Project Name : **A Machine Learning Approach for Anomaly Detection in Industrial Control Systems Based on Data Sensing**

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# Introduction

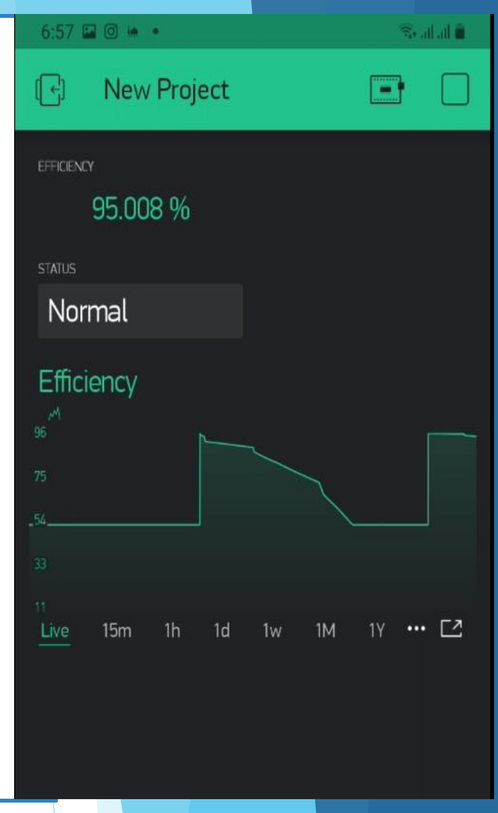
As part of the digital transformation, industry Rev 4.0 and the supporting technologies such as Internet of Things (IoT), Artificial Intelligence (AI), Machine Learning (ML) and Cloud Computing can all be used to migrate the traditional and conventional operation, monitoring and control mechanism to be smarter and more autonomous.

Anomalies in the production process of current factories may occur due to many factors; external or internal cyber attach that target the flow of the production line, malfunction in one of the mechanical or control parts of the facility, unexpected obstacles or delays that affect the transition or the service time between production stages, equipment's miss calibration or passed scheduled maintenance . Such factors may not be easily detected especially if it is minor, early detection is crucial before cascaded or butterfly effect propagates and the operation of the entire line gets congested or even suspended.

Although autonomous production lines are mainly operated via complex robots and vision based inspection and control devices, it can be simplified as a set of sensors and actuators. Sensors signals are collected by PLC and another set of suitable actuator signals are released based on predefined control logic. Such input and output signals can be collected and pre-processed and finally entered to a ML algorithm to classify it and decide whether it represent a normal or abnormal operation mode.

# Objective

A) The main purpose of this project is to detect anomalies in factory production line via adding smart technologies to the current traditional lines to ease the migration of the technology.
B) Build a prototype that emulate a production line (conveyor belts, PLC, industry grade proximity sensors, Motors) and add additional components (microcontrollers, cloud service, LCD display) to sense the data and process it and migrate it to the cloud without major reconstruction of the equipment connectivity.
C) To emulate and model realistic service delays similar to the ones that bigger more complex factories experience during each stage of the production line.
D) To prove the feasibility of the detection mechanism with acceptable accuracy rate




# Methodology

- Big Factories are able to process different items using multiple robots at each stage. The delays of processing (service time) is near gaussian distribuation.
- The project relies on the operation logic control of the production line as shown next figure to determine which senor data need to be collected and at which interval.
- Once the raw data (Delays) are collected it is sent to a microcontroller capable of running a machine learning algorithm (Naieve Bays) to classify each production cycle data epoch as Normal/Abnormal
- Normal epoch cycle are the one that has gaussian distribuation delays at each sensor according to pre estimated measure during the training cycle of the ML Algorithm.

# Tools and Models

**PLC**

The control ladder diagram of the PLC shown next figure is part of the logic used to autonomously control the production line actuators. S7-200 is used for this purpose

**Box Muller Transform**

The sensor delays are considered of random uniform distribution nature, but to reflect a proper delay model that emulate the bigger complex factories service times, the distribution should be transformed to a gaussian one with specific mean and standard deviation. Box-Muller transform can be used for this purpose:

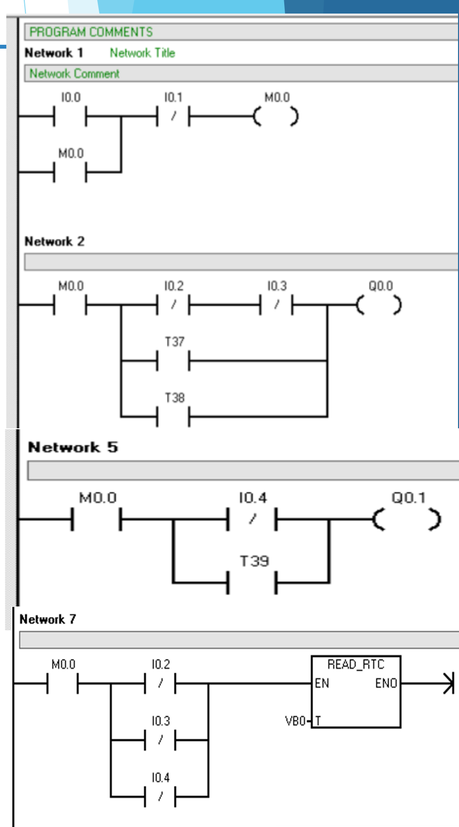
$$Z_0 = \sqrt{-2\ln U_1}\cos(2\pi U_2)$$

$$Z_1 = \sqrt{-2\ln U_1}\sin(2\pi U_2)$$

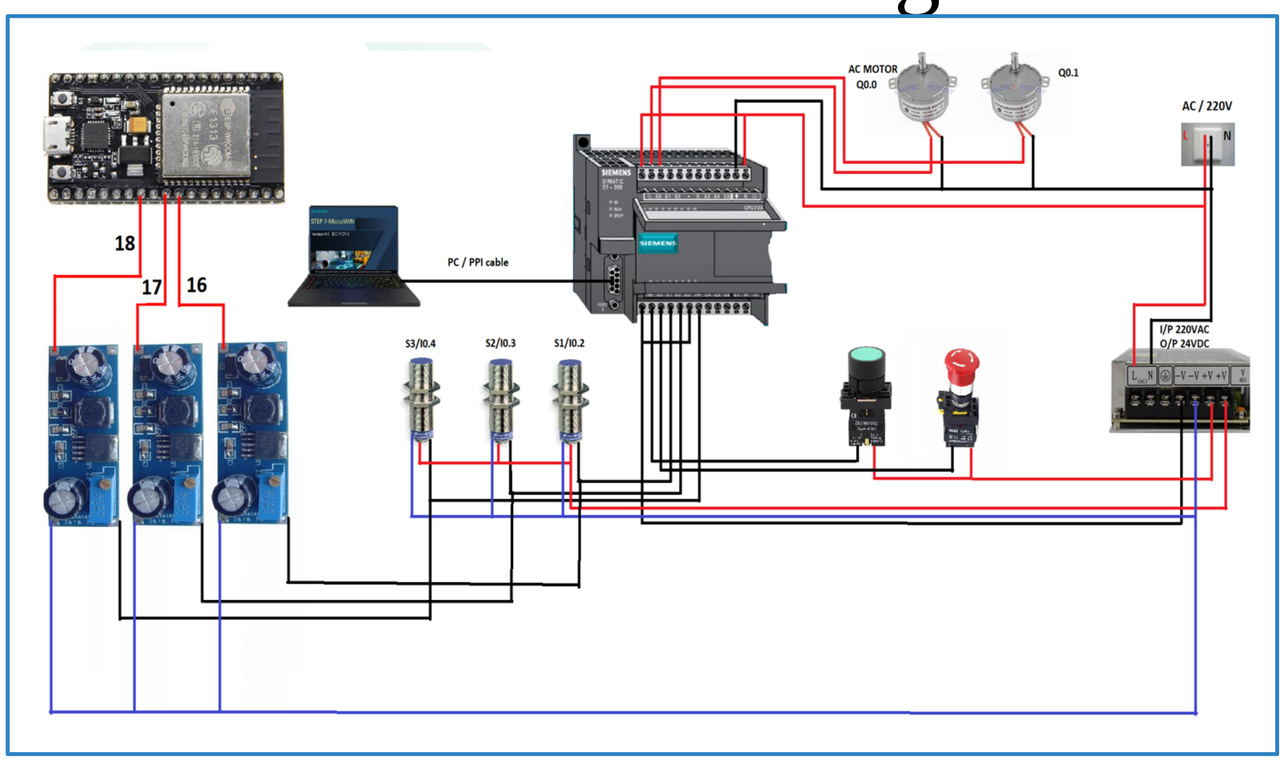
**Naieve Bays**

The ML algorithm (Naive Bays) counts on the conditional probabilities of the features and outputs to decide the current round expected outcome:

$$\hat{y} = \underset{k\in\{1,\ldots,K\}}{\operatorname{argmax}}\ p(C_k)\prod_{i=1}^{n} p(x_i \mid C_k)$$




# Framework Design




# Sample Production Line