Electric Drives & Motor Control with Predictive Maintenance

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Run to Failure Maintenance – what is it?

> When a machine breaks down, fix it

> If it ain't broke, don't fix it

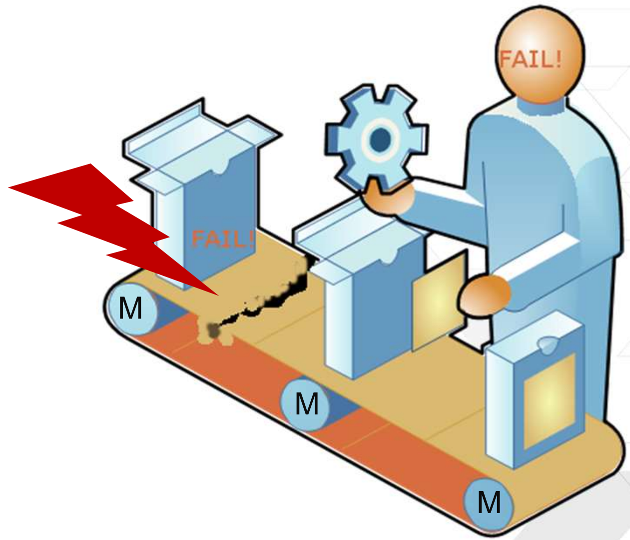
> Reactive management technique "fire fighting"

> The most expensive maintenance management

  > Unscheduled shutdown

  > Emergency maintenance team calls

VERY BAD

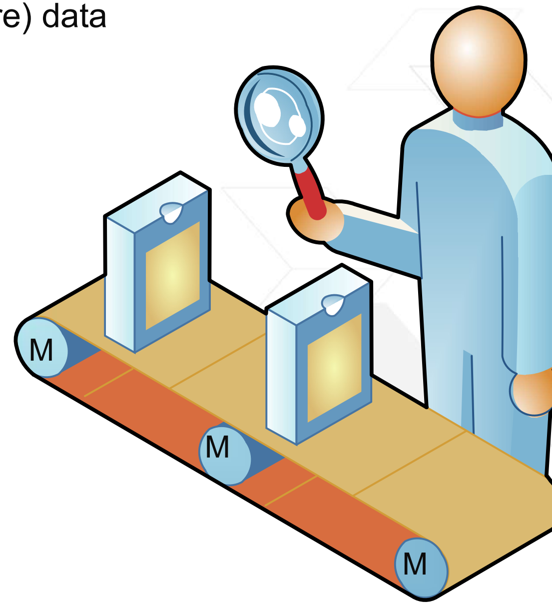


Scheduled Maintenance - what is it?

COSTLY
UNNECESSARY REPAIRS

- Time based maintenance using **MTTF** (Mean Time To Failure) data
- Identified critical assets likely to fails and estimate MTTF
- Use asset inspection (Proof Test) at scheduled time
- MTTF of a product changes with its use:
  - Pumping water
  - Pumping salt water
  - Pumping dirty water

  Different MTBF
- Can produce costly shut-down if done too early
- Can fail catastrophically using generic MTBF



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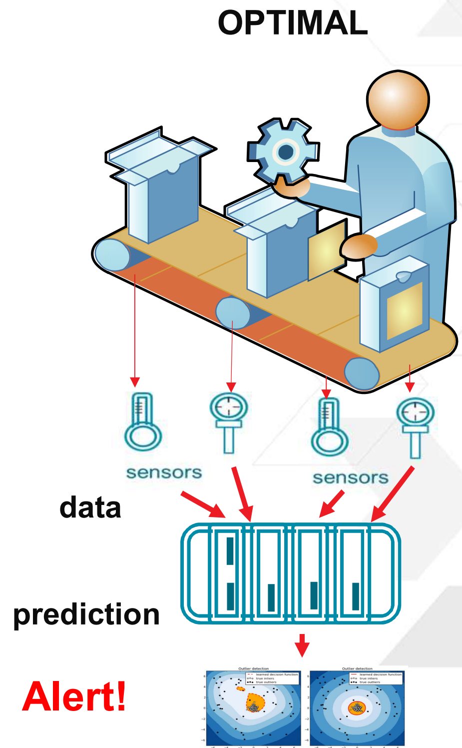
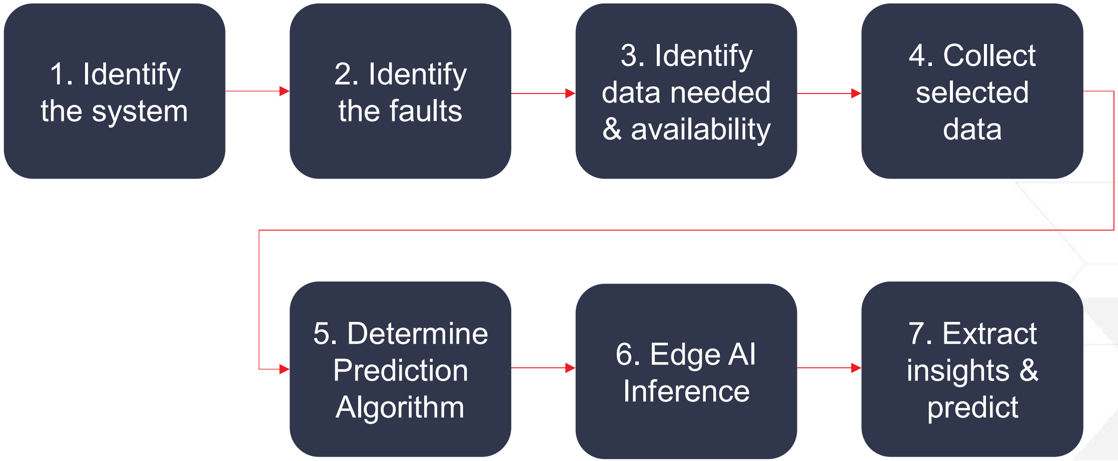
Predictive Maintenance – what is it?

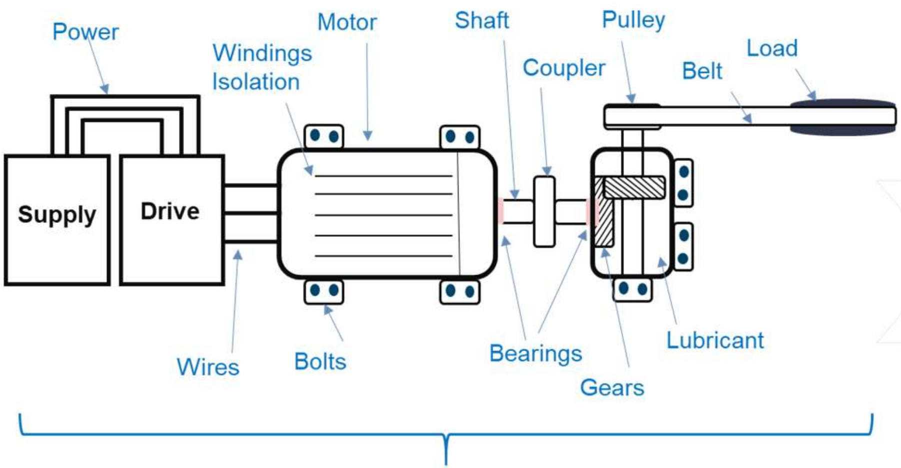
- **Method for timely maintenance execution**
- **Additional Benefits**
  - Optimum Availability
  - Optimum Operating Conditions
  - Optimum Utilization of Maintenance Resources
- **Uses sensors to continuously collect asset data**
  - Sensors already available in the system
  - Sensors deployed for the maintenance
- **Estimate maintenance with prediction algorithms**
  - Model Based
  - Rule Based
  - Machine Learning Based



7 Steps to Prediction



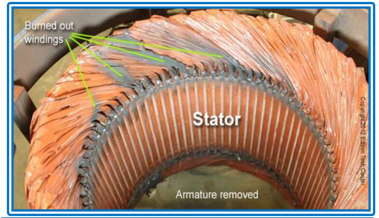
Step 1. Identify the system
Use Case – Power Train

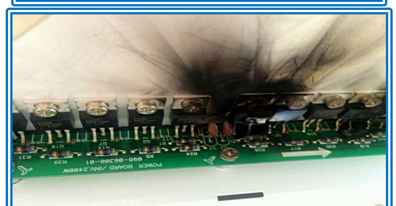


The system

Step 2. - Sources of Faults

- **Electrical faults**
  - Open or short circuit in motor windings
  - Isolation degradation
  - High resistance contact to conductor
  - Wrong or unstable ground
- **Mechanical faults**
  - Broken rotor bars or magnet
  - Cracked end-rings
  - Bent shaft
  - Bolt loosening
  - Bearing failure
  - Gearbox failure
- **Outer motor drive system failures**
  - Inverter system failure
  - Unstable voltage/current source
  - Shorted or opened supply line

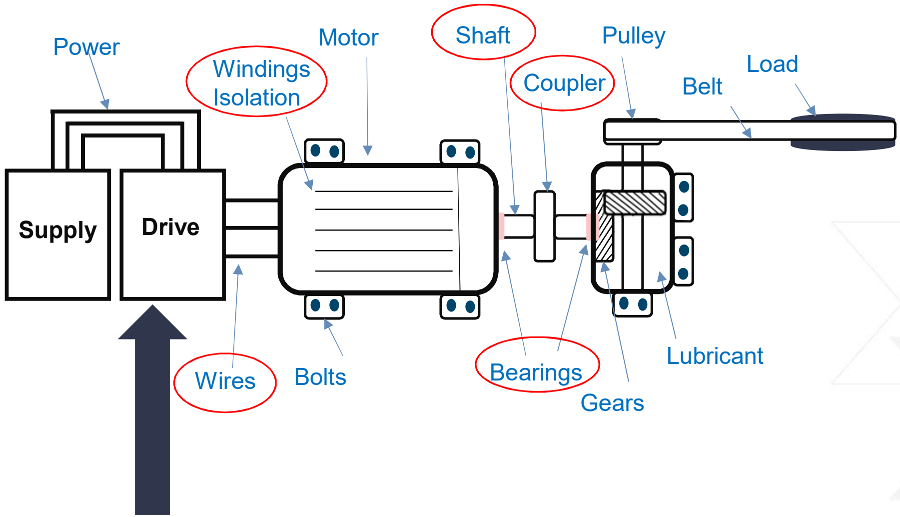




MANY FAILURE MODES

MANY DATA SETS FOR FAILURES AND NORMAL BEHAVIOUR

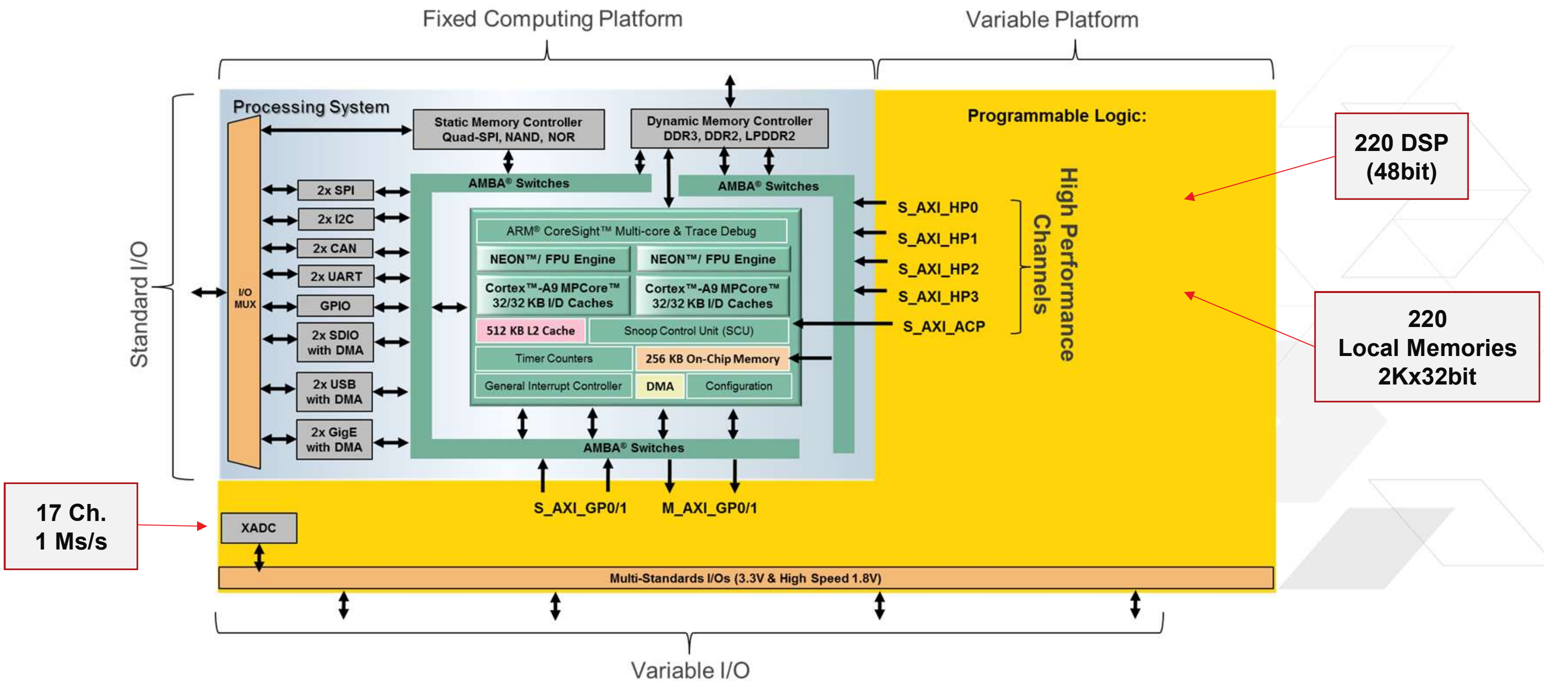
STEP 3. Identify data needed and data availability



Using the Drive's variables for prediction

Step 4. - How do we collect the data?

Platform 1: Zynq-7000 All Programmable SoC



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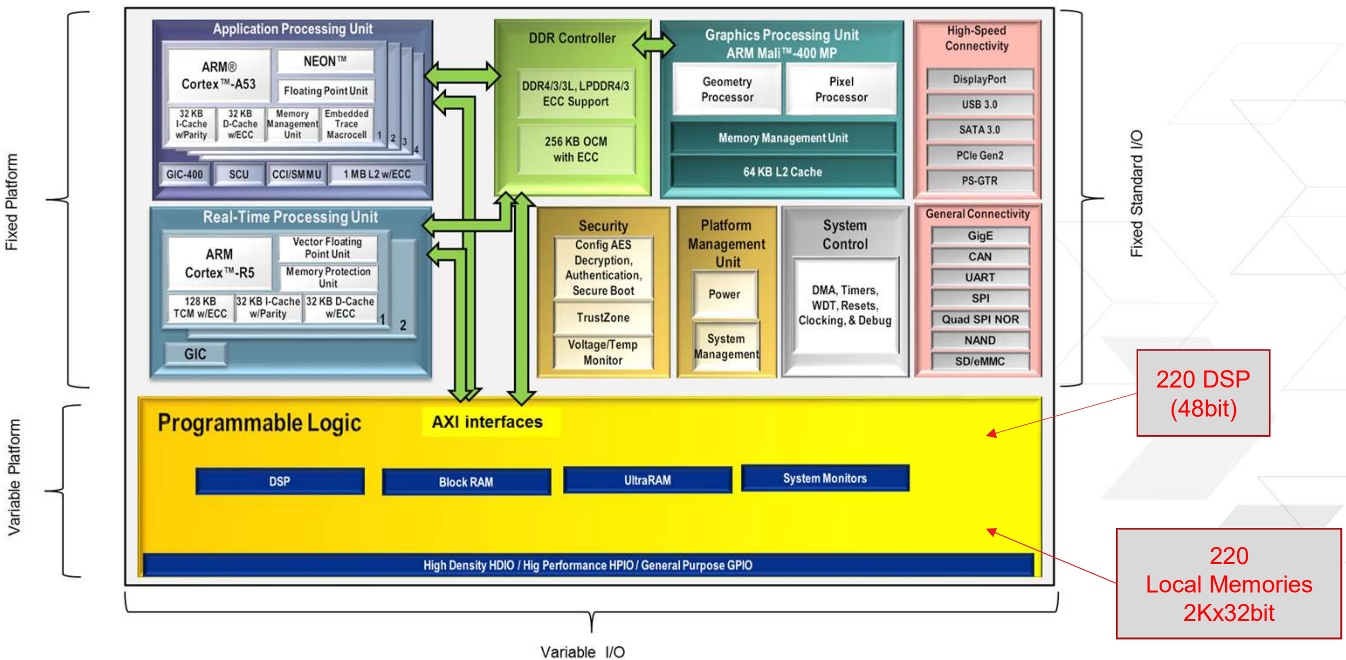
Step 4. - How do we collect the data?

Platform 2: Zynq UltraScale +



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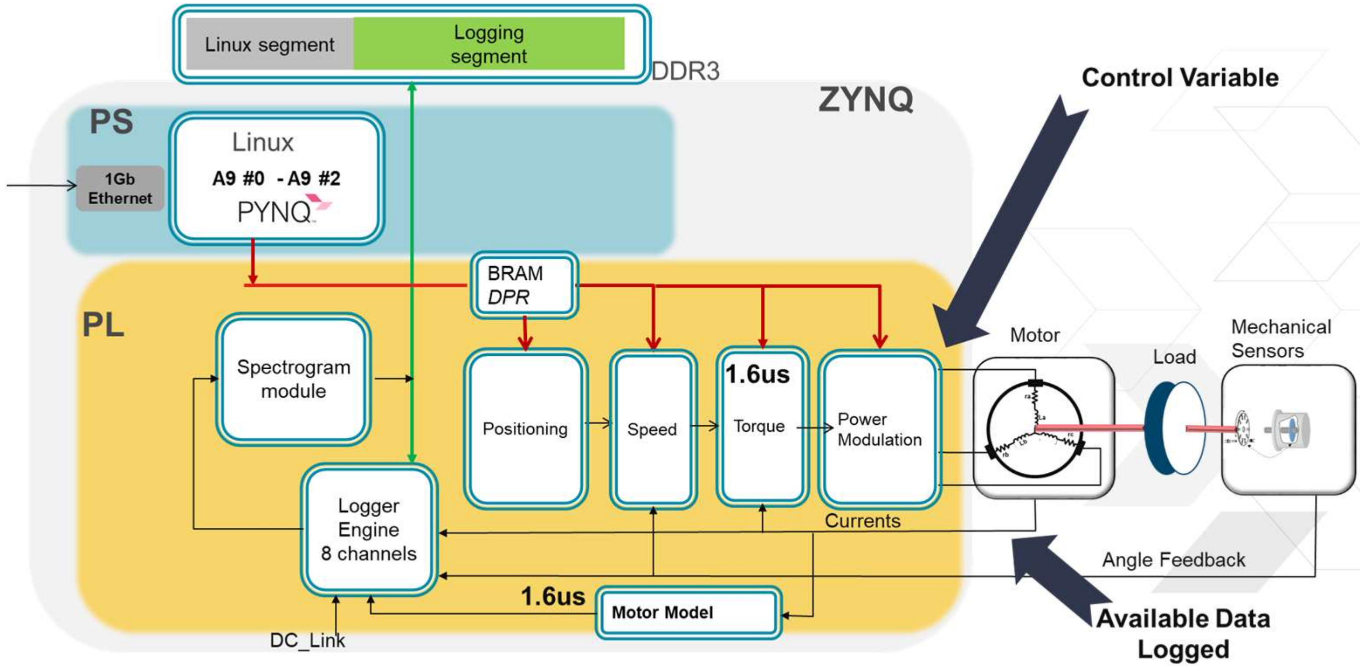
Step 4. - How do we collect the data?

Drivers control & available data is logged!



Step 5. Determine Prediction Algorithm & Approach

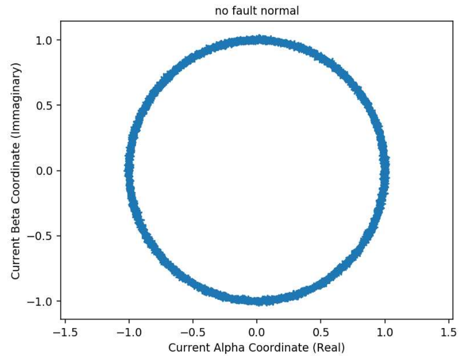
- ***SUPERVISED***
  - *We posses knowledge of the features*
    - *There is expected outcome*
    - *Data is labeled*
    - *Time of occurrence*
  - *We posses knowledge of the system*
    - *A model is available*
    - *A model can be inferred*
  - *We can use….*
    - *DNN / CNN*
    - *Decision Trees*
    - *Classifiers*

- ***UN-SUPERVISED***
  - *No knowledge of the output*
    - *Determine pattern or grouping*
    - *Data is unlabeled*
    - *Time may be unknown*
  - *Self Guided Algorithm….*
    - *K-Learn*
    - *Autoencoders*
    - *Generative adversarial networks*

Step 5. Determine Prediction Algorithm & Approach

In this use case: Supervised Learning

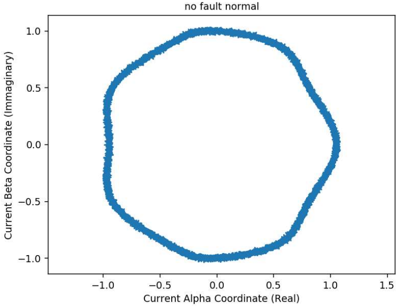
Collect Currents Iα, Iβ → Plot Iα, Iβ in X, Y → Plot Shows Normal or Perturbed → Save the X, Y plot as image → Use CNN for “image” classification



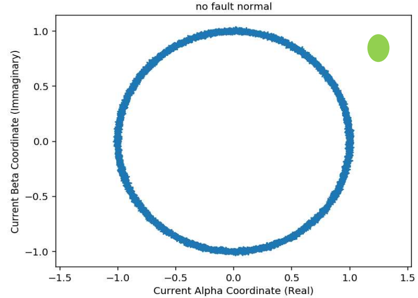
Transformed from “non vision” into “vision” to use CNN

Step 5. Determine Prediction Algorithm & Approach

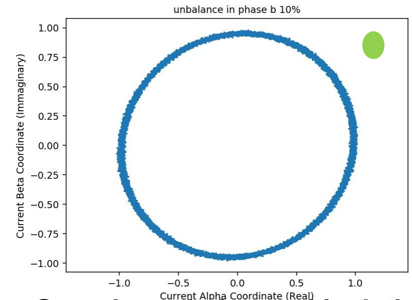
Normal Motor with Saliency



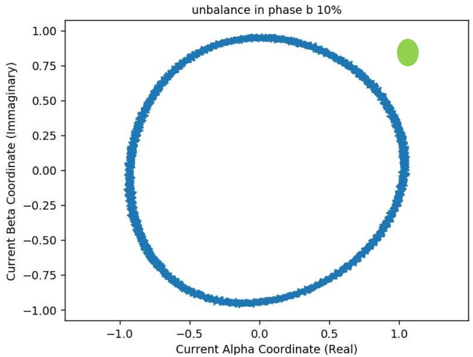
Normal Motor No Saliency



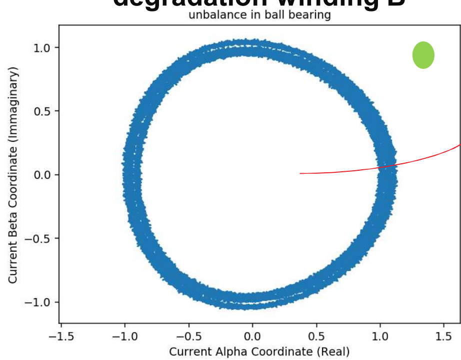
Higher contact resistance Phase b



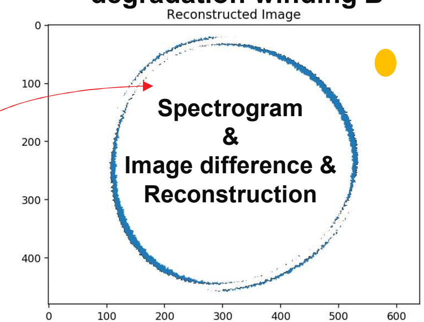
Isolation degradation winding B



Gear degradation and isolation degradation winding B



Gear degradation and isolation degradation winding B



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Step 6. Edge AI Inference

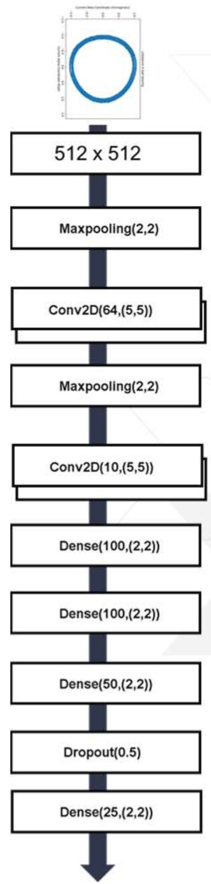
Creating Trained Model

Front End

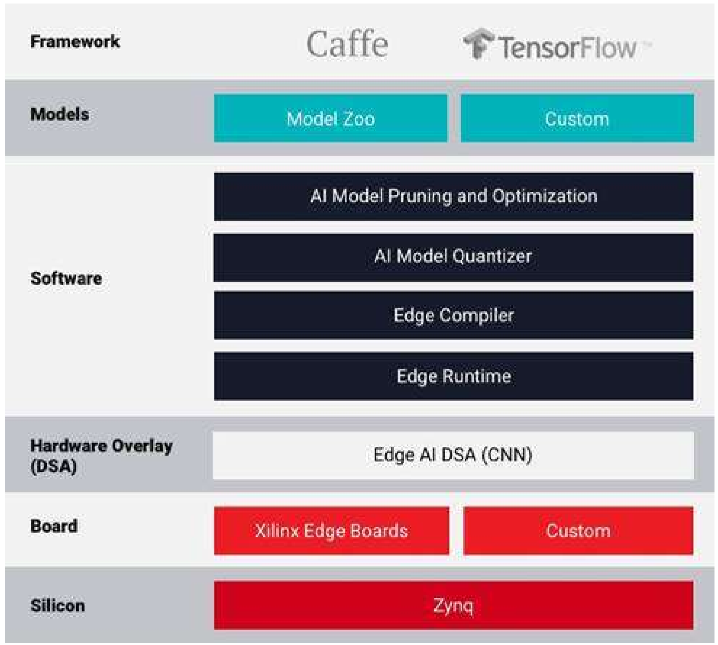
Keras

Backend

TensorFlow



Step 6. Edge AI Inference
Using Xilinx Edge AI Platform



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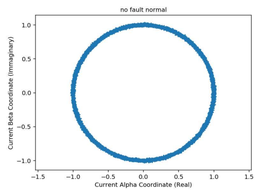
Step 7. Extract Insights & Predict

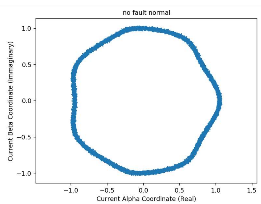
Inputs Image



Output Prediction

Normal Motor

Inputs Image



Output Prediction

Motor with Saliency

Explore Xilinx Edge AI

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Edge AI Tutorials

Tutorial	Description
CIFAR10 Caffe Tutorial (UG1335)	Train, quantize, and prune custom CNNs with the CIFAR10 dataset using Caffe and the Xilinx® DNNDK tools.
Cats vs Dogs Tutorial (UG1336)	Train, quantize, and prune a modified AlexNet CNN with the Kaggle Cats vs Dogs dataset using Caffe and the Xilinx DNNDK tools.
ML SSD PASCAL Caffe Tutorial (UG1340)	Train, quantize, and compile SSD using PASCAL VOC 2007/2012 datasets with the Caffe framework and DNNDK tools, then deploy on a Xilinx ZCU102 target board.
DPU Integration Lab (UG1350)	Build a custom system that utilizes the Xilinx Deep Learning Processor (DPU) IP to accelerate machine learning algorithms.
Yolov3 Tutorial with Darknet to Caffe Converter and Xilinx DNNDK (UG1334)	Use the Yolov3 example, which converts the Darknet model to Caffe model and uses the DNNDK tool chain for quantization, compilation, and deployment on the FPGA.
MNIST Classification with TensorFlow (UG1337)	Learn the DNNDK v3.0 TensorFlow design process for creating a compiled `.elf` file that is ready for deployment on the Xilinx® DPU accelerator from a simple network model built using Python. This tutorial uses the MNIST test dataset.
CIFAR10 Classification with TensorFlow (UG1338)	Learn the DNNDK v3.0 TensorFlow design process for creating a compiled `.elf` file that is ready for deployment on the Xilinx® DPU accelerator from a simple network model built using Python. This tutorial uses the CIFAR-10 test dataset.

- ***Get Started with Xilinx Edge Ai***
- **https://github.com/Xilinx/Edge-AI-Platform-Tutorials**
- **https://www.xilinx.com/products/design-tools/ai-inference/ai-developer-hub.html#edge**

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Intelligent.

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