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# Karakuri IoT – The Concept and the Result of Pre-Study

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**Abstract.** Although scholars and practitioners are actively discussing the potential benefits of introducing Internet of Thing (IoT) in production, IoT is still as an expensive solution in terms of investment and high technological threshold. Manufacturing companies seek a simpler and lower-cost approach to adopting IoT technologies in production, allowing companies to take advantage of the knowledge and innovation capabilities of people close to shop floor operations. This paper introduces the concept of "Karakuri IoT" – simple and low-cost IoT-aided improvements driven by the people close to shop floor operations. A pre-study is conducted to examine the feasibility of the concept. This paper presents the results of the pre-study.

**Keywords.** Kaizen, IoT, Production, Karakuri

## 1. Introduction

Recent development of Internet of Things (IoT), envisioned as every object has a digital identify and can connect to a data network [1], enables manufacturing companies to advance their factories toward the era of information-intensified factory operations. Application of various kinds of sensors, Information and Communication Technology (ICT) devices, and cloud data storage and computing services bring opportunities to integrate and share rich, timely, and accurate information in production environments [2]. The integration and sharing can reduce data latency, analysis latency, and decision latency. This leads to higher responsiveness and agility in production operations [3]. However, despite the acknowledged potential of introducing IoT in production, IoT is still an expensive solution in terms of hardware and software investment, high technological threshold, and uncertainty entailed by adopting new technologies [4].

It would be beneficial for manufacturing companies to have a simpler and lower-cost approach to adopting IoT technologies in production, allowing companies to take advantage of the knowledge and innovation capabilities of people close to shop floor operations. To respond to this challenge, the authors of this paper have initiated a research project whose purpose is to enable production workers to easily build and implement simple and low-cost IoT-aided improvement solutions at the production shop floor by providing them with a modular hardware and software system. In this paper, this simple and low-cost IoT-aided improvement driven by the people close to shop floor operations as *Karakuri IoT*. The idea of Karakuri IoT and its supporting

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modular hardware and software system is new and thus an initial step of the research project was to evaluate the potential of the idea from users' perspective and its technical feasibility. For this reason, a pre-study was conducted in cooperation with a Swedish manufacturing company. The purpose of this paper is firstly to explain the concept of Karakuri IoT and its supporting modular system, and secondly to present the results of the pre-study.

## 2. The Concept of Karakuri IoT and its Supporting Modular System

The concept is inspired by Karakuri kaizen that has been widely acknowledged and practiced among a number of Japanese manufacturing companies. Karakuri is a Japanese word meaning "mechanism" or "trick". Karakuri kaizen is an improvement by creating simple and low-cost mechanical devices that automates some parts of the shop floor operations [6]. Those devices operate by utilizing natural physical phenomena such as gravity force, wind, magnetic force, etc. without electrical nor pneumatic power sources [5]. Those devices are often made by shop floor workers and leaders based on their creativity without much assistance of engineers [6]. Karakuri kaizen has become a movement among Japanese manufacturing companies so that Karakuri kaizen exhibitions are organized annually since 1993 [5]. In doing Karakuri kaizen, modular fixturing and framing systems provided by manufacturers such as Yazaki and USU, which are nowadays frequently used for self-made parts shelves at assembly lines, are often used as a platform to build the mentioned kind of mechanical devices [7]. An apparent benefit of Karakuri kaizen is an improvement of shop floor operations through low-cost mechanical automation. However, one of the major reasons why Karakuri kaizen has been widely practiced in Japan is the empowerment of production workers. Karakuri kaizen provide employees opportunities to exert their creativity to build own improvement solutions [7].

The idea of Karakuri IoT is raised by the question of "is it possible to realize IoT-based Karakuri Kaizen, in a similar way that the mechanical-based Karakuri kaizen has been supporting the shop floor operations?". In recent years, lower cost of sensors, communication and computation devices, and various kinds of cloud services has been ever more available [8]. This increases the possibility of building local, simple, and low-cost IoT-aided improvement solutions at the shop floor, possibly done by the people close to shop floor operations. The current challenge of making such IoT-aided improvement solutions is a relatively high technological entry-threshold for them. Making those solutions usually requires the knowledge of designing of electrical circuits and programing languages.

If there is a modular hardware and software system that allows to combine those "modules" (e.g. sensors, communication devices, cloud services) in an extensively simple way, without the knowledge of electrical circuits and programming languages, like building with LEGO blocks, it can substantially reduce the entry-threshold for improvement actors to build and implement local, simple, and low-cost IoT-aided improvement solutions. As the modular fixturing and framing systems have been a key enabler of mechanical-based Karakuri kaizen, the modular hardware and software system can be a key enabler for Karakuri IoT.

By an analogy of the mechanical-based Karakuri kaizen, Karakuri IoT supported by the mentioned modular system may bring several potential benefits:

- Realizing low-cost automation at the shop floor especially related to information flow and decision-making
- Bringing production workers new opportunities for improvement
- Empowering workers by exerting their creativity to build IoT-aided improvement solutions by themselves
- Higher chance to attract younger workers to shop floor operations, assuming that they tend to be more interested or skilled in dealing with information technologies
- Enabling democratizing innovation in terms of implementing IoT in production, in contrast to top-down implementation of a complex and large-scale IoT-enabled system driven by engineering experts

## 3. Method of the Pre-study

The concept of Karakuri IoT and its supporting modular system seems to be new in literature and the potential benefits of the concept has been so far hypothetical. Therefore, the authors of this paper conducted a pre-study with two objectives: 1) identify the potential of the concept from the users' perspective, and 2) identify technical feasibility of the modular system. The study was intended to collect much knowledge related to these two objectives, so that a decision can be made later whether the potential and feasibility of the concept is large and realistic enough to proceed to a larger project whose aim is to realize the concept. The pre-study was conducted from November 2017 to March 2018 by the authors in this paper. The team of the authors is a multi-disciplinary one because they specialized in different research areas, kaizen and innovation in production, industrial IoT, and user experience, respectively. To meet the objectives, two things are conducted: 1) a review of use-case reports describing the implementation of IoT in production in Japan, and 2) two workshops at a collaborating manufacturing company.

The review was undertaken for the both objective. Since the mechanical-based Karakuri kaizen has been widely practiced among Japanese manufacturing companies, it was assumed that similar efforts to Karakuri IoT might be done at Japanese companies. Identification of such efforts may bring some implications as to the user potential and the technical feasibility of Karakuri IoT and its supporting modular system.

The workshops were done mainly for the first objective. The collaborating company is a large multi-national manufacturer of heavy-duty vehicles for construction. The workshops were undertaken at one of a production site in Sweden. Participants of the workshops were from different functional groups; assembly operations, machinery operations, paint shop, logistic, IT, production engineering, and maintenance. At the first workshop with 20 participants, the concept of Karakuri IoT and the modular system was explained and they were ask to identify what kind of kaizen was possible with the concept. A brainstorming was made in groups and the results were shared among the participants.

The second workshop was planned based on the result of the first workshop. At the first one, the participants identified a number of problems that could be solved by Karakuri IoT. The team of the authors initially thought to select one of the problems, develop conceptual solutions, and present them at the second workshop for discussion.

However, the team considered that it would be better for participants to generate conceptual solutions by themselves, because the key concept of Karakuri IoT is people close to the problems solving the problems by themselves. With this thought and being inspired by user-centered design approaches such as [9], so-called Karakuri IoT modular cards were created. Examples of the cards are shown in Figure 1.

The cards were considered as a mock-up of the modular system consisting of different hardware and software modules. About 40 provisional cards are created. Joker cards, for instance Joker sensor, were also made in order to leave participants freedom to create their own modules. At the second workshops with six participants, they were asked to generate conceptual solutions to a problem chosen from the first workshop, using the Karakuri IoT modular cards. After those two workshops, the team and some of the participants reflected upon to the potential of Karakuri IoT and its supporting modular system.

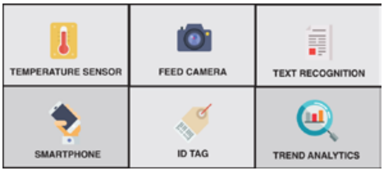


**Figure 1.** Examples of Karakuri IoT modular cards

## 4. Results of the Pre-study and Analysis

In the literature review, about 70 use-case reports describing the implementation of IoT in production were reviewed. They were from a book [10], reports from an industrial and academy collaborative society e.g. [11], and industry-oriented journals such as IE review [12] and Factory Management [13]. These use-cases had different scale and complexity in solutions. Some of them involved large-scale, complex, seemingly expensive implementations of IoT-aided solutions in the production. While some others use-cases dealt with simple, low-cost, and in-house oriented implantation of IoT in production, which were similar to the idea of Karakuri IoT. Fourteen use-cases were found relevant to Karakuri IoT. Some examples are shown in below:

- In order for an operator to effectively monitor the condition of the ten CNC machines, a device with a cheap optic sensor connected to a small computing and wireless communication unit was placed in front of each machine's tower light (i.e. Andon light). The light status is stored in the cloud. Current as well as historical data can be displayed in mobile phones and tablets. The most part of this system was made in-house, and the cost of the system was significantly lower than that could be purchased externally [12].
- A web camera is placed in front of each production analysis board located in different parts of the production shop floor. The status of the board is stored in the cloud. Any employee is able to see the current and historical status through ICT devices [12].

Those fourteen use-cases did not mention how the solutions were made. Assumingly, the implementation required some knowledge of programing or electrical circuit design. Thus, these cases are not exactly the same as Karakuri IoT. Even though, the review of those cases have implied that there is a clear need of small-scale, low-cost, in-house oriented implementation of IoT-aided solutions in production. In addition, the use-cases have also shown the technically feasibility of combining inexpensive sensor, wireless communication devices, and cloud services to create and implement IoT-aided solutions in production. To realize the intended hardware and software modular system, a technology that enables to combine those "modules" in a significantly simpler way needs to be developed. The authors estimates that realization of the technology is likely achievable.

Further, the review of the 70 use-case reports have revealed that several practitioners and scholars discussed the following points that also imply the potential of Karakuri IoT and its supporting modular system:

- A major challenge of the large-scale and top-down implementation of IoT in production is the uncertainty of its pay-off. Mangers have difficulties in estimating the negative consequences entailed by substantially increasing the complexity of the system [11].
- A bottom-up approach to implement IoT in production allows an organization to gradually learn how to utilize IoT in production, and eventually obtain a clearer vision on how IoT-enabled factory can look like in future [13].
- Low-cost and small-scale implementation of IoT can be a temporary solution. It can be easily modified and replaced, compared to a larger and more rigid system [10].

The first workshop resulted in identification of 34 problems or ideas that the participants thought could be solved or realized with the concept of Karakuri IoT and the modular system. Some examples are shown in below:

- Employees operating washing machines for gear components sometimes have to walk around the shop floor to find washing baskets used for the machines. Is there any simple way to avoid this?
- When employees send work orders to the maintenance division, they have to go through several steps within the company's resource planning system. Is there any simpler way to put those work orders?
- A simple way of automatically logging short stoppage of machines would be appreciated.

After the workshop, a discussion was made with two informants of the company who also attended the workshop. They told that most of the participants perceived that Karakuri IoT and its supporting modular systems have a large potential to help their improvement activities. The participants also thought the bottom-up focused approach that Karakuri IoT employs is interesting and at the same time inspiring.

The problem choses for the second workshop was "the finding-washing-basket problem" which was identified in the first workshop. The second workshop resulted in the participants generating six conceptual solutions to the problem, using the Karakuri IoT modular cards. These solutions had a difference in complexity. For instance, a simpler solution consists of push buttons and color lights, indicating when the basket is used at which place (four modular cards were used). While, a more complex solution employs multiple layers of sensing, real-time information display, and trend analytics (ten modular cards were used). At the end of the workshop, all of the participants and the team of authors reflected upon the workshop. General impression of the workshop was positive. The participants perceived that the modular cards helped them to focus on the conceptual phase thinking through various alternatives. According to them, the discussion of solutions of this scale tends to jump onto the technical details of a single concept, which can be dominated by technical experts. The participants also perceived that the modular cards facilitated multi-disciplinary work to generate solutions. The cards functioned as "a common language" for the participants with different expertise and technical knowledge to discuss the solutions based on the shared symbols. Further, the authors also identified the potential benefit of the scalability and reconfigurability of the modular system. The complexity of a solution made of the modular system can be easily changed by adding or removing modules. This may help companies to experiment, and eventually identify a right level of automation in terms of information handling. The reconfigurability implies that the modular system can be also used as a prototype of a larger and more permanent IoT-enabled system to verify or identify its effectiveness or weakness.

## 5. Conclusions

In this paper, the concept of Karakuri IoT and its supporting modular system is explained, then the results of the pre-study are presented. The pre-study was conducted in order to see whether the potential and feasibility of the concept is large and realistic enough to proceed to a larger project to realize the concept.

As shown in the previous section, the pre-study has shown multiple evidence indicating that Karakuri IoT and the modular system can be well perceived by improvement actors, and that the concept is technically realizable. Therefore, the authors have decided to proceed to a larger project. The founding for the large project has been awarded, involving five more collaborating companies and one more research institution. More papers as to Karakuri IoT will be produced throughout the project.

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