SMART GLASSES FOR MAINTENANCE

Augmented reality

Bachelor thesis in Augmented reality in maintenance

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Thesis work Smart Glasses company Plasman

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Abstract

Smart glasses are an augmented reality (AR) solution, which can provide necessary information to the maintenance works. This work method utilizes and enhances the productivity withing the maintenance sector though an AR device. Workers in this kind of labor performs hand-busy tasks and the smart glasses that is provided, suggested and researched well about will complement the workers working conditions. This project is carried out by the school Chalmers in Gothenburg and within the company Plasman.

The maintenance team in the producing factory Plasman wants to implement a suggestion in Augmented reality device (Smart glasses) into their department.

Overall, AR devices have the potential to revolutionize how companies operate, engage with customers, train employees, and innovate in various industries, leading to improved efficiency, productivity, and customer satisfaction.

Research question, what type of information is wanted (output), how will the information be interpreted. Collecting valuable data from the workers and their input of what type of demands they want and need.

Plasman's headquarters are in Windsor, Canada and Gothenburg, Sweden, with 5500 employees participating in the development, manufacturing, engineering, and sales. Currently, the company operates in Sweden, Belgium, Norway, Portugal, Mexico, USA, China, Japan, and Czech Republic. The products capabilities include single/source solutions for injection molding, tooling, chroming, paint applications and assembly. From concept state to completion, Plasman provides innovative and powerful solutions that ensure the right delivery with the right part to the customer when they need it, just in time. **Literature review**: Work related to smart glasses in industries like such as Plasman (industry 4.0).

The student has performed three years of studies in mechanical engineering, which provides the project well and fits expertise needed. This thesis work is performed alone by one student and thankfully also by the support of the supervisors.

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Abbreviations

AR	Augmented reality
VR	Virtual reality
HMD	Head mounted display
AI	Artificial intelligence
IOT	Internet of things
KPI	Key performance indicators

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1 Introduction

Augmented reality facilitates a wider understanding of the user's perception, which makes it effective and popular in industry. The perception in this industry is very important when regarding problem solving and trouble shooting. Augmented reality assists the operator in performing more efficiently, faster, and better approaches. User cases situations are more complex, and the knowledge is lacking when it comes to solving situations along with the wide experience in the maintenance sector.

Figure 1 Augmented reality: Reality experience (Barroso, M. 2021)

Augmented reality (AR) is a technology that enhances the user's perception of reality by overlaying digital content onto the real world, usually through a mobile device or smart glasses. AR allows users to interact with virtual objects in real-time, while still being aware of their physical surroundings.

AR technology works by using a camera or sensor to detect real-world objects or environments and then using computer algorithms to superimpose digital content onto them. This can be used for a variety of applications, such as gaming, education, marketing, and training.

One of the primary benefits of AR is its ability to provide users with a more immersive and engaging experience, allowing them to interact with virtual objects in a natural and intuitive way. AR can also be used to enhance learning and training experiences, by providing interactive and visual aids to help users better understand complex concepts and procedures.

In addition to its consumer applications, AR is also being used in industries such as manufacturing, healthcare, and architecture to improve efficiency and accuracy. For example, AR can be used to guide technicians through complex assembly processes, to visualize and plan surgeries, or to visualize and simulate building designs. Overall, augmented reality is a powerful technology with a wide range of potential applications, which is still evolving and improving as new advancements are made in computer vision, machine learning, and hardware design.

The maintenance sector observes a higher demand to get answers very immediately while doing tasks in an increasingly digital world, where access to information or the widest range of services is instantly ensured through a device with an internet connection. Routine tasks. In a work setting, we encounter the requirement for quicker responses to the problems we are facing where there is a natural tendency to equip one's face towards the situation.

A new reality known as Industry 4.0 has emerged as a result of the rapid advancement of technology that we have been watching during the years. This new revolutionary industry aspires for a set of technologies, including Artificial Intelligence (AI), Machine Learning, Internet of Things (IOT), and Augmented Reality (AR) devices, and processes, to be able to work in an integrated manner throughout the various

phases of the manufacturing process and the various levels of the value chain, allowing for self-sufficient production, integrated operations, decentralize decisions and minimal human intervention. All aspects mentioned are working together in an interplay and connection with knowledge through all are extremely difficult to achieve.

1.1 Background

Today, in the maintenance sector in industry, maintenance technicians take care of breakdowns and tasks that occurs frequently and prevents them from occurring again and prevent issues from occurring at all. (Kim, J 2020). In most cases in industry, these workers move around in a factory by bike or other transport vehicle and fix problems and incidents. This industry has a robust environment that can be small tractors to large lifts, even to machines that presses bodies together due to that the majority in the car industry makes their owns chassis, (Kim, J 2020). The maintenance staff in this industry is perceived to be quite extensive due to that the problems can differ greatly and understanding everything to the best is aspired but rarely achieved. To solve these, smart glasses are suggested and implemented as a helpful solution in the factory. Plasman is a Lean implemented producing company which aspect as just-in-time, conveyor belts and lead times are critical aspects to consider within the efficiency and productivity. Plasman started this project to be done hence the reason that it has a great possibility to increase key performance indicators (KPI); faster maintenance work & “smarter working” leads to more efficient runtime in the producing factory.

1.2 Purpose

The aim of this Bachelor thesis is to suggest a tool for the maintenance worker in the factory located in Gothenburg, Sweden. The tool will help the worker solve the difficult problems and issues in maintenance. To achieve the aim, this project investigates what type of smart glasses through augmented reality and communication of the tool will be. Investigation of such knowledge will be discussed to get a feeling of what type of feedback will be the most suitable for the user of the glasses.

1.3 Goal

The goal of this thesis project will be to analyze the market along with the different types of augmented reality devices the market has. Later, providing the most fitted hardware and software with a work description of the tool to the maintenance staff. Hopefully to implement this method even more through the company e.g., training and sort of virtual reality.

1.4 Boundaries (Limitations)

The project will be conducted approximately into 15-20 weeks and multiple purposes will be asked from this project, the company wants a lot of properties into this glasses that will be provided but due to the limitations only the most important factors will be discussed and moved further to investigate, hardware and software of the glasses.

1.5 Delimitations

Limitations due to the many aspects that are asked from this project are due to the not implemented factor in the company, it’s a first use type of category in the company and the maintenance staff will be the first one to get implementation of such tool into the company. Factors within the aspect of economy will not be takin into account due to the first-time application in the factory and it is only seen as a victory if package is implemented.

2.0 Theory

2.1 Augmented reality

To get a better understanding of how Augmented reality devices work a deeper understanding is needed on how the system within the software and its processes is defined from definition to definition. The picture below shows the steps in AR devices from sequences and functions.

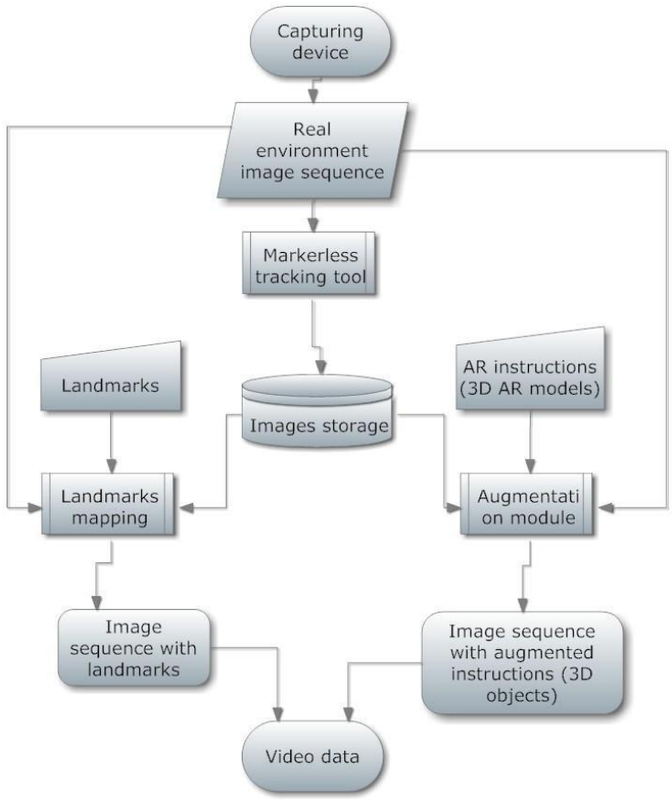

Figure 2, *Augmented Reality - An Improvement for Computer Integrated Manufacturing - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/AR-process-flow-diagram_fig1_272605743 [accessed 7 Jun, 2023]*

In the flow of events the first step follows from the diagram above, “capturing device” is the device that displays the event or action e.g., the smart glasses camera. From this aspect everything is key, key to display the real environment into sequences from images to voice communication to even store images and even stories of events that have occurred. The diagram shows that separate aspects come in hand as a parallel function such as landmarks, instruction within the module e.g., modules that pops up to give information to the user, information can be text windows in form direction or just simple information about the event. When an event or action is needed, the following steps are required to solve the situation. For example, when you change the fluid liquid on the window wipers cleaning you have different steps that are required to be done to perform the task. Task one can be to pop up the hood from the lever you need to pull to later to lift the hood and step 2 fill in the liquid and so on step 3 etc. and so on. The video data shows the final step and that is the aspect of the view and interception of the user of the glasses.

Beside the figure (figure 2) can AR be summarized in 5 steps (Doemer, R. 2022):

1. Video capturing
2. Tracking
3. Registration
4. Visualization
5. Output

Augmented reality in this perspective has a very interesting application and is experienced as very vast (Bondrea I, 2011), It has been confirmed that AR technologies enhance industrial development in a technology aspect. Production costs and times are lowered by this evolution and increased quality within

the processes when relating to marks that can be recognized by the technology, it has been shown and proved in the facilities it has been implemented in (Bondrea I, 2011). One downfall about this technology that it includes industries that is changing all the time due to the factor that these factories always expand and improves then therefore the reality becomes due to the update so when the Augmented reality is implemented it is important that it gets updated frequently all the time within the industry so well within the processes (Malnati, P. (2022).

2.2 AR applications

Examples of augmented reality applications. (Appstores, marketplaces 2023)

2.2.1 Gaming:

AR games like Pokémon Go, Ingress, and Harry Potter: Wizards Unite allow users to explore their real-world surroundings and catch virtual creatures, complete quests, and interact with other players.

2.2.2 Education:

AR applications can be used in education to create interactive learning experiences. For example, the Anatomy 4D app allows students to explore the human body in 3D.

2.2.3 Retail:

AR applications can help customers visualize products before they make a purchase. For example, IKEA's Place app allows users to see what furniture would look like in their home before they buy it. Navigation: AR applications like Google Maps can overlay directions and information onto the real world to help users find their way around.

2.2.4 Advertising:

AR applications can be used to create immersive and engaging advertising experiences. For example, the Pepsi Max "Unbelievable Bus Shelter" used AR to create a surreal experience for people waiting for a bus.

2.2.5 Art and entertainment:

AR applications can be used to create interactive art installations and performances. For example, allows artists to add augmented reality content to their artworks.

2.2.6 Healthcare:

AR applications can be used in healthcare to create simulations and training programs for medical professionals. For example, help healthcare professionals locate veins for blood draws and IV placement.

These are just a few examples of the many different types of augmented reality applications that exist. As the technology continues to evolve, we can expect to see even more innovative uses of AR in the future.

2.3 Why AR? Reduce errors & accidents.

A study (Akhmetov, T. 2022) shows that around 340 million people worldwide are in a form of accident within different work environments, in today’s industry 4.0 the manufacturing and machines regarding CNC and different labor are getting more and more complex along with the emerge of industry 4.0 and together with the complexity and more automation more things are in play within the processes, therefore moving machines and moving bodies are in play when tasks are performed. More harm can be done to the human body and more severe incidents are occurring because of that (Akhmetov, T. 2022).

There are number of studies that have been made to clarify and show that AR assists within industry 4.0 (Jisoo, H. 2011). When working in the automated industry today many aspects correspond to Lean, meaning that tasks are performed in a strategic and planned way with a planned beginning and an end, flow. If a worker is walking up to perform the task that is assigned in the process and if a single task before that has not been performed, it can lead to accident or in worst case harm to the human body or even the system therefore the augmented reality assists and confirms by artificial intelligence that it is safe to perform the task or by any other chance warns the system that somethings errors/lacks (Akhmetov, T. 2022).

Another implementation of reducing errors beside AR was made back in the 1960s by Shigeo Shingo who was an engineer at Toyota, the idea that was developed was Poka-yoke. It was a process that reduced errors and failure. The industry today (industry 4.0) is all about preparations and making right in the first step (Al Ayyubi, M. C. 2020), to have the correct article, hardware, raw material in the right place at the right time is a huge key to efficiency. It affects the worker in a way of mental stress and harmony in work. (Al Ayyubi, M. C. 2020).

Taking the right thing in the right time, when a worker is tasked to take an item or a part the person working in the station with poka-yoke/AR implemented must acknowledge to the system that he or she has taken the right item to be put in use for the process if not the whole system becomes in a state of pause until the worker has acknowledged the sequence of the process. Augmented reality works in a similar way when regarding the confirmation of the acknowledge part but in a more advance way but still in the way of mistake proofing and to ensure that the right aspects and criteria are being met to ensure and infill a safe and efficient work environment (Mura, M. D. 2016).

“Smart working” is a common phrase that are being used in today’s novelty of industries, which is characterized by real-time data openness regarding resources, operations, and key performance indicators (KPIs) (such as the quality of generated goods), has altered how people and machines collaborate with one another. By evaluating vast amounts of data and clever algorithms, technology & data collections tend to help humans make better decisions about things like whether to adjust machine settings or the order in which to carry out production orders. Moreover, technology and people might collaborate to carry out specific production or assembly procedures e.g., by using augmented reality. Due to the numerous interconnected interdependencies, working smarter makes factory work for humans more enjoyable but also more complex due to the vast rate of evolution within the industries. (A, Rüedy. 2022)

Industry 4.0 and smart factories are closely related concepts. Smart factories are manufacturing facilities that incorporate Industry 4.0 technologies, such as the Internet of Things (IoT), robotics, artificial intelligence, and data analytics, to create a more efficient and connected production process. In a smart factory, machines and devices are interconnected and communicate with each other and with humans in real-time, allowing for more automated decision-making processes. This results in a production process that is optimized for efficiency, reduces waste and downtime, and improves overall productivity and quality. (A, Rüedy. 2022).

One of the key benefits of a smart factory which includes the use of AR is the use of data analytics and machine learning, which allows for more accurate predictions of maintenance needs, leading to fewer equipment failures and longer lifespans for machines. The use of predictive analytics also helps to identify potential bottlenecks and inefficiencies in the production process, allowing for continuous improvement and optimization. (Kumar, A. 2020)

Smart factories and Industry 4.0 technologies are transforming the manufacturing and industrial sectors, creating new opportunities for innovation and growth. However, the adoption of these technologies also requires significant investments in infrastructure, equipment, and training. Companies that successfully embrace smart factories and Industry 4.0 technologies are likely to be more competitive and successful in the long run. (Kumar, A. 2020)

2.4 State of the art with an advance

Augmented reality (AR) is an area that are in huge advance since the 1990s, the area of knowledge is continuously increasing in numbers since the beginning. (Felix, R 2022)

Augmented Reality is a technology that overlays digital information, images, or 3D models onto the real world. AR technology uses a camera, sensors, and software to recognize and track real-world objects and then display digital content on top of them. (Peng, C-C. 2022)

Virtual reality (VR) can be mixed up with augmented reality (AR), the differences and comparisons between the two follow as; The benefit between Augmented reality against Virtual reality (VR) is that the user can still integrate with the real environment while in VR the user is locked into a dimension/reality. VR gives a deeper experience hence the aspect of getting locked in. (Steiger, L. (2014)

Information and communication are the major aspects correlating to productivity & efficiency within industries (industry 4.0), (A, Rüedy. 2022). Data is key, hence in today's industry 4.0 are more and more systems and processes automated.

Augmented reality as an application has a wide range of application in different industries beside industrialization & production. Education, computer games, medicine, tourism and even healthcare are sectors that the reality has been applied to (Arena F, 2022). In order to have a successful working augmented reality device several criteria are acquired to be achieved. Therefore, regarding building, designing and manufacture the hardware and software of AR devices development need to have an extensive range of engineers, doctors, technicians, managers. (Peng, C-C. 2022)

2.5 Development areas of AR device execution

Many aspects and areas are to consider related to the augmented reality, simply buying a device and implementing it sounds good but is a haste decision, worst case scenario is that something is not working fully correct and is not optimized to its fully in its implementation can lead to harm and danger to the user hence safety reasons (Peddie, J. 2017). A fully and deep understanding in following aspects are needed to achieve a successfully performance and developed a good working AR-device. (Peddie, J. 2017)

Successfully AR device: Defines within the interaction between individuals and computers. The computer, which manages the virtual portion of the user's environment, and the human users are exchanging information. This is referred to as human-computer interaction (HCI) in technical terms. HCI involves with the development, assessment, and use of interactive computer-based systems as well as the related phenomena. (Doermer, R. 2022)

Audio technology
Camera technology
Display technology
Ergonomics and user interfaces
Geometric and trigonometric mathematics
Image processing techniques and processes
Manufacturing engineering
Optics and optometry
Physiology
Positional, tracking, and location methodology
Power management
Processors (CPUs. GPUs, DSPs)
Software engineering

Table 1, Development areas.

There are many points and blanks that need to be researched and analyzed, therefore when companies and users tend to use AR-devices along with the software's it needs to have a trustworthy costumer value, being able to rely on the product (Peddie, J. 2017).

2.6 Maintenance today with AR

Maintenance in Industry 4.0, combined with augmented reality (AR), offers significant advantages in terms of efficiency, accuracy, and cost-effectiveness. AR technology can provide real-time information, virtual overlays, and step-by-step guidance to maintenance technicians, enhancing their capabilities and reducing the time required for troubleshooting and repairs.

Maintenance is a critical aspect of Industry 4.0, as the integration of advanced technologies in manufacturing processes can lead to more complex and sophisticated machinery, which requires specialized and continuous maintenance. In Industry 4.0, maintenance activities are often supported by digital technologies, such as predictive maintenance, which uses sensors and analytics to monitor equipment and identify potential issues before they occur. Predictive maintenance can reduce downtime, increase equipment lifespan, and optimize maintenance schedules, which ultimately leads to cost savings and improved productivity. AR is a technology which is also being used as a predictive tool, hence the ability to inform the systems and users of possible capabilities that may occur due to the data read. For

example, if a certain type of value has a low respectively high limit it can inform if the value is above or under. (Kumar, A. 2020)

Important aspects of maintenance in Industry 4.0 are the use of augmented reality (AR) and virtual reality (VR) technologies, which can enhance training and support maintenance activities. AR can provide technicians with real-time information and guidance, such as step-by-step instructions, technical manuals, and 3D models of equipment, while VR can simulate complex maintenance scenarios, allowing technicians to practice and develop their skills in a safe and controlled environment. (Kumar, A. 2020)

Overall, maintenance in Industry 4.0 requires a shift from reactive to proactive maintenance practices, leveraging digital technologies to monitor, analyze, and optimize maintenance activities, and supporting technicians with advanced tools and training methods. (A, Rüedy. 2022)

By leveraging augmented reality within Industry 4.0, maintenance processes become more efficient, accurate, and streamlined. AR enhances technician capabilities, reduces downtime, and improves overall equipment reliability. It also contributes to the creation of a knowledge-sharing ecosystem, allowing organizations to capture and transfer expertise more effectively. (A, Rüedy. 2022)

There are several types of use in maintenance today through AR,

Remote Assistance: Using virtual overlays and annotations, AR enables distant specialists to give on-site personnel real-time direction. Technicians can use smartphone applications or wear AR-enabled equipment like smart glasses to obtain instructions, schematics, and pertinent data right in their field of vision. For the purpose of guiding technicians through difficult maintenance chores, remote specialists can view the equipment, highlight individual components, and provide directions.

Augmented Visualization: AR overlays can provide technicians with a visual representation of hidden components, wiring diagrams, or maintenance procedures. This enables them to see virtual layers on physical equipment, making it easier to identify issues, follow repair procedures, and assemble or disassemble complex machinery.

2.7 The trend of the AR market

The reality of AR needs two things, the first factor is one device with a camera and the second part is an AR software, from tablets, phones to smart glasses.

Augmented reality as itself describes different goals and research explains all aspects correlating to it. From databases from 1992 to 2019 indicators has been used to be evaluated (Gupta, B. M 2020). The research has shown that augmented reality has a 54% growth when it relates to its sector.
Comparison between different glasses that are currently on the market is searched to get a feeling on what is the most common diverse what types of needs different users have.

Studies have shown and are providing a better and deeper understanding of how consumers use augmented reality and how it is interpreted. (Smink, A. R. 2022). The studies were defined from 5 different aspects, 1) Prevalence, 2) user characteristics, 3) gratification, 4) what type of preference of AR and lastly 5th, difference types of software's of apps on AR. The people attending to the survey were people from 18-65 years old.

	Shopping Apps ($N = 138$)	Entertainment Apps ($N = 357$)	Information Apps ($N = 157$)	Social Media Apps ($N = 325$)
1 time	21.7%	7.8%	11.5%	7.7%
2 to 3 times	39.9%	21.1%	33.1%	16.0%
4 to 5 times	23.2%	15.6%	21.0%	16.6%
6 to 10 times	1.1%	12.2%	14.6%	12.6%
More than 10 times	5.1%	43.3%	19.7%	47.1%

Note. In-app usage of the augmented reality function is based on the first-mentioned app within the app category.

Table 2. frequency use of AR function. Source: Augray industry virtual try on 2022

Augmented reality is a better fit in engineering cases between VR versus AR, especially when it relates to maintenance (Peng, C-C., 2022). Augmented reality can easily be used from a mobile phone hence the main future with Augmented reality is to project and display virtual information from Head-mounted device (HMD) while performing work. Augmented reality has a good future withing the maintenance sector (Peng, C-C., 2022). Augmented reality is not only for training and direction but also for provides a

reduction in errors and increasing efficiency during repair tasks and maintenance. The reality that AR provides reduces errors. Augmented reality is a big key and aspect when it comes to industrial factories such as Plasman hence, sectors such as equipment and machines repairs are the ones with most accidents that are occurring more frequently (Peng, C.-C. 2022) because of machinal failure and humans' errors. AR is therefore very high-valued when relating to maintenance.

A lot of work is still demanded by humans due to the industry 4.0 due to it brings more and more automation into the factories nowadays. Most of the producing factories today has lean implemented, factories are basically running 24hours of a day and machines are not pausing or standing still, the most heavily and robust systems/machines are considered often as bottlenecks, the bottlenecks are considered to have a big impact corresponding to efficiency in factories.

Augmented reality is used as a tool to reduce or enhance a few aspects that have a major aspect in the producing making industries such as, time, maintenances, inspections, control, adequate information, and better knowledge. (Peng, C.-C.)

Augmented reality is a technology that has existed for a while and is running rival towards industries hence the aspect of providing experiences within multisensory that combines and merges the realities that exist (Oliveria, F 2022). Trend is a word that is fitting in this type of market and is used worldwide but also has been seemed as evolutionary (Peng, C.-C.). One reason is the pandemic situation that occurred with COVID-19 that gave the world a total change when it comes to work condition and working methods, people are not always where they need to be at the time needed. The reality that is used interpreted and concludes the aspects of images, texts or animation and in some cases also as a communication device.

The market for augmented reality has been developed for a while since its beginning and is constantly upgrading and evolving into newer features and newer developments. This timeline illustrated in the figure below shows how augmented reality has evolved during its lifetime.

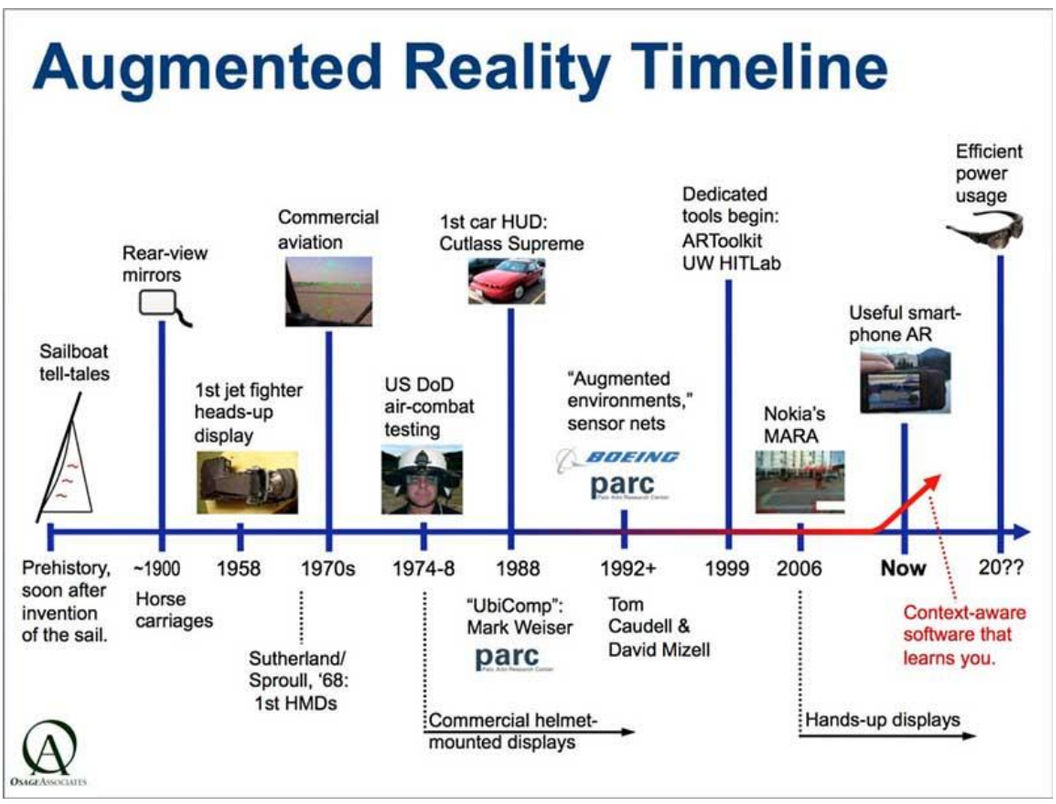

Figure 3, source; crystalslink 2019

The market is not new regarding its novelty and has been familiar for a while now but uses of glasses or to say head mounted display (HMD) are in this century. This century reflects almost everywhere when relating to augmented reality devices, devices which work as a headset or as a helmet but also as a camera as well. Today the aspects are in direct, live, or indirect view of an environment that can be described in real world interpretation both from within the lens and from the outside world.

2.7 Why AR to Plasman

The overall main reason behind augmented reality in this project is focused on a primary issue regarding maintenance; the maintenance sector is described as hand-busy tasks, whenever approaching a problem or using tools both hands are not often available (Zhu, D 2015), therefore an understanding on following topics will be discussed to give insight in which user-cases and sectors AR is involved with.

Augmented reality as a communication tool will be discussed along with research in the theory frame regarding development questions across implementation and software. The market along with applications will give insight to provide better understanding in the reality, how augmented reality was in the beginning to what it has become today, its novelty and evolution.

3.0 Method

The design of the method where designed to understand how to reach the goal, consists of approach in literature/theory studies behind the market & technology of augmented reality, understanding in industry 4.0 lean implemented producing factories, devices and industries regarding connected to Plasman, brainstorming with personnel, understanding of the maintenance teams need & wishes for the products needs within the team (requirement specification), feel and experience different products (resellers), analyze Plasman's maintenance teams work habits/routines & documentation, costumer experiences and reviews with AR technology & products.

The approach in the method was a mixed approach with the means to answer the research questions regarding the goal in chapter 1.

The conducted approach in methods follows as:

- Explore the market for smart glasses devices and software supporting the glasses.
- Develop a working methodology on how to use smart glasses for maintenance jobs.
- Conduct trials at the production facility to test and evaluate the method, hardware, and software.
- Get feedback from users with advantages and disadvantages of smart glasses.

Data collection in theory methods was inspired from Chalmers library & Scopus and product information and experiences was taken from resellers with visits and reviews. The keywords that were being highlighted in the search engines directed to the sources in forms of academic journals, books, reviews and conferences.
Key words in searches: "*Maintenance & augmented reality", "industry 4.0", "Augmented reality & industry 4.0", "Augmented reality devices", "Smart maintenance", "Smart glasses", "Smart factory", "Smart glasses & maintenance", "Smart glasses & industry 4.0"* and *"Smart glasses & smart maintenance".*

Multiple search results were found from the search results and a proper view and understanding of the content was necessary before the multiple sources was put in use in this thesis.

When the project was carried out the realization was that this is a first-time implementation of technology into the company, the implementation of Smart Glasses to the maintenance personnel. Therefore, a schedule was drawn up to form a time-plan. The time-plan is preliminary, many aspects and matters of issue may change during the processes.

4.0 Results

4.1 Requirement definition of demands from the Glasses

The most important part and the first step in the project was to define what is asked from this type of smart glasses against the personnel. The student together with the maintenance staff brainstormed all types of ideas and discussed what aspects/features are mandatory to be compulsory and what is classed as a plus if the function is available. The plus is defined as; if the function is not needed but if its available it can benefit but it is not included of the development goal from the glasses. If we take a car for example, the main function for the car is to be driving forward, braking, steering etc. and aspects such as stereo music are not a main function that is really needed but is experienced as a satisfying factor by the user. Same theory aspects will be for the glasses in this case. Hence the development of glasses, what is needed? What is wanted? What is mandatory? What is the most suitable?

4.2 Requirement specification table

1.1	Communication between user and expert.
1.2	Doing the initiative to the call.
1.3	No special software is demanded, extern source -> connected to call
2.0	Optical feedback, preferable when noisy environment.
2.1	Voice command, screenshot the situation from the glasses.
2.2	Opportunity to record the user's visual input from the glasses, do a collection of ´ films/data to a database.
3.	Battery life < 2h results in bad. External battery solution?
4.	Ergonomic
4.1	Extern hand-using tools/sensors.
4.2	Multiple members in the communication call between user and external experts.
4.3	Trends, critical, follow up, alarms the operator.
4.4	Trust expertise
4.5	QR-code makes it possible to suck up information from the situations or stations.
4.6	Connect to internet, perhaps show manuals for different machines in the glasses.

Table 3 requirement table

Everything listed on the table is all types of ideas that were brought up in the brainstorming and unfortunately every aspect cannot be prioritized/focused on hence to limitations; If all types of properties were wished for it would have ended up with perhaps nothing, being optimistic that only the most vital aspects to be focused on.

The numbers in the table are corelating to the priority category of function, every aspect as listed could not be wished for therefore the limitation and focus into this project will be set to the points from 1-3. These properties are asked by the glasses and the others are nice to have, not needed but seen as an extra benefit if available. The requirements 1-3 were analyzed and discussed with the staff in the brainstorming and together all parts agreed to the focus would be set on 1 to 3.

4.2.1 Communication between user and expert

As a member of the maintenance staff in Plasman, workers cannot rely on the fact that their expertise is optimal all the time, the knowledge is sometimes lacking or is just delayed in the process, multiple times does errors and systems take several hours or days to fix. Maintenance and repairs costs huge amounts of money for lean-implemented companies such as Plasman hence the aspects of Lean, Just-in-time & production in flows.

The aspect of the communication between user and expert is the most vital criteria of the demands from the device. The maintenance staff describes the situation as; "sometimes the user in the factory needs both hands and is hand-busy during the tasks in the meanwhile needing to communicate with an expert regarding a machine or fix which makes it even more complicated and hand-busy". The expert can even be in different area codes/regions/countries. This tool provides reliability in the process and much more effectiveness, the expert can give directives while the user of the AR device has both hands available for

tasks therefore the function 1.1 (table 1) is one of the most important factors when looking into development on what type of glasses will be searched and suggested on towards the maintenance staff. (Korchagin, A 2022)

4.2.2 Initiative to call

This aspect of the glasses is not optimal but is surely needed; you as a user of the technology should have the possibility to make a call whenever you want.

4.2.3 Software license

As a user of this service and tool no such need as a special software should be required external from the company, easy to open sources and external links to communication. (Http – link). The connection towards costumers should not require the costumer in the receiving end any special software required, simply opening a link should be the option towards connection with the device in receiving end e.g., with costumers & experts.

4.2.4 Optical feedback

This feedback is an input from the person in the call to the user of the glasses and features like highlighting or marking an object/surface that is being focused on.

Figure 4

Figure 5 highlighted surface

The optical feedback can be in the form of highlighting a surface, the user gets the feed directly from an optical point of view. The feature is very suitable when the environment is very noisy and if the user is unfamiliar with the orientation within the processes.

4.2.5 Voice command, screenshot the situation.

The opportunity to not use the hand for a few functions should be available in an extent within the glasses, hence the hand-busy work that the maintenance worker usually observes it as. (Zhu, D 2015). The functions can e.g., be" start video"," stop video" and "screenshot".

4.2.6 Data of events

Maintenance within the company is very complex, the variety of problems and issues are extensive, hence the large number of processes in the factory. The feature to record events, upload events or incidents is a fitting tool for further discussion or analyze of the situation to later use them as a learning purpose & preventative maintenance. If a worker solved a problem and a worker to the colleague don't have the expertise for the same task, then this is a good tool and properties within the software.

4.3 Exploring HoloLens 2

The HoloLens 2 glasses are a very popular augmented reality device on the market, it follows up with many popular features and are very excessive in its properties. The glasses are tested to be very effective and enhanced within production and quality (Wass, A., & Löwenborg Forsberg, E. 2017).

For Plasmans need this hardware & software are optimal but the aspects correlating to ergonomics are shown to be demanding (Wass, A., & Löwenborg Forsberg, E. (2017). The Hololens are specificized up to a weight of 2874 grams, consideration into ergonomics is bad in long-term use of the glasses.

Figure 6, HoloLens 2 glasses Source: Microsoft HoloLens, Mixed Reality Technology for Business, (2021)

Plasman maintenance workers consider battery time to be an important aspect hence to requirement table (table 3). Consideration this example of HoloLens 2 has a battery time up to two to three hours. The battery hours are not optimal when considering the time to perhaps solve problems. Problems occur frequently and randomly and if the device has been used for example in the morning to later address a situation later in the afternoon will become an issue, the device need to be available all the time if needed so a problematic scenario regarding battery life will not be current.: Microsoft HoloLens, Mixed Reality Technology for Business, (2021)

4.3.1 Exploring RealWear Navigator™ 500

RealWear Navigator 500 is an Augmented reality device that's belongs in the category Smart Glasses. The glasses have a very advanced camera that has multiple fine features, features such as a 48-megapixel camera with low light video capture. The glasses are light weight, easily adjusted by flexible adjustments. The ability to zoom in is an option simply by using voice command or manual option by hand. Hence the ability to zoom the RealWear Navigator retains the high-quality image that it provides. The company RealWear uses the word Augmented Reality to *"Assisted Reality"* which seems a little vain but also true. This tool is an excellent fit regarding protecting the safety of the employees within the company.

One flaw regarding the output on the lens; When the eye wants to focus on something that is relatively close to the eye it seems blurry firstly but then afterwards the eye adapts a little bit but therefore the concentration of the muscle in the eyes it gives a combination of discomfort and headache as can be related to the majority of almost everyone. This display gives a good comfort regarding muscle contraction during the wield due to the full HD quality and the ability to move the lens of desirable distance of the user of the glasses but after a long while discomfort will be experienced.
The Navigator 500 provides a concept of mixed realities, this concept generates different applications that allows the problem to be tangled down with input from the eye, it enhances information that is overlaid which can be confirmed as a boost in identifying the surface that is focused on.

Figure 7 Real wear Navigator 500^{tm} Source: (Real wear 2023)

4.4 Currently working methods

As stated, several times a maintenance worker has a broad vide of variety when it relates to work tasks and to have an optimal expertise of it all is almost impossible, hence that the factories expands nowadays and systems within industry 4.0 begins to get more complex and complicated with time. (Ding, B. 2023)

When related to tangled down problems regarding information, data and visual input of information are the most important keys to solve issues, problems and tasks, the first step to solving a problem is to identify the problem correctly. If the problem is not discovered or introduced properly the solution or the fix will be overkill or in some cases just a complete failure. (Yang, N. 2022)

In order to get an understanding on how the maintenance team in the factory operates and deals with problems a full day were spent with the team, where insight, standards, responsibility, working methods and other related tasks that indulges in the work were analyzed, observed and noted:

A normal day for a maintenance worker in Plasman follows as: the team has a location in the producing factory in Gothenburg and consists of a group of 6-8 people. This team covers the entire factory's layouts of machines, processes, incidents, maintenance questions and preventions purposes. The factory is dispositioned with a lot of producing and cutting technologies machines. The worker in the productions operates as machine operators and are idle waiting for the next part/step in the process, either loading machines with material or as a form of inspection and control sequence. The maintenance crew answer to all types of questions regarding producing, cutting, lighting, and machines in the factory. Everything that corresponds to output of materials from the factory is the maintenance team’s duty & responsibility.

The factory in Gothenburg is a plastic part producing factory in the latest technology regarding injecting molding, punching, and bending. These methods require heavy robust machines and supervision, maintenance is required from them daily to weekly. Checking the values regarding for e.g., fill rate in the tank to once a week switch a filter in the injection molding machines. These types of tasks are performed within the maintenance team and so much more. The team normally have too much to handle and are often under a lot of pressure from the organization to correct deviations and errors in time and preventing feature events.

The working team in Gothenburg’s factory consists of 3 shifts, day, evening, and night. Factories just as these as in Volvo are running 24/5 and even more in cases of delays in the weekends. The many work hours of the systems make it run all the time and the maintenance team's duty is to make the hours running to be as optimal as possible, fixing the current situations, prevent issues that may appear in the future, a sort of prevention maintenance.

The maintenance team is located within the production factory in Gothenburg and is working as a team to optimize the questions related to maintenance. Team members support each other in tasks, everyone is working together on the matter of production, in some more advanced cases does only a few members have the knowledge to sort out some specific problems regarding machine maintenance therefore

recording events (table 3) regarding specification 3.2.6 Data of events is well observed to be useful, to share events and to use the data as learning & education.

When the day shift has ended does the maintenance team register what has been done and what issues have been active in the day to later prepare the evening shift for the work so the right circumstances are available for all teams within maintenance.

The department has every machine documented and registered as files in the form of binders in their maintenance staff room. The binders work as a tool to get a deeper understanding of how the machines work, what types of load use, how often service should be carried out and other important information related to service and maintenance. The factory team must always work towards the standard set by the organization and issue provisions in cases of incidents, accidents, and deviations in the plant. Such things can be that a safety aspect is missing in the machine or that safety helms are not worn by the personnel and even that a wet floor can be seen as an error. The team works effectively to remove these to prevent them from occurring again and to study/analyze how they initially became an active problem.

The maintenance team has a broad variety of materials and machines in their warehouse stored as logistic, as safety stock. If a machine part is broken or damaged, they have a backup in their storage. The AR device has the possibility to integrate that storage data when walking up and scanning a machine, so standstills don’t occur due to lack of materials and components.

Discussion with the maintenance team gave a lot of aspects towards their tasks and it seemed controversial to bring up but particularly one aspect seemed very important to discuss in their current working situation: The personnel need the right knowledge and experience in the status of a maintenance worker. Many times, the team gets new personnel who need much training and is missing the experience that is required to manage the facility's duties. Understanding on every machine, process and maintenance need for every station & process is extremely difficult to achieve. Some workers have 1-2 decades of experience and still does not achieve the full potential of understanding in the whole plant. Therefore, this project complementation that aspect hence the augmented reality device that collects data and makes decision clearer.

As a maintenance worker in this time in industries of production factories, the aspect of maintenance and the workers that is responsible for the factory's maintenance is a very important factor and aspect for the facilities results hence the ability to manage and fix errors and to prevent them for happening. The work that the maintenance team put in is relatively close to the facilities output. A fixer, carer, and helper are words that often define the worker towards maintenance and in some cases also as a savior.

4.4.1 Conduct trials at the production facility to test and evaluate method, hardware, and software

Research on what type of AR device has been set and Real wear navigator became a choose of test/trials hence the resellers opportunity and interest to visit the office and perform the services the product has. Contact with different resellers had been made and a factory visit with TeamViewer regarding devices and software’s had been planned to investigate and conduct trial/demo on the product to get a deeper understanding and evaluation of the working method. 22nd of September together with all parts consider in the project's parts attended and following information was validated.

Contact with different reseller was made and the one reseller who sticking out from them all was a reseller from the big company TeamViewer who has many years of experience in the area of augmented reality, service towards tech companies as costumers including software’s & hardware’s.
The hardware flew in from Poland and came to Plasman’s headquarter in Gothenburg Sweden. with the reseller and the characteristics was determined to be very robust and noticeable as a premium product instantly.

Trial on site was experienced as a terrific opportunity to evaluate the glasses to see if they were what they were seemed to be, therefore trial was the final aspect before suggesting implementation of the smart glasses real wear navigator 500. The trial was conducted together with the necessary parts considering implementing the glasses, maintenance engineers, maintenance technicians, operational manager, reseller and the student.

Methods in the trial was conducted followed by step-by-step instructions with a flexible platform to have the possibility to integrate a lot of o features such as external sensors/data for example. The most usable user cases for the maintenance team with software is service, guided diagnostics and instant troubleshooting with the ability to enhance result, performance, and effectiveness within the division.
A key aspect of the glasses during the demonstration was that the glasses were shown to give faster inspection/assignment from the worker performing using the device. A demonstration was made that showed an individual working in a sequence with a combustion engine versus same sequence without the glasses, 40 % faster was the person performing with the Real Wear navigator 500[tm].

The 40 % was observed as: The person does not have to move between locations to document or integrate with the many sources of documentation, they are instantly downloaded and integrated together with the user. The person is shown what to pick, in which order and with good comfort along with the visual input from the glasses on.

The glasses primally function as a device are adding another dimension to the workplace, translating analogues instructions, manuals etc. Manuals for machines are certainly needed many cases when regarding machines due to the many complexes producing machines the factory enfolds. The smart glasses can be integrated with any log, manual or instruction wished to add into the eye of the beholder. Additionally adding contents and interactive elements to the users to inform and use spatial tracking to find point-of-interest, checkpoints, and assembly positions for example.

4.4.2 Development a working method with the Real Wear Navigator 500[tm]

Following Working methods were clarified and explained in the event of trials where the equipment expert and reseller from Poland arrived in Sweden to demonstrate the device and gave the project all necessary information regarding, methods, instruction and software's.

The real wear navigator 500 works with most personal protective equipment. The glasses assist to engage, empower, and elevate the worker within the maintenance department. Connection and collaboration with experts which follows with directives and instructions. Visualization of internet of things including for example data. Downtime is a factor that is the key for the working method to comprehend to also improve quality and productivity within the employee using them. Downtime is the one thing that decreases the output in a factory, when something is going idle, breaks down along with waiting are huge losses related to Lean producing factories due to the material flows.

Considering the glasses into the department's working life is a question to grasp on because the smart glasses are not the first and mainly tool for the division, the smart glasses as mentioned before can enhance aspects of the departments statistics and result such as downtime, idleness, errors, MTBF, and other related maintenance effect & aspects. Working together with the device will be handled successfully with proper training and knowledge of the device, how to interact with the hardware and software to further develop a standard on what is to be performed and expected of them.

In case of events in the working hours of the maintenance team the glasses will be stationed in a set location for them to be grabbed and used whenever felt necessary. The glasses will put all the events and documentation from the start of the sequence they were involved into to the end to ensure successful documentation of the courses of events. Another great feature is that the user can create everything that is desired to pop up in the lens of the glasses, creating framework or dialogues events and even sequences of events as a working method or be introduced as an inspection list in form of pictures, videos or documentation. The working method is very flexible when relating to what the glasses tasks are, they can be integrated into almost every software that currently exists and implementation of what they are meant to do is very controversial. The glasses can assist to be used for pick assist in terms of a logistic manner and even user cases when remoting users and a lot more. Why the working method is compressive is because the implementation of the AR device can be done in multiple ways and if everything is tried to be implemented it will result in too much is tried to apply therefore only a few working methods will be applied firstly and thereafter if potential is seen much more can be done and some aspect so far has been discuses as "Gold worth" if were implemented. When related to a logistical manner on where to transport items as a pick assist it will be ensured to 99,99 % accuracy for picking it is almost impossible to pick/choose item.
When working with maintenance in this case inspections will be done such as implementing QR-codes, when the QR-code is read by the glasses on the surface of the machine or station the user will have to

program beforehand what event or information is wanted in the event to be obtained with. Then the programmed sequence is linking to the QR-code so the event is downloaded and prepared to be used. In the below the software indulged with the glasses shows the program/software included from TeamViewer where the department can program and structure how the event/sequence is performed by the user. From initiating start event to fully complete operation, tasks, inspection & sequence. The program works towards creating 2D AR workflows by drag & drop

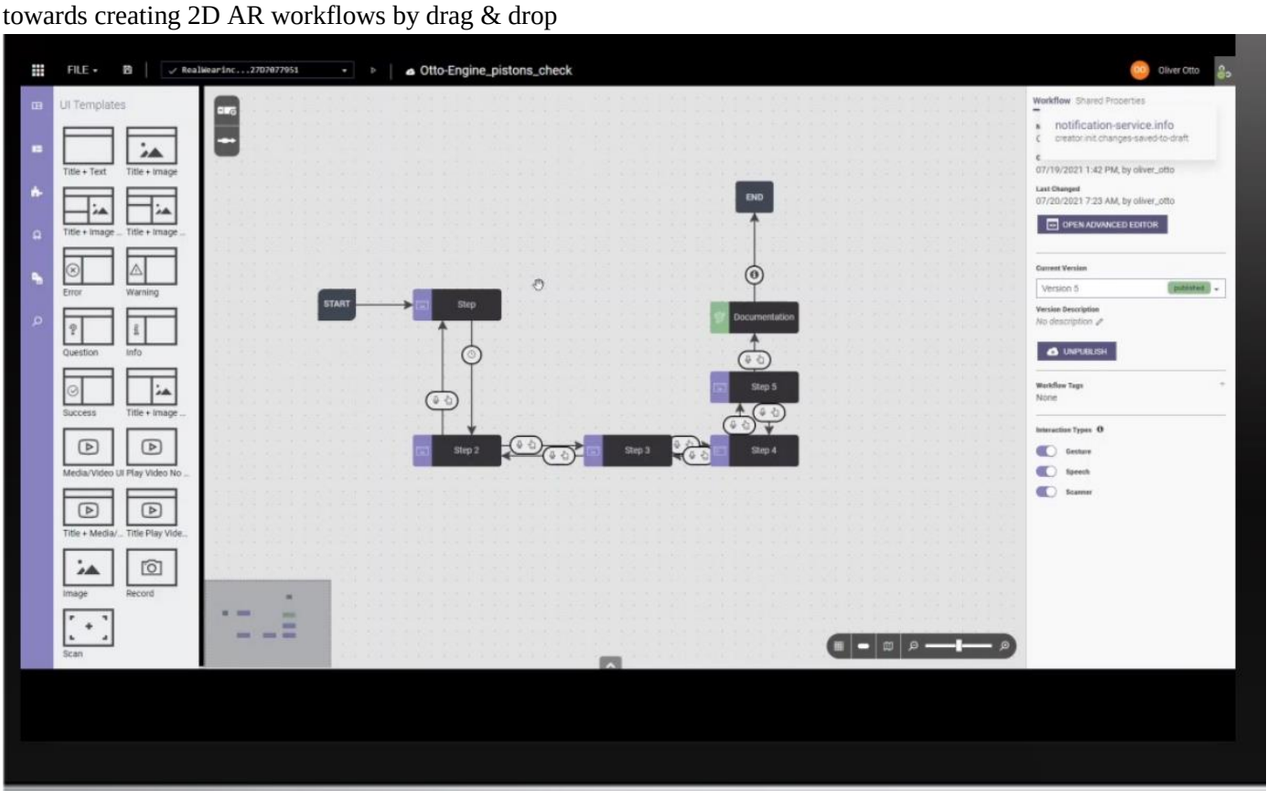

Figure 8, Software Workflow of events

Another user case is safety of the environment likely as inspections and control of important vital such as pressure, temperature and fill rate of the load on the machine that melts plastic pellets to form shells to later ensure warning signal if someone is missing important safety equipment as helmets or glasses.

Connection with the individual who wears the glasses with experts or other parts of the events to discuss gives a deeper insight of information hence the ability to draw, highlight and to give directives to the user from their smartphone, PC or tablet. It works as a communication call and the number of members included in the call can be many.

4.5 Feedback from user benefits and downfalls

Trials were made together will all considered parts in the factory, maintenance worker, maintenance manager, operation manager and facility manager. Reseller from TeamViewer had great insight in benefits from the software and device.

The feedback and output from this part is vital towards the implementation due to the experience and value of the hardware & software the managers and operators observe. Their thoughts and feedback are important because they can sense future development of smart glasses and they are the ones getting a tool implemented in their working environment therefore the feedback here is very necessary. During the demonstration of the glasses a lot of aspects were seen as positive and a good return of investment by the purchase of the glasses along with-it software.

Lists of opportunities the glasses enhance explained by TeamViewer: Source; TeamViewer presentation/pitch.

- Easy transformation of knowledge is an incredibly positive benefit from the glasses.
- More ergonomic with smart glasses
- Boosts productivity
- Gives clearer structure
- Reduce error rate
- Hands free process/operations
- Swapable battery
- Producing whatever scenario is wanted from the software, sequence list or list of events shown in the lens by QR-cod.

- User do not need to return to Pc to document down what has been performed or statuses etc. It is all documented down by the scenario/event and downloaded as a file by choice, Pdf-file, or word-file if so, wished among the choices.
- Faster problem solution
- Easy knowledge transfer
- Reduced costs for service
- You-see-What-I-See technology assistants via glasses and using aspects like zoom, screensharing and recording sessions.
- Shorter inspection time
- Paperless inspections
- Fully voice-controlled interaction for each required documentation step
- A full paperless process is more secure and even more environmentally friendly
- Assembly instructions shown on the smart glasses
- Greater flexibility
- Connections to the multiple software's within the factory such as WMS (web map service) and other integrated circuits.

The POV from the maintenance technician followed as, “From the dealer technician perspective, they just turn on their smart glasses and accept an incoming call, then it is like my specialists are there looking over their shoulder to help resolve the problem.”

The glasses have a lot of consumers & companies as costumers around the world and one of the most famous companies such as Coca-Cola uses real wear navigator 500 as an AR device to ensure 99.9% accuracy in their work, used for picking information, confirmation aspect and 10% more performance on picking. Reducing error rate and better ergonomics are also aspects the glasses provide to the users and are very ideal when relating to multi orders picking. The glasses as stated earlier are easy to integrate with many software and external devices, a good aspect is security for example. Detection if an individual is missing safety equipment such as safety helmet and alerts and notify the deviation to the user of the smart glasses in a manner of safety precautions.

4.6 AR devices put to evaluation

	Device	Google Glass Enterprise Edition 2	MICROSOFT HOLOLENS 2	Lenovo thinkreality a3	lenovo thinkreality a6	RealWear Navigator™ 500	VuZIX M-SERIES
Function							
Display		Transparent	Waveguide optics	Stereoscopic 10809, 45 pixels per degree pixel density display	Waveguide optics Binocular AR views	Golden Pearl display	Waveguide optics Full-color DLP display
Camera		MP 1080p30 Video	8 megapixels 1080p 30fps 4 light cameras 2 IR cameras	1080p per eye	13 MP RGB rolling shutter camera Two fish-eye camera	48MP camera sensor	8 MP 720p 30fps or 1080p 24fp
Battery Capacity		800 mAh	16.5Wh	-	6800 mAh	2600 mAh	470 mAh
Battery Life		8 hours	2 - 3 hours	phone-like battery life	4 hours	8 hours swappable battery	4 to 6 hours
Control and Navigation		Voice command Touchpad	Voice command, Hand gesture, Eye tracking, Head motion	Voice command Gesture Controller	3DoF hand controller Voice command Gesture and gaze control	Controll apps, voice command, gesture controller	Touchpad Control Apps Voice Command
Operating System		Android	Holographic Processing Unit (HPU)	-	Android	Andriod, Browser, PC, Iphone	Android
Built-in Speaker		Yes	Yes	Yes	Yes	Yes	Yes
Built-in Microphone		Yes	Yes	Yes	Yes	Yes	Yes
Data Port		USB 2.0	USB C	USB	USB	USB-C	-
Connectivity		WiFi Bluetooth USB	USB Bluetooth WiFi	USB WiFi Bluetooth Display Port 1.4	USB WiFi Bluetooth	Wifi, Bleaututh 4G/5G	Bluetooth WiFi
Weight		46 grams	2874 grams	30 grams	240 grams	272 grams	90 grams
Price		999$	$3,500	$1,499	$2,295	$ 2,500	$799,99

Table 5: AR devices

The different devices in this table were set to evaluation with the different functions/aspects on the left column that are considered the most relevant ones when considering a device to the maintenance team.

An AR device has almost 30-40 functions and factors to consider but the ones on the table (table 5) were the focus in this project due to the requirement table (table 3).
Aspects as price where not relevant to consider due to the one-time purchase corresponds to the KPI's enhancements within the production facility. Weight (ergonomics), connectivity, operating system, battery life where the most vitals ones to consider within Plasman's maintenance team due to the aspects of Lean and industry 4.0 hence the requirement specification set in table (table 3).
Aspects such as connectivity was focused due to the connections question that were brought up in the brainstorming with the maintenance team. The team need the device to work whenever felt necessary. Operating system where focused hence the reason if Plasman wants to reach out to external parts such as machine owners of diverse machines (leasing machines) and the external companies & parts should not be obligated to download any additional software or program to connect to the AR-connection in Plasman. Simply connecting to the SMS or Http: link.

5.0 Discussion

In this section, discussion regarding finding of limitation, difficulties and deviations that occurred during the project. Mainly purpose regarding on how to implement device & software with the correct approach to “sell” the idea to a department/company with possibilities on future thoughts.

5.1 Approach of method

One aspect is worth to mention is if this project or similar would be done again. This projects method was handed out by the company, “we want to implement this idea”, “you should be able to provide this information to us regarding the idea”, this gave a feeling on what to do, in which steps. The methods corresponded to achieving the goal in 1.3.

If for example implementation of AR was wished to be done without knowing what exactly is looking for in the use-case would perhaps result with confusion and a lot of distraction. Many devices are expensive such as the popular ones Microsoft HoloLens 2 and in the most cases are a complex expensive device not optimal and can be experienced as heavy and a loss. Therefore, I would suggest reading about Augmented reality devices, look in the current situation on what is bad for e.g., efficiency, productivity or accuracy in the user-cases today without AR and see if a device can assist and enhance those aspects. Focus on what is the most vital properties within the device & software, Battery? Compatibility? Connection? Price? Lens size and so on.

5.2 Conduction of trial

In the event of trials many hours were spent due to connections issues, because AR requires specific hardware capabilities, such as cameras, sensors, and processing power. Ensuring compatibility and optimal performance across a wide range of devices can be complex due to connectivity and connection. AR relies on accurate tracking of real-world objects or environments and aligning virtual content with them. Achieving precise tracking and alignment can be challenging, especially in dynamic or unpredictable environments such as Plasman where many systems and objects are interfering with one another.

Understanding on what type of device exactly is needed to implement was also experienced as a difficulty hence the aspect of so many devices & software’s the market has. A deep understanding on the needs is well put to be understood. Therefore, discussion for e.g., with an experienced worker in the apartment of AR implementation is needed, the worker has experience on what is missing perhaps needed and what can be better.

Regarding the trials. What type of device is wanted to test was a difficulty due to the many resellers. Contact with many local stores was made and almost none of the resellers offered “free trials” on site. Also, the aspect of implementing was almost only about selling the idea to the managers in the plant, “Why do we want to invest in this?”. To be able to sell the product is well needed, to have a good pitch & to be well informed on what types of question will be asked about the product. In this projects case a reseller from Poland came within the international company TeamViewer arrived and gave demonstrations on different devices along with software. It gave a trustworthy experience on how the device is supposed to be working, a good hand-on felling was experienced which facilitates the event. The conduction of trial was the most vital aspect of suggesting a device to the company, the reseller was experienced, had knowledge and its her/his job to pitch/sell the idea. The personnel, managers workers need to experience a good pitch and demonstration of output, service & software to even suggesting an augmented reality device. It can be done alone without a resellers expertise and experience but be well prepared in that case.

5.3 Requirement specification

The table developed (table 3) in the result 3.2 was a huge start factor on how to begin and gave the vital aspects in the conclusion later. Discussion and brainstorming with the team from morning to lunch on what they need, what they want, what they wished for. The maintenance team wanted a lot from the device, many aspects where greatly mentioned but, limitations must be set if something is supposed to be delivered. Perhaps 30 to 40 aspects were brought up in the brainstorming that day and after proper

research and investigation the requirements had to be narrowed down to a few to ensure a delivery. The student narrowed down to 20 down to later 10 with the team, to later to the developed (table 3) in the results.

5.4 Future work

In the user-cases of the smart glasses, implementation of everything was not the goal. The goal was to implement and provide a fitting hardware and software with a work description of the tool to the maintenance staff. Hopefully in the future it will be manageable to implement this method even furthermore through the company through training and other sorts of realities. Combination with other external devices is also a user case to work with in the future, there are ring scanners, smart watches & wrist-worn scanners to be integrated with the real wear navigator 500 to detect for example vibrations, stress and other related factors.

5.4.1 Newly hired personal training & education

Normally new hired employees are trained and educated together with an experienced employee. The state of being a trainee gives an availability that is not efficient and gives the interception that the new hired person is not managing on his/her own. Therefore, training together with the collaboration device (Smart glasses) can be used to get a faster learning in skills and safety. The person learning together with the reality learns in a deeper way of understanding the environment and the skills needed. Another aspect is that for e.g., the experienced worker that is supposed to train the new hired employee needs less time educating the trainee. The time together with the employee is reduced which results to he/she can spend their valuable time providing their work into important tasks within their job description. In many cases industrial facilities are crowdy and the machines are hidden and are not accessed easily. The trainee using the augmented reality are experiencing the situation in a simulation in a comfortable and safe environment.

Training is a method that can be implemented within the company through the implementation of the smart glasses real wear navigator 500^{tm}, one of the points as training is to replay the recorded scenarios to evaluate them and study them. Benefits from this is when the same situation occurs makes it more familiar & comfortable with the approach of the solution. Fewer errors occurs and the training gets more efficient, normally is learning performed through normal follow 1:1 with an experienced worker in the team which is a fantastic opportunity but hence to the limitation of the people in this division is remarkably busy in time due to the big responsibility laying on their shoulders. The layout of the factory is very complex and crowded and many times does the maintenance worker need to climb, crawl and jump to destinations to maintain machines, pipes and other related objects. The glasses complement so the trainee can watch and inspect the sequence later in a safe environment without needing to focus on other aspects besides learning the methods and precautions of maintenance.

5.4.2 Digital self-learning of correct procedure on real object

USER-CASE: Digital self-learning of correct procedure on real objects
VALUE PROPOSITION: Efficiency gained through digital self-learning and practice during training with less involvement of experts / trainers
CUSTOMER PAIN POINTS:
→ Limited resources of trainers / experts
→ Must train many new employees in the shortest time possible
Since trainers are less involved per training, fewer trainers can train more trainees
→ Increase the number of max. participants per training
→ Reduction of personnel costs of a trainer per training

Table 4, self-learning.

5G Connectivity: The rollout of 5G networks will significantly enhance AR experiences in maintenance. With high-speed, low-latency connectivity, technicians can access and transmit data in real-time, enabling more efficient remote assistance and seamless collaboration with experts. 5G connectivity will also support the integration of AR with other technologies like IoT and cloud computing, further enhancing maintenance capabilities.

Enhanced Collaboration and Knowledge Sharing: Future developments in AR will focus on improving collaboration and knowledge sharing among maintenance teams. Technicians will be able to share their AR views with remote experts, conduct virtual meetings, and collaborate in real-time on maintenance tasks. This will facilitate faster problem-solving, knowledge transfer, and overall efficiency in maintenance operations.

As AR technology continues to advance, we can expect to see exciting developments that will revolutionize maintenance processes. These advancements will not only increase productivity and accuracy but also enable technicians to leverage cutting-edge technologies for more effective equipment maintenance.

5.5 Device implementation

Exactly on which type of device is recommended and chosen to implement or suggested to a department within maintenance is different from company to company. For this project aspects regarding Plasman's prerequisites such in Lean and productivity was the important focus hence the swapable battery aspects, for the glasses to be always available.

Before selecting an AR device, a wide understanding in the environment is needed along with a well put requirement specification and brainstorming with the personnel in the team. Perhaps the Real wear navigator 500^{tm} would have been an unsuccessful fit in another company and the Microsoft HoloLens 2 would have been a great fit regardless of the battery capacity on 3 hours.

When suggesting the device to Plasman multiple aspects were wanted and focused on, many different functions exist but focusing on everyone was not possible due to the delimitations set in chapter 1.5.

The factory for Plasman is working as mentioned 24 hours a day and for the glasses to go idle and wait for charging is an unnecessary loss; therefore, the Real Wear Navigator 500 is a great fit for that aspect due to the ability to change an empty battery to a full one in a matter of seconds. Another great reason on why the device is a great fit is that Realwear Navigator 500 tm provides an optimal 4x zoom while still obtaining full HD quality. When opening files and manuals the user can enhance the zoom in the output to get a clear picture on what he/she want to obtain. The glasses are drop tested, water resistant (IP66), and even dustproof therefore resistant in the most challenging working environments. Working in a factory comes always with a lot of noise and the glasses come with the latest features for noise cancellation with 4 digital microphones. Aspects to mention within the device with great opportunities are document navigator, audio recorder, video recorder, Cloud Sync, Media player, Calculator, Pedometer, Timer, Webpage viewer, and Code reader. All these opportunities are an active choice to use to implement in a working method.

6.0 Conclusion

Six different types of augmented reality smart glasses were lifted for evaluated towards suggestion to the department within Plasman in the table (table 5). The most important aspects are only to consider in this project due to the boundaries to it, aspects such as battery life, connectivity and weight are the most severe ones to consider due to ergonomics along with time saving and internet of things. The function on the left side in the table has been set towards an evaluation of the most fitting smart glasses to the section in maintenance.

The **6th** one in the table (table 5) **Real Wear Navigator 500** was set to be the most fitted type of smart glasses from the list hence the aspect battery life and operating system.

Contact and communication with different machine owners abroad with the knowledge of their machines along with the possibility to have both hands available when having dialogues with them answering with an Http: link was one of the winning arguments when selecting Real Wear Navigator 500™. The battery aspects were the most vital one this project, when having a device with an optimal use of the battery. Working as a power tool, when the battery is empty switch to a fully loaded one in seconds. These aspects were the winning ones related to choosing the AR-device to a suggestion to the maintenance team within Plasman.

The purpose of this project with the aim & goal included when selecting an working method and AR-device to Plasman was done and it has been lifted to the followed years budget as an suggestion.

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