

Data Export Summary

- PERCEPTION AXIS® supports 'BVH format data' export
 - BVH format is industry standard
 - BVH format consists of displacement and orientation of major body segments
 - Check *M. Meredith et al's Motion Capture Format Explained* for further information
- PERCEPTION AXIS® supports 'Calculation Data' export under condition for research purpose
 - Calculation data consist of displacement, velocity, orientation, acceleration, angular speed of each major body segment
 - X, V and Q are defined in Global axis system, Acc and gyro are defined in sensor module axis system
 - There are 21 body segments with calculation data. The data of the extra 4 body segments without sensor module come from interpolation of adjacent sensor modules
- Datavisualizer is a plotting tool comes with PERCEPTION AXIS® for a better visualization of BVH and Calculation data

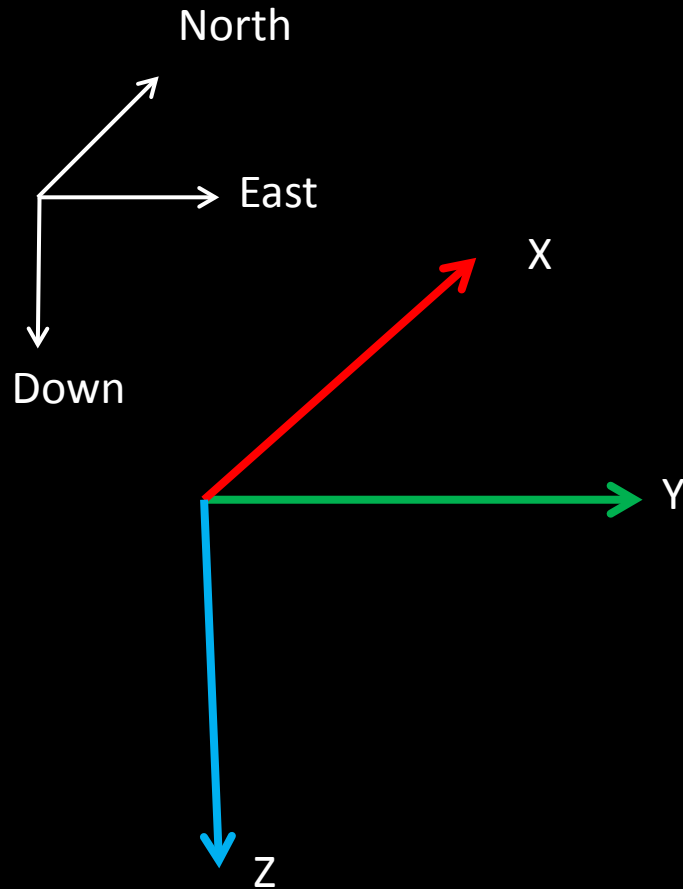
Coordinate definition

- BVH data
 - Displacement
 - Defined in local coordinate system of parent body segment
 - For hip (root): X -> north, Y -> up, Z -> east
 - Angles
 - Configurable, with default sequence YXZ
 - Defined in local coordinate system of parent body segment

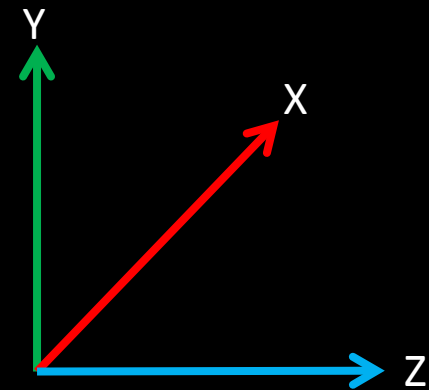
Coordinate definition

- Calculation data
 - Displacement (x,y,z)
 - Global N-E-D (north-east-down)
 - Please note that the origin of this coordinate system is the hip position at the first frame
 - Velocity(x,y,z)
 - Global N-E-D
 - Quaternion(s,x,y,z)
 - Representing body segment orientation
 - Defined in Global BVH axis coordinate system
 - Gyroscope(x,y,z)
 - Sensor module original gyro data
 - X- button Y-USB port Z-LED downward
 - Accelerometer(x,y,z)
 - Sensor module original acceleration data
 - X- button Y-USB port Z-LED downward

Global axis system

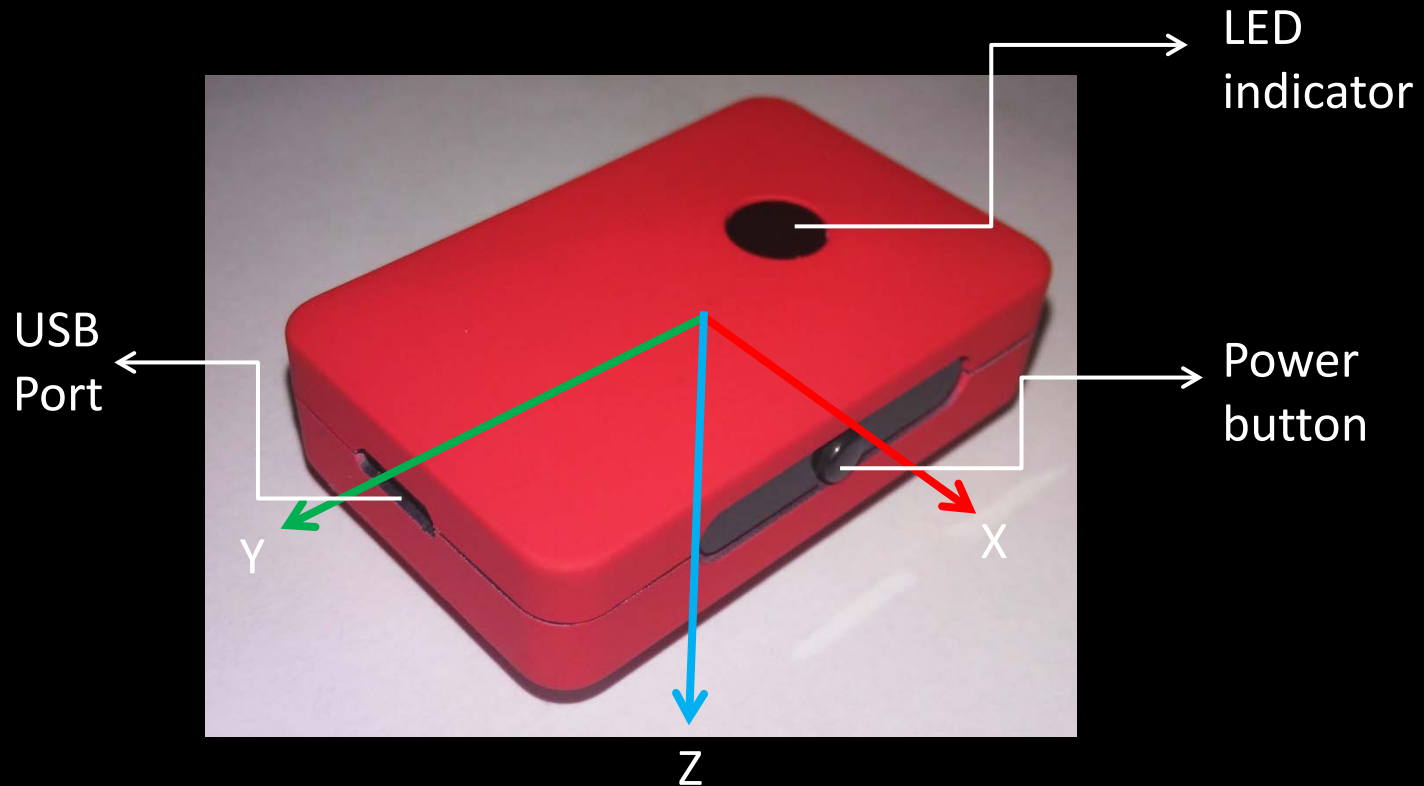


Global axis in calculation data



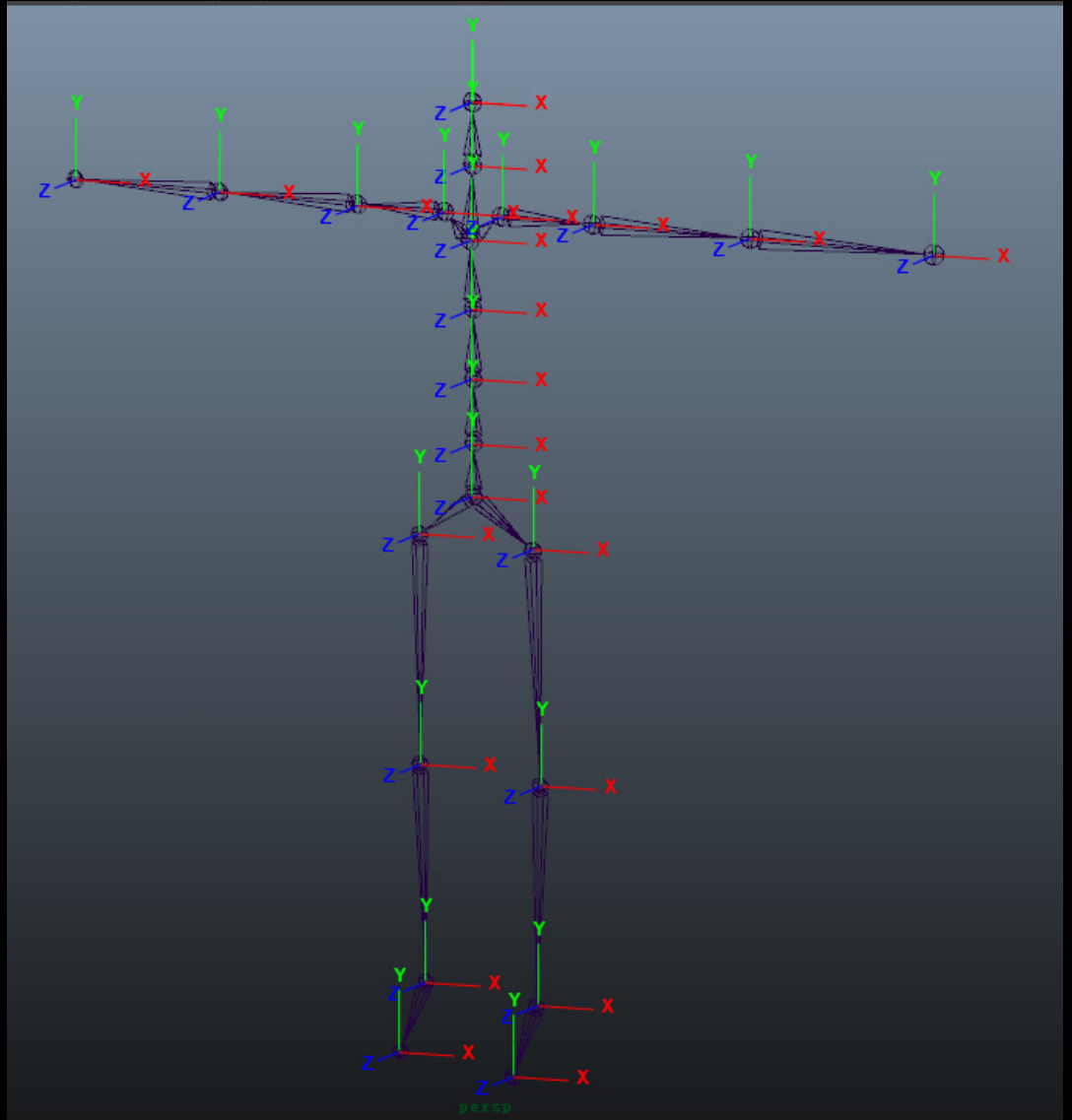
Global axis in BVH data

Sensor module axis system



BVH bone axis system

- Initial bone pose
 - T-pose
- Initial bone axis
 - X -> Left
 - Y -> Up
 - Z -> Forward



Unit system

- BVH data
 - Displacement (cm)
 - Angle (degree)
- Calculation data
 - Displacement (meter)
 - Velocity(m/s)
 - Quaternion (N/A)
 - Gyroscope (rad/s)
 - Accelerometer (g)

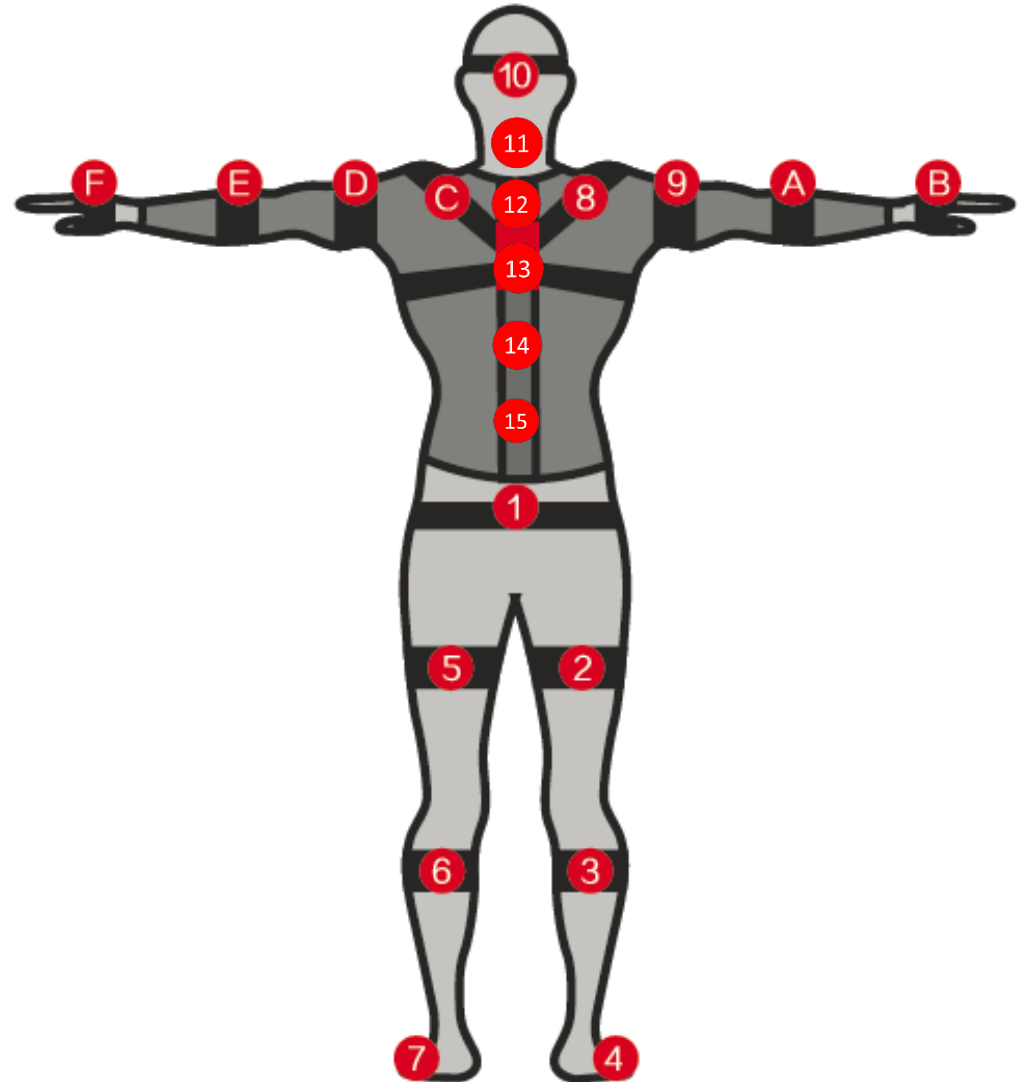
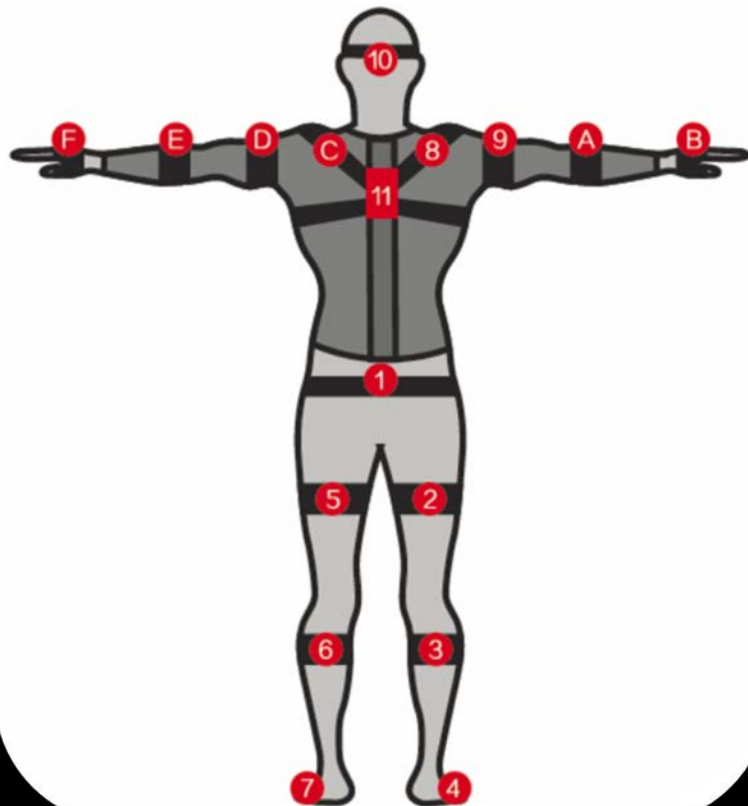
BVH data

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
130		}													
131	}														
132	MOTION														
133	Frames:	1234													
134	Frame	Time:	0.01												
135	0	0	0	0	0	0	-0.05	90.19	0.29	51.89	-9.14	-3.72	-9.28	0	0.02
136	0	0	0	0	0	0	-0.05	90.19	0.3	51.86	-9.14	-3.73	-9.28	0	0.03
137	0	0	0	0	0	0	-0.05	90.18	0.31	51.83	-9.13	-3.73	-9.28	0	0.03
138	0	0	0	0	0	0	-0.04	90.18	0.32	51.8	-9.14	-3.75	-9.28	0	0.03
139	0	0	0	0	0	0	-0.04	90.18	0.32	51.76	-9.13	-3.74	-9.28	0	0.03
140	0	0	0	0	0	0	-0.04	90.17	0.33	51.74	-9.13	-3.75	-9.28	0	0.04
141	0	0	0	0	0	0	-0.04	90.17	0.33	51.7	-9.13	-3.74	-9.27	0	0.05
142	0	0	0	0	0	0	-0.04	90.17	0.34	51.69	-9.13	-3.75	-9.27	0	0.05
143	0	0	0	0	0	0	-0.04	90.17	0.34	51.67	-9.13	-3.75	-9.27	0	0.06
144	0	0	0	0	0	0	-0.04	90.17	0.34	51.65	-9.14	-3.74	-9.27	0	0.07
145	0	0	0	0	0	0	-0.04	90.17	0.33	51.62	-9.14	-3.72	-9.26	0	0.09
146	0	0	0	0	0	0	-0.04	90.17	0.31	51.61	-9.13	-3.7	-9.26	0	0.11
147	0	0	0	0	0	0	-0.04	90.17	0.3	51.61	-9.12	-3.7	-9.26	0	0.11
148	0	0	0	0	0	0	-0.03	90.18	0.28	51.6	-9.09	-3.68	-9.26	0	0.12
149	0	0	0	0	0	0	-0.04	90.18	0.26	51.59	-9.08	-3.65	-9.26	0	0.13
150	0	0	0	0	0	0	-0.04	90.19	0.24	51.51	-9	-3.61	-9.27	0.01	0.13
151	0	0	0	0	0	0	-0.04	90.2	0.21	51.49	-8.99	-3.58	-9.28	0.01	0.13
152	0	0	0	0	0	0	-0.05	90.21	0.17	51.42	-8.89	-3.53	-9.28	0.01	0.13
153	0	0	0	0	0	0	-0.06	90.21	0.14	51.32	-8.8	-3.48	-9.28	0.01	0.13
154	0	0	0	0	0	0	-0.06	90.22	0.1	51.21	-8.72	-3.42	-9.29	0.01	0.12
155	0	0	0	0	0	0	-0.07	90.23	0.05	51.11	-8.64	-3.36	-9.29	0.02	0.12
156	0	0	0	0	0	0	-0.08	90.23	0	51.04	-8.58	-3.32	-9.28	0.02	0.1
157	0	0	0	0	0	0	-0.1	90.23	-0.05	50.92	-8.51	-3.25	-9.28	0.02	0.11
158	0	0	0	0	0	0	-0.11	90.23	-0.11	50.84	-8.43	-3.2	-9.27	0.02	0.09
159	0	0	0	0	0	0	-0.12	90.24	-0.17	50.77	-8.36	-3.14	-9.27	0.02	0.08
160	0	0	0	0	0	0	-0.12	90.24	-0.24	50.71	-8.29	-3.09	-9.27	0.02	0.07
161	0	0	0	0	0	0	-0.12	90.23	-0.31	50.66	-8.25	-3.04	-9.27	0.02	0.06
162	0	0	0	0	0	0	-0.12	90.23	-0.37	50.62	-8.2	-3	-9.27	0.02	0.06
163	0	0	0	0	0	0	-0.12	90.23	-0.44	50.61	-8.16	-2.97	-9.27	0.02	0.05

Calculation data

bone map index

17 sensors vs. 21 bones



Calculation data

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Zd:	-0.0094	0.9997	0												
2	bones:	21														
3	bone:	0.0165	0.9925	0.1214	0.1538	0.9835	-0.0954	0.0212	0.9859	-0.166	-0.2478	-0.8641	-0.4381	0.0937	0.9956	-0.0097
4	bone1:	-0.9935	0.03	-0.1103	-0.0003	0.0966	0.9953	0.9983	-0.0299	-0.0502	-0.9631	0.1706	0.2083	-0.1457	0.004	-0.9893
5	L:	0.0105	0.21	0.21	0.0253	0.21	0.21	0.0253	0.08	0.1325	0.13	0.0875	0.08	0.1325	0.13	0.0875
6	LD:	0.0942	0.21	0.21	0.0884	0.21	0.21	0.0884	0.08	0.1325	0.13	0.0875	0.08	0.1325	0.13	0.0875
7																
8																
9	01-X-x	01-X-y	01-X-z	01-V-x	01-V-y	01-V-z	01-Q-s	01-Q-x	01-Q-y	01-Q-z	01-A-x	01-A-y	01-A-z	01-W-x	01-W-y	01-W-z
10	0.0008	0.0038	0.0132	-0.0034	0.0088	0.0002	0.897	-0.0857	0.4335	0.0058	-0.0273	0.9844	-0.0391	-0.0174	0.0174	-0.0174
11	0.0008	0.0039	0.0133	0.0005	0.0085	0.0002	0.8971	-0.0858	0.4333	0.0056	-0.0273	0.9922	-0.0391	0	0	-0.0174
12	0.0008	0.004	0.0133	-0.004	0.0059	-0.0004	0.8973	-0.0858	0.4331	0.0056	-0.0273	0.9922	-0.0391	-0.0174	0.0174	-0.0174
13	0.0008	0.004	0.0133	0.0005	0.0073	-0.0013	0.8973	-0.0859	0.4329	0.0055	-0.0273	0.9961	-0.0391	0	0.0174	-0.0174
14	0.0008	0.0041	0.0133	-0.0046	0.0055	-0.0014	0.8975	-0.0858	0.4325	0.0054	-0.0273	0.9922	-0.0391	-0.0174	0.0174	-0.0174
15	0.0008	0.0042	0.0134	-0.0025	0.0058	-0.0019	0.8976	-0.0858	0.4324	0.0054	-0.0234	0.9922	-0.0391	0	0	-0.0174
16	0.0008	0.0042	0.0134	-0.0013	0.0012	-0.0032	0.8977	-0.0858	0.4321	0.0054	-0.0273	0.9922	-0.0391	0	0.0174	-0.0174
17	0.0008	0.0043	0.0134	-0.0027	0.0056	-0.0042	0.8978	-0.0858	0.432	0.0054	-0.0273	0.9961	-0.0391	0.0174	0	-0.0174
18	0.0009	0.0043	0.0135	-0.0022	-0.002	-0.0053	0.8979	-0.0858	0.4318	0.0053	-0.0195	0.9961	-0.0391	0	0	0
19	0.0009	0.0042	0.0135	-0.0011	-0.003	-0.0068	0.8979	-0.0858	0.4317	0.0054	-0.0195	1.0078	-0.0352	0.0174	-0.0174	0
20	0.0009	0.0042	0.0135	-0.0036	-0.01	-0.0092	0.898	-0.0858	0.4314	0.0056	-0.0156	1.0117	-0.0352	0	-0.0523	0
21	0.0009	0.004	0.0134	-0.0042	-0.0146	-0.0104	0.8981	-0.0856	0.4314	0.0056	-0.0156	1.0156	-0.0313	-0.0174	-0.0523	0
22	0.0009	0.0039	0.0134	-0.004	-0.0117	-0.0117	0.8981	-0.0856	0.4314	0.0056	-0.0156	1.0156	-0.0313	-0.0174	-0.0523	0
23	0.0009	0.0037	0.0134	-0.005	-0.0196	-0.0133	0.8981	-0.0852	0.4313	0.0057	-0.0117	1.0156	-0.0195	-0.0523	-0.0174	0
24	0.0009	0.0035	0.0133	-0.0058	-0.0122	-0.0146	0.8983	-0.0843	0.431	0.0057	-0.0117	1.0156	-0.0156	-0.0523	-0.0174	0
25	0.0009	0.0033	0.0132	-0.0054	-0.0249	-0.0154	0.8985	-0.0843	0.4308	0.0058	-0.0078	1.0039	-0.0117	-0.0698	0	0.0174
26	0.0009	0.0029	0.0131	-0.0063	-0.0352	-0.0146	0.8986	-0.0839	0.4307	0.0059	0	0.9961	0	-0.1047	0	0.0174
27	0.0008	0.0026	0.0131	-0.0102	-0.036	-0.014	0.8989	-0.0831	0.4301	0.0059	0	0.9922	0	-0.1396	0.0174	0.0174
28	0.0007	0.0022	0.013	-0.0122	-0.0336	-0.0141	0.8993	-0.0822	0.4295	0.006	0	0.9805	0	-0.1047	0.0523	0.0174
29	0.0006	0.0018	0.0129	-0.0096	-0.0445	-0.0122	0.8998	-0.0813	0.4287	0.006	0	0.9766	0	-0.1396	0.0523	0.0523
30	0.0005	0.0014	0.0128	-0.0109	-0.0406	-0.0108	0.9002	-0.0806	0.428	0.0061	-0.0078	0.9805	0	-0.1047	0.0698	0.0523
31	0.0004	0.0009	0.0128	-0.0182	-0.0528	-0.008	0.9005	-0.0799	0.4275	0.0062	-0.0156	0.9766	0	-0.1396	0.0698	0.0523
32	0.0003	0.0003	0.0128	-0.0164	-0.0452	-0.0057	0.9009	-0.0791	0.4266	0.0063	-0.0195	0.9727	-0.0039	-0.1047	0.0698	0.0174
33	0.0002	-0.0002	0.0128	-0.0113	-0.0513	-0.0039	0.9013	-0.0783	0.4261	0.0064	-0.0195	0.9727	-0.0039	-0.1047	0.0523	0.0523
34	0.0001	-0.0009	0.0128	-0.0131	-0.0608	-0.002	0.9016	-0.0775	0.4256	0.0066	-0.0234	0.9688	-0.0078	-0.1396	0.0523	0.0523
35	0	-0.0015	0.0127	-0.0021	-0.0585	-0.0006	0.9018	-0.0768	0.4252	0.0066	-0.0234	0.9727	-0.0117	-0.0698	0.0523	0.0523
36	0	-0.0022	0.0128	-0.0052	-0.0619	0.0015	0.902	-0.0763	0.4249	0.0069	-0.0273	0.9727	-0.0156	-0.0698	0.0174	0.0523

Accelerometer and gyroscope data

- The original sensor module reading
 - Rely on both the movement and orientation of the sensor module
- The accelerometer reading **includes** the gravity acceleration
- Unit
 - Accelerometer (Acc): g
 - Gyroscope (Gyro): rad/s

Example Acc and Gyro Data

04-A-x	04-A-y	04-A-z
0.0977	-0.5352	0.8242
0.0977	-0.5352	0.8242
0.0977	-0.5352	0.8242
0.0977	-0.5352	0.8242
0.0977	-0.5352	0.8242
0.0938	-0.5391	0.8281
0.0977	-0.5352	0.8242
0.0938	-0.5234	0.8164
0.0977	-0.5352	0.8281
0.0938	-0.5313	0.8281
0.0938	-0.5391	0.8281
0.0938	-0.543	0.8281
0.1016	-0.5469	0.8242
0.1016	-0.5469	0.8242
0.1016	-0.543	0.8242
0.1016	-0.5469	0.8242
0.1016	-0.5469	0.8281
0.1055	-0.5508	0.8242
0.0977	-0.5469	0.8242
0.1016	-0.5469	0.8164
0.1094	-0.5469	0.8164

Reading of foot acceleration at still

04-W-x	04-W-y	04-W-z
-0.0174	-0.0174	0
0	-0.0174	-0.0174
-0.0174	-0.0174	0
-0.0174	-0.0174	-0.0174
-0.0174	0	0
-0.0174	-0.0174	-0.0174
-0.0174	-0.0174	-0.0174
-0.0174	-0.0174	0
-0.0523	-0.0174	0
-0.0523	-0.0174	0
-0.0523	-0.0174	0
-0.0523	-0.0523	-0.0174
-0.0523	-0.0174	-0.0174
-0.0523	0	-0.0523
-0.0523	-0.0174	-0.0174
-0.0523	-0.0174	-0.0174
-0.0174	-0.0523	0
-0.0174	-0.0523	-0.0174
-0.0174	-0.0174	0
0	-0.0174	0

Reading of foot angular velocity at still

Note: The Acc data are not close to 0 as they include the gravity acceleration

The Acc data are not close to (0, 0, 1) as the sensor has a tilt angle

Calculation quaternion data

- Presenting the body segment orientation
 - Not the sensor module orientation
 - Not related to the mounting of sensor module
- Defined in global BVH axis coordinate system
 - The axis definition is the same with BVH global axis system
 - It is NOT defined in parent body segment, it is global (Different to BVH format)

Example data (1)

01-Q-s	01-Q-x	01-Q-y	01-Q-z
0.897	-0.0857	0.4335	0.0058
0.8971	-0.0858	0.4333	0.0056
0.8973	-0.0858	0.4331	0.0056
0.8973	-0.0859	0.4329	0.0055
0.8975	-0.0858	0.4325	0.0054
0.8976	-0.0858	0.4324	0.0054
0.8977	-0.0858	0.4321	0.0054
0.8978	-0.0858	0.432	0.0054
0.8979	-0.0858	0.4318	0.0053
0.8979	-0.0858	0.4317	0.0054
0.898	-0.0858	0.4314	0.0056
0.8981	-0.0856	0.4314	0.0056
0.8981	-0.0855	0.4314	0.0056
0.8981	-0.0852	0.4313	0.0057
0.8983	-0.0849	0.4311	0.0057

Calculation quaternion of hip

51.89	-9.14	-3.72
51.86	-9.14	-3.73
51.83	-9.13	-3.73
51.8	-9.14	-3.75
51.76	-9.13	-3.74
51.74	-9.13	-3.75
51.7	-9.13	-3.74
51.69	-9.13	-3.75
51.67	-9.13	-3.75
51.65	-9.14	-3.74
51.62	-9.14	-3.72
51.61	-9.13	-3.7
51.61	-9.12	-3.7
51.6	-9.09	-3.68
51.56	-9.06	-3.65

BVH angle of hip (YXZ order)

Note that as BVH angle of hip is also global, the quaternion data match the BVH angle data

Example data (2)

01-Q-s	01-Q-x	01-Q-y	01-Q-z
0.897	-0.0857	0.4335	0.0058
0.8971	-0.0858	0.4333	0.0056
0.8973	-0.0858	0.4331	0.0056
0.8973	-0.0859	0.4329	0.0055
0.8975	-0.0858	0.4325	0.0054
0.8976	-0.0858	0.4324	0.0054
0.8977	-0.0858	0.4321	0.0054
0.8978	-0.0858	0.432	0.0054
0.8979	-0.0858	0.4318	0.0053
0.8979	-0.0858	0.4317	0.0054
0.898	-0.0858	0.4314	0.0056
0.8981	-0.0856	0.4314	0.0056
0.8981	-0.0855	0.4314	0.0056
0.8981	-0.0852	0.4313	0.0057
0.8983	-0.0849	0.4311	0.0057

Calculation quaternion of hip

02-Q-s	02-Q-x	02-Q-y	02-Q-z
0.8532	-0.0046	0.5199	0.0429
0.8533	-0.0047	0.5197	0.0429
0.8533	-0.0047	0.5196	0.0429
0.8534	-0.0047	0.5194	0.043
0.8536	-0.0048	0.5191	0.0431
0.8537	-0.0048	0.5189	0.0431
0.8539	-0.0047	0.5186	0.0429
0.8541	-0.0049	0.5184	0.0429
0.8544	-0.0048	0.5178	0.0426
0.8548	-0.0047	0.5172	0.0422
0.8555	-0.0043	0.5161	0.0418
0.8563	-0.0039	0.5148	0.0413
0.8567	-0.0038	0.5141	0.0409
0.8576	-0.0032	0.5128	0.0405
0.8583	-0.0026	0.5116	0.0402

Calculation quaternion of RightUpLeg

11.12	5.27	9.29
11.13	5.25	9.31
11.15	5.25	9.31
11.14	5.24	9.33
11.15	5.23	9.34
11.15	5.22	9.34
11.14	5.24	9.32
11.12	5.24	9.32
11.08	5.27	9.29
11.01	5.32	9.24
10.9	5.4	9.19
10.75	5.47	9.13
10.65	5.52	9.08
10.49	5.6	9.04
10.37	5.66	8.99

BVH angle of RightUpLeg

Note that as the global orientation of the hip and RightUpLeg are similar, their calculation quaternion are close, but the BVH angle is small as it is relative to hip

Get bone direction with quaternion

- Convert quaternion to DCM (direction cosine matrix)
 - $\text{dcm}(1,1) = q_s^2 + q_x^2 - q_y^2 - q_z^2;$
 - $\text{dcm}(1,2) = 2 * (q_x * q_y + q_s * q_z);$
 - $\text{dcm}(1,3) = 2 * (q_x * q_z - q_s * q_y);$
 - $\text{dcm}(2,1) = 2 * (q_x * q_y - q_s * q_z);$
 - $\text{dcm}(2,2) = q_s^2 - q_x^2 + q_y^2 - q_z^2;$
 - $\text{dcm}(2,3) = 2 * (q_y * q_z + q_s * q_x);$
 - $\text{dcm}(3,1) = 2 * (q_x * q_z + q_s * q_y);$
 - $\text{dcm}(3,2) = 2 * (q_y * q_z - q_s * q_x);$
 - $\text{dcm}(3,3) = q_s^2 - q_x^2 - q_y^2 + q_z^2;$
- The direction of bone axis is the row vector of DCM calculated above

Get bone direction with quaternion

- Quaternion of hip: [0.897 -0.0857 0.4335 0.0058] (q_s , q_x , q_y , q_z)
- The DCM matrix is calculated as:
 - 0.6241 -0.0639 -0.7788
 - -0.0847 0.9852 -0.1487
 - 0.7768 0.1588 0.6094
- The direction vector of hip is:
 - X-Axis: [0.6241 -0.0639 -0.7788]
 - Y-Axis: [-0.0847 0.9852 -0.1487]
 - Z-Axis (face direction): [0.7768 0.1588 0.6094]
- Note: North -> [1 0 0], Up -> [0 1 0], East -> [0 0 1]