PHM for Manufacturing Industry with IoT and Cloud Platform

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UNIST

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- Monitoring System for Smart Factory
  - Internet of Things (IoT)
  - Cloud Computing
- PHM with IoT and Cloud Platform
  - IoT Sensors
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  - Communication to Cloud Platform
  - Web-based Display Dashboard
- Conclusion

PHM Status on Current Factory Floor

- PHM (Prognostics and Health Management)

- Machinery-dependent PHM
  - Installed as the machinery is designed
- Centralized data center for PHM
  - Inefficiency in data management
- PHM only available for core components
  - Maintenance not available for many of the equipment
- Snapshot data acquisition
  - No historical data considered
- Decision-making based on thresholds
  - Low accuracy for PHM results

PHM for Smart Factory

- Increased factory complexity and diverse productions
  - Increase in loss cost due to unforeseen failures and accidents
  - Increased importance of the equipment maintenance field
- Importance of managing factory data (massive data)
- The advent of the Smart Factory
  - Need for new communications and computing technology
    - Internet of Things (IoT) and Cloud Computing
  - Lead to changes in PHM

Internet of Things (IoT)

- Technology that connects all sorts of things (Embedded Systems) to the Internet

- Connection network between things forming an intelligent network for sensing, networking, and data processing
  - **Sensing Technology**
  - Wire-wireless communication and network infrastructure technology
  - IoT service interface technology

- Sensors can be equipped for data acquisition
  - Acceleration, gyro, camera, temperature, etc.

- Applicability of PHM on factory floor

http://efergy.com

Cloud Computing

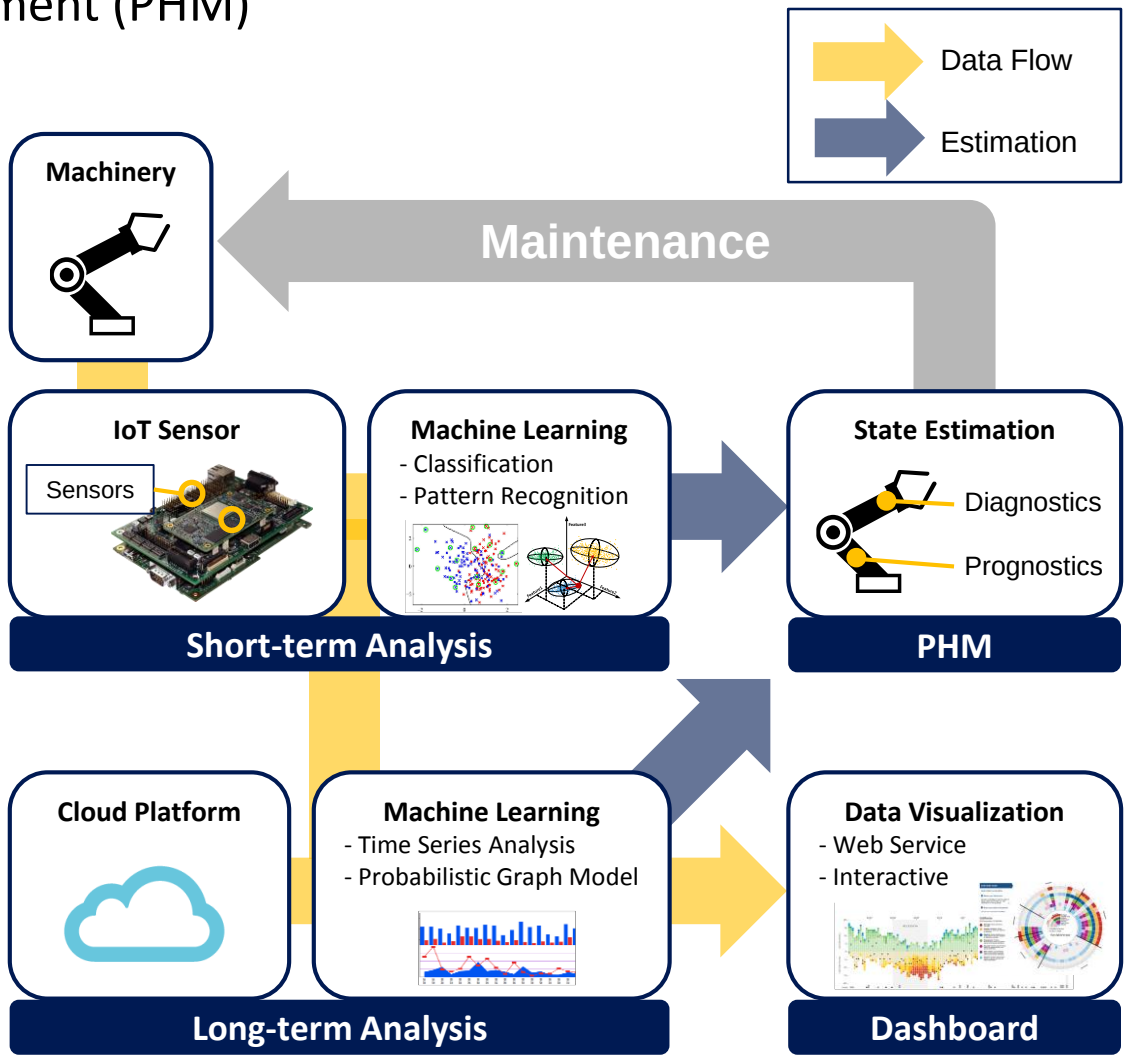
- Internet-based computing technology
  - Web based-software service where the program is set within the Internet utility data server and executed only when used
  - On-demand Computing
  - Reduction in system management costs

- Cloud Platform
  - Set of technologies and toolset that are needed when developers create applications that are run within the cloud or utilize the services provided by the cloud
  - Server construction possible with low cost and manpower
  - Services provided by companies such as IBM, Google, and Amazon

IBM	Google	Amazon
		

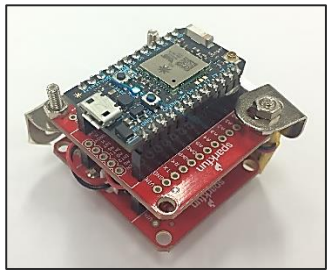
PHM with IoT and Cloud Platform

- Prognostic Health Management (PHM)
  - Short-term Analysis
    - IoT Sensors
    - Local
    - Analysis of current health
    - Fault mode classification
  - Long-term Analysis
    - Cloud Computing
    - Integrated
    - Trend analysis based on utilization of accumulated data
    - Time series and causality analysis
- Display Dashboard
  - Data Visualization
    - Intuitive Information
    - Interactive Information
  - Web-based Service



IoT Sensors

- IoT system composition
  - Wi-fi microcontroller
  - IMU accelerometer
  - Li-Ion battery



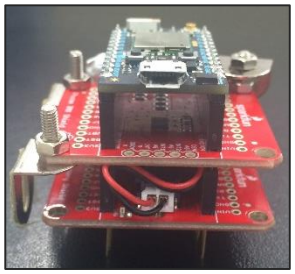
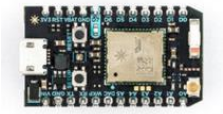
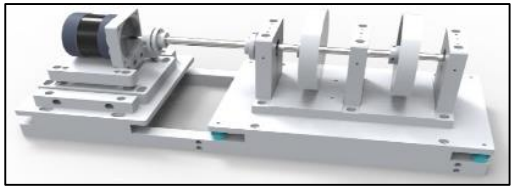
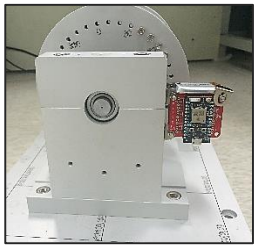


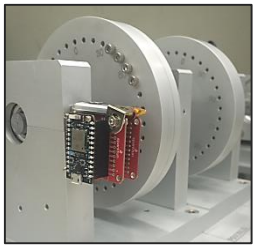
	Image	Specifications
Particle Photon		Broadcom BCM43362 Wi-Fi chip STM32F205 120Mhz ARM Cortex M3 1MB flash, 128KB RAM https://store.particle.io/
IMU Sensor		3 acceleration channels 16-bit data output 1 kHz Sample Rate https://www.sparkfun.com

* Wi-fi Communication Maximum Speed : 11 MBit/s

- Acquisition of Training Set
  - Rotor testbed made by Signallink Inc.



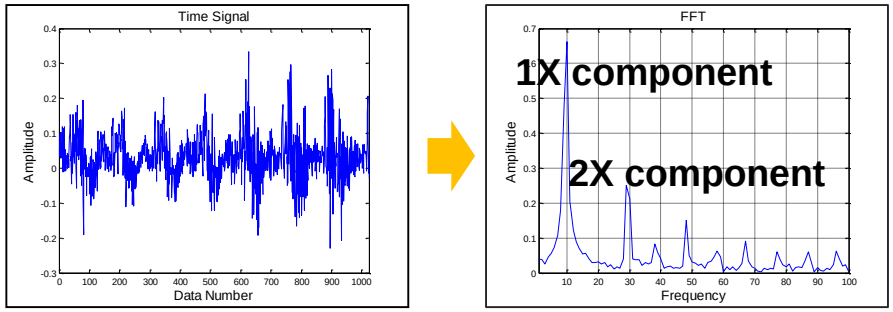


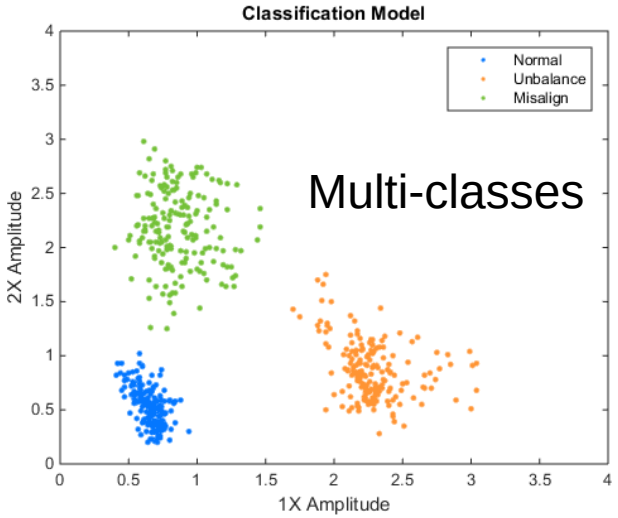


Rotor Testbed			
RPM	1500		
Fault Mode	Normal	Unbalance	Misalignment
Sensor Position	Bearing Housing		
Sensor	X-axis accelerometer		
Sample Rate	1 kHz		

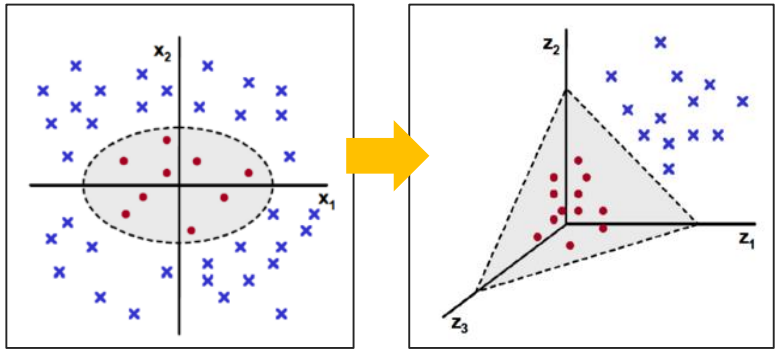
Machine Learning for PHM Algorithm

- Generate Feature Space
  - Feature : 1X Amplitude, 2X Amplitude

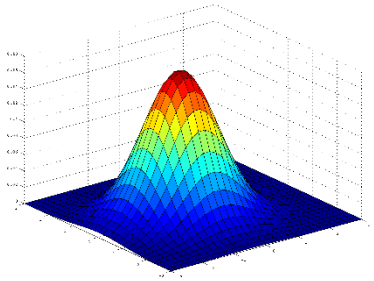




- Linear classification for non-linear data
  - Kernel Trick
  - Radial Basis Function (RBF) Kernel



Data becomes linear separable in high-dimensional space



$$K(x, x') = \exp\left(-\frac{\|x - x'\|^2}{2\sigma^2}\right)$$

Machine Learning for PHM Algorithm

- Logistic Regression for multi-classes
  - Multi-class classification
  - Using softmax function

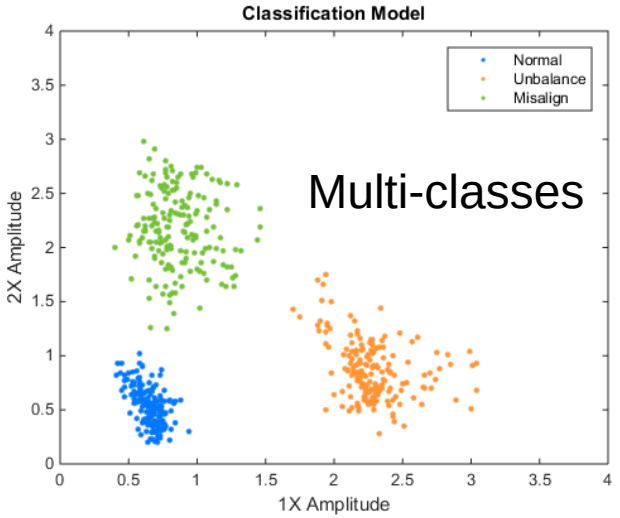
$$P\left(y=j \mid x^{(i)}\right)=\frac{\exp\left(\theta_j^T x^{(i)}\right)}{\sum_{l=1}^{k}\exp\left(\theta_j^T x^{(i)}\right)}$$

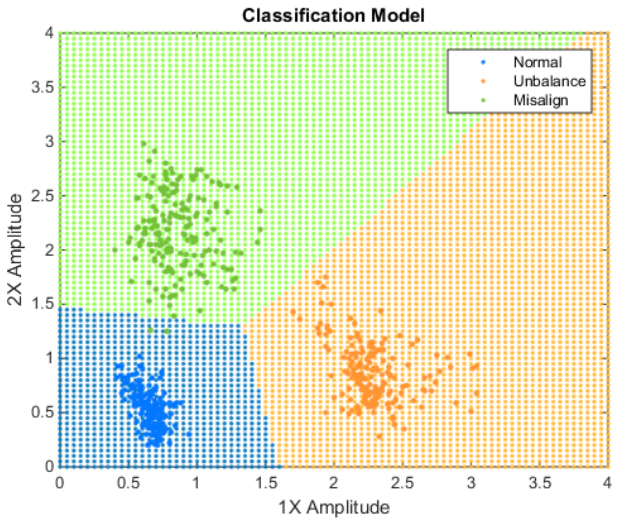
j : class
k : class number
x : feature vector

$$J(\theta)=-\frac{1}{m}\left[\sum_{i=1}^{m}\sum_{j=1}^{k}1\left\{y^{(i)}=j\right\}\log\frac{\exp\left(\theta_j^T x^{(i)}\right)}{\sum_{l=1}^{k}\exp\left(\theta_j^T x^{(i)}\right)}\right]$$

- Optimization

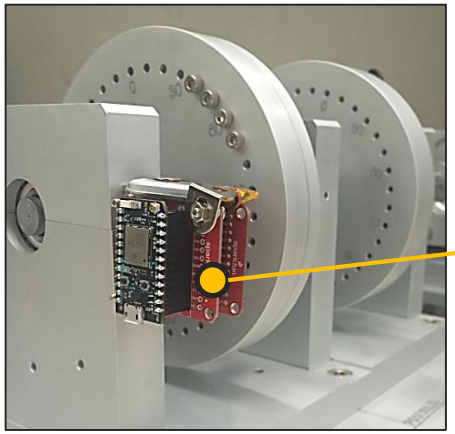
$$\min_{\theta} J(\theta)$$

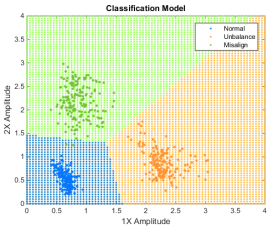


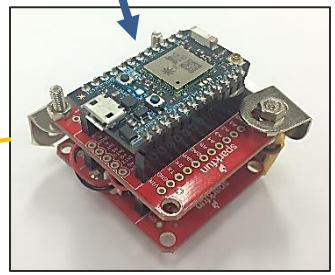


IoT Sensor with Machine Learning Embedded

- Algorithm embedded (C++)
  - Feature Extraction Function
  - Classification model

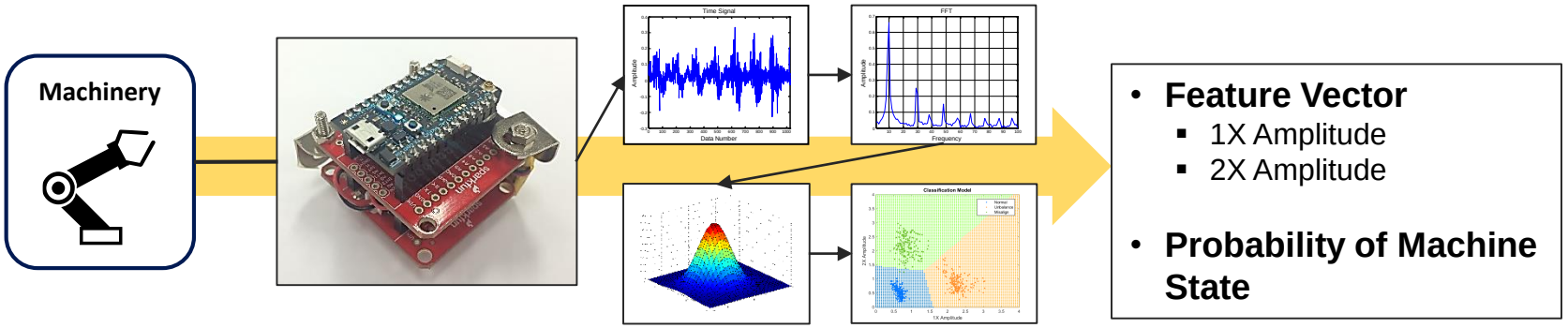






- Data Acquisition
- FFT
- RBF Kernel
- Logistic Regression

- Real-time data processing

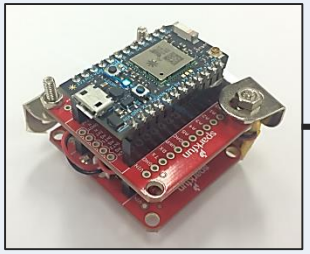


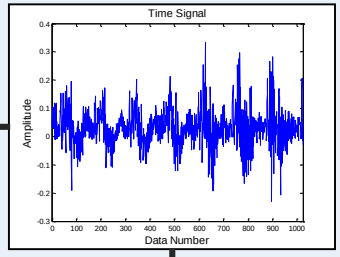
- **Feature Vector**
  - 1X Amplitude
  - 2X Amplitude
- **Probability of Machine State**

IOT-based PHM Framework

Machinery

IoT with Machine Learning





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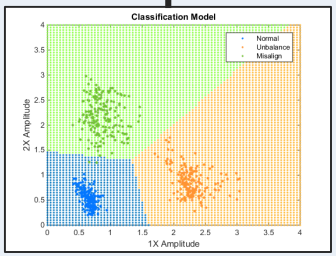


Cloud Platform

- Web-based Service
- Data Visualization

- **Intuitive Information**
- **Access Through Various Devices**

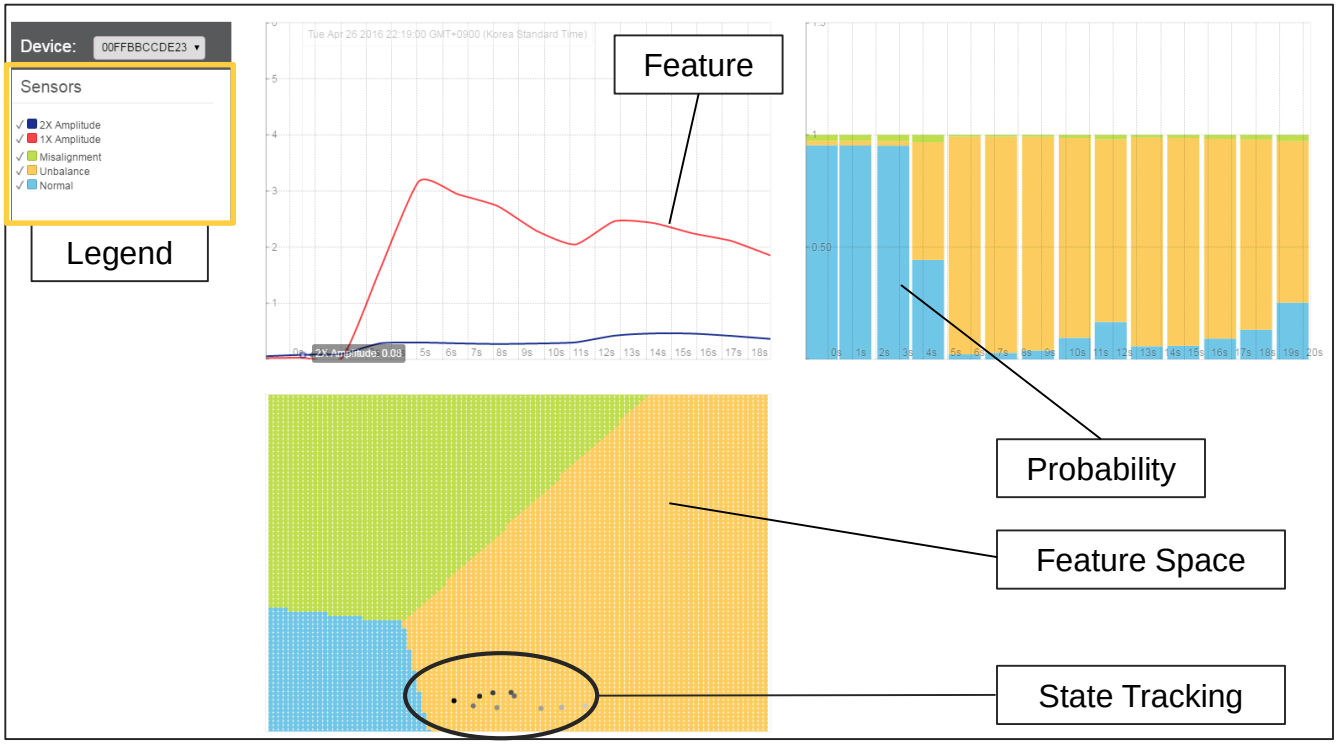
Data compression

- **Feature Vector**
  - 1X Amplitude
  - 2X Amplitude
- **Probability of Machine State**

Not raw data, but health information

Web-based Dashboard

- Web based service using Cloud Server
  - Accessible with mobile devices or computers
- Feature Information
- Probability of Machine state



Desktop web browser

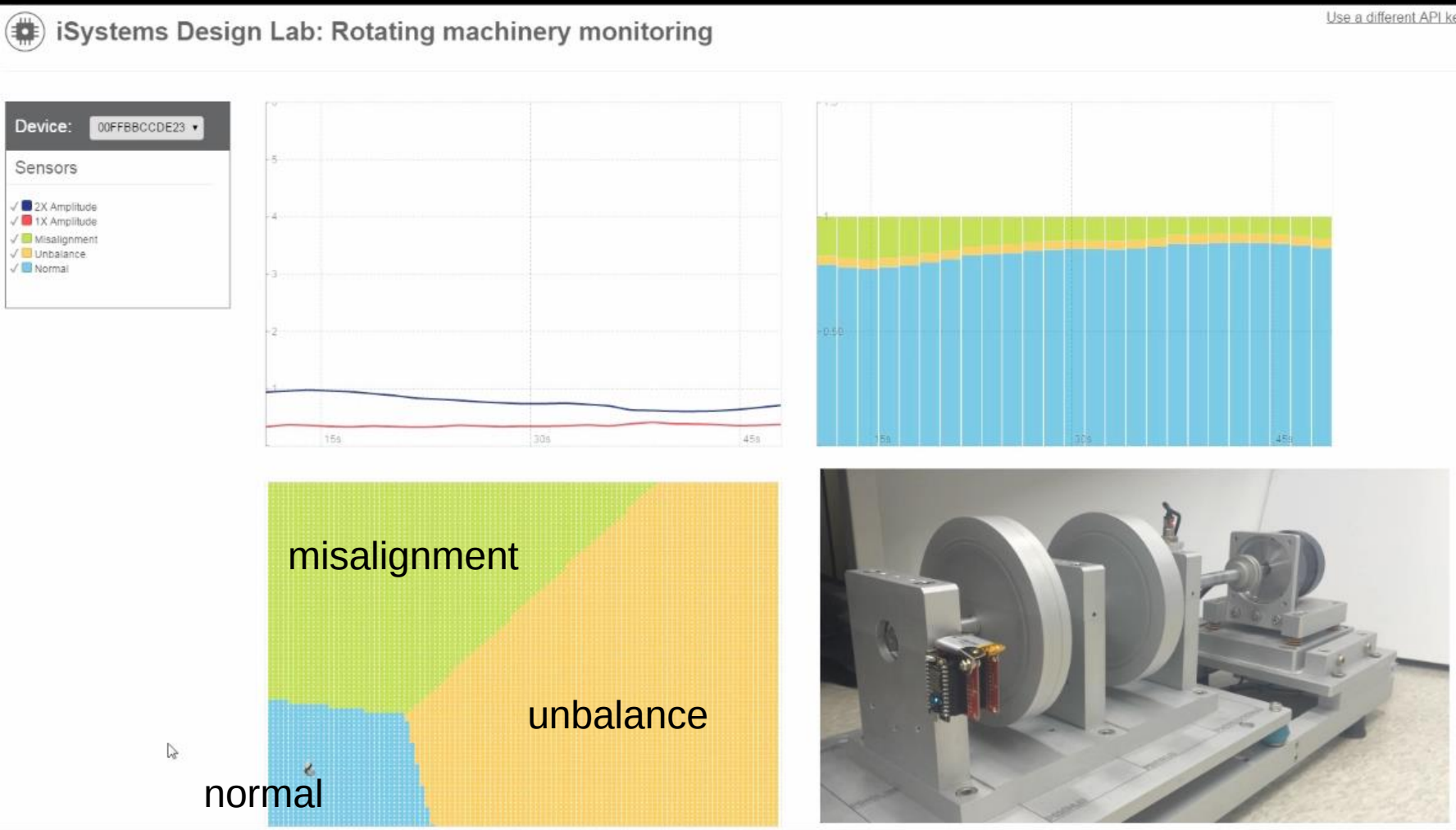
Mobile devices

Demo

Demo: Normal


iSystems Design Lab: Rotating machinery monitoring
Use a different API key and Auth Token
Device:
00FFBBCCDE23
Sensors
2X Amplitude
1X Amplitude
Misalignment
Unbalance
Normal
misalignment
unbalance
normal

Demo: Normal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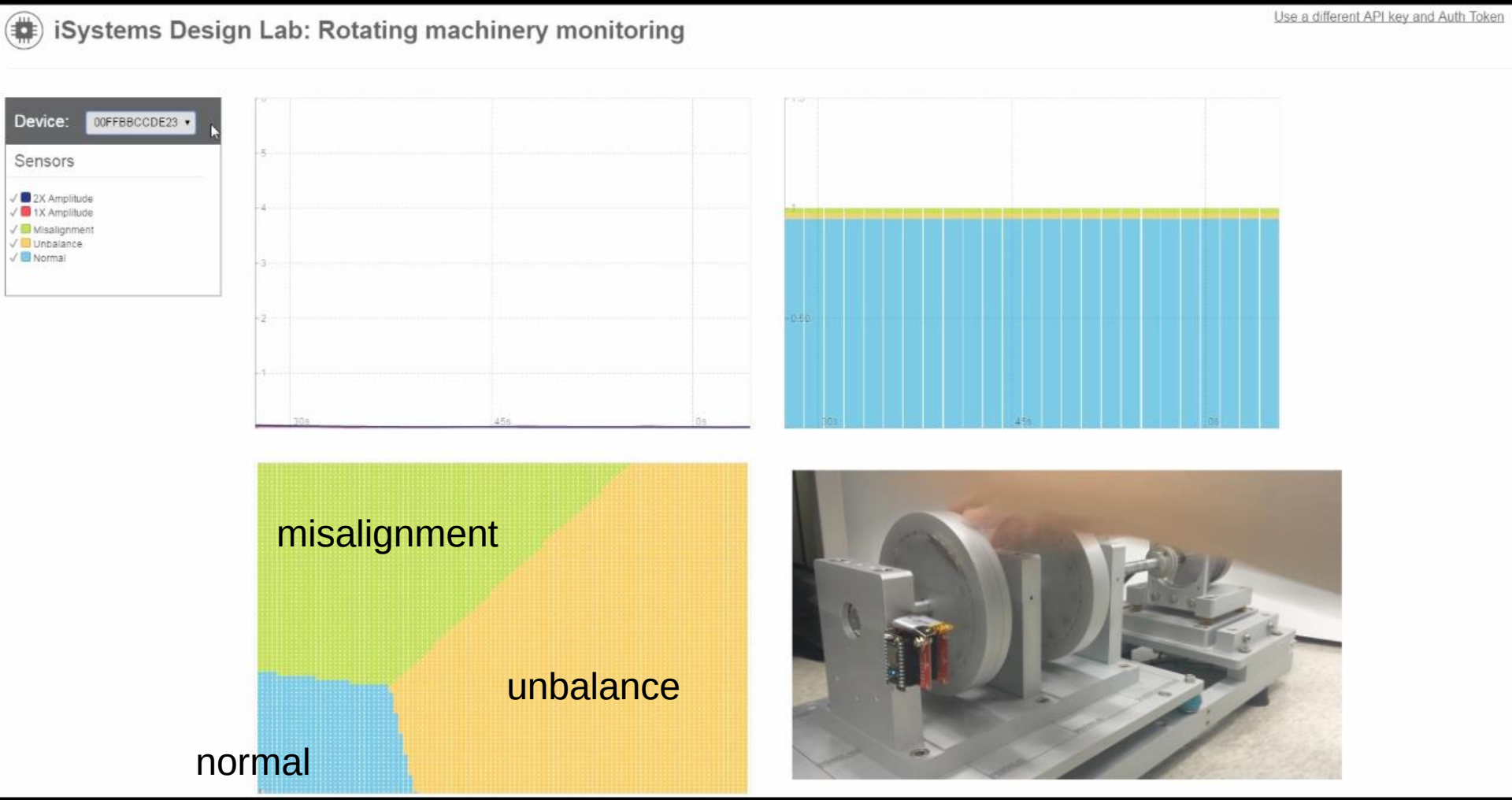
Unbalance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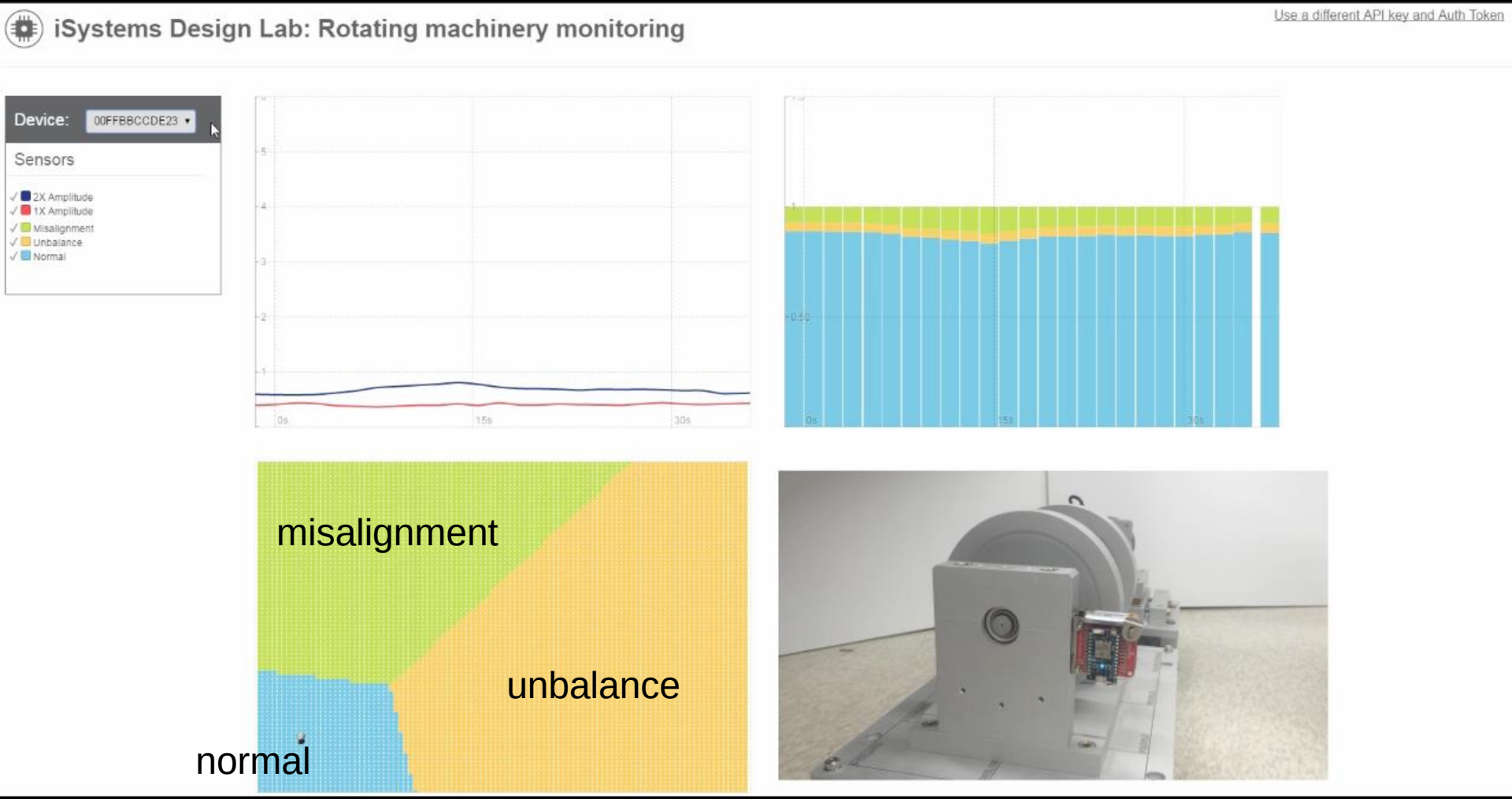
Misalignment



Conclusion

- Build sensors based on IoT and machine learning algorithms
  - Wire-less data acquisition
  - Feature Extraction
  - Non-linear and multi-class classification
  - Short-term Analysis

- Utilize Cloud Platform

- Future plans
  - Implementation of long-term analyses utilizing cloud resources
    - Trend analysis of machinery using time data
    - Causality analysis of machinery based on accumulated diagnosis data
  - Machinery diagnosis based on sensor networks
    - Diagnosis algorithm using multiple IoT sensors
    - Comparison and combination of data between machinery