Outcomes, Insights and Best Practices from IIC Testbeds: MQM Testbed

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INTRODUCTION

In order to extend the usefulness of the published Testbeds in the Testbed Program of the Industrial Internet Consortium (IIC), the Testbed Working Group has developed an initiative to interview the contributors of selected testbeds, to showcase more insights about the testbed, including the lessons learned through the testbed development process. This initiative enables the IIC to share more insights and inspire more members to engage in the Testbed Program.

This article highlights the recently completed Manufacturing Quality Management (MQM) Testbed. The information and insights described in the following article were captured through an interview conducted by Mr. Joseph Fontaine, Vice President of Testbed Programs at IIC, with Dr. Mitch Tseng, Distinguished Consultant of Huawei Technologies. Mitch is an active member in the IIC where he has been serving as co-chairs of both the Innovation Task Group and the Edge Computing Task Group. In September 2017, Mitch was recognized by his peers and bestowed the IIC Testbed Award for his leadership and contribution to the MQM Testbed. His nomination cited the importance of the testbed in "modernizing and increasing the efficiency of China's manufacturing facilities necessary to maintain manufacturing performance and to reduce impact on the environment."

MQM TESTBED – FROM CONCEPT TO REALITY

The MQM Testbed, has, as the name would imply, an obvious focus on using "quality" as the key to manage and improve the existing (brown-field) manufacturing process. The core focus of the MQM Tested is on "manufacturing process." The objective of the MQM Testbed is to retrofit old factories, particularly in China, to ensure, under the architecture illustrated in the IIC's Industrial Internet Reference Architecture (IIRA) [1] , along with the addition of new technologies and Internet of Things (IoT) processes, a smooth transformation of modernizing can be performed with tangible benefits in a production improvement. After a two year effort, the MQM Testbed has been developed and successfully deployed in two productions lines – air-conditioners and kitchen vents – in one of Haier's factories in Qingdao, China, with demonstrable improvements.

The biggest reward for members working on this testbed is the sense of fulfilment and satisfaction throughout the process that an idea was brought from concept to implementation; and better yet, the results exceeded the client's expectation. Furthermore, by adding IoT elements to the manufacturing process and demonstrating to the client (a traditionalist OT partner), the testbed team showed that the IoT process with IT elements worked well in helping Haier improve their manufacturing process. The visible improvement to its old production line immediately won the trust of Haier's management. The testbed team did not take the approach of attempting to refine a process (although that may come in the future). The primary focus was to reduce the RMA (returned merchandise

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[1] Industrial Internet Reference Architecture, Industrial Internet Consortium 2017, www.iiconsortium.org/IIRA

authorization) cost by improving the manufacturing quality. The reason this approach was chosen was because the feedback loop required for fine-tuning at this stage of the process did not exist. In the initial phase, the focus was on how certain platforms can help, especially on the analytical engines described in the IIRA.

One key factor contributing to the MQM Testbed's success was paying careful attention to the specific challenge chosen by the client for the testbed to address; in this case, making improvements to the false detection rate on the failed products of the production line was an issue the client cared about and was willing to work to improve. Haier, in spite of hearing all of the hype about how IoT process can help them, had never tried to act on it due to the risk of disrupting their existing manufacturing process. Despite an initial level of skepticism and even resistance to IoT concepts, the MQM Testbed was so successful that Haier now wants to create an internal branch to renovate all of their production processes. Originally, the focus of this testbed was on one of Haier's air-conditioner production lines. Then, because the results were so successful, Haier agreed to expand the MQM Testbed to a second line - kitchen vents.

CHALLENGES

Many factors affect production line quality in factories. The challenge faced in the air conditioning production line is that centered on a welding station where the cooling tubes at the heat exchanger are connected. The heat exchanger is the most crucial part of the air-conditioner and the most difficult part to be detected should there be a leak caused by the welding process. Initially, the first goal was to improve efficiency of the welding process and eliminate any point of failures.

However, trouble immediately arose because the team discovered it was almost impossible to add sensors and a controller to the old welding robots of the welding station.

Due to high temperatures and the intensive sparks generated during welding, the testbed team found it impossible to apply any kind of sensor into the welding station unless the sensor was pre-installed on the welding robot. The team reported this problem in one of the regular testbed updates during one of IIC's quarterly meetings and solicited help from other IIC members. FujiFilm and Olympus who both have experience and solutions in welding quality control, came forward to help and offered their solutions through thermal imaging. However, the solutions offered are good for post-welding quality check and the team found, again, that the solutions cannot be integrated easily with the existing system. The clock was ticking and the chance to find a quick solution was running out.

Since an immediate solution was not available, the team decided to seek an alternative solution. The first step was to re-examine the whole production process and see if there were other angles to be used. The initial approach focused on the production side of the production line and was deemed impractical. The team decided to take a field trip and get familiar with the actual production line. The focus had been on the production station, but the team felt there is something in the process they had possibly overlooked, especially on the quality control process. When the engineering team arrived at the factory, they soon discovered that the quality control process was very primitive and there was a lot of room for improvement.

ALTERNATE SOLUTION

It is typical that when a factory process is not significantly broken, it is often left intact as long as the throughput of the products met the minimum requirement: Changing the layout or moving the equipment around will cause direct impact on the production flow and production schedule. Although the team found outdated quality control processes were used to detect defects making it an obvious target for improvement, the design team felt a different tactic was needed to convince the client the change was necessary and that the new solution would greatly improve the status quo. The team was surprised to see the quality check of the whole process relied on the judgement from experienced professional examiners to listen to the noise when the air-conditioner was turned on at the end of the assembly line. The decision whether to pass or fail each air-conditioner was made by the listener's subjective decision. Although the method looked obsolete, the client seemed to be content with a three-listener rotation team to perform the task. That made the proposed change more challenging as the new solution needed to be easily understood by the client and the results would be required to be significantly better. The only complaint the existing process drew was, sometimes, the fail/pass (faulty product being passed) rate was higher than normal and, as a result, the management and the logistic team was not happy when many products were returned after shipment.

The design team went back to the lab and start redesigning the MQM Testbed based on three requirements:

1. The testbed shall minimize the disruption of the current production process and maintain a non-intrusive approach to test the product;
2. An automated objective measure for quality check shall be used;
3. The result must be at least 30% better than the status quo.

Furthermore, it is necessary to find a quick solution to meet the timeline of the MQM Testbed deliverable dates since three months had gone by. The task seemed straightforward, replacing the listeners with a machine, but the devil was in the details.

Although the most discrete characteristic of the manufacturing lines involves welding, the new focus of the MQM Testbed was on improving the quality control through acoustics analysis and analytics of the end products. The core of the experimentation was around how IoT could be applied to this environment and how analytics for acoustics could improve the accuracy rate of correctly detection of defected products.

There are three major sections in the IIRA: sensors and sensory network, analytic platform and management. The MQM Testbed uses an analytic engine to perform the computation and assessment of quality control to determine the pass/fail of the product. Data must be collected in the field to train the artificial intelligence (AI)-based analytic engine. The process needed to be fine-tuned to ensure it can be used for the design of the production line. While designing the MQM Testbed, picking up the acoustic signal and the data presentation for control and management were straightforward. However, it may have been problematic to find a useful analytic engine that can be trained for acoustic noise detection.

Fortunately, there was an AI-based analytic engine solution, based on technology from

Huawei, which enables a system to pick up the field signals and train the system, based on the collected data and previous results. This leads to correct decision-making based upon the preset policies and rules. This analytic engine was originally built for another project. The team was lucky to have it modified for the MQM Testbed. The only criteria communicated to the AI–based analytic engine development team was that the analytic engine must make the right call with the focus on avoiding faulty detection by passing a product that is actually defected. Fortunately, the analytic engine was easily modified to suit this purpose. If not, additional delay may have occurred if the testbed team needs to start over.

AI-BASED ANALYTIC ENGINE

Up to this point, people may question using an AI-based analytic engine for this acoustic detection task as overkill. The process may take place with a dedicated machine and does not need to involve many computations. An AI-based analytic engine, such as the one provided, performs machine learning and deep learning, which requires not only the computing power of an ARM processor[2], but also some other processors like Graphics Processing Unit (GPU) and CPU to support it. This was a conscious decision by the testbed team because it could help yield an additional benefit for the MQM Testbed: with the AI-based analytic engine, the MQM Testbed was not only very useful for the simple acoustic detection task, it could also be used for other purposes in the future.

It is important to note that the training data

sets for the AI-based analytic engine may not be easily acquired. The key to machine learning is the training data sets. Project partners provided field recorded data from machines in good working order (passing data) and the machines being returned (failing data) after shipping. Colleting the failure data sets was not an easy task because the quantity of the failed machines is relatively small for the short data collecting period. As a result, the data set size of the failing data is much smaller compared to the size of the data set for passing data. All data sets are fed into the learning process of the machine to train the machine to identify the difference between passed and failed states. The machine eventually established a passing state and failed states through testing, training and fine-tuning. This analytical engine development is very important as the AI-analytic engine is not something available off-the-shelf. For users who plan to modernize an existing plant, the complexity of the project cannot be underestimated.

TESTBED COLLABORATION

One challenge of promoting the MQM Testbed is that colleagues from Haier have been unable to travel to IIC meetings to share their knowledge with members. The testbed spokesperson has communicated MQM Testbed conversations to IIC members with the goal of developing this testbed further within IIC. While other IIC members may have similar analytic engines, there are aspects that are unique to Huawei's approach for the Testbed as IIC members are able to duplicate the process and develop

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[2] An ARM processor is one of a family of CPUs based on the RISC (reduced instruction set computer) architecture developed by Advanced RISC Machines (ARM). TechTarget, How to choose the best hardware for virtualization.

their own success stories. Through this collaboration, the process, different phases, elements and needs associated with the IIRA structure used by the MQM Testbed will be further explored, reinforcing the usefulness and importance of the IIRA framework.

The MQM Testbed has pulled many of the Chinese IIC members together for next generation manufacturing work. This project started two years ago when the IIC ecosystem was still developing. There is a strong need from China to have something similar to Germany's Industrie 4.0. MQM triggered the emergence of China Manufacturing 2025 in the Smart Manufacturing category. The IIC's testbed program is a good way to group all of the interests in China together.

Furthermore, it is IIC that brought the MQM Testbed partners together. CAICT is a research entity of the Chinese government focusing on new technology trends for China that would provide more global visibility. Under the guidance of China's policy, CAICT was seeking the technology trends and it found the work of the IIC Testbed Program to be a perfect fit for testing some of the foundational work already begun in China. Huawei and China Telecom, considered two strong IT entities, also discovered that the IIC Testbed Program is a great home for helping OT entities, such as Haier, by providing connectivity and solutions. As a result, in addition to the MQM Testbed, Huawei is collaborating with more IIC members and has several testbeds in the pipeline.

LESSON LEARNED

Managing Expectation of the OT Partner

Initially, Haier was reluctant to join the MQM Testbed because they did not feel ready to have a strong IoT presence in manufacturing, especially on the production line renovation. But with the help of CAICT and China Telecom, they decided to give it a try. Huawei showed them some of the IIC testbed results and help them during every step of the work. Two years later, the MQM Testbed is reporting great success and Haier management is very pleased with the work.

Bringing an end user on board quickly at the beginning of an Industrial IoT (IIoT) project has proven to be a very significant step. It is also important to help partners, who are not familiar with IoT, build confidence, want to participate in this leading edge IoT effort and add to their existing process. Often, companies will just want to consider proven solutions which they can purchase and implement right away. However, no matter how ready the off-the-shelf solution may be, additional efforts are required to turn any new IoT solution into the one that can fit the user's needs. In this case, the user, Haier, gained the confidence to try leading edge IoT technology (AI-based analytic engine), benefited from it and eagerly helped drive the adoption. The MQM Testbed also helped the testbed team learn something different than the conventional IoT approach. Technology vendors often think that they have a solution for everything. They create something in-house and then seek to sell it to the world. The problem is that the users have specific needs. As a result, the frustration caused by the mismatch of this ill-managed demand-supply relation is growing. Through the exercise of the MQM Testbed, the testbed team learned that there are great products not being used and there are users that urgently need solutions, but no one is providing these solutions because the vendors have not taken the time to sit down with the end users,

understand their specific needs and identify the elements and the process required to solve the problem.

IIC Foundational Documents as Resources

Two technical documents which have benefited this Testbed greatly are the IIC's IIRA and the Industrial Internet Security Framework (IISF). Because these two documents were available at the start of the MQM Testbed, they helped the testbed team easily lay out all that needed to be done to renovate Haier's production process. Part of the reason Haier was initially reluctant to adopt IoT technology in their production process is because they have long-standing, separate routines across all of their different channels. The plans to implement IoT systems would require them to adapt a new architecture, which they were not yet prepared to do. The IIRA clearly describes the three-tier architecture the testbed team was recommending and provided a "visual" to support how all the IoT elements played together. With the guidance of the IIRA and the testbed team's understanding of the challenges and elements of structuring the projected solution, Haier understood the steps and requirements and agreed to move forward with the project.

There are implicit concerns about moving systems to the internet: exposure to the outside world, vulnerability to attacks, damage to the factory, etc. The first phase of the testbed project was managed locally so cyber security was not a primary concern. Fully automating so that Haier can link all of its factories in their own multi-site requires the cyber security risk to be addressed. At that time, the IISF provided guidance for Haier to understand the importance of taking security and safety matters very

seriously. The IIRA and IISF were important resources from a technical perspective and were also used to help articulate the role of IoT for the end user. Their importance is also apparent in the collaborative nature of the publishing of these documents – because the IIRA and the IISF were each produced by a teams of experts from a wide spectrum of member organizations of the IIC, the documents carry a universal acceptance that the underlying recommendations and best practices will apply across solutions and vendors – not just a recommendation from Huawei, but a widely respected approach for the industry.

Small Change, Huge Improvement

The task of retrofitting the existing factory required in this project was not as difficult as originally thought because the initial assumption was they would need a high level of integration. However, a simple reevaluating of the design was all that was needed. Using the quality checking station as an example the testbed team originally thought they would need to retrofit the welding station with high tech sensors integrated with the welding head to monitor the welding process. After reviewing the whole process, the work was refocused on the quality check station, which proved to be a more manageable spot for the testbed. Furthermore, the trial run of the AI-based analytical engine did not provide satisfactory results: The microphone on the quality check station also picked up additional ambient noise. With some experimentation, the analytics were not able to filter out the ambient factory noise effectively. The performance was eventually optimized by placing the tested unit and the microphone in a "sound proof" chamber at the test station.

Respect the Client and Work with Them

Originally, the client was not in favor of modifying the existing production because of the interruption that would occur and the additional burden which would be placed on personnel working in the field. For the people in the production line, the initial collaboration was somewhat problematic because any change added to the production line would potentially impair the productivity. In order to gain the trust and cooperation of operators, the team adopted rules to minimize the impact on the operators. For example, systems could only be tested after work shifts ended. The system would then be re-stored before the next shift began. After several iterations, the production line managers became supportive and helped to conduct the testbed in more constructive manner. While technology is very important, how everyone works together is even more crucial.

Let Results Speak for Themselves

The testbed team's efforts improved the accuracy of positively identifying passed equipment - from 95% to 99% accurate. The testbed team achieved a more significant improvement in the accuracy of identifying false positives which climbed from 50% to 95%.

Haier management was so impressed with the results of the testbed that they are now exploring where they may apply this process to other production lines. The testbed team proposed a solution and convinced management to try a modified process. They had experienced some setbacks initially but they re-evaluated the situation, modified their process quickly and returned with newer and better solutions. Eventually, the team persevered and delivered a solution with outstanding results, in the promised time frame. At the end, the testbed team delivered a real IIoT implementation with tangible results for Haier Group.

Throughout the life of a testbed, as lessons are learned, adjustments are made and results are generated, testbed teams must be always thinking about the next broader step. For a project to be successful, the technical directive the testbed is intended to address must be in the forefront of everyone's mind.

Engineering the Trust

When starting a new project, it is imperative to understand the needs of the end user. During the course of this testbed, the partners' input was solicited, discussed, explored and implemented. They were educated about the process and kept apprised of the results. This fosters trust.

The testbed team took the necessary time to cultivate that trust. The IIRA was very helpful in this regard because once the principles of the IIRA were shared, the testbed team could clearly develop their plan to modernize the existing production process. The team showed Haier what was missing from their current process and showed them how the proposed solution would solve their problem. There is no magic bullet or one-size-fits-all approach. It takes hard work and collaboration among all partners.

COLLABORATION WITH IIC MEMBERS

When the MQM Testbed proposal was delivered, the testbed team had already started the preparation to design the whole project. The first step was to look at the entire project and then focus on the welding section. With this focus, the whole project was designed in the Huawei Shannon Lab in

Beijing. It was not until few months later when the testbed team went to the field that they realized their initial plan to improve the welding process was not possible. As mentioned earlier, they came back to the IIC to seek a member with the expertise to assist them in the welding station. During a quarterly testbed update, the MQM Testbed team announced the challenge they were facing and called for assistance. Olympus has expertise in welding equipment. They recommended the testbed team use thermal imaging - an infrared camera on the welding section. The testbed team went back to the lab to try this recommendation. They later found it was not feasible to integrate this infrared camera with the existing robots.

Another IIC member, FujiFilm, offered a suggestion based upon X-ray film. The testbed team considered the X-ray film idea and weighed the solution which required significantly reconfiguring the welding robots and the solution is designed for post processing so it was not a right fit.

Although these recommendations were eventually not incorporated into the testbed design, they showed a great value of the IIC which offers innovators a network of experts with abundant knowledge and technologies in the IoT space. Within this network, there are plentiful opportunities for members to jump in to offer guidance and possibly resources to contribute to help moving these testbeds and real-world implementations forward.

These recommendations from Olympus and FujiFilm triggered the testbed team to rethink the design and decide where to focus. They helped the team discover that the quality control process was insufficient, thus zeroing in on the element which became the basis for their final solution. All that was needed on the analytics side were some modifications to support the new quality control process.

IIoT projects typically involve adoption of a wide range of technologies and practical knowledge from different industries. The brick wall felt by some in a project may not be as hard to overcome for others who have been there and learned from past experiences. Furthermore, although the initial solution offered may not always fit the needs, the support and interests from fellow IIC members can sometimes – as is true for the MQM Testbed – help trigger a different approach, a regrouping and pointing the project in a better direction. The IIC quarterly meetings are a great opportunity to proactively connect with people and expand a project's resource pool.

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