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Exploring the possibilities of using image recognition technology to create a hybrid lean system for pulse methodology

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Abstract

Processes in product development are becoming more and more complex. A multitude of engineering disciplines are involved in the development of new products. New lean and agile methods arise. Pulse methodology is a lean deviation management methodology introduced by Scania in 2003, and since then many Swedish companies adapted it. It is based on synchronizing the company by frequently having short meetings (aka. pulse meetings) and visualizing the deviations using traffic coded magnets on whiteboards (aka. pulse boards). Even though the whiteboards lack providing efficient communication between distributed teams, still the users appreciate the simplicity of them. In this research, we presented a new methodology called hybrid pulse methodology, which solves the communication issues exist in the baseline methodology. We tested the methodology at the workshops we held in the companies, in simulated global meeting settings, using the demonstrator we developed for the methodology. This research contributes to the lean literature with a new methodology that ensures the synchronization of global organizations by providing efficient communication between distributed teams without damaging the baseline methodology.

Keywords: Visual management; deviation management; hybrid systems; distributed teams

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1. Introduction

Pulse is a lean deviation management methodology developed by Scania in 2003. The name comes from the analogy between doctors checking the pulse of their patients to follow the patients' health and managers having meetings to check the status of the company. Pulse methodology (PM) consists of two main components: pulse meetings and pulse boards. The purpose of the pulse meetings is to synchronize the company. Pulse meetings are held regularly among managers. The frequency of the meetings can vary from once a week to once a day depending on the workload; higher the workload, more frequently the meetings are. The meetings generally last around 15 minutes. Attendees stand in front of the pulse board and give brief information about their status while updating the board accordingly. Fig. 1(a) shows a pulse meeting, while an attendee is sharing his project's status with the other attendees. PM uses pulse boards to track and manage deviations. Fig. 1(b) shows a mock-up of a real pulse board. They have much flexibility and the ways they were used were unique to each company we studied. There is no strict definition about the structure of pulse boards. The baseline, however, is a large whiteboard with cells where X-axis and Y-axis represent different functions, departments, projects, products etc. The color of the magnets resting on the cells shows the status of the intersection that creates that cell (e.g., status of a product in marketing department). Depending on the company, there are generally three and sometimes four different colors to display the status. The color of the magnet reflects what kind of deviation to consider. Meanings of the colors may also vary for each company. Some of the colors and their meanings are as follows:

- Red: Big deviation; new deviation; deviation without a solution at hand
- Yellow: Small deviation; deviation with a solution at hand
- Green: No deviation; solved deviation
- White: No activity; no deviation

Two trends can be discerned today in product and production development: increased virtualization and increased visualization. Increased virtualization comes from product lifecycle management, systems engineering and process management. It ensures that development teams see the latest versions of the information whenever and wherever they want using digital tools. Increased visualization comes from the lean paradigm and has resulted in simple and often physical tools and methods such as PM and the pulse boards. The implementation of enhanced visualization shows that visual management with standard whiteboards exhibits a simplicity that is appreciated by the users[1]. Furthermore, whiteboards provide the haptic feeling of using real objects and have low barriers-to-entry comparing the digital boards. Whereas, digital boards (i.e., digital board software) require time and money investments in the form of developing them in-house or buying them from a third party along with TVs or projectors to display them, and educating the employees about how to use them.

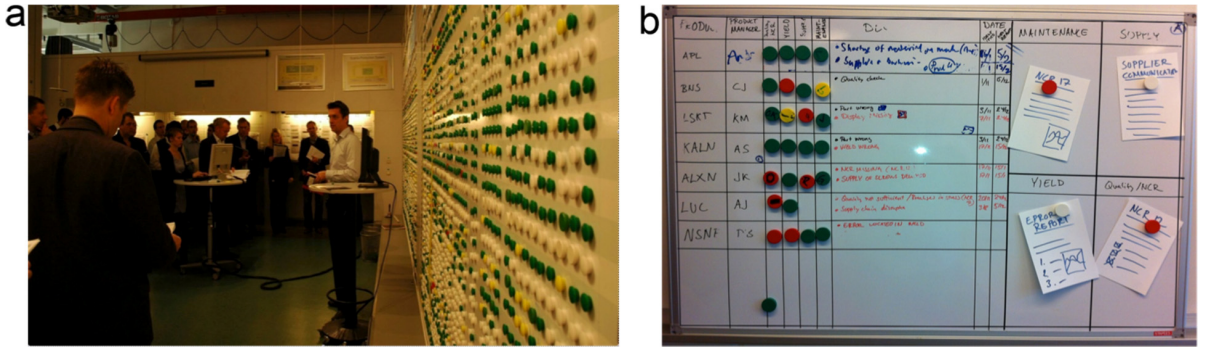

Fig. 1. (a) pulse meeting[2]; (b) pulse board.

Globalization of organizations leads to a knowledge gap between geographically distributed teams working in the same organization[3]. This creates the need of support for efficient communication[4]. In order to avoid the time consumption and cumbersome nature of information exchange between distributed teams, methods and tools to help and facilitate the communication is needed[5]. Baseline pulse methodology (BPM) is based on whiteboards, however these boards fail to provide efficient communication support between distributed teams. This issue has strong implications on the usefulness of the PM; failing to provide efficient communication means failing to fulfill one of the most important main goals: synchronizing the organization.

There are vendors that are specialized on developing digital visual management tools. Since these tools are developed as one-size-fits-all, companies who buy these software needs to adjust the way they work according to the purchased software. However, it should be other way around. IT systems are just enablers, they are the ones that should be adapted to the way that the companies work[6]. Even if companies purchase very customized software, it will still affect the way they work[7]. The affect may come as an improvement, however still it will make the company lose time while adjusting to the new reality.

To summarize, pulse boards need to be improved in order to provide efficient communication between distant offices. Increased virtualization can help pulse boards to be improved; digital pulse boards would increase communication efficiency between distant offices. However, adopting IT tools is problematic for companies and users like using whiteboards. This creates a dilemma: pulse boards should be improved in order to provide efficient communication, but any kind of change on the boards would negatively affect the companies.

This research paper is a part of a Swedish research project for improving efficiency of the Swedish companies in the global arena. The case company for this paper is a Swedish product development company in the telecommunications industry. In this research, we tried to solve the dilemma explained in the previous paragraph. Our goal was to improve the communication capabilities of physical pulse boards (i.e., whiteboards) to facilitate the management of distributed offices by making use of increased virtualization, while keeping the whiteboards in use. We developed a methodology, which we called hybrid pulse methodology (HPM), based on the BPM and hypothesized that it solves this dilemma. We developed a demonstrator, based on the requirements we gathered from the case company, in order to test our hypothesis. The demonstrator is a hybrid tool that combines the strength of both physical and digital boards using image recognition technology. We tested the demonstrator at the workshops we held at the premises of three different Swedish companies that are part of the main research project that was explained above. Alongside with the case company, one automotive safety systems manufacturer and one dental implants manufacturer joined the workshops. The dental implants manufacturer had the experience of using the digital boards therefore provided valuable feedback.

The structure of this research paper is as follows. The introduction chapter continues with giving information about a similar application. After that, how the research was carried out is explained in the second chapter. The research results and the analysis regarding them are presented under the third chapter. In this chapter we presented the way the company uses PM, explained HPM by comparing it with BPM, mentioned shortly about the demonstrator we used to demonstrate HPM, and finally presented the feedbacks of the three companies that joined the workshops. In the fourth chapter we discussed the validity of the results, and effects of the methodology on sustainability. The paper finishes with the conclusion chapter where we summarized the study and shortly mentioned about the future work.

1.1. Similar applications – The lego calendar

The lego calendar is a team calendar concept that comprises synchronized physical and digital calendars. It was developed by Vitaminsdesign in 2013, to improve the ability of organizing the teams[8]. The physical calendar in the concept is a wall-mounted calendar made only by lego bricks, as given in Fig. 2(a). Each row represents a month, and each column represents a day in that month. Inside the month rows, team members have their own smaller rows that show their work schedule for that month. These smaller rows are represented by a lego avatar in the beginning of each row, in the first column. Each project has its own color and the lego bricks that have these colors represent a half-day spent on these projects. The lego calendar in Fig. 2(a) shows the work schedule of six team members for the first fifteen days of a month. The digital calendar in the concept is a Google Calendar. Fig. 2(b) shows the digital copy of the physical calendar in Fig 2(a), in week-view between 5th and 11th day of the month.

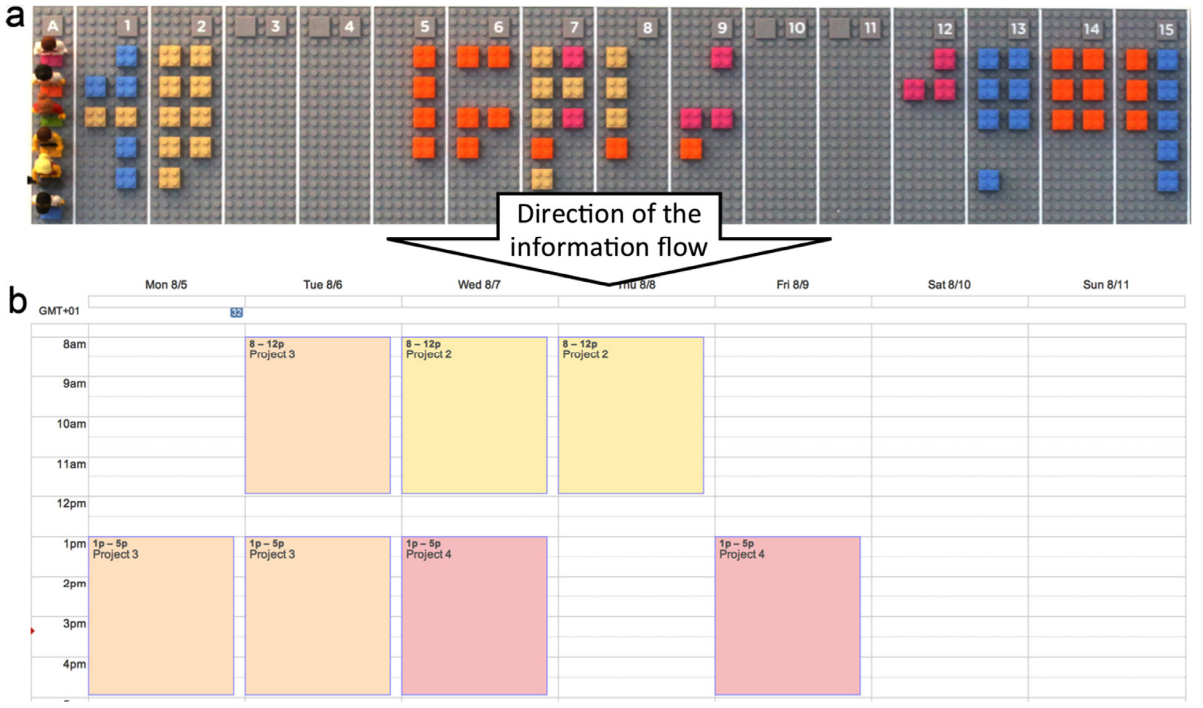

Fig. 2. (a) physical lego calendar[8] (first 15 days of the month); (b) digital copy of the physical calendar (week view between 5th and 11th).

The physical calendar is situated in an immediate place where the team members work, so that they can do changes on it directly and have a look at it to get a quick overview of the work schedule. After they make a change on it, they take a photo of it and email the photo to a special address, which then updates the digital calendar. The digital calendar is used by the team members that are on business trips, when they need to check the work schedule. As shown in Fig. 2, the system does only one-way information transformation that is from physical to digital calendar. This means that the system cannot update the physical calendar using the digital one. Therefore the team members that are on business trips cannot make any changes on the calendar themselves unless they ask help from someone in the main office where the board is situated.

The lego calendar concept was developed one year after we developed HPM and the demonstrator along with it. The lego calendar and HPM are very similar regarding the tools they use. Therefore with small changes both can be used instead of each other. For instance, the lego calendar can be used as a pulse board as follows. Small rows may represent the departments and columns may represent the products in a company. Considering the lego calendar in Fig. 2(a) as a pulse board, it would show the deviations at six departments over fifteen products in a company. The colored lego bricks that are staying at the row and column intersections represent the deviations in those intersections. The colors of them indicate the severity of the deviations. Just like in the lego calendar concept, one can take a photo of the board and email it to the address that would do the image recognition and update the digital version consequently. The only necessary change for this step is to change the calendar template with a pulse board template. Likewise, with the small changes we described above, the demonstrator we developed for HPM can be used instead of the lego calendar.

2. Methodology

We carried out this research in the following three steps respectively: describing the problem, prescribing a solution for the problem, and testing the prescription. The first step is a qualitative study, and it includes understanding how the case company works today with PM, and gathering the requirements for the new system (i.e.,

tools and processes). As Maxwell[9] suggests, we used triangulation for gathering data in the first step in order to increase the validity. Triangulation requires collecting data from a variety of sources by using different methods[10]. In order to provide variety in the way of gathering data, we used interviews and observations in the case company. We provided variety in the sources of data by interviewing employees with different roles in the company.

The second step of the research includes concept development, and prototyping a demonstrator. After gathering the requirements at the first step, we started the second step with the concept development where we come up with 3 different concepts. The concepts were new methodologies along with their own tools and processes. We chose the best one according the following criteria: ease of developing a demonstrator to present and test the methodology, and ease of creating the simulated test environment at the companies to test the methodology. After deciding on the methodology, we continued the research with prototyping the demonstrator. During the prototyping stage, we used extreme programming, which is an agile software development methodology, to deliver the software with a low defect rate[11]. We worked with one-week iterations. Each iteration consists of the following steps: deciding on the features to implement, implementing the decided features, and testing the implemented features. We continued this way of working until the demonstrator came to a level of maturity that it is possible to use it to present and test the methodology at the workshops.

We concluded the research by testing the methodology in the companies. This step includes workshops we held in the companies. During these workshops we presented the methodology using the demonstrator in a simulated global pulse meeting setting. After making the attendees see the system in use and get hands-on experience, we gathered their feedbacks.

3. Research results and analysis

In this chapter we will present the results and analysis of the interview, observations, and workshops we did at the companies that joined this research.

3.1. Pulse methodology in the case company

The case company is a Swedish telecommunication company, which has around 1800 employees worldwide. The Swedish office being the headquarters, they have offices in Europe and United States. They use PM at the highest management level of the company to manage the deviations in their products. The pulse structure of the company is as follows. The company is having pulse meetings once a week, on Mondays 15:00 o'clock CET (Central European Time). The reason of having the meetings at 15:00 CET is, considering the local time difference, to make the offices in United States be able to join the meetings with the European offices. The meetings last between fifteen to thirty minutes. The headquarters host the pulse meetings. The regular attendees of the pulse meetings are: product managers, department managers, and a meeting coordinator. The attendees at the headquarters gather at the meeting room. The remote offices use videoconference to connect to the headquarters meeting room, where also the pulse board of the company is situated. During the meetings, the distant offices see the pulse board through the webcam mounted on the ceiling of the meeting room.

Shortly before the meetings, all the attendees in all three offices gather at their respective meeting rooms. The meetings start by the meeting coordinator at the headquarters starting to share the live video stream with the remote offices. The company pulse board forms the agenda of the meeting; it shows the order of the speakers. Project managers share the status of their products and update the pulse board accordingly in turn; according to the place of their names on the pulse board, the one at the top being the first and the one at the bottom being the last speaker. After product managers share the status of each product, they ask the department managers if there are any further deviations that they have regarding that product. Likewise, the department managers answer this question in turn according to the place of their names on the board, the one at the leftmost being the first and the one at the rightmost being the last. Product managers update the board accordingly if the department managers have further deviations. Product managers sitting in the headquarters perform these updates themselves. However, when the turn comes to the other product managers that reside in the remote offices, the meeting coordinator in the headquarters performs the updates for them. The meeting ends after all the product managers and the department managers share the status of their products and departments, respectively. After the meeting finishes, the meeting coordinator at the

headquarters takes a photo of the pulse board and shares it with the other offices so that they can see the last state of the board until the next meeting.

Fig. 1(b) shows a mock-up board we made from the original pulse board of the case company. The structure of the board is as follows. The board is comprised of two parts. In the first part, which is from the left edge of the board till the end of the color magnets, the statuses of the deviations are displayed. In the second part, which is from the end of the color magnets till the right edge of the board, descriptions of the deviations are displayed. In the first part, X-axis represents the products along with the responsible product managers and Y-axis represents the departments. Colors of the magnets on each cell show the status of the intersection that creates that cell (e.g., status of product-1 at the supply department). They use three colors in their pulse structure. The meanings of the colors are as follows:

- Red: Big deviation
- Yellow: Small deviation
- Green: Solved deviation

The second part consists of three smaller parts; from left to right: short descriptions of the deviations, date information showing when the deviations were identified and when the status of the deviations will be updated next time, and the attached detailed reports about the deviations.

3.2. Hybrid pulse methodology

The BPM uses physical pulse boards. They are easy to use but not efficient when it comes to global meetings. Therefore companies seek the remedy at using digital pulse boards, which have broad communication possibilities thanks to the IT backbone. However, they have high barriers-to-entry comparing the physical pulse boards. We developed the HPM in order to make use of the good traits of physical and digital pulse boards. Table 1 compares the traits of physical and digital boards along with the hybrid system that we developed in detail. As seen, the hybrid system combines the benefits and eliminates the drawbacks of each board; it combines the simplicity of physical boards with the communication and data storage capabilities of digital boards.

Table 1. Physical boards vs. digital boards vs. (*) hybrid system.

Physical boards	Digital boards
The display (whiteboard) is cheap*	The display (e.g., TV) is expensive
Data on the board is temporary	Data on the board is everlasting on the servers*
Backtracking deviation history is not possible	Backtracking deviation history is possible*
Hard to save, copy, and share the data	Easy to save, copy, and share the data*
Only accessible within local premises	Accessible from anywhere, anytime*
Haptic feeling of using real objects*	No (or simulated) haptic feeling
Does not provide support for global meetings	Provides support for global meetings*

HPM is an expansion of BPM. Just like BPM, HPM is also based on pulse meetings and pulse boards. The differences between the two are the type of pulse boards they use and how they use them. BPM uses only physical pulse boards, whereas HPM uses both physical and digital ones. The digital boards in HPM are exact copies of the physical boards and the demonstrator we developed for HPM keeps them up-to-date. The ways the methodologies use the boards can be compared by looking at how they use them during the meetings and outside the meetings. During the pulse meetings, BPM uses the physical boards to visualize the status of the company for the local attendees. If there are distant offices joining the meetings, the main office can share a live video stream with them, just like the case company does. However, we found out that the distant attendees are not satisfied by this solution because they cannot clearly see the details on the board from the video feed. In comparison, HPM uses physical boards to visualize the deviations for the local attendees, and uses digital boards to do the same job for the remote attendees. The demonstrator projects every change on the physical board to the digital board right away so that the

remote attendees can see the up-to-date information. Unlike the situation in the BPM, in HPM the distant attendees can see all the information on the boards clearly thanks to the digital boards. This eliminates the interruptions like the remote attendees asking for the clarification about information on the board that they cannot see clearly from the video feed. Outside the pulse meetings, BPM uses physical boards as information boards (aka. information radiators[12]). Companies put the boards in the company corridors so that employees can see the status of the company at random occasions while they are just passing by. Remote offices of the companies that use BPM cannot benefit from the pulse boards outside the pulse meetings. One solution is to share a photo of the board with the remote offices as the case company does. However, this is not a remedy for all companies. Some of the companies that we held workshops update their pulse boards only during the pulse meetings; some others update them also outside the meetings to eliminate the time spent updating the boards during the meetings to have more time for discussion. For the latter ones, sharing the photo does not constitute a solution since the photo will be outdated during the week. In comparison, outside the pulse meetings, HPM uses the physical boards exactly as BPM, as explained above. In addition, it makes use of the digital boards to provide up-to-date information to the remote offices. The demonstrator notices any change on the physical board and updates the digital board accordingly. This fits the need of the companies that updates the board even outside the pulse meetings.

3.3. The demonstrator

The demonstrator (Fig. 3) is a tool we developed specifically for HPM, to be able to demonstrate the methodology in the workshops. In HPM, physical boards are the master boards, whereas digital boards are used only to publish the information on the master board with the distant offices. This means that in HPM physical boards are used for both reading and writing, whereas digital boards are used only for reading. Therefore the demonstrator provides only one-way information transformation: from physical to digital. It ensures that the digital pulse boards are always up-to-date with the master physical board. It comprises hardware and software modules. The hardware module comprises a webcam that takes pictures of the physical pulse board, and a computer that runs the software module. The software module consists of two applications: an image recognition application that controls the webcam and transforms the information on the physical board to a digital one; and a web-based application that forms the template for the digital representation of the physical board.

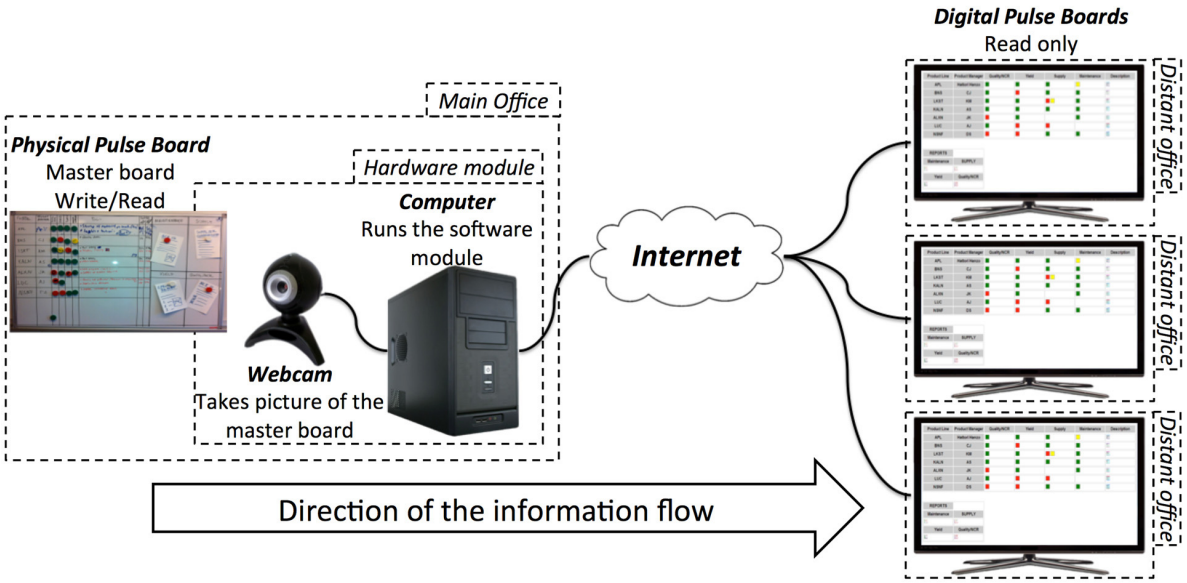

Fig. 3. the demonstrator

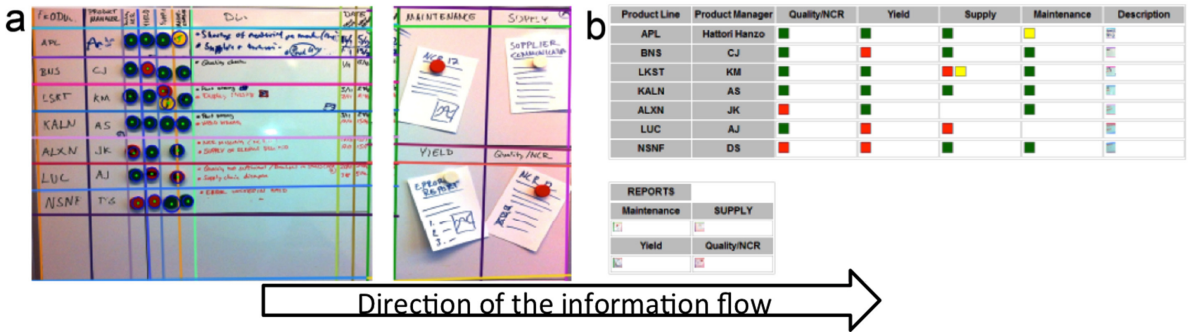

Fig. 4. (a) image recognition application analyzing the image; (b) digital copy of the pulse board.

The transformation from physical to digital board is given at Fig. 4. The steps of this transformation can be shortly described as follows. As seen in Fig. 1(b), the board has a different line structure at the reports section comparing the rest of the board. Therefore, the image recognition application first divides the image into two small images, and then detects the lines for both images given as in Fig. 4(a). Using this information, cell coordinates and the places of the cells are identified. Cell coordinates give information about the location of the cell (e.g., x=2, y=4). Cell place refers to the pixel-wise place of the cell on the image. Since the structure of the board is fixed, the cell coordinates of deviation descriptions and reports are hard-coded into the program. Using both this hard-coded information and the original cell coordinates, the information cells, namely the deviation descriptions and reports, are cut down. Those cut cells are then used directly in the digital board, shown as in Fig. 4(b), as small images. Finally, magnets' places and colors are detected. Comparing the magnet and the cell places, the program Figures out which cell the magnet belongs to.

3.4. Results from the workshops

The companies that attended to the workshops agreed on that HPM combines the simplicity of pulse boards with the communication and data storage capabilities of digital boards. Furthermore, the company that had been using digital boards mentioned the following advantage of HPM. The company has been using the digital pulse boards for 1 year for their local projects. The digital boards run on computers, which means that in order to use them one should start the computer, login to the operating system, and then login to the digital board. This takes around three minutes using the three years old company computers. Considering that the pulse meetings last around 15 minutes, starting the digital board eats up around 20% of the meeting time. Using physical boards would eliminate this loss of time. This means that using HPM, which uses physical boards as the master board, would achieve 20% timesaving at that company. During the workshops, we had brainstorming sessions with the companies, where we elaborated on a use-case that shows another advantage of the methodology. The company that has been using digital pulse boards mentioned that they faced with some problems when they started using the digital boards. They had been using physical boards and after that they made a clear cut and directly started using the digital boards. In some occasions they could not make the digital boards run due to some bugs in the system. During those occasions, they had to have pulse meetings without a pulse board until a technician comes and fixes the problem. They stated that the most important thing in PM is coming together at the pulse meetings, however without a pulse board the meetings are not as efficient. Furthermore, if companies have many important data on the boards, the possible failures in the system until it becomes stable may lead to losing the important data. We figured out the following solution for the companies that are using physical boards and want to start using only digital boards. Instead of making a clear cut, having a transition period where companies use the digital boards, and keep and update the physical boards alongside as backups can avoid this kind of inconveniences. In case of a failure in the digital boards, the company can continue having their pulse meetings using the physical boards. The companies agreed on that if a future demonstrator manages two-way information transformation, then HPM would also be useful for the companies that are in the transition period.

During the workshops we got three negative comments regarding the demonstrator we developed. The first negative comment was about the fact that the demonstrator works only for one-way information transformation: physical to digital. They stated that the digital copy of the board will be updated automatically, however the interconnected boards still should be updated manually. If the demonstrator can manage the two-way information transformation like the digital pulse systems, then HPM can also achieve significant timesaving comparing by updating the interconnected boards automatically. The second negative comment was about saving the deviation descriptions as images rather than texts. The companies stated that saving the deviation descriptions in text format would give them the possibility to search particular deviations inside the database. The last comment was about the technology used in the system. They mentioned that they are skeptical about the robustness of the image recognition technology. They stated that, even though this is not a safety critical system, still the users have to trust the system to use it. Otherwise, this would be just another system that the company purchased but no one uses.

4. Discussion

In this paper we presented a semi-IT based (i.e., hybrid) methodology, and stressed on the technical details. The research results of Konig et al.[13], McGaughey&Roach[14], Steinhilper et al.[15], and Waterson et al.[16] can be misinterpreted as technical issues are not important comparing to methodology related issues. However, the reality is that they meant indeed they both are equally important[17]. This validates our findings, that is the feedbacks regarding the benefits and drawbacks of the methodology are dependent on the technological issues of the demonstrator.

Regarding the sustainability, the methodology we developed is better at environmental sustainability comparing to digital pulse systems. Digital pulse boards need digital displays like TV screens. This means that outside the pulse meetings, these screens would be running whole day, which leads to electricity consumption and consequently increasing the carbon footprint of the companies. However, HPM uses physical pulse boards to display the status of the company at the corridors. Therefore, assuming that a future demonstrator achieves two-way information transformation, then this will eliminate that electricity consumption.

5. Conclusion

In this paper we introduced a new deviation management methodology called hybrid pulse methodology. We tested the methodology at the workshops in simulated global pulse meeting settings using the demonstrator we developed based on the image recognition technology. We hypothesized that the methodology increases the communication capabilities of the companies while letting them keep their old physical boards, and it combines the simplicity of physical pulse boards with the communication and data storage capabilities of digital ones. The results showed that our hypotheses about the methodology were right. This means that the methodology fulfills the requirements of the case company by bringing benefits of digital pulse boards without changing the current system in use. This can be generalized as follows: the methodology increases the communication, data storage, and data history backtracking capabilities of the global companies that centrally manage the deviations in the whole company from the main office. Furthermore, the results from workshops showed that the methodology is also useful for the companies that are in the transition period of passing from using only physical boards to using only digital boards.

The results showed that the hybrid pulse system is better than the physical pulse system for all conditions. However, comparing hybrid and digital pulse systems is not as easy. Both have their strong and weak points. The results showed that all the weak points of the hybrid pulse system are related to the demonstrator, not the methodology itself. This means that a demonstrator, which provides two-way information transformation and uses another robust technology that would get higher acceptance level from the user than the image processing technology has gotten, has the potential of making the hybrid pulse system take the lead of that comparison.

The future work for this study is as follows. Developing a new demonstrator as explained in the previous paragraph, adjusting the methodology so that it makes use of the two-way information transformation feature, and finally having a comparison test between this new methodology and digital pulse systems. Another feature that we plan to add is to have human and machine-readable IDs on the magnets so that one can refer to a particular deviation while having pulse meetings and save the information about that deviation in the database in a structured way.

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