

tinyML[®] Summit

Miniature dreams can come true...

March 28-30, 2022 | San Francisco Bay Area



www.tinyML.org

Suitability of TinyML for predictive maintenance in high-tech manufacturing

Prepared for TinyML Summit

March 29th , 2022



Chris Knorowski, SensiML CTO

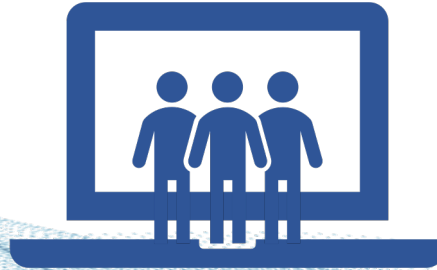
Steven Hauser, Adapdix Director of Product Management

Introduction to SensiML

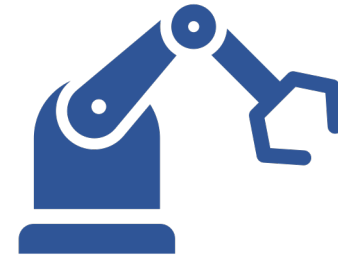
We Sell: TinyML toolkit for Smart Sensors



To: Application developers and system integrators



To enable: rapid development of novel applications for edge devices



SensiML Analytics Toolkit - Market Leading AutoML Technology for IoT Endpoint Algorithms

Introduction to Adapdix

We Enable
Next-level Operational
Efficiency & Cost Savings

45% Avg. Maintenance Savings

50% Avg. UDT Reduction

33% Avg. Cycle Time Savings

20% Avg. UPH Increase

Software For
Autonomous Operations

100's Exabytes of Data Ingested

2000+ Models Deployed

100,000+ Anomalies Resolved

100's of Machines Optimized

Benefitting
Global Leaders

2 of the largest, global
Semiconductor Manufacturers

Top 10 Semiconductor OEMs

Fortune 500 Communication
Companies

Adapdix Enables Autonomous Systems

High-Tech Manufacturing Predictive Maintenance

Case Study

- A leading semiconductor manufacture to add predictive maintenance to a photonic optical alignment manufacturing process

The Challenge

- Unplanned downtime through unexpected equipment or process failure drives high cost and low OEE
- Identifying failure root causes in complex system is challenging without high visibility into all the processes

Implemented multistep process to prevent downtime and improve yield

- Identify issues with the current process leading to low yield
- Identify indications of equipment failure to prevent downtime
- Improved yield by increasing the throughput units/hour
- Once the manufacturing process is finalized, identify deviations/anomalies in behavior

The final solution was successfully deployed on over 100 machines in the factory

Successfully Increased throughput by over 50%

Industrial AI: Advanced Analytics at Scale

Complex Integration, Data and Communications

OEM Equipment



Inputs/Outputs

- Sequencing
- Timing
- Latency
- Control
- Memory
- Computational order
- Anomaly detection
- *Programmable logic*

Synchronization

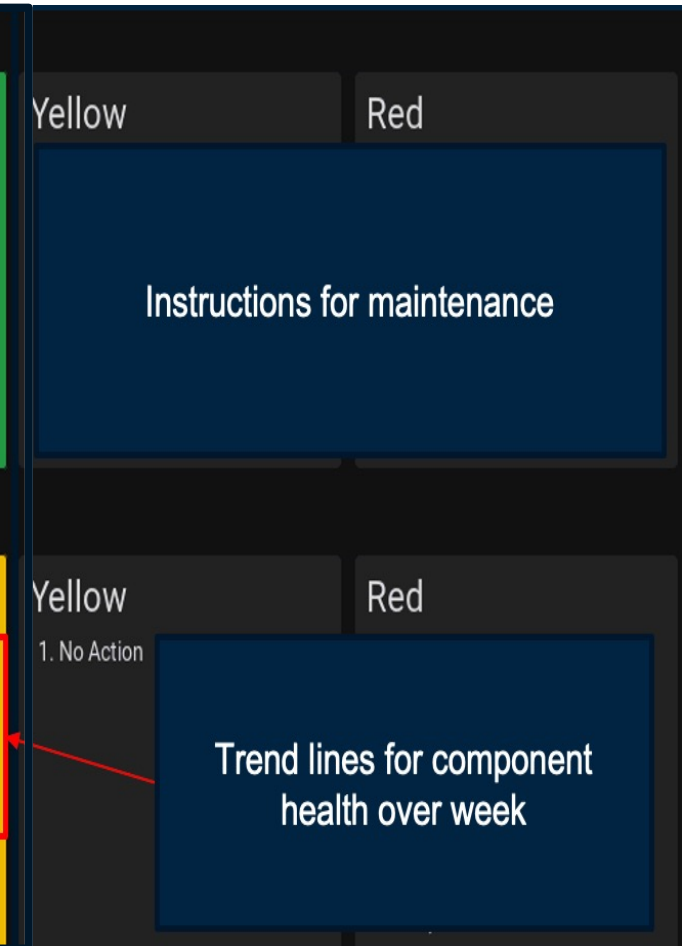
Raw Data and ML Outputs



Summary Health



Preventative Maintenance Actions



Communication

Sensor/Device

Process Application

Automated Action

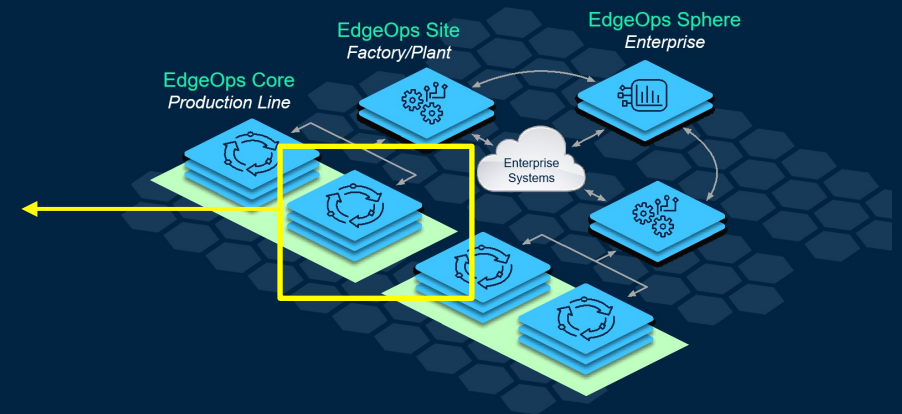
Where Does TinyML Fits into the Solution?

- Using **Adapdix EdgeOps Autonomous Systems Platform** to orchestrate data flow, analytics, monitoring and automate the tool workflow
- Used **SensiML** to build **TinyML** models for real-time time-series classification and **anomaly** identification

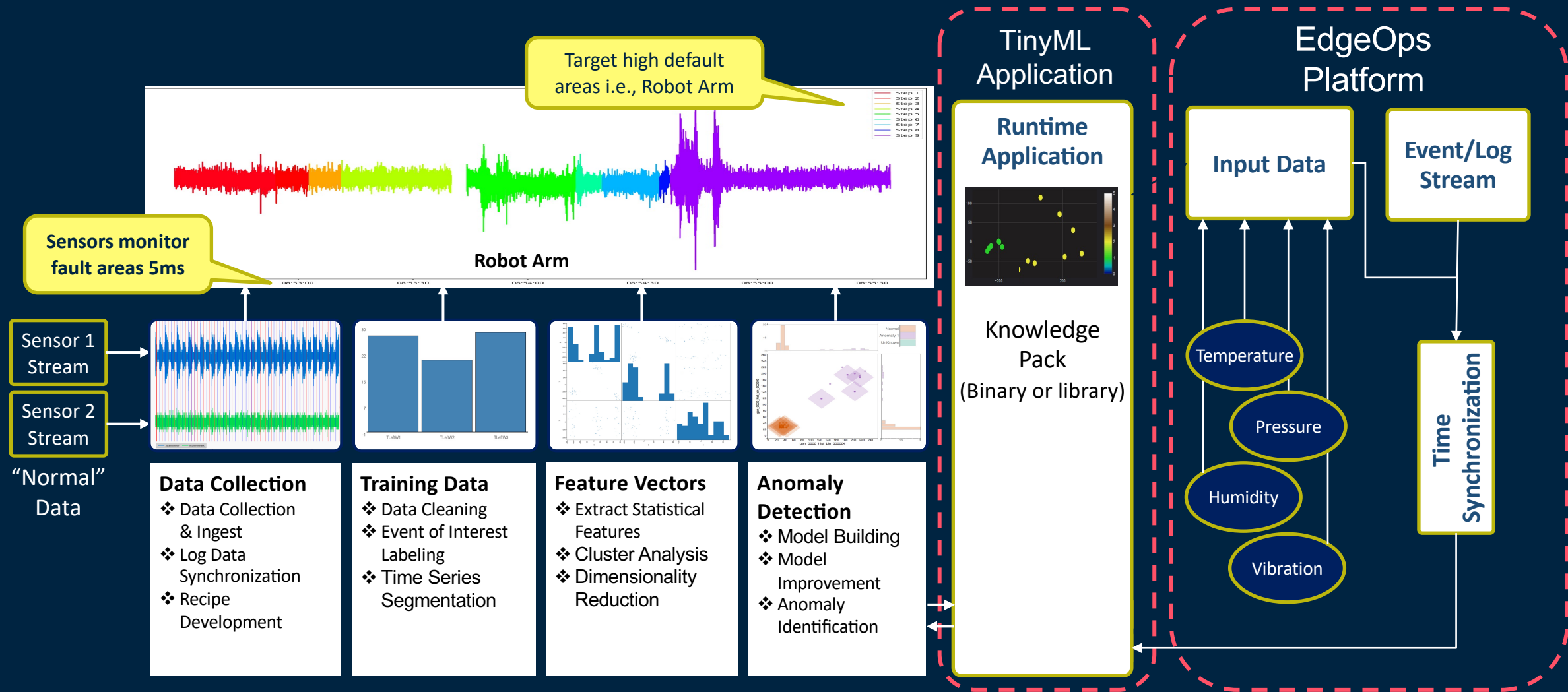
TinyML is only a part of the solution

Makes deploying models easier and provides flexibility in how close ML models can run to the sensor data

Allows you to run multiple models in commodity hardware in real-time



Architecture & TinyML Integration



SensiML Data Capture Lab: Data Curation Made Simple

The screenshot displays the SensiML Data Capture Lab interface, which is divided into several panels:

- Project Explorer:** A table listing collected data files and their status.
- Mode: Label Explorer:** A panel for labeling data segments, showing waveforms and segment boundaries.
- File Properties:** A panel showing metadata for the selected file, including segments and their status.
- Media Player:** A panel for playing the video associated with the selected file.

Project Explorer Table:

Status	Video	File	Segments	Uploaded	Device	Gesture	Robot Arm	sensor	set
●	●	RobotMovement.csv	15	3/15/2022 8:42 AM	RSL10 S	reach_lift	Robot 1	gravity	trair
●		RobotMovement_002.csv	23	3/15/2022 8:42 AM	RSL10 S	reach_lift	Robot 1	gravity	test
●		RobotMovement_003.csv	0	3/15/2022 8:42 AM	RSL10 S	reach_lift	Robot 1	gravity	test
●		RobotMovement_004.csv	0	3/15/2022 8:42 AM	RSL10 S	reach_lift	Robot 1	gravity	test
●		RobotMovement_LiftStand.csv	0	3/15/2022 8:42 AM	RSL10 S	lift_stand	Robot 1	gravity	test
●		RobotMovement_LiftStand_002.csv	0	3/15/2022 8:42 AM	RSL10 S	lift_stand	Robot 1	gravity	test

File Properties Table:

Id	Label	Start	Length	Time	Status
1	Gesture1	189	189	00:00:01:890	●
2	Gesture2	431	232	00:00:02:320	●
3	Gesture4	706	241	00:00:02:410	●
4	Gesture6	1150	75	00:00:00:750	●
5	Gesture7	1273	84	00:00:00:840	●
6	Gesture1	1565	198	00:00:01:980	●
7	Gesture2	1807	229	00:00:02:290	●
8	Gesture4	2082	258	00:00:02:580	●
9	Gesture6	2526	75	00:00:00:750	●
10	Gesture7	2650	99	00:00:00:990	●
11	Gesture1	2942	196	00:00:01:960	●

Time-Series
Mark segment
others based o

Project Explorer
Lists all available data
collected and its status

Metadata Labeling
t classifications and
extual metadata

Annotation Window
ed visual cues about
ensor data waveforms

SensiML Analytics Studio: Efficient AutoML for Edge Sensing

Query Labeled Data

Easily Filter based on metadata

AutoML for Edge AI

Select Feature, algorithm parameters, Tune max model size

Model Visualization

Explore model parameters, visualize features, and model metrics

Test Model

Test Model and validate offline

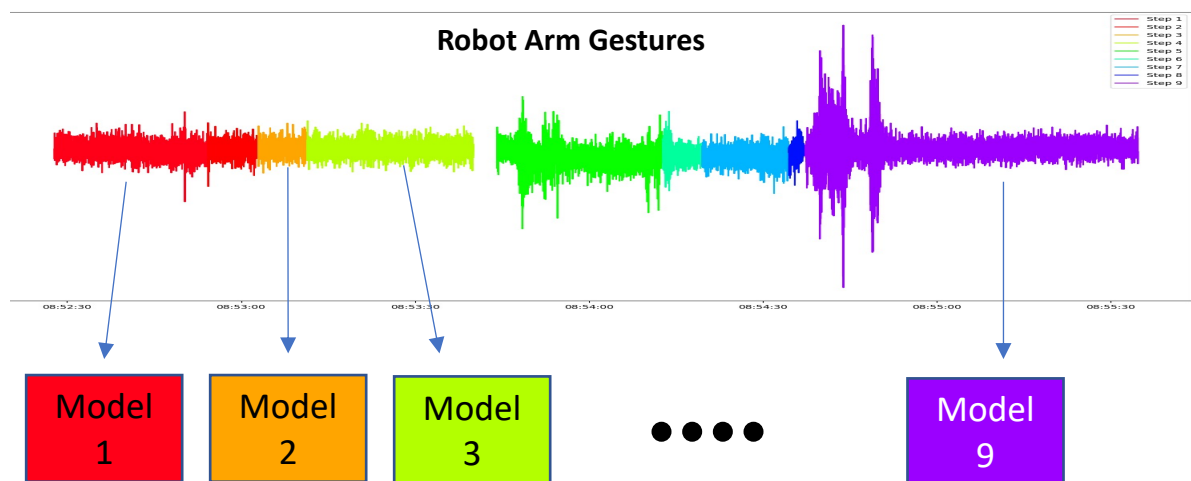
Download Model

Download Library, Binary or Source code optimized for target device

The screenshot displays the SensiML Analytics Studio interface. The top navigation bar shows the project name 'Project: Boxing Glove Gestures Demo' and the user 'chris.knorowski@sensiml.com'. The left sidebar contains a menu with options: Project Summary, Prepare Data, Build Model, Explore Model, Test Model, Download Model, Get Started, Demos, Documentation, and Support. The main content area is titled 'Model: Right_Glove_Gestures_rank_4' and features a 'Download Knowledge Pack' section. This section lists 'Target Device Options' with dropdown menus for HW Platform (ARM GCC Generic), Processor (ARM Cortex M4), Float Options (Hard FP), Compiler (GNU Arm Embedded (none-eabi) 9.2.1), Format (Library), Data Source (Arduino BLE AccGyro), Application (SensiML AI Model Runner), and Output (Serial). Below these options is an 'Advanced Settings' link and a large blue 'DOWNLOAD' button. To the right of the download options is a 'Knowledge Pack information' section. This section includes a 'Class Map' with buttons for 1 - Cross, 2 - Hook, 3 - Jab, 4 - Overhand, 5 - Unknown, and 6 - Uppercut. It also lists 'Sensor configurations' with details for Name (Arduino BLE AccGyro), Plugin (Nano33 BLE Sense), Sources (Name: Motion, Sample Rate: 119, Sensors: Accelerometer, Gyroscope), and 'Application' details (Name: SensiML AI Model Runner, Description: Provides example code to feed sensor data into a SensiML Knowledge Pack model). At the bottom right, there is a 'Device Profile Information' section showing 'Estimated Memory Usage' (SRAM Used: 2400 Bytes, Stack Size: 790 Bytes, Flash Used: 4359 Bytes) and 'Estimated Latency' (Feature Extraction Latency: 141050 (1.76313 ms), Classifier Latency: 11000 (0.13750 ms), Total Latency: 152050 (1.90063 ms)).

SensiML Python SDK

- Programmatic access to model building
- Python API for data visualization and manipulation



Pipelines 🔗

A pipeline is a container for a series of data processing steps. The pipeline object allows you to get an existing pipeline or create a new one with a given name. With this object, you can set input data sources, add transforms, feature generators, feature selectors, feature transforms and classifiers. An example pipeline is shown below.

Examples:

```
client.pipeline = 'my_pipeline'

client.pipeline.set_input_query('ExampleQuery')

client.pipeline.add_transform('Windowing')

# Feature Generation
client.pipeline.add_feature_generator(
    [
        {'subtype_call': 'Time', 'params': {'sample_rate': 100}},
        {'subtype_call': 'Rate of Change'},
        {'subtype_call': 'Statistical'},
        {'subtype_call': 'Energy'},
        {'subtype_call': 'Amplitude', 'params': {'smoothing_factor': 9}}
    ]
)
```

Multi Model Knowledge Pack

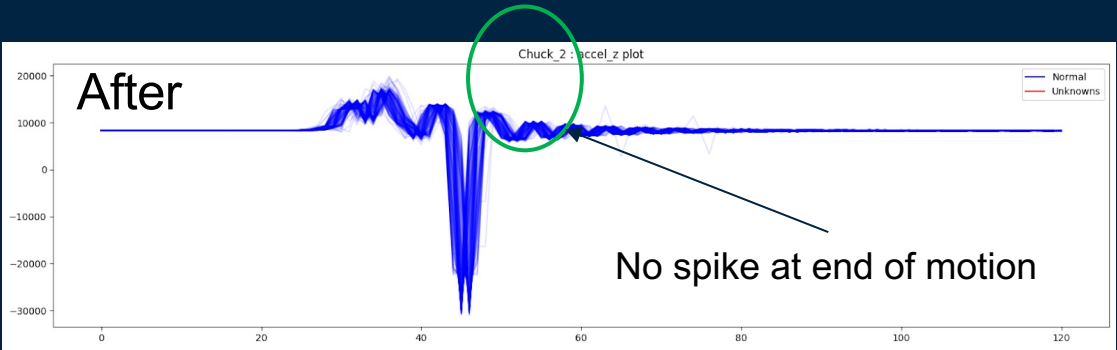
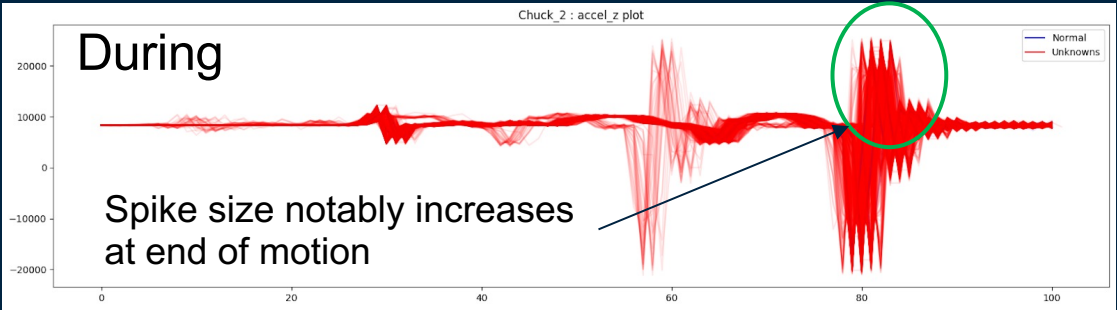
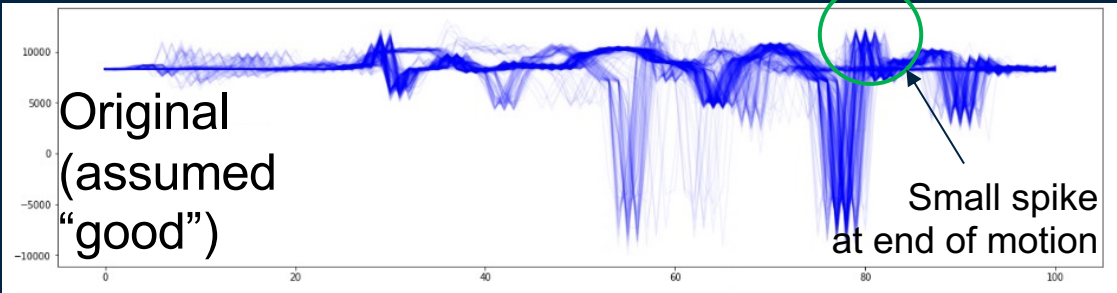
If you want to download multiple Knowledge Packs at once you will need to use the programmatic interface. Models can either be Parent or Children Models. Parent models require a **source**. Children models require a **segmenter_from** and **parent** flag. Optional flags are **results** which allows a **Child** model to be called depending on the output of a Parent model.

The model graphs are defined in the kb_description. The format for multiple parent models is as follows:

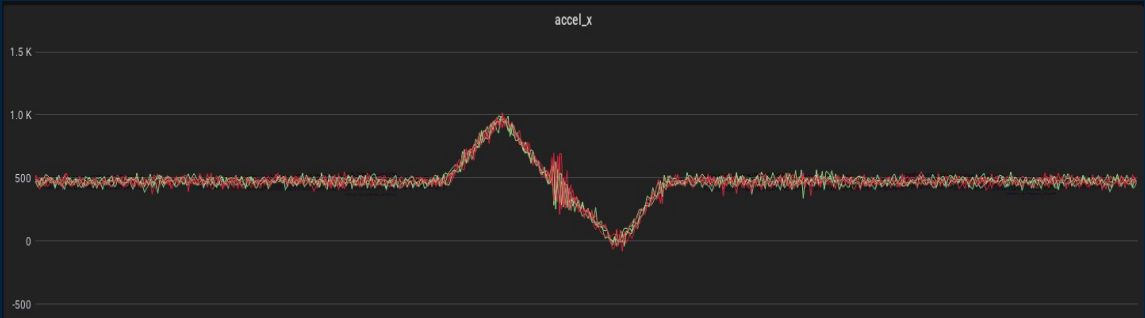
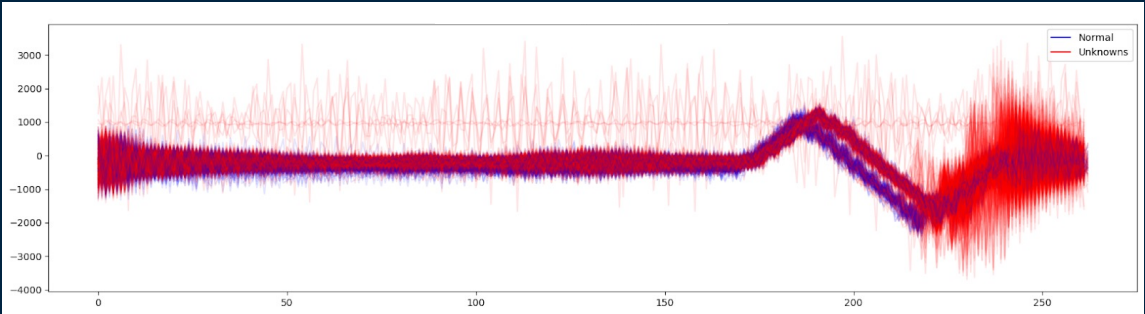
```
{
  "MODEL_1": {
    "source": "<CAPTURE CONFIG UUID>",
    "uuid": "<Model UUID>"
  },
  "MODEL_2": {
    "source": "<CAPTURE CONFIG UUID>",
    "uuid": "<Model UUID>"
  },
  "MODEL_3": {
    "source": "<CAPTURE CONFIG UUID>",
    "uuid": "<Model UUID>"
  }
}
```

Preventative Maintenance Around Equipment Motion

Pneumatic Actuators



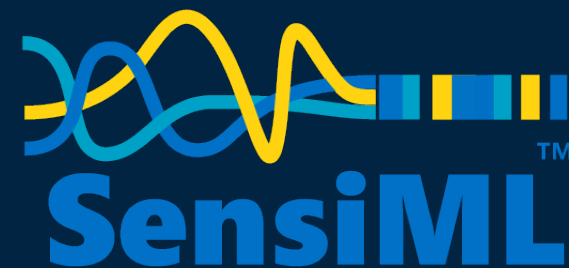
Linear Motor Stage



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support@sensiml.com

<https://sensiml.com>

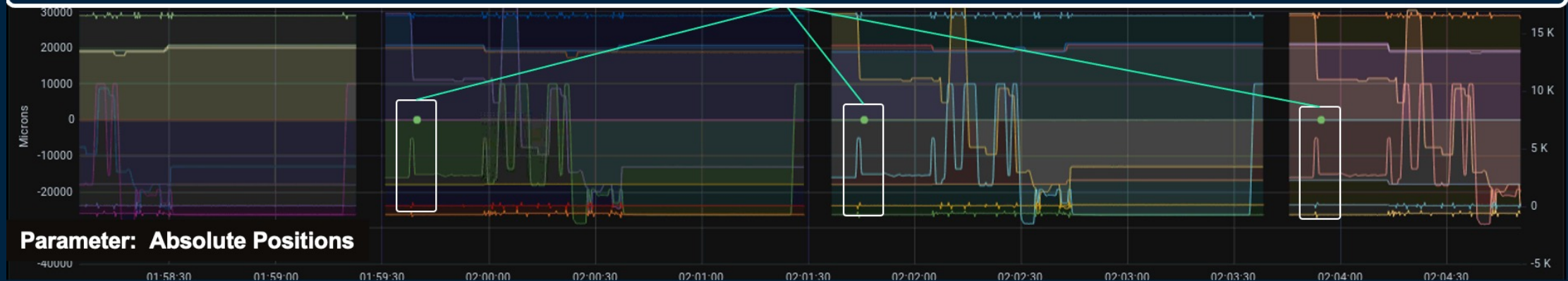
Chris Knorowski
chris.knorowski@sensiml.com

Additional Detail

Unit-level Fault Traceability



Tag, correlate, monitor and trace unit-level faults/anomalies for any parameter(s)

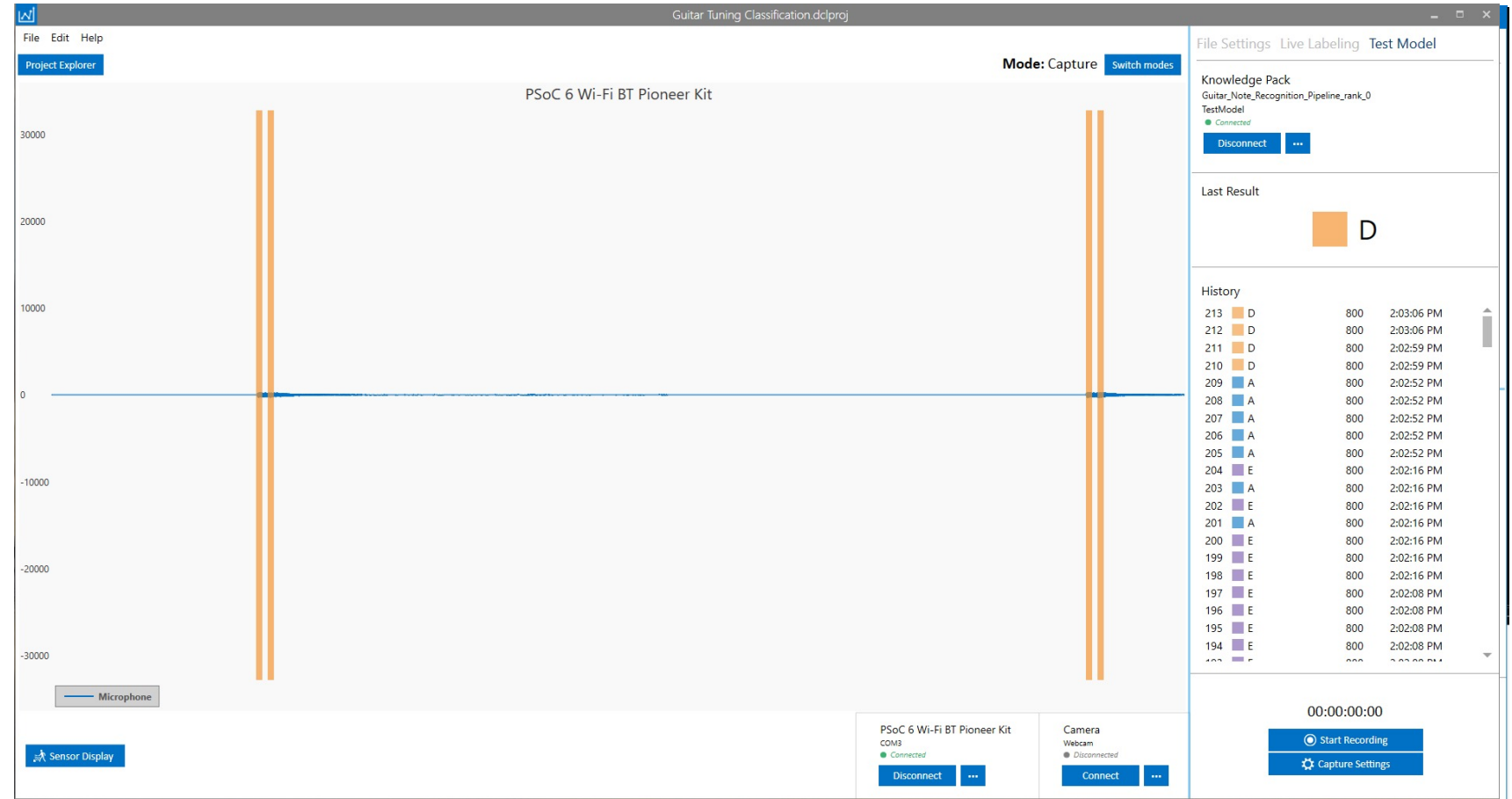


Vibration Use Cases











SensiML Data Capture Lab: Data Collection and Validation

- Capture Sensor Data:
 - WiFi/TCP/IP
 - BLE
 - USB Serial Port
 - Import CSV, WAV
- Easily Collect Metadata
- Programmable File Naming
- Live Labeling
- Real Time Model Validation
- Video Capture/Synchronization



EdgeOps Platform: Key Features & Benefits

Features		Benefits	
	Millisecond Synchronization and Stitching of IT and OT Data		Autonomous systems control minimizes waste, improves throughput
	No-Code Configuration, Reporting, Alerts, and Analytics		Easy to use , up to the second visibility saves time and money.
	Separated, but Integrated Computing and Storage		Optimizes your Hybrid Cloud environment to reduce costs while increasing visibility
	Optimized Data Routing across Edge and Cloud Endpoints		Reduces costs of infrastructure and storage

Equipment Improvement Area

Improvement approach:

- Model Power readings
- Alert if anomalies exceed 15%

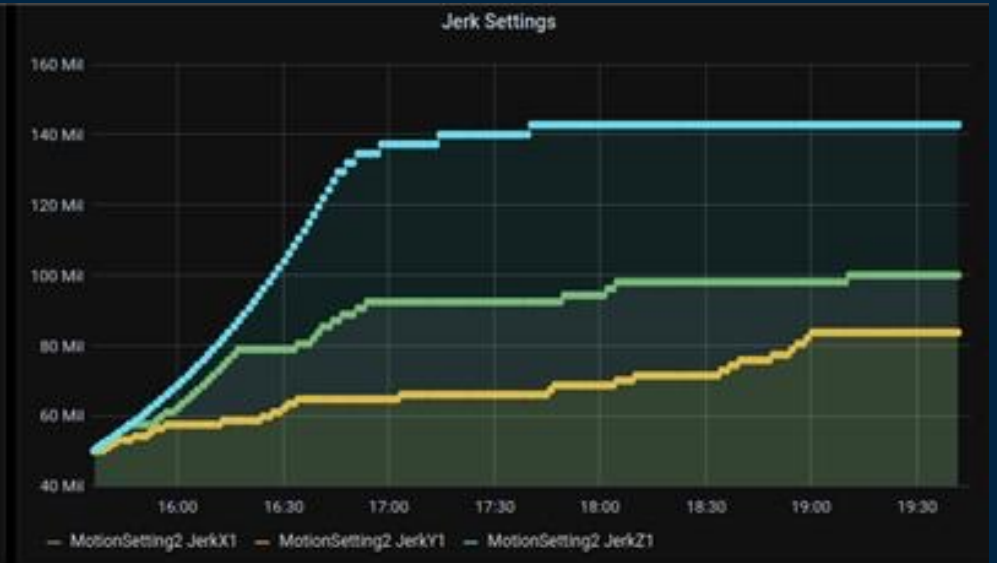
Benefit:

- Decrease downtime due to Low Power



Adaptive Controls

EdgeOps
Feedback



Equipment
Changes





AONdevices

arm

ASPINITY

brainchip
The Neuromorphic Computing Company

CEVA®

Deeplite

EDGE IMPULSE

emza
visual sense

FotaHub

GREENWAVES
TECHNOLOGIES

Grovetly Inc.

Himax

HOTC

imagimob

infineon

itemis

KLIKA·TECH
GLOBAL IOT SOLUTIONS

LatentAI

LATTICE
SEMICONDUCTOR

Micro.ai

OmniML

NXP

POI

Plumerai

PROPHESSEE

Qeexo

Qualcomm

Rackner

RealityAI®
Engineering Solutions for the Edge

REEXEN
technology

RENESAS

SAP

seeed
The IoT Hardware Enabler

SensiML

Sony Semiconductor
Solutions
Corporation

ST
life.augmented

SA STREAM ANALYZE

synaptics®

SynSense

SYNTIANT

Tensil.ai

TensorFlow

XMOS

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