International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 05 | May 2019 www.irjet.net p-ISSN: 2395-0072

Early Detection of Sensors Failure using IoT

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Abstract - *Modern control systems rely heavily on their sensors for reliable operation. Failure of a sensor could destabilize the system, which could have serious consequences to the system's operations. Therefore, there is a need to detect and accommodate such failures, particularly if the system in question is of a safety critical application. The performance of sensor and associated signal processing circuit decides quality of the output. Sensor manufacturers take appropriate care of performance, but various onsite conditions hamper sensor's performance and leads to sensor failure. The sensors used in industry and in IoT applications, also face problems due to communication link, communication supporting circuitry. The sensor's performance is limited by environmental parameters such as-Heating, Moisture, Humidity, Vibration, and Electromagnetic Interference (EMI) - Due to EMI higher voltages are generated. In this paper, a sensor failure prediction model is presented. The sensor failure prediction involves collection of sensor output data and implementation of algorithms to anticipate impending failure. Algorithm represents behavior of system, by identifying the factors contributing to sensor failure then a predictive model is defined. This modelling is followed by the test data to check the reliability of the predictive model*.

Key Words: **sensors, data analysis, fault detection, artificial Intelligence (AI), failure prediction**

1. INTRODUCTION

Increasing demands on reliability and safety of technical plants require early detection of process faults. Sensors are vital components of any control system. They inform the controller about its environment and the state of the system. With increasing safety, performance, and automation requirements, control systems are increasingly sophisticated and are heavily reliant on their sensors. However, sensors are often considered as the weak link in these systems. Any sensor failure could degrade the system's performance and possibly lead to total system failure. The impact of the failure depends on the application domain. In safety critical applications, any failure could result in damage to property or environment and in a worst case scenario, result in loss of life. Therefore, sensor failure detection, identification, and accommodation is an important area of research in the safety critical systems domain.In a typical industry there are hundreds of pieces of equipment in each store, spread across thousands of store locations across geographic locations. In such scenarios, it becomes difficult to schedule preventive maintenance – more so due to false alarms raised by rule-based systems that turn out to be less serious alerts upon actual inspection, such as an open door on a refrigeration unit. Advanced predictive methods will enable you to switch from scheduled preventive maintenance to predictive maintenance. This developer pattern is intended for anyone who wants to experiment, learn, enhance, and implement a new method for predicting equipment failure using IoT sensor data. Sensors mounted on IoT devices, automated manufacturing robot arms, and process monitoring control equipment collect and transmit data on a continuous basis. The first step is to identify any substantial shift in system performance using time-series data generated by a single IoT sensor.

Once a change point is detected in a key operating parameter of the IoT equipment, it makes sense to follow it up with a test to predict if this recent shift will result in the failure of a piece of equipment. This pattern is an end-to-end walk-through of a prediction methodology that utilizes multivariate IoT data to predict equipment failures. A prediction algorithm using is implemented for this purpose. We use predictive packages in statistics/Pattern/AI with sample sensor data loaded into the cloud. Once an anomaly is detected in a system using change point detection, a failure prediction based on predictive analytics models can identify an upcoming failure condition in advance. Based on this detection, a proactive prescriptive action can be taken. This proactive action in traditional applications are typically scheduled maintenance activities.

2. Literature review

The literature review of this research topic has been reviewed from last 10 years, in order to find out work carried by various researchers. There are many systems available

Tomáš Kuzin, Tomáš Boroviˇcka has suggested a predictive maintenance strategy for sensors using condition monitoring and early failure detection based on their own collected measurements. He had used different approaches based on feature extraction and status classification time series modelling, and anomaly detection using auto encoders. All methods were able to detect failures before they occurred and thus proved to be applicable only for condition monitoring and utilized for predictive maintenance of sensor parts.

Yu Liu,Yang Yang, Xiaopeng Lv, and Lifeng Wang proposed a framework for online sensor fault detection. They had used use the Statistics Sliding Windows (SSW) to contain the recent sensor data and regress each window by Gaussian distribution. The regression result can be used to detect the data value fault by using Group-based fault detection (GbFD) algorithm and tested the framework with a simulation dataset extracted from real data of an oil field. Test result shows that (GbFD) detects 95% sensor fault successfully. This research approach is not applicable on other dataset

Sharma, A.B. et al. proposed specific algorithms for fault detection. Four different classes of approaches for detecting Outlier, spike, "Stuck-at", High Noise or Variance faults are discussed. Rule-based Methods Estimation-based Methods Time-series-based Methods Learning-based Methods. The advantage of these methods is that they can simultaneously detect and classify faults.

Mahmoud Reza Saybani*, Teh Ying Wah, Amineh Amini and Saeed Reza Aghabozorgi Sahaf Yazdi presented a method for detecting anomalies in a sensor data, as well as to predict next occurrence of a sensor failure. For anomaly detection, this research used MATLAB's fuzzy logic toolbox tools.To predict sensor fault, the original time series were used to create a new 'derived time series'.

Results of two models								
	Final Estimated values		Actual	Estimation value 1		Actual	Estimation of value 2	
Sensor Id	All-Data-PASW	All-Data-SQL	Values 1	PASW v.14	SQL 2008	Values 2	PASW v.14	SQL 2008
01	214	191	229	217	129	137	221	133
02	249	249	240	249	245	292	258	258
03	251	268	582	249	249	327	254	254
04	257	157	272	266	150	132	259	259
05	221	261	234	225	250	99	224	234
06	222	237	148	217	257	198	222	258
07	214	135	108	198	144	213	201	178
08	231	340	334	240	229	254	213	239
09	235	298	128	234	163	131	242	244
10	226	163	102	222	308	237	230	115
11	250	250	110	248	244	261	258	135
12	217	205	351	238	243	273	215	164
13	254	154	282	257	258	301	257	315
14	261	263	323	258	258	101	258	251
15	233	116	289	233	211	288	233	155
16	240	196	317	242	163	212	237	287
17	217	268	112	218	129	104	225	177
18	240	242	300	233	233	118	228	105

Figure: Results of two forecasting models.

Two prediction models known as 'auto regressive integrated moving average' and 'autoregressive tree models' were used against the new time series to predict next occurrence of sensor failure.

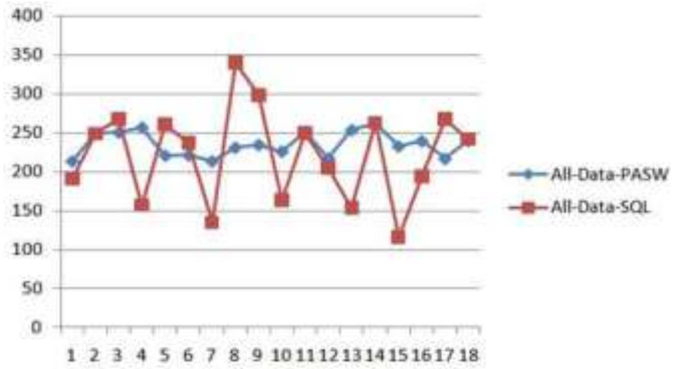

Figure: Graph of the final prediction.

This research used 5999 records for training and 5631 records for testing the model. This model achieved a classification accuracy of 100%. Models used in this paper are capable of detecting anomalies in a time series.

Swajeeth Pilot. Panchangam, V. N. A. Naikan has documented the common failure modes of electronic sensors. FRACAS method and its effectiveness for reliability studies of sensors based on the real failure modes observed in practice. FRACAS (Failure Reporting and Corrective Action System), is most widely used physics of failure method for useful reliability analysis. In this paper major failure modes of sensors are identified and their effects on sensor performance are studied.

For energy-intensive industries to reduce the energy consumption and emission Yingfeng Zhang, Shuaiyin Ma, Haidong Yang, Jingxiang Lv, Yang Liu proposed A big data driven analytical framework. Useful information are mined by integrating big data and energy consumption analysis. Energy-efficient decisions can be made based on the proposed framework. Then, two key technologies of the proposed framework, namely energy big data acquisition and energy big data mining, are utilized to implement energy big data analytics. Finally, an application scenario of ball mills in a pulp workshop of a partner company is presented to demonstrate the proposed framework. The results show that the energy consumption and energy costs are reduced by 3%and 4% respectively. These improvements can promote the implementation of cleaner production strategy and contribute to the sustainable development of energy-intensive manufacturing industries.

Ameeth Kanawaday Aditya Sane explores the use of Autoregressive Integrated Moving Average (ARIMA) forecasting on the time series data collected from various sensors from a Slitting Machine, to predict the possible failures and quality defects, thus improving the overall manufacturing process.

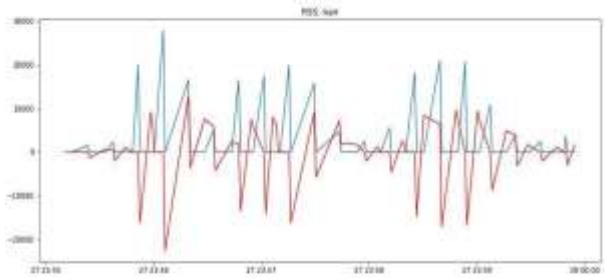

Figure: Plot of ARIMA model.

Data generated from the Slitting machine was collected using sensors and pushed to the cloud. This data was sampled per second and collected for a period of one month. Approach consists of two stages. The first incorporates data analysis, clustering and supervised learning methods to gain insights from the data and the second follows the first to add predictive models using ARIMA. Used predictive analysis which proves to be a viable design solution for industrial machine prognostics.

Yasser M. Madany El-Sayed A. El-Badawy Adel M. Soliman introduced fault detection prediction analysis of multi-sensor architecture to study different number of sensors with different arrangement architectures and to detect transient faults in each sensor. Then, a new proposed pseudo sensor enhancement method (PSEM) is presented and investigated to isolate and compensate for the transient faults. The proposed PSEM: i) has better confidence through the use of more than one sensor to confirm the true path; ii) it reduces the ambiguity by joint information from multiple sensors to reduce the set of hypotheses about the true path, iii) it improves the fault detection and iv) increase the robustness of isolation and compensation of the transient fault during its fault.

Matt Higger, Student Member, IEEE, Murat Akcakaya, Member, IEEE, and Deniz Erdogmus, Senior Member, IEEE proposed a sensor-failure-robust fusion rule assuming that only first order characteristics of a probabilistic sensor failure model are known. Under this failure model, computed the expected Bayesian risk and minimize this risk to develop the proposed fusion method. The algorithm is implemented in MATLAB 2012b. They have computed the expected risk of a fusion rule for a given sensor characteristic which minimizes risks under any sensor failure model.

Dejing Konga*, Chengwei Qinb, Yong Hec, and Lirong Cuia proposed sensor-based calibration in this paper is an extended method to improve the system reliability they proposed shock models based on the two patterns are valuable to the real problems. it is concluded that the calibration associated with the shock process can enhance safety of the system operating in an uncertain dynamic environment A system with calibrations experiences dependent competing failure processes. Shocks' magnitudes are associated with inter-arrival times and arrival times. Instant calibrations are executed to rejuvenate the external sudden damage. Overall degradation comprises of internal and external degradation measurement. Explicit reliability expressions and simulations are given for models.

Wolfgang Graniga,*, Lisa-Marie Fallerb, Hubert Zanglb, showed the influence of sensor system measurement uncertainties to sensor system reliability and ways to meet reliability targets. A general model to handle measurement uncertainties is defined they optimized the sensor output concerning reliability to provide sensor output values within specification limits.

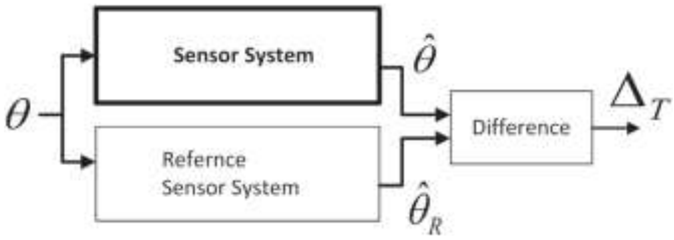

Figure: configuration during sensor system calibration or verification.

They have optimization of Sensor system considering dependent parameters like Temperature, stress, air pressure etc. External interference (stray field, EMC) Lifetime drifts This can be done by statistical methods applying optimal design of experiment methodologies. Statistical optimizations benefit from the fact that we do not need to measure the influencing parameter but design the sensor system in a way that external influencing parameters have lowest possible effects. These reduced uncertainties increase the reliability of these sensor systems to fulfil all the required specifications.

Nagdev Amruthnath, Tarun Gupta proposed a Condition-based predictive maintenance strategy that made a significant influence in monitoring the asset and predicting the failure of time. historical data and incapable of classifying new faults accurately will be overcome with a new methodology using unsupervised learning for rapid implementation of predictive maintenance activity which includes fault prediction and fault class detection for known and unknown faults using density estimation via Gaussian Mixture Model Clustering and K-means algorithm and compare their results with a real case vibration data. This implementation involves the major components of predictive maintenance such as collection of physics-based data, predicting faults and predicting the type of fault using different machine learning algorithms such as principal component analysis (PCA) for dimensionality reduction, Hoteling T2 statistic for fault detection, density estimation via Gaussian Mixture Model Clustering Algorithm and K-means clustering for fault class prediction With the above implementation, they were able to predict the faults with 82.96% accuracy

Giuseppe Mancoa,_, Ettore Ritaccoa, Pasquale Rulloe, Lorenzo Galluccid, Will Astillc, Dianne Kimberc, Marco Antonelli described an application ,developed to predict and explain door failures on metro trains diagnostic data processing for fault detection purposes. This basically involves four steps: acquisition, pre-processing, model induction and model evaluation. Analysis of event-based monitoring of complex systems for predictive maintenance. An unsupervised technique for early detection of faults from diagnostic data. A method for characterizing failures and distinguish them from normal behaviour. In this paper they described the results of a research project which explores machine learning techniques to detect failures.

Rukmani Pa, Gunda Krishna Tejab, M Sai Vinayc, Bhanu Prakash Reddy Kd discussed new technologies which monitors the industrial parameters. Here, they have used the software technologies like image processing machine learning to monitor some of the industrial parameters like temperature reading of the respective machines, voltage supply to the equipment, inside environment of the industry, pressure level, inventory monitoring and management so on.

LogID	DATA	Logdate	LogTime
1	temp-21	03/04/2018	06:17:17
2	g-abnormal_579	03/04/2018	06:29:52
3	g-abnormal_577	03/04/2018	06:30:17
4	g-abnormal_579	03/04/2018	06:30:42
5	temp-21	03/04/2018	06:31:07
6	Unauthenticated	03/04/2018	06:31:33
7	temp-21	03/04/2018	06:31:58
8	g-abnormal_572	03/04/2018	06:32:24
9	g-abnormal_573	03/04/2018	06:32:49
10	g-abnormal_567	03/04/2018	06:33:15
11	g-abnormal_569	03/04/2018	06:33:40

Figure: Values Uploaded To Cloud Using IoT

Change in reading of the values can be a massive effect. All the sensor values will be updated in cloud as well as into the excel sheet. We can analyse the sensor values by processing it in Hadoop finally they concluded that using the latest technologies in industrial monitoring can help humans to take control of risk taking situations.

3. CONCLUSION

Sensors are an important part of any control system. A failure in a sensor could degrade the system's performance and can destabilize the system's operation. Therefore, it is important for a system to have the ability to detect and accommodate sensor failures to maintain its reliability. In this work, we present an effective approach for prediction of sensor failure caused by various environmental factors that effect on commonly used sensors in industry. Our proposed work in this research is, Environmental and other physical parameters are sensed by additional sensors, mounted around the sensor under test. The data collected on local side is transferred to cloud. The output from these sensors in the cloud is analyzed. The related work done up till on this is having less accuracy and sensors are considered in a network. We have considered for individual sensor.With this implementation, we are able to predict the sensor failure with 98-99% accuracy as this prediction is applicable for all nonlinear systems.This proposed system have growth in accuracy and maintenance of sensor can be done that intern fulfil reliability requirements. Early fault detection can minimize plant downtime, extended equipment life, increase the safety and reduce manufacturing costs.

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