

# Visualization of the Unconscious in Quality Inspection in Manufacturing

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## Abstract

In quality inspection, which is the final stage of the manufacturing process, there is an operational manual on how the object should be inspected. In this study, we followed the gaze of the workers to search for the "way of looking" at the objects to be inspected, which is not described in the manual.

As a result of experiment, we found a difference between the reciprocating eye movements that occur in skilled worker and the static state of newcomers. It is suggested that this indicates a way of looking at inspection that has been unconscious until now.

*Keywords:* Skill Transfer, Experienced Worker, Reciprocal Motion, Quality Inspection, Manufacturing

## 1. Introduction

Contributions With the widespread use of IoT and AI, robotization has made remarkable progress in manufacturing processes, but the gap in labor productivity between small and medium-sized firms, which are inferior to large firms, is widening (SME Agency, 2018). As a matter of fact, there are still many handy manual operational processes in the sites of SMEs, and human resource development through improvement activities and creativity is required. For this reason, the authors have been conducting research on organizational learning in SMEs in terms of the skill transfer and improvement of work efficiency (Nagayoshi and Nakamura, 2017).

While daily improvement activities are being carried out at workplaces, the reality of efforts to improve work

efficiency is that they are often focused on work procedures, which are merely defined in work instruction handbook. Therefore, the authors decided to focus on quality inspection, which is greatly influenced by human resources, and to analyze the skilled worker from the perspective of human resource development. At this time, we believe "work procedures" are insufficient for quality inspection, and how do they actually inspect the precautions written in the work instruction handbook? Therefore, the authors decided that gaze measurement would be effective against visual inspection, and conducted an experiment using eye tracking system in this paper.

The history of gaze measurement is very old. In the past, the direct observation method was used to observe the movement of the cornea and capillaries with the naked eye, and the afterimage method was used to project

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\*Refer to the first author's laboratory web page : <https://j-nakamuralab.com/>

the generated afterimage on the retina onto a screen and quantitatively measure the movement (Hashimura, et al., 2015). When it comes to the current direct observation method, for example, Tobii Technology's Tobii Pro Glass 3, has 16 LEDs and 4 eye cameras built into the lens to measure eye movements (Tobii Technology, 2021a), and we take this Glass as a tool to observe eye tracking for quality inspection worker in a manufacturing factory.

## 2. Quality Inspection of Fuel Cell Piping

The pipes used in household fuel cells are long and narrow. Since the pipes are bent at several points, the quality inspection has to be done manually (Fig. 1). In other words, inspection by machine is currently difficult. The fittings at the edge of the pipe and the exterior are inspected for scratches, dents, deformations, and other abnormalities. In this process, the bent parts are inspected for wrinkles, and the fittings of both edge sides of the pipe in particular are slightly protruding, making them difficult to see from some angles. For this reason, we look at the edges from various angles to see if there are burrs, scratches, dirt, etc., and if so, we polish them with a file or brush. Once the five products that have passed the appearance inspection are assembled, they are placed in a neat row and inspected again for comparison of appearance.



Figure 1: Image of piping (actually 3D instead of 2D)

In this paper, with the cooperation of Nihon Pipe System Co., Ltd. the workers of visual inspection of fuel cell piping were asked to wear glasses for eye measurement and to perform ordinary quality inspection work.

## 3. Methods

The gaze measurement experiment was carried out as follows.

- Location: The factory of Nihon Pipe System Co., Ltd.
- Date: Tuesday, August 3, 2021
- Workers: 1 veteran (the most skilled worker)

As mentioned above, the object of the quality inspection is the piping of the fuel cell, and the final product is the eco-cute. We paid attention to the edge where the notes on the test were written and observed carefully while playing back the gaze measured video. In order to capture changes in a particularly short period of time, the video was played back at 1/16th the normal speed.

## 4. Result

As a result of the eye-tracking of the experienced operator, the quality inspection of 15 pipes in 377.56 seconds was recorded. The average speed of the inspection was 20 seconds per pipe, although there were some inspections of five pipes side by side for comparison and re-inspection of one of the 15 pipes.

In eye-tracking, fixation is often extracted and the location of the gaze is observed. However, since the time required for the quality inspection of piping is so short that the extraction of fixation is limited, we decided to capture the movement of the eye and follow its trajectory. Among the inspection processes, we focused on the inspection of both side edges, which requires changing the angle of gaze, and found that the longest time was 0.521s while the shortest was 0.181s. The results are shown in Figures 2 and 3. We can see that both eye movements look like a reciprocating motion.

As for the pipes that were noticed during the visual inspection, those pipes are to be polished with a brush to remove burrs. Immediately afterwards, the edges are held with both hands to check its condition after polishing. Figure 4 shows the trajectory of this process. As in Figs. 2 and 3, we found that a reciprocating motion is performed.

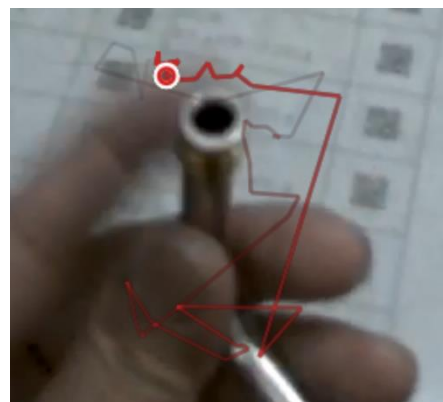


Fig. 2 Experiences worker's inspection of edges  
(The duration of the movement is 521ms)

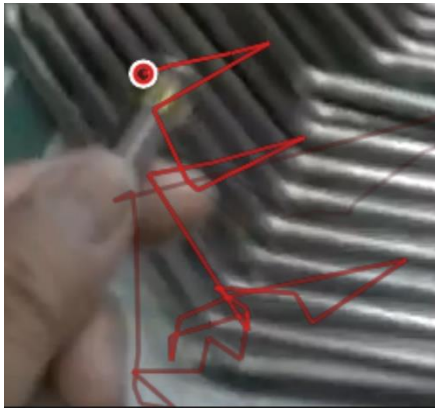


Figure 3: Edge inspection of experienced worker  
(The duration of the movement is 181ms)

Since the time required for the inspection was less than one second, it turned out that the workers themselves were so unconscious that they were not even aware that they were reciprocating.)

## 5. Discussion

Here, let us consider the reason for the reciprocating motion of the eyes in quality inspection. Denso Corporation is using eye tracking for inspection at some manufacturing sites called Nishio-Seisakujo, where the key point of the test is to let the gaze flow as if spelling out the letter "2" as shown in Figure 4 (Tobii Technology, 2021b).

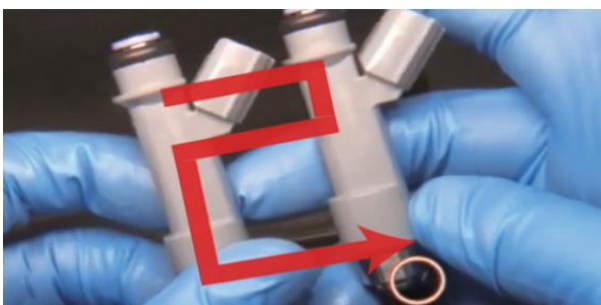


Figure45: Key points of quality inspection at Denso  
(citing inspected images from (Tobii Technology,2021b)

The Denso case is described as if spelling out the letter "2", which can be broadly interpreted as a reciprocal motion of the eyes.

The above interpretation might support the following three points which could be inferred.

First, since the act of searching for a problem is a part of the normal inspection process, the pattern of concentrating on a fixed point may not be possible. Rather, the fixed pointed gazing pattern may occur after a flaw as an example is found in a quality inspection.

Second, the remarkable factor is the reciprocating motion. At first glance, it appears as if the subject is going through a trial-and-error process of looking at the target and then checking it again while slightly moving backward. However, since this is done in a very short period of time, less than one second, it can be inferred that the reciprocating motion of the eye itself is unconsciously performed.

Third, the question is whether the reciprocal motion of the eye is left-right, up-down, or diagonal. In Figs. 2 to 4, the eye movements are generally left-right, although there are some angular variations in the eye movements. On the other hand, in Figure 1, the gaze is up and down, and the reciprocating motion is quite short. This may be due to the difference in the shape of the object and the angle at which the gaze flows.

Fourth, with regard to inspecting the edge of the pipe viewing from the front of the edge as if you were looking at the cross section of the pipe, it takes more time than setting the pipe on its side looking across the edge, as mentioned in the chapter of result. The cross section is checked against the circumference of pipe, while the side is in a sense a straight line. This may have an effect on the speed. In addition, it is easy to understand that it takes more time to brush the same section after than before.

By the way, gaze can be further divided into three types: Tremor, Drift, and Microsaccade (Martinez-Conde, at al., 2004). Tremor is a small back-and-forth motion that makes observation difficult, Drift is the initial gaze that occurs simultaneously with Tremor or during Microsaccade, and Microsaccade is a short and fast viewpoint motion to correct Drift (Cornsweet, 1956).

The reciprocating motion of the eye in this paper may be Tremor, Microsaccade, or Drift, but it needs to be further explored in the future. In this paper, we focused on the edge of the pipe, but we also observed large reciprocal eye movements such as ①→②→③ and ③→②→① when we viewed the pipe from the side as shown in Fig. 1.

The most interesting feature of these reciprocating movements of the eye is that even in a very short time, decision-making could be executed to evaluate the test results. That means, even though the reciprocating movements are unconscious, judgments are made consciously by individual. This might be similar to driving a car, where instantaneous judgement, its evaluation and one's decision-making, are carried out simultaneously.

## 6. Conclusion

In this paper, we visualized and discussed the eye movements during the quality inspection of piping. Reciprocating eye movements were found during the quality inspection, although unconsciously, and the factors behind them were discussed. The analysis is based on the measurement results of only one experienced worker, and the limitation is unavoidable. The bottleneck is that it is not possible to obtain a large number of samples due to the limited number of workers for quality inspection, but this becomes a management issue in terms of skill transfer and human resource development.

In the future, we would like to conduct research on the visualization and analysis of the differences between experienced and new workers, as well as the view of piping from the side, which will lead to the skill transfer.

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## Authors Introduction

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