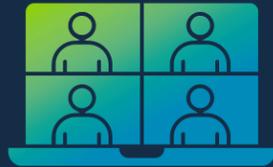**arm** AI

Solving real-world challenges using AI on Arm with Neuton TinyML

Intelligent Agent
Neuton

Sumit Kumar, Embedded Engineer & Blair Newman, CTO

September 20, 2022

© 2022 Arm

arm AI

Welcome!

Tweet us: @ArmSoftwareDev -> #AIVTT

Check out our Arm Software Developers YouTube channel

Signup now for our next AI Virtual Tech Talk: www.arm.com/techtalks

Our Upcoming Arm Tech Talks

Date	Title	Host
September 20th	Solving real-world challenges using AI on Arm with Neuton TinyML	Neuton.ai
October 11th	Introducing a common operator set for Machine Learning accelerators – TOSA	Arm
November 8th	Energy-Efficient ML Vision application development with Arm Ethos-U65 microNPU from NXP and Arcturus	NXP & Arcturus

Visit: www.arm.com/techtalks

arm AI

Presenters

Sumit Kumar is a high school graduate who founded a community of high schoolers involved in learning IoT and coding skills, called the steptostem.com community.

His daily routine involves dealing with electronics, code, distributed storage and cloud APIs. He also has keen interest in AI model compression and high performance TinyML solutions. For fun, he participates in many hackathons and workshops too!

Within the community request, Sumit has worked around a use case in the agricultural field geared to enhance agricultural products & fertilizers logistics.

vilaksh01@gmail.com

Blair Newman

With strong tech expertise and 20+ years of leadership experience, Blair Newman provides unprecedented insights into the future of AI's development and use. As Neuton's CTO, Blair is engaged in overseeing our business solutions as well as ensuring high-quality services are delivered to our clients.

Prior to Neuton, Blair held various leadership roles at T-Systems North America, a Division of Deutsche Telekom, being responsible for providing strategic direction and leadership in the areas of Dynamic Services (Cloud Computing), SAP Hosting, Application Operations, Managed Hosting and Infrastructure Services.

Blair.Newman@neuton.ai

arm AI

Outline

- About the Neuton.ai Platform

- Case Study – Innovative AI solution for farmers with Arm and Neuton
  - Problem statement and POC
  - Creation of tiny ML models for Arm Cortex-M4 processors
  - Model embedding to Arduino Pro board and Demo

arm AI

Taking the Next Step in AI at the Edge

Neuton – The First Neural Network Framework that empowers you to build models with minimal size and without loss of accuracy

- automatically
- in one iteration
- without compression

arm AI

Neuton.ai

Provider of Full-scale TinyML Solutions

Exceptionally Tiny Models without Loss of Accuracy

Explore a novel approach to bringing extra capabilities to edge devices

Less than

1 kb

is an average model size achieved by our neural framework

Even tiny

8-bit

microcontrollers can be AI-driven and run robust neural networks

Up to

1,000 times

smaller models compared to other existing algorithms

Only

1 iteration

is enough to build an accurate, fast and incredibly tiny model

arm AI

Neuton vs Others

TensorFlow Lite


❌ Large memory footprint

❌ Slow inference

❌ Requires knowledge of data science for configuration

❌ Requires compression techniques

❌ Does not support 8 and 16-bit MCUs

Neuton Based on the Unique Neural Network Framework

✅ Incredibly small models

✅ Fast inference

✅ Perfect for tasks with complex dependencies

✅ No compression techniques required

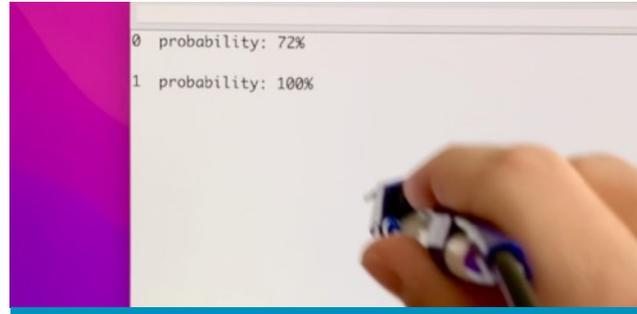✅ Native embedding into 8, 16, and 32-bit MCUs

Non-neural Algorithms
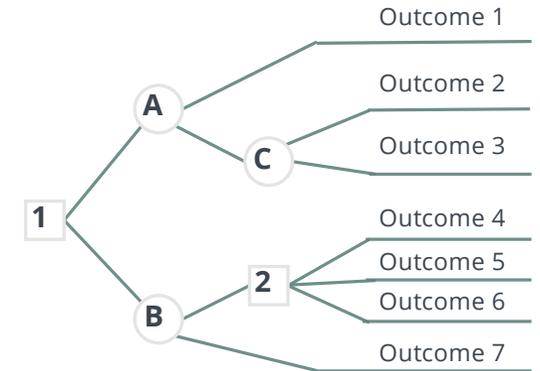
❌ Either does not solve tasks with complex dependencies

❌ Or have a large footprint

arm AI

Solutions by Leveraging Neuton TinyML
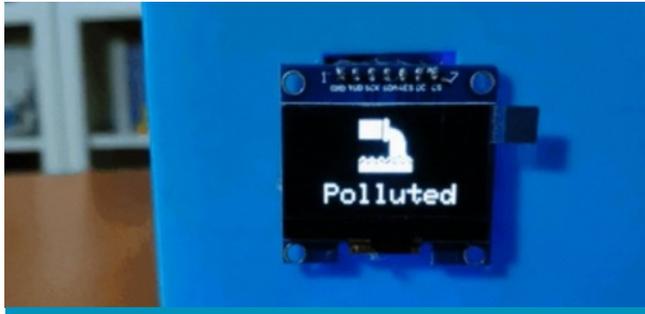
PREDICTIVE MAINTENANCE

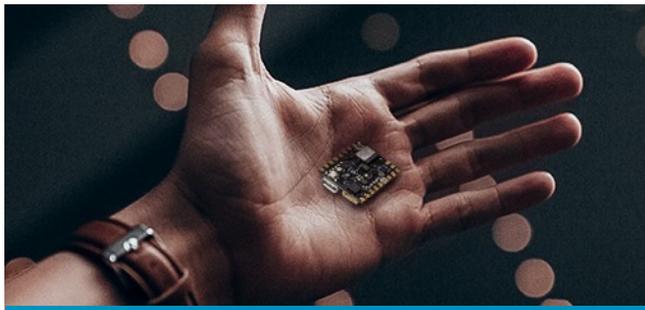Prevent equipment failures directly on the device

HUMAN INTERFACES

Build smart control systems based on gestures, voice, or motion

ASSET TRACKING & MONITORING

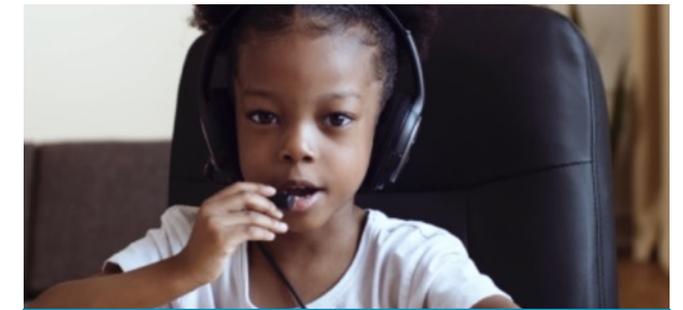Determine the status and location of all your devices

WAKE WORDS

Run low-power tiny models to constantly capture and trigger events to wake up the main controller

CLASSIFY SOUND EVENTS

Recognize different events: baby crying, glass breaking, alarm, etc

VOICE ACTIVITY DETECTION

Detect presence or absence of human speech

arm AI

Silicon Agnostic

Deployable on any Arm device

AMD

ARDUINO

ST life.augmented

MICROCHIP

infineon

onsemi

Qualcomm

RENESAS

NXP
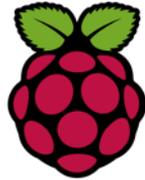
and many others...
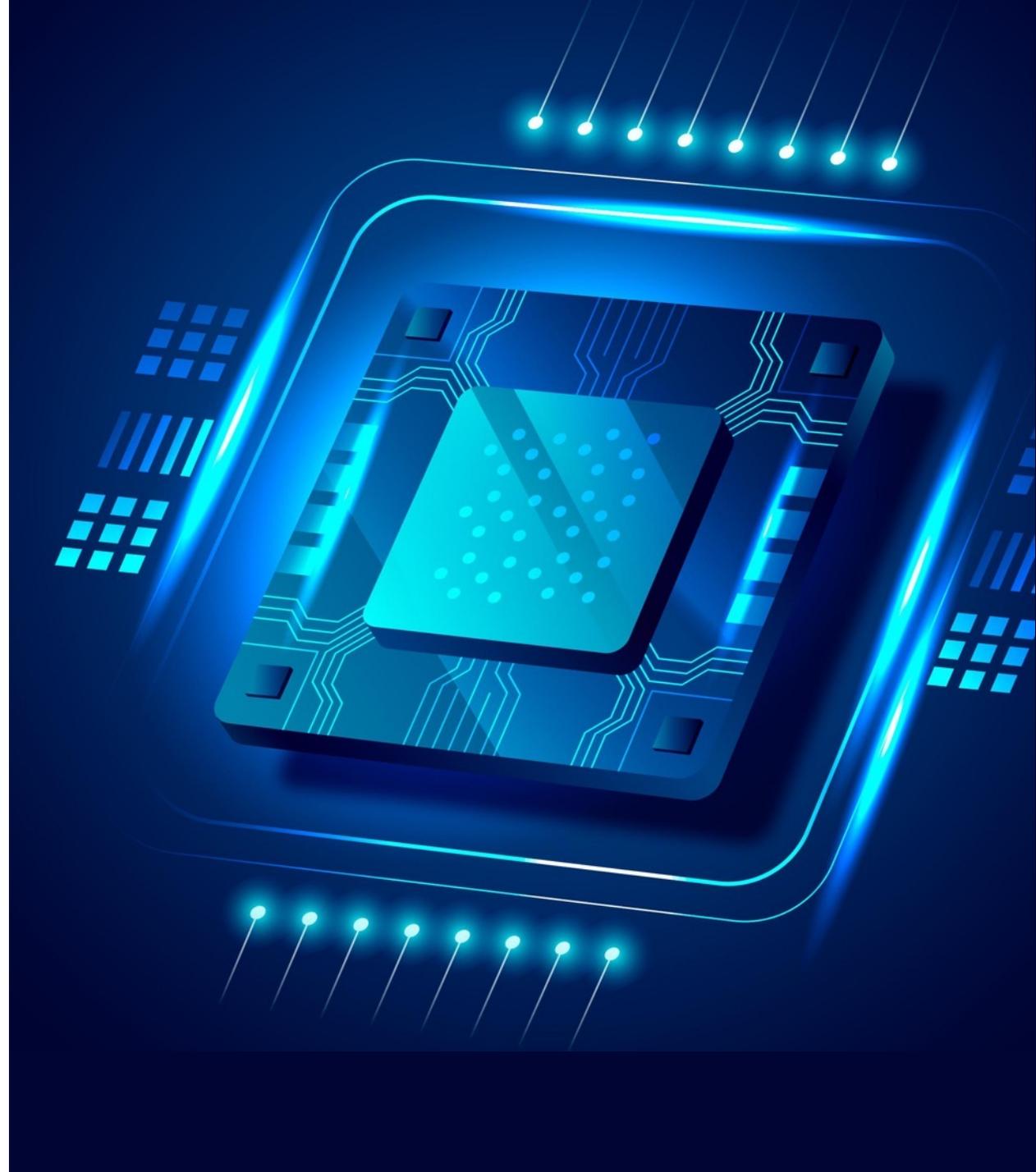
Neuton as an AutoML Solution

Automatically build extremely tiny models and embed them into any Arm-based microcontroller

Upload your data

Neuton will automatically build a model of optimal size and accuracy

Download your model and embed it into an Arm microcontroller

Make inferences right on the device
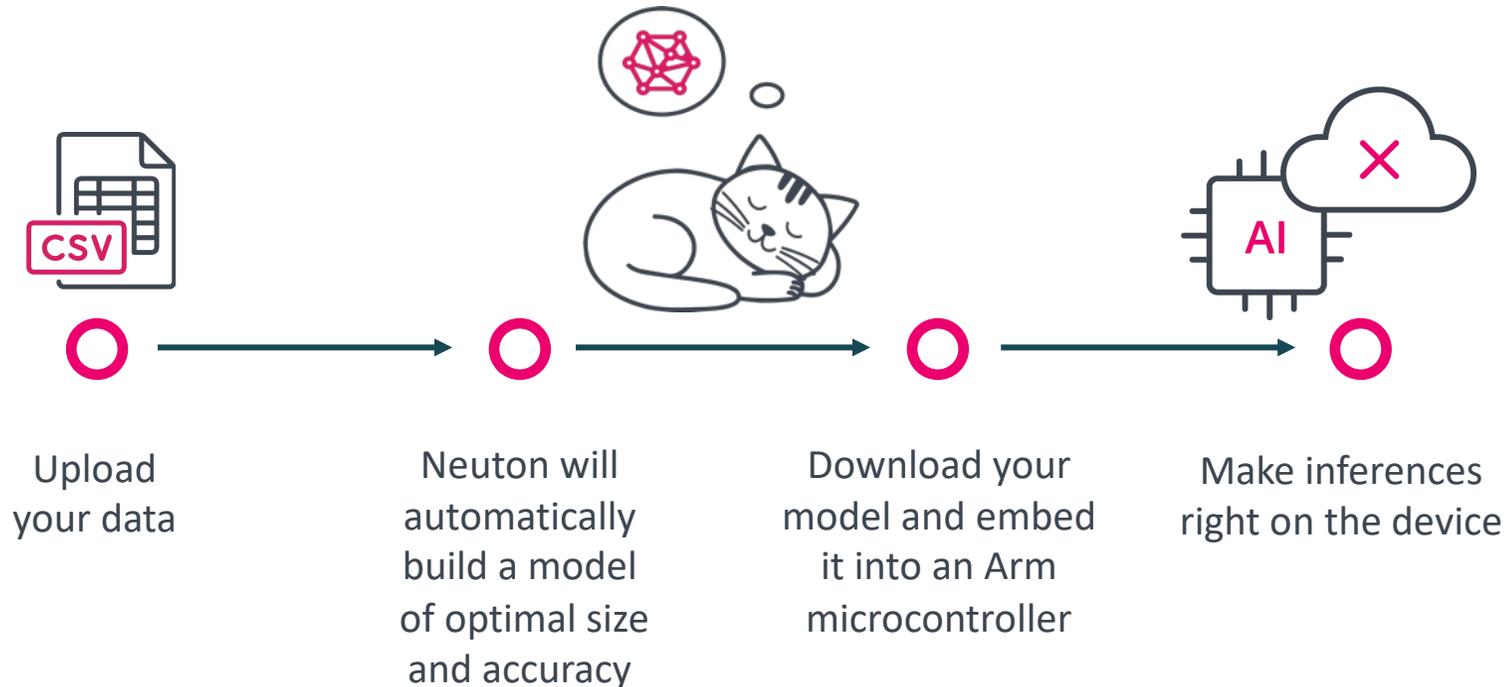
☑ No-Code SaaS Solution

☑ No Data Science experience required

☑ Fully automated pipeline

Free for developers

arm AI

Case Study
Innovative AI solution for farmers with Arm and Neuton

by Sumit Kumar

arm AI

Neuton in Action

AI Solution for farmers with an Arduino PRO board Nicla Sence ME

powered by an Arm Cortex-M4 processor

© 2022 Arm

Why are smart technologies needed in agriculture?
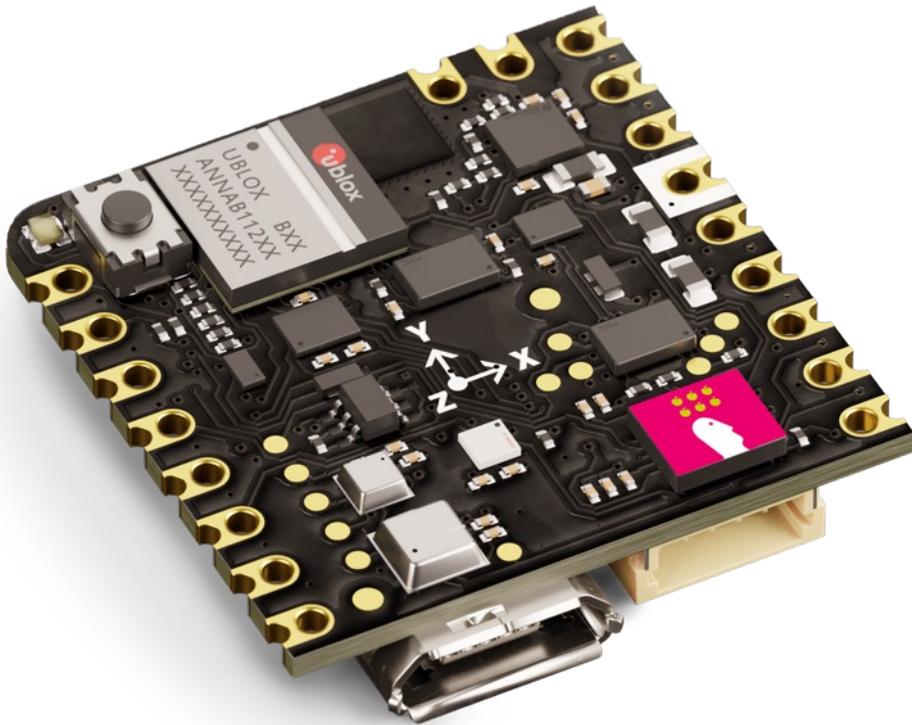
/////////// **Need to produce**

enough for the growing world while protecting natural resources

Source: FAO, 2017. The future of Food and Agriculture by 2050

▲ **Demand** ▼ **Supply**

50 % More food, feed, & biofuel needed

17 % Harvest losses

~10 Bn World population

~12 Mil Hect. of agricultural land loss annually

70 % More meat needed for developing nations

20 % Reduction in arable land per capita

arm AI

Major Problem for Agrochemical Product Companies

Production of fake pesticides on the rise in the EU

Ten arrests and 11500 tons of illegal pesticides seized as part of Operation Silver Axe VII

26 JUL 2022

2.3 Billion more people until 2050

>250.5 billion USD agrochemical market

>30 billion USD illegal crop protection market

arm AI

Problem # 1 Statement

Agricultural product transportation is yet another challenge.

Studies by the Logistics Bureau have shown that a staggering 33% of food is lost or wasted and that fresh products spend about half of their shelf life in the shipping process.

We will address the prediction of unacceptable conditions which may occur during the transportation route.

Solution

All cereal-type commodities have strict requirements in terms of container conditions for safe delivery.

For our example, we will predict the spoilage of Arabica.

- Packaging - (jute or sisal bags) free air circulation.
- Temperature: 0-20 C
- Relative Humidity: 50 - 65% (priority is preventing condensation)
- tVOC: 0-220 good, 221-660 moderate, < 661 high (unit ppb). A lower value means less contaminated air.
- eCO_2: safe 0-1200 ppm. A lower value means better air circulation. **Insufficient ventilation may result in fermentation and rotting of coffee beans in bags as a result of increased CO2 and inadequate supply of atmospheric oxygen.**

Utilization of an MCU with Temperature/Humidity/ TVOC/eCO2 sensors as inputs to a Machine Learning model, which will predict the emergence of unacceptable conditions during coffee transportation.

arm AI

Problem # 2 Statement

During transportation, fertilizers
are exposed to certain risks connected with
unauthorized container openings:

Accidental opening contaminates the
product

Deliberate opening for illegal reasons
(counterfeit)

Solution

Utilization of a smart movement sensor to control the integrity of the fertilizer container, which will detect if the container lid had been opened during transportation.

A Machine Learning model will interpret the accelerometer values of the sensor and detect if the lid of the container had been opened.

This can provide two potential benefits:

1. Analysis of detections registry after the fertilizers delivery, which will help detect the potential counterfeit.

2. Dynamic notification of the container opening detection during transportation, which will empower to take action on the spot.
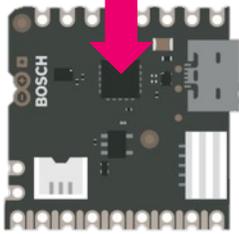
arm AI

Smart Label Layout

AD Product name

Composition

Company address

Restriction

Usage

Hazards
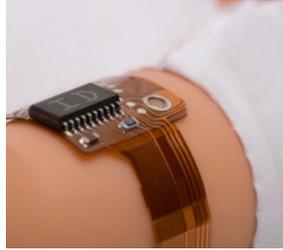
Price

Product info

arm AI
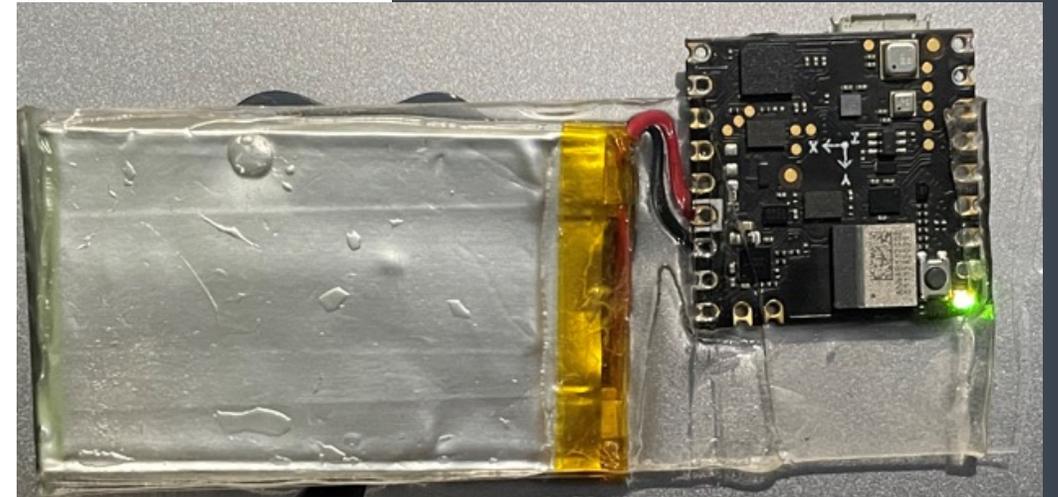
POC

Tiny ML condition monitoring models built automatically on the Neuton Platform and embedded to MCU

Arduino Nicla Sense ME

- 64 MHz Arm® Cortex-M4
- BHI260AP motion sensor system with integrated AI
- BMM150 magnetometer
- BMP390 pressure sensor
- BME688 4-in-1 gas sensor with AI

Low-powered MCUs:

- environmental data (temperature, humidity, pressure, tVOC)
- package opened or not status (seal broken or not)
- tinyML condition monitoring

Fleet Management firmware and LTE-M cellular/LoRA network deployment.

- Low data consumption
- Fleet monitoring
- Remote update and debugging
- Highly secure

Blockchain

- Secure contracts
- Traceable
- Farmer and company can track the status of any product using query API
- Immutable

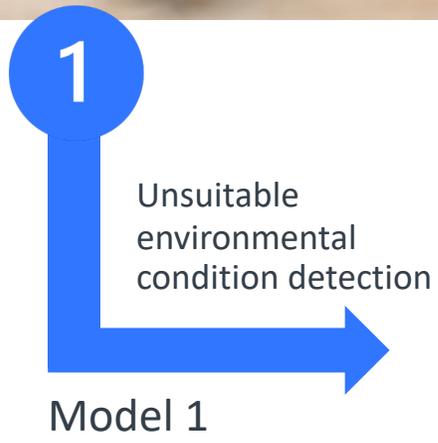**Public QR Code** that can be used to view all public product data from the company.

Also, reveal the delivery status of any new Bayer product.

arm AI

Why Arm

Agriproduct companies produce tons of products, implementing such solution are often associated with high costs and complexities. **Let's see how we feel Arm helps to bridge this gap:**

	Non-Arm	Arm Cortex-M Family
$	More investment in toolchain, compilers, developers, etc. in case of vendor change	Transition possible without rewriting the source code, optimized for low-cost, high-volume applications
	Limited peripherals, hard to implement deep sleep modes	Range of peripherals, fewer lines of code for deep sleep and changing CPU-speeds
	Less performance compared to silicon area requirements	Extremely small packages with greater performance
	Manual optimizations, bigger code size with time	Code compression benefits, including DSP like performance,
	Very few developers, lesser technical support	Better high-level language, technical and software-library support

arm AI

ML Models for Arm Cortex-M4 Processors and Bosch Sensors

BHI260AP   BME688   BMP390   BMM150

2 Model 2

Agrochemical Bottle/Package opening detection

1 Unsuitable environmental condition detection

Model 1

arm AI

Features Used for Our Models

Temp	Humidity	tVOC	eCO2	Container	target
13	57	297	134	1	0
17	58	107	1011	1	0
17	31	3737	10174	1	1
18	53	116	547	1	0
12	53	380	711	0	0
3	56	330	961	1	0
0	60	118	202	0	0
13	53	432	497	0	
0	53	392	523	1	
15	35	4674	2212	1	
3	56	245	195	0	0
36	18	3159	894	0	1
9	53	2265	14159	1	1
4	58	2332	1139	1	1
15	62	270	408	1	0
11	55	514	817	1	0
0	52	655	1069	1	0
-16	55	1580	14655	0	1

MODEL 1	MODEL 2
Unsuitable environmental condition detection (BME688 sensor)	Agrochemical Bottle/Package opening Detection (BHI260AP IMU sensor)
Temperature [°C]	**X-axis**
Humidity [%]	**Y-axis**
TVOC [ppb]	**Z-axis**
eCO2 [ppm]	
Container (concealed/non_concieled)	
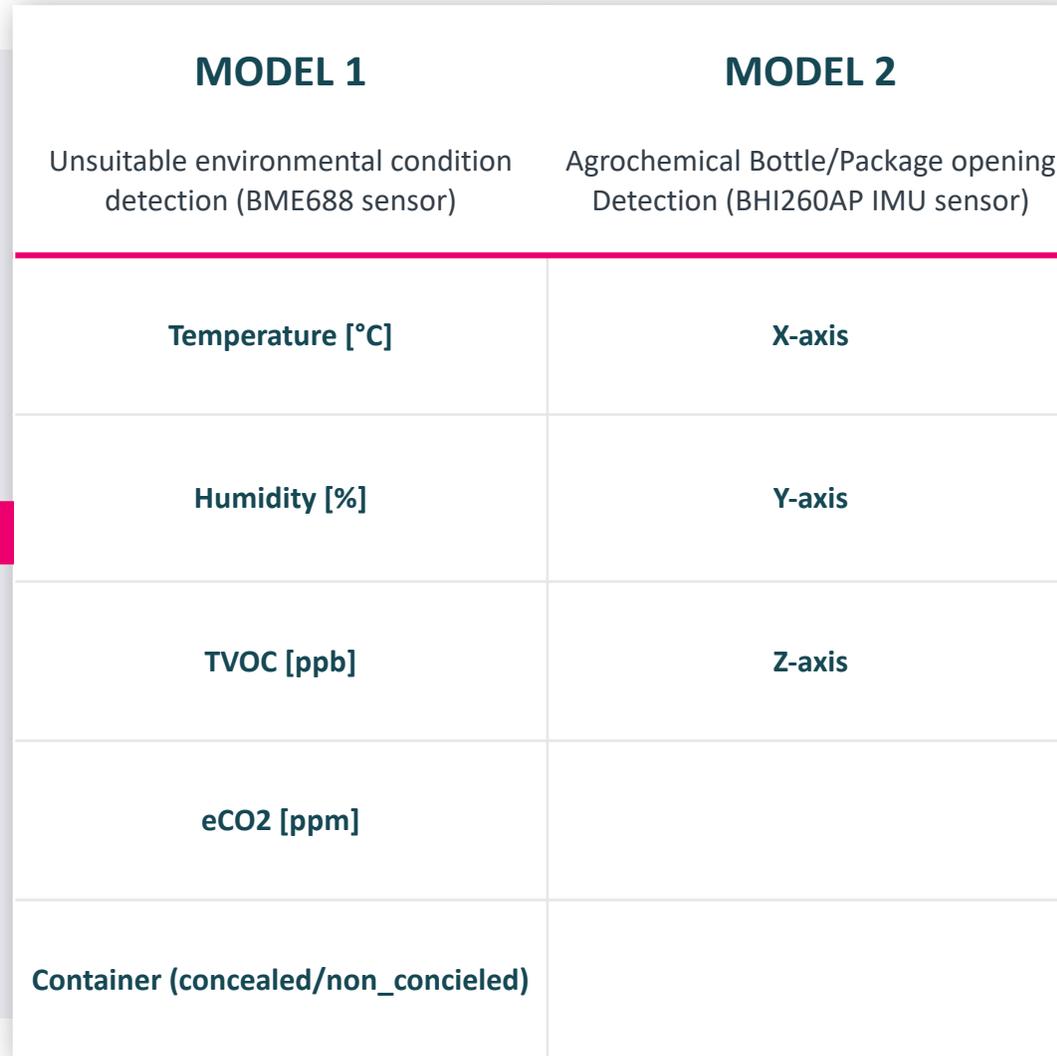
accel_x	accel_y	accel_z	target
21.03	1.73	-6.35	1
21.03	1.73	-6.35	1
21.03	1.41	-2.67	1
19.38	1.41	-2.67	1
19.38	1.41	-2.67	1
19.38	1.41	-2.67	1
19.38	1.41	-2.67	1
19.38	1.41	-2.67	1
19.38	1.41	-2.67	1
20.4	1.02	-5.57	1
20.4	1.02	-5.57	1
20.4	1.02	-5.57	1
20.4	1.02	-5.57	1
20.4	1.02	-5.57	1
20.4	1.02	-5.57	1
20.4	1.02	-5.57	1
20.4	1.02	-4	1
20.87	1.49	-4.08	1
20.87	1.49	-4.08	1
20.87	1.49	-4.08	1
20.87	1.49	-4.08	1
20.87	1.49	-4.08	1
20.87	1.49	-4.08	1

arm AI

Creating TinyML Models on the Neuton Platform

1

Selecting solution type and solution name

Neuton supports the following types of data:

- Audio data (TinyML)
- Sensor data (TinyML)
- Tabular data

© 2022 Arm

Creating TinyML Models on the Neuton Platform

2 Uploading a training dataset and choosing target

Creating TinyML Models on the Neuton Platform

3

Selecting Task Type and Metric

There are different metric options for training the model

Neuton also works for "Regression" and "Multi Classification" tasks

arm AI

Creating TinyML Models on the Neuton Platform

Digital Signal Processing

Windowing

- ○ In Number of Rows/Samples
- ● In Duration

Window size: 3000 ms   Frequency: 100 Hz

- ○ Auto Determination

Estimated SRAM
4.0 kB

Feature Extraction

x_value 🗑
Global peak to peak of high frequency, Global peak to peak of low frequency, Mean, Max, Min, Petrosi ... ✏

y_value 🗑
Global peak to peak of high frequency, Global peak to peak of low frequency, Mean, Max, Min, Petrosi ... ✏

z_value 🗑
Global peak to peak of high frequency, Global peak to peak of low frequency, Mean, Max, Min, Petrosi ... ✏

Feature Selection

Choose Method: Recursive Feature Elimination v   ☑ Remove Lag Features

---

4

Selecting DSP Settings for the IMU data

x_value

Select features

- **+ Amplitude** (2)
- **+ Statistical** (11)
- **– Frequency** (0)
  - ☐ FFT first peak power
  - ☐ FFT first peak frequency
  - ☐ FFT second peak power
  - ☐ FFT second peak frequency
  - ☐ FFT third peak power

Cancel   OK

Neuton allows users to select Feature Extraction methods from a range of techniques

arm AI

Creating TinyML Models on the Neuton Platform

Target metric: Accuracy 0.996919
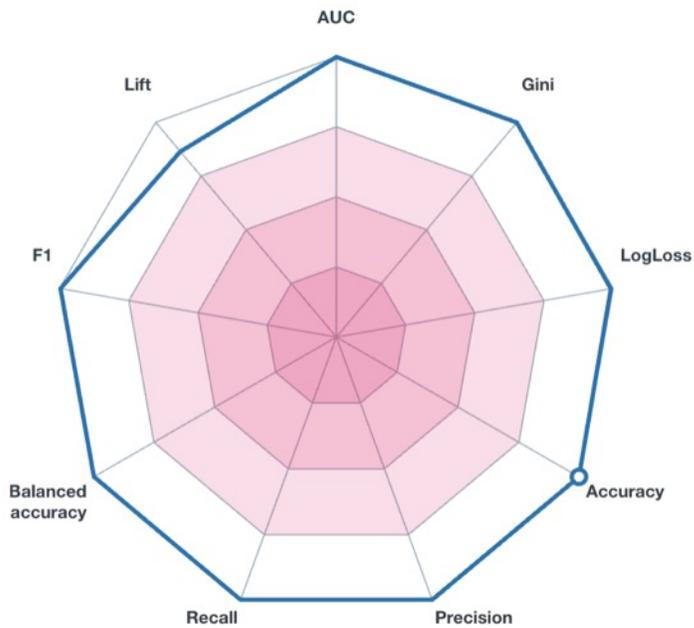
Analytic's Tools

Task type: **Binary Classification**
Target variable: **target**

Training dataset: **env_container_60K.csv**
Processed dataset: **processed_train.csv**

Metrics

Model Quality Index: 99%

Name	Validation metric
↑ AUC	0.999130
↑ Gini	0.998260
↓ LogLoss	0.015931
↑ Accuracy	0.996919
↑ Precision	0.995824 0.998682
↑ Recall	0.999178 0.993314
↑ Balanced accuracy	0.996246
↑ F1	0.997498 0.995991
↑ Lift	1.993838

Good   Critical

5

Trained Model C Library

C Library   Download

Total Footprint ?

Estimated for: ARM Cortex-M4

■ Model
1.5 kB
282 coefficients

■ Calculator
1.7 kB

■ Preprocessing
0 kB

0.2 kB
SRAM
■ 0
■ 0.172
■ 0

3.0 kB
FLASH
■ 1.5
■ 1.5
■ 0
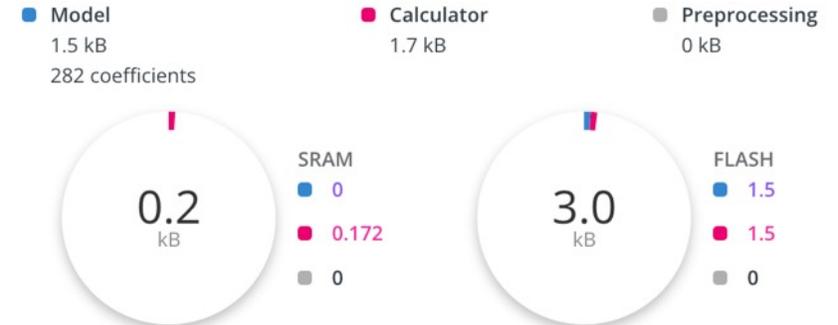
Once the model training is finished, you get a C library which can be embedded in any Arm MCU.
We choose Arm Cortex M4

arm AI

TinyML Model Ready for Embedding

Name	Size	Packed	Type	Modified	CRC32
..			File folder		
converted_models	646,872	205,362	File folder		
neuton	33,622	10,147	File folder		
target_values	16	18	File folder		
README.md	5,555	2,339	MD File	9/2/2022 4:01 ...	5DA5901D

arm AI

Neuton Advantage

ML SPACE

Data acquisition

Training/validation dataset

Model

Design Model
- **Automated NN creation**
- **Cross validation**

TensorFlow

Arch

Intelligent Agent
Neuton

Model quantization
TensorFlow Lite

- **Accurate model in 1 iteration**
- **Smaller in size than TF model**
- **No post-training quantization needed**
- **Out-of-the-box 8/16/32-bit model**

Quantized model

Convert to C-byte array

EMBEDDED SPACE

Application development
for **Microcontrollers**

ARM Microcontroller

Quantized model as C array

arm AI

Embedding to Nicla Sense ME

NEUTON TINYML MODEL	MODEL 1 ON MCU Unsuitable environmental condition detection	MODEL 2 ON MCU Agrochemical Bottle/Package opening detection
Ram usage	0.2 kb	1.7 kb
Flash usage	2.9 kb	5.7 kb
Inference time	235 us	231 us
Accuracy	0.99	0.97

arm AI

1 SMART LABEL 2 RISK ANALYSIS 3 VERIFICATION 4 INSPECTIONS 5 VISIBILITY 6 REPORTING

∧ daml   **∧ daml**

Smart Package Label Report Template

Company (Bayer & Bayer)

Raise inspection and alert

Agriculture Commission

Verified Public Publication

- ☑ Package reached destination?
- ☑ Environmental condition?
- ☑ Package Opened or Not?
- ☑ Suspicious delay?

- ☑ In-situ inspection
- ☑ Farmer help
- ☑ Bayer and Bayer Distributors

Private Company/ Public

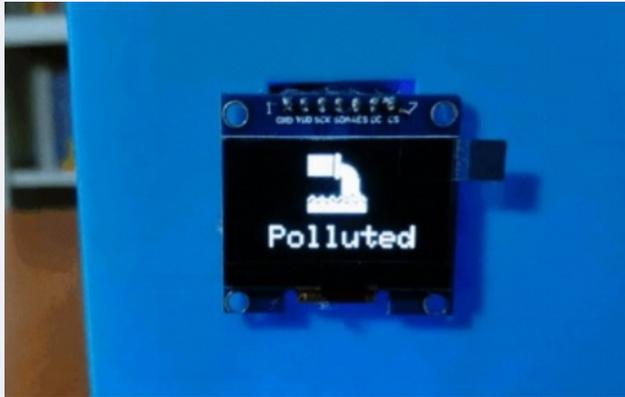**Verified Publication (Public View)**

arm AI

Video Demo with the Solution

arm AI

Other Neuton TinyML Use Cases from community

WATER POLLUTION MONITORING

Solve the problem of water pollution using preventive measures instead of simple monitoring.

PREDICTIVE MAINTENANCE OF WATER PUMPS

Learn how to use RSL10 sensors and Neuton to run models for timely pump maintenance.

TINYML WEATHER STATION

Build a tiny weather station with an 8-bit model for predicting the probability of snow.

REAL-TIME SMOKE DETECTION

Implement sensor fusion and TinyML to detect smoke and get notified if a fire starts.

AIR QUALITY MONITORING

Create a TinyML model to detect the concentration of various chemical gases in the air.

arm AI

Giveaway

Intelligent Agent
Neuton

12 lucky winners will be chosen randomly from attendees

10 e-books:

- IoT Edge Computing with MicroK8s
- Interactive Visualization with Julia

2 Arduino Pro Boards
Portenta H7 Lite Connect

The winners will be announced
22 Sep in our Social Media

arm AI

Thank you!

Tweet us: @ArmSoftwareDev -> #AIVTT

Check out our Arm Software Developers YouTube channel

Signup now for our next AI Virtual Tech Talk: www.arm.com/techtalks

arm AI

AI Virtual Tech Talks Series

Thank You

Danke

Merci

谢谢

ありがとう

Gracias

Kiitos

감사합니다

धन्यवाद

شكرًا

תודה