COL788 Embedded Systems
Part 2 Report
How Machine Learning Core (MLC) works on STM sensors

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Problem Statement:

Todo: Reproduce Yoga pose estimation with Sensortilebox, STBLE app and Unico, as Unico works on Linux laptops. You can use Unicleo/AlgoBuilder if you have windows machine. You can collect and label you own training data for fun, or use the datalogs given. But you must load these logs in Unico, train the decision tree and deploy the UCF back on SensorTile.box to run.

Background:

The SensorTile.box has the LSM6DSOX inertial sensor module. This can sample sensors like 3-axis accelerometer and 3-axis gyroscope, process the sensor data with filters, extract features from time windows of data and use the features to run decision tree classifiers and detect events. All these are done in hardware, without involvement of the Cortex M4 CPU core. Interrupts are sent to the CPU core, based on the events detected. Applications shows a list of applications that follow this pipeline on LSM6DSOX module. Configurations shows a set of software tools like the ST Ble Sensor Android app, STM32Cube Programmer, Unicleo, Unico, Algobuilder, and their configurations and flows with different hardware platforms to train/test MLC. Some slide decks describing the tools and workflow are workflow1, and workflow2.

Steps Followed:

Followed these github link steps-
https://github.com/STMicroelectronics/STMems_Machine_Learning_Core/tree/master/configuration_examples/example_1_sensortilebox_stble_unico

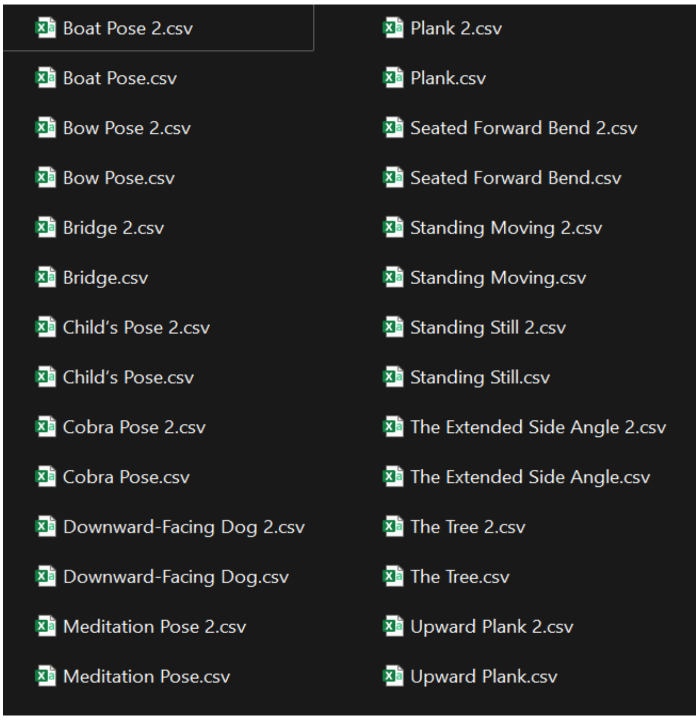
1. Installed UNICO

Link - https://www.st.com/en/development-tools/unico-gui.html

2. Used Available Datalogs

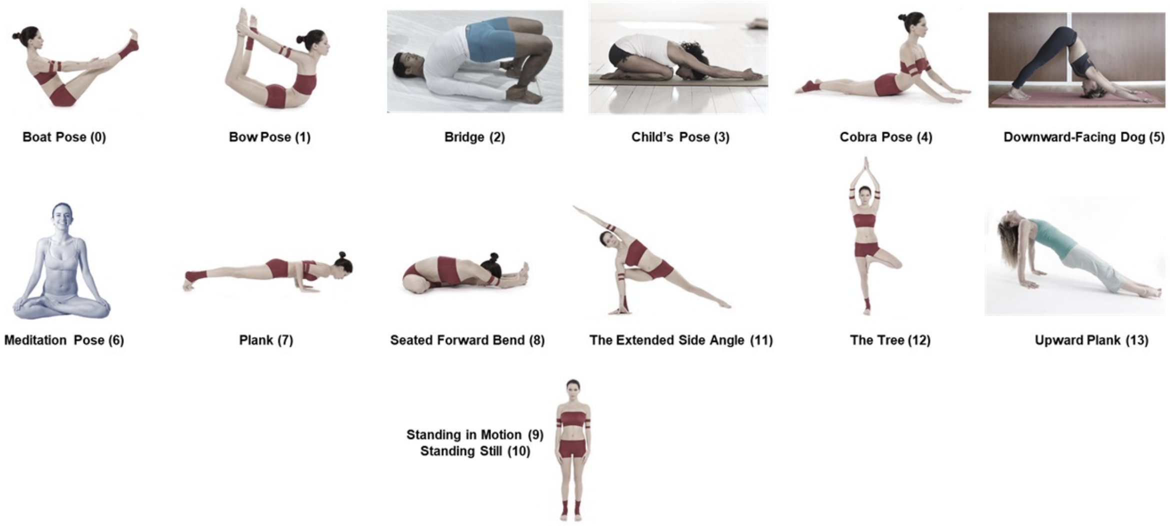
The MLC will be configured to recognize 14 different classes corresponding to 12 different Yoga positions (see picture below) and 2 Non-Yoga positions (standing still and in motion). This is the list of values that MLC0_SRC register can have and corresponding class label:

0 = Boat Pose
1 = Bow Pose
2 = Bridge
3 = Child's Pose
4 = Cobra's Pose
5 = Downward-Facing Dog
6 = Meditation Pose
7 = Plank
8 = Seated Forward Bend
9 = Standing in Motion
10 = Standing Still
11 = The Extended Side Angle
12 = The Tree
13 = Upward Plank
Used data available in csv format- We have 2 files for each position (total 28 files) corresponding to 2 persons performing the yoga poses each for around 10 seconds.



Boat Pose 2.csv
Boat Pose.csv
Bow Pose 2.csv
Bow Pose.csv
Bridge 2.csv
Bridge.csv
Child's Pose 2.csv
Child's Pose.csv
Cobra Pose 2.csv
Cobra Pose.csv
Downward-Facing Dog 2.csv
Downward-Facing Dog.csv
Meditation Pose 2.csv
Meditation Pose.csv
Plank 2.csv
Plank.csv
Seated Forward Bend 2.csv
Seated Forward Bend.csv
Standing Moving 2.csv
Standing Moving.csv
Standing Still 2.csv
Standing Still.csv
The Extended Side Angle 2.csv
The Extended Side Angle.csv
The Tree 2.csv
The Tree.csv
Upward Plank 2.csv
Upward Plank.csv

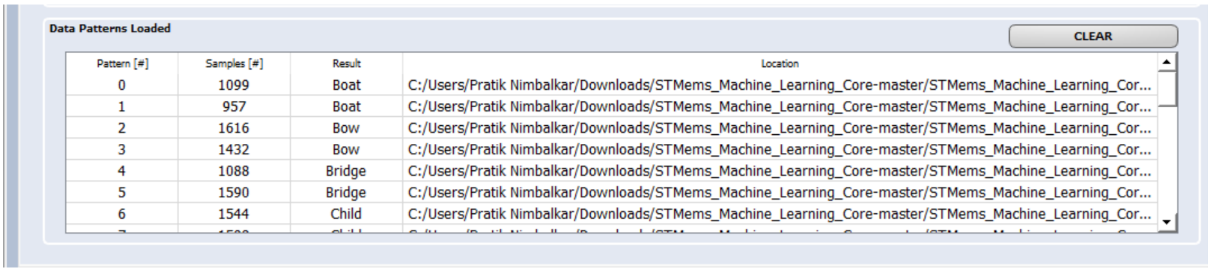
These 14 yoga positions are given in below image-



We used datalogs available here - https://github.com/STMicroelectronics/STMems_Machine_Learning_Core/tree/master/configuration_examples/example_1_sensortilebox_stble_unico/1_datalogs

2. Load and Label Data Logs

Loaded the 28 datalogs into UNICO and divided them into 14 labels.

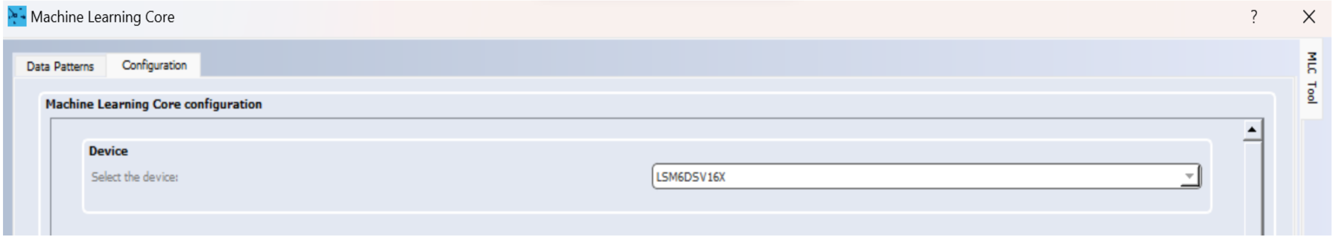


Data Patterns Loaded

Pattern [#]	Samples [#]	Result	Location
0	1099	Boat	C:/Users/Pratik Nimbalkar/Downloads/STMems_Machine_Learning_Core-master/STMems_Machine_Learning_Cor...
1	957	Boat	C:/Users/Pratik Nimbalkar/Downloads/STMems_Machine_Learning_Core-master/STMems_Machine_Learning_Cor...
2	1616	Bow	C:/Users/Pratik Nimbalkar/Downloads/STMems_Machine_Learning_Core-master/STMems_Machine_Learning_Cor...
3	1432	Bow	C:/Users/Pratik Nimbalkar/Downloads/STMems_Machine_Learning_Core-master/STMems_Machine_Learning_Cor...
4	1088	Bridge	C:/Users/Pratik Nimbalkar/Downloads/STMems_Machine_Learning_Core-master/STMems_Machine_Learning_Cor...
5	1590	Bridge	C:/Users/Pratik Nimbalkar/Downloads/STMems_Machine_Learning_Core-master/STMems_Machine_Learning_Cor...
6	1544	Child	C:/Users/Pratik Nimbalkar/Downloads/STMems_Machine_Learning_Core-master/STMems_Machine_Learning_Cor...

As we can see, we have two for Boat, two for Bow and so on.

Selected our Device - LSM6DSV16X

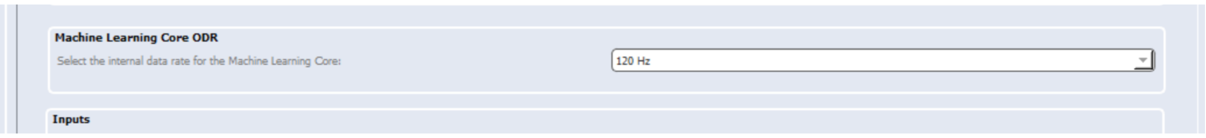


Machine Learning Core configuration

Device

Select the device: LSM6DSV16X

The Machine Learning Core (MLC) is configured to run at 120 Hz, computing features on windows of 60 samples, therefore the Decision Tree classifier output is updated two times per second (120 Hz / 60 = 2 Hz).

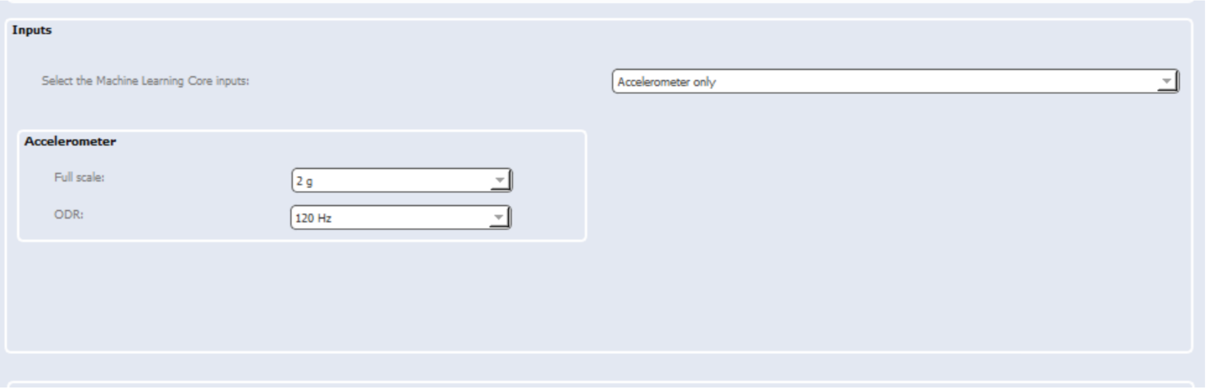


Machine Learning Core ODR

Select the internal data rate for the Machine Learning Core: 120 Hz

Inputs

The accelerometer is configured with ±2 g full scale and 120 Hz output data rate.



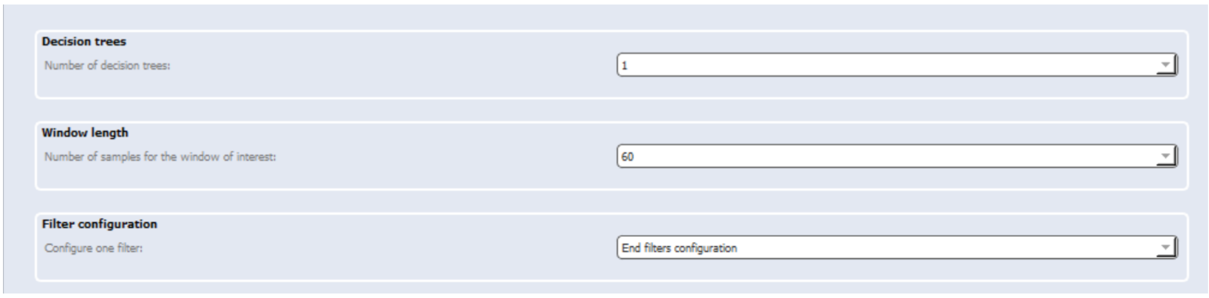
Inputs

Select the Machine Learning Core inputs: Accelerometer only

Accelerometer

Full scale: 2 g

ODR: 120 Hz



Decision trees

Number of decision trees: 1

Window length

Number of samples for the window of interest: 60

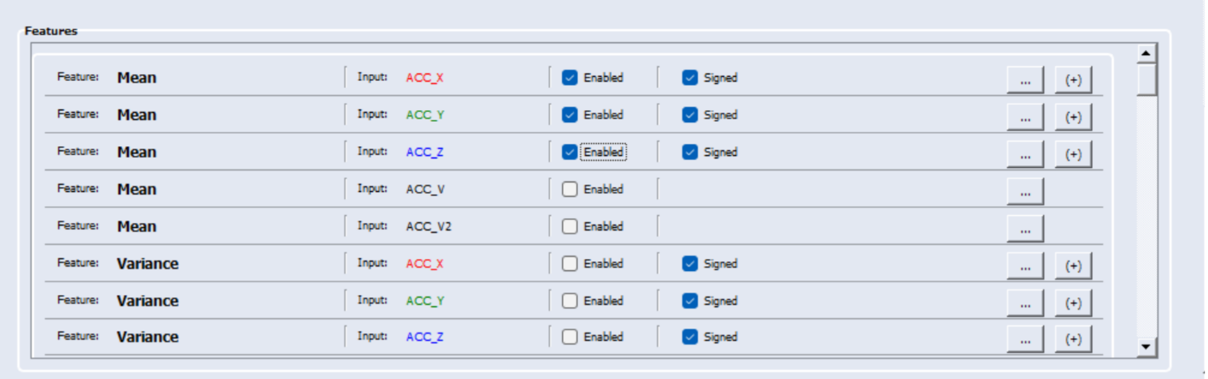
Filter configuration

Configure one filter: End filters configuration

Windows of - 60 samples
Decision Tree - 1
Filter Configuration - End filters

Three different features are computed:

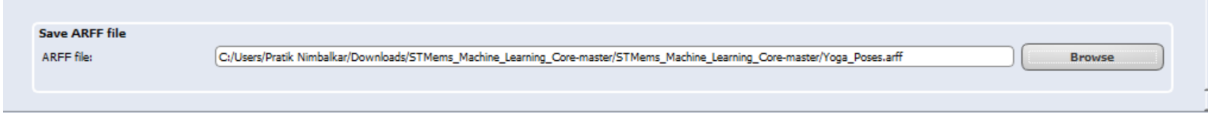
Mean on accelerometer X axis
Mean on accelerometer Y axis
Mean on accelerometer Z axis
One decision tree with around 20 nodes has been configured to detect the different classes.
A meta-classifier has not been used.



Features

Feature:	Mean	Input:	ACC_X	☑ Enabled	☑ Signed	...	(+)
Feature:	Mean	Input:	ACC_Y	☑ Enabled	☑ Signed	...	(+)
Feature:	Mean	Input:	ACC_Z	☑ Enabled	☑ Signed	...	(+)
Feature:	Mean	Input:	ACC_V	□ Enabled		...	
Feature:	Mean	Input:	ACC_V2	□ Enabled		...	
Feature:	Variance	Input:	ACC_X	□ Enabled	☑ Signed	...	(+)
Feature:	Variance	Input:	ACC_Y	□ Enabled	☑ Signed	...	(+)
Feature:	Variance	Input:	ACC_Z	□ Enabled	☑ Signed	...	(+)

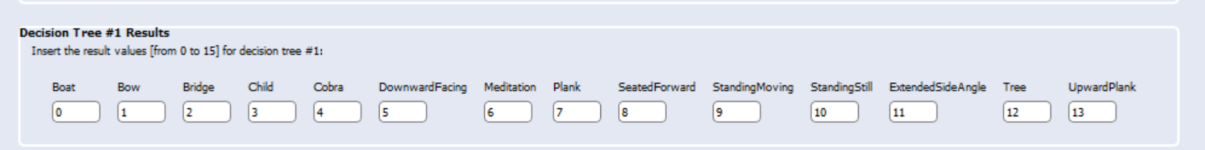
Saved the ARFF file -



Save ARFF file

ARFF file: C:/Users/Pratik Nimbalkar/Downloads/STMems_Machine_Learning_Core-master/STMems_Machine_Learning_Core-master/Yoga_Poses.arff

Decision tree results -



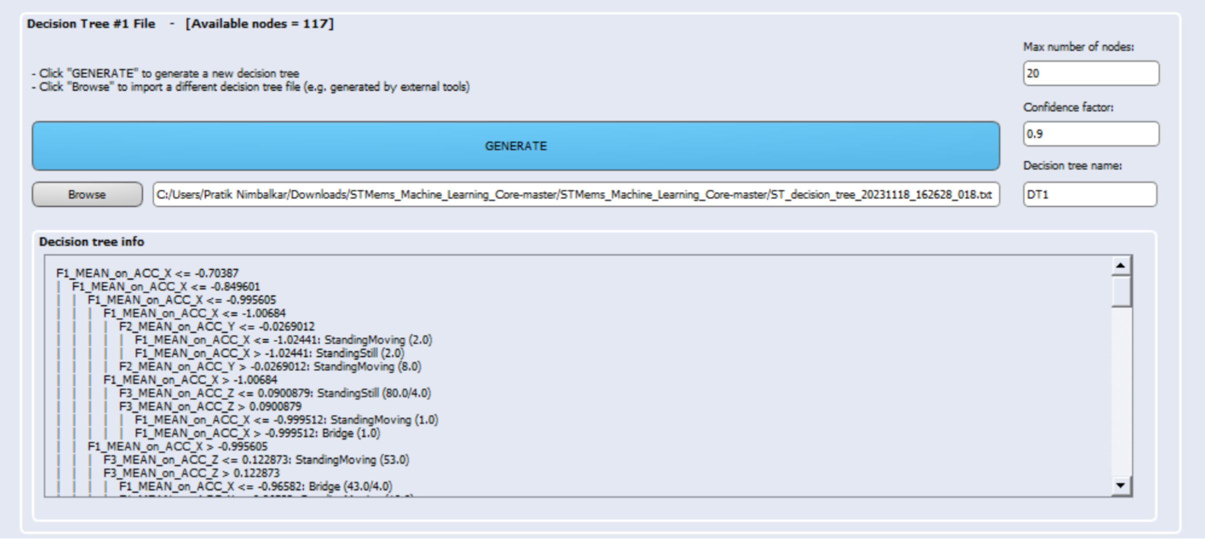
Decision Tree #1 Results

Insert the result values [from 0 to 15] for decision tree #1:

Boat	Bow	Bridge	Child	Cobra	DownwardFacing	Meditation	Plank	SeatedForward	StandingMoving	StandingStill	ExtendedSideAngle	Tree	UpwardPlank
0	1	2	3	4	5	6	7	8	9	10	11	12	13

3. Design the Decision Tree Classifier

One decision tree with around 20 nodes has been configured to detect the different classes.



Decision Tree #1 File - [Available nodes = 117]

- Click "GENERATE" to generate a new decision tree
- Click "Browse" to import a different decision tree file (e.g. generated by external tools)

Max number of nodes: 20

Confidence factor: 0.9

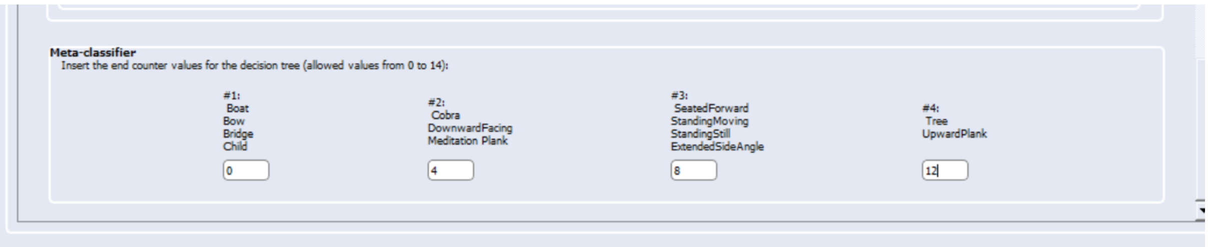
Decision tree name: DT1

C:/Users/Pratik Nimbalkar/Downloads/STMems_Machine_Learning_Core-master/STMems_Machine_Learning_Core-master/ST_decision_tree_20231118_162628_018.txt

Decision tree info

```
F1_MEAN_on_ACC_X <= -0.70387
|   F1_MEAN_on_ACC_X <= -0.849601
|   |   F1_MEAN_on_ACC_X <= -0.995605
|   |   |   F1_MEAN_on_ACC_X <= -1.00684
|   |   |   |   F2_MEAN_on_ACC_Y <= -0.0269012
|   |   |   |   |   F1_MEAN_on_ACC_X <= -1.02441: StandingMoving (2.0)
|   |   |   |   |   F1_MEAN_on_ACC_X > -1.02441: StandingStill (2.0)
|   |   |   |   F2_MEAN_on_ACC_Y > -0.0269012: StandingMoving (8.0)
|   |   |   F1_MEAN_on_ACC_X > -1.00684
|   |   |   |   F3_MEAN_on_ACC_Z <= 0.0900879: StandingStill (80.0/4.0)
|   |   |   |   F3_MEAN_on_ACC_Z > 0.0900879
|   |   |   |   |   F1_MEAN_on_ACC_X <= -0.999512: StandingMoving (1.0)
|   |   |   |   |   F1_MEAN_on_ACC_X > -0.999512: Bridge (1.0)
|   |   F1_MEAN_on_ACC_X > -0.995605
|   |   |   F3_MEAN_on_ACC_Z <= 0.122873: StandingMoving (53.0)
|   |   |   F3_MEAN_on_ACC_Z > 0.122873
|   |   |   |   F1_MEAN_on_ACC_X <= -0.96582: Bridge (43.0/4.0)
```

Clicked on “GENERATE” to generate the decision tree.

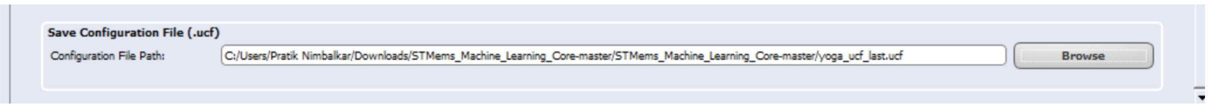


Meta-classifier

Insert the end counter values for the decision tree (allowed values from 0 to 14):

#1:	#2:	#3:	#4:
Boat Bow Bridge Child	Cobra DownwardFacing Meditation Plank	SeatedForward StandingMoving StandingStill ExtendedSideAngle	Tree UpwardPlank
0	4	8	12

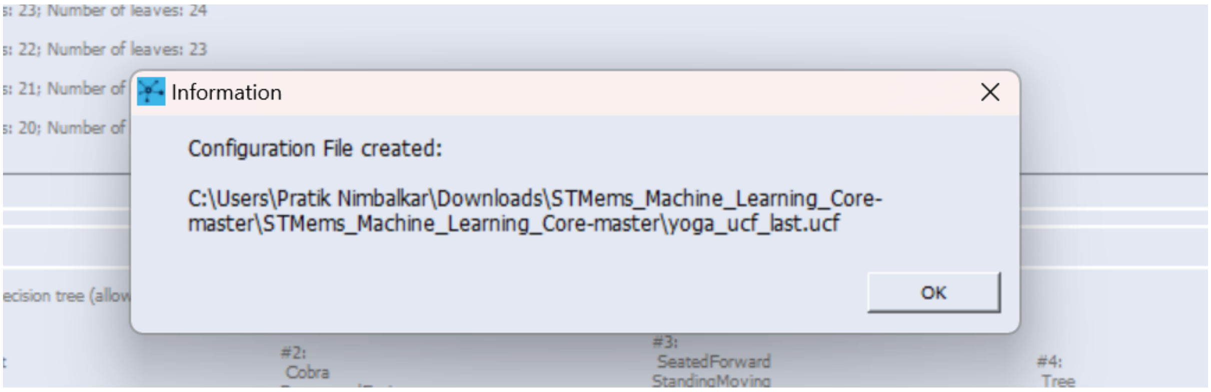
Inserted 0,4,8,12 values in the Meta classifier.



Save Configuration File (.ucf)

Configuration File Path: C:/Users/Pratik Nimbalkar/Downloads/STMems_Machine_Learning_Core-master/STMems_Machine_Learning_Core-master/yoga_ucf_last.ucf

Saved the UCF file

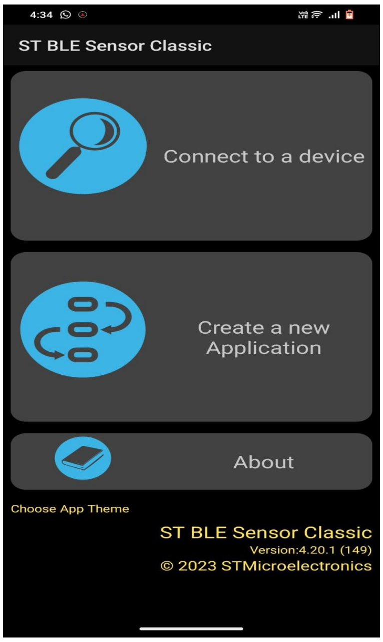


Configuration File created:

C:\Users\Pratik Nimbalkar\Downloads\STMems_Machine_Learning_Core-master\STMems_Machine_Learning_Core-master\yoga_ucf_last.ucf

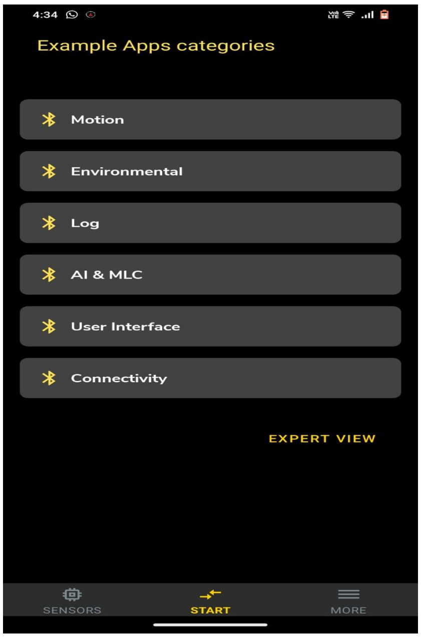
File created.

4. Using the Mobile App ST BLE Sensor Classic

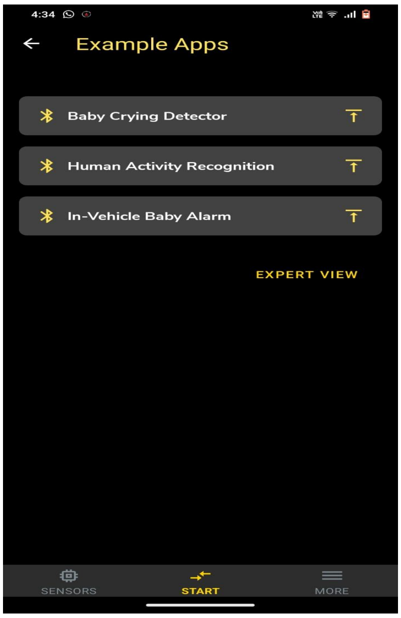


ST BLE Sensor Classic
Version:4.20.1 (149)
© 2023 STMicroelectronics

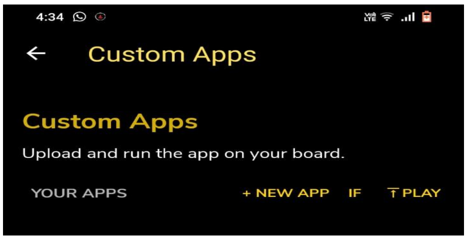
Created new application



Selected AI and MLC

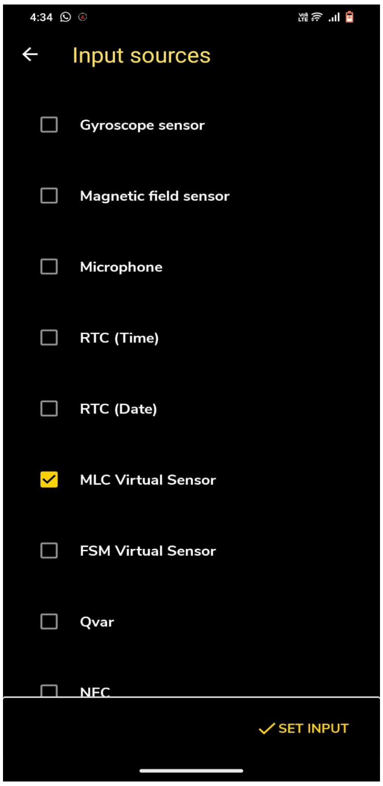


Expert View



Upload and run the app on your board.

+new app

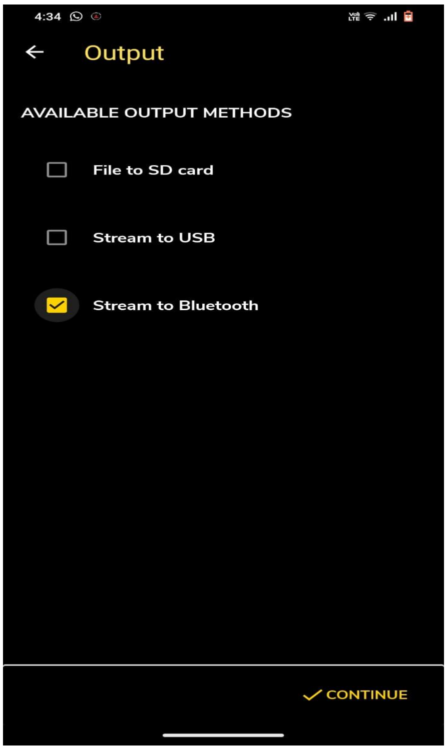


Input sources

- ☐ Gyroscope sensor
- ☐ Magnetic field sensor
- ☐ Microphone
- ☐ RTC (Time)
- ☐ RTC (Date)
- ☑ MLC Virtual Sensor
- ☐ FSM Virtual Sensor
- ☐ Qvar
- ☐ NFC

✓ SET INPUT

Select input source as MLC virtual sensor



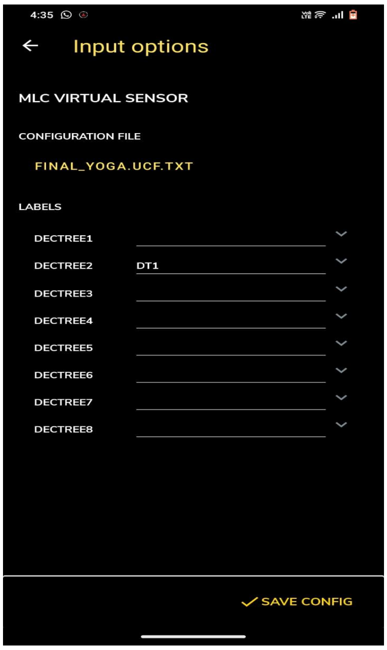
Output

AVAILABLE OUTPUT METHODS

- ☐ File to SD card
- ☐ Stream to USB
- ☑ Stream to Bluetooth

✓ CONTINUE

Output- stream to bluetooth



Input options

MLC VIRTUAL SENSOR

CONFIGURATION FILE

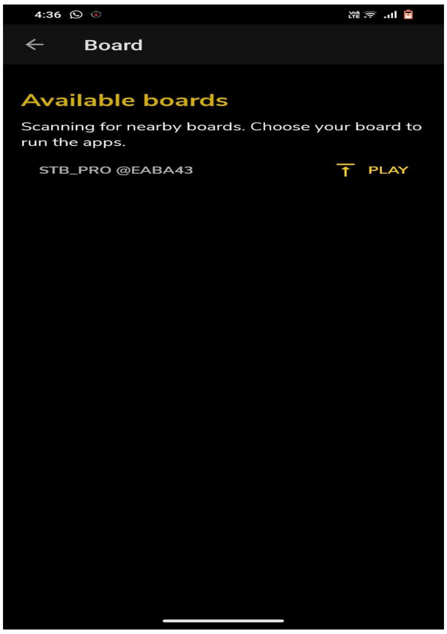
FINAL_YOGA.UCF.TXT

LABELS

DECTREE1	
DECTREE2	DT1
DECTREE3	
DECTREE4	
DECTREE5	
DECTREE6	
DECTREE7	
DECTREE8	

✓ SAVE CONFIG

Selected my generated UCF file and named it



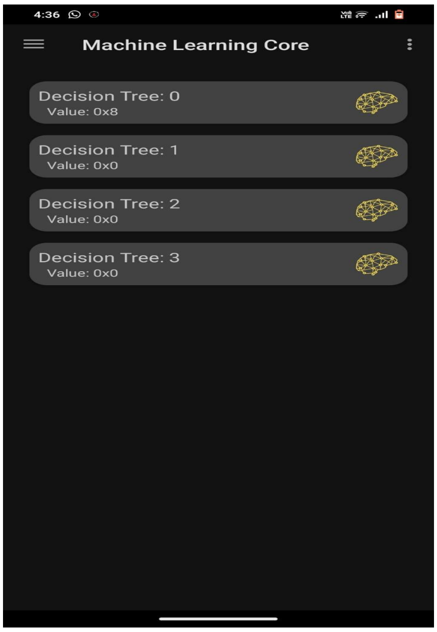
Board

Available boards

Scanning for nearby boards. Choose your board to run the apps.

STB_PRO @EABA43 PLAY

Selected the board and loaded the data Successfully, auto connected with board



Machine Learning Core

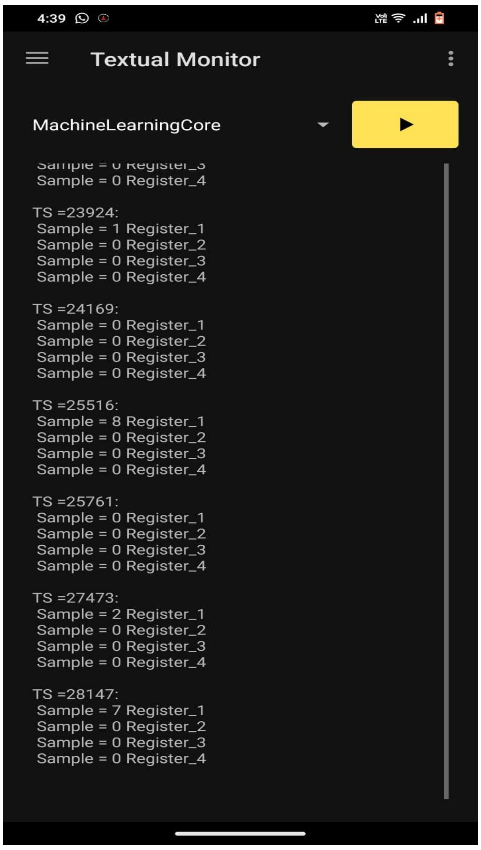
Decision Tree: 0
Value: 0x8

Decision Tree: 1
Value: 0x0

Decision Tree: 2
Value: 0x0

Decision Tree: 3
Value: 0x0

Decision trees visible

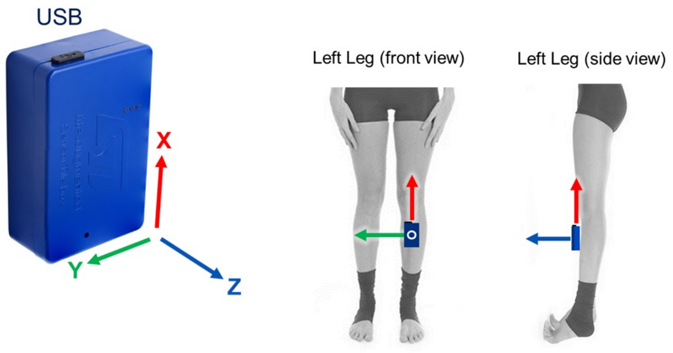


Textual Monitor

MachineLearningCore

```
 Sample = 0 Register_3
 Sample = 0 Register_4

TS =23924:
 Sample = 1 Register_1
 Sample = 0 Register_2
 Sample = 0 Register_3
 Sample = 0 Register_4

TS =24169:
 Sample = 0 Register_1
 Sample = 0 Register_2
 Sample = 0 Register_3
 Sample = 0 Register_4

TS =25516:
 Sample = 8 Register_1
 Sample = 0 Register_2
 Sample = 0 Register_3
 Sample = 0 Register_4

TS =25761:
 Sample = 0 Register_1
 Sample = 0 Register_2
 Sample = 0 Register_3
 Sample = 0 Register_4

TS =27473:
 Sample = 2 Register_1
 Sample = 0 Register_2
 Sample = 0 Register_3
 Sample = 0 Register_4

TS =28147:
 Sample = 7 Register_1
 Sample = 0 Register_2
 Sample = 0 Register_3
 Sample = 0 Register_4
```

Performed yoga and monitored in Textual Monitor by keeping the sensortile box stuck to my left leg, below the knee.



Plank (7), Forward Bend (8) detected successfully as can be seen.
Rest yoga positions also detected successfully.