WEBINAR EMBARCADOS

Inscreva-se!

IA no mundo real:
Aplicações embarcadas com MPLAB Machine Learning Suite

Rodrigo Britto
Engenheiro de Aplicações da Microchip

MICROCHIP

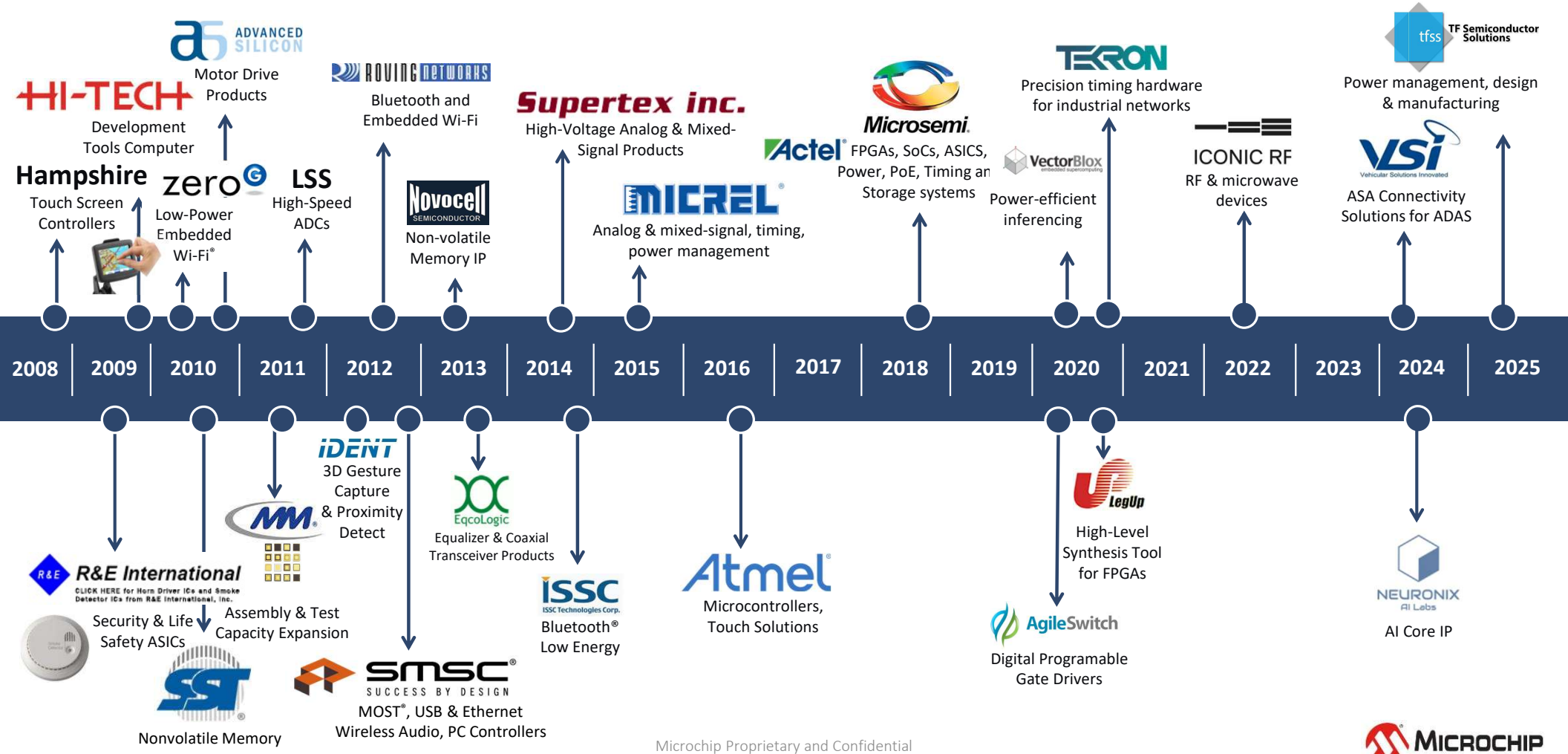
AI/ML Practical Solution

A Leading Provider of Smart, Connected and Secure Embedded Control Solutions

Rodrigo Britto

May 2026

Expanding Microchip Solutions Through Acquisitions



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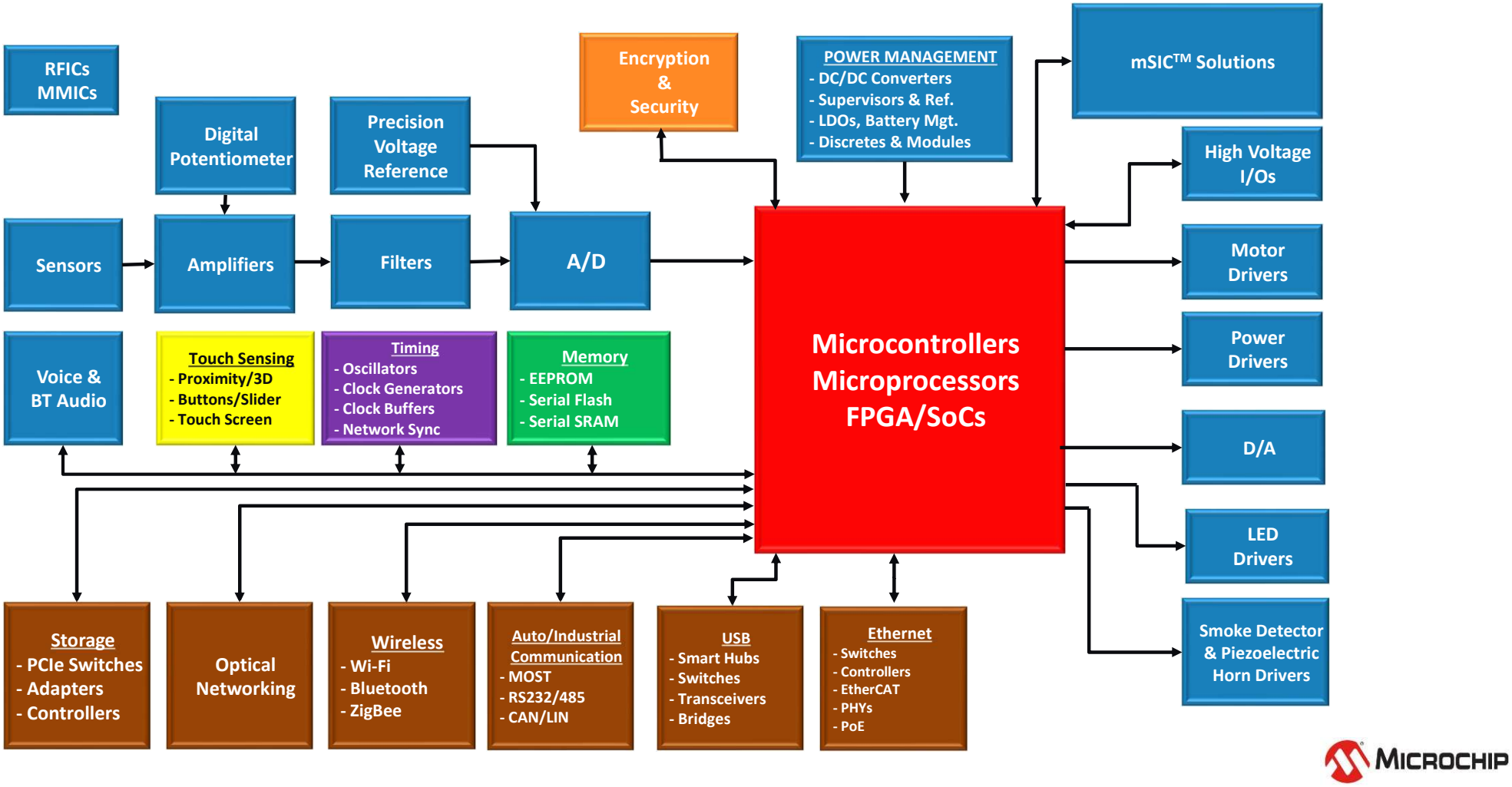
Microchip's Strategic Focus

Microchip Products Portfolio



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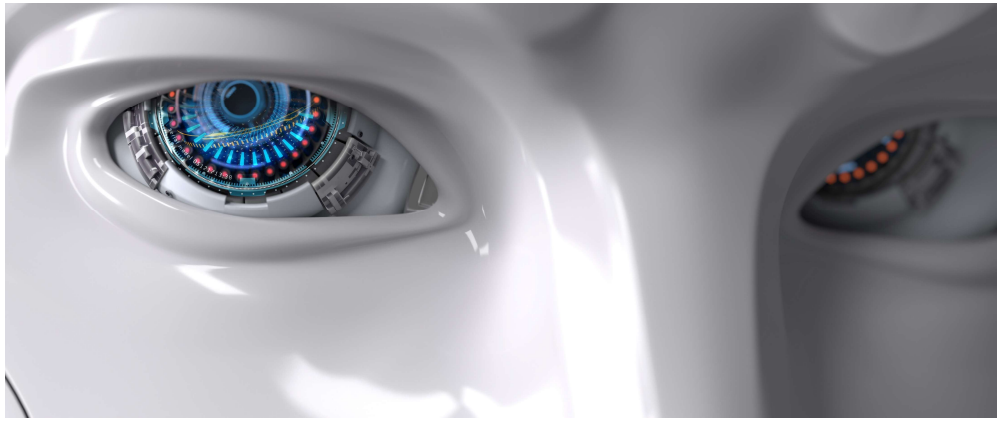
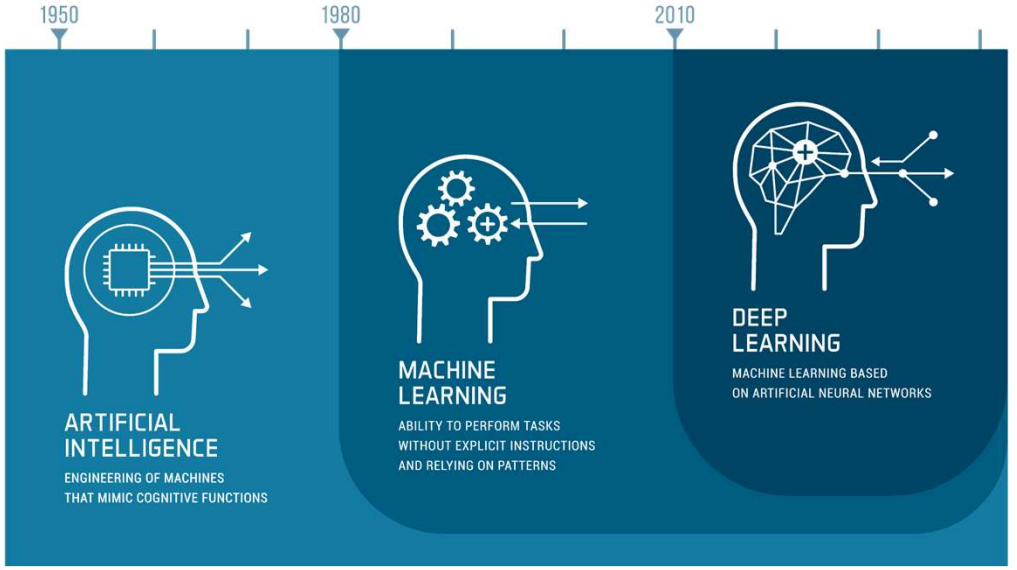
Artificial Intelligence

and Machine Learning

What is AI, ML and DL ?

- **Artificial Intelligence**
  - A non-human program or model that can solve sophisticated tasks
- **Machine learning**
- **Field of artificial intelligence that enables computers to learn from and make decisions based on data without being explicitly programmed for specific tasks**
- **Deep Learning**
  - Subset of machine learning that involves neural networks with multiple layers which can learn progressively higher-level features from raw input data





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JC1

Why ML at the Edge?

Edge Data Processing near the Source of Data Generation

- **Enable new applications**
  - Real-time inference with low latency
  - Enabling safety, real time interaction, navigation etc.
  - Keep data local for privacy sensitive applications
  - Stand-alone applications
    (no dependence on upstream connection)

- **Better customer experience**
  - Faster response time

- **Reduce power consumption**
  - No need for fast, real-time communication link

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Slide 8

JC1 Did you create these diagrams? If so, they should be ok to stay in the presentation. If not, they need to be from the DAM.

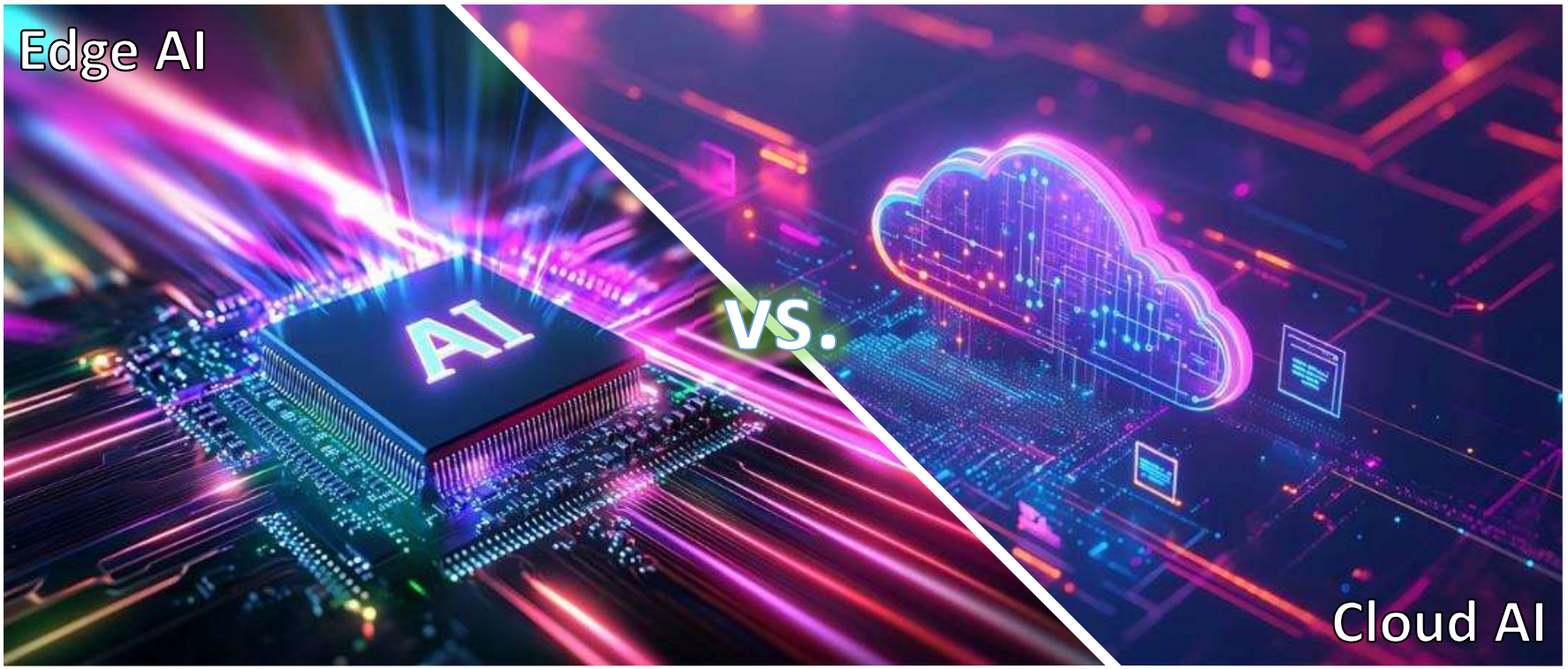
James Peru - C68183; 2024-06-28T20:24:09.306

DWM1 0 These have previously been presented by the AIML team at public conferences but since I cannot find a reference to attribute it has been removed.

Darren Wenn - M91145; 2024-07-04T08:31:42.490

Edge AI vs. Cloud AI

"Edge AI" and "Cloud AI" refer to two different approaches to deploying Artificial Intelligence (AI) systems, each with its own characteristics, advantages, and use cases



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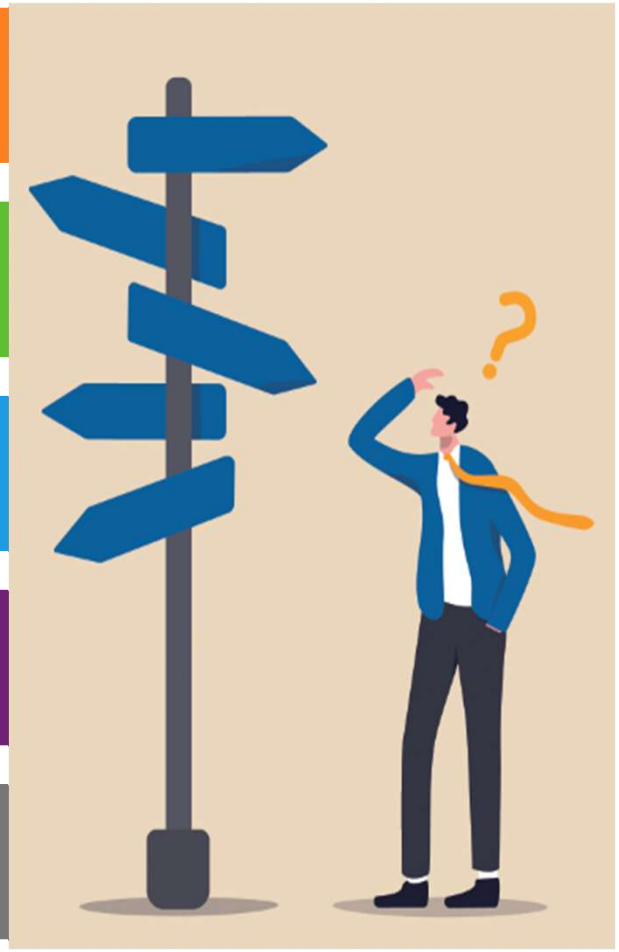
Why Choose Edge AI For Your Product?

- Lower latency
- Sensitive data kept at node
- Reduced cost on edge vs. cloud
- Lower power consumption
- Time to market



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Edge AI: Meeting Market Trends

Model Optimization for Edge Deployment

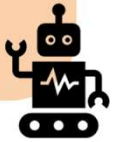
Sparsity Reduction & Pairing Techniques
Low Power
Small Space
Low Cost

On-device Learning & Personalization

Data Privacy
Personalized Experiences

Multi-modal Sensor Fusion

Dynamic Environments
Robust Data Analytics
Context-Aware



Energy-aware and Event-driven Architectures

Optimize Compute Power
Extend Battery Life

AI Auditing at the Edge

Functionality
Explainability
Bias-Free
Comply With Regulations

Security and Trust in Edge AI

Authorized Use
Data Protection

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ML Edge Applications

Smart Embedded Vision

Enhanced quality and productivity at factories

Machine assistance for faster, better diagnosis

Surveillance / security with granular, real-time monitoring and response

Smart Human Machine Interface (HMI)

Local processing for voice interactive appliances

Real time, interactive gesture recognition

Smart Predictive Maintenance

Detect ageing / environment driven degradation

Predict and prevent system failures

Water / hazardous leak detection and alarm

Why is it so popular *now*?

- **Advancements in computational power**
  - Vastly parallel operations
  - Virtual computing and Data Centers
- **Large Datasets**
  - Example data
- **Algorithms**
  - New algorithms
  - Accessibility
- **Automation**
  - ‘Intelligence’ and automation
  - Sustainability

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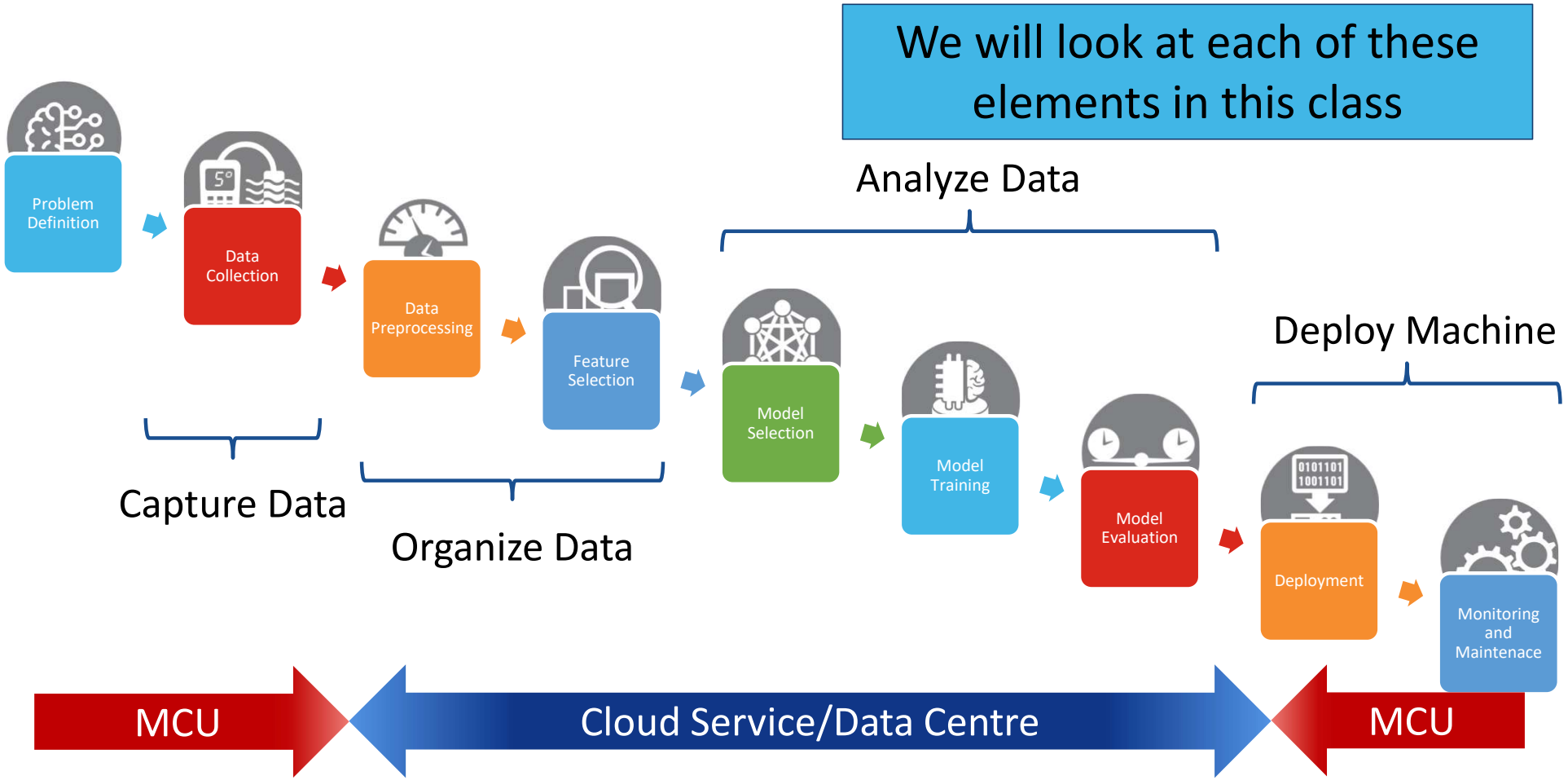
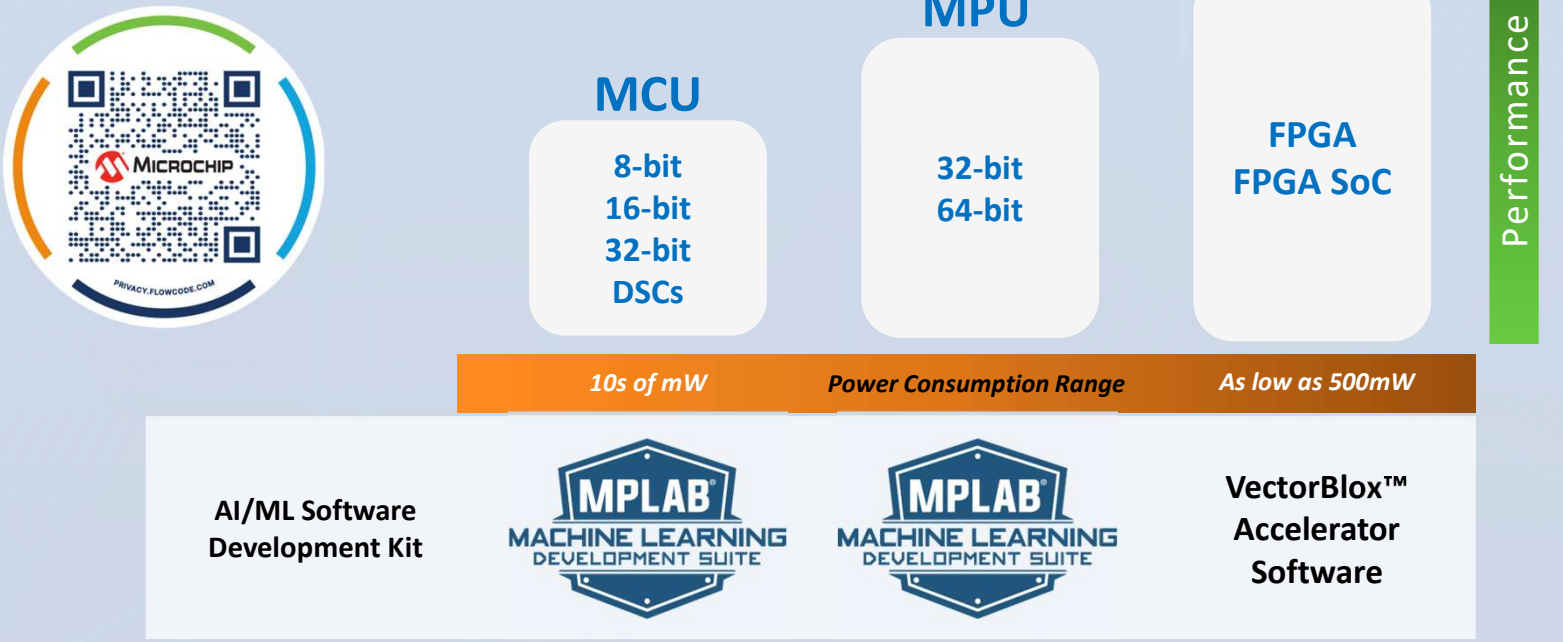
Machine Learning Development Flow



Why Edge AI With Microchip?

Solutions Based on Your Computing Needs

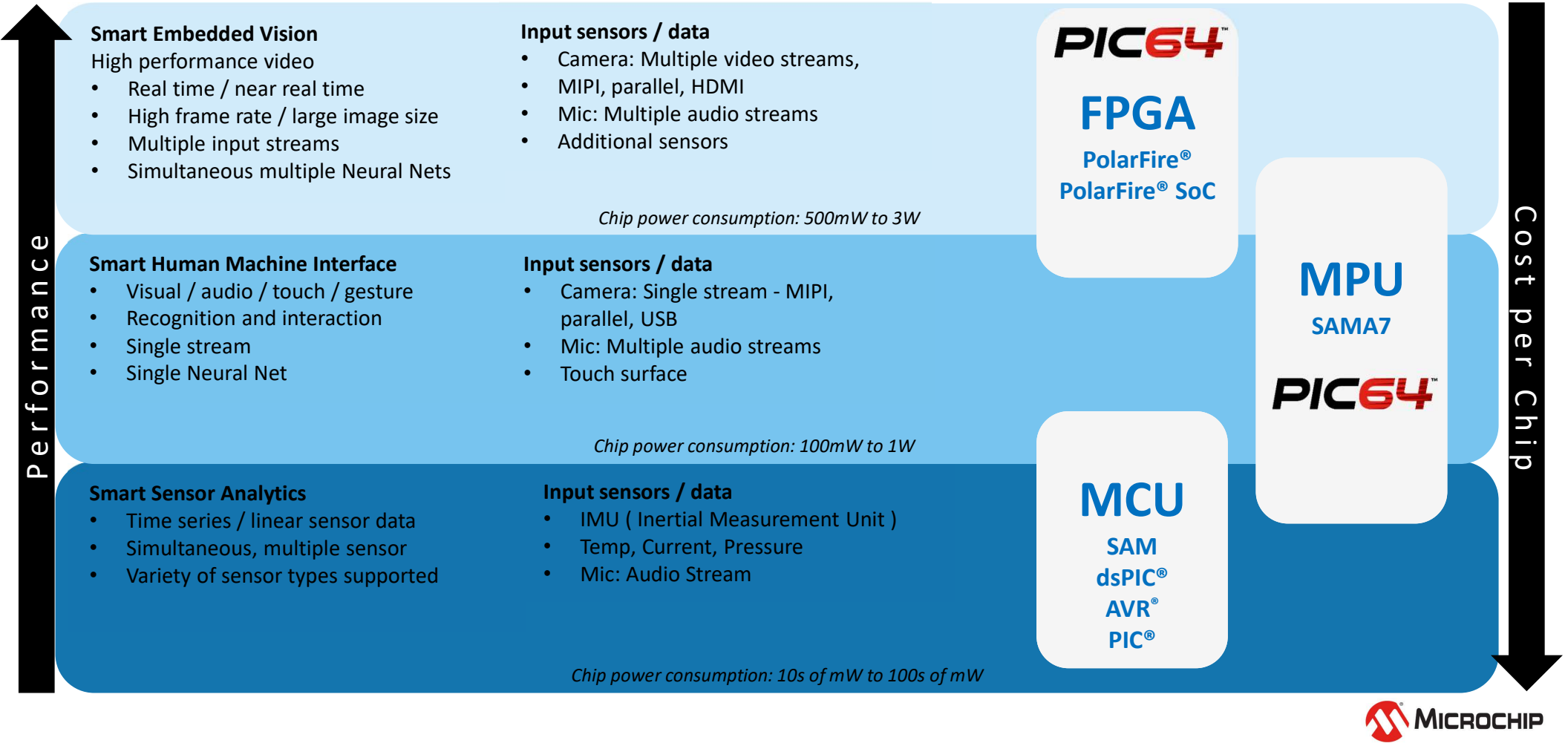


System-Level Solutions

- Security
- Power Management
- Connectivity
- Sensor Interfacing

Long Product Lifetimes. Customer-Driven Obsolescence

Microchip Platforms for Edge AI Use Cases



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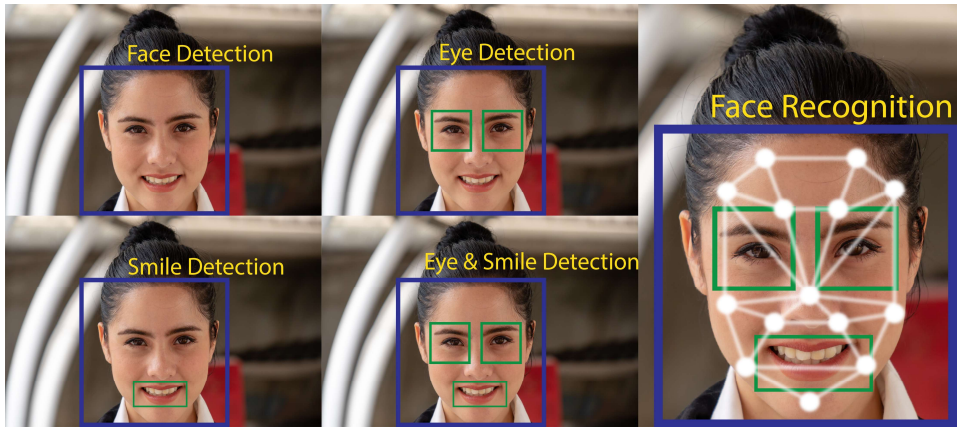
Data Collection

Selecting and organizing with just a little Data Science

Selecting and Collecting our data

- **To train a model we need data**
  - Lots of it
    - Deep Learning might need 1000s to Millions of samples
  - Coverage
    - Statistically significant – adequate domain coverage
  - Diversity
    - Representative Sampling
      - Events that occur 80% of the time should compose 80% of the data
  - Quality
    - Properly labelled
  - Test/Validation Split
    - 80/10/10
- **Where to get the data**
  - Acquire it
  - Buy it
  - Build it



Example MS COCO

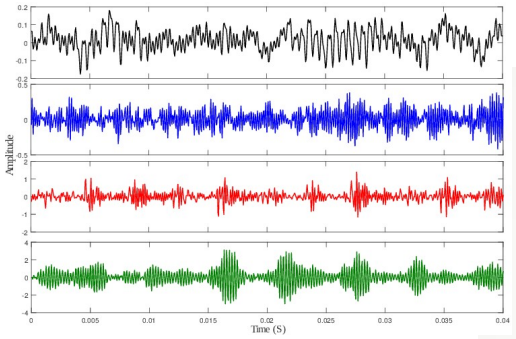
- The Microsoft Common Objects in Context
  - Database is a large-scale dataset for object detection, segmentation, and captioning
- 80 object categories with a wide range from everyday scenes
  - Diverse and Complex Scenes
  - Closely resemble real-world scenarios
- Detailed annotations
  - Object bounding boxes
  - Segmentation masks
  - Image captions
- Over 200,000 labelled images
  - More than 1.5 million object instances
- Image Captions
  - Each image is provided with at least five different captions written by human annotators
- The dataset is pre-divided into training, validation, and test sets
- Updated yearly
- Free for researchers

Example MNIST

- **Collection of handwritten digits widely used for training and testing in the field of machine learning and computer vision**
- **70,000 images**
  - 60,000 training samples
  - 10,000 testing samples
- **Image Properties**
  - Grayscale images (0-255 levels)
  - Size of 28x28 pixels
- **Labels (Metadata)**
  - Each image is labelled with the digit it represents (0 through 9)
- **Benchmark for evaluating the performance of image processing systems**
- **Availability**
  - The dataset can be freely downloaded for use with various data science and machine learning libraries
- **Useful for creating Convolutional Neural Networks**

Vibration Analysis

- **Bearing Data Center (CWRU)**
  - Vibration sensor samples at 12kHz
  - EDM Artificial Damage



- **Machinery Failure Data**
  - Extensive set of vibration readings
  - Also common failure modes for broad range of machines
- **NASA Acoustics and Vibration Database**
  - Great for building rockets

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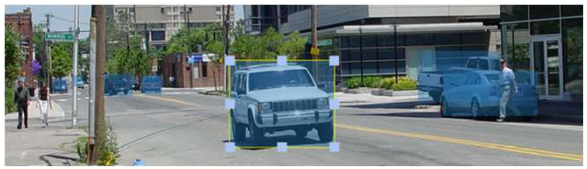
Obtaining Datasets

- **Limited number of *free* datasets**
  - Check licenses
- **Dataset Providers**
  - Kaggle (public datasets)
    - Subsidiary of Google
  - Companies that will create a dataset (for a fee)
    - Scale AI
    - MTurk (Amazon Mechanical Turk)
      - Crowdsourced marketplace for data labelling
  - Most focus on image analysis or Generative AI
- **Create your own**
  - Sometimes only viable option
    - New products/fields-of-play
    - Where data confidentiality is important
  - You know your data
    - *But you can be too close to it*

kaggle



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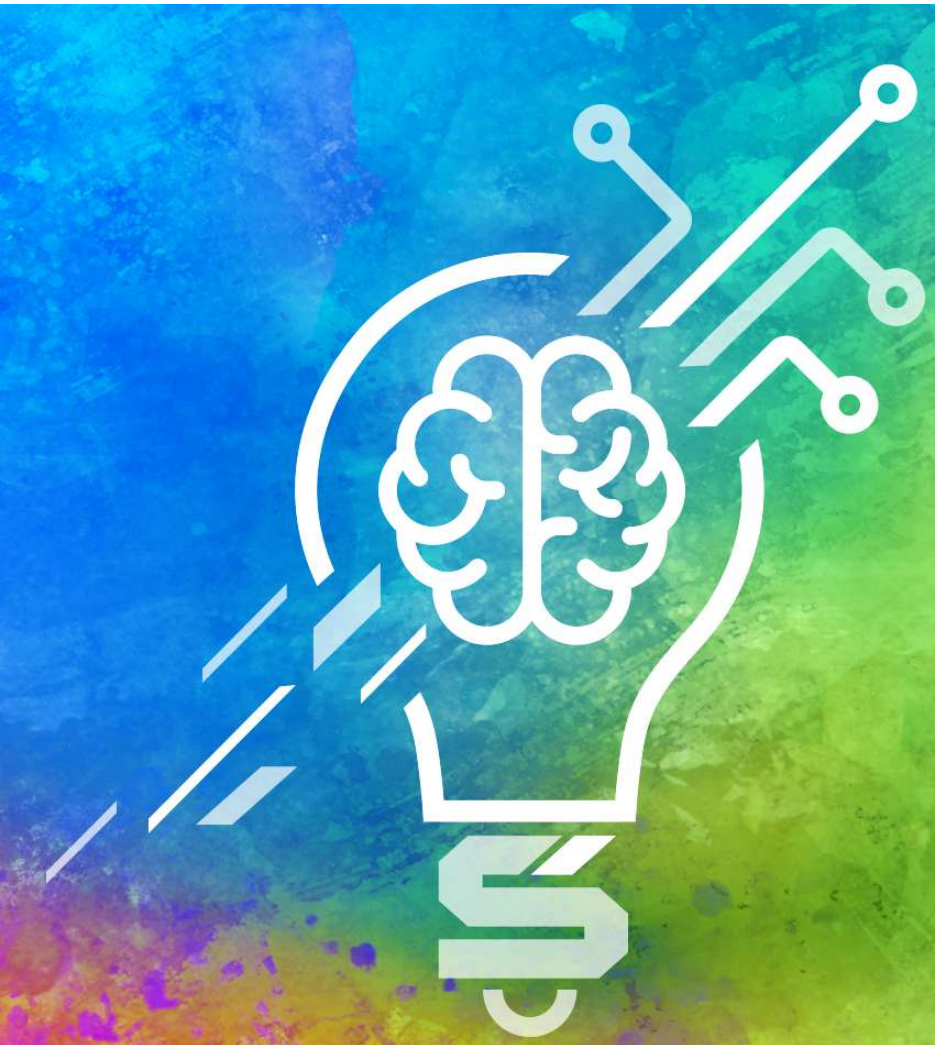
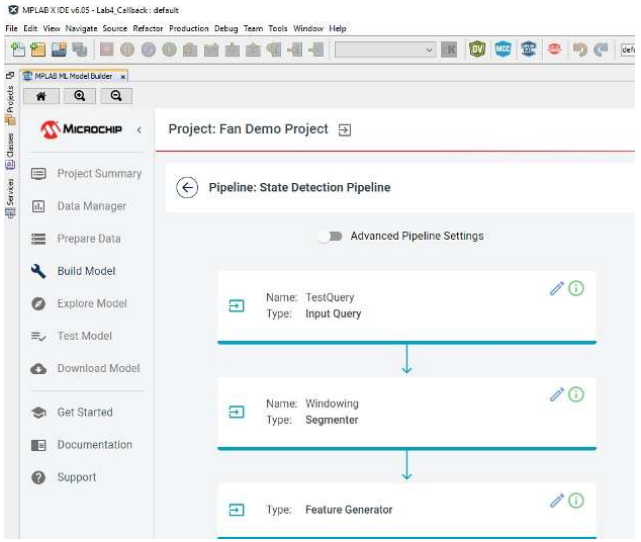


MPLAB® Machine Learning Development Suite

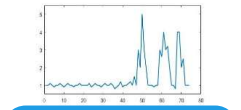
Taking the Complexity out of AIML

MPLAB® ML Development Suite

- **Create compact supervised and anomaly-detection algorithms that can run on edge based MCUs and MPUs**
- **Automate each step of the ML flow process**
  - Data preparation
  - Label and filter data
  - Feature extraction
  - Training
  - Validation
  - Deployment
- **Create ML pipelines that are ready for production**
- **Generate AutoML-powered code**
  - Create a prototype in days or weeks (or 3 hours)
- **Fine-tune aspects of your algorithm**
  - Advanced users can develop with Google Colab or Jupiter Notebooks
- **Firmware generation for 8-, 16- and 32-bit XC compilers**
  - Library and Source Code export options



MPLAB ML Dev Suite Ecosystem



Sensor Signals

[IMU, Voltage, Current, Temperature, Gas, etc.]

More Info

MPLAB MACHINE LEARNING DEVELOPMENT SUITE

Train | Model | Simulate | Download

Debugger

MCU/ MPU

MPLAB X IDE

- **Battery State Monitoring** (Good vs Degrading Battery)
- **Arc Fault Detection**
- **Knockout Detection** (Battery)
- **Motor Condition Monitoring** (Predictive Maintenance)
- **Audio Applications** (Keyword Spotting)
- **Gas Detection** (Coffee Bean Identification)
- **Gesture/Activity Detection**
- **…Other**

Application Domains

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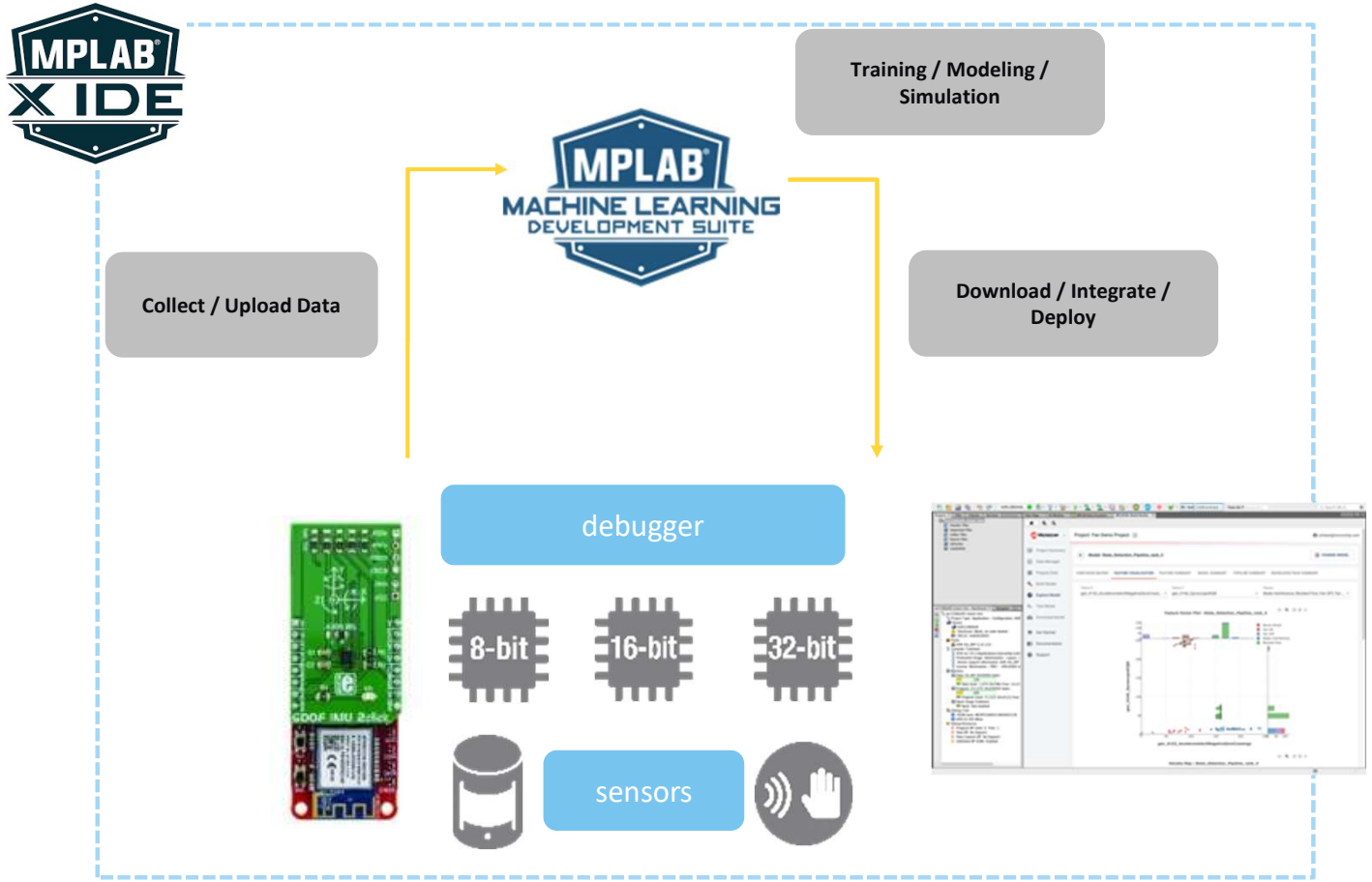
New Integrated MPLAB ML Development Suite



More Infos

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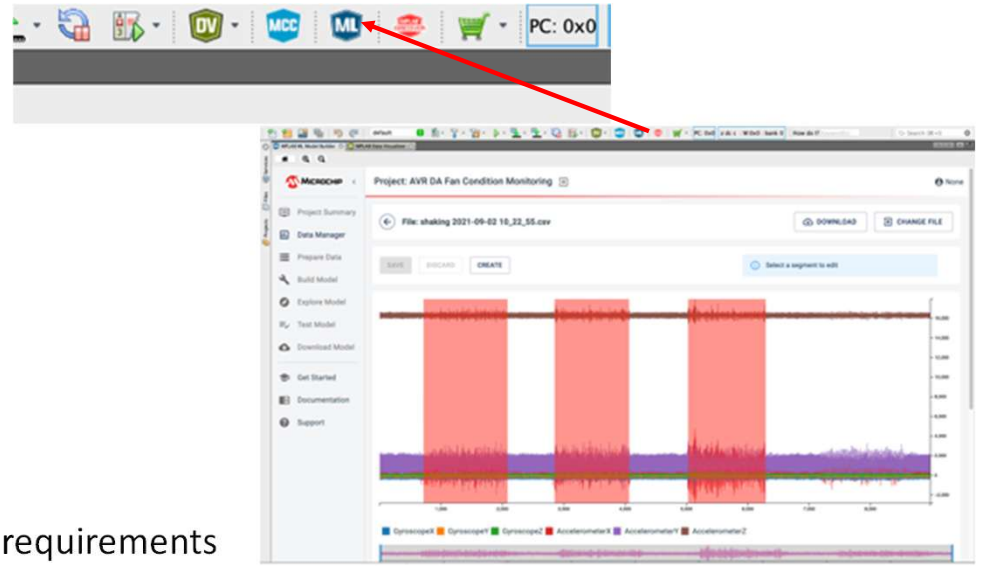
What is unique

- **Complete flow from data collection to deployment**

- **Fully integrated within MPLABX IDE**
  - Running on MCHP servers
  - AutoML mode with options for experts
  - Support XC8/16/32
  - ML model library (Zoo) with small footprint and low CPU requirements



MPLAB MACHINE LEARNING DEVELOPMENT SUITE

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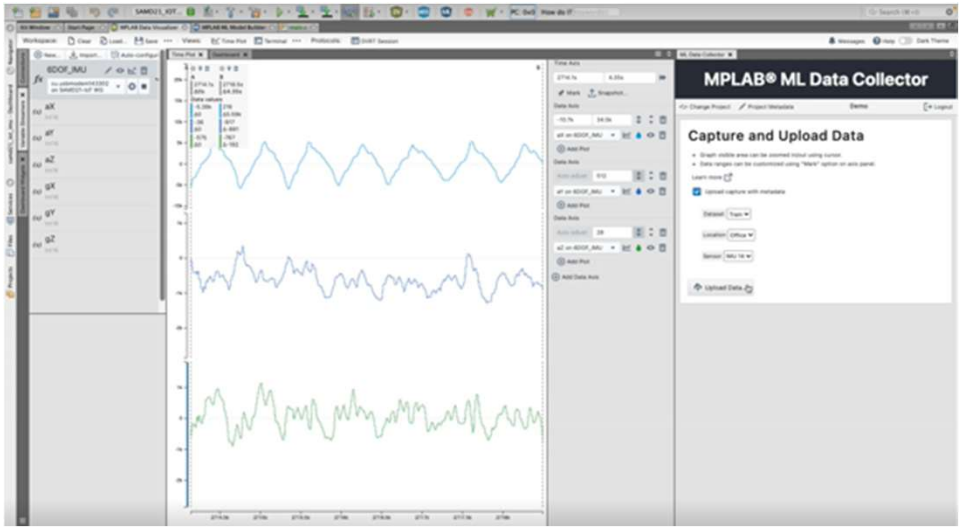
MPLAB Machine Learning Development Suite

ML Data Collector – Plugin to MPLAB Data Visualizer



- Capture/Upload Sensor Data
- Create Metadata Labels

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MPLAB Machine Learning Development Suite

ML Model Builder – Data Manager

- Data Segmentation
- Data Labelling
- Import New Data (CSV, WAV)
- Export Data

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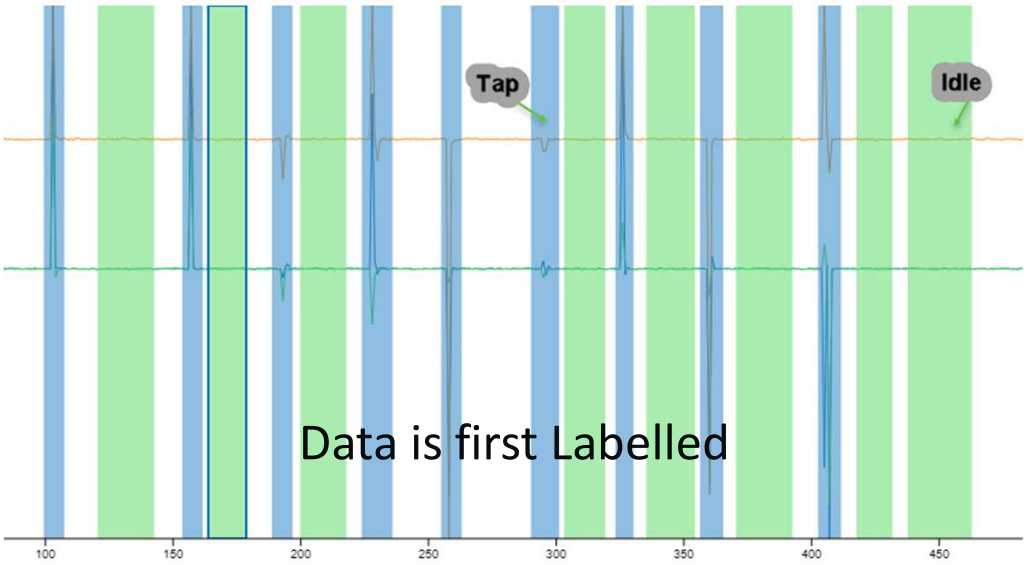
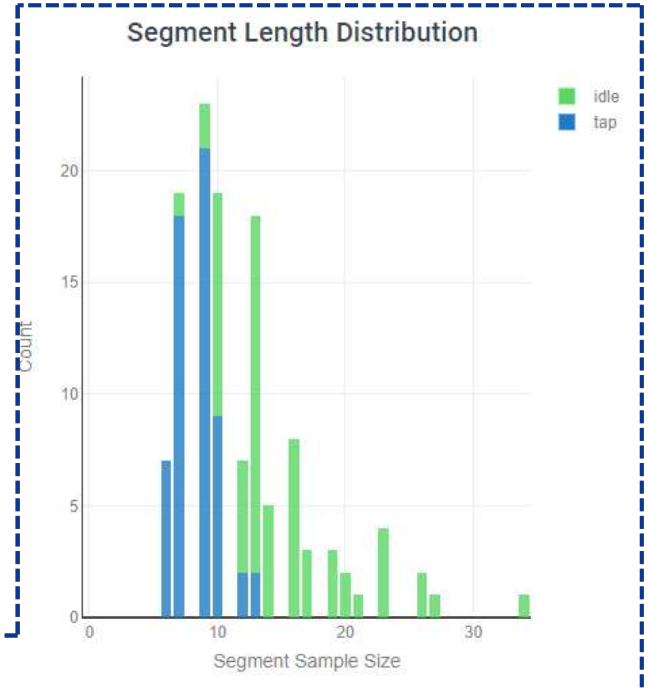
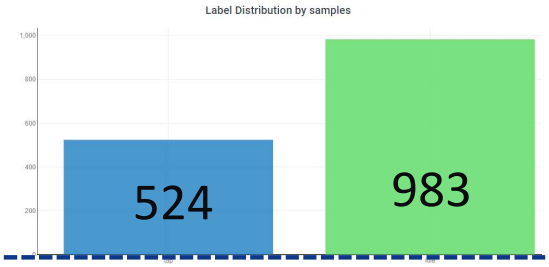
Labeling Data and Creating Queries



Data is first Labelled





Query is created

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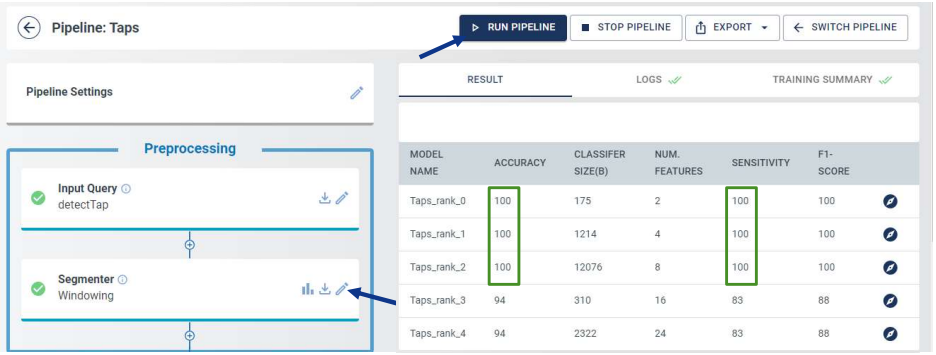
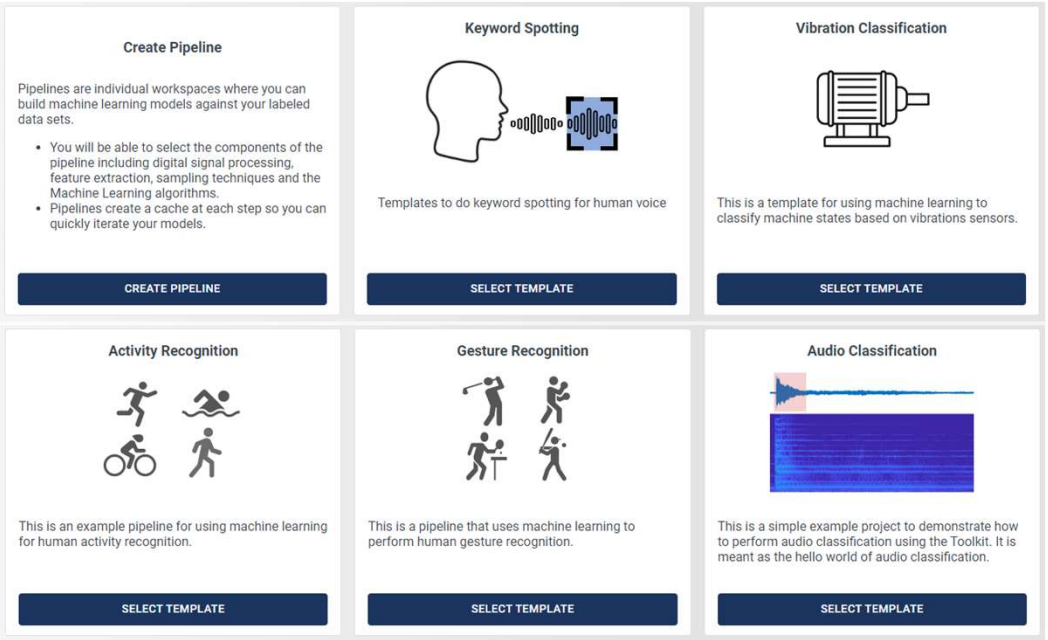
Developing a model

- **Select A Template**





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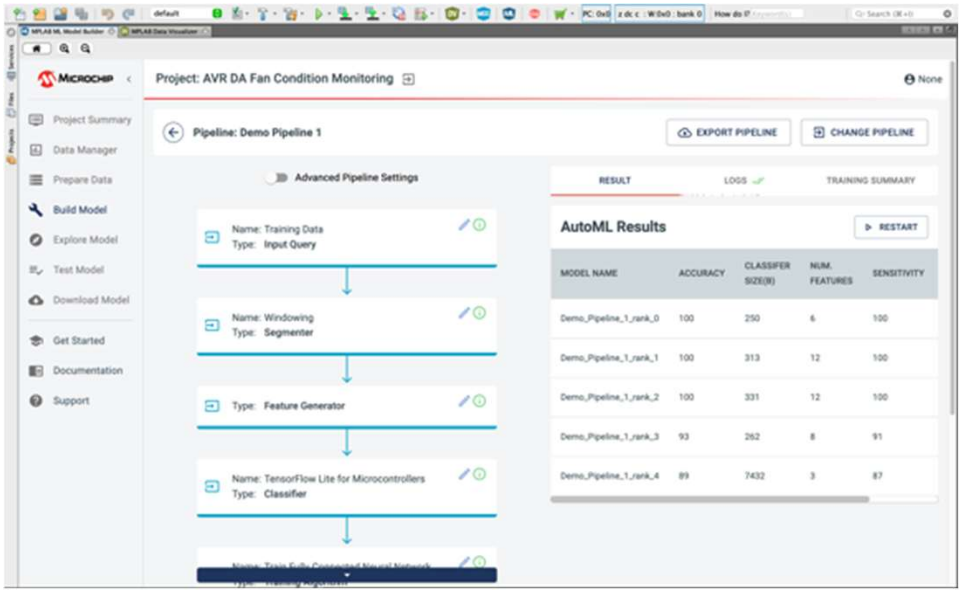
ML Model Builder – Build Model



- **AutoML Optimization OR Manual Control**
  - Feature Extraction
    - Column Fusion
    - Amplitude
    - Rate of Change
    - Frequency
    - Statistical
    - Area
  - Classifier Type
    - xGBoost
    - Random Forest
    - Radial Basis Function
    - Hierarchical Clustering
    - Neural Network

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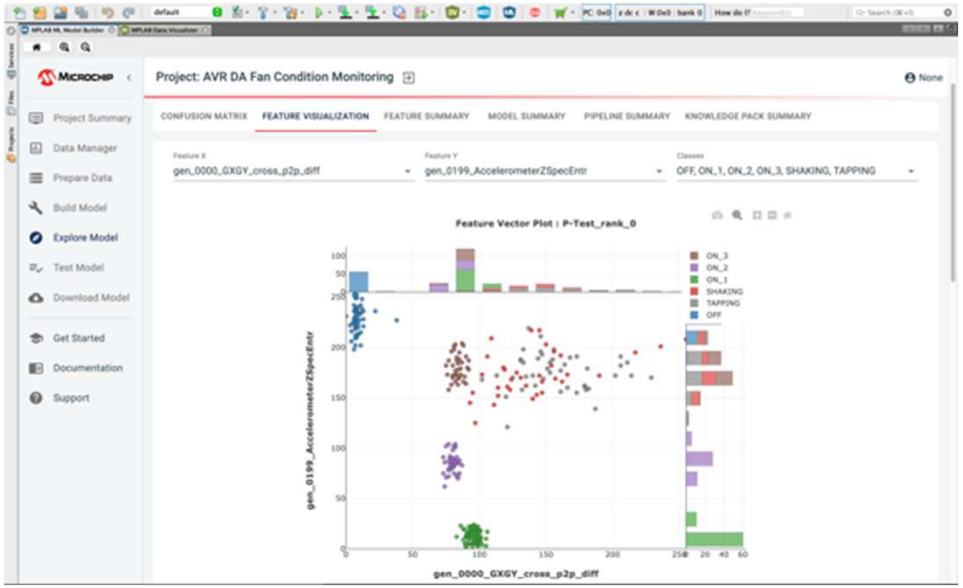
MPLAB Machine Learning Development Suite

ML Model Builder – Explore Model



- Training/Validation Accuracy
- Feature Visualization
- Feature Summary
- Model/Pipeline Summary

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Check Results

- **Multiple output models**
  - Rank0 output will likely be the best
- **MPLAB® Machine Learning Development Suite outputs multiple diagnostics**
  - Look under Explore Model
  - Feature visualization
    - How well features are clustered according to classification
      - Feature Vector Plot
      - Density Map
  - Feature Summary
    - Indication of what features are used to classify the results
      - Mainly frequency
      - Amplitude
      - Shape

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Gesture Confusion Matrix

Below is the confusion matrix for the test dataset. Note that the classes are highly imbalanced so accuracy is not a good indicator of overall performance.

	Unknown	figeight	idle	unknown	updown	wave	wheelcw	UNK	Ground Truth	Suppport	Sensitivty(%)
Unknown	0	0	0	0	0	0	0		0	0	
figeight	0	28	0	2	0	0	0		2	30	93.33
idle	0	0	135	0	0	0	0		9	135	100.00
unknown	0	0	0	56	0	0	4		4	60	93.33
updown	0	0	0	0	11	0	0		1	11	100.00
wave	0	0	0	0	0	30	0		2	30	100.00
wheelcw	0	0	0	2	0	0	27		2	29	93.10
Predicted	0	28	135	60	11	30	31		20	295	
Pos_Predic(%)		100.00	100.00	93.33	100.00	100.00	87.10			Acc(%)	97.29

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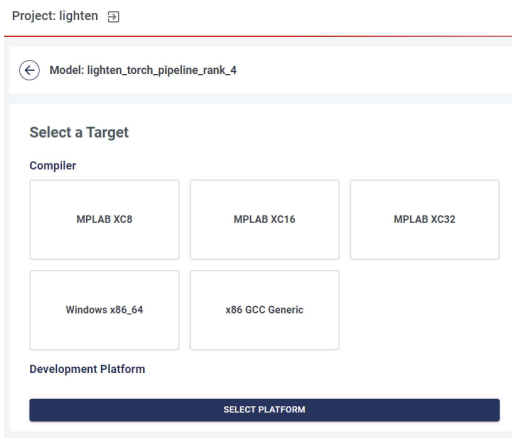
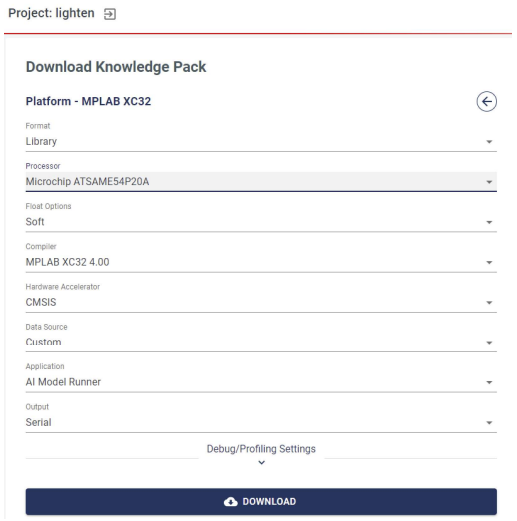
Deploy Result

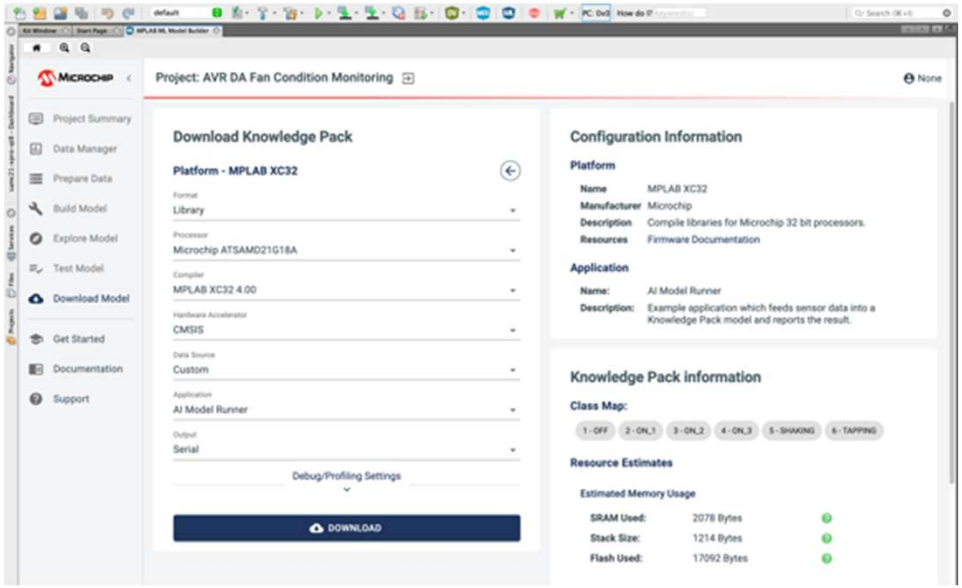
- **Select the optimal pipeline**
  - Achieve your desired performance
  - Verify the results with test data
  - Take more samples
- **Select your compiler target**
  - Select the processor
- **Create and download the knowledge pack**
  - zip file
  - Library (libmplabml.a)
  - Header files (6)
  - Source output is possible
  - Separate License
- **For this demo, only three function calls needed**
  - kb_model_init()
  - kb_reset_model()
    - Called after every run of the model
  - kb_run_model()
    - Add new data to the model and classify it





MPLAB Machine Learning Development Suite

ML Model Builder – Download Model



- **XC8/16/32 Support**
- **Source Code License Option**
- **Resource Estimates**
  - Memory Usage
  - Latency

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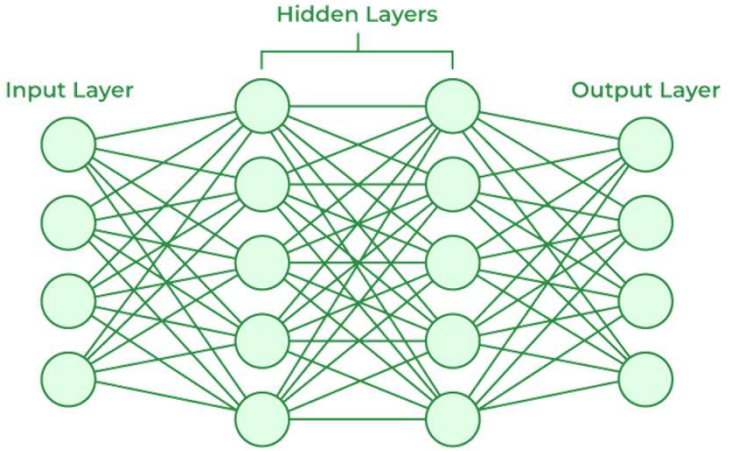
Analysing your data

Selecting and Building the Model

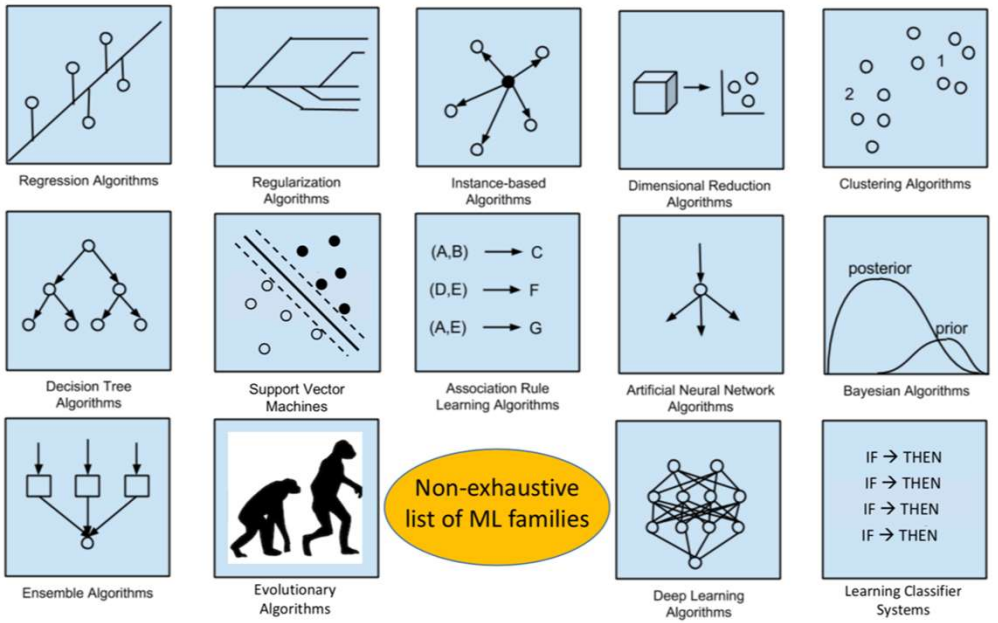
AIML Models

- **When asked to draw an AIML Model**
  - 9 out of 10* would draw this
- **A Neural Network**
  - With inputs (sensors, processed data)
  - Hidden layers (weights and sums)
  - Output Classifiers (majority functions, min-max)
- **BUT Not all AIML models are Neural Networks**
  - *Machine learning*
    - *Field of artificial intelligence that enables computers to learn from and make decisions based on data without being explicitly programmed for specific tasks.*



What ML Model To Use?

- **To build an application we need to know what type of model to use**
  - Not all models are neural networks
  - Depends on application space
  - Hire a PhD
  - Try using AutoML
    - Use information about problem space
    - Try multiple architectures
    - Find optimum model
    - Mapping inputs to classifications



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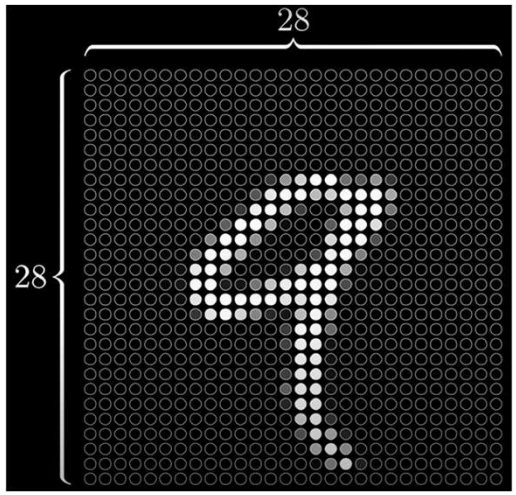
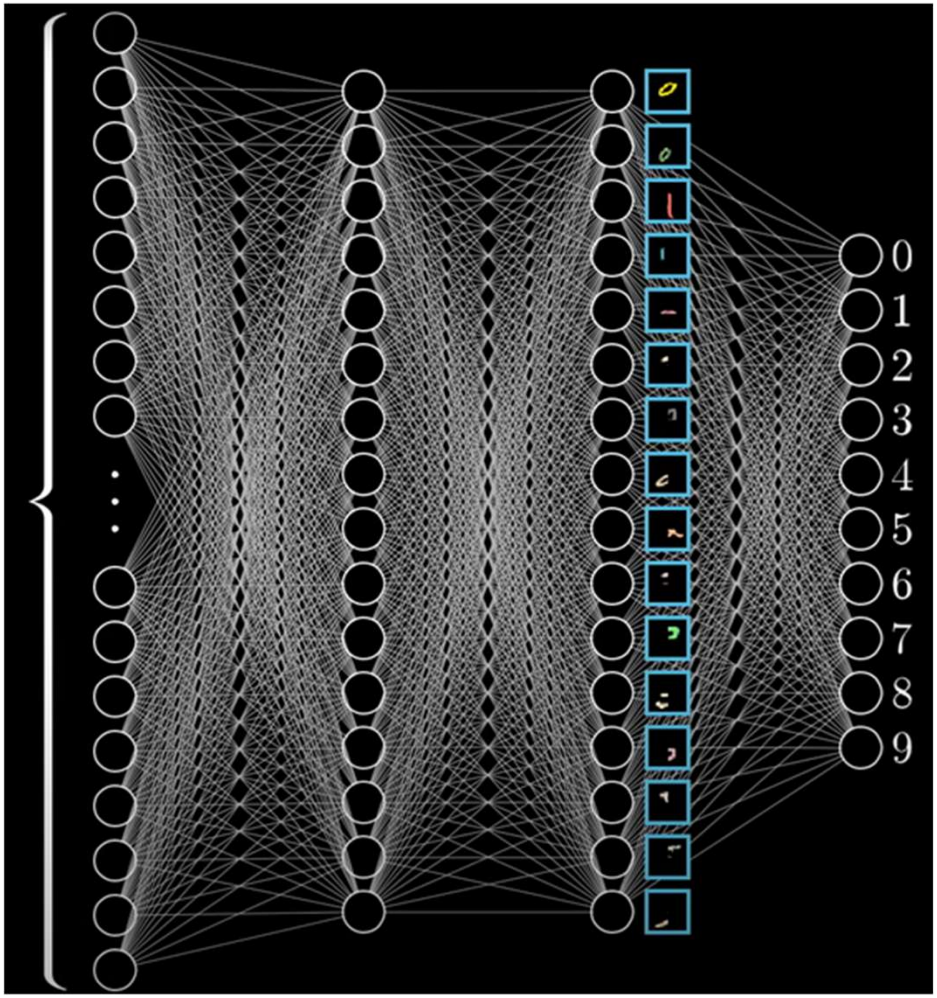
Artificial Neural Network

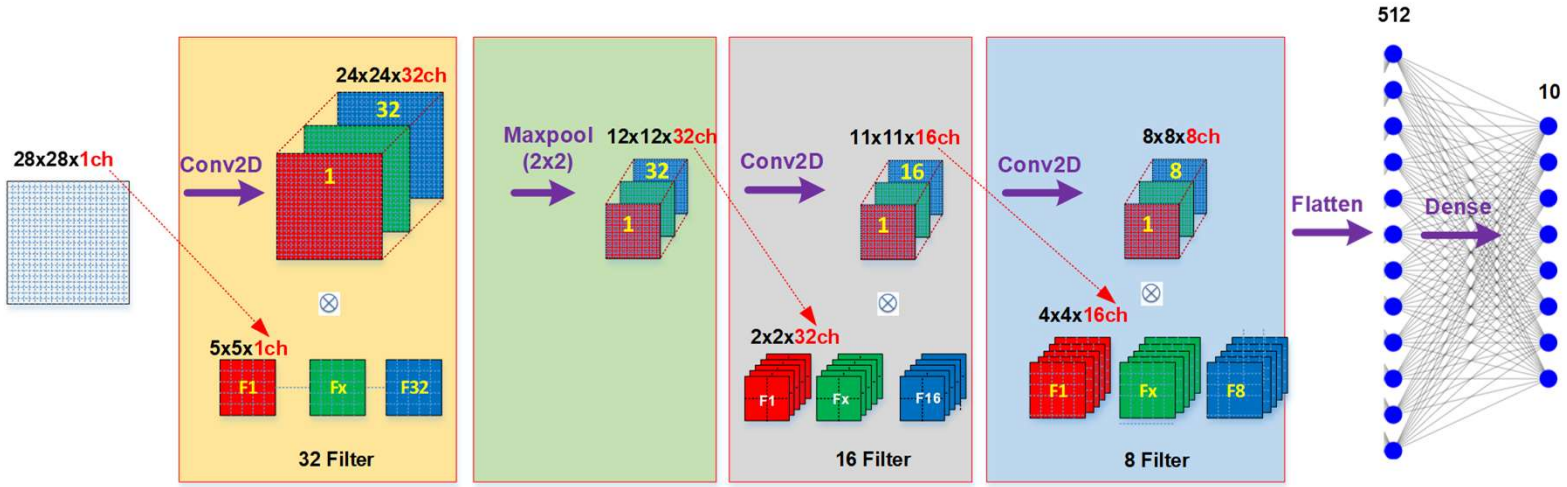
- **Fully connected layers of neurons**
  - Best for tabular data, time series forecast, basic classification
- **Touch example**
  - Touch sensor with resolution of 28 X 28 means 784 pieces of data to feed into the network with 10 desired outputs
  - ANN is trained to detect patterns labelled 0-9 based on touch information from the touch pad





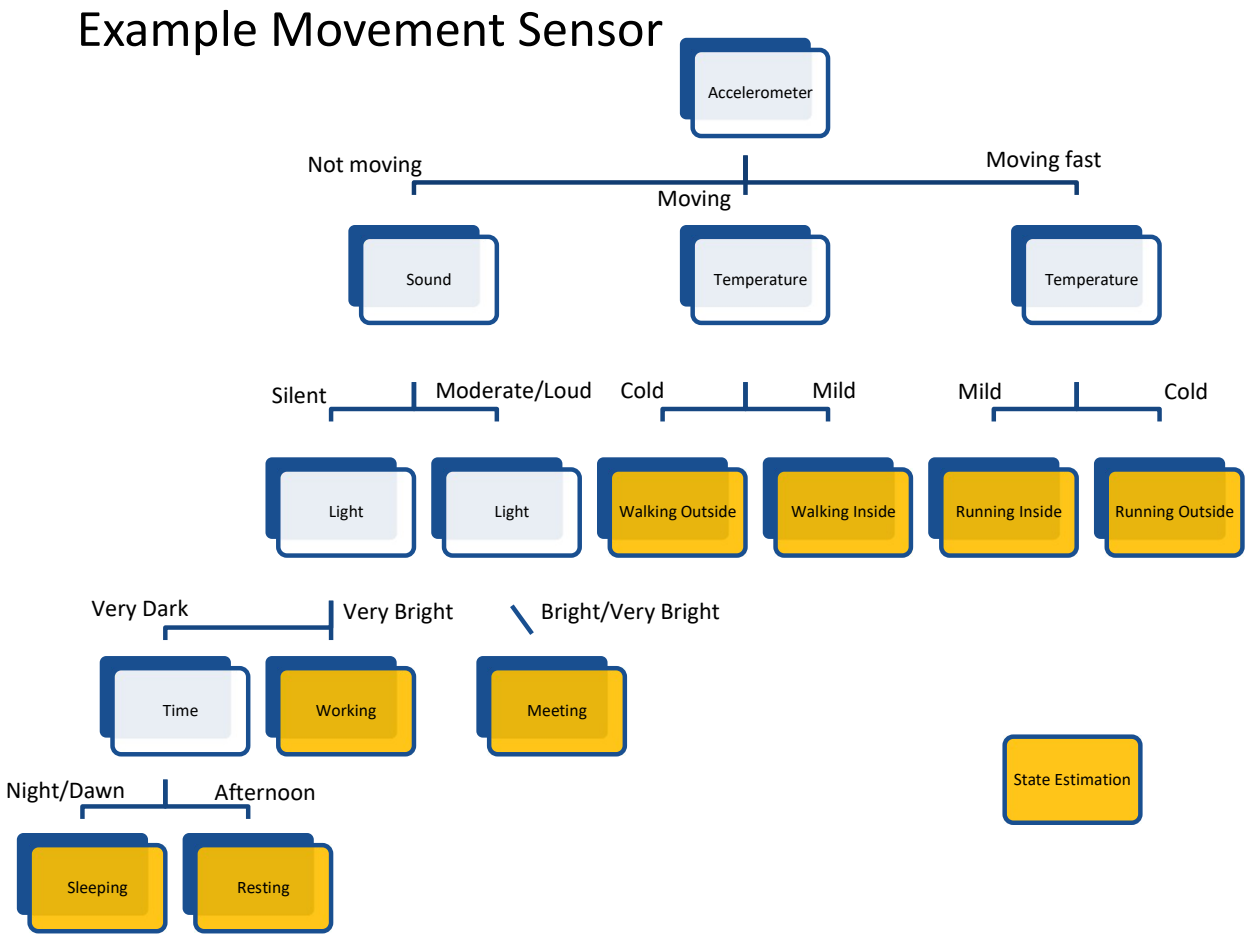
Convolutional Neural Network

- **Convolutions applied to local input regions**
  - For example, edge detection, textures, shapes
  - Best for spatially related data
- **Example for Digit Recognition**



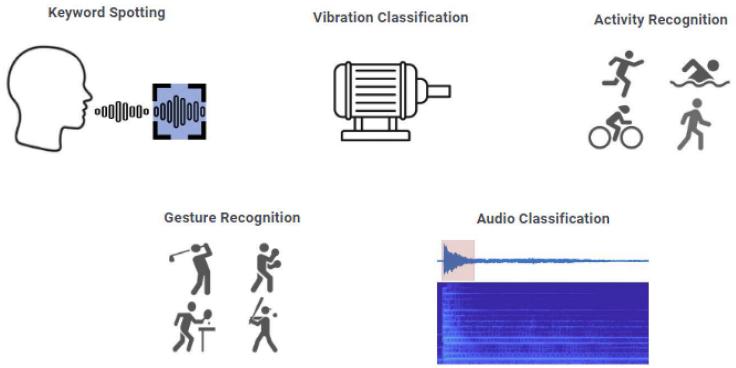
Decision Tree

- **Tree-like graph of decisions and possible consequences**
  - Each node is a feature
  - Branching is decision rule on that feature
  - Training requires splitting rule generation and pruning
    - Can be overfitted



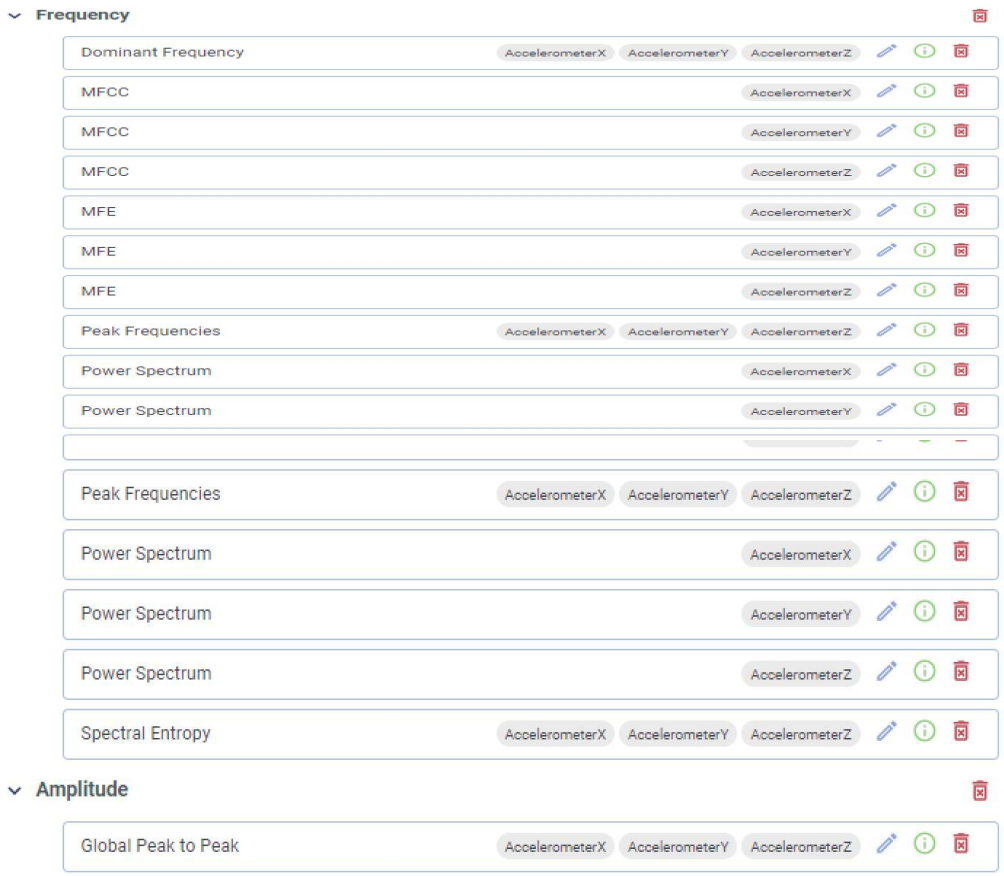
Selecting the Model

- **Depending upon the problem space different models may be more appropriate**
  - Certain architectures suit different problems
    - YOLO (You only look once) well suited to object detection using deep convolutional neural network
    - CNN can be used for vibration analysis but others like Bayesian networks might be better
  - MPLAB® ML Suite Templates
    - Keyword Spotting
    - Vibration Classification
    - Activity Recognition
    - Gesture Recognition
    - Audio Classification



ML Suite Vibration Template

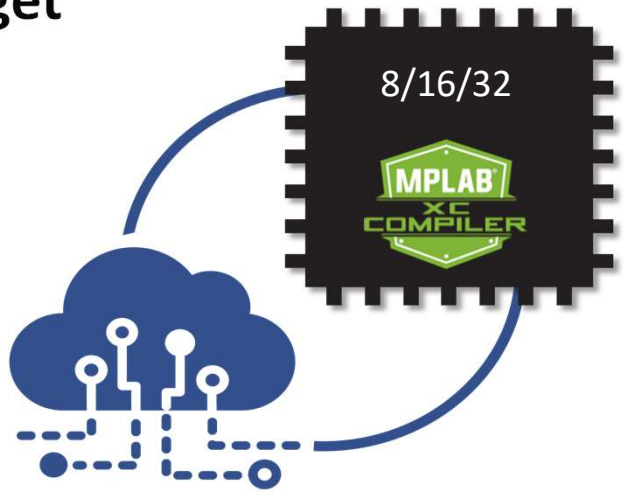
- **Example for Vibration Analysis**
  - Heavily focussed on Frequency
    - Dominant
    - MFCC
    - MFE
    - Peak frequencies
    - Power Spectrum
  - Amplitude
    - Global Peak to Peak
- **Good starting point for designs**
  - Or create your own pipeline



Deploying the Model

Model Deployment

- **The model exists in the cloud**
  - Mathematical filters
  - Transformations
  - Python code
- **Needs to be converted to run on Embedded Target**
  - Converting precision
    - Doubles->char or int
    - Possibly involving regeneration
  - Convert language
    - Python to ‘C’ library
    - Account for architecture (8/16/32bit)
- **Implement calls to model**
  - Integrate it into your code



MICROCHIP

Silicon Platforms for ML Edge

Smart Embedded Vision
High performance video
- Real time / near real time
- High frame rate / large image size
- Multiple input streams
- Simultaneous multiple DNNs

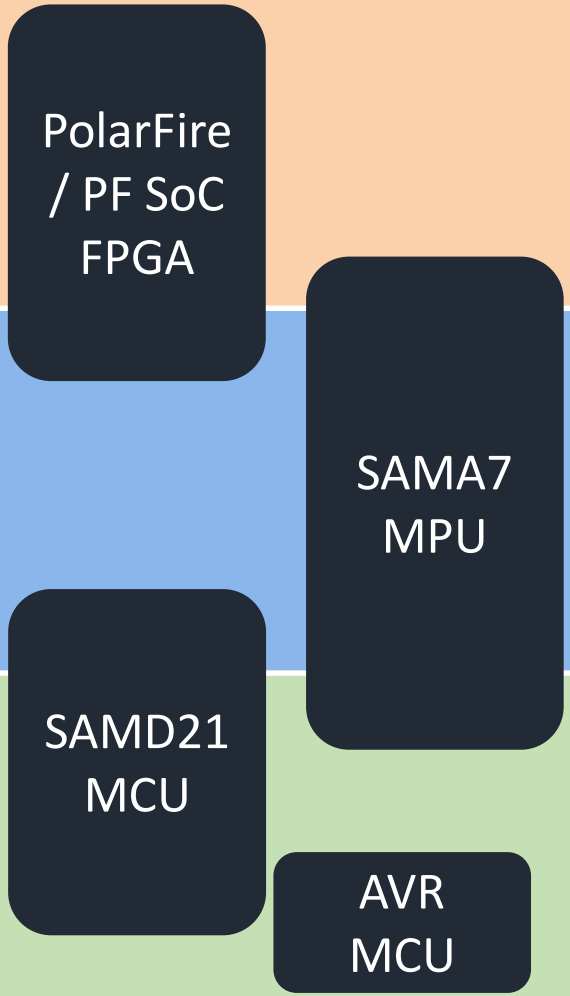
Input sensors / data
Camera: Upto 4 interfaces
MIPI, parallel, HDMI
Mic: Multiple audio streams
Additional sensors

Smart HMI
- Visual / audio / touch / gesture
- Recognition and interaction
- Single stream

Input sensors / data
Camera: MIPI, parallel, USB
Mic: Multiple audio streams
Touch surface

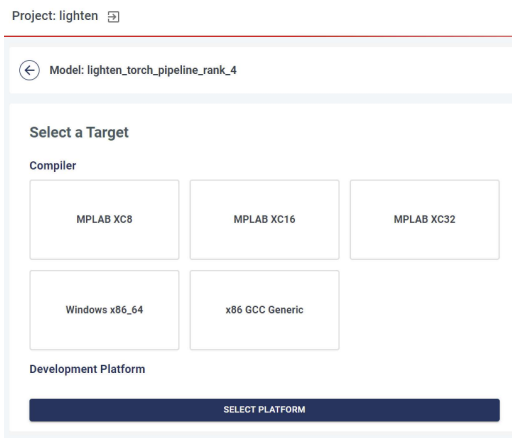
Smart Predictive Maintenance
- Time series / linear sensor data
- Simultaneous, multiple sensor
- Variety of sensor type supported

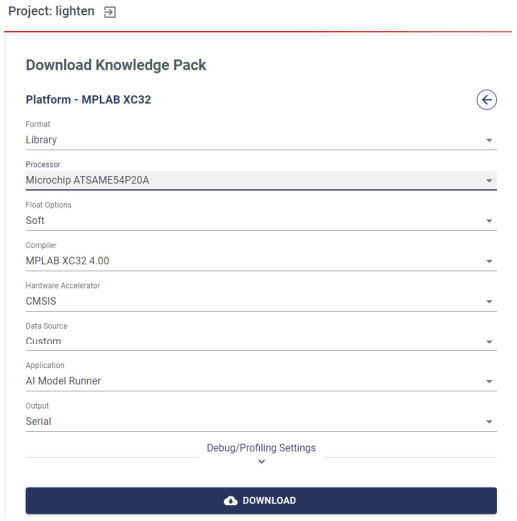
Input sensors / data
IMU (Inertial Measurement Unit)
Temp, Current, Pressure
Mic: Audio Stream



Deploying

- **Select the optimal pipeline**
  - That achieves your desired performance
  - Verify the results with test data
    - Take more samples
- **Select your compiler target**
  - Select the processor
- **Create and download the knowledge pack**
  - zip file
    - Library (libmplabml.a)
    - Header files (6)
  - Source output is possible
    - Separate License
- **For this demo only 3 function calls needed**
  - kb_model_init()
  - kb_reset_model()
    - called after every run of the model
  - kb_run_model()
    - add new data to the model and classify it





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Obrigado !!!