

# Modal Symbolic Learning: Appetizer

```
In [1]: using Pkg
        Pkg.activate(".")
        Pkg.instantiate()
        Pkg.update()
        Pkg.status()
```

```
Activating project at `~/Desktop/modal-symbolic-learning-course`
Updating registry at `~/.julia/registries/General`
Updating git-repo `https://github.com/JuliaRegistries/General.git`
No Changes to `~/Desktop/modal-symbolic-learning-course/Project.toml`
No Changes to `~/Desktop/modal-symbolic-learning-course/Manifest.toml`
```

```
Status `~/Desktop/modal-symbolic-learning-course/Project.toml`
[a93c6f00] DataFrames v1.6.1
[7806a523] DecisionTree v0.12.4
[7073ff75] IJulia v1.24.2
[033835bb] JLD2 v0.4.38
⚠ [add582a8] MLJ v0.19.5
[c6f25543] MLJDecisionTreeInterface v0.4.0
[e54bda2e] ModalDecisionTrees v0.3.3
[91a5bcd] Plots v1.39.0
[7b3b3b3f] Sole v0.3.1
[b002da8f] SoleLogics v0.6.12
[4249d9c7] SoleModels v0.5.3
[2913bbd2] StatsBase v0.34.2
[9a3f8284] Random
```

**Info** Packages marked with ⚠ have new versions available but compatibility constraints restrict them from upgrading. To see why use `status --outdated`

```
In [2]: # Import libraries for statistics & Machine Learning
        using Random
        using DataFrames
        using MLJ
        using Plots
```

```
In [3]: # Import the Sole framework
        using Sole

        # Load an example time-series classification dataset as a tuple (DataFrame,
        X, y = Sole.load_arff_dataset("NATOPS");
```

```
In [4]: y
```

Out[4]: 360-element CategoricalArrays.CategoricalArray{String,1,UInt32}:

```
"I have command"  
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```

In [5]: X

Out[5]: 360×24 DataFrame

335 rows omitted

Row	X[Hand tip l]	Y[Hand tip l]	Z[Hand tip l]	X[Hand tip r]	Y[Hand tip r]	Z[Hand tip r]	X[Hand tip l]
	Array...	Array...	Array...	Array...	Array...	Array...	Array...
1	[-0.519771, -0.52758, -0.531415, -0.517159, -0.510312, -0.518154, -0.50362, -0.485176, -0.466677, -0.444535 ...	[-2.14011, -2.18043, -2.18425, -2.16547, -2.16635, -2.18836, -2.17162, -2.15248, -2.08072, -2.00607 ...	[-0.957224, -0.970778, -0.970232, -0.960666, -0.962437, -0.970488, -0.966847, -0.96441, -0.972943, -0.979085 ...	[0.675893, 0.699281, 0.673774, 0.700096, 0.765257, 0.980454, 1.43803, 1.78334, 2.08495, 2.32037 ... ...	[-2.31794, -2.36398, -2.48698, -2.3176, -2.34228, -2.34828, -2.24596, -1.8102, -1.28214, -0.703666 ...	[-0.254602, -0.246883, -0.252635, -0.235782, -0.13363, 0.051243, 0.078424, 0.274688, 0.335957, 0.390646 ...	[-0.519771, -0.52758, -0.531415, -0.517159, -0.510312, -0.518154, -0.50362, -0.485176, -0.466677, -0.444535 ...
	[-0.45501, -0.458937, -0.465048, -0.471251, -0.470015, -0.464627, -0.462666, -0.460253, -0.459572, -0.456737]	[-2.17597, -2.1638, -2.17779, -2.17766, -2.17848, -2.16689, -2.15667, -2.13474, -2.13435, -2.13855]	[-1.04234, -1.03616, -1.03756, -1.03275, -1.02525, -1.03115, -1.02558, -1.01884, -1.01701, -1.01059]	[0.755717, 0.778103, 0.755128, 0.751274, 0.742517, 0.743311, 0.786792, 0.730863, 0.730482, 0.732217]	[-2.45044, -2.33026, -2.44767, -2.43509, -2.44371, -2.42475, -2.25219, -2.38539, -2.38603, -2.35704]	[-0.210761, -0.181256, -0.213764, -0.206785, -0.222643, -0.214863, -0.169845, -0.20958, -0.202703, -0.201438]	[-0.519771, -0.52758, -0.531415, -0.517159, -0.510312, -0.518154, -0.50362, -0.485176, -0.466677, -0.444535 ...
	[-0.489753, -0.48607, -0.484529, -0.492771, -0.492031, -0.493076, -0.491979, -0.493256, -0.493156, -0.487527 ...	[-1.55293, -1.54966, -1.55206, -1.55821, -1.556, -1.56055, -1.55812, -1.5648, -1.56414, -1.56731 ...	[-0.907814, -0.911305, -0.92587, -0.921268, -0.928352, -0.928697, -0.932141, -0.930564, -0.933592, -0.932622 ...	[0.632831, 0.633167, 0.637368, 0.640823, 0.635858, 0.63401, 0.634496, 0.637154, 0.640618, 0.643018 ...	[-1.61526, -1.61763, -1.62374, -1.61861, -1.62068, -1.62244, -1.62164, -1.6257, -1.62654, -1.62966 ...	[-0.63772, -0.637168, -0.644338, -0.651686, -0.653233, -0.654332, -0.651011, -0.6489, -0.654768, -0.653883 ...	[-0.489753, -0.48607, -0.484529, -0.492771, -0.492031, -0.493076, -0.491979, -0.493256, -0.493156, -0.487527 ...
	[-0.400825, -0.414617, -0.407231, -0.397206, -0.366296, -0.354333, -0.371938, -0.386065, -0.408146, -0.415736]	[-1.6062, -1.62319, -1.61939, -1.6173, -1.58341, -1.5697, -1.55188, -1.54089, -1.52865, -1.52388]	[-0.989828, -0.990365, -0.998319, -0.994962, -0.994991, -0.983351, -0.976952, -0.975923, -0.963954, -0.953944]	[0.558287, 0.447356, 0.452128, 0.525122, 0.651756, 0.77637, 0.948441, 1.09432, 1.30458, 1.42438]	[1.56275, 1.58349, 1.59581, 1.60302, 1.55387, 1.53016, 1.47453, 1.47069, 1.45205, 1.39396]	[0.526364, 0.534895, 0.553634, 0.564454, 0.478762, 0.47897, 0.444671, 0.328608, 0.29968, 0.242647]	[-0.489753, -0.48607, -0.484529, -0.492771, -0.492031, -0.493076, -0.491979, -0.493256, -0.493156, -0.487527 ...
	[-0.521346, -0.518394, -0.522321, -0.519893, -0.521016, -0.521524, -0.523362, -0.511653, -0.512519, -0.511312 ...	[-1.72326, -1.72407, -1.72326, -1.72352, -1.72479, -1.72389, -1.7244, -1.76782, -1.76903, -1.76877 ...	[-0.581362, -0.578159, -0.586091, -0.582611, -0.583196, -0.582819, -0.580284, -0.57613, -0.576047, -0.575067 ...	[0.480245, 0.413413, 0.425131, 0.420865, 0.481781, 0.483458, 0.415258, 0.429159, 0.449354, 0.476563 ...	[-1.72509, -1.79325, -1.77693, -1.78382, -1.72083, -1.72458, -1.80616, -1.77722, -1.78057, -1.79041 ...	[-0.749465, -0.814978, -0.79228, -0.801608, -0.754548, -0.74575, -0.806902, -0.788115, -0.775095, -0.768625 ...	[-0.521346, -0.518394, -0.522321, -0.519893, -0.521016, -0.521524, -0.523362, -0.511653, -0.512519, -0.511312 ...
	[-0.514448, -0.518708, ...	[-1.79175, -1.77926, ...	[-0.64696, -0.640021, ...	[0.71045, 0.665733, ...	[-1.57885, -1.64564, ...	[-1.16744, -0.986366, ...	[-0.514448, -0.518708, ...

Row	X[Hand tip l]	Y[Hand tip l]	Z[Hand tip l]	X[Hand tip r]	Y[Hand tip r]	Z[Hand tip r]	X[Hand tip l]
	Array...	Array...	Array...	Array...	Array...	Array...	Array...
	-0.521672,	-1.77711,	-0.630712,	0.621122,	-1.68675,	-0.849024,	-0.521672,
	-0.525064,	-1.77828,	-0.616814,	0.557295,	-1.81935,	-0.767521,	-0.525064,
	-0.514835,	-1.77587,	-0.62093,	0.519791,	-1.76374,	-0.725116,	-0.514835,
	-0.507935,	-1.76419,	-0.621969,	0.48524,	-1.76348,	-0.723884,	-0.507935,
	-0.521132,	-1.77843,	-0.621552,	0.481703,	-1.78189,	-0.743611,	-0.521132,
	-0.517193,	-1.77882,	-0.624645,	0.488414,	-1.7849,	-0.736042,	-0.517193,
	-0.517363,	-1.77992,	-0.621028,	0.485208,	-1.78435,	-0.731239,	-0.517363,
	-0.51327]	-1.77987]	-0.626299]	0.479489]	-1.78333]	-0.733958]	-0.51327]
	[-0.57022,	[-1.91196,	[-0.753404,	[0.459493,	[-1.90089,	[-0.764456,	[-0.57022,
	-0.562064,	-1.90369,	-0.748702,	0.464525,	-1.87507,	-0.766048,	-0.562064,
	-0.565967,	-1.90527,	-0.747062,	0.461903,	-1.89495,	-0.757716,	-0.565967,
	-0.562913,	-1.90405,	-0.7541,	0.455969,	-1.89809,	-0.756718,	-0.562913,
	-0.567557,	-1.90318,	-0.751551,	0.460419,	-1.87756,	-0.767963,	-0.567557,
	-0.566175,	-1.90619,	-0.749891,	0.465137,	-1.87972,	-0.767328,	-0.566175,
	-0.566748,	-1.90959,	-0.75006,	0.445696,	-1.9182,	-0.754985,	-0.566748,
	-0.561748,	-1.89934,	-0.748899,	0.458416,	-1.88876,	-0.757794,	-0.561748,
	-0.55966,	-1.8948,	-0.745352,	0.4603,	-1.8717,	-0.759314,	-0.55966,
	-0.556271	-1.89346	-0.74102 ...	0.46256 ...	-1.86988	-0.755372	-0.556271
4	...	...	-0.704626,	2.09097,	...	...	...
	-0.530846,	-1.87427,	-0.713649,	1.91878,	-0.790038,	-0.437201,	-0.530846,
	-0.535016,	-1.87535,	-0.720423,	1.58165,	-1.22432,	-0.560395,	-0.535016,
	-0.537207,	-1.88059,	-0.721149,	1.21182,	-1.5668,	-0.625109,	-0.537207,
	-0.533389,	-1.8954,	-0.720037,	0.941954,	-1.69141,	-0.675635,	-0.533389,
	-0.530497,	-1.89976,	-0.727544,	0.708641,	-1.78663,	-0.628565,	-0.530497,
	-0.532508,	-1.89333,	-0.718666,	0.537249,	-1.85248,	-0.654884,	-0.532508,
	-0.522586,	-1.90898,	-0.731909,	0.464884,	-1.9406,	-0.668321,	-0.522586,
	-0.53489,	-1.91169,	-0.73111,	0.459635,	-1.96856,	-0.737166,	-0.53489,
	-0.534332,	-1.92236,	-0.727761]	0.46293]	-1.96701,	-0.740219,	-0.534332,
	-0.54071]	-1.92444]			-1.9625]	-0.737878]	-0.54071]
	[-0.624417,	[-1.84287,	[-0.789348,	[0.58095,	[-1.83512,	[-0.748908,	[-0.624417,
	-0.626031,	-1.84026,	-0.786501,	0.57809,	-1.83411,	-0.753321,	-0.626031,
	-0.625388,	-1.84688,	-0.768675,	0.579865,	-1.83304,	-0.749488,	-0.625388,
	-0.62798,	-1.84182,	-0.779753,	0.577963,	-1.83161,	-0.758251,	-0.62798,
	-0.624838,	-1.84628,	-0.775049,	0.576101,	-1.82641,	-0.764208,	-0.624838,
	-0.623534,	-1.84354,	-0.77593,	0.576345,	-1.82692,	-0.764563,	-0.623534,
	-0.626624,	-1.84273,	-0.770693,	0.575145,	-1.82371,	-0.768688,	-0.626624,
	-0.626658,	-1.83752,	-0.771605,	0.579263,	-1.81809,	-0.772309,	-0.626658,
	-0.622853,	-1.83289,	-0.773377,	0.579383,	-1.81299,	-0.774509,	-0.622853,
	-0.622373	-1.83472	-0.76946 ...	0.579958	-1.81521	-0.774836	-0.622373
5	...	...	-0.831481,	...	...	...	...
	-0.606563,	-1.68283,	-0.841451,	2.07734,	0.210206,	0.212435,	-0.606563,
	-0.611505,	-1.72178,	-0.848442,	2.11504,	-0.240879,	0.104328,	-0.611505,
	-0.614609,	-1.77294,	-0.851784,	2.1128,	-0.761203,	-0.043032,	-0.614609,
	-0.607108,	-1.80126,	-0.846179,	1.91689,	-1.25598,	-0.286689,	-0.607108,
	-0.598554,	-1.81198,	-0.850705,	1.5704,	-1.64153,	-0.430668,	-0.598554,
	-0.621197,	-1.87223,	-0.837824,	1.18571,	-1.92075,	-0.572304,	-0.621197,
	-0.625199,	-1.89073,	-0.816053,	0.803449,	-2.01471,	-0.638792,	-0.625199,
	-0.644386,	-1.89526,	-0.801157,	0.617248,	-1.99813,	-0.682752,	-0.644386,
	-0.657226,	-1.9043,	-0.795484]	0.555628,	-1.98928,	-0.718812,	-0.657226,
	-0.663721]	-1.91686]		0.519571]	-2.0021]	-0.761999]	-0.663721]
6	[-0.502501,	[-2.17556,	[-1.09413,	[0.631689,	[-2.39645,	[-0.174365,	[-0.502501,
	-0.502525,	-2.15613,	-1.07683,	0.624567,	-2.35991,	-0.166227,	-0.502525,
	-0.499415,	-2.18516,	-1.09008,	0.638725,	-2.39196,	-0.164783,	-0.499415,
	-0.501144,	-2.19291,	-1.09044,	0.640064,	-2.35874,	-0.171156,	-0.501144,
	-0.502677,	-2.15844,	-1.07624,	0.617619,	-2.39011,	-0.171868,	-0.502677,
	-0.501937,	-2.14539,	-1.06987,	0.609287,	-2.38913,	-0.168856,	-0.501937,

Row	X[Hand tip l]	Y[Hand tip l]	Z[Hand tip l]	X[Hand tip r]	Y[Hand tip r]	Z[Hand tip r]	X[Hand tip l]
	Array...	Array...	Array...	Array...	Array...	Array...	Array...
7	-0.500699,	-2.17194,	-1.07743,	0.623102,	-2.4044,	-0.167825,	-0
	-0.501717,	-2.14695,	-1.07267,	0.614398,	-2.3628,	-0.166135,	-0
	-0.501963,	-2.13512,	-1.0659,	0.60629,	-2.33339,	-0.168217,	-0
	-0.504734	-2.12584	-1.0586 ...	0.591307	-2.39623	-0.164987	-0
	...	...	-0.994042,	... 1.1434,	...	...	...
	-0.43365,	-2.05511,	-1.00038,	0.936468,	-2.29177,	0.248703,	-0
	-0.436541,	-2.07088,	-1.00443,	0.81356,	-2.33778,	0.315796,	-0
	-0.447761,	-2.07849,	-1.00719,	0.748232,	-2.32335,	0.30116,	-0
	-0.456823,	-2.09125,	-1.01067,	0.70633,	-2.31428,	0.181476,	-0
	-0.460775,	-2.10468,	-1.02072,	0.715475,	-2.39301,	0.109893,	-0
	-0.467277,	-2.12407,	-1.02934,	0.701832,	-2.30433,	0.069707,	-0
	-0.464943,	-2.13097,	-1.0372,	0.708491,	-2.44085,	0.072417,	-0
	-0.469757,	-2.16563,	-1.04505,	0.711467,	-2.4951,	0.054247,	-0
	-0.468361,	-2.1762,	-1.04952]	0.724143]	-2.50935,	0.056288,	-0
	-0.469486]	-2.19243]			-2.53032]	0.068829]	-0
	[-0.488461,	[-2.17242,	[-0.968068,	[0.56396,	[-2.39541,	[-0.189166,	[-0
	-0.489463,	-2.18203,	-0.970886,	0.595508,	-2.32961,	-0.156892,	-0
	-0.487539,	-2.18057,	-0.972168,	0.563289,	-2.40599,	-0.183036,	-0
	-0.495673,	-2.18011,	-0.964309,	0.562872,	-2.4037,	-0.188968,	-0
	-0.498767,	-2.16312,	-0.968031,	0.569912,	-2.38496,	-0.182562,	-0
	-0.492156,	-2.16706,	-0.964959,	0.59887,	-2.30025,	-0.155315,	-0
	-0.492845,	-2.1655,	-0.965357,	0.597455,	-2.29899,	-0.159691,	-0
	-0.484968,	-2.16417,	-0.96689,	0.59935,	-2.29647,	-0.162753,	-0
	-0.482085,	-2.16289,	-0.961591,	0.588259,	-2.34951,	-0.167263,	-0
	-0.480355	-2.16507	-0.971308	0.616466	-2.34849	-0.126656	-0
	...	...	...	...	...	...	...
	-0.493495,	-2.20638,	-0.946976,	1.90101,	-1.68622,	0.428323,	-0
	-0.492836,	-2.24703,	-0.954752,	1.68372,	-2.01573,	0.353664,	-0
	-0.49895,	-2.26315,	-0.957002,	1.45597,	-2.27071,	0.283833,	-0
	-0.503093,	-2.27173,	-0.954402,	1.22308,	-2.44548,	0.227649,	-0
	-0.509026,	-2.2962,	-0.956824,	1.03946,	-2.54653,	0.192813,	-0
	-0.513016,	-2.3206,	-0.959061,	0.896663,	-2.61704,	0.144374,	-0
	-0.515636,	-2.28483,	-0.951237,	0.789375,	-2.58102,	0.100455,	-0
	-0.523701,	-2.26507,	-0.939096,	0.750815,	-2.42942,	0.056708,	-0
	-0.519121,	-2.30022,	-0.95456,	0.748015,	-2.45797,	0.020836,	-0
	-0.512226]	-2.30896]	-0.970996]	0.753018]	-2.3098]	-0.010608]	-0
8	[-0.468105,	[-1.86535,	[-0.697004,	[0.51303,	[-1.89671,	[-0.72422,	[-0
	-0.410602,	-1.89011,	-0.708269,	0.535447,	-1.86846,	-0.706672,	-0
	-0.473909,	-1.87105,	-0.681783,	0.526609,	-1.87776,	-0.716476,	-0
	-0.475146,	-1.87014,	-0.685562,	0.529012,	-1.86998,	-0.716994,	-0
	-0.465564,	-1.86305,	-0.700491,	0.516169,	-1.90863,	-0.720904,	-0
	-0.459415,	-1.86513,	-0.698824,	0.514988,	-1.90658,	-0.726877,	-0
	-0.408703,	-1.88585,	-0.712602,	0.515586,	-1.89158,	-0.722421,	-0
	-0.407192,	-1.88192,	-0.714313,	0.504798,	-1.91002,	-0.730964,	-0
	-0.406746,	-1.88197,	-0.709702,	0.504606,	-1.9078,	-0.734788,	-0
	-0.471503	-1.86255	-0.683408	0.531836	-1.88441	-0.696653	-0
	...	...	...	...	...	...	...
	-0.403425,	-1.70318,	-0.694703,	1.64002,	0.980896,	-0.583728,	-0
	-0.38908,	-1.71049,	-0.696871,	1.79941,	0.775941,	-0.670627,	-0
	-0.388014,	-1.71516,	-0.685235,	1.99117,	0.411292,	-0.697702,	-0
	-0.376936,	-1.72376,	-0.698665,	2.07635,	0.105297,	-0.731501,	-0
	-0.386189,	-1.72854,	-0.689877,	2.11726,	-0.240116,	-0.745341,	-0
	-0.383457,	-1.75506,	-0.695257,	2.06097,	-0.606455,	-0.771108,	-0
	-0.379303,	-1.78602,	-0.711887,	1.95247,	-0.99533,	-0.766031,	-0
	-0.379167,	-1.83142,	-0.716584,	1.74608,	-1.35875,	-0.755091,	-0
	-0.35105,	-1.82577,	-0.716449,	1.46703,	-1.59084,	-0.675288,	-0
	-0.37192]	-1.85042]	-0.711233]	1.22156]	-1.78522]	-0.632553]	-0

Row	X[Hand tip l]	Y[Hand tip l]	Z[Hand tip l]	X[Hand tip r]	Y[Hand tip r]	Z[Hand tip r]	X[
	Array...	Array...	Array...	Array...	Array...	Array...	Ai
9	[-0.568195,	[-1.79059,	[-0.629271,	[0.574572,	[-1.82092,	[-0.617017,	[-(
	-0.572936,	-1.78162,	-0.631997,	0.572953,	-1.82256,	-0.615382,	-0
	-0.571337,	-1.78303,	-0.629313,	0.58065,	-1.8185,	-0.612141,	-0
	-0.577742,	-1.77291,	-0.636701,	0.576566,	-1.81975,	-0.614752,	-0
	-0.562071,	-1.79029,	-0.635508,	0.576827,	-1.81878,	-0.611139,	-0
	-0.563401,	-1.79301,	-0.634023,	0.576204,	-1.81891,	-0.616751,	-0
	-0.56426,	-1.7906,	-0.639724,	0.578404,	-1.81806,	-0.615291,	-0
	-0.56251,	-1.79415,	-0.637628,	0.575839,	-1.82086,	-0.615829,	-0
	-0.567891,	-1.78852,	-0.638034,	0.571202,	-1.82313,	-0.618155,	-0
	-0.568983	-1.78192	-0.642679	0.578351	-1.8185 ...	-0.617481	-0
	...	...	...	...	1.05829,	...	...
	-0.572375,	-1.71373,	-0.59198,	1.11163,	0.920416,	-0.349956,	-0
	-0.573012,	-1.712,	-0.595464,	1.28867,	0.710814,	-0.491946,	-0
	-0.570897,	-1.71488,	-0.590844,	1.47037,	0.407749,	-0.653769,	-0
	-0.571727,	-1.71719,	-0.597421,	1.62137,	0.04714,	-0.814871,	-0
	-0.572124,	-1.724,	-0.599602,	1.73751,	-0.35929,	-0.892301,	-0
	-0.56665,	-1.73081,	-0.605654,	1.76605,	-0.776797,	-0.952159,	-0
	-0.568694,	-1.73278,	-0.595905,	1.68489,	-1.13484,	-0.969561,	-0
	-0.576087,	-1.74117,	-0.590594,	1.51916,	-1.41145,	-0.944127,	-0
	-0.577822,	-1.74922,	-0.592675,	1.30435,	-1.55159]	-0.865372,	-0
	-0.576184]	-1.7542]	-0.593041]	1.10295]		-0.795585]	-0
10	[-0.517579,	[-1.73887,	[-0.693497,	[0.514507,	[-1.83433,	[-0.711129,	[-(
	-0.515374,	-1.74072,	-0.691899,	0.526694,	-1.81353,	-0.706901,	-0
	-0.517325,	-1.7397,	-0.687666,	0.549404,	-1.76559,	-0.695049,	-0
	-0.516505,	-1.73405,	-0.692099,	0.506781,	-1.82393,	-0.725259,	-0
	-0.514786,	-1.73453,	-0.686091,	0.550714,	-1.76616,	-0.690311,	-0
	-0.513077,	-1.73561,	-0.6872,	0.548035,	-1.76641,	-0.68963,	-0
	-0.518725,	-1.7393,	-0.693279,	0.542946,	-1.7819,	-0.702482,	-0
	-0.520816,	-1.71604,	-0.690005,	0.536573,	-1.79043,	-0.705599,	-0
	-0.519732,	-1.72597,	-0.68333,	0.54797,	-1.76682,	-0.698506,	-0
	-0.521663	-1.73219	-0.693432	0.515168	-1.8396 ...	-0.715266	-0
	...	...	...	...	0.671155,	...	...
	-0.470503,	-1.72644,	-0.746989,	2.05311,	0.405484,	-0.295706,	-0
	-0.478416,	-1.73147,	-0.737197,	2.01937,	0.170111,	-0.343539,	-0
	-0.476322,	-1.73613,	-0.732215,	2.0615,	-0.095538,	-0.356921,	-0
	-0.483407,	-1.75607,	-0.722234,	2.14439,	-0.391807,	-0.385912,	-0
	-0.494542,	-1.76061,	-0.737401,	2.14045,	-0.683817,	-0.405628,	-0
	-0.497023,	-1.78371,	-0.737225,	2.15822,	-0.992354,	-0.440152,	-0
	-0.503007,	-1.80105,	-0.742772,	2.0852,	-1.32681,	-0.444337,	-0
	-0.511892,	-1.82082,	-0.742642,	1.93771,	-1.56162,	-0.468822,	-0
	-0.516592,	-1.83392,	-0.749105,	1.70293,	-1.79568]	-0.478764,	-0
	-0.506665]	-1.84493]	-0.749828]	1.46727]		-0.456275]	-0
11	[-0.631494,	[-1.98071,	[-0.747038,	[0.856043,	[-2.03258,	[-0.865939,	[-(
	-0.629032,	-1.98581,	-0.74841,	0.857518,	-2.0345,	-0.864099,	-0
	-0.630474,	-1.98407,	-0.747703,	0.851185,	-2.03402,	-0.862266,	-0
	-0.628314,	-1.98487,	-0.75014,	0.859634,	-2.03329,	-0.86024,	-0
	-0.625873,	-1.98305,	-0.754128,	0.858619,	-2.03401,	-0.852186,	-0
	-0.620084,	-1.98431,	-0.759453,	0.854354,	-2.034,	-0.85945,	-0
	-0.622708,	-1.98929,	-0.75647,	0.905673,	-2.02314,	-0.842965,	-0
	-0.615488,	-1.98398,	-0.766852,	1.16508,	-1.8548,	-0.9574,	-0
	-0.604842,	-2.00128,	-0.762574,	1.42501,	-1.60643,	-1.05019,	-0
	-0.609029	-1.99469	-0.767539	1.71238 ...	-0.912175	-1.05552 ...	-0
	...	...	...	1.209,	...	-0.972505,	...
	-0.614349,	-1.96031,	-0.729413,	1.07754,	-1.78783,	-0.913282,	-0
	-0.623253,	-1.97189,	-0.732674,	0.957434,	-1.91655,	-0.893715,	-0
	-0.624818,	-1.97785,	-0.739823,	0.851525,	-2.02219,	-0.822636,	-0
	1368,	-1.98624,	-0.731681,	0.757334,	-2.06767,	-0.784828,	-0

Row	X[Hand tip l]	Y[Hand tip l]	Z[Hand tip l]	X[Hand tip r]	Y[Hand tip r]	Z[Hand tip r]	X[Hand tip l]
	Array...	Array...	Array...	Array...	Array...	Array...	Array...
	-0.615468, -0.620129, -0.619546, -0.617533, -0.623453, -0.620921]	-1.98397, -1.97893, -1.97566, -1.97111, -1.96347, -1.97802]	-0.733116, -0.739864, -0.741084, -0.742643, -0.748294, -0.737384]	0.744572, 0.701962, 0.779988, 0.778182, 0.778619]	-2.06231, -2.04269, -2.01127, -1.73125, -1.7347, -1.73614]	-0.733635, -0.782048, -0.759991, -0.75973, -0.756357]	-0.733635, -0.782048, -0.759991, -0.75973, -0.756357]
12	[-0.628575, -0.621757, -0.631781, -0.634901, -0.628957, -0.637745, -0.635805, -0.629445, -0.632091, -0.635745 ... -0.591855, -0.582347, -0.588977, -0.598174, -0.599671, -0.619432, -0.621313, -0.628482, -0.633884, -0.627249]	[-1.64959, -1.65482, -1.6445, -1.65008, -1.65215, -1.64652, -1.64085, -1.65269, -1.64934, -1.64933 ... -1.65049, -1.66718, -1.6695, -1.67345, -1.67695, -1.6821, -1.68837, -1.69011, -1.68936, -1.69211]	[-0.826129, -0.820825, -0.825739, -0.822362, -0.825972, -0.82397, -0.82843, -0.827873, -0.833039, -0.834004 ... -0.850629, -0.836348, -0.83736, -0.830908, -0.825183, -0.81275, -0.804439, -0.805276, -0.816357, -0.813985]	[0.63093, 0.630534, 0.619773, 0.626157, 0.621542, 0.621468, 0.613933, 0.637572, 0.767764, 1.01477 ... 1.33375, 1.03323, 0.808823, 0.693519, 0.658938, 0.589302, 0.627916, 0.67699, 0.70274, 0.72096]	[-1.73747, -1.73717, -1.7373, -1.73898, -1.7427, -1.74377, -1.73731, -1.74702, -1.75181, -1.73828 ... -1.70125, -1.79771, -1.87956, -1.89704, -1.86995, -1.96147, -1.91128, -1.85101, -1.8577, -1.83568]	[-0.701359, -0.702162, -0.706464, -0.704693, -0.705164, -0.697885, -0.693803, -0.691132, -0.704814, -0.670501 ... -0.380183, -0.407226, -0.445143, -0.422019, -0.475656, -0.479682, -0.47908, -0.507252, -0.51364, -0.539279]	[-0.701359, -0.702162, -0.706464, -0.704693, -0.705164, -0.697885, -0.693803, -0.691132, -0.704814, -0.670501 ... -0.380183, -0.407226, -0.445143, -0.422019, -0.475656, -0.479682, -0.47908, -0.507252, -0.51364, -0.539279]
13	[-0.635968, -0.613303, -0.636138, -0.635273, -0.636906, -0.633466, -0.633318, -0.628543, -0.627045, -0.624422 ... -0.61882, -0.614184, -0.626042, -0.633471, -0.634397, -0.639003, -0.645128, -0.654244, -0.651518, -0.649729]	[-1.96703, -1.98867, -1.96746, -1.9631, -1.96258, -1.96333, -1.96385, -1.9627, -1.96265, -1.96134 ... -1.84131, -1.85966, -1.85407, -1.83433, -1.84256, -1.83536, -1.82502, -1.82088, -1.82251, -1.80934]	[-0.661007, -0.672837, -0.656478, -0.658991, -0.65884, -0.659275, -0.655378, -0.658712, -0.654345, -0.651957 ... -0.577366, -0.578097, -0.565833, -0.580407, -0.577185, -0.581951, -0.598315, -0.612136, -0.617067, -0.631079]	[0.630916, 0.629885, 0.629919, 0.630639, 0.629542, 0.63015, 0.630143, 0.630747, 0.630963, 0.629108 ... 2.06203, 2.03448, 1.9007, 1.64908, 1.37607, 1.14622, 0.918773, 0.727559, 0.594801, 0.538287]	[-2.01777, -2.01644, -2.01636, -2.01498, -2.01403, -2.01435, -2.01093, -2.01459, -2.01451, -2.01158 ... -0.037665, -0.489951, -0.950234, -1.36542, -1.63791, -1.74946, -1.86018, -1.92242, -1.96731, -1.97118]	[-0.713973, -0.720726, -0.720042, -0.715272, -0.72197, -0.720044, -0.719547, -0.715168, -0.712008, -0.717159 ... -0.679075, -0.752105, -0.784518, -0.804115, -0.727146, -0.627818, -0.604224, -0.602402, -0.59308, -0.614281]	[-0.713973, -0.720726, -0.720042, -0.715272, -0.72197, -0.720044, -0.719547, -0.715168, -0.712008, -0.717159 ... -0.679075, -0.752105, -0.784518, -0.804115, -0.727146, -0.627818, -0.604224, -0.602402, -0.59308, -0.614281]
349	[-0.616689, -0.614287, -0.616339, -0.611394, -0.615198, -0.652625,	[-1.94958, -1.94994, -1.94992, -1.95348, -1.93972, -2.09082,	[-0.755485, -0.760594, -0.755267, -0.755398, -0.751462, -0.75515,	[0.664354, 0.657678, 0.663926, 0.653829, 0.672965, 0.729495,	[-2.00496, -2.03505, -2.01516, -2.05454, -2.06293, -2.0968,	[-0.547348, -0.552963, -0.548251, -0.563437, -0.571891, -0.557266,	[-0.547348, -0.552963, -0.548251, -0.563437, -0.571891, -0.557266,

Row	X[Hand tip l]	Y[Hand tip l]	Z[Hand tip l]	X[Hand tip r]	Y[Hand tip r]	Z[Hand tip r]	X[
	Array...	Array...	Array...	Array...	Array...	Array...	Ai
	-0.758759,	-2.07774,	-0.740546,	0.949406,	-1.96131,	-0.713681,	-0
	-0.926013,	-2.07786,	-0.726338,	1.34799,	-1.51774,	-0.837412,	-0
	-1.16653,	-2.03293,	-0.712166,	1.67983,	-0.880203,	-0.903952,	-0
	-1.45786 ...	-1.95337	-0.657644	1.83766 ...	-0.12666	-0.789053	-0
	-0.634068,	...	...	0.595432,	...	...	...
	-0.638292,	-2.01936,	-0.700128,	0.637802,	-2.20064,	-0.568336,	-0
	-0.638414,	-2.01745,	-0.702082,	0.679586,	-1.99626,	-0.569397,	-0
	-0.633326,	-2.01658,	-0.69888,	0.636176,	-1.91715,	-0.532565,	-0
	-0.629956,	-2.01221,	-0.70226,	0.597256,	-1.99687,	-0.553386,	-0
	-0.624907,	-2.01132,	-0.701131,	0.593704,	-2.19972,	-0.551853,	-0
	-0.628131,	-2.00823,	-0.708299,	0.595663,	-2.19755,	-0.553435,	-0
	-0.623601,	-1.99968,	-0.705904,	0.594957,	-2.19723,	-0.551775,	-0
	-0.621252,	-1.99785,	-0.705396,	0.59227,	-2.19504,	-0.55471,	-0
	-0.619131]	-1.99715,	-0.706151,	0.590825]	-2.19353,	-0.553742,	-0
		-1.99688]	-0.706053]		-2.19285]	-0.553014]	-0
350	[-0.596139,	[-1.67946,	[-0.41818,	[0.496632,	[-1.6367,	[-0.739211,	[-0
	-0.596019,	-1.68074,	-0.410148,	0.49866,	-1.63157,	-0.742347,	-0
	-0.594476,	-1.67967,	-0.404465,	0.496747,	-1.63873,	-0.733166,	-0
	-0.591199,	-1.68043,	-0.404289,	0.50127,	-1.63019,	-0.738768,	-0
	-0.59016,	-1.68028,	-0.397016,	0.493619,	-1.63165,	-0.734405,	-0
	-0.587625,	-1.67404,	-0.404511,	0.49165,	-1.63523,	-0.734872,	-0
	-0.589226,	-1.68079,	-0.393309,	0.497987,	-1.62979,	-0.736452,	-0
	-0.59427,	-1.67452,	-0.403948,	0.49167,	-1.63167,	-0.734485,	-0
	-0.614432,	-1.66515,	-0.41825,	0.516722,	-1.59549,	-0.784128,	-0
	-0.712729	-1.63637	-0.471417	0.582021	-1.48439	-0.965686	-0
	...	...	...	...	...	...	...
	-0.575696,	-1.6783,	-0.358823,	0.430446,	-1.70408,	-0.707477,	-0
	-0.57971,	-1.66726,	-0.375101,	0.429438,	-1.7138,	-0.698281,	-0
	-0.582036,	-1.66698,	-0.372223,	0.434283,	-1.70738,	-0.703048,	-0
	-0.585876,	-1.66767,	-0.371538,	0.434753,	-1.70491,	-0.703093,	-0
	-0.576416,	-1.6741,	-0.370928,	0.433317,	-1.69697,	-0.706035,	-0
	-0.57689,	-1.67276,	-0.37131,	0.432706,	-1.70152,	-0.702741,	-0
	-0.578217,	-1.67021,	-0.378007,	0.429335,	-1.71372,	-0.694049,	-0
	-0.57949,	-1.66882,	-0.373494,	0.431152,	-1.70201,	-0.696337,	-0
	-0.578794,	-1.66735,	-0.373474,	0.432418,	-1.70447,	-0.688899,	-0
	-0.575571]	-1.66801]	-0.379876]	0.429916]	-1.70052]	-0.695393]	-0
	[-0.937442,	[-2.10495,	[-0.445069,	[0.593855,	[-2.01059,	[-0.460162,	[-0
	-1.02995,	-1.96835,	-0.419463,	0.611397,	-2.01198,	-0.438999,	-0
	-0.985338,	-1.95082,	-0.494451,	0.602737,	-2.019,	-0.433038,	-0
	-0.828794,	-2.09426,	-0.546546,	0.584278,	-2.02334,	-0.449091,	-0
	-0.719483,	-2.13928,	-0.592364,	0.563043,	-2.07292,	-0.514482,	-0
	-0.764852,	-2.08863,	-0.584375,	0.581611,	-2.11766,	-0.526686,	-0
	-0.790658,	-2.23229,	-0.554674,	0.588664,	-2.14359,	-0.511987,	-0
	-0.906044,	-2.28766,	-0.464802,	0.595967,	-2.12517,	-0.479525,	-0
	-1.06143,	-2.27454,	-0.479882,	0.595967,	-2.2062,	-0.090289,	-0
	-1.24269 ...	-2.06905	-0.533597	0.858367,	-2.03789	0.001343	-0
	-1.11567,	...	...	1.31364 ...	...	...	...
	-0.915111,	-1.9192,	-0.758341,	0.827272,	-2.15671,	-0.13886,	-0
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	-0.758403,	-2.02532,	-0.632757,	0.625905,	-1.95421,	-0.553127,	-0
	-0.722961,	-2.04187,	-0.6223,	0.608621,	-1.96479,	-0.572179,	-0
	-0.661048,	-2.00124,	-0.690714,	0.608801,	-1.95365,	-0.632077,	-0
	-0.674346,	-1.94335,	-0.73709,	0.613776,	-1.95082,	-0.637166,	-0
	-0.687475,	-1.91709,	-0.740402,	0.596233,	-1.93788,	-0.669985,	-0
	-0.68439]	-1.91269,	-0.738781,	0.588538,	-1.94164,	-0.66622,	-0
		-1.90738]	-0.740575]	0.590146]	-1.88977]	-0.659614]	-0



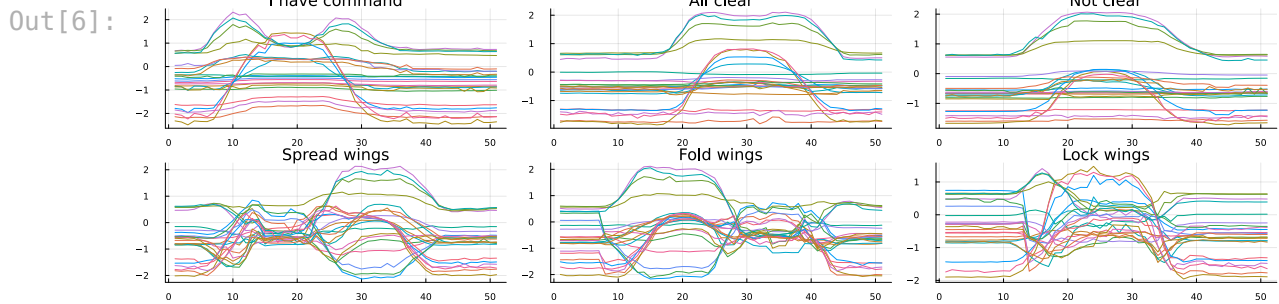
Row	X[Hand tip l]	Y[Hand tip l]	Z[Hand tip l]	X[Hand tip r]	Y[Hand tip r]	Z[Hand tip r]	X[
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	-0.584801,	-1.91826,	-0.701766,	0.685074,	-1.82025,	-0.687236,	-0
	-0.59971,	-1.97002,	-0.747765,	0.686095,	-1.87301,	-0.726534,	-0
	-0.595148,	-1.97009,	-0.744019,	0.681547,	-1.86164,	-0.726996,	-0
	-0.59403,	-1.966,	-0.744061,	0.680452,	-1.8572,	-0.728512,	-0
	-0.591524,	-1.94677,	-0.72129,	0.681045,	-1.83805,	-0.706081,	-0
	-0.591834,	-1.94209,	-0.711405,	0.684939,	-1.83235,	-0.696437,	-0
	-0.591661	-1.93865	-0.707665	0.676113	-1.82618	-0.698008	-0
	...	...	...	...	...	...	...
	-0.631753,	-2.05116,	-0.40507,	0.660947,	-1.90219,	-0.650799,	-0
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	-0.604525,	-1.97911,	-0.569021,	0.590117,	-1.87824,	-0.729737,	-0
	-0.578524,	-1.93749,	-0.649807,	0.57134,	-1.87888,	-0.740974,	-0
	-0.539126,	-1.94224,	-0.70869,	0.574835,	-1.88442,	-0.743894,	-0
	-0.486437,	-1.95526,	-0.75495,	0.595796,	-1.89448,	-0.735067,	-0
	-0.4675,	-1.95181,	-0.780949,	0.619714,	-1.90057,	-0.731009,	-0
	-0.453359,	-1.94552,	-0.791049,	0.625665,	-1.90804,	-0.713037,	-0
	-0.445844,	-1.94973,	-0.774547,	0.638661,	-1.90383,	-0.708452,	-0
	-0.454189]	-1.96401]	-0.751589]	0.6339]	-1.91231]	-0.695166]	-0
	[-0.466582,	[-1.71874,	[-1.03662,	[0.59468,	[-1.84908,	[-0.365797,	[-(
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	-0.500828,	-1.64664,	-1.078,	0.735446,	-1.90322,	-0.378178,	-0
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	-0.552448,	-1.6056,	-1.15505,	1.15693,	-1.73999,	-0.545071,	-0
	-0.453876,	-1.52025,	-1.40861,	1.48269,	-1.51691,	-0.604943,	-0
	-0.439888	-1.30873	-1.56395 ...	1.78098 ...	-1.05561	-0.635584	-0
	...	...	-0.820564,	0.40946,	...	...	...
	-0.715931,	-1.81162,	-0.976599,	0.618935,	-1.63182,	-0.569574,	-0
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	-0.696927,	-1.972,	-1.08675,	0.640586,	-1.90622,	-0.139989,	-0
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	-0.492768,	-1.85807,	-1.07486,	0.636803,	-1.83122,	-0.267517,	-0
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	-0.411497]	-1.65299]		-1.75888]	-0.385993]		-0
353	[-0.466582,	[-1.71874,	[-1.03662,	[0.59468,	[-1.84908,	[-0.365797,	[-(
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	-0.432809,	-1.58583,	-0.954459,	0.602656,	-1.85237,	-0.344981,	-0
	-0.480658,	-1.70418,	-1.04864,	0.641599,	-1.85198,	-0.34665,	-0
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	...	...	-0.820564,	0.40946,	...	...	...
	-0.715931,	-1.81162,	-0.976599,	0.618935,	-1.63182,	-0.569574,	-0
	-0.734048,	-1.98329,	-1.03893,	0.637069,	-1.88926,	-0.114756,	-0
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	-0.643663,	-1.93991,	-1.09675,	0.635214,	-1.89375,	-0.165661,	-0
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	-0.422277,	-1.83981,	-1.03899,	0.632184,	-1.80992,	-0.306533,	-0
	-0.389059,	-1.81063,	-1.04458,	0.609569,	-1.7971,	-0.329637,	-0
	-0.394768,	-1.75395,	-1.0622]	0.601727]	-1.7638,	-0.362193,	-0
	-0.411497]	-1.65299]		-1.75888]	-0.385993]		-0
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	-0.477738,	-1.89595,	-0.705428,	0.618775,	-1.76486,	-0.854097,	-0
	-0.455724,	-1.88366,	-0.734485,	0.598823,	-1.75967,	-0.872344,	-0
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	-0.62565,	-1.95207,	...	0.562149,	...	...	...
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	-0.529874,	-1.98885,	-0.710816,	0.554589,	-1.79338,	-0.937481,	-0

Row	X[Hand tip l]	Y[Hand tip l]	Z[Hand tip l]	X[Hand tip r]	Y[Hand tip r]	Z[Hand tip r]	X[Hand tip l]
	Array...	Array...	Array...	Array...	Array...	Array...	Array...
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	[-0.686893, -0.690966, -0.710514, -0.771405, -0.865657, -1.10153, -1.28476, -1.3701, -1.17664, -0.759236 ...	[-2.04375, -2.05011, -2.07035, -2.08768, -2.11075, -2.08723, -2.01236, -1.89968, -1.62723, -1.3901 ... ...	[-0.763731, -0.739648, -0.709582, -0.698519, -0.695876, -0.734551, -0.780351, -0.911202, -1.30088, -1.56614 ... ...	[0.619419, 0.641105, 0.677359, 0.750174, 0.969919, 1.55344, 1.8599, 2.083, 1.98471, 1.68652 ... ...	[-2.08314, -2.08161, -2.08674, -2.08547, -2.02839, -1.70898, -1.29341, -0.711759, 0.182653, 0.622182 ...	[-0.63965, -0.621357, -0.591876, -0.534126, -0.468331, -0.174424, -0.017619, 0.10863, 0.149411, 0.097924 ...	[-0.686893, -0.690966, -0.710514, -0.771405, -0.865657, -1.10153, -1.28476, -1.3701, -1.17664, -0.759236 ...
	-0.590119, -0.586947, -0.58872, -0.586027, -0.586456, -0.587513, -0.590223, -0.588903, -0.591829, -0.591138]	-2.01395, -2.0175, -2.01779, -2.00809, -2.00814, -2.00896, -2.01059, -2.01857, -2.0202, -2.01936]	-0.750251, -0.749495, -0.755412, -0.75954, -0.761369, -0.763274, -0.76296, -0.76822, -0.767053, -0.773619]	0.736513, 0.739569, 0.743421, 0.743809, 0.735055, 0.766925, 0.749379, 0.748856, 0.740557, 0.744968]	...	-0.510329, -0.509272, -0.517616, -0.512647, -0.534151, -0.5225, -0.516237, -0.519779, -0.529337, -0.530785]	-0 -0 -0 -0 -0 -0 -0 -0 -0 -0
	[-0.525938, -0.516073, -0.5177, -0.516002, -0.517101, -0.531324, -0.598619, -0.632816, -0.641388, -0.624213 ...	[-1.69259, -1.70519, -1.70824, -1.72114, -1.72487, -1.74597, -1.73602, -1.70956, -1.66064, -1.55737 ...	[-0.514372, -0.521267, -0.51823, -0.507091, -0.489786, -0.500235, -0.559973, -0.659927, -0.761855, -0.891289 ...	[0.385693, 0.391897, 0.387426, 0.391813, 0.416009, 0.49509, 0.833951, 1.08184, 1.34254, 1.6102 ... ...	[-1.71975, -1.72145, -1.72375, -1.72402, -1.73314, -1.73277, -1.60902, -1.50969, -1.29886, -0.787043 ...	[-0.715464, -0.711937, -0.712161, -0.714993, -0.70302, -0.716358, -0.748026, -0.79191, -0.858587, -0.998692 ...	[-0.525938, -0.516073, -0.5177, -0.516002, -0.517101, -0.531324, -0.598619, -0.632816, -0.641388, -0.624213 ...
	-0.506511, -0.53477, -0.536864, -0.537779, -0.545924, -0.540783, -0.544388, -0.550136, -0.546228, -0.545995]	-1.7578, -1.67215, -1.66308, -1.6627, -1.64937, -1.66342, -1.66382, -1.66711, -1.67062, -1.66981]	-0.536724, -0.524299, -0.517065, -0.522152, -0.517777, -0.526417, -0.521008, -0.531884, -0.52938, -0.531231]	0.473226, 0.439757, 0.435853, 0.444632, 0.418755, 0.410171, 0.416042, 0.413618, 0.409138, 0.410571]	...	-0.702175, -0.710662, -0.711929, -0.700321, -0.716329, -0.719247, -0.716009, -0.72007, -0.723947, -0.720406]	-0 -0 -0 -0 -0 -0 -0 -0 -0 -0
	[-0.440887, -0.452221, -0.447185, -0.451468, -0.451852, -0.460196, -0.454885, -0.456595, ...	[-1.90444, -1.91917, -1.91652, -1.92718, -1.92486, -1.93992, -1.93326, -1.931, ...	[-1.07556, -1.08468, -1.08069, -1.08455, -1.08098, -1.08955, -1.08634, -1.08236, ...	[0.601969, 0.607711, 0.600509, 0.620354, 0.619002, 0.601562, 0.59883, 0.585152, ...	[-2.15266, -2.17978, -2.19577, -2.043, -2.03998, -2.21929, -2.21141, -2.21772, ...	[-0.432073, -0.435872, -0.42879, -0.406766, -0.410107, -0.432601, -0.431501, -0.438689, ...	[-0.440887, -0.452221, -0.447185, -0.451468, -0.451852, -0.460196, -0.454885, -0.456595, ...

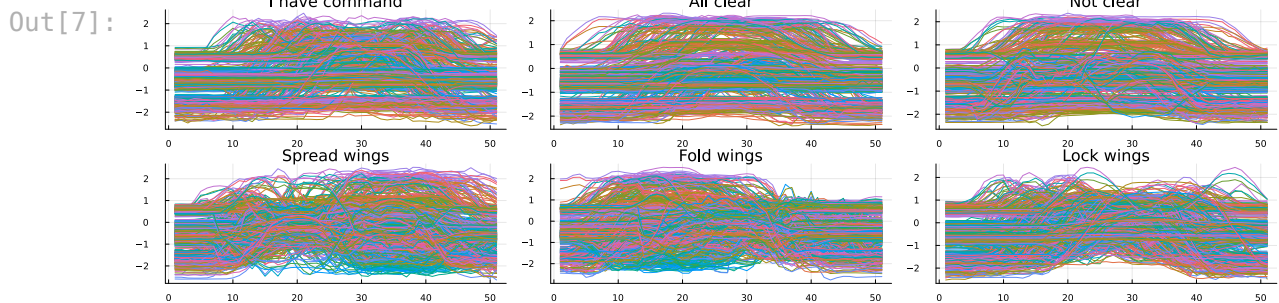
Row	X[Hand tip l]	Y[Hand tip l]	Z[Hand tip l]	X[Hand tip r]	Y[Hand tip r]	Z[Hand tip r]	X[Hand tip l]
	Array...	Array...	Array...	Array...	Array...	Array...	Array...
	-0.453205, -0.469354 ...	-1.89117, -1.90504 ...	-1.07372, -1.08595 ... -1.38186, ...	0.58419, 0.583967 ...	-2.21474, -2.23002 ...	-0.431665, -0.434617 ...	-0 -0 ...
	0.181187, -0.131194, -0.541423, -0.777776, -0.953652, -1.04438, -0.984894, -0.891926, -0.788926, -0.698249]	-1.18755, -1.39716, -1.36595, -1.59362, -1.67972, -1.74415, -1.83087, -1.86974, -1.92518, -1.86742]	-1.4358, -1.35391, -1.36938, -1.34895, -1.24551, -1.14865, -1.07423, -1.03839, -1.01313]	1.82576, 2.01202, 1.99811, 2.14004, 1.9395, 1.61937, 1.20757, 0.874289, 0.691181, 0.562766]	0.350891, 0.023507, -0.423043, -0.812878, -1.24957, -1.70558, -2.05941, -2.229, -2.24742, -2.19937]	-0.097338, -0.017904, 0.118915, 0.111467, 0.145836, 0.084069, 0.021073, -0.070298, -0.066992, -0.291861]	-0 -0 -0 -0 -0 -0 -0 -0 -0 -0
358	[-0.647672, -0.653511, -0.642305, -0.6383, -0.637352, -0.641916, -0.641393, -0.641784, -0.644001, -0.646141 ... -0.224099, -0.500692, -0.682501, -0.758069, -0.765982, -0.72369, -0.645501, -0.624031, -0.62637, -0.628032]	[-1.6173, -1.61051, -1.60491, -1.59955, -1.60063, -1.60052, -1.60037, -1.60233, -1.61603, -1.62083 ... -1.3884, -1.479, -1.63708, -1.65932, -1.664, -1.6762, -1.69198, -1.6986, -1.69814, -1.69324]	[-0.505743, -0.499972, -0.497074, -0.500385, -0.494025, -0.496815, -0.49508, -0.503109, -0.513043, -0.515419 ... -0.97989, -0.827817, -0.673086, -0.504513, -0.400298, -0.340097, -0.315575, -0.317331, -0.321467, -0.327659]	[0.500621, 0.496023, 0.498986, 0.498838, 0.504341, 0.500749, 0.503862, 0.504645, 0.505147, 0.504536 ... 0.293131, 0.443811, 0.581705, 0.631393, 0.575838, 0.527186, 0.534738, 0.529456, 0.518023, 0.517005]	[-1.61356, -1.61504, -1.61717, -1.61682, -1.61745, -1.61724, -1.6164, -1.6166, -1.61653, -1.61602 ... -0.727617, -1.1854, -1.55158, -1.64122, -1.65639, -1.67336, -1.67886, -1.68227, -1.6856, -1.68569]	[-0.682743, -0.680679, -0.674725, -0.676847, -0.673253, -0.674156, -0.676122, -0.674299, -0.673238, -0.675257 ... -1.2196, -1.11147, -0.889893, -0.700757, -0.638817, -0.619261, -0.614219, -0.615918, -0.62318, -0.623297]	[-0 -0 -0 -0 -0 -0 -0 -0 -0 -0 ... -0 -0 -0 -0 -0 -0 -0 -0 -0 -0
359	[-0.476117, -0.4705, -0.474443, -0.475678, -0.475745, -0.476801, -0.466286, -0.470162, -0.466426, -0.456026 ... -0.310213, -0.498413, -0.660566, -0.792202, -0.859166, -0.837351, -0.769369, -0.684986, -0.545003, -0.53447]	[-1.70846, -1.7099, -1.70912, -1.70614, -1.70891, -1.70891, -1.70919, -1.70437, -1.71174, -1.71172 ... -1.01014, -1.24986, -1.4634, -1.57394, -1.71292, -1.80086, -1.85209, -1.84221, -1.8798, -1.78985]	[-0.5028, -0.509458, -0.508224, -0.509525, -0.508446, -0.505009, -0.504267, -0.49798, -0.500755, -0.489398 ... -1.27009, -1.1431, -1.00582, -0.793894, -0.569638, -0.399036, -0.319151, -0.279739, -0.295245, -0.332945]	[0.379579, 0.380022, 0.381541, 0.37959, 0.387175, 0.383584, 0.39284, 0.397443, 0.395351, 0.395874 ... 0.733999, 0.871185, 0.973005, 0.972278, 0.867967, 0.770433, 0.654358, 0.552439, 0.431852, 0.378889]	[-1.62798, -1.63086, -1.63214, -1.63089, -1.62406, -1.63349, -1.62449, -1.60594, -1.59181, -1.58358 ... 0.25072, -0.203643, -0.645084, -1.02025, -1.43843, -1.60047, -1.74759, -1.79286, -1.89259, -1.82064]	[-0.840636, -0.834709, -0.83162, -0.833223, -0.83019, -0.823642, -0.817607, -0.812333, -0.80052, -0.792545 ... -1.65719, -1.75717, -1.73933, -1.55679, -1.24865, -1.06737, -0.932671, -0.84789, -0.79027, -0.771634]	[-0 -0 -0 -0 -0 -0 -0 -0 -0 -0 ... -0 -0 -0 -0 -0 -0 -0 -0 -0 -0

Row	X[Hand tip l]	Y[Hand tip l]	Z[Hand tip l]	X[Hand tip r]	Y[Hand tip r]	Z[Hand tip r]	X[
	Array...	Array...	Array...	Array...	Array...	Array...	A
360	[-0.553245,	[-1.69493,	[-0.756008,	[0.569726,	[-1.8093,	[-0.448892,	[-0
	-0.551704,	-1.69349,	-0.762863,	0.570003,	-1.80937,	-0.45103,	-0
	-0.548044,	-1.69951,	-0.760376,	0.573506,	-1.80944,	-0.445198,	-0
	-0.544929,	-1.7085,	-0.756736,	0.572164,	-1.80935,	-0.449493,	-0
	-0.546446,	-1.71117,	-0.756973,	0.621714,	-1.8126,	-0.440023,	-0
	-0.546651,	-1.71164,	-0.758584,	0.696098,	-1.85915,	-0.397585,	-0
	-0.554797,	-1.70638,	-0.766189,	0.876118,	-1.8061,	-0.392426,	-0
	-0.580788,	-1.68895,	-0.790081,	1.12203,	-1.67266,	-0.419542,	-0
	-0.634431,	-1.66512,	-0.83163,	1.47091,	-1.36509,	-0.481797,	-0
	-0.679319	-1.63018	-0.879984	1.64837 ...	-1.061 ...	-0.566341	-0
	...	...	...	0.503982,	-1.84879,	...	...
	-0.605506,	-1.76228,	-0.568478,	0.51867,	-1.81557,	-0.39616,	-0
	-0.606554,	-1.75493,	-0.590416,	0.550847,	-1.82067,	-0.374028,	-0
	-0.662612,	-1.74816,	-0.601258,	0.56638,	-1.82043,	-0.372259,	-0
	-0.709257,	-1.73299,	-0.618041,	0.586101,	-1.8186,	-0.369527,	-0
	-0.727722,	-1.72764,	-0.641417,	0.585824,	-1.8199,	-0.37349,	-0
	-0.721847,	-1.72671,	-0.648827,	0.581762,	-1.81979,	-0.374199,	-0
	-0.687693,	-1.725,	-0.660898,	0.575169,	-1.8188,	-0.375562,	-0
	-0.655425,	-1.72086,	-0.674366,	0.572896,	-1.81805,	-0.382328,	-0
	-0.627145,	-1.71081,	-0.687214,	0.568447]	-1.81838]	-0.383967,	-0
	-0.613324]	-1.70149]	-0.689185]			-0.382463]	-0

```
In [6]: # Let's inspect an instance for each class.
plot(map(i->plot(collect(X[i,:]), labels=nothing,title=y[i]), 1:30:180)...,
```



```
In [7]: # *All* instances, grouped by class
plot(map(i->plot(collect(eachrow(X[i:(i+30),:]), labels=nothing,title=y[i]
```



```
In [8]: # Randomly split the data: 20% training, 80% testing
N = nrow(X)
perm = randperm(Random.MersenneTwister(1), N)
train_idx = perm[1:round(Int, N*.2)], test_idx = perm[round(Int, N*.2)+1:end]
```

```
println("Using $(length(train_idx)) instances for training")
println("Using $(length(test_idx)) instances for testing")
```

Using 72 instances for training

Using 288 instances for testing

In [9]: DecisionTreeClassifier = @load DecisionTreeClassifier pkg=DecisionTree verbose

```
# Instantiate the CART decision tree learning algorithm
model = DecisionTreeClassifier(;
```

Out[9]: DecisionTreeClassifier(  
 max\_depth = -1,  
 min\_samples\_leaf = 1,  
 min\_samples\_split = 2,  
 min\_purity\_increase = 0.0,  
 n\_subfeatures = 0,  
 post\_prune = false,  
 merge\_purity\_threshold = 1.0,  
 display\_depth = 5,  
 feature\_importance = :impurity,  
 rng = Random.\_GLOBAL\_RNG())

In [10]: *# Bind data to learning algorithm*  
dt\_mach = machine(model, X, y)  
  
*# Training fails!*  
@time fit!(dt\_mach; rows=train\_idx)  
  
report(dt\_mach).print\_tree()

```

└ Warning: The number and/or types of data arguments do not match what the specified model
  supports. Suppress this type check by specifying `scitype_check_level=0`.

  Run `@doc DecisionTree.DecisionTreeClassifier` to learn more about your model's requirements.

  Commonly, but non exclusively, supervised models are constructed using the syntax
  `machine(model, X, y)` or `machine(model, X, y, w)` while most other models are
  constructed with `machine(model, X)`. Here `X` are features, `y` a target, and `w`
  sample or class weights.

  In general, data in `machine(model, data...)` is expected to satisfy

      scitype(data) <: MLJ.fit_data_scitype(model)

  In the present case:

      scitype(data) = Tuple{Table{AbstractVector{AbstractVector{Continuous}}}, AbstractVector{Multiclass{6}}}}

      fit_data_scitype(model) = Tuple{Table{<:Union{AbstractVector{<:Continuous}, AbstractVector{<:Count}, AbstractVector{<:OrderedFactor}}}, AbstractVector{<:Finite}}}
└ @ MLJBase ~/.julia/packages/MLJBase/ByFwA/src/machines.jl:230
[ Info: Training machine(DecisionTreeClassifier(max_depth = -1, ...), ...).
  3.864844 seconds (7.37 M allocations: 459.086 MiB, 5.06% gc time, 99.62% compilation time)

```

```

MethodError: no method matching round(::Vector{Float64}; sigdigits::Int64)

Closest candidates are:
  round(::Union{Float16, Float32, Float64}, ::RoundingMode{ToZero}) got uns
  upported keyword argument "sigdigits"
    @ Base float.jl:392
  round(::Union{Float16, Float32, Float64}, ::RoundingMode{Down}) got unsup
  ported keyword argument "sigdigits"
    @ Base float.jl:393
  round(::Union{Float16, Float32, Float64}, ::RoundingMode{Up}) got unsuppo
  rted keyword argument "sigdigits"
    @ Base float.jl:394
  ...

Stacktrace:
 [1] #print_tree#109
      @ ~/.julia/packages/DecisionTree/0Dw1P/src/DecisionTree.jl:238 [inlined]
 [2] print_tree
      @ ~/.julia/packages/DecisionTree/0Dw1P/src/DecisionTree.jl:231 [inlined]
 [3] #print_tree#107
      @ ~/.julia/packages/DecisionTree/0Dw1P/src/DecisionTree.jl:198 [inlined]
 [4] print_tree(tree::DecisionTree.Root{Vector{Float64}, UInt32}, depth::Int
64, indent::Int64; sigdigits::Int64, feature_names::Nothing)
      @ DecisionTree ~/.julia/packages/DecisionTree/0Dw1P/src/DecisionTree.jl:2
01
 [5] print_tree (repeats 2 times)
      @ ~/.julia/packages/DecisionTree/0Dw1P/src/DecisionTree.jl:200 [inlined]
 [6] (::MLJDecisionTreeInterface.TreePrinter{DecisionTree.Root{Vector{Float6
4}, UInt32}})()
      @ MLJDecisionTreeInterface ~/.julia/packages/MLJDecisionTreeInterface/cIW
Ga/src/MLJDecisionTreeInterface.jl:20
 [7] top-level scope
      @ In[10]:7

```

```

In [11]: # All instances have the same length
length.(X)

```

Out[11]: 360×24 DataFrame

335 rows omitted

Row	X[Hand tip l]	Y[Hand tip l]	Z[Hand tip l]	X[Hand tip r]	Y[Hand tip r]	Z[Hand tip r]	X[Elbow l]	Y[Elbow l]
	Int64	Int64	Int64	Int64	Int64	Int64	Int64	Int64
1	51	51	51	51	51	51	51	51
2	51	51	51	51	51	51	51	51
3	51	51	51	51	51	51	51	51
4	51	51	51	51	51	51	51	51
5	51	51	51	51	51	51	51	51
6	51	51	51	51	51	51	51	51
7	51	51	51	51	51	51	51	51
8	51	51	51	51	51	51	51	51
9	51	51	51	51	51	51	51	51
10	51	51	51	51	51	51	51	51
11	51	51	51	51	51	51	51	51
12	51	51	51	51	51	51	51	51
13	51	51	51	51	51	51	51	51
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
349	51	51	51	51	51	51	51	51
350	51	51	51	51	51	51	51	51
351	51	51	51	51	51	51	51	51
352	51	51	51	51	51	51	51	51
353	51	51	51	51	51	51	51	51
354	51	51	51	51	51	51	51	51
355	51	51	51	51	51	51	51	51
356	51	51	51	51	51	51	51	51
357	51	51	51	51	51	51	51	51
358	51	51	51	51	51	51	51	51
359	51	51	51	51	51	51	51	51
360	51	51	51	51	51	51	51	51

```
In [12]: # Maybe let's unwind the temporal axis?
X_static = Matrix(X)
cols = []
for i_var in 1:size(X_static, 2)
    var_unroll = hcat(X_static[:,i_var]...)
    push!(cols, eachrow(var_unroll))
end
```



```
end
X_static = DataFrame(cols, ["$n[$i]" for n in names(X) for i in 1:51])
```

Out[12]: 360×1224 DataFrame 1124 columns and 335 rows omitted

Row	X[Hand tip l][1]	X[Hand tip l][2]	X[Hand tip l][3]	X[Hand tip l][4]	X[Hand tip l][5]	X[Hand tip l][6]	X[Hand tip l][7]
	Float64	Float64	Float64	Float64	Float64	Float64	Float64
1	-0.519771	-0.52758	-0.531415	-0.517159	-0.510312	-0.518154	-0.503
2	-0.489753	-0.48607	-0.484529	-0.492771	-0.492031	-0.493076	-0.4919
3	-0.521346	-0.518394	-0.522321	-0.519893	-0.521016	-0.521524	-0.5233
4	-0.57022	-0.562064	-0.565967	-0.562913	-0.567557	-0.566175	-0.5667
5	-0.624417	-0.626031	-0.625388	-0.62798	-0.624838	-0.623534	-0.6266
6	-0.502501	-0.502525	-0.499415	-0.501144	-0.502677	-0.501937	-0.5006
7	-0.488461	-0.489463	-0.487539	-0.495673	-0.498767	-0.492156	-0.4928
8	-0.468105	-0.410602	-0.473909	-0.475146	-0.465564	-0.459415	-0.4087
9	-0.568195	-0.572936	-0.571337	-0.577742	-0.562071	-0.563401	-0.564
10	-0.517579	-0.515374	-0.517325	-0.516505	-0.514786	-0.513077	-0.5187
11	-0.631494	-0.629032	-0.630474	-0.628314	-0.625873	-0.620084	-0.6227
12	-0.628575	-0.621757	-0.631781	-0.634901	-0.628957	-0.637745	-0.6358
13	-0.635968	-0.613303	-0.636138	-0.635273	-0.636906	-0.633466	-0.6333
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
349	-0.616689	-0.614287	-0.616339	-0.611394	-0.615198	-0.652625	-0.7587
350	-0.596139	-0.596019	-0.594476	-0.591199	-0.59016	-0.587625	-0.5892
351	-0.937442	-1.02995	-0.985338	-0.828794	-0.719483	-0.764852	-0.7906
352	-0.595625	-0.593605	-0.588495	-0.584801	-0.59971	-0.595148	-0.594
353	-0.466582	-0.469372	-0.43454	-0.432809	-0.480658	-0.500828	-0.5323
354	-0.500404	-0.502824	-0.504771	-0.505733	-0.505021	-0.510656	-0.4777
355	-0.686893	-0.690966	-0.710514	-0.771405	-0.865657	-1.10153	-1.284
356	-0.525938	-0.516073	-0.5177	-0.516002	-0.517101	-0.531324	-0.5986
357	-0.440887	-0.452221	-0.447185	-0.451468	-0.451852	-0.460196	-0.4548
358	-0.647672	-0.653511	-0.642305	-0.6383	-0.637352	-0.641916	-0.6413
359	-0.476117	-0.4705	-0.474443	-0.475678	-0.475745	-0.476801	-0.4662
360	-0.553245	-0.551704	-0.548044	-0.544929	-0.546446	-0.546651	-0.5547

```
In [13]: # Bind data to learning algorithm
dt_mach_static = machine(model, X_static, y)
```

```

# Train!
@time fit!(dt_mach_static; rows=train_idxs);

report(dt_mach_static).print_tree()

# Compute accuracy
yhat = predict_mode(dt_mach_static; rows=test_idxs)
acc = MLJ.accuracy(yhat, y[test_idxs])
println("Accuracy: $(acc)")

```

[ Info: Training machine(DecisionTreeClassifier(max\_depth = -1, ...), ...).

0.830826 seconds (1.21 M allocations: 93.503 MiB, 2.64% gc time, 95.07% compilation time)

Feature 77 < -1.282 ?

└ Feature 790 < 1.396 ?

└ 3 : 12/12

└ Feature 499 < 1.055 ?

└ Feature 1006 < -1.4 ?

└ 1 : 16/16

└ 5 : 4/4

└ Feature 184 < 1.53 ?

└ 3 : 1/1

└ 5 : 5/5

└ Feature 380 < -0.02374 ?

└ Feature 680 < -0.3382 ?

└ 4 : 13/13

└ Feature 199 < 0.5233 ?

└ 4 : 1/1

└ 6 : 7/7

└ Feature 525 < -0.07192 ?

└ 2 : 12/12

└ 6 : 1/1

Accuracy: 0.5868055555555556

```

In [14]: println(names(X_static)[73])
          println(names(X_static)[790])

```

Y[Hand tip l][22]

X[Wrist r][25]

```

In [15]: feature_importances(dt_mach_static)

```

```

Out[15]: 1224-element Vector{Pair{Symbol, Float64}}:
  Symbol("Y[Hand tip l][26]") => 0.3919728191493403
  Symbol("X[Wrist r][25]") => 0.15879837719523981
  Symbol("Y[Elbow l][23]") => 0.15430650160975126
  Symbol("Y[Wrist l][17]") => 0.08149246071839794
  Symbol("Y[Thumb l][37]") => 0.0787799819908887
  Symbol("X[Elbow r][40]") => 0.06189215649217878
  Symbol("Y[Elbow r][15]") => 0.02775124659197857
  Symbol("X[Hand tip r][46]") => 0.02372646104198667
  Symbol("X[Hand tip r][31]") => 0.02127999521023807
  Symbol("X[Hand tip l][1]") => 0.0
  Symbol("X[Hand tip l][2]") => 0.0
  Symbol("X[Hand tip l][3]") => 0.0
  Symbol("X[Hand tip l][4]") => 0.0
  ⋮
  Symbol("Z[Thumb r][40]") => 0.0
  Symbol("Z[Thumb r][41]") => 0.0
  Symbol("Z[Thumb r][42]") => 0.0
  Symbol("Z[Thumb r][43]") => 0.0
  Symbol("Z[Thumb r][44]") => 0.0
  Symbol("Z[Thumb r][45]") => 0.0
  Symbol("Z[Thumb r][46]") => 0.0
  Symbol("Z[Thumb r][47]") => 0.0
  Symbol("Z[Thumb r][48]") => 0.0
  Symbol("Z[Thumb r][49]") => 0.0
  Symbol("Z[Thumb r][50]") => 0.0
  Symbol("Z[Thumb r][51]") => 0.0

```

```

In [16]: X_mean = DataFrame(mean.(Matrix(X)), ["mean($n)" for n in names(X)])

```

Out[16]: 360×24 DataFrame

335 rows omitted

Row	mean(X[Hand tip l])	mean(Y[Hand tip l])	mean(Z[Hand tip l])	mean(X[Hand tip r])	mean(Y[Hand tip r])
	Float64	Float64	Float64	Float64	Float64
1	-0.441529	-1.99325	-0.974478	1.17753	-1.13
2	-0.433127	-1.55045	-0.954742	0.927408	-0.379
3	-0.514139	-1.76206	-0.624403	0.702343	-0.627
4	-0.54604	-1.86853	-0.725127	1.08656	-0.584
5	-0.608619	-1.7987	-0.827025	1.00417	-0.43
6	-0.452965	-1.9987	-1.01116	1.07126	-1.06
7	-0.475165	-2.09609	-0.941348	1.23749	-0.965
8	-0.402244	-1.79774	-0.706467	1.21315	-0.449
9	-0.581116	-1.75254	-0.618155	1.03402	-0.639
10	-0.483915	-1.74924	-0.720024	1.33397	-0.624
11	-0.611767	-1.9223	-0.736676	0.991164	-0.24
12	-0.595399	-1.63924	-0.862169	1.19874	-0.368
13	-0.647034	-1.87037	-0.628469	1.18445	-0.731
⋮	⋮	⋮	⋮	⋮	
349	-0.528628	-1.47935	-0.871592	0.871904	-0.614
350	-0.391091	-1.24245	-0.649191	0.429929	-0.759
351	-0.294253	-1.21454	-0.883526	0.727772	-0.610
352	-0.149389	-1.0713	-0.864521	0.560025	-0.542
353	-0.423029	-1.19482	-1.04728	0.938631	-0.554
354	-0.26923	-1.38106	-0.871616	0.453254	-0.792
355	-0.342298	-1.4574	-0.950301	1.01039	-0.930
356	-0.134113	-1.10602	-0.824465	0.750383	-0.467
357	0.097314	-1.13352	-1.00926	0.985647	-0.620
358	-0.191882	-1.13238	-0.680037	0.579504	-0.473
359	-0.323847	-1.13138	-0.822845	0.649077	-0.54
360	-0.196397	-1.13002	-0.815892	0.803101	-0.52

```
In [17]: # Bind data to learning algorithm
dt_mach_mean = machine(model, X_mean, y)

# Train!
@time fit!(dt_mach_mean; rows=train_idxs);
```

```
report(dt_mach_mean).print_tree()

# Compute accuracy
yhat = predict_mode(dt_mach_mean; rows=test_idx)
acc = MLJ.accuracy(yhat, y[test_idx])
println("Accuracy: $(acc)")
```

0.012304 seconds (11.21 k allocations: 831.303 KiB, 89.54% compilation time)

```
Feature 20 < -1.249 ?
├ Feature 23 < -0.7454 ?
│   └ Feature 14 < -1.301 ?
│       └ Feature 16 < 1.062 ?
│           └ Feature 1 < -0.4752 ?
│               └ 3 : 2/2
│                   └ Feature 3 < -0.6793 ?
│                       └ 1 : 10/10
│                           └ 5 : 4/4
│                               └ Feature 1 < -0.3344 ?
│                                   └ Feature 9 < -0.0677 ?
│                                       └ 3 : 10/10
│                                           └ 5 : 1/1
│                                               └ 4 : 2/2
└ Feature 20 < -0.9186 ?
    └ 4 : 11/11
        └ Feature 11 < -0.4066 ?
            └ Feature 8 < -0.4618 ?
                └ Feature 4 < 0.7178 ?
                    └ 2 : 1/1
                        └ 6 : 4/4
                            └ 2 : 11/11
                                └ Feature 19 < -0.448 ?
                                    └ 6 : 4/4
                                        └ 4 : 1/1
```

Accuracy: 0.5625

[ Info: Training machine(DecisionTreeClassifier(max\_depth = -1, ...), ...).

In [18]: feature\_importances(dt\_mach\_mean)

```

Out[18]: 24-element Vector{Pair{Symbol, Float64}}:
  Symbol("mean(Y[Thumb l])") => 0.4791426225511836
  Symbol("mean(Y[Thumb r])") => 0.11855588688427983
  Symbol("mean(Z[Hand tip l])") => 0.0750540336604416
  Symbol("mean(X[Hand tip l])") => 0.05539064800441363
  Symbol("mean(Y[Elbow l])") => 0.051129205956262525
  Symbol("mean(X[Wrist r])") => 0.047341464077600454
  Symbol("mean(Y[Elbow r])") => 0.047081868037396314
  Symbol("mean(Y[Wrist l])") => 0.04550508659728294
  Symbol("mean(X[Thumb l])") => 0.03472627003491997
  Symbol("mean(Z[Elbow l])") => 0.026377918698496972
  Symbol("mean(X[Hand tip r])") => 0.019694995497722176
  Symbol("mean(Y[Hand tip l])") => 0.0
  Symbol("mean(Y[Hand tip r])") => 0.0
  Symbol("mean(Z[Hand tip r])") => 0.0
  Symbol("mean(X[Elbow l])") => 0.0
  Symbol("mean(X[Elbow r])") => 0.0
  Symbol("mean(Z[Elbow r])") => 0.0
  Symbol("mean(X[Wrist l])") => 0.0
  Symbol("mean(Z[Wrist l])") => 0.0
  Symbol("mean(Y[Wrist r])") => 0.0
  Symbol("mean(Z[Wrist r])") => 0.0
  Symbol("mean(Z[Thumb l])") => 0.0
  Symbol("mean(X[Thumb r])") => 0.0
  Symbol("mean(Z[Thumb r])") => 0.0

```

```

In [19]: X_features = DataFrame([
  eachcol(mean.(Matrix(X)))....,
  eachcol(maximum.(Matrix(X)))....,
  eachcol(minimum.(Matrix(X)))....,
], ["$f($n)" for n in names(X) for f in ["mean", "max", "min"]])

```

Out[19]: 360×72 DataFrame

335 rows omitted

Row	mean(X[Hand tip I])	max(X[Hand tip I])	min(X[Hand tip I])	mean(Y[Hand tip I])	max(Y[Hand tip I])
	Float64	Float64	Float64	Float64	Float64
1	-0.441529	-1.99325	-0.974478	1.17753	-1.13545
2	-0.433127	-1.55045	-0.954742	0.927408	-0.379828
3	-0.514139	-1.76206	-0.624403	0.702343	-0.627035
4	-0.54604	-1.86853	-0.725127	1.08656	-0.584427
5	-0.608619	-1.7987	-0.827025	1.00417	-0.43575
6	-0.452965	-1.9987	-1.01116	1.07126	-1.06485
7	-0.475165	-2.09609	-0.941348	1.23749	-0.965224
8	-0.402244	-1.79774	-0.706467	1.21315	-0.449356
9	-0.581116	-1.75254	-0.618155	1.03402	-0.639092
10	-0.483915	-1.74924	-0.720024	1.33397	-0.624704
11	-0.611767	-1.9223	-0.736676	0.991164	-0.24062
12	-0.595399	-1.63924	-0.862169	1.19874	-0.368009
13	-0.647034	-1.87037	-0.628469	1.18445	-0.731339
⋮	⋮	⋮	⋮	⋮	⋮
349	-0.528628	-1.47935	-0.871592	0.871904	-0.614831
350	-0.391091	-1.24245	-0.649191	0.429929	-0.759488
351	-0.294253	-1.21454	-0.883526	0.727772	-0.610082
352	-0.149389	-1.0713	-0.864521	0.560025	-0.542136
353	-0.423029	-1.19482	-1.04728	0.938631	-0.554863
354	-0.26923	-1.38106	-0.871616	0.453254	-0.792699
355	-0.342298	-1.4574	-0.950301	1.01039	-0.930284
356	-0.134113	-1.10602	-0.824465	0.750383	-0.467471
357	0.097314	-1.13352	-1.00926	0.985647	-0.620846
358	-0.191882	-1.13238	-0.680037	0.579504	-0.473543
359	-0.323847	-1.13138	-0.822845	0.649077	-0.54487
360	-0.196397	-1.13002	-0.815892	0.803101	-0.52948

```
In [20]: # Bind data to learning algorithm
dt_mach_features = machine(model, X_features, y)

# Train!
@time fit!(dt_mach_features; rows=train_idx);
```

```
# report(dt_mach_features).print_tree()
```

```
# Compute accuracy
```

```
yhat = predict_mode(dt_mach_features; rows=test_idx)  
acc = MLJ.accuracy(yhat, y[test_idx])  
println("Accuracy: $(acc)")
```

0.061459 seconds (151.81 k allocations: 10.587 MiB, 95.59% compilation time)

Accuracy: 0.6180555555555556

[ Info: Training machine(DecisionTreeClassifier(max\_depth = -1, ...), ...).

```
In [21]: feature_importances(dt_mach_features)
```

```
Out[21]: 72-element Vector{Pair{Symbol, Float64}}:
```

```
Symbol("max(X[Wrist l])") => 0.39197281914934023  
Symbol("mean(Z[Thumb l])") => 0.18132225305149965  
Symbol("max(X[Elbow r])") => 0.16741068900972056  
Symbol("mean(Y[Thumb l])") => 0.06544665501303142  
Symbol("min(Z[Elbow l])") => 0.04649458245137583  
Symbol("min(Z[Wrist r])") => 0.028902043776759926  
Symbol("min(X[Thumb l])") => 0.02835735767872674  
Symbol("min(Y[Thumb l])") => 0.027751246591978564  
Symbol("min(Y[Wrist r])") => 0.024712997421798815  
Symbol("min(Y[Elbow r])") => 0.022598081318570353  
Symbol("min(Y[Thumb r])") => 0.015031274537197792  
Symbol("mean(X[Hand tip l])") => 0.0  
Symbol("max(X[Hand tip l])") => 0.0  
⋮  
Symbol("max(X[Thumb l])") => 0.0  
Symbol("max(Y[Thumb l])") => 0.0  
Symbol("max(Z[Thumb l])") => 0.0  
Symbol("min(Z[Thumb l])") => 0.0  
Symbol("mean(X[Thumb r])") => 0.0  
Symbol("max(X[Thumb r])") => 0.0  
Symbol("min(X[Thumb r])") => 0.0  
Symbol("mean(Y[Thumb r])") => 0.0  
Symbol("max(Y[Thumb r])") => 0.0  
Symbol("mean(Z[Thumb r])") => 0.0  
Symbol("max(Z[Thumb r])") => 0.0  
Symbol("min(Z[Thumb r])") => 0.0
```

```
In [22]: using ModalDecisionTrees
```

```
# Instantiate the learning algorithm
```

```
mdt_model = ModalDecisionTree(; relations = :IA7);
```

```
In [23]: # Bind data to learning algorithm
```

```
mach = machine(mdt_model, X, y)
```

```
# Train!
```

```
@time fit!(mach; rows=train_idx)
```

[ Info: Precomputing logiset...

[ Info: Training machine(ModalDecisionTree(max\_depth = nothing, ...), ...).



103.101365 seconds (888.51 M allocations: 46.521 GiB, 10.85% gc time, 44.55% compilation time)

```
Out[23]: trained Machine; caches model-specific representations of data
         model: ModalDecisionTree(max_depth = nothing, ...)
         args:
           1: Source @524 ↪ Table{AbstractVector{AbstractVector{Continuous}}}
           2: Source @155 ↪ AbstractVector{Multiclass{6}}
```

```
In [24]: # Compute accuracy
yhat = predict_mode(mach; rows=test_idx)
MLJ.accuracy(yhat, y[test_idx])
```

Out[24]: 0.7847222222222222

```
In [25]: report(mach).printmodel(true; show_metrics = true)
```

```
■ (G)min[X[Hand tip l]] ≥ 0.428173
| ✓ (G)(min[X[Hand tip l]] ≥ 0.428173 ∧ (G)min[X[Wrist l]] < -1.536833)
| | ✓ (G)(min[X[Hand tip l]] ≥ 0.428173 ∧ (G)(min[X[Wrist l]] < -1.536833 ∧
(A0)min[X[Hand tip l]] ≥ 0.428173))
| | | ✓ Spread wings : (ninstances = 8, confidence = 1.0, coverage = 1.0)
| | | ✗ Fold wings : (ninstances = 12, confidence = 1.0, coverage = 1.0)
| | | ✗ Lock wings : (ninstances = 14, confidence = 1.0, coverage = 1.0)
| ✗ (G)min[Y[Hand tip r]] ≥ 0.847021
| | ✓ I have command : (ninstances = 14, confidence = 0.93, coverage = 1.0)
| | ✗ (G)min[Z[Hand tip l]] ≥ -0.62357
| | | ✓ (G)(min[Z[Hand tip l]] ≥ -0.62357 ∧ min[Y[Hand tip r]] < -1.850843)
| | | | ✓ All clear : (ninstances = 4, confidence = 0.75, coverage = 1.0)
| | | | ✗ Not clear : (ninstances = 7, confidence = 1.0, coverage = 1.0)
| | | ✗ All clear : (ninstances = 13, confidence = 0.92, coverage = 1.0)
```

```
In [26]: # Access model
tree = report(mach).model

# Extract the corresponding ruleset
ruleset = listrules(tree; use_shortforms = true);

# Print ruleset
printmodel.(ruleset; show_metrics = false, threshold_digits = 2, variable_na
```

■  $\langle G \rangle ((\min[X[\text{Hand tip l}]] \geq 0.43) \wedge \langle G \rangle ((\min[X[\text{Wrist l}]] < -1.54) \wedge (\overline{A0})(\min[X[\text{Hand tip l}]] \geq 0.43))) \rightarrow \text{Spread wings}$

■  $\langle G \rangle ((\min[X[\text{Hand tip l}]] \geq 0.43) \wedge \langle G \rangle (\min[X[\text{Wrist l}]] < -1.54)) \wedge [G]((\min[X[\text{Hand tip l}]] \geq 0.43) \rightarrow ([G]((\min[X[\text{Wrist l}]] < -1.54) \rightarrow (\overline{A0})(\min[X[\text{Hand tip l}]] < 0.43)))))) \rightarrow \text{Fold wings}$

■  $\langle G \rangle (\min[X[\text{Hand tip l}]] \geq 0.43) \wedge [G]((\min[X[\text{Hand tip l}]] \geq 0.43) \rightarrow ([G](\min[X[\text{Wrist l}]] \geq -1.54))) \rightarrow \text{Lock wings}$

■  $\langle G \rangle (\min[Y[\text{Hand tip r}]] \geq 0.85) \wedge [G](\min[X[\text{Hand tip l}]] < 0.43) \rightarrow \text{I have command}$

■  $\langle G \rangle ((\min[Z[\text{Hand tip l}]] \geq -0.62) \wedge (\min[Y[\text{Hand tip r}]] < -1.85)) \wedge [G](\min[X[\text{Hand tip l}]] < 0.43) \wedge [G](\min[Y[\text{Hand tip r}]] < 0.85) \rightarrow \text{All clear}$

■  $\langle G \rangle (\min[Z[\text{Hand tip l}]] \geq -0.62) \wedge [G](\min[X[\text{Hand tip l}]] < 0.43) \wedge [G](\min[Y[\text{Hand tip r}]] < 0.85) \wedge [G]((\min[Z[\text{Hand tip l}]] \geq -0.62) \rightarrow (\min[Y[\text{Hand tip r}]] \geq -1.85)) \rightarrow \text{Not clear}$

■  $[G](\min[X[\text{Hand tip l}]] < 0.43) \wedge [G](\min[Y[\text{Hand tip r}]] < 0.85) \wedge [G](\min[Z[\text{Hand tip l}]] < -0.62) \rightarrow \text{All clear}$

```
In [27]: first_rule = ruleset[1]
first_and = antecedent(first_rule)

println("First formula, translated:")
println(SoleLogics.experimentals.formula2natlang(first_and; threshold_digits=2))

println()
println("All formulas, translated:")

for (i_rule, rule) in enumerate(ruleset)
    println()
    println("[$i_rule]")
    print("IF\t")
    and = antecedent(rule)
    consq = consequent(rule)
    println(SoleLogics.experimentals.formula2natlang(and; threshold_digits=2))
    print("THEN\t")
    println(consq)
end
```

First formula, translated:

$\exists$  interval where  $((\min[V1] \geq 0.43) \text{ and } (\exists \text{ interval where } ((\min[V13] < -1.54) \text{ and } (\exists \text{ preceding, partially overlapping interval where } (\min[V1] \geq 0.43))))))$

All formulas, translated:

[1]

IF  $\exists$  interval where  $((\min[V1] \geq 0.43) \text{ and } (\exists \text{ interval where } ((\min[V13] < -1.54) \text{ and } (\exists \text{ preceding, partially overlapping interval where } (\min[V1] \geq 0.43))))))$

THEN ■ Spread wings

[2]

IF  $(\exists \text{ interval where } ((\min[V1] \geq 0.43) \text{ and } (\exists \text{ interval where } (\min[V13] < -1.54)))) \text{ and } (\forall \text{ intervals (whenever } \min[V1] \geq 0.43 \text{ holds, also } \forall \text{ intervals (whenever } \min[V13] < -1.54 \text{ holds, also } \forall \text{ preceding, partially overlapping intervals } (\min[V1] < 0.43))))$

THEN ■ Fold wings

[3]

IF  $(\exists \text{ interval where } (\min[V1] \geq 0.43)) \text{ and } (\forall \text{ intervals (whenever } \min[V1] \geq 0.43 \text{ holds, also } \forall \text{ intervals } (\min[V13] \geq -1.54)))$

THEN ■ Lock wings

[4]

IF  $(\exists \text{ interval where } (\min[V5] \geq 0.85)) \text{ and } (\forall \text{ intervals } (\min[V1] < 0.43))$

THEN ■ I have command

[5]

IF  $((\exists \text{ interval where } ((\min[V3] \geq -0.62) \text{ and } (\min[V5] < -1.85))) \text{ and } (\forall \text{ intervals } (\min[V1] < 0.43))) \text{ and } (\forall \text{ intervals } (\min[V5] < 0.85))$

THEN ■ All clear

[6]

IF  $((\exists \text{ interval where } (\min[V3] \geq -0.62)) \text{ and } (\forall \text{ intervals } (\min[V1] < 0.43))) \text{ and } (\forall \text{ intervals } (\min[V5] < 0.85))) \text{ and } (\forall \text{ intervals (whenever } \min[V3] \geq -0.62 \text{ holds, also } \min[V5] \geq -1.85))$

THEN ■ Not clear

[7]

IF  $((\forall \text{ intervals } (\min[V1] < 0.43)) \text{ and } (\forall \text{ intervals } (\min[V5] < 0.85))) \text{ and } (\forall \text{ intervals } (\min[V3] < -0.62))$

THEN ■ All clear