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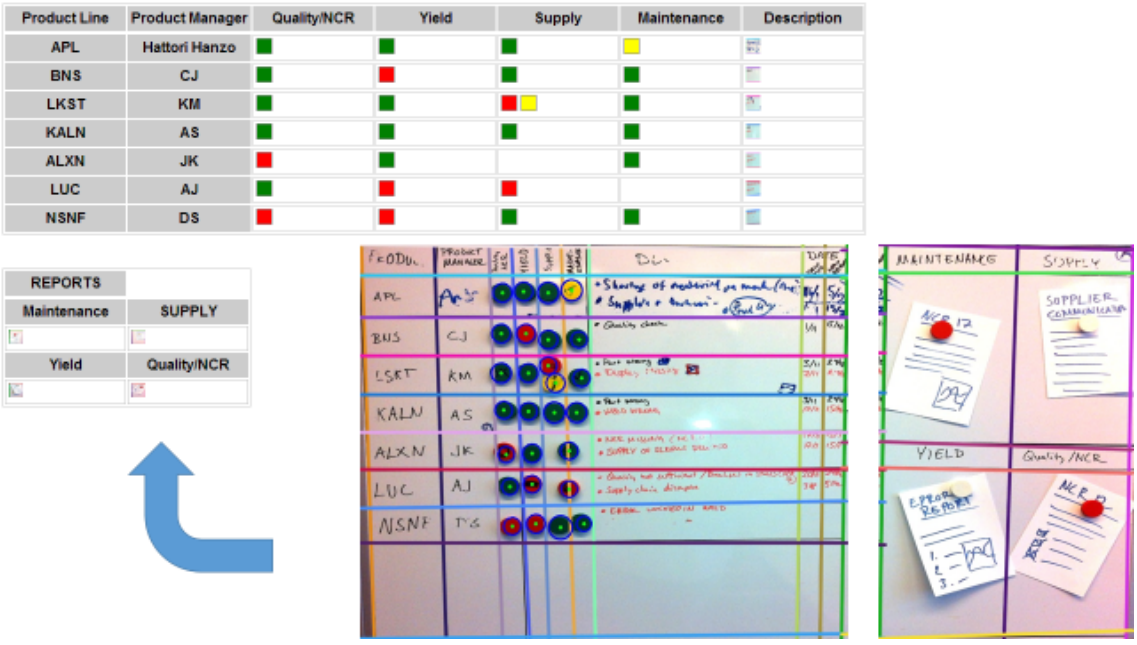

Development of an Electronic Lean Planning System for Product Development (PULSE)

Investigating Means of Digitizing Physical Pulse Boards and Usability Issues

Master of Science Thesis

Onur Kaya

Department of Product and Production Development
Division of Product Development
CHALMERS UNIVERSITY OF TECHNOLOGY
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Technical report no xxxx:xx
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Printed in Sweden by
Chalmers Reproservice
Gothenburg, Sweden 2012
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SUMMARY

As the technology continues to advance, products become more and more complex. In order to cope with this complexity of the products and survive in this market of fierce competition, product developing companies use methodologies like Lean and Agile. Pulse is one of those methodologies coined by Scania, Sweden at 2003. The name Pulse come from ”taking the Pulse of the company” referring to monitoring the progress in the company. Pulse methodology comprises of weekly held meetings (aka. Pulse meetings) and visual management boards (aka. Pulse boards) used during those meetings.

Today Pulse boards are useful but not perfect. Big companies generally have distant offices. Having meetings with those distant offices, each office should update their boards. This is obviously a very redundant way of working and also far away from being lean. Just like the example given above, companies demand more functionality from Pulse boards. Today this kind of tools exist but none of them can be pointed out as the best. Last but not least those tools, which are developed in order to aid companies, come along with their own problems.

In this thesis, ways to aid the needs of the companies tried to be found. In order to come up with a good solution it is very important to have a good knowledge about the background and also to understand the problem perfectly. Therefore the research work starts with background research and company interviews. As second step, tools are developed while taking into account the knowledge gathered at the first step. As the last step, feedback of the companies were taken about the developed tools and adjustments made accordingly. This last step was an on-going process during the time this master thesis was being written.

Keywords: Pulse, product development, managing deviations, visual management boards

ACKNOWLEDGEMENTS

This master thesis was carried out at Chalmers University of Technology at the Department of Product and Production Development, Division of Product Development, in collaboration with Volvo. I am thankful for the help and guidance that Dag Bergsjö and Amer Catic, my main supervisors, provided. I am also grateful to Staffan Olsson for the supervision he provided.

I want to also thank Johannes Vestlund and Anton Lindgren, who are very talented programmers, for their valuable work.

Finally I want to thank all the writers who have shared their precious time to support the information growth of the online open source community.

This research financially supported by Volvo.

Gothenburg, October 2012

Onur Kaya

Acronyms

PM - Product Management

PD - Product Development

PB - Pulse Boards

PPB - Physical Pulse Boards

VPB - Virtual Pulse Boards

DPB - Digital Pulse Board

LVC - Live Video Conference

PVMB - Physical Visual Management Board

DVMB - Digital Visual Management Board

OCR - Optical Character Recognition

UI - User Interface

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1 Introduction

This chapter aims to make the reader familiar with the master thesis by giving concise information about it. The chapter starts with giving information about the needs of PM and PD activities. It also gives information about the solutions exist today. Those solutions are analysed and evaluated from both usefulness and usability point of view. Following this, the problems of Pulse meetings and Pulse boards are discussed at the problem description section. These problems can be grouped in two categories; the ones none of the solutions exist today addresses and the ones that are created by those solutions. After that, the chapter continues with telling about the motivation, aim, research questions and limitations of the research.

1.1 Background

In product developing companies the development process is becoming more and more complex. A multitude of engineering disciplines are involved in the development of the new products and the process, guidelines and checklists that supports the new product development needs to be continuously improved. New lean and agile methods such as Pulse planning are used in order to reduce the amount of administration in development projects.

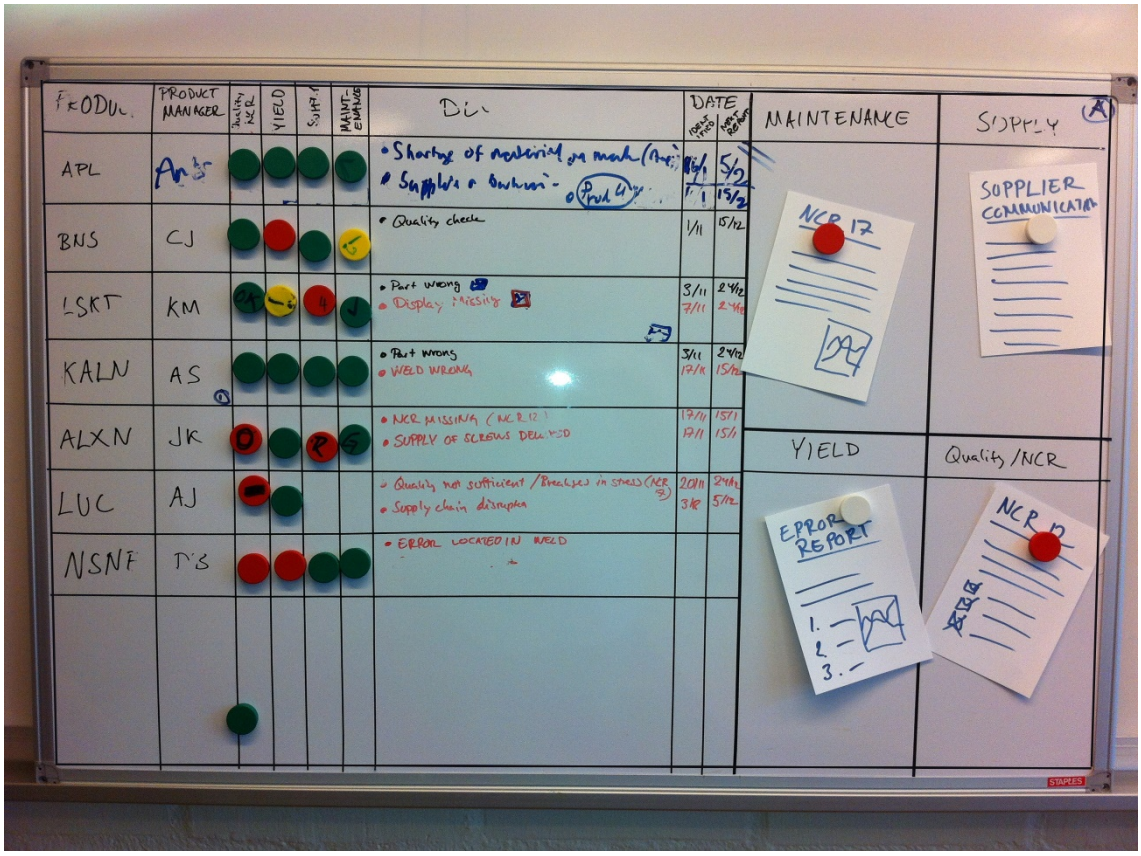

Figure 1. An example of Pulse board

PULS boards are one of the planning tools used during Pulse meetings. It gives a general overview about how is the development going with all the products in the company. Different companies have their own way of using this tool but generally 3 different colors of magnets are used to show how is different stages of the product development is going;

- Red: Deviation (that needs attention to be solved)
- Yellow: Deviation (that is under control, e.g. has a solution planned)
- Green: No deviation

Following the magnet, there is a small description about the deviation, which is then connected to the detailed report. All those information is present on one board, helping the managers to get a fast overview about the progress. An example of Pulse board is given at Figure 1.

There are PM and PD needs that PVMBs cannot aid. Most of those needs are referred as *must have* functionalities by companies therefore finding a solution for them is very important. This also shows the importance of this research.

Today's big companies have offices physically scattered all around the world. Even national companies (for ex. defense industry) have offices spread all around the country. Different processes of the same product are handled in those different offices. In order to follow the process inside those distant offices, managers should travel to the main office at least once every week. Pulse meetings are done to reduce the lead-time by constantly controlling the flow. Taking this into account, *managers travelling to the main office for a ten-minute meeting* is obviously unacceptable. Somehow the managers should share the information about the progress they are having with the rest of the company. This creates the first need that the PPBs cannot aid.

Figure 2. An example of a big and full PB

Most of the products being produced today are quite complex. The increased complexity of the products means increased volume of information on the PB about the product therefore larger boards. This creates a big problem for using PPBs. One has to work manually on a physical board, which means for example if one would like to reach

a report about a particular deviation, one has to track down this information manually on the board. This would be troublesome and time consuming. Pulse boards and Pulse meetings are used in order to reduce the lead-time therefore this losing time because of manual data tracking must be fixed.

Another bad side of using PPBs is that they are not flexible to expansions. Adding totally new project without deleting another can cause problems with PPBs, as the space on the board is limited. Board on the Figure 2 is a very good example of this.

The board on Figure 2 is already full. In case the company wants to add a new product, they have to prepare another PB. Furthermore, companies sometimes change the way they work. This would require changing the structure of the board as well.

There are tools existing today that solve some of the problems of current PPBs have. Some of them indeed address all of the needs of the companies. Some tools should be used alongside with PPBs while others can form total standalone solutions. Here some of these tools would be discussed regarding their pros and cons.

1.1.1 Excel Sheets

Physical planning tools can be simulated virtually using excel sheets. Those templates can be found from Internet even for free. An example template of Pulse board is given at Figure 3.

Product	Product Manager	Quality/NCR	Yield	Supply	Mintenance	Description	Identified D.	Next Report D.	Mintenance	Supply
APL	An Jr						16/1	5/2		
BNS	CJ					Yield check	1/11	15/12		
LSKT	KM					Shortage of supply	1/11	24/12		
KALN	AS						3/11	24/12	Yield	Quality/NCR
ALXN	JK					Quality and Supply check	3/11	24/12		
LUC	AJ						17/11	15/1		
NSNF	PS					Quality and Yield check	20/11	24/12		

Figure 3. An example of using excel sheets as Pulse board

They can be prepared very quickly. The example in Figure 3 is prepared within 10 minutes. With the help of scripts, its functionality can be further improved. For example it is possible to link the reports directly so that users can reach the reports they want just by clicking the magnets. Doing so, the loss of time due to tracking down the board would be completely solved. Also it would be possible to present more information on the board while not making the board too big and too complicated.

Excel files are digital files therefore they are very easy to copy and share. They occupy very little space in a hard disk therefore they can be shared with all the stakeholders within milliseconds. Also Dropbox can be used to share files. Dropbox stores the files on the cloud so that anybody who wants to reach the file can download it immediately. It even provides history backtracking for Pro Account users. Furthermore, in order to increase and facilitate the collaboration between colleagues, Google Docs can be used which provides the feature that lets people to work on the same document simultaneously. Google Docs provides services such as reaching previous versions of the file and seeing who made which changes on the file. Another advantage of being an IT solution is facilitating the expansions and adjustments on the structure of the board. PBs made from excel sheets do not have limitation of space.

Besides all those pros, there are also disadvantages for using excel-sheets to track progress of companies. The best way of using excel sheets as PBs is using the combination of *local office program + Dropbox* or *Google Docs*. Collaboration and sharing, no doubt, are very important at PD and PM activities but there is another aspect overwhelms these needs; secrecy. In today's market, image is everything. Even project managers sometimes hide that there are problems in the project, which they do not know how to solve, while reporting to the higher managers. Projecting this threat of losing personal image to losing company image would easily make the possible outcomes clear in the presence of information leakage. Of course there will be some problems, which cannot be solved. Those problems would eventually reach the customers but it is only natural that companies prefer this happening as late as possible.

Another negative point of using excel sheets as Pulse boards is that, it requires close human-computer interaction. Here the word "close" is used referring that one needs to use a keyboard and a mouse in order to perform the required actions at the excel sheet. This means focusing on the computer and neglecting what is happening in the meeting for the one using the excel sheet. One of the very reasons of having Pulse meetings is to make people come together in a social, face-to-face manner and make them talk about status quo. Therefore it is obvious that excel sheet solution is not a way that big companies would like to use.

1.1.2 Live Videoconference

As described in the previous chapter, one of the main reasons of having Pulse meetings is to make people come together and discuss face-to-face in a social way. This may require managers to travel ridiculously long distances weekly or even daily basis. One of the ways of solving this problem is using live videoconferences.

LVC in a way physically connects distant places. One scenario of using LVC for meetings can be that the company uses only one PB and it resides at the main office. Remote offices that are working on the same product would join the meeting through LVC along the main office. The people sitting at the main office would handle all the adjustments on the board. The people sitting at the remote offices share the information they have regarding how the PD process is going at their offices. According to this information the people sitting in the main office update the main board. Another scenario would be having multiple replicas of the PB in all the offices. Furthermore the solution given at the previous chapter, PBs made from excel sheets, can be used in combination with LVC. LVC software have features like desktop sharing which facilitates collaboration on the same excel sheet greatly.

Although having LVC seems like a good way of solving the PM and PD needs of the companies, it also brings other problems along with it. Having one main board at the main office would create a situation where remote offices cannot reach the information on the board whenever they want. On the other hand having replicas of the same board at all the remote offices would cause lots of unnecessary loss of time due to redundant work. The source of this redundancy is that; people at the distant offices has to make the same changes on their boards together with all other offices to keep all the boards updated and synced. At first glance this does not look like a big loss of time but considering those meetings only last 10 minutes and in some cases handled daily, the magnitude of redundant work and lost time would be obvious. Last but not least the

working hours of the remote offices should coincide in order to have LVCs. Companies like Google has offices all around the world and the placement of those offices, which are mostly working on the same product, are made so that the working hours do not coincide, on purpose. The reason behind this is that in case of a problem arises, the office that is on duty can respond directly. It is obvious that this kind of global companies cannot use LVC as a solution.

1.1.3 Visual Planning Boards

Visual planning boards (Figure 4) give a quick look of the present projects and how they are proceeding. Using this tool, one can see what project or which task has been assigned to whom. Because of its detail oriented nature, only using this tool for a company would lead loss of time because of focusing on unnecessary information. Focusing too much on details would consequently lead to missing important points which can be seen only from the big picture. Therefore using this tool instead of Pulse Boards would create more problems. Using it alongside with Pulse Boards would be a plausible solution. Because of being a physical solution it would also inherit the same problems that Pulse Boards have which we are trying to solve.

Figure 4. Visual planning board (courtesy of xqa)

1.1.4 Specialized IT Tools

IT tools for PM and PD are comprised of programs made by software giants like IBM, Microsoft or smaller companies whose products focus on PM and PD. Because of the nature of those IT tools, they have lots of features, even the ones that some companies will not use. The reason of being over-armed is that those tools are created as one-size-fits-all. Thanks to putting everything in one package, any company can use these tools regardless of their size. These heavily armed tools are useful when companies cooperate and PLM exchange is needed as all can use those tools. Having the same systems would make it so easy for the companies to integrate the systems.

Thanks to their nature, that is being IT based, those tools solve lots of needs of the current PM and PD needs of the companies. Those features of IT tools that aid the needs of the companies also comprise their advantages over PVMBs. One of those features is information sharing. The information on those tools are stored on the computers which

means it is possible to access them from anywhere and anytime. Another feature is automatic data finding. On traditional PVMBs one needs to manually track down the information flow on the board in order to reach the report they want. This can take long time and be troublesome for big boards. Using an IT based tool, one can reach the needed information as fast as a click of a mouse. Likewise, routine tasks can be automated. Last but not least, they are environment friendly. At first it may easily be overlooked. Please imagine how many teams exist within an organisation, how many members each team has and how many Post-it notes they use daily. This would give an idea about the paper waste a company creates. Of course comparing other actions of the companies that increase their carbon footprint, using Post-it notes may seem very small. Nevertheless tearing down trees while it is possible to save them is not a good way of working for today's companies which gives great importance to sustainability.

As explained here those tools have lots of good sides and solve lots of needs but they create new needs and problems as well. Unlike clothing industry, at software industry one-size-fits-all means being the biggest comprising everything, not being the middle size solution. As we know from the Swedish battle-ship Vasa, which was also over-armed, it is hard to use them and they sink easily. Not only using but also learning how to use these tools takes precious time of the employees and managers. Furthermore, because of including lots of functionalities that are even may not be used by the companies, these tools are generally very expensive.

1.2 Problem Description

In order to support the work with identifying problems and resolving them quickly, new lean planning tools needs to be developed. The Pulse planning system fills an important gap between administrative planning and helps with agile planning.

We want to keep all the positive sides of a physical Pulse Board while developing the IT tool. It is very important that the software can represent the problems in a development project visually with an easy to use interface. The software should function in a way that the users would be able to start using it without needing any instructions. In order to achieve this smooth transition of users from physical to virtual PB, the design and the interaction of the software should be similar with PPBs'.

Using PPBs is intuitive and straightforward but still it can become troublesome with big boards. Tracking descriptions and reports would be hard if there are many too many magnets (representing problems) and/or too are many products present in the company. Having an IT solution would help the user reach the needed information with just few clicks. This would save a lot of time and work comparing to finding the information manually.

The way the companies, which has offices situated in different locations, use PPBs is very inefficient. Each office has to update their board manually for every change happened at the other offices. In order to increase efficiency it is very important that the information on the board can be shared and viewed by offices in different geographical locations in an easy manner. Therefore a web-based IT solution is obviously in need today.

There are general advantages of an IT solution against a physical one like being flexible for adding and deleting information. Even though most big companies use English as the common company language, some offices may prefer to use local languages. An IT solution can be integrated with an online translation service so that even using local languages would be possible. As stated above, a web-based solution can be reached anywhere, which makes accessing and changing data on the board for the responsible personnel easy.

The master thesis work is supported by several industrial companies that follow the development of new support tools for product development at Chalmers. It is important that the software is designed to fit the intended customers.

1.3 Purpose

The purpose of this master thesis is to find ways to digitize the tools used in Pulse meetings, such as Pulse boards. In order to do that, the features that the companies expect from these tools would be investigated first. Having a good knowledge about what is really needed, current solutions would be evaluated according to their capability of solving the needs. After finding out which points are not covered by the current solutions, ways to implement a new tool covering those needs would try to be found. The purpose here is also to find ways to digitize the PPBs. After finding a possible solution, a prototype would be realized in order to investigate the usability issues and compare that to PPBs.

1.4 Goals

- Create an image recognition program that finds place and color of cells and magnets on a Pulse Board.
- Create web-based application representing the PPB.
- Connect these two applications in order to have smooth transition between physical to virtual Pulse Board.

1.5 Research Questions

- *Is it possible, if so what are the ways to connect a physical Pulse Board with a virtual one?*
  Some companies want to continue using physical boards but also think positive about having an assisting IT solution. Some of them prefer using VPB only in their main office and keep using physical ones at the remote offices. In both cases a smooth transition between physical and virtual Pulse board is needed. Therefore ways to provide this transition is very important.

- *What are the benefits of a physical pulse board compared to a virtual Pulse board?*

The purpose of this research question is to investigate the customers perceived benefits with using a digitized version of a physical pulse board, and compare it to fully digital versions such as an excel sheet or a web based solution.

- *What are the usability issues concerning physical Pulse boards?*
  Today many companies use Pulse boards and considered as a very useful tool but like every tool it can be further developed. There are both advantages and disadvantages of using a PPB. The disadvantages constitute the main reasons of trying to find an IT based solution and the problems we are trying to fix with this new IT tool.

- *What are the usability issues concerning virtual Pulse board?*
  The Pulse meeting has been seen as very important for functional Pulse and it is important that the meeting is not disrupted by difficult to use software and problems. Therefore those issues need to be find in order to design a user friendly VPB which PPB users can start using directly without any instructions.

1.6 Delimitations

Character recognition at the RealPulse application is out of scope. It is decided just showing the picture of a report cell would be enough. Doing so, possible errors of OCR would be eliminated.

As with most of the image processing applications, lighting conditions of the room that the pulse board is situated is very important. As the black borderlines would mix with shadows, the program will not give good results.

The prototype is designed for the structure of the board given at Figure 1.This means that the current version only runs for this board. This does not form a big delimitation as the software can be adjusted just by changing parameters to be used for other Pulse boards as well.

Since the lines and objects trying to be recognized are very small and the board is quite big, low-resolution cameras will not do the work. Therefore there is a limitation for the resolution of the camera to be used.

2 Methodology

In this chapter the ways and strategies used to carry out this master thesis are going to be told.

2.1 Research Approach

The aim of this master thesis is to digitize PPBs while adding it functionalities to aid the needs of the companies. In order to achieve this, the whole research is carried within three steps shown in Figure 5.

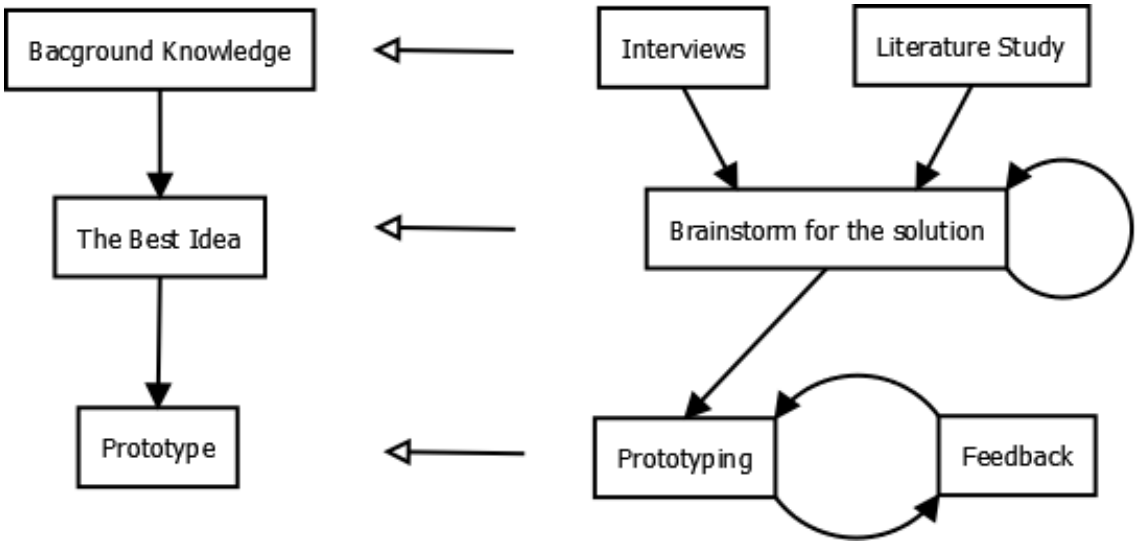

Figure 5. The research approach

In order to come up with a good solution for the problem, the first step is to understand the problem and the needs right. In the same way, in order to understand the problem and the needs right, one needs to understand the basics of the environment. Here the environment is referring the PD and PM activities and Pulse meetings. Therefore the research is started with getting background knowledge about the issue. Two sources are used in this process;

- Literature studies from books and published papers
- Company interviews where the managers joining the Pulse meetings are interviewed.

After getting a clear image about the background, the needs and the problems to be solved, ways to solve them began to be searched as the second step. At the end of this step, the *relative best* way of solving the problem was decided. More information on why it is called the relative best way would be discussed under the related headline.

In software development one of the most frequent problem is that misunderstanding what the customer really wants. In order to solve that problem, today almost all the software-developing companies make the customer take part in the software development processes. Therefore, in order to come up with a solution, the software development was begun after getting a clear image of the background and the company requirements. Software development forms the third step. Following the best practices,

in this research the customers were asked to take part in the software development process.

2.2 Data Collection

In this chapter the readers will be informed about how the background information was gathered. Two sources were used in this process. First one was books and published papers. General knowledge about the subject was gathered using this source. The aim was to come up with not only a general solution but also company specific ad-hoc solutions. Therefore interviews with the companies were held in order to further increase the background knowledge. Company specific information gathered during those interviews helped learning how each company was implementing the paradigm.

2.2.1 Literature Study

Literature review comprises of reading books and published papers. Specific information about Pulse does not exist in the literature. Therefore in order to understand this specialized version of controlling PD activities, the basics of PD studied from the literature first.

As the research project had tight deadlines, reading pinpointed materials had great importance. The key to find pinpointed material is to find the best keywords. The Help of supervisors was asked to find the best search keywords in order to begin the literature study.

Literature study was begun by reading the materials that the supervisors recommended. After the completing reading those materials, a good knowledge about the topic has been gathered. This was not only useful for coming up good solutions for the company needs but also finding good keywords to be used at further literature study.

2.2.2 Interviews

Having interviews is one of widely used techniques for collecting qualitative data (Singer and Shull, 2007). Qualitative data is more useful while gathering data about the feelings and experiences of users regarding the tool (Bryman, Bell, 2007). Interviews comprise the most important part of the data collection along with the feedback sessions. Feedback sessions were held with the companies after the prototype presentations. More about this would be discussed in the further chapters. Thanks to the literature study, general background knowledge about the topic was gathered. However this research was focused on more specific case, that is Pulse meetings and Pulse boards. Furthermore there is a lack of information about this topic in the literature, which increases the importance of the interviews even more.

The companies to be interviewed were selected according to the following criteria;

- Being situated in Gothenburg/Sweden
- Supporting this research

- Using Pulse methodology

After deciding on which companies to be interviewed, interviewees were chosen. In order to get right and the best information, it is very important to have interviews with people, who are directly involved in Pulse meetings, using the related tools. There are two kinds of Pulse meetings;

- Project/Product/Line managers having meeting with the team members in order to discuss and track the progress of the PD they are responsible of
- Project/Product/Line managers having meeting with other managers in order to discuss and track the progress of all the PD in the company

As this research is focused on the meetings where all the PD activities of the company is monitored and discussed, interviewees are chosen from managers.

In order to be efficient, that is getting maximum amount of information within shortest time, interviews were carried out with one-on-one and face-to-face fashion. Only one manager was chosen within each company to have interview. Another reason of choosing just one interviewee for each company was not to take valuable time of the managers.

Each interview was aimed to last maximum 1 hour in order to be efficient for both interviewer and the interviewee. The number of the meetings was variable. In average, two interviews was enough in order to get most of the information.

Interviews were recorded by the interviewer's laptop's microphone, which gives higher quality comparing the mobile phones. Thanks to this high quality recording, the things talked at the interview were easily documented. Later this document further analysed and shared with the supervisors.

Open-ended questions were prepared before each meeting. The number of the questions was tried to be made as few as possible. As the intention of interviews was to get information from the interviewee as much as possible, it is interviewer's job to arrange the best conditions in order to facilitate this.

2.3 Brainstorming for the Solution

After learning about the background of the subject and what exactly companies need, brainstorming stage was started. The aim was to find the relative best idea to be implemented for the next step. Brainstorming stage (Figure 6) started with finding and compiling possible solutions for the companies needs. After that the best idea was selected among those possible solutions. The solution selected to be implemented was the best among the found solutions, not among all the possible solutions. Therefore it is addressed as the relative best solution. The criteria considered finding the relative best solution were;

- Trade-off between ease of implementation (developing the software) and usefulness
- Facilitation for possible upgrades and integrations
- The convenience of companies for technology transition

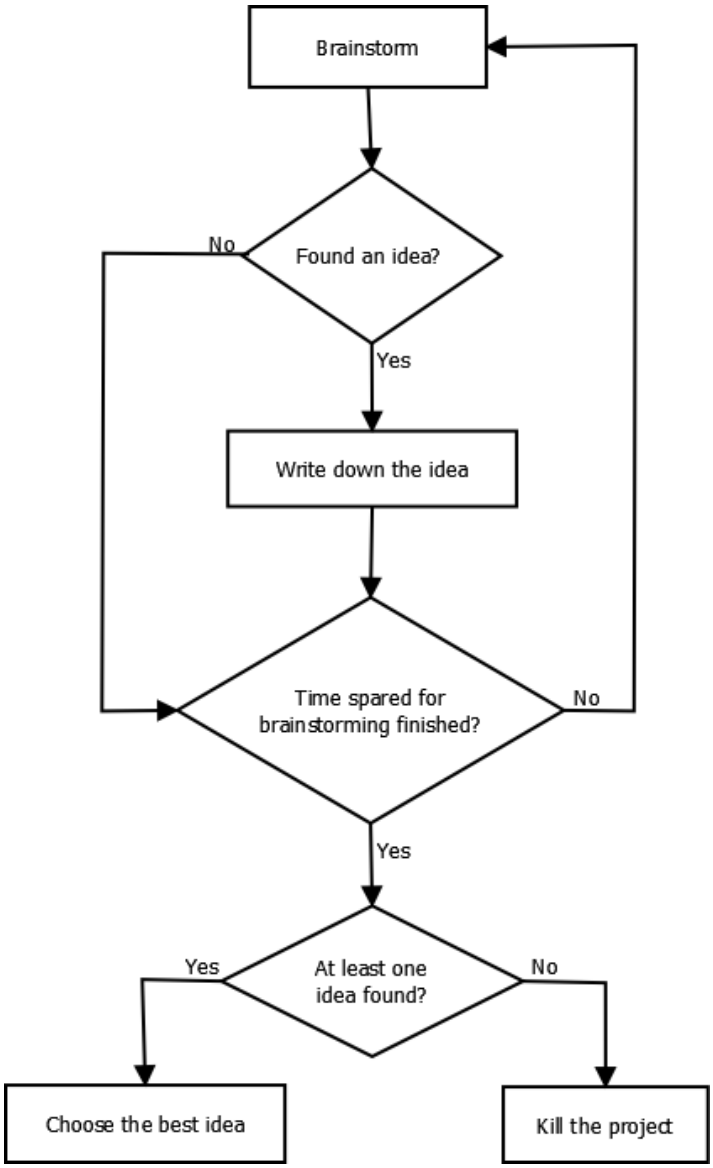

Figure 6. Brainstorming flowchart

2.4 Prototyping

After finding the relative best idea, that is the best idea among the found possible solutions, we began realizing the solution. The prototyping stage (Figure 7) was an on-going process, which was still on progress during the time this thesis was being written.

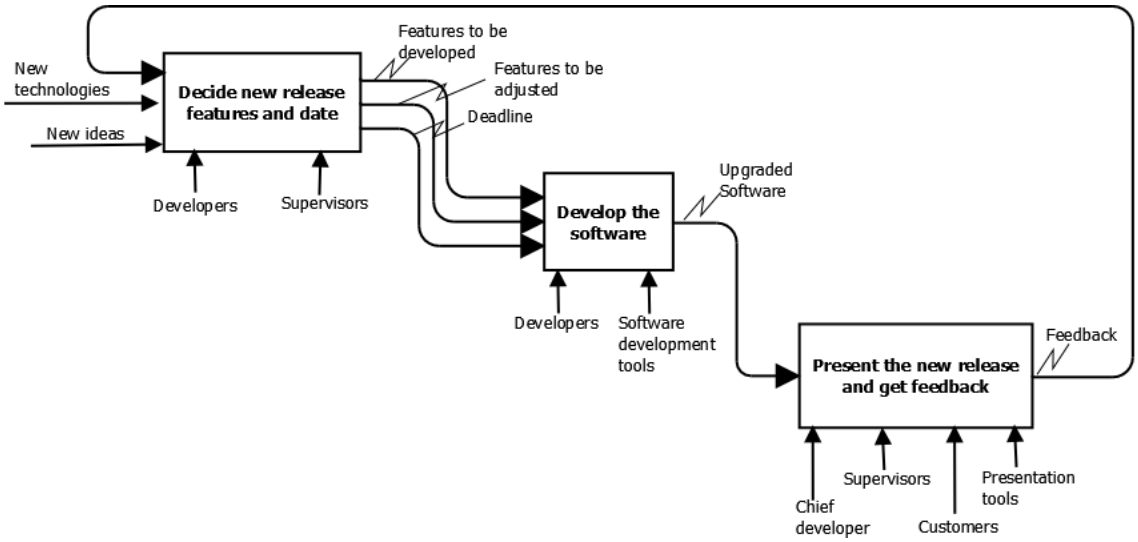

Figure 7. Prototyping IDEF0 diagram

The prototyping stage started with the relative best idea that had been decided to be implemented. The ideas and ways to implement them that has been documented at the brainstorming stage were used while transforming them into programming tasks. Deadlines for each programming task has been decided along with each programming task. As it is an on-going process, with each new idea found, each new technology emerged and each feedback received, this task and deadline decision stage is re-performed.

The decision of programming tasks and their deadlines followed by implementing them by the programming team. After each deadline the development team delivered the new version of the software as planned. More about this step is told at the next headline.

After the development team delivered of the new version of the software, the software was presented to the related companies and their feedback was taken. The feedback was written down which was then used as the input for the meetings mentioned before where programming tasks and deadlines are decided.

2.4.1 Software Development

Software development (Figure 8) was carried out by weekly iterations. At the beginning of each week software development team and supervisors of the project have a meeting. These meetings comprises of two parts. At the first part the previous week's work was examined. After that at the second part, the coming week's goals were decided. After that, the software development team developed and tested the software simultaneously till the deadline. At the next meeting the last state of the software was presented to the supervisors. There were also bigger iterations than those weekly iterations. After each big iteration, a version new version of the software was released and presented to the companies. In case the programming team could not finish all the planned programming tasks until the big iteration deadline, the software was adjusted to be stable instead of having half working features. That means taking out buggy and incomplete functionalities.

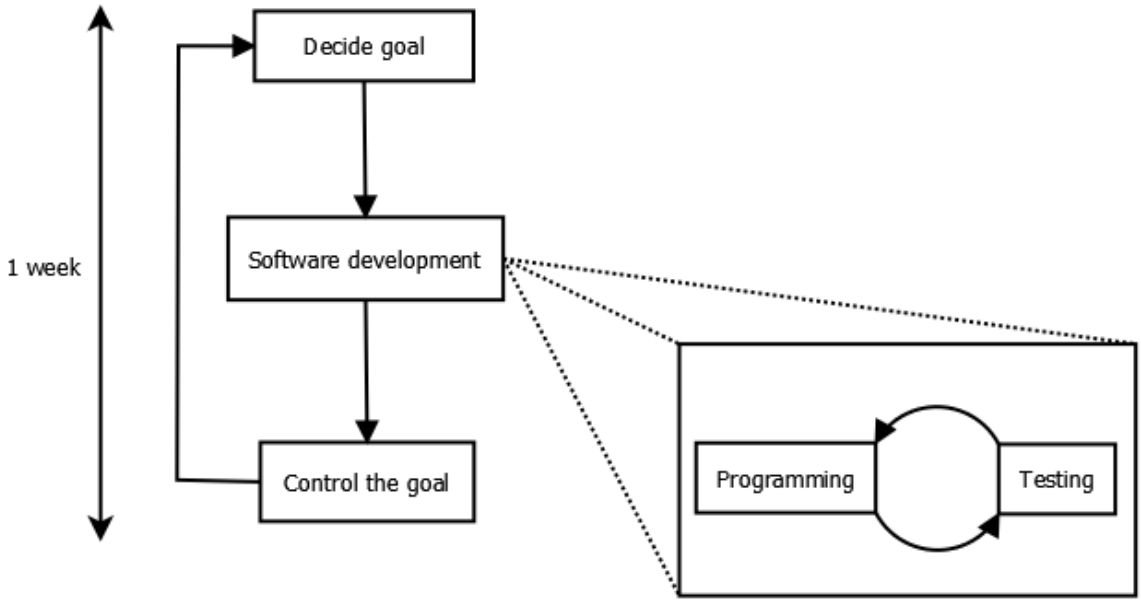

Figure 8. Software development flowchart

3 Frame of Reference

In this chapter the underlying information about the research area is given. This information would be useful for;

- Understanding the problems by learning the root of the subject
- Learning the solution recipes that exist in the literature today
- Analysing the results by forming the background knowledge

The chapter is formed under three main headlines;

- Product development
- Lean & Lean development
- Pulse

Under Product Development headline, after a general description, information about product development processes and distributed product development teams are given. Lean development section starts with the information about its roots. After that, information about Lean tools, principles, Lean IT and Lean management systems are given. The chapter is concluded with the information about Pulse, where the knowledge was mostly gathered from the companies applying that methodology.

3.1 Product Development

Product development works with creating new or modifying existing products in order to deliver benefits to the customer. (Business Dictionary)

3.1.1 Product Development Process

As it is said in Ulrich and Eppinger 2011, ”a product development process is the sequence of steps or activities that an enterprise employs to conceive, design, and commercialize a product”. Companies may employ strictly planned development process whereas others may not even have a common routine. Among the companies having a predefined process, each and every one of them uses different processes. Even one organisation may use different processes for their every different project. Having a well-defined development process is useful for the organisations because;

- Assuming the process is designed to give a level of quality to the product, following this process would assure the quality of the product
- Each member of the team would know what, when, how to do stuff therefore the coordination would be assured
- Deadlines predefined by the process would lower the delays of the project
- Having an established process would give the managers the ability to monitor the process and find problems easier and faster
- A clearly defined and documented process facilitates further improvements (Ulrich and Eppinger, 2011)

3.1.2 Distributed Product Development Teams

Facilitating team members work close (for ex. in the same office) would make them collaborate easier therefore increase the overall effectiveness. Thanks to developments in telecommunication technology, today even globally distributed project teams can collaborate very effectively.

The possible reasons to have distributed product development teams can be;

- Better and easier to get information about the local markets
- Availability to reach the technical expertise all around the world
- The need to be close to suppliers and manufacturing facilities
- Cheaper workforce
- The need to outsource work to overseas in order to increase product development capacity (Ulrich and Eppinger, 2011)

3.2 Lean & Lean Development

According to Taj (Taj, 2008); ”Lean means manufacturing without waste”. Lean thinking, as a superset of lean development, targets all the activities of an organisation aiming to maximize the value delivered to customer while minimizing every kind of waste (time, workforce, material etc.). Lean development paradigm comes from the Toyota just-in-time philosophy, which aims “producing quality products efficiently through the complete elimination of waste, inconsistencies, and unreasonable requirements on the production line” (Toyota Vision and Philosophy, 2009). (INCOSE, 2011).

3.2.1 Lean Tools vs. Lean Principles

In order to make a company develop constantly and use the adjusted forms of best practices for long-time, lean principles should be embedded to the company culture. Only then the lean tools can be used as performance enablers. Tools change and develop as needs change and new technologies arise but principles lasts forever (Bell and Orzen, 2011)

In order to be successful, it is very important for a company to set the company objectives and core principles, which acts as a compass for all the organisational actions. So that everybody would work towards the same goal in harmony without drifting away from the common objectives (Covey, 1992). Furthermore, companies should create their own goals and principles taking into account their own values and beliefs. Doing so, in contrast to taking other companies principles directly, those self-created principles last long. (Bell and Orzen, 2011)

3.2.2 Lean IT

According to Womack and Jones 2003; ”Lean IT engages people, using a framework of Lean principles, systems, and tools, to integrate, align, and synchronize the IT organization with the business to provide quality information and effective information

systems, enabling and sustaining the continuous improvement and innovation of processes". Lean IT has two aspects;

- Supports the continuous improvement of business processes
- Improves the performance of IT processes and services (Womack and Jones, 2003)

Organisations are composed of functional departments, which work together in order to deliver services or products to the customer. The greater the coordination and alignment of those departments, the higher the organisational effectiveness. Information systems as a framework encompass this network of departments (Figure 9) inside a company enabling communication and coordination. (Bell and Orzen, 2011)

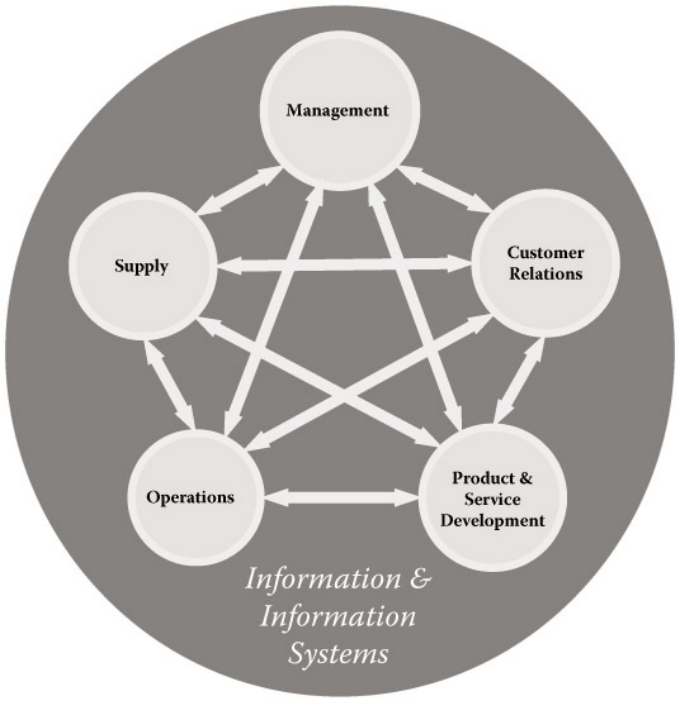

Figure 9. Information and information system as a framework (Bell and Orzen, 2011)

Companies can save lots of time by automating routine tasks, which are most of the time frustrating. That extra saved time can be used by individuals for tasks that need creativity. Improving the processes further would help the company to develop alignment of;

- Strategy vertically; from top till bottom, people working in every level, understands how their daily work contributes to the common goals and objectives of the company
- Stakeholders horizontally; making stakeholders take part across every process so that increasing the value being given to customer
- Information systems vertically and horizontally; ensure that IT both enables strategy and adds value to all the actions of the company.

In order to have these alignments last long, a lean management system is required. (Bell and Orzen, 2011)

3.2.3 Lean Management System

Companies that want to lower waste and increase the value given to the customer, try to get the Lean IT tools thinking that would be the fastest way. Indeed in short term that is a fast way of getting started. But in the long term, problems would start to arise. Having education only on how to use these tools are not enough. First a company should invest on making people understand standard lean methodologies (Lean IT, 2002). This journey towards a Lean organisation with Lean IT tools starts with education of the management level for Lean methodologies. After that the managers should prepare a roadmap for this transition (Nash and Poling, 2007).

In lean, the management focuses on creating standardized processes, which nonstop delivers value to the customers. A lean management system, in order to be effective, must be:

- Easy to both understand and execute
- Provides guidance without getting in the way
- Flexible; open to creativity and innovation (Bell and Orzen, 2011)

3.3 PULS

Scania introduced pulse, as a lean PD system technique, in 2003 and since then it became really popular in Sweden (Kristofersson & Lindeberg, 2006). Pulse aims at synchronization of the organisation by a visual planning board (Pulse board) and weekly meetings (Pulse meetings). (Preechachanchai and Wangwacharakul, 2011)

3.3.1 Pulse Meetings

Checking how the project team is progressing is very important in order to keep the team working continuously on the right track. One of the best ways to achieve this is to have Pulse meetings.

PULS meetings are generally held once a week. The frequency of having Pulse meetings depends on the current situation of the team. In the case of crisis at projects, teams may have Pulse meetings even several times a day. During the times when everything is going smoothly, meeting once a week would be sufficient.

PULS meetings are held in front of the team's Pulse board (discussed under the next headline) where the entire team standing in front of it. These are short meetings and lasts about ten minutes. During this ten minutes, team members talk briefly about tasks that they started or completed. They also talk about problems and risks if there is any. The main point of having these meetings is to get a fast look on the teams' progress. The problems and issues mentioned during the meetings are not solved at Pulse meetings. There may be team members who are not related to the issue or more people may be needed from other teams or managers to solve the problem. Therefore trying to solve those problems at Pulse meetings is not practical. Instead, further meetings to solve those issues must be arranged during Pulse meetings.

3.3.2 Pulse Board

PULS boards are indispensable parts of Pulse meetings. They form the visual focus points of those meetings. Team members stand in front of them, facing towards the board while having Pulse meetings. Team members in turn goes next to the board and makes the changes according to the events happened while explaining them to the team members.

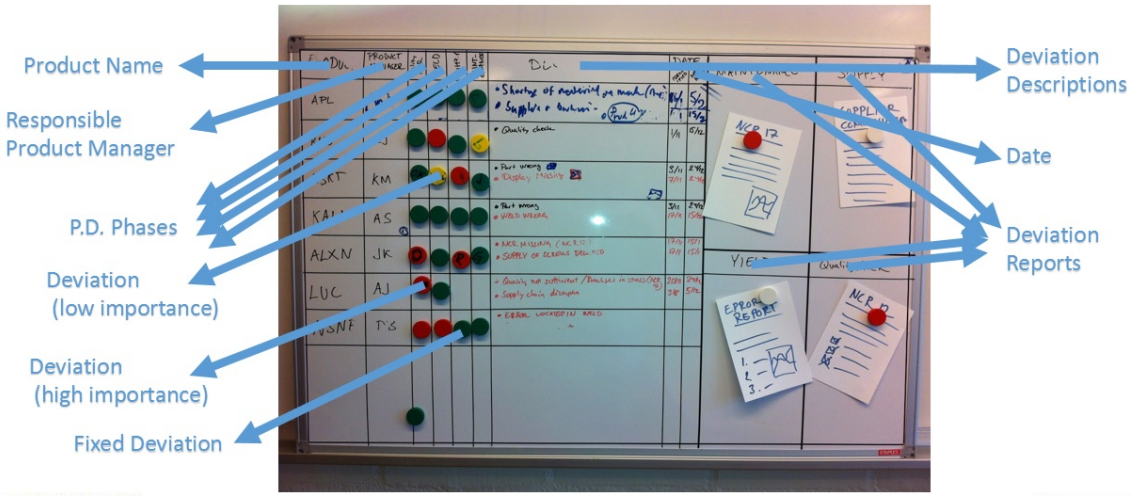

Figure 10. Pulse board with descriptions

4 Results

In this chapter main outcomes and the inferences from the research are presented.

4.1 Process Model for Physical Pulse board

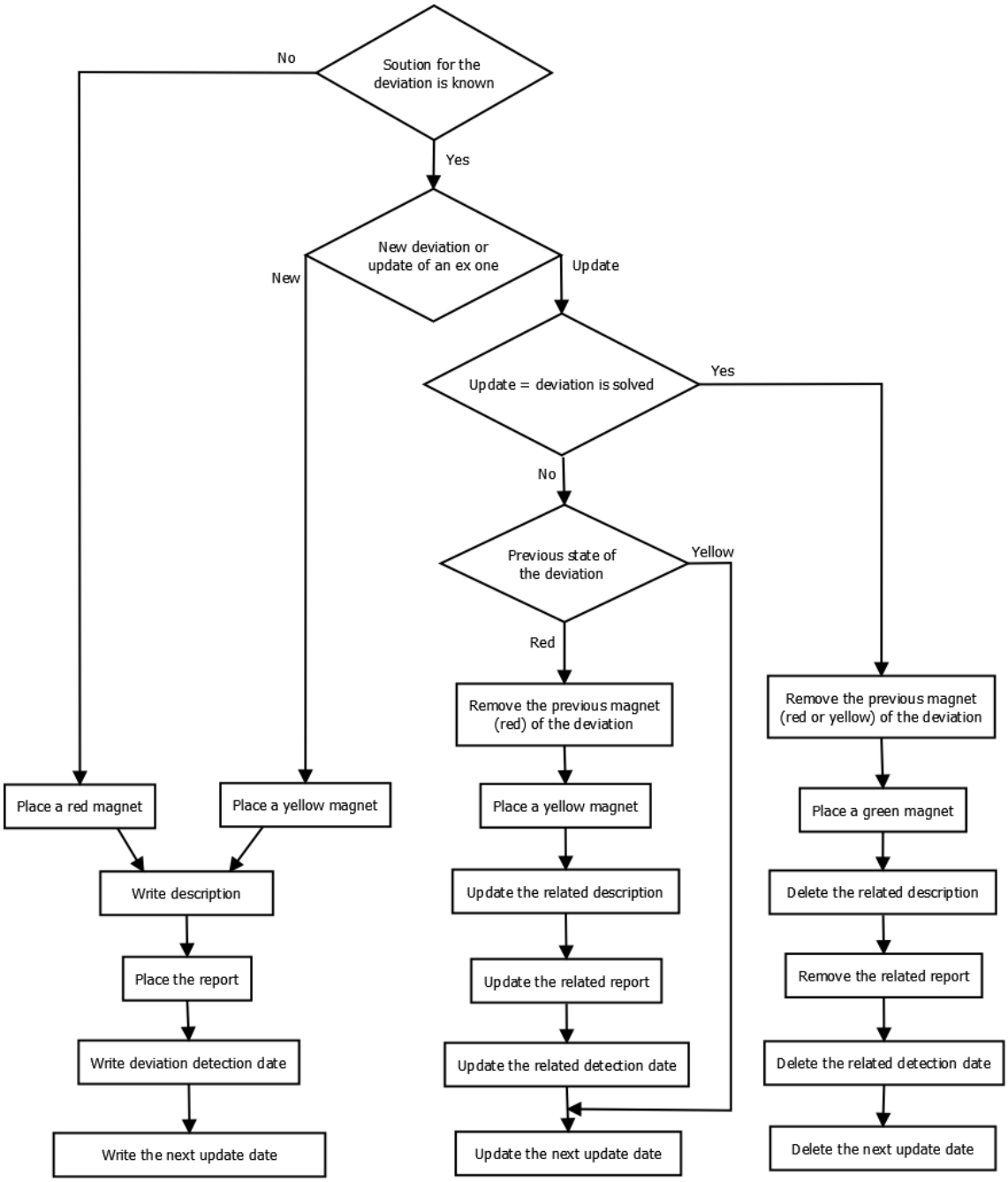

Figure 11. Pulse board process model

During Pulse meetings there is a pattern that all product managers follow while using the Pulse board. They all follow these steps in turn for each deviation they have in the product line they are responsible of. Each product manager goes in front of the Pulse

board when their turn comes and starts giving brief information about the first deviation they want to inform the attendees. If it is a new deviation and the solution for it is currently unknown; they place a red magnet on the related cell, writes a short description about the deviation, places a detailed report and writes detection and next update date. If the solution is known then they place a yellow magnet and follow the same remaining steps given above. If it is not a new deviation but an update of an old one, there are three possible outcomes. It can be that a solution for previous deviation, of which solution is unknown before (red magnet), is found. In that case the product manager replaces the related red magnet with a yellow magnet and follows the same remaining steps given above. Another possibility is that a previously detected deviation, of which solution was also known (yellow), could not be solved yet and its next-update-date has come. In that case the product manager just updates the next-update-date. The third situation can be that finally the deviation is solved. In that case the related yellow magnet is replaced with a green one and all the remaining information about the deviation is removed/deleted from the board. This finalizes information sharing about that deviation and they start with another one.

4.2 Technical Information about the Software

The image processing application is developed using OpenCV. OpenCV is an open source computer vision library available for C/C++, python and Java (Android). In order to be fully open source, Linux-Eclipse environment is used for the development. Test pictures, which would be used to measure the program's performance, was taken by IPhone 4's camera. In order to represent the captured physical board in the virtual world, a template was created using HTML and CSS. It was given functionality like moving magnets between cells using JavaScript and jQuery.

4.3 Effects of Local Time Difference on Pulse Meetings

Digital Pulse boards indeed facilitate the meetings between distant offices with the help of LVC but there is a limit for the distance. The working hours of the distant offices that join the meeting should coincide. For the companies, which have offices all over the world, the solution to overcome this problem would be;

- Make the distant offices having coinciding working hours have meetings together (would be around 3 meetings to cover the whole world)
- Prepare a short report or record a video of the meeting and then share this with the other group of distant offices

Other than grouping offices according to working hours, a company can make the managers work over-time. So that with just one meeting all the offices can be synchronized. Other than these not so convenient solutions, some functionalities can be added to the digital boards to facilitate this situation. Digital boards can store the changes made while recording the users' voice, which gives information about change. This data would be received by the next group of distant offices, which geographically resides west of the previous group. This next group first have their digital board updated automatically by going through the data recorded by the previous group. The difference here between preparing documentation (and/or recording sound/video) and having the digital board to do this by automatically is that the other groups do not need to update

their boards manually. The board would do that automatically on the fly while showing each change. Apparently this would save a lot of time and frustration.

4.4 A Hybrid System; Physical + Virtual Board

Companies find PVMBs very useful and they use them quite widely. They are very effective for tracking the progress and synchronising the organisation. Teams put their board on a hallway where people can see it while passing by. The motivations behind this are;

- The team members can present their success to the company. This would both create the feeling of glory inside them and would form a team spirit which would increase their collaboration
- Managers can get a fast look on teams' progress for example while going to toilet
- Teams seeing other teams' boards would create a positive competition.

But also there are points that PVMBs are not enough;

- Synchronising geographically distributed teams
- Version control that is keeping both old and latest state of the board in a database
- Limited work space
- Hard to change the structure of the board (lines etc.)
- Redundant work caused because of updating the interconnected boards manually

In order to aid those needs, developers created digital boards; yet they are not silver bullets by themselves. Negative points of the digital boards are;

- They take away the haptic feeling and ease of use coming from intuitiveness
- As mentioned before companies want those boards available and visible on the hallways at all times. Therefore using digital boards, companies would need to buy hundreds of TVs or projectors

Because of these reasons, companies want to use physical and digital boards at the same time. For some companies buying hundreds of TVs and the electricity those TVs would consume may not a problem. But even they want to use physical and digital boards at the same time during the period of transition from physical to digital boards.

Using physical and digital boards at the same time would create redundant work which would lead to loss of time and frustration. After having meeting using either physical or digital boards, one would need to update the other one accordingly. No need to mention that interconnected physical boards would still need to be updated manually. In order to solve this problem we created image recognition software, which transfers the information on physical boards to digital boards with the help of a camera. Even though it only provides one-way transition (physical to digital, not digital to physical) the companies that use physical and digital boards at the same time gave positive feedbacks. A scenario of using this hybrid system is given below;

1. Hold the Pulse meeting using PPB
2. At the end of the meeting take the photo of the board
3. Give this photo as input to the image recognition software
4. The software would update the related VPB automatically
5. The updated VPB would update the digital boards, that are interconnected with it, automatically

5 Analyses

In this chapter results are analysed and the research questions, given in the introduction chapter, are reflected over according to the results gathered from the research.

5.1 Interaction with Digital Pulse Boards

One needs to use mouse or keyboard (or touch screen) in order to interact with a DVMB. Therefore the haptic feeling of using real objects is taken away. But still there are ways to have a kind of simulated haptic feeling and intuitive usability. One can use Wii remote controller and the digital pen for Wii combination to create the haptic feeling of using real objects. Another solution can be using Kinect where people would use hand gestures and movements to control the digital board. Employing those tools would not only help the attendees of the meeting make their actions on the board faster but also would make everybody focus on the board. A company using mouse-keyboard or tablet to control DPBs, the users would focus on the control tool to make the changes they want on the board. This would cause minor distractions. Considering the possible number of changes on the board during a meeting, those minor distractions would sum up and create a big inconvenience because of the attendees drifting away from the subject to be focused.

5.2 Feature-richness vs. Clean User Interface

Being in the team that does the brainstorming and deciding on the structure of the software, one can get excited of putting more fancy functionalities, which may seem just right. One can think, ”we give all, they choose what they want” or ”the more, the better” as the best strategy for the software development. Putting lots of functionalities would make the user interface full of buttons and so on. The developers would know how to make a certain action like where to click but having a crowded user interface would cause new users have hard time finding what they want. In order to employ lots of functionalities and at the same time make the user interface clean and organised, developers generally group the functionalities. That means, users need to make more clicks in order to reach the function they want. It is obvious that such software would make companies lose time. Companies first need to teach the employees how to use the new tool. Also during the time the employees use this software there would be a time loss because of its grouped structure consisting of many levels. Especially in the case of developing a software that is going to be used in the lean methodology, the tool itself not being lean would be absurd. Therefore the trade-off between employing functionalities and keeping the user interface clean has great importance.

5.3 Reflections over Research Questions

1) Is it possible, if so what are the ways to connect a physical Pulse Board with a virtual one?

Today thanks to the technology, which is developing non-stop, physical and virtual world are connected. Even though we are not in the ubiquitous computing age yet, still we are surrounded with tablets, smartphones and sensors. Those gadgets connect real and virtual world and assure the smooth transition in between. Thanks to advanced sensors, we can simulate all of our senses. That means if we can sense something, computers can do it too.

As it is explained in the methodology part, the way to solve this problem was chosen among the other possible ways found at the brainstorming stage. The new technology should be easy to use, preferable something already people are familiar with, and exists everywhere just like ubiquitous computing. As mentioned before, everyone owns a smartphone today therefore it was selected as the medium. Smartphones comes with lots of useful sensors. Thanks to advancements on electronics, today even smartphones have high-resolution cameras, which can be used as the sensor to transfer a physical board to a virtual one.

Figure 12. Transformation from physical to virtual Pulse board

The transformation from physical to virtual board using image processing is given at Figure 12. The steps of this transformation are:

1. The lines and places of magnets are detected.
2. Colour detection is applied on the magnets.
3. Information cells are found of which places are hard coded in the program.

Magnets are represented as coloured squares on the virtual board. As it is mentioned at the delimitations part, OCR was not applied therefore the program stores only the pictures of the information cells.

2) What are the benefits of a physical pulse board compared to a virtual Pulse board?

Companies like having the team boards always available and visible at the hallways. Physical boards are quite convenient to be used as a constant status display whereas digital boards do not give as much convenience. They are also easy to access whenever

needed but having them being displayed all the time at the hallways would require a TV or a projector which would consume electricity. On the other hand, using physical boards means using papers, post-it notes etc. where a digital board would be more sustainable.

There are some default advantages of digital information comparing to physical information written on papers. Digital information is everlasting, assuming backups are periodically done. It is very easy to multiplicate and to share it. Today computers, tablets, smartphones exist everywhere which means one can access these information wherever and whenever needed. But on the other hand, being on the Internet makes the information vulnerable for hackers. This risk does not apply for information residing on a paper inside company's office. These differences between digital and physical information also exist between digital and physical boards. Furthermore digital pulse boards are way more flexible for adjustments and expansions. One can easily add new lines, change colours of post-it notes or completely alter the design with just few clicks. Thanks to being IT based, all actions done on digital boards can be stored. Therefore one can easily backtrack all the information on the board.

3) What are the usability issues concerning physical Pulse boards?

When it comes to usability issues, the advantages of physical tools comes from the haptic feeling of touching physical objects and knowing how to use it intuitively. For instance, rotating a physical object using a CAD program can be given as an example to give an idea about the advantages of haptic and intuitive feeling. Everybody knows how to move and rotate a real physical object (!) but it requires some power and strength. Moving and rotating a virtual object through a CAD program may not be intuitive but it will not require any power or strength. That may be an extreme example but clearly explains the advantages of haptic feeling and knowing how to use a tool intuitively. It is mentioned that one needs to use strength to make an action with a physical tool. But as our context is Pulse boards where magnets, papers and pens are used, that disadvantage is obviously not valid.

There is a common problem with stationery tools; they need to be constantly supplied. In the middle of the meeting post-it notes may finish or board marker ink may finish. There may be even situations where accidentally a permanent board marker is used. These would cause trouble for the attendees of the Pulse meeting. People would focus on solving those unnecessary problems in that short time, instead of focusing company problems. These kinds of situations may seem unimportant. But they would not only be frustrating but would also have crucial negative effects on the team and eventually on the company.

4) What are the usability issues concerning virtual Pulse boards?

One of the things that computers outrun humans is finding information, for example a document among thousands of others. On a physical Pulse board, one needs to track down data on the board in order to find the report about the deviation (s)he is interested in. Using a DPB, reports can be linked to the magnets so that with just one click, users

can reach the report they are looking for. This creates a great convenience for the users while saving time.

In the case of a Pulse meeting of a distributed team, even ten-minute meetings can become exhausting. The reason is that in any kind of scenario with physical Pulse boards (either just one main board residing in the main office or multiple replicas of the Pulse board residing in every office) attendees of the meeting should do extra and redundant work. Employing a digital board would completely eliminate this hindrance. A scenario of Pulse meeting with distant offices can be given as:

- The meeting is held through LVC
- DPB is being used
- DPB is controlled via tablets
- DPB is projected to a big screen using a TV or a projector

With the set-up given above, the meeting can be held smoothly without any inconvenience or redundant work. People at distant offices can make the updates they want on the digital board through their tablet and then all the other attendees' boards would be instantly and automatically updated.

6 Conclusion

This master thesis has presented a baseline methodology for tracking deviations in product development and production called Pulse. Pulse boards is a physical tool consisting of whiteboards and magnets to visualize deviations to whole project teams and corporate management, together with regular meetings to take the pulse of the organization the combination of pulse boards and meetings has shown to be a very successful methodology in industry. The purpose of this master thesis has been to investigate how the methodology and process behind Pulse can be digitized and connected to the corporate IT-back bone in order to achieve better support global development teams, low maturity products, and management functionality such as history and traceability.

The study shows that it is possible to work with image recognition software to track changes of a physical pulse board. Further it is possible to use the technology to publish the information on the pulse board in real time on the intranet. This is useful for companies that today struggle with keeping several boards up to date and where they use some technology or method to coordinate the pulse boards e.g. excel sheets or photographs of the board.

However, this way of working requires that you have one "master" pulse board, and that this master is always correct. Having concurrent versions of pulse boards is very difficult and requires either manual corrections or very advanced and costly means of changing or updating pulse boards automatically. If this is the case and that the company requires several concurrent pulse boards then it is recommended to move to a totally digital system where all pulse boards are managed digitally. In this case the use of image recognition of pulse boards could work as a bridge from physical pulse boards towards only digital pulse boards.

Concerning usability issues of a pulse board, it has been shown that companies prefer different alternatives. In a company where the physical pulse board works well then the physical pulse and the meeting around the physical pulse board is highly appreciated. The move to a digital pulse board is in this case difficult from a usability point of view, but can be motivated with better coordination between sites and better data management capabilities. Further, the touch and feel of a digital board will not be as good as a physical board on the other hand, a digital board gives other types of usability advantages such as easier linking to for example deviation reports. It cannot be said that a physical board is better than a digital board, only that they have different types of advantages

7 Future Work

The image recognition software mentioned in this master thesis was developed to prove the concept, not to be commercialized directly. It was tested and its parameters were adjusted with a small set of example pictures taken from the Pulse board given at Figure 1. Therefore at the time this master thesis was being written, it could only detect the pictures in the test set with 100% precision. Its performance was tested with other pictures but the need of a fine adjustment on the parameters was obvious. The first step of presenting the concept to the companies was to show that it is possible to use image recognition software to transfer the information from a physical board to a virtual one. For this step, the software not necessarily needed to work with high accuracy. Just showing how it works is acceptable. But this step is only useful to inform the companies that this kind of solution is possible. Companies would have an idea if they need such a tool and whether it is useful. But in order to fully decide if it would fit in the way they work, they require seeing the tool in use, which constitutes the second step. In order to realize the second step of presenting the tool to the companies, the image recognition software should have a high accuracy. After that, in case the companies are further interested in the technology and want to have it, commercialisation step would begin. That would require the software to be worked with minimum 99% accuracy. Therefore developing the image recognition software to increase its accuracy has a great importance and constitutes a big part of the future work for this master thesis.

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Paper A

Development of an Electronic Lean Planning System for Product Development (Pulse)

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Abstract. In product development companies the development process is becoming more and more complex. A multitude of engineering disciplines are involved in the development of new products. Guidelines and checklists that support new product development are continuously evolving. New Lean and Agile methods arise. One of the methods that have gotten a lot of public attention (at least in Sweden) is the Pulse planning board. This research was carried out in order to understand how companies manage deviations by the use of Pulse boards and possible benefits for integrating these solutions with an IT-backbone. After getting a clear picture of what the companies need, a prototype tool was created upon which the users' feedback was taken. Their feedback was analysed and the application was adjusted and further developed based on the results of that feedback.

1 Introduction

Two trends can be discerned today in product and production development; increased virtualization and increased visualization. Increased visualization comes from the Lean paradigm and has resulted in simpler and often physical methods/tools such as visual planning boards and checklists. Increased virtualization comes from PLM, Systems Engineering and process management. It ensures that development teams see the right versions of the information whenever and wherever they want. The implementation of enhanced visualization shows that visual planning with standard whiteboards exhibit a simplicity that is appreciated by the users (Lindlöf and Soderberg, 2011). But they have some limitations such as:

- The difficulty for supporting geographically distributed teams
- Inability to connect (link) information
- Inability to backtrack the information on the boards
- No version control

Digital versions of those boards solve all those needs but they come with their own complications. Therefore using both physical and digital boards at the same time by combining their strengths would be useful. But such a system would require redundant work. After having a meeting with one type of board (either physical or digital), the other one needs to be updated manually. In order to solve that problem we developed an image recognition program as a part of this research. Thanks to this software, companies can use physical boards at their meetings and have their digital boards updated automatically simply by taking a photo of the physical board.

1.1 Managing Deviations in Product Development

At managerial meetings where development progress is discussed, companies need tools to see all the current deviations at one place. Therefore, these visualization tools

should be able to represent all the information in a clean and structured way. Some product development companies use whiteboards in order to manage all the deviations. Using those boards, managers can see the current state of product development activities and act upon them accordingly. Companies require more functionality from these boards, though. Some of those needs can be counted as information sharing, backtracking history, ease of access at all times and facilitating meetings of distributed teams.

1.2 Research Questions

RQ1. How do companies work today with physical Pulse boards to visualize and manage deviations in development?

This research question aims to discover both how Pulse boards are used and what the underlying methodology and information model looks like. These practices will be further compared to alternate solutions such as IT or SE tools on the market.

RQ2. What are the consequences of digitalizing the Pulse board methodology?

This question aims to investigate how Pulse boards could be managed digitally. What would be the impact on the Pulse board meeting (both advantages and disadvantages e.g., usability). In particular, how could digitalization contribute to global product development? In order to evaluate RQ2 a software prototype needs to be developed and evaluated.

1.3 Report Outline

This paper is organized as follows. In Section 2, the ways and strategies used to carry out the research are laid out. In Section 3, the main conclusions drawn from the research are presented. In Section 4 the research results are further evaluated. In Section 5 reflections on the results are given. Section 6 summarizes the conclusions of this research and identifies the future research directions.

2 Methodology

This research was carried out with three main steps as given at Figure 1. In order to come up with a good solution to meet the needs of the companies, the research was started with a two-way knowledge gathering. For this step the research group was divided into two; the library and the company group. Each group looked for information at the place their group name infers. After getting information from both literature and companies, the concept development stage was begun in order to come up with a tool that solves the needs of the companies. At the end of the concept development stage, the best idea was selected among the ones that were discussed. Thus began an on-going cycle; developing a prototype, getting feedback from companies, and making adjustments accordingly.

From the literature studies, no further information could be gathered other than topics like Lean, Agile, Scrum and product development. As the main focus point of the research was Pulse methodology, the interviews formed the most important part of the background knowledge gathering part. Four Swedish companies (two heavy vehicle manufacturers, one communications company and one company in the material handling industry) have been involved in this research. The researchers have been involved in several workshops and performed 12 qualitative interviews.

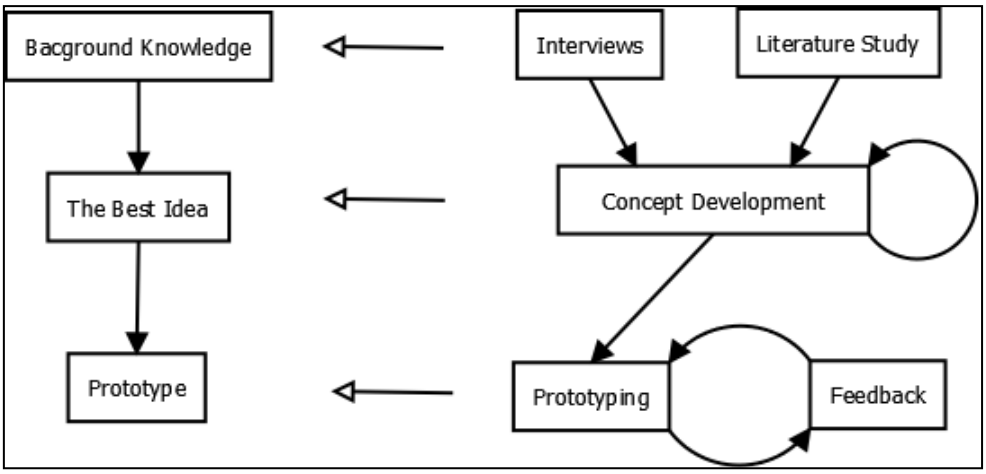

Figure 1. The research approach

The concept development stage consisted of finding and compiling as many solutions as possible and selecting the best idea from among those solutions. As the solution selected to be implemented was the best one among the found solutions, not among all the possible solutions, it was addressed as the relative best solution. The criteria considered finding the relative best solution was: ease of implementation, usefulness and facilitation for possible upgrades and integrations

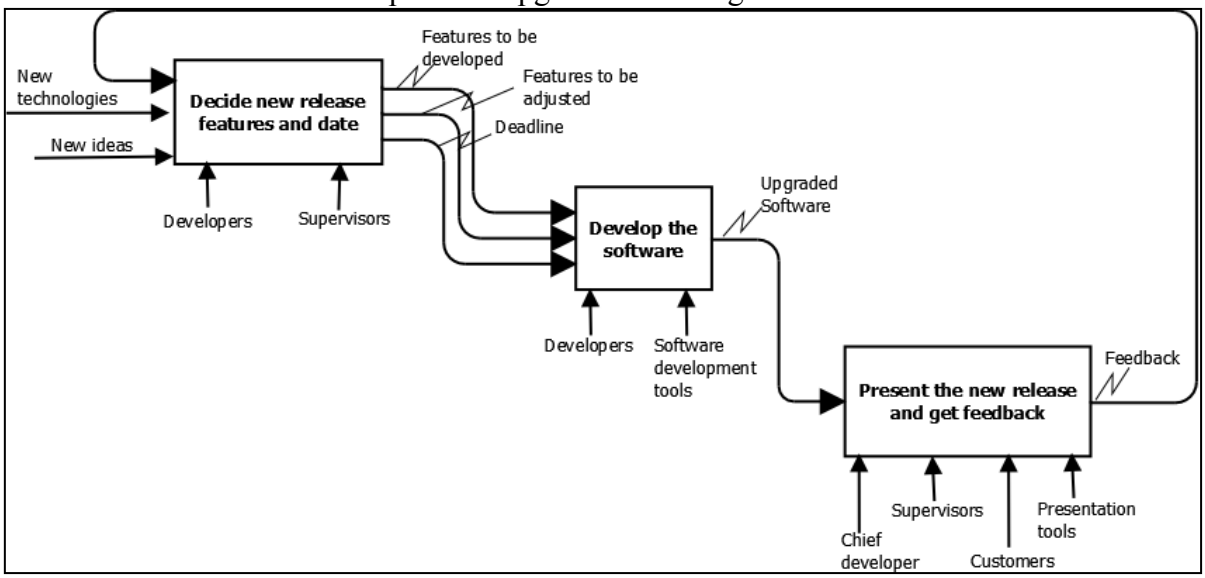

Figure 2. The Prototyping diagram

The ideas and ways to implement them, which had been documented at the concept development stage, were used at the prototyping stage (Figure 2) while transforming them into programming tasks. Deadlines for each programming task were decided upon and then the tasks were implemented. As it was an on-going process, with each new idea, new technology, and new feedback, this cycle was repeated. Upon the delivery of each new version by the software development team, the software was presented to the applicable companies and their feedback was taken and used when planning the programming tasks.

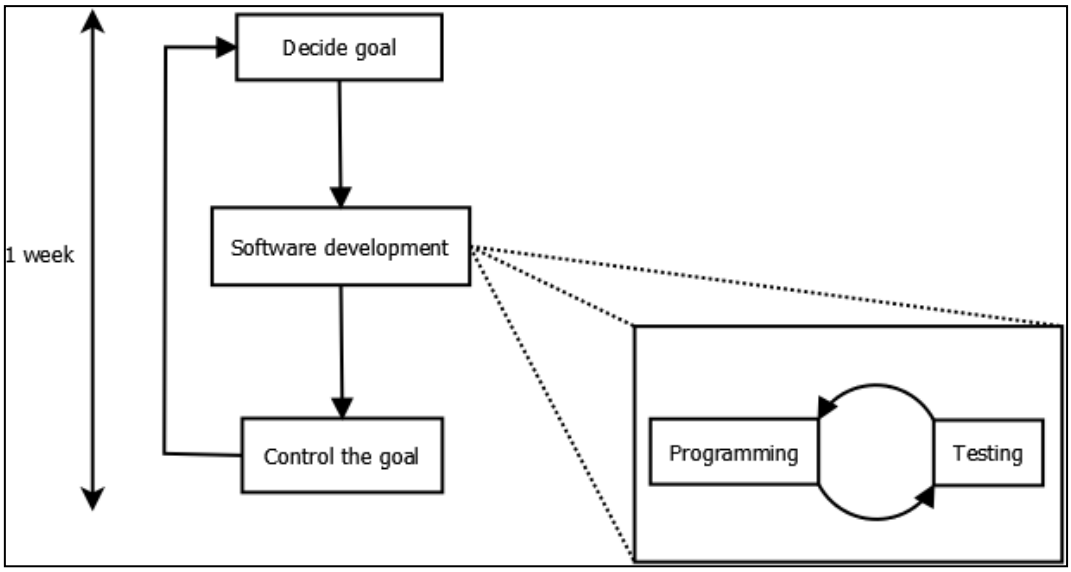

Figure 3. Software development flowchart

Software development (Figure 3) was carried out with weekly iterations. At the beginning of each week, the software development team and project supervisors had a meeting to outline that week's goals and also check the previous week's work. After deciding the next tasks, the software development team developed and tested the software simultaneously until the deadline. At the next meeting, the latest state of the software was presented to the supervisors. Other than weekly iterations, there were also larger iterations where new versions of the software were released to the companies for their feedback. In the case of not being able to complete all the planned programming tasks, the program was adjusted to be stable (removing bugs or incomplete features).

3 Results

3.1 Pulse Boards and Pulse Methodology

The name "Pulse" comes from "taking the pulse of the company" referring to monitoring the progress in the company. The Pulse board is an easy to use physical tool, which tracks and manages deviations in development. The simple layout and intuitive interface of the Pulse planning board is used to reduce the amount of administration in development projects that are often impeded by complicated and complex IT tools and deviation trackers. Pulse methodology comprises of two main components; Pulse meetings and Pulse boards. Pulse meetings are held regularly among managers. Attendees stand in front of the Pulse board and give brief information about the progress of their projects while updating the board accordingly. Pulse boards have much flexibility; for example, they can be used to track deviations in the production and supply chain of a company's products (Figure 4). The ways the Pulse board were used were unique to each company studied; there is no strict definition of how a Pulse board should look like or what kind of information it can contain. The baseline, however, is a large whiteboard with an X-axis and a Y-axis to represent different functions or projects in a company. A user can track deviations concerning these axes by using some sort of indicator such as a post-it note or a magnet.

Generally three (sometimes four) different coloured magnets are used in order to display the status. The colour of the magnet reflects what kind of deviation to consider:

- Red magnet: Deviation (that needs attention)
- Yellow magnet: Deviation (that is under control)
- Green magnet: No deviation

- White magnet: Sometimes a white magnet can be used to illustrate that there are no on-going activities at all within this sector.

In Figure 4 the Y-axis represents products in the market phase. The second column represents the responsible product manager. The next four columns represent different production activities such as Quality defects, Yield, Supply and Maintenance. In the larger column next to the magnets, comments concerning the deviations are written down in order for product owners and managers to know what deviation is tracked. The date fields indicate at which date the deviation was identified and when the management team (at the Pulse board) will next be updated on the status of the deviation. Finally there are four large squares where printed documents and quality reports can be attached for more information about an on-going activity. This gives the logical flow from product line to deviation, to deviation-comment, to report about the deviation.

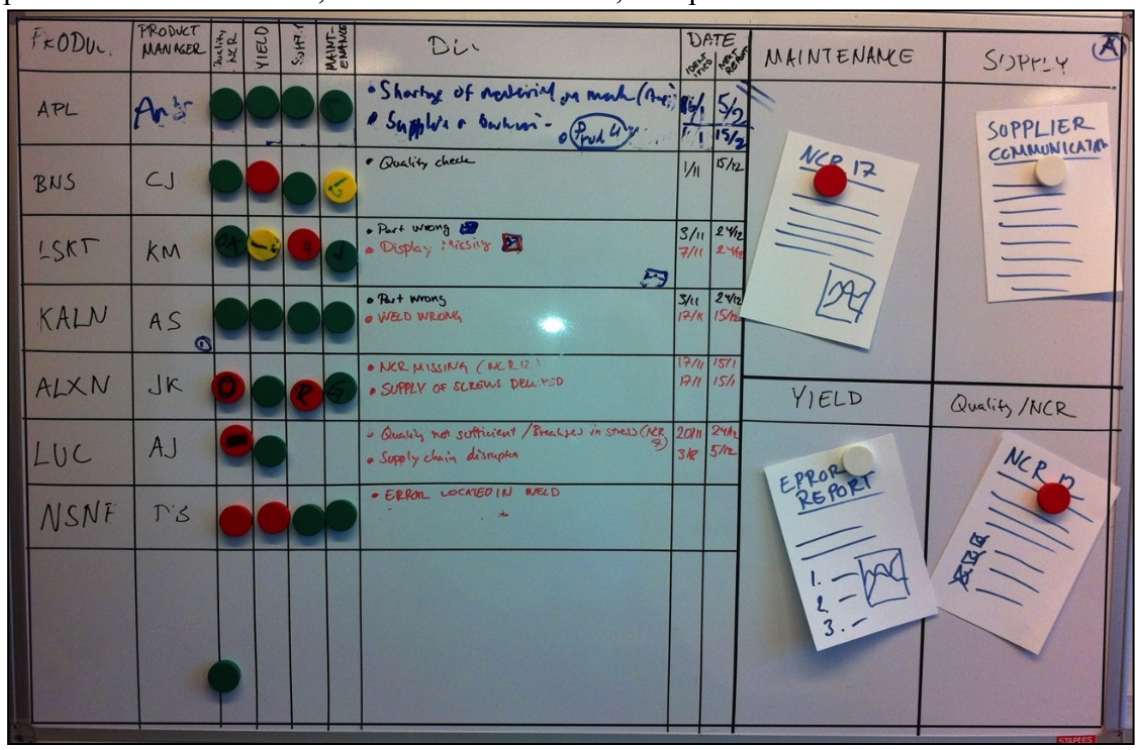

Figure 4. Pulse board (A mock up modeled from a real Pulse board used to track deviations in production)

Project boards, as the one shown in Figure 4, are often aggregated to a corporate or management board. One example of such corporate Pulse board is shown in Figure 5. Used as a regular methodology at one of Sweden's most successful automotive manufacturer it shows that the Pulse methodology can track many deviations and be used in the development of complex products. However, companies that have tried to mimic this methodology have fallen short when for example global development teams meet, when the product or products has a low maturity, or when the history and traceability of deviations is of high importance.

Figure 5. A corporate Pulse board, weekly Pulse meeting in front of a huge corporate Pulse board for tracking the deviations in an R&D organization. (Johansson, R&D Factory)

3.2 Process Model for Physical Pulse Board

During Pulse meetings, there is a pattern that all product managers follow while using the Pulse board. The process model for physical Pulse board is given at Figure 6. They follow these steps in turn for each deviation they have in the product line they are responsible for. Each product manager goes in front of the Pulse board and starts giving a brief overview about a deviation. If it is a new deviation and the solution for it is unknown; the manager places a red magnet on the related cell, writes a short description on the descriptions cell about the deviation, places a detailed report on the reports cell and writes detection and the next expected update date on the dates cells. If the solution is known then the manager places a yellow magnet and follows the same remaining steps given above. If it is not a new deviation but an update of an old one, there are three possible outcomes: It can be that a solution for a previous deviation, for which the solution was unknown before (red magnet), is found. In that case the product manager replaces the related red magnet with a yellow magnet and follows the remaining steps given above. Another possibility is that a previously detected deviation, for which the solution was known (yellow), could not be solved yet and it is time for its status update. In that case the product manager just updates the next-update-date. The third situation might be that the deviation is solved. In that case the related yellow magnet is replaced with a green one and all the remaining information about the deviation is removed/deleted from the board. This finalizes the information sharing about that deviation and the product manager continues with the next one.

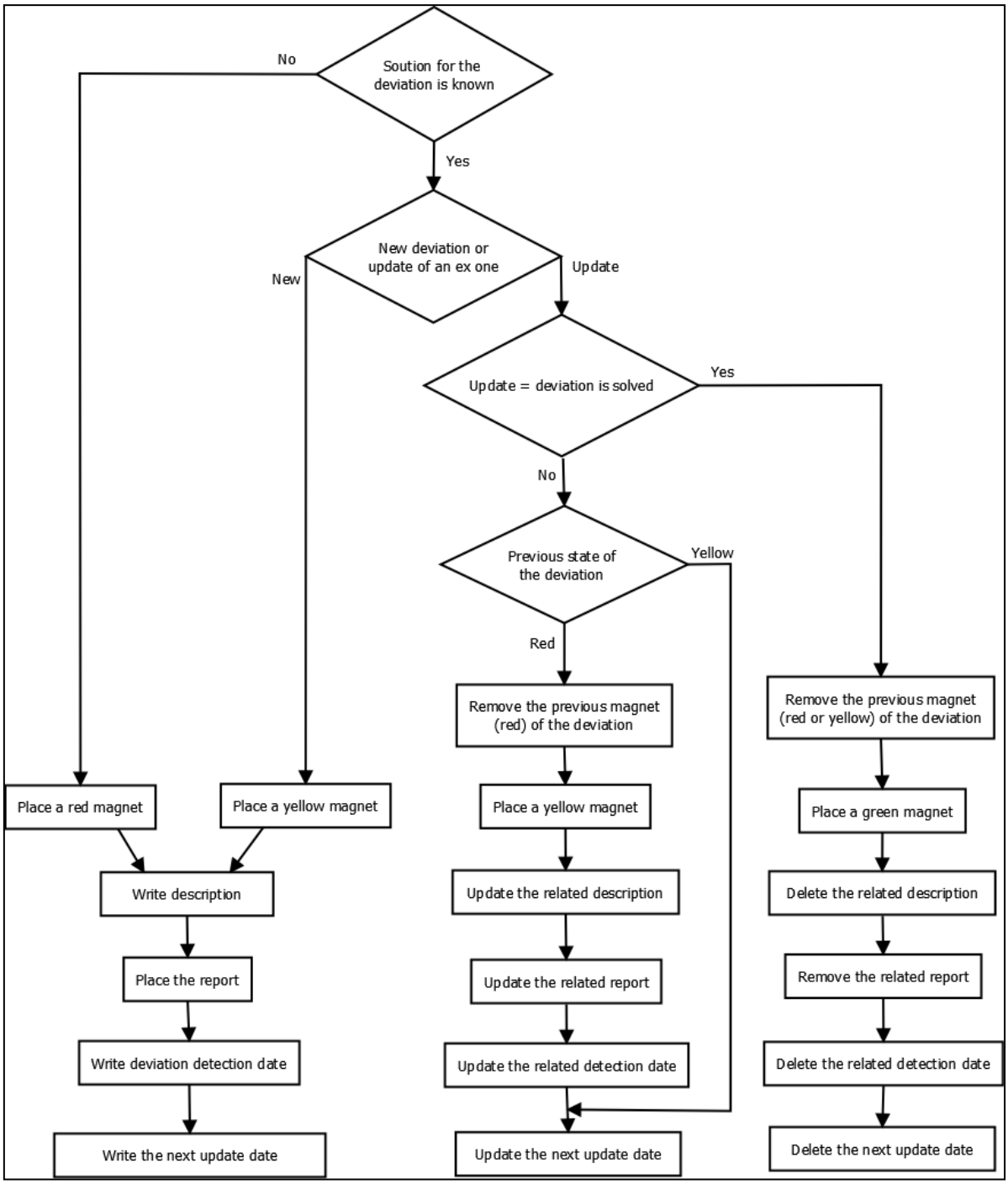

Figure 6. Pulse board process model

3.3Design of Software Prototype for Pulse Meetings

Smartphones are extremely prevalent in today's business world and were thus selected as the medium for the application. Smartphones have high-resolution cameras which can be used as the sensor for this image recognition application.

The transformation from physical to virtual board, using the image processing software, is given at Figure 7. The steps of this transformation can be shortly given as follows. As seen in Figure 7, the board has a different line structure for the reports section than the rest of the board. Therefore, the image is divided into two small images and the lines are detected for both images. Using this information, cell coordinates and the places of the cells are identified. Cell coordinates give information about the location of the cell (for instance, x=2 and y=4). Cell place refers to the pixel-wise place

of the cell on the image. Since the structure of the board is known, 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 (deviation descriptions and reports) are cut down. Those cut cells are then used directly in the digital board as small images. That means, instead of using optic character recognition, we preferred to put the images of these cells on the digital boards to prevent any erroneous character recognition. Finally, magnets' places and colours are detected. Comparing the magnet and the cell place, the program figures out which cell the magnet belongs to. Magnets are represented as coloured squares on the graphical user interface of the virtual board.

The image processing application was developed using OpenCV. OpenCV is an open source computer vision library available for C/C++, python and Java (Android). In order to be a fully open source, Linux-Eclipse development environment was used. Test pictures, which would be used to measure the program's performance, were taken by IPhone 4's camera (5 megapixel). In order to represent the captured physical board in the virtual world, a template was created using HTML and CSS. Features like moving magnets between cells were added using JavaScript and jQuery.

The program comprises of two smaller applications; an image processing application that transfers the information from a physical board to a digital one and a web based application which forms the template for the digital representation of the physical board. The Development process was still in progress during the time this research paper was being written.

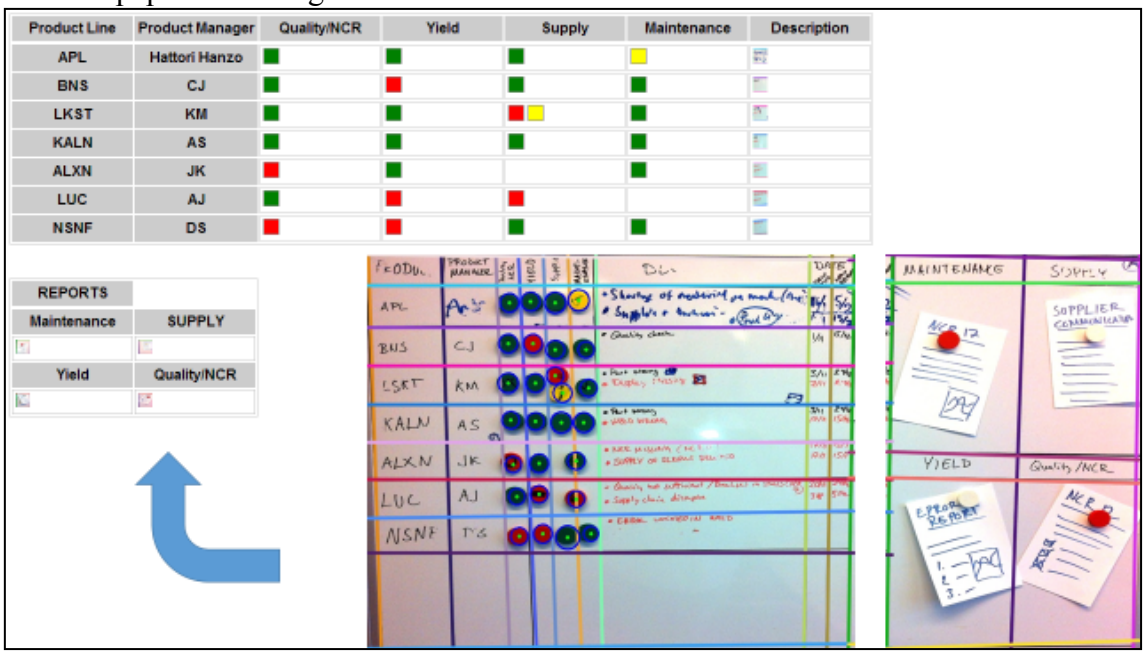

Figure 7. Transformation from physical to virtual Pulse board

4 Analyses

4.1 Possible Use Scenarios of Digital Pulse Boards

Physical visual management boards are very effective for tracking progress and synchronizing the whole organization. Teams put their board on a hallway where people can see it while passing by. The motivations behind this can be counted as;

- Team members can present their success to the company. This would both contribute to employee satisfaction and pride and would form a team spirit, which would encourage their collaboration.
- Managers can get a fast look at teams' progress while passing by
- Teams seeing other teams' boards would create a positive sense of competition.

There are points that physical visual management boards are not enough;

- Synchronizing geographically distributed teams
- Keeping information history
- Changing the structure of the board (e.g., matrix structure)
- Updating the interconnected boards automatically

Digital boards solve those needs but they are not silver bullets by themselves. Negative points of the digital boards are;

- They remove the haptic feeling and ease of use which comes from intuitiveness
- Companies would need to buy hundreds of TVs or projectors to display the digital boards

Simplex Hybrid System. For some companies buying hundreds of TVs and paying the bill for the electricity that those TVs would consume may not be a problem. In order to combine the strengths of both physical and digital boards, companies may want to use them at the same time. Some companies may plan to use just digital boards. It would be more convenient to have a transition time towards using a fully digital solution instead of changing the way the company works abruptly. Therefore even the companies planning to employ a fully digital system would preferably use both physical and digital boards during the transition period.

Using physical and digital boards at the same time would create redundant work, which would lead to loss of time and frustration. After having a meeting using either physical or digital board, one would need to update the other one accordingly. No need to mention that the interconnected physical boards would still need to be updated manually. In order to solve this problem we created an image recognition program, which transfers the information from physical boards to digital boards with the help of a camera. Even though it only provides one-way transition (simplex), the companies that use physical and digital boards at the same time gave positive feedbacks. A scenario of using this hybrid system can be given as follows;

6. Hold the Pulse meeting using physical Pulse boards
7. At the end of the meeting take a photo of the Pulse board
8. Give this photo as input to the image recognition program
9. The software would update the related virtual Pulse board automatically
10. The updated virtual Pulse board would automatically update the digital boards that are interconnected with it

Duplex Hybrid System. The tools that were developed for this research provide only one-way transition; that is, from physical to digital world. But for a real hybrid system a two-way information transition (duplex) is needed. A possible way to have our system expanded in the future is to use robots. A robot hand can make the updates on physical boards according to the changes made on the digital boards. This system seems to take out the redundancy of updating the boards manually. There are trade-offs between having this work done by an employee and having a machine to update the boards automatically. If this task were given to engineers and managers, they would spend time for a routine task instead of working on problems that would require innovation and creativity. But having junior product managers do these tasks would give them experience. A person, who would be paid monthly, can be employed specifically for this

routine task. This may become more costly in the long run compared to buying a robot to do this task since the company would pay a big amount for the robot just once. On the other hand possible maintenance costs and unexpected breakdowns should be also taken into account.

Fully Digital Solution. With the advancements in technology, digital tools become more and more efficient: higher capacity (e.g., speed), lower the price and electricity consumption. That means TVs with touch-screen would be cheaper and would consume less electricity in close future. Furthermore, preparing a small Pulse board (e.g., Figure 4) costs around 1000 SEK (whiteboard, line-tapes and magnets). Therefore the business case for a fully digital system seems to become more popular in close future. Using such a system would be as follows:

- All the Pulse boards would be saved in the servers.
- Employees would be able to reach these boards through devices like smartphones and tablets anytime, anywhere.
- Meetings would be held in front of touch-screen TVs, which would display the digital boards.
- All the routine work (e.g., updating interconnected boards) would be handled automatically.

4.2 Interaction with Digital Pulse Boards

One needs to use a mouse and keyboard (or touch-screen) in order to interact with a digital visual management board. Therefore the haptic feeling (e.g, using real magnets) is taken away. Furthermore, at a company using mouse and keyboard or tablet to control digital Pulse boards, the users would focus on the control tool to make changes. A TV or a projector would display these changes. This means there would be two attention points in the room during the meeting: the user with the controller tool and the digital display. That would cause minor distractions. Considering the possible number of changes made on the board during a meeting, those minor distractions would accumulate. But still there are ways to have a kind of simulated haptic feeling. One can use Wii remote controller and digital pen combination to mimic the physical sensation of using real objects. In this scenario one can use digital pen to move the magnets and to write descriptions and dates on the display (TV or projection screen) to make changes on the digital board. Another solution could be using a Kinect camera where people would use hand gestures and movements to control the digital boards. Employing these tools would not only help the users make their actions on the board faster but also would make everybody focus on the board as both controlling and displaying actions would be handled by the same screen.

4.3 Feature Richness vs. a Clean User Interface

Being involved in concept development and designing software features can give one a sense of, ”we give all, they choose what they want” or ”the more, the better” as the best strategy for the software development. Putting lots of functionalities would make the user interface full of buttons. The developers would know how to make a certain action (e.g., where to click to add a new deviation) but having a crowded user interface would be difficult for new users. In order to employ lots of functionalities and at the same time make the user interface clean and organized, one can group the functions (e.g., MS Office user interface). Users would need to make more clicks in order to reach the function they want. It is obvious that such software would deplete company time. Companies would first need to teach the employees how to use the new tool. Also employees using this software would lose time because of its grouped

structure consisting of many levels. Especially in the case of developing software that would be used in Lean methodology, the tool itself not being Lean would be absurd. Therefore the trade-off between employing functionalities and keeping the user interface clean should be carefully considered.

4.4 Effects of Local Time Difference on Pulse Meetings

Digital Pulse boards indeed facilitate the meetings between distant offices with the help of live videoconference, but there is a limit in distance. The working hours of the distant offices should coincide. Therefore live videoconference is only useful for the distances that the local time difference is no more than the duration of daily work. For instance, in a company where working hours are between 8:00 – 17:00, in order to have a meeting between two distant offices the local time difference should be lower than 9 hours. Companies that have offices all around the world could overcome this problem by:

- Arranging meetings around offices that have coinciding working hours
- Prepare a short report or record a video of the meeting and then share this with the other groups of distant offices
- Managers work over-time so that with just one meeting all the offices can be synchronized

Other than these not-so-convenient solutions, some features can be added to the digital boards to facilitate a solution. Digital boards can save the changes while recording the users' voice. This data would be received by the offices, which geographically reside west of the original group. This next group has their digital board updated automatically with the data from the original group. The board would do this automatically on the fly while showing each change. This would save a lot of time.

5 Discussion

5.1 Physical vs. Digital Boards

Some companies like having the team boards always available and visible in the hallways. Physical boards are quite convenient used as status displays whereas digital boards do not give as much convenience. Digital boards would require a TV or a projector, which would consume electricity. On the other hand, using physical boards means consuming paper.

There are some default advantages of using digital information stored on a hard-disk compared to physical information written on a paper. Digital information is everlasting, provided that backups are periodically done. It is very easy to duplicate and share. Today computers, tablets, and smartphones can easily be used to access the digital information wherever and whenever needed. On the other hand, being on the Internet makes the information vulnerable for hackers. This risk does not apply for information residing on a paper inside the office. The differences between digital and physical information also exist between digital and physical boards. Moreover, digital Pulse boards are more flexible for adjustments and expansions. One can easily add new lines, change colour of post-it notes or completely alter the design with just few clicks. All actions done on digital boards can be saved and backtracked later on. Figure 8 gives the comparison between physical and digital boards.

Table 1. Physical vs. digital boards

Physical board	Digital board
Has no display needs	Needs a TV or a projector to be displayed
Consumes physical products (paper, ink,	Consumes electricity

etc)	
Data on the board is temporary	Data on the board is everlasting
Not possible to backtrack information history	Information history backtracking is possible
Hard to multiplicate	Easy to multiplicate
Hard to share	Easy to share
Only accessible within company	Accessible from anywhere, anytime
No risk for information leakage	Risk of information leakage
Not flexible for structural adjustments	Flexible for structural adjustments
Limited space to use (e.g., to write descriptions and place reports)	Unlimited space to use
Haptic feeling of using real objects	No (or simulated) haptic feeling
Intuitive use	Intuitiveness depends on the graphical user interface
Stationery must be continuously supplied	Self sufficient
Causes no distraction, focuses attention on the Pulse board	Causes distraction due to separate controller (e.g., tablet) and display (e.g., TV or projector)
Information (e.g., reports) needs to be tracked down manually	Automatic data finding (e.g., linking reports to the magnets)
No support for distributed teams	Supports distributed team meetings
Interconnected boards need to be updated manually (redundant work)	Interconnected boards are updated automatically

5.2 Usability Issues

Usability Issues Concerning Physical Pulse Boards. When it comes to usability issues, the advantages of physical tools come from the haptic feeling of touching physical objects and intuitively knowing how to use it. For instance, rotating a physical object using a CAD program can be used as an example of the advantages of haptic and intuitive feeling. Everybody knows how to move and rotate a physical object. Moving and rotating a virtual object through a CAD program may not be as intuitive; one would need to get instructions on how to use it. That may be an extreme example but the advantages are clear.

There is a common problem with stationary tools; they need to be constantly supplied. In the middle of a meeting, post-it notes may be finished or board marker ink may run out. A permanent board marker can accidentally be used to write on the board. Noticing this at another meeting, while trying to delete it, would be quite frustrating. People would focus on solving those unnecessary problems in that short time, instead of focusing on company problems. These situations may seem minor, but they would be frustrating and would also have crucial negative effects on the efficiency of the team and eventually on the company.

Usability Issues Concerning Digital Pulse Boards. On a physical Pulse board, one needs to track down data on the board in order to find the report about a deviation. Using a digital Pulse board, reports can be linked to the magnets so that with just one click, users can reach the report they are looking for. This creates convenience for the digital board users.

In the case of a Pulse meeting of distributed teams, even ten-minute meetings can become exhausting because in any kind of scenario with physical Pulse boards (either just one main board residing in the main office or multiple replicas of the Pulse board

residing in every office) meeting attendees would do extra and redundant work. Employing a digital board would completely eliminate this inconvenience. A scenario of Pulse meetings with distant offices can be given as:

- The meeting is held through live video conference
- Digital Pulse board is being used
- Digital Pulse board is controlled via tablets
- Digital Pulse board is projected to a big screen using a TV or a projector

With the setup given above, the meeting can be held smoothly without any inconvenience or redundant work. People at distant offices can make the updates they want on the digital board through the control tool they prefer and then all the other attendees' boards would be instantly and automatically updated.

6 Conclusions and Future Work

Conclusions. This paper has presented a baseline methodology that is called Pulse for tracking deviations in product development and production. Pulse board is a physical tool consisting of whiteboards and magnets. It helps to visualize deviations to all the project teams and corporate management, together with regular meetings to take the Pulse of the organization. The combination of Pulse boards and Pulse meetings has shown to be a very successful methodology in industry. The purpose of this paper has been to investigate how the methodology and process behind Pulse can be digitized and connected to the corporate IT-backbone in order to achieve better support for global development teams, low maturity products, and management functionality.

The study showed that it is possible to work with an image recognition program to track changes of a physical Pulse board. Furthermore it is possible to use the technology to publish the information on Internet in real time. This is useful for companies that struggle with keeping several boards up to date.

However, this way of working requires having one "master" Pulse board, which is always correct. Having concurrent versions of Pulse boards is very difficult. It requires either manual corrections or very advanced and costly means of automatically changing/updating Pulse boards. If a company requires several concurrent Pulse boards then it is recommended to move to a totally digital system where all Pulse boards are managed digitally.

Concerning usability issues of a Pulse board it has been shown that companies prefer different alternatives. In some companies physical Pulse boards work just fine and having meetings in front of is highly appreciated. The move to a digital Pulse board is in this case difficult from a usability point of view, but can be motivated with better coordination between sites and better data management capabilities. Furthermore the touch and feel of a digital board will not be as good as a physical one. On the other hand; a digital board gives other types of usability advantages such as linking deviation reports. One cannot say that a digital board is better than a physical one, but only that they have different types of advantages.

Future Work. The image recognition program mentioned in this research paper was developed to prove the concept, not to be commercialized directly. It was tested and its parameters were adjusted with a small set of example pictures taken from the Pulse board given at Figure 1. Therefore at the time this research paper was written, the program was only working for the pictures in the test set with 100% precision. Its performance was tested with other pictures but the need of a fine adjustment on the parameters was obvious. The first step for presenting the concept to the companies was to show that it was possible to use an image recognition program to transfer the information from a physical board to a virtual one. For this step, the software was not

required to work with high accuracy, so long as it worked. But this step was only useful in showing the companies that transforming information from physical to digital boards is possible. Thanks to this step, companies would have an idea if they need such a tool and whether it would be helpful for them. But in order to fully decide if it would fit in the way they work, they require seeing the tool in use. This constitutes the second step. In order to realize the second step of presenting the tool to the companies, the image recognition software should have a high accuracy. After that, if the companies are more interested in the technology and want to have it, the commercialization step would begin. That would require the software to be working with even higher accuracy. Therefore developing the image recognition program to increase its accuracy is very important.

Previously mentioned duplex system that provides two way data transition between physical and digital boards forms another future direction of this research. Such a system is assumed to be too expensive therefore can be considered as an overkill to create convenience. Considering that currently this work is done by managers, engineers or secretaries who are paid monthly, in the long run such a system may even become cheaper. There may be some usability issues that would make using such a system (e.g., a robot arm) problematic in the office environment..

The current virtual board developed for this research only facilitates the meetings with distant offices that have coinciding working hours. But global companies have offices all around the world and they need systems to facilitate the meetings of all those offices in order to synchronize the company. The possible ways to solve this need would be researched.

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Biography

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Acknowledgements

We thank Staffan Olsson, the leader of our software development team, for his valuable work and guidance he provided to the development team. We also thank the software development team; Johannes Vestlund and Anton Lindgren, who are in their first years of their BSc studies and yet very good programmers, for their valuable work.