QUALITY TRANSFORMATION: SMART QUALITY & AUTO-HOLDING IN THE ERA OF INDUSTRY 4.0

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ABSTRACT

This paper presents a transformative approach to quality management through Smart Quality and Auto-holding implementation in the era of 4IR. The initiative reduces analysis time and reaction time from more than 12 hours to 1 hour by automating manual processes through real-time monitoring and triggering systems. The solution features end-to-end automation, centralized information management, self-service scalability and sustainability.

The system enables automated alerts for certain high severity defects, commonly known within the company as Severity 1 and Critical Failure Modes (CritFM) streamlining the quality control process through automated data collection, analysis, and escalation procedures. The automated alerts contain the needed information on which parts to Auto-hold preventing and containing it to prevent its impact on the customer and succeeding processes.

This transformation demonstrates significant improvements in operational efficiency, quality control, and response time, aligning with 4IR principles of IIOT, smart automation and data-driven decision-making.

1. 0 INTRODUCTION

Quality optimization is an integral part of manufacturing excellence, presenting valuable opportunities for continuous improvement throughout the production pipeline. By addressing quality variations proactively, manufacturing plants can significantly enhance their yield and strengthen their KPIs. This focus on quality creates a pathway to greater sustainability by reducing rework requirements, minimizing carbon footprints, and maximizing resource efficiency. Each quality challenge identified becomes a catalyst for process innovation, driving both operational excellence and environmental stewardship in modern manufacturing facilities.

Since the company is working to both mitigate environmental impacts and answering to market demands, the company is committed to designing end-of-life product recyclability. The company has also established global minimum requirements for handling and disposing of e-waste from its facilities and offices to minimize negative environmental impact, automating such tasks increases both the environmental and business impact.

Smart Quality and Auto-holding, which was developed with technologies under the 4th industrial revolution, are introduced to eliminate manual processing which by estimate takes more or less than 12 hours and cuts it down to an estimate by an hour. Implementing such solutions help with reduced manual touchpoints, having centralized information available, real-time notification and alerts, automated detection and centralized integration. This also contributes to lessening the carbon footprint of preventing a defective part shipped out only to return and be reworked, as well as preventing the continuation of the said defective part to continue down the pipeline process.

Smart Quality and Auto-holding also features tasks distribution related to the defective part where engineers can follow their Out-of-Control Action Plan (OCAP), which assists in determining the cause of the defective part to be addressed to lessen further occurrences of the defect.

1.1 The Fourth Industrial Revolution

The 4th Industrial Revolution, or most known as 4IR, conceptualizes rapid change to technology, industries, and societal patterns and processes in the 21st century due to increasing interconnectivity and smart automation, this encompasses the following benefits:

- Autonomous actions
- Self-optimizing
- Agility & flexibility
- Prescriptive solutions
- End-2-End connectivity
- Optimized resources
- Analytics

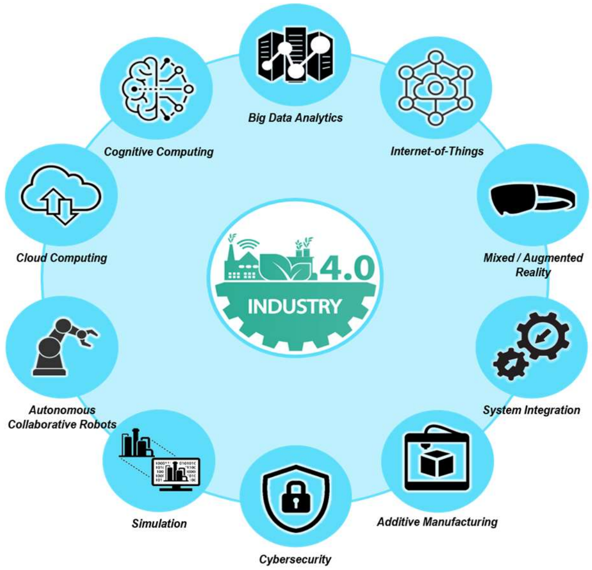

Fig. 1. List of 4IR technologies made known and readily accessible.

With the above ready solutions, the project utilized Industrial Internet-of-Things or most known as IIOT, System Integration and Big Data Analytics. The combination of these 4IR technologies fully automates the information gathering process, efficiently boosting the speed and precision of identifying defective parts and preventing further processing of the identified defective part.

1.1.1 Industrial Internet-of-Things

Industrial Internet-of-Things or IIOT is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction made to cater, or tailor fit even to the company's industrial needs.

Technologies under this 4IR branch utilize more interactions be it human-to-human, human-to-computer or even computer-to-computer, and these interactions commonly transfer information requested across a network.

This is one of the fundamental technologies to connect various systems, applications and data sources that would create centralized integration and centralized data sources.

1.1.2 System Integration

System Integration refers to the process by which multiple individual subsystems or sub-components are combined into one all-encompassing larger system thereby allowing the subsystems to function together. In other words, the symbiosis created through system integration allows the main system to achieve the overarching functionality required by the organization.

By having both Smart Quality and Auto-Hold integrated with each other, both data and analysis are aligned with one another being one source of truth. Identification of the affected parts are easily identified as the information is shared between applications.

1.1.3 Big Data Analytics

Big data analytics is the use of advanced analytic techniques against very large, diverse big data sets that include structured, semi-structured and unstructured data, from different sources, and in different sizes from terabytes to zettabytes.

As the project deals with data coming from multiple parts and multiple processes, where 1 main part consists of multiple subparts, and even those subparts also contain more subparts. The amount of data being processed comes at the millions number and having to manually process and identify defective parts of this caliber of data will take a while without using big data analytics.

2. 0 REVIEW OF RELATED WORK

Not Applicable.

3.0 METHODOLOGY

With the purpose of upholding the best quality products it is optimal to have a system in place that should replace the existing manual process. The vision is to develop applications to be a centralized system capable of automating alerts and interlinked with a holding system became the solution to combat this problem.

3.1 Identifying and Improving the Process

Quick and decisive actions must be done to uphold quality in par with sustainability, and the best and foremost solution is to always improve the process and lessen the carbon footprint, this also includes removal of any manual process and replacing it with automation.

Identifying the current process will help in narrowing which process can be combined or eliminated and most of these processes are manual ones.

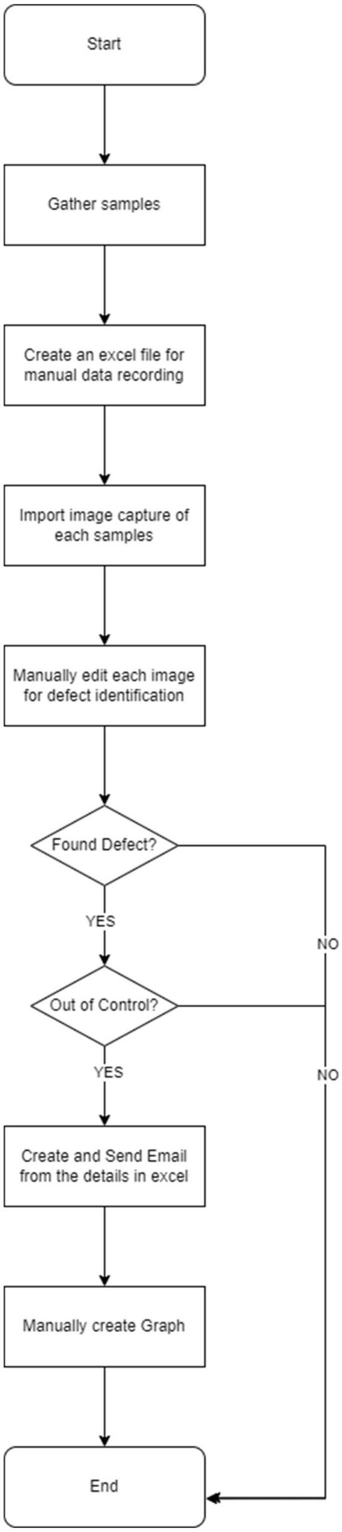

Fig. 2. Manual Process Steps before Smart Quality.

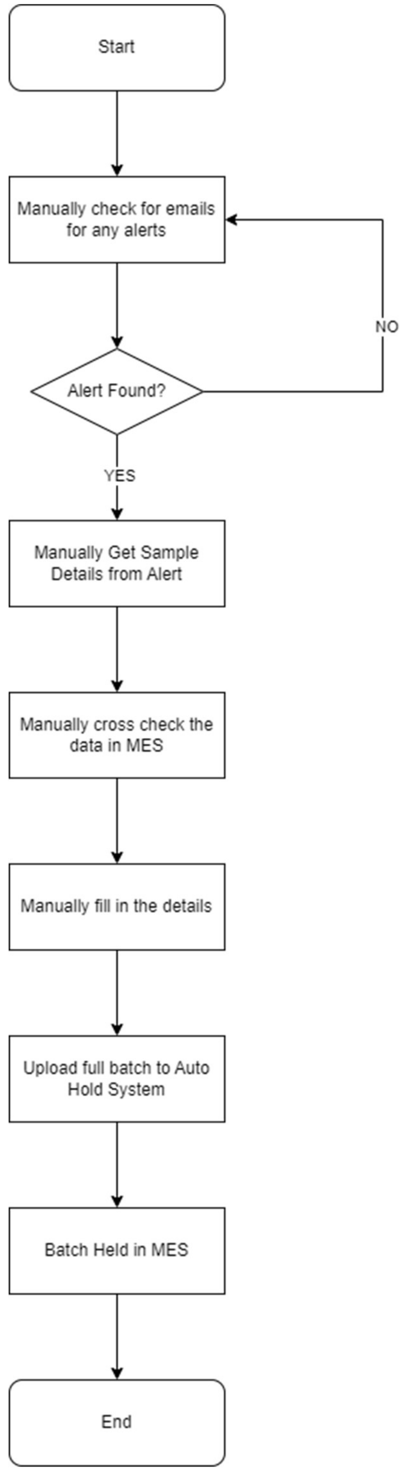

Fig. 3. Manual Process Steps before Auto Hold.

After the identification of the manual process shown in the previous figures, we can now safely determine steps and technologies to be eliminated and improve them. Combining and eliminating extra steps should shorten the processing time and be a steppingstone in quick decisions and upholding quality in relation to sustainability.

Identification of the necessary technologies is crucial to address the process improvements, we did it using IIOT technologies, such as React JS, Node JS, Docker and Kubernetes.

React JS is a free and open-source JavaScript library primarily used for building user interfaces (UI) with improved user experience (UX). It also has a multitude of reusable and robust components that can address the following identified manual pain points; excel input, image selection, image judgement and graph creation. Converting these pain points into React JS greatly reduces the time it takes for one to start the Quality Process.

Node JS is a free, open-source, cross-platform JavaScript runtime environment, which means it can handle real time calculations, data extractions, data manipulation and other systematic processes such as, emails, alerts and notifications. This then addresses the rest of the manual processes to be improved or removed.

Docker and Kubernetes are technologies that are responsible for making this solution easily deployable to any computer system, be it via local servers or cloud-based servers, they ensure that the solution is scalable to accommodate small businesses to large enterprises. This combination of technology is also responsible for data storage, data retention and data manipulation.

The following shows how the solution interacts with each other and how the improved steps look like.

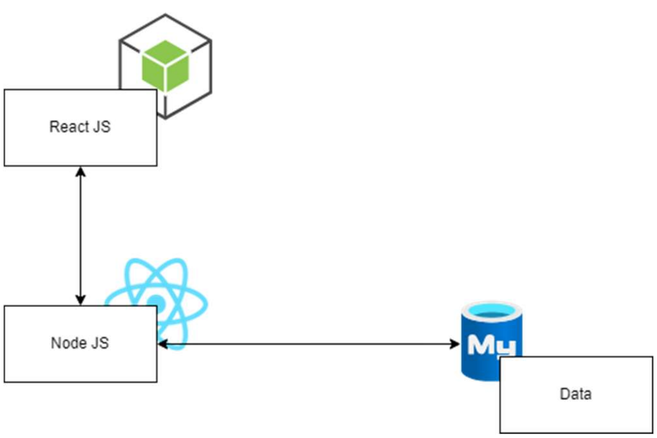

Fig. 4. High Level Architecture.

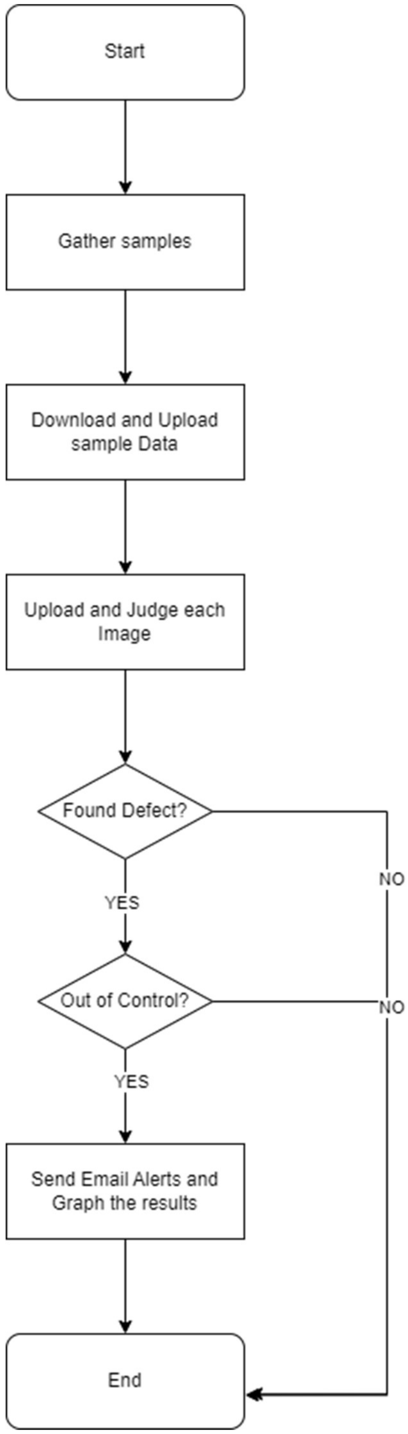

Fig. 5. Smart Quality Process.

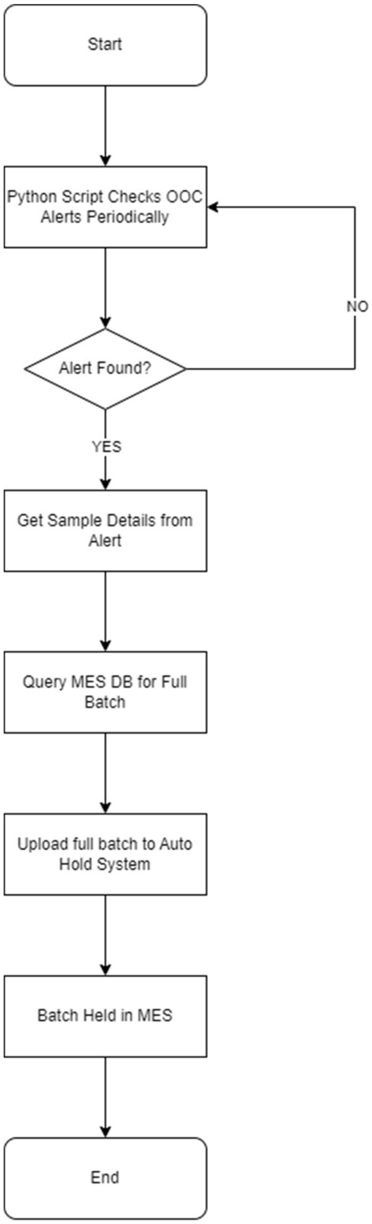

Fig. 6. Integrated Auto Hold Process.

The following will then describe how the improved process step's function.

3.2 Automating the Image Defect Recognition

The manual checking of each image is what takes up most of the time during this process as it can contain bias from human eyes, thus the need to train an AI to identify the defect found in the images in such precision that is at a greater level than a human eye. The manual Visual inspection can only achieve around 80% to 85% accuracy[1] when identifying good parts vs defect parts, but this will still vary depending on the experience and skill of the inspector and this is all done in one micron to three microns.

We leveraged the Visual Geometry Group (VGG) architecture for its simplicity and effectiveness. The network takes a constant input image size of 512 x512 grayscale pixels. Convolutional layers, followed by max-pooling layers, are used throughout the network. These layers extract features from the images and reduce their spatial dimensions. Making the detection process better.

Finally, a sigmoid activation function is applied to the final layer for multiclass classification tasks. Sigmoid is chosen because the model is expected to classify an image that belongs to multiple classes independent of each other. Each output neuron in the final layer corresponds to a binary decision ("1" for presence and "0" for absence) for a specific class. Sigmoid activation is preferred as we only need to detect the presence of a defect. The whole architecture is presented in Figure 7. This will increase the accuracy of max 85% to a new range of 88% to 90%[2].

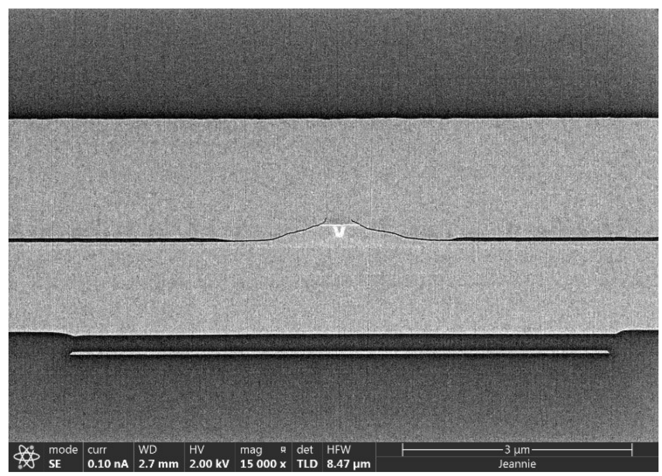

Fig. 7. Sample of good part

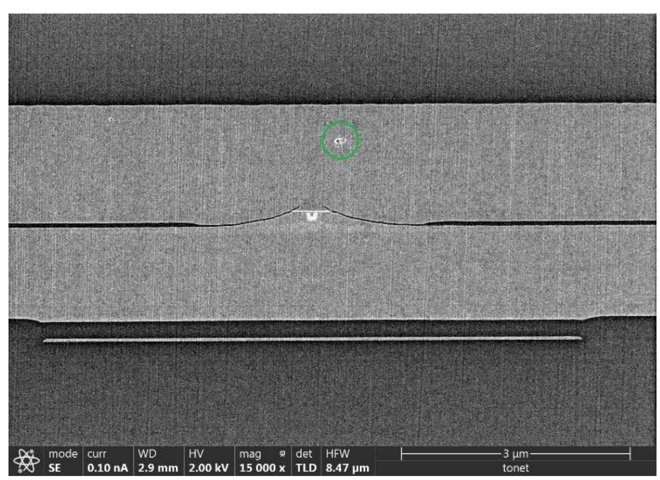

Fig. 8. Sample of defective part

With this image detection in place, we can move it anywhere in each to the process, as to where it is needed, in this case this image identification is needed in Smart Quality to record any defects found.

3.3 Automations and Centralizing Data

The manual data gathering must first be addressed to greatly increase the effectiveness of the solution. Semi-automating to Automating the data gathering helps make the data become standardized, consistent, efficient for processing and the centralized source of one truth.

This can be done by introducing templated data upload, scheduled data and data pipeline. Introducing a templated data upload allows the data to be standardized and consistent, ensuring that the correct data and its corresponding data type is recorded properly, ensuring that when it is processed and retrieved the correct data is displayed, easily recognizable and common across the interlocked systems.

Having Scheduled data retrieval ensures that the data is always fresh and available in a real-time manner. This also means that data being retrieved or injected is also standardized and consistent, further cementing the fact that the data will be the single source of truth and being the main data library.

Lastly having a data pipeline can make the source of data efficient, comprehensive, standardized and consistent. When supplied to the interlocked application the data is easily recognizable and consumed properly by the interlocked application so that the information is shown flawlessly without any loss during the translation process.

With such data automation in place, judgement and identification of any defect parts will no longer be done manually where it takes at the very least 12 hours to complete, the identification and information of relative affected parts for auto-hold will then be interpreted by the interlocked Auto-hold application in a real-time manner preventing its shipment to the customer. Tasks related to the OCAP can be done efficiently with the alerts and notifications done in an automatic manner.

This then creates the centralized data library that can supply data not only to the interlocked Auto-hold but to any other application that will use this common and standardized data source. The significant output of using IIOT and System Integration together.

3.4 Alerts and Notifications

Having the data automated and centralized opens a multitude of opportunities on how the data can be interpreted and how it can be used to send automated alerts, notifications and used as benchmarks to identify limits and product specifications.

From the previous manual process of taking roughly a minimum of 12 hours to identify the defective part, manually creating the email alert and sending it, automating it reduces it to roughly an hour. Automated alerts are sent out in a timely manner to notify engineers and technicians of any identified defective part, this in turn is used for the interlocked auto-hold application. There is no further need for creating manual emails, greatly reducing any manual touchpoints, delays and miscommunications brought by manual alerts.

The same automated alerts are also used to send out information and tasks related to the engineer's and technician's OCAP, to address the identified defective part and which process, its specifications and its settings it was processed.

The same alert can be used as basis by the interlocked auto-hold application to identify any same batch of parts that was processed the same way the defective part was processed. Thus, effectively preventing the defective parts along with the parts of the same batch to be shipped out to the customer or continue down the process pipeline, reducing carbon footprints of back-and-forth shipment and rework.

4.0 RESULTS AND DISCUSSION

Using the approaches described in this paper's earlier section, the turn-around time of defect identification has been reduced significantly from half a day to an hour. Information is no longer passed manually to auto-hold the part and is done automatically also reducing the identification process of all affected parts from three quarters of a day to 2 hours. These comparisons are then represented in the table below.

Activity	Unit	Without Smart Quality and Auto-Hold	With Smart Quality and Auto-Hold
Defect Identification	Hours	12	1
Parts Holding	Hours	18	2

Table 1. Time improvements upon Implementation

5.0 CONCLUSION

In conclusion, due to the technologies and solutions put in place efficiency of identifying defective parts and holding them has increased significantly before when it was done manually. Since the data is centralized, as well as available to the interlocked systems, information is flawlessly flowing reducing the lead time for identification of defective parts. Defective parts and their associated batches are no longer shipped out, reducing carbon footprint for the back-and-forth travel of the defective parts. Processes, system, settings and specifications are reviewed and improved by having automated alerts and notifications in place.

6.0 RECOMMENDATIONS

With the success of this project other Western Digital manufacturing sites are considering applying Auto-Hold to the different high severity defects and Critical Failure Modes that were previously identified as Not Suitable for Auto-Hold. Newly identified high severity defects and Critical Failure Modes are automatically considered to be part of the centralized database within Smart Quality.

7.0 ACKNOWLEDGMENT

The team acknowledges the contributions of the members of Operations Excellence, specifically Dave Tablante, Marvin Meneses, Maria Venus Gambito, Alberto Zaldivar and Janoah de los Santos as core members of the Scrum team. Wichit Chamnannawa, Maria Angela Pieza and Sudhir Devadiga as the Product Owners and Stakeholders of the Project.

8.0 REFERENCES

1. "Defect Detection Using Visual Inspection" by M. U. Ahsan et al. (Springer).
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9.0 ABOUT THE AUTHORS

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10.0 APPENDIX