





Augmented Reality in Preventive Maintenance

Bachelor's thesis in Production Systems

JONNA BENGTSSON, HANNA KRAFT, ALI MOHAMUD AND HANNES MÄKI

Department of Industrial and Materials Science CHALMERS UNIVERSITY OF TECHNOLOGY Gothenburg, Sweden 2018

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Abstract

Augmented reality is a rapidly evolving technology with potential applications in many areas including maintenance. This thesis aims to describe the development process of an application for an augmented reality headset displaying instructions for a preventive maintenance task. The application was used to evaluate potential advantages and existing challenges of using AR technology in the said context. The initiative of the project originated from an ongoing collaboration between Swedish Match and Chalmers University of Technology to facilitate cooperation between academia and industry. Resources in form of access to relevant machinery and human resources, as well as documentation on the machine, were provided by the Swedish Match.

The method used in this project was to develop an application and conducting a user study. The application that was developed guided the user visually on how to perform specific maintenance tasks. One part of the user study was user testing of the application. The user study also included an interview with a maintenance employee at the company as well as observations of an employee performing a maintenance task.

The result from the user testing indicated an overall positive view on the application. From observing the participants of the user test, it was clear though, that some participants had problems with the augmented reality headset. Taking these result in consideration together with the known theory of human factors and technical knowledge, a conclusion was drawn that AR technology has potential, but is not yet completely suitable for use in this or similar contexts.

Sammandrag

Förstärkt verklighet, även kallat AR efter engelskans förkortning för förstärkt verklighet (augmented reality), är en snabbt växande teknik med potentiella tillämpningar inom många områden, bland annat inom förebyggande underhåll. Syftet med denna rapport är utvärdera möjligheten för användning av AR inom förebyggande underhåll.

En underhållsapplikation användes för att uppnå projektets syfte vilket var att evaluera potentiella fördelar och utmaningar med AR i ovan nämnda kontext. Initiativet för projektet uppkom ur ett pågående samarbete mellan Swedish Match och Chalmers tekniska högskola för att främja samarbete mellan forskning och industri. Resurser i form av tillgång till en relevant maskin, mänskliga resurser och dokumentation för maskinen tillhandahölls av Swedish Match.

Metoden som användes i projektet var att utveckla en applikation och utföra användarstudier. Applikationen guidade användaren visuellt i att utföra specifika underhållsuppgifter. En del av användarstudien var användartester av applikationen. Användarstudien bestod även av en intervju med en anställd på Swedish Match samt observationer av en anställd som utförde ett underhållsarbete.

Resultatet från användarstudierna indikerade på en generellt positiv syn på applikationen. Från att ha observerat deltagarna av användartesten, så var det dock uppenbart att vissa användare hade problem med AR-glasögonen. Genom att ta detta resultat i beaktning tillsammans med teorin om den mänskliga faktorn och tekniskt kunnande, så kunde en slutsats dras att AR-tekniken har potential, men att den ännu inte är helt lämplig att användas i denna kontext eller liknande.

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1 Introduction

Augmented reality (AR) is a technology that has increased in popularity over the last few years. AR lets the user see the real world together with a layer of computergenerated information. AR is usually utilized by augmenting visual input but can also be used to augment sense, hearing, smell, and taste [2].

Large companies, such as IKEA, has already seen the potential of AR by utilizing this technology in a smartphone application that makes it possible for the customer to visualize how IKEA furniture would look in their home before purchasing it [3].

Augmented reality is used on different platforms, although mainly in smartphones and AR-headsets. AR could possibly have many uses in industry, for example, visualization of instructions. A study conducted by the American society of civil engineers showed that instructions for assembling LEGO using animations in AR resulted in a shorter completion time of the task and fewer assembly errors in comparison to using written instructions [4].

Construction is another sector where AR is predicted to have bright future. The Swedish construction company Skanska is already exploring the potential of integrating AR-glasses in their safety helmets as an aid for their builders. One of its potential uses would be displaying blueprints. Skanska believes it would increase the construction workers focus and shorten work time [5]. Another field of application for the AR-glasses is in maintenance. A company that is in the stages of implementing this is Coca-Cola Company who aims to utilize AR for maintenance on the bottling equipment so they can get information while having their hands free. Another aspect is that they had to fly in an expert from Germany, but now the maintenance worker can be guided remotely through the AR-headset. Coca-Cola aims to reduce cost, improve quality control and efficiency throughout their supply chain [6].

1.1 Background

Another company that explores the potential of utilizing new technologies for maintenance is Swedish Match. The idea of AR-glasses as an aid while performing maintenance work emerged from the problem with paper instructions are seldom being used. The AR-glasses could possibly display instructions in a way so they are used by the maintenance workers.

E-DIG is an initiative at Chalmers University of Technology that focuses on smart industry and aims to increase the digitization skills for employees such as operators and maintenance technicians [7]. One of the partner organizations is Swedish Match which previously collaborated in a virtual reality project. This project is not a part of E-DIG but ventures into a similar area as previous collaboration and therefore the cooperation continues. Swedish Match has provided information and resources for this project.

There are different kinds of maintenance performed in a company, such as daily maintenance and preventive maintenance. In Swedish Match facilities the daily maintenance is often short and performed at infrequent times whereas preventive maintenance is performed during scheduled longer breaks. Due to this, the utilization of augmented reality headset seemed most useful in preventive maintenance.

1.2 Aim

The purpose is to explore and evaluate the suitability of using AR for instructions in preventive maintenance by developing and evaluate an augmented reality application.

1.3 Scope

Preventive maintenance is performed on a regular basis on most machinery in Swedish Match's production facilities. All provided written instructions were similar on a structural level disregarding the machine. Because of this, it was deemed to be unnecessary to evaluate more than one of these machines. The scope of this thesis was therefore narrowed down to one machine and its corresponding preventive maintenance instructions.

Due to constraints of resources, such as time, the parameters of the evaluation in this study will be limited. Factors such as economics, organizational culture, and implementation processes will only be mentioned briefly if it is required to facilitate the studies main purpose.

2 Theory

In this chapter, theories applied in the thesis will be presented. For clarity, the chapter is divided into three sections each covering one area of interest with the intention to together provide a complete theoretical basis.

2.1 Technical theory

The technical theory explains augmented reality-technology and its history. The hardware specifications of the used Meta 2 headset and the range of software used in the project.

2.1.1 Augmented reality

Augmented reality is a mix of multiple technologies that combines real and virtual information in an interactive way [2]. The earliest known example of augmented reality is from 1962 when cinematographer Morton Heilig designed a motorcycle simulator called Sensorama [2]. In 1972, Myron Kreuger created Videoplace, a laboratory which surrounded the user with an artificial reality and let the user interact with it [2]. Today AR-technology is used in many different areas including mobile apps, instruction visualization and military heads-up displays [2]. See figure 1 for an example of how AR can look.



Figure 1: Capture of an augmented reality object displayed through AR-glasses

The technology behind AR-headsets works on the same principle as the human eye. Light rays bounce off objects and are redirected into the eye. For the digital objects, there is a need for artificial light sources, the light rays are then redirected to the eyes. To be able to mix the real world with the digital world a combiner is used. A combiner works by selective redirect of the lights from the real world and the digital with a partial mirror [8].

Augmented reality can be divided into marker-based AR and location-based AR. Location-based AR means that the AR-software uses location awareness to assign digital content while marker-based AR means integrating a virtual 3D model into a physical object.

2.1.2 Hardware

For this project, the Meta 2 AR-headset, see figure 2, was used. The Meta 2 is an AR-headset produced by the Meta company. It was released in 2016 as the successor to the Meta 1 headset. The target group of the headset is developers, and there are no commercial products for the headset as of yet. The full specifications for the Meta 2 headset can be seen in appendix A.1 [11].



Figure 2: The meta 2 headset

The Meta 2 displays images on its visor which consists of a half-silver mirror. The images are displayed using an LCD panel. Since the visor is transparent and partially reflective, the user is able to both see the reflected images as well as the physical world [11]. The headset uses multiple sensors to merge data together as to create a digital layer in real-time. The sensors regularly do this so that the 3D-models updates continuously and the 3D-model is fixed in space. This means that the user can move around with the AR-headset but the object is always in the same place regardless of where the user is positioned [12].

Meta 2 uses location-based tracking with internal sensors by using an algorithm that combines data from a camera, with the acceleration and movement of the

wearer [11]. Also, unlike other AR-systems, the Meta 2 uses an algorithm for positional tracking that can begin tracking the wearer's position immediately, without any prior calibration [11]. To get a clear visual experience as possible, the Meta 2 software makes it possible for users to create a profile with a personal calibration of the user's interpupillary distance (IPD), which is the distance between the pupils [10].

The Meta 2 headset is in some ways an empty shell in the regard that it can not display the augmented objects without software. The software is part of the Meta 2 software development kit, and not a part of the Meta 2 headset. It must, therefore, be tethered to a resource demanding computer and use its processor and graphics card. This results in reduced flexibility and mobility for the user. The full specifications for a computer able to run the Meta 2 can be seen in appendix A.2 [11].

The Meta 2 software development kit lets the wearer interact with digital objects. The user can either grab or hover on objects. The Meta 2 supports one-hand grabbing interactions for dragging objects across the user's field of view as well as twohanded grabbing interactions for moving objects and also for changing the size of objects.

The Meta 2 is the headset with the widest field of view available on the market today [11]. A wide field of view similar to the field of view of the human eye, makes the headset feel less unnatural. A smaller field of view decreases the possible use and experiences of the AR-glasses as the augmented objects can only be visible in a smaller area.

2.1.3 Software

The software section contains an introduction and description of the software used in this project.

2.1.3.1 Unity

The applications developed in this project was developed on the game engine Unity. Unity is a free-to-use platform for developing both 2D and 3D applications, see figure 3. Unity was released in 2005 by Unity Technologies [20]. Today, Unity is the most popular game engine with about 770 million users [24]. Unity supports a large number of platforms such as smartphone operative systems, computer operating systems, gaming consoles and virtual- and augmented reality headsets. Unity lets the developer drag-and-drop objects into a scene, and then use a scripting language, to program the components of the scene. C# was used for the scripts in this project. C# is a flexible, object-oriented programming language created by Microsoft [23]. The user can also use several tools such as an animation tool that lets the user animate several aspects of a scene, including changing the position of objects and activating and deactivating objects.



Figure 3: The Unity platform

Unity supports the Meta 2 software development kit (SDK). An SDK is a set of programming tools that can be used to develop applications for a specific development platform, for example, an AR-headset or a video game console [13]. The Meta 2 software development kit contains built-in functions that can be used when interacting with the Meta 2 headset. For example, there are functions that check if the user's hand is grabbing or hovering om an object, as well as methods for checking if a user has let go of the object. There are also Meta buttons and a Meta canvas which can be used to make a graphic user interface where the user can use their hands to interact with buttons, check boxes and sliders [19].

2.1.3.2 CAD

The 3D-objects used in the applications were created by using computer-aided design (CAD). CAD is a general term of software for creating digital drawings of 3D objects. There are different types of CAD-programs specialized for different purposes such as digital fabrication, visualization and simulations [14]. In this project the CAD-software CATIA V5 was used as well as the surface modelling software Alias Autostudio.

2.2 Production

The preventive maintenance tasks in this project is performed in a production setting. The maintenance task is performed on a bottom-label machine which is a part of the production process for two production lines. The bottom-label machine attaches a label to the bottom of the boxes. It does so by routing the band of labels from the dispenser through different rollers before attachment. The productions are running at all hours except when preventive maintenance is performed. For this, the productions stop for that particular line.

2.2.1 Preventive maintenance

Maintenance is the task to restore a failed equipment or keep equipment operational. There are different types of maintenance, in this thesis, the focus will lay on preventive maintenance which is conducted to prevent and postpone a failure occurring and is performed regularly [15]. Preventive maintenance results in better control of when components should be replaced and a decreased risk of failure during production [15].

Preventive maintenance at Swedish Match is performed once a month during the evening. The production is temporally stopped and every component is checked. This includes either performing a specified task that gets done every time such as cleaning rollers or check to see if a component needs replacement.

2.3 Human factors and usability

This section aims to explain theories about underlying cognitive processes affecting the user of the AR-headset and the physical aspects of wearing it. Theory used to support the design choices in the applications is also presented.

2.3.1 Perception, memory and attention

Attention is a way for the brain to direct its available capacity to process only sensory input important for the current situation and to screen out less important stimuli [17]. Another aspect is how information is processed. Information is stored in the long-term memory by connecting it to networks where each piece of information is linked to already existing pieces of information in the memory [17]. For example, the word "shark" is connected to the physical being of a shark which is connected to "fish", " which is connected to "animal" and so on. Perception heavily relies on these networks because it allows us to predict how an object behaves in the world and how to recognize and interact with not previously encountered objects based on what information the object can be associated with [17].

A specific part of the long-term memory is called the perceptive memory, which stores knowledge about recognition of objects, words, and surroundings. This part of the memory is crucial for the subconscious understanding of the world that allows us to navigate through our surroundings without reflecting the function of every object [17].

2.3.2 Reducing risk of errors

AR-technology is argued to decrease the potential risk for errors made by novice users [30]. By granting the access to retrieve information through the AR-headset, inexperienced users gain benefits similar to those of an expert recalling information of the task from memory [30].

2.3.2.1 Design guidelines

Applied design throughout the software development phases of this thesis will be presented in this section. The first applied principle is consistency. Meaning is that similar tasks within a system should be performed in similar ways [29]. Another principle is visual clarity meaning the application of appropriate contrasts between objects, using text and symbols large enough to easily be read, and to have a colour scheme complying with existing conventions [29]. To support users with colour vision deficiency used colour schemes should be in the blue or yellow spectrum. [28].

There are two ways a person understands how an object or system should interact with [26]. The first is called "knowledge in the world" and means that necessary information is obtained from the surrounding environment. The second way is through "knowledge in the head" where the person relies on the recollection of previous training or experience [26]. How easy it is to interpret information in the world depends on how efficient the information exploits natural mapping, and constraints [26]. No prior training is required but the interpretative process uses less cognitive capacity if assisted by the recollection of previously learned patterns. This makes systems that rely on knowledge in the world excellent for first-time users but tends to be less suitable for experienced users who favour high efficiency. All types of instructions rely on "knowledge in the world", the user gets necessary information by interpreting elements in the environment.

2.3.3 Physical Ergonomics

The physical effects of wearing the AR-headset in the context of this thesis needs to be considered in an evaluation of the suitability. Static load during extended periods of time increases the risk of strain and muscle fatigue related injuries [1]. When the headset is worn it moves the head's centre of gravity, causing the head to tilt forward. Muscles in the neck counter the motion in order to keep the head in an upright position. The physical properties such as the weight, shape and centre of mass of the Meta 2 headset resembles a set of head-mounted night vision goggles used by military helicopter pilots. Studies have indicated a correlation between wearing night vision goggles and neck pain among helicopter pilots [22].

3 Methodology

The methodology chapter explains the process and the different methods used in the thesis. Figure 4 shows a schematic figure over the workflow and the different parts of the project.



Figure 4: Schematic figure over the workflow of the project

3.1 Demo application

To achieve experience in developing AR-applications and to gain an understanding of how users perceive AR, a demo application was developed. The development of the demo also proved useful in learning how to work with the software and hardware. The demo consisted of an application where the instructions would be used as an aid for performing a task on a physical model which can be seen in figure 5.



Figure 5: Picture of the physical model used in the demo

The demo application instructed on two main tasks, the first task was to open a box by rotating the lock and open the lid. This first task was specifically chosen since it was simple and intuitive. This was to make the user comfortable with using AR before taking on more demanding tasks. The second main task was connecting components to a circuit board. If the task was done correctly when pressing a button an LED lights up. This task was chosen because not everyone might have enough knowledge about electronics to be able to connect the circuit but it is easy to do when given instructions.

3.1.1 Development and finished demo application

The first step of development was to break down the main tasks into smaller subtasks so that each part was a different instruction. All instructions followed a common framework to conform with the usability principle of consistency in the application. This was achieved by using the same way of transferring information in all instructions. Each consisted of an animation accompanied by text. Parts of 3D-objects were highlighted in blue. The user could navigate forward or backwards through the application by grabbing and releasing 3D arrows. The arrows changed colour from blue to yellow when grabbed to give affirmation to the user that they had successfully pressed the arrow. The choice of colour was based on the design principle of visual clarity.

3.1.1.1 Walkthrough of demo application

In figure 6 the first instruction can be seen. The first thing the user sees when starting the demo is a welcome text with brief instructions on how to navigate through the application. This was done with the intention that the user should not have to jump straight into instructions when starting the demo.



Figure 6: Welcome scene displayed with the AR-headset

The second instruction is for opening the lock and this is shown with an animation that rotates the lock. This instruction can be seen in figure 7



Figure 7: Instruction to rotate the lock displayed with the AR-headset

The third instruction is an animation that swings open the lid to reveal an Arduino board. The instruction can be seen in figure 8. Both the physical and digital Arduino board already has two green cables connected to it to make the demo less lengthy and give the user a point of reference for placing the other components of the circuit.



Figure 8: Instruction to open the lid displayed with the AR-headset

The first task is to connect the resistor, see figure 9. To guide the user there are coloured and number squares from different reference points on the augmented object.



Figure 9: Instruction to connect the resistor displayed with the AR-headset

The same guidelines are used for the next instruction when the user has to connect the button on the board, see figure 10.



Figure 10: Instruction to connect the button displayed with the AR-headset

For the sixth instruction, as seen in figure 11, different colours together with text are used to guide the user on which way the LED should be placed.



Figure 11: Instruction to connect the LED displayed with the AR-headset

After connecting all the components, a text is displayed for the user, urging them to press the button to light the LED. This can be seen in figure 12 This step helps the user make sure that they performed all the tasks correctly.



Figure 12: Instruction to press the button displayed with the AR-headset

Lastly, a text congratulating the user on finishing the demo is displayed, this is to let the user know that the demo is completed. See figure 13 for reference.



Figure 13: Final scene displayed with the AR-headset

3.1.2 Software

The application was made by animating 3D objects in Unity together with scripts attached to certain 3D objects. The arrows used for navigating through the instructions had and an integer variable called Counter that was incremented each time the user released the arrow. This was achieved through the function onRelease() which is a part of the Meta 2 SDK. The integer value was used in the update() function which is a standard Unity function that updates once every frame [21]. The variable kept track of the state of the application, i.e. what objects to make active and inactive, and what objects to highlight.

The animations were done in Unity's animation tool. A script attached to the digital box controlled the animations. The animation control script kept track of the variable Counter and displayed the correct animation based on the value of the variable. Most of the 3D-objects used in the demo were created in the CAD software CATIA V5 and Alias Autostudio, whilst others were collected from free-to-use sites, and some were created in Unity.

3.1.3 User testing

Two separate events of testing were conducted. The first user test took place at a trade fair for maintenance where visitors of the fair got a chance to participate. In figure 14 the set up at the maintenance fair can be seen. The user test took place over the course of two days. The user test at the maintenance fair was done with the expectation that a majority of the visitors at the fair had experience with maintenance and could potentially give useful insights.



Figure 14: Picture of the demo set up on the maintenance fair

Later on, it was decided that more participants for user tests would be needed due to a small number of survey answers, and a series of more traditional user tests were held in a controlled environment at Chalmers University of Technology. This time where the participants exclusively Chalmers students. Except for different settings and user profiles, all users performed the same set of tasks with the same instructions visualized in the Meta 2 headset. Afterwards, the participants of both sessions were asked to fill in a survey.

3.2 Maintenance application

With the information gathered from an interview, observations and given instructions for a specific maintenance task was it possible to develop a maintenance application.

3.2.1 Interview

To gain more information on how preventive maintenance was performed and key aspects that could influence the application and the result, an interview with an employee from Swedish Match was conducted. The employee that was interviewed is working as a maintenance worker and has knowledge about maintenance at Swedish match in particular.

The interview was a semi-structured interview. This is an interview where the interviewee is asked a number of predetermined, often probing questions and are allowed to answer freely. Relevant topics are further investigated by asking additional questions in order to get more extensive information. This is a suitable method to probe the research area and investigate potential aspects of special interest [16].

The interview started with simple questions such as employment path and the interviewee's age. From this, it is possible to draw some conclusions on which questions might be appropriate to ask when continuing the interview. For example, if the person is new to their job it may not be appropriate to ask if something has changed since the person started, as they are probably still in learning. Another aspect is that the person interviewed can get comfortable with the situation without having to answer more demanding questions.

After these first questions, the interview moved on to general questions about maintenance and then more specific questions about the bottom-label machine and its current instructions for preventive maintenance. The interview initially consisted of broad questions about the subject with the purpose to probe for areas of special interest and to help the interviewee to get in the desired mindset by starting to think about the topic. As the interview proceeded, the questions gradually became more specific to get more detailed information. The next step of the interview was to ask what could go wrong with the machines, how often do they malfunction or break down, how to fix it, and where to turn for help. This is a strategy for the later stages of the interview as the person that is interviewed might be uncomfortable with talking about mistakes that they might have done. It may make it easier to talk about it if they more comfortable with the situation of being interviewed.

The final part of the interview was to ask about a previous virtual reality project that took place at Swedish Match earlier as well as AR. This is to get a feel for how this project may be received when finished. This was selected to be the final topic in order to avoid associations to the virtual reality project that might influence the answers.

3.2.2 Observation

To be able to make an application with instructions on how to perform a preventive maintenance task, it was important to understand every step of the task. Therefore an observational study was conducted when preventive maintenance for the bottomlabel machine was performed. The observation study was also a way to get useful information for evaluation of AR as an aid for preventive maintenance.

During preventive maintenance, a GoPro camera was mounted on the chest of the operator that recorded the procedure. During the recording session, the operator was training a coworker on how to perform the preventative maintenance tasks. The procedure was recorded rather than just observed when conducted to be able to go through the material afterwards. Another reason that the procedure was recorded was to not affect or influence the work in any way.

3.2.3 Breakdown of workflow

The video recording from the observation needed to be analyzed to be useful. Therefore the recorded workflow was divided into smaller segments were each corresponded to one of the tasks of the given instructions. In the table 1 the instructions for preventive maintenance of the bottom-label machine are translated into English. The original Swedish instructions can be found in appendix A.3.



- Check the dispensing unit, Remove and clean all wheels, ball bearings and rollers.
- Check abrasive rubber, adjust the height if abnormal wear or bad pressure.
- Check the pendulum and the break strap.
- Clean the print head and check that the surface looks undamaged.
- Check that the belt goes straight, listen for noise
- Clean and check all rollers in the foil cassette
- Clean all sensors.
- Check for possible air leakage.

As the application would be evaluated by a user test it would be too time-consuming for the participants of the user test to perform the whole set of instructions. Therefore it was necessary to make a selection of which tasks the participant should be performing. The recording showed that the work is not evenly distributed over the different task. Some task takes very short time to complete and some take significantly longer time. The duration of the task effects which task could be suitable for the application. It was also taken into account the time constraints of the project and therefore it is preferable to pick tasks that would be easier to visualize. Taking in regards both of these aspects, the tasks 'Check the dispensing unit, Remove and clean all wheels, ball bearings, and roller' and 'Check the pendulum and the break strap' were picked.

With specific tasks chosen, the two segments for this task could be divided into even smaller segments. Every separate step of the segment was noted. These separate steps would then provide the base for the different instructions in the maintenance application.

3.2.4 Functional model

Combined with the machine assigned to the project being located in a restricted hygiene zone, and the preventive maintenance task's non-frequent scheduling. Its hectic production schedule made it difficult to develop the application at the site of the actual machine. This supported the decision to make a scale model resembling parts of the machine suitable for the maintenance tasks selected for the application.

The construction of the model included a wide variety of manufacturing techniques

ranging from digital fabrication through CAD, 3D-printing, laser cutting to traditional woodworking methods. The CAD model of the machine provided by the manufacturer was used as a template to make CAD files of the parts that were to be 3D-printed or produced by laser cutting. Figure 15 shows the completed functional model.



Figure 15: Picture of the functional model

The functional model affected which instructions could be used as the model is not an exact replica of the machine. Therefore the instructions 'remove and clean the ball bearings' and 'check the break strap' were removed because they were not possible to perform on the functional model.

3.2.5 Development and finished maintenance application

The application was developed so that all instructions are consistent in how to display information. All instructions consist of animations together with highlighting of 3D-objects in yellow to make the user focus on them. The user navigated through the program by pressing arrows. These arrows were blue and turned yellow when the user successfully grabbed and released. This was to reassure the user that the arrow had been pressed. Recommendations for visual clarity was complied with, both in the selection of colours and shape of the arrows. The arrows had a timer as to hinder the user from accidentally double pressing the arrow and skipping instructions.

3.2.5.1 Walkthrough of maintenance application

The first step of the application is the welcome menu, see figure 16. By pressing the Meta 2 button with either a finger or a computer mouse, the user goes on to the next menu.



Figure 16: Welcome menu displayed with the AR-headset

The next menu lets the user choose a production line, see figure 17. The application only supports two production lines at the moment, but the design of the menu is meant to make it look more realistic, and indicate that there is a possibility of adding more lines to the application in the future. To make it clear to the user which lines are available, these specific lines are written in bold.



Figure 17: Menu showing choice of production line displayed with the AR-headset

The last menu consists of different machines, just like the line menu, only one choice is available and written in bold text, but several other options are displayed. See figure 18 for reference.



Figure 18: Menu showing choice of machine displayed with the AR-headset

After choosing a machine, the whole machine is displayed at first so the user can verify that they chose correctly, see figure 19. The user can now press arrows to navigate through the instructions.



Figure 19: Whole machine displayed with the AR-headset

The next step consisted of the machine zooming in towards the user while fading away leaving a small part of the machine. This is done since the whole machine is too big, and to let the user focus on the part of the machine that matters for the instructions.

The first task consists of unscrewing a set of screws. This was visualized through an animation showing an Allen key screwing, and then screws being removed from the plate. The Allen key was highlighted in yellow as to make the user focus on it. See figure 20 for reference.



Figure 20: Instruction to remove the screws displayed with the AR-headset

The next instruction shows the plate being removed, see figure 21. The plate was also highlighted to draw the users attention to it.



Figure 21: Instruction to remove the plate displayed with the AR-headset

The following instruction displays a liquid being applied to a rag from a bottle, see figure 22.



Figure 22: Instruction to apply liquid to rag displayed with the AR-headset

Thereafter, the rag was used to clean rolls on the machine. This was shown with an animation, and the rolls that were to be cleaned was highlighted in yellow. This can be seen in figure 23.



Figure 23: Instruction to wipe the rolls displayed with the AR-headset

The user was thereafter asked to attach the plate and screw back the screws. After the first three tasks, a checklist pops up, where the user confirms the tasks that have been performed, see figure 24.



Figure 24: Checklist displayed with the AR-headset

The next step for the user was to test the wheel of the machine. This was visualized by an animated hand spinning the wheel on the machine. The wheel was lit up in yellow for clarity, see figure 25 for reference.



Figure 25: Instruction to check the wheel displayed with the AR-headset

Lastly, the user was asked to check the wheel. The first part of this instructions consisted of pulling the wheel forwards and check the strap and pendulum. Finally, the user was asked to put the wheel back. The wheel was in this case also highlighted up. After completion of all tasks, the checklist was displayed once again. Lastly, a menu with an exit button was displayed to let the user know that the tasks were finished. See figure 26.



Figure 26: Final scene displayed with the AR-headset

3.2.6 Software

The application was made in Unity and all scripts were written in C#. Most of the CAD-models for the application was provided by Swedish Match. Some were also produced in CATIA V5 and Alias Autostudio. Some objects were found on free-to-use sites. The CAD-drawings where converted to a suitable file type for Unity with Alias Autostudio.

The menus in the application were made using a Meta 2 canvas since this allows the user to interact with the menu with their hands. The user navigates through the instructions using arrows that are grabbed and released. This is achieved through the function onRelease() which is a part of the Meta 2 SDK. On the release of the arrow, a variable is set to true. An if-statement in the update() function checks if the variable is true, and also if a timer is less than or equal to zero. If the timer has not yet reached zero, the variable is set to false, and a timer counts down. If the variable is set to true and the timer is less than, or equal to zero, an integer variable called Counter is incremented. The variable Counter is used in a series of if-statements to determine which instruction is being displayed.

3.2.7 User testing

To evaluate how well users understood the instructions displayed in the application, user testing was conducted. A workshop was held at the Swedish Match factory in Gothenburg. The participants were Swedish Match employees and were asked to perform the tasks displayed with the AR glasses on the functional model of the machine. Before performing the task the participants were given a brief guide on how to interact and navigate while using the AR-application. The guide can be seen in appendix A.4.

3.3 Survey

A survey is a way to collect peoples opinions on a number of predetermined questions. The answers can be compared and it may be possible to draw conclusions from the survey when multiple people are answering the same questions. A survey was used to evaluate the application. After testing the application, the users were asked to fill in a survey where they rated the experience and their perceived performance when using the AR glasses.

The questions were chosen specifically to find out the users impression of the application and suggestions for potential improvements. The survey also contained information about the user's previous experience with AR and whether that would affect the usability. Another question was chosen to see if there is a connection between the age of the user and their impression of the application. Finally, the survey contained a question asking whether the user worked in maintenance and if they believed AR-technology could be used in their field of work.

The questions could be rated on a discrete scale with the integers one to six except for the questions where the answers can only be yes or no and for leaving feedback. A scale from one to six means there is no middle ground where the one answering questions can be indifferent. In the survey, a score of four or higher was considered positive, while a score of three or lower was considered negative.

4 Result

In this following section, results from used methods will be presented

4.1 Demo application

The results from the demo consist of survey results and observations that were used for the construction of the demo.

4.1.1 Observations of the participants of the user testing

By observing the participants of the user tests, several conclusions were drawn on how an AR-application should be designed to prevent errors. These observations, as seen in table 2 below, is divided into categories. The categories are based on the underlying reason for why the event occurred.

Category	Observation
	Didn't understand how the arrows functioned
Not enough information	Didn't understand the function of the circle
of how to use the headset	Required oral instructions to understand and
	complete the task
	Forgot to apply the instructions in real life
	Hesitant to look closely on the AR object
Unaccustomed with AR	Had trouble switching attention between the phys-
	ical model and its digital replica
	Did not manage to perform hand gestures correctly
Design desisions	Didn't read the explanatory text and therefore
Design decisions	missed key information

Table 2: Observations categorized from the demo application

4.1.2 Survey

In total 22 people answered the survey after completing the demo, see appendix A.5 for all answers. They were between the age categories '30 or younger' to '50 or older'. Of the people answering, 68% were under 30 years old.

The survey questions concerning the rating of the demo can be seen in table 3. The table shows how many testers were positive regarding the different aspects.

Tuble 0. Reput of burvey quebtione	that were rated over rour
Survey question	Percentage of people that
Survey question	rated four or higher
What was your general impression of	01 07
the demo?	91 /0
How well did you understand the	82 %
instructions?	
How sure are you that the task in the	
demo was performed correctly	86 %
according to the instructions?	
Could AR applications be of use in your	82 0%
company today or in the near future?	

Table 3: Result of survey questions that were rated over four

Out of the 22 people answering the survey, all 11 persons who had tried augmented reality or virtual reality before rated a four or higher to the all the questions in table 3.

4.2 Maintenance application

The results of the maintenance application consist of results taken from the interview as well as results from observing the preventative maintenance being performed and answers from the survey conducted during the user testing.

4.2.1 Interview

The interview of a Swedish Match employee gave input on different aspects of the project. The transcribed interview in its entirety can be seen in the appendix A.6. It became apparent that the instructions are not used by the workers as instructions but rather as a checklist. The instructions were also very broad and didn't go into details on how to perform the different task. The reason for why the instructions were not being used seemed to be because the maintenance worker knew the task at hand and had different ways to get help when something was unclear and therefore did not use the instructions. To get help the employee has to call a coordinator who then called different people to get someone to help the employee.

Another aspect that was brought up in the interview was the attitude towards the previous virtual reality project and the possibility of an augmented reality workshop. The person that was interviewed expressed a positive attitude towards both.

4.2.2 Observation of performing maintenance tasks

The visit at Swedish Match's factory to record preventive maintenance being used on the bottom-label machine resulted in approximately one hour of recorded material. The recorded material included a full run through of the maintenance task. Since the operator was teaching a new employee to perform the tasks, the video also included vocal instructions on the tasks. During the observations of the employee performing the preventive maintenance tasks, no instructions were used, not as an aid to know what to do, nor to check that every task had been done.

4.2.3 Survey

There were 16 people who answered the survey after testing the application. Out of them have 68.8~% worked with or have previous experience working with maintenance and 62.5~% had tried augmented reality or virtual reality before. The distribution between different ages of the people who answered the survey can be seen in table 4.

Table 4: Dist	ribution of age o	i the people w	vno answered	the survey
Ago	30 years or	30-40	40-50	50 years or
Age	younger	years old	years old	older
Percentage	6.3%	18.8 %	56.3~%	18.8~%

Table 4: Distribution of age of the people who answered the survey

Table 5 shows the result of the questions which evaluated the application. The table shows the percentage of people who rated the application a four or higher. All answers can be seen in appendix A.7

Table 5: Result of survey questions that were	rated higher	than four	on a scale i	from
one <u>to six</u>				1

Survey question	Percentage of people that rated 4 or higher
What was your general impression of the demo?	87.6 %
How well did you understand the instructions?	93.7 %
How sure are you that the task in the demo was performed correctly according to the instructions?	93.7 %
Could AR applications be of use in your company today or in the near future?	87.5 %

The additional feedback that was received in the survey brought up that some participants had difficulties with using the application and that some users saw potential in the technology.

5 Discussion

The following section contains discussion about the results with regards to methodology and theory.

5.1 User experiences of visual interfaces in AR

Most persons trying out the application expressed that they had a positive experience, and they seemed to be impressed with both the technology and the demo. First-time users of AR found it difficult to interact with the AR-interface. This could result from a lack of instructions on how to use AR and the Meta 2 glasses.

A significant number of the first-time users showed a tendency to completely disregard the more familiar 2D-objects (text) in order to pay focused attention to the less recognizable 3D-objects, leading to the information provided in the text not being noticed. As described in the theory chapter, recognition of objects happens partly by processing sensory input and placing it into information networks in the long-term memory. Lack of previous encounters with a digital object appearing in the physical world may cause problems to place it into the recollections from the perceptive memory and therefore be a contributing factor causing the user to exclusively focus on it. This phenomenon may arguably be worth to consider by developers at the time being but as the use of AR-headsets becomes more common it is likely to become of less importance.

In order to avoid this conflict between text and interactive 3D-objects in the maintenance application, it was decided to exclusively display information through one medium simultaneously. When the user is navigating the menus all information is text-based and during the actual instructions all text is removed and the information is transferred to the user by animations and colour highlighting of different 3D-objects.

5.2 User studies

Interviewing a Swedish Match employee was a part of the user study conducted during this project. In the interview, it was expressed that the instructions are not used to guide the employee but rather as a checklist of tasks to be done. Another part of the user study gave different results. When observing a different maintenance worker perform the task on the machine where the instructions were never used. To some extent, all types of instructions rely on "knowledge in the world" since the user get necessary information by interpreting elements in the environment rather than relying on recollection from memory. To follow maintenance instructions is therefore arguably more time-consuming than recollecting how to perform the task from previous training, knowledge, and experience. Since the tasks carried out during preventive maintenance was well known to the operators involved in this study. It would arguably be less efficient to follow instructions visualized in an AR-headset. The maintenance task discussed in this thesis was scheduled once every month. On a task done more infrequently, instructions might be more useful as the maintenance worker might not recall every step of the process. It could also be so that instructions are more suitable for someone new to task and therefore needs more guidance.

In the interview, it was discussed what to do when someone is uncertain on how to perform a task. The present method is to call a coordinator who calls someone to help. Using the AR-headset to display instructions could possibly eliminate the need for this method of getting help.

5.2.1 User testing

Another form of user study conducted in this project was user testing. The separate user testing for the demo and the application have similar results even though there was a variance of the distribution of age groups as well as the experience of AR. Overall the people testing the demo were positive to it. For both user tests, at least 82% were positive to the questions. For the second user test conducted at Swedish Match a larger part of the participates had experience of maintenance work. There was also a high percentage of participants that believed this could be used in their company today or in the near future. As the application was a way of evaluating if AR could be used for maintenance, this could indicate that it could be used to aid maintenance work.

The workshop was performed with a smaller group of participants which does not give a broad base to draw conclusions from. Therefore the result may not be entirely representative of the user group. The positive results from the surveys may also reflect the wow-factor first-time users experienced and the overall lack of incitement to express negative feedback. The premises of the workshop was arguably perceived as an occasion to try a new exciting technology rather than a pre-study for a technology that could change their work situation. Because of this, results of the survey should be used accordingly. The validity limits the usage of the drawn conclusions about the potential of AR technology rather than if the technology should be implemented in the organization's maintenance operations.

Another aspect is that the result might have been more positive if the participants of the user testing were more experienced with using augmented reality. The difficulties with using augmented reality, noticed during observations while participant's conducted the user test, often were with how to interact with the augmented object correctly. As there is a learning curve for every new thing, this included, people who had difficulties using the AR-application may feel differently if they had multiple attempts. This is supported by the result of the surveys were users who had tried augmented reality or virtual reality before rated the application higher. The result might also be more positive if the participants had the opportunity to calibrate the headset after their IDP. Lack of calibration might result in less sharp images and reduced functionality of the hand interactions. This problem is a result of a slow calibrations process for the Meta 2 headset but this problem and the problem with only having one attempt might have been reduced if the user testing was done in a different way, for example, if the user testing was conducted in a way so that the participants had time to calibrate the headset and do multiple attempts.

5.3 Potential sources of error

During the user testing, several sources of error were observed. At the first cycle of user testing of the demo, some of the participants did not get enough information about how to interact with the application. This was later remedied by letting the user read a brief guide printed on paper before putting on the headset. The difference in provided instructions may have had an unaccounted impact on the results. When a participant of the user tests did not manage to proceed through the test, the test leader often assisted by vocal instructions. When and how this extra assistance was offered is not documented and unaccounted for in the outcome.

During the interview, the person responsible for the project at Swedish Match was present during the entirety of the interview. This may have affected the interviewee's answers to questions regarding their work.

5.4 Challenges

Head-mounted AR is a relatively recent invention, and even though the AR-industry is growing rapidly, major improvements in the technology are needed before AR can reach its full potential. The Meta 2 headset at its 500 grams can be quite strenuous to wear. This combined with it being tethered to a computer and a power outlet makes it quite unpractical to use for longer periods. The headset also has problems with occlusion, where the digital objects are rarely occluded by physical objects when wearing the headset even though the digital object is perceived by the user as if it should be behind the physical object. For example, when using a user interface, the user's hand looks like it is behind the interface when the user interacts with it. An example of this can be seen in figure 19. This could indicate a problem with the internal sensors when scanning the environment, or the algorithm which calculates the distance between the headset and physical elements in the user's field of view.

Due to the novelty of AR-technology, and Meta 2 glasses, in particular, there are few commercial products made for AR-headsets and little information on how to design and develop AR-applications. This proved a challenge when designing the applications in the project. Especially since there was barely any documentation on how to use the Meta 2 SDK with Unity.

During the user testing, many participants wished that the application would give some feedback when a task was done correctly. Due to the limitations of the software of the Meta 2 glasses, and the time constraints, it was not possible to incorporate any sort of image recognition. This seems like a natural next step for the application when there is support for image recognition.

6 Conclusion

The aim of the thesis was to evaluate augmented reality as an aid for preventive maintenance. The evaluation was based on applied theory and the development of an AR maintenance application which could be evaluated as a part of a user study together with an interview and observations.

Results from an interview with a maintenance worker showed that the instructions were not used for instruction, but rather as a checklist as the instructions were not detailed enough, and the employee knew how to perform the tasks already. The observational study of the preventive maintenance showed that the instructions were not used at all by that employee. It is possible that instructions are more frequently used in maintenance tasks performed less often since the operator might not recall how to perform the tasks. When in the need of assistance, the employee called a coordinator that called a more experienced worker in to help. This points to a potential use for the AR-glasses as they can display instructions on how to complete the task without the need for extra help.

The evaluation of the AR maintenance application was done with a user test. It was found that maintenance operators were in general positive to adopt the technology, required that some technical issues are solved. AR is a new technology and many participants tried it for the first time, this might have affected the result as there is a certain wow-factor. The participants are not only trying it out as a potential aid in their work but as an exciting experience. Another factor was that interacting with AR may not be intuitive for first-time users and this led to some interaction problems that arguably resulted in more negative feedback of the application.

Regardless of the other results, there are some challenges that make an unavoidable impact. The AR-headset is heavy and is quite strenuous to wear and it is tethered to both a computer and a power outlet. This is something that might prevent the usability of the AR-headset. There is also a problem with occlusion and the lack of feedback when using the headset.

In conclusion, evaluating the different aspects shows that augmented reality as an aid in maintenance is not possible as of today. There is potential for the technology but augmented reality must be further developed to be useful. Using AR as an aid in a maintenance setting might be more useful for a more infrequent task or in a learning setting where the user is less experienced performing the task.

6. Conclusion

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A Appendix

A.1 Specifications for Meta 2

The following specifications of the Meta 2 is listed on the products website.

- 90-degree field of view
- $\bullet~2.5\mathrm{K}$ resolution, 60Hz refresh rate
- $\bullet\,$ Hand interaction and postional tracking sensors 720p front-facing RGB camera
- Weighs 500g
- four surround speakers
- three microphones

A.2 Specifications for computer to use with Meta 2

- **OS:** Windows 10 (64-bit)
- **Processor:** Intel® CoreTM i7-6700 Processor or AMD AMD FXTM 9590, equivalent or better
- Memory: 16 GB RAM DDR4 or more
- Graphic Card: NVIDIA GeForce GTX 970 or AMD Radeon R9
- Video Output:1x HDMI 1.4b port
- **USB:** 2x USB 3.0 ports
- **3D Engine:** Unity 5.6 or higher
- Hard Drive Space: 2 GB or more

A.3 Preventive maintenance instructions for bottomlabel machine

Översyn av bottenetikett

- Kontrollera dispenseringsenheten, Plocka loss och gör rent alla hjul, kullager och valsar.
- □ Kontrollera mothållsgummi, ställ in höjden vid onormalt slitage eller dåligt tryck.
- □ Kontrollera pendeln och bromsremmen.
- □ Rengör skrivarhuvud och kontrollera så att ytan ser oskadad ut.
- □ Kontrollera att bandet går rakt, lyssna efter missljud.
- □ Rengör och kontrollera alla valsar i foliekassetten.
- Rengör alla givare.
- □ Kontroll av eventuellt luftläckage.

A.4 Guide on how to interact and navigate in the AR-application.



Interaction with objects



Navigation



2018-03-14 12	2018-03-14 15.	2018-03-13 15.	2018-03-14 13.	2018-03-14 14.	2018-03-14 15.	2018-03-13 14.	2018-03-21 10.	2018-03-21 14.	2018-03-14 13.	2018-03-14 13.	2018-03-21 10.	2018-03-21 10.	2018-03-13 14.	2018-03-21 11.	2018-03-26 14.	2018-03-26 13.	2018-03-14 12.	2018-03-26 14.	2018-03-14 13.	2018-03-26 13.	2018-03-26 13.	Tidstämpel
34.52	51.17	10.38	01.08	45.14	21.43	12.47	34.32	12.34	29.19	24.40	18.06	13.41	29.11	11.34	08.55	37.49	46.31	18.07	23.23	48.23	58.31	
+00	50+	50+	50+	40-50	40-50	30-40	30 or younger	30 or younger	30 or younger	30 or younger	30 or younger	30 or younger	30 or younger	30 or younger	30 or younger	30 or younger	30 or younger	30 or younger	30 or younger	30 or younger	30 or younger	Age
NO	Yes	No	No	No	No	No	No	No	Yes	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Do you work with, or have experience of performing maintenance tasks?
Yes, Virtual reali	Yes, Both	No	No	No	No	Yes, Both	Yes, Virtual reali	Yes, Virtual reali	Yes, Virtual reali	Yes, Virtual reali	Yes, Virtual reali	Yes, Both	Yes, Both	Yes, Both	No	N	No	No	No	No	No	Have you tried Augmented and/or Virtual - Reality before?
INO	N	No	No	No	No	No	t No	t No	tNo	tNo	tNo	No	No	No	No	N	No	No	No	No	No	If Yes, was it in a work related situation
	n cn	4	N	0	4	ъ	5	4	6	IJ	G	cn.	G	IJ	6	cn.	IJ	4	0	0	w	What was your general impression of the demo
0	σ	ω	w	u	4	5	0	σı	6	6	0	C1	4	4	6	ω	5	4	σ	5	5	How well did you understand the instructions
																						How sure are you that the task in the demo was performed correctly according to the instructions?
4	4	4	2 1	4	3	4	9	6	5	5	2	5	6	4	6	0	9	6	с л	5	3	Could AR applications be of use in your company today or in the near future?
Saknar Ok nar man nar gjort ratt placering	Ergonomics is very important. Service techs are often in very special places and are in particular positions (because many or most machines are not designed for maintenance). They need to use there eyes and head not only for AR purposes.							Placeringen av modellen var inte optimal, annars var det jättebra				Oh god yes, AR applications can and will be a huge part of industry, maintenance och construction.		Super fun and interesting project		Svårt att se, jobbigt med mycket skrivna instruktioner samt en lite pillig demo. Men konceptet är väldigt bra och jag tror det skulle kunna vara användbart, dock behöver nog lite träning för att vänja sig vid denna typen av instruktioner.	hell yeah		Till skolutbildning skulle det här vara ett bra område att utforska			Additional feedback

A.5 Survey for the demo application

A. Appendix

A.6 Transcribed interview

M = Maintenance worker, I = Member of project group

I - Yes ehm då kan vi börja. Hur länge har du jobbat på Swedish Match? M - I 25 år.

I - Juste och hur länge har du jobbat med FU?

M - hmmm cirka 15 år

I - okej, är det vanligt att man har jobbat relativt länge då med FU eller finns de dem som har jobbat väldigt kort och så?

M - Ja de är de är olika en del kommer in som är utbildade mekaniker och dem och dem kan ju sätta igång i direkt. Jag har ju gått den långa vägen om man säger så. I - Ja, hur ser den ut är de?

M - Ja börja jobba här som operatör och köra maskinerna först då och sen så tyckte jag det var intressant och jag fick möjlighet att lära mig hur maskinerna funkade och sen så har jag fått massa utbildningar i annat teknik då i oklart o svarvning o fräsning o ja

I - Juste kommer det eftersom då eller går man någon utbildning i början innan man?

M - Det kommer eftersom

I - Det kommer eftersom

M - Ehhm och de är företaget som betalar utbildningarna då

I - Juste

M - Ah

I - Kanon. Ehm kan gå in lite mer specifikt då på det är alltså den här maskinen för bottenetiketter då som vi kommer att att arbeta med då

M - Mmh

 ${\rm I}$ - Ehm hur lång tid ungefär tar det att utföra ett FU på på den? Vi har nu har det blivit lite anteckningar där också men

(Slår till ljudinspelaren med papprena svårt att höra) M - Ja de. Vi har det uppdelat så vi på dagskift, jag som jobbar dagskift

I - Ja

M - Jag har hand om FU på matchpackarna dem som tillverkar portionssnusen och dem på kvällen dem har kvällsmekanikerna. Dem har omkringutrustningen så de här är ju kvällsmekanikerna som gör det här arbetet.

I - Okej

M - Eh men jag kan tänka mig att. Igår hade vi en kille här som gjorde ett ehm en ah han gjorde en totalrenoveringen av det här

I - Okej

M - och det tog en timme ungefär för honom att byta ut filter och allt möjligt för både, nä de var inte på den här maskinen utan det var på det var på stockettiket och kartongettiket var det ja. Men det här FU tar ungefär en halvtimma man byter valsar, drivvalsar ehh spänner upp ehm remmar och så där så ungefär en halvtimma timma en halvtimma till en timma ungefär

I - Juste

M - På en eh etikett då. Det är både bottenettiket och stämpelverk då

I - Ja

M - och drivning

I - Varierar de mycket på hur mycket som har slitis eller vad som behövs bytas ut och så från gång till gång?

M - Ehh mm ja asså de kan ju man kan ju råka på att byta hela den här mattan också om den har tagit för mycket stryk så då då får man räkna med ett par timmar om man ska byta mattan till exempel. Sen finns det ju andra dem här kedjedrivningen det tar väl en timma. Så de de är väldigt olika hur det slits men dem här är väldigt bra så det slits ju inte så mycket. Det som slits väldigt mycket är drivningen på det, drivvalsar. Det här gummit då det tar ju mycket stryk då för det blir ju väldigt mycket att den jobbar ju hela tiden

I - Ah

M - Ah

I - Märker man det på plats dem jag menar man behöver byta dem här större?

M - Man märker man märker ju när de börjar vandra. När datummärkningen börjar vandra. Då märker man det först och då kan man ju spänna åt den drivvalsen lite grann

I - Juste

M - Två tre gånger innan drivvalsen är så pass nedsliten så man måste byta ut den då ah

I - Okej

M - och det tar ungefär byta en sån tar en halvtimma ungefär

I - Juste

M - mm

I - Och det sker på kvällstid?

M - Eh vi vi ah det sker oftast på FU det kan ju också ske mitt i drift

I - Juste

M - Om det blir så att det börjar vandra i drift så om den har spänts upp för många gånger så får vi ah stänga ner den och byta valsen då. Det är en gummivals som sitter här mitt i som driver allting då

I - Vi var och kollade på den precis. Fick en genomgång så vet exakt vart du menar M - Ja

I - Yes. Ah ehm då har vi då skrivit ut dem. Här vi har vi då dem instruktionerna då för just den här maskinen. Tänkte att vi kan gå igenom dem lite en och en och så. Kan du beskriva lite kortfattat vad man gör då? Kan börja med den här första M - Eh kontrollera dispensering, plocka loss och gör rent ah de allting ska gå så lätt som möjligt och allting ska ju snurra

I - Ja M - Det får ju inte vara att man känner på en sån här metallrulle att de hugger i den eller nått. Då är det ett kullager som måste bytas ut då.

I - Juste

M - Ehm ah ja drivvalsen, motorerna de de dem är ehmm ehm dem byter vi väldigt sällan ehm vad heter dem våra motorer till, stegmotorer steg

I - Stepmotorer nä nä?

M - Nä en stegmotor den gör bara sin

I - Ah juste

M - Den har inga givare eller någonting den gör sin rotation hela tiden då

I - Juste

M - Så det byter vi väldigt sällan och då behöver vi elektriker till hjälp också I - Juste så det är ingenting som ni gör på

M - Nä det gör vi inte det gör vi inte på FU

I - Juste

M - Eh vill du ha tid ungefär hur lång tid det här tar att kolla upp det här?

I - Eh ja om du

M - Jaa. 20 minuter

I - 20 minuter

M - ah

I - Ja och skulle du säga att det är svårt eller nått som kan gå fel om man jämför med dem andra stegen?

M - Nä det kan va det kan va att någon kil har det har blivit något paj på en kil eller någonting att vi får ha en en nån typ av. Det står still i skallen på mig nu. Eh avdragare

I - Ah juste

M - att vi behöver någon avdragare att det är någonting som har dratt åt sig och sådär men det är väldigt sällan och då behöver man fila upp det och putsa till det. Det är väldigt sällan det händer.

I - Juste. Tack då kan vi gå vidare till nästa

M - Kontrollera pendeln och bromsremmen. Den gick sönder igår på linjen. Det tar ungefär tio minuter att byta en såndär. De tiden som tar är den tiden det tar att gå bort till förrådet och hämta *Skratt*

I - Okej

M - Sen är det bara att sätta på den liksom och köra igång igen så så det är den tiden

I - Det var den som satt på baksidan av de

M - Mmh ah precis det är den som bromsar upp hela den här stora rullen

I - Juste men det är en lätt grej då att byta?

M - Väldigt lätt och det är väldigt väldigt sällan att nån går sönder

I - Juste

M - Det händer någon gång per år

I - Okej, är det så att dem blir sämre och s
ämre och sen går dem sönder?

M - Nä igår gick den sönder i själv bottningen liksom

I - Ja

M - Den släppte bara. Den var väl gammal och sliten

I - Okej

M - Men den har hängt med i ett par år så sällan är de det sker

I - Grymt

M - Ehm ja det här rengöring av skrivarhuvud och sånt här det gör jag ju till och från. Det gör ju operatörerna också.

I - Juste

 ${\rm M}$ - Då får man ju stänga av eh strömmen och göra rent med ett speciellt medel då I - Ja

M - Ehum för det blir ju att det blir lite avlagringar och så lite klister och sånt där som sätter sig där och då får man göra lite rent med en speciell typ av sprit då.

I - Juste. Är det en gång om dan eller flera gånger per dag eller?

M - Eh en gång i veckan

I - En gång i veckan

M - Ah

I - Ja

M - Det ska göras oftare men det behövs inte göras oftare för så så känsligt är det inte men en gång i veckan tycker jag det är jättebra att göra det. Då får man en fin stämpel

I - Märker man ganska snabbt om det behövs göras?

M - Ja asså för de vi har väldigt känsliga kameror nu så det spottar ut direkt hör ej ordet

I - Juste

 ${\rm M}$ - om det är så att det blir en otydlig text då reagerar kameran direkt och då måste man släppa på skrivarhuvudet och göra rent

I - Juste

M - Det märker man direkt

I - Ja

M - Ja

I - Kanon

M - Rengöring, kontrollera alla valsar, foliekassetten de är tio minuters jobb.

 ${\rm I}$ - Juste och sen dem givarna där är det samma med något medel och tops?

M - Ah de är nån trasa med vanlig rödsprit där igenom dem här givarna då.

I - Juste

M - Ah så så och de är väldigt sällan faktiskt att det blir något kladdigt äckligt där. I - Juste

M - Luftläckage det har vi ingenting på dem här maskinerna. Inte vad jag kan höra i fabriken

I - Nä

M - Dem är tystaste maskinerna vi har här

I - Okej det är ju skönt. Yes. Om det skulle så att det bliri något som man missar eller att det blir något som är fel på sån kvälls FU är det först på dan dagen efter då när driften kommer igång som man märker det eller?

M - Ja det är det. Eh man märker ju väldigt tydligt då när dem har gjort ett kvälls FU men det brukar inte ta så lång tid dem ställer in det så gott dem kan i manuell körning

I - Juste

M - och sen märker ju jag ganska snabbt när jag börjar köra med doser att det behöver spännas lite här eller lite där för det är två drivenheter en där uppe och en där nere

I - Ja

M - och de fixar man till på högst fem minuter.

I - Okej, juste. Om det skulle vara nån sån eller det kanske inte händer men om det skulle vara nån större sån grej finns det sånt utrymme då asså som dagställare då att göra att ta lite tid eller jag venne hur det funkar med

M - Ja det måste det ja det är självklart. Vi måste ju få igång det så så snabbt som möjligt och det är väl inte så att någon står och rappar mig med någonting men

det är ju klart att man det här är ju om inte det här kommer igång så får vi ju inte ut någonting från linjen liksom. Så det här är ju självklart en viktig punkt. Det prioriterar man ju först.

I - Juste. När var det senast du såg dem här instruktionerna?

M - Ummh ah jag har aldrig sett den här förut.

I - Juste

M - Nä men det kan ju ha med att göra att jag har inte med här FUrna att göra. Om du frågar kvällsställarna kanske dem ser det här

I - Ja

M - för jag har ju papper på det jobbet jag måste göra

I - Juste

M - på själva packarna

I - Ja

M - Som jag måste gå igenom vid varje mitt, vid varje FU.

I - Juste

M - Det har jag med mig varje gång jag gör mitt FU det kanske dem har också dem här

I - Ah

M - så det får dem svara för

I - Juste så har vi lite kanske också inte är samma för dig men såg lite också här på slutet att man ska fylla i lite ah att man har vem som är ansvarig och såna grejer och sen vad är det här Tekla? (Svårt att höra vad som sägs papper stöter i ljudinspelaren)

 ${\rm M}$ - Ja då avrapporter man ju sitt FU och hur lång tid det har tagit och vilka reservdelar man har bytt ut då

I - Juste

M - Ja det gör man vid varje FU

I - Det är genom nått dataprogram då?

M - Ja

I - Juste

M - Mmh

I - Är det smidigt att använda?

M - Ja vi bytte väl för ett år sen nu, vad kan det vara? Ja men det funkar bra

I - Det funkar bra

M - Ah. Vi har bytt några gånger under årens gång

I - Ah

M - Men nu har vi börjat komma igång

I - Juste. Vet du vad som det används till den dem rapporterna?

M - Det är en uppföljning såklart asså för att se om det är någon speciell maskin som krånglar ah som utmärker sig

I - Ah juste

M - Så kan det ju vara något helt annat än att jag går och byter en reservdel hela tiden

I - Ja

M - Så då måste så då ska systemet larma för det eller då ska den märka av att liksom att den här skiljer sig jättemycket från alla andra likadana maskiner

I - Juste

M - Det är därför vi har sånt system

I - Ah. Är det dataprogrammet själv då som gör det eller är det nån som

M - Vi har ju anställda som, Johan och Jörgen, som jobbar på heltid med det här

I - Juste okej grymt. Då ska vi se här om jag har något mer. Eh juste om det är nått om du nån gång känner att nu kanske du har stenkoll på det mesta men låt säga kanske i början när du börja med FU om det är något som du känner är ah det här har jag inte riktigt koll på.

M - Hm

I - Hur vad går man hur går man tillväga då?

M - Ehm men nä då har vi ett system att vi har en samordnare och är det nånting då som jag inte har gjort tidigare och jag inte känner till

I - Ja

M - Så kontaktar jag honom och då ringer han vidare till folk som har jobbat med saker och ting tidigare. Så kommer dem ut och så får man lära sig hur det fungerar I - Juste

M - Ja

I - Händer det ofta att de är folk som

M - Ja det händer ju titt som tätt det gör det att man behöver hjälp med något man inte känner kan vara någon ny sak som suttis upp på maskinen eller de kan va vad som helst eller något gammalt som man inte vet riktigt hur det ska vara. Men då får man ju hjälp direkt och de har våra chefer varit väldigt tydliga med att att man ska inte stå typ en halv dag och försöka

I - Juste

M - plocka ihop det eller utan de får man får lära sig och jag får hjälp direkt det får jag ju det finns alltid nån som

I - Juste

 ${\rm M}$ - som kan det. Om vi inte kan det så tar vi ofta hit folk som lär upp oss när vi köpt in helst nya maskiner sånt där så

I - Ah

M - Ah

I - Juste. Ehm jag vet att Swedish Match tidigare har haft ett projekt där man har gjort ritat upp hela fabriken med såna virtual reality

M - Ah dem har gjort det en gång i alla fall

I - Känner du till den?

M - Nä jag tyvärr så hann jag aldrig med att och testa det men mina arbetskamrater som gjorde det tyckte det var väldigt fräckt. Då det projektet gick har gått väldigt bra tycker jag

I - Ah

M - Mmh

I - Är det liksom en ganska positivt inställning som

M - Alla som jag har pratat med som gjorde det tyckte det var väldigt bra och det blev väldigt bra också så

I - Juste. Tror du att det skulle finnas ett intresse för att kanske ha en workshop eller liknande med och få prova lite såna AR då är det är alltså att du ser både verklighet M och digitala grejer på din skärm?

M - Det tror jag det är jättestort intresse utav

I - Juste

M - För det som dem tog in på en linje som har gjorts om ganska ordentligt nu då 540 ehm dem som var med i det projektet då och hade dem här kamerorna på sig dem tyckte att det var väldigt väldigt bra hjälpmedel

I - Ah juste. Kanon. Ehm har du någon kommentar generellt eller nått som, nån fråga som missats att ställa eller sådär angående eller om du ah. Angående vad som helst egentligen

M - Eh ah svårt att svara på

I - Ibland så händer det ju så att man sitter och kommer på åh juste det här ja

M - Det var väl lite fel att jag fick just den här då eftersom jobbar ju självklart med det här hela dagarna men det är ju inte jag som utför själva underhållet på den I - Juste

M - utan jag gör ju underhållet på portionssnus-maskinen då

I - Den som stod brevid där

M - Ah den som producerar, ah juste, den som producerar snuset då

I - Ah

M - Det här är ju bara för etikettering då och datummärkning då

I - Ja

M - Mmh

I - Men jag tycker att vi har fått med mycket bra åsikter och kommentarer. Jag har lärt mig jättemycket i alla fall

M - Oj då okej

I - Men det var det vi hade

M - Inget mer?

I - Får tacka så mycket

M - Tack själva

I - Kanske vi återkommer om vi antingen har följdfrågor eller om workshop

M - Nä men alltså jag har bara hört jättebra saker om det. Dem tyckte att dem jag prata med, jag har pratat med dem flesta som var med där inne och dem tyckte det var toppen alltså. Så det var synd att jag missade det där.

I - Ah

M - Tyvärr. Det var en bra grej faktiskt. Det var något helt nytt för Swedish Match det var första gången

I - Ah juste men kanon då är vi klara

M - Ja tack

I - Tack

A. Appe	endix	
A.7	Survey	fc

A.7 Survey for the application

	4	0		4	No	Yes, Both	Yes	1 50+	2018-05-07 14.54.3
	2	5		CP.	No	Yes, Augmented reality	Yes	8 50+	2018-05-07 16.23.4
	5	5	5.	(J)	No	No	Yes	50+	2018-05-07 14.39.1
Bilden flyttade fokus mellan "enter" slag Maskinen fick inte plats i bilden. svårt att bedöma avstånd.	G	о	-	u	No	Yes, Virtual reality	Yes	8 40-50	2018-05-07 15.05.5
Nice to see the technic but I think it is too early for us. Good to know what we can do in the future though.	N	σı σı	-	4	Yes	Yes, Both	Yes	1 40-50	2018-05-07 14.43.0
	s	6	5.	(J)	Yes	Yes, Both	Yes	5 40-50	2018-05-07 13.38.4
	4	5	-	4	Yes	Yes, Both	Yes	3 40-50	2018-05-07 13.22.4
	4	4	-	4	No	No	Yes	40-50	2018-05-07 13.13.5
Det var lite svårt att hantera 3C med händerna, dvs vilket avstånd det man skulle greppa var på.	GI	0	-	4	Yes	Yes, Both	No	6 40-50	2018-05-07 14.59.2
Mycket barnsjukdomar. Behöver fungera avsevärt smidigare när det gäller de grundläggande funktionerna.	сл	ω ω	-	1	No	No	No	1 40-50	2018-05-07 14.47.5
	5	01 01	-	4	No	No	No	5 40-50	2018-05-07 14.22.0
	5	4		5	Yes	No	No	3 40-50	2018-05-07 13.33.0
	5	5	-	4	No	Yes, Virtual reality	Yes	5 30-40	2018-05-07 15.57.4
	5	5	5	CP (No	Yes, Virtual reality	Yes	5 30-40	2018-05-07 15.28.5
Glasögonen kändes lite klumpiga. Viktigt att de inte känns i vägen eller begränsar når man arbetar vid/i en maskir	IJ	σı σı		4	No	No	Yes	6 30-40	2018-05-07 14.12.1
Tekniken behöver ufvecklas men jag ser definitivt nytta av tekniken när den mognat. T-sav behöver glasögonen bli lättare och mindre. Även kunnas läasa av mer noggrant. Vissa trotelser behöver man göra om flera gånger på grund av att systemet inte känner av nörelsen.	ω	ол	•	A	Yes	Yes, Virtual reality	2	3 30 or younger	2018-05-07 14.08.0
Additional feedback	Could AR applications be of use in your company today or in the near future?	How sure are you that the task in the application was performed correctly according to the instructions?	How well did you understand the instructions?	What was your general impression of the application?	If Yes, was it in a work related situation	Have you tried Augmented and/or Virtual -Reality before?	Do you work with, or have experience of performing maintenance tasks?	Age	Tidstämpel