



Developing Machine-Learning Applications on the Raspberry Pi Pico

DAY 2: Machine-Learning Tools and Process Flow

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THE SPEAKER



Jacob Beningo

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Beningo Embedded Group - President

Focus: Embedded Software Consulting

An independent consultant who specializes in the design of real-time, microcontroller based embedded software. He has published two books:

- <u>Reusable Firmware Development</u>
- MicroPython Projects
- Embedded Software Design (https://bit.ly/3PZCtNO)

Writes a weekly blog for DesignNews.com focused on embedded system design techniques and challenges.

Visit <u>www.beningo.com</u> to learn more ...

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Course Sessions

- Getting Started with the Raspberry Pi Pico and Machine Learning
- Machine-Learning Tools and Process Flow
- Collecting Sensor Data Using Edge Impulse
- Designing and Testing a Machine-Learning Model
- Deploying Machine-Learning Models and Next Steps







How to Integrate Machine Learning with Microcontrollers



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- 1) What problem are you trying to solve?
- 2) What are the models' inputs?
- 3) Do the inputs need to be processed?
- 4) What are the features?
- 5) What are the outputs?
- 6) How is the output processed?
- 7) Will this run on an MCU?





The Machine Learning Process Flow

1.	Identify the Problem to be Solved
2.	Acquire Dataset(s)
3.	Train Neural Network
4.	Deploy Model to Embedded System
5.	Iterate the Design/Model





A General High-Level Software Architecture







Software Architecture Tasks





Task Architecture







How experienced are you with Machine Learning?

- Zero Experience
- Have done some light reading
- Trained a model
- Deployed to a microcontroller
- Other







Microcontroller Focused Tools







Tool Categories

1.	Existing Datasets
2.	Dataset Collection and Labeling
3.	Neural Network Training
4.	Deployment



Options for getting Training Data

- 1) Online Data Sets
- 2) Generate it
- 3) Collect it
- 4) Buy it



Collecting it is the most interesting ... (and the most work)





TensorFlow Lite for Microcontrollers

- Runs machine learning models on microcontrollers
- Core run-time is ~16kB
- Does not require an OS (can run baremetal)
- Written in C++ 11
- Several example cases already available:
 - Hello World
 - Keyword spotting (Micro speech)
 - Gesture detection (Magic wand)
 - Person detection (Image processing)

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Edge Impulse was designed for software developers, engineers and domain experts to solve real problems using machine learning on edge devices without a PhD in machine learning.

www.edgeimpulse.com

Edge Impulse

Creating your first impulse (100% complete) Every Machine Learning project starts with data. You can capture data from a development board or your phone, or import data you already collected. Teach the model to interpret previously unseen data, based on historical data. Use this to categorize new data, or to find anomalies in sensor

LET'S COLLECT SOME DATA

mpulse design

Create impulse

Dashboard

Data acquisition

Device

- Spectral features
- Spectrogram
- NN Classifier
- Anomaly detection
- 🔀 Retrain model
- 2 Live classification
- Model testing **~**
- Versioning

readings.

Acquire data

Design an impulse

Deploy

Package the complete impulse up, from signal processing code to trained model, and deploy it on your device. This ensures that the impulse runs with low latency and without requiring a network connection.

★ GETTING STARTED: CONTINUOUS MOTION RECOGNITION

GETTING STARTED: RESPONDING TO YOUR VOICE

GETTING STARTED: ADDING SIGHT TO YOUR SENSORS







What is your experience with machine learning tools?

- Have not used one
- Launched or am launching a product with one
- DIY Project
- Other











Thank you for attending

Please consider the resources below:

- <u>www.beningo.com</u>
 - Blog, White Papers, Courses
 - Embedded Bytes Newsletter
 - <u>http://bit.ly/1BAHYXm</u>
 - Embedded Software Design
 - <u>https://bit.ly/3PZCtNO</u>



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