onto your SenseGlove, this calibration step is not required.

Fingers

The SenseGlove needs to know its wearer's finger lengths and -starting positions in order to calculate the proper joint angles. When a new SenseGlove object is created, a default hand model is used.

The SenseGlove team has developed an algorithm to determine the wearer's finger lengths and MCP joint positions, based on three positions shown below, which is wrapped in the *SenseGlove_Object.NextCalibrationStep()* method.

The algorithm is based on 'determining the radius and origin of a circle, based on 3 points'. In this situation, the MCP joint is the origin, and the total finger length is the radius. By multiplying the total finger length with a set of ratio's, it determines the individual lengths. For this algorithm, any three points will do, but the further apart the three calibration points are, the more accurate the result.



The first time the *NextCalibrationStep()* is called, no position is stored, but a (debug) message is printed.

By calling the *NextCalibrationStep()* method three more times for each of the steps, you can complete the calibration, receiving new instructions with each step. Once the last calibration step completes, the *SenseGlove_Object* fires the *OnCalibrationFinished* event, which can be used to rescale your hand model.

Creating your own calibration

You might decide to try your hand at making your own calibration algorithm, or maybe you want to load the last calculated finger lengths. The *SenseGlove_Object* offers two wrapper functions to interact with the finger lengths used in the DLL: The *GetFingerLengths()* and *SetFingerLengths()* methods.

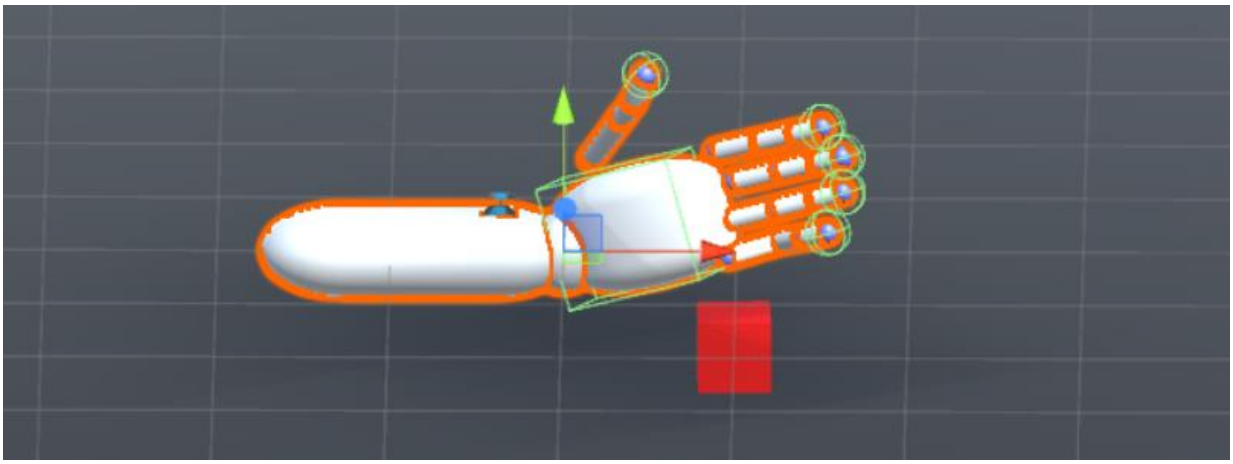
The *GetFingerLengths()* method gives you a 5x3 array containing the lengths of each finger segment of each finger, in mm. The *SetFingerLengths()* method takes the same 5x3 array as an input, and updates the finger lengths that are used in the DLL. The latter method should be used when your custom calibration algorithm finishes, so that the mathematical model has access to the latest finger lengths.

If you're also working with the MCP or CMC joint positions, you can update these using the *GetStartJointPositions()* and *SetStartJointPositions()* method. These work with another 5x3 method containing the x,y,z positions of the first joints or each finger, relative to the common origin.

Grabbing and Interacting

The SenseGlove GrabScript uses a series of colliders to determine when an object can be interacted with up, and when this interaction should end.

Currently, the SenseGlove can interact with an object if it is being touched by the thumb collider(s) or the hand palm, and at least one other finger collider. These settings can be changed through the *SenseGlove_PhysGrab* script.



The object itself determines which type of interaction it provides. The SenseGlove grab script will only interact with a *GameObject* that has a *SenseGlove_Interactable* script attached to it. That way, the glove will not unintentionally pick up any GameObject that is part of the background.

SenseGlove_Interactable objects

This script can be extended to create dynamic controls, such as levers, buttons or drawers.

Currently, its only available extension is the *SenseGlove_Grabable* script, which one can attach to any object with a rigidbody. With this script, the object can be picked up by the SenseGlove's grab script.

Gesture Recognition

Is currently not implemented, but is on the list of features for version 1.0.

Working with Glove Data

The *SenseGlove_Object* allows access to its *GloveData*, which can be seen as a 'snapshot' of the SenseGlove's values for this particular frame. This *GloveData* is updated with every *Update()* event in Unity, and can be accessed by other scripts using the *GetGloveData()* method.

Upon connecting, the DLL will begin to load glove-specific data from the SenseGlove, referred to as 'constants', which takes a few milliseconds. These constants include the lengths and number of segments in the glove, as well as other data that is required before it can begin calculations. It is therefore advised to subscribe your scripts that are dependent on *GloveData* for their initialization to the *OnGloveReady* event of the *SenseGlove_Object* script. This event fires just after the constants have been received and parsed.

Note that the *GloveData* is a copy from the one contained within the DLL, and that any changes made to this object will not be passed back to the SenseGlove. If you wish to change any of the values within the SenseGlove (which you shouldn't unless you know what you are doing), use the wrapper functions provided through the *SenseGlove_Object* script.

Format & Notation

The *GloveData* follows anatomical terms; always working from thumb to pinky, from proximal (closest to the body) to distal (furthest from the body).

All Euler angles in the DLL are given in radians, while all positions are given in millimeters, relative to a common origin. Both the hand and the glove positions are relative to this common origin.

Multidimensional Arrays

Within the DLL, you will find a number of multidimensional arrays. These are used to separate the different types of data for each joint in the hand and the glove. Because one can iterate over these arrays, this keeps the models flexible.

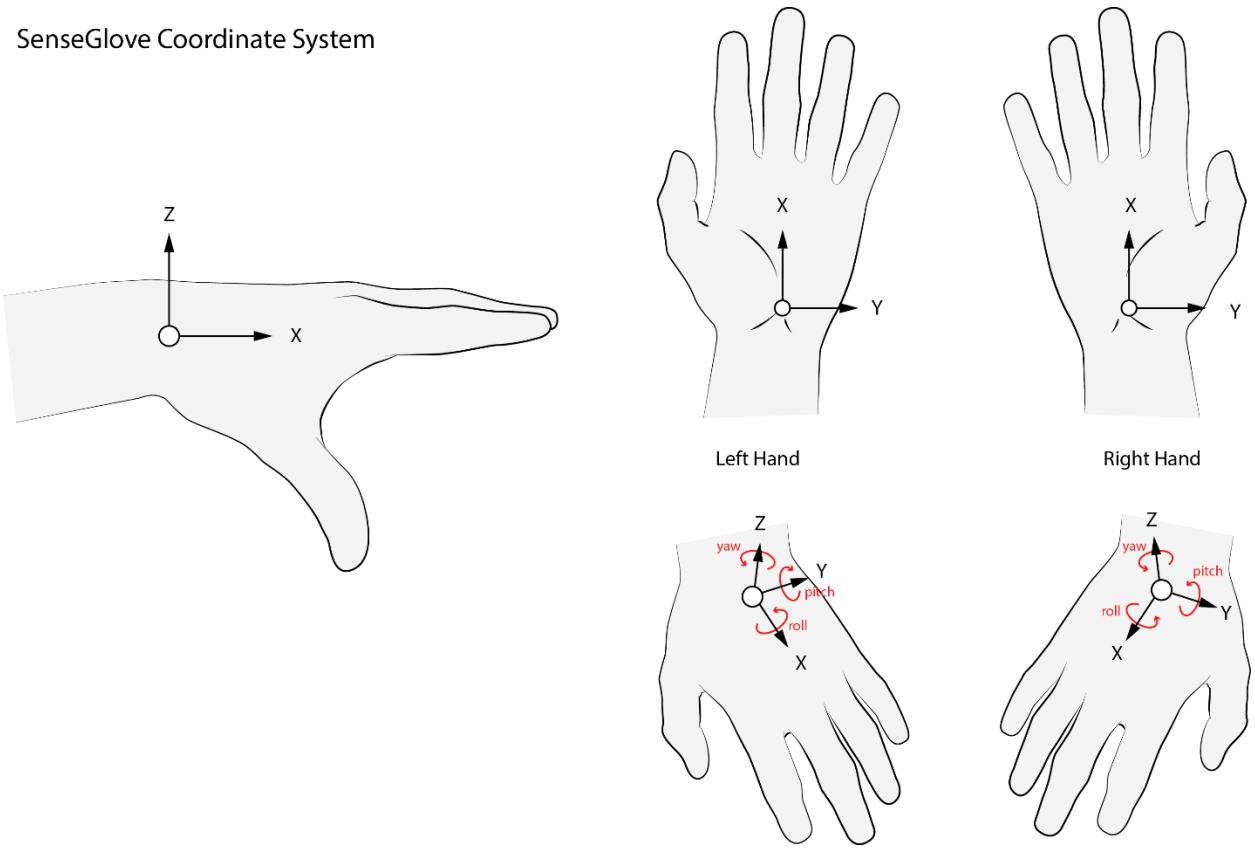
When dealing with 2-dimensional (N x M) arrays, the first index (N) is used to indicate the fingers, from the thumb (0) to the pinky (4). The second index (M) is used to access a specific point / joint in that array, from proximal to distal. For example, the "Glove Angles" received from the SenseGlove are given in this format.

In a 3-dimensional array (N x M x O), the same rules apply. The third index (O) is used to access the x, y, z, or w value, in that order, of the selected point.

Coordinate System

The most important thing to note is that the SenseGlove DLL uses a right-handed coordinate system, and that both the left- and right hand use the same coordinate system:

SenseGlove Coordinate System



- The x-axis is aligned along the metacarpal bone of the middle finger.
- The y-axis points towards the thumb of the right hand, and towards the pinky of the left hand.
- The z-axis runs perpendicular to the other two, from the dorsal side of the hand.

- Pronation / Supination, a.k.a. the twist of the finger, is the angle around the x-axis (roll).
- Flexion / Extension of the finger is the angle around the y-axis (pitch). Per the notation of Physiotherapists; flexion is positive while extension is negative.
- Abduction / Adduction, a.k.a. the spreading of the fingers, is the angle around the z-axis (yaw).

Unfortunately, Unity uses a left-handed coordinate system, which means that the x and y coordinates, as well at the quaternion rotations require correction. It is possible to convert between the right-handed coordinate system in the DLL and Unity's left-handed coordinate system using the functions in the *SenseGlove_Util* script.

General Data

Any data that tells you something about the SenseGlove before making any of the calculations. This data lends itself well for debugging or UI purposes.

Variable name	Variable Type	Description
dataLoaded	Boolean	Indicates if glove-related variables have been loaded from the SenseGlove.
deviceID	String	Identifier unique to this SenseGlove.
gloveVersion	String	The hardware version of the glove.
firmwareVersion	String	The firmware version running on the glove Microcontroller.
isRight	Boolean	Tells you if this is a left- or righthanded SenseGlove.
batteryLife	-	Not implemented. The remaining battery life.
activeTime	-	Not implemented. The time this SenseGlove has been activated for.
gloveValues	float[5][]	The angles, in radians, received from the SenseGlove. Sorted per finger.
imuValues	float[4]	The raw xyzw values of the SenseGlove's Inertial Measurement Unit.

Hand Model

By far the most complex dataset to work through, the *handModel* contains all there is to know about the kinematic model of the fingers and thumb. It uses the *gloveValues* to calculate each of the following variables:

Variable name	Variable Type	Description
gloveRelPos	float[3]	Position of the common origin relative to the wrist
gloveRelOrient	float[4]	Quaternion rotation of the common origin relative to the wrist
approximations	bool[5]	Check if the current hand values are based on an approximation; e.g. the fingertip is too far to reach.
gloveLengths	float[5][][3]	The lengths [xyz] of each segment of the glove in mm.
gloveStartRotations	float[5][4]	The starting quaternion rotations of each glove segment.
gloveRotations	float[5][][4]	The quaternion rotations of the glove joints, relative to the common origin.
gloveAngles	float[5][][3]	The Euler angles relative to the previous link / phalange. [pronation, flexion, abduction]
glovePositions	float[5][][3]	The x,y,z position, in mm, of the glove joints relative to the common origin.
handLengths	float[5][3][3]	The lengths of the finger phalanges. Of these, the x-coordinate is most relevant.
handStartRotations	float[5][4]	The starting quaternion rotations of the MCP joints of the fingers and the CMC joint of the hand.
handRotations	float[5][4][4]	The quaternion rotations of the finger, relative to the common origin.
handAngles	float[5][3][3]	The Euler angles relative to the previous link / phalange. [pronation, flexion, abduction]

handPositions	float[5][4][3]	The x,y,z position, in mm, of the finger joints relative to the common origin.

A wrapper function named Get() is available for the handModel, which will help you retrieve the hand-related data that is right for you.

Wrist

Contains the Euler and quaternion angles of the wrist. It uses the *imuValues* to calculate the following variables:

Variable name	**Variable Type**	**Description**
Qwrist	float[4]	The latest Quaternion rotation of the wrist, with hardware compensation.
QforeArm	float[4]	The latest rotation of the object designated as the foreArm, if any is available.
Qrelative	float[4]	The quaternion rotation of the wrist, relative to the foreArm.

Creating your own hand model

The SenseGlove_Wireframe model will suffice for testing purposes, but eventually you might want to add you own hand model to your project. To do this, you only require an active *SenseGlove_Object* script in your scene. You model must have reference to this script in order to access its *GloveData*. You can use the *SenseGlove_WireFrame* script as an example on how to access the *GloveData* and how to use it in you model.

If your model depends on the *GloveData* for initialization, you should subscribe to the *SenseGlove_Object.OnGloveReady* event, which fires just after all *GloveData* has been loaded from the SenseGlove, and the kinematic model is ready.

You could choose to let your model re-scale its finger lengths to match that of the user after they complete the calibration of their fingers. If so, you can subscribe to the OnCalibrationFinished() event, which fires just after the new finger lengths are determined.

Force Feedback

The SenseGlove achieves its force-feedback by braking its glove sections in the grasping direction.

The force feedback is not yet integrated into the DLL at this revision of the Documentation. However, several considerations have already been made:

1. You can expect to send your force-feedback commands to the SenseGlove via a wrapper function in the *SenseGlove_Object* script; “SendForceFeedbackCommands()”.

2. This method will allow you to specify the type of response (step/ramp/pulse), its intensity, and its duration.

3. The DLL will verify if the SenseGlove you are trying to reach has force-feedback capabilities. If not, the command is not sent. This means you can call the function without having to check if your SenseGlove actually has this capability.

4. You will be able to check your SenseGlove’s capabilities through a *HasFunction()* method of the *SenseGlove_Object* script, which will take a *GloveFunctions* enumerator as input.

    a. For example “ if (mySenseGlove.HasFunction(GloveFunction.ForceFeedback)) { } ”

F.A.Q.

Hardware Troubleshooting

Q: My SenseGlove keeps disconnecting, then connecting again.

A: The SenseGlove is trying to initialize its Inertial Measurement Unit; the sensor that measures wrist movement. This chip has trouble 'waking up' sometimes, so we have to keep resetting it until it does. The glove should sort itself out in a few seconds, but if you cannot stand the connection sound, try unplugging the glove, then plug it back in.

Q: My virtual fingers are moving erratically or are spasming.

A: Unfortunately, the SenseGlove prototypes see heavy use during their lifetime, and it is possible that some of the sensors have been worn out. Please contact the SenseGlove team to arrange a suitable replacement.

Q: One or more of my virtual fingers are not moving.

A: Open the diagnostics scene and check the model of the SenseGlove. Try to move a few of the individual segments of your glove to test if they are moving as expected. If none of them are moving, please ensure the glove is still connected and is not resetting itself. If some of the glove segments are not moving, or are moving in an odd way, one of the sensors might be broken. Please contact the SenseGlove team to arrange a suitable replacement.

Q: The SenseGlove wrist orientation does not match that of my hand.

A: Not all Inertial Measurement Units are positioned the same way inside each SenseGlove. Prototypes 1 to 11 make use of a software based correction contained within the SenseGlove_Object script to compensate. If you are using prototype 1 to 11, this issue is fixed by updating your Unity Package to at least version 0.7, which contains all of the hardware corrections.

Prototypes 12 and onward will have this hardware correction built into their firmware. If you are using one of these gloves and the wrist orientation does not match, contact the Adjuvo Team.

Q: I don't feel any force feedback. Is my SenseGlove broken?

A: Your SenseGlove is fine. The first prototypes do not have force feedback yet.

Software Development

Q: Why do I have to wait before the DeviceScanner has identified my SenseGlove(s)? Can you not just give me a list of all connected SenseGloves?

A: Because in Unity, we can only access a list of all connected Serial Port addresses, nothing more.

Certain other devices, such as Arduino boards, WIFI-dongles or USB-screens, also work via Serial Ports and will show up in this list. To ensure we are not trying to connect to your screen, we send an identification request to every connected device, which takes the SenseGlove a few milliseconds to respond to, hence the real-time delay.

Q: Why does the glove take a few milliseconds to get 'ready'?

A: Because each glove has different size(s), certain hardware-related variables are actually stored on the device itself. Until we know these variables, it is impossible to perform kinematic calculations.

After identification, we load these variables, such as the lengths of each glove segment, from the device which, again, takes a few milliseconds to complete.

If you require glove-related variables for initialization, you can subscribe to the *OnGloveReady* event of the *SenseGlove_Object* Script for your setup methods.

Q: Why is the keyword 'this' used so frequently in your code?

A: Unity Scripts contain a lot of global variables (class attributes), which are used together with local or temporary variables. We use the 'this' keyword to make a clear distinction between a global variable and local variables.

Q: Why did you use a right-handed coordinate system if Unity uses a left-handed coordinate system?

A: Because the mathematics behind the SenseGlove were not initially designed with Unity in mind. The coordinate system was chosen to be intuitive from a physiotherapy point of view.