

tinyML® Talks

Enabling Ultra-low Power Machine Learning at the Edge

“Enabling Low Power ML at the Edge-tinyML Shenzhen Kick-off Networking Meetup”

微型机器学习分享会小组深圳首聚

Chaihuo x.factory, B622, Design Commune, Vanke Cloud City,
Dashi 2nd Road, Nanshan District, Shenzhen

January 21, 2022



www.tinyML.org





tinyML Talks Strategic Partners

AONdevices

arm

Deeplite

EDGE IMPULSE

emza
visual sense

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GREEN WAVES
TECHNOLOGIES

Grovety Inc.

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GLOBAL IOT SOLUTIONS

LatentAI
Adaptive AI for a Smarter Edge

maxim
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NOW PART OF
ANALOG
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Additional Sponsorships available – contact Olga@tinyML.org for info

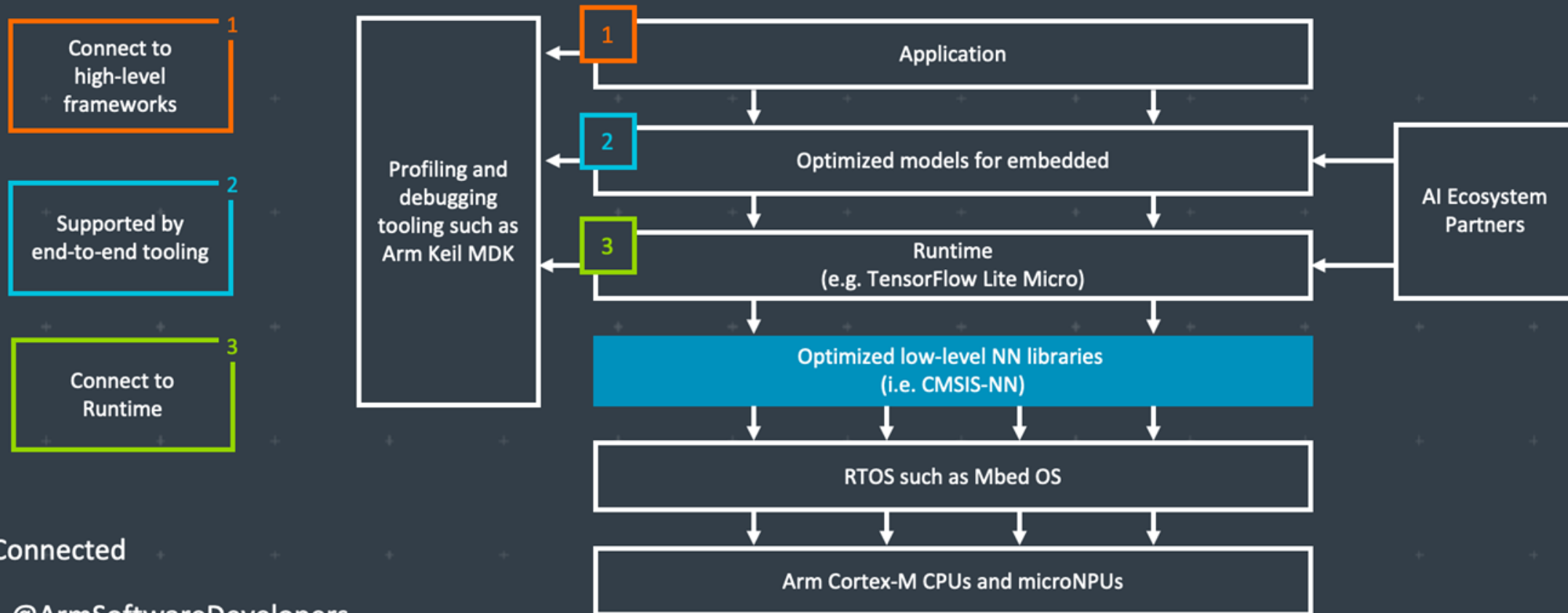
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Executive Strategic Partners

Arm: The Software and Hardware Foundation for tinyML



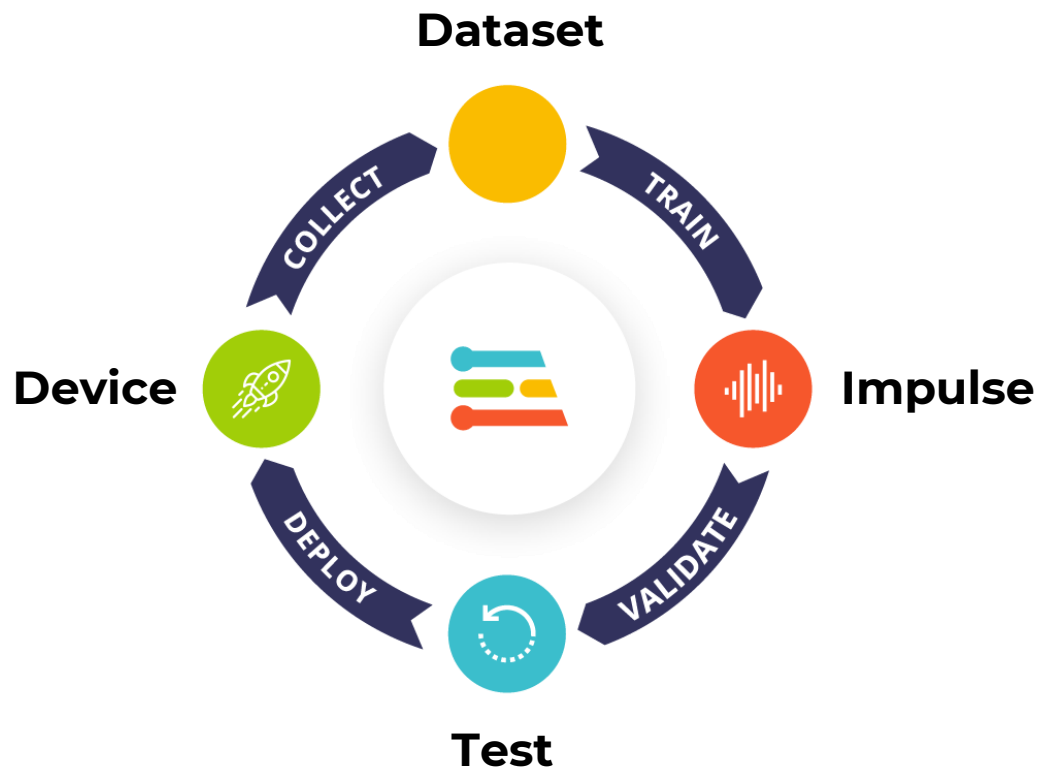
Stay Connected

 @ArmSoftwareDevelopers

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Resources: developer.arm.com/solutions/machine-learning-on-arm

EDGE IMPULSE The leading edge ML platform



www.edgeimpulse.com

The screenshot shows the Edge Impulse web interface for a "SPECTRAL FEATURES (CONTINUOUS GESTURES DEMO)" project. The interface includes a sidebar with navigation options like Dashboard, Devices, Data acquisition, Impulse design, EON Tuner, Retrain model, Live classification, Model testing, Versioning, and Deployment. The main content area displays training parameters for a training set:

Training set	
Data in training set	18m 29s
Classes	6 (drink, fistbump, idle, snake, updown, wave)
Window length	2000 ms.
Window increase	120 ms.
Training windows	6,873

Below the parameters is a green "Generate features" button. To the right, the "Feature explorer (6,819 samples)" section shows a 3D scatter plot with axes labeled accX RMS, accY RMS, and accZ RMS. A legend identifies the classes: drink (blue), fistbump (orange), idle (green), snake (red), updown (purple), and wave (brown). At the bottom right, the "On-device performance" section shows a processing time of 11 ms and a peak RAM usage of 5 KB.

Qualcomm
AI research

Advancing AI research to make efficient AI ubiquitous

Power efficiency

Model design, compression, quantization, algorithms, efficient hardware, software tool

Personalization

Continuous learning, contextual, always-on, privacy-preserved, distributed learning

Efficient learning

Robust learning through minimal data, unsupervised learning, on-device learning

A platform to scale AI across the industry



Perception

Object detection, speech recognition, contextual fusion



Reasoning

Scene understanding, language understanding, behavior prediction



Action

Reinforcement learning for decision making



Edge cloud



Cloud



IoT/IIoT



Automotive



Mobile

SYNTIANT

End-to-End
Deep Learning
Solutions
for
TinyML & Edge AI



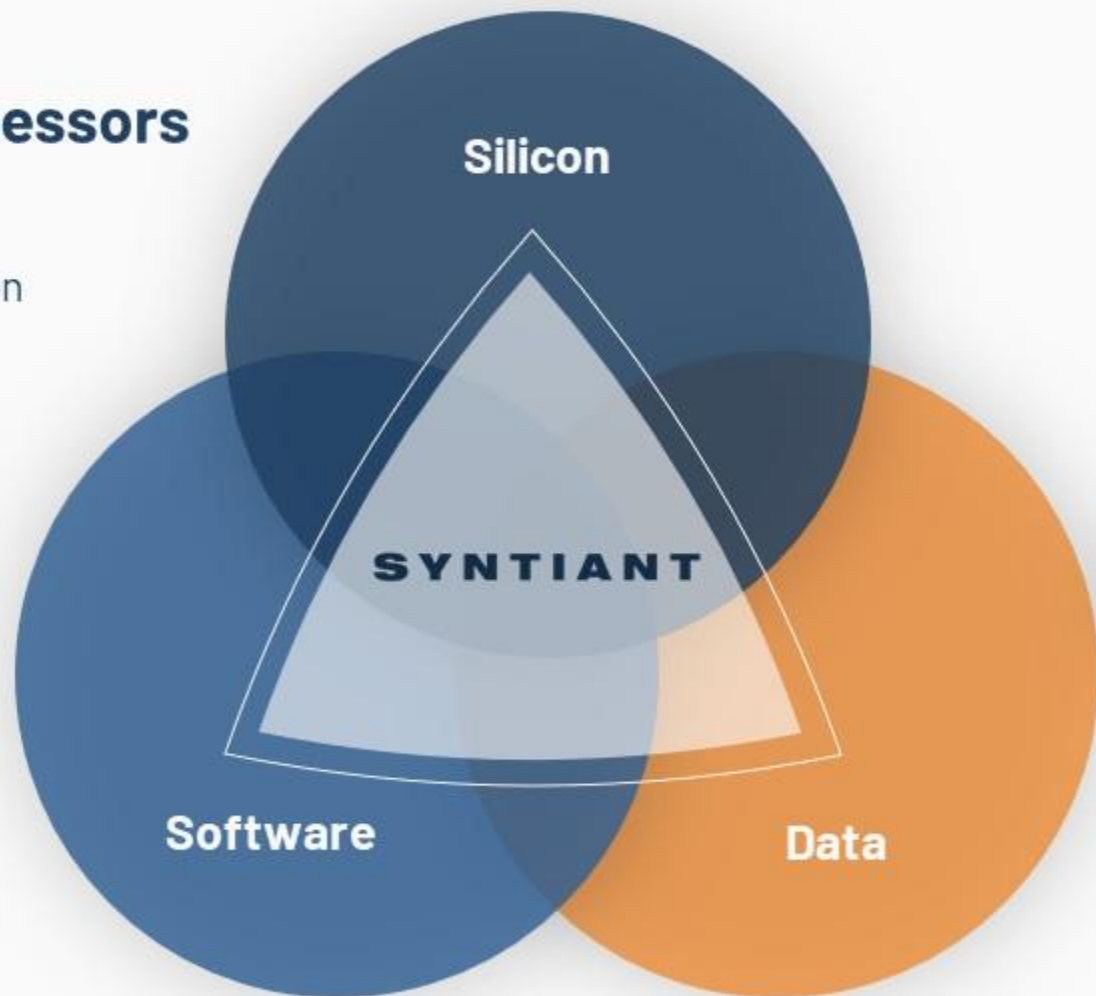
Neural Decision Processors

- At-Memory Compute
- Sustained High MAC Utilization
- Native Neural Network Processing



ML Training Pipeline

- Enables Production Quality Deep Learning Deployments



Data Platform

- Reduces Data Collection Time and Cost
- Increases Model Performance



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Platinum Strategic Partners



WE USE AI TO MAKE OTHER AI FASTER, SMALLER AND MORE POWER EFFICIENT



Automatically compress SOTA models like MobileNet to <200KB with **little to no drop in accuracy** for inference on resource-limited MCUs



Reduce model optimization trial & error from weeks to days using Deeplite's **design space exploration**



Deploy more models to your device without sacrificing performance or battery life with our **easy-to-use software**

BECOME BETA USER bit.ly/testdeeplite

mobilityXlab

arm



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GLOBAL IOT SOLUTIONS



Reality AI[®]

Add Advanced Sensing to your Product with Edge AI / TinyML

<https://reality.ai>



info@reality.ai



[@SensorAI](https://twitter.com/SensorAI)



[Reality AI](https://www.linkedin.com/company/reality-ai)

**Pre-built Edge AI sensing modules,
plus tools to build your own**

Reality AI solutions

Prebuilt sound recognition models for
indoor and outdoor use cases

Solution for industrial anomaly detection

Pre-built automotive solution that lets cars
“see with sound”

Reality AI Tools[®] software

Build prototypes, then turn them into
real products

Explain ML models and relate the function
to the physics

Optimize the hardware, including
sensor selection and placement

BROAD AND SCALABLE EDGE COMPUTING PORTFOLIO

Microcontrollers & Microprocessors

Arm® Core



Arm® Cortex®-M 32-bit MCUs
Arm ecosystem, Advanced security, Intelligent IoT



Arm®-based High-end 32 & 64-bit MPUs
High-resolution HMI, Industrial network & real-time control



Arm® Cortex®-M0+ Ultra-low Power 32-bit MCUs
Innovative process tech (SOTB), Energy harvesting

Renesas Synergy™ Arm®-based 32-bit MCUs for Qualified Platform
Qualified software and tools

Renesas Core



Ultra-low Energy 8 & 16-bit MCUs
Bluetooth® Low Energy, SubGHz, LoRa®-based Solutions



High Power Efficiently 32-bit MCUs
Motor control, Capacitive touch, Functional safety, GUI



40nm/28nm process Automotive 32-bit MCUs
Rich functional safety and embedded security features

Core technologies

AI

A broad set of high-power and energy-efficient embedded processors

Security & Safety

Comprehensive technology and support that meet the industry's stringent standards



Digital & Analog & Power Solution

Winning Combinations that combine our complementary product portfolios

Cloud Native

Cross-platforms working with partners in different verticals and organizations

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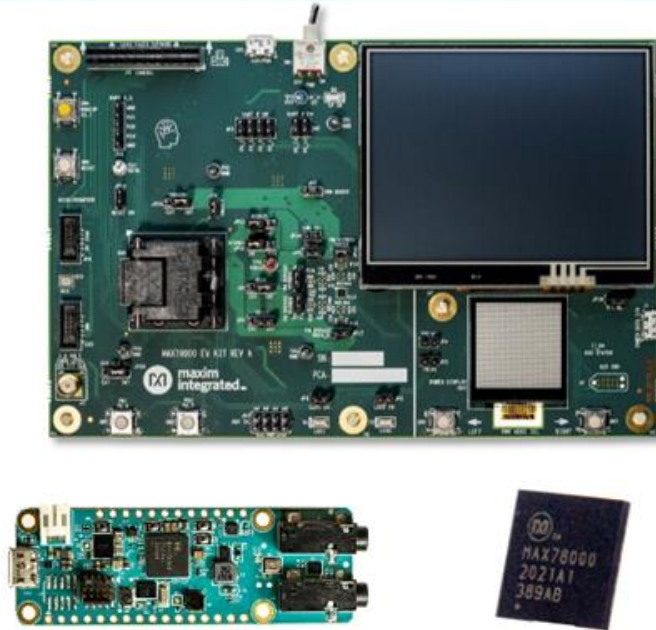


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Maxim Integrated: Enabling Edge Intelligence

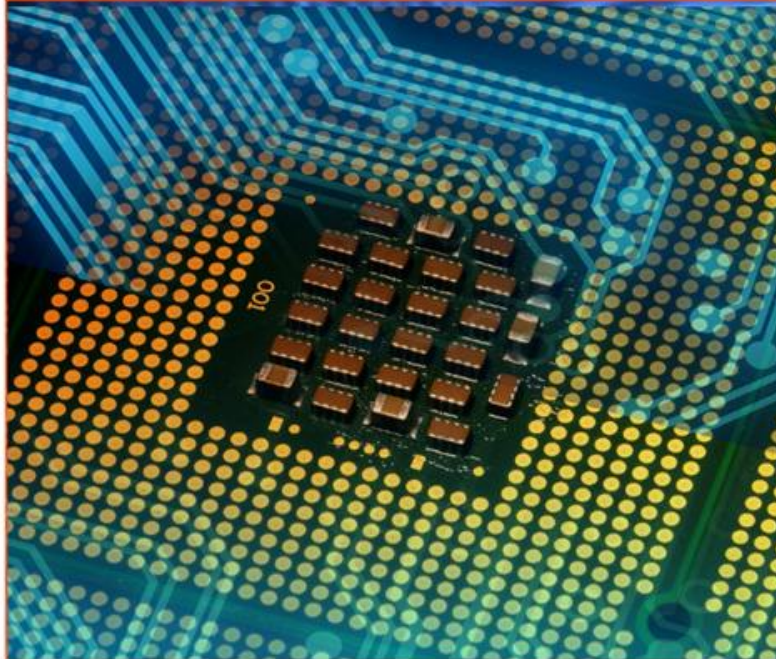
Advanced AI Acceleration IC



The new MAX78000 implements AI inferences at low energy levels, enabling complex audio and video inferencing to run on small batteries. Now the edge can see and hear like never before.

www.maximintegrated.com/MAX78000

Low Power Cortex M4 Micros



Large (3MB flash + 1MB SRAM) and small (256KB flash + 96KB SRAM, 1.6mm x 1.6mm) Cortex M4 microcontrollers enable algorithms and neural networks to run at wearable power levels.

www.maximintegrated.com/microcontrollers

Sensors and Signal Conditioning



Health sensors measure PPG and ECG signals critical to understanding vital signs. Signal chain products enable measuring even the most sensitive signals.

www.maximintegrated.com/sensors



Latent AI

Adaptive AI for the Intelligent Edge

[Latentai.com](https://latent.ai)

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Micr .ai

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NXP



seeed studio

The IoT Hardware Enabler



Build Smart IoT Sensor Devices From Data

SensiML pioneered TinyML software tools that auto generate AI code for the intelligent edge.

- End-to-end AI workflow
- Multi-user auto-labeling of time-series data
- Code transparency and customization at each step in the pipeline

We enable the creation of production-grade smart sensor devices.



sensiml.com

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life.augmented



SynSense

SynSense builds **sensing and inference** hardware for **ultra-low-power** (sub-mW) **embedded, mobile and edge** devices. We design systems for **real-time always-on smart sensing**, for audio, vision, IMUs, bio-signals and more.

<https://SynSense.ai>



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Silver Strategic Partners

AONdevices



Grovety Inc.





tinyML Summit 2022

Miniature dreams can come true...

March 28-30, 2022

Hyatt Regency San Francisco Airport

<https://www.tinyml.org/event/summit-2022/>

*The Best Product of the Year and the Best Innovation of the Year awards are open for nominations between **November 15** and **February 28**.*

tinyML Research Symposium 2022

March 28, 2022

<https://www.tinyml.org/event/research-symposium-2022>

More sponsorships are available: sponsorships@tinyML.org



tinyML Trailblazers Series

Success Stories with Joel Rubino
(CEO & Co-founder of Cartesium)

LIVE ONLINE February 2nd, 2022 at 8 am PST



Register now!



Join Growing tinyML Communities:



7.8k members in
42 Groups in 33 Countries

tinyML - Enabling ultra-low Power ML at the Edge

<https://www.meetup.com/tinyML-Enabling-ultra-low-Power-ML-at-the-Edge/>



2.5k members
&
4.4k followers

The tinyML Community

<https://www.linkedin.com/groups/13694488/>





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www.youtube.com/tinyML



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4.33K subscribers

5.9k subscribers, 337 videos with 170k views

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tinyML Summit 2021 tiny Talks: Person Detection... 18:26

tinyML Summit 2021 tiny Talks: Using Neural... 19:03

tinyML Summit 2021 Keynote: Adaptive Neural... 55:15

tinyML Summit 2021 Keynote: millJoules for... 99:43

tinyML Summit 2021 Market Opportunities for Edge AI 51:28



活动流程 Event Schedule

- 19:00-19:30 签到 Check-in
- 19:30-19:40 开场 Soft Opening by Eric Pan
- 19:40-20:10 破冰环节 Ice Breaking with Self Introductions
- 20:10-20:30 冯磊 : TinyML主题分享 《让 TinyML变得更加简单》
“How to Make TinyML Easier” Talk by Lei Feng
- 20:30-21:00 开放讨论 Open Discussions & Mingle
- 21:00 -21:05 大合照 Group Photo

T I N Y



破冰环节 Ice breaking with self introductions

- 姓名 Name
- 公司 Company
- 个人背景简介 Personal Background
- 其他你想分享的内容 Others Things that you would love to share



TinyML主题分享 《让 TinyML变得更加简单》 “How to Make TinyML Easier” Talk



冯磊 Lei Feng

Seeed Studio机器学习应用与技术支持负责人

A complex wireframe sphere composed of many thin lines, creating a mesh-like structure that recedes into the distance, set against a white background.

让 TinyML 更加简单

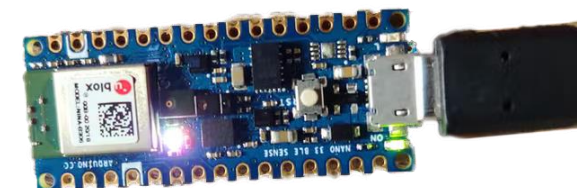
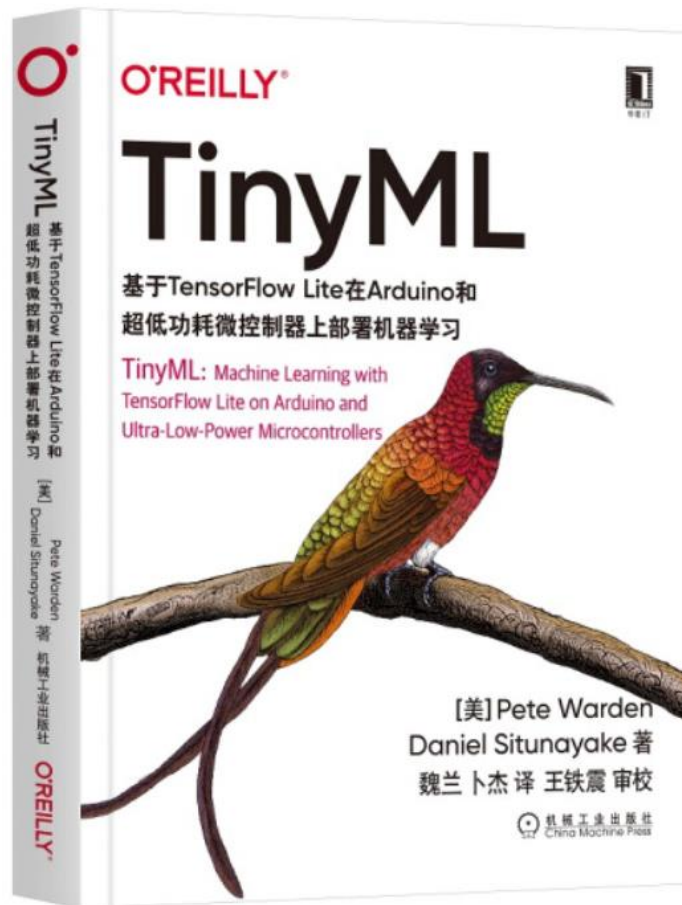
降低『嵌入式机器学习』门槛的努力



大纲

- TinyML应用的门槛
- 小目标：无编程和机器学习经验也能快速上手 TinyML
- 一些有趣的收获
- 共同探索未知领域

TinyML应用的门槛



```
train_hello_world_model.ipynb  
文件 修改 视图 输入 代码执行程序 工具 帮助  
目录 + 代码 文本 复制到云编辑器  
Train a Simple TensorFlow Lite for Microcontrollers model  
Configure Defaults  
Setup Environment  
Dataset  
Generate Data  
Add Noise  
Split the Data  
Training  
Design the Model  
Train the Model  
Plot Metrics  
Training a Larger Model  
Design the Model  
Train the Model  
Plot Metrics  
Generate a TensorFlow Lite Model  
Generate Models with or without Quantization  
Compare Model Performance  
Generate a TensorFlow Lite for Microcontrollers Model  
Deploy to a Microcontroller  
部分  
The data is split as follows:  
1. Training: 60%  
2. Validation: 20%  
3. Testing: 20%  
The following code will split our data and then plots each set as a different color:  
# We'll use 60% of our data for training and 20% for testing. The remaining 20%  
# will be used for validation. Calculate the indices of each section.  
TRAIN_SPLIT = int(0.6 * SAMPLES)  
TEST_SPLIT = int(0.2 * SAMPLES + TRAIN_SPLIT)  
# Use np.split to chop our data into three parts.  
# The second argument to np.split is an array of indices where the data will be  
# split. We provide two indices, so the data will be divided into three chunks.  
x_train, x_test, x_validate = np.split(x_values, [TRAIN_SPLIT, TEST_SPLIT])  
y_train, y_test, y_validate = np.split(y_values, [TRAIN_SPLIT, TEST_SPLIT])  
# Double check that our splits add up correctly  
assert (x_train.size + x_validate.size + x_test.size) == SAMPLES  
# Plot the data in each partition in different colors:  
plt.plot(x_train, y_train, 'b', label='Train')  
plt.plot(x_test, y_test, 'r', label='Test')  
plt.plot(x_validate, y_validate, 'g', label='Validate')  
plt.legend()  
plt.show()
```

```
hello_world-2 | Arduino 1.8.15  
文件 编辑 项目 工具 帮助  
hello_world-2 arduino_constants.cpp arduino_main.cpp arduino_output_handler.cpp constants.h main_functions.h model.cpp model.h output_handler.h  
1 /* Copyright 2020 The TensorFlow Authors. All Rights Reserved.  
2  
3 Licensed under the Apache License, Version 2.0 (the "License");  
4 you may not use this file except in compliance with the License.  
5 You may obtain a copy of the License at  
6  
7 http://www.apache.org/licenses/LICENSE-2.0  
8  
9 Unless required by applicable law or agreed to in writing, software  
10 distributed under the License is distributed on an "AS IS" BASIS,  
11 WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied.  
12 See the License for the specific language governing permissions and  
13 limitations under the License.  
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16 #include <TensorFlowLite.h>  
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18 #include "main_functions.h"  
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20 #include "tensorflow/lite/micro/all_ops_resolver.h"  
21 #include "constants.h"  
22 #include "model.h"  
23 #include "output_handler.h"  
24 #include "tensorflow/lite/micro/micro_error_reporter.h"  
25 #include "tensorflow/lite/micro/micro_interpreter.h"  
26 #include "tensorflow/lite/schema/schema_generated.h"  
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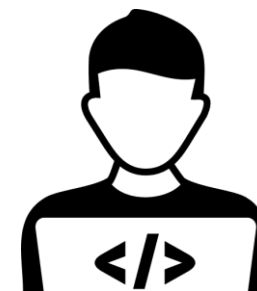
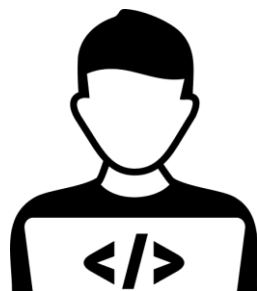

嵌入式机器学习工程化流程



硬件设备编程能力

机器学习编程能力

硬件设备编程能力



有木有没那么难的
TinyML应用解决方案



DEVELOPMENT BOARDS

Overview

ST B-L475E-IOT01A

Arduino Nano 33 BLE Sense

Arduino Portenta H7 + Vision shield

OpenMV Cam H7 Plus

Himax WE-I Plus

Nordic Semi nRF52840 DK

Nordic Semi nRF5340 DK

Nordic Semi nRF9160 DK

Nordic Semi Thingy:91

SiLabs Thunderboard Sense 2

Sony's Spsense

Syntiant TinyML Board

TI CC1352P Launchpad

Eta Compute ECM3532 AI Sensor

Eta Compute ECM3532 AI Vision

Raspberry Pi 4

NVIDIA Jetson Nano

Intel-based Macs

Linux x86_64

Mobile phone

Porting guide

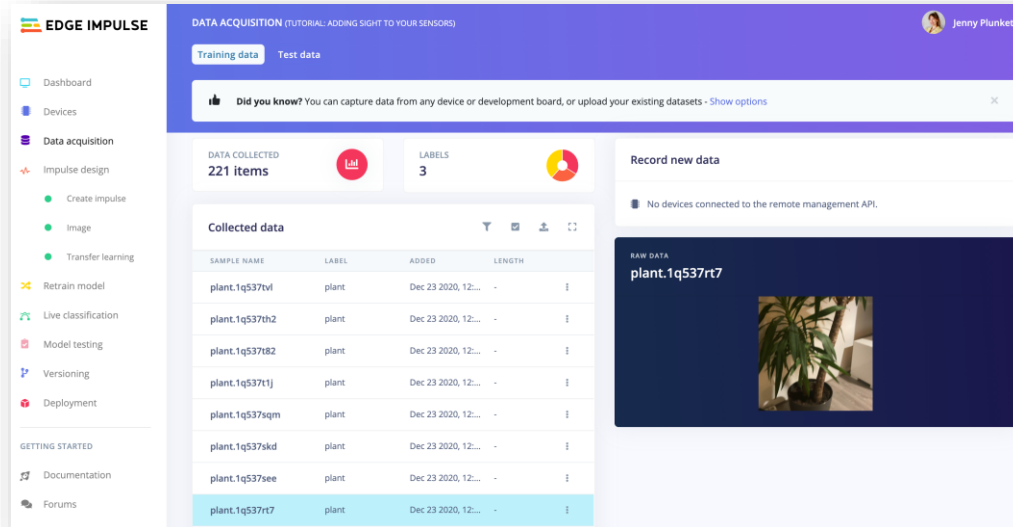
COMMUNITY BOARDS

Seed Wio Terminal

Agora Product Development Kit

Arducam Pico4ML TinyML Dev Kit

Blues Wireless Swan



EDGE IMPULSE DATA ACQUISITION (TUTORIAL: ADDING SIGHT TO YOUR SENSORS)

Training data | Test data

Did you know? You can capture data from any device or development board, or upload your existing datasets - Show options

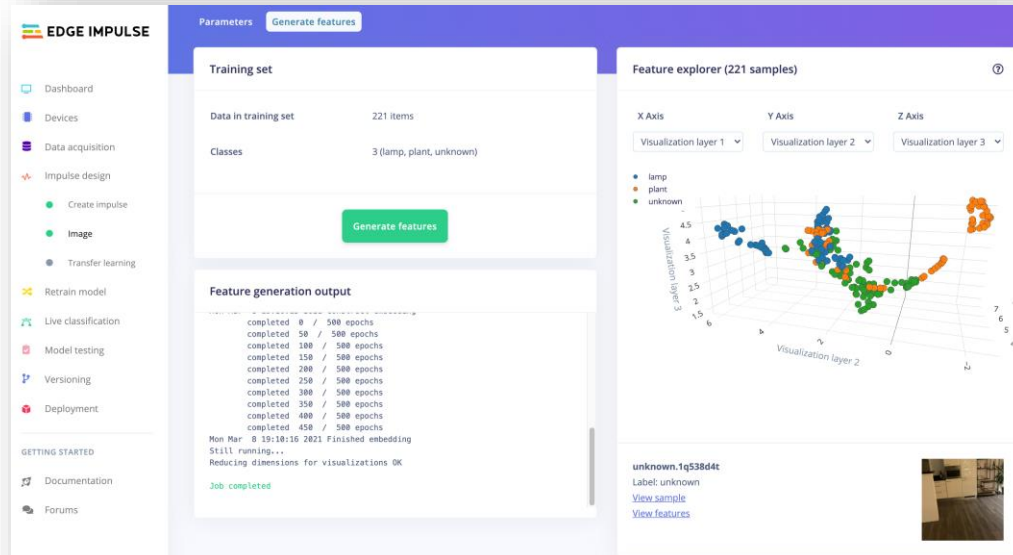
DATA COLLECTED: 221 items | LABELS: 3

Record new data

No devices connected to the remote management API.

RAW DATA: plant.1q537rt7

SAMPLE NAME	LABEL	ADDED	LENGTH
plant.1q537tvl	plant	Dec 23 2020, 12:...	-
plant.1q537th2	plant	Dec 23 2020, 12:...	-
plant.1q537t82	plant	Dec 23 2020, 12:...	-
plant.1q537t1j	plant	Dec 23 2020, 12:...	-
plant.1q537sqm	plant	Dec 23 2020, 12:...	-
plant.1q537skd	plant	Dec 23 2020, 12:...	-
plant.1q537see	plant	Dec 23 2020, 12:...	-
plant.1q537rt7	plant	Dec 23 2020, 12:...	-



EDGE IMPULSE Parameters | Generate features

Training set

Data in training set: 221 items

Classes: 3 (lamp, plant, unknown)

Generate features

Feature generation output

```

completed 0 / 500 epochs
completed 50 / 500 epochs
completed 100 / 500 epochs
completed 150 / 500 epochs
completed 200 / 500 epochs
completed 250 / 500 epochs
completed 300 / 500 epochs
completed 350 / 500 epochs
completed 400 / 500 epochs
completed 450 / 500 epochs
Mon Mar 8 19:18:16 2021 Finished embedding
Still running...
Reducing dimensions for visualizations OK
Job completed
  
```

Feature explorer (221 samples)

X Axis: Visualization layer 1 | Y Axis: Visualization layer 2 | Z Axis: Visualization layer 3

- lamp
- plant
- unknown

unknown.1q538d4t
Label: unknown
[View sample](#)
[View features](#)

Model

Model version: Quantized (int8)

Last training performance

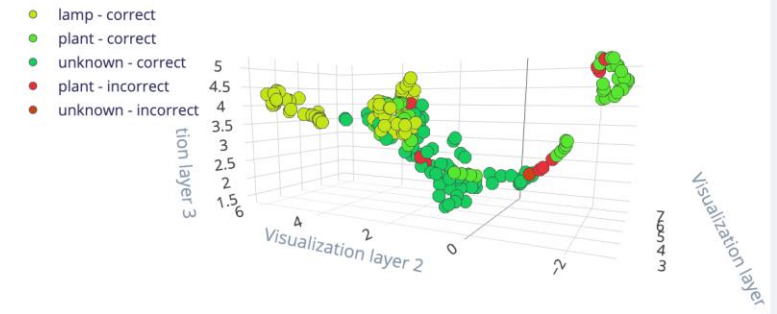
ACCURACY
97.8%

LOSS
0.09

Confusion matrix

	LAMP	PLANT	UNKNOWN
LAMP	100%	0%	0%
PLANT	0%	91.7%	8.3%
UNKNOWN	0%	0%	100%
F1 SCORE	1.00	0.96	0.98

Feature explorer



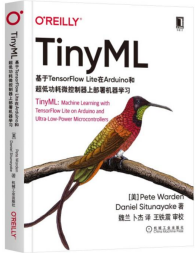
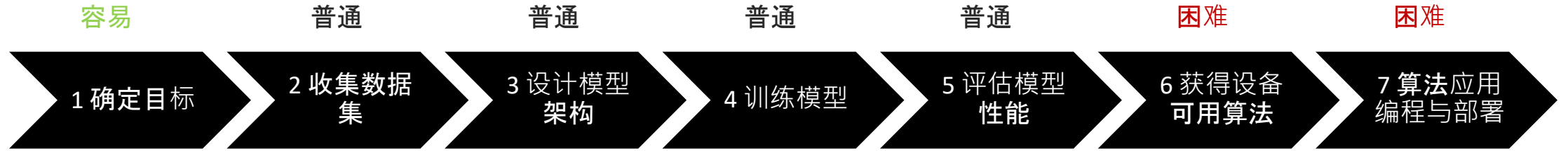
On-device performance

INFERRING TI...
859 ms.

PEAK RAM USAGE
297.0K

ROM USAGE
577.6K

EDGE IMPULSE



California Plants

 Label

 Train

 Use

All Images 80 %

Fern 75 %

Madrone 85 %

Toyon 78 %

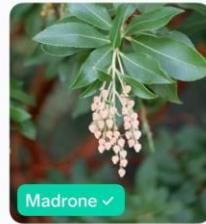
Manzanita 82 %

80% of your images are predicted correctly,
20% incorrectly.

All Images

View

Correct 80%



Incorrect 20%



TinyML

无编程和机器学习经验

也能快速上手

“I have a
dream”





Wo Terminal

ARM Cortex-M4F core running at 120MHz (Boost up to 200MHz)

4 MB External Flash, 192 KBRAM

WiFi, BT

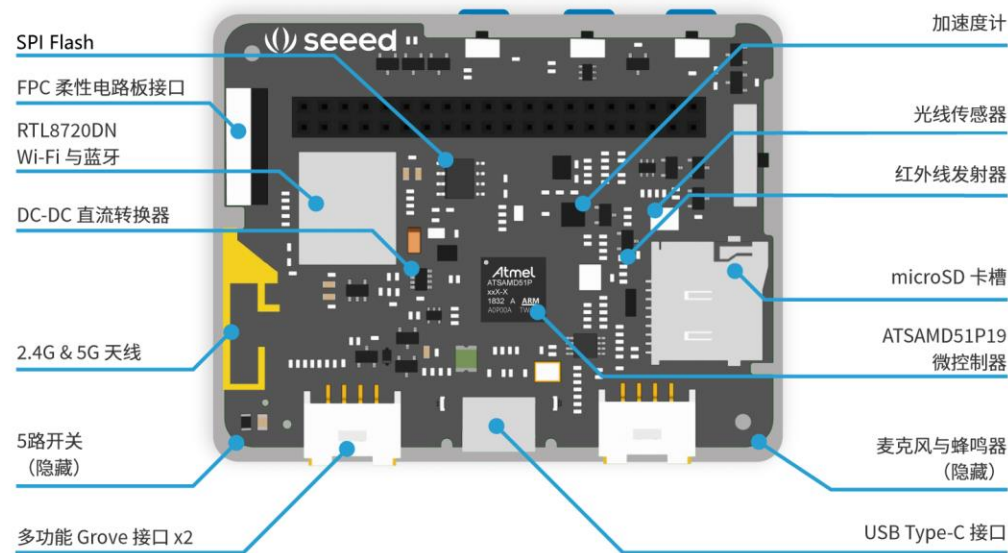
LCD screen

板载加速度计，麦克风，蜂鸣器，microSD卡槽，光传感器和红外发射器

MicroSD Card Slot, 5-Way Switch, Programmable Buttons

Grove 接口

Raspberry Pi 40-pin Compatible GPIO

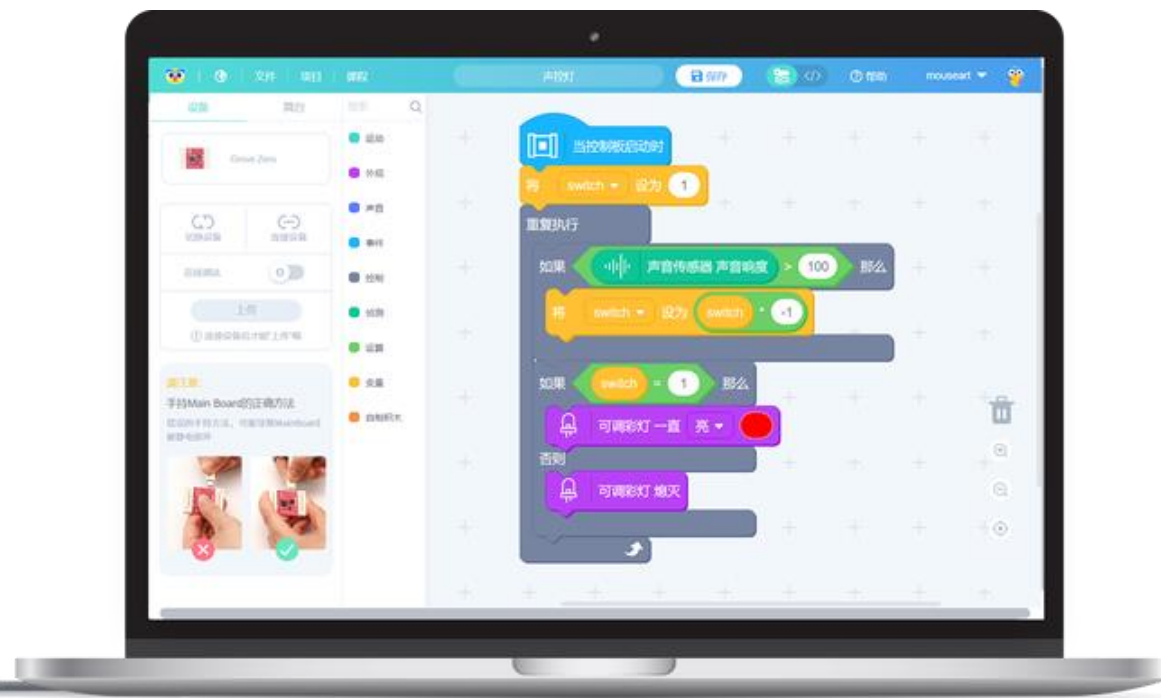
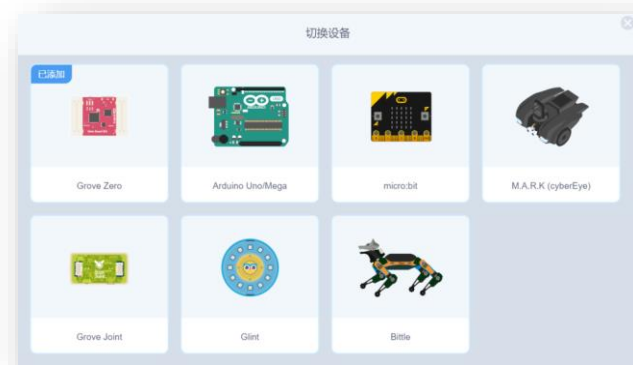
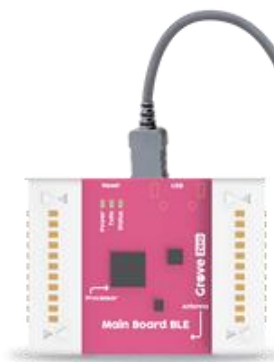




Codecraft

赋予硬件灵魂的图形化编程工具

EDGE IMPULSE



4个月后.....

codecraft | 教程 | 首页

简单, 易用。Wio Terminal 支持嵌入式机器学习了!

选择硬件进行编程

舞台模式

Grove Zero

Arduino (Uno/Mega/BeginnerKit)

micro:bit

M.A.R.K (CyberEye)

支持嵌入式机器学习

Bittle

Wio Terminal

我的作品

Codecraft 教程

汉语翻译机

1课时 4-8岁 简单 图形化编程

躲避彩虹蛇

1课时 6-12岁 图形化编程 中等

眼泪消防员

1课时 图形化编程 中等 6-12岁

笨鸟倒飞

1课时 图形化编程 中等 6-12岁

表情大师

1课时 图形化编程

wt1 | 文件 | 教程 | 保存 | 帮助 | Leon

设备 | 舞台

Wio Terminal

切换设备
连接设备

串口监视器

上传

① 连接设备后才能查看“串口监视器”哦

嵌入式机器学习

创建与选择模型

数据采集

训练与部署

使用与编程

内置加速度计识别动作

内置光线传感器识别手势

内置麦克风识别唤醒词

外接多通道气体传感器识别味道

我的模型

内置加速度计识别动作

t1

2022-01-21 00:56:30

内置加速度计识别动作

jsd1

2021-08-31 15:19:26

内置加速度计识别动作

m1

2021-07-21 17:26:52

推荐应用

手势识别模型

按照屏幕提示, 在Wio Terminal底下做挥拳和瓦肯举手礼, 它可以...

上传

声音识别模型

按照屏幕提示, 对着Wio Terminal用叉子敲击玻璃杯, 或者对它说...

上传

空间运动识别模型

按照屏幕提示, 拿着Wio Terminal做出翻转, 水平摇晃, 上下晃动...

上传

安装应用素材

如果Wio Terminal上传推荐应用后黑屏, 需要先安装应用素材

重置闪存 | 下载图片

小白的 TinyML 现场体验活动



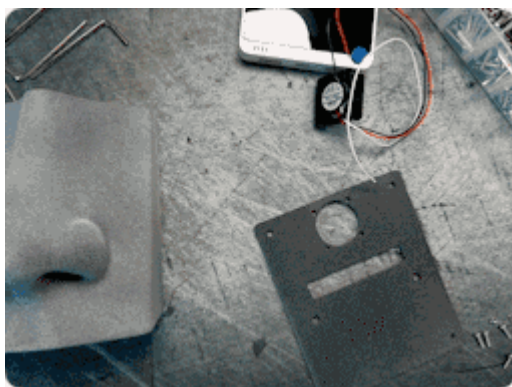


Benjamin Cabé



Principal Program Manager
Microsoft

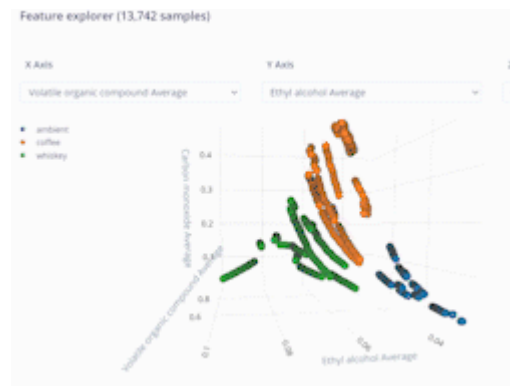
人工鼻子



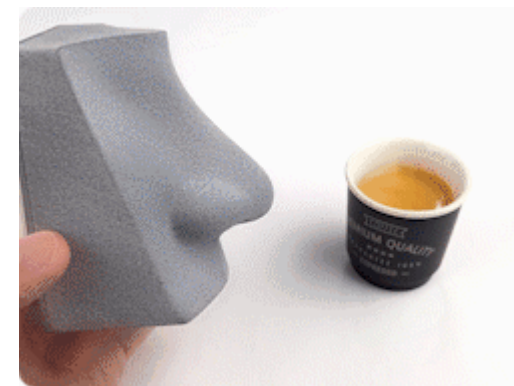
硬件组装



数据采集



模型训练

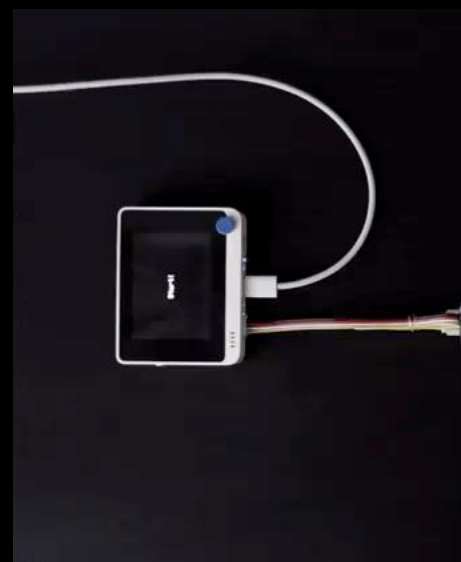
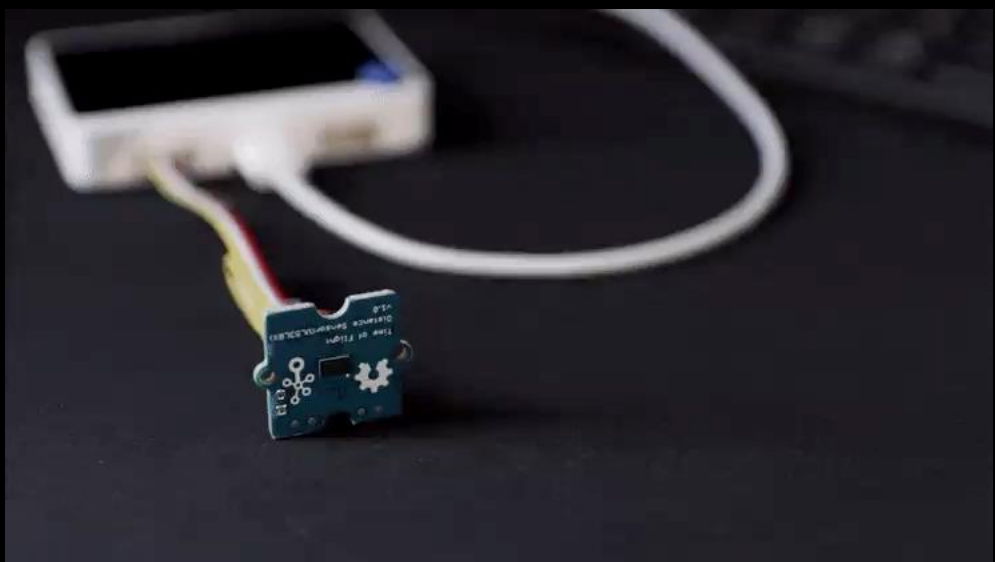


部署和使用



乔纳森·谭
新加坡国立大学

单个 TOF 传感器 实现手写识别





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TinkerGen / No-code-Programming-to-Get-Started-with-TinyML
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Your Name change some address ✓ Latest commit 185ef2e on 8 Oct 2021 History

2 contributors

95 lines (65 sloc) 14.3 KB

license MIT build Codecraft PRs welcome

English

图形化编程之嵌入式机器学习入门 —— 用 Wio Terminal 玩转 TinyML

本课程旨在通过 Wio Terminal 和图形化编程工具 Codecraft 向初学者介绍嵌入式机器学习 (TinyML) 的基础知识。

Hello World of AI



seed | USB OTG Support | TINY ML | Highly Integrated Design | Codecraft Graphical Programming

Get Started with Wio Terminal

Seeed Studio 于2021年6月发布了一个专题: Hello World of AI, 在这个专题上介绍了图形化编程工具 Codecraft 已支持嵌入式机器学习 (TinyML), 并展示了使用和 Wio Terminal 进行嵌入式机器学习的项目。TinkerGen (在中国称为柴火创客教育) 是 Seeed Studio 负责教育产品的团队, 我们认为 Codecraft 对 TinyML 的支持有着非常重大的意义, 它极大的降低了用户学习和使用 TinyML 技术的门槛。用户不需要面对复杂的编程环境, 算法知识, 就能通过浏览器和图形化编程, 简单快速的开始着手为 TinyML 项目采集数据、训练模型和编程部署。为此, 团队撰写了《图形化编程之嵌入式机器学习入门 —— 用 Wio Terminal 玩转 TinyML》课程, 并以 PDF 的方式提供给用户下载。为了能帮助更多的用户和教育机构, 使用和推广这一另人激动人心的技术。我们进一步在 GitHub 上开源了整个课程。

课程基本信息

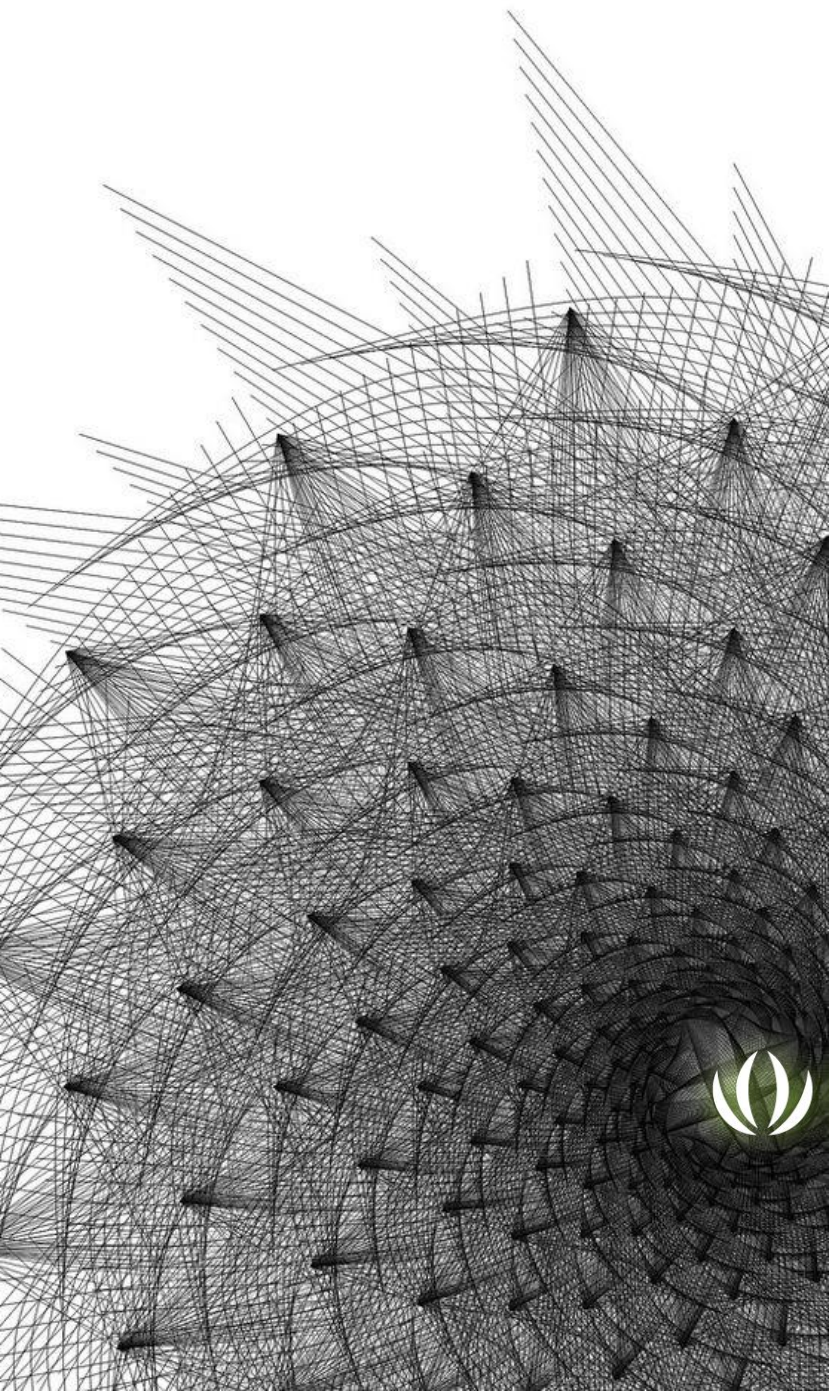


图形化编程之嵌入式机器学习入门
用 Wio Terminal 玩转 TinyML

Hi Wio

Seeed Studio 的 TinyML 图形编程平台“Codecraft”入围 2022 年 BETT 奖





才刚刚开始

Just started.



T I N Y



关于tinyML的开放话题 Some tinyML topics for open discussions

- ML vs tinyML
- 微型机器学习vs嵌入式机器学习？
- 你的tinyML的初识和渊源？
- tinyML有哪些局限？
- tinyML深圳系列活动：
 - 1) 线上vs线下？
 - 2) 最想获得什么？

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tinyML - Enabling ultra-low Power ML at the Edge-Shenzhen

<https://www.meetup.com/tiny-ml-enabling-ultra-low-power-ml-at-the-edge-shenzhen/>
<https://www.meetup.com/pro/tinyml/>

7.7k members in
43 Groups in 33 Countries
33个国家43个小组
7700+活跃成员



tinyML[®] Talks

Enabling Ultra-low Power Machine Learning at the Edge



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