MPLAB Machine Learning Development Suite
AIML1001 v1.1

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

CAE Taiwan
Microchip Technology Inc.
2025 March

SMART | CONNECTED | SECURE

Class Objectives

- **Before this class:**
  - Basic C programming language design skills
- **When you finish this course, you will be able to:**
  - The basic information to implement AI/ML at the edge.
  - Be familiar with MPLAB Machine Learning Model Builder.
  - Enable to configure and deploy model on small processors.
- **You won’t be able to learn:**
  - Making you an Artificial Intelligence/ML expert.
  - Build a Large language model.

Agenda (1/2)

- Software Prerequisite and Installation
- Hardware Prerequisite
- What is Artificial Intelligence ?
- Why Edge AI ?
- MPLAB® Data Visualizer
  - 🛠 Lab0 Data Visualizer for 6DOF Sensor data
- Set Goal and Problem Identification
  - 🛠 Lab1 Initial Setup
- Data Logging and Upload
  - 🛠 Lab1 Data Collecting
- Labeling and Prepare Data
- MPLAB® Machine Learning Development Suite
  - 🛠 Lab2 Data Labeling and Preparation

Agenda (2/2)

- **Model Pipeline and Training**
  - 🛠 Lab3 Model Pipeline
  - 🛠 Lab3 Training
- **Model Evaluation and Deploy**
  - 🛠 Lab4 Model Evaluation
  - 🛠 Lab4 Model Deploy
- **Knowledge Pack, Main Flow, and State Machines**
- **Summary**
- **Appendix**
  - Install the ML Data Collector & ML Model Builder
  - Create and Login MPLAB ML Account
  - Porting Deploy Model to Custom Project
  - JSON Decoder helper Library
  - Large Language Models

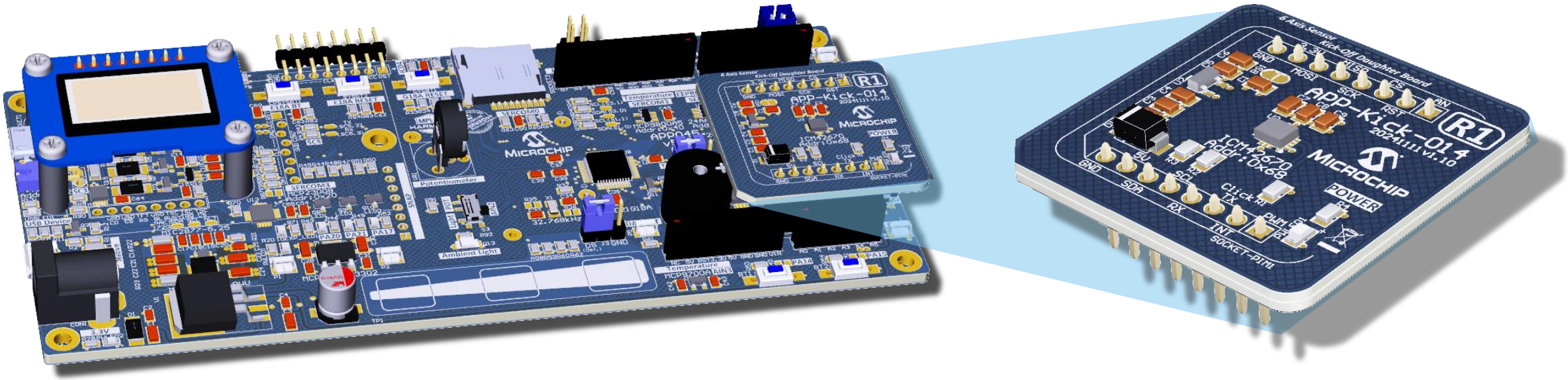
Software Prerequisite and Installation

- **MPLAB® X IDE v6.20** https://www.microchip.com/mplab/mplab-x-ide
- **MPLAB® XC32 v4.45** https://www.microchip.com/mplab/compilers
- **SAMD21 DFP v3.6.144 (Device Family Pack download from X IDE Tools Packs)**
- **CMSIS v6.1.0 (Common Microcontroller Software Interface)**
- **MPLAB® Data Visualizer v1.3.1677**

  (Embedded with MPLAB X IDE v6.20, upgrade is necessary)
- **MPLAB® ML Model Builder v1.1 (Customer install in Plugin of MPLAB X IDE)**
- **MPLAB® ML Data Collector v1.2 (Customer install in Plugin of MPLAB X IDE)**
- **Apply "myMicrochip" account (Register in ML Model Builder after installed)**

Hardware Prerequisite

- **APP045 v5.0 R2 EV Board with SAMD21**
- **APP-Kick-014 the Accelerometer and Gyroscope (6DOF) daughter board**
- **Micro USB cable x 1**
- **On-Board Debugger** **(APP045 v5.0 R2 available)**



MICROCHIP

What is Artificial Intelligence ?

Artificial Intelligence and Machine Learning

1950

Turing Test

1956

Scientific Conference

2016 AlphaGo

2022

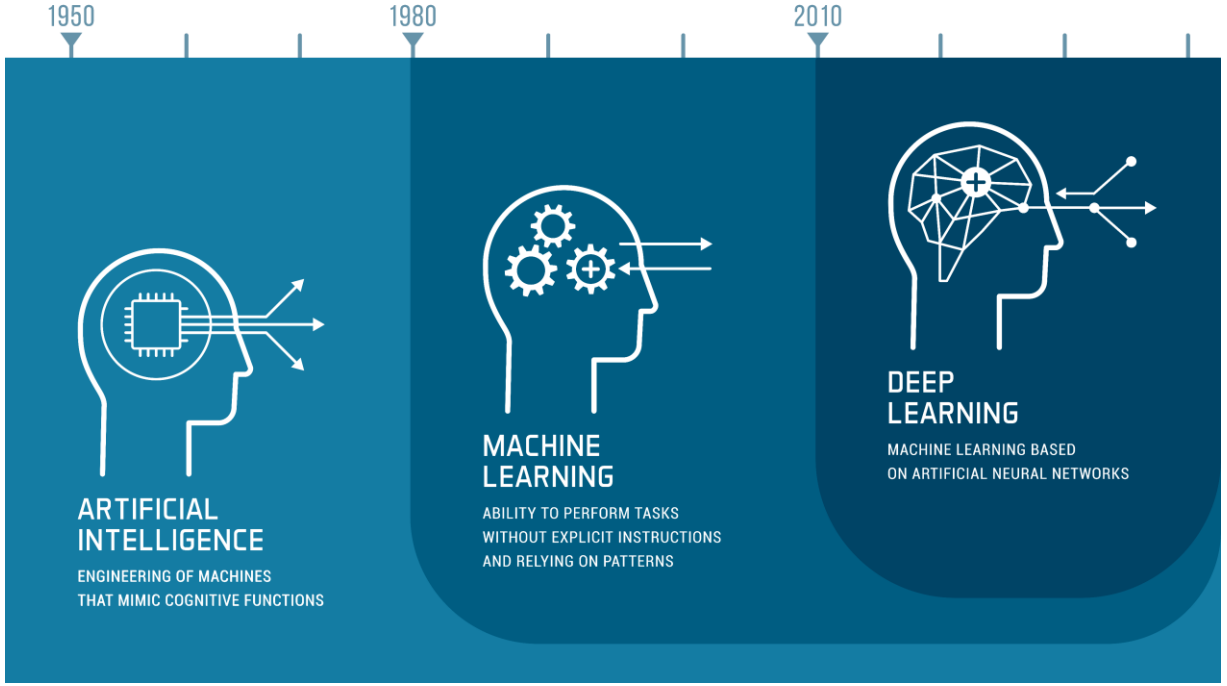
ChatGPT

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.kkbox.com%2Ftw%2Ftc%2Fplaylist%2F4r37sH_49kvNiO5yhX&psig=AOvVaw1MRhXzKnfyYw8JNI4NEnAr&ust=1721092820634000&source=images&cd=vfe&opi=89978449&ved=0CBEQjRxqFwoTCKCm29bwp4cDFQAAAAAdAAAAABAJ
https://www.google.com/url?sa=i&url=https%3A%2F%2Fmedium.com%2F%40shinyagrey%2F%25E4%25BA%25BA%25E6%25A9%259F%25E5%25B0%258D%25E5%25BC%2588%25E4%25B9%258B%25E5%25A4%2596%25E7%259A%2584%25E6%2594%25B6%25E7%25A9%25AB-alphago-%25E7%25B4%2580%25E9%258C%2584%25E7%2589%2587%25E8%25A7%2580%25E5%25BE%258C%25E6%2584%259F-4b1672a25cd9&psig=AOvVaw31gSxo6vURLrHmTKBzoPE-&ust=1732946827646000&source=images&cd=vfe&opi=89978449&ved=0CBQQjRxqFwoTCOC_nJTwgIoDFQAAAAAdAAAAABAE

MICROCHIP

AI, ML and DL

- **AI (Artificial Intelligence):** technology that enables computers and machines to simulate human intelligence and problem-solving capabilities.
- **ML (Machine Learning):** a type of artificial intelligence (AI) focused on building computer systems that learn from data.
- **DL (Deep Learning):** a subset of machine learning that uses multi-layered neural networks, called deep neural networks, to simulate the complex decision-making power of the human brain.

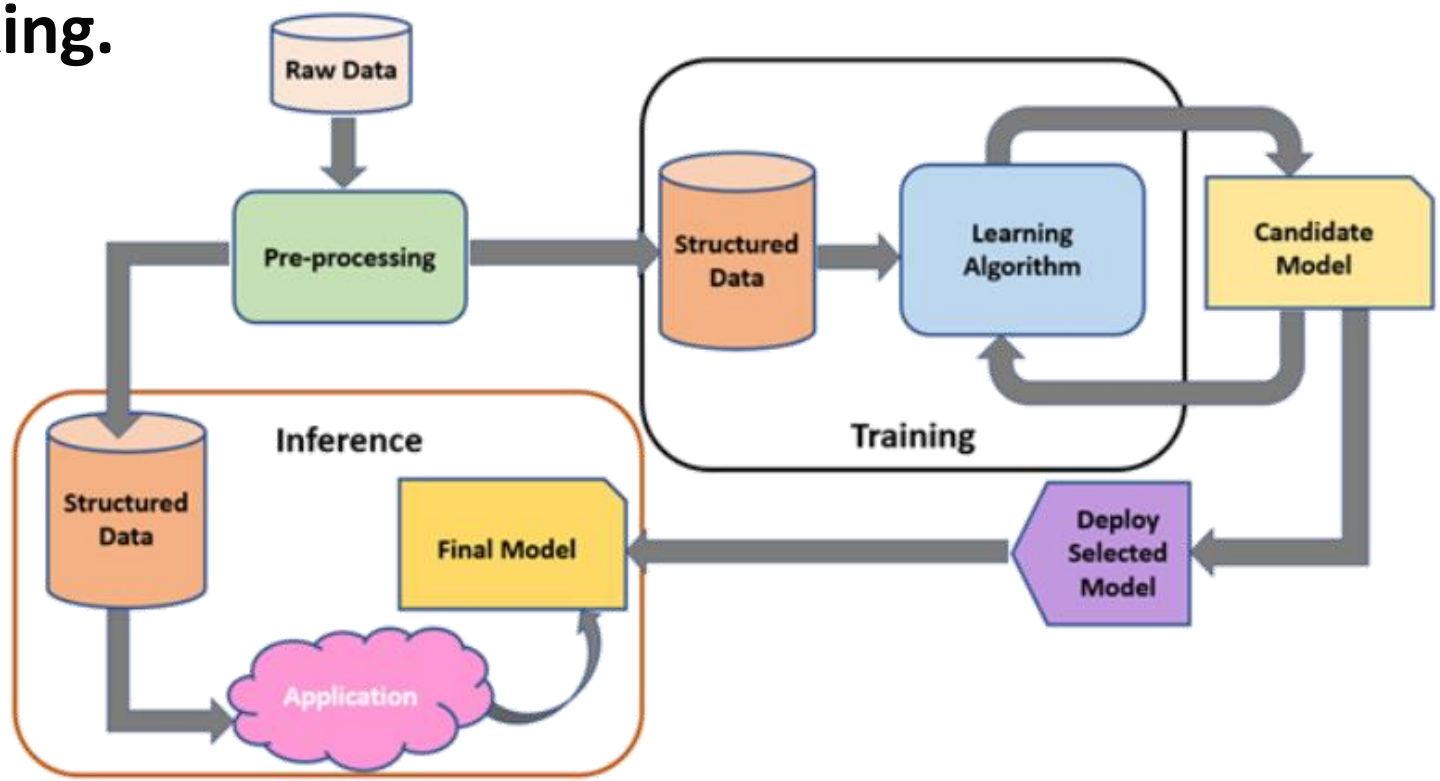


Why is it so popular now?

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

Machine Learning

- Machine learning (ML) is a technique of using computers to predict things based on past observations.
- A set of algorithmic methods that discovers patterns from seemingly unrelated data, providing you with important information to facilitate decision making.



4 kinds of Machine Learning

Supervised Learning

Give label and data

Give the standard answer while training.

Un-supervised Learning

Unlabeled data

Provide examples. Let computer find the underlying rules in the examples.

Semi-supervised Learning

Small amount of labeled data
+
Large amount of unlabeled data

Reinforcement Learning

Unlabeled data

Tell computer whether the steps are correct, the machine will modify by environment and experience.

https://www.youtube.com/watch?v=kopoLzvh5jY

MICROCHIP

Supervised Learning

Let’s take memorizing English words as an example….

Supervised Learning

By Flash Cards

Have clear answers and feedback.

Un-supervised Learning

By reading lots of book

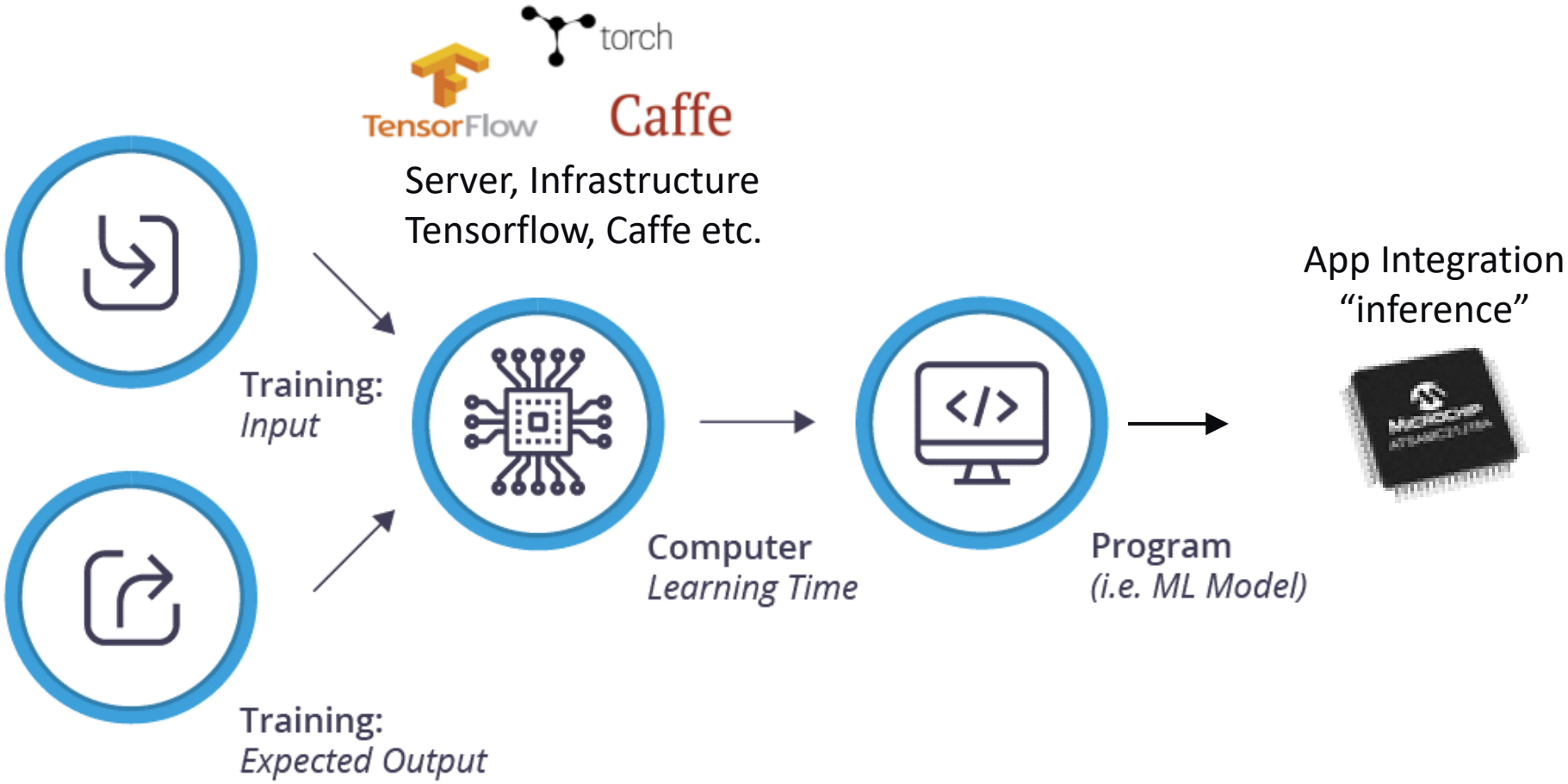
There is no clear answer, rely on your own discovery and understanding.

Semi-supervised Learning

By Prefix, Root, and Suffix

Combines known information with new learning.

How does Supervised Learning work?

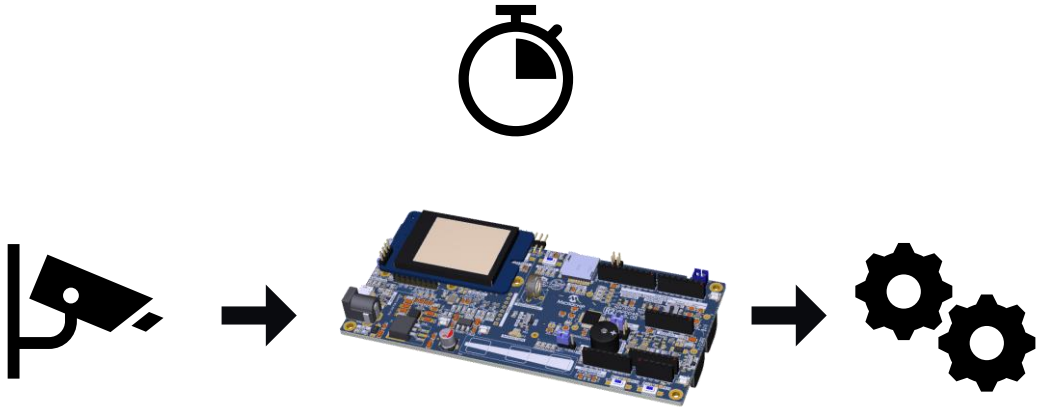


Why Edge AI ?

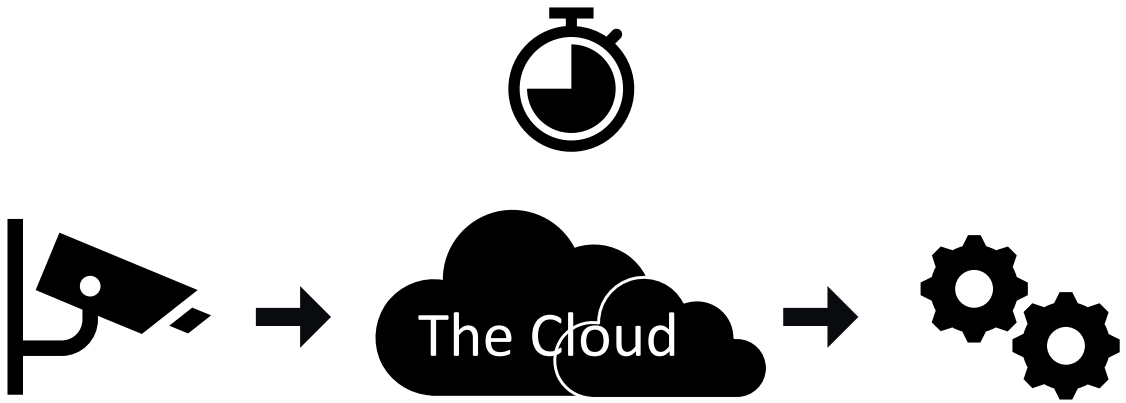
Differences between Edge computing & Cloud computing

- **Edge Computing:** The data is calculated directly on the local side. It can overcome the problem of data transmission delay and facilitate instant judgment and decision-making.
- **Cloud Computing:** Cloud computing is the delivery of computing services over the internet (the cloud).

Edge computing



Cloud computing



MICROCHIP

Why AI at the Edge?

- **Edge AI:** Execute the application of artificial intelligence algorithms on edge computing nodes such as embedded devices and sensors.
- **Edge is the location of Data Processing near the source of Data Generation**

Privacy and Security

Data stays on the device, gets processed locally.

Reduce Power Consumption

Stay operational for longer periods of time.

Real Time Operation

Process data real-time on the edge device, without having to wait for a response back from the cloud.

Reduce Cost

Save on compute costs, storage, and less communication.

ML Edge Applications

Smart Embedded Vision

Enhanced quality and productivity at factories

Machine assistance for faster, better

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

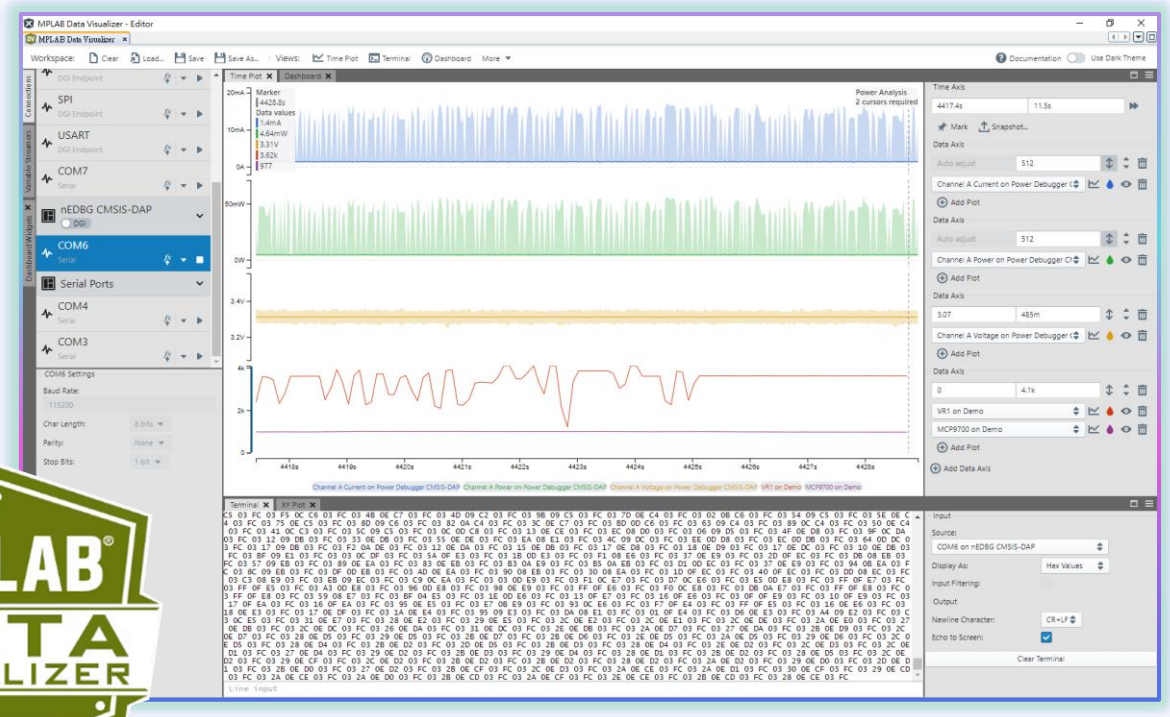
MICROCHIP

MPLAB® Data Visualizer

MICROCHIP

MPLAB® Data Visualizer

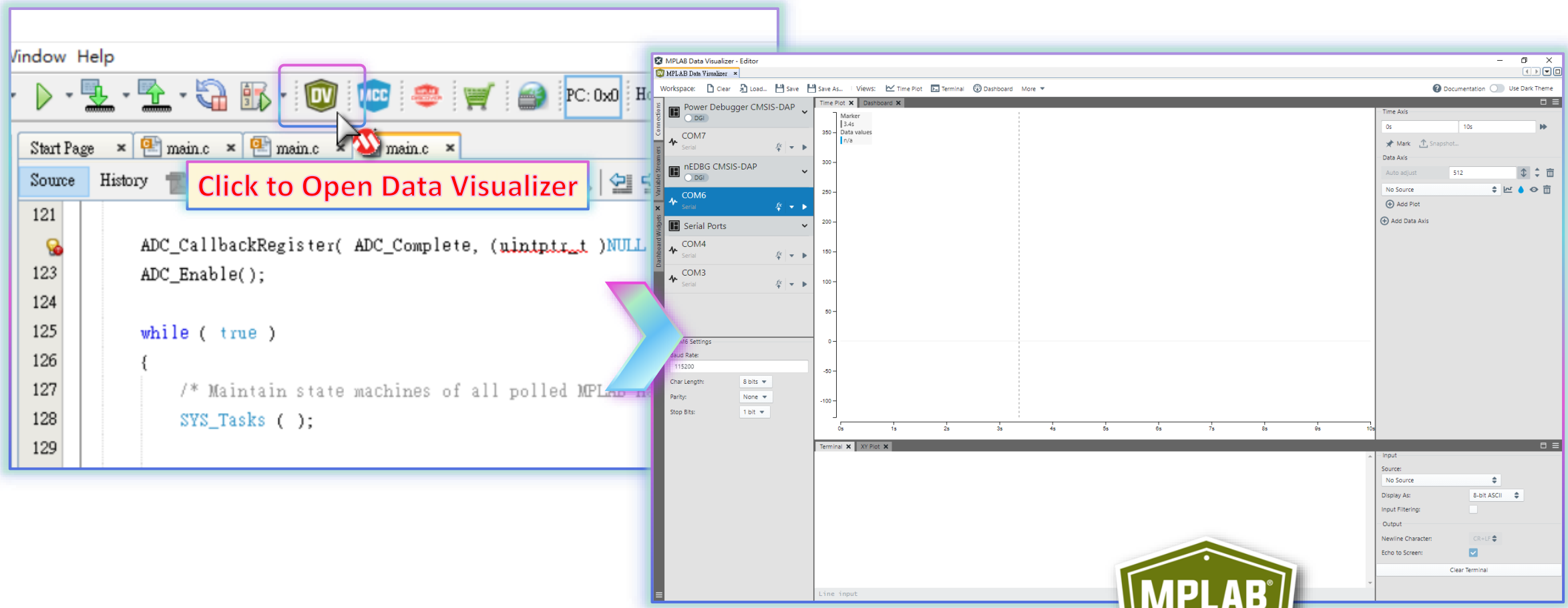
- MPLAB Data Visualizer is a program used for processing and visualizing data.
- It can receive data from various sources such as the DGI (Data gateway Interface) and COM ports.
- And has a graph plotter and an oscilloscope, a terminal and a configurable dashboard with buttons, sliders, and various indicators. It can decode protocols and log data to file.
- It‘s an MPLAB X IDE plugin and cross platform standalone application. It’s installed at X IDE right. don’t need do anything before use.



View Data Stream format for DV

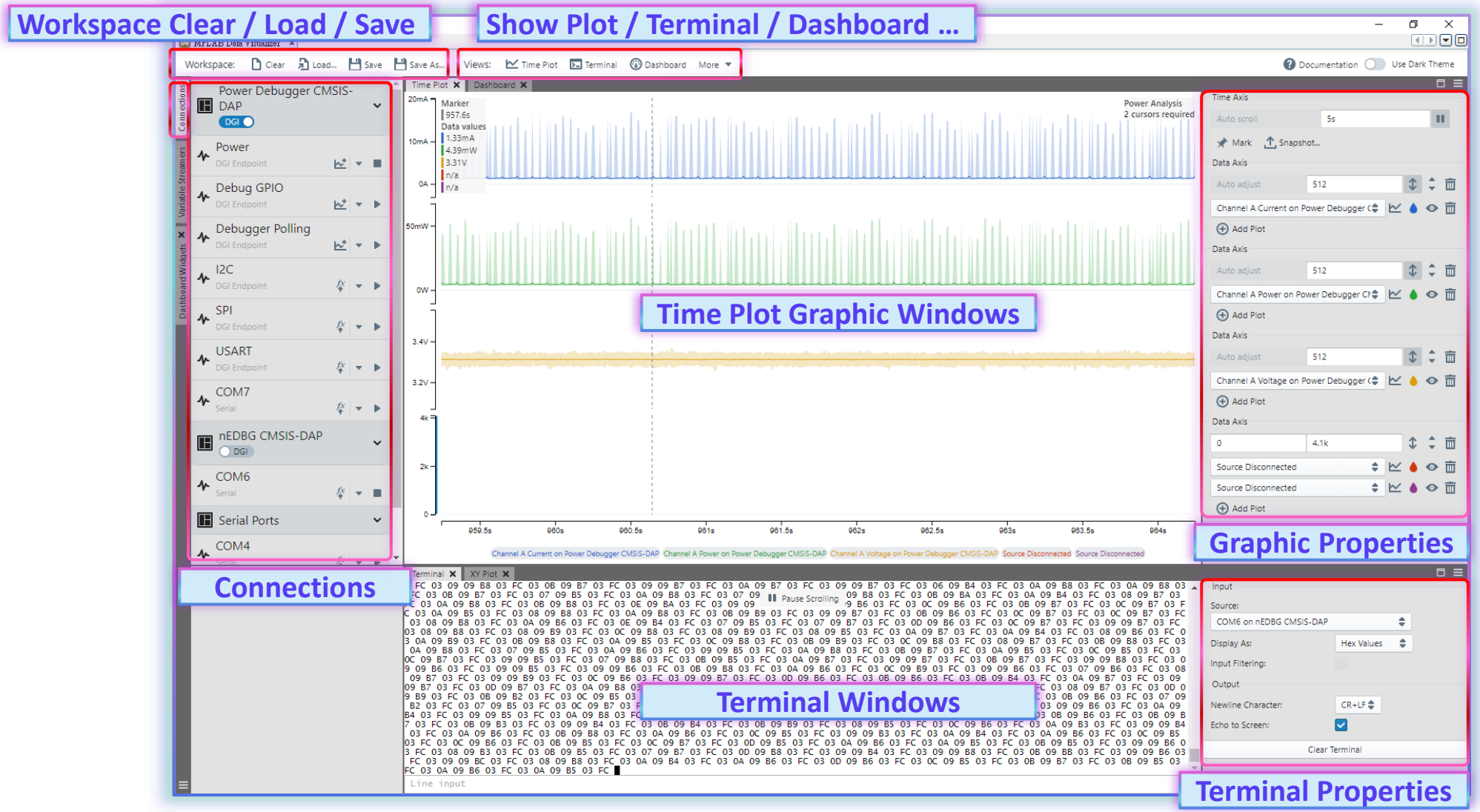
MPLAB® Data Visualizer

- To open MPLAB Data Visualizer. You can click icon in MPLAB X IDE.



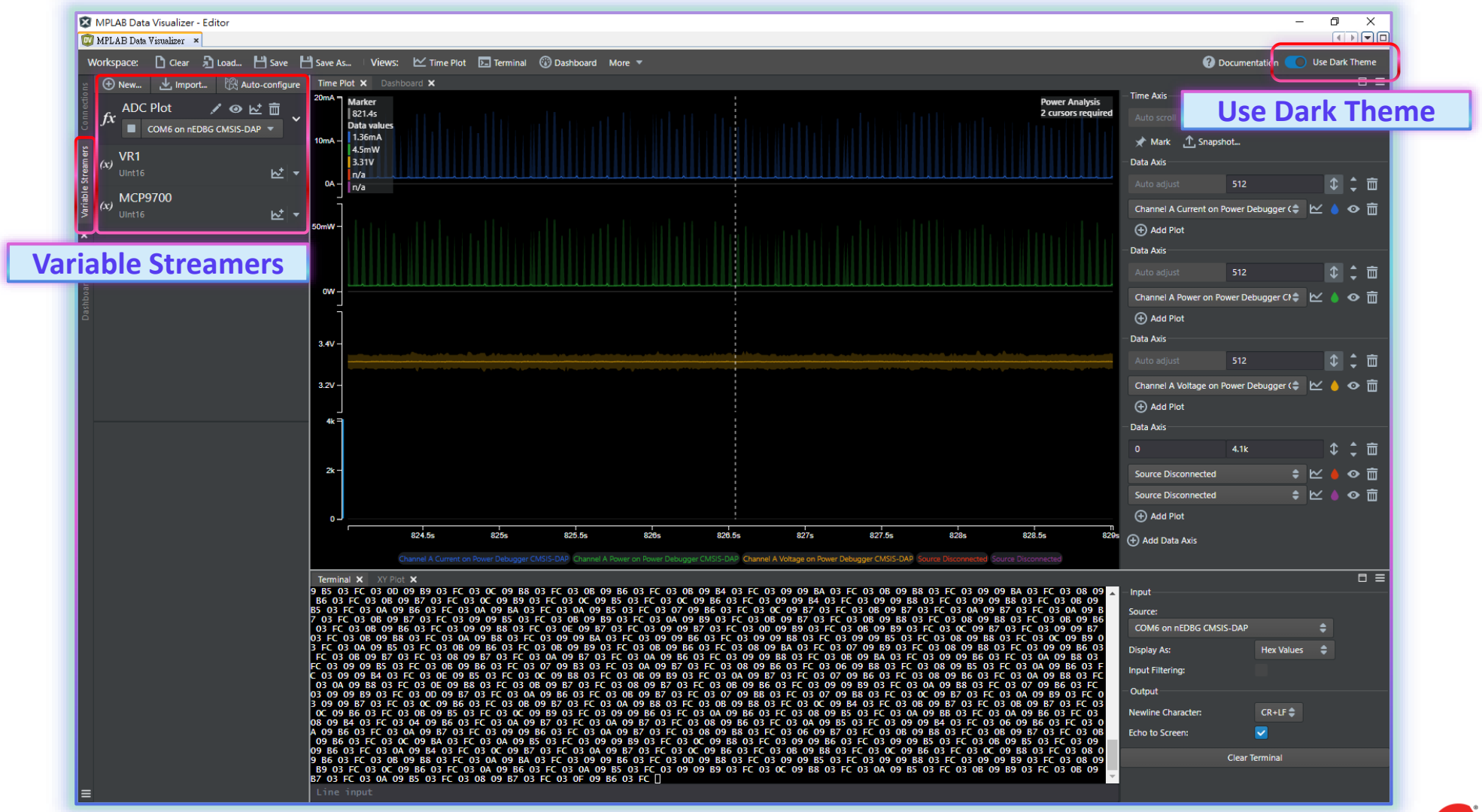
MPLAB® Data Visualizer

Workspace of MPLAB Data Visualizer



MPLAB® Data Visualizer

Variable Streamers and Dark Theme of MPLAB Data Visualizer



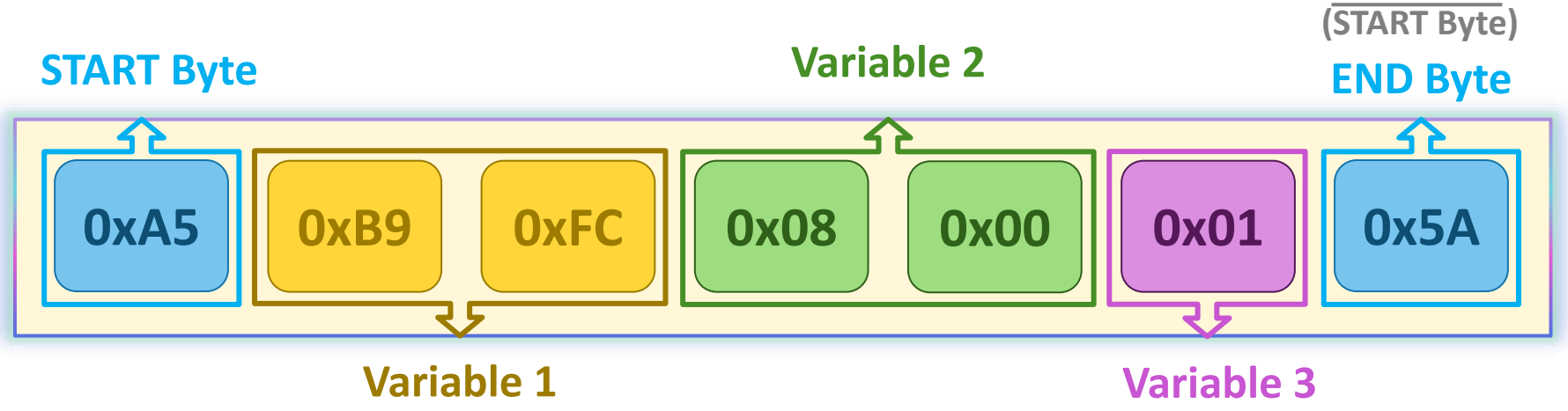
MICROCHIP

MPLAB® Data Visualizer

Data Stream Format for DV

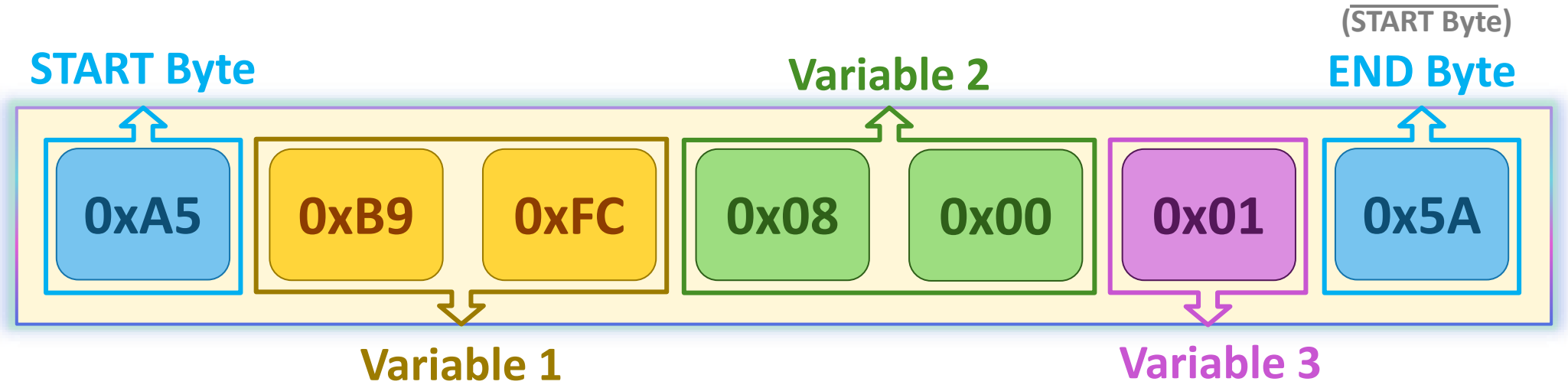
- **The Data Stream Format is processed in the same order as the variables specified in the Variable Streamer.**
  - Data must be given as little-endian values.
  - The start byte can be arbitrary, but the end byte must be the inverse of the Start byte.

Type	Size (Bytes)
int8	1
int16	2
int32	4
uint8	1
uint16	2
uint32	4
float32	4
float64	8



MPLAB® Data Visualizer

Data Stream Format for DV



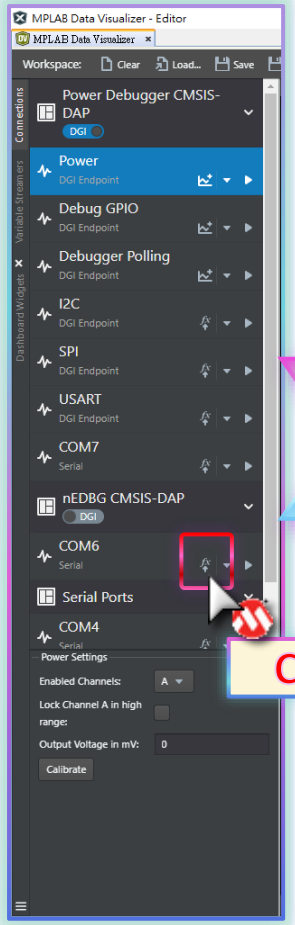

```
printf("%c%c%c%c%c%c%c",
        0xA5,
        variable[0] & 0xff, (variable[0]>>8) & 0xff,
        variable[1] & 0xff, (variable[1]>>8) & 0xff,
        BT1_Get() & 0x01,
        ~(0xA5));
```

MICROCHIP

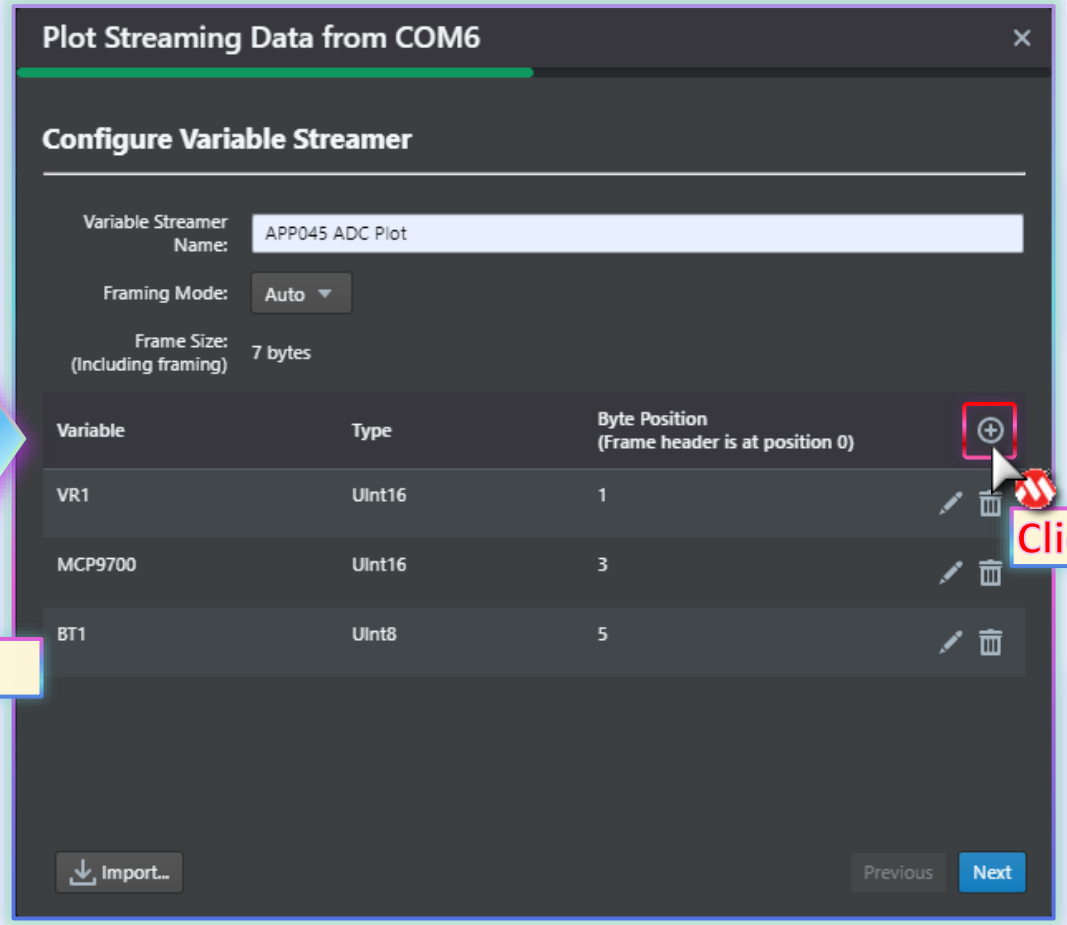
MPLAB® Data Visualizer

Data Streamer Setting

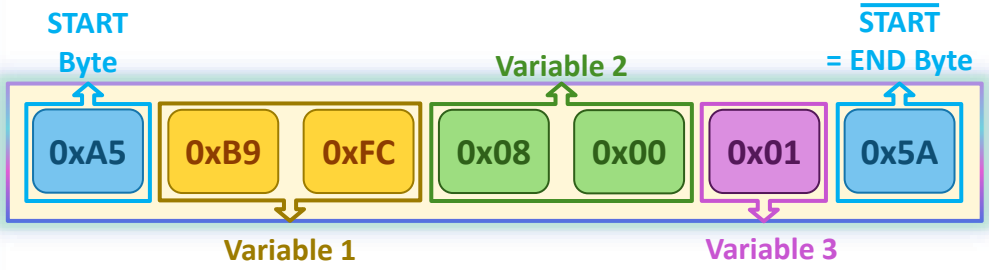
- **The correspond format of Data Streamer must be setting at MPLAB Data Visualizer.**



Click



Click to add Variable

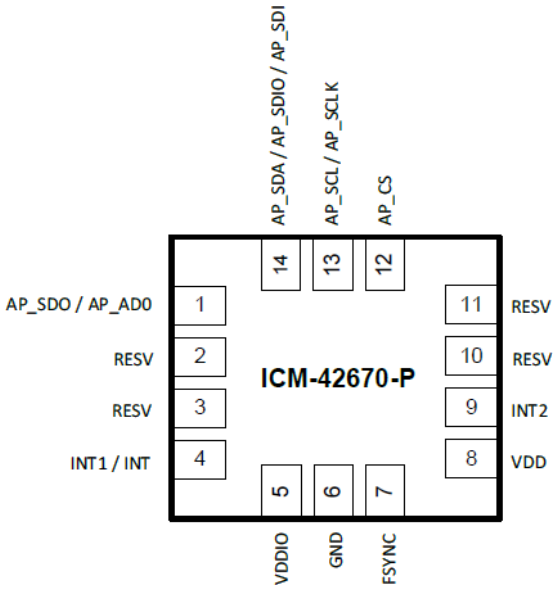


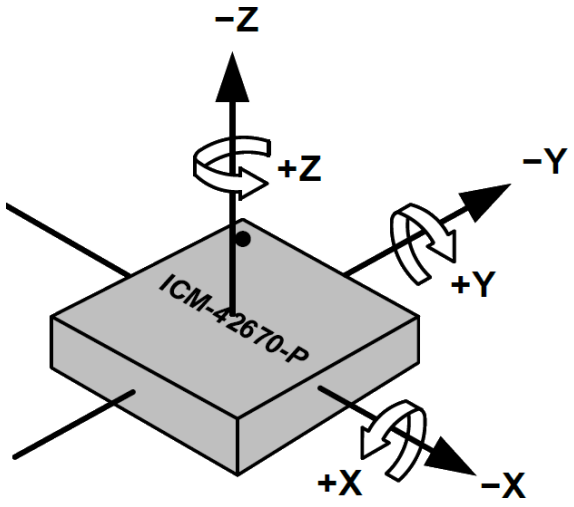

```
printf("%c%c%c%c%c%c%c",
                0xA5,
                variable[0] & 0xff, (variable[0]>>8) & 0xff,
                variable[1] & 0xff, (variable[1]>>8) & 0xff,
                BT1_Get() & 0x01,
                ~(0xA5));
```

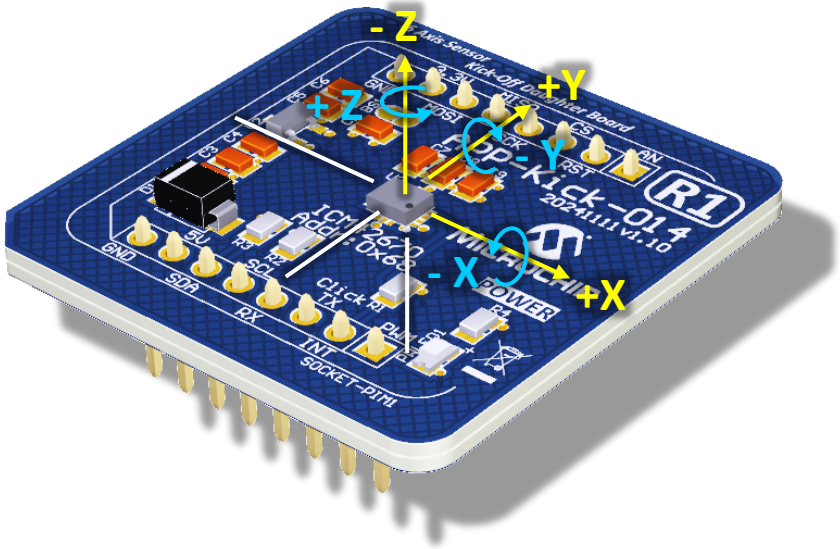
MICROCHIP

APP-Kick-014 6DOF Motion Sensor Board (TDK ICM-42670P)

- The APP-Kick-014 is design for 6DOF (Degree Of Freedom) Motion Application.
- The TDK ICM-42670-P is a high performance 6-axis MEMS MotionTracking™ device that combines a 3-axis gyroscope and a 3-axis accelerometer.
- It has a configurable host interface that supports I3CSM, I2C, and SPI serial communication, features up to 2.25 Kbytes FIFO and 2 programmable interrupts with ultra-low-power wake-on-motion support to minimize system power consumption.

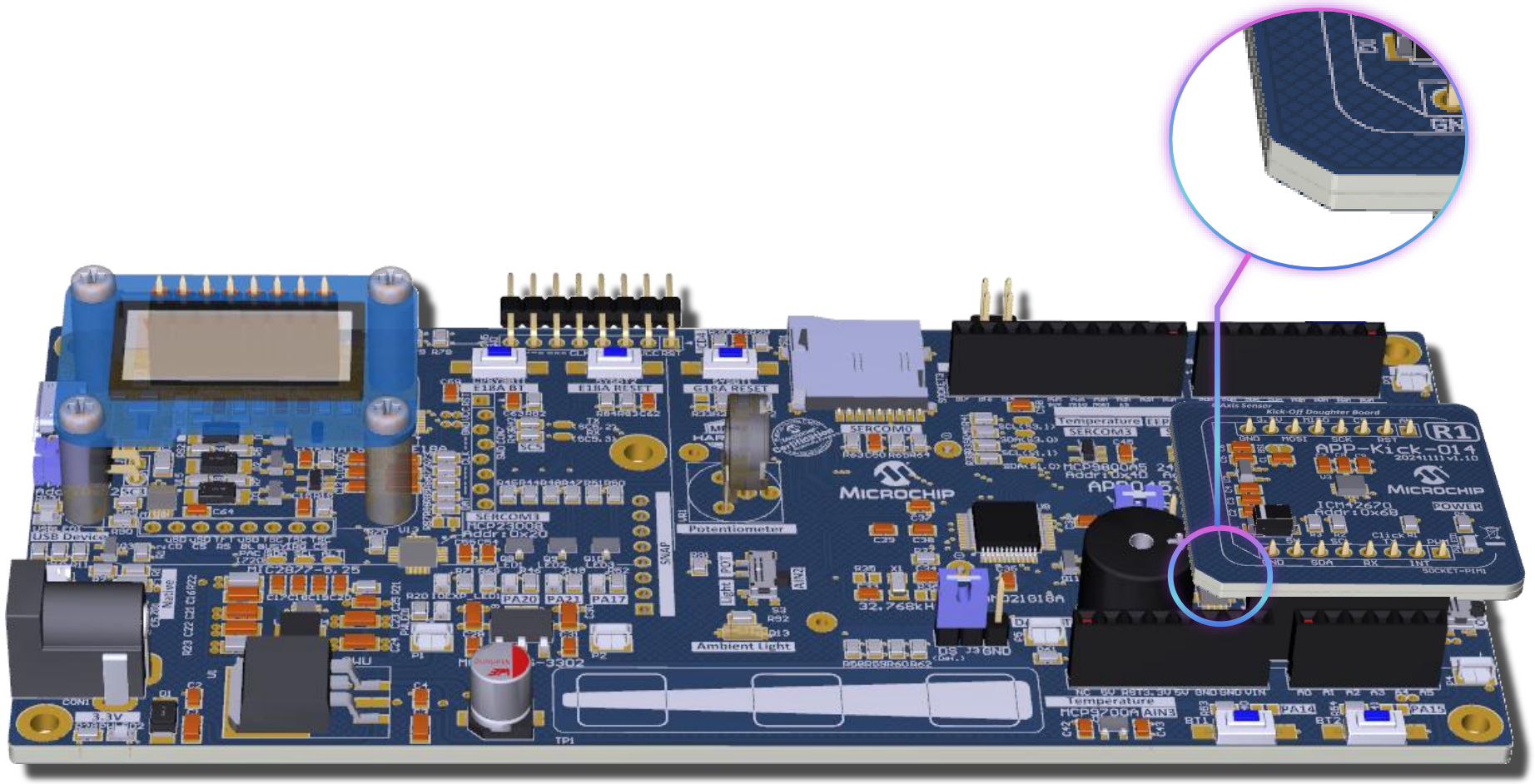






MICROCHIP

APP045 and APP-Kick-014 Assembly



MICROCHIP

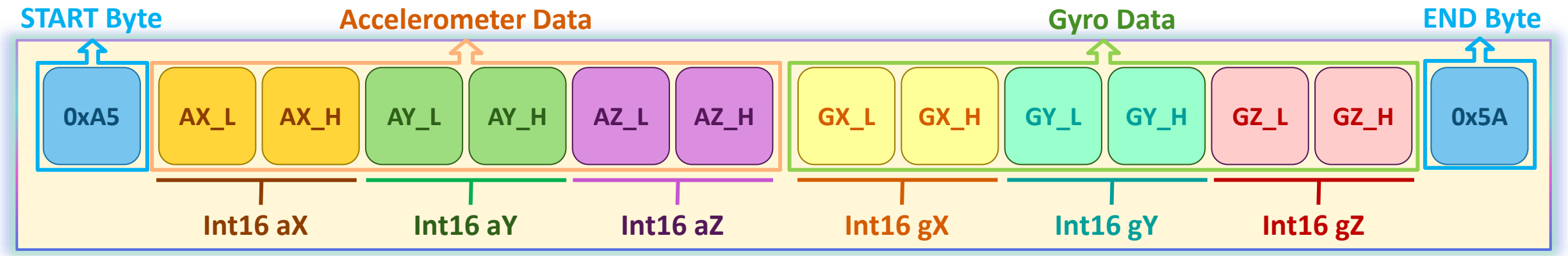
🛠 Lab 0
Data Visualizer for 6DOF Sensor data

Boxing Recognition by Machine Learning

MICROCHIP

🛠 Lab0 Data Visualizer for 6DOF Sensor data

- Try using MPLAB Data Visualizer to view Gyro and Accelerometer data from the 6-axis motion sensor ICM-42670P.
- You will need to disable the UART messaging you did in the previous Lab and add the new DV protocol as below.
- Load pre-stored DV workspace file to quick config DV's Time Plot.



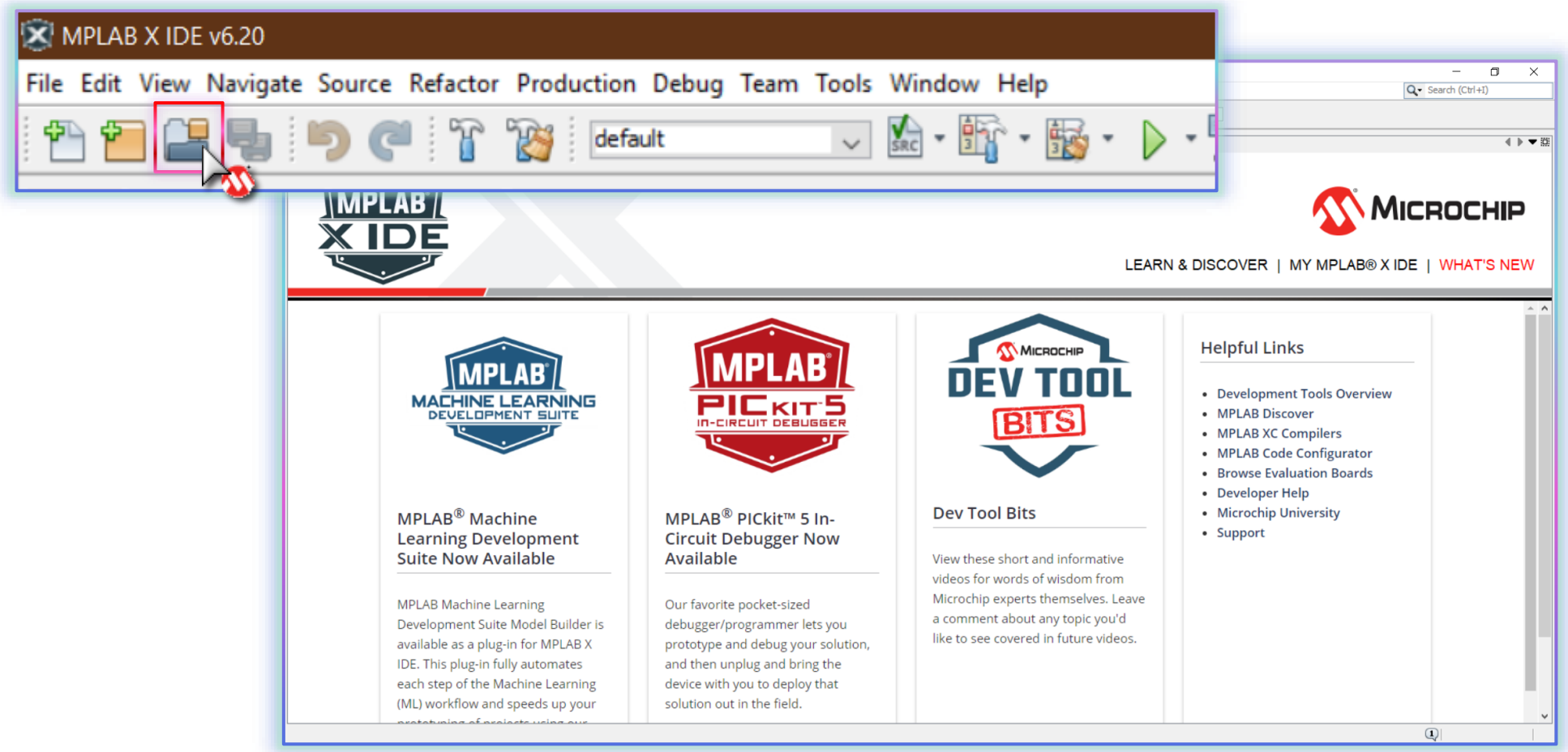
Let's go!

MICROCHIP

🛠 Lab0 Data Visualizer for 6DOF Sensor data

Step 1

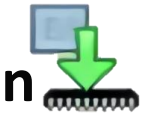
- Open “\AIML1001\Lab0_6DOF_Data_Visualizer\Lab0_6DOF_Data_Visualizer.X” .

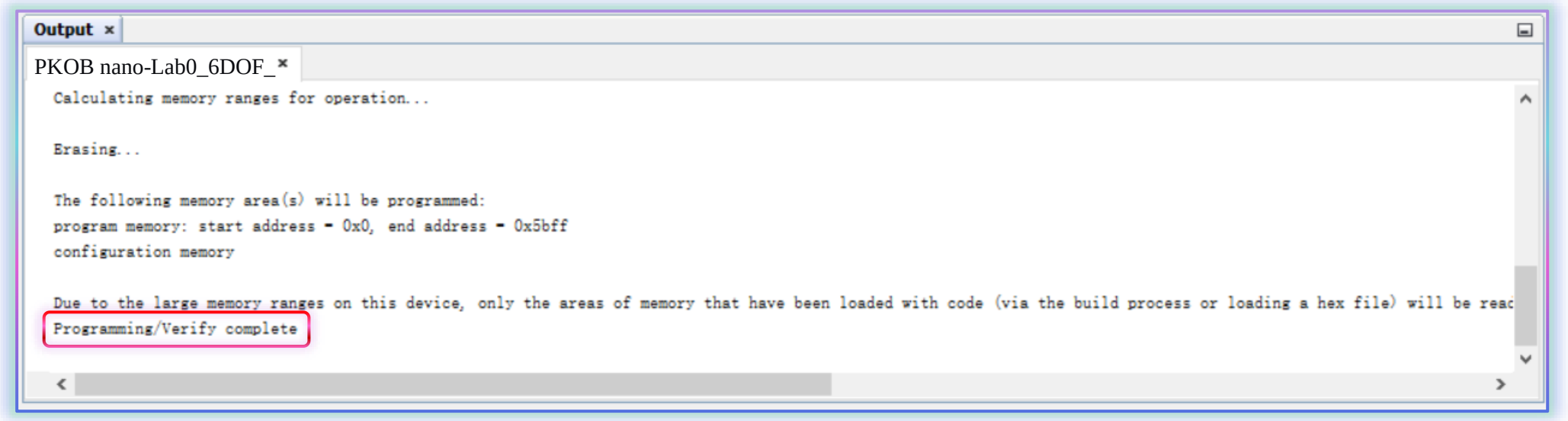


MICROCHIP

🛠 Lab0 Data Visualizer for 6DOF Sensor data

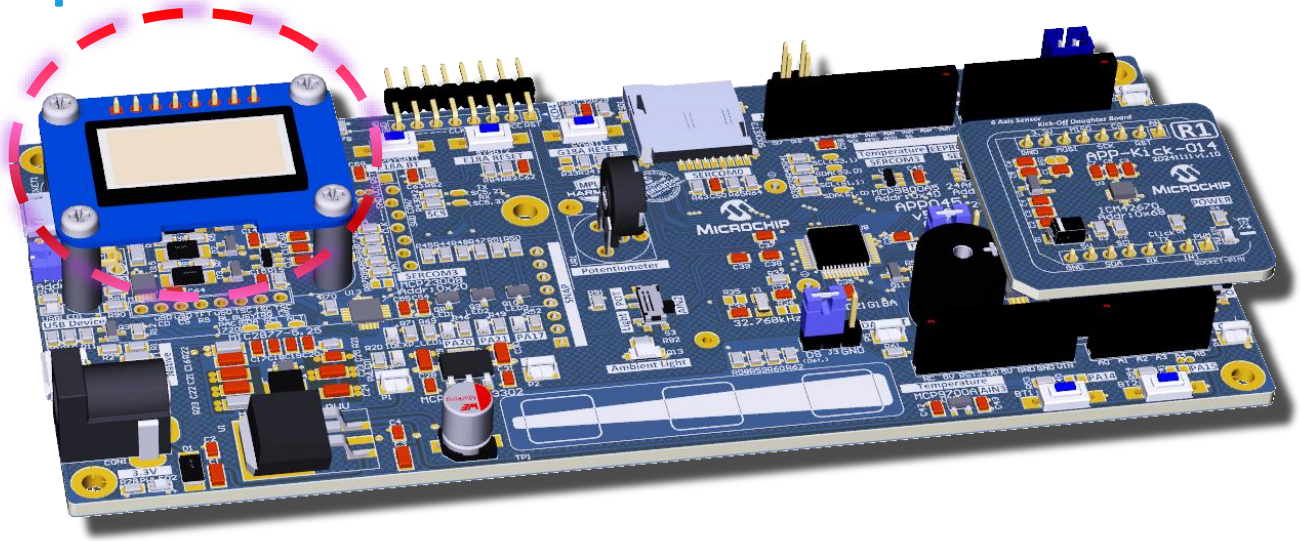
Step 2

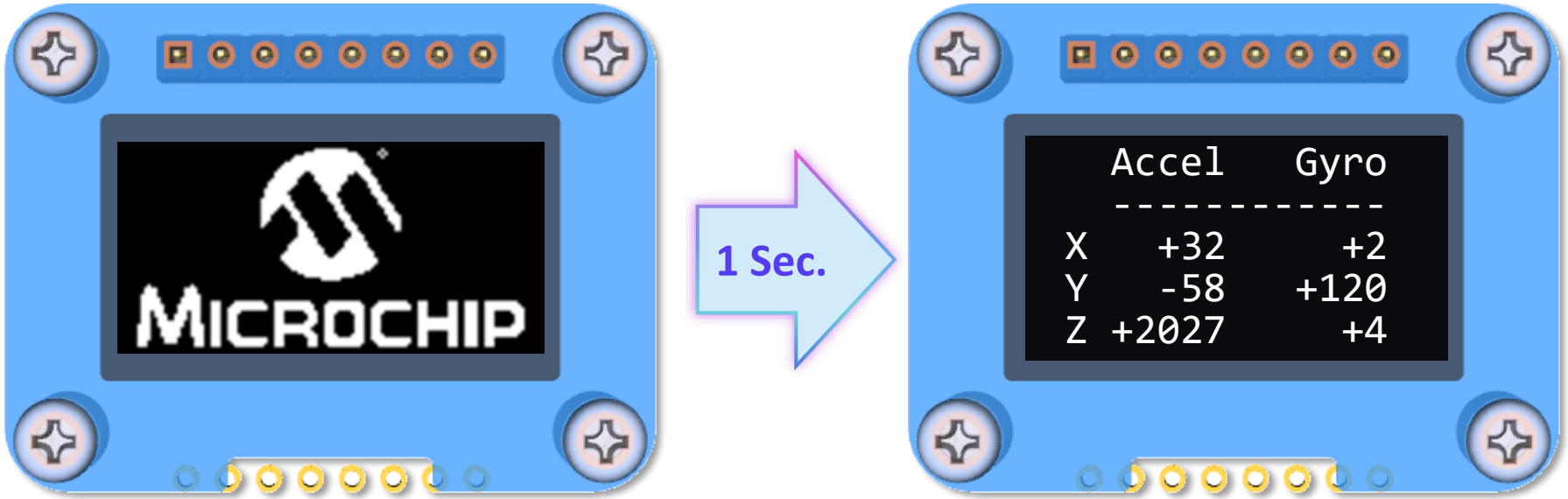
- Click on icon and select **Clean and Build Project** to compiler your project.
- Click on icon  to **Mark and Program** to EVB and check if any fault while Programming.
- Output Window will show ***Programming/Verify Complete***.



🛠 Lab0 Data Visualizer for 6DOF Sensor data

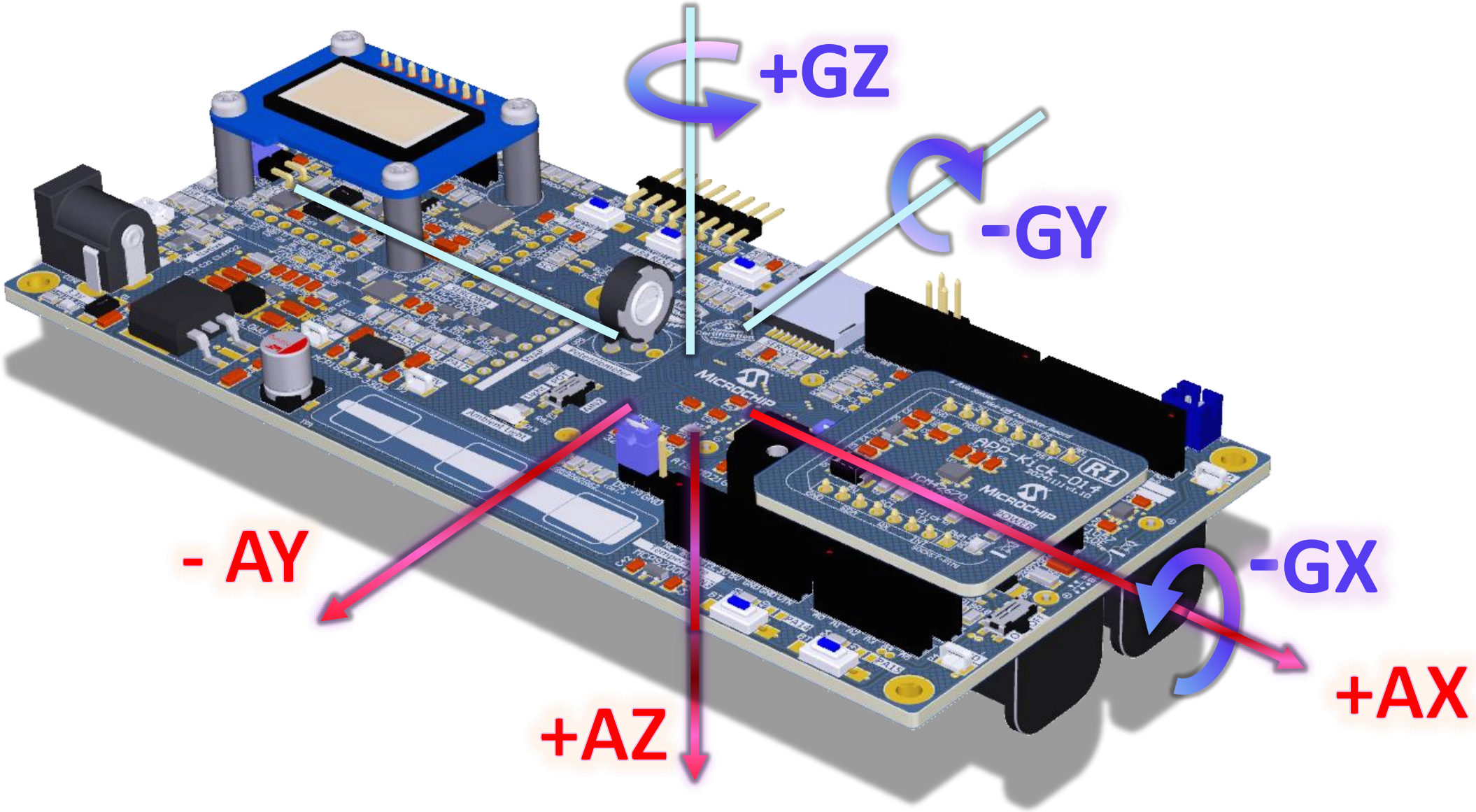
OLED Sensor Data Output





MICROCHIP

The Sensor Axis of APP045 and APP-Kick-014



MICROCHIP

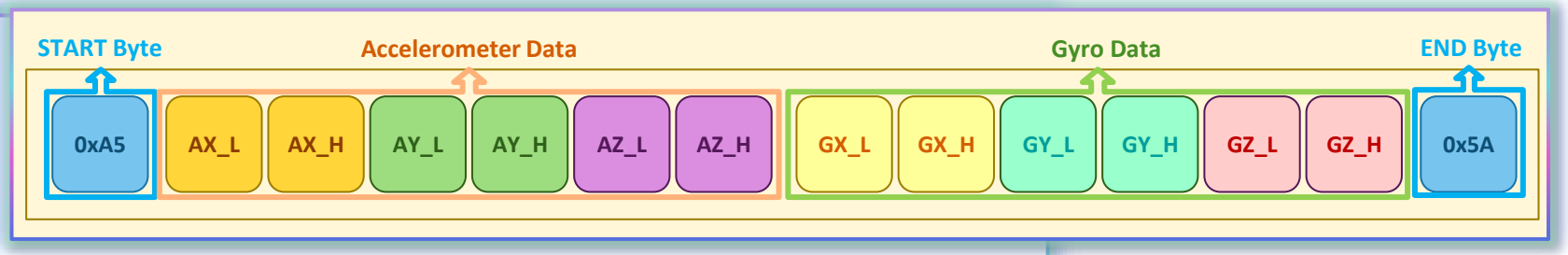
🛠 Lab0 Data Visualizer for 6DOF Sensor data

Step 3

- Find TODO 0.01 and modify the #if 1 to #if 0 at Line 212.

Line 212

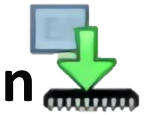
```
int main (void)
{ …
  while ( true )
  { …
// TODO 0.01
#if 0
            sprintf((char *) USARTRTxBuffer, "    Accel    Gyro" );
            LCM_DrawString(0, 0, (char *) USARTRTxBuffer);
            …
#else
            sprintf( USARTRTxBuffer,
                     "%c%c%c%c%c%c%c%c%c%c%c%c%c%c",
                     0xA5,
                     AxisOutByte_Accel[1], AxisOutByte_Accel[0],
                     AxisOutByte_Accel[3], AxisOutByte_Accel[2],
                     AxisOutByte_Accel[5], AxisOutByte_Accel[4],
                     AxisOutByte_Gyro [1], AxisOutByte_Gyro [0],
                     AxisOutByte_Gyro [3], AxisOutByte_Gyro [2],
                     AxisOutByte_Gyro [5], AxisOutByte_Gyro [4],
                     ~(0xA5));
            SERCOM5_USART_Write( USARTRTxBuffer, 14 );
#endif
```

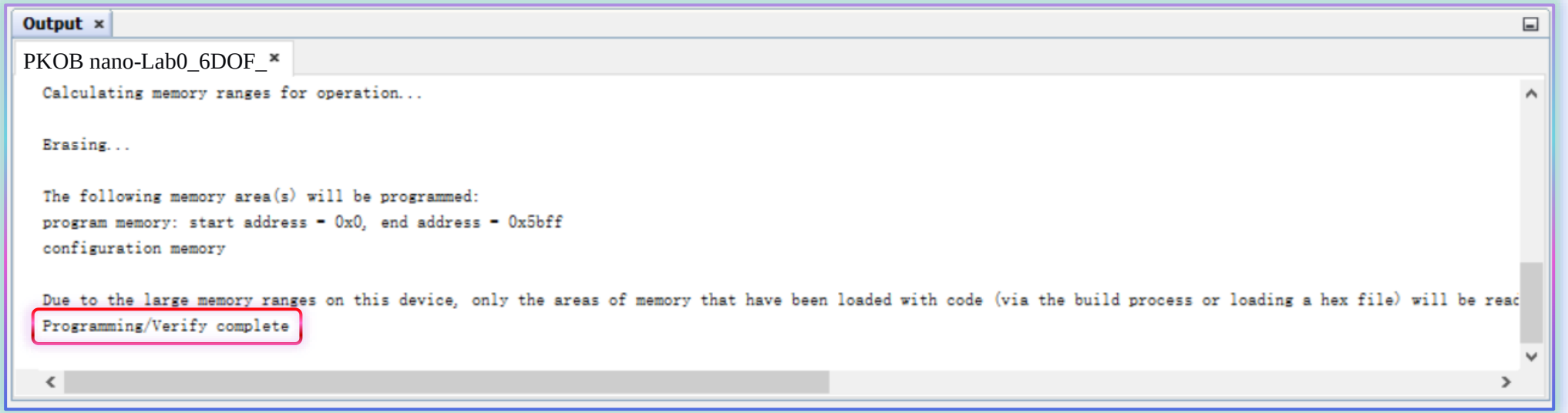


MICROCHIP

🛠 Lab0 Data Visualizer for 6DOF Sensor data

Step 4

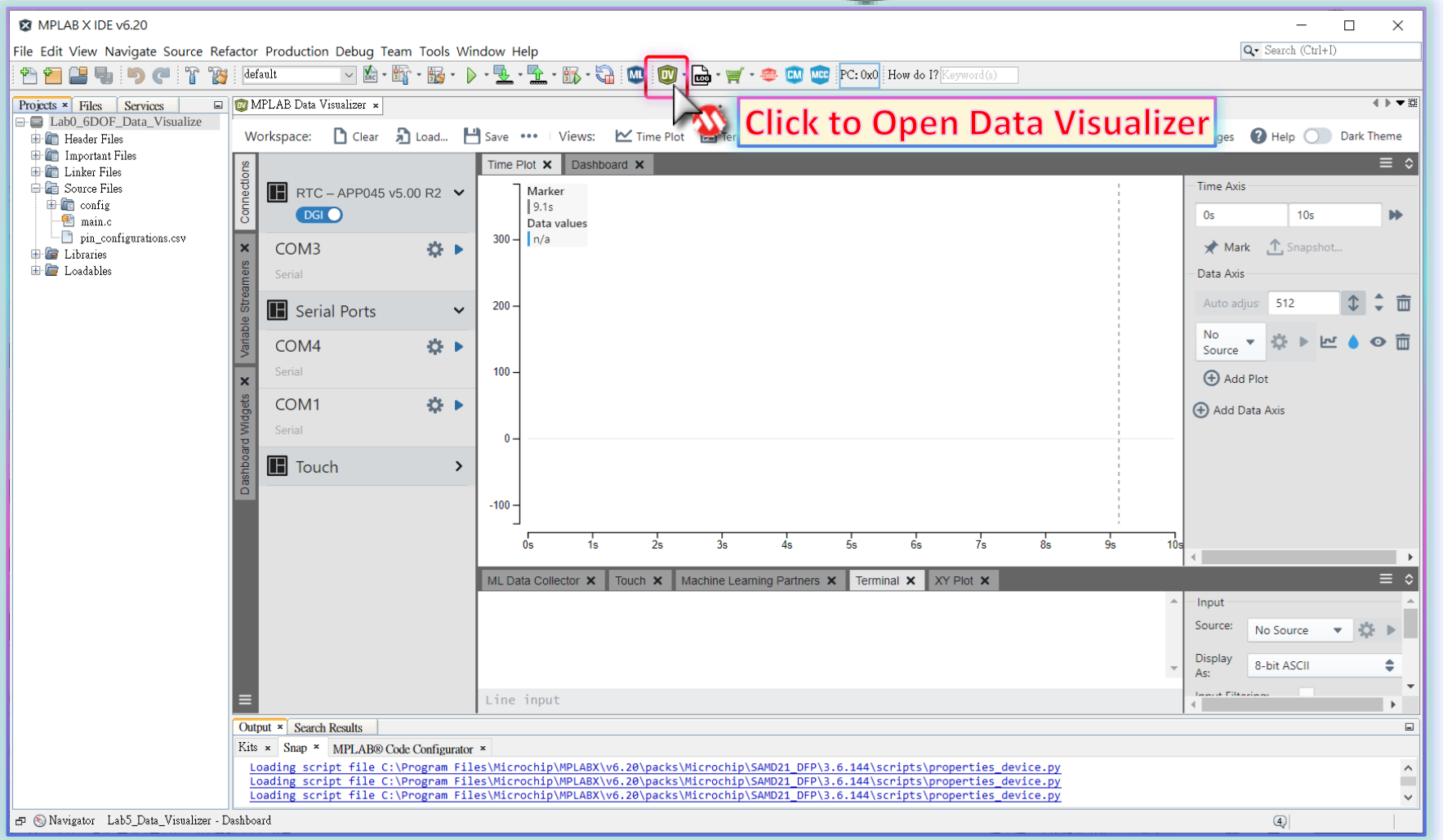
- Click on icon and select Clean and Build Project to compiler your project.
- Click on icon  to Mark and Program to EVB and check if any fault while Programming.
- Output Window will show *Programming/Verify Complete*.



🛠 Lab0 Data Visualizer for 6DOF Sensor data

Step 5

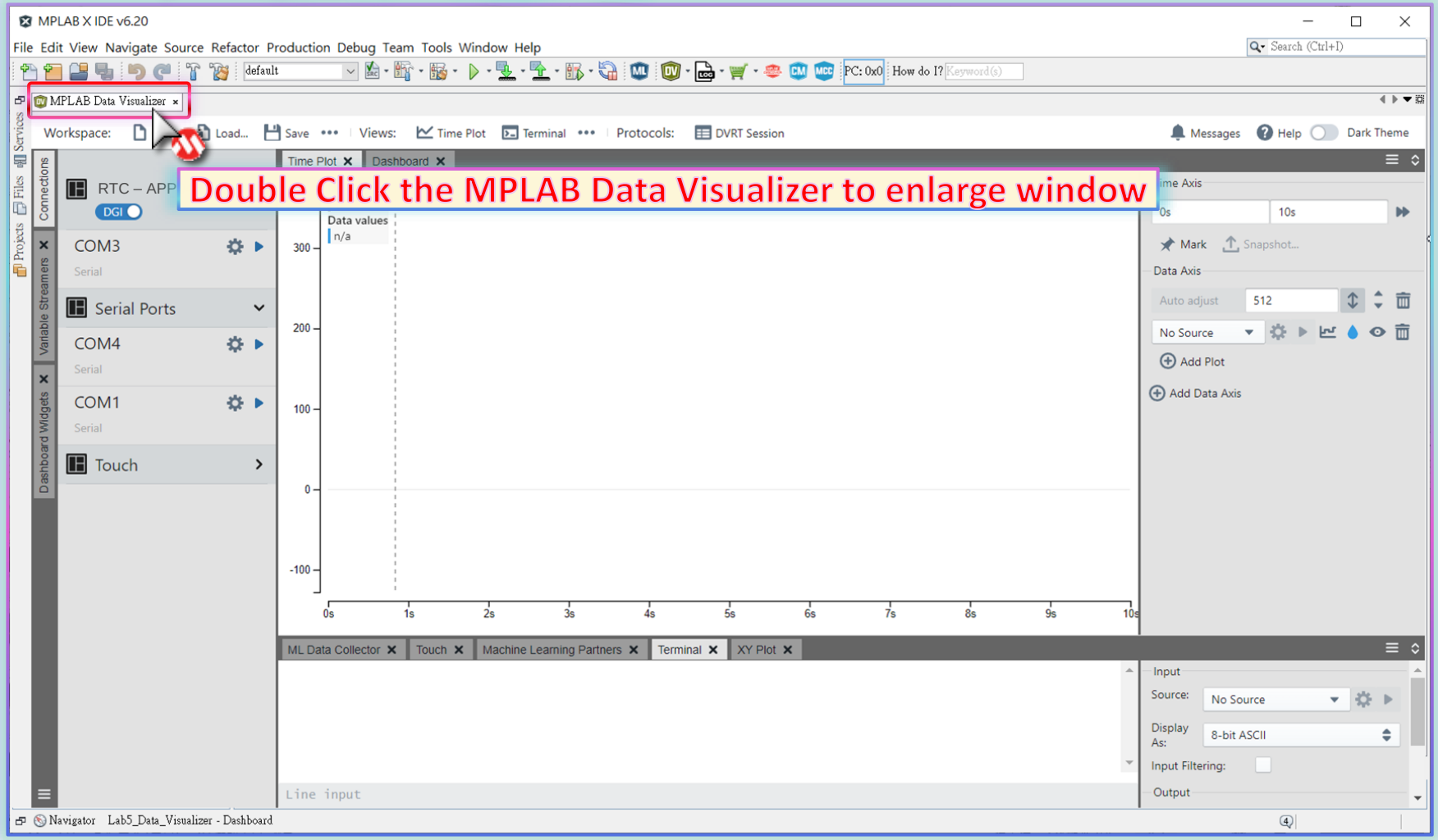
- **Open MPLAB Data Visualizer by click the icon**



🛠 Lab0 Data Visualizer for 6DOF Sensor data

Step 6

- **Double-Click on MPLAB Data Visualizer tab to enlarge DV window.**

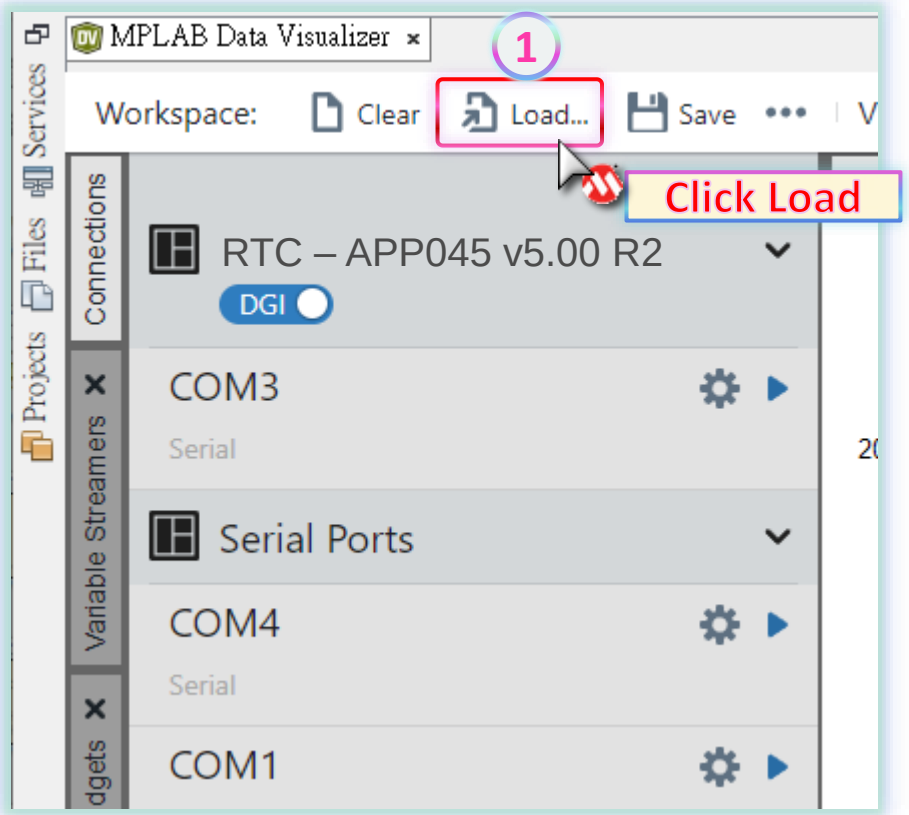


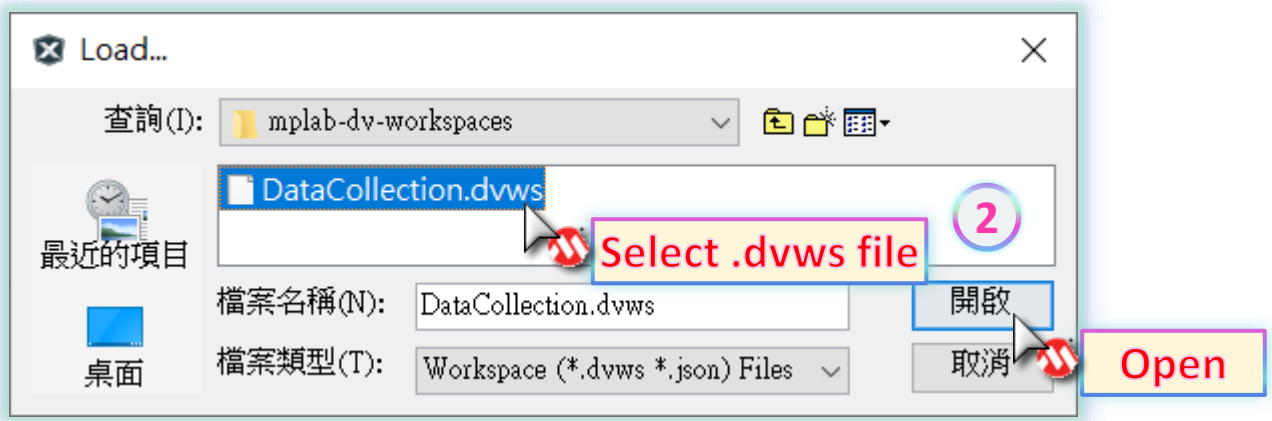
MICROCHIP

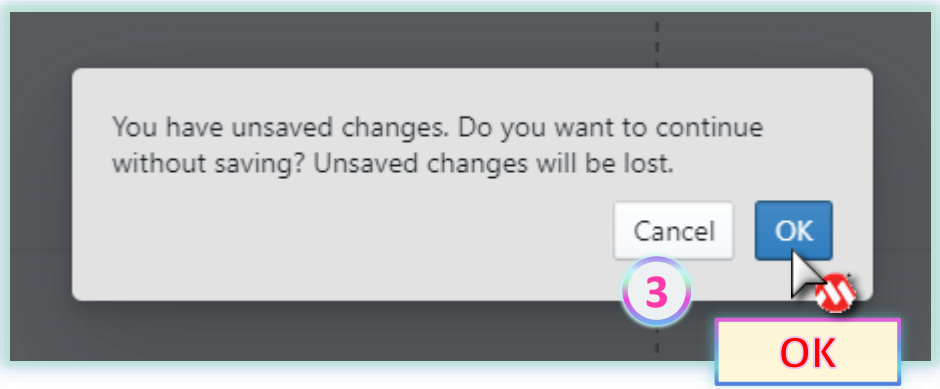
🛠 Lab0 Data Visualizer for 6DOF Sensor data

Step 7

- **Load Workspace file DataCollection.dvws in \AIML1001\Recourse\mplab-dv-workspace**



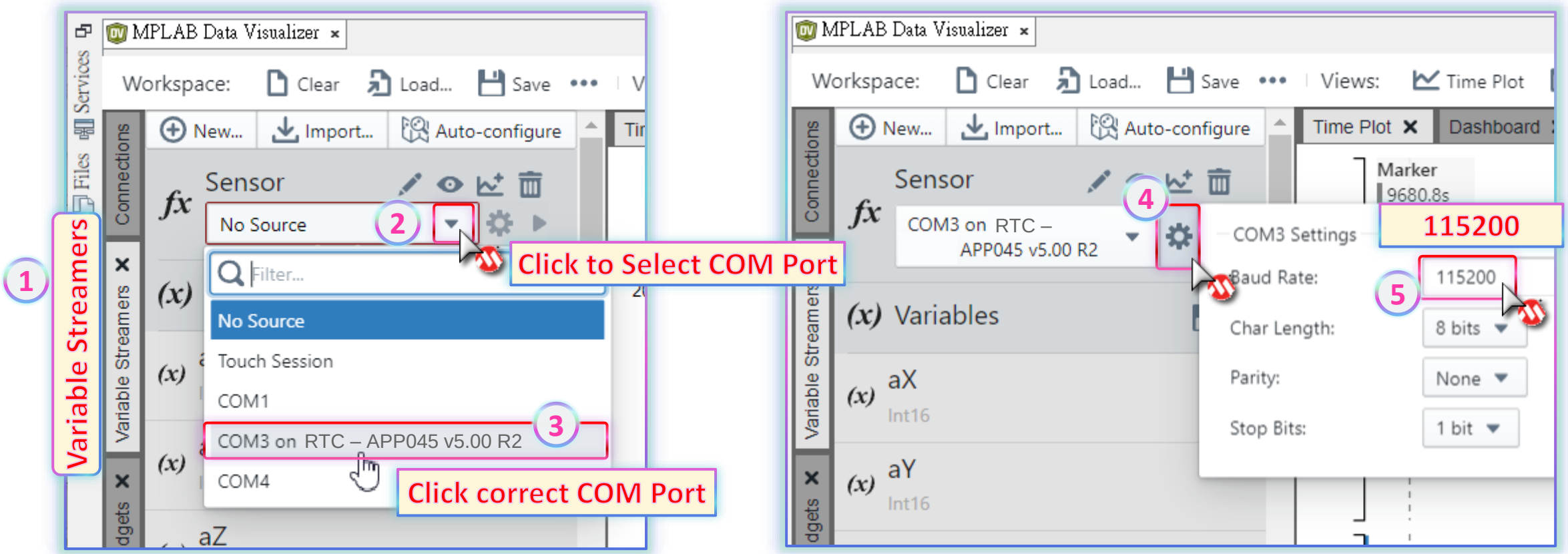




🛠 Lab0 Data Visualizer for 6DOF Sensor data

Step 8

- Click on ▾ to select correct COM port and then click on ⚙ to config as 115200-n-8-1.

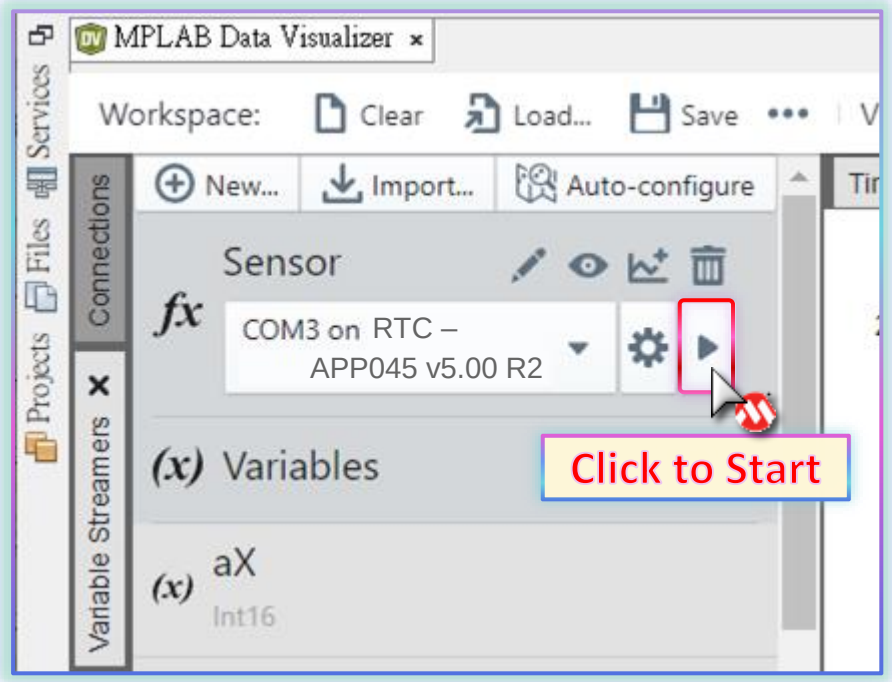


MICROCHIP

🛠 Lab0 Data Visualizer for 6DOF Sensor data

Step 9

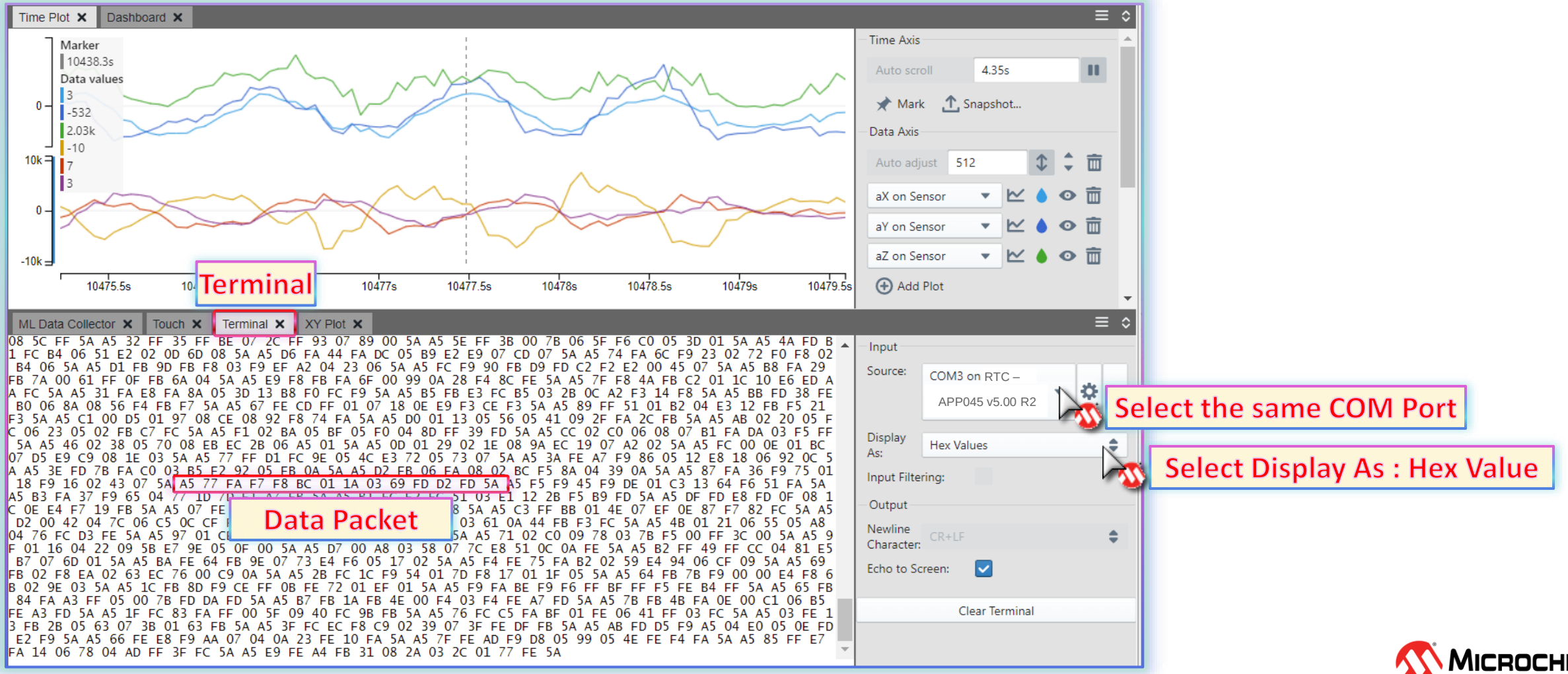
- **Click on ▶ to start Data Stream output raw data waveform in Time Plot output.**



🛠 Lab0 Data Visualizer for 6DOF Sensor data

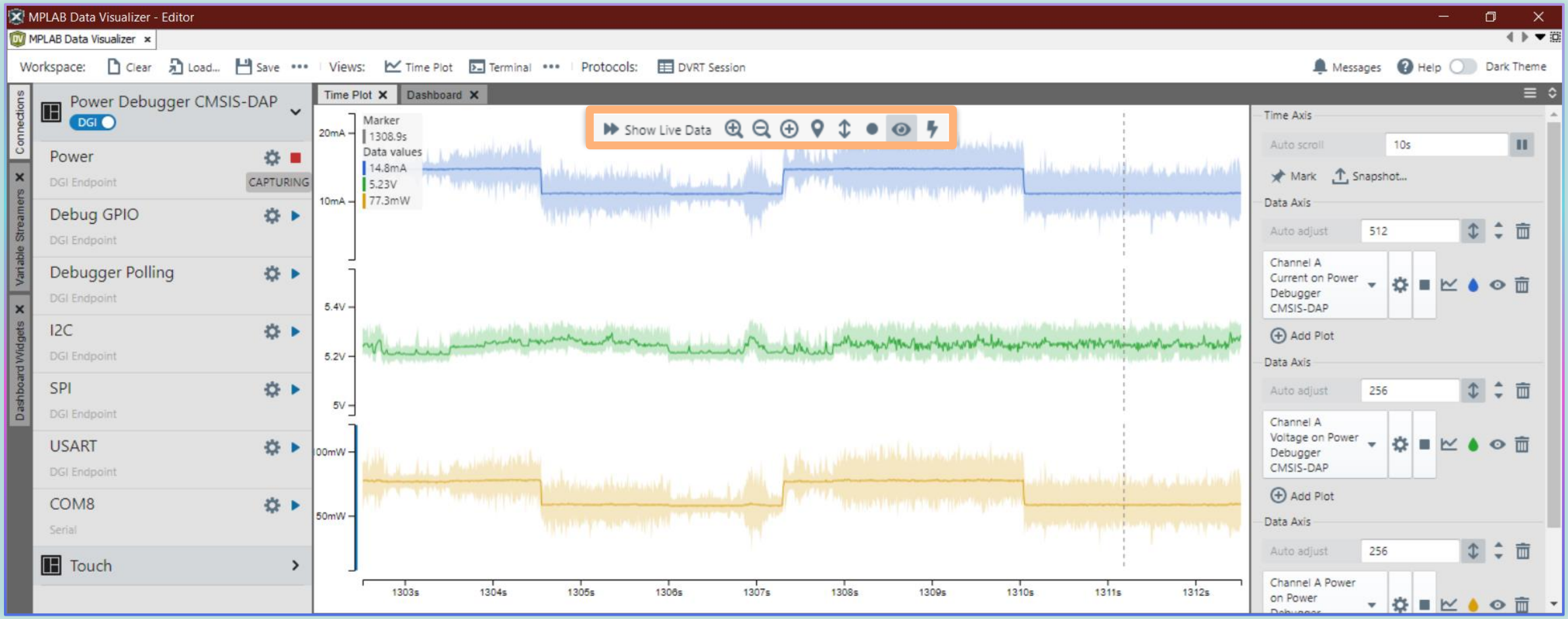
Step 10

- **Check DV protocol Raw Data on Terminal Window.**



MPLAB® Data Visualizer

Data Axis and Plot of Time Plot (Waveform Viewer)



MPLAB® Data Visualizer

Toolbar Control of Time Plot

Show the information of all cursors. Including bandwidth, Time period, and Frequency

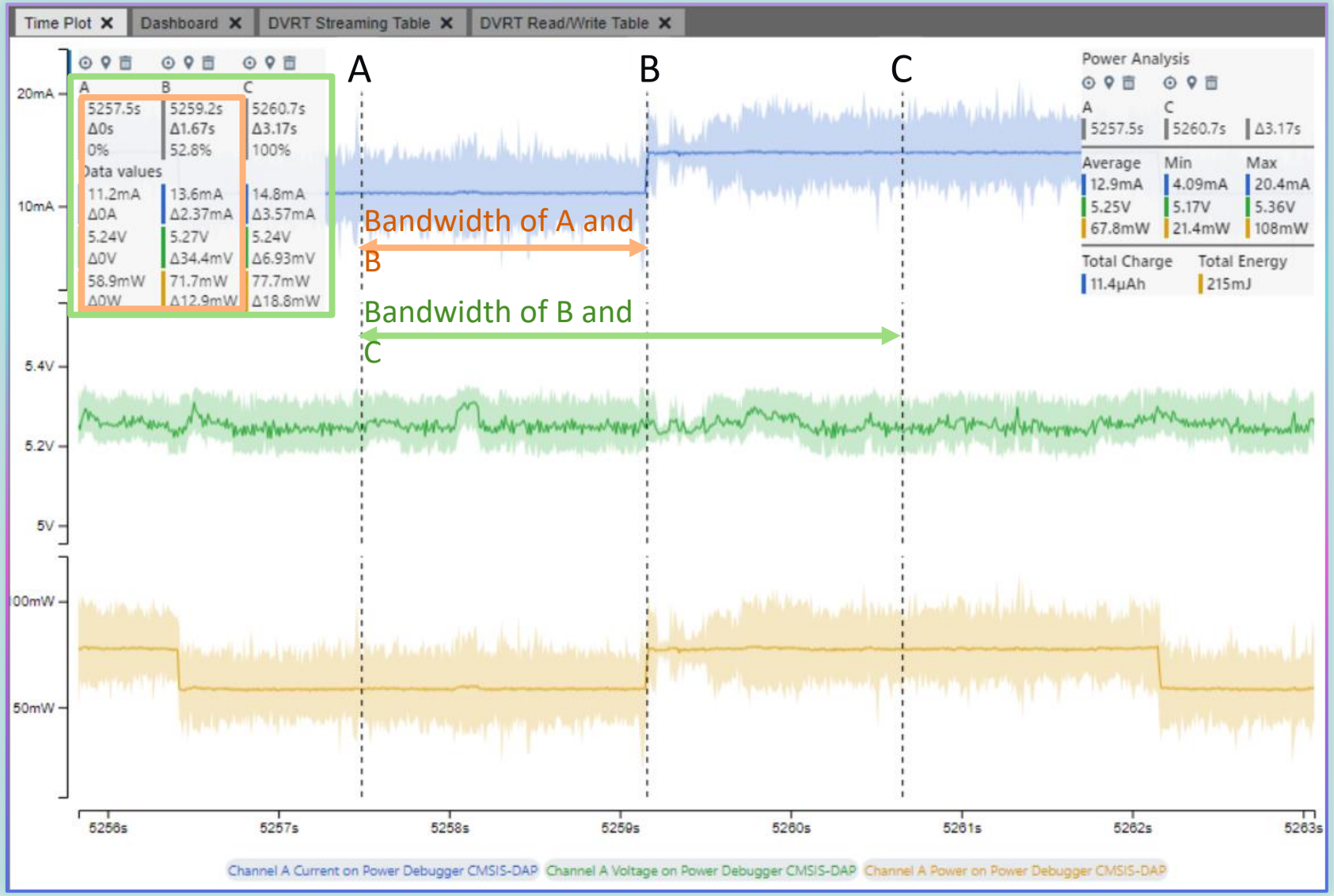
Need cursor to show the window.

Click to show/hide the Axis.

MICROCHIP

MPLAB® Data Visualizer

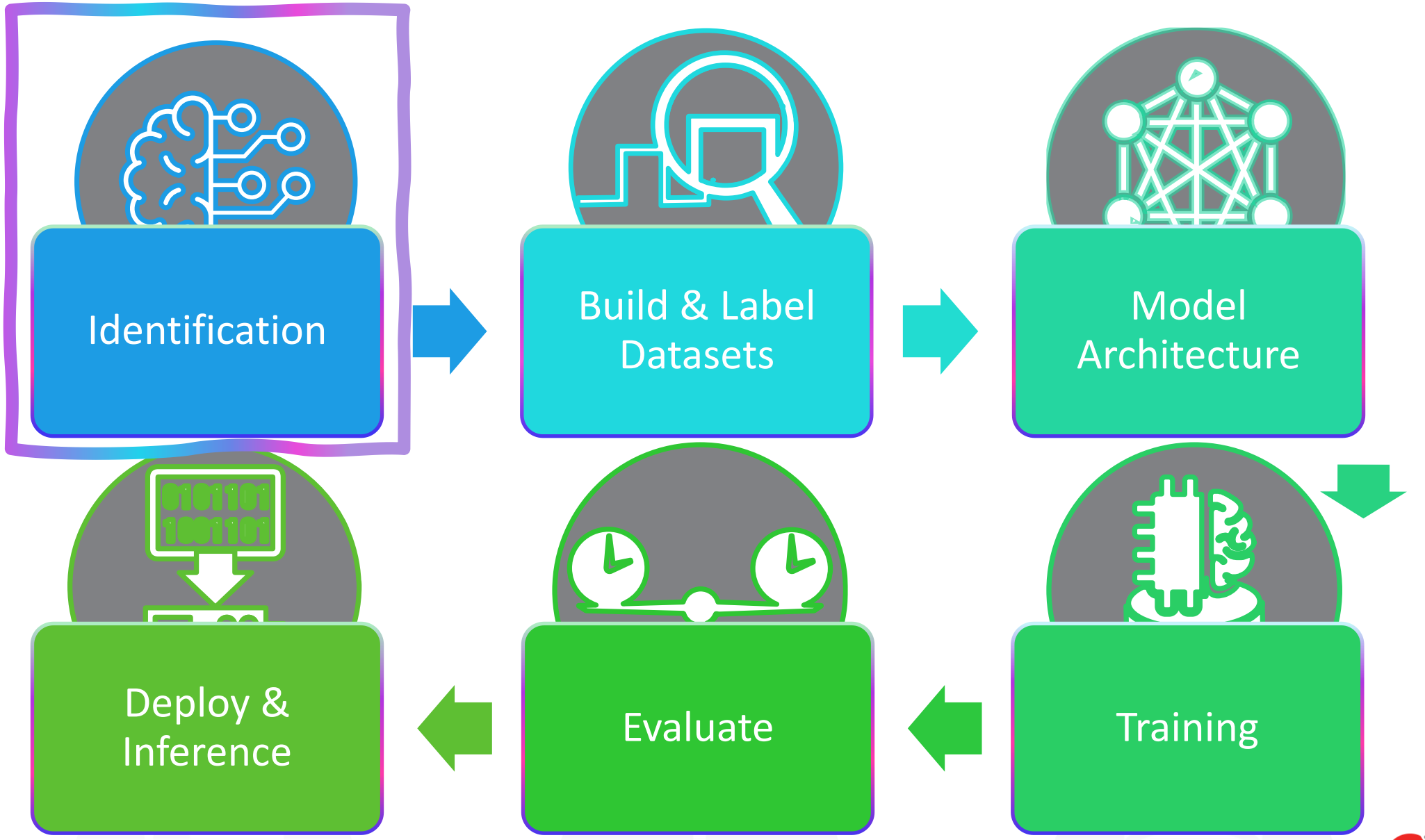
Cursor Delta Time Measurement by Time Plot



MICROCHIP

Set Goal and Problem Identification

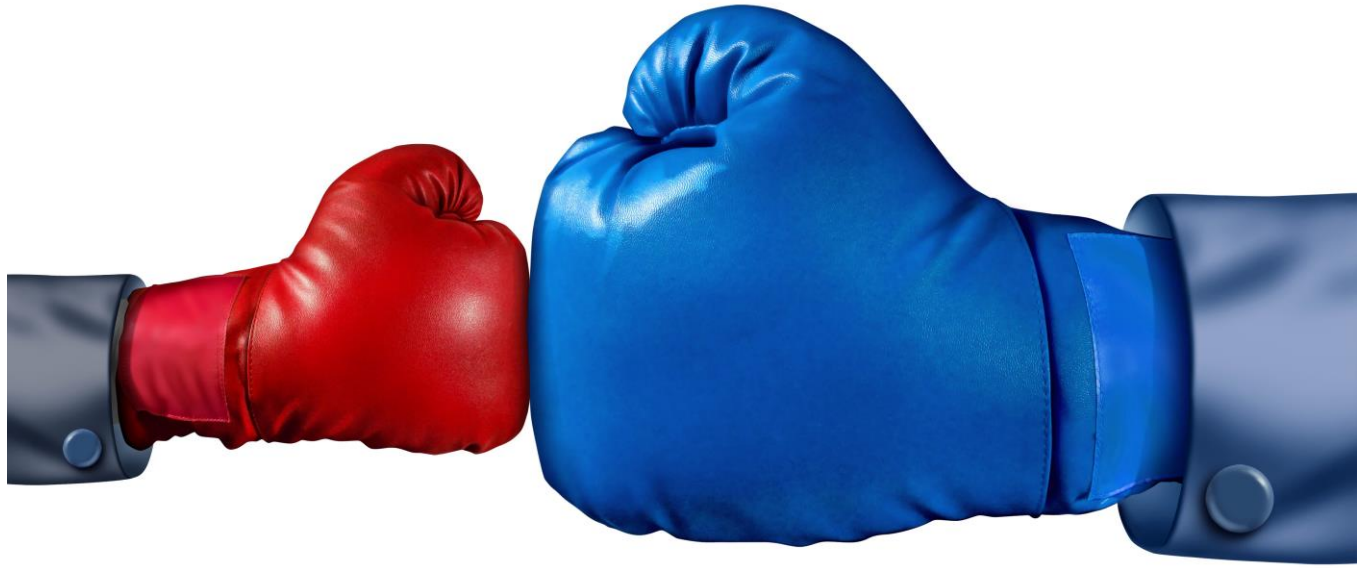
Machine Learning Workflow



MICROCHIP

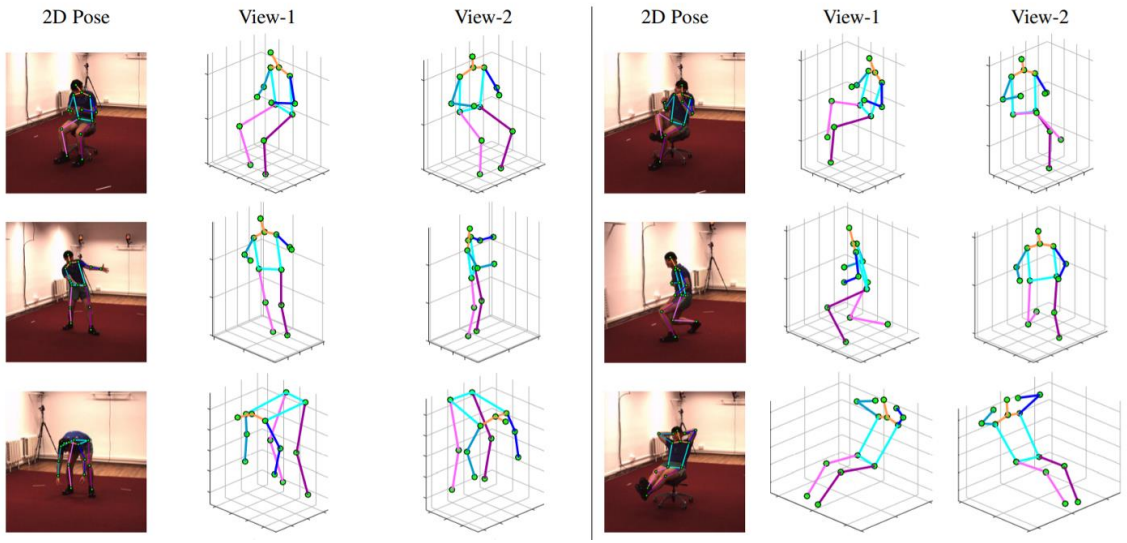
What is the goal of today?

- **Build a boxing recognition model and deploy it on the APP045 development board with 6-axis motion sensor ICM42670.**
- **The model should recognize 4 different movements, which is:**
  - Straight
  - Right hook
  - Uppercut
  - Freeze



Problem Identification

- **Detect boxing action posture**
  - Straight, Uppercut, Right Hook, Freeze.
- **Classic approach(es)**
  - Camera, Computer vision
  - Dynamic system, Hand tracking
- **Let's try Machine Learning**
  - Does it offer any benefits?
    - Development speed?
    - Accuracy?
    - Code size?



🛠 Lab 1
Initial Setup and Data Collecting

Boxing Recognition by Machine Learning

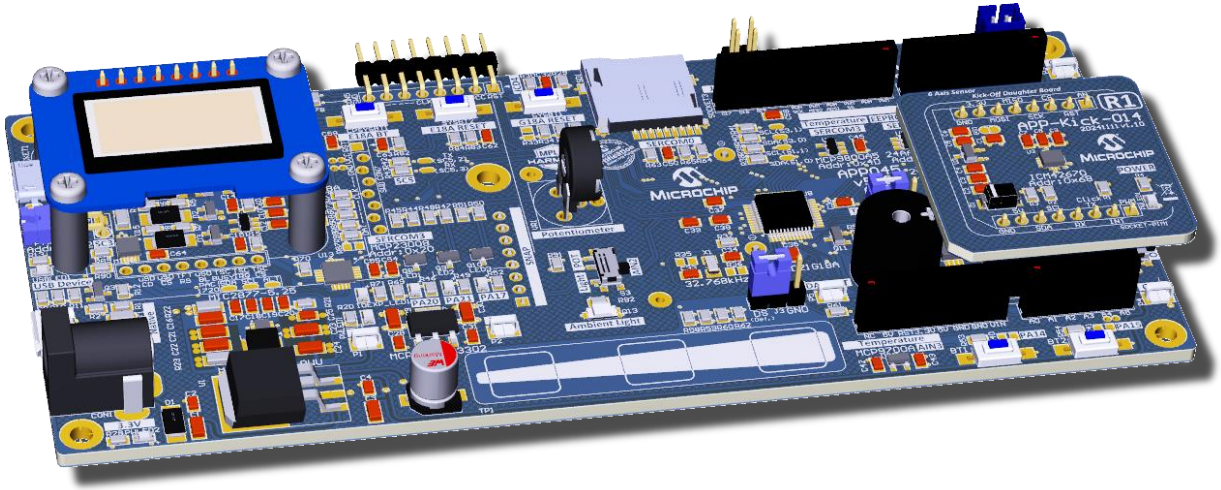
MICROCHIP

🛠 Lab1 Initial Setup and Data Collecting

Boxing Recognition by Machine Learning

- **Verify the hardware setup and open the project.**
  - APP045 v5.0 R2 EV Board with SAMD21
  - APP-Kick-014 Accel and Gyro (6DOF) daughter board
- **Program the project and make sure it performs data samples in 3 different modes.**
- **Create a ML project by ML Data Collector.**
- **Collect sample data set for Straight, Uppercut, and Right hook three actions, and observing good labelling practice.**

Let’s go!

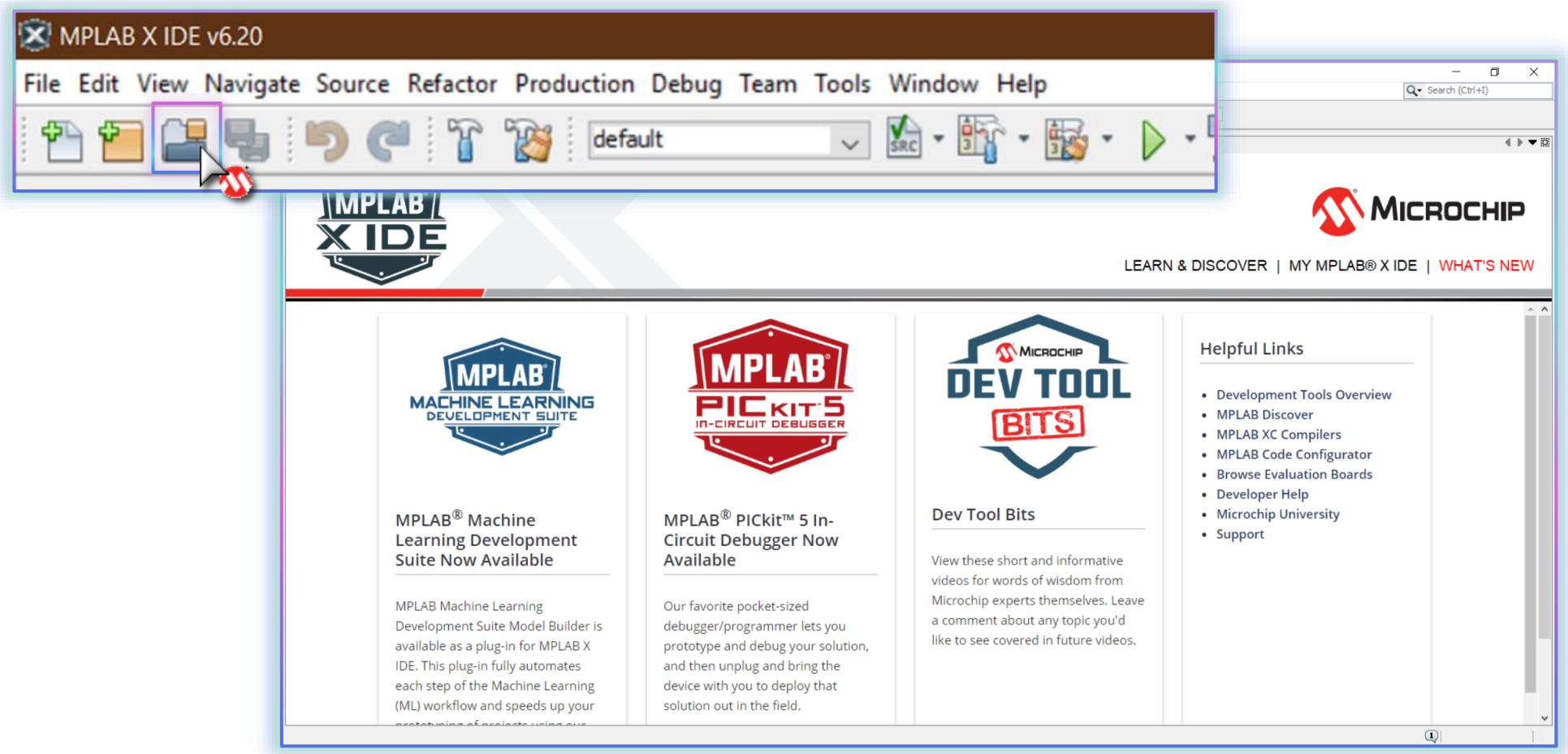


MICROCHIP

🛠 Lab1 Initial Setup and Data Collecting

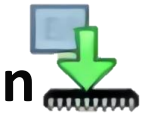
Step 1

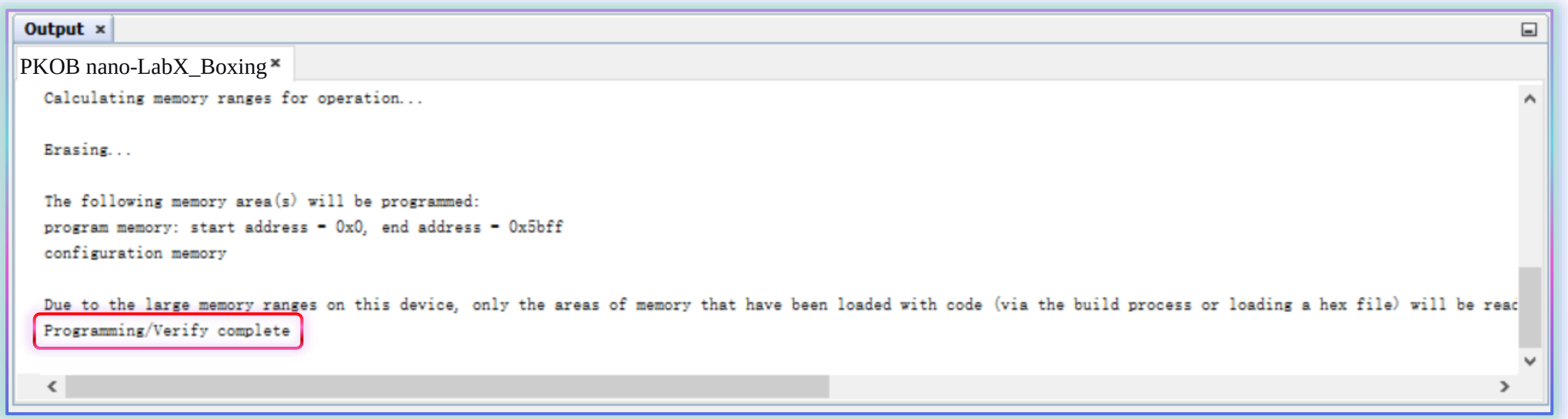
- Open “\AIML1001\LabX_BoxingPoseAIML\LabX_BoxingPoseAIML.X”.



🛠 Lab1 Initial Setup and Data Collecting

Step 2

- Click on icon and select Clean and Build Project to compiler your project.
- Click on icon  to Mark and Program to EVB and check if any fault while Programming.
- Output Window will show *Programming/Verify Complete*.



🛠 Lab1 Initial Setup and Data Collecting

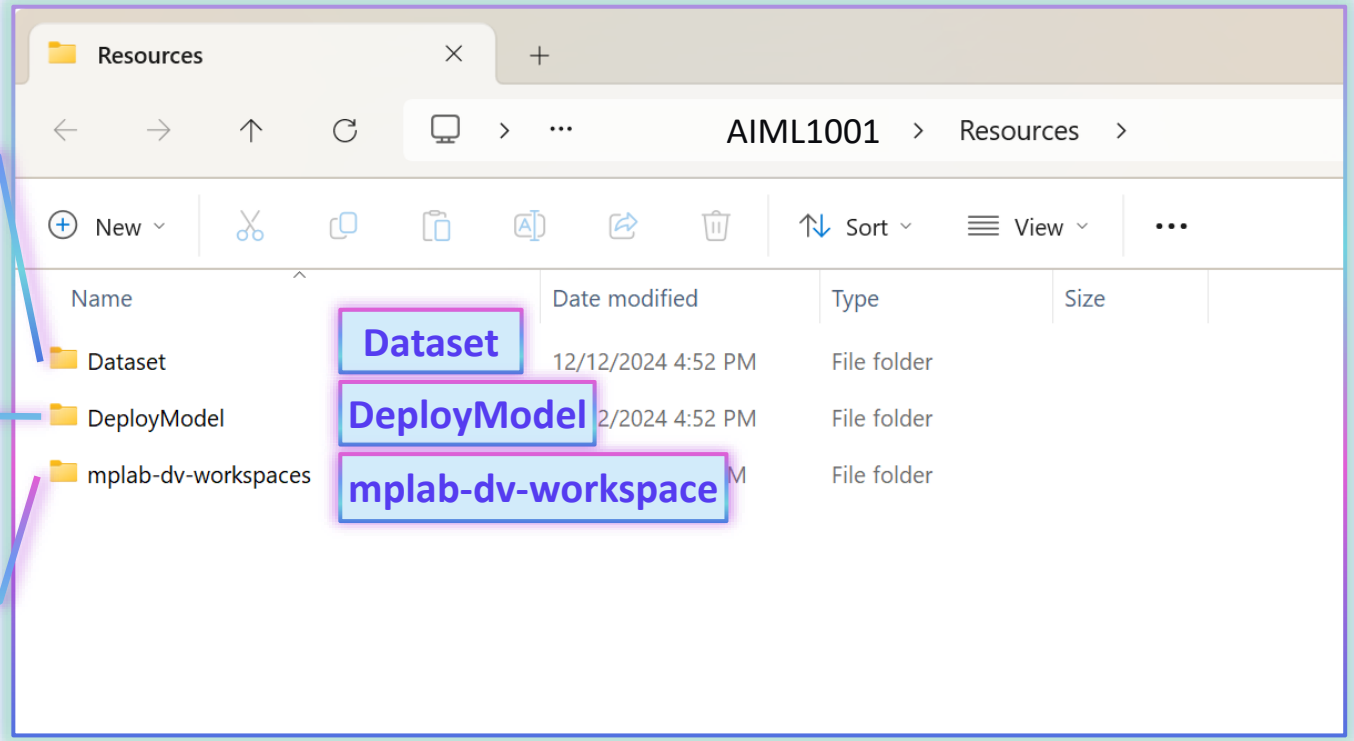
Step 3

- **Let's see the folder "\AIML1001\Resources" in the project.**
- **There are three folders, which is Dataset, DeployModel, and mplab-dv-workspaces.**

Dataset: The folder for you to save all the dataset collected in following steps.

DeployModel: Save the final model you download.

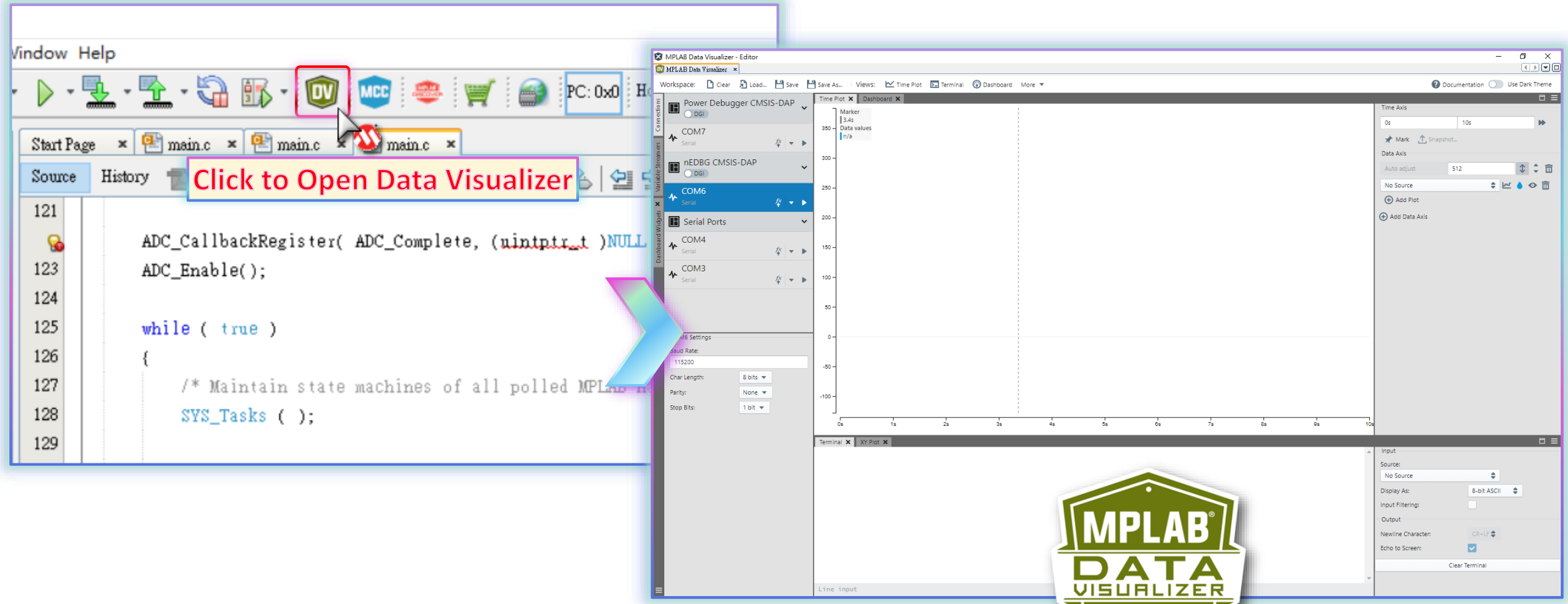
mplab-dv-workspaces: The workspace settings of DV.



🛠 Lab1 Initial Setup and Data Collecting

Step 4

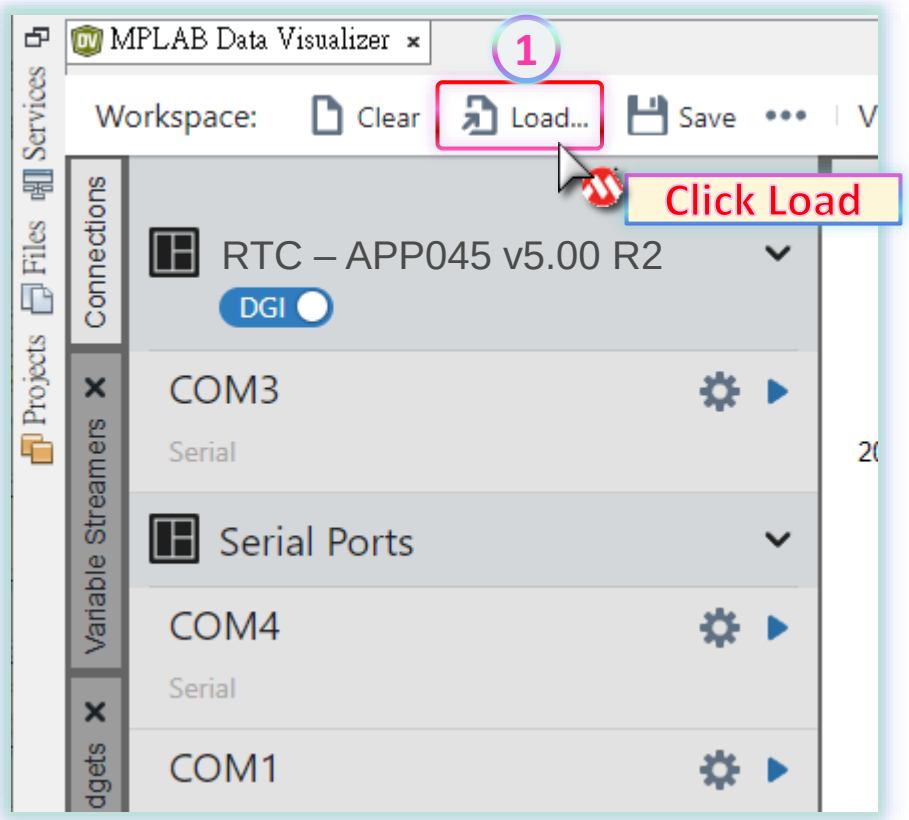
- **Open Data Visualizer. Click icon .**

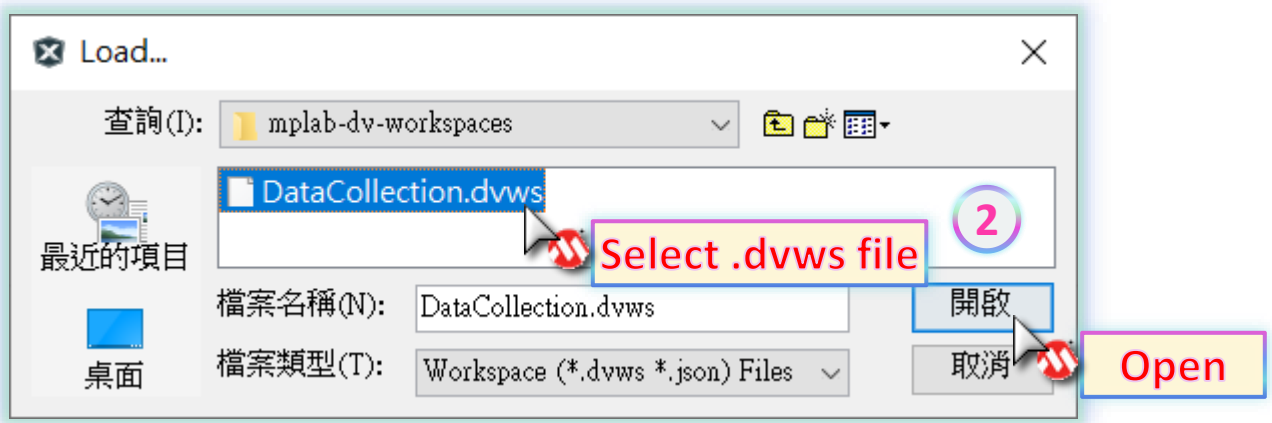


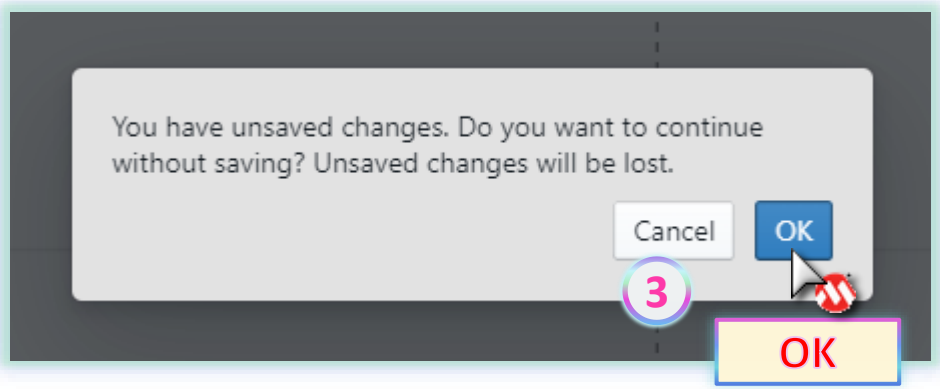
🛠 Lab1 Initial Setup and Data Collecting

Step 5

- **Load Workspace file DataCollection.dvws in \AIML1001\Recourse\mplab-dv-workspace**



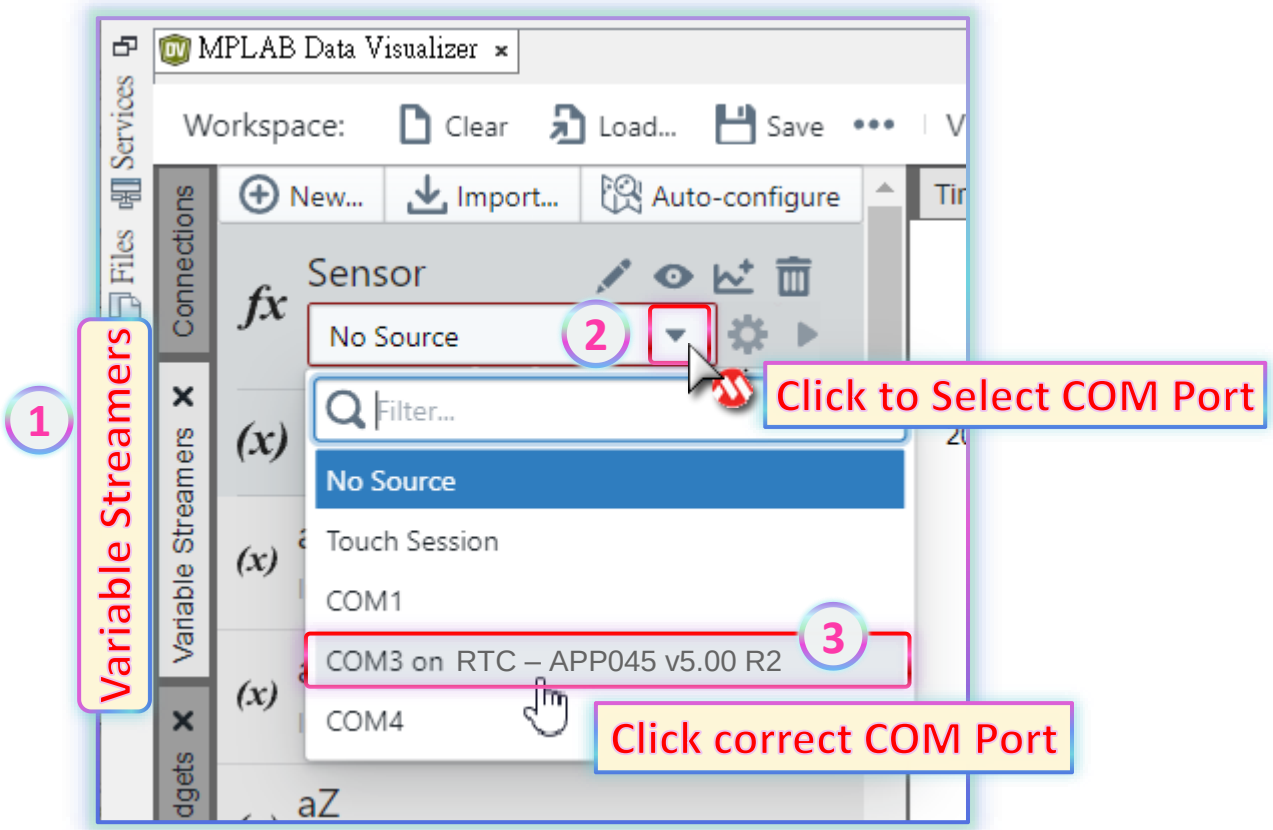




🛠 Lab1 Initial Setup and Data Collecting

Step 6

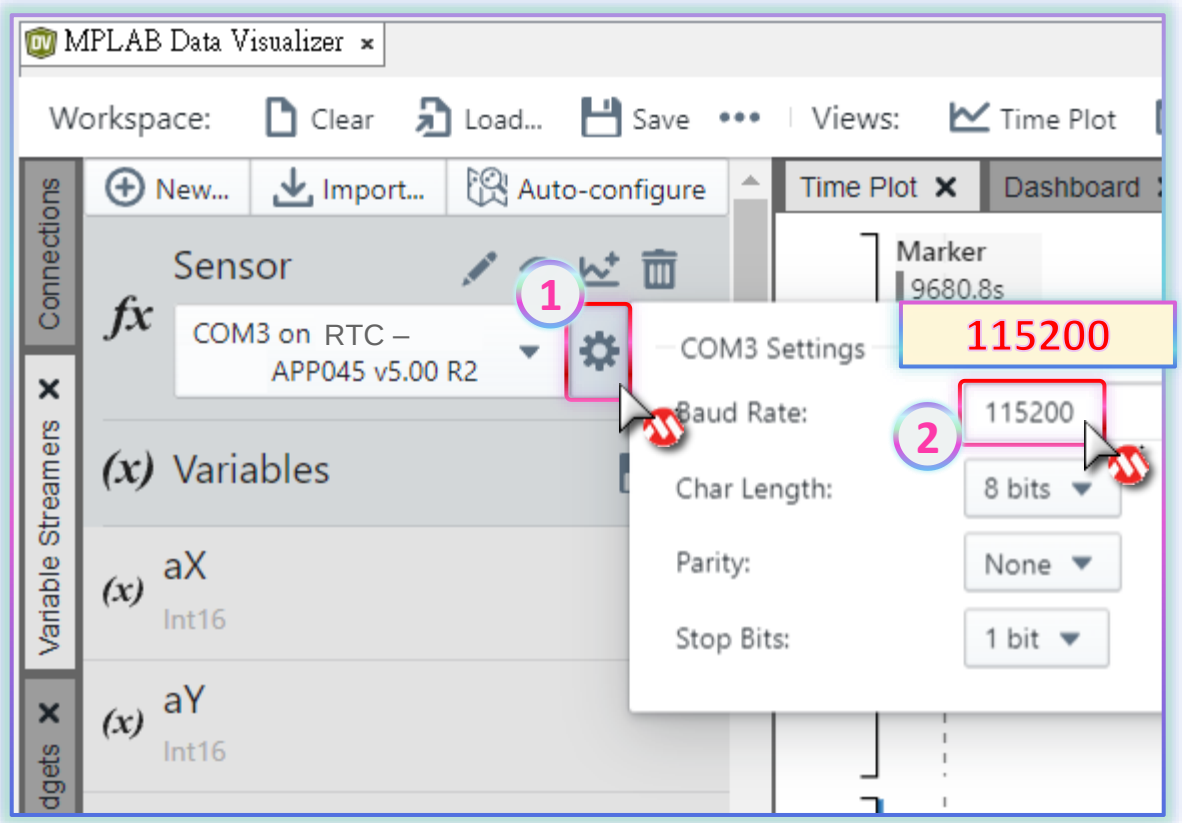
- Go to left tab "Variable Streamers" > Sensor > No Source > COMxx



🛠 Lab1 Initial Setup and Data Collecting

Step 7

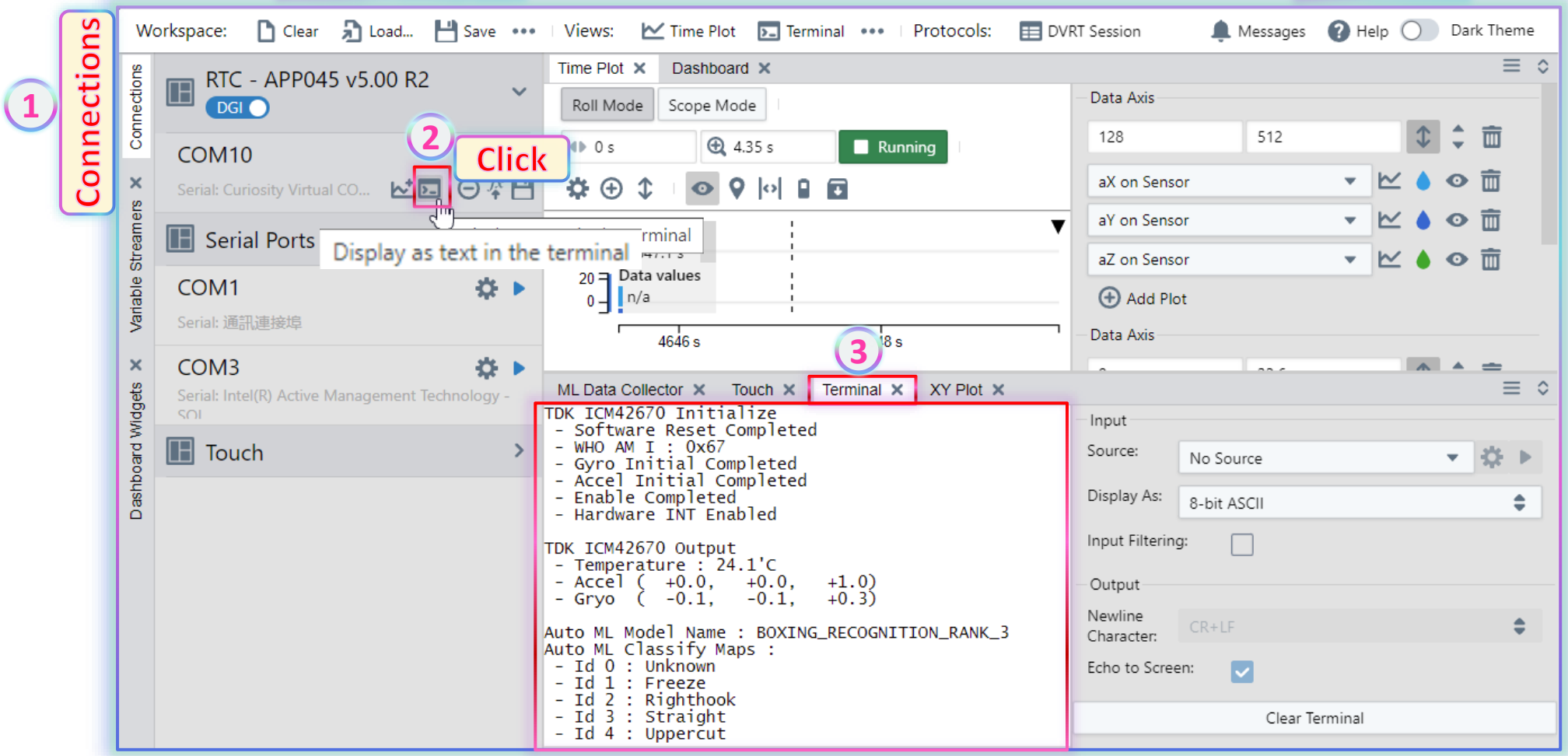
- **Sensor > ⚙(Source Option) > Baud Rate: 115200**



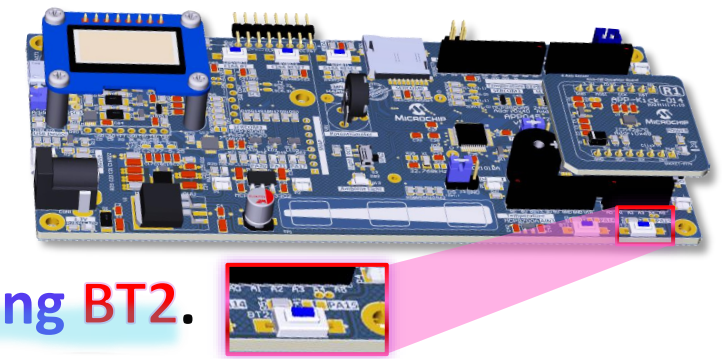
🛠 Lab1 Initial Setup and Data Collecting

Step 8

- Go to left tab "Connections" Click on and display the text in Terminal output.



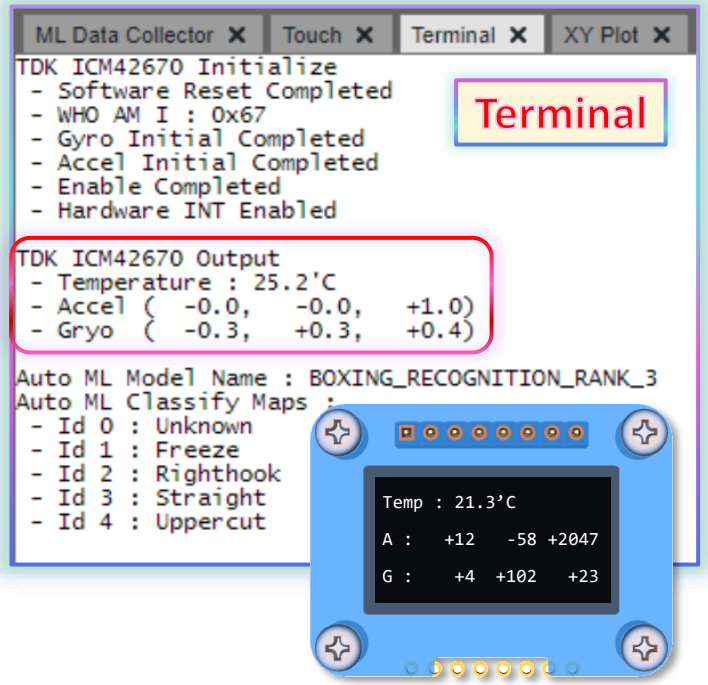
🛠 Lab1 Initial Setup and Data Collecting



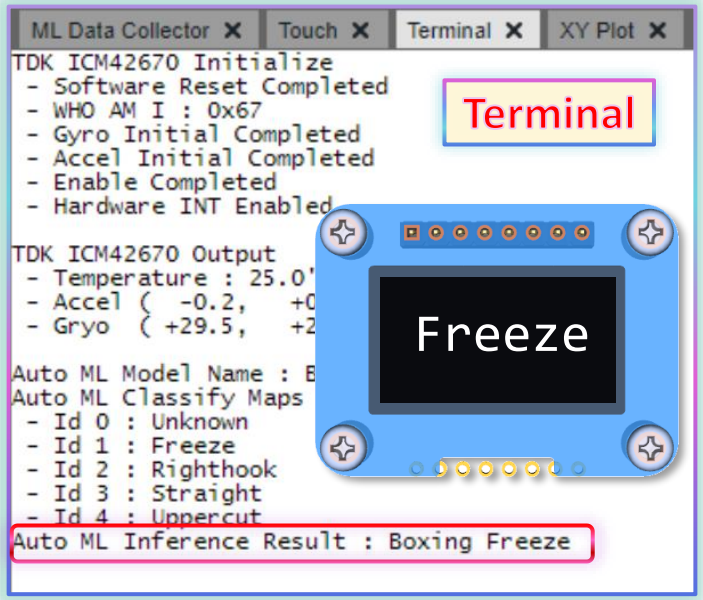
Step 9

- **There are 3 different modes, we can switch the mode by pressing BT2.**
  - **Mode 1**: Display 6DOF Sensor Data in DV Terminal and OLED.
  - **Mode 2**: Display **Boxing Stance classification results** of preset ML model in DV Terminal and OLED.
  - **Mode 3**: Display 6DOF Sensor Data waveform in Time Plot of Data Visualizer (For Data Collection).

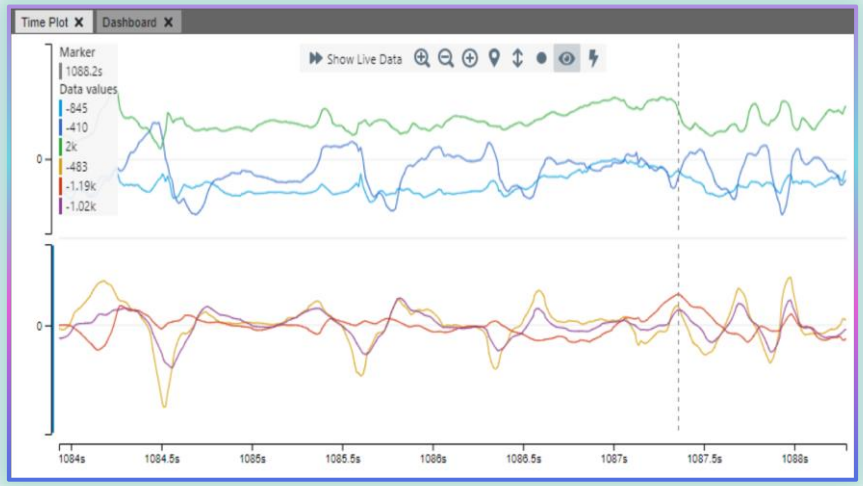
Mode 1



Mode 2



Mode 3

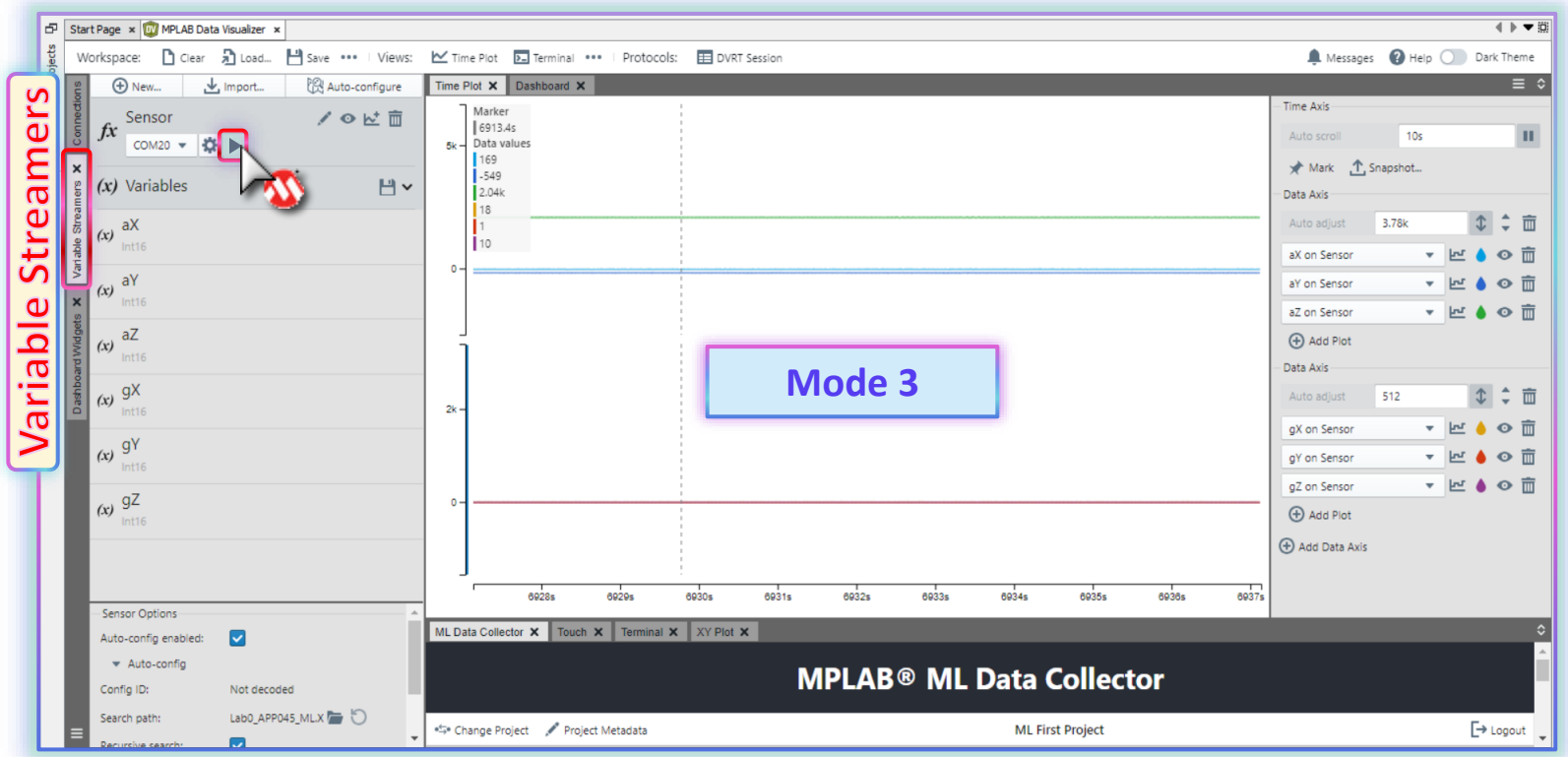


Time Plot

🛠 Lab1 Initial Setup and Data Collecting

Step 10

- **Finally! We are going start collecting data.**
- **Press BT2 two times to switch the mode to Mode 3.**
- **Start Variable Streamers, Click ▶ icon**

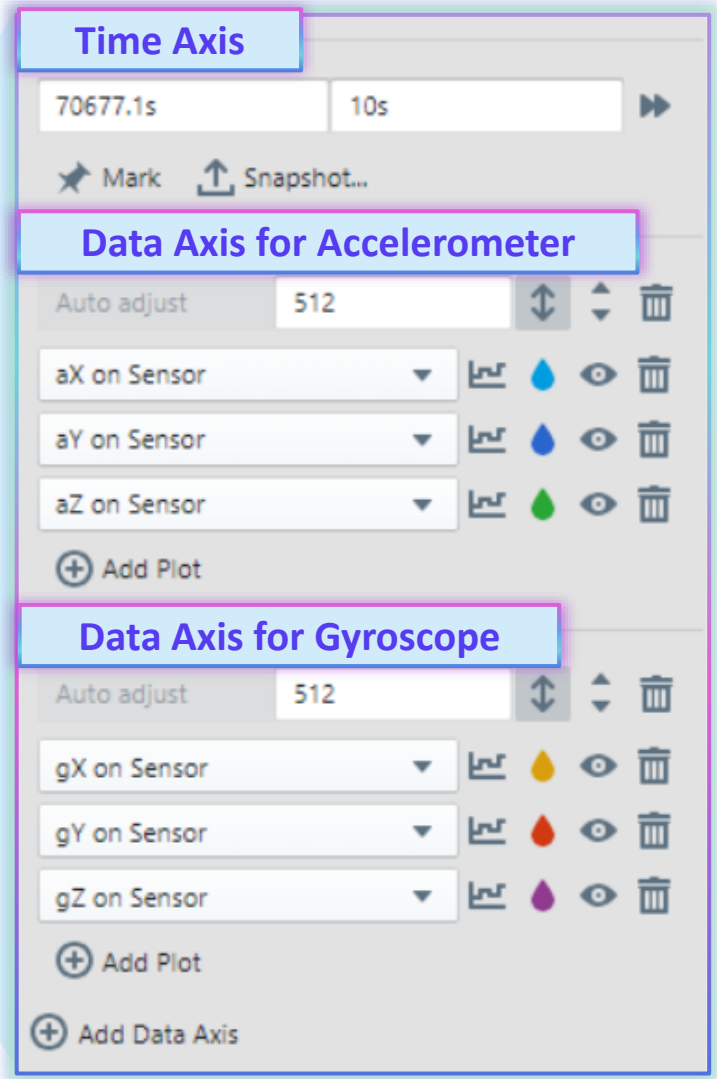


MICROCHIP

🛠 Lab1 Initial Setup and Data Collecting

Step 11

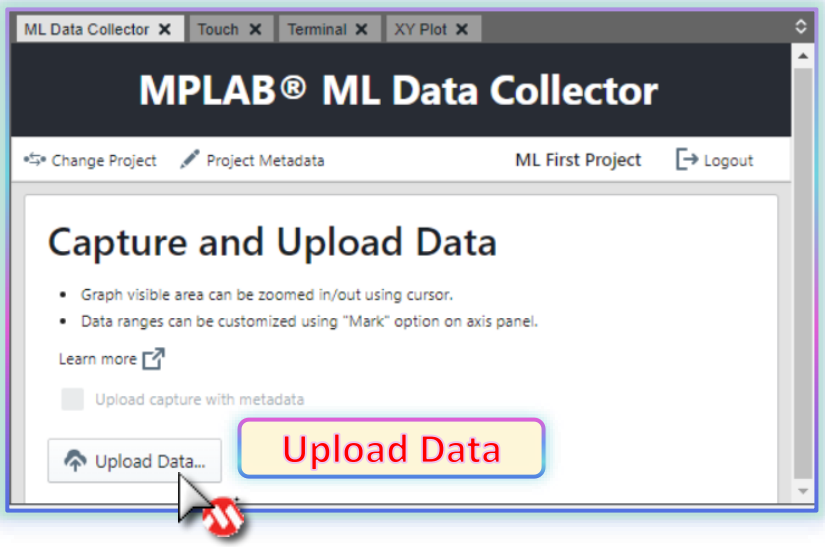
- **Time Plot Graphic Window will show the raw data.**



🛠 Lab1 Initial Setup and Data Collecting

Two Ways to Capture and Upload Data

1. **Upload and save Data by MPLAB ML Data Collector. The data will be saved to .csv file in your local PC and upload to the ML Project you created automatically.**



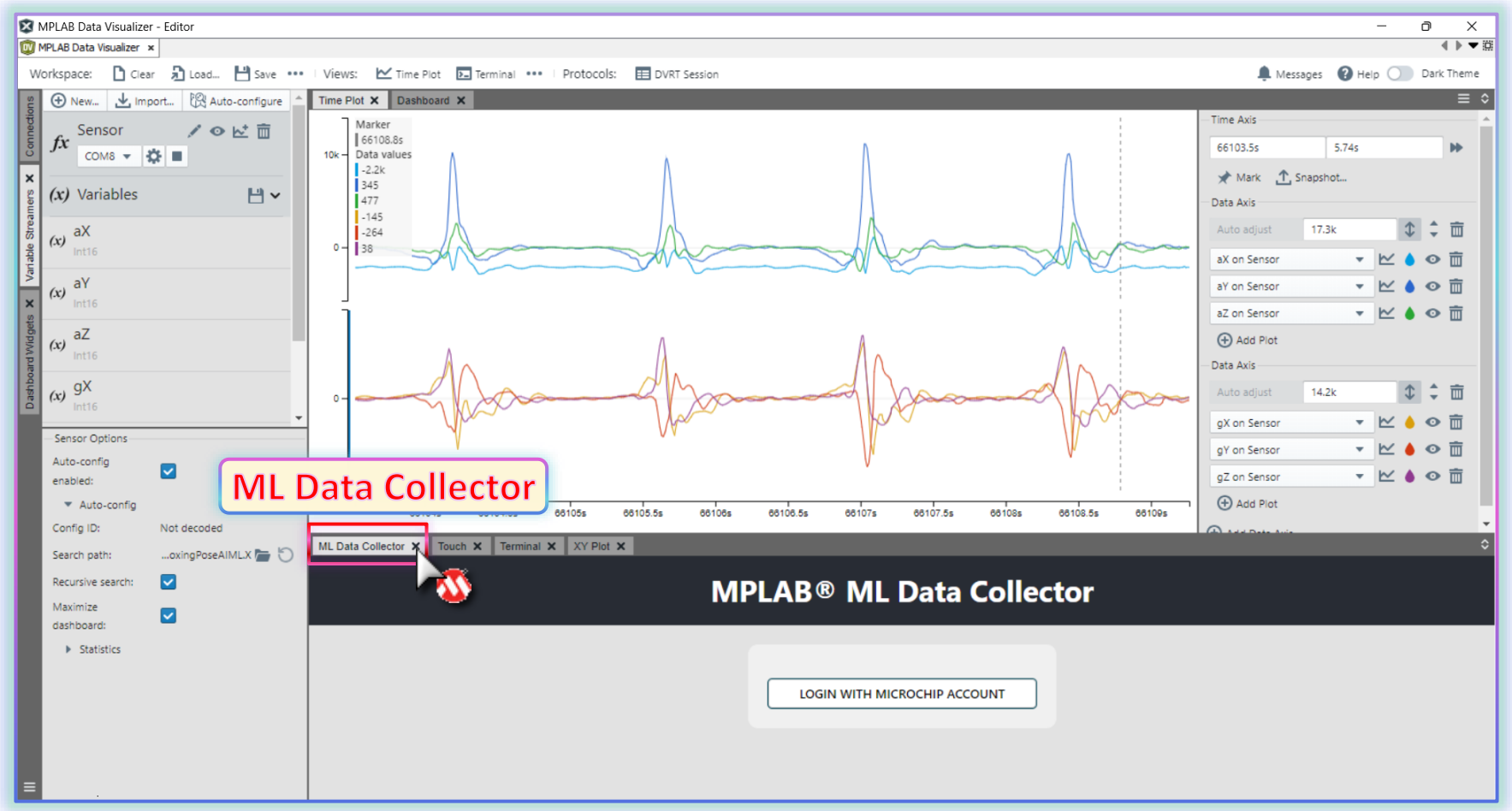
2. Snapshot Data by click on in Time Plot of DV to save the .csv file in your local PC. Then upload the .csv file to the ML Project you created manually.

MICROCHIP

🛠 Lab1 Initial Setup and Data Collecting

Step 12

- **Choose ML Data Collector tab in the below window.**



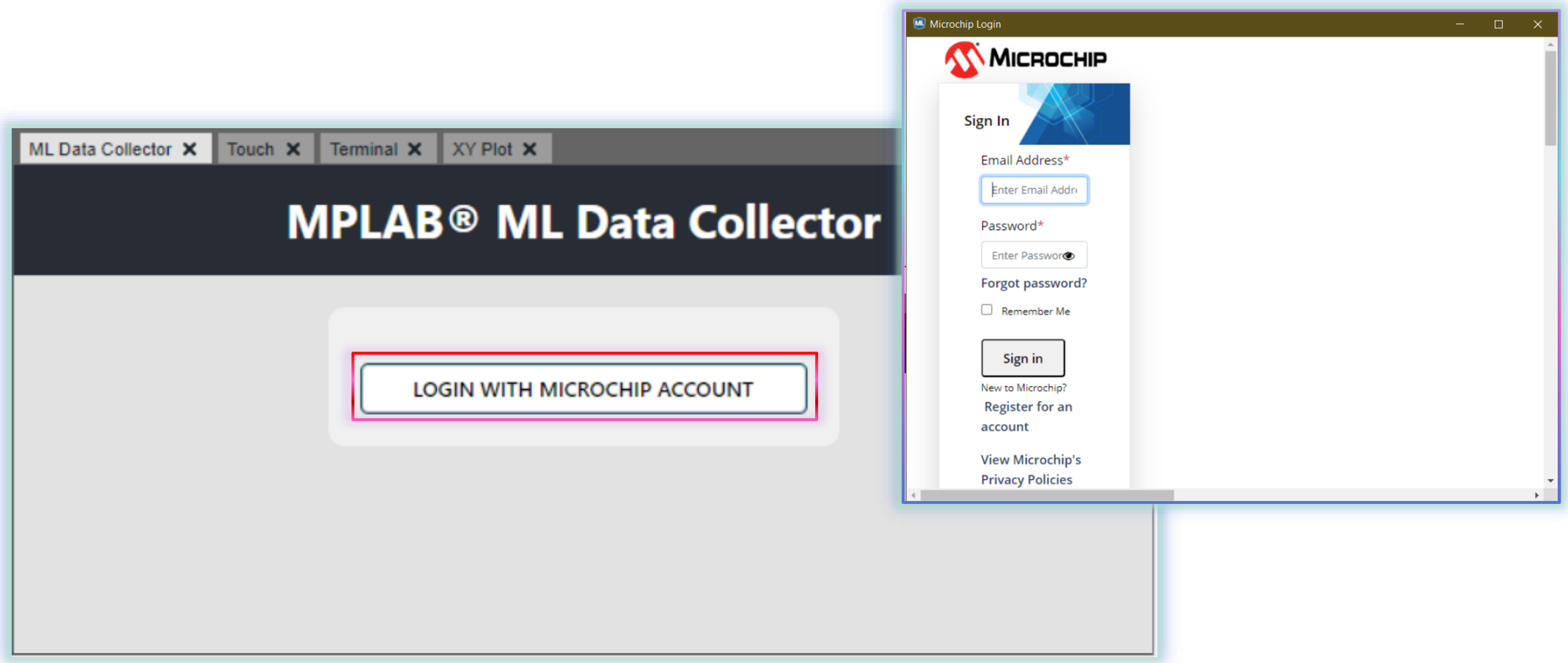
Appendix : Install the ML Data Collector & ML Model Builder

MICROCHIP

🛠 Lab1 Initial Setup and Data Collecting

Step 13

- **Log in with your myMicrochip credentials in the MPLAB ML Data Collector tab.**



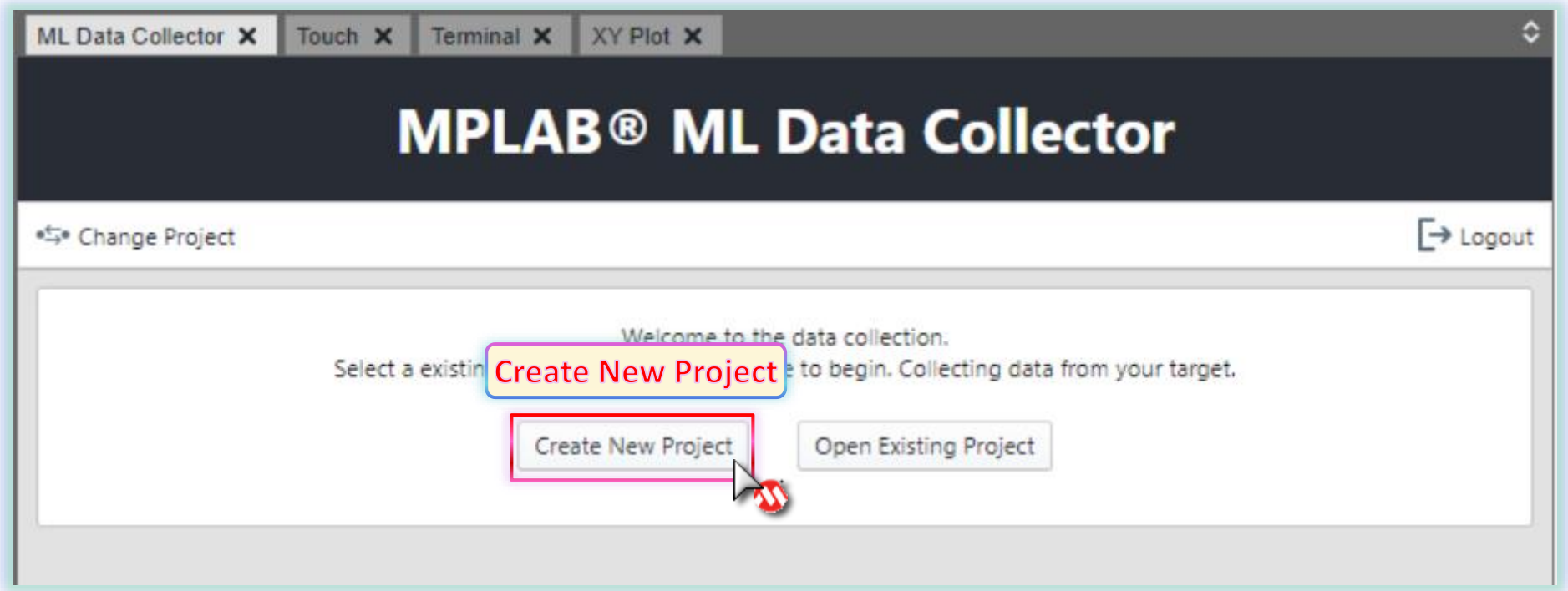
Appendix : Create and Login MPLAB ML Account

MICROCHIP

🛠 Lab1 Initial Setup and Data Collecting

Step 14

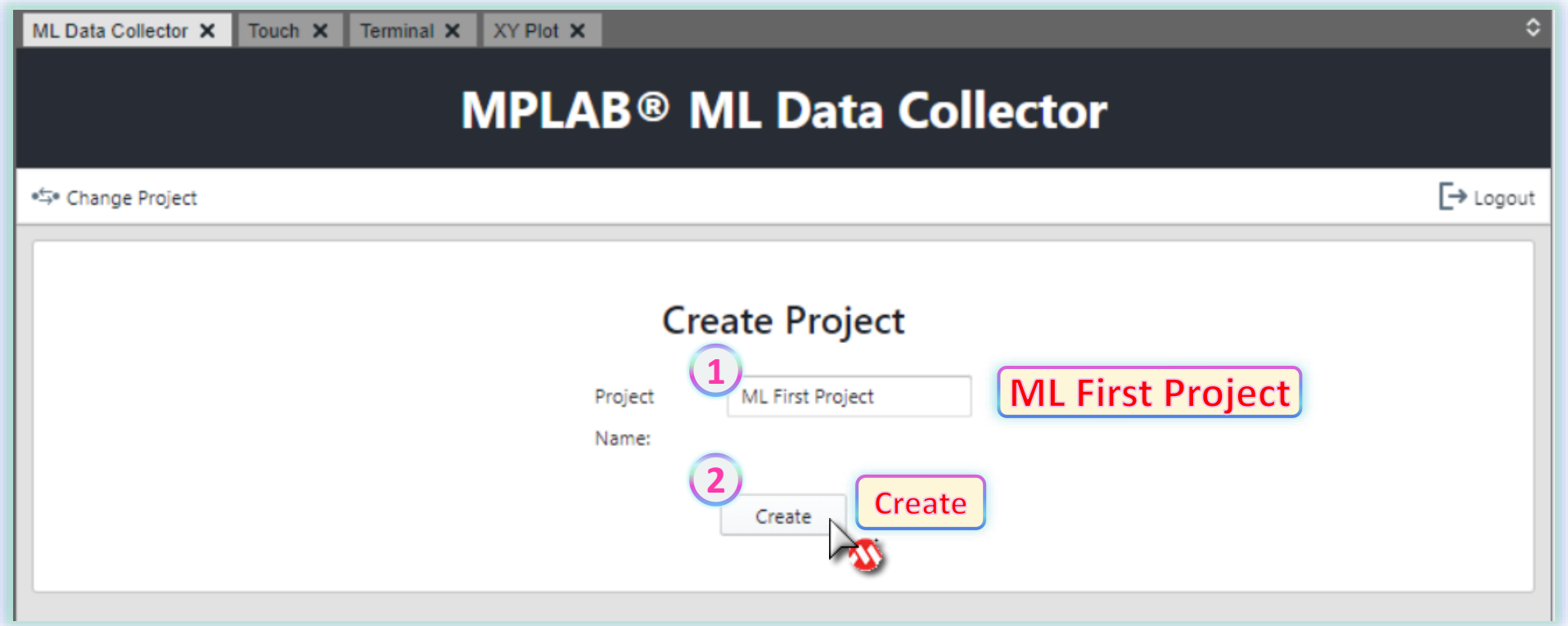
- **Click the Create New Project button.**



🛠 Lab1 Initial Setup and Data Collecting

Step 15

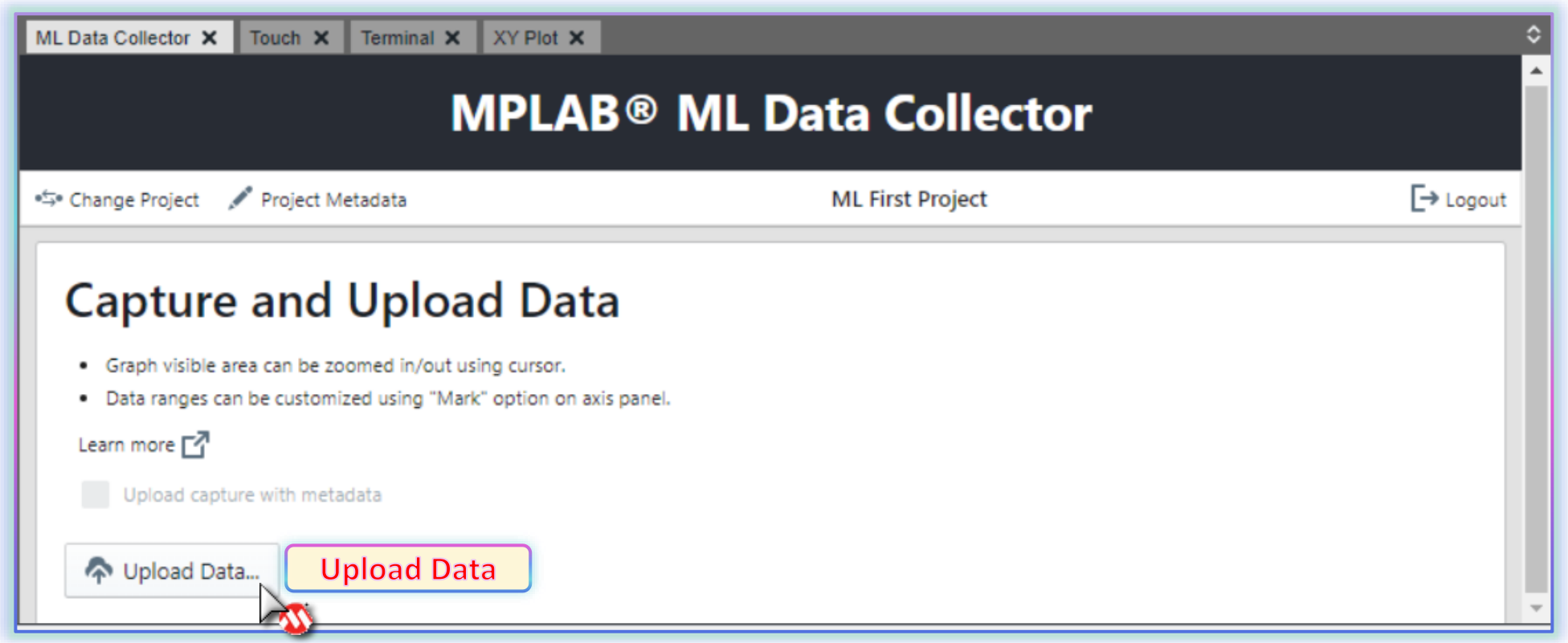
- **Input a name for your project.**
  Project Name: ML First Project



🛠 Lab1 Initial Setup and Data Collecting

Step 16

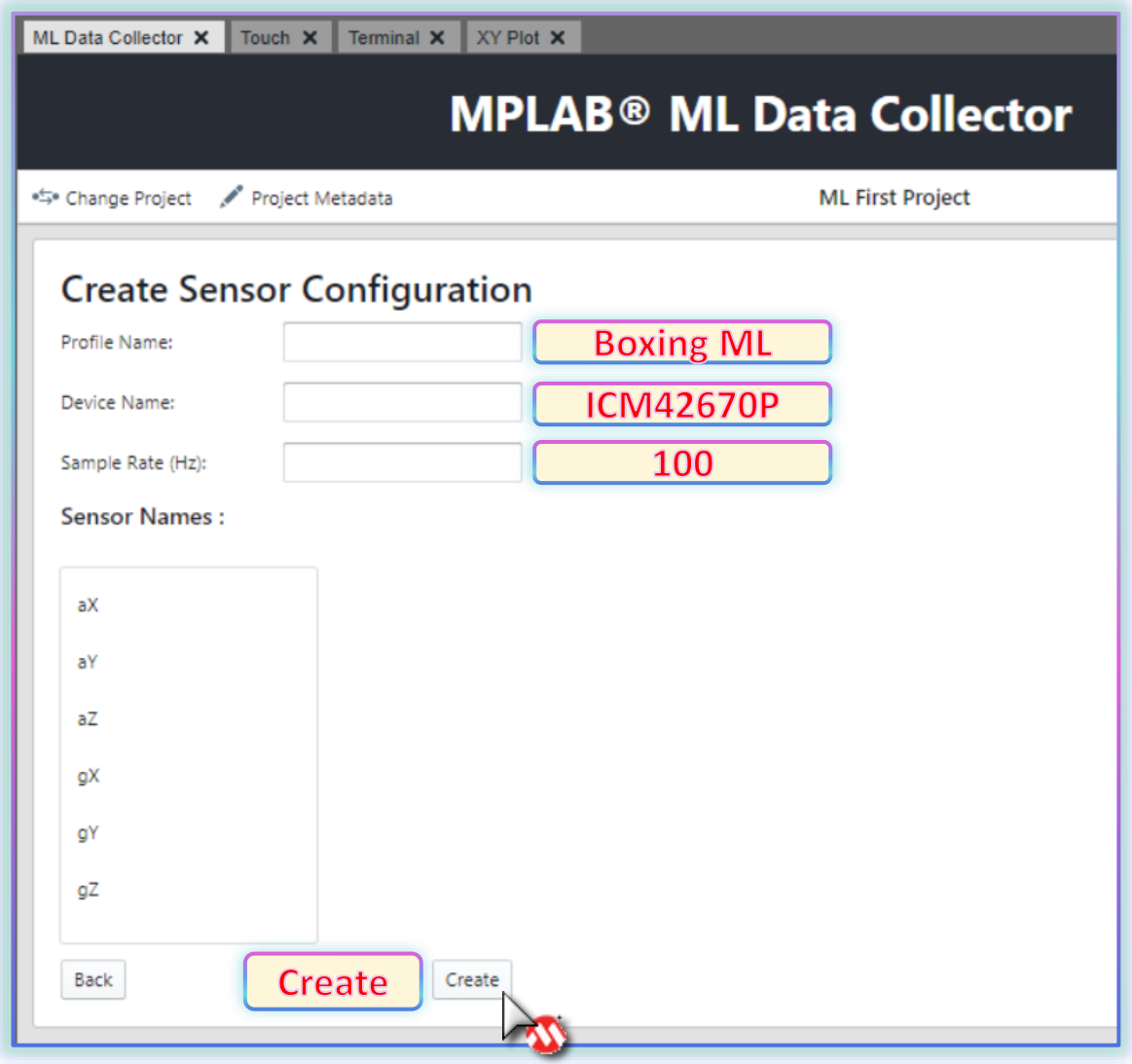
- **Upload and save Data by ML Data Collector**
- **Click Upload Data**



🛠 Lab1 Initial Setup and Data Collecting

Step 17

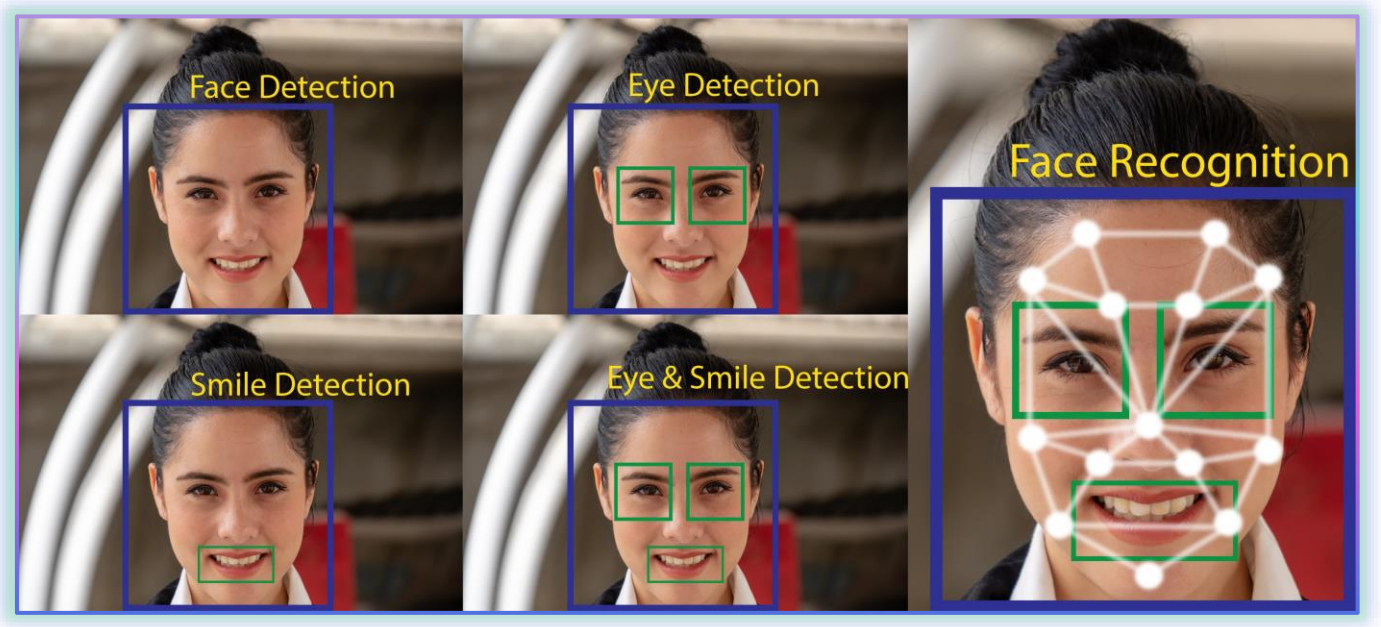
- **Profile Name: Boxing ML**
- **Device Name: ICM42670P**
- **Sample Rate (Hz): 100Hz**



Data Logging and Upload

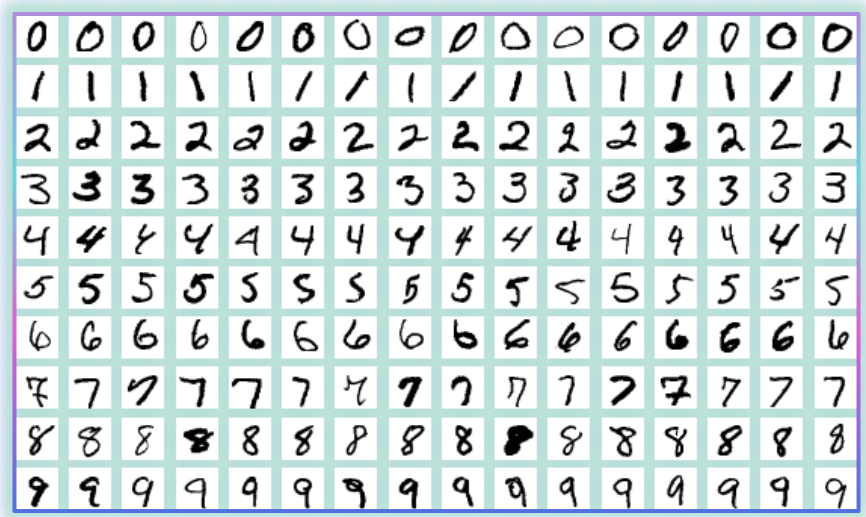
Select and Collect dataset

- **Data is the basis of model training.**
  - Quantity
  - Quality
  - Diversity
  - Performance evaluation
  - Ethical
- **Where to get the data?**
  - Acquire it
  - Buy it
  - Build it



Example MNIST

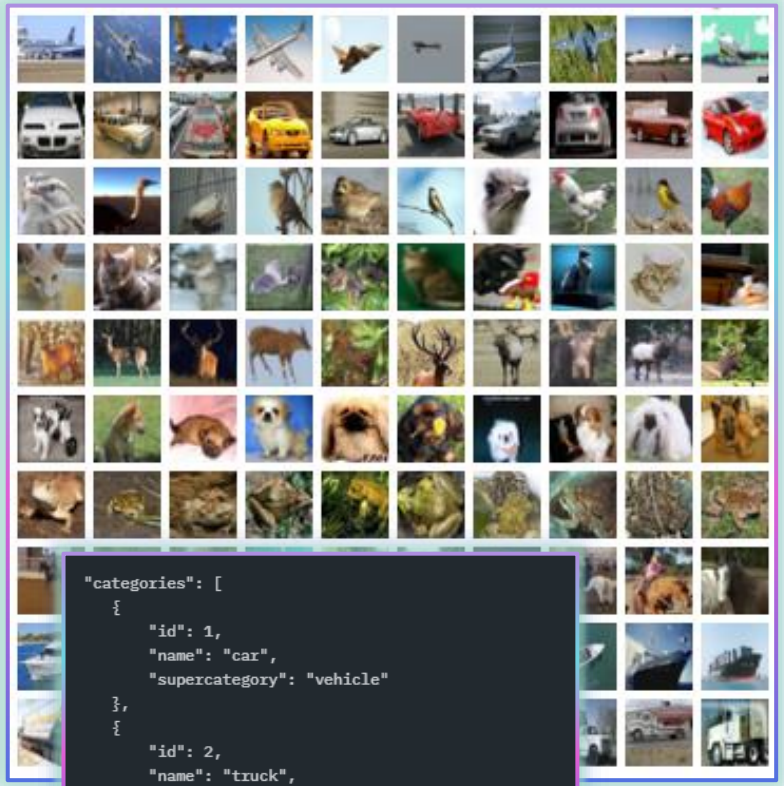
- **Collection of handwritten digits widely used for training and testing in the field of machine learning and computer vision**
- **70,000 images**
  - 60,000 training samples
  - 10,000 testing samples
- **Image Properties**
  - Grayscale images (0-255 levels)
  - Size of 28x28 pixels
- **Labels**
  - 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**



Example MS COCO

- **The Microsoft Common Objects in Context – Object detection, segmentation, and caption. Pre-divided into training, validation, and test sets**
- **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**
- **Image Captions**
- **Updated yearly**
- **Free for researchers**


```
"annotations": [
  {
      "id": 1,
      "image_id": 1,
      "category_id": 1,
      "segmentation": [
          [
              [
                  56.97,
                  56.97
              ],
              [
                  56.97,
                  56.97
              ],
              ...
          ]
      ],
      "area": 2351.45,
      "bbox": [
          56.97,
          56.97,
          56.97,
          56.97
      ],
      "iscrowd": 0
  }
  ...
]
```

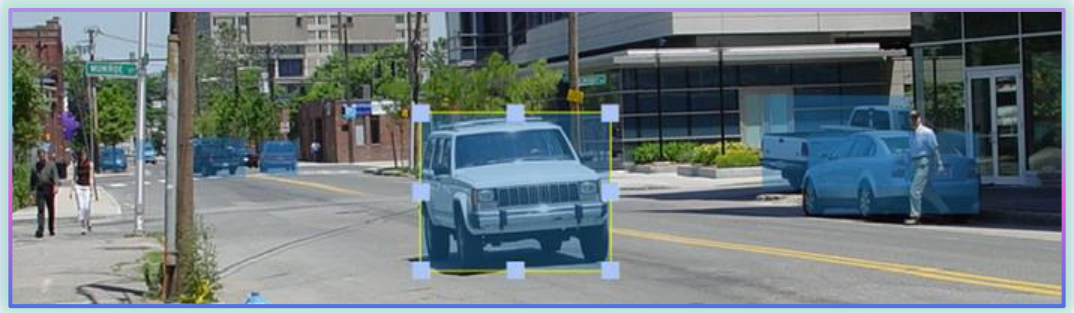




```
"categories": [
  {
      "id": 1,
      "name": "car",
      "supercategory": "vehicle"
  },
  {
      "id": 2,
      "name": "truck",
      "supercategory": "vehicle"
  }
]
```

Obtaining Datasets

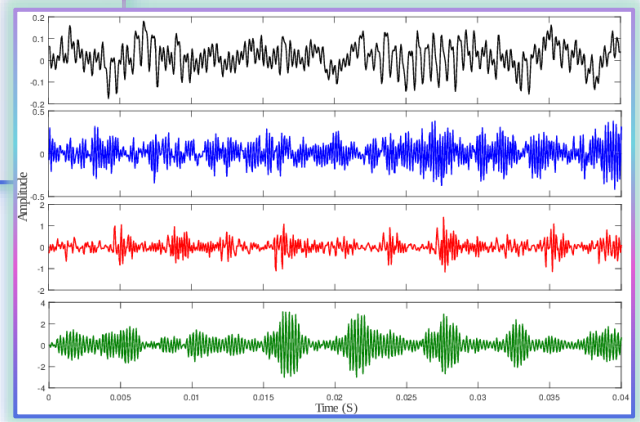
- **Limited number of *free* datasets**
  - Check licenses
- **Dataset Providers**
  - Kaggle (public datasets)
    - Subsidiary of Google
  - Companies that will create a dataset (for a fee)
    - Scale AI
    - MTurk (Amazon Mechanical Turk)
      - Crowdsourced marketplace for data labelling
  - Most 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



Vibration Analysis

- **Bearing Data Center (CWRU)**
  - Vibration sensor samples at 12kHz
  - EDM Artificial Damage
- **Machinery Failure Data**
  - Extensive set of vibration readings
  - Common failure modes for broad range of machines
- **NASA Acoustics and Vibration Database**
  - Great for building rockets



🛠 Lab1 Initial Setup and Data Collecting

Step 18

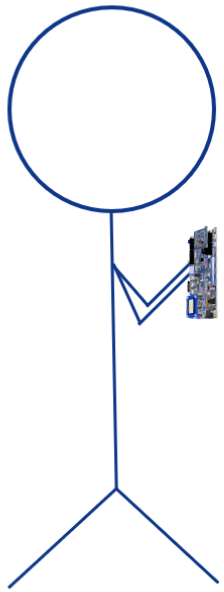
- Before starting capture data, you can first observe the results of different actions motion sensor.
- Ensure uniformity and quality in executing every action.
- Start moving your body, perform Straight, Uppercuts, and right hooks 15 times each, and save them into three different files.
- It is *recommended* that the length of each data file should not longer then 30 seconds while today's training.
- It is *recommended* perform one movement per second, and rest for about one second between each movement, and the rest interval can be regarded as an action- Freeze.
- Proper data organization and naming rules will facilitate data retrieval and analysis.

🛠 Lab1 Initial Setup and Data Collecting

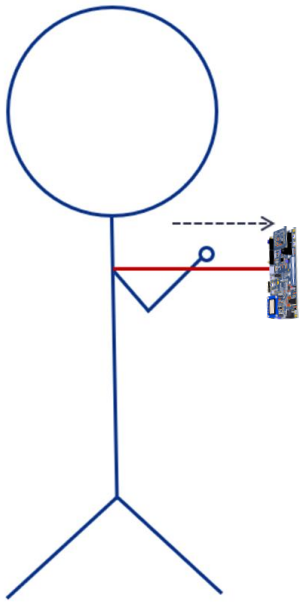
Step 19

- **How to do Straight, Right hook, and Uppercut?**

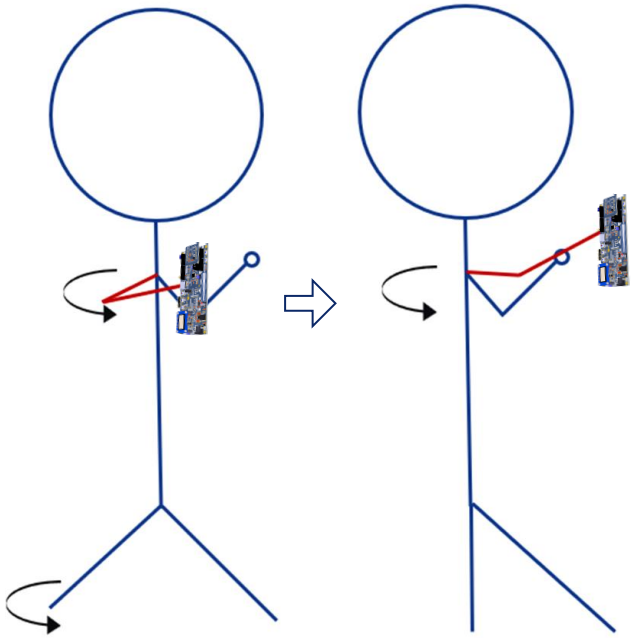
Freeze
(Ready Position)



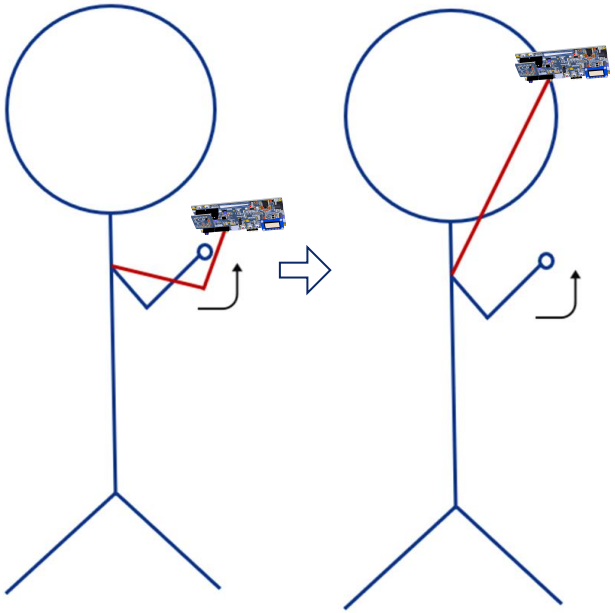
Straight



Right hook



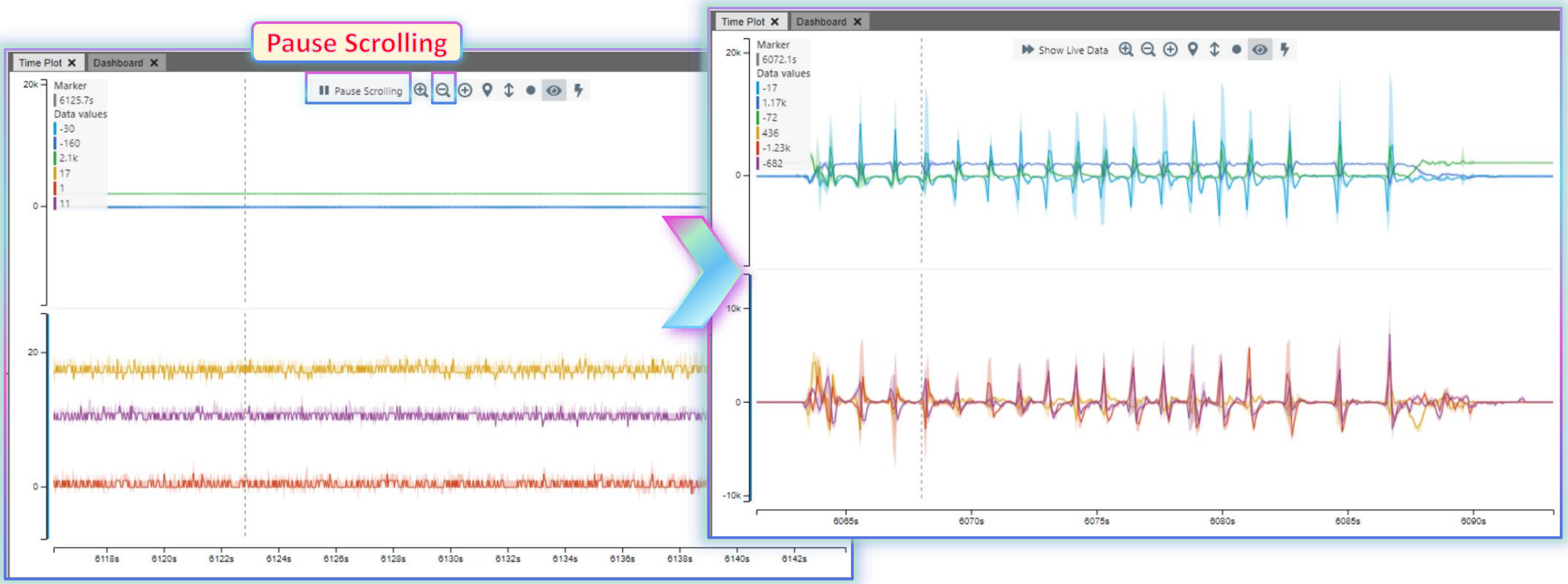
Uppercut



🛠 Lab1 Initial Setup and Data Collecting

Step 20

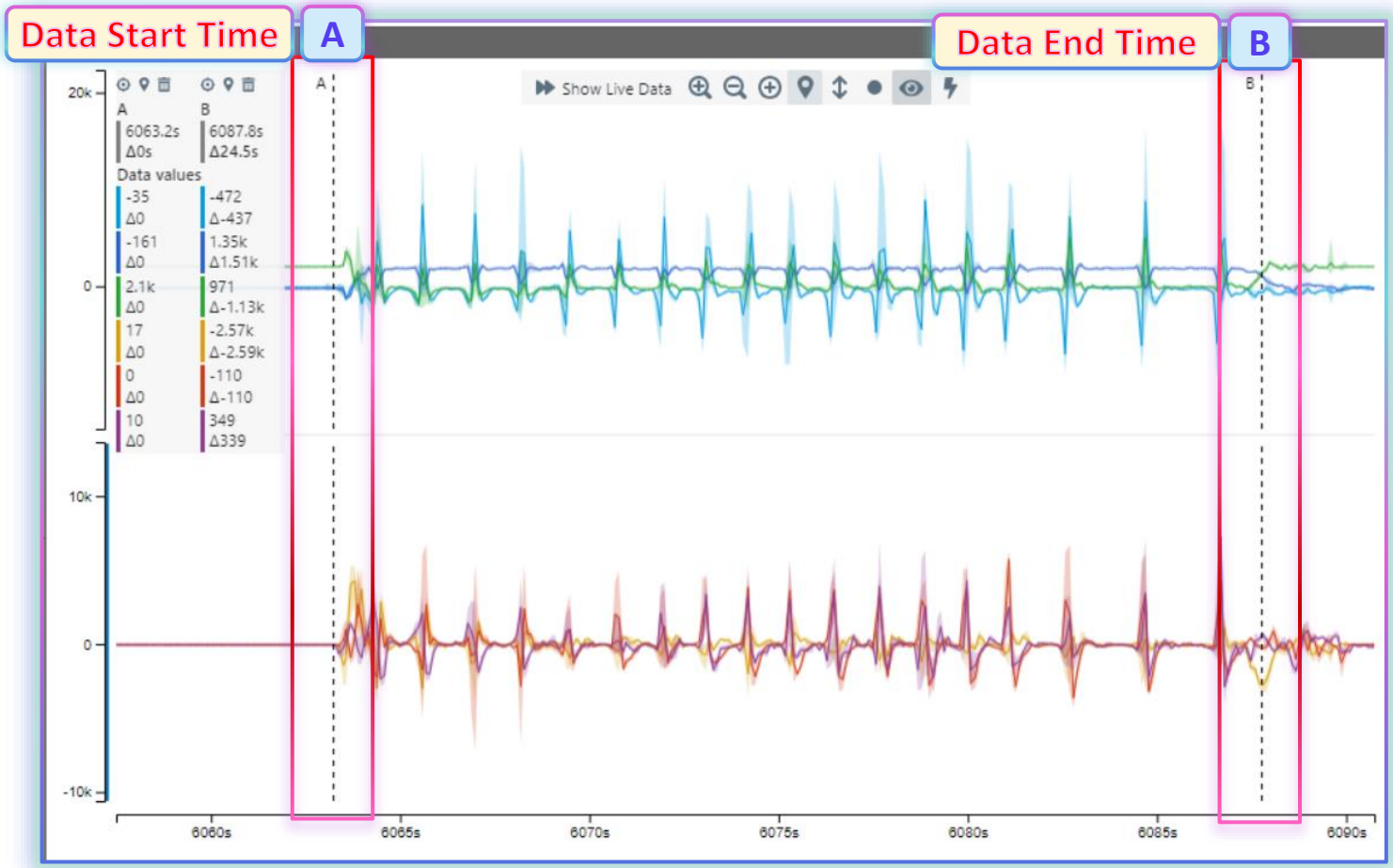
- Click Pause Scrolling and to zoom out the window to show the all actions your do.



🛠 Lab1 Initial Setup and Data Collecting

Step 21

- Add two vertical cursor and move to the time you start and stop the movements.

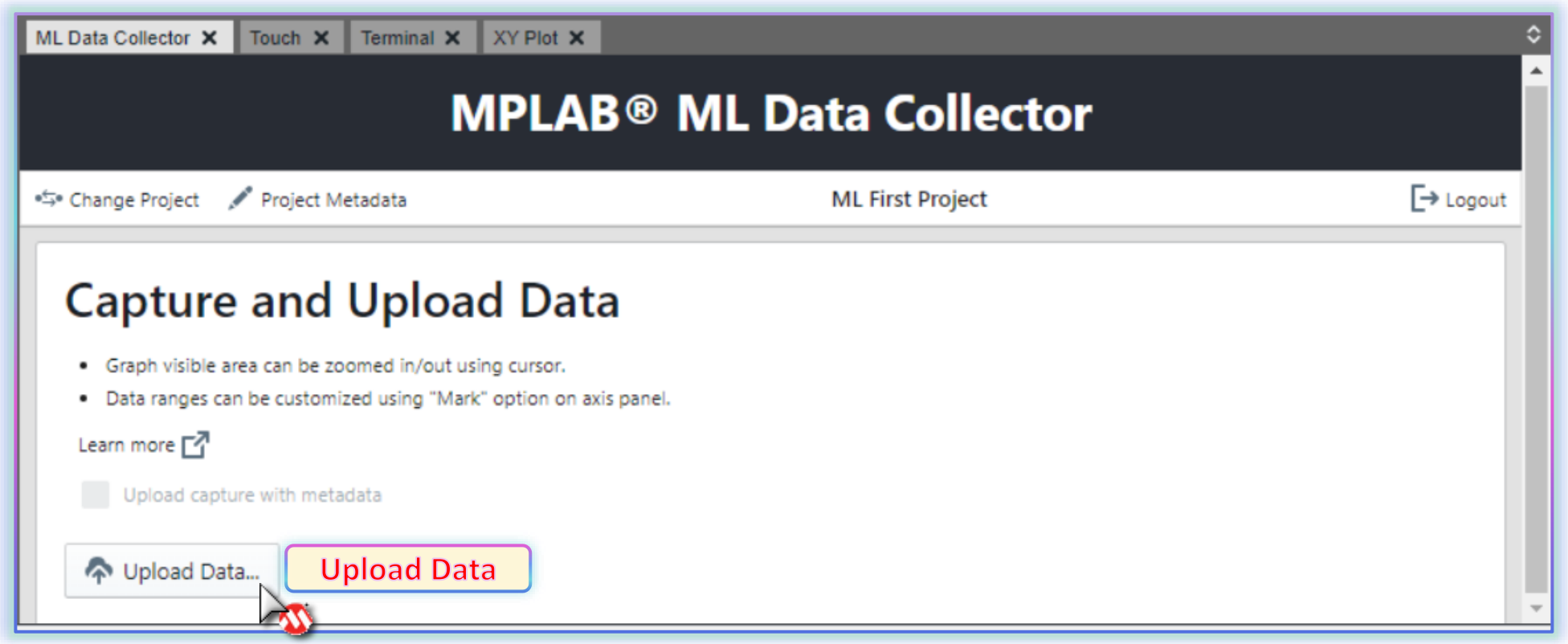


MICROCHIP

🛠 Lab1 Initial Setup and Data Collecting

Step 22

- **Capture and Upload Data in ML Data Collector**
- **Click Upload Data**



🛠 Lab1 Initial Setup and Data Collecting

Two Ways to Capture and Upload Data

1. Upload and save Data by MPLAB ML Data Collector. The data will be saved to .csv file in your local PC and upload to the ML Project you created automatically.

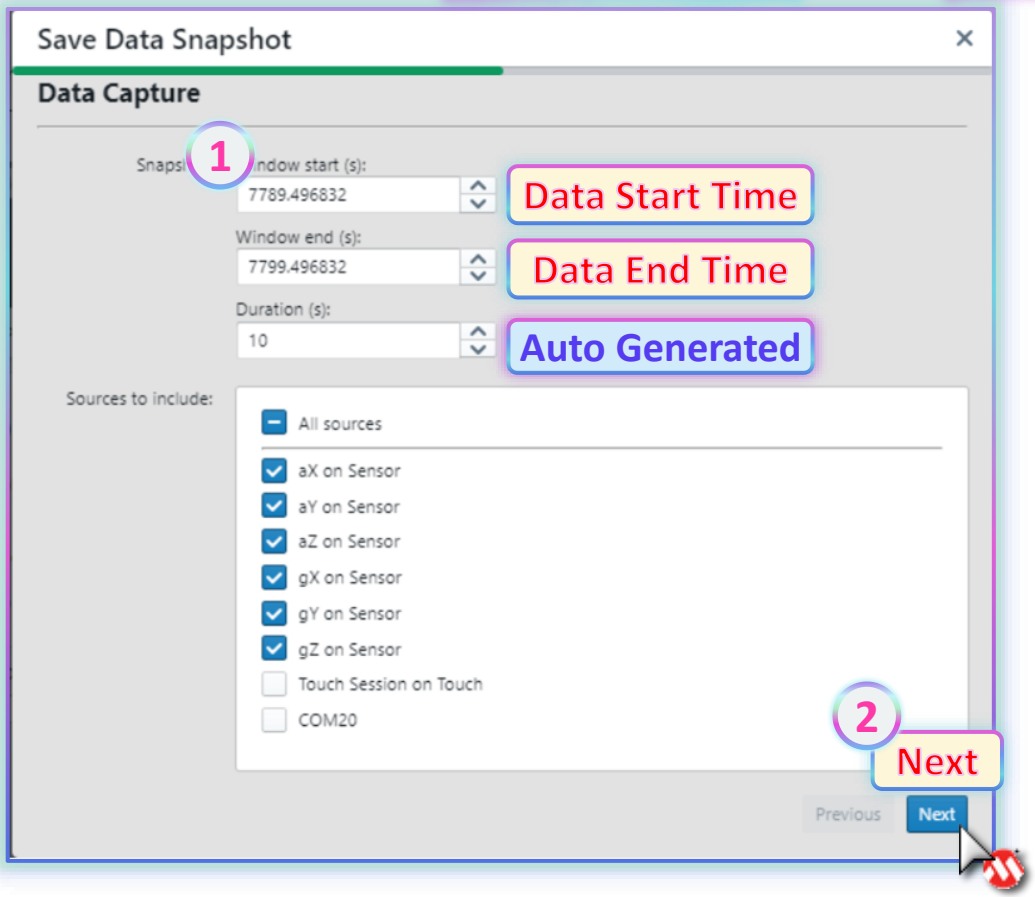
2. Snapshot Data by click on in Time Plot of DV to save the .csv file in your local PC. Then upload the .csv file to the ML Project you created manually.

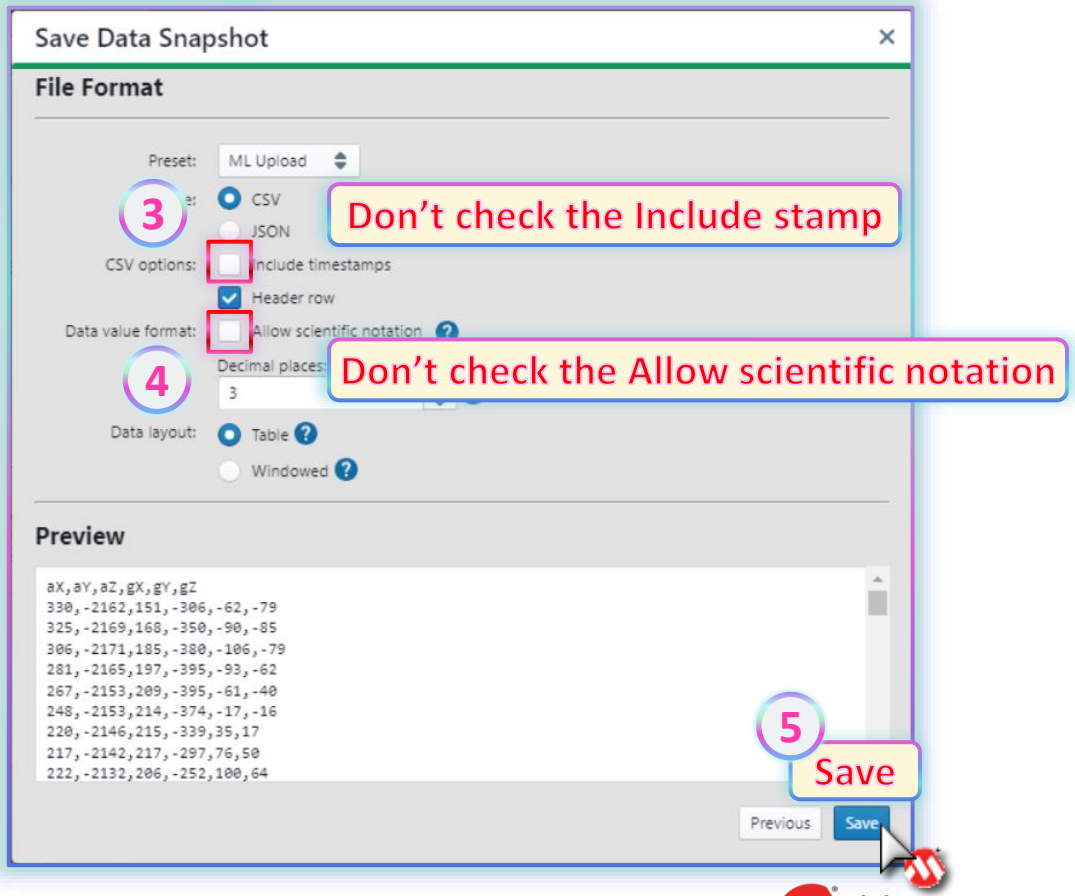
MICROCHIP

🛠 Lab1 Initial Setup and Data Collecting

Step 23

- Enter the time period of the movement to take snapshot. (Use cursor A and B automatically)
- Don't check the Include stamp and Allow scientific notation.



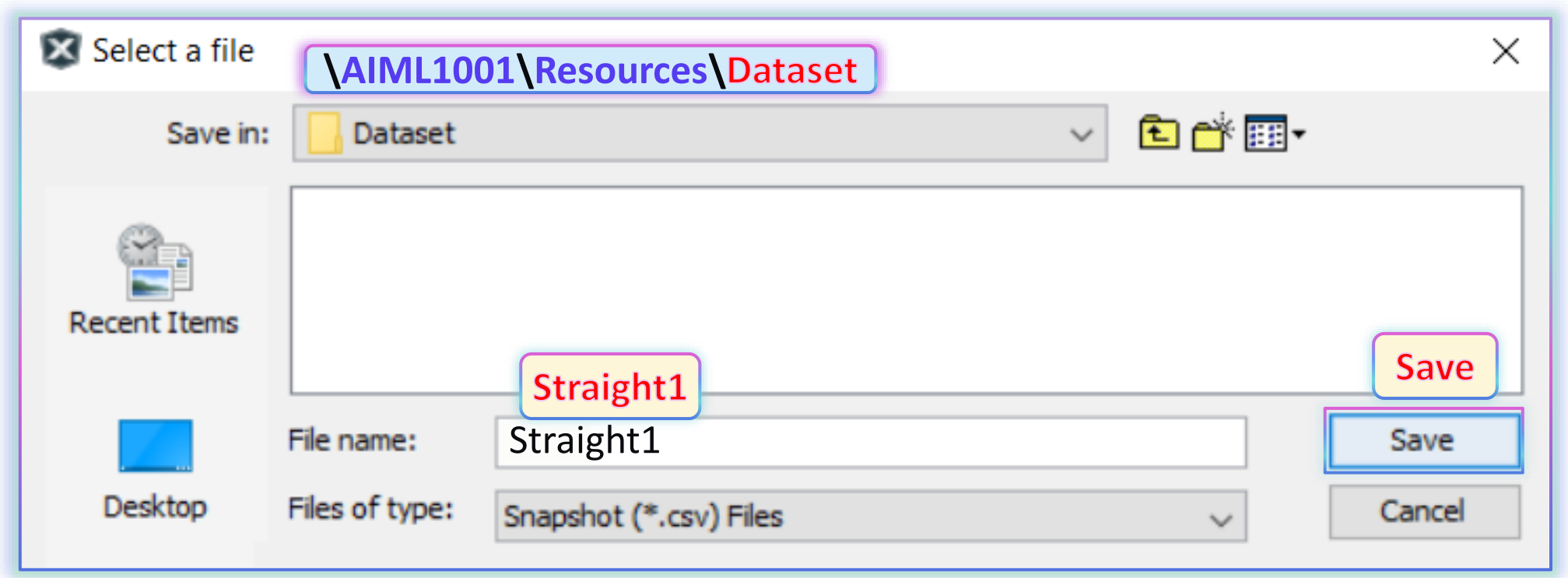


MICROCHIP

🛠 Lab1 Initial Setup and Data Collecting

Step 24

- Save the .csv files in folder "\AIML1001\Resources\Dataset".
- Name the file as Straight1.



🛠 Lab1 Initial Setup and Data Collecting

Result

- **Show File uploaded successfully after the dataset uploaded successfully to the cloud under your myMicrochip account.**

- **Repeat step 19 to step 24.**
  Build, Upload and Save all the data file.
  - Straight1.csv.
  - Uppercut1.csv.
  - Righthook1.csv.

Labeling and Prepare Data

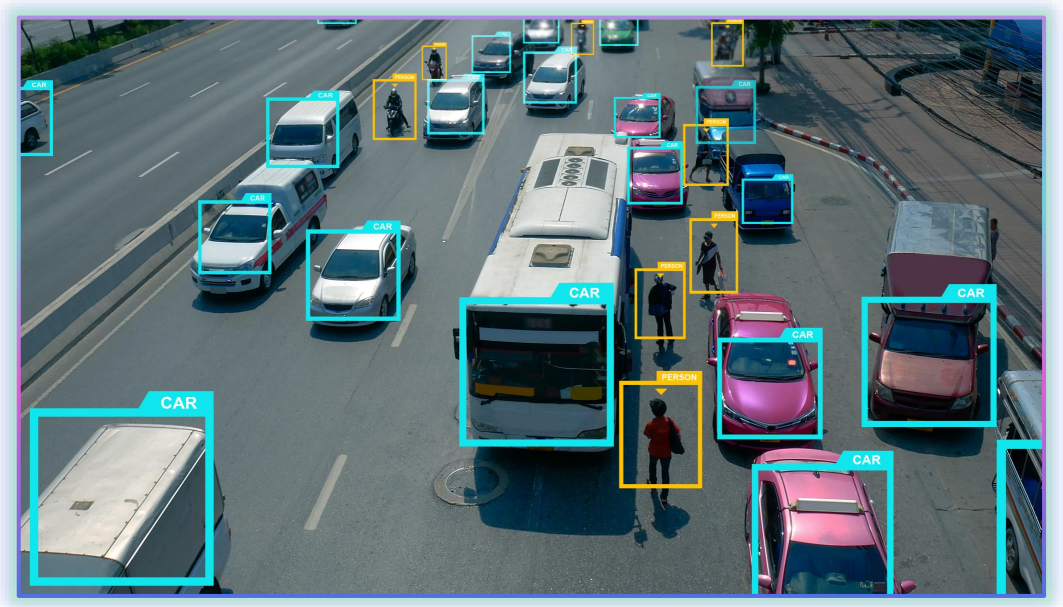
The importance of data

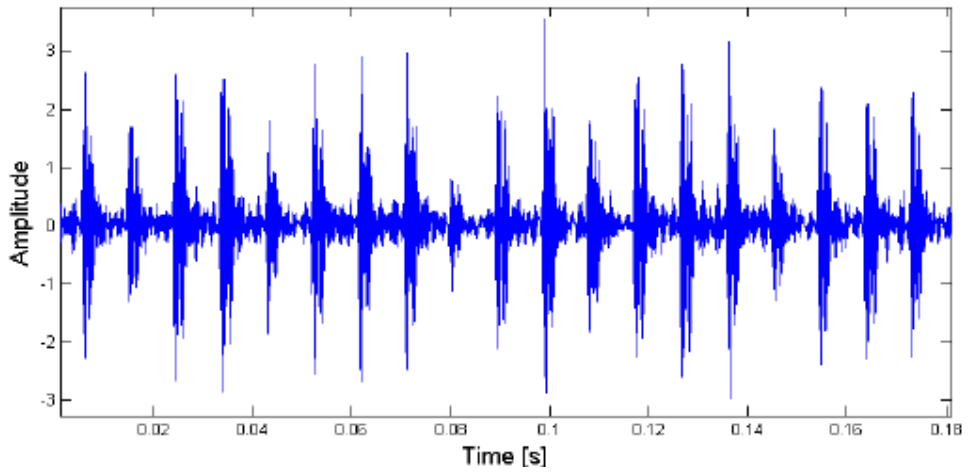
- **Google's Research Director Peter Norvig has been quoted many times on the value of more data in analytics:**
  - "We don't have better algorithms. We have more data."
  - "Simple models and a lot of data trump more elaborate models based on fewer data."

Organize and label data

- **How to Organize and label data?**
  - By Application
  - By Purpose

- **Things to note**
  - Consistency and Quality
  - Quality Control of Labeled Data
  - Marking tools and platforms





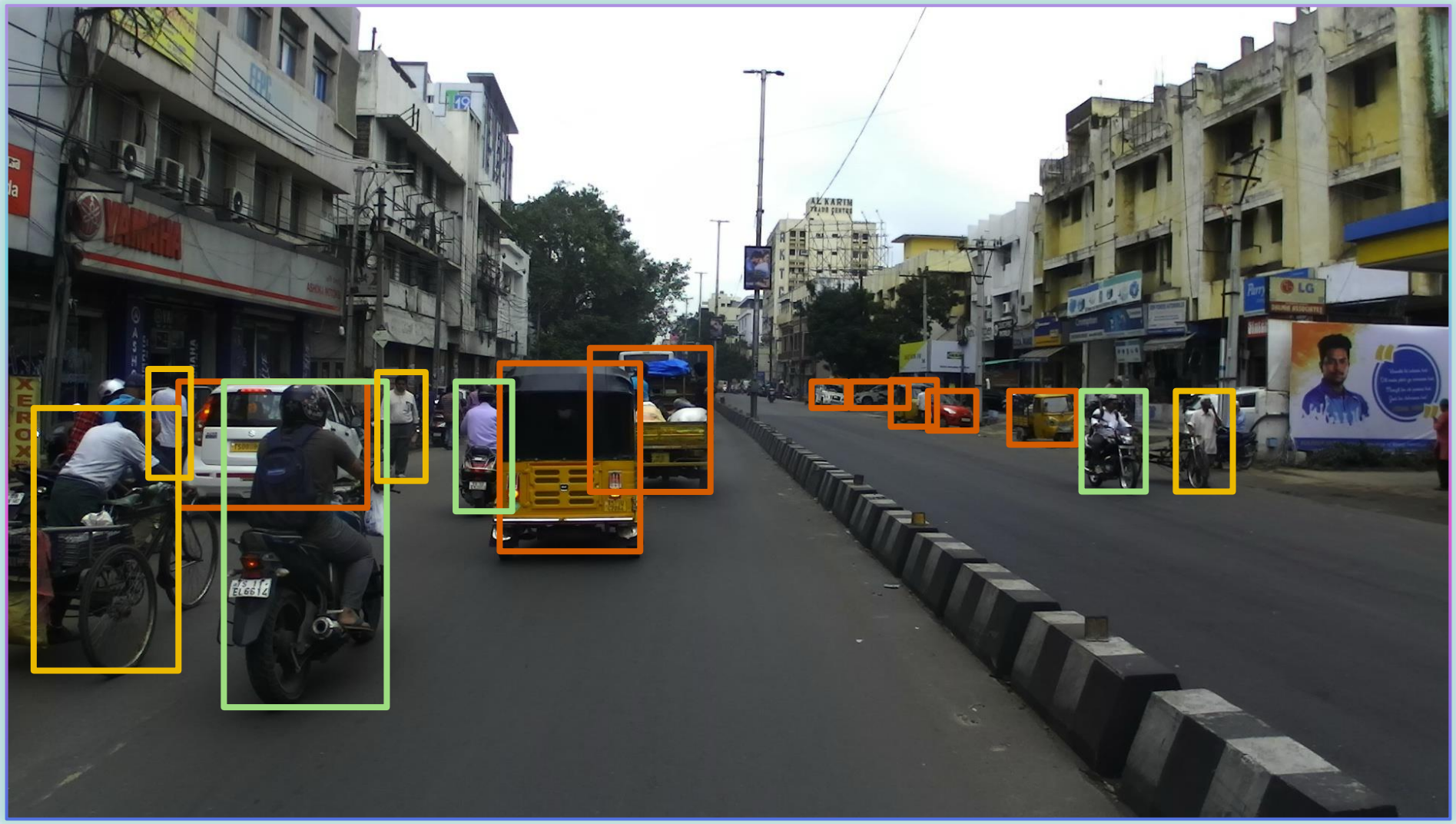
What do you see in this picture?

- **What will you label this Picture ?**

MICROCHIP

What do you see in this picture?

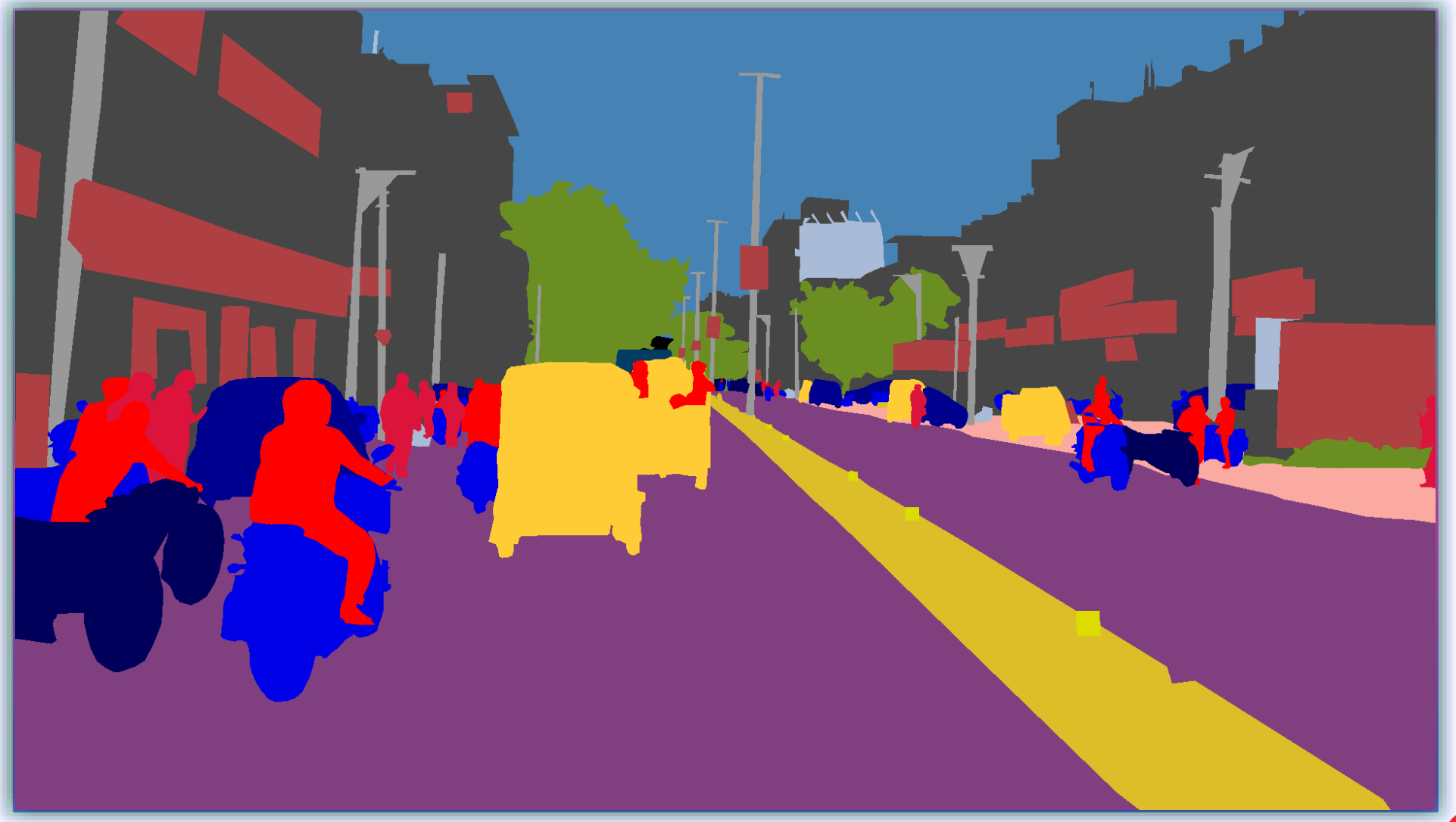
- **By Application - In Object Detection…**



MICROCHIP

What do you see in this picture?

- **By Application - In Semantic Segmentation…**

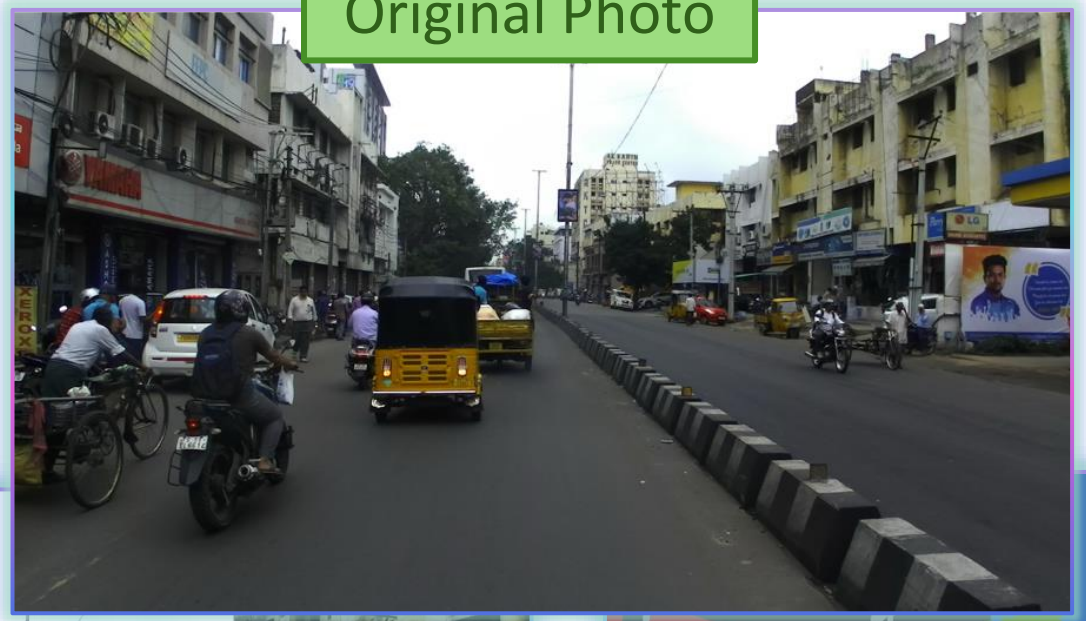


MICROCHIP

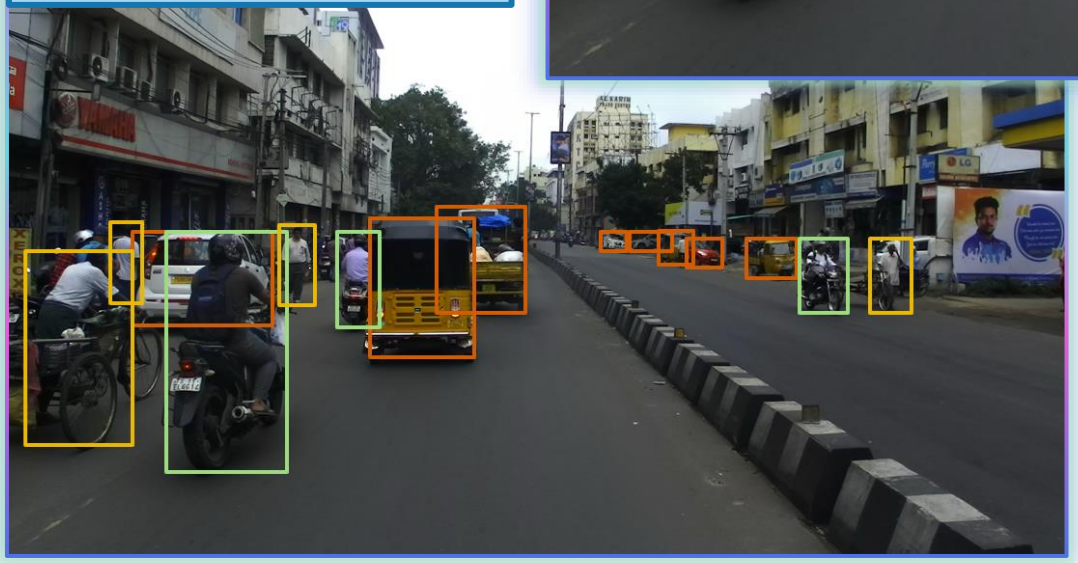
What do you see in this picture?

- **By Application**

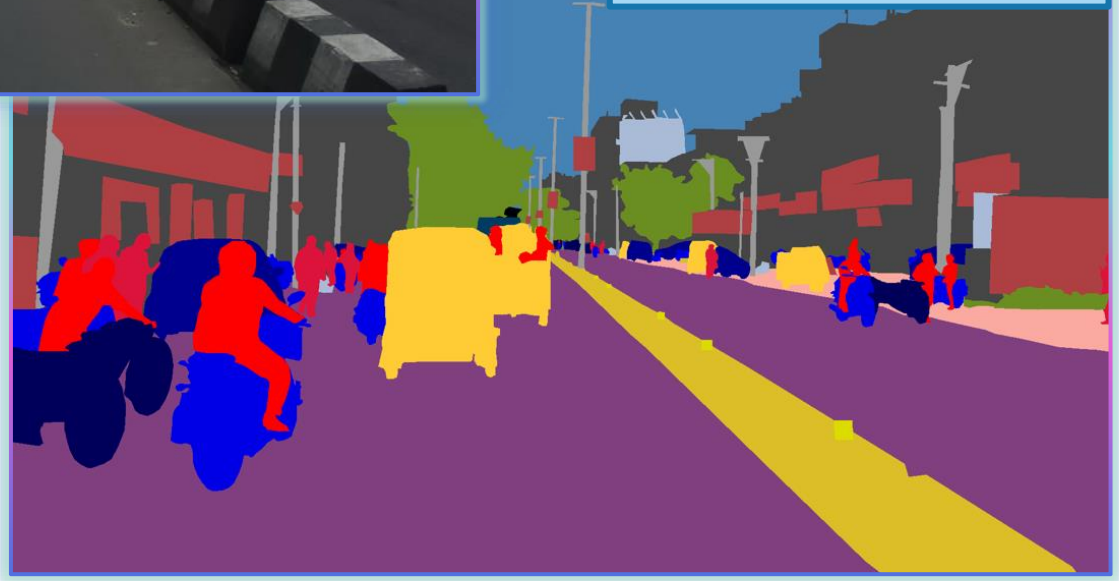
Original Photo



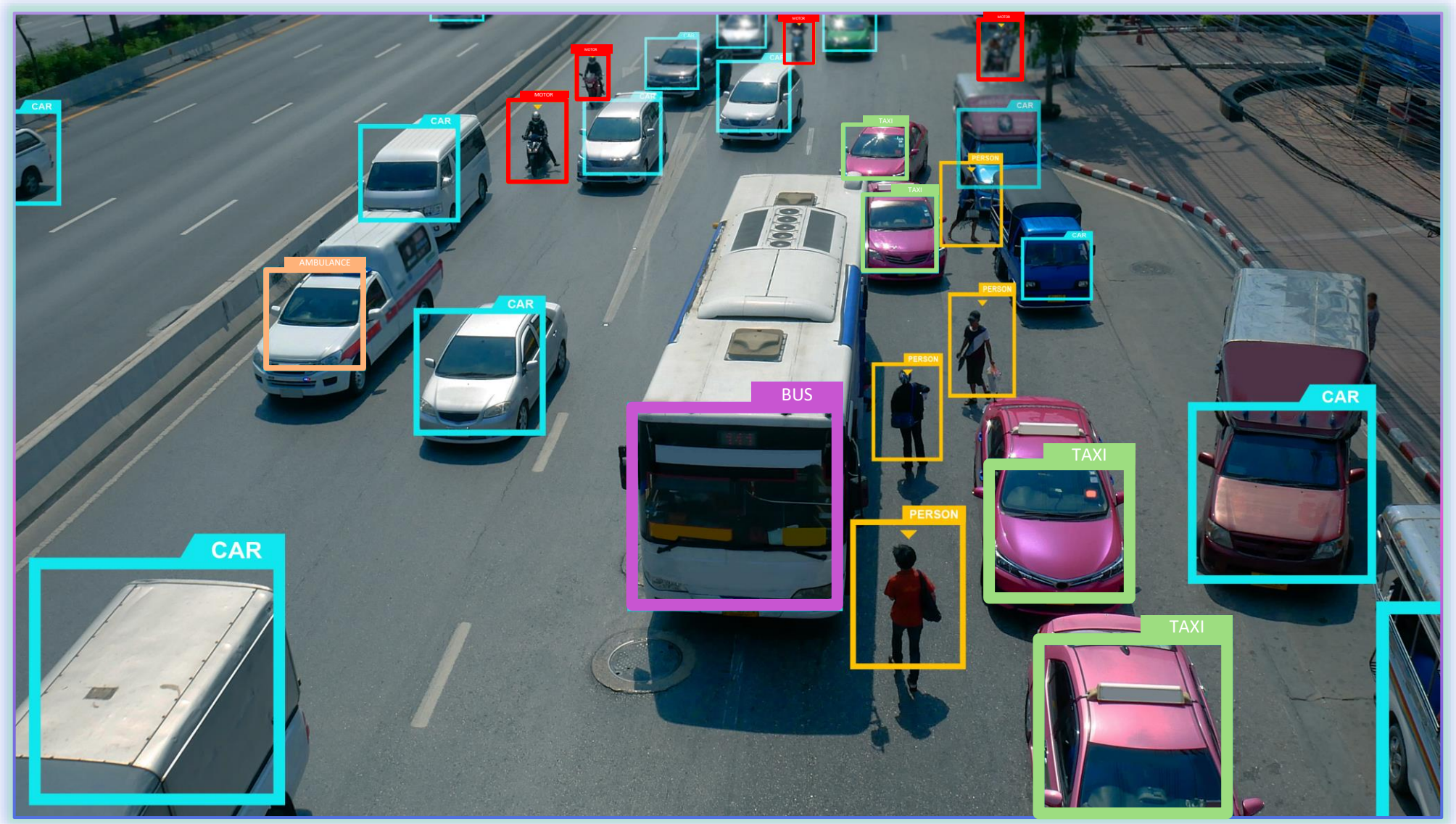
Object Detection



Semantic Segmentation



What will you select in this picture?



MICROCHIP

Segment Label and Metadata

- **Segment Label:** Describe the types of our events.
  - The outputs from the classifier.
- **Metadata:** Data about the data. Provide the description of the dataset and define custom information that can be used in training.
  - Data quality management
  - Feature engineering
  - Model training and evaluation
  - Model tracking and version management

Segment Label and Metadata

- **Take 2025 Winter Elite training materials as example…**

Metadata

Title: 2025 Winter Elite Training Materials

Author: Microchip Taiwan CAEs

Publisher: Microchip

Publication date: 2025/02/10

Chapter: 11

Segment

Catalog:

- Section 1: SAMD21 ARM Cortex-M0+ Microcontroller Introduction

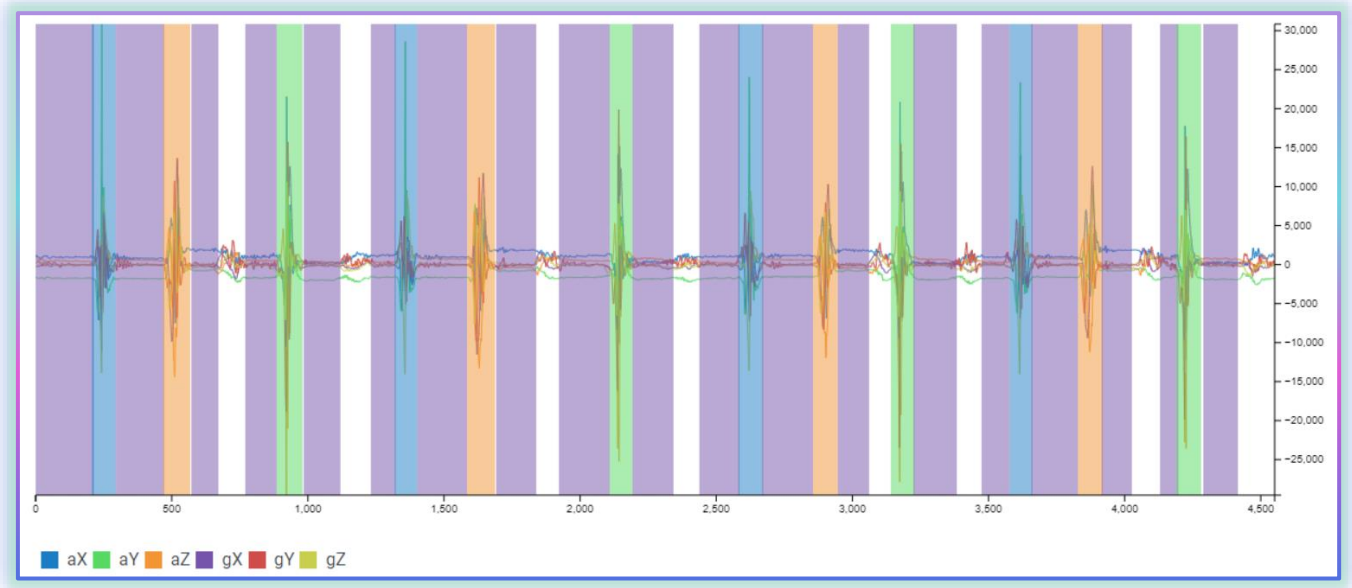
  …

- Section 10: SERCOM - SPI - OLED SSD1306
- Section 11: Machine Learning Boxing Recognition

MICROCHIP

Example Data of Boxing Recognition

- **Boxing demo**
  - Accelerometer (AX, AY, AZ)
  - Gyroscope (GX, GY, GZ)
- **Multiple Events**
  - Each signal has ‘quiet’ spells
  - Amplitude, spectrum vary
- **Metadata**
  - Dominant hand
  - Gender

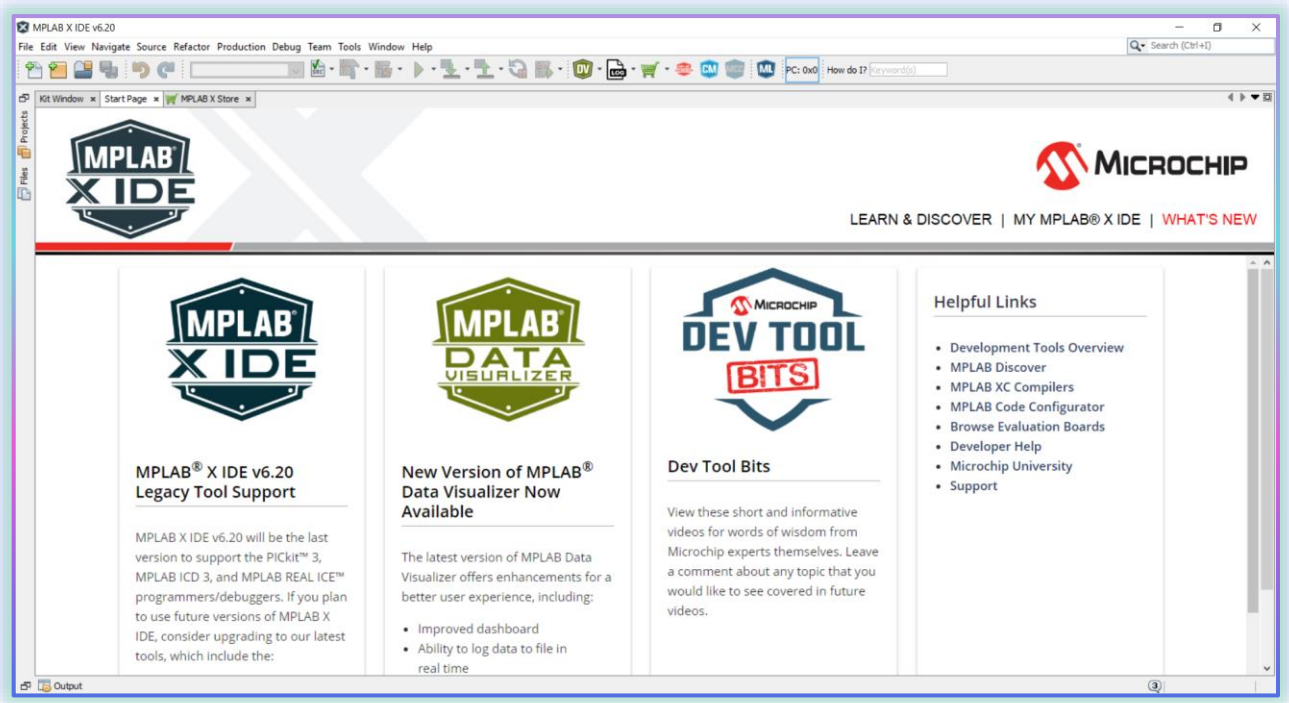


MPLAB® Machine Learning Development Suite

MICROCHIP

MPLAB® Machine Learning Development Suite

- **The MPLAB ML Model Builder plug-in is an application that filters and optimizes your labeled sensor data through machine learning algorithms. It generates a model (Knowledge Pack) ready to be flashed into the firmware of your device of choice.**



MPLAB®
MACHINE LEARNING
DEVELOPMENT SUITE

MICROCHIP

MPLAB® Machine Learning 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
- **Generate AutoML 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® Machine Learning Development Suite

Licensing Information for MPLAB ML Development Suit

	Evaluation License	Pro License
Price	Free	$99/year
Supported Silicon	Microchip 8-, 16-, 32-bit MCUs and dsPIC® DSCs	
Data	1 GB	Up to 10 GB
Labels	2500	Unlimited
Output	Library	Source Code
AutoML CPU Time	5H/month	250H
Application	Evaluation Only	Production
Where to Purchase/Install	Free MPLAB X IDE Plug-in	SW67G42A

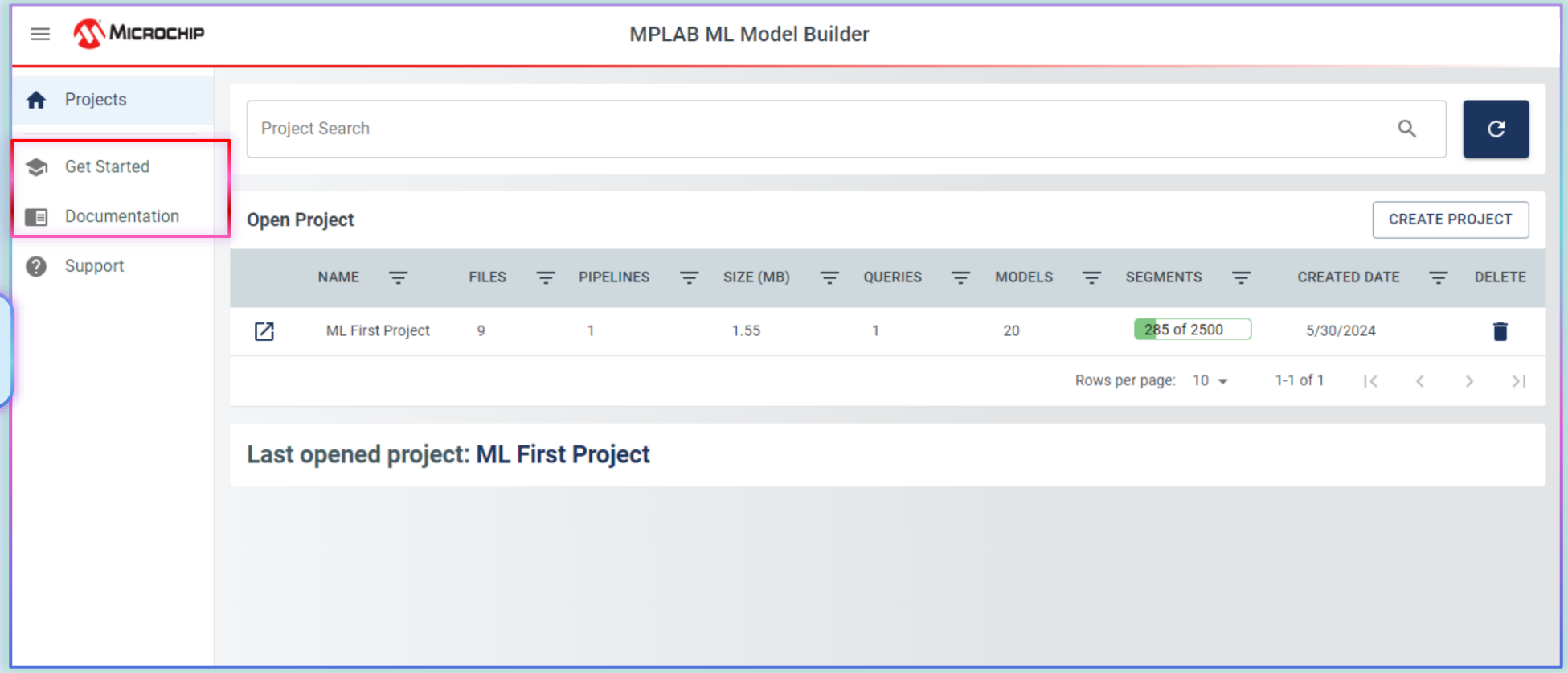
MICROCHIP

The Workspace of ML Development suite

- **Home Page of ML Development suite**

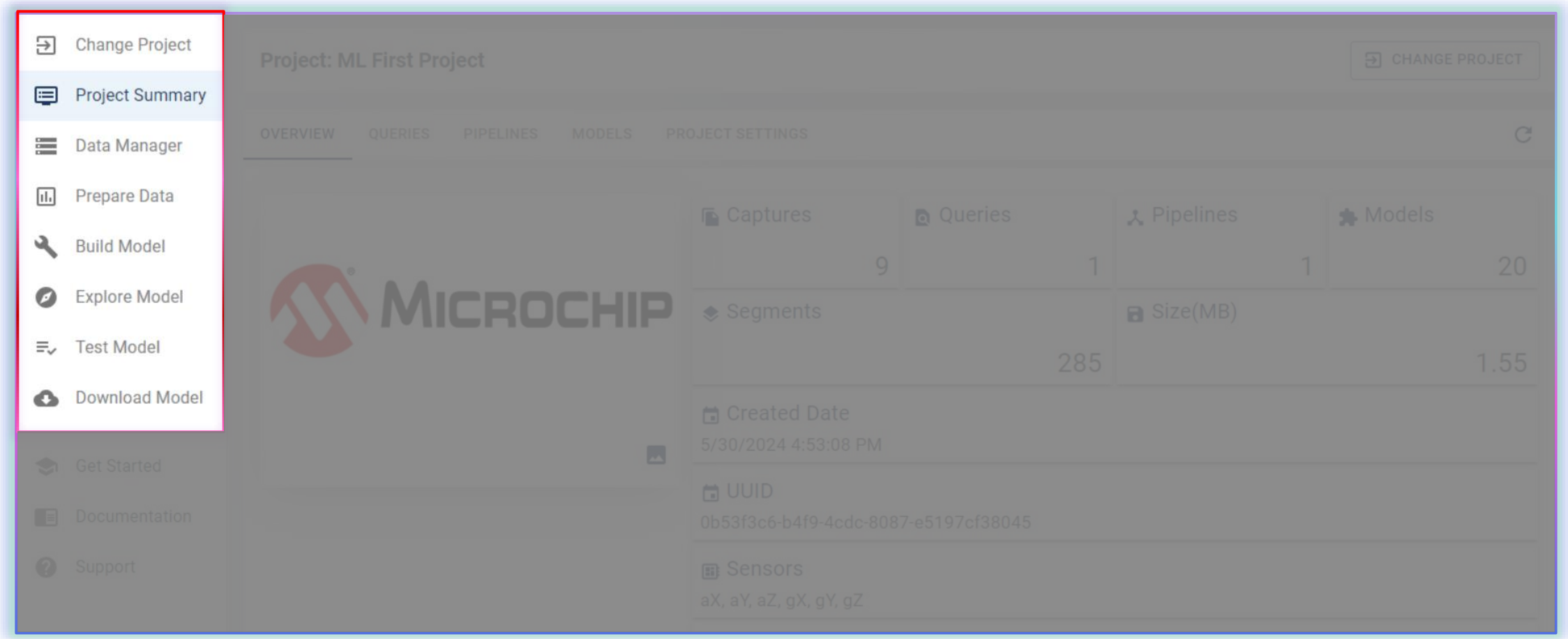
Get Started & Documentation

The link of the User Guide



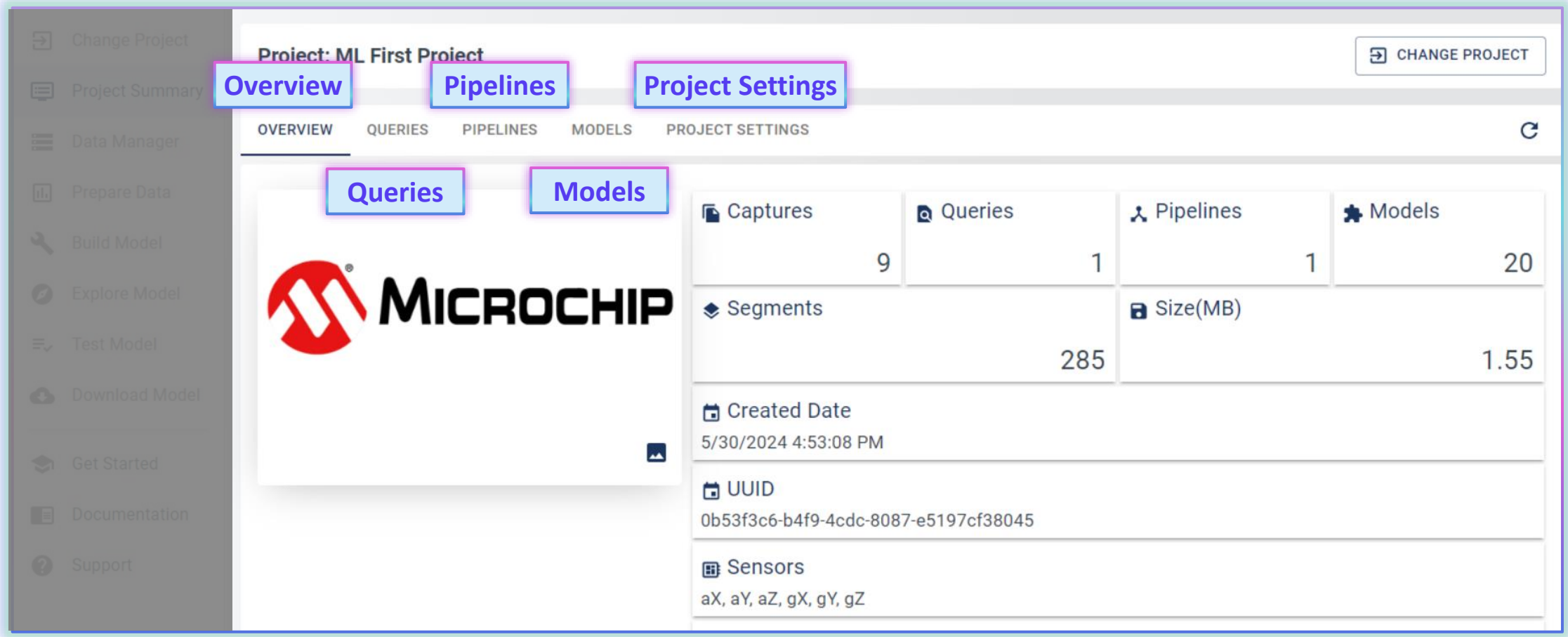
The Workspace of ML Development suite

- **Each step of the ML flow process.**



The Workspace of ML Development suite

- The Overview, Queries, Pipelines, Models, and Project Settings of the project.



🛠 Lab2
Data Labeling and Preparation

Boxing Recognition by Machine Learning

MICROCHIP

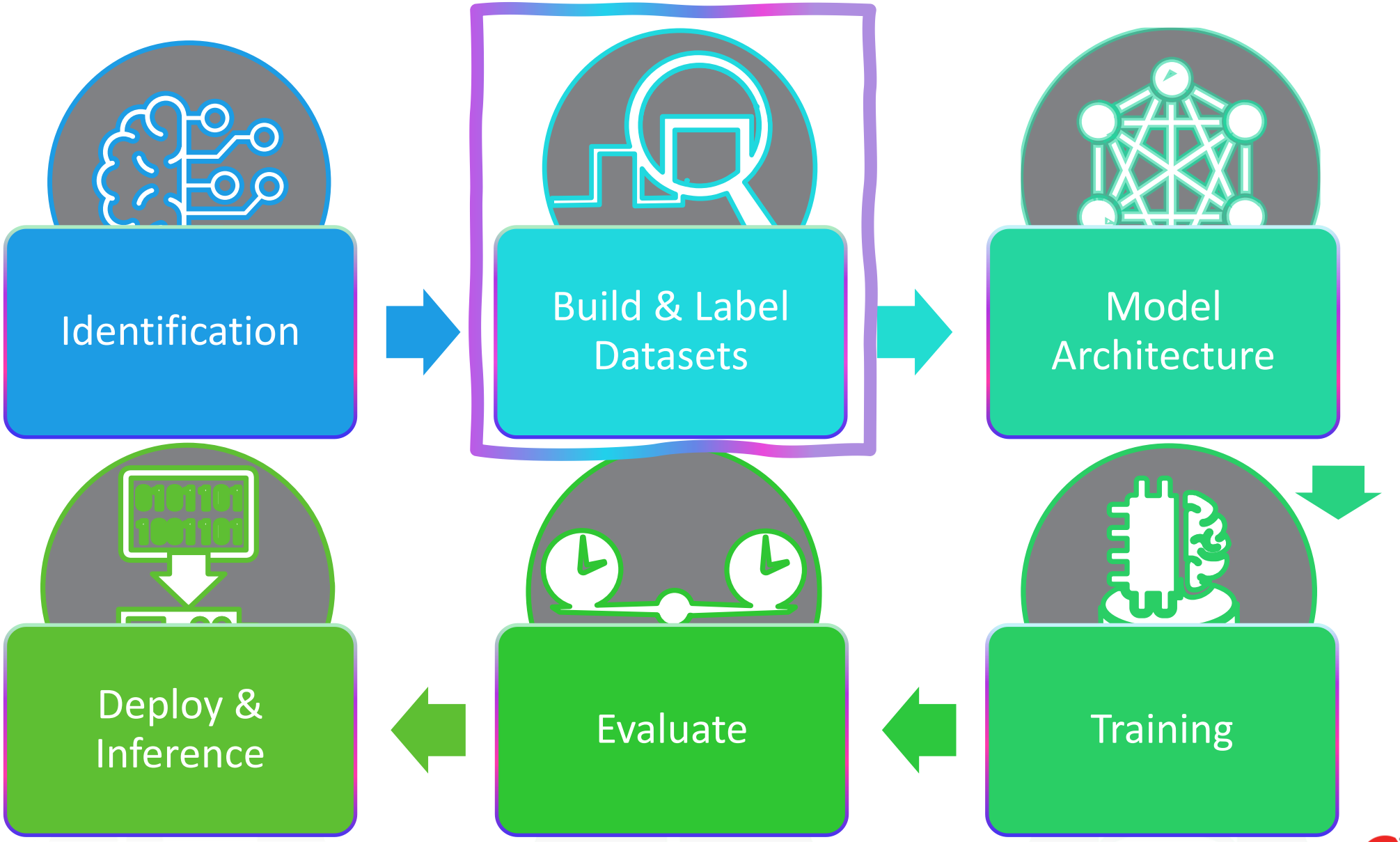
🛠 Lab2 Data Labeling and Preparation

Boxing Recognition by Machine Learning

- **Try to segment and label the data. This will be a lengthy process but is also the most important part to get the best results.**
- **Start the ML Builder plugin and log into your account.**
- **Opened the project you created and add 4 labels of the boxing movements to the project.**
  - Straight
  - Uppercut
  - Right hook
  - Freeze
- **Label the data for the model generation.**

Let’s go!

Machine Learning Workflow

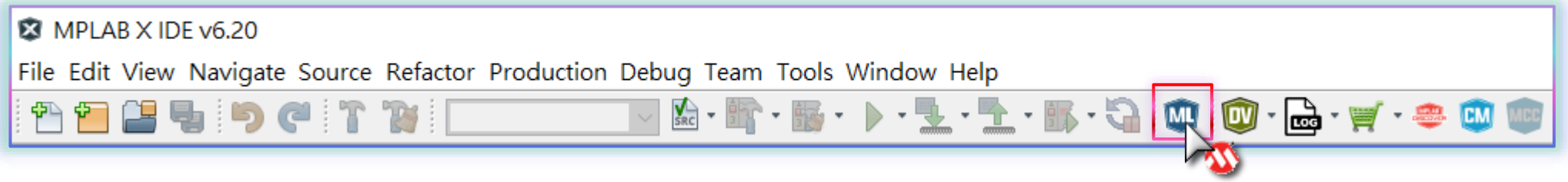


MICROCHIP

🛠 Lab2 Data Labeling and Preparation

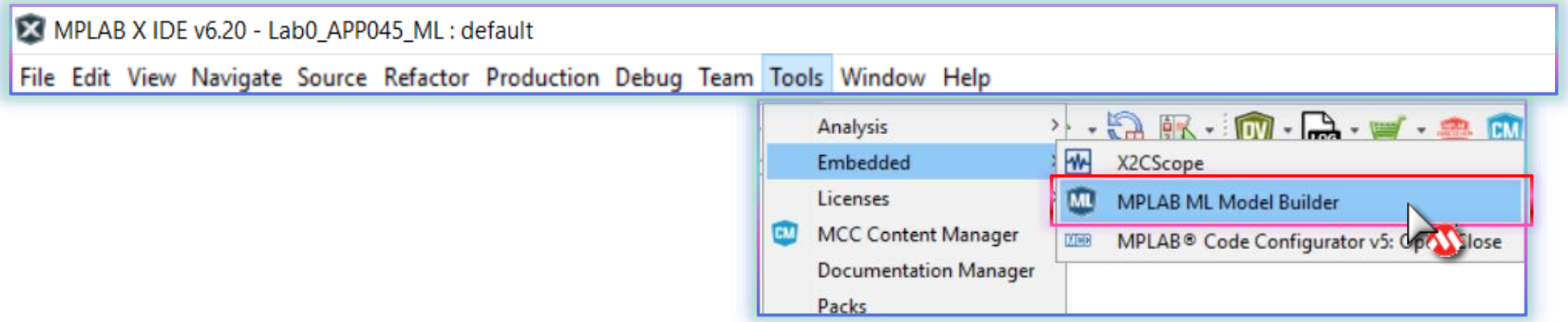
Step 1

- **Click ML icon**



OR

- **Tools > Embedded > MPLAB ML Model Builder**



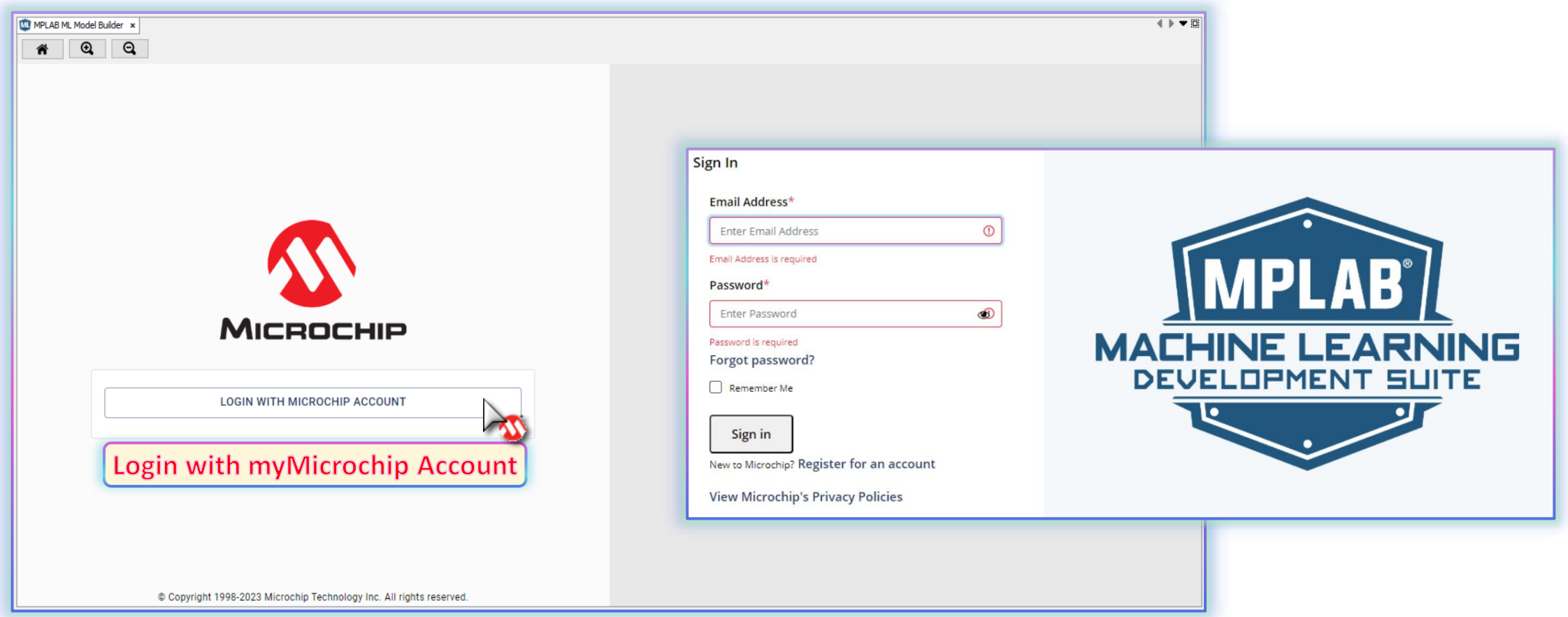
Appendix : Install the ML Data Collector & ML Model Builder

MICROCHIP

🛠 Lab2 Data Labeling and Preparation

Step 2

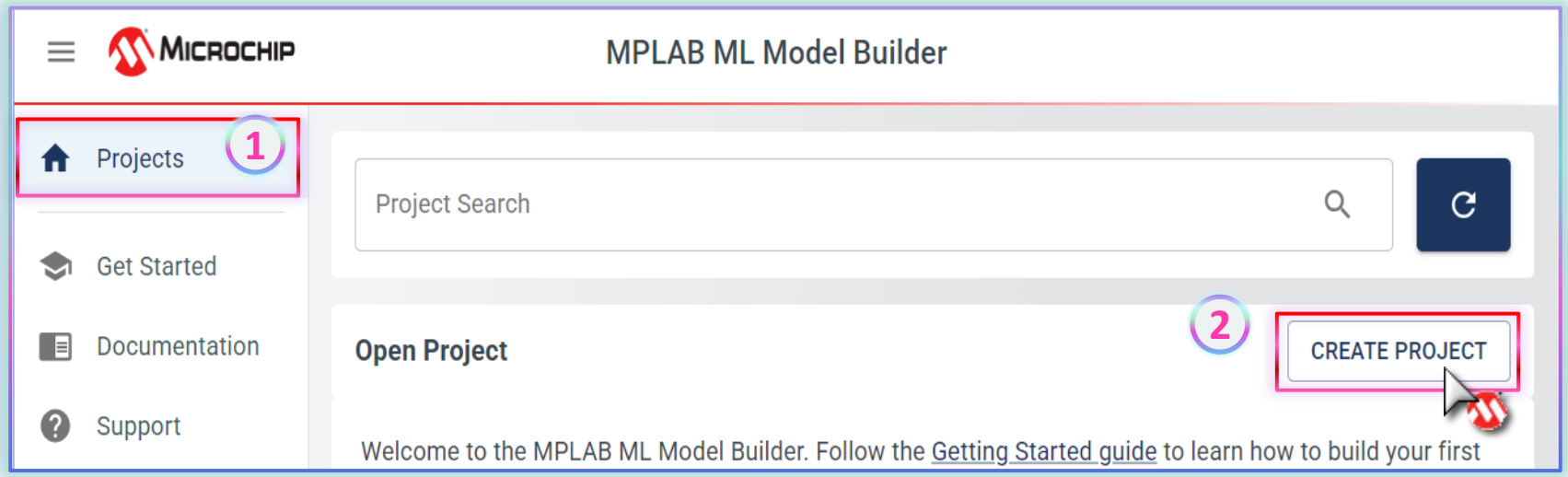
- **Log in with your myMicrochip account.**



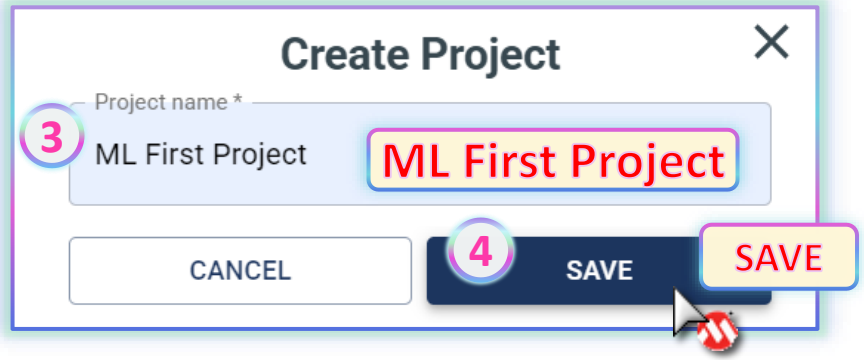
🛠 Lab2 Data Labeling and Preparation

Create a New Project in ML Model Builder

- **Click on CREATE PROJECT, if you have not created one using ML Data Logger.**



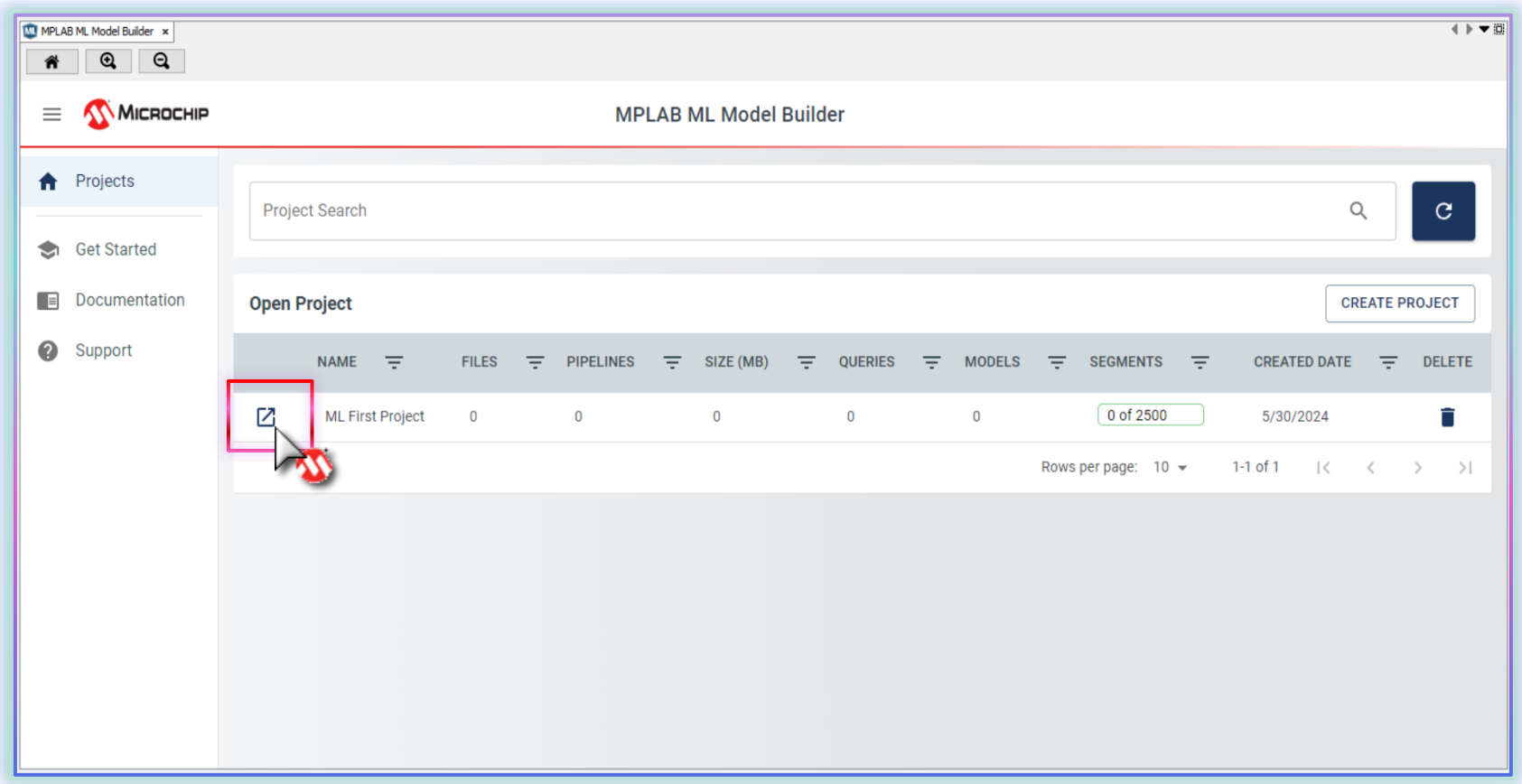
- **Input Project Name: ML First Project for your project then click SAVE**



🛠 Lab2 Data Labeling and Preparation

Step 3

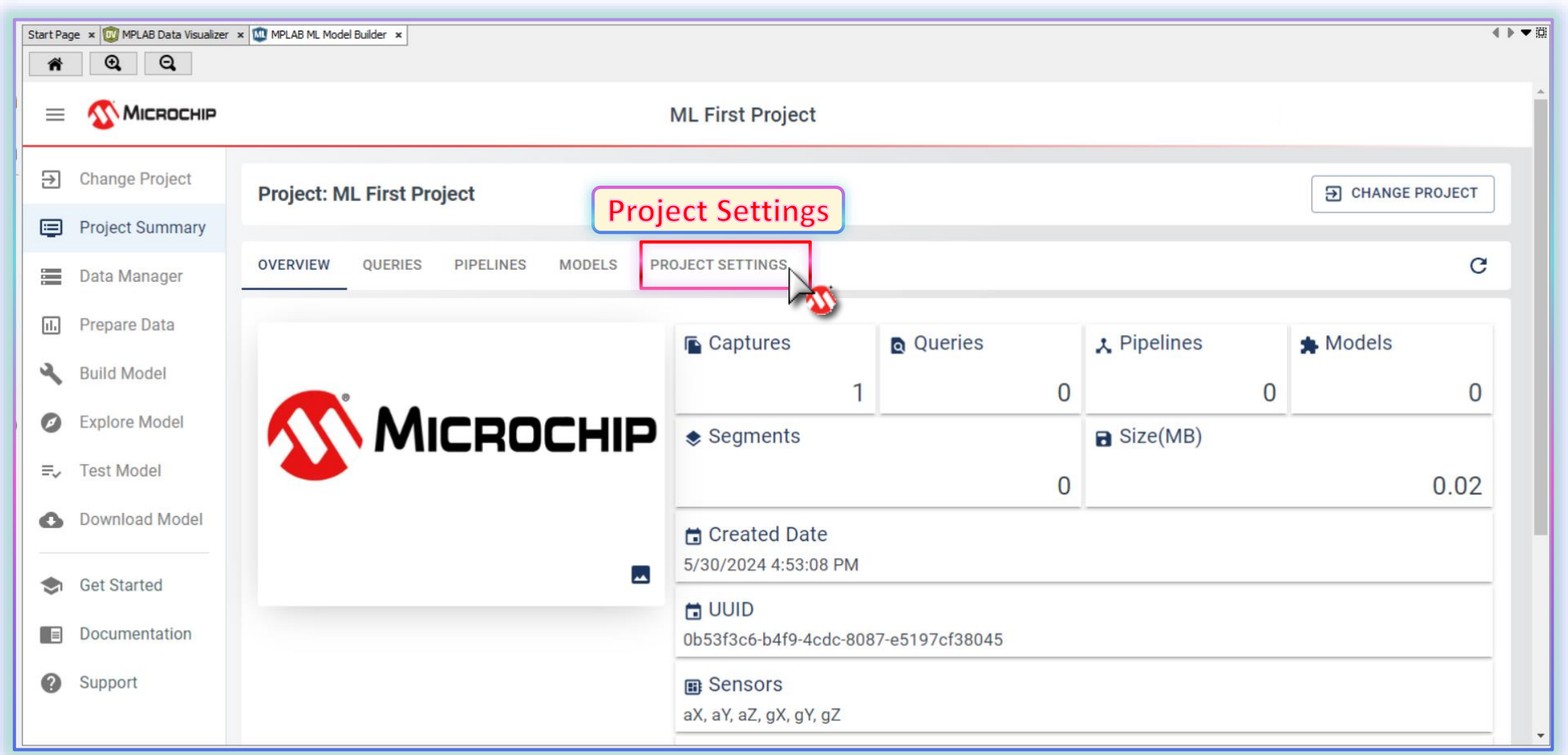
- **The project we built will show on the welcome page.**
- **Click icon to open ML First Project.**



🛠 Lab2 Data Labeling and Preparation

Step 4

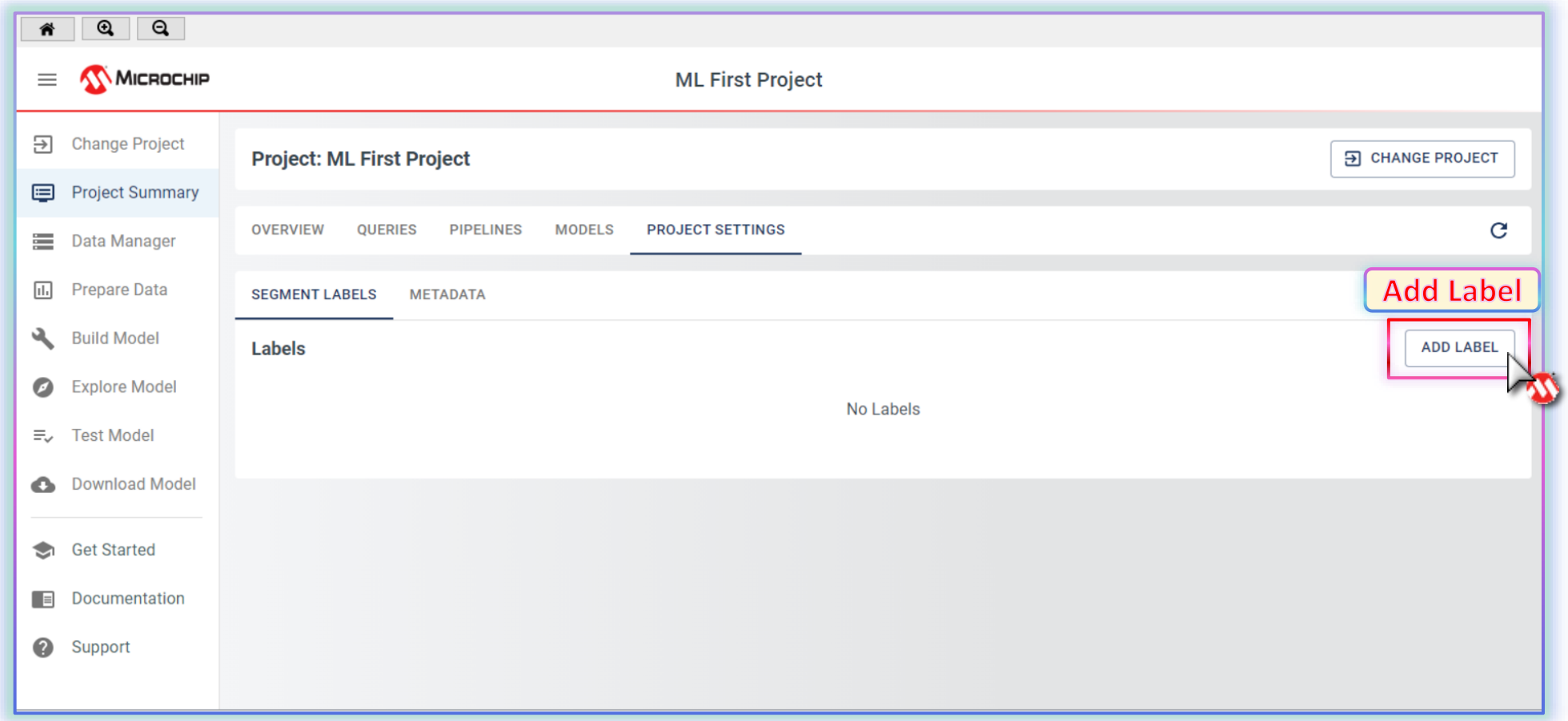
- Click Project Settings.



🛠 Lab2 Data Labeling and Preparation

Step 5

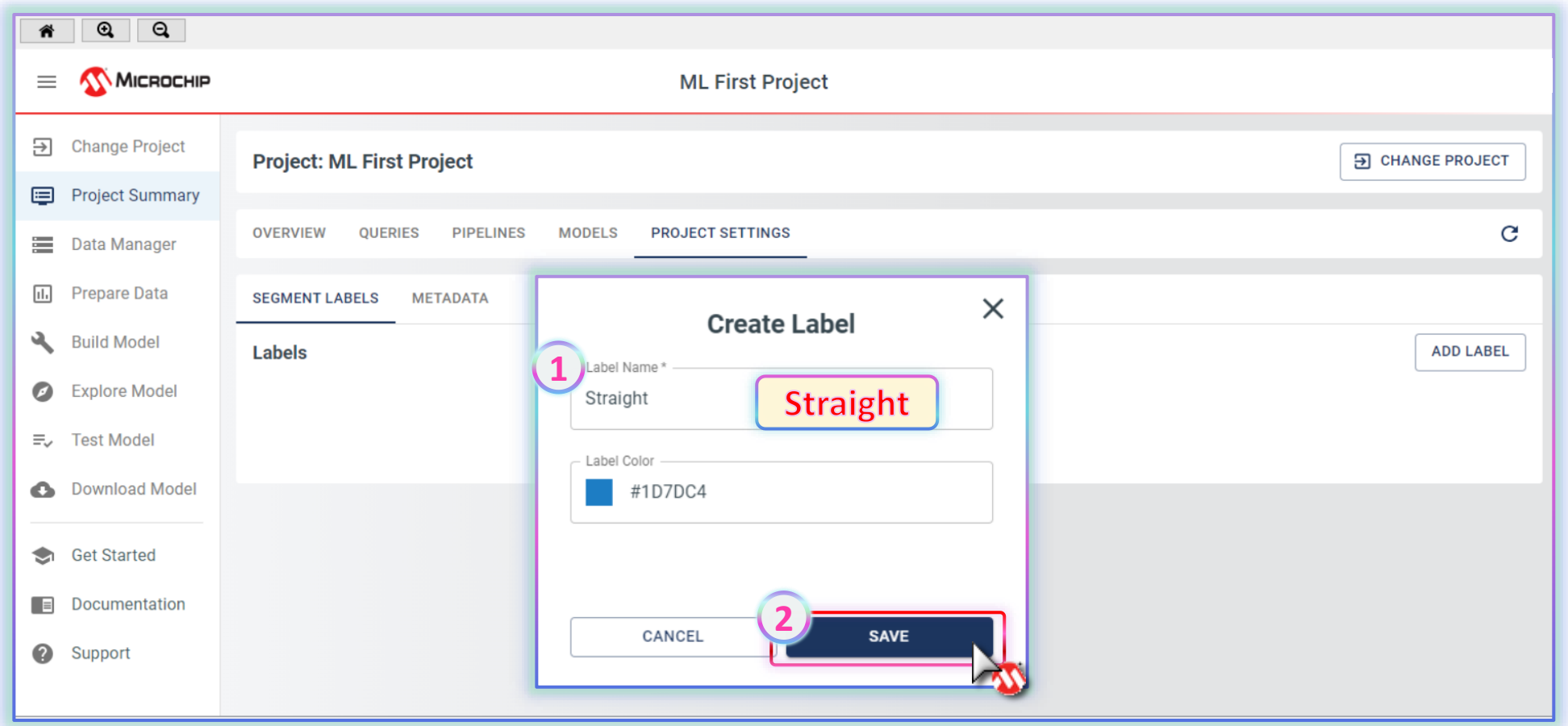
- **Add Label**.



🛠 Lab2 Data Labeling and Preparation

Step 6

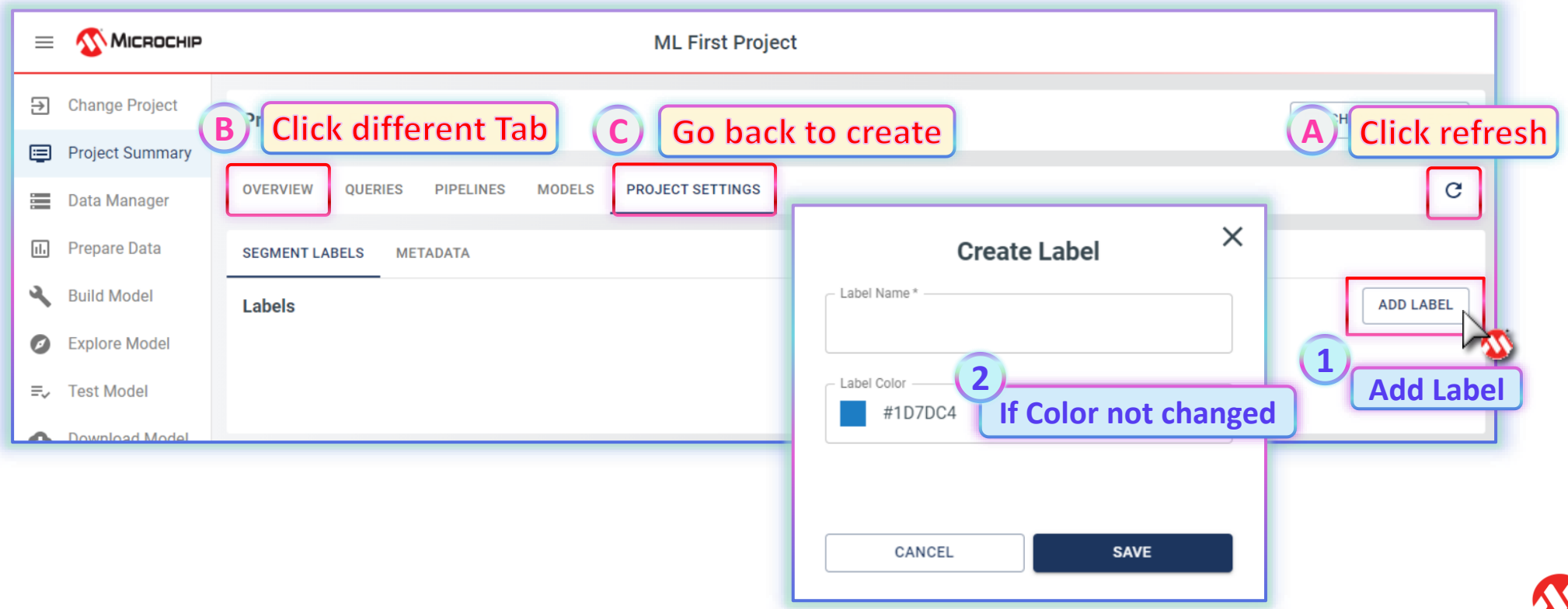
- Create Label.



🛠 Lab2 Data Labeling and Preparation

HINT

- As you add labels, (1) (2) the color of each label you add will change.
  If you find that the Label color does not change,
  (A) Try clicking ↻ to refresh the GUI or
  (B) (C) Click on a different label and then go back to create another label name.



🛠 Lab2 Data Labeling and Preparation

Step 7

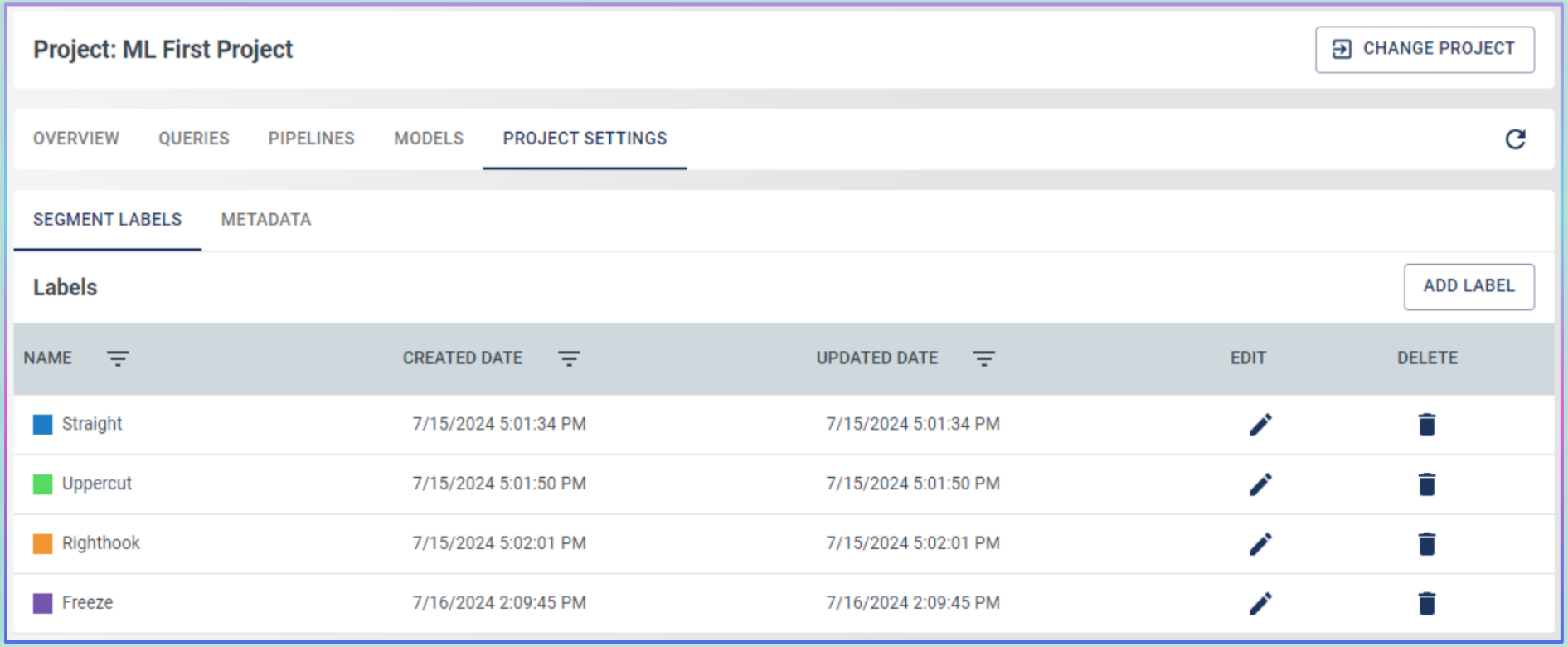
- **Repeat the step 5 to step 6 to add segment label. Make sure that the Label color for each label is different.**
  - **Straight**
  - **Uppercut**
  - **Righthook**
  - **Freeze**

Straight

Uppercut

Righthook

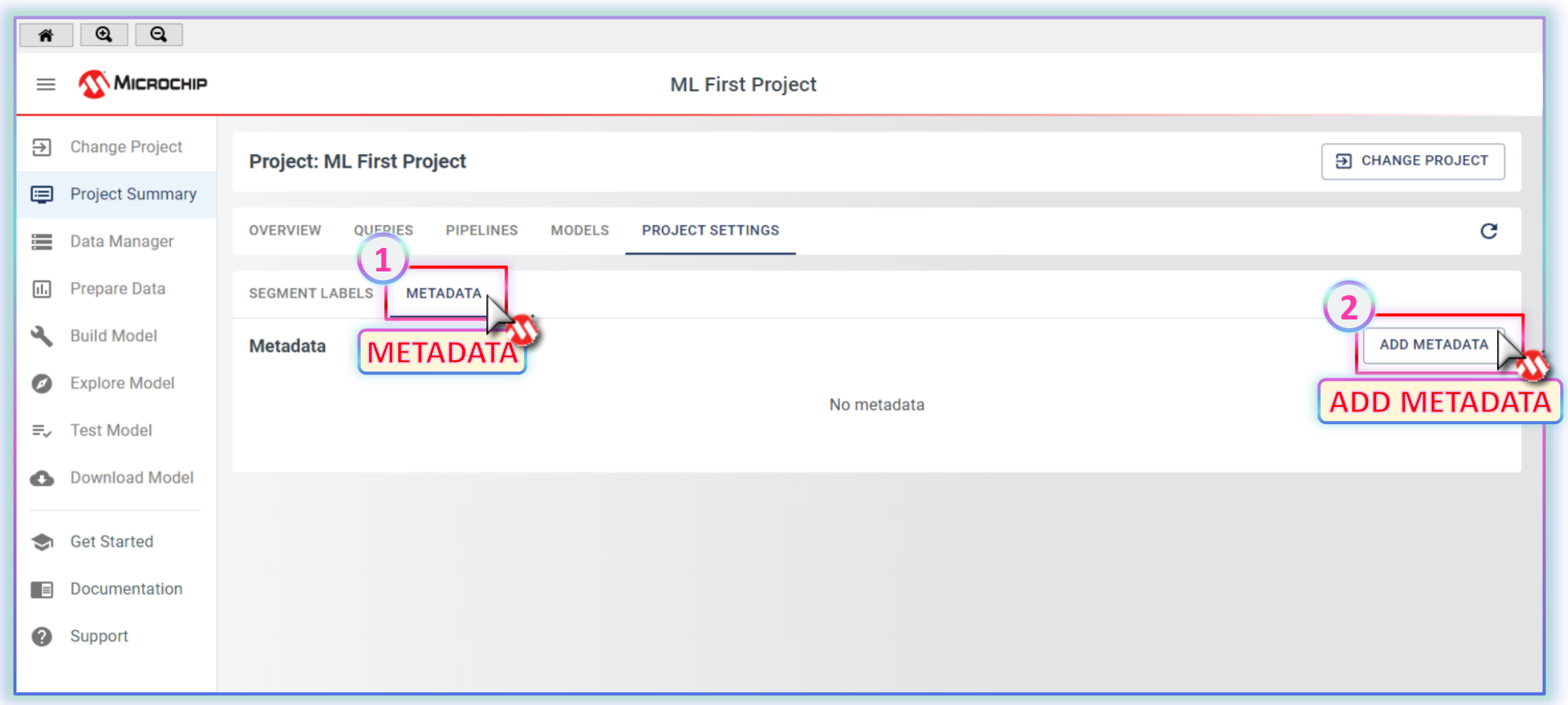
Freeze



🛠 Lab2 Data Labeling and Preparation

Step 7-1 (Optional)

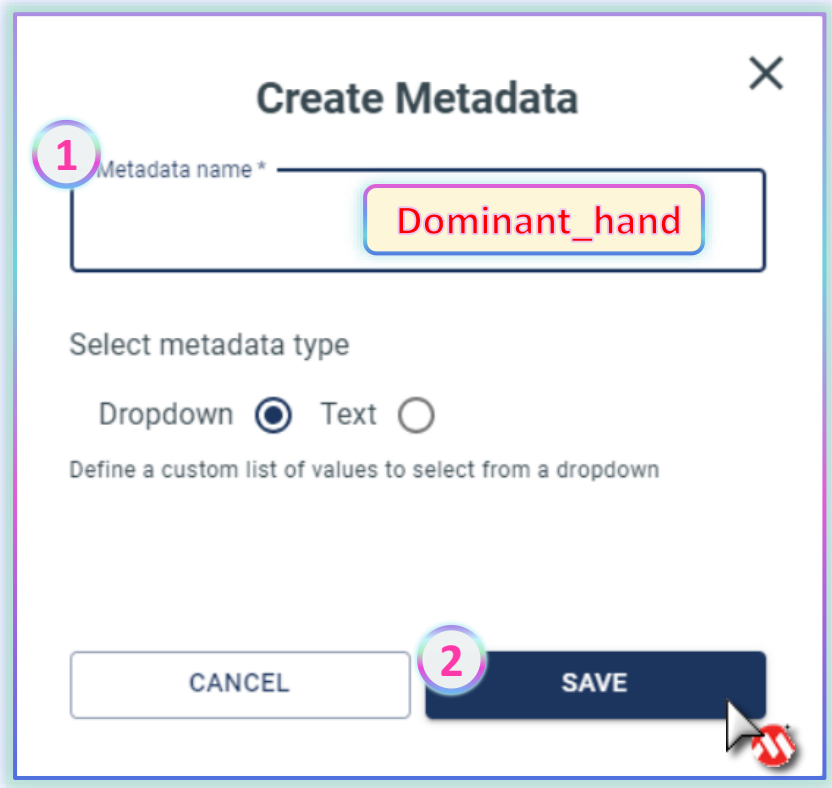
- **Add Metadata.**

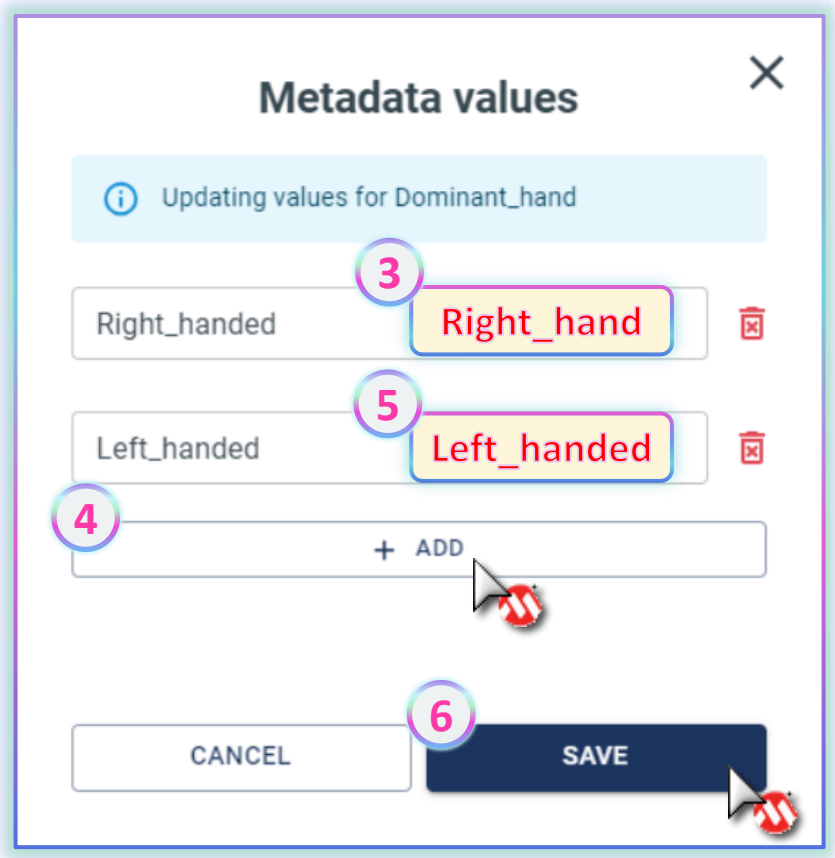


🛠 Lab2 Data Labeling and Preparation

Step 7-2 (Optional)

- **Create Metadata name and Metadata values.**





🛠 Lab2 Data Labeling and Preparation

HINT

- Now we are going to start the "Data Labeling" works !!
- The next steps are probably the most important but also the most boring part of the machine learning training process.

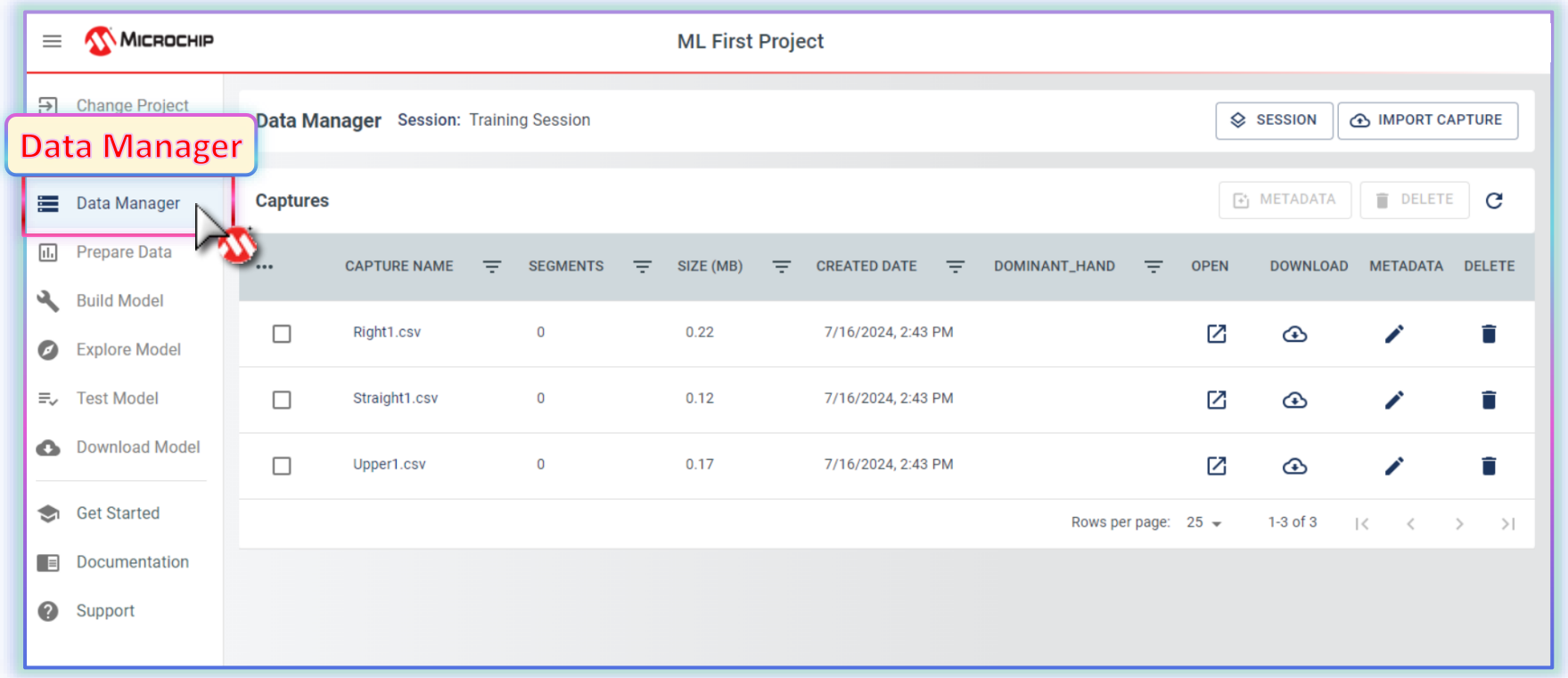
But please be patient !

- Observe the aX, aY, aZ, gX, gY, and gZ raw data firstly, then start labeling data, even slightly differences may impact the training result.
- If the event doesn't belong to any label, keep it empty to avoid confusing training.
- Repeat step 8 to step 14 to complete label all sections and files.

🛠 Lab2 Data Labeling and Preparation

Step 8

- Click Data Manager. The collected data files can be found in the Data Manager page.



🛠 Lab2 Data Labeling and Preparation

Two Ways to Capture and Upload Data

1. Upload and save Data by MPLAB ML Data Collector. The data will be saved to .csv file in your local PC and upload to the ML Project you created automatically.

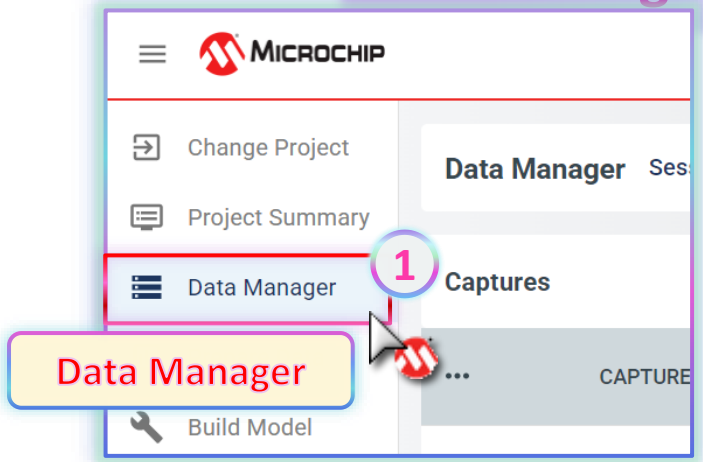
2. Snapshot Data by click on in Time Plot of DV to save the .csv file in your local PC. Then upload the .csv file to the ML Project you created manually.

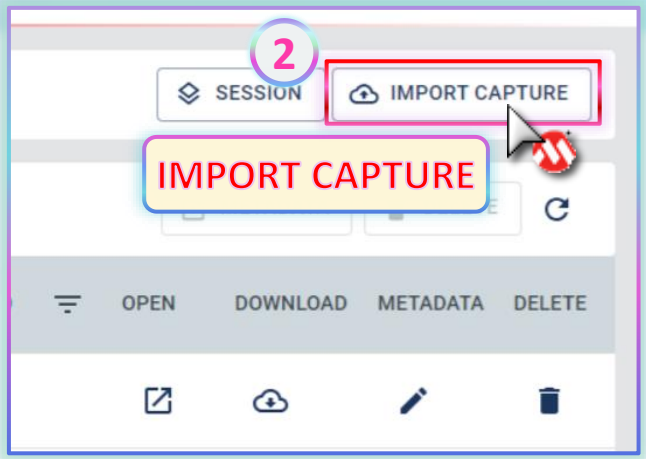
MICROCHIP

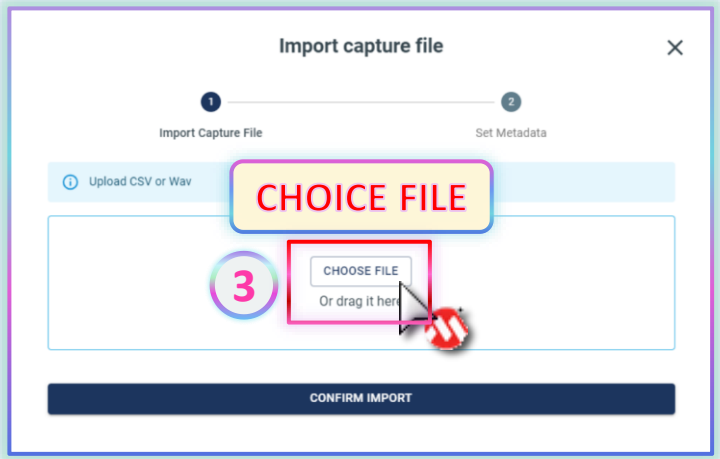
🛠 Lab2 Data Labeling and Preparation

Import the Snapshot .csv files

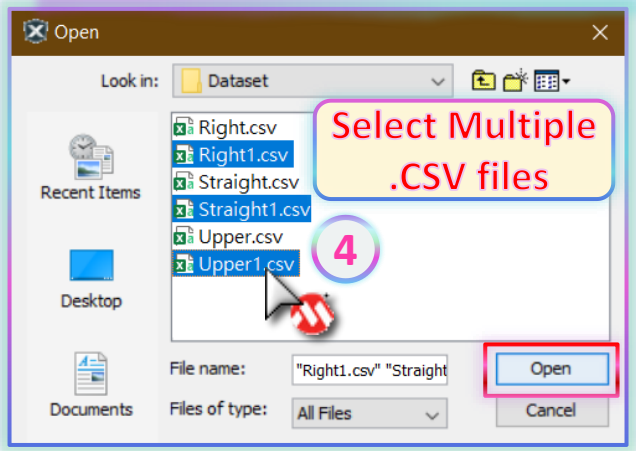
- Click on Data Manager > IMPORT CAPTURE > CHOICE FILE.

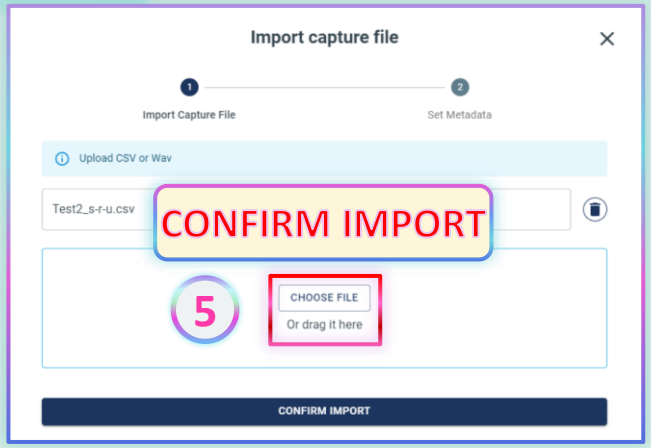


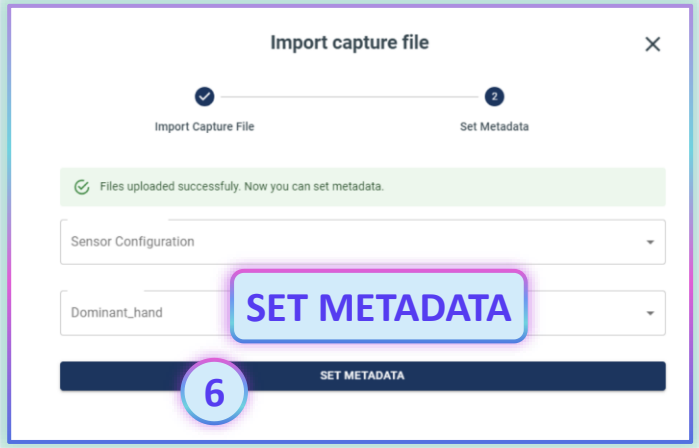




- Select multiple .CSV you stored then CONFIRM IMPORT > SET METADATA(optional).



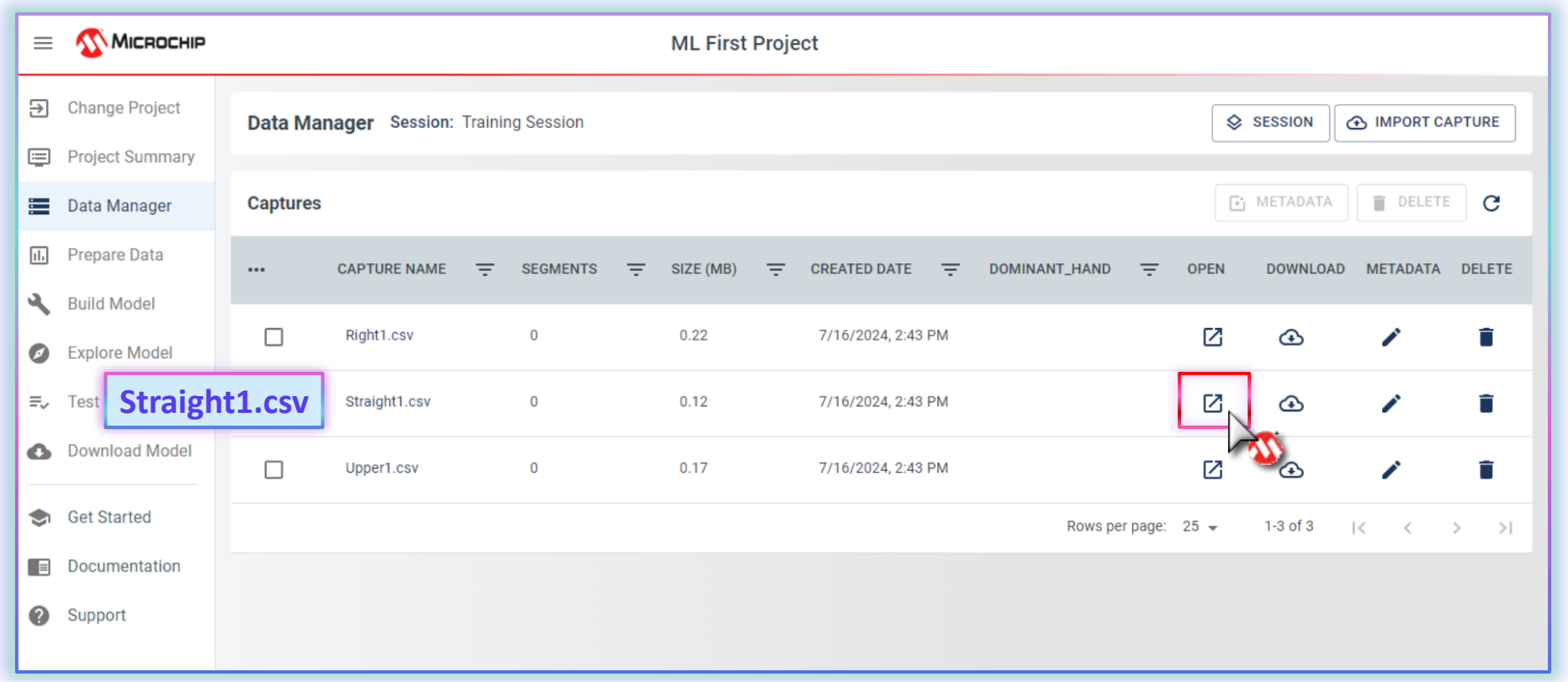




🛠 Lab2 Data Labeling and Preparation

Step 9

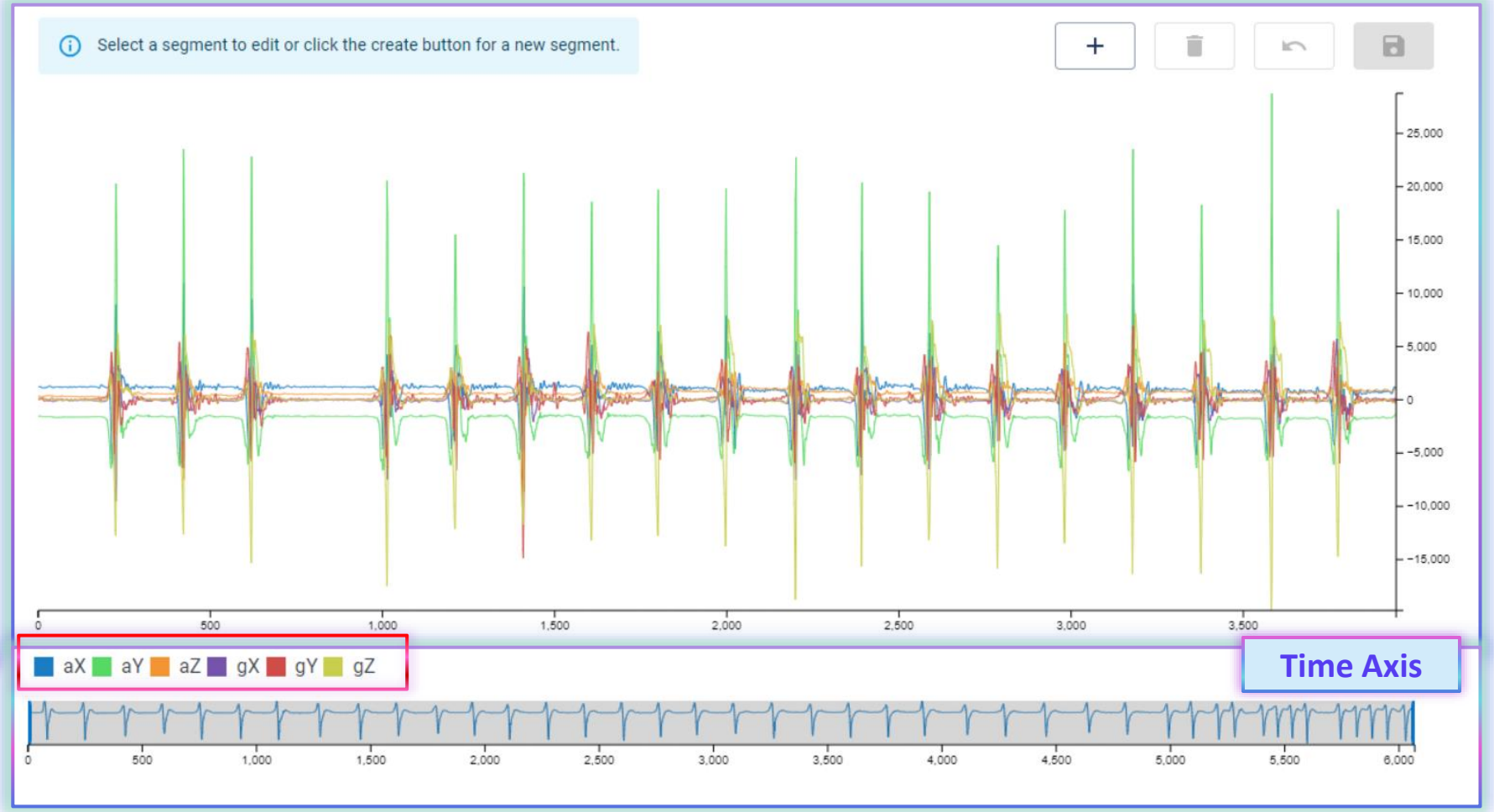
- **Let's start labeling our data, which also means define segments.**
- **Open Straight1.csv data.**



🛠 Lab2 Data Labeling and Preparation

Step 10

- **Segment: Define where an event is located in your sensor data file.**



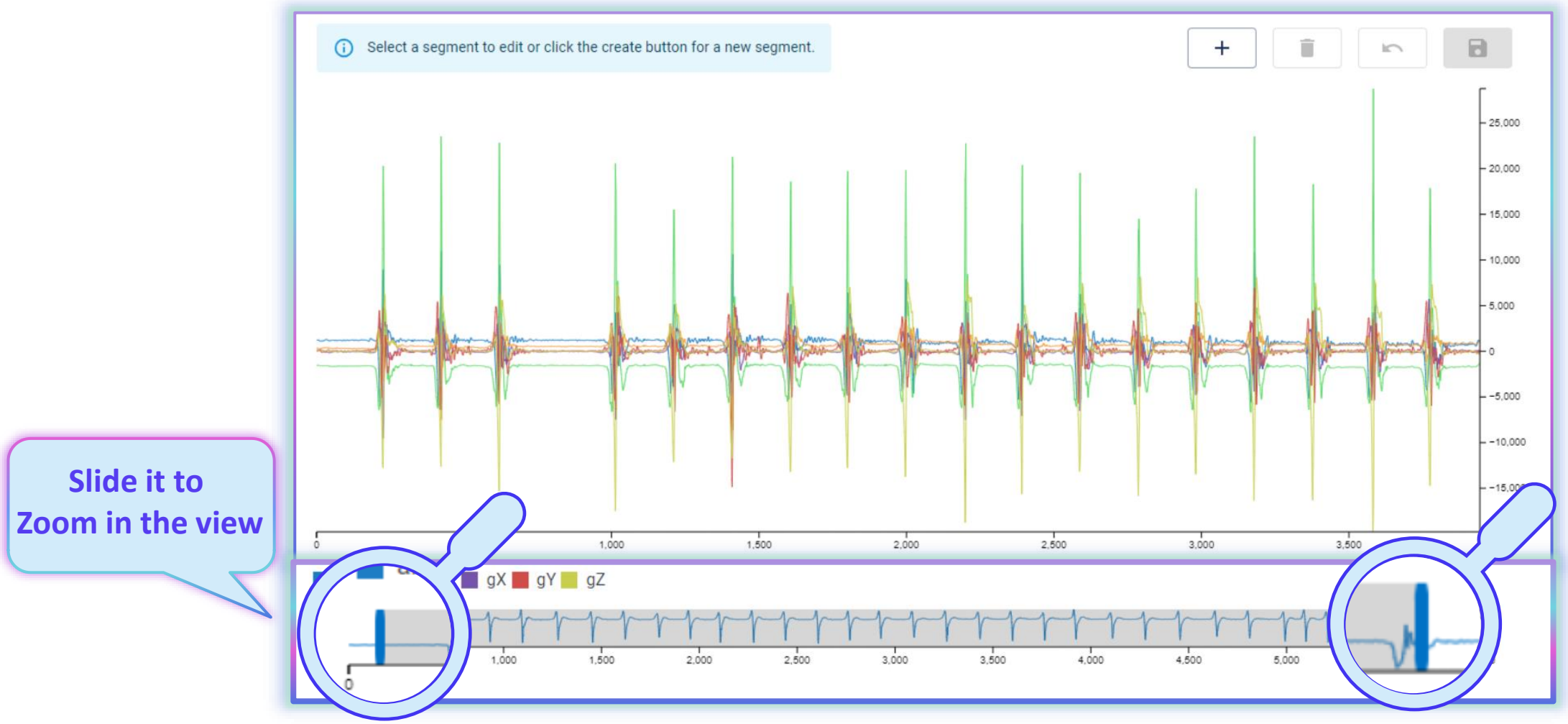
Click to show or hide the selected raw data.

MICROCHIP

🛠 Lab2 Data Labeling and Preparation

Step 11

- You may zoom in to view the detail of the file.

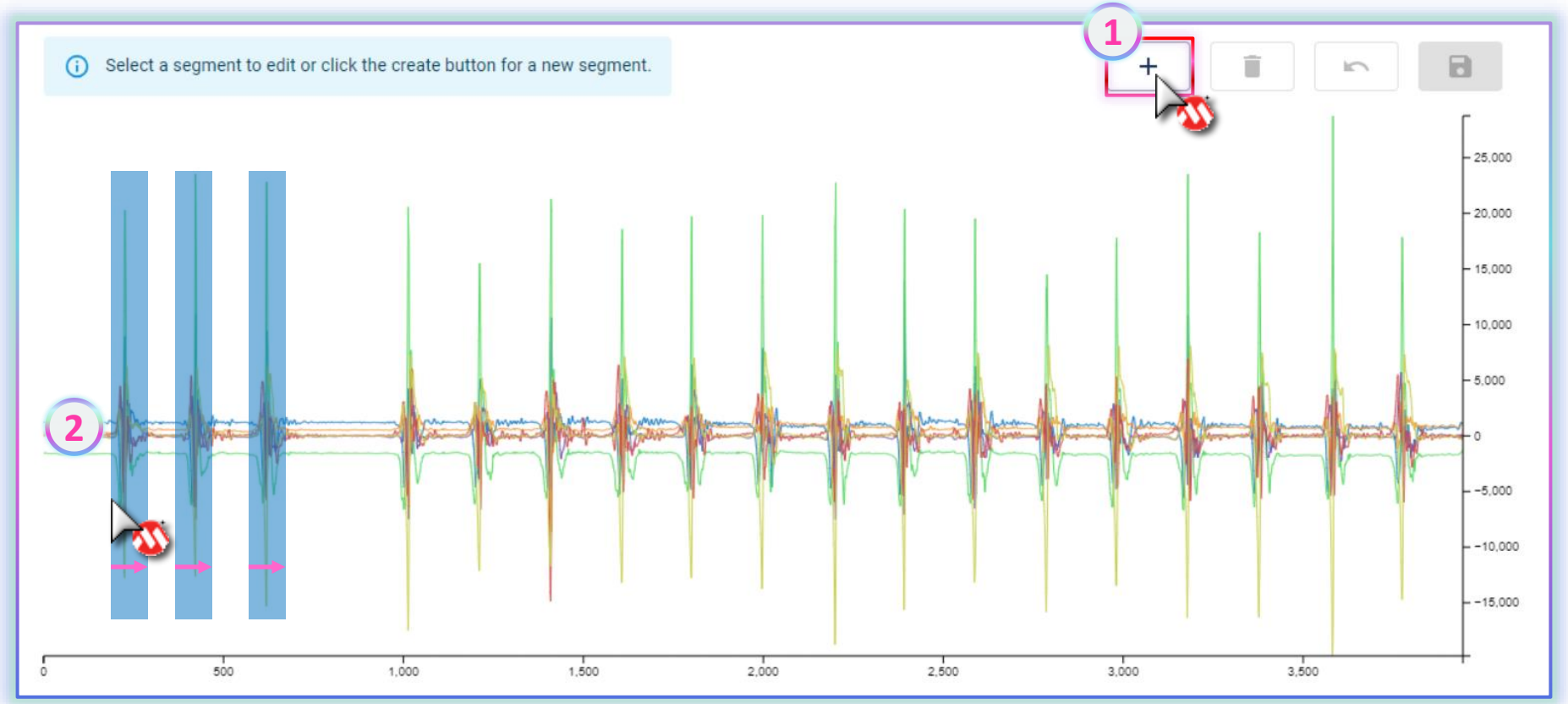


MICROCHIP

🛠 Lab2 Data Labeling and Preparation

Step 12

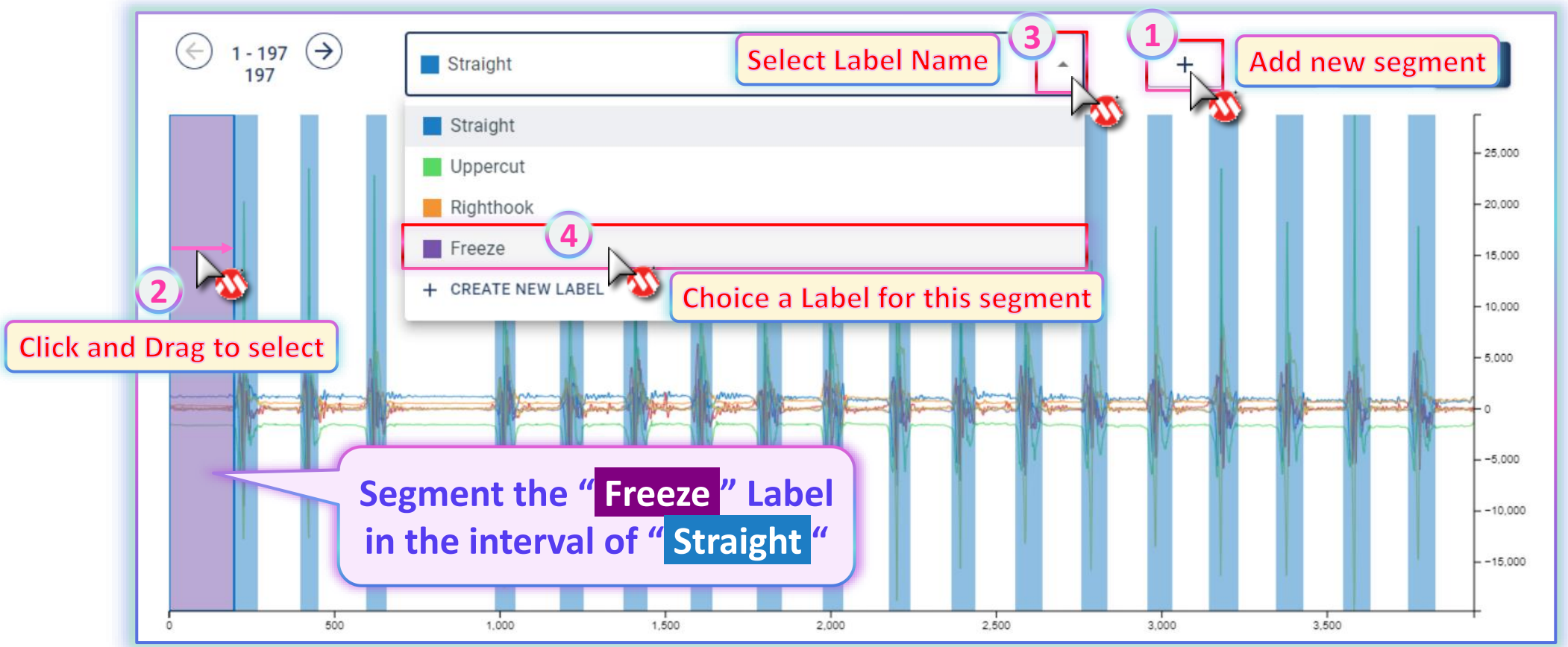
- Click [+] to add segment.
- Move the cursor over the chart, then Click and Drag the area that will be marked as an event. This will place a new segment in the file.



🛠 Lab2 Data Labeling and Preparation

Step 13

- **Click and Drag to select the segment first, then choose the label for the corresponding selection segment.**

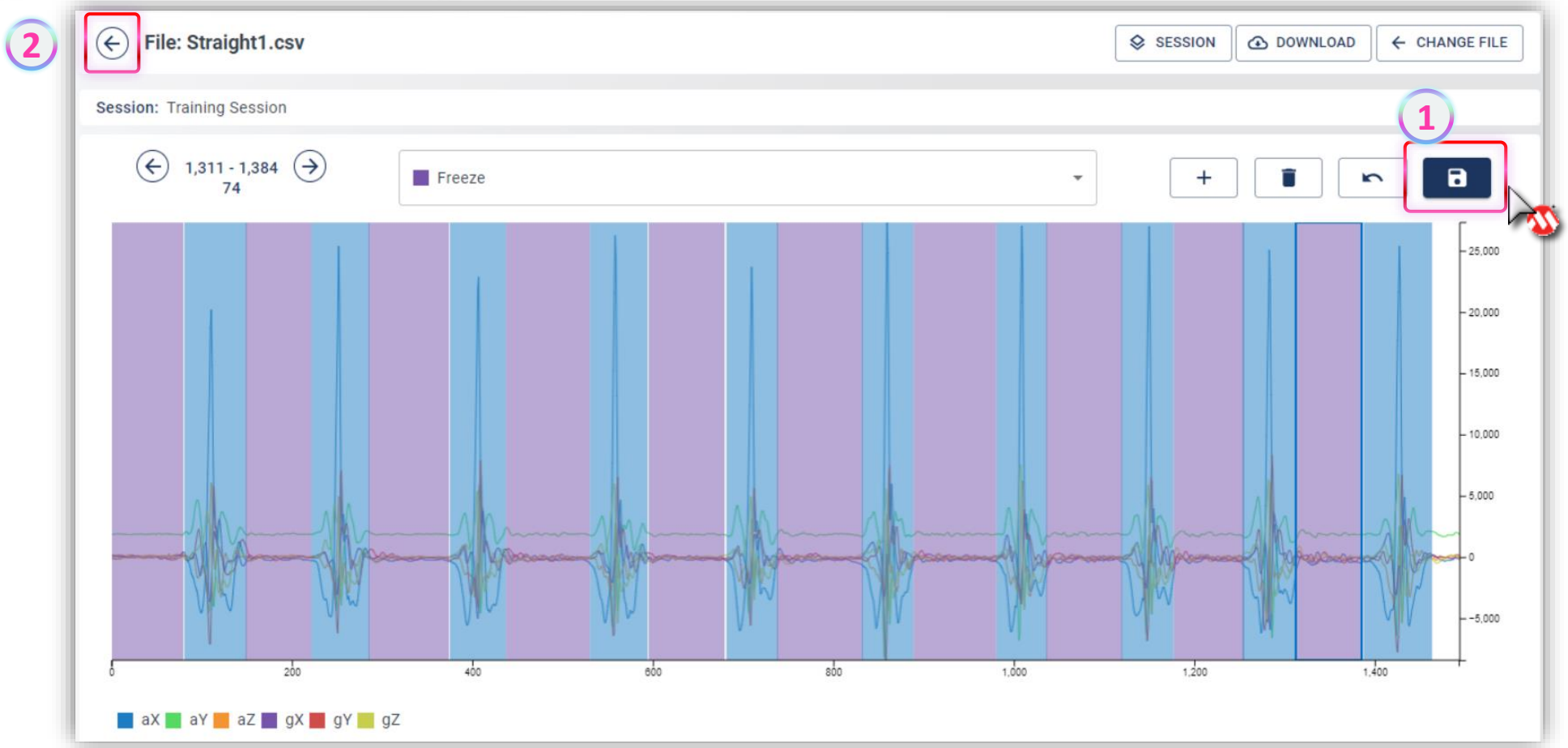


MICROCHIP

🛠 Lab2 Data Labeling and Preparation

Step 14

- **Finish labeling the segment in each dataset then Click to save.**
- **Remember to click "save" anytime!**

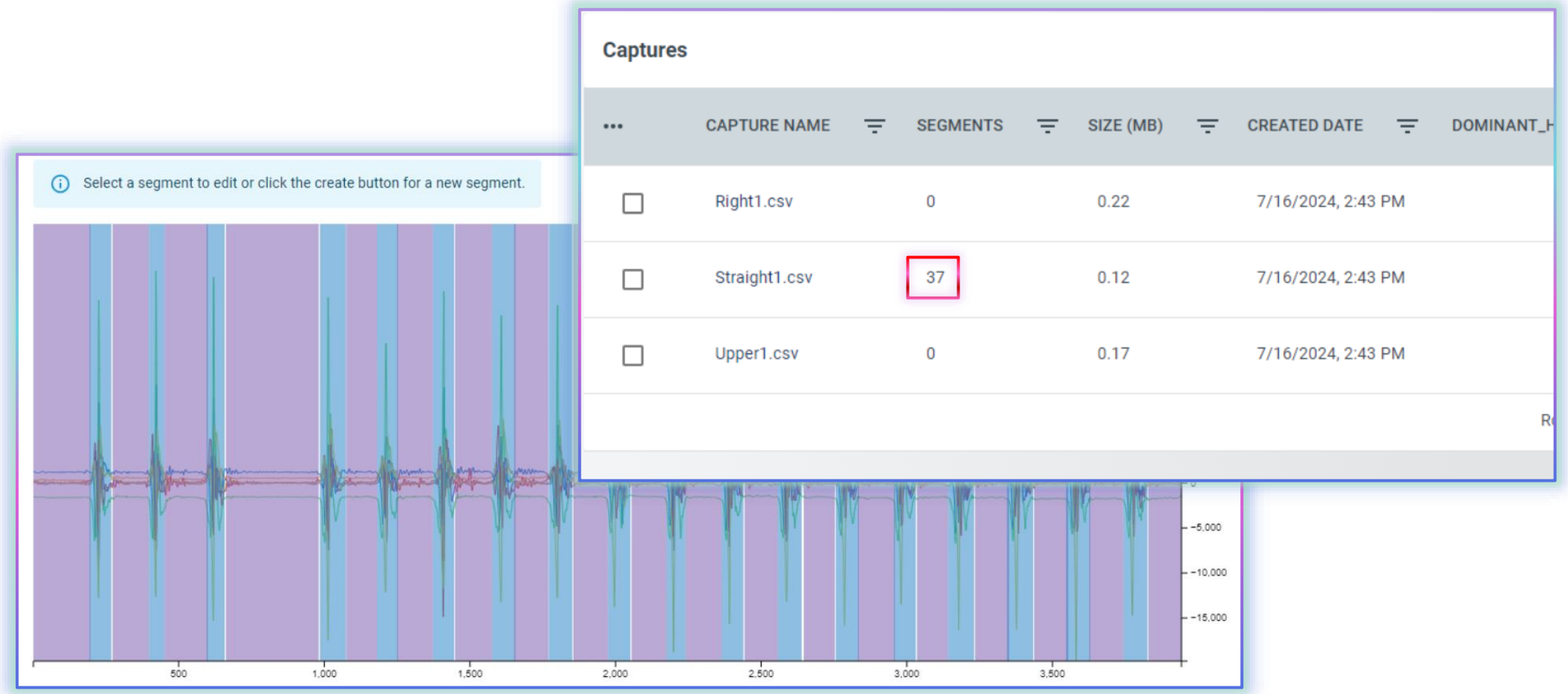


MICROCHIP

🛠 Lab2 Data Labeling and Preparation

Step 15

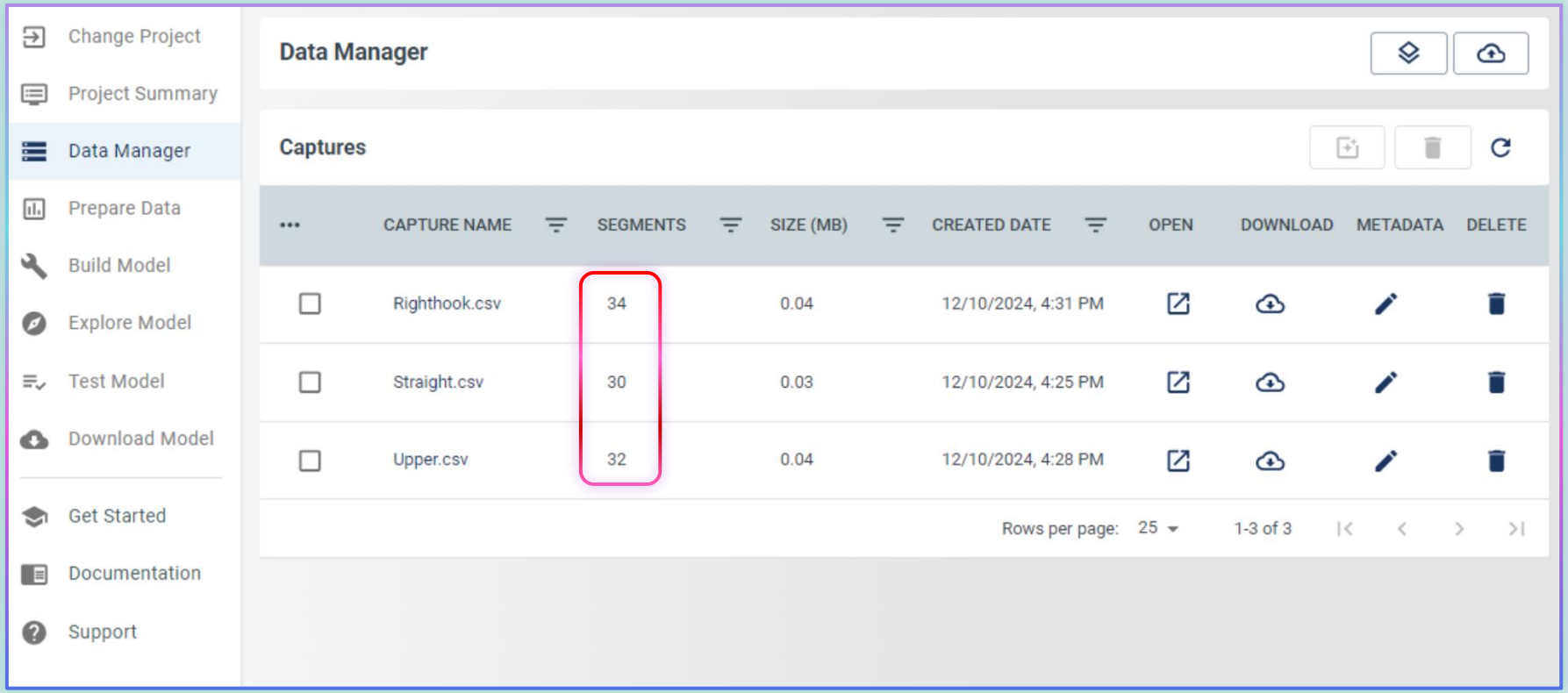
- **The data manager will show the number of segments in each data.**



🛠 Lab2 Data Labeling and Preparation

Result

- Repeat step 9 to step 15 to label all the segment and file.
- Make sure you label and save all the dataset. There will be number in the SEGMENTS column.



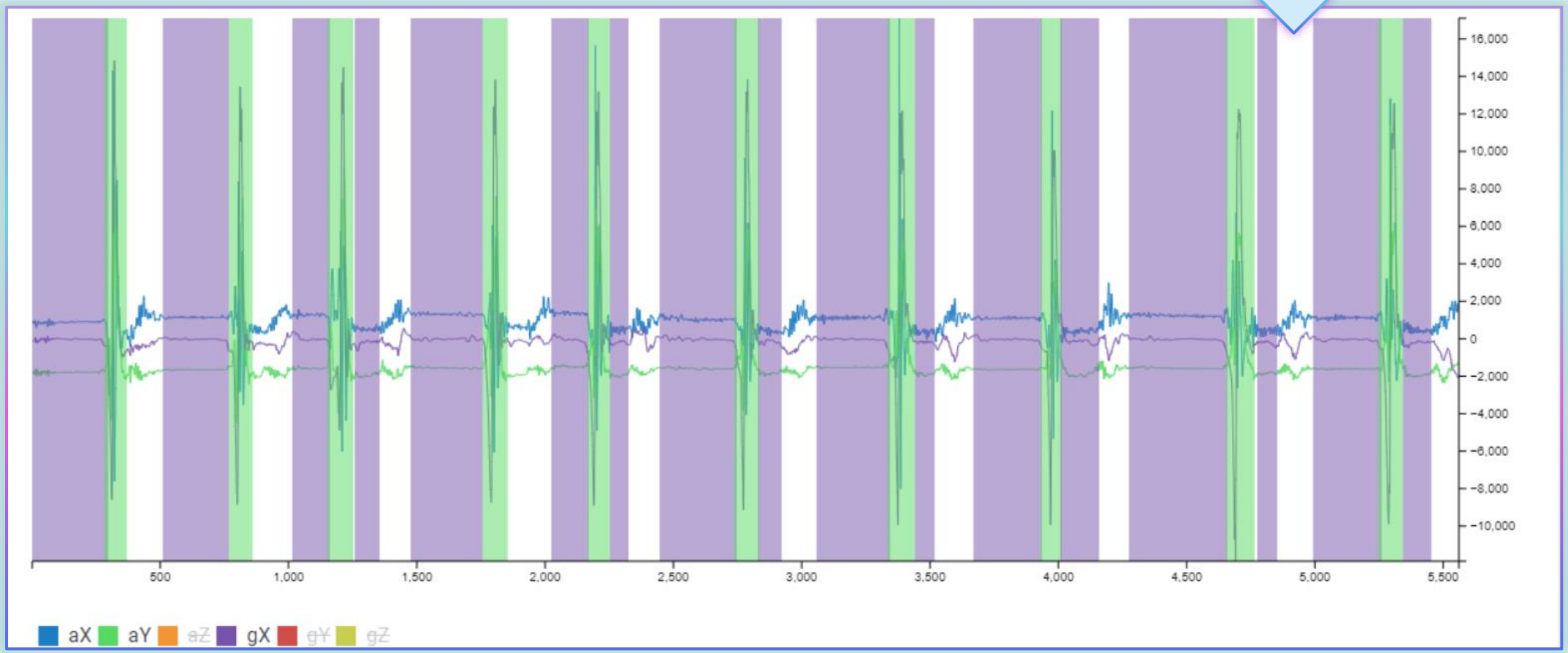
MICROCHIP

🛠 Lab2 Data Labeling and Preparation

Result & Discussion

- Take Uppercut1.csv as example.

Why keep this unlabeled?
Is it also an uppercut?



MICROCHIP

Model Pipeline and Training

Querying the data

Querying data:

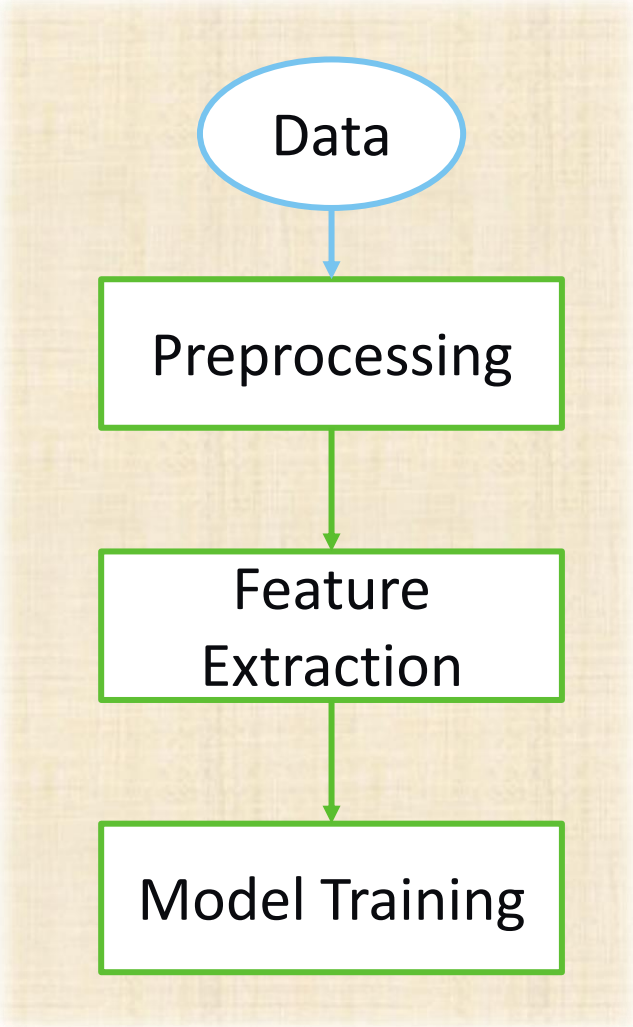
The process of extracting data from a database, repository or other source for use in training a machine learning model.

- **Only a subset may be required**
- **Metadata comes in useful**
  - Only select samples from right-handed
  - Or samples taken by male
- **Create models better tuned for certain scenarios or markets**

Build Model - Pipeline

The model training process includes three main processes ：

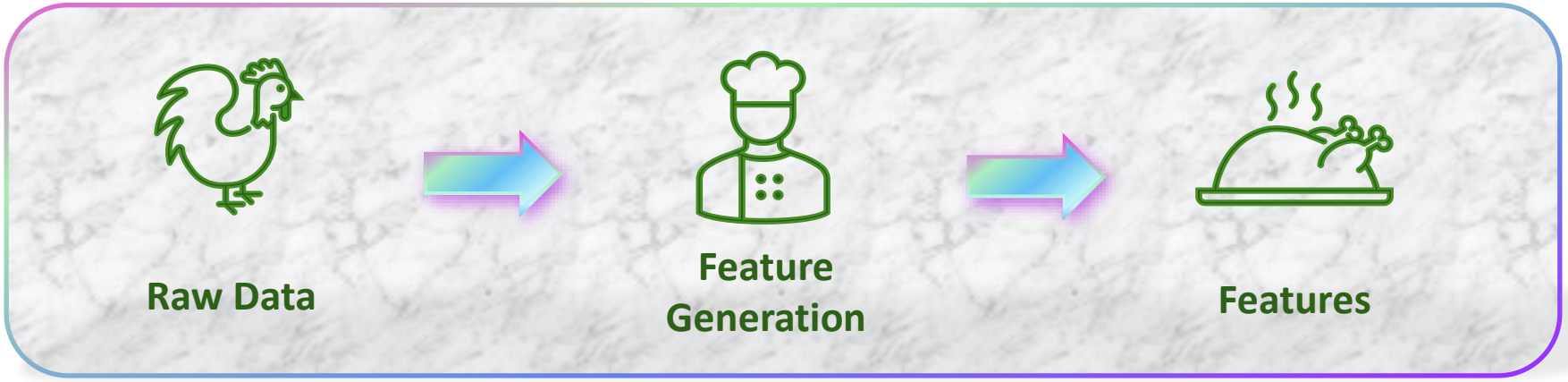
- **Preprocessing**
  - Input Query
  - Segmenter
  - Sensor Transform
- **Feature Extraction**
  - Feature Generator
  - Feature Selector
- **Model Training**



MICROCHIP

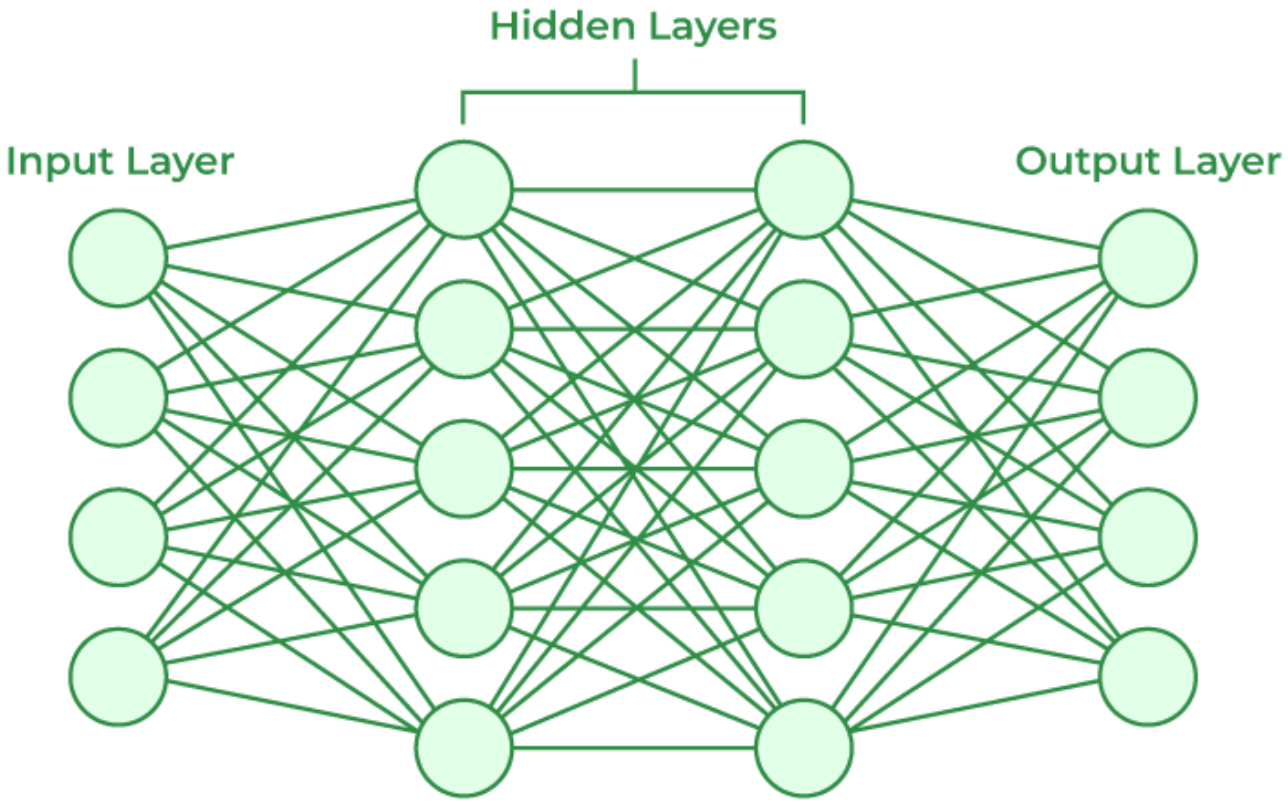
Feature Generation

- "More data beats clever algorithms, but better data beats more data," said Peter Norvig.
- The process of converting raw data into a format that a machine learning model can understand. May include extracting information from the raw data, creating new features, or transforming the data to improve the performance of the model.
  - Which sensor data to use
  - Generate features
  - Select features
  - Classification



AI/ML Models

- **How does an AI/ML model look like in your mind?**

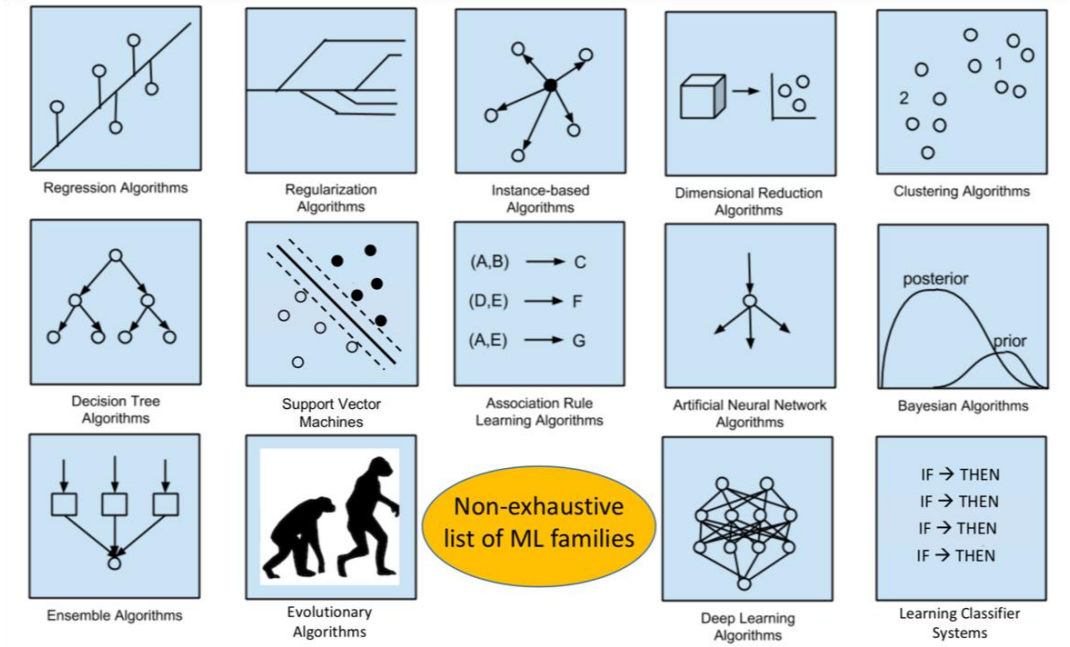


The answer is……Yes and no.

Not all AIML models are Neural Networks.

ML Models

- Not all models are neural networks
- **To build an application we need to know what type of model to use.**
- 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 (convolutional neural network) can be used for vibration analysis but others like Bayesian networks might be better.



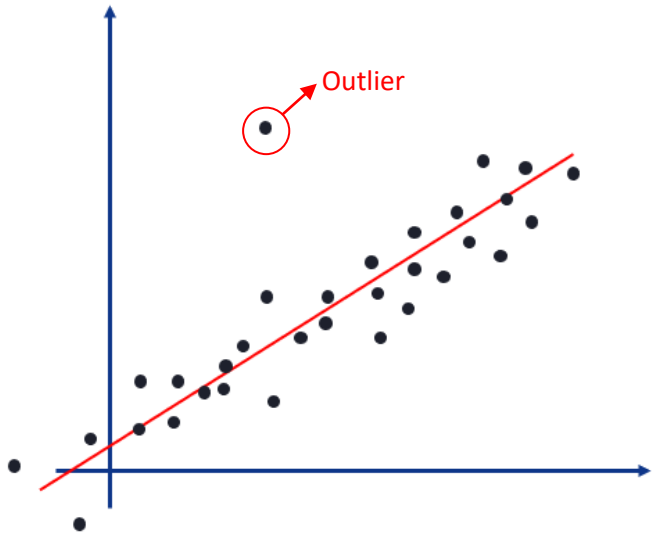
MICROCHIP

Common ML model

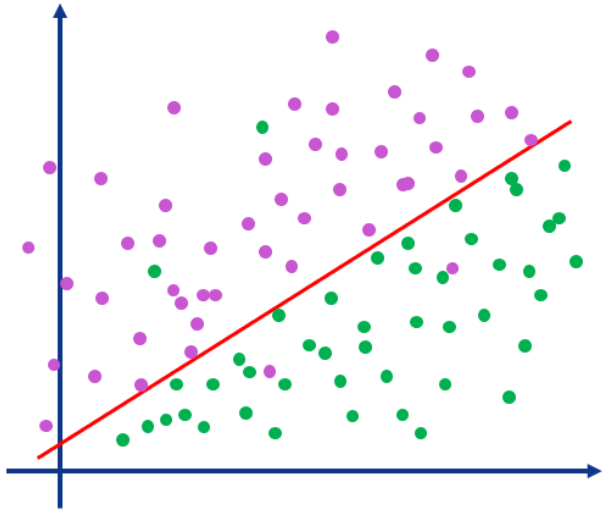
- **Supervised Learning**
  - Linear/Logistic Regression
  - Decision Tree
  - Support Vector Machine
- **Unsupervised Learning**
  - K-means Clustering
  - Hierarchical Clustering
- **Deep Learning**
  - CNN
  - RNN

Supervised Learning - Linear/Logistic Regression

- **Linear Regression**
  - Find the relationship between independent variables and dependent variables.
  - Example:
    - Optimize pricing strategies
    - Demand analysis



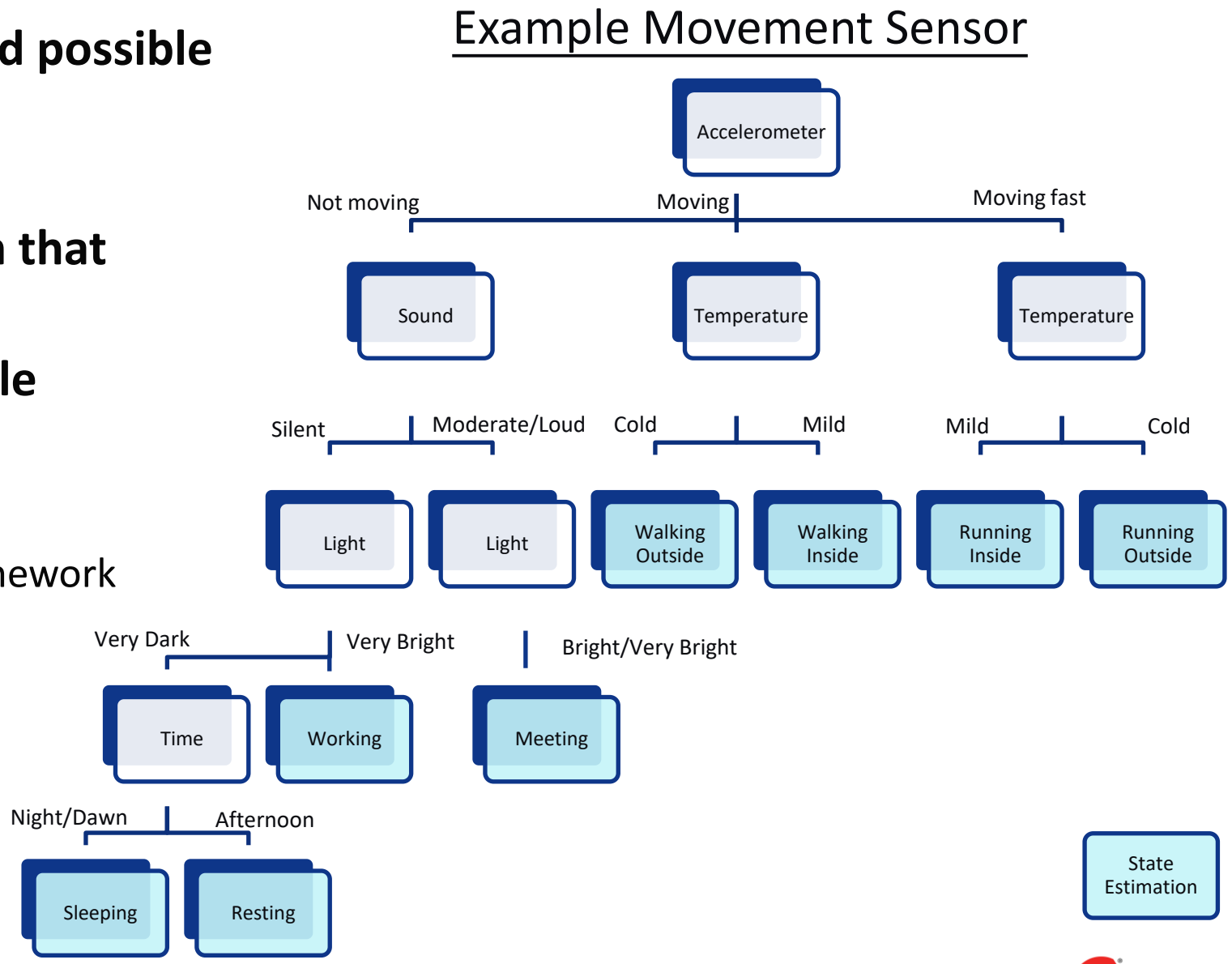
- **Logistic Regression**
  - The output of logistic regression is binary, either 1 or 0.
  - Example:
    - Whether there is fraud based on transaction behavior patterns
    - Whether a tumor is malignant



Supervised Learning - Decision Tree

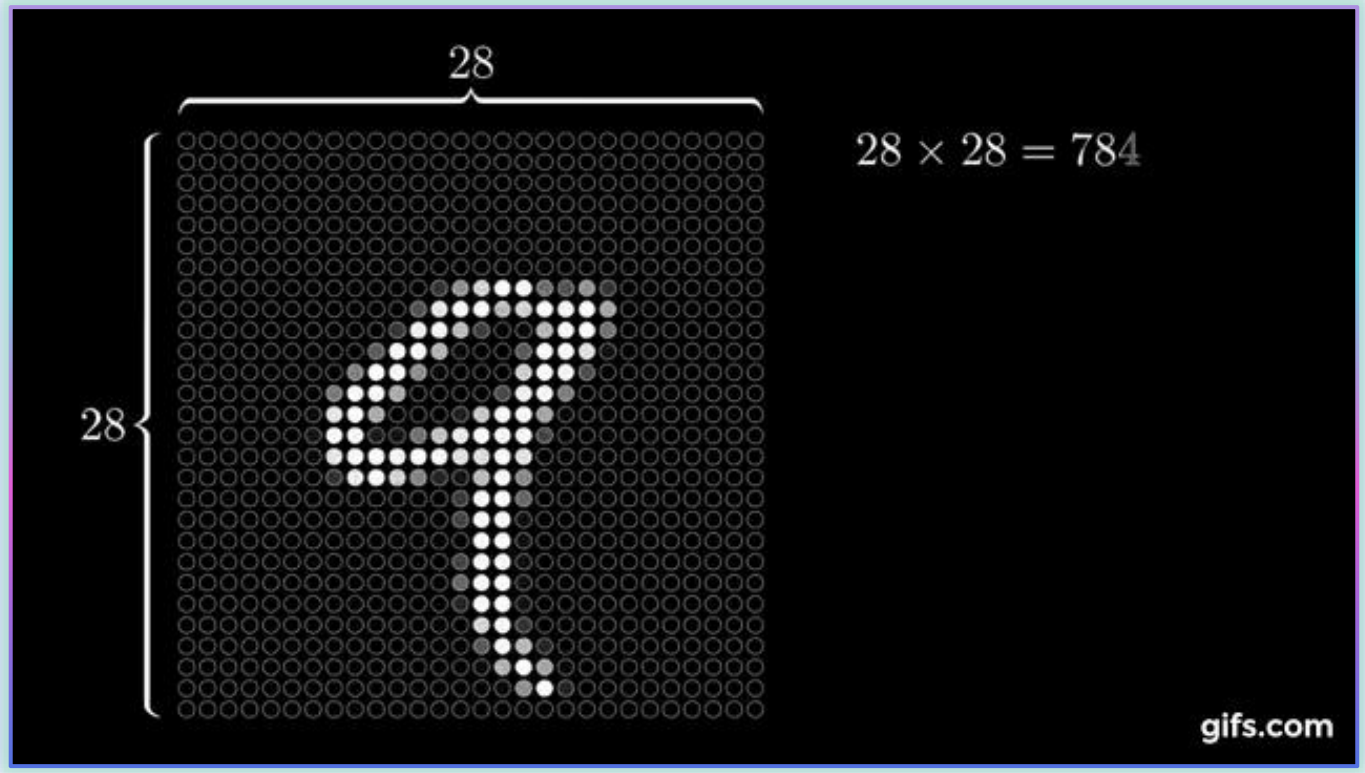
Tree-like graph of decisions and possible consequences

- **Each node is a feature**
- **Branching is decision rule on that feature**
- **Training requires splitting rule generation and pruning**
- **Example:**
  - Provide a decision-making framework



Deep Learning – Artificial Neural Network

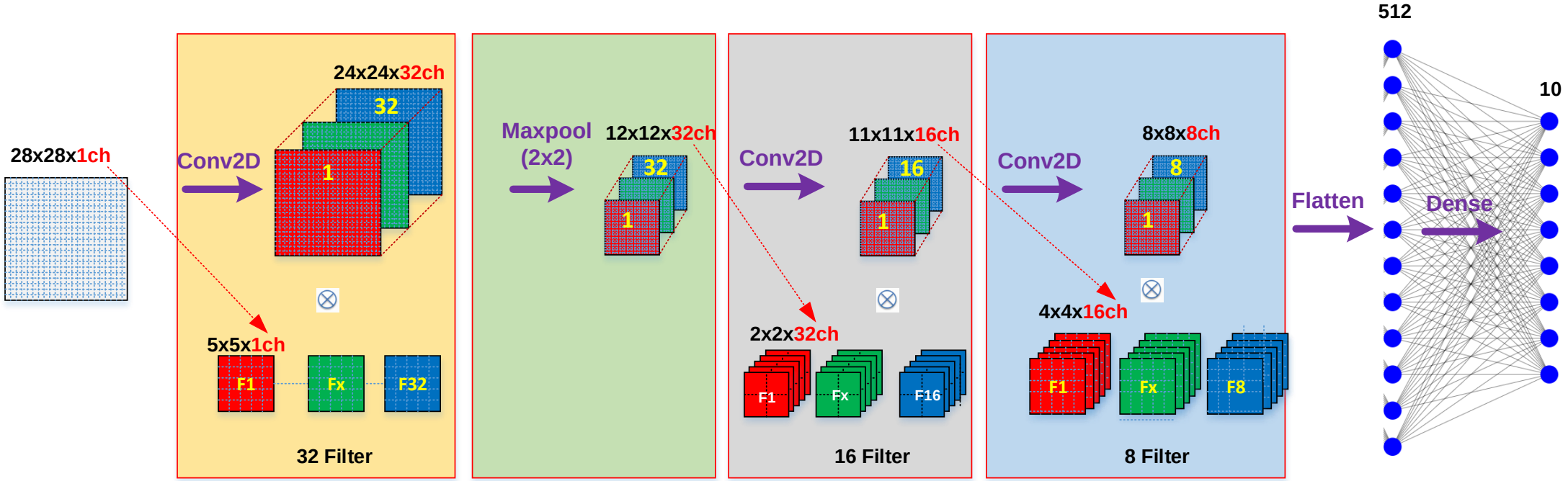
- **Fully connected layers of neurons**
  - Best for tabular data, time series forecast, basic classification.
- **Touch example**
  - Touch sensor with resolution of 28 X 28 means 784 pieces of data to feed into the network with 10 desired outputs.



A network which classifies images into one of 10 numbers —full video by 3Blue1Brown

Deep Learning – Convolution Neural Network

- **Convolutions applied to local input regions**
  - The architecture most commonly used in image recognition.
  - Best for spatially related data
- **Example:**
  - Image Classification, Edge Detection



AutoML

Automated machine learning, AutoML is the process of automating the time-consuming, iterative tasks of machine learning model development.

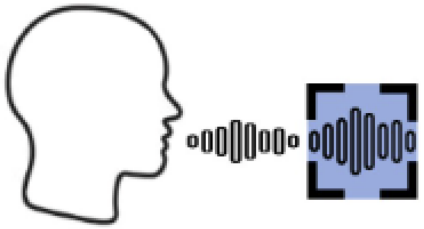
- **Implement ML solutions without extensive programming knowledge**
- **Save time and resources**
- **Apply data science best practices**
- **Provide agile problem-solving**

Select the Model

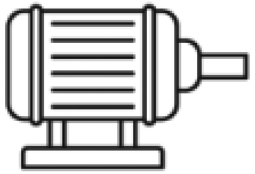
MPLAB® ML Suite Templates

- Keyword Spotting
- Vibration Classification
- Activity Recognition
- Gesture Recognition
- Audio Classification

Keyword Spotting



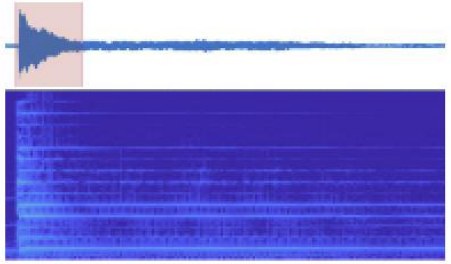
Vibration Classification



Activity Recognition

Gesture Recognition

Audio Classification



🛠 Lab3
Model Pipeline and Training

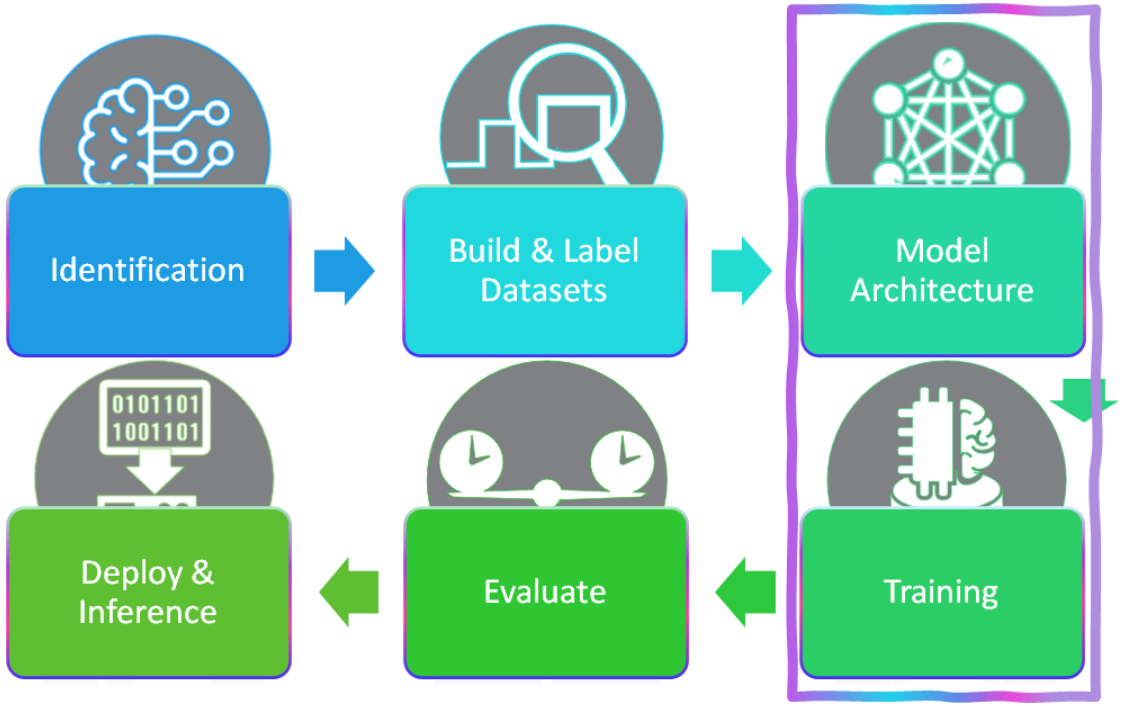
Boxing Recognition by Machine Learning

MICROCHIP

🛠 Lab3 Model Pipeline and Training

Boxing Recognition by Machine Learning

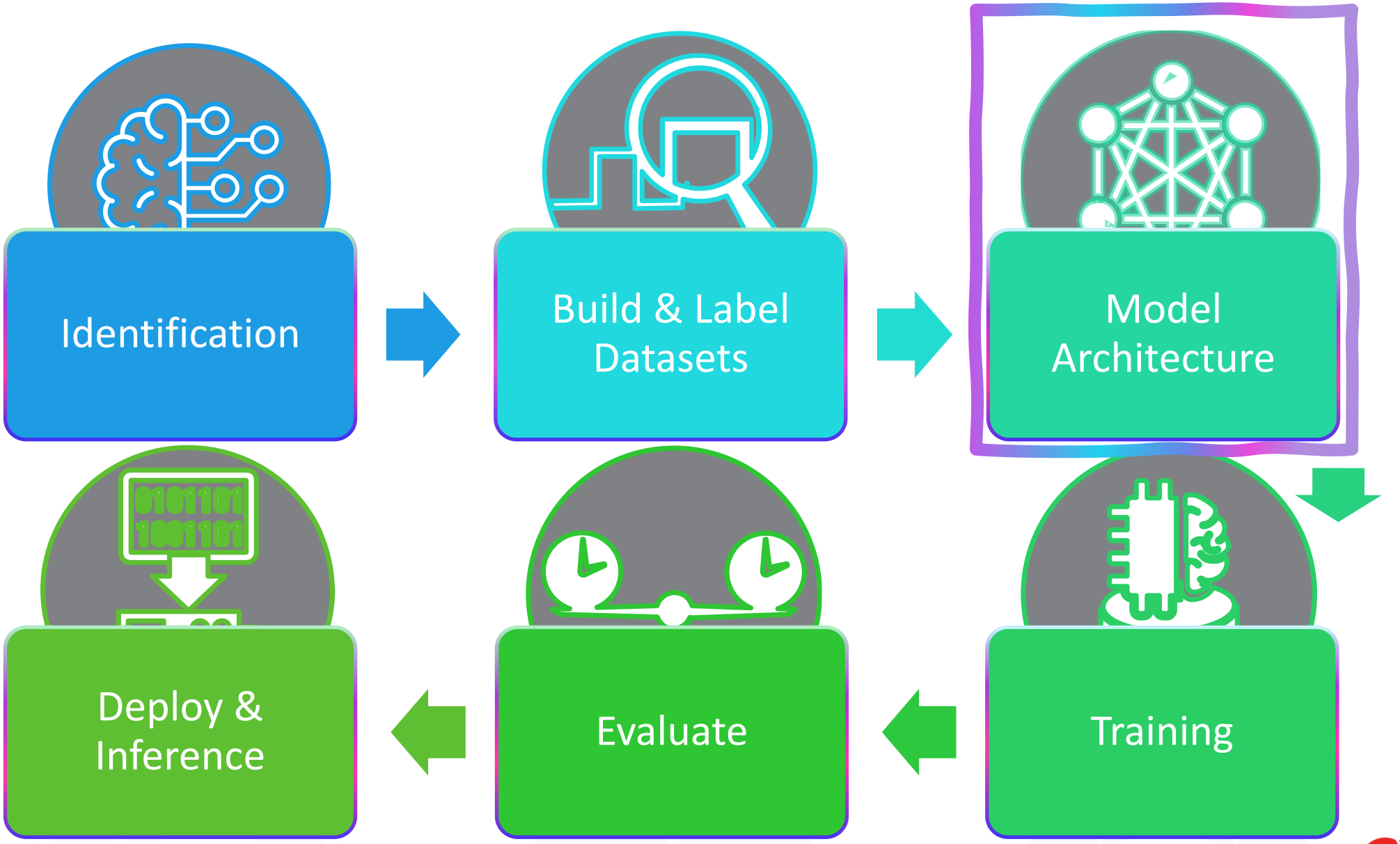
- Create a query for the data and then pass these data into the model builder.
- Select the proper model for the project, and the model builder will need to configure with some initial settings to help it understand how to best process the training sets.
- Start Training your unique model.



Let’s go!

MICROCHIP

Machine Learning Workflow

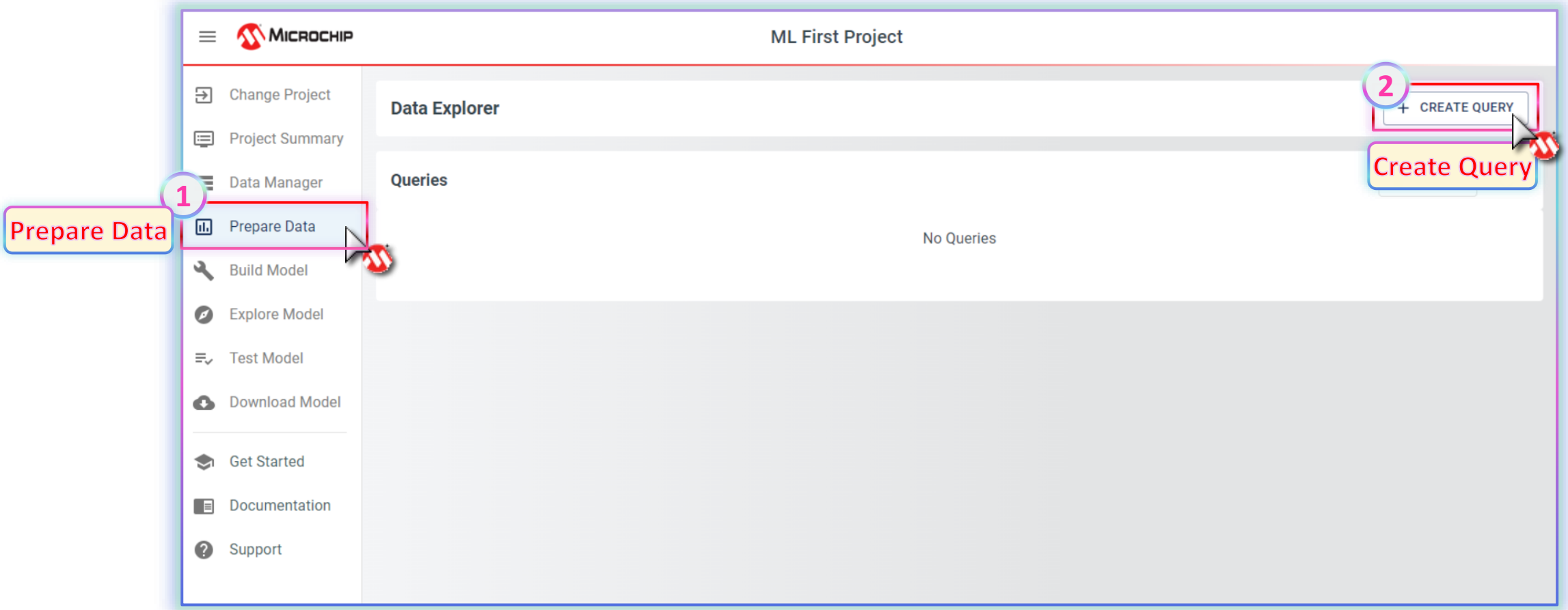


MICROCHIP

🛠 Lab3 Model Pipeline and Training

Step 1

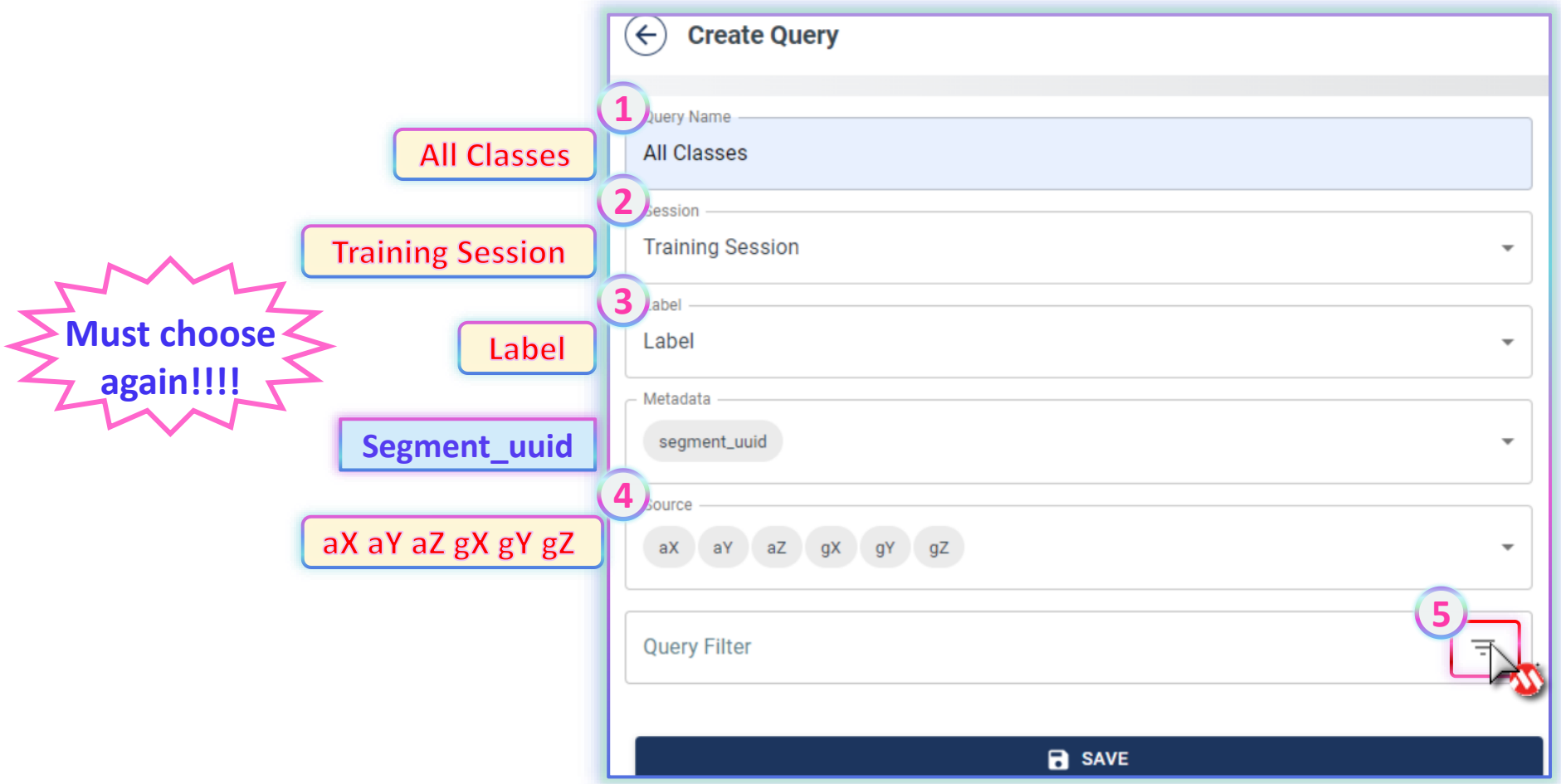
- Click Prepare Data -> Create Query



🛠 Lab3 Model Pipeline and Training

Step 2

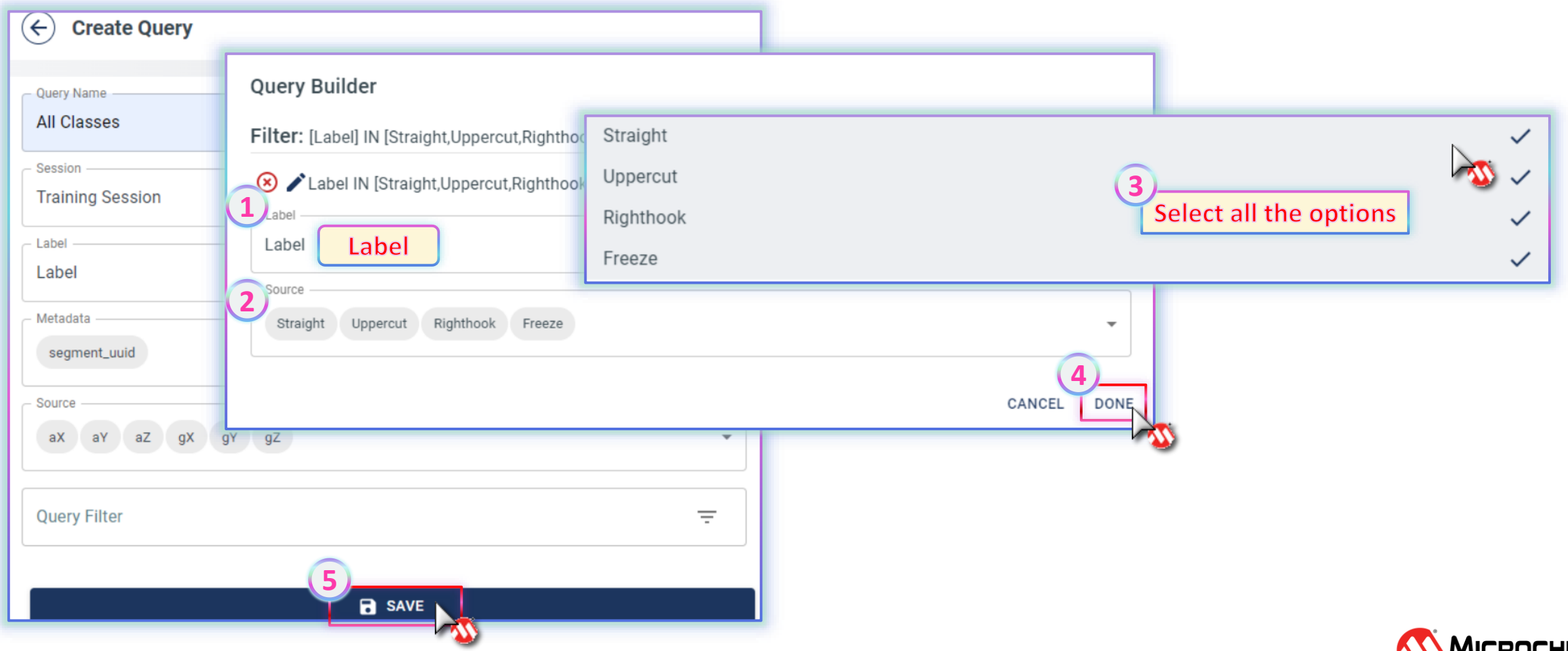
- **Select and Fill in all the blank.**



🛠 Lab3 Model Pipeline and Training

Step 3

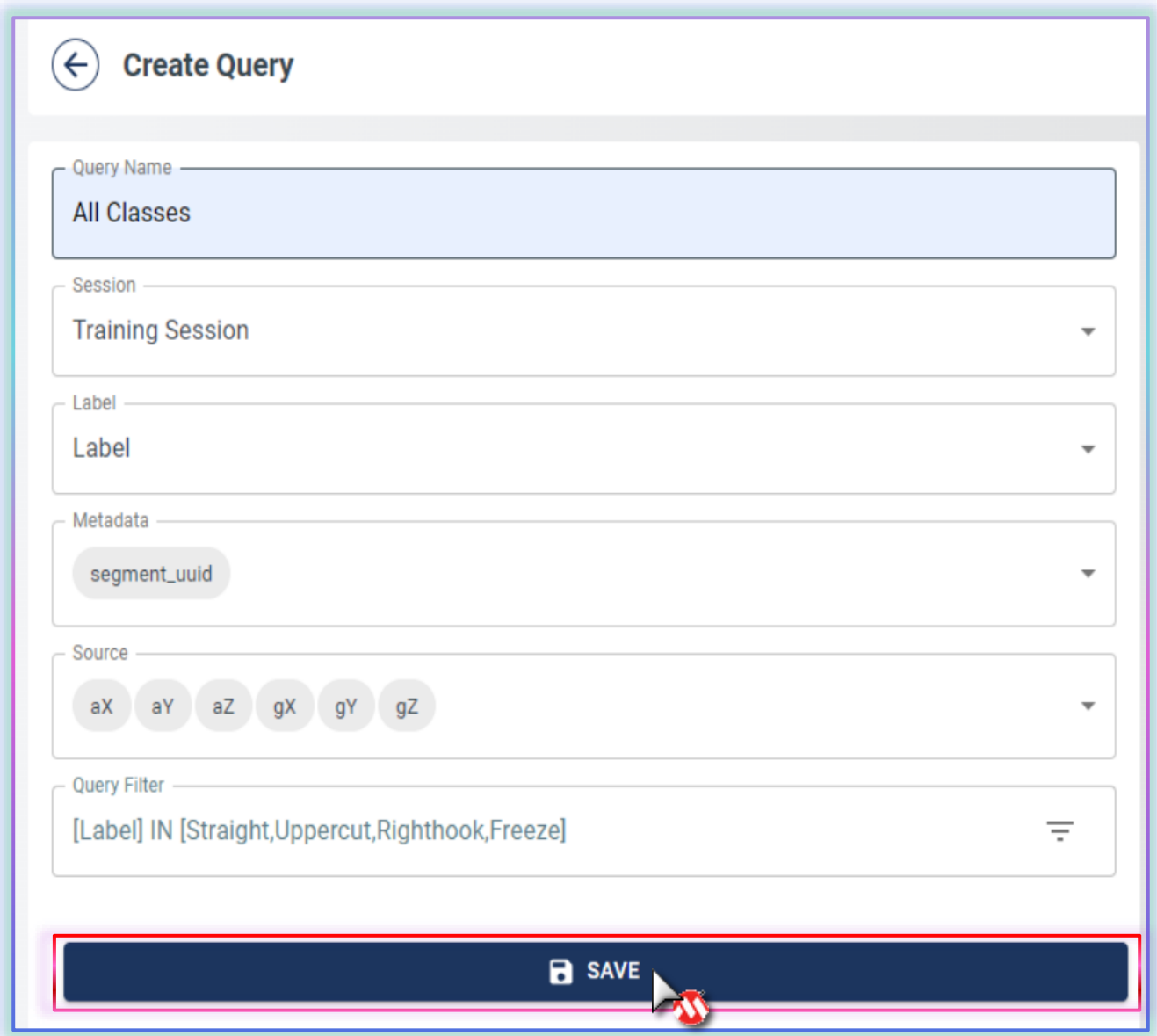
- **Click ⊽ to open the list**



🛠 Lab3 Model Pipeline and Training

Step 4

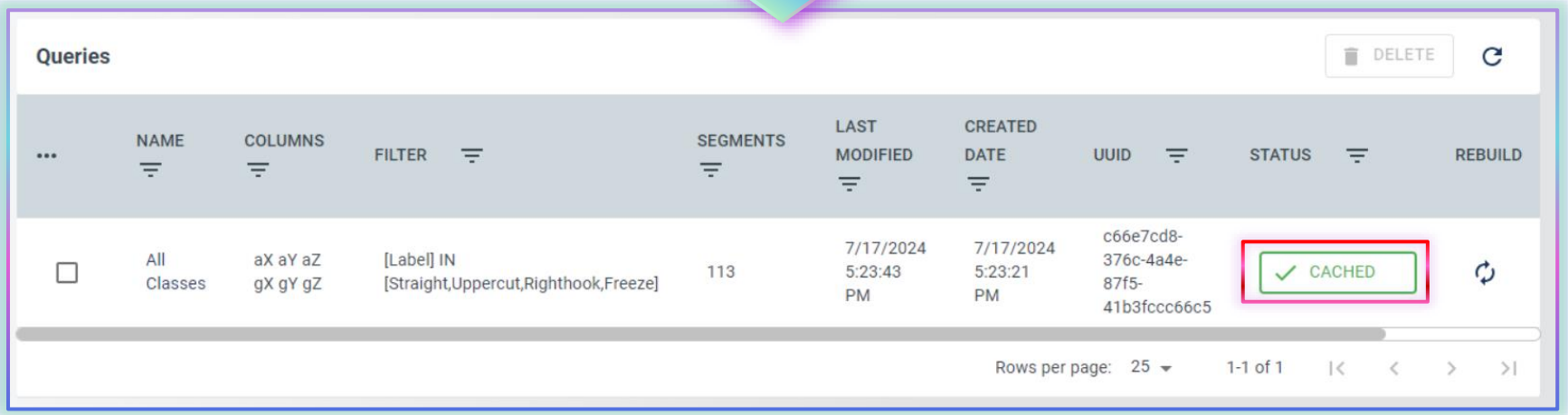
- **Save the Query.**



🛠 Lab3 Model Pipeline and Training

Step 5

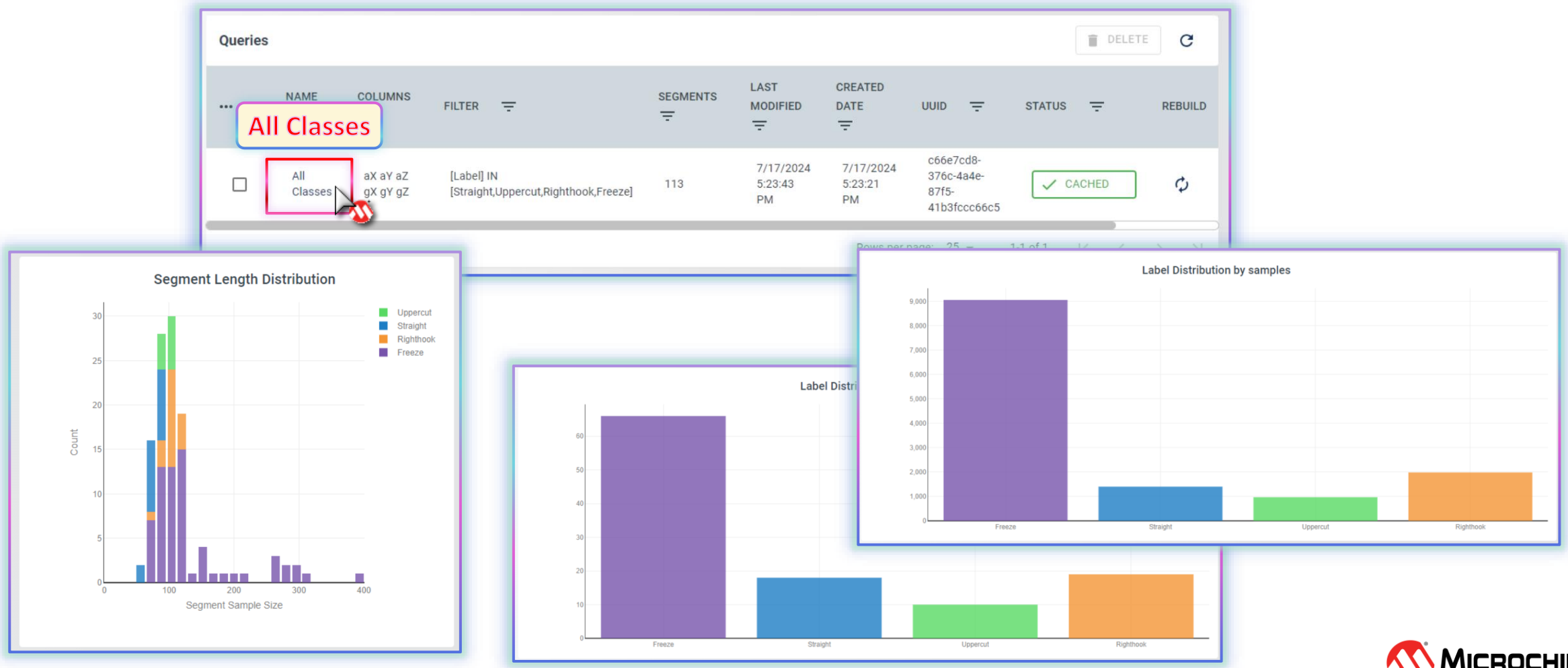
- **Click 🔄 to build Cache.**



🛠 Lab3 Model Pipeline and Training

Step 6

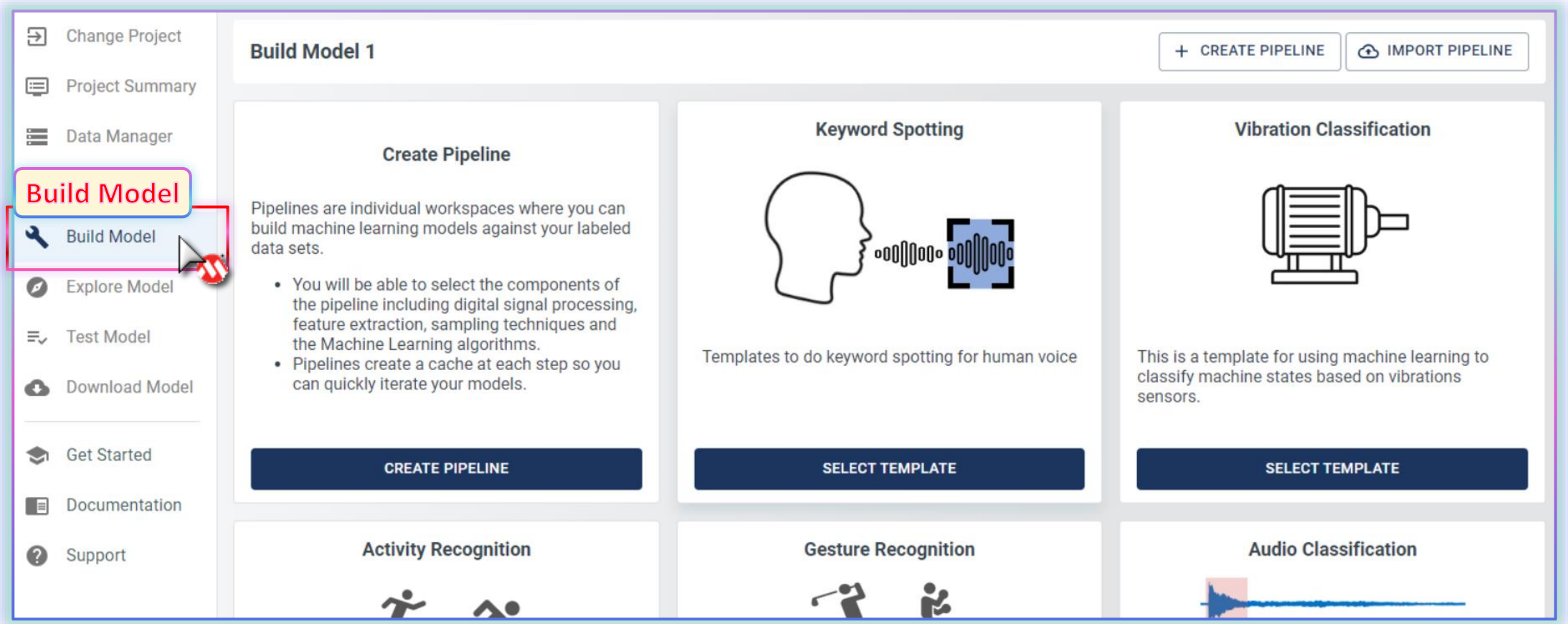
- **Click the name of queries - All classes to see details.**



🛠 Lab3 Model Pipeline and Training

Step 7

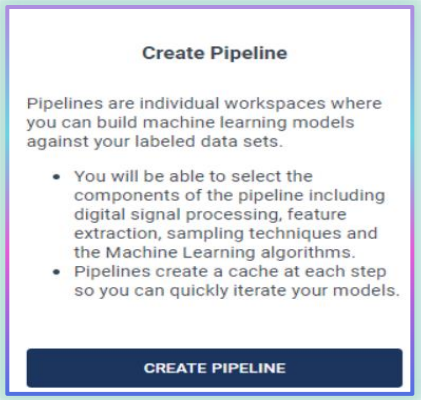
- **Click Build Model**



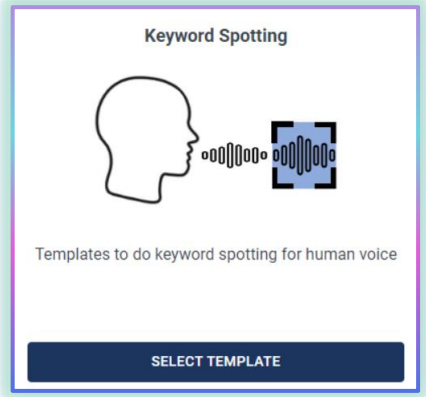
🛠 Lab3 Model Pipeline and Training

Step 8

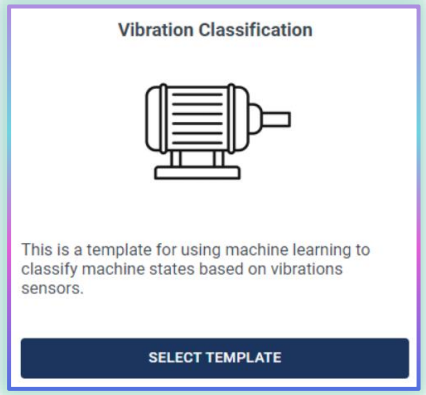
- **MPLAB® ML Suite Templates, choose Gesture Recognition.**



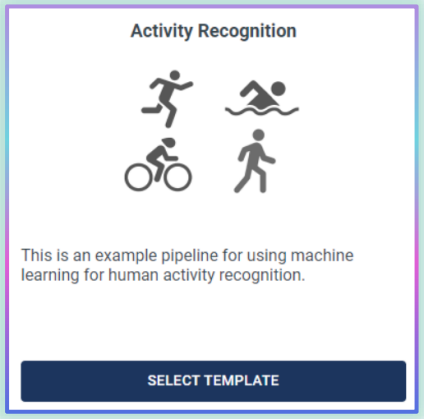
Create Pipeline



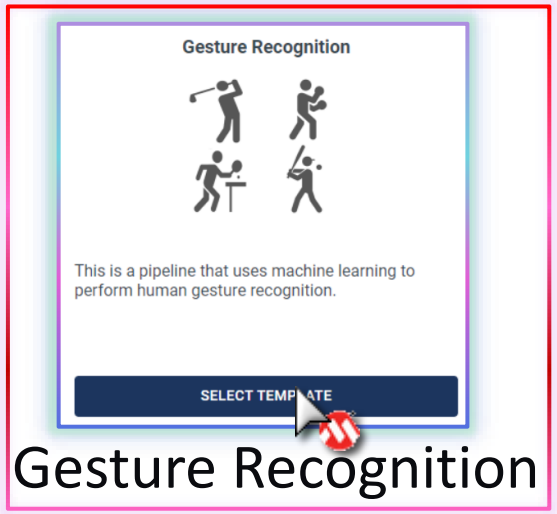
Keyword Spotting



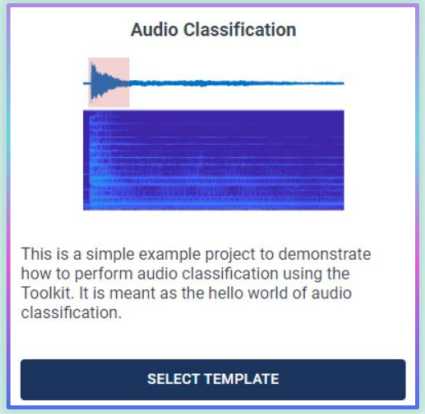
Vibration Classification



Activity Recognition



Gesture Recognition



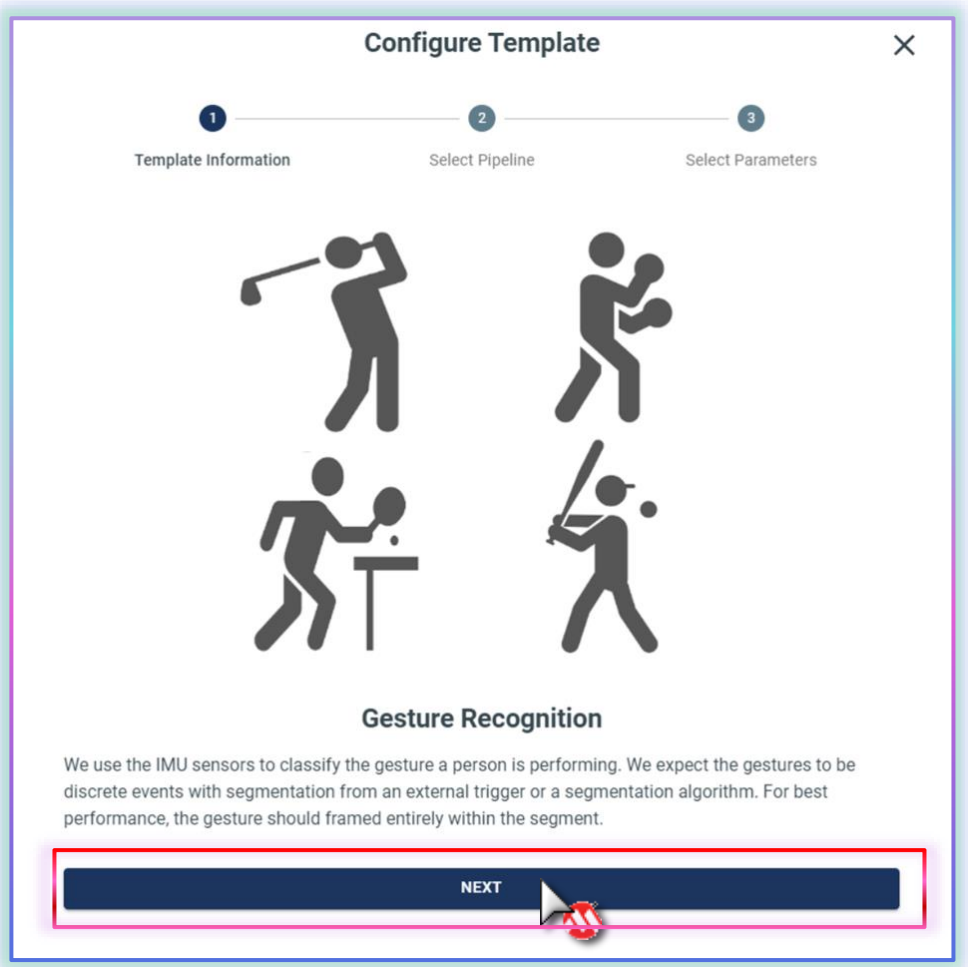
Audio Classification

MICROCHIP

🛠 Lab3 Model Pipeline and Training

Step 9

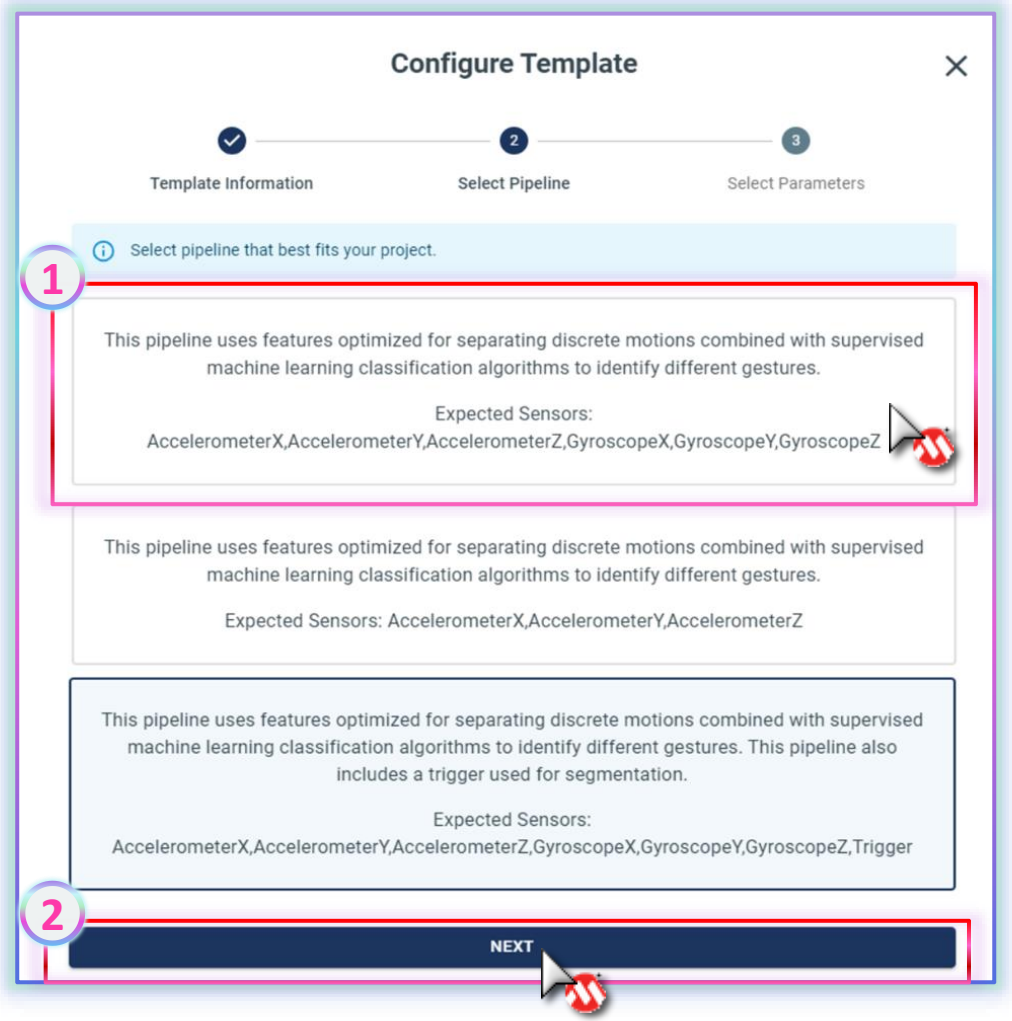
- **Slide to bottom and click next.**



🛠 Lab3 Model Pipeline and Training

Step 10

- **It will auto select the pipeline that best fits.**
- **Choose the 1st one.**

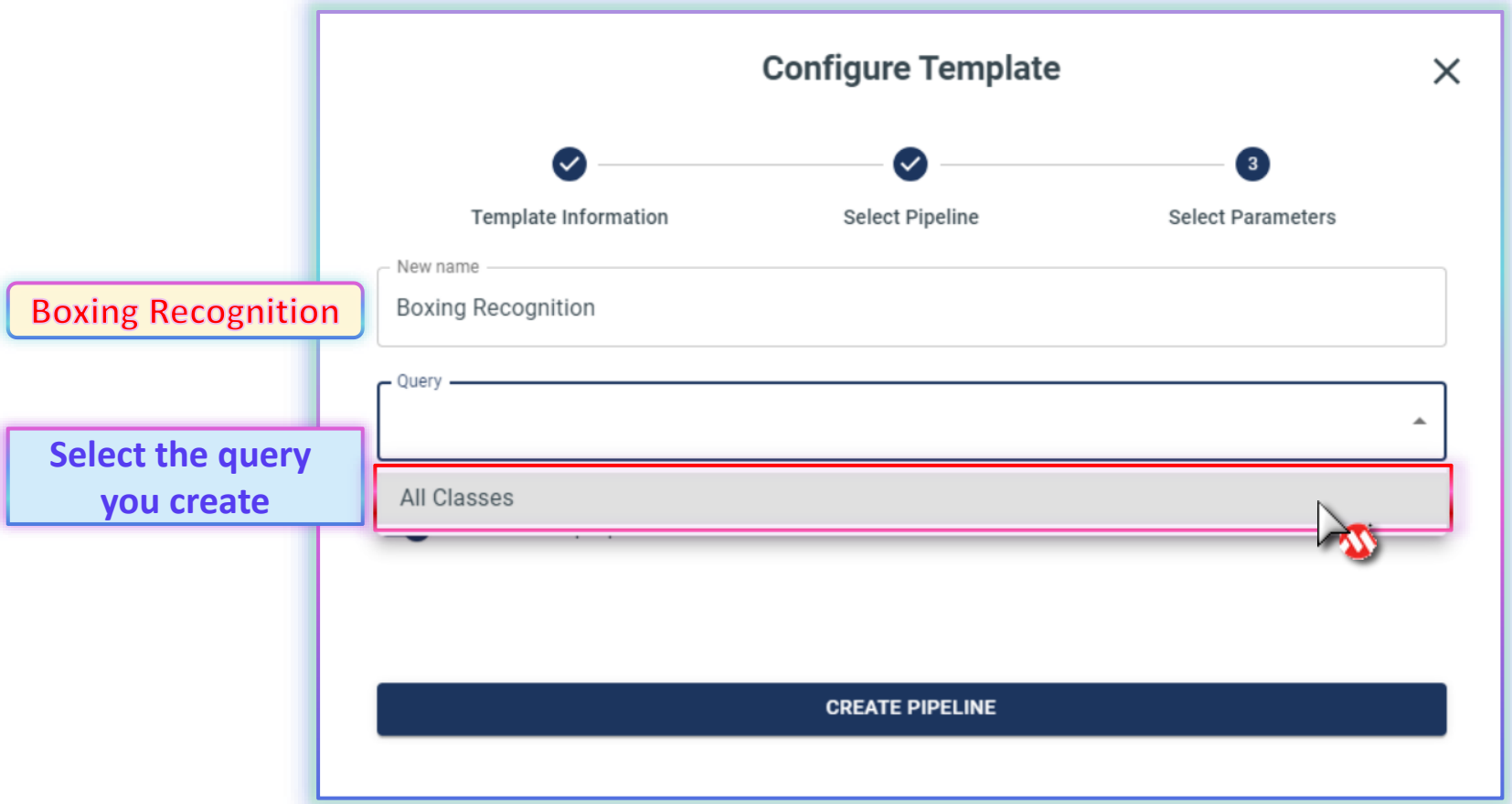


MICROCHIP

🛠 Lab3 Model Pipeline and Training

Step 11

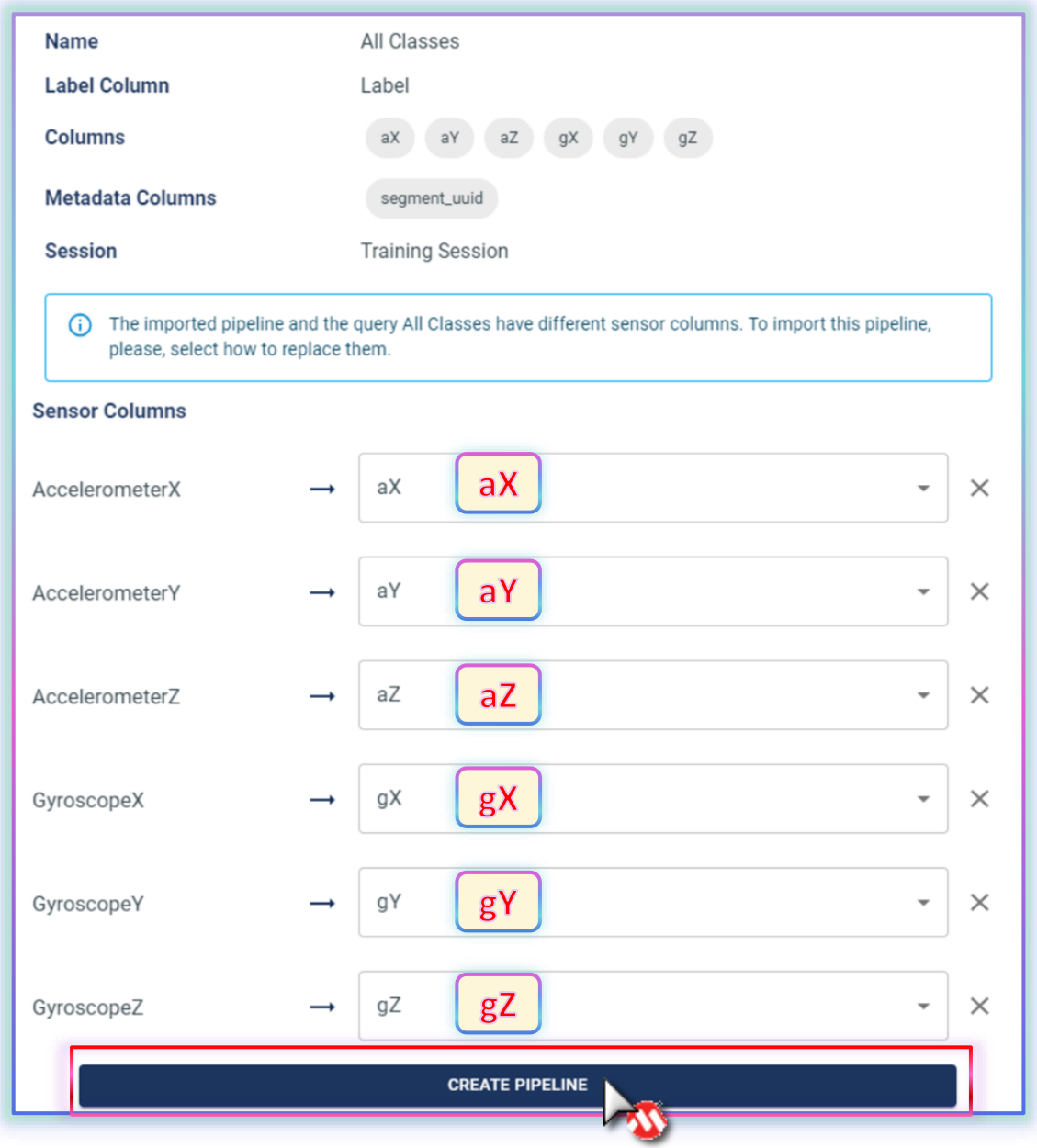
- **Name the model Boxing Recognition.**
- **Choose the Query.**



🛠 Lab3 Model Pipeline and Training

Step 12

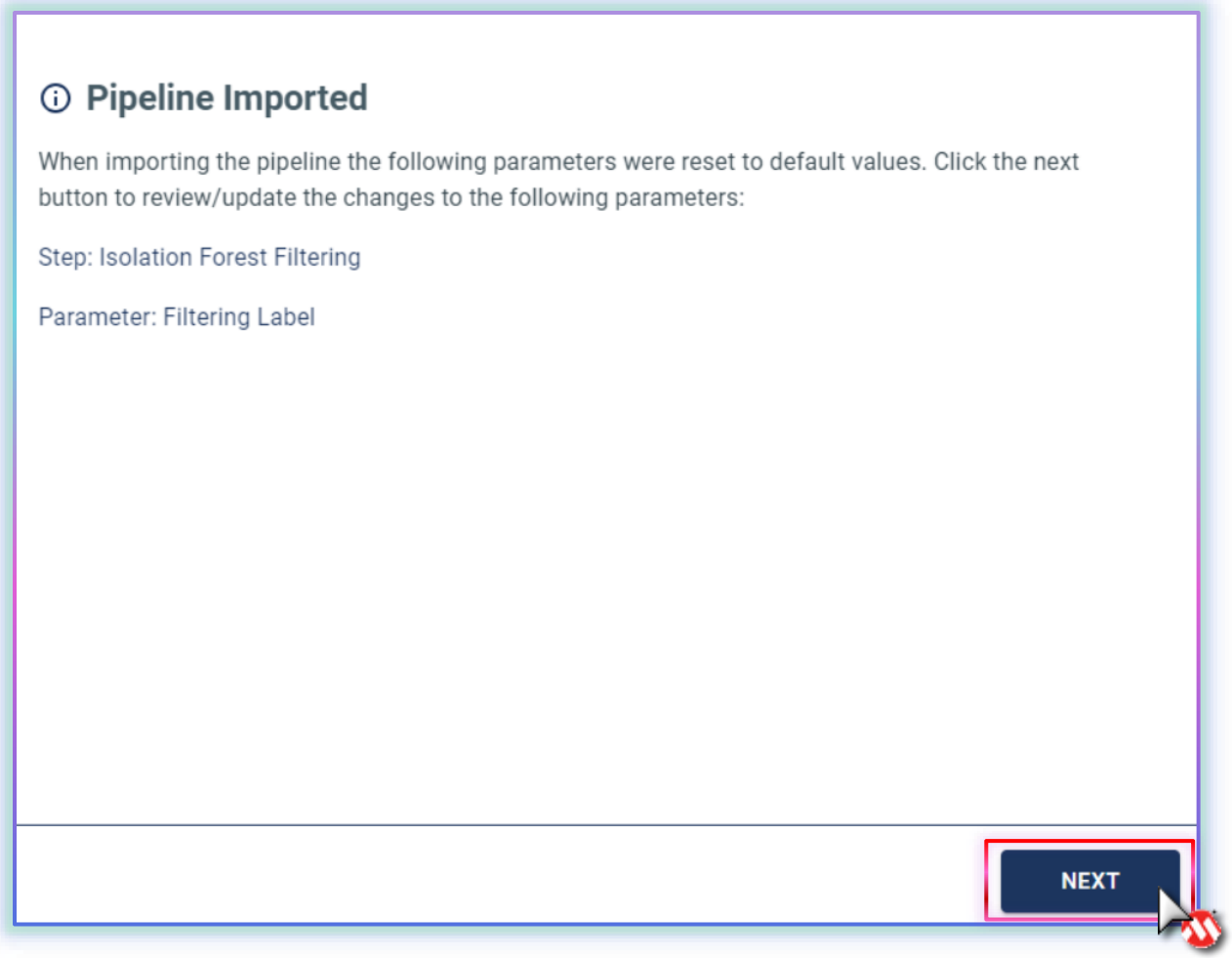
- **Fill in all the sensor Columns.**



🛠 Lab3 Model Pipeline and Training

Step 13

- **Click next.**



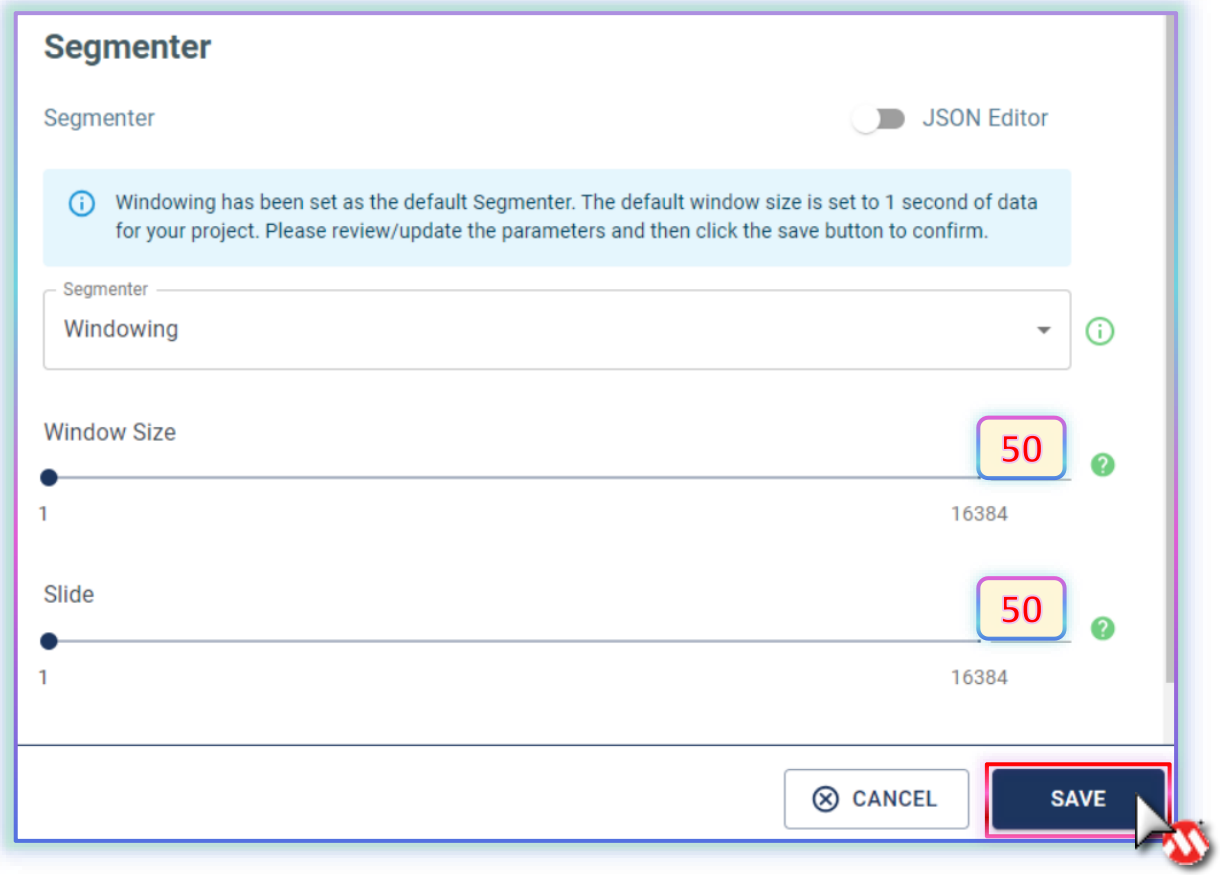
🛠 Lab3 Model Pipeline and Training

Step 14

- **Adjust and confirm the segmenter.**

- **Window Size: “100” refers to the window size in samples.**
  - By picking “Windowing” and “100” on 100 hz data, there is a 1 second window size. Which means every 1 second you will get a new classification.

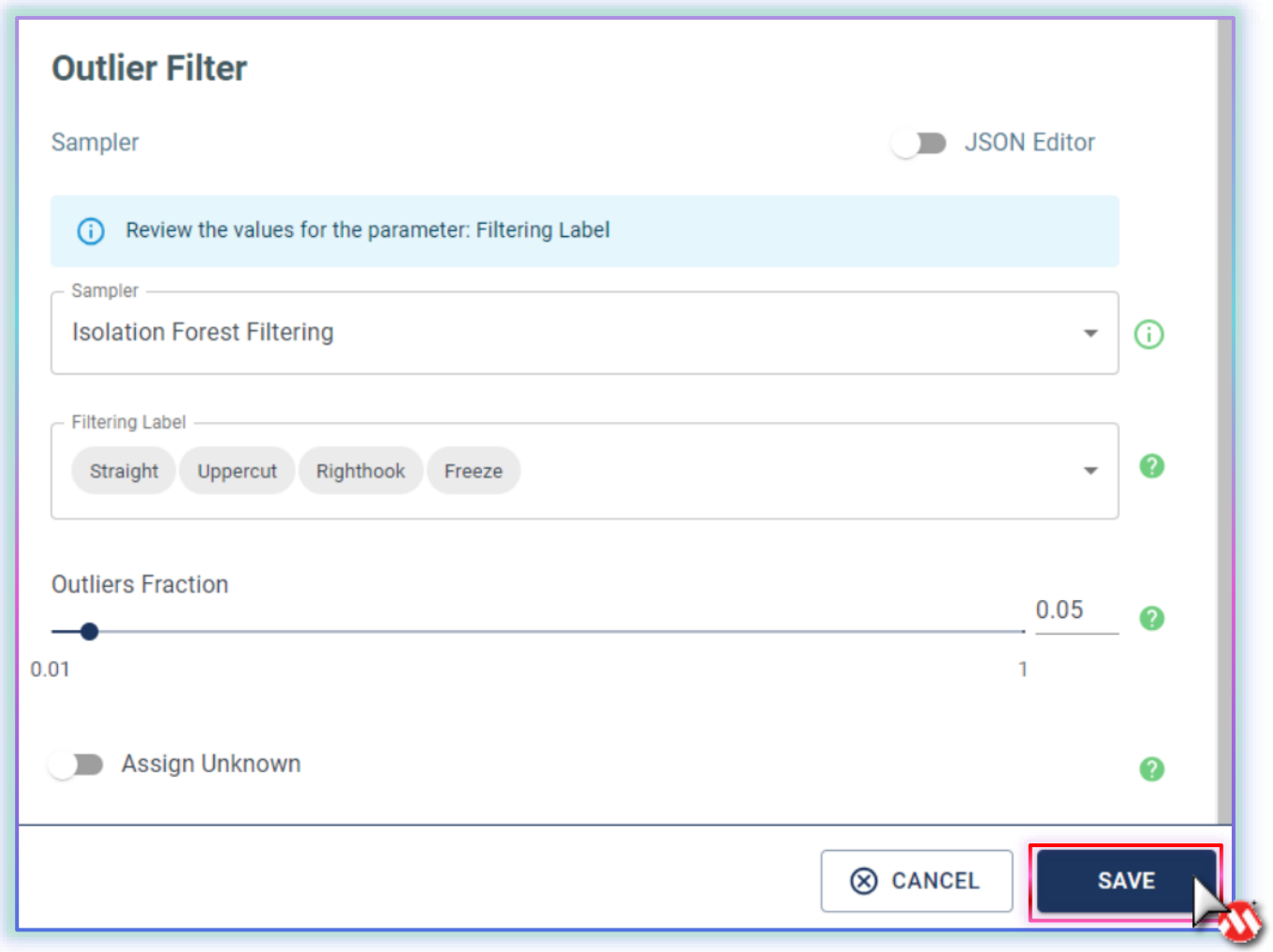
- **Slide: Control the amount of overlap between this signal and the last.**



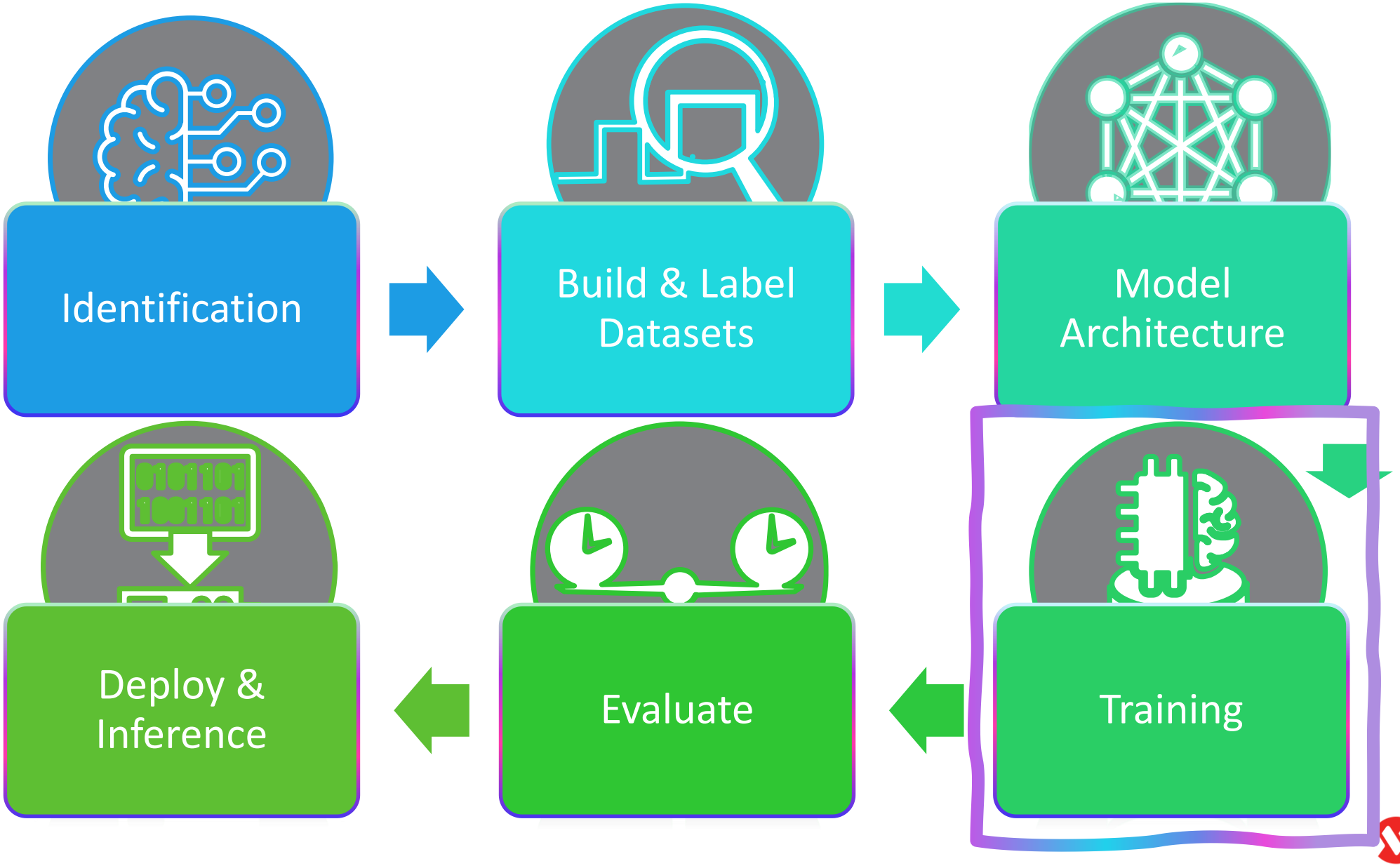
🛠 Lab3 Model Pipeline and Training

Step 15

- **Adjust and confirm the outlier filter.**



Machine Learning Workflow

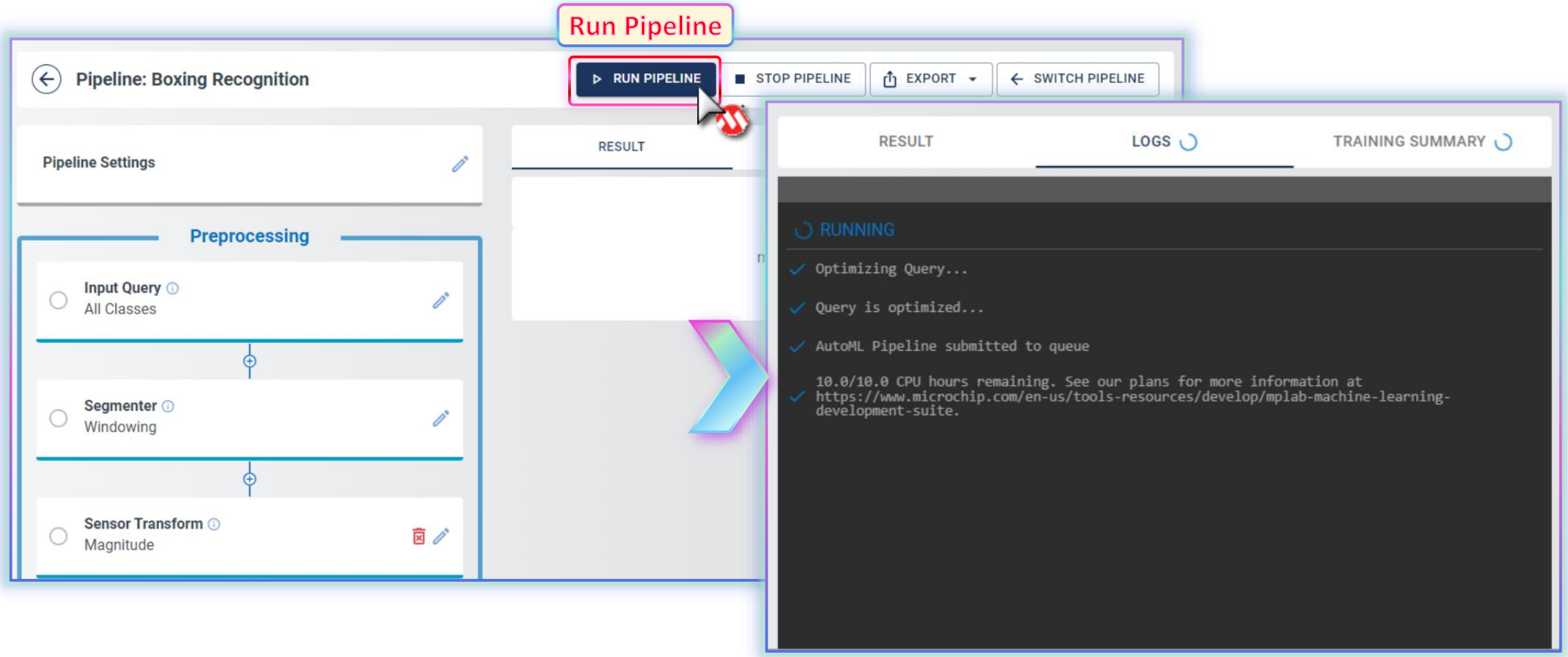


MICROCHIP

🛠 Lab3 Model Pipeline and Training

Step 16

- **Start running pipeline, and wait…**



🛠 Lab3 Model Pipeline and Training

Result

- **Training Complete! 5 different models generated.**

RESULT | LOGS | TRAINING SUMMARY

COMPLETED

```
Status: Running, Time: 0:05:03, Iteration 2/2, Step: 5/8, Name: Feature Selec
Population: 1
Status: Running, Time: 0:05:08, Iteration 2/2, Step: 5/8, Name: Feature Selec
Population: 1
Status: Running, Time: 0:05:13, Iteration 2/2, Step: 6/8, Name: Isolation For
Filtering, Population: 1
Status: Running, Time: 0:05:18, Iteration 2/2, Step: 7/8, Name: Min Max Scale
Population: 1
Status: Running, Time: 0:05:23, Iteration 2/2, Step: 8/8, Name: Model Trainin
Population: 16
Status: Running, Time: 0:05:28, Iteration 2/2, Step: 8/8, Name: Model Trainin
Population: 16
Status: Running, Time: 0:05:33, Iteration 2/2, Step: 8/8, Name: Model Trainin
Population: 16
Status: Running, Time: 0:05:38, Iteration 2/2, Step: 8/8, Name: Model Trainin
Population: 16
```

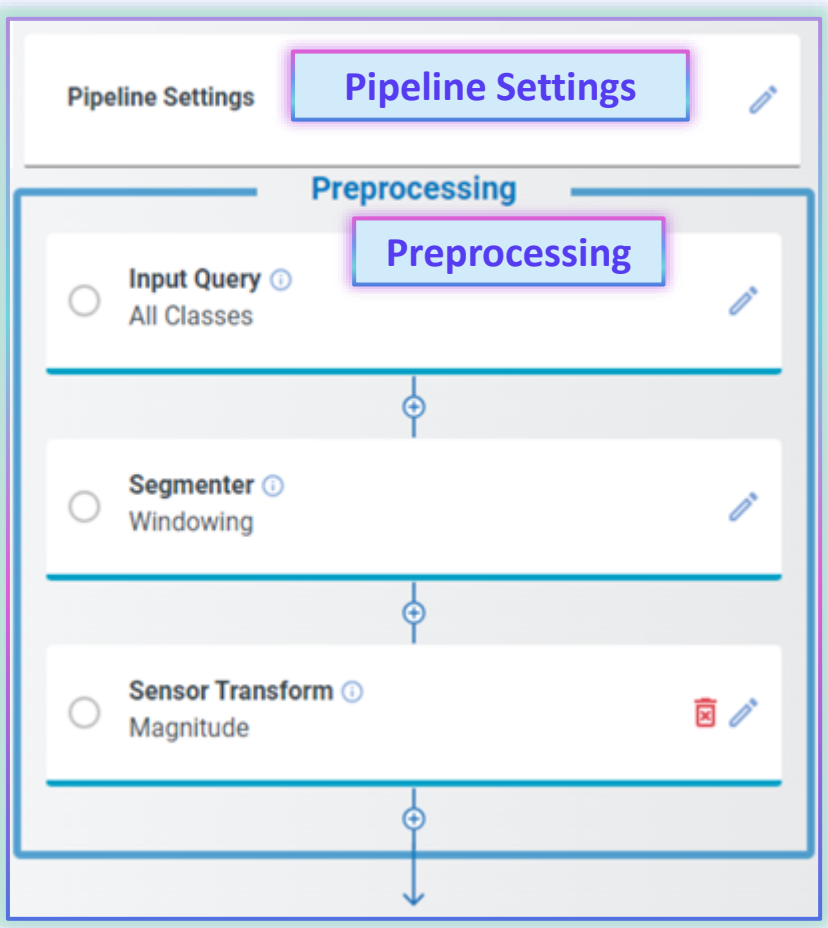
RESULT | LOGS | TRAINING SUMMARY

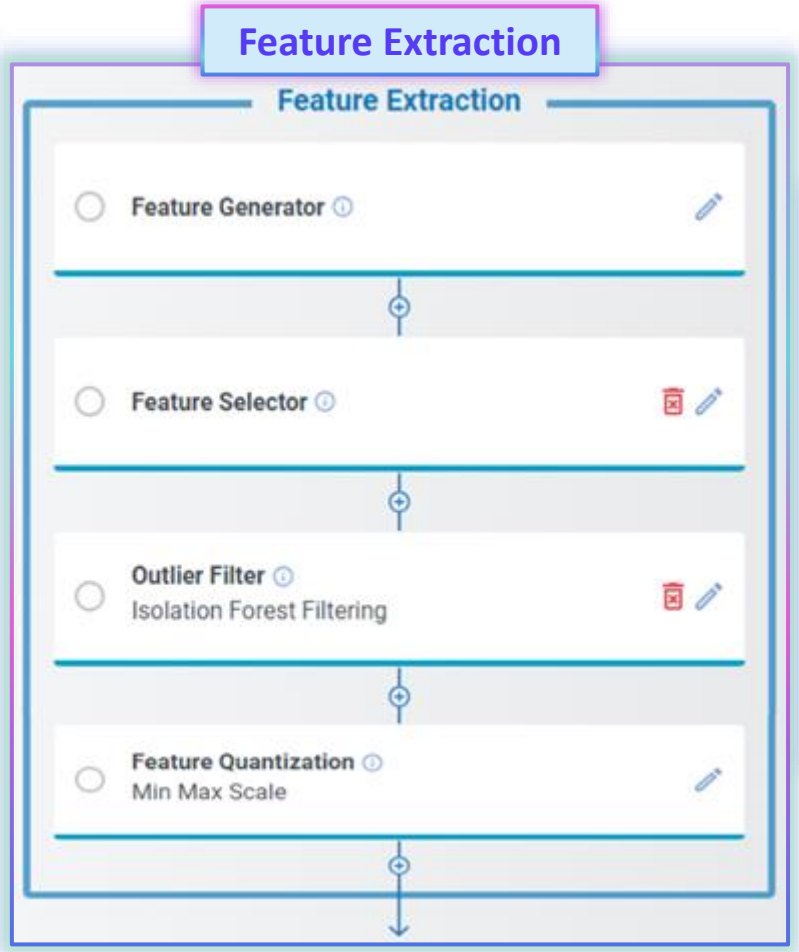
MODEL NAME	ACCURACY	CLASSIFER SIZE(B)	NUM. FEATURES	SENSITIVITY	F1-SCOR
Boxing_Recognition_rank_0	100	1376	2	100	100
Boxing_Recognition_rank_1	100	1096	3	100	100
Boxing_Recognition_rank_2	100	193	8	100	100
Boxing_Recognition_rank_3	100	239	8	100	100
Boxing_Recognition_rank_4	100	232	12	100	100

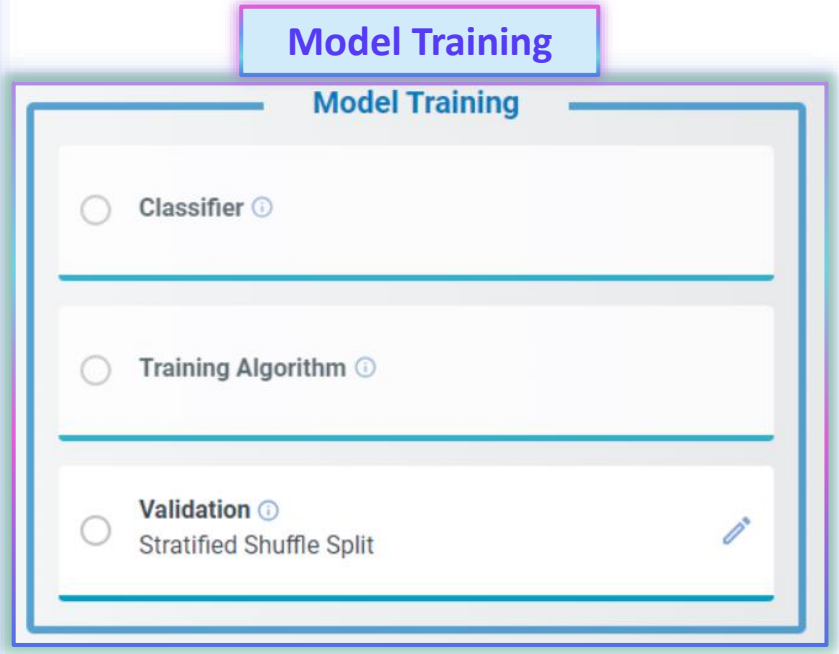
🛠 Lab3 Model Pipeline and Training

Pipeline Settings

- **Pipeline overview, Click ✎ to edit.**







Model Evaluation and Deploy

How good is the model?

5 models generated

- **rank_4 will usually be the best**

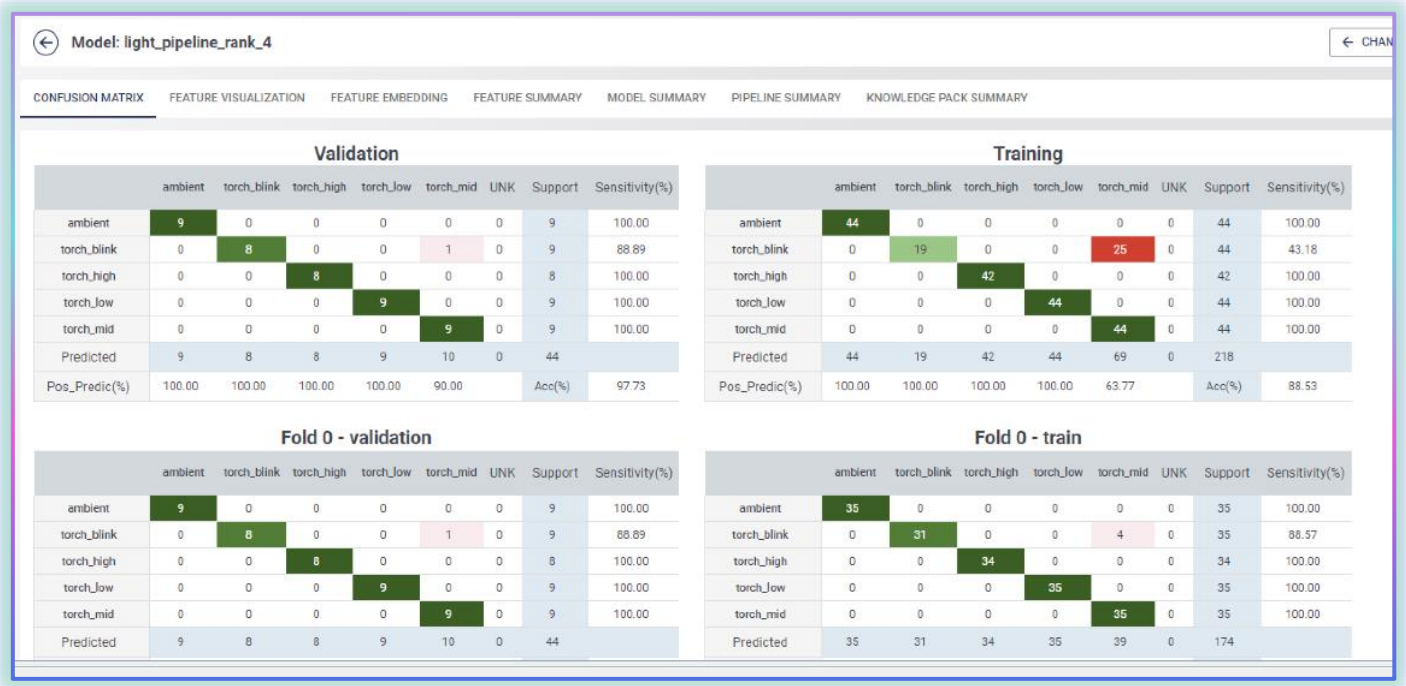
  But may not be the smallest or fastest

- **Model tested against inputs**

  Using stratified split

Confusion Matrix

- **An important summary**
- **Compare actual against predicted**



Model: light_pipeline_rank_4

CONFUSION MATRIX | FEATURE VISUALIZATION | FEATURE EMBEDDING | FEATURE SUMMARY | MODEL SUMMARY | PIPELINE SUMMARY | KNOWLEDGE PACK SUMMARY

Validation

	ambient	torch_blink	torch_high	torch_low	torch_mid	UNK	Support	Sensitivity(%)
ambient	9	0	0	0	0	0	9	100.00
torch_blink	0	8	0	0	1	0	9	88.89
torch_high	0	0	8	0	0	0	8	100.00
torch_low	0	0	0	9	0	0	9	100.00
torch_mid	0	0	0	0	9	0	9	100.00
Predicted	9	8	8	9	10	0	44	
Pos_Predic(%)	100.00	100.00	100.00	100.00	90.00		Acc(%)	97.73

Training

	ambient	torch_blink	torch_high	torch_low	torch_mid	UNK	Support	Sensitivity(%)
ambient	44	0	0	0	0	0	44	100.00
torch_blink	0	19	0	0	25	0	44	43.18
torch_high	0	0	42	0	0	0	42	100.00
torch_low	0	0	0	44	0	0	44	100.00
torch_mid	0	0	0	0	44	0	44	100.00
Predicted	44	19	42	44	69	0	218	
Pos_Predic(%)	100.00	100.00	100.00	100.00	63.77		Acc(%)	88.53

Fold 0 - validation

	ambient	torch_blink	torch_high	torch_low	torch_mid	UNK	Support	Sensitivity(%)
ambient	9	0	0	0	0	0	9	100.00
torch_blink	0	8	0	0	1	0	9	88.89
torch_high	0	0	8	0	0	0	8	100.00
torch_low	0	0	0	9	0	0	9	100.00
torch_mid	0	0	0	0	9	0	9	100.00
Predicted	9	8	8	9	10	0	44	

Fold 0 - train

	ambient	torch_blink	torch_high	torch_low	torch_mid	UNK	Support	Sensitivity(%)
ambient	35	0	0	0	0	0	35	100.00
torch_blink	0	31	0	0	4	0	35	88.57
torch_high	0	0	34	0	0	0	34	100.00
torch_low	0	0	0	35	0	0	35	100.00
torch_mid	0	0	0	0	35	0	35	100.00
Predicted	35	31	34	35	39	0	174	

Confusion Matrix

- **The Confusion Matrix tab shows the averaged confusion matrix for the validation data.**

What's the prediction? Positive/Negative

Is the prediction correct? True/False

Pos_Predic(%):

$$\frac{TP}{TP + FP} \times 100\%$$

Sensitivity (Recall)(%):

$$\frac{TP}{TP + FN} \times 100\%$$

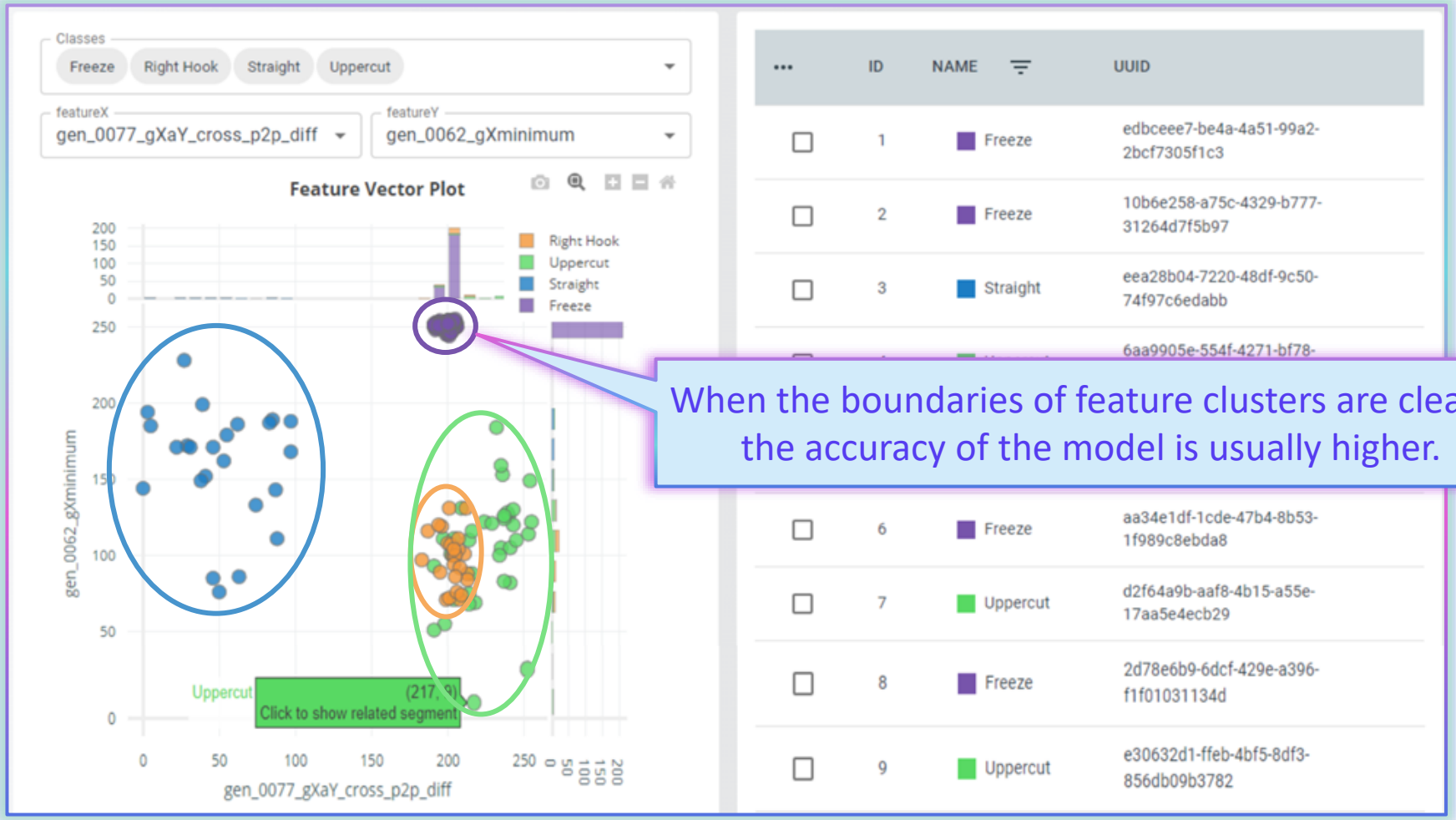
Accuracy(%):

$$\frac{TP + TN}{TP + FN + FP + TN} \times 100\%$$

Confusion Matrix		Predicted	
		Yes	No
Actual	True	**TP** (True Positive)	**FN** (False Negative)
	False	**FP** (False Positive)	**TN** (True Negative)

Feature Visualization

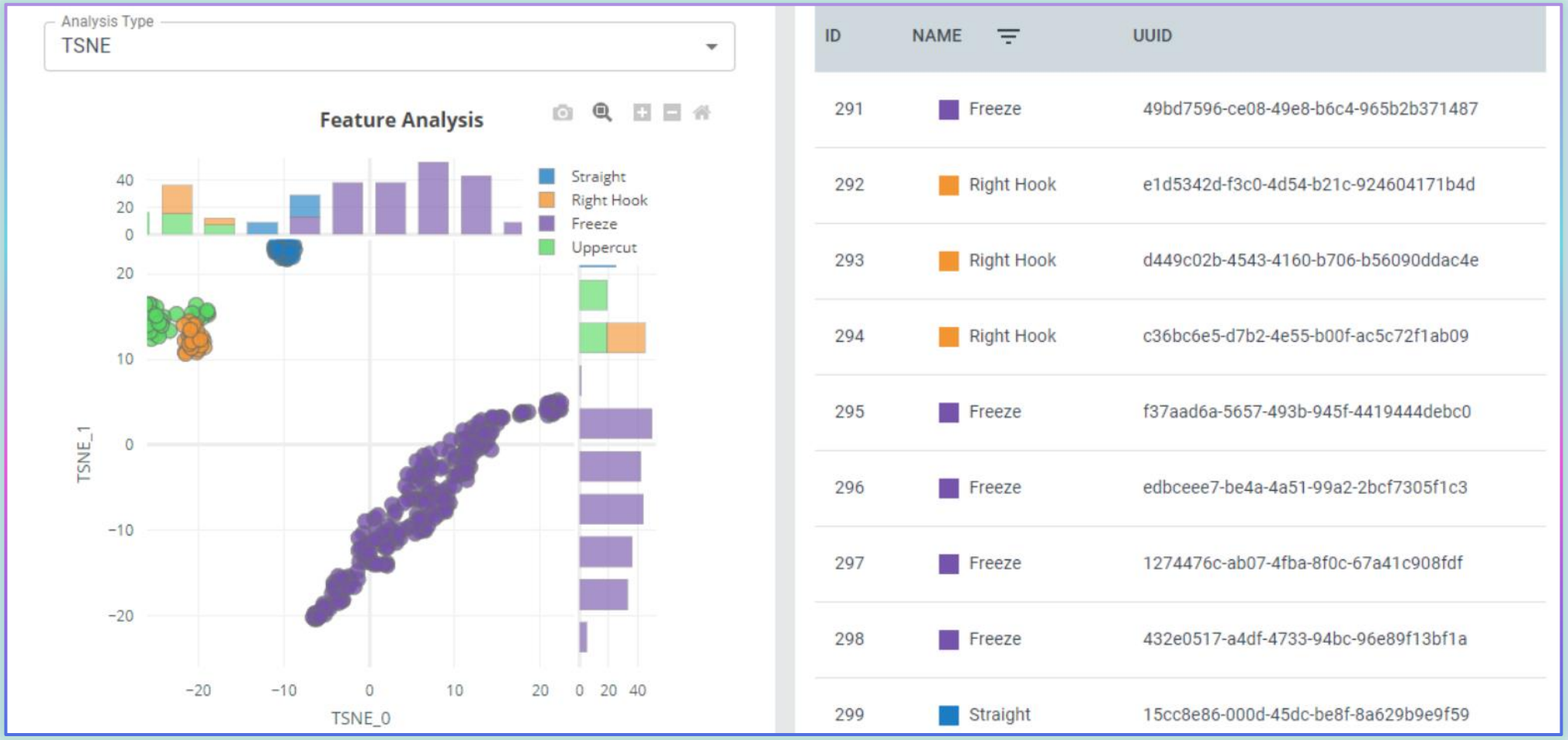
- **Provide feature visualization as a 2-D comparison plot and feature insights chart.**
- **How well features are clustered according to classification.**



When the boundaries of feature clusters are clearer, the accuracy of the model is usually higher.

Feature Embedding

- **The Feature Embedding tab provides three different embedding algorithms: UMAP, PCA, and TSNE.**

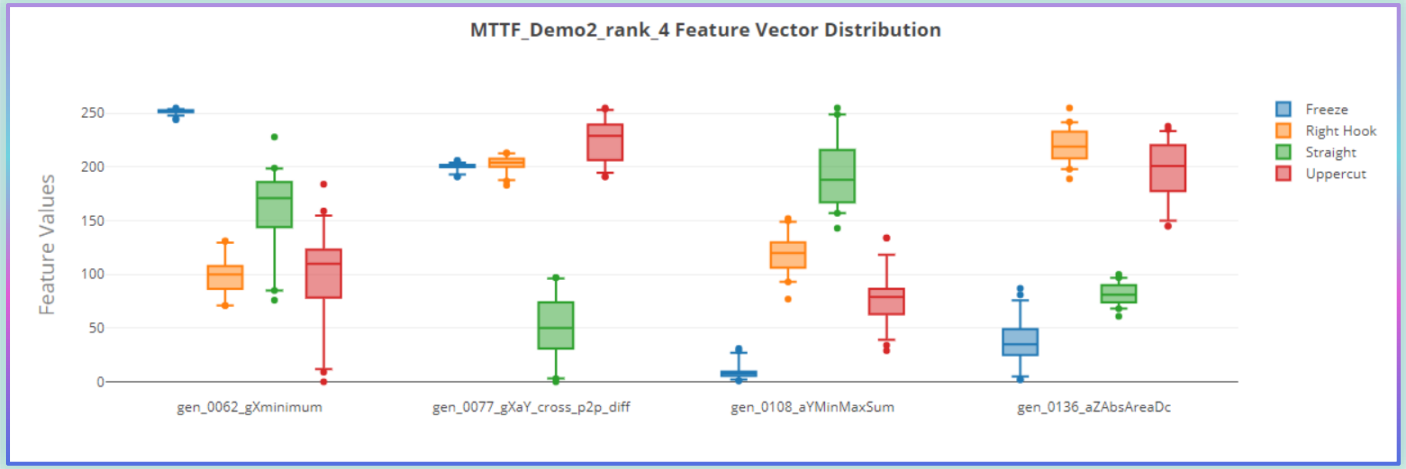


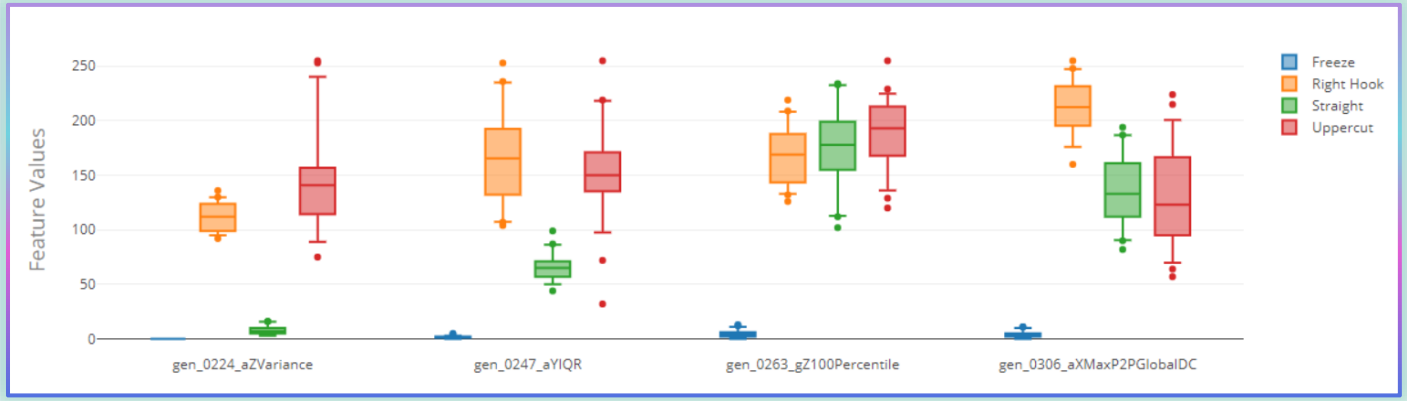
Feature Summary

- **Indication of what features are actually used to classify the results. Contain information about the features that are used during the feature extraction step of the Knowledge Pack.**

FEATURE	CATEGORY	GENERATOR	SENSORS
gen_0062_gXminimum	Statistical	Minimum	gX
gen_0077_gXaY_cross_p2p_diff	Column Fusion	Two Column Peak To Peak Difference	gXaY
gen_0108_aYMinMaxSum	Amplitude	Global Min Max Sum	aY
gen_0136_aZAbsAreaDc	Area	Absolute Area of Low Frequency	aZ
gen_0224_aZVariance	Statistical	Variance	aZ
gen_0247_aYIQR	Statistical	Interquartile Range	aY
gen_0263_gZ100Percentile	Statistical	100th Percentile	gZ
gen_0306_aXMaxP2PGlobalDC	Amplitude	Global Peak to Peak of Low Frequency	aX

1-8 of 8





Model Summary

- **The Model Summary tab describes the classifier, classifier parameters, and training algorithm that was used to generate the final model.**

CLASSIFIER	UUID	OPTIMIZER	NEURONS	CLASSIFICATION_MODE	DISTANCE_MODE
PME	d6027a4e-5937-4547-b9fd-0dcf0381855f	RBF with Neuron Allocation Optimization	14	KNN	LSUP

1-1 of 1

CATEGORY	CATEGORY ID	AIF	PATTERN
Uppercut	4	62	126,237,72,201,149,154,129,104
Right Hook	2	43	119,196,129,207,124,130,194,160
Freeze	1	100	251,200,8,73,0,3,5,9
Straight	3	100	171,22,215,79,5,87,233,90
Uppercut	4	37	68,214,81,161,97,120,211,174
Uppercut	4	59	107,199,134,214,134,203,210,95
Right Hook	2	41	94,204,130,222,122,163,187,244
Right Hook	2	53	84,213,100,198,110,107,188,208
Uppercut	4	58	126,240,80,217,162,144,197,102
Uppercut	4	78	111,197,134,228,149,153,139,125
Right Hook	2	55	92,208,100,200,102,160,174,203
Uppercut	4	76	131,209,67,145,75,108,229,224
Uppercut	4	100	55,198,51,145,89,32,163,159
Right Hook	2	100	71,199,95,224,113,253,149,176

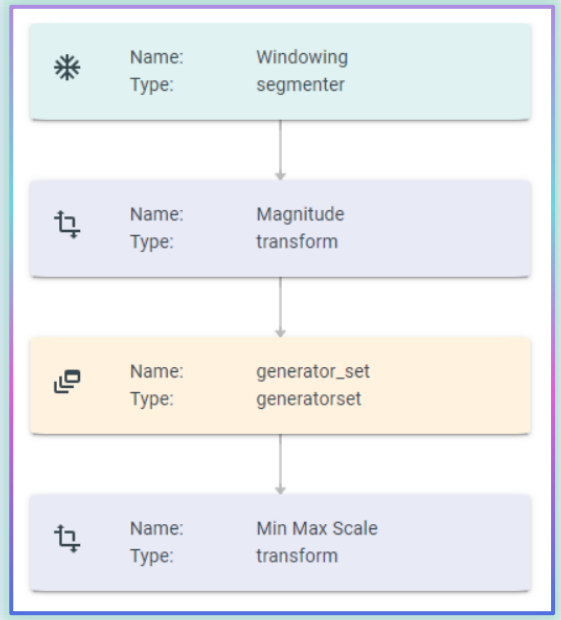
1-14 of 14

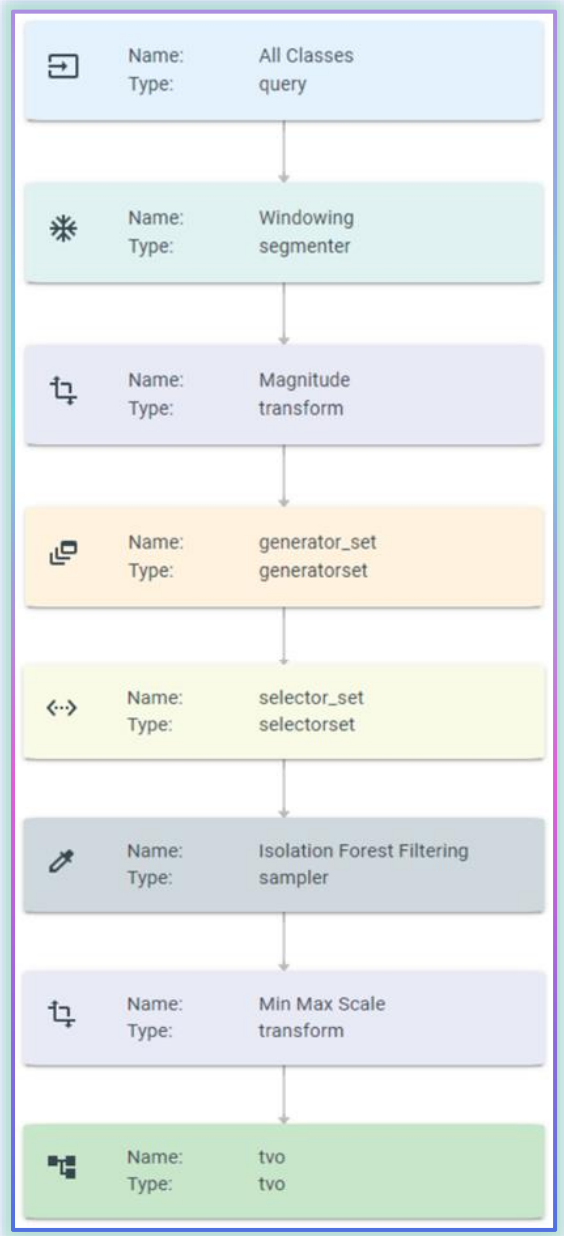
MICROCHIP

Pipeline & Knowledge Pack Summary

- **Pipeline summary consists of data input, signal conditioning, signal preprocessing, feature extraction, *sampling*, and *model training*.**

- **Knowledge Packs summary consists of data input, signal conditioning, signal preprocessing, feature extraction, and classification.**





🛠 Lab4
Model Evaluation and Deploy

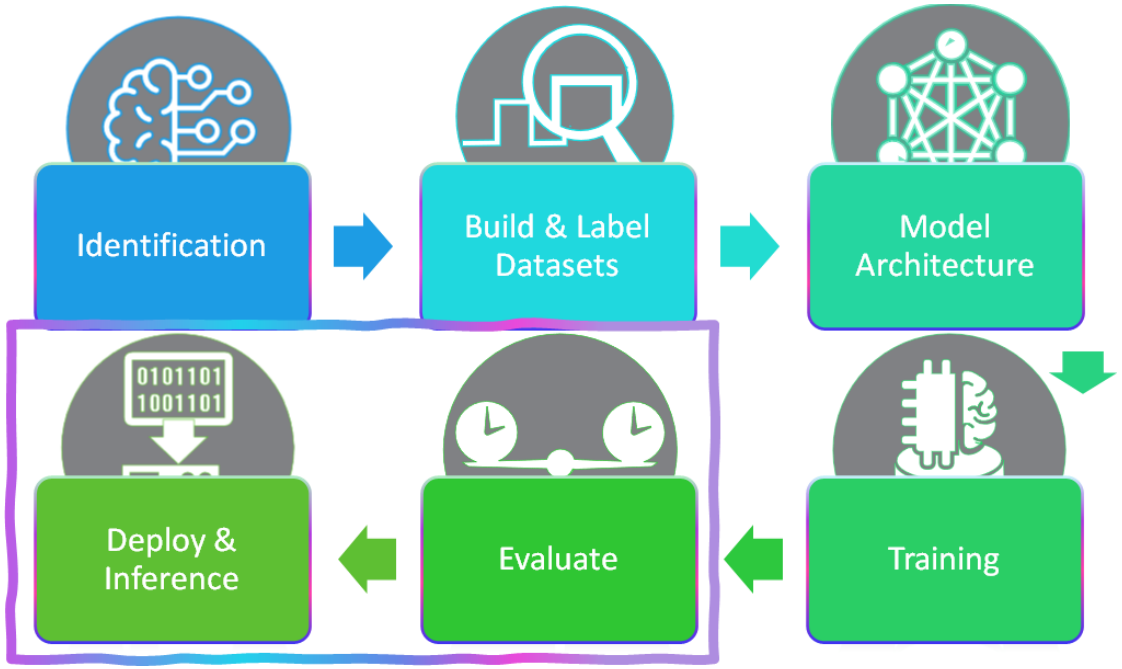
Boxing Recognition by Machine Learning

MICROCHIP

🛠 Lab4 Model Evaluation and Deploy

Boxing Recognition by Machine Learning

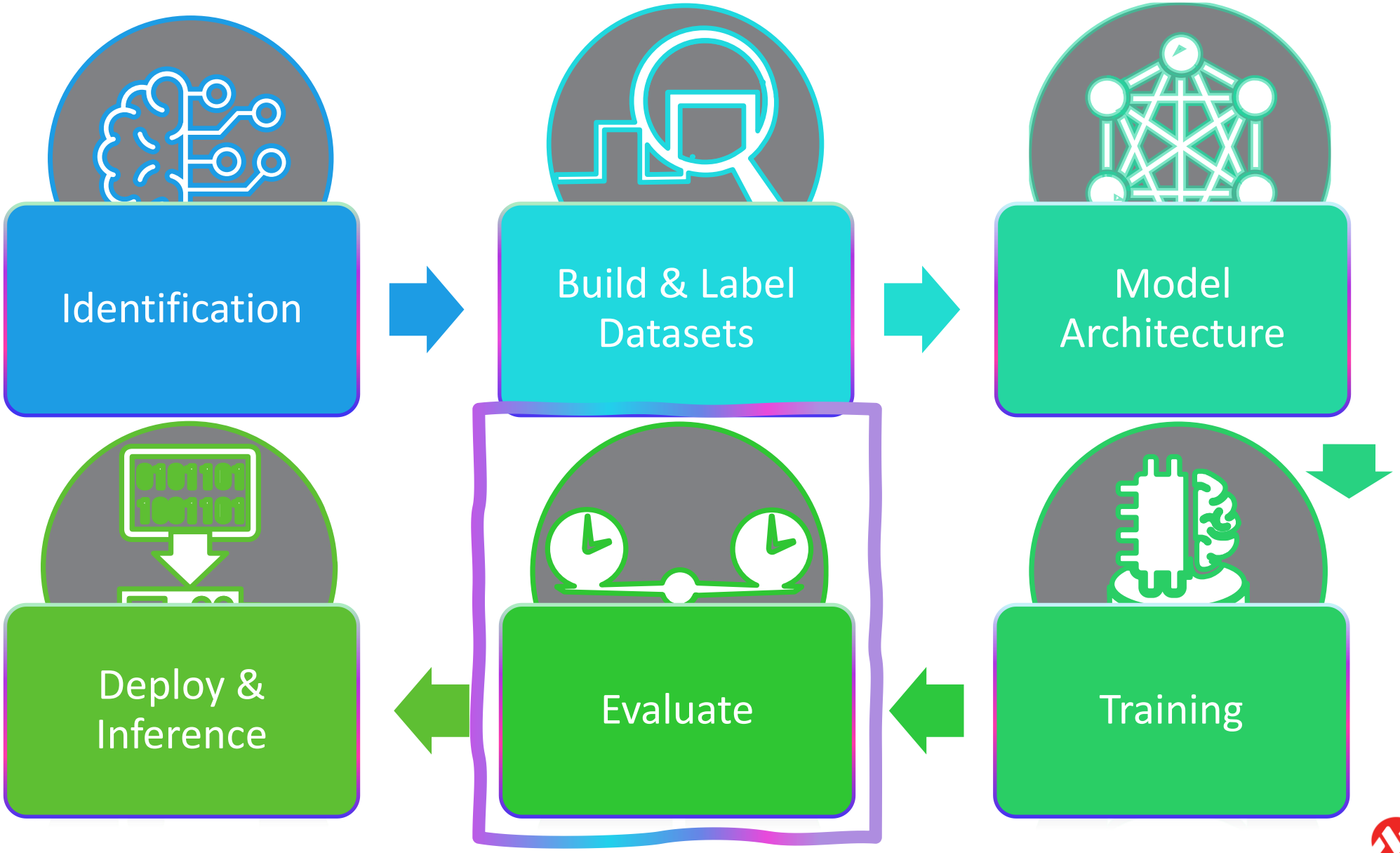
- Look and observe the results and select one of the model to test and inference.
- View the detail of the model by exploring the model.
- Download the trained model as a library file, deployed the model to the MCU.
- Start inferencing your model.



Let’s go!

MICROCHIP

Machine Learning Workflow

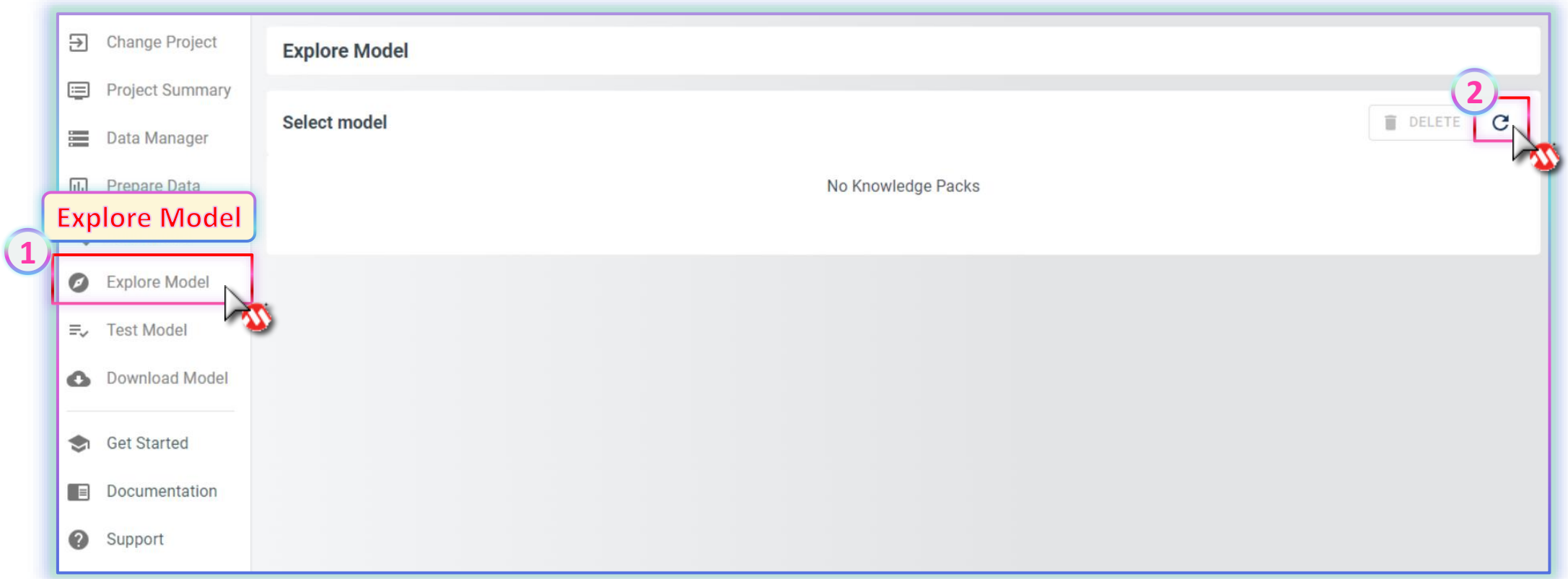


MICROCHIP

🛠 Lab4 Model Evaluation and Deploy

Step 1

- **Click Explore model and ↻ to reload.**



🛠 Lab4 Model Evaluation and Deploy

Step 2

- **The details of 5 model will show on the window.**
- **Click rank_4 model to explore it. (Usually rank_4 is the best)**

Select model

DELETE

•••	NAME	CLASSIFIER	ACCURACY	MODEL SIZE (BYTES)	FEATURE COUNT	PIPELINE	CREATED DATE	UUID	EXPLORE	TEST	DOWNLOAD	RENAME	DELETE
☐	Boxing_Recognition_rank_4	PME	100.00 %	259	12	Boxing Recognition	7/18/2024 3:53:03 PM	9faa0712-69c7-4d53-971f-a3914588a878					
☐	Boxing_Recognition_rank_3	PME	100.00 %	193	8	Boxing Recognition	7/18/2024 3:53:03 PM	c0c01323-e35a-41b8-a187-6b9dcf3bcc43					
☐	Boxing_Recognition_rank_2	PME	100.00 %	216	8	Boxing Recognition	7/18/2024 3:53:03 PM	44661fed-3f22-488e-b39e-71ba2666b1aa					
☐	Boxing_Recognition_rank_1	PME	100.00 %	1348	3	Boxing Recognition	7/18/2024 3:53:03 PM	acceb015-efbb-429e-b955-f4597c2302b1					
☐	Boxing_Recognition_rank_0	Decision Tree Ensemble	100.00 %	1352	2	Boxing Recognition	7/18/2024 3:53:03 PM	d80ddabc-0e07-43c0-9751-0b500df91c6e					

🛠 Lab4 Model Evaluation and Deploy

Step 3

- **The window will show confusion matrix, feature visualization, feature embedding…etc of the model.**

CONFUSION MATRIX | FEATURE VISUALIZATION | FEATURE EMBEDDING | FEATURE SUMMARY | MODEL SUMMARY | PIPELINE SUMMARY | KNOWLEDGE PAC >

Validation

	Freeze	Right Hook	Straight	Uppercut	UNK	Support	Sensitivity(%)
Freeze	43	0	0	0	0	43	100.00
Right Hook	0	5	0	0	0	5	100.00
Straight	0	0	5	0	0	5	100.00
Uppercut	0	0	0	8	0	8	100.00
Predicted	43	5	5	8	0	61	
Pos_Predic(%)	100.00	100.00	100.00	100.00		Acc(%)	100.00

Training

	Freeze	Right Hook	Straight	Uppercut	UNK	Support	Sensitivity(%)
Freeze	215	0	0	0	0	215	100.00
Right Hook	0	26	0	0	0	26	100.00
Straight	0	0	25	0	0	25	100.00
Uppercut	0	0	0	39	0	39	100.00
Predicted	215	26	25	39	0	305	
Pos_Predic(%)	100.00	100.00	100.00	100.00		Acc(%)	100.00

Fold 0 - train

	Freeze	Right Hook	Straight	Uppercut	UNK	Support	Sensitivity(%)
Freeze	172	0	0	0	0	172	100.00
Right Hook	0	21	0	0	0	21	100.00
Straight	0	0	20	0	0	20	100.00
Uppercut	0	0	0	31	0	31	100.00
Predicted	172	21	20	31	0	244	
Pos_Predic(%)	100.00	100.00	100.00	100.00		Acc(%)	100.00

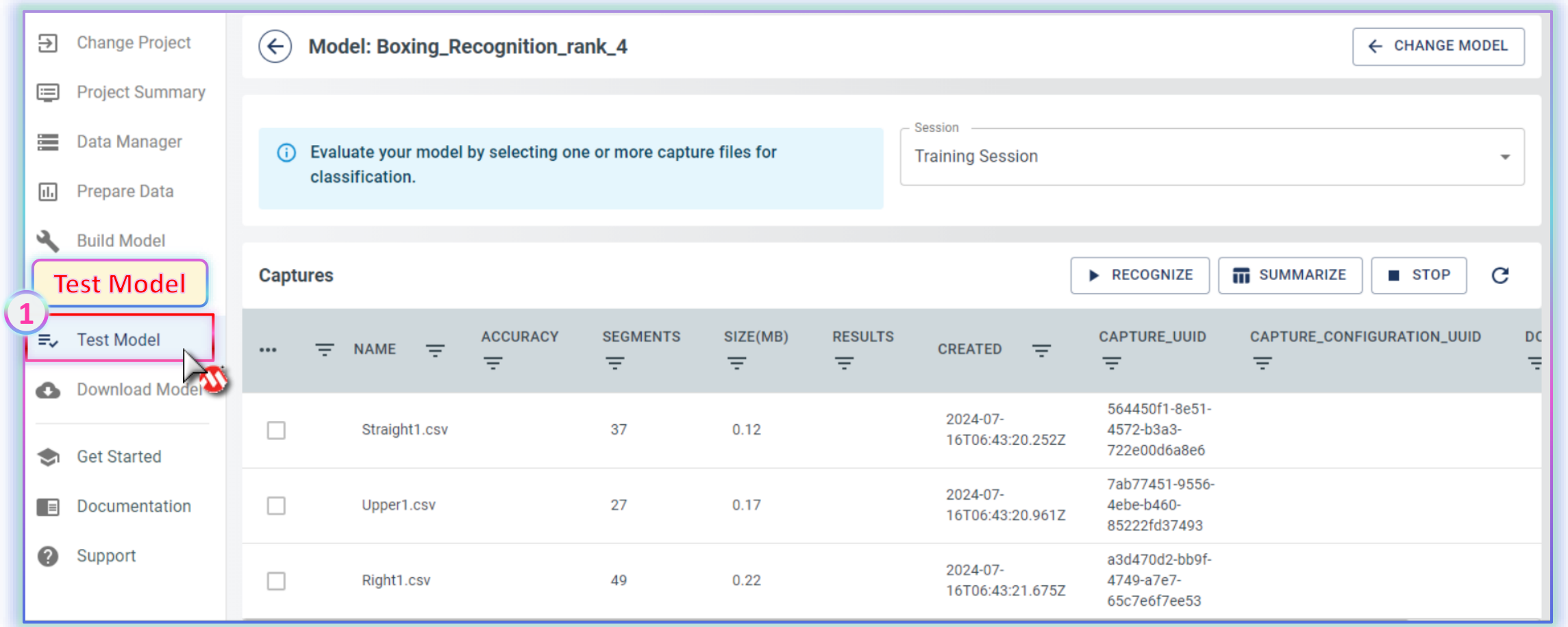
Fold 0 - validation

	Freeze	Right Hook	Straight	Uppercut	UNK	Support	Sensitivity(%)
Freeze	43	0	0	0	0	43	100.00
Right Hook	0	5	0	0	0	5	100.00
Straight	0	0	5	0	0	5	100.00
Uppercut	0	0	0	8	0	8	100.00
Predicted	43	5	5	8	0	61	
Pos_Predic(%)	100.00	100.00	100.00	100.00		Acc(%)	100.00

🛠 Lab4 Model Evaluation and Deploy

Step 4

- Click Test model.

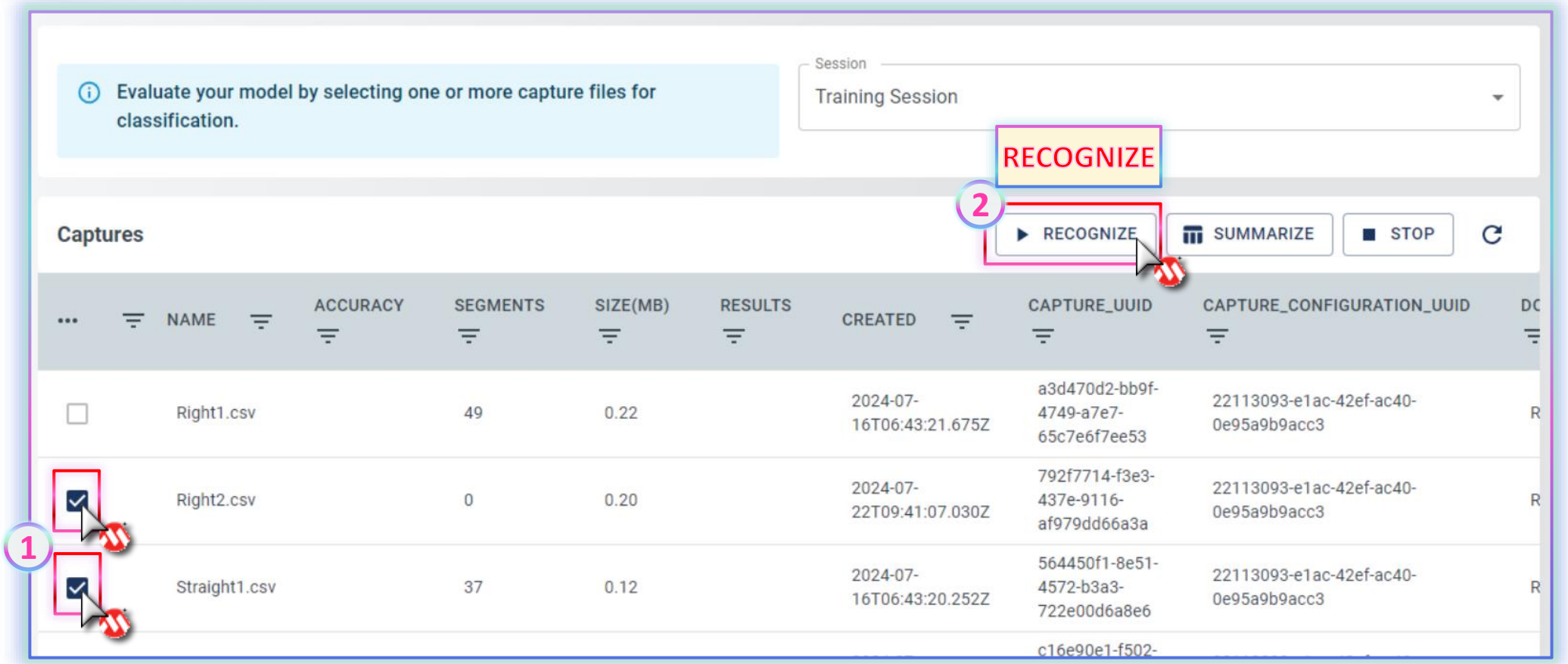


MICROCHIP

🛠 Lab4 Model Evaluation and Deploy

Step 5

- Select ☑ the files which want to test, may be multiple.
- Click RECOGNIZE and wait.

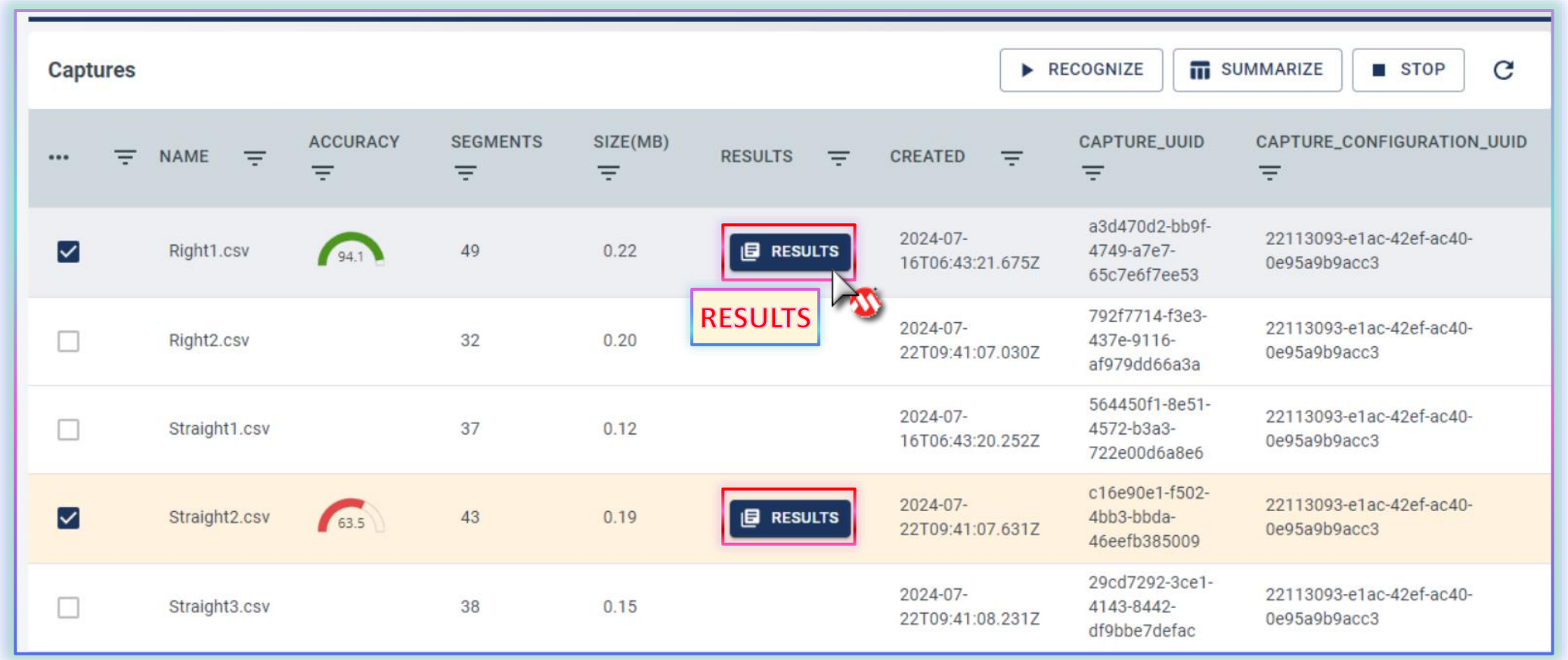


MICROCHIP

🛠 Lab4 Model Evaluation and Deploy

Step 6

- **The result will show in the result field.**
- **Click RESULTS to view details.**



...	NAME	ACCURACY	SEGMENTS	SIZE(MB)	RESULTS	CREATED	CAPTURE_UUID	CAPTURE_CONFIGURATION_UUID
☑	Right1.csv	94.1	49	0.22	RESULTS	2024-07-16T06:43:21.675Z	a3d470d2-bb9f-4749-a7e7-65c7e6f7ee53	22113093-e1ac-42ef-ac40-0e95a9b9acc3
☐	Right2.csv		32	0.20		2024-07-22T09:41:07.030Z	792f7714-f3e3-437e-9116-af979dd66a3a	22113093-e1ac-42ef-ac40-0e95a9b9acc3
☐	Straight1.csv		37	0.12		2024-07-16T06:43:20.252Z	564450f1-8e51-4572-b3a3-722e00d6a8e6	22113093-e1ac-42ef-ac40-0e95a9b9acc3
☑	Straight2.csv	63.5	43	0.19	RESULTS	2024-07-22T09:41:07.631Z	c16e90e1-f502-4bb3-bbda-46eefb385009	22113093-e1ac-42ef-ac40-0e95a9b9acc3
☐	Straight3.csv		38	0.15		2024-07-22T09:41:08.231Z	29cd7292-3ce1-4143-8442-df9bbe7defac	22113093-e1ac-42ef-ac40-0e95a9b9acc3

🛠 Lab4 Model Evaluation and Deploy

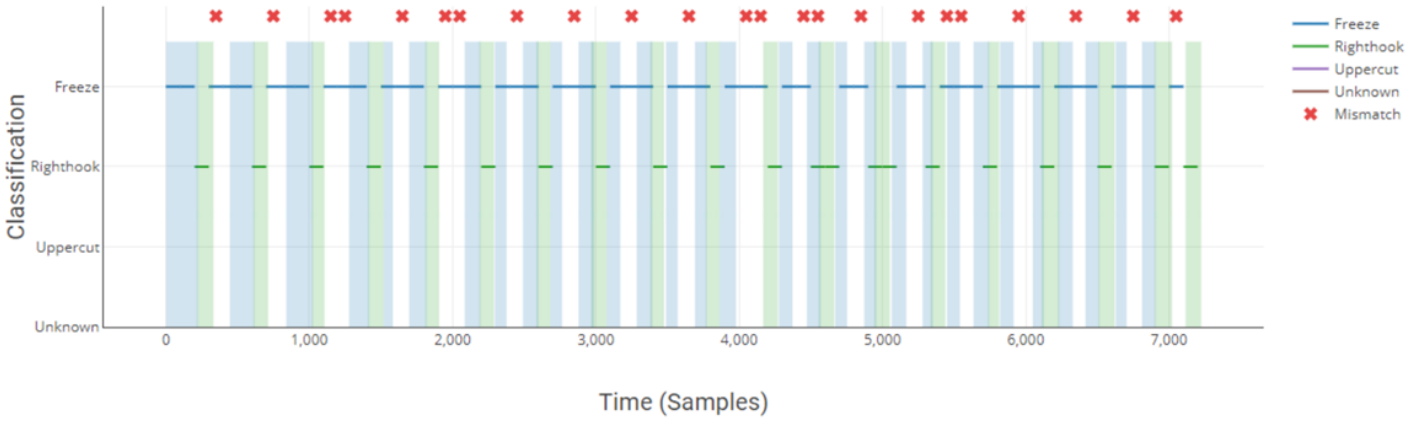
Step 7

- **Slide to the bottom to view detail.**

Boxing_Recognition_rank_4 - Right1.csv

	Freeze	Righthook	Unknown	Uppercut	UNK	Ground Truth	Support	Sensitivity(%)
Freeze	30	3	0	0		30	33	90.91
Righthook	0	18	0	0		19	18	100.00
Unknown	0	0	0	0		0	0	
Uppercut	0	0	0	0		0	0	
Predicted	30	21	0	0		49	51	
Pos_Predic(%)	100.00	85.71					Acc(%)	94.12

Classification Chart - Boxing_Recognition_rank_4 - Right1.csv

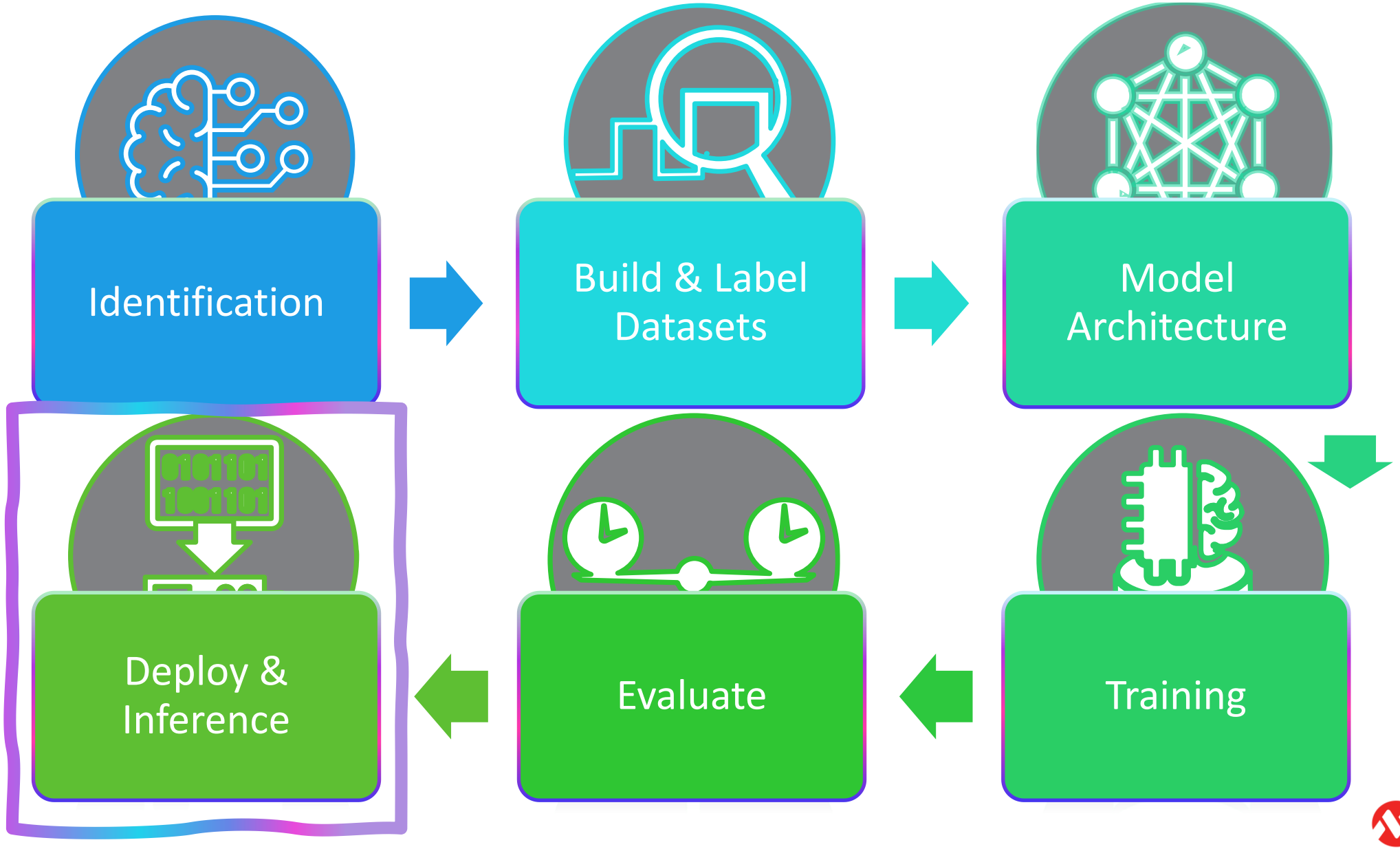


MICROCHIP

Review from Start to End

階段		步驟	拳擊姿態識別
Project Summary		Segment Labels (標籤建立)	決定需要識別的拳擊動作類別以及元數據分類
		Metadata (元數據建立)	決定需要元數據劃分類型 (可選)
Data Manager		Data Labeling (數據標籤標註)	標記數據集中每段數據所對應的拳擊動作
		Metadata Given (元數據賦予)	記錄感測器型號、測量條件、動作執行者資訊等 (可選)
Prepare Data		Create Query (查詢建立)	根據標籤與元數據來準備適當的拳擊數據
Build Model	Preprocessing (數據預處理)	Select Template Model (選擇模型範本)	選擇合適的模型範本 (如 Gesture Recognition)
		Input Query (輸入查詢)	使用 Create Query 產生的數據作為模型輸入數據
		Segmenter (資料分割器)	依據固定時間窗口(如 1 秒)或動作觸發事件切割數據片段
		Sensor Transform (感測器轉換)	進行感測數據預處理，如座標旋轉、標準化或濾波
	Feature Extraction (特徵提取)	Feature Generator (特徵生成器)	計算每個片段的統計特徵 (如平均加速度, 最大角速度, 頻率域特徵等)
		Feature Selector (特徵選擇器)	選擇對於區分不同拳擊動作最有效的特徵
		Outlier Filter (異常值過濾器)	去除明顯異常的動作，如誤觸感測器導致的錯誤數據
		Feature Quantization (特徵量化)	透過數值縮放與離散化，使特徵符合模型輸入需求
	Model Training (模型訓練)	Classifier (分類器)	設定模型分類類型，如決策樹、SVM、神經網絡等
		Training Algorithm (訓練演算法)	選擇並執行合適的訓練算法，如隨機森林、KNN、深度學習等
		Validation (驗證)	使用交叉驗證或留存數據集驗證模型的準確性
Explorer Model		Select Model (選擇模型)	選擇適合的 AI 模型來進行識別
		Model Explorer (模型探索)	查看模型的分類效果 (如 Confusion Matrix, feature visualization/embedding)
Test Model		Test Model (測試模型)	使用測試數據評估模型準確度
Download Model		Model Deploy (模型部署)	下載並部署模型到目標設備，如微控制器 (MCU) 或邊緣設備

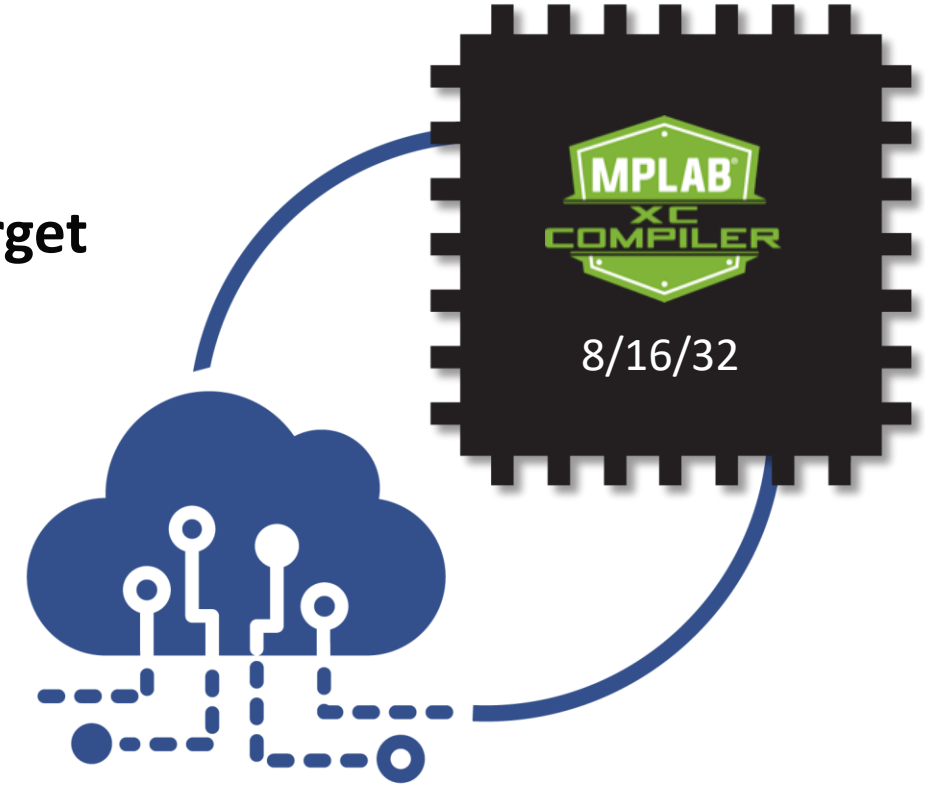
Machine Learning Workflow



MICROCHIP

Deploy the model

- **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



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: Up to 4 interfaces
MIPI, parallel, HDMI
Mic: Multiple audio streams
Additional sensors

PolarFire / PF SoC FPGA

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

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

SAMA7 MPU

SAMD21 MCU

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

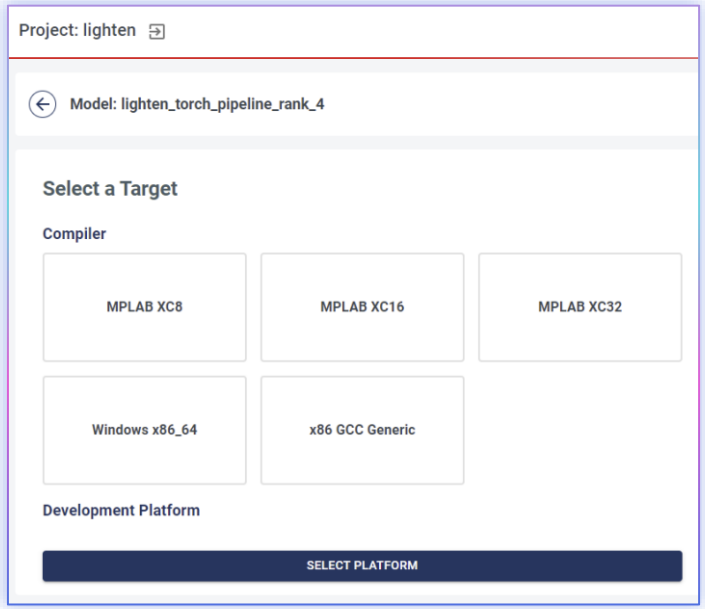
Input sensors / data
IMU (Inertial Measurement Unit)
Temp, Current, Pressure
Mic: Audio Stream

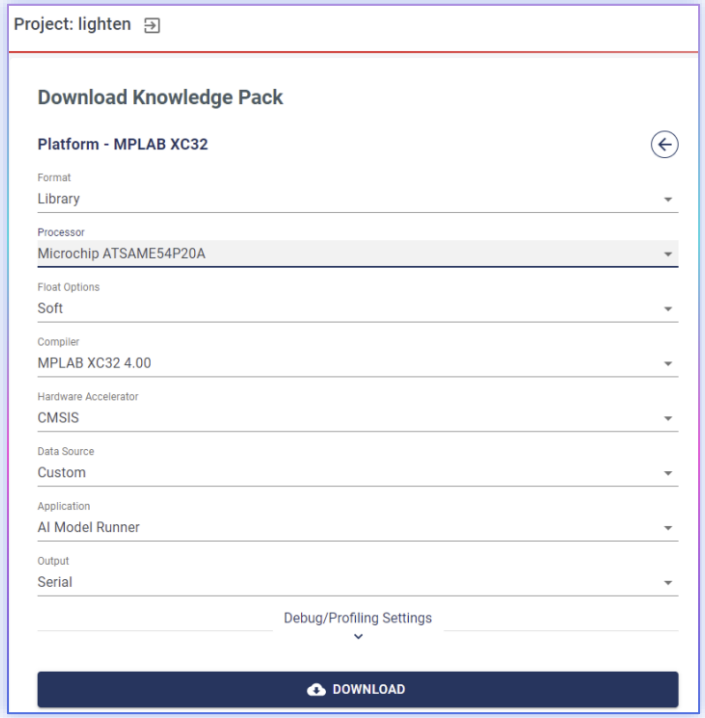
AVR MCU

MICROCHIP

Deploy the model

- **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





Deploy the model

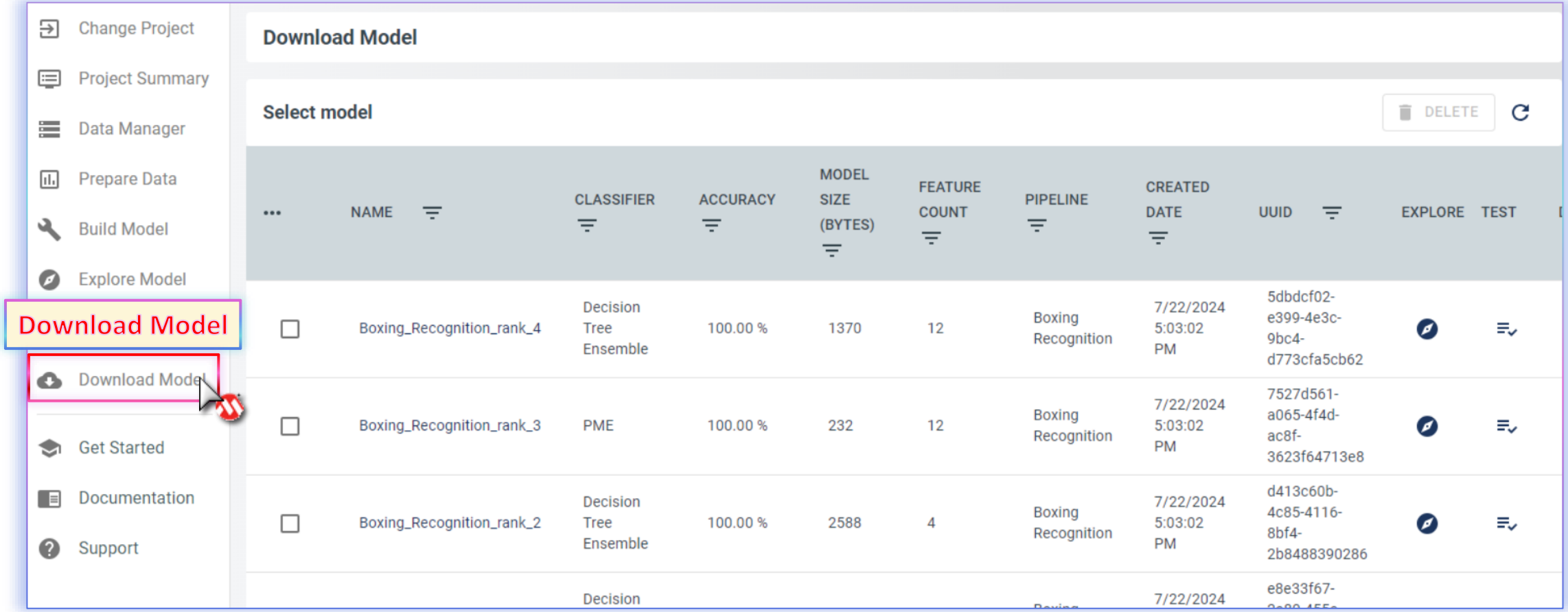
- **To interface with a Knowledge Pack, use the files that get downloaded with your Knowledge Pack.**
  - Kb.h
  - sml_recognition_run.c

- **For this demo only 3 function calls needed**
  - kb_model_init() : Before any other functions are called, must initialize the Knowledge Pack.
  - kb_reset_model() : Called after every run of the model
  - kb_run_model() : Add new data to the model and classify it

🛠 Lab4 Model Evaluation and Deploy

Step 8

- **Select Download Model**



🛠 Lab4 Model Evaluation and Deploy

Step 9

- **Choose the model rank 4 and click to download library.**

May Skip this step.
It will choose the model you explored in previous step automatically.

Select model

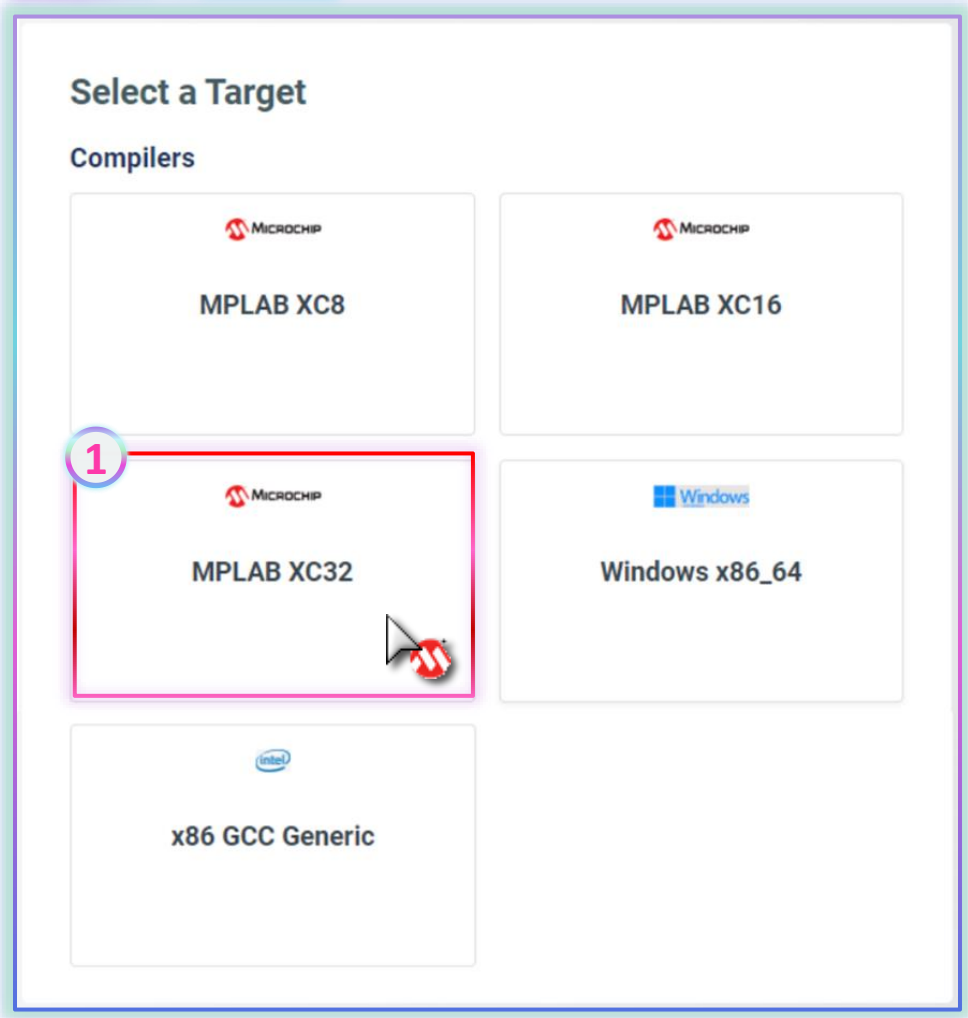
...	NAME	CLASSIFIER	ACCURACY	MODEL SIZE (BYTES)	FEATURE COUNT	PIPELINE	CREATED DATE	UUID	EXPLORE	TEST	DOWNLOAD	RENAME	DELETE
☐	Boxing_Recognition_rank_4	Decision Tree Ensemble	100.00 %	1370	12	Boxing Recognition	7/22/2024 5:03:02 PM	5dbdcf02-e399-4e3c-9bc4-d773cfa5cb62					
☐	Boxing_Recognition_rank_3	PME	100.00 %	232	12	Boxing Recognition	7/22/2024 5:03:02 PM	7527d561-a065-4f4d-ac8f-3623f64713e8					
☐	Boxing_Recognition_rank_2	Decision Tree Ensemble	100.00 %	2588	4	Boxing Recognition	7/22/2024 5:03:02 PM	d413c60b-4c85-4116-8bf4-2b8488390286					

MICROCHIP

🛠 Lab4 Model Evaluation and Deploy

Step 10

- **Select MPLAB XC32.**



🛠 Lab4 Model Evaluation and Deploy

Step 11

- **Configure the knowledge pack -> DOWNLOAD**

Library

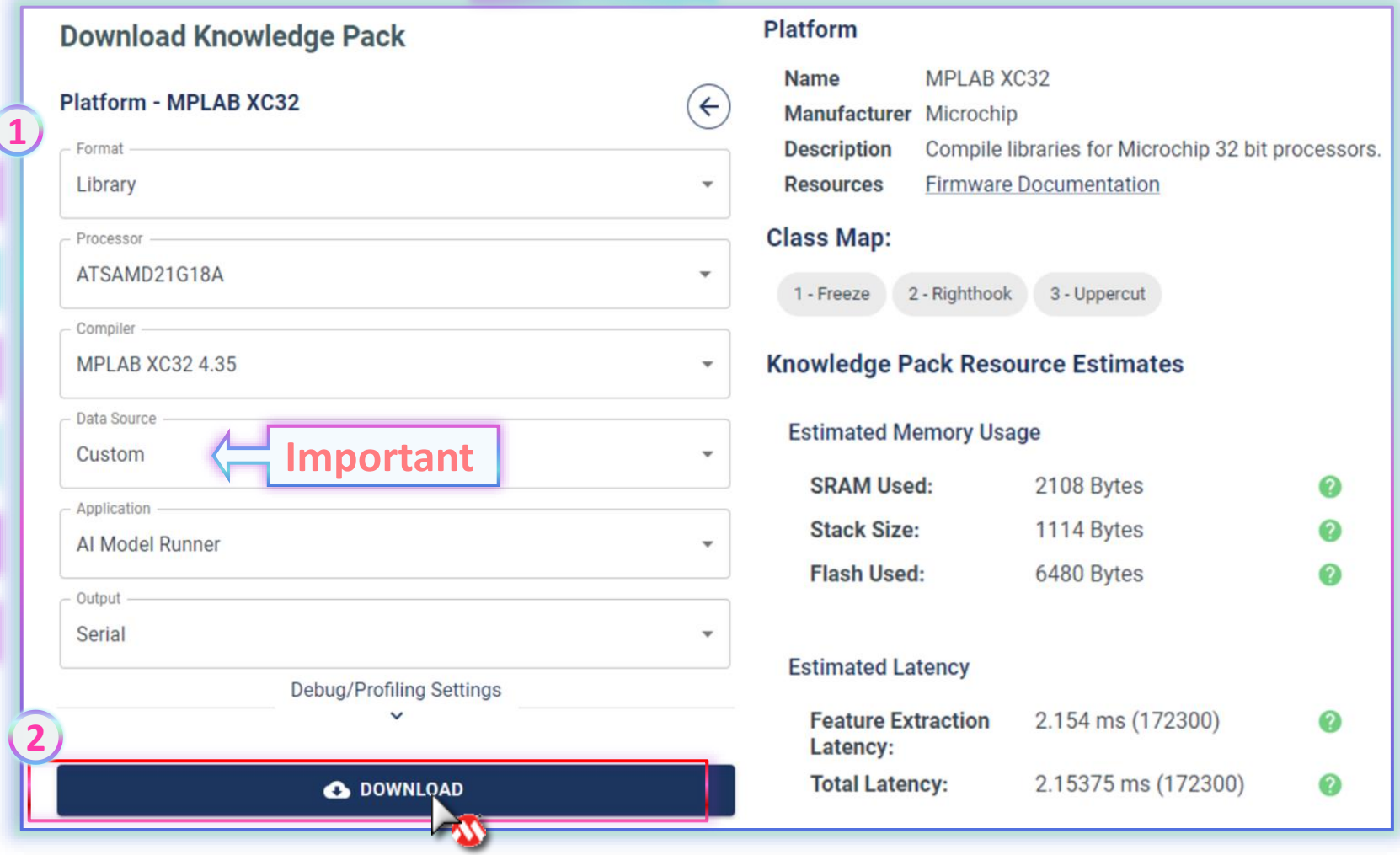
ATSAMD21G18A

Library

Custom

AI Model Runner

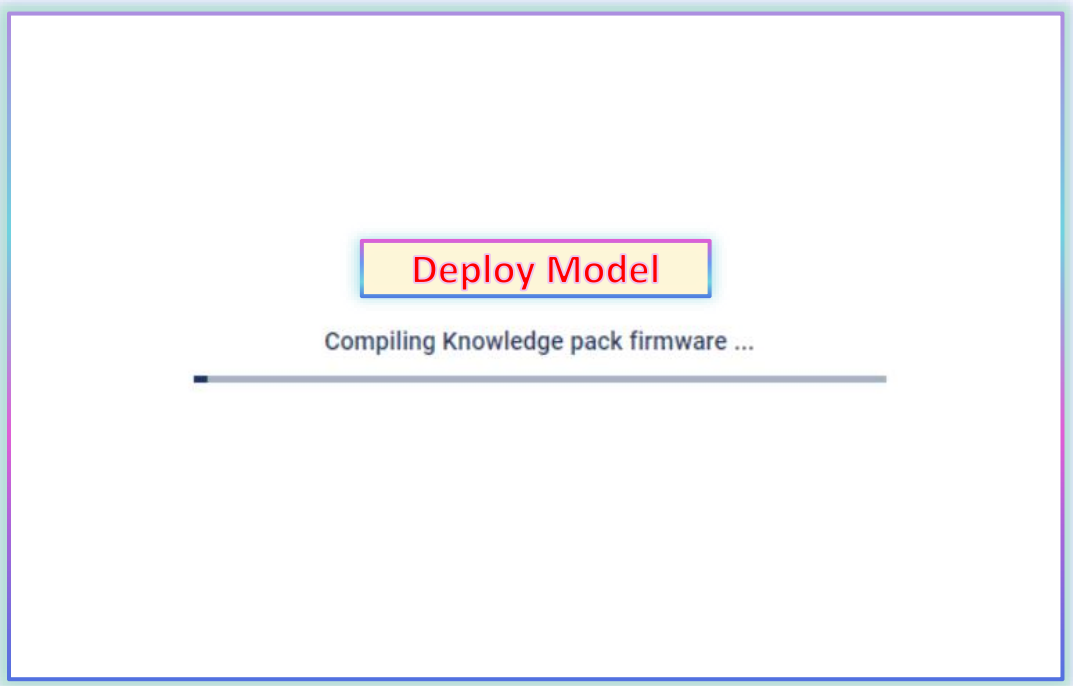
Serial

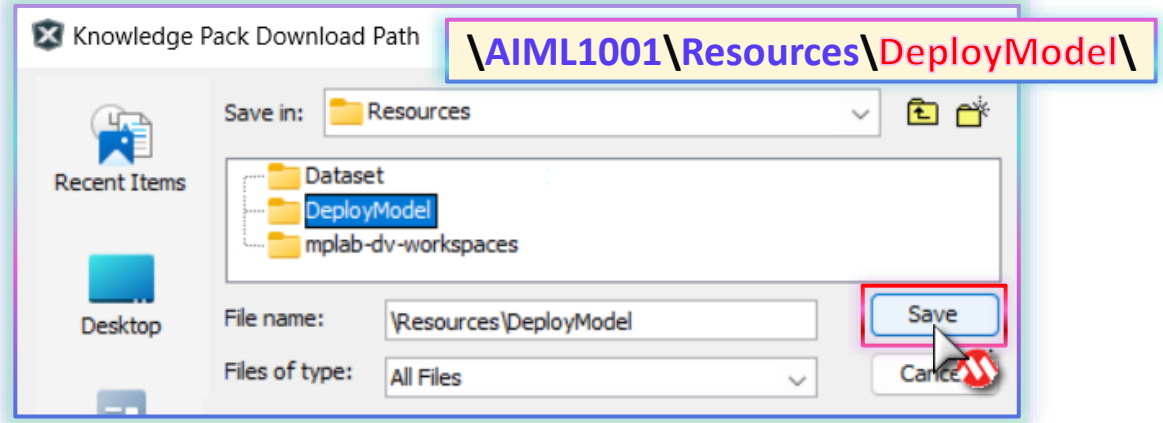


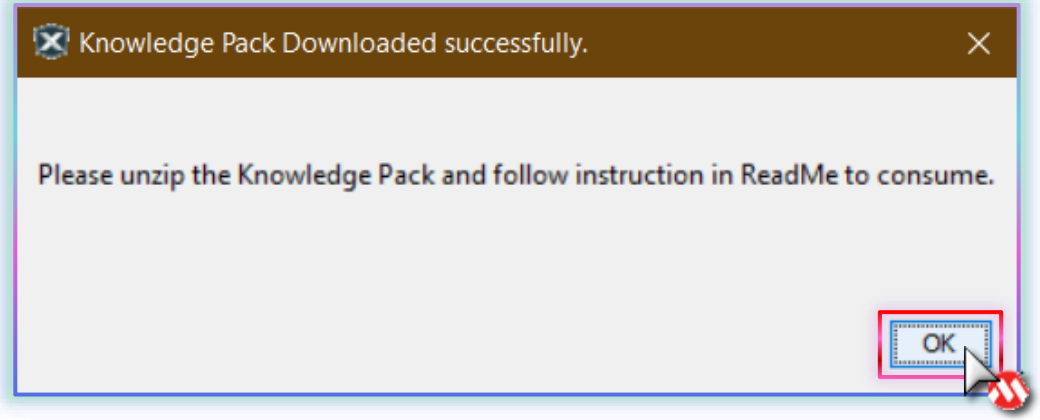
🛠 Lab4 Model Evaluation and Deploy

Step 12

- **Save the zip file under "\AIML1001\Resources\DeployModel\".**





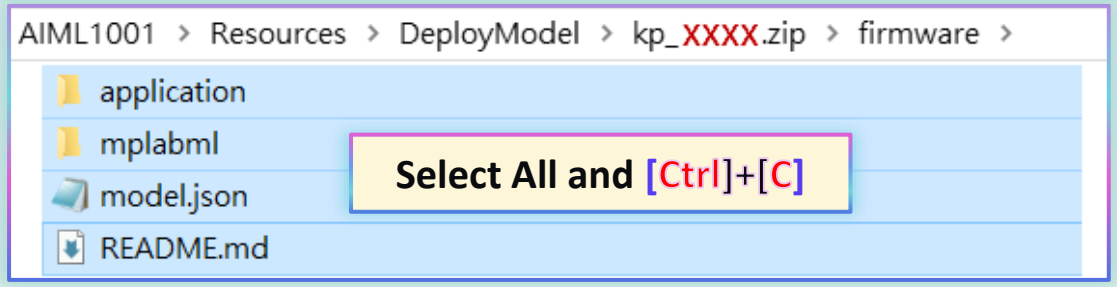


🛠 Lab4 Model Evaluation and Deploy

Step 13

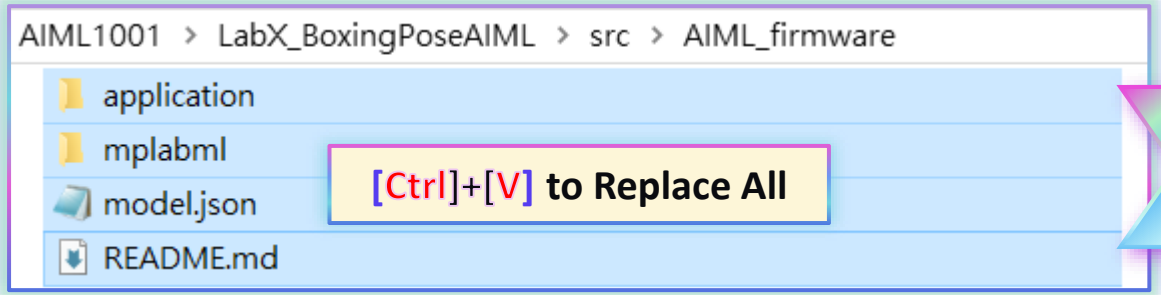
- **Open downloaded Deploy Model [kp_XXXX].zip file in "\DeployModel", Enter its folder "\firmware" and Select all files, press [Ctrl]+[C] to copy all files in it.**

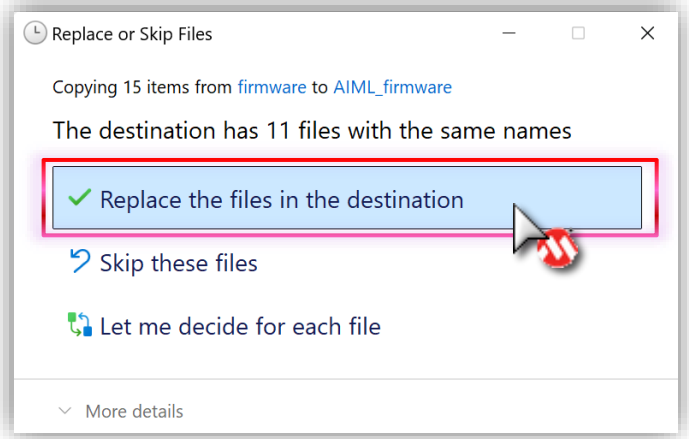
\AIML1001\Resources\DeployModel\[kp_XXXX].zip\firmware*.*



- **Go to "\AIML1001\LabX_BoxingPoseAIML\src\AIML_firmware", Paste and overwrite all files by [Ctrl]+[V]**

\ AIML1001\LabX_BoxingPoseAIML\src\AIML_firmware\





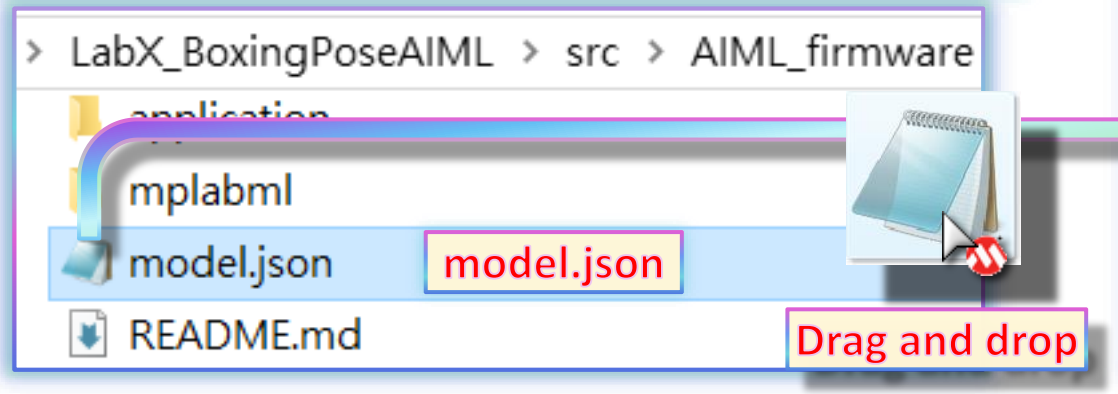
MICROCHIP

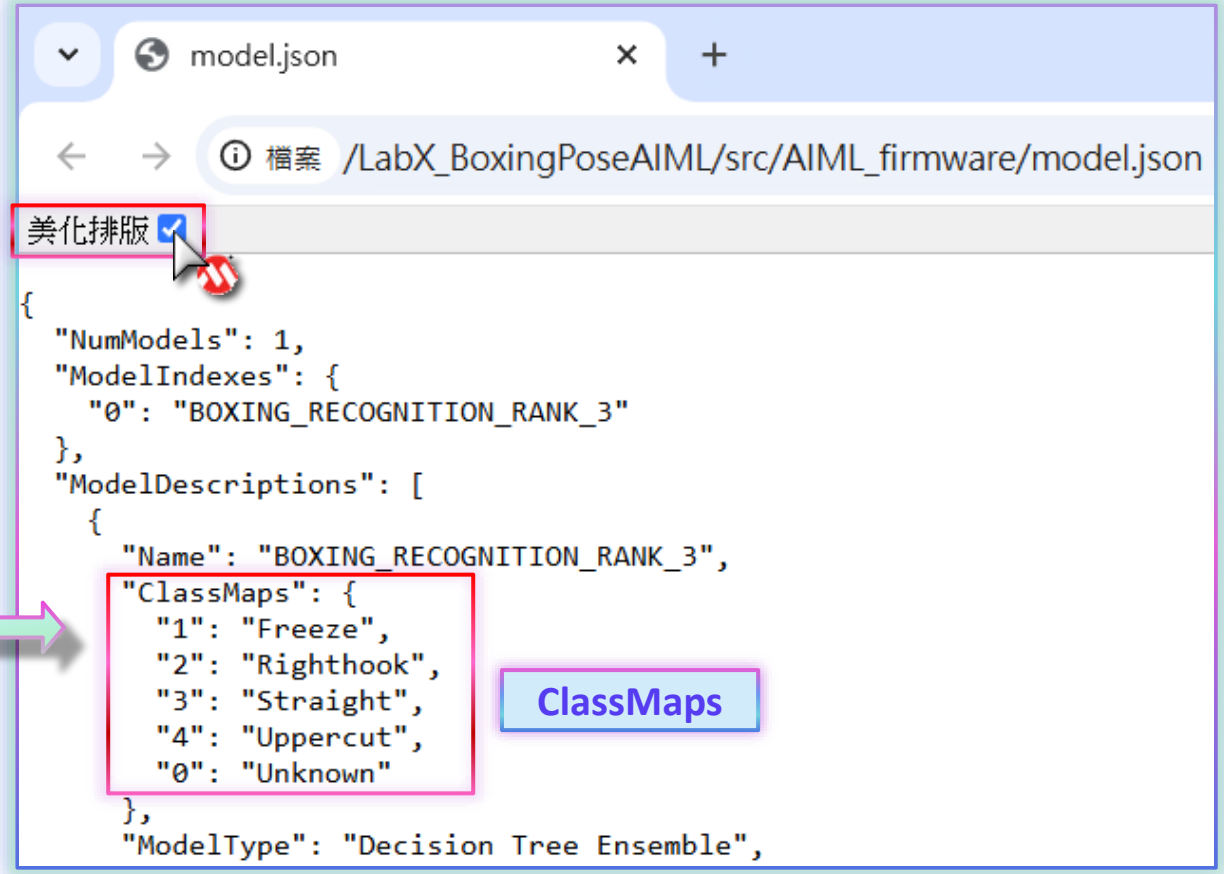
🛠 Lab4 Model Evaluation and Deploy

Step 14

- Open the Chrome web browser
- Find a JSON file “model.json” in “\LabX_BoxingPoseAIML\src\AIML_firmware”.
- Drag and Drop it to Chrome.
- Check the “Pretty-print” option.
- Look at the “ClassMaps” section in the JSON file.

\ AIML1001\LabX_BoxingPoseAIML\src\AIML_firmware\

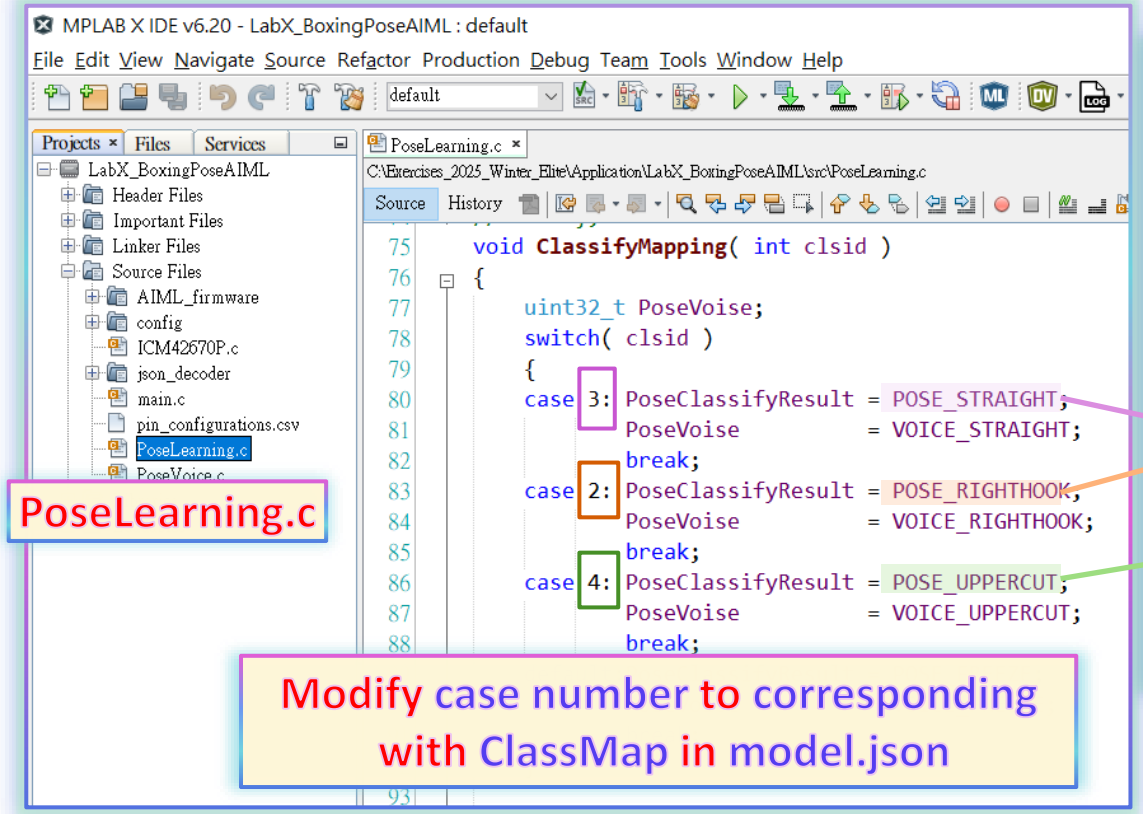


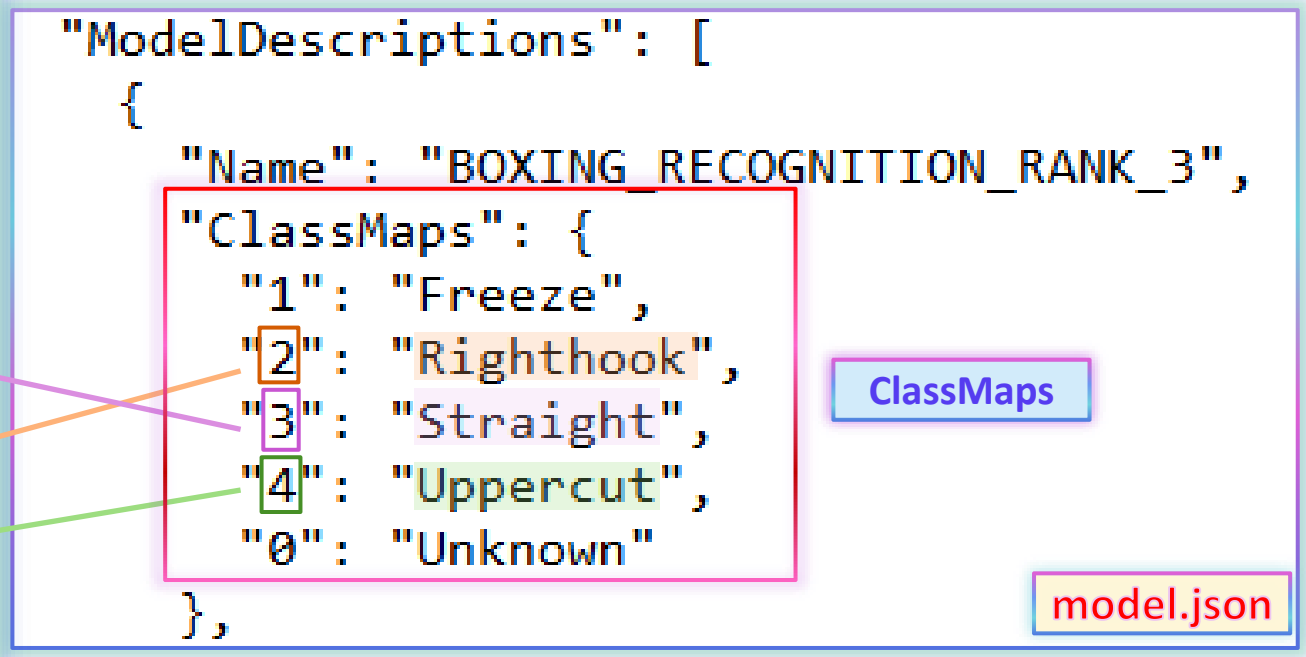


🛠 Lab4 Model Evaluation and Deploy

Step 15

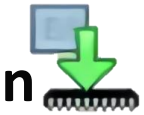
- Open “PoseLearning.c” of current project LabX_BoxingPoseAIML in MPLAB X IDE.
- Look at Line 80, 83, 86 and make sure the case number of pose is correct mapping to ClassMaps in deploy Mode JSON file. If not, replace with the corresponding number.

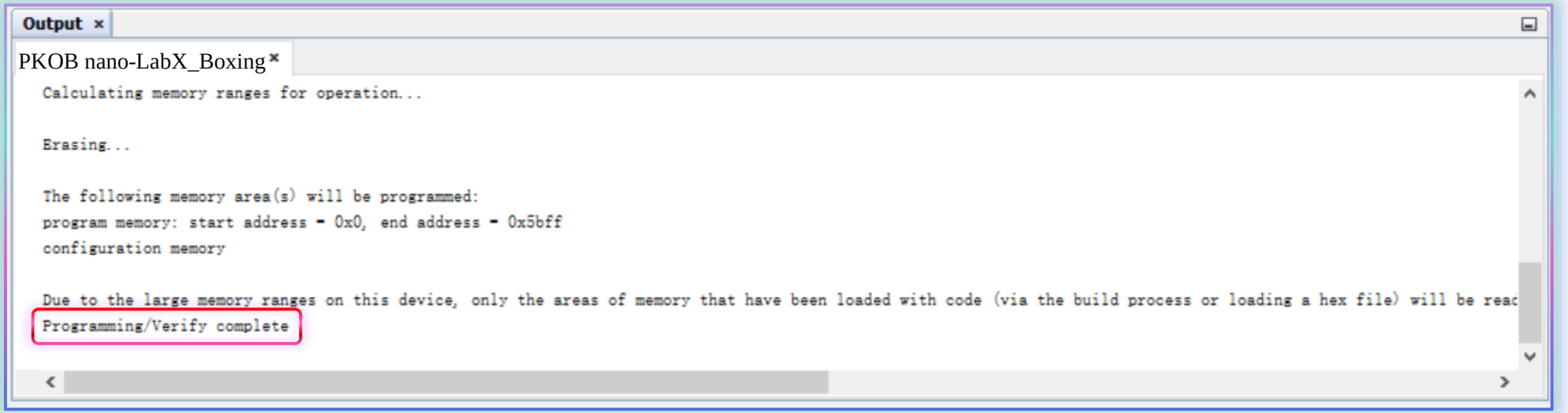




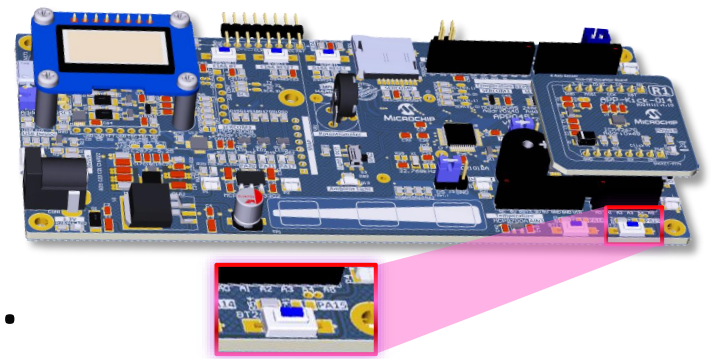
🛠 Lab4 Model Evaluation and Deploy

Step 16

- Click on icon and select **Clean and Build Project** to compiler your project.
- Click on icon  **to Mark and Program** to EVB and check if any fault while Programming.
- Output Window will show ***Programming/Verify Complete***.

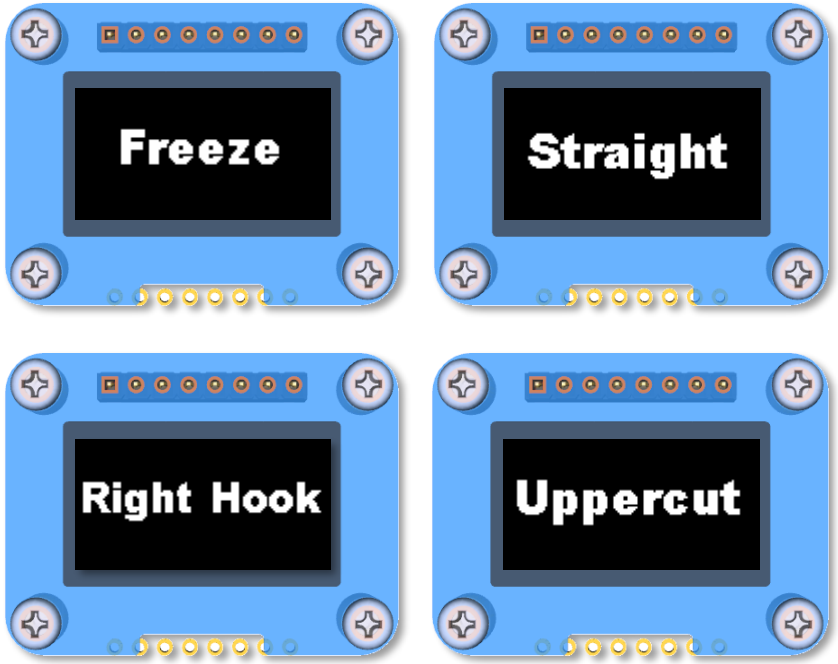


🛠 Lab4 Model Evaluation and Deploy



Result

- **Switch the operating mode to Mode 2 by press one time of BT2.**
  - Mode 1: Display 6DOF Sensor Data in DV Terminal and OLED.
  - Mode 2: Display **Boxing Stance classification results** of preset ML model in DV Terminal and OLED.
  - Mode 3: Display 6DOF Sensor Data waveform in Time Plot of Data Visualizer (For Data Collection).
- **Start doing some boxing!!!**



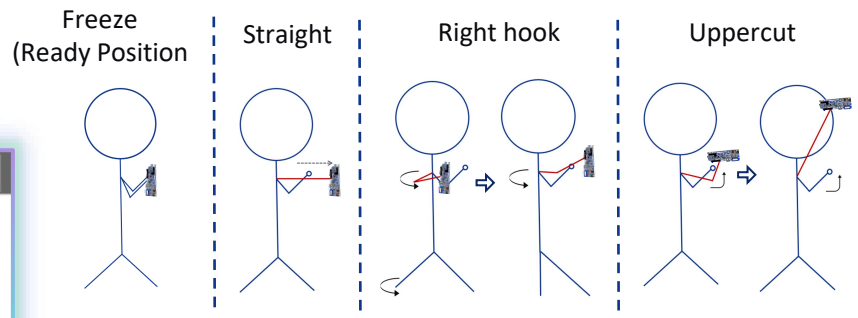
Mode 2

Terminal

```
ML Data Collector ✕   Touch ✕   Terminal ✕   XY Plot ✕
TDK ICM42670 Initialize
 - Software Reset Completed
 - WHO AM I : 0x67
 - Gyro Initial Completed
 - Accel Initial Completed
 - Enable Completed
 - Hardware INT Enabled

TDK ICM42670 Output
 - Temperature : 25.0'C
 - Accel (  -0.2,   +0.2,   +1.0)
 - Gryo  ( +29.5,   +2.4,  -12.6)

Auto ML Model Name : BOXING_RECOGNITION_RANK_3
Auto ML Classify Maps :
 - Id 0 : Unknown
 - Id 1 : Freeze
 - Id 2 : Righthook
 - Id 3 : Straight
 - Id 4 : Uppercut
Auto ML Inference Result : Boxing Freeze
```



Terminal

```
Auto ML Inference Result : Boxing Freeze

Auto ML Inference Result : Boxing Straight

Auto ML Inference Result : Boxing Right hook

Auto ML Inference Result : Boxing Uppercut
```

MICROCHIP

Knowledge Pack,
Main Flow, and State Machines

MICROCHIP

Composition of ML Deploy Model Knowledge Pack

Folders and Files

- AIML_firmware
  - model.json
  - README.md
  - application
    - sml_recognition_run.c
    - sml_recognition_run.h
  - mplabml
    - inc
    - lib
      - libmplabml.a

model.json: Contains the structure and parameters of the machine learning model.

README.md: Description file, including the integration of knowledge pack.

application: Contains the main code for running machine learning models. Responsible for loading models, processing input data, performing inference.

mlpabml: The inc folder contains header files (.h), which define various functions and structures used in the project. libmplabml.a is the library of the related to ML.

Composition of ML Deploy Model Knowledge Pack

model.json

- **Contains the structure and parameters of the machine learning model. If you want to see the graphical interface, you can view it in the ML Model Builder of Explore model.**


```
{
  "NumModels": 1,
  "ModelIndexes": {
    "0": "BOXING_RECOGNITION_RANK_3"
  },
  "ModelDescriptions": [
    {
      "Name": "BOXING_RECOGNITION_RANK_3",
      "ClassMaps": {
        "1": "Freeze",
        "2": "Righthook",
        "3": "Straight",
        "4": "Uppercut",
        "0": "Unknown"
      },
      "ModelType": "Decision Tree Ensemble",
      "FeatureNames": [
        "gX25Percentile",
        "aXAbsAreaDc",
        "aYAbsAreaDc",
        "aXP2P",
        "gZMaxP2PGlobalDC",
        "gXgZ_cross_mean_diff",
        "gYaX_cross_mean_diff",
        "aYaZ_cross_p2p_diff"
      ],
```


Model name.

ClassMaps: {“1”: “Freeze”}

“1’ stand for the output

“Freeze” stand for the meaning of output

Feature Summary: what features are actually used to classify the results. All the parameter of the feature is also included.

MICROCHIP

Composition of ML Deploy Model Knowledge Pack

sml_recognition_run.c

- **Includes functions for:**
  - **Running inference**: Processing incoming sensor data and passing it through the trained model.
  - **Handling model output**: Interpreting classification or anomaly detection results.
  - **Integrating with firmware**: Ensuring real-time execution and efficient resource use on microcontrollers.

```
void sml_output_results(uint16_t model, uint16_t classification)
{
   memset(serial_out_buf, 0, SERIAL_OUT_CHARS_MAX);
   kb_sprint_model_result(model, serial_out_buf, false, false, true);
   printf("%s\n", serial_out_buf);
}

int32_t sml_recognition_run(int16_t *data, int32_t num_sensors)
{
   int32_t ret;
                        ret = kb_run_model((int16_t *)data, num_sensors, KB_MODEL_BOXING_RECOGNITION_RANK_3_INDEX);
                        if (ret >= 0){
                                    sml_output_results(KB_MODEL_BOXING_RECOGNITION_RANK_3_INDEX, ret);
                                    kb_reset_model(0);
                        };
   return ret;
}
```

MICROCHIP

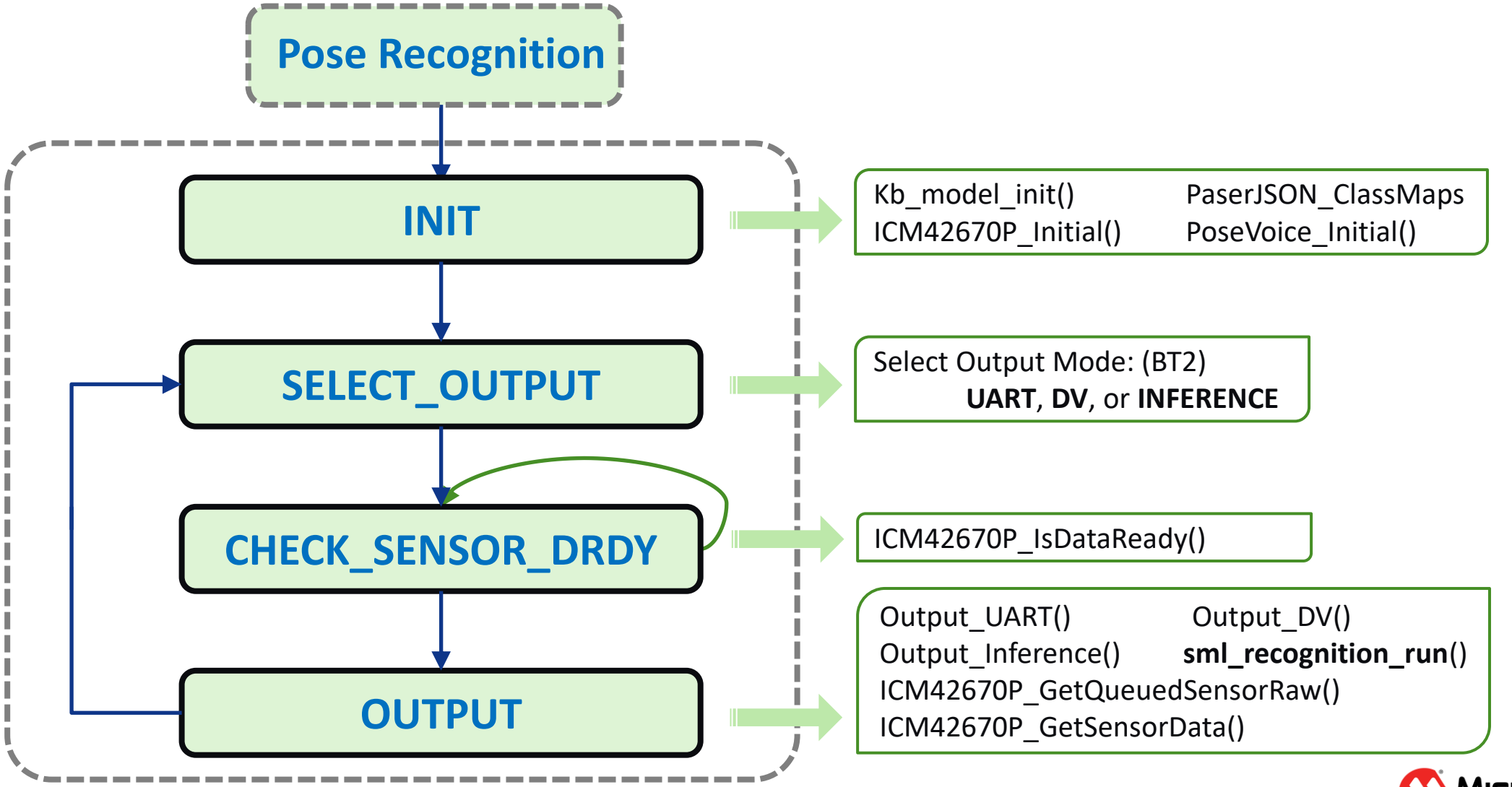
Composition of ML Deploy Model Knowledge Pack

libmplabml.a

- **A static library file to provides precompiled machine learning functions optimized for embedded systems for microcontrollers.**
- **Header Files for Interface Functions :**
  - **kb.h**
    - **The main header file that includes function prototypes and references to other knowledge base (KB) files.**
    - **Provides an interface to interact with the ML model and run inferences.**
  - **kb_define.h**
    - **Contains macro definitions and constants used across the KB system.**
    - **Defines buffer sizes, thresholds, and model-specific parameters.**
  - **kb_output.h**
    - **Manages the output format of the machine learning inference.**
    - **Defines structures or functions to handle classification results, anomaly detection, etc.**
  - **kb_typedef.h**
    - **Defines custom data types (typedefs, structs, and enums) used in the KB system.**
    - **Ensures consistency across different hardware and software implementations.**
  - **model_json.h**
    - **Contains the ML model in a serialized JSON format (converted into C header form).**
    - **Stores model architecture, weights, and metadata needed for inference.**
  - **testdata.h**
    - **Likely includes predefined test data for validating the model during development.**
    - **Used for debugging and verifying inference correctness without live sensor input.**

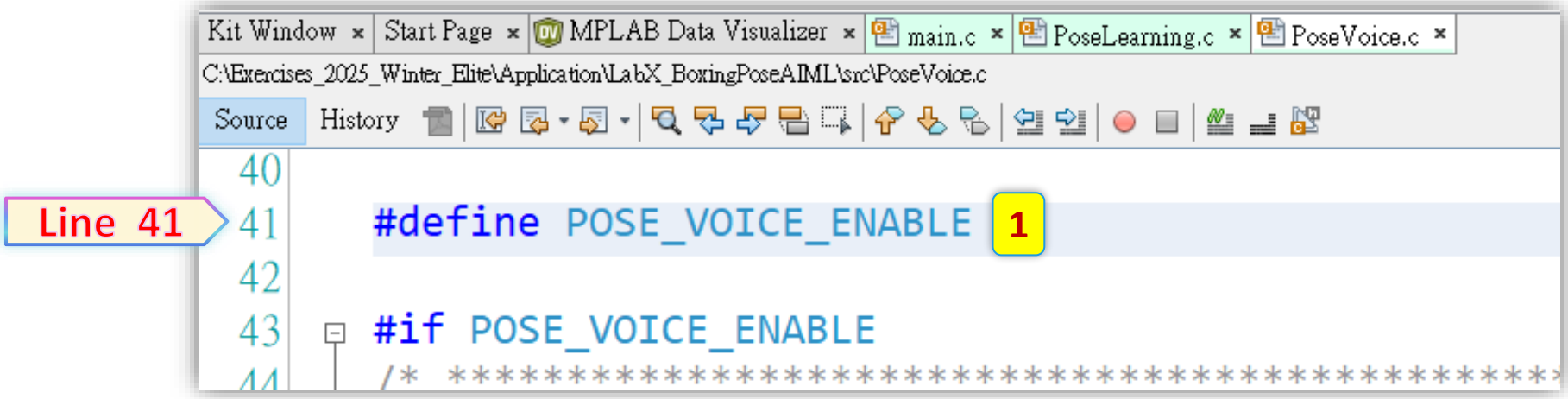
Main Flow and State Machines

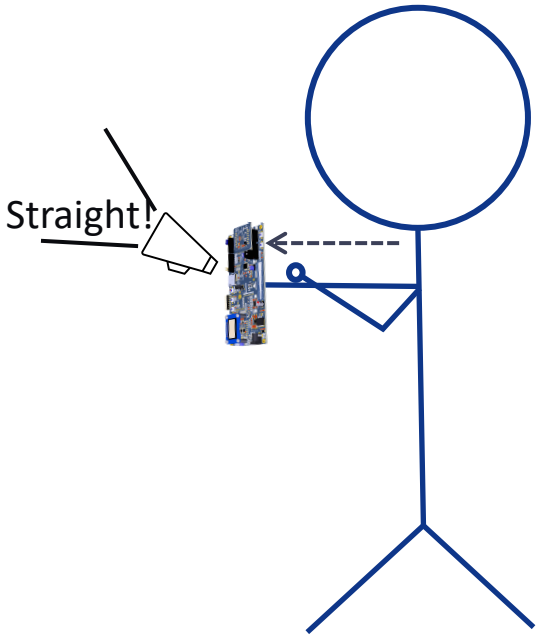
- **The State Machine implemented in "PoseLearning.c" as below.**



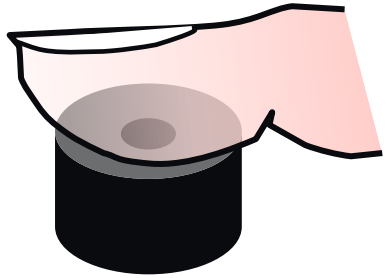
PCM Voice for Boxing Pose

- We have implemented a PCM voice as a hidden bonus in the current application.
- Open “PoseVoice.c“ file.
- Modify the #define POSE_VOICE_ENABLE to 1 in Line 41.
- Program again and enjoy it !





- Thumb on the Buzzer will make the PCM Voice clearer and louder ! (Or use a tap)



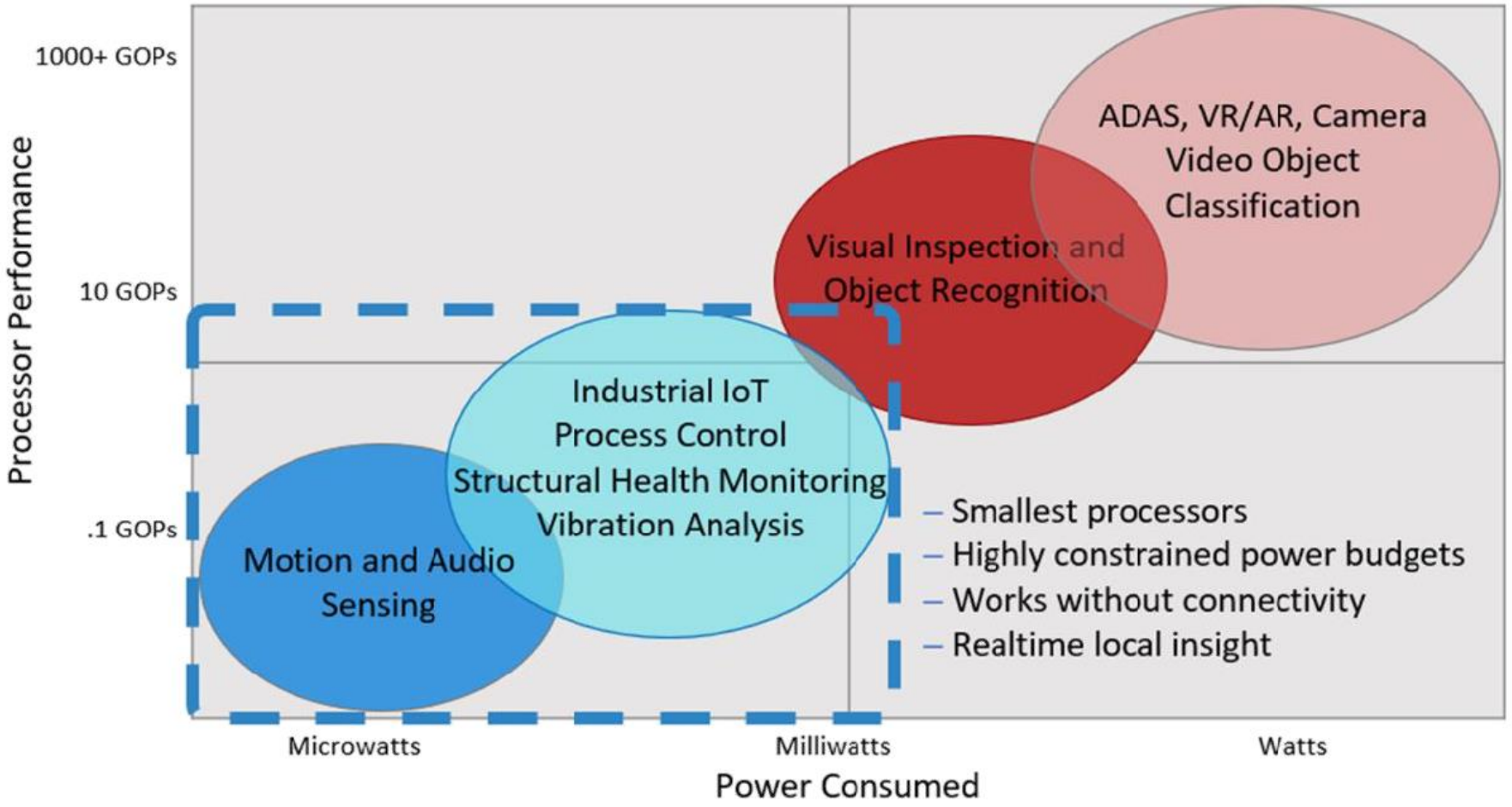
Summary

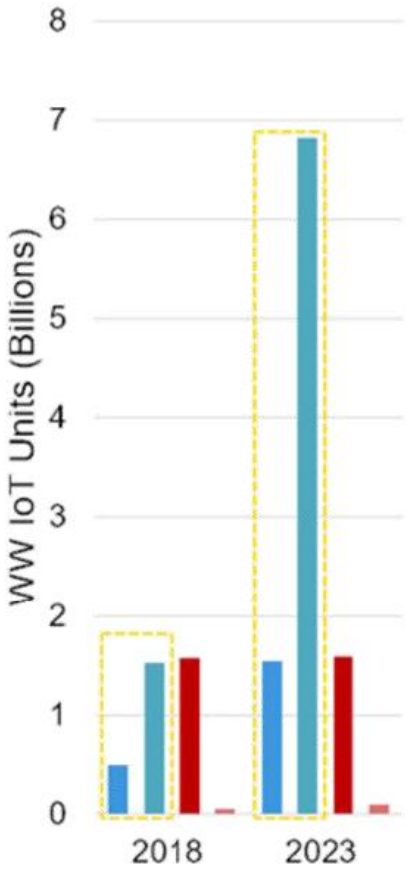
MPLAB® ML Suite

- **The ML Suite Plugin in MPLAB X is a plugin**
- **Behind this is a rich API based on SensiML**
  - Easily accessed from Python
  - Customize functions
  - Feature extraction
- **Can tuned by Jupyter Notebooks**
  - Web-based live notebooks
  - Code
  - Notes
  - Visualization

Related document

MPLAB® ML Suite Addresses Billions of Time-Series IoT Endpoints





Source: IHS 2017

MICROCHIP

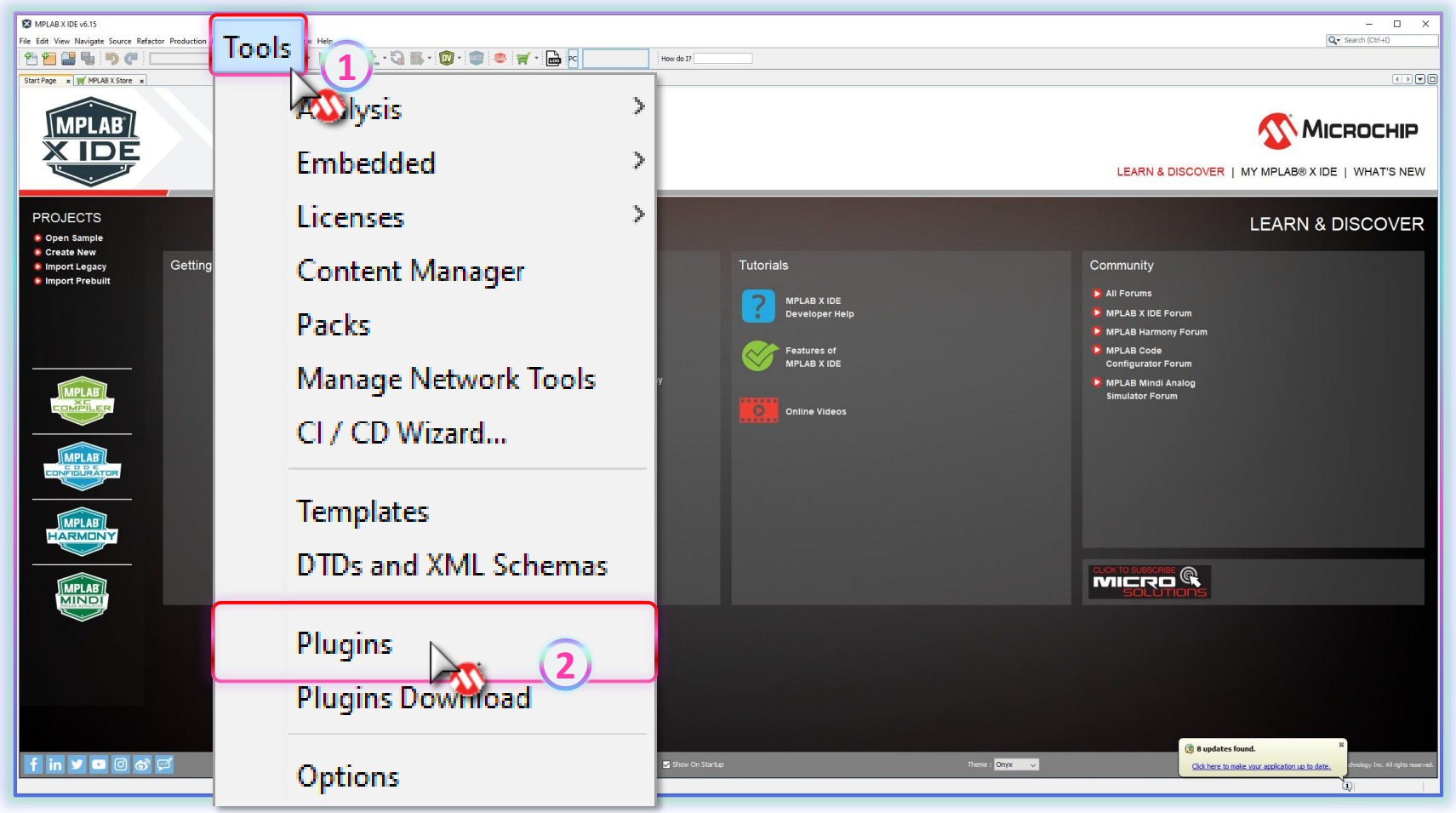
Appendix

Install the ML Data Collector & ML Model Builder

Install the ML Data Collector & ML Model Builder

Step 1

- **Open Plugins installer**

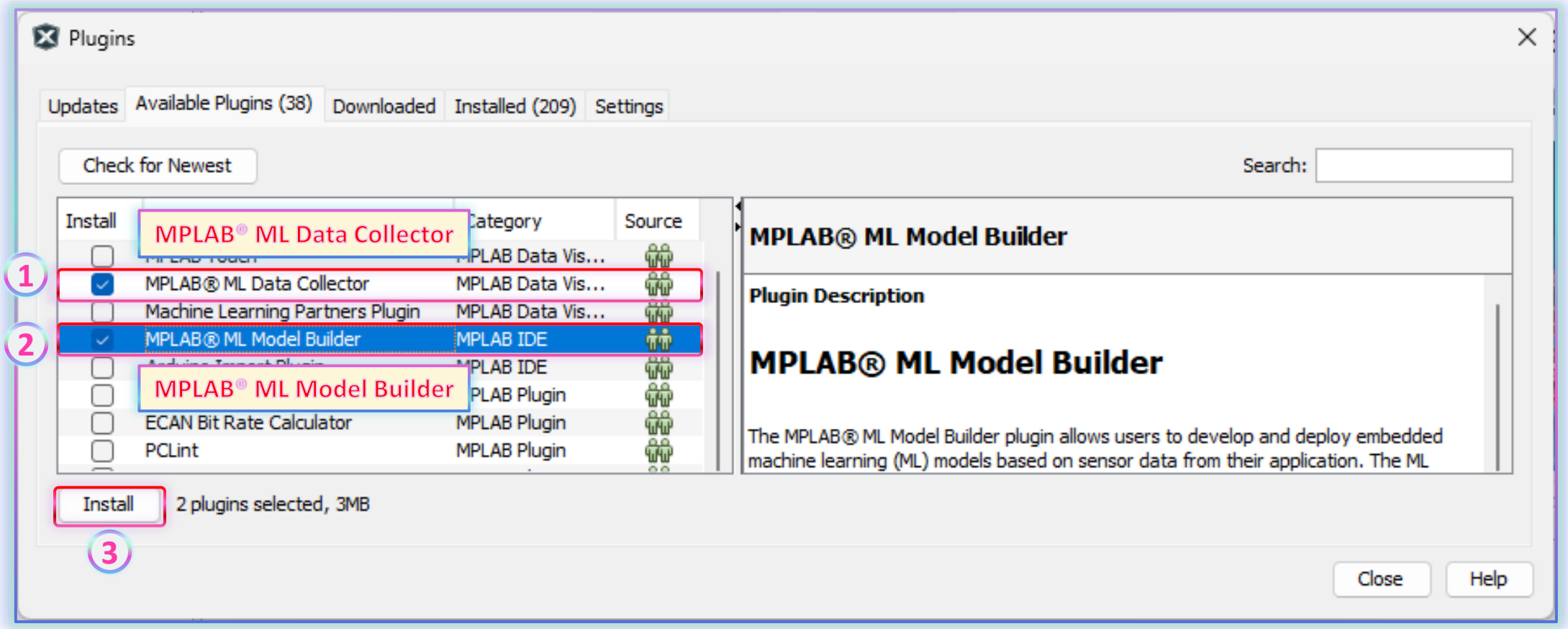


MICROCHIP

Install the ML Data Collector & ML Model Builder

Step 2

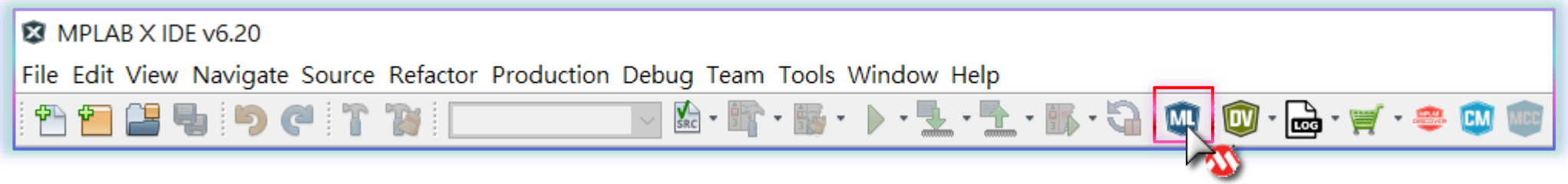
- **Install the "MPLAB ML Dara Collector" and "MPLAB ML Model Builder" Plugins.**



Install the ML Data Collector & ML Model Builder

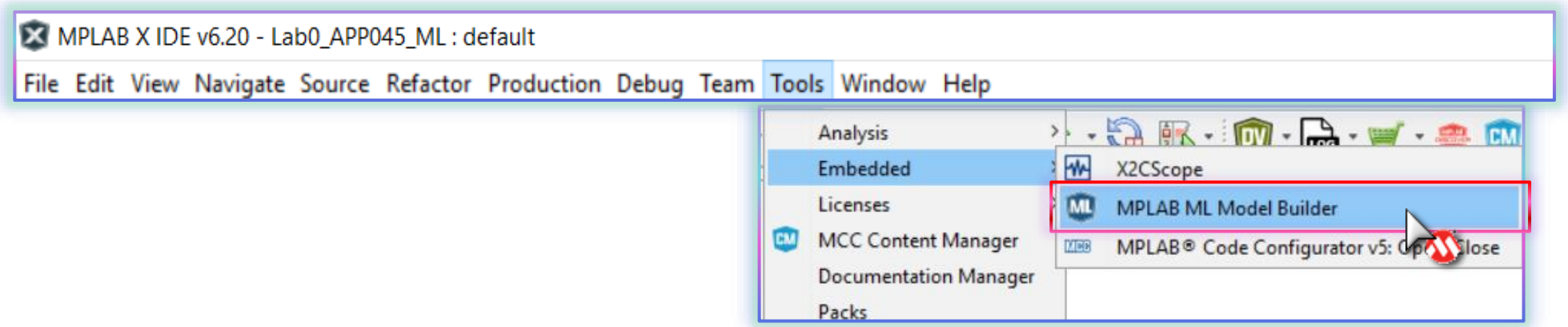
Step 3

- **After install completed, please check your MPLAB X IDE to find the ML Model builder.**
- **Click ML icon**



OR

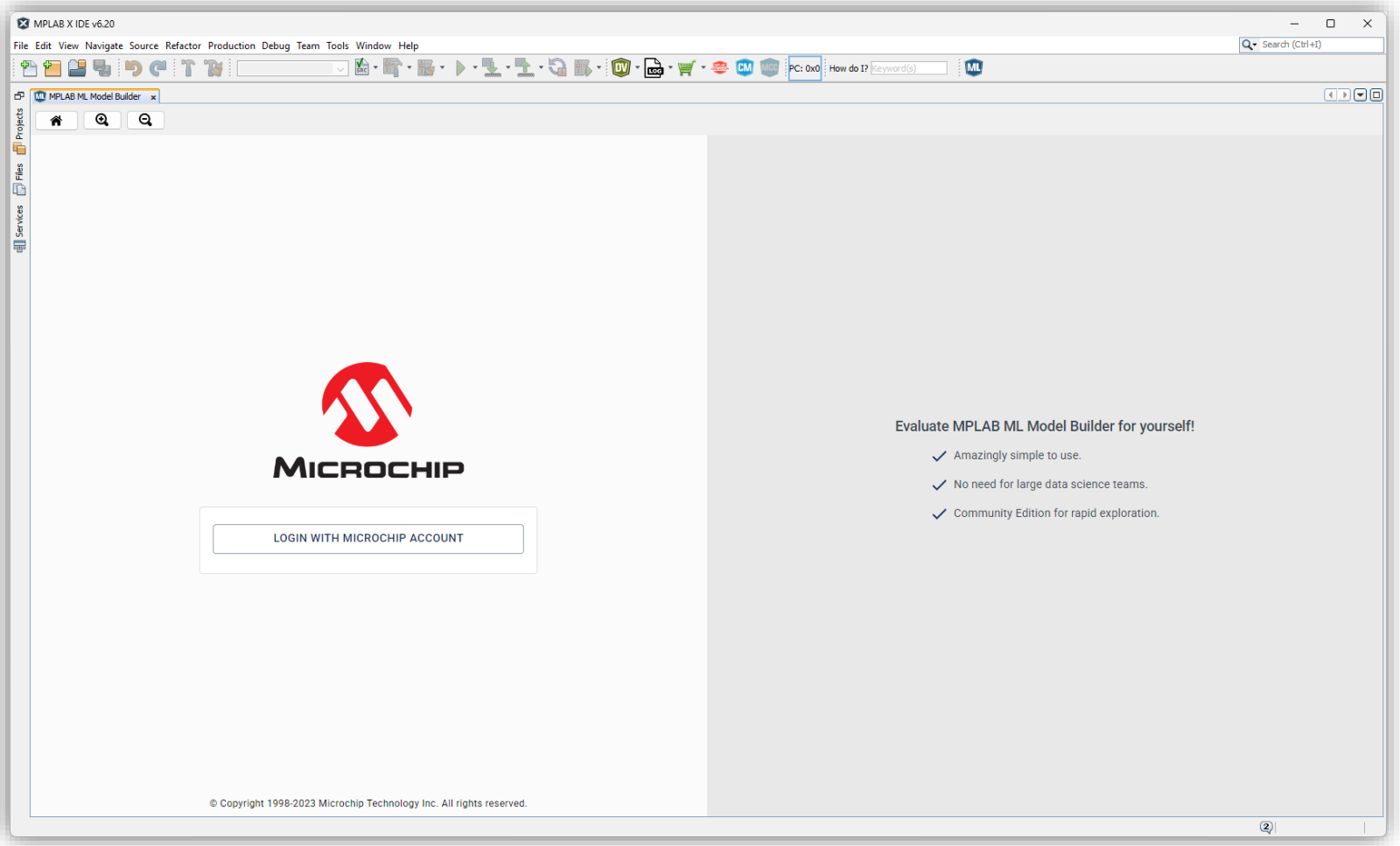
- **Tools > Embedded > MPLAB ML Model Builder**



Create and Login MPLAB ML Account

Create MPLAB ML Account

- This course must have a MPLAB ML Account to continue, please create it first !

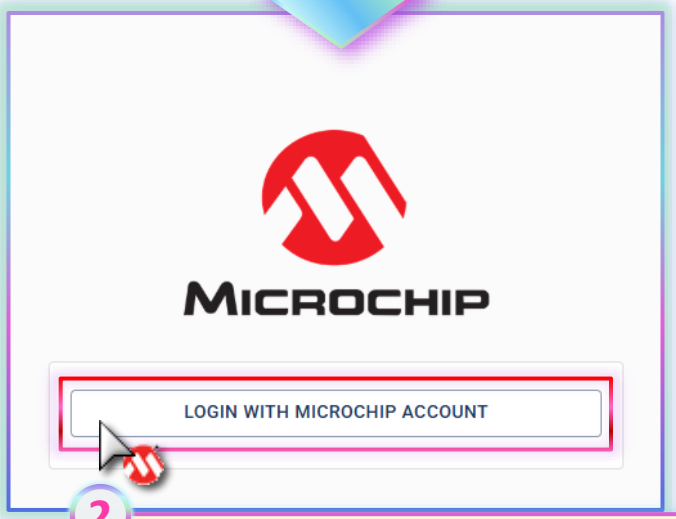


MICROCHIP

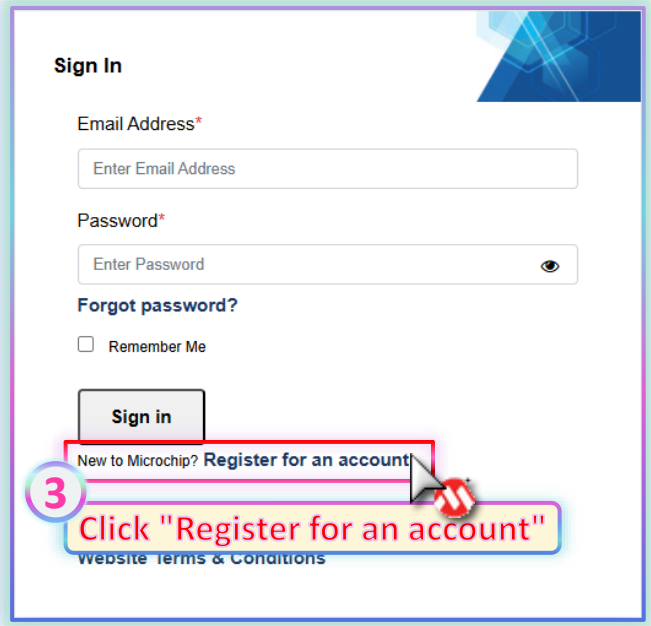
Create MPLAB ML Account

- **Create a MPLAB ML Account.**

1 Click on the icon to open MPLAB ML Model Builder



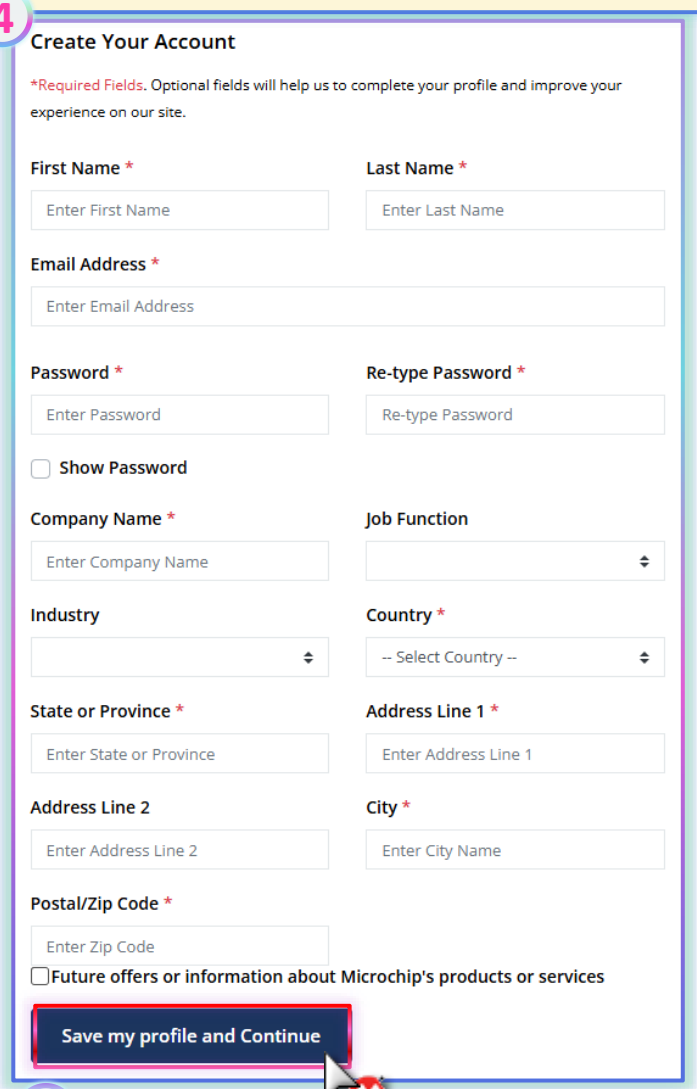
2 Click "Login with Microchip Account"



3 Click "Register for an account"

Fill in your information
(Please do not fill in wrong information arbitrarily !)

4

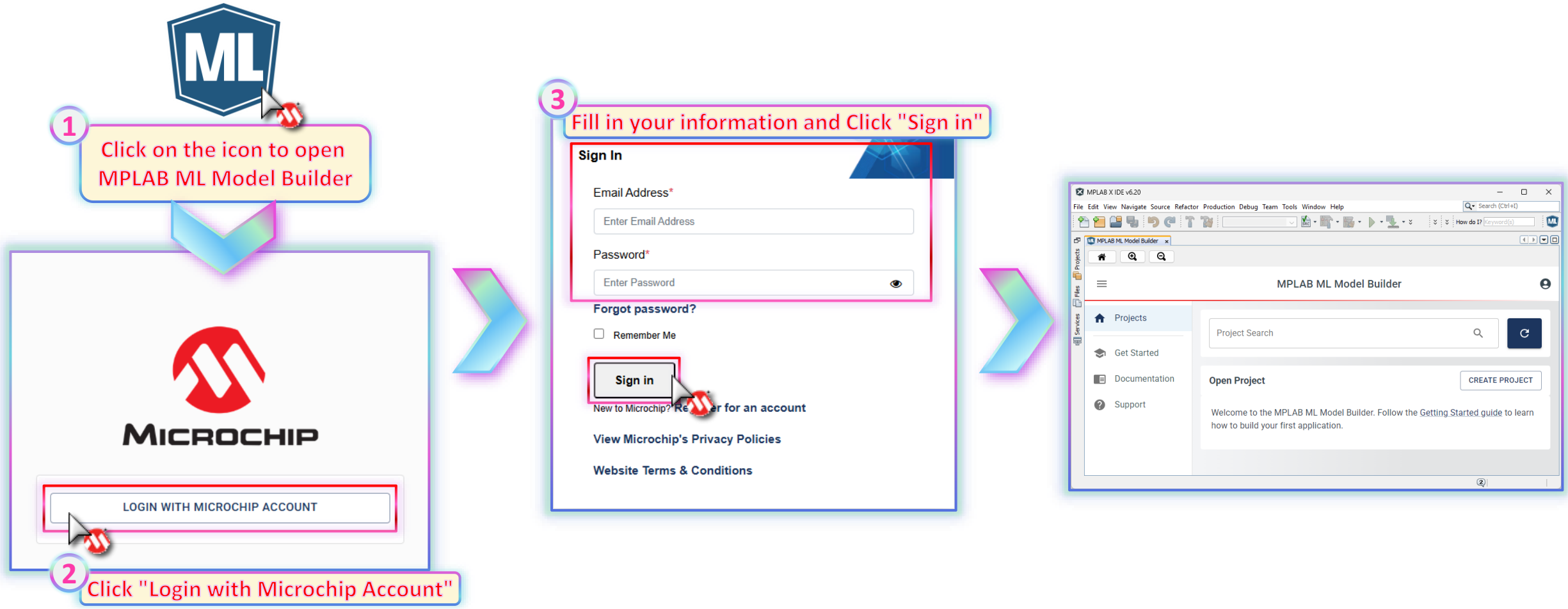


5 Click "Save my profile and Continue"

MICROCHIP

Login MPLAB ML Account

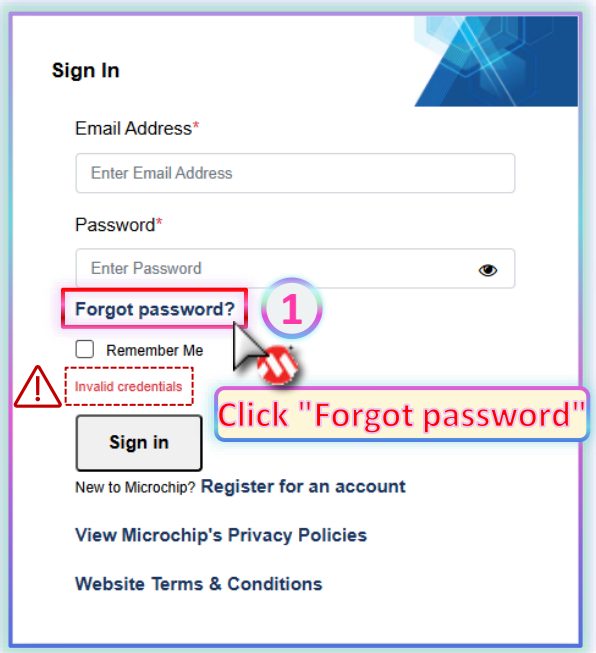
- **Login your MPLAB ML Account.**



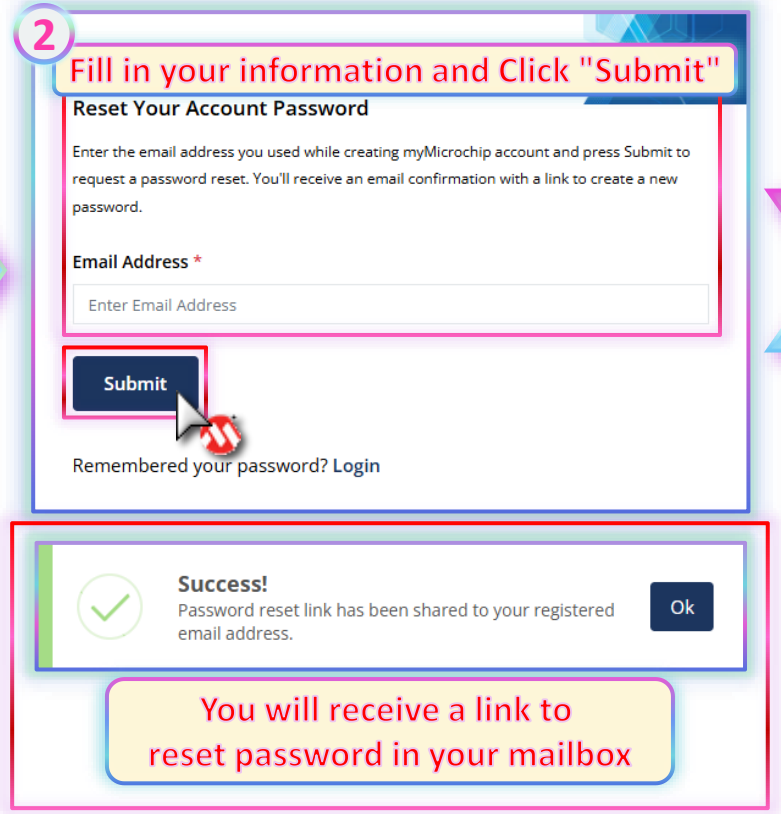
Login MPLAB ML Account

⚠ Invalid credentials

- **Please try to Reset Your Password when the "Invalid credentials" message appears.**



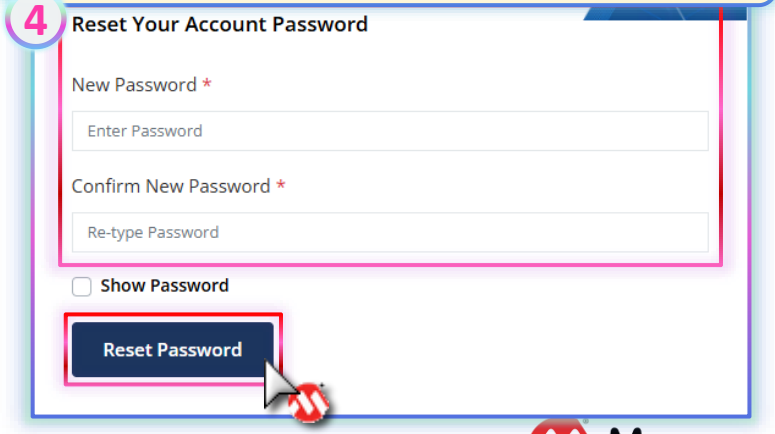
Click "Forgot password"



You will receive a link to reset password in your mailbox

Find the email in your mailbox and click "click here"

Fill in your password and Click "Reset Password", then login to your account again.



MICROCHIP

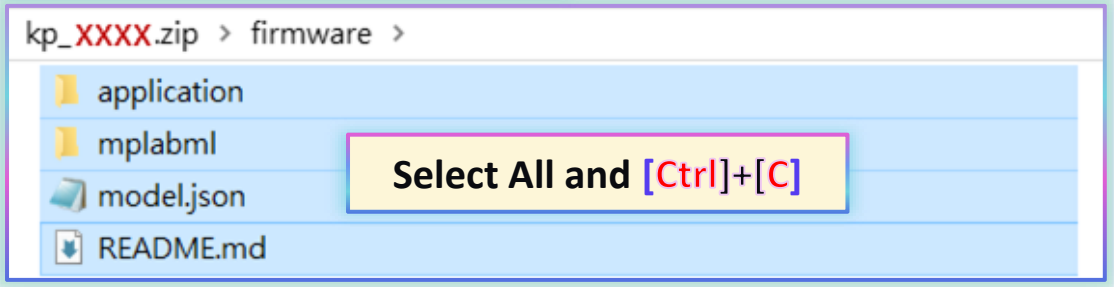
Porting Deploy Model to Custom Project

Porting Deploy Model to Custom Project

Step 1

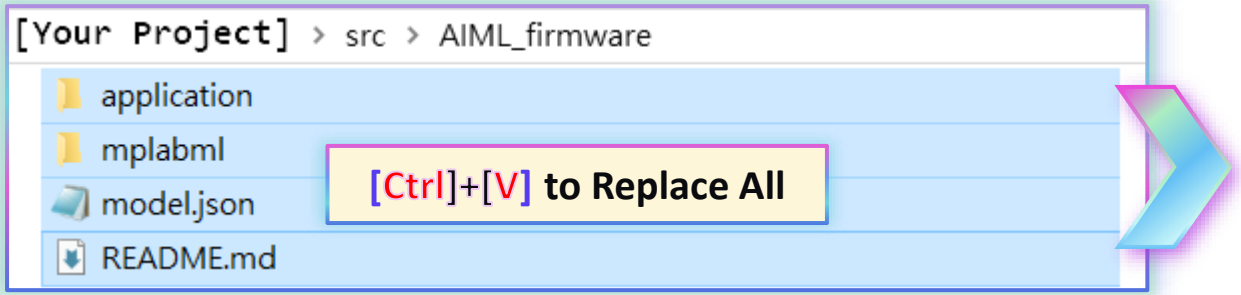
- **Open downloaded ML Deploy Model [kp_XXXX].zip,**
  Enter its folder "\firmware" and Select all files, press [Ctrl]+[C] to copy all files in it.

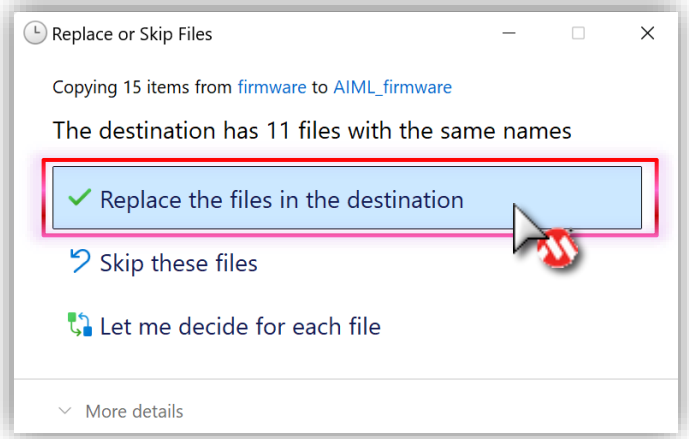
\[kp_XXXX].zip\firmware*.*



- **Create a folder "AIML_firmware" under "\[Your Project]\src\",**
  Paste all files copied from above step by [Ctrl]+[V]

\[Your Project]\src\AIML_firmware\



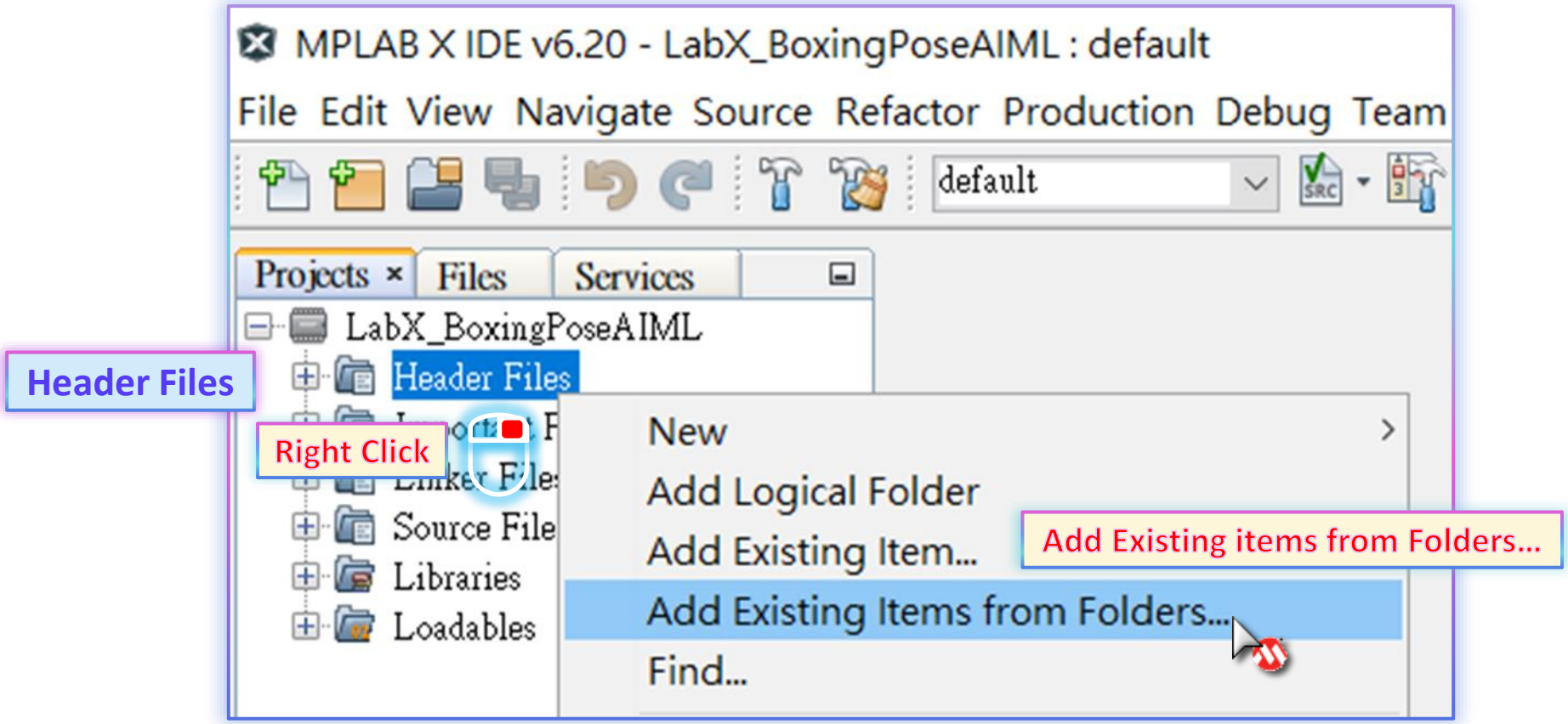


MICROCHIP

Porting Deploy Model to Custom Project

Step 2

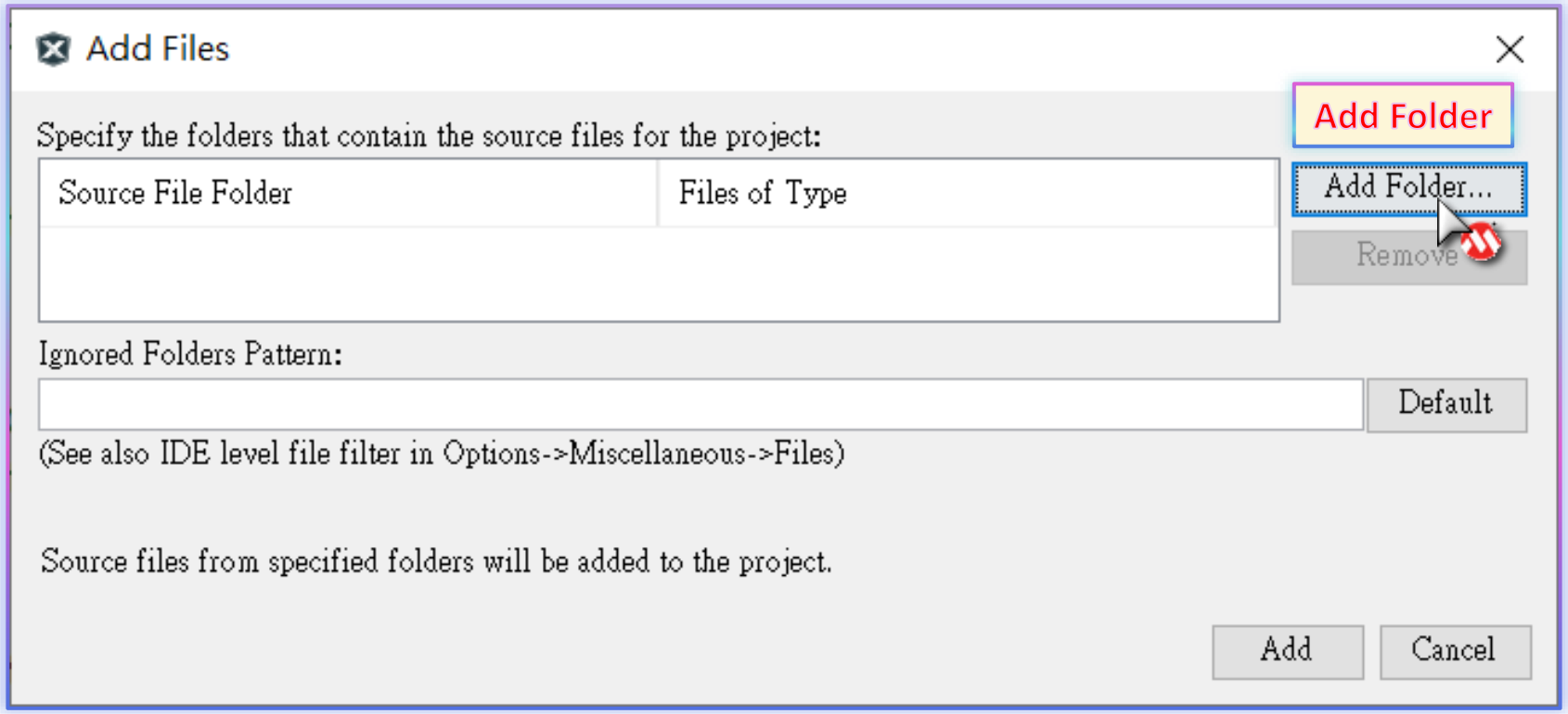
- **Open your project in MPLAB X IDE.**
- **Right click on Header Files -> Add Existing Items from Folders.**



Porting Deploy Model to Custom Project

Step 3

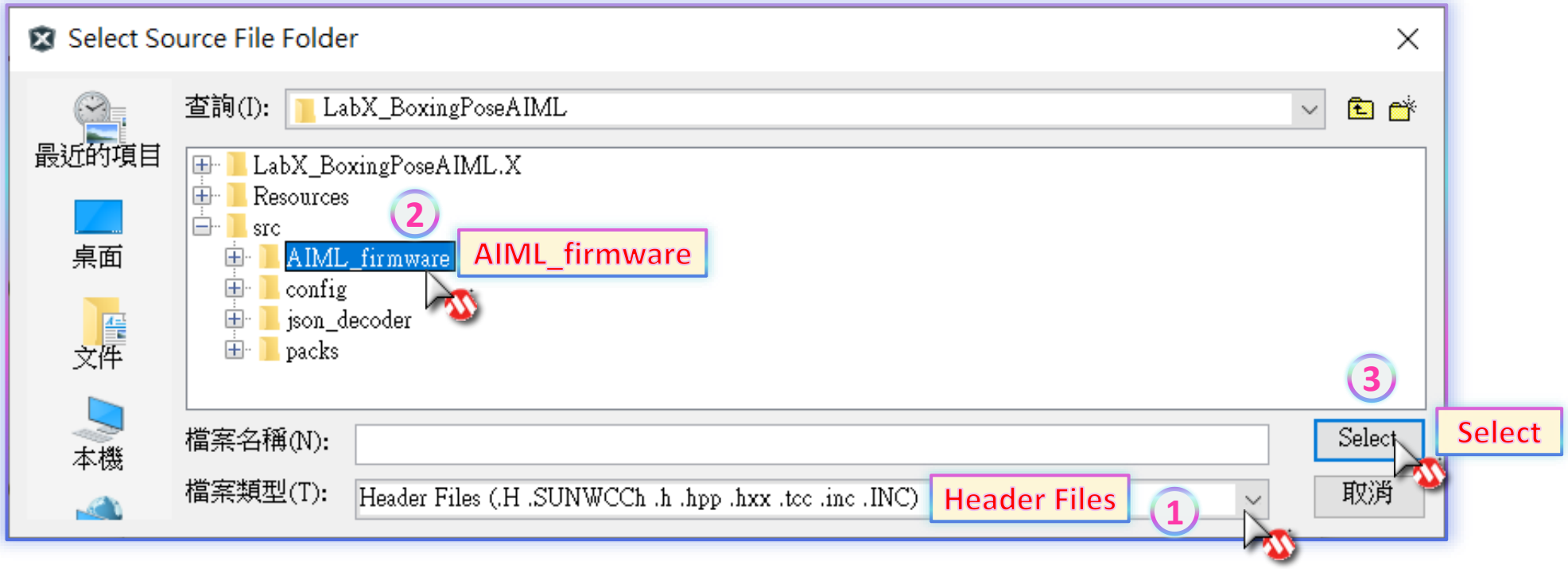
- Click Add Folder.



Porting Deploy Model to Custom Project

Step 4

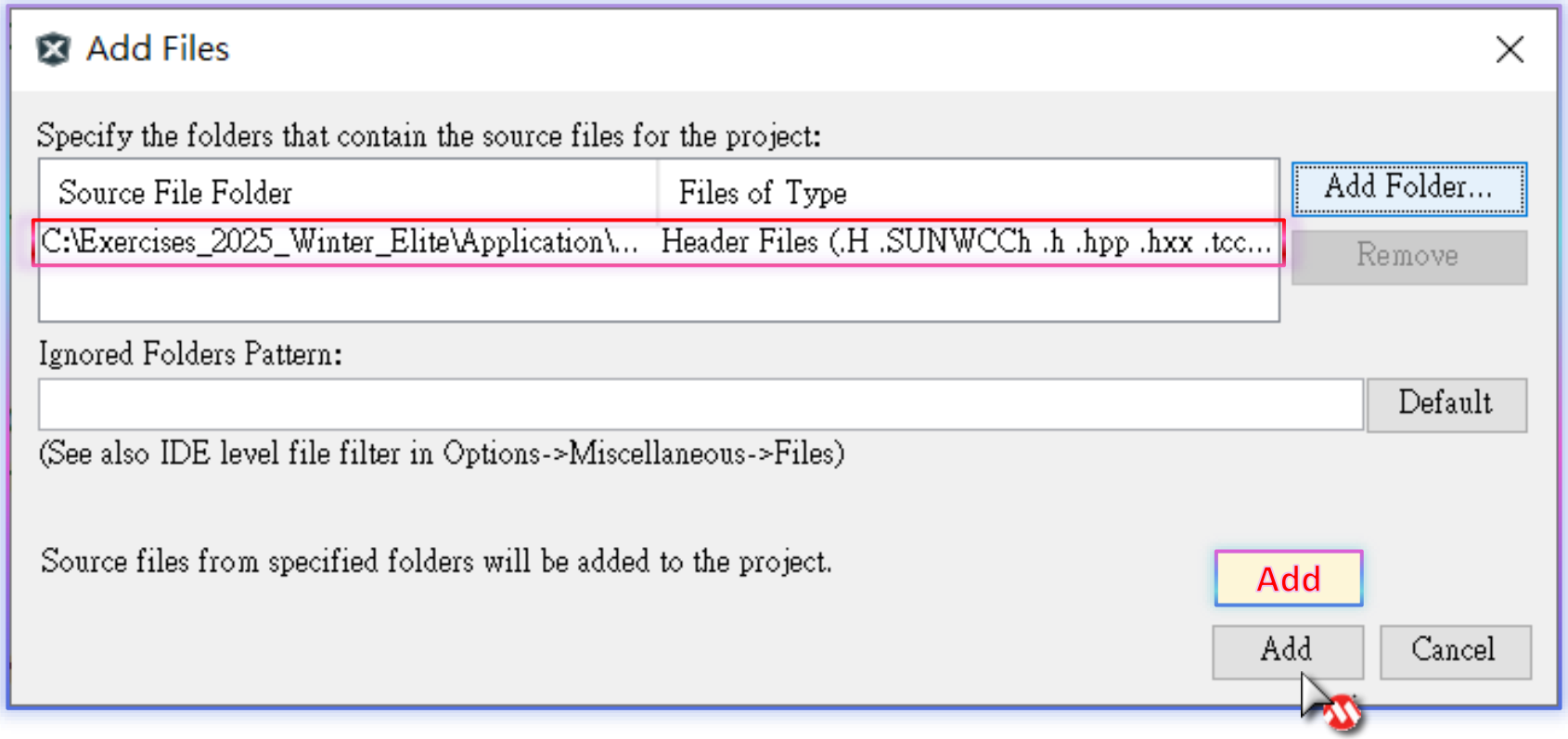
- Choice Files of type : Header Files (.H .SUNWCCh .h .hpp .hxx ……)
- Select folder “\[Your Project]\src\AIML_firmware\”
- Click Select.



Porting Deploy Model to Custom Project

Step 5

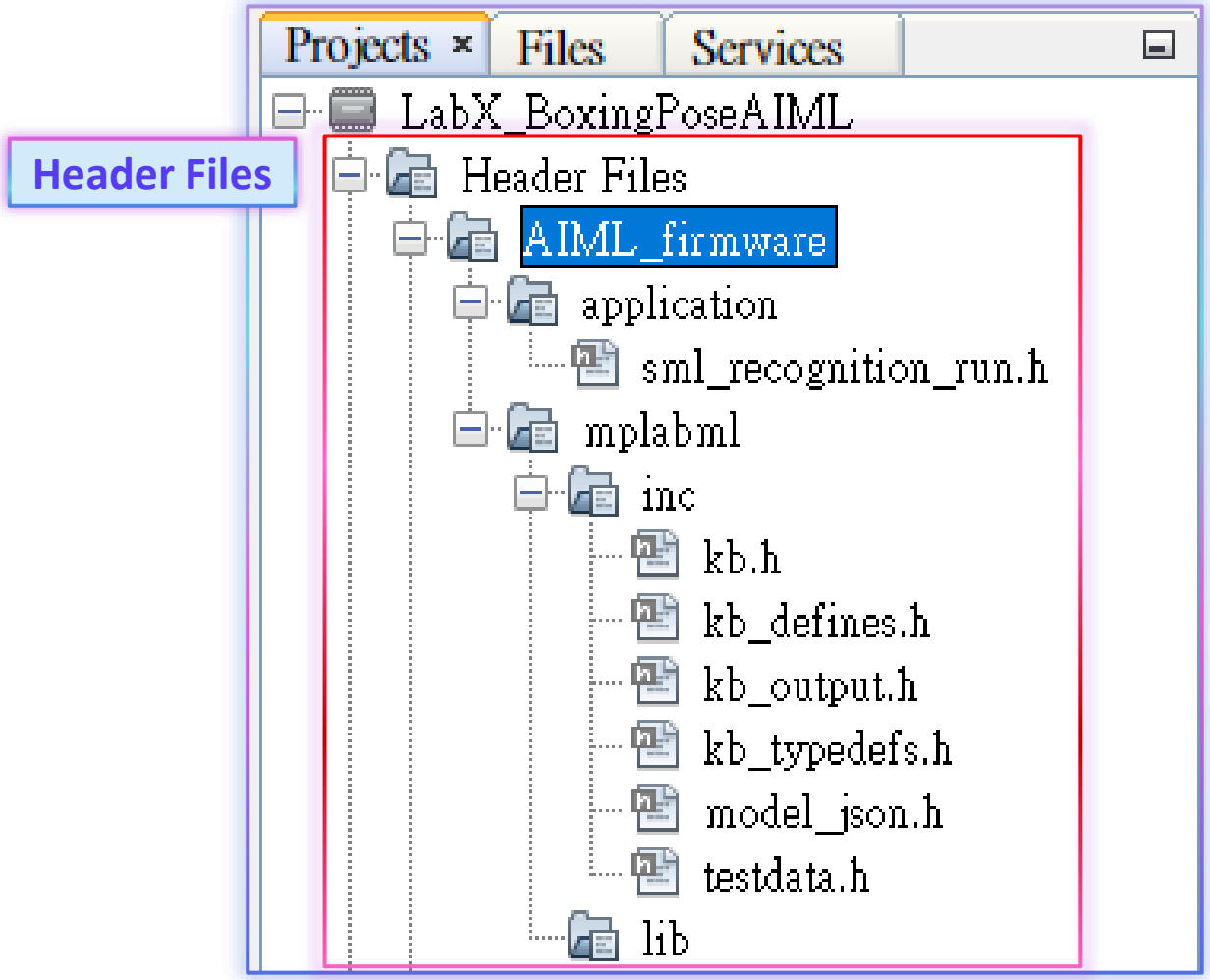
- **Click Add then all the .h files in folder ”\AIML_firmware\” will be added to project.**



Porting Deploy Model to Custom Project

Step 6

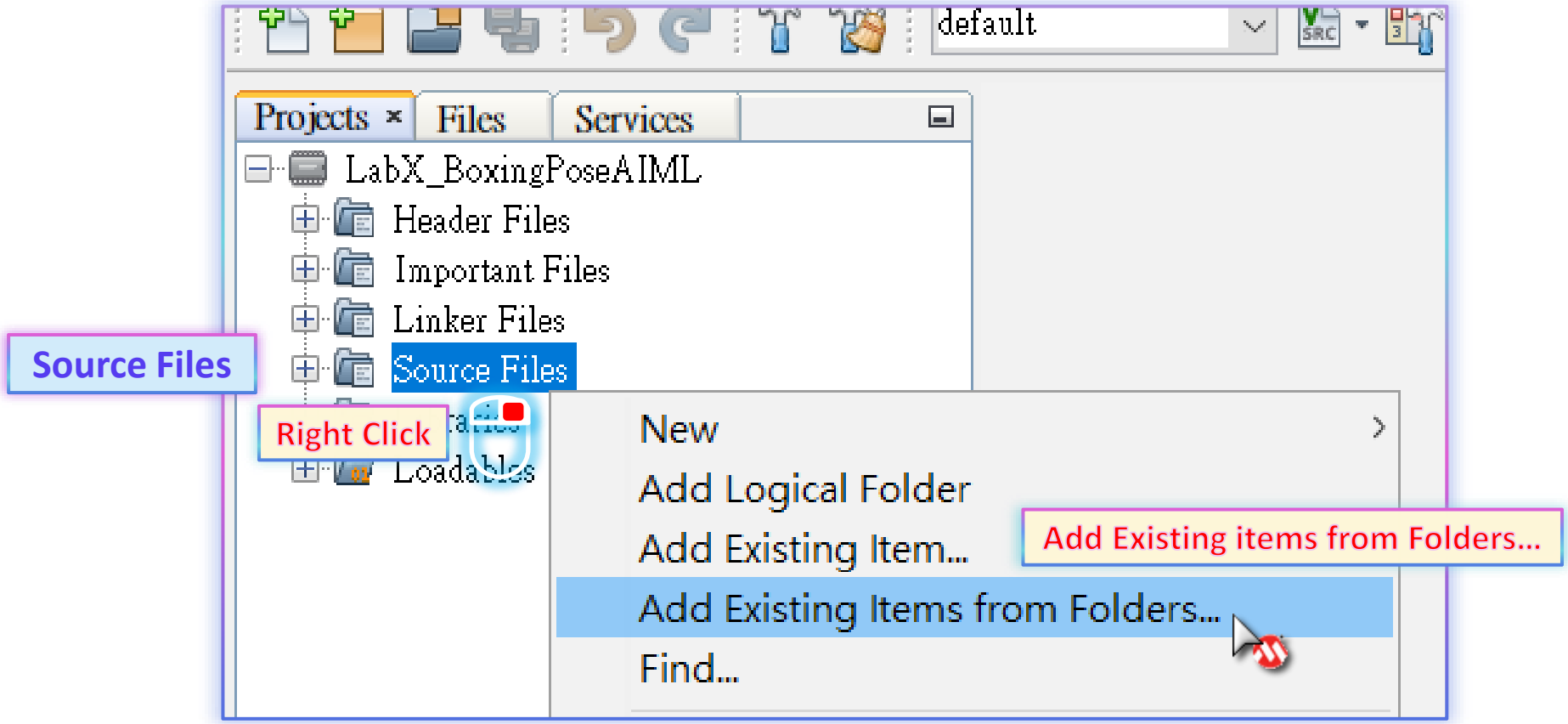
- **Check if all the .h files in ”\AIML_firmware\” are added into Header File folder.**



Porting Deploy Model to Custom Project

Step 7

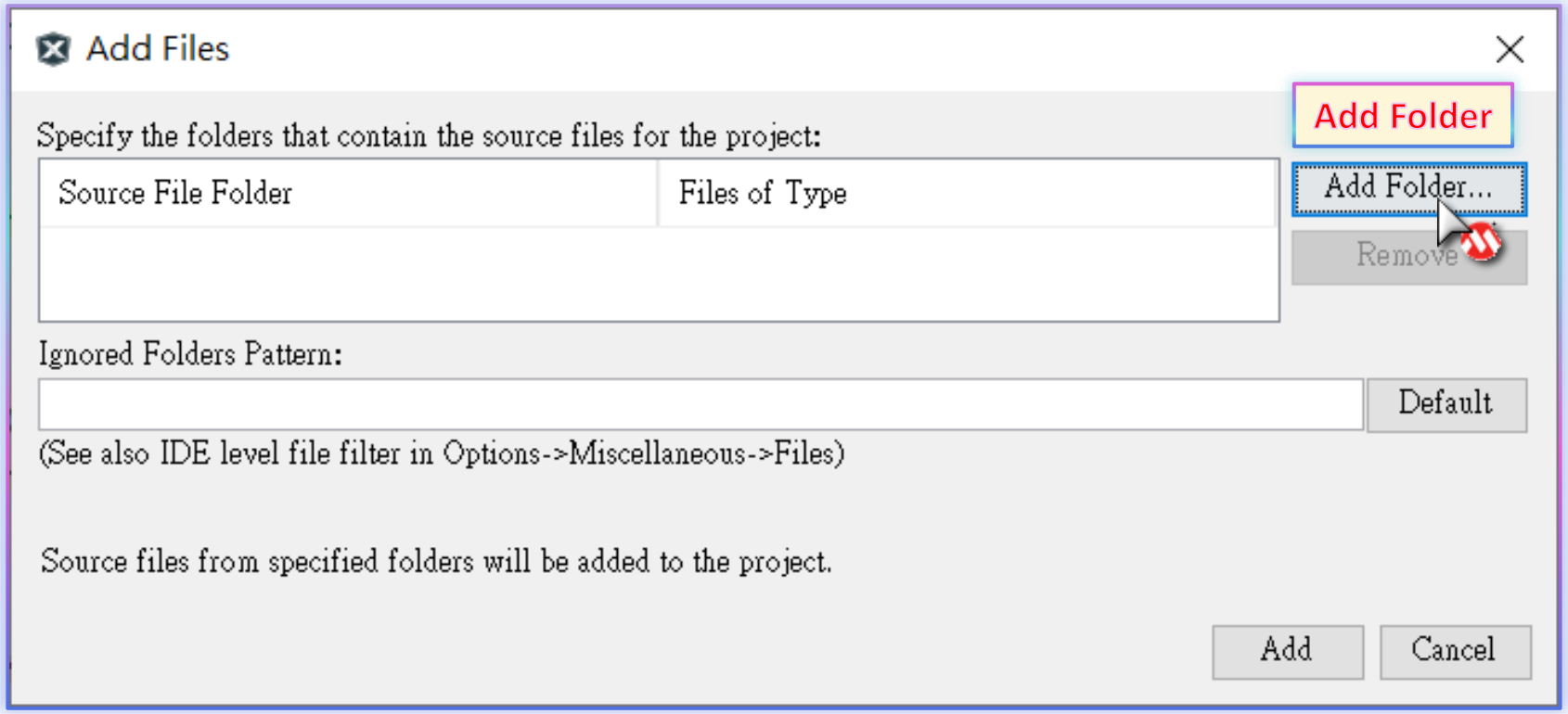
- **Return your project in MPLAB X IDE.**
- **Right click on Source Files -> Add Existing Items from Folders.**



Porting Deploy Model to Custom Project

Step 8

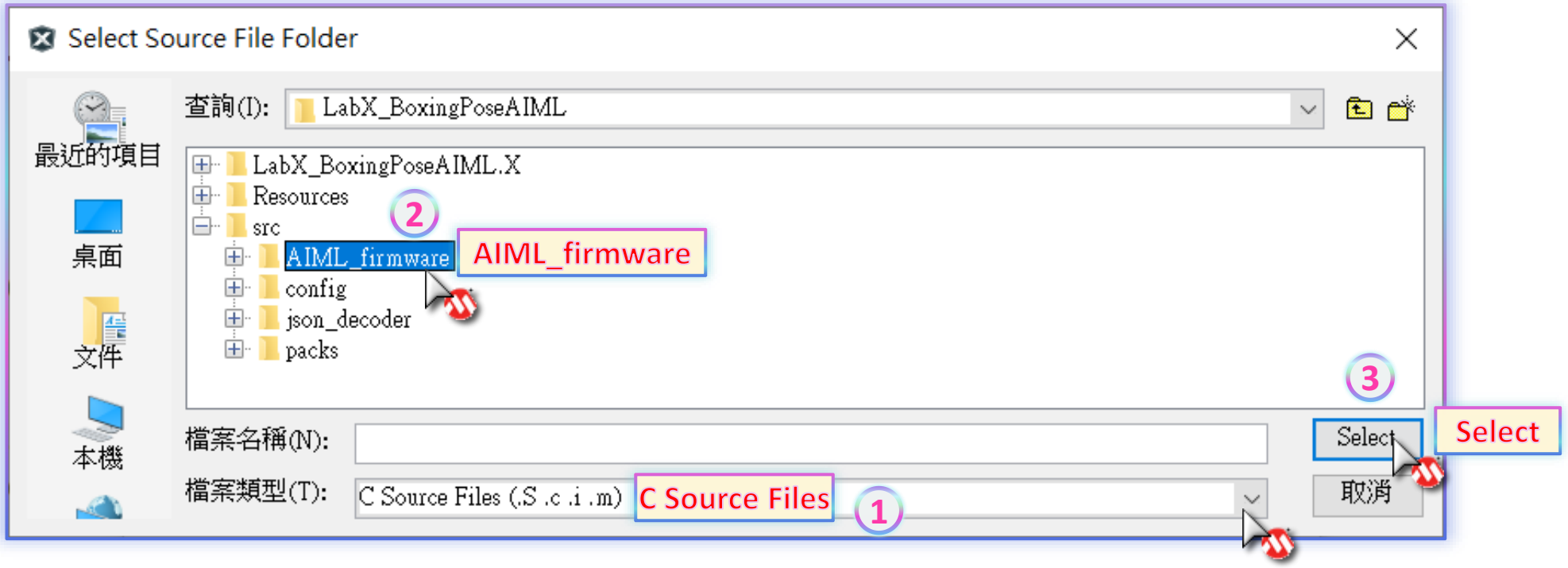
- Click Add Folder.



Porting Deploy Model to Custom Project

Step 9

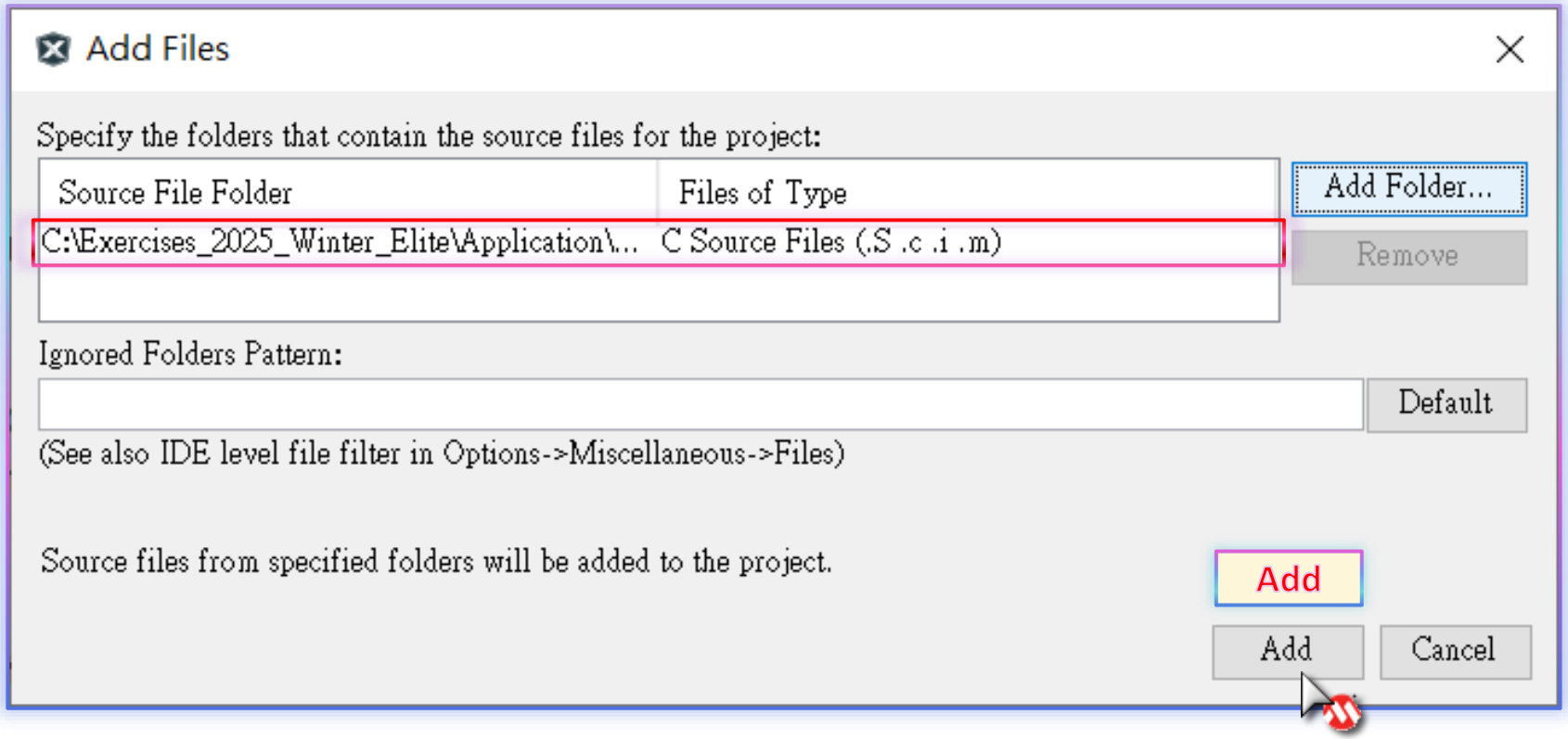
- Choice Files of type : C Source Files (.S .c .i .m)
- Select folder “\[Your Project]\src\AIML_firmware\”
- Click Select.



Porting Deploy Model to Custom Project

Step 10

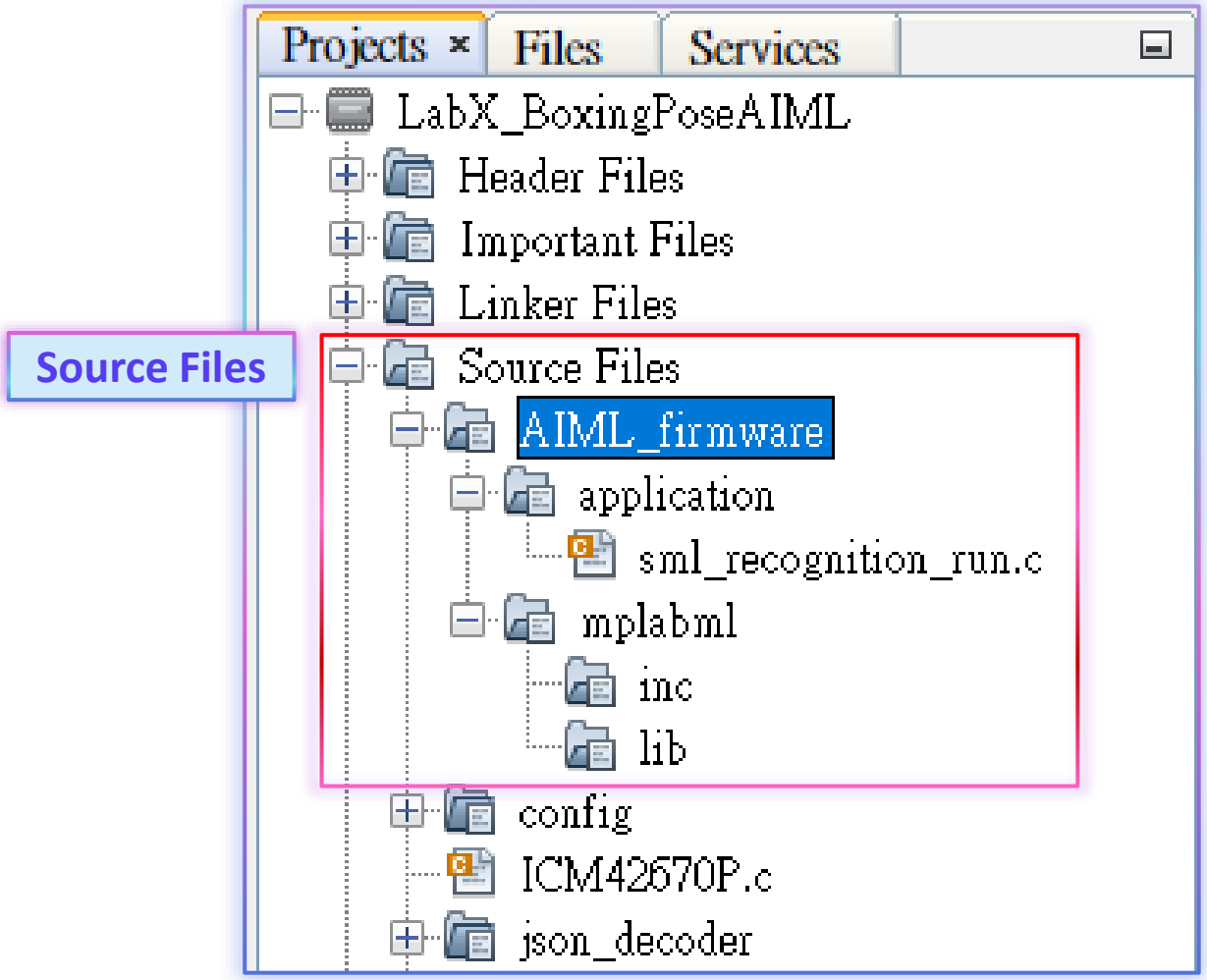
- **Click Add then all the .c files in ”\AIML_firmware\” will be added to project.**



Porting Deploy Model to Custom Project

Step 11

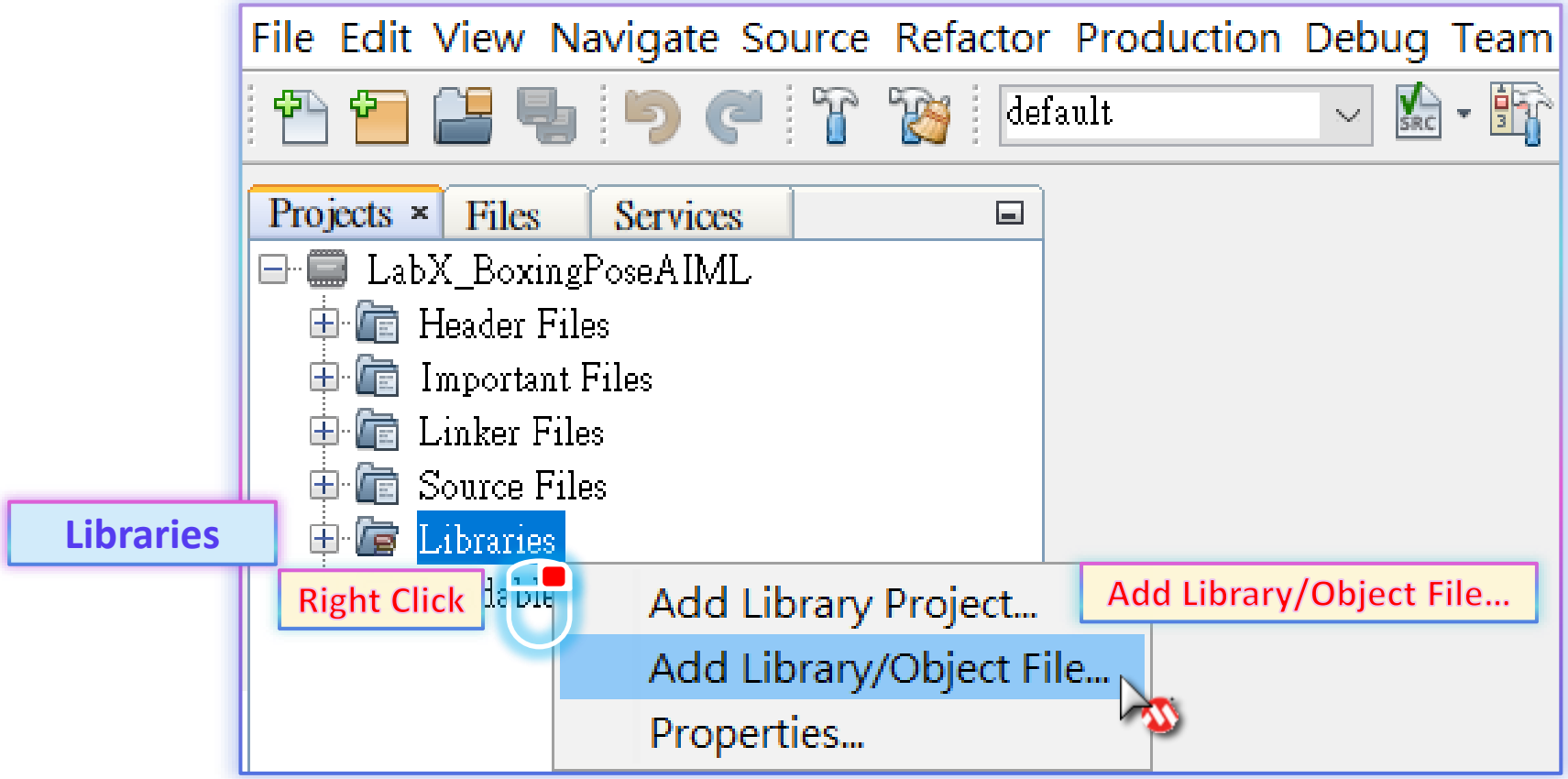
- **Check if all the .c files in ”\AIML_firmware\” are added into Source File folder.**



Porting Deploy Model to Custom Project

Step 12

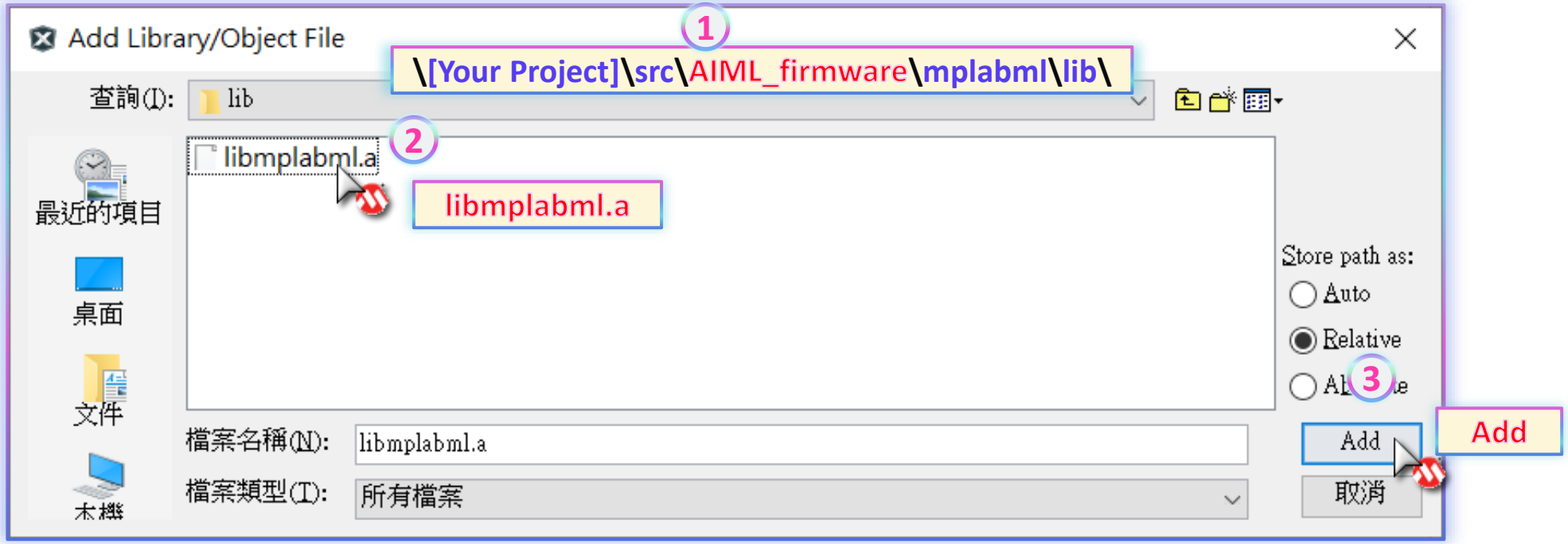
- **Return your project in MPLAB X IDE.**
- **Right click Libraries -> Add Library/Object File…**



Porting Deploy Model to Custom Project

Step 13

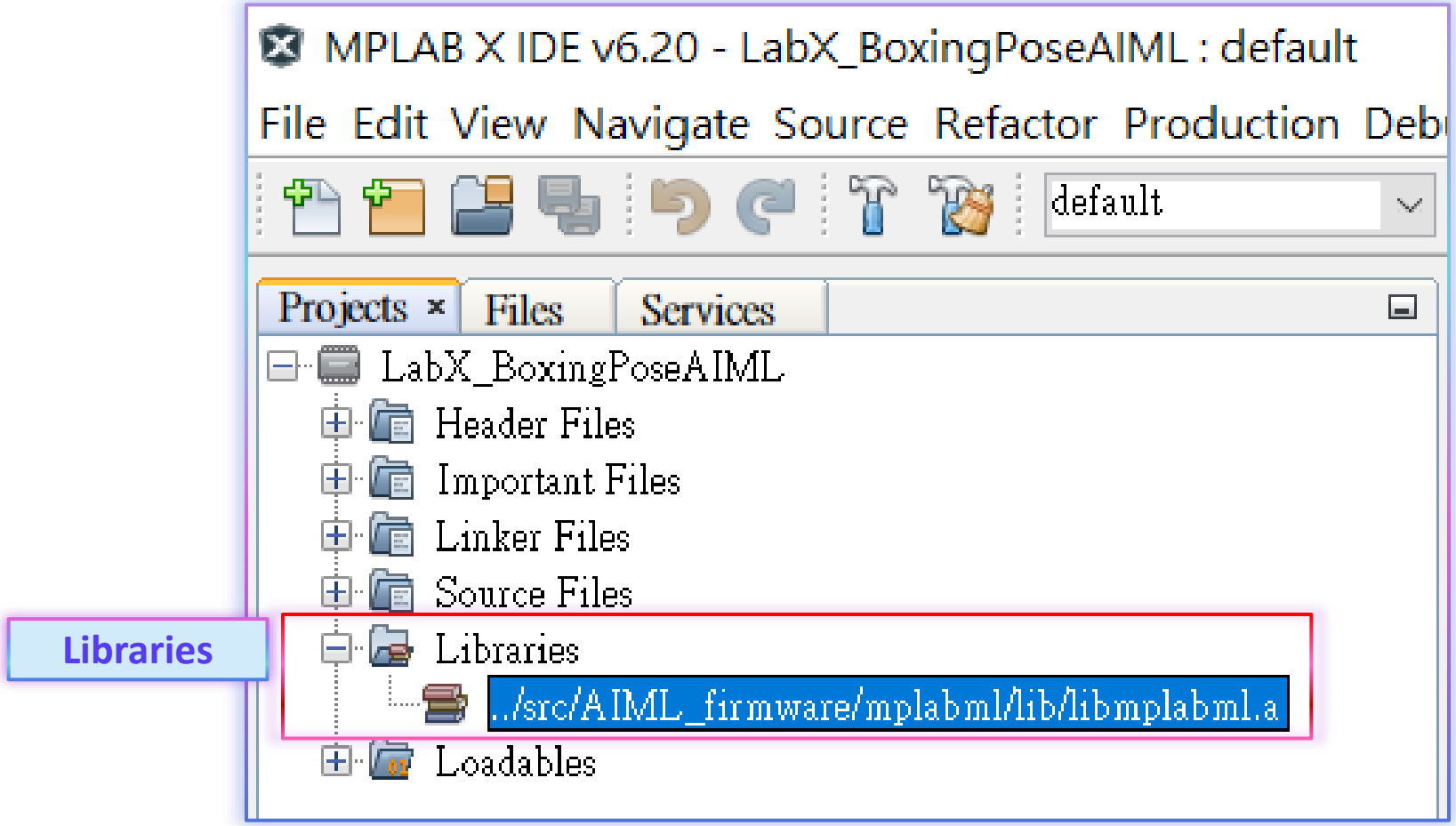
- Find the folder “\[Your Project]\src\AIML_firmware\mplabml\lib\”
- Select Library file libmplabml.a
- Click Select.



Porting Deploy Model to Custom Project

Step 14

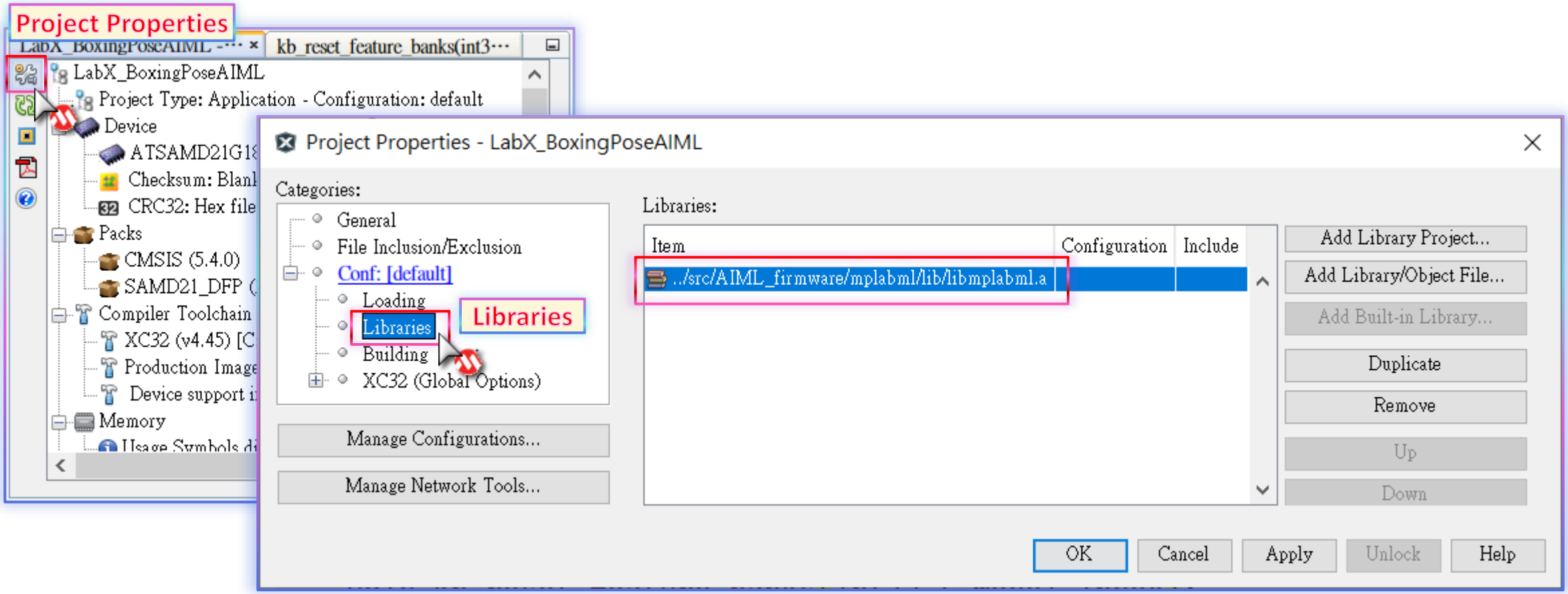
- **Check if the libmplabml.a files are added into Libraries folder of your project.**



Porting Deploy Model to Custom Project

Step 15

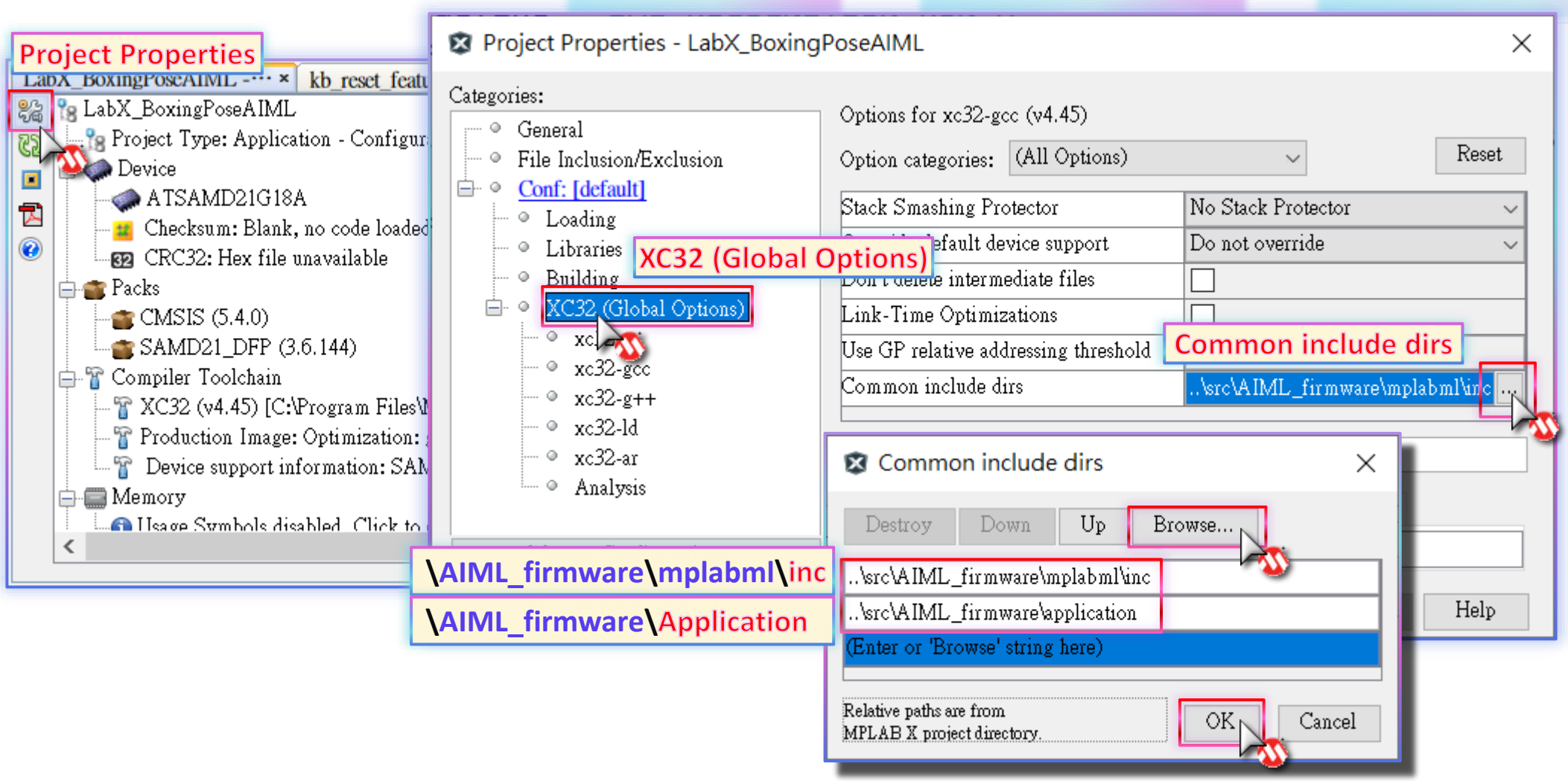
- **You could also check to the libraries file in Project Properties by click on .**



Porting Deploy Model to Custom Project

Step 16

- Add ”\mplabml\inc” & “\application\” in \AIML_firmware\” to Common include dirs.



Porting Deploy Model to Custom Project

Step 17

- **The example Auto ML model inference result.**

```
#include "sml_recognition_run.h“

#define SNSR_NUM_AXES 6

void ICM42670P_GetQueuedSensorRaw( uint16 *SensorRaw ) {...}

void Inference( void )
{
    int32_t ClassMapsId;
    uint16_t SensorRawData[SNSR_NUM_AXES];

    while( ICM42670P_GetQueuedSensorRaw( SensorRawData ) )
    {
        ClassMapsId = sml_recognition_run( (int16_t *)SensorRawData, SNSR_NUM_AXES );
        printf( "Auto ML Inference Result : %d“, ClassMapsId );
    }
}
```

Sensor Raw Function

Sensor Raw Data

ML Inference Function

model.json

```
"ModelDescriptions": [
  {
    "Name": "BOXING_RECOGNITION_RANK_3",
    "ClassMaps": {
      "1": "Freeze",
      "2": "Righthook",
      "3": "Straight",
      "4": "Uppercut",
      "0": "Unknown"
    },
```

ClassMapsId

ML Data Collector | Touch | Terminal | XY Plot

```
Auto ML Inference Result : 1
```

Output

MICROCHIP

JSON Decoder helper Library

JSON Decoder helper Library

Step 1

- **There has a JSON decoder library been implemented in LabX_BoxingPoseAIML project. It's helpful to auto parser the model_json.h (model.json converted into C header form) to get correct mapping of Classified ID of you deployed Model.**

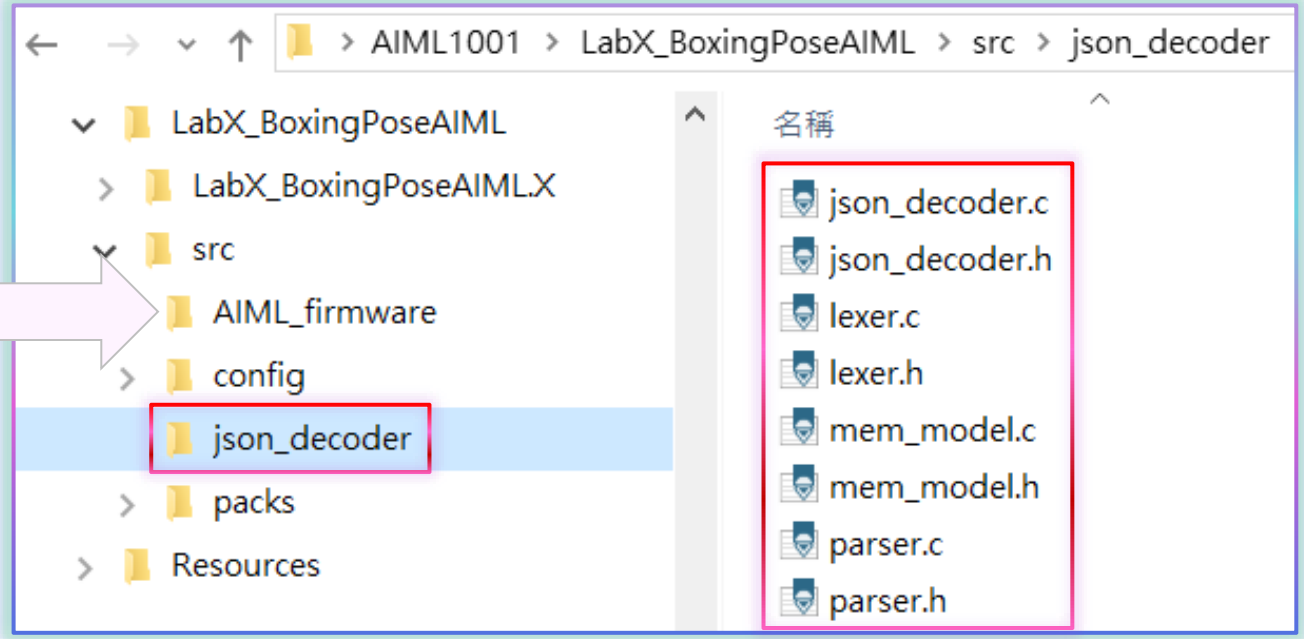
```
#ifndef __MODEL_JSON_H__
#define __MODEL_JSON_H__

const char recognition_model_string_json[] =
{"{\"NumModels\":1,\"ModelIndexes\":{\"0\":\"BOXING_REC
OGNITION_RANK_3\"},\"ModelDescriptions\":[{\"Name\":\"B
OXING_RECOGNITION_RANK_3\",\"ClassMaps\":{\"1\":\"Freez
e\",\"2\":\"Righthook\",\"3\":\"Straight\",\"4\":\"Uppe
rcut\",\"0\":\"Unknown\"},\"ModelType\":\"DecisionTreeE
nsemble\",\"FeatureFunctions\":[\"25thPercentile\",\"Ab
soluteAreaofLowFrequency\",\"AbsoluteAreaofLowFrequency
\",\"GlobalPeaktoPeak\",\"GlobalPeaktoPeakofLowFrequenc
y\",\"TwoColumnMeanDifference\",\"TwoColumnMeanDifferen
ce\",\"TwoColumnPeakToPeakDifference\"]}]}"};

int32_t recognition_model_string_json_len =
sizeof(recognition_model_string_json);

#endif /* __MODEL_JSON_H__ */
```

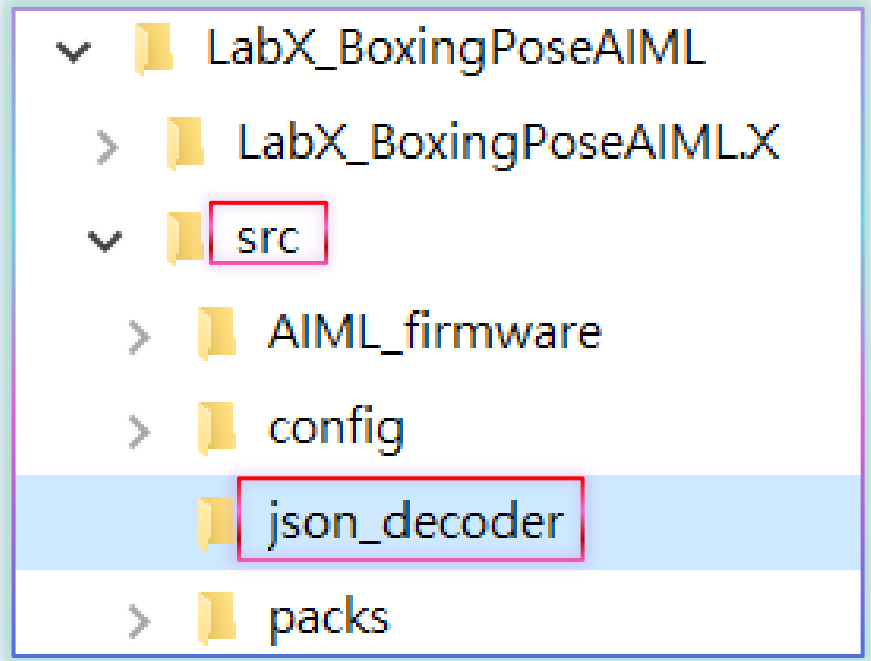
model_json.h

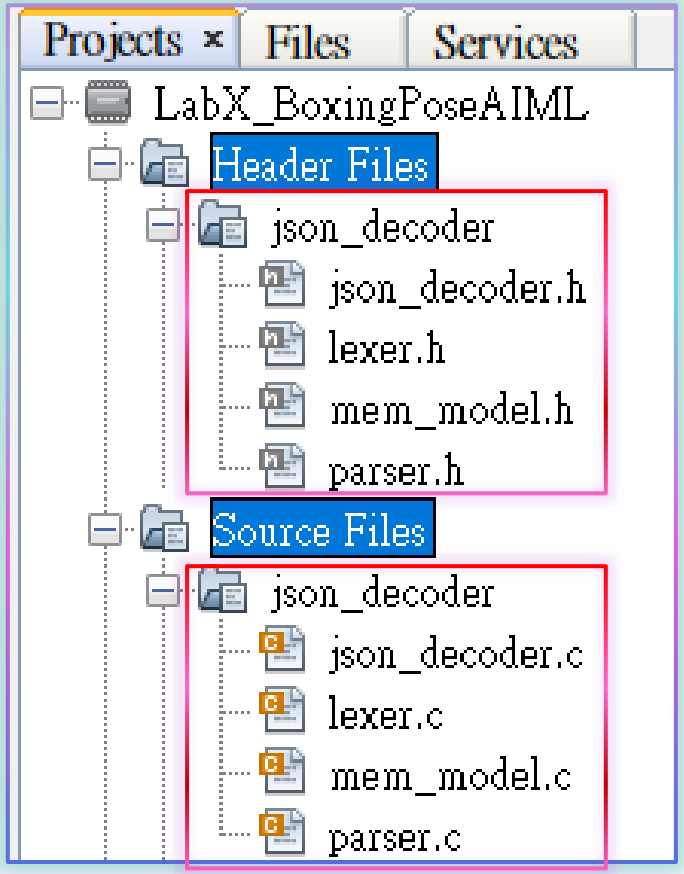


JSON Decoder helper Library

Step 2

- Copy whole ”\json_decoder\” folder to under “\src” folder of your project.
- Add *.h and *.c into “Header Files” and “Source Files” of your Project in MPLAB X IDE.

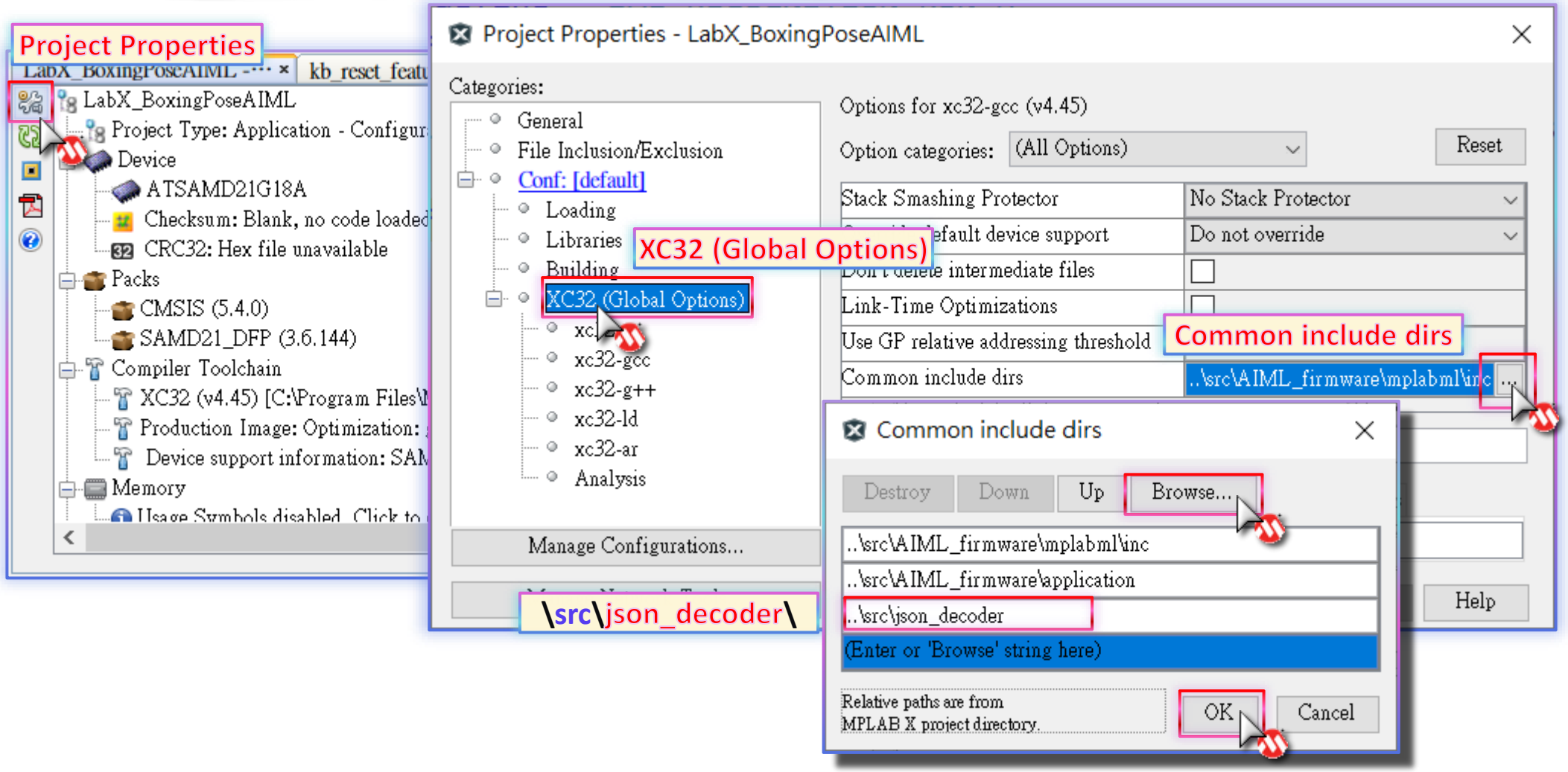




JSON Decoder helper Library

Step 3

- Add ”\src\json_decoder\” to Common include dirs.



JSON Decoder helper Library

Step 4

- **The example to add JSON Decoder helper Library into your project.**

```
#include "json_decoder.h"
#include "model_json.h“

#define MODEL_NAME_LENGTH    50
#define CLASSIFY_ID_MAXIMUM  5
#define CLASSIFY_NAME_LENGTH 20

typedef struct
{
    char ModelName[MODEL_NAME_LENGTH];
    char ClassMaps[CLASSIFY_ID_MAXIMUM][CLASSIFY_NAME_LENGTH];
} MODEL_DESCRIPTIONS;

MODEL_DESCRIPTIONS DeployModel;

void ParserJSON_ClassMaps( char *string_json, int32_t string_json_len )
{
    char jsonbuffer[500];
    jsonNode_t *root, *objModelDescriptions;
    jsonNode_t *objClassMaps;
```

JSON Decoder helper Library

Step 5

- **The example to add JSON Decoder helper Library into your project.**

```
    memcpy( jsonbuffer, string_json, string_json_len );

    JSON_DECODER_fromString(jsonbuffer);
    JSON_DECODER_getRoot(&root);
    JSON_DECODER_getObject(root, "ModelDescriptions", &objModelDescriptions);
    JSON_DECODER_getObject(objModelDescriptions, "ClassMaps", &objClassMaps);
    JSON_DECODER_getString(objModelDescriptions, "Name", MODEL_NAME_LENGTH, DeployModel.ModelName);

    printf("Auto ML Model Name : %s\r\n", DeployModel.ModelName );

    printf("Auto ML Classify Maps :\r\n");
    for( int Clsid=0 ; Clsid<CLASSIFY_ID_MAXIMUM ; Clsid++ )
    {
        char ClsidStr[2];
        memset( DeployModel.ClassMaps[Clsid], 0, CLASSIFY_NAME_LENGTH );
        sprintf( ClsidStr, "%d", Clsid );
        JSON_DECODER_getString(objClassMaps, ClsidStr, CLASSIFY_NAME_LENGTH, DeployModel.ClassMaps[Clsid]);
        printf(" - Id %d : %s\r\n", Clsid+16, Clsid, DeployModel.ClassMaps[Clsid] );
    }
}
```

JSON Decoder helper Library

Step 6

- **The example to add JSON Decoder helper Library into your project.**

```
void ParserJSON_ClassMaps( char *string_json, int32_t string_json_len )
{...}

void main( void )
{
    kb_model_init();
    ParserJSON_ClassMaps( (char *)recognition_model_string_json, recognition_model_string_json_len );
}
```

Text array and length in model_json.h

```
#ifndef __MODEL_JSON_H__
#define __MODEL_JSON_H__

const char recognition_model_string_json[] =
{"{\"NumModels\":1,\"ModelIndexes\":{\"0\":\"BOXING_RECOGNITION_RANK_3\"},\"ModelDescriptions\":[{\"Name\":\"BOXING_RECOGNITION
_RANK_3\",\"ClassMaps\":{\"1\":\"Freeze\",\"2\":\"Righthook\",\"3\":\"Straight\",\"4\":\"Uppercut\",\"0\":\"Unknown\"},\"ModelT
ype\":\"DecisionTreeEnsemble\",\"FeatureFunctions\":[\"25thPercentile\",\"AbsoluteAreaofLowFrequency\",\"AbsoluteAreaofLowFrequ
ency\",\"GlobalPeaktoPeak\",\"GlobalPeaktoPeakofLowFrequency\",\"TwoColumnMeanDifference\",\"TwoColumnMeanDifference\",\"TwoCol
umnPeakToPeakDifference\"]}]}"};

int32_t recognition_model_string_json_len = sizeof(recognition_model_string_json);

#endif /* __MODEL_JSON_H__ */
```

model_json.h

MICROCHIP

JSON Decoder helper Library

Result

- **The JSON parser example is using the LabX_BoxingPoseAIML.X project.**

ML Data Collector | Touch | Terminal | XY Plot

```
Auto ML Model Name : BOXING_RECOGNITION_RANK_3
Auto ML Classify Maps :
 - Id 0 : Unknown
 - Id 1 : Freeze
 - Id 2 : Righthook
 - Id 3 : Straight
 - Id 4 : Uppercut
```

Parser Result

model_json.h

```
#ifndef __MODEL_JSON_H__
#define __MODEL_JSON_H__

const char recognition_model_string_json[] =
{"{\"NumModels\":1,\"ModelIndexes\":{\"0\":\"BOXING_RECOGNIT
ION_RANK_3\"},\"ModelDescriptions\":[{\"Name\":\"BOXING_RECO
GNITION_RANK_3\",\"ClassMaps\":{\"1\":\"Freeze\",\"2\":\"Rig
hthook\",\"3\":\"Straight\",\"4\":\"Uppercut\",\"0\":\"Unkno
wn\"},\"ModelType\":\"DecisionTreeEnsemble\",\"FeatureFuncti
ons\":[\"25thPercentile\",\"AbsoluteAreaofLowFrequency\",\"A
bsoluteAreaofLowFrequency\",\"GlobalPeaktoPeak\",\"GlobalPea
ktoPeakofLowFrequency\",\"TwoColumnMeanDifference\",\"TwoCol
umnMeanDifference\",\"TwoColumnPeakToPeakDifference\"]}]}"};

int32_t recognition_model_string_json_len =
sizeof(recognition_model_string_json);

#endif /* __MODEL_JSON_H__ */
```

model.json

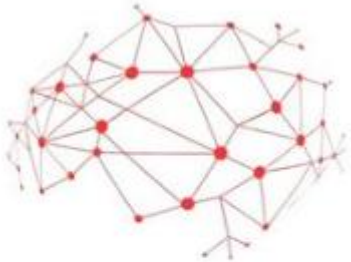
```
{
  "NumModels": 1,
  "ModelIndexes": {
    "0": "BOXING_RECOGNITION_RANK_3"
  },
  "ModelDescriptions": [
    {
      "Name": "BOXING_RECOGNITION_RANK_3",
      "ClassMaps": {
        "1": "Freeze",
        "2": "Righthook",
        "3": "Straight",
        "4": "Uppercut",
        "0": "Unknown"
      },
      "ModelType": "Decision Tree Ensemble",
```


MICROCHIP

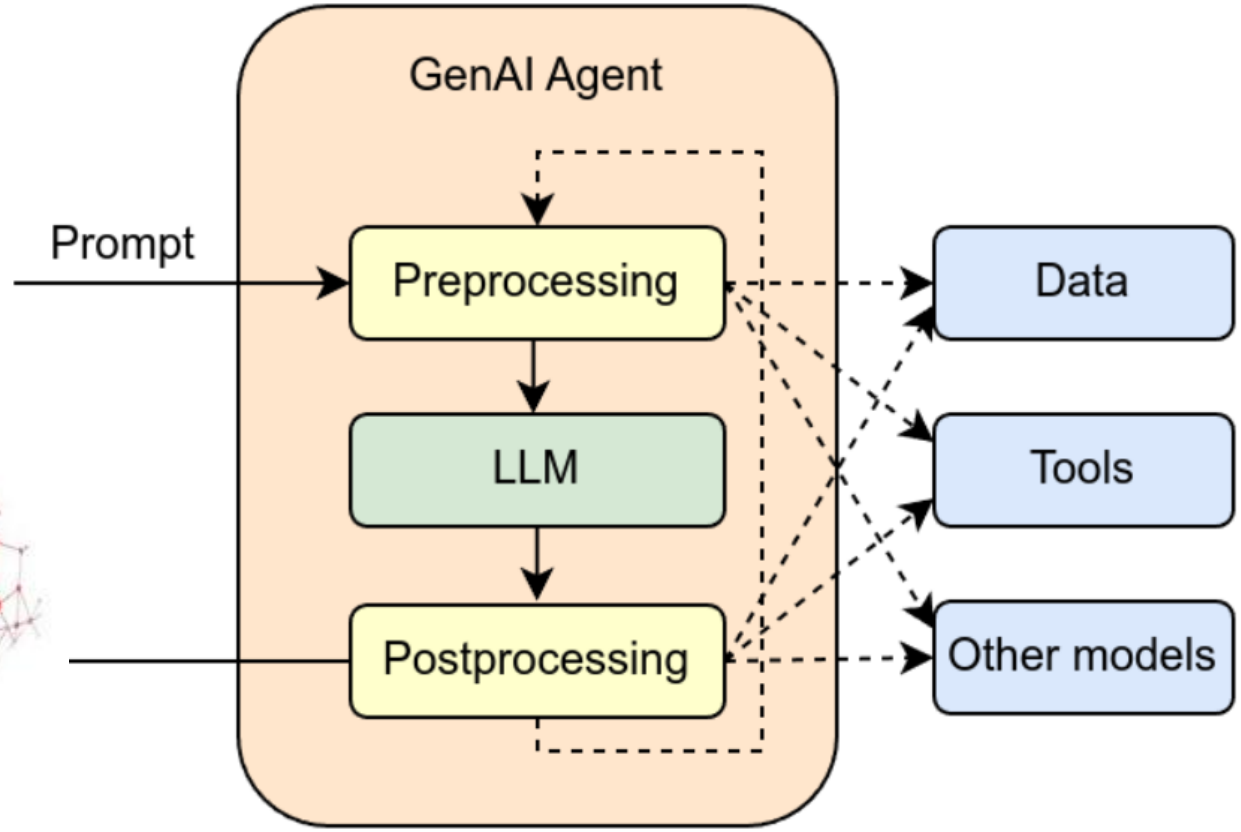
Large Language Models

Generative AI

- G-AI models learn patterns and structures of input data and produce new data with similar characteristics.
- Input data such as instructions, images, etc. for G-AI is often prompted by Large Language Models.
- G-AI creates new content such as text, videos., pictures, audio, etc.

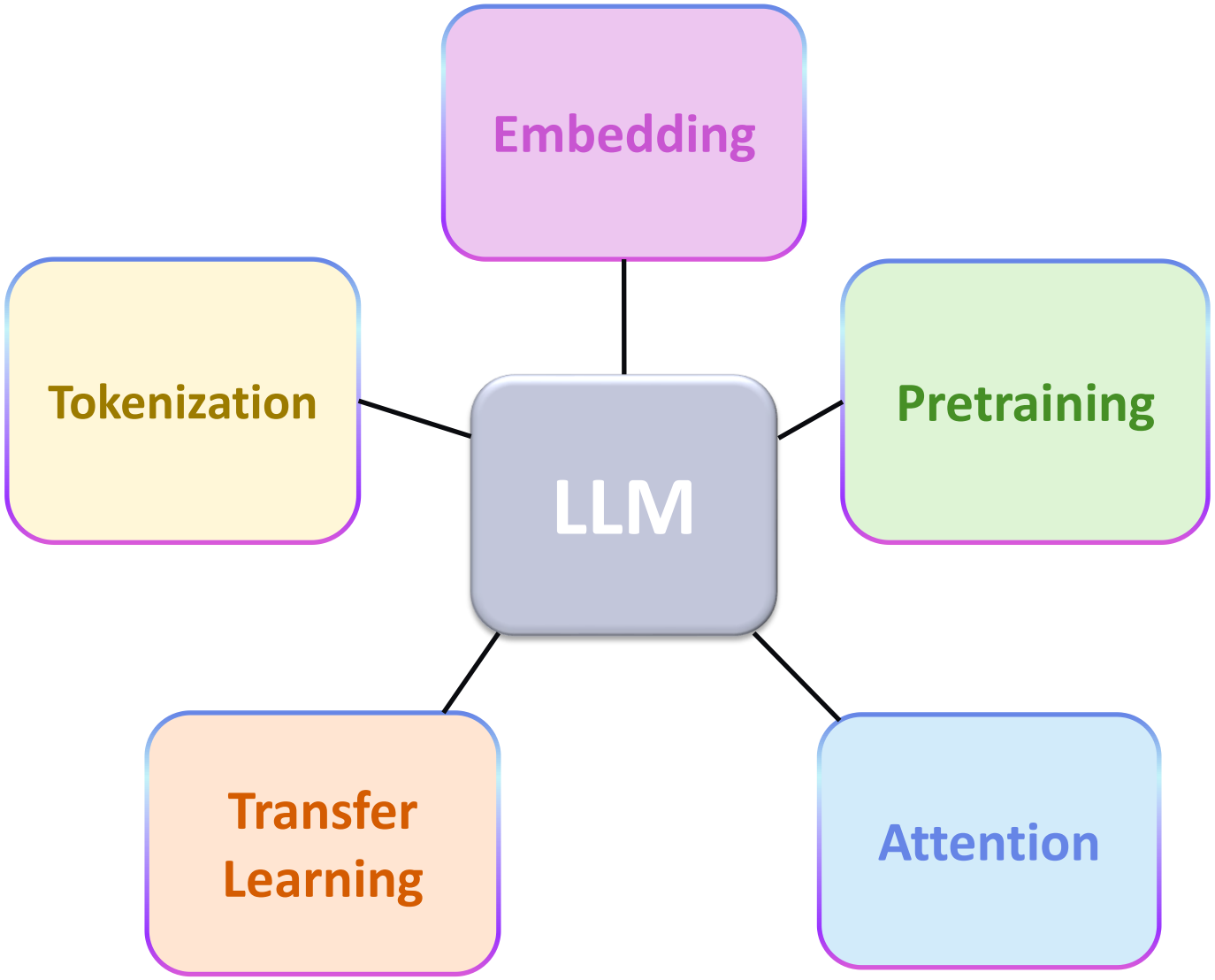


Generative AI



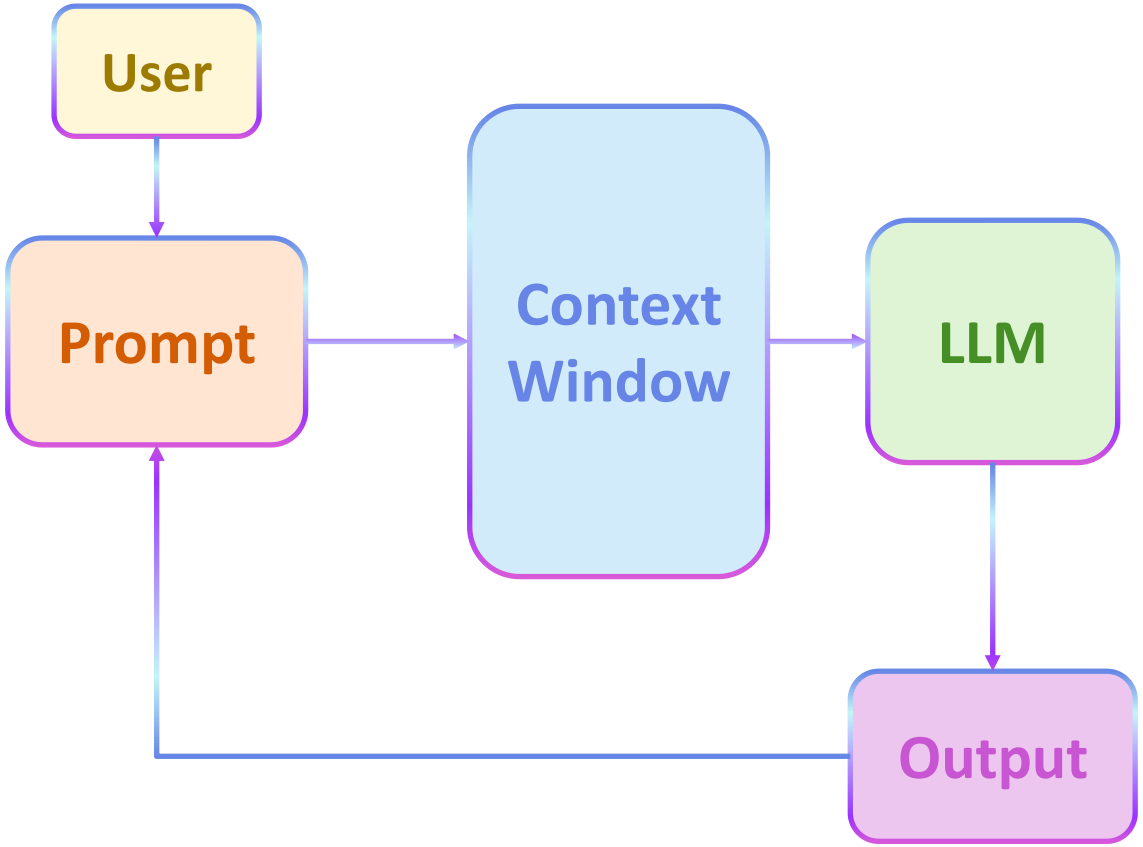
Large Language Models

- **LLM's are transformer-based Deep Neural Networks(DNN)**
- **Transformer is a DL architecture developed by Google and based on multi-head attention mechanism.**
- **Transfer Learning**
- **Popular LLM:**
  - OpenAI's ChatGPT
  - Microsoft's Copilot
  - Meta's LLaMA
  - Anthropic's Claude model
  - Mistral AI's models



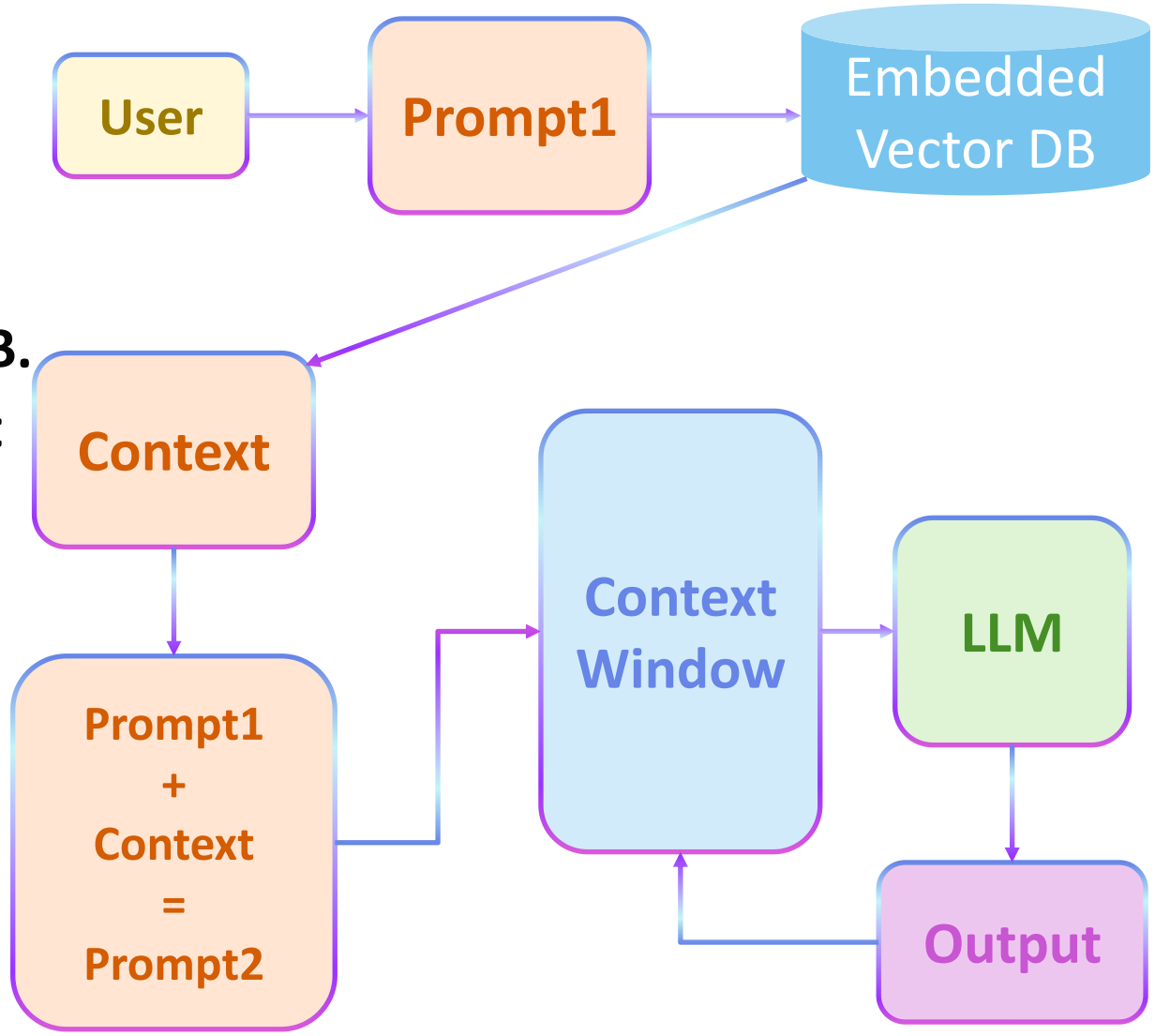
Interfacing with basic LLM prompt

- User initiate session with an initial prompt.
- Prompt goes to LLM context window.
- LLM uses prompt to generate output.
- Output is added to the context window along with additional prompts.



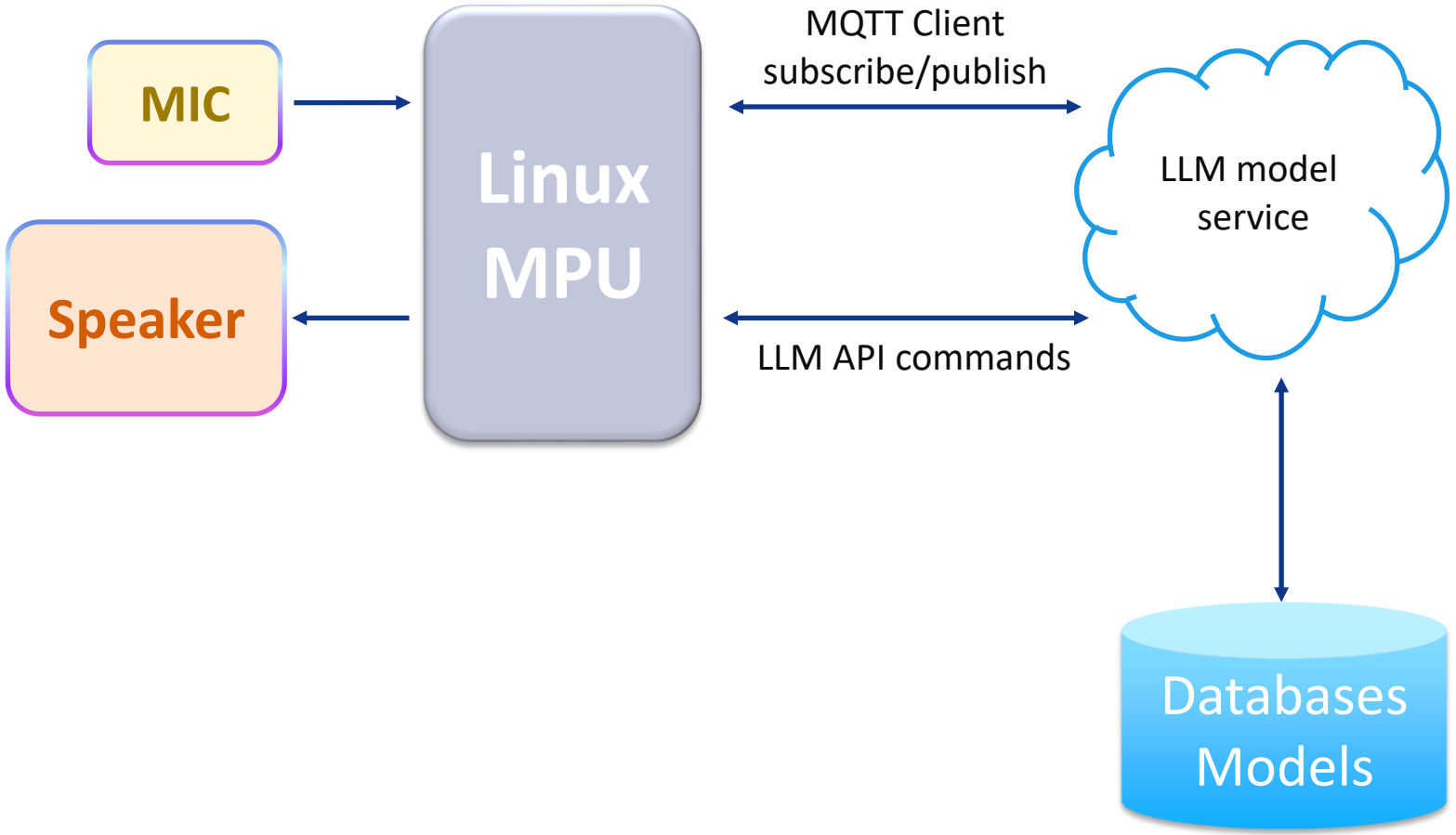
Retrieval Augmented Generation LLM prompt

- RAG provides a performance improvement as compared with LLM alone by reducing bad responses and focusing LLM on relevant data.
- Initiates prompt will search in the vector DB.
- The original prompt is added to the context and the expanded prompt.
- LLM generates output.
- Add New prompts until the output is satisfactory.



Connecting HW to LLM

- Use LLM API's to get answers and return natural language on hardware.
- HW uses inputs from the microphone to take in speech and write text then sends a text prompt to the LLM.
- The LLM responds to the text prompt, then the MPU uses text to speech the read the response out loud on the connected speaker.



Microchip Trademarks

https://www.microchip.com/en-us/about/legal-information/microchip-trademarks

Trademark	Description/Appropriate Nouns	Notes
ClockWorks®	configurator, device, family, product, series	US only
CodeGuard™	security	
CryptoAuthentication™	development library, device, family, IC, library	
CryptoAutomotive™	development kit, security IC, technology	
CryptoCompanion™	chip	
CryptoController™	solution, TPM, trusted platform module	
CryptoMemory®	cryptographic security IC, IC	
CryptoRF®	device, transponder	
dsPIC®	DSC, digital signal controller	
dsPIC®	dsPIC® logo	
dsPICDEM™	demonstration board, development board	
dsPICDEM.net™	board	
Dynamic Averaged Matching™ (DAM™)	architecture	
ECAN™	solution, technology	
Espresso T1S™	device	
EtherGREEN™	family, platform, technology	
EtherSynch®	family, platform, technology	US only
EyeOpen™	cable compensation	
Flashtec®	controller, family, product	US only
flexPWR®	technology	
Frequency on Demand®		Registered in other countries (not US)
GestIC®	controller, sensing, technology	
GridTime™	device, GNSS time server, time server	
HELDO®	family, regulator	
Hyper Speed Control®	architecture, family	US only
HyperLight Load®	mode	US only
In-Circuit Serial Programming™ (ICSP™)	programming capability	
IdealBridge™	dual MOSFET-bridge rectifier, rectifier	
IGaT™	board, demonstration board	
IGLOO®	device, family, FPGA, series	
INICnet™	sniffer, technology	

Note: *Always check with the Legal Department for the most current trademarks.

Trademark	Description/Appropriate Nouns	Notes
IntDrive™	driver board, integrated solution, power module	
Intelligent Paralleling™	technology	
IntelliMOS®	family, power stage family	US only
Inter-Chip Connectivity™	technology	
JitterBlocker™	attenuator, family	
JukeBlox®	platform, technology	
jukeblox®	JukeBlox® registered word mark with a design	Image is not registered; this is a graphic treatment with the registered word mark
KeeLoq®	protocol, security IC, technology	
Kleer®	technology	
KLEER®	Kleer® registered word mark with a design	Image is not registered; this is a graphic treatment with the word mark
Knob-on-Display™ (KoD™)	device, family, HMI, knob designer, position wizard, solution, technology, touch controller, user interface, widget configurator	
LANCheck®	online design review, online review, review	
Libero®	design file, designer, IDE, SoC design suite, software, tool	US only
LinkMD®	cable diagnostics, diagnostics engine, family, technology	
MarginLink™	signal integrity testing	
maxCrypto™	controller-based encryption, encryption	
maxStylus®	solution	
maxTouch®	family, studio, technology, touchscreen controller	
maxView™	driver, storage manager, tool	
MediaLB®	bus, controller, device	
megaAVR®	device, MCU, microcontroller	
memBrain™	neuromorphic memory product, product, solution, technology	
	Microchip logo	Please do not use this logo; always use the Microchip name and logo.

Note: *Always check with the Legal Department for the most current trademarks.

Trademark	Description/Appropriate Nouns	Notes
MICROCHIP	Microchip name and logo	This is the vertical representation; the horizontal representation is also available.
Microsemi	Microsemi logo	Do not use
Microsemi®		Do not use
Mindi™	analog simulator, analog simulator tool	
MiWi™	application, coordinator, mesh, network, protocol, software, stack, wireless networking protocol	
MOST®	board, cooperation, design, device, evaluation kit, NetServices, network, platform, product, specification, system, technology	
MOST®	MOST® logo	
motorBench®	development suite	US only
MPASM™	assembler	
MPE™	device, product	
MPLAB®	**Nouns:** C compiler, compiler, development ecosystem, ICD, ICE, IDE, IPE, in-circuit debugger, in-circuit emulator, integrated development environment, integrated programming environment, library, programmer, server, starter kit, universal device programmer, XC compiler **Tool Names:** AI Edge, Analog Designer, Analysis Tool Suite, Code Configurator, Connect Configurator, Data Visualizer, Discover, Extensions, Harmony, Mindi™, Network Creator, PICkit™, Programmer-to-Go, Programmer-to-Go Mobile App, PTG, SiC Power Simulator, Snap, Xpress	
MPLAB® CERTIFIED	MPLAB® Certified logo	
MPLIB™	librarian, object librarian	

Note: *Always check with the Legal Department for the most current trademarks.

Trademark	Description/Appropriate Nouns	Notes
MPLINK™	linker, object linker	
mSiC™	bare die, diode, gate driver, module, MOSFET, product, solution, technology	
mTouch®	development kit, evaluation kit, library, sensing solution, solution, technology	US only
MultiTRAK™	technology	
NetDetach™	technology	
Omniscient Code Generation™ (OCG)	compilation technology	
OptoLyzer®	network analysis tool, studio, tool	
PIC®	assembler, device, MCU, microcontroller	
PIC32®	PIC32 logo	
PIC64™	PIC64 logo	
PICDEM™	demonstration board	
PICDEM.net™	Internet/Ethernet demonstration board	
PICkit™	debugger, development tool, in-circuit debugger, on-board, programmer, starter kit, tool	
picoPower®	technology	
PICSTART®	development programmer	
PICtail™	board, daughter board	
PolarFire®	device, family, FPGA, kit, SoC, System-on-Chip	
PowerSmart™	designer, development suite, digital control library	
Precision Edge®	family, product family	US only
ProASIC®	architecture, board, family, FPGA, kit	US only
ProASIC Plus®	architecture, device, family, FPGA, switch	US only
Prochip Designer®	software suite	
PureSilicon™	oscillator, technology	
QMatrix™	device, sensor	
QTouch®	board, composer, configurator, device, development platform, library, project builder, sensor, solution, technology, tool	
Quiet-Wire®	enhanced EMI technology, family, technology	

Note: *Always check with the Legal Department for the most current trademarks.

Trademark	Description/Appropriate Nouns	Notes
Ripple Blocker™	attenuator, family of linear regulators, product line, technology	
REAL ICE™	in-circuit emulator	
RTAX™	FPGA	
RTG4™	FPGA	
SAM-BA®	applet, application, host, in-system programmer, ISP, monitor, software	
SAM-ICE™	emulator	
SenGenuity®	product, sensor	
Serial Quad I/O™ (SQI™)	family, Flash device, product	
Silicon Storage Technology®		Japan only
simpleMAP™	protocol	
SimpliPHY™	device, family, product	
SmartBuffer™	device, IC	
SmartFusion®	evaluation kit, FPGA, SoC, System-on-Chip	US only
SmartHLS™	compiler, compiler software, IDE, software	
SMART-I.S.™	technology	
SpyNIC®	device	
SST®	Acronym for Silicon Storage Technology	
SST® A Microchip Technology Company	SST logo	
STK®	starter kit	
storClad™	encryption technology, technology	
SuperFlash®	device, kit, macro, memory, technology	
SuperSwitcher™	buck regulator, family, regulator	
SuperSwitcher II™	family	
Switchtec™	family, product line, switch, technology	
Symmcom®		China only
Symmetricom®		
SynchroPHY™	device, family, product	
SyncServer®	clock, device, instrument, oscillator, server	

Note: *Always check with the Legal Department for the most current trademarks.

Trademark	Description/Appropriate Nouns	Notes
SyncWorld®	ecosystem program, timing	US only
Tachyon®	controller, family, platform, product, technology	
The Embedded Control Solutions Company®		US only; should be in italics
TimeCesium®	primary frequency reference, product	US only
TimeHub®	platform, system	US only
TimePictra®	platform, software suite, synchronization management system	US only
TimeProvider®	clock, enhanced PRTC, ePRTC, extension, system, grandmaster, kit, module, product, series, server, shelf	US only
TimeSource®	PRC, PRS, primary reference clock, primary reference source, shelf, system	
tinyAVR®	MCU, microcontroller	
Total Endurance™	software model	
TSHARC™	controller, touchscreen controller	
Turing™	hardware security module, programmer	
UNI/O®	bus, communication protocol, firmware, hardware port, memory chip	
USBCheck™	design review	
VarISense™	technology	
VectorBlox™	accelerator, intellectual property, IP, platform, SDK, software development kit, solution, tool, tool chain, tool flow	
Vectron®	oscillators, products	
VelocityDRIVE™	CT, configuration tool, product, solution, software platform, SP	
VeriPHY™	cable diagnostics algorithm, cable diagnostics software suite	
ViewSpan™	technology	
WiperLock™	technology	
XMEGA®	Custom Logic (XCL), device, family, MCU, microcontroller, series	
XpressConnect™	retimer	
ZENA™	analyzer, software, wireless adapter	
ZL®		US only

Note: *Always check with the Legal Department for the most current trademarks.

Trademark	Description/Appropriate Nouns	Notes
	Adaptec "a" logo	Registered in other countries (not US)
Adaptec®	adapter, cable, controller, driver, family, product, series, software, solution	
Adjacent Key Suppression™	technology	
AgileSwitch®	device, digital programmable gate driver, driver, family, gate driver	US only
AKS™	technology	
Analog-for-the-Digital Age™	AIPD family tagline	
Any Capacitor™	stable	
AnyIn™	capability, feature, structure	
AnyOut™	capability, feature	
Augmented Switching™	technology	
AVR®	architecture, CPU, device, family, MCU, microcontroller	
AVR®	AVR® logo	
AVR Freaks®	forum	
BesTime®	technology	
BitCloud®	SDK, software development kit	
BlueSky®	firewall, subscription service, technology	
BodyCom™	development kit, system, technology	
chipKIT®	I/O shield, board, hardware, network, platform, software	
chipKIT®	chipKIT logo	
Clockstudio™	application, program, software, utility	

Note: *Always check with the Legal Department for the most current trademarks.

MICROCHIP