SciTinyML
Scientific Use of Machine Learning on Low Power Devices

Regional Workshop - Africa

Hands-on Lab with Edge Impulse
Motion Classification

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Hands-on lab for motion classification
Case Study: Mechanical Stresses in Transport

Classes to study
- Maritime
- Terrestrial (or Rail)
- Lift
- Idle
Pre-Processing Data
Design a Model
Train a Model
WebUSB works fine with Chrome
<table>
<thead>
<tr>
<th>NAME</th>
<th>ID</th>
<th>TYPE</th>
<th>SENSORS</th>
<th>REMOTE</th>
<th>LAST SEEN</th>
</tr>
</thead>
</table>
Label: terrestrial
Label: LIFT
Label: maritime
Label: idle
Original Dataset

Training Set

Test Set

Training Set

Validation Set

Test Set

Machine Learning Algorithm

Final Model

Training, tuning, evaluation

Final Performance Estimate
If automatic split is not good, proceed with manual split.
Dataset is balanced (has representative samples from all classes) and split 80%/20%
Pre-Processing Data
- Design a Model
- Train a Model
**Model**

**Last training performance** (validation set)

- **Accuracy:** 99.9%
- **Loss:** 0.01

**Confusion matrix** (validation set)

<table>
<thead>
<tr>
<th>Class</th>
<th>IDLE</th>
<th>LIFT</th>
<th>MARITIME</th>
<th>TERRESTRIAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>IDLE</td>
<td>100%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>LIFT</td>
<td>0%</td>
<td>23.4%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>MARITIME</td>
<td>0%</td>
<td>0%</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td>TERRESTRIAL</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>100%</td>
</tr>
</tbody>
</table>

**Feature explorer** (full training set)

- accX RMS
- accY RMS
- accZ RMS

**On-device performance**

- *Inferencing time*: 1 ms.
- *Peak RAM usage*: 1.7K
- *Flash usage*: 19.0K
Pre-Processing Data

Design a Model

Train a Model

Dataset

Acquire Training Data

Train Machine Algorithms

Impulse

• Pre-Processing Data
• Design a Model
• Train a Model

Edge Device

Deploy

Edge On Edge

Validate

Test Data Flow

Tests
- Pre-Processing Data
- Design a Model
- Train a Model
Deploy your impulse

You can deploy your impulse to any device. This makes the model run without an internet connection, minimizes latency, and runs with minimal power consumption. Read more.

Create library

Turn your impulse into optimized source code that you can run on any device.

- C++-library
- Arduino library
- Cube MX CM355-PACK

- WebAssembly
- TensorRT library

Build firmware

Or get a ready-to-go binary for your development board that includes your impulse.

- ST IoT Discovery Kit
- Arduino Nano 33 BLE Sense
- Ela Compute ECM332 AI Sensor
- SLabs Thunderboard Sense 2
- Hihex WE-I Plus
- Nordic nRF52840 DK + KS02A1

- Nordic nRF52840 DK + KS02A1
- Nordic nRF9160 DK + KS02A1
- Nordic Things91
### Build output

- **Creating job...** OK (ID: 1646706)
- **Writing templates...** Writing templates OK
- **Copying Edge Impulse SDK...** Copying Edge Impulse SDK OK
- **Compiling OOM model...** Compiling OOM model OK
- **Removing clutter and updating headers...** Removing clutter and updating headers OK
- **Creating Arduino library...** Created Arduino library OK

### Built Arduino library

Add this library through the Arduino IDE via:

`Sketch > Include Library > Add .ZIP Library...`

Examples can then be found under:

- **File > Examples > EdgeImpulse --> Nano Motion Classification_Inferencing**

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### Performance metrics

<table>
<thead>
<tr>
<th>Optimization</th>
<th>RAM Usage</th>
<th>Latency</th>
<th>Confusion Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantized (int8)</td>
<td>19.0K</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>Unoptimized (float32)</td>
<td>1.8K</td>
<td>1 ms</td>
<td></td>
</tr>
<tr>
<td></td>
<td>21.3K</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** Estimates for Cortex M4F ROM11
void setup() {
    // put your setup code here, to run once
}

void loop() {
    // put your main code here, to run repetitively
}
```cpp
void setup() {
    // put your setup code here, to run on
    }
}

void loop() {
    // put your main code here, to run rep
    }
```
Model Inference
Sampling...
Predictions (DSP: 20 ms., Classification: 0 ms., Anomaly: 0 ms.):
  idle: 0.00000
  lift: 0.00000
  maritime: 0.00000
  terrestrial: 0.99609
Starting inferencing in 2 seconds...
Sampling...
Predictions (DSP: 20 ms., Classification: 1 ms., Anomaly: 0 ms.):
  idle: 0.00000
  lift: 0.00000
  maritime: 0.00000
  terrestrial: 0.99609
Starting inferencing in 2 seconds...

#include <IESTI01__Nano_Motion_Classification_inferencing.h>
#include <Arduino_LSM6DS1.h>

#define CONVERT_G_TO_MS2 9.80665f

static bool debug_nn = false; // Set this to true to see e.g. features general

Done in 6.027 seconds
reset();
Predictions (DSP: 29 ms., Classification: 0 ms., Anomaly: 0 ms.): terrestrial [0, 0, 0, 0, 0, 0, 0, 0, 0]

**include <IESTI01__Nano_Motion_Classification_inferencing.h>
#include <Arduino_LSM6DS1.h>

**Constant defines**
define CONVERT_G_TO_MS2 9.80665f

**Private variables**
static bool debug_n = false; // Set this to true to see e.g. features
static uint32_t run_inference_every_ms = 200;
static rtos::Thread inference_thread(osPriorityLow);
static float buffer[EI_CLASSIFIER_DSP_INPUT_FRAME_SIZE] = {0};
static float inference_buffer[EI_CLASSIFIER_DSP_INPUT_FRAME_SIZE];

**Forward declaration**
void run_inference_background();

**Brief Arduino setup function**
void setup()
{
  // put your setup code here, to run once:
  Serial.begin(115200);
  Serial.println("Edge Impulse Inferencing Demo");

  if (IMU.begin())
  {
    ei_printf("Failed to initialize IMU!
    ");
  }
  else
  {
    ei_printf("IMU initialized!
    ");
  }
}

Done up loading.

Done in 6.034 seconds reset()
TinyML motion classification uses on Real Life
Using the Internet of Things for Agricultural Monitoring

“We aim to deploy a variety of sensors for agricultural monitoring. One of the projects involves using accelerometer sensors to monitor activity levels in dairy cows with a view to determining when the cows are on heat or when they are sick.”

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Kenia

https://sites.google.com/site/cwainadekut/research
Predict and classify common Elephant behavior

Aggressive

Standing

Sleeping

Thanks