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Empirical Study: Benefits and Practical Implications  
of Using Augmented Reality in the Automotive  
Industry

*Bachelor of Science Thesis in Software Engineering and Management*

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### **Empirical Study: Benefits and Practical Implications of Using Augmented Reality in the Automotive Industry**

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# Benefits and Practical Implications of Using Augmented Reality in the Automotive Industry

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**Abstract** - Augmented Reality emerged from the field of Virtual Reality more than forty years ago and since then there has been many projects that have demonstrated how the technology can be used as an aiding tool for a wide range of tasks and procedures. Despite this there are very few empirical studies which focus on the practical implications and potential benefits of using Augmented Reality. The goal of this paper is to investigate the practical implications and potential benefits of applying Augmented Reality in the area of maintenance and repair procedures in the automotive industry. We interviewed Volvo Trucks employees working in the support network to capture their particular needs. The analysis revealed three interrelated themes in terms of perceived needs. This is followed by a discussion on how Augmented Reality could be used to address those needs. The paper provides insights on the possibilities of Augmented Reality application in the area of maintenance and repair. It also provides suggestions for future research in the field of AR in the automotive industry and beyond.

**Keywords-** *augmented reality; augmented reality benefits, augmented reality application, augmented reality in automotive industry.*

## 1 INTRODUCTION

Augmented Reality (AR) is defined as direct or indirect view of the real world that has been augmented with superimposed computer-generated information (Azuma, 1997). AR (Appendix A for Terms & Abbreviations) allows the users to enhance their perception of reality by adding computer-generated information over the physical world (Azuma, 1997). AR has potential to provide a fast and automatic way of retrieving information about the surroundings. The computer-generated information, called augmentation, is both interactive and digitally manipulable and can be used to

provide information about everyday objects. The technology is on the verge of a true break-through and its popularity, among developers and end-users alike, is constantly growing (Carmigniani, et al., 2012). The introduction of Augmented Reality on mobile devices, such as smartphones and tablets, has allowed the technology to gain widespread attention and influence our everyday life. Augmented Reality has been proven effective in many domains and successful applications of the technology in the past seem to suggest that it has potential to be used as an assistance tool for most tasks and procedures.

Within the industrial environments, maintenance procedures present an important way of guaranteeing quality to the customer. Maintenance and repair of complex machinery involves many different procedures where tight regulations often demand access to manuals, schematics and other supporting tools (Schwald and de Laval, 2003). Henderson and Feiner (2011) observe that manufacturing and maintenance present interesting and opportunity-filled domains for application of Augmented Reality. In light of this, the study investigates 1) how AR can aid employees, working in Volvo Trucks' support network, in their day-to-day work and 2) potential benefits that AR can bring to the company.

Although there is a considerable amount of studies on the application of Augmented Reality there are few qualitative studies that give an overview of the benefits and the practical implementations of using the technology. This study aims to fill this knowledge gap. The present study applies a qualitative research design to address the research questions. Specifically, it is based on interviews with employees working in Volvo Trucks'

support network, to achieve a better understanding of their work processes and needs.

Two main contributions of this paper are:

- Provides insights on the possibilities of AR application for practice, in particular the area of maintenance and repair.
- Provides suggestions for future research in the field of AR in the automotive industry and beyond.

## 1.1 Overview

The first section introduces the reader to Augmented Reality and the aim of this paper. The second section presents a literature review of the state-of-the-art AR technologies including; different AR devices, related work and limitations and challenges related to the AR technology. The third section describes the research approach and limitations. The fourth section presents our findings based on the analysis of the interview data. Section five discusses potential uses and benefits of AR, and finally, in section six the main conclusions of the research are presented.

## 2 A REVIEW OF STATE-OF-THE-ART AUGMENTED REALITY TECHNOLOGIES

In 1966 Ivan Sutherland created the first Augmented Reality (AR) system, which was a window to the virtual world (Sutherland, 1968). In 1990, in Tom Caudell's and David Mizell's article, the term "Augmented Reality" was coined. They discussed the advantages of Augmented Reality versus Virtual Reality (Caudell and Mizell, 1992). Later, in 1997, Ronald Azuma provided an acknowledged definition of AR by presenting the first survey on Augmented Reality and in the same year, Steve Feiner and his colleges presented the first mobile Augmented Reality system (Wagner, D, n.d.).

Recently, there have been many prominent examples of AR in action (Sawers, 2012) and the technology has become notable in past few years (Meetup, 2012). Moreover, the future of Augmented Reality has been deemed bright as researchers believe that in the next five years there will be some significant advances in field of AR and that it will gradually integrate into our everyday lives (Bonsor, 2012) (Sawers, 2012).

With this backdrop, it is clear that AR has the potential to change the way people interact with their surroundings by 1) greatly simplifying the process of

accessing information about their surroundings and 2) allowing the user to digitally manipulate his or her surroundings.

## 2.1 Augmented Reality Devices

The main components of any Augmented Reality (AR) device are displays, input devices, tracking devices and processors (Carmigniani, et al., 2012). The biggest difference between various AR devices is in the display technology that they implement. There are several different types of displays technologies. In this section we will describe the three most common types of AR display techniques and list the advantages and the disadvantages of each type. Most of the displays can be categorized in one of the following categories: Head Mounted Displays (HMD), Handheld Display and Spatial Display.

### 2.1.1 Head-Mounted Displays

Just as the name indicates, Head-Mounted Displays (HMD) are worn on the head or on the helmet of the user. They place both images from the physical world and registered virtual graphical object over the user's view of the world (Carmigniani, et al., 2012). Head attached display (HAD) and Head worn display (HWD) are also Head-Mounted Displays but with small differences (Bimber and Raskar, 2006). Head-Mounted Displays are usually separated into:

- **Video see-through** head-mounted displays (see **Figure 1**) use video mixing and display the merged images in a closed-view head mounted display (Bimber and Raskar, 2006). The real-world view is captured with camera/s mounted on the users gear and the computer-generated images are electronically combined with the video representation of the real world (Edwards, Rolland and Keller, 1993).



**Figure 1:** Video see-through HMD that includes cameras for capturing the real-world scene

- **Optical see-through** head-mounted displays are using half-silvered mirrors or transparent LCD displays to allow the view of physical world to pass through the lens and overlay computer generated information over it to present augmented scene over the user's eyes (Carmigniani, et al., 2012). Some examples of AR devices implementing this technology are: Sony Glasstron, SAAB AddVisor, nVision Industries and KEO Sim Eye XL100A (Butz, 2006).

Google is also developing AR eyeglasses (see **Figure 2**) for entertainment, information and Augmented Reality. The project is called Project Glass and it is making use of HMD display (Gannes, 2012). The HMD display has a horizontal frame that rest on a wearer's nose, with wider strip of computer and small clear displays on the right field of vision (Gannes, 2012). This prototype presents a new kind of HMD that is smaller and slimmer than previous designs.



**Figure 2:** Google's "Project Glass" AR glasses

HMD displays have some weaknesses (Bimber and Raskar, 2006), such as, limited field of view and visual perception issues due to the constant image depth.

### 2.1.2 Handheld Displays

Handheld displays are small computing devices with display that fits into the user's hand (Carmigniani, et al., 2012). All of these devices combine processor, memory, display and interaction technology in one device. Handheld displays that adapt AR usually use video see-through technique (Carmigniani, et al., 2012). Recent increases in hardware capabilities and computing power on smart phones and tablets have allowed these devices to become very promising platform for AR (Carmigniani, et al., 2012). Mobility, powerful CPUs, powerful cameras, more accurate GPS, accelerometer and compass are some of the characteristics that make handheld devices a good platform for AR.

Researchers at the Vienna University of Technology and the Graz University of Technology recommend the use of low cost handheld devices instead of specialized and expensive hardware for Augmented Reality (Wagner, 2007). They argue that most people already own a handheld device that they are familiar with and know how to operate, and since the computing capabilities on most of today's handheld devices allows for AR applications there is no need for specialized AR devices unless the situation requires them.

The problem with some handheld devices like smartphones is that their relatively small display does not allow for optimal use of AR and the user might feel restricted. In this case tablets are a better option, since they have larger displays and more powerful CPUs. But tablets bring with them new challenges, they are more expensive and too heavy for single handed use. However, like any technology, tablets are bound to get cheaper and lighter in the future and Carmigniani, et al. (2012) believes that tablets are a promising platform for AR applications.

### 2.1.3 Spatial Displays

Spatial displays are making use of digital projector and tracking technologies to display graphical information onto physical objects (Carmigniani, et al., 2012) without requiring users to carry or wear a display. They aim to detach most of the hardware from the user and incorporate it into the environment. Spatial displays can be separated by the method they use to augment the surroundings. Usually they implement video see-through, optical see-through or direct augmentation of the environment.

### 2.1.4 Comparison of the Augmented Reality Display Techniques

As mentioned, there are different display techniques for an AR device. All of them are different and they all have their own strengths and weaknesses. Looking at it from the practice perspective it is important to know the advantages and the disadvantages of each technique. Depending on what purpose the AR system is used for, one technique might be more suitable than the other. In this section we describe the advantages and disadvantages connected to each display technique described in this chapter. This information is vital for anyone wanting to design and implement an AR system since it would be one of the initial development decisions that would have to be taken.

According to Carmigniani, et al. (2012) and Butz, (2006) the perceived advantages and disadvantages of the respective technique are:

### *I. HMD Video see-through*

#### **Advantages:**

- Good synchronizations of the virtual and real
- Complete visualization control
- Camera can be used for tracking as well

#### **Disadvantages:**

- Requires user to wear camera
- Unnatural perception of the real environment
- Not effective for collaborative work

### *II. HMD Optical see-through*

#### **Advantages:**

- Allows for natural view of the real world
- High resolution of real world objects
- No delay between motion and real world images
- Real world object can be focused at their correct distance

#### **Disadvantages:**

- Delay
- Jittering of the computer generated data
- Not effective for collaborative work

### *III. Handheld*

#### **Advantages:**

- Portable
- Widespread familiarity

#### **Disadvantages:**

- Expensive
- Small display on some devices
- Some devices too heavy for single hand use

### *IV. Spatial*

#### **Advantages:**

- Displays graphical information directly onto physical objects
- Can be adopted using off-the-shelf hardware components
- Supports multiple users

#### **Disadvantages:**

- Usually not portable

Note that handheld and spatial AR devices can implement both video see-through and optical see-

through techniques and can therefore include more advantages and/or disadvantages related to the respective technique.

## **2.2 Augmented Reality in Applied Settings**

As mentioned, Augmented Reality (AR) allows users to enhance their vision of reality by providing virtual information that cannot be directly accessed by their own senses (Azuma, 1997). This allows for a great number of possible application areas, and AR presents itself as a general purpose tool whose potential seems limited only by the imagination of the development team. Clearly there are technological limitations as well, since AR systems usually require a significant processing power and memory, but as the hardware capability of everyday devices increases so does their ability to support Augmented Reality.

While there are many possible application domains for AR, we will focus on describing the ones that are relevant and applicable to the work environment of the Volvo Trucks support employees. We will present two application domains that we think can, directly or through some adaptation, be applied to the Volvo Truck support employee's work-method (tasks, procedures). These are:

### **2.2.1 Manufacturing and Maintenance Procedures**

Tasks where it is required to perform an established sequence of activities while interacting with objects in the physical environment occur in many domains. These tasks often require some kind of support that is designed to help the user perform the procedure successfully. This is especially true for manufacturing and maintenance where tight regulations often call for use of manuals, schematics and other aids (Henderson and Feiner, 2011). Henderson and Feiner (2011) observe that manufacturing and maintenance present interesting and opportunity-filled domains for application of AR.

In the past there have been many approaches to deliver fast, reliable and supportive assistance tools such as paper manuals, schematics and computer-based documentation. AR has potential to replace all of these by introducing a more automatized and interactive way of accessing and manipulating information derived from physical objects.

Neumann and Majoros (2002) suggest that almost all manufacturing and maintenance tasks can be divided into two phases, the *workpiece* or *psychomotor* phase and the *informational* or *cognitive* phase. In the

*psychomotor* phase the user often performs physical manipulations like measuring, comparing, aligning and adjusting configurations or components. This is normally accompanied by the *cognitive* phase, in which the user locates the information needed to proceed with the *psychomotor* phase. This information is typically in a form of paper instructions like manuals or schematics that provide information on how to execute a certain task in the *psychomotor* phase. This separation of procedural activities into two phases is further supported by Richardson (2004) and his college that observed a similar division of activities in assembly tasks.

The most obvious use for AR would be in the *cognitive* phase, but some projects have shown that AR could be used in the *psychomotor* phase just as effectively, and in many cases it has been possible to merge the two phases into a single activity. There have been several projects where AR systems have been used for assembly, maintenance and repair of complex machinery.

Reiners, et al. (1998) demonstrated a prototype AR system for car door assembly that made use of 3D CAD models retrieved from the construction and production database. The user was presented with instructions on how to assemble a car door through a HWD device (see **Figure 3**). The prototype was demonstrated at the Hannover Industrial Fair where a number of visitors tried the system. This showed that the system was able to handle only the users with previous experience in the field. One of the benefits of the system that was noted was that it allowed the system to be integrated into the existing infrastructure and feed off data generated for other purposes, thus giving added value to that data.



**Figure 3:** Real world scene with superimposed 3D model that was designed in the production stage. The scene is a moving instruction for that particular part. (Reiners, et al., 1998)

A similar prototype designed to assist the user in servicing a laser printer by providing instructions

through a HWD device, was developed and tested by Feiner, Macintyre and Seligman (1993).

Baird and Barfield (1999) tested the effectiveness of Augmented Reality for assembly procedures, compared to the traditional instruction aids like paper and computer manuals. Subjects were asked to assemble a computer motherboard with the aid of: paper manual, computer manuals, opaque AR display and see-through AR display. The experiment showed Augmented Reality was a better instructional method for assembly of motherboards than both computer-aided and the traditional paper based instructions. Augmented Reality solutions were also shown to be faster than the traditional ones.

Another study of the effectiveness of Augmented Reality was done by Tang, et al. (2003). They studied the effectiveness of AR in assembling toy blocks and found that users made fewer mistakes when using HWD device as instructional tool compared to traditional methods. They also observed that AR has potential to relieve mental workload on assembly tasks. Further, they found that over-reliance on AR systems can present an issue and the phenomenon of tunnel-attention can in some cases reduce the performance of the user by distracting him from the important matters that require attention.

Henderson and Feiner (2011) explored how AR can provide assistance for mechanics during maintenance and repair tasks. A prototype AR application for assisting mechanics in navigating and repairing inside the cramped interior of an armored vehicle turret was designed and tested. Through HWD the mechanics were able to see "...on-screen instructions, attention-directing symbols, overlaid labels, context-setting 2D and 3D graphics, and animated models" that were overlaid over the mechanic's natural view. This AR application was primarily designed to help the mechanic start various tasks. Henderson and Feiner observed that the AR system allowed the mechanics to move more quickly when compared to their standard employed methods and allowed them to locate tasks faster and easier. Also, they noted that mechanics made fewer head movements during task localization. An additional benefit that was observed was that assistance during the tasks allowed the mechanics more time between different instances and, consequentially, reduced the mental workload. The professionally trained mechanics that were part of the experiment expressed support for the approach and praised it for its intuitiveness and the satisfaction it provided.

### 2.2.2 Design and Testing Procedures

AR systems can also help in the design and testing process by allowing users to test different scenarios in a semi-virtual world before applying it in the real world. Computer generated input can be super-imposed on to the users natural sight or a real-world scene, in order to test different configurations, scenarios and patterns before applying them in the practice.

Previous work in the area has shown that AR can be used to visualize different designs and give the user a sense of how certain changes would fit into the final product. Thomas (1999) investigated how AR could be used to visualize design for a building, modification to a building or extension to an existing building relative to its physical surroundings. Through informal testing, he found that by using AR the user was able to get an improved sense of space and a feeling for the design as well as size and location.

Webster, et al. (n.d.) developed an AR system for improving the construction of space frames in buildings. The system allowed the user to get a sense of where the columns and the re-bars inside of the columns are located even though they were hidden behind a finished wall. They found that the system enabled workers to avoid hidden features like electrical wiring and other structural elements as they were making changes to the structure. Further, Webster, et al. (n.d.) argue that this has potential to speed up maintenance and repair operations and also reduce the amount of accidental damage to the structure.

Another project showed that AR could also be used as a collaboration tool when working on design tasks. Ahlers, et al. (2008) presented a distributed AR system that can enable the users at remote sites to collaborate on design tasks through a shared virtual model that acts as a substitute for a real physical object. They describe how AR systems can be extended to support a multi-user collaboration for an easier design process. They conclude that collaborative AR systems can provide benefits such as increased maintainability, by separating the model from the view. Ahlers, et al. (2008) also point out that collaborative AR systems present building block for cooperation and awareness. Later, they expanded the system to enable mechanics that are working on car engine, to consult with a remote expert about the details of the repair. They argue that the ability to see visible components annotated and to be able to examine objects could improve education, training, embedded design, and any situation requiring skilled user interaction in a real-world setting. They conclude that the details of the procedures can be left to the computer, letting the

mechanics or the expert work directly on the task at hand.

## 2.3 Limitations and Challenges of Augmented Reality Technology

Despite the considerable improvement of the Augmented Reality (AR) technology over the years, there are still challenges that need to be overcome. In this section we describe some of the technological and human-related challenges connected to the AR technology.

### 2.3.1 Technological Challenges

Below we list some of the important technological challenges that would have to be considered before attempting to build an AR system. These are:

#### I. Tracking Technique

The biggest problem in real time 3D tracking lies in the complexity of the scene due to changing conditions and the motion of the targeted objects. Moving objects may separate or merge due to occlusion or image noise and target objects may also change in appearance due to varying light conditions (Zhou, Duh and Billingham, 2008).

Another limitation related to tracking is that objects in the distance cannot be reliably reconstructed and are, therefore not used when the camera input is processed. In this case, the system cannot find identifiable markers like corners and edges on the targeted object which means that the system was not able to recognize the object (Zhou, Duh and Billingham, 2008).

#### II. Augmented Reality Displays

There are a number of problems related to the displays of AR devices that should be considered. For example, HMDs are flexible and portable, but if the user is required to wear them over an extended period of time, they might get uncomfortable, both to the head and the eyes. Also, they have a limited field-of-vision and thus cannot effectively support collaborative work (Zhou, Duh and Billingham, 2008).

Spatial AR displays can supported multiple users, are much easier on the users eye, reduce motion sickness and distraction but have one big disadvantage; they are generally not mobile. Handheld devices are usually mobile but have other problems like tracking, small display and unreliable sensors.



### III. Connectivity

Many of today's AR systems rely on the internet to provide data needed to display the augmented scene on the display. For example, most of AR applications on today's smartphones depend on the data downloaded from the internet, based on the user's position that is retrieved from the GPS. This might present a problem if the user is in an area that is lacking internet coverage, especially so, if the AR application needs to retrieve a large amounts of data from the internet (Sung, 2011).

### IV. Augmented Reality on Smartphones

In Sung's article (2011) the AR expert Steve Feiner argues that "The model of smartphone AR is not good enough at the moment". Feiner states that most of today's smartphones do not have satisfactory sensors to be able to provide and support a user friendly AR system. He identifies the camera and the GPS in the smartphones as the biggest obstacles, due to the fact that they do not provide accurate enough data.

Most of today's GPS systems are simply not accurate enough to provide reliable data needed for the AR system that is dependent on knowing the exact position of the user. The standard GPS is accurate within nine meters which is usually not accurate enough. This presents a bigger problem for AR applications on smartphones than on specialized AR devices, since smartphones are not designed to support AR and are, therefore, usually equipped with a lower quality GPS. Further, the camera in most smartphones does not provide 1:1 relation with the real world; this causes a distorted vision of the reality and becomes a problem when the system has to merge the real and the augmented fast and synchronized (Sung, 2011).

Another issue is the precision of the sensors. Even if the GPS is completely accurate, the AR application needs to accurately provide data that shows which direction the user is facing, the angle between the device and the target object and the position of the device at that moment. All of this needs to be calculated in an instant, in order for the system to be able to sync computer generated with the real world. This is hard since the sensors like gyroscope, accelerometer and compass are often not as accurate as they need to be. This is especially true for smartphones where less accurate and cheaper sensors are sometimes used in order to cut the production costs. Since the camera has no real perception of what it sees, the system needs good accurate sensors to be able to sync the virtual with the real world scene in real-time and in a believable manner (Sung, 2011).

Nevertheless, Feiner is still optimistic when comes to the future of AR on smartphones and can already see an improvement in the area. He mentions that companies like Qualcomm and Nokia are already working on improving their chip technology and making it more tailored for AR systems by improving the communication with the sensors.

### **2.3.2 Human-related Challenges**

Aside from the technical challenges there are some human related challenges that must be overcome before AR can become a socially accepted technology. From a practice perspective this presents important information for anyone considering building an AR system since these challenges would have to be addressed before the implementation. These are:

#### I. Distraction and Over-reliance

The interface of the system must be adapted to be simple and useful in order to avoid overloading the user with information (Krevelen and Poelman, 2010). The interface should be able to provide the required information while allowing the user to be aware of his surroundings. Designing an interface that does not distract with unnecessary information will help prevent the user from missing important cues from his environment. This phenomenon is often called tunnel-vision or tunnel attention and can be addressed by following some general guidelines when designing AR interfaces. At BMW, Bengler and Passaro (2004) came up with some guidelines for AR system design in cars. They suggest that all AR interfaces should have:

- No moving or obstructing imagery
- Only information that improves performance
- Only use information that does not distract, intrude or disturb given different scenarios, in order to avoid side effects like tunnel vision and cognitive capture
- Make it easy for the user to be able to distinguish between the augmentations and reality; for that reason, all superimposed computer-generated data should be easily recognizable as such

#### II. Interface on Smartphones

In Sung's (2011) article Steve Feiner points out that the interface of smartphone AR systems must improve. He argues that too many of today's smartphone AR interfaces are more concerned with how to fit all the

augmentation on the small screen than to actually consider what is necessary and what is not. Feiner points out that smartphone AR interfaces must become more usable, understandable and helpful, and that this can be achieved by designing smarter low level interfaces. He describes an example where an AR system only shows information about objects that are close to the user, or hides the information until it is desired by the user.

### *III. Social Acceptance*

Just like for any other new technology, getting people to use AR may present a bigger challenge than expected. When new technologies are introduced the users are affected on both practical and social level and the process of change requires knowledge about not only the new system but also its domain. Nilsson and Johansson (2007) argue that an introduced system or interface should have as many positive effects on the user and his work as possible, while also reducing the negative effects. Further, they state that essential usability awareness implies that the interface or system should not be harmful or confusing to the user, but rather assist the user in the tasks. Since AR is a relatively new technology for most people, it may take some time getting used to before they start to recognize its benefits. Zhou, Duh and Billinghurst (2008) state that many factors play a role in social acceptance of AR, ranging from unobtrusive fashionable appearance i.e. gloves, helmets etc. to privacy concerns. However, the introduction of the AR technology on mobile devices like smartphones and tablets has allowed the technology to slowly enter our everyday life.

## 3 RESEARCH APPROACH

This section describes the research approach used in this study.

### 3.1 Approach

We applied a qualitative research approach (Creswell, 2007) which was based on interviews. The research was split into two phases:

- Researching the state-of-the art in Augmented Reality
- Interviewing Volvo Trucks employees working in the support network

A qualitative approach was chosen in order to get a deeper understanding of Volvo Trucks employee's work

environment and the challenges that they are facing in a typical workday (Trochim, 2002).

#### 3.1.1 Research Setting

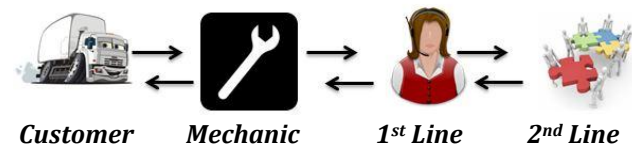
Volvo Trucks is a global truck manufacturer based in Sweden and owned by the Volvo Group. The first Volvo truck was manufactured over 80 years ago and today the company is the second largest heavy-duty truck brand in the world. Currently it employs over 19,000 people with a global support network consisting of over 2,300 service facilities, offering solutions for customers in over 140 countries. The facilities differ in setup, size, number of employees and work methods that they employ.

The research was conducted on two premises:

- Volvo IT office in Lindholmen, Sweden
- Volvo Trucks 2<sup>nd</sup> line support office in Lundby, Sweden

#### 3.1.2 ARGUS – Volvo Case Management System

ARGUS is Volvo Trucks' case-management system. If there is a problem on the truck that mechanics are unable to solve, they create an ARGUS case. The case can then be viewed by multiple parties working in different departments. All of the participants of this research use ARGUS for communicating on various cases, except for some rare occasion when a phone or e-mail is used. The system can be accessed online and has a slightly configured interface for each department. The system is used to create and update cases but also for searching previous solutions and communications within a case. A typical form for creating an ARGUS case includes vehicle information, description of the problem, summary of the problem and attachments (pictures, videos) related to the problem.



**Figure 4:** Shows how different departments and parties communicate on a typical ARGUS case

### 3.2 Data Collection

A total of five interviews with respondents from three different departments were conducted. The respondents are working in Volvo Trucks' support network in three different countries; Sweden, England and Belgium. With

the permission of the respondents the interviews were recorded. Care was taken to assure that the participants were completely anonymous and that their answers would not be identifiable in any subsequent report. This allows the respondents to feel relaxed and have more confidence in their answers which, according to Creswell (2009), generates more truthful data.

### 3.2.1 Interviews

Two interview guides were designed (Appendix D), one for the mechanics and one for the back-end offices (1<sup>st</sup> line and 2<sup>nd</sup> line support). Both guides included three sections: collection of demographic data, questions about the participants work and questions about ARGUS cases. The guides included questions that were open-ended and designed to promote discussion and get the respondents to talk freely about their work. This approach reduced the risk of “leading” questions that sometimes direct the conversation into undesired directions (Creswell, 2009). Accordingly, we were able to ensure that we had minimal impact on respondent’s answers and reduce the risk of steering the interview towards Augmented Reality.

The difference between the two guides was that the guide for the mechanic was more focused on getting insights into the procedure of obtaining the data required for creating a case. The interview guide was then reviewed by representatives from Volvo Trucks and Volvo IT to ensure relevance of the questions.

There were three telephone interviews; two conducted with respondents in England and one conducted with a respondent in Belgium. There were also two on-site interviews conducted with employees from Volvo Trucks 2<sup>nd</sup> line support at their office based at Lundby, Sweden. Originally, it was planned that all of the interviews would be conducted on site; however, this was made impossible due to scheduling constraints. Creswell (2010) argues that interviewing the respondents in their work environment will produce better data because the subject feels more relaxed due to the familiarity of the surroundings. Further, he believes that the researchers are able to get a better perception on the importance of the different segments of data provided by the respondents. For this reason, it was considered important for the research to not only conduct telephone interviews, but also to do interviews in respondents usual work environment.

All interviews were recorded in order to ensure that no data gets overlooked. Approximately five hours of material was collected during the interviews. Each interview lasted between 45 to 60 minutes.

### 3.2.2 Participants

Participants in this study were selected from different departments of Volvo Trucks’ global support network and they were chosen by Volvo Trucks in order to help us get a better understanding of the different stakeholders involved in the process, their daily work and the main challenges that they encounter in a typical workday. The decision of choosing participants from the different departments was based on the fact that different departments have different requirements, different tasks and procedure and different perspectives on things. This approach enabled us to capture several aspects of the work environment and, consequentially, to get a better picture of the work being done.

Based on the data gathered from those interviews we were able to get an overview of their work, their role and the challenges that they are facing in their work. Below follows a brief description of each role.

#### I. Mechanic

One mechanic participated in this research. The main purposes of his workshop is repairing and maintaining trucks and busses that are brought in by the customer. In case that the mechanics cannot repair or solve a problem, they escalate the problem to the 1<sup>st</sup> line support by creating a report of the case in Volvo’s case management system, ARGUS. Before a mechanic raises a case they check Field Service Tips (tips that are released by Volvo Trucks technical support team) to check for available tips that are relevant to their problem.

The mechanic that was interviewed works in a typical maintenance and repair workshop environment. Mechanics use different technologies in their daily work such as laptops, mobile phones and various Volvo testing tools.

#### II. 1<sup>st</sup> line support

Aside for the mechanic, two employees in 1<sup>st</sup> line support also participated in this research. They are part of the technical team working in the 1<sup>st</sup> line support office locates in Gent, Belgium. Their typical workday starts by checking ARGUS for new cases that have been raised by the mechanics. They choose a case based on its priority which is provided by the mechanics according to the severity of the problem. Then they study the case and try to provide a solution for the mechanics if possible, otherwise, they make sure that all input data is provided in the right form before progressing it to 2<sup>nd</sup> line support through ARGUS. This includes translating the case into the correct language, making sure that the

priority is correct and that all of the fields are filled in. The respondents from the 1<sup>st</sup> line support work in a normal office environment where they use computers and telephones to communicate with other departments.

### *III. 2<sup>nd</sup> line support*

Two employees represented second line support. Employees working in the 2<sup>nd</sup> line support are experts in the field that have more knowledge than the mechanics and the 1<sup>st</sup> line support employees. They are usually split into eight functionality groups where each group is specialized in different parts of the truck. They also have a supervisor that is responsible for receiving the case and assigning it to the correct functionality group. The supervisor has an overview of the work done in all functionality groups and can provide assistance if necessary. Once they have found a solution to a problem they update the case in the ARGUS system where it is visible to the mechanics. In some rare cases they use the phone to communicate the solution directly to the mechanics. The 2<sup>nd</sup> line support office located in Lundby is technically oriented with a normal office setup but also includes a workshop-like area where the employees can go to the trucks in order to study them and test different scenarios and solutions. Phones and computers are used in 2<sup>nd</sup> line support's daily work.

### **3.3 Data Analysis**

The transcribed data gathered from the interviews was analyzed by applying the guidelines for thematic analysis. Braun and Clarke (2006) suggest six steps for thematic analysis:

1. Transcribing the data from the interviews by reading them and noting the initial ideas
2. Coding the interesting features of data from interviews
3. Searching for different themes by gathering the codes from the previous step into potential themes
4. Reviewing the themes from step one and two and generate a thematic map based on the analysis
5. Defining clear names for each theme
6. Producing academic report based on the analysis

This is further supported by Creswell (2009) who states that the common themes should be organized into abstract sets of information and this process should be continued until the researcher feels that there are a comprehensive and satisfactory number of common themes from which to draw conclusions.

The transcripts of the data were studied on several occasions and the initial themes were noted. Different

themes were chosen on the basis of perceived need highlighted by the respondents. This allowed the researchers to develop a general sense of the data and have a good overview of the recurring themes. Any common ground and emerging patterns in the data was noted as potential theme. The collected themes were then reviewed and labeled with explanatory names. Next, different segments of what was considered to be high-value data, that provides a satisfactory answer for the asked question, were collected and organized into groups under different themes according to their features. This was continued until the researchers felt that there was an adequate number of a relevant material to draw conclusions from. Some quotes extracted from the data were chosen to illustrate each theme. The themes were then presented and discussed with the Volvo IT representatives to ensure relevancy. Finally a thematic map consisting of two research questions, the observed themes and the participant's quotes; was developed to ensure a good overview of the analysis for future references.

### **3.4 Validation**

To validate the findings a workshop with the representatives from Volvo IT and Volvo Trucks was organized. It included a session where the data was presented and followed by a discussion in order to confirm the validity of the themes that were distilled.

### **3.5 Limitation**

Due to scheduling issues we were not able to conduct a fieldwork by observing the mechanics in their natural environment during a typical workday. Again, the workshop with Volvo IT and Volvo Trucks representatives was used to minimize the negative effect and confirm the interview data.

## **4 FINDINGS**

In this section we present our findings based on the analysis of the interview data.

### **4.1 Quality of Input**

The most important and recurring themes highlighted by the respondents in the interview was the quality of input that each department receives on a typical ARGUS case. Input refers to information required for creating an ARGUS case i.e. vehicle information, problem description, problem summary, problem priority and others. Several respondents state that the input on some

of the mandatory fields, when creating an ARGUS case, is not sufficient and sometimes needs to be sent back in order to be completed or revised. The most frequent issues when it comes to input are:

- The initial input is not good
- The summary is not good
- Bad translations of the description
- Description of the problem is not explanatory or in the wrong language
- Required fields are sometimes left unfilled
- Attachments (pictures, videos) are not descriptive enough

#### **4.1.1 Initial Input**

Most of the respondents, in particular the employees working in the back-end offices (1<sup>st</sup> and 2<sup>nd</sup> line support), highlighted a need for better input. According to the data obtained from the interviews, the issue seems to be that the input that the mechanics provide is not good enough. One of the respondents working in the 2<sup>nd</sup> line support noted that if the initial input is not correct it will complicate things down the line and in some case must be sent back to be revised. Another respondent from the same department observed that better input allows them to solve a case easier and faster. Considering these observations, it seems that by aiding the mechanic in their work would increase the 1<sup>st</sup> and 2<sup>nd</sup> line supports ability to solve the case. This could potentially have a direct impact on the time necessary to provide a solution for a case.

The mechanics, who are the ones that create a case and input the initial information, state that one of their biggest challenges is to not lose the correct story referring to the truck information and the description of the problem that they observe on a truck.

*“One of the challenges that we encountered in a workday is losing the correct story ...”*

Regarding the quality of input the respondents from 1<sup>st</sup> line support observe that the input that they get from the mechanics is not satisfactory. He noted that:

*“Sometimes we got poor information about the problem from the dealer<sup>1</sup>.”*

A respondent from 1<sup>st</sup> line support observed that sometimes they have to contact the mechanic in order to get a better description of the problem. He stated that:

*“Sometimes when the dealer sends us a message we need to send them back another message and say what do you mean? Can you explain more? ...”*

The 1<sup>st</sup> line respondents also point out the importance of getting the correct initial information from the mechanics. They note that good initial input from the mechanics ensures a good flow-of-work and that if the initial input is bad the case may be sent back to be revised, which takes time.

*“The accuracy of the first description is really important, since if the first description is not accurate, it will go wrong for down the line.”*

1<sup>st</sup> line support employees suggest that by improving the quality of information that they receive from the mechanics would also improve the quality input that gets progressed to them.

*“It is good to improve the quality of information that we receive from the customers<sup>2</sup> and in this case we will not asking for additional questions”*

*“If the dealer asks their question in really clear and detail way it would improve the current process ...”*

Likewise, the 2<sup>nd</sup> line support respondents stressed the importance of good input. They state that good input increases their ability to solve cases and that they can provide better solutions to the mechanics if they provide them with descriptive input.

*“A big challenge here is to have the best input in order to solve the problem...”*

Similarly, another respondent from 2<sup>nd</sup> line mentioned that if they receive a more descriptive input they will be able to provide more descriptive output.

*“... the poor input will give poor output and vice versa, if we have rich input the output will be rich as well. ”*

#### **4.1.2 Bad Translations**

Another respondent from the 1<sup>st</sup> lines support acknowledged that sometimes they progress bad information due to uncertainty. One respondent also

<sup>1</sup> Mechanic is referred to as “dealer” in the quote.

<sup>2</sup> Mechanic is referred to as “customer” in this quote.

noted that; if there is nobody responsible for translation the case into a certain language, they will use Google translate to translate it.

*"Sometimes we are not hundred percent successful in translating every single activity in the case, and instead of that, we summarized what has happened, It will be frustrating for back-end office to not understand every activity."*

The respondents from the 2<sup>nd</sup> line office pointed to a similar issue. They noted that the translations obtained in this way do not provide satisfactory description due to many industrial and work- terms that are not familiar to Google translate and therefore do not make sense once they have been translated.

*"Sometimes first line support use Google translator to translate the cases for us."*

*"Sometimes we got strange descriptions, because the first line supports do not know the language in a shift and they use Google translator to translate it."*

### **4.1.3 Communication via ARGUS Case Management System**

Respondents from the 1<sup>st</sup> and 2<sup>nd</sup> line support noted that it is, sometimes, easier to communicate their solutions over the phone due to the complexity of the problem.

## **4.2 Mobility and Accessibility**

In mobile computing, mobility refers to characteristics of device to handle information access, communication and business transactions while in state of motion. Most respondents expressed a need for more mobility, either in their work setup or in ARGUS. In particular, the respondents that were doing on-site maintenance and testing procedures on the trucks since they had to move more in order to complete their daily tasks. They mentioned that this can be a time-consuming if the procedure involves a sequence of tasks that have to be done on separate locations.

### **4.2.1 Mobility in the Workshop Setup**

A matter brought up by the mechanic was that they needed more mobility in the tools that they are using and that their current work setup was not as mobile as they would like it to be. He observed that the computer that is used for the performing diagnostics has to stay connected due to bad battery life. He also mentioned

that, because of the battery life, the computer is never used for anything else than truck diagnostics. The lack of mobility in the current setup requires the mechanics to move in order to retrieve material like tools, manuals, schematics and maintenance records.

The mechanic observed that in order to take a picture of a problem, to use as an attachment for an ARGUS case, he would have to leave the truck in order to locate the camera, take a picture of the problem, go to a desktop computer, do manipulations like shrinking or highlighting the problem and then attaching it to the case. He also expressed that he would like more mobility in tools that they are using.

*"...for transforming the pictures we need to go to computer and connect the camera to the computer and then send it to the help desk<sup>3</sup>"*

He continued:

*"... using iPad or iPhone will make the process much more easier."*

He also expressed a need for more mobility in the tools that they are using for performing diagnostics on the truck.

*"... we want techTool to be more mobile, more adaptable and easy to use."*

Further he observed that the laptop used for the diagnostics has a weak battery and cannot be considered mobile and is therefore never used for anything other than for performing diagnostic on the trucks.

*"Laptop which is taken with us in workshop while we are working with the truck has low battery life."*

One respondent from 2<sup>nd</sup> line support, who sometimes needs to go to the truck, to test various problems and solutions against the truck, mentioned that it would be really helpful to have the schematics on a tablet like iPad. According to him, this would enable him to check the wiring schematics from the location of the truck. Currently, he uses paper schematics but also sees some advantages in having them on a tablet, mainly, because of the interactivity and increased accessibility that they would offer.

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<sup>3</sup> Help desk in this quote is the 1<sup>st</sup> line support desk

*"...it will be good to have electronic schematics in iPad..."*

#### **4.2.2 ARGUS on Mobile Devices**

What underlines the need for mobility is that all of the respondents desired some form of solution for ARGUS on mobile devices. Some respondents highlighted the need of the employees to have a case-handling system on mobile devices. At least one respondent from each department highlighted a need for ARGUS on mobile devices as expressed by one mechanic:

*"... if there is an option to create a case from iPad, it would be really useful, because you can have the information at the vehicle and check against what we got on the vehicle"*

A participant from the 2<sup>nd</sup> line support noted that there is a lack of computer in his office and that ARGUS on mobile devices would speed up the process of including attachments for a case.

*"If we have input via mobile phone it would be really good, because the problem in today's workshop is lack of number of computers and it will increase the speed of the process and it will be much easier to attach the files."*

Another respondent from 2<sup>nd</sup> line support mentioned that he would like to have ARGUS on smartphones.

*"It would be really helpful to have ARGUS on smartphone to send information directly by phone..."*

Similarly, one of the respondents from the 2<sup>nd</sup> line support pointed out that we live in a digital world and that they have to adapt to the new technology that is available. The same respondents remarked that a case-handling system on mobile devices would enable him to solve cases since he would have access to truck information and the latest updates on a case, when not in office.

*"While we have ARGUS on phone we can solve the case while I am at home or travel."*

Given that all of the respondents desired ARGUS on mobile devices it was important to understand the extent of familiarity with mobile devices among the mechanics. In regarding to this, the mechanic estimated

that a big majority of the workers in his workshop own a smartphone.

*"...95% of mobile in workshops are iPhone or Android phones."*

### **4.3 Usability**

The third theme that emerged from the analysis of the data was usability of the ARGUS system interface.

#### **4.3.1 ARGUS**

The 1<sup>st</sup> and the 2<sup>nd</sup> line support seem to agree on the usability of ARGUS. Some of the respondents desired a more adapted interface for the different departments so that for example the 2<sup>nd</sup> line support does not see the information that only 1<sup>st</sup> line support needs. The participants pointed out:

*"ARGUS system is not a good system and it is not user friendly."*

Another respondent working in the 2<sup>nd</sup> line support observes that since ARGUS is static, it affects the usability of the system, because they can only access the system while they are in the office.

*"Biggest problem with ARGUS is complexity of using it, the system is static..."*

## **5 DISCUSSION**

This section discusses the findings and how Augmented Reality (AR) can address the perceived need of Volvo Trucks support employees in order to aid them in their day-to-day work and, thus, provide benefits to the company.

The present study supports the existing literature on the perceived benefits for AR on maintenance and repairing procedures. More importantly, that AR is best used as an aid for practical procedures, specifically, when merging the physical work (e.g. executing repairs) with the information-retrieving process (e.g. obtaining manuals).

In light of this, there are several ways that AR can aid the Volvo Trucks support employees in their day-to-day work. AR systems can provide easy access to information like manuals and maintenance records, easy input of vehicle information or assistance in design procedures.

## 5.1 Quality of Input

Several participants highlighted a need for better input for a typical ARGUS case. There are several ways Augmented Reality can address this. In this section we will present two potential approaches.

### ***5.1.1 Easy access to information to improve input and mobility***

AR has potential to simplify the process of retrieving necessary truck information and, thus, deliver a more mobile mechanism for retrieving any kind of material related to the truck, on the site of the truck. Manuals, schematics and maintenance records stored in a database would be easily accessible by scanning different parts of the truck. If integrated with ARGUS, it would enable for easier input of vehicle information into the case form, since the mechanics would be able to scan vehicle information i.e. the VIN number, the registration number, the truck's mileage; and it would be automatically included in the case. A Study done by Webster, et al. (n.d.) leads us to believe that AR could also be used to visualize hidden information on a truck i.e. wires, pipes, beams and parts that are hidden inside of the truck or non-graphical information like heat, voltage, warnings, maintenance schedules etc.

Easy access to truck information by using AR could be achieved either by scanning the part of the truck or by having unique labels on parts that the system would be able to scan and recognize. By scanning the truck part, the system would be able to register the shape of the part in 3-dimensional space and compare it against a database of 3D models of other truck parts. In the case of the label approach, the AR system would scan the label as a 2D image that is then analyzed and compared against a database of other labels. Both approaches can be used to enable the mechanics to retrieve necessary vehicle information, relevant to the problem, by a simple action of scanning a part or a label on a part.

Both approaches could be used to address the need for mobility in the tools, since the mechanics would not have to move as much if they need to locate i.e. a manuals, schematics or maintenance records. Both approaches have advantages and disadvantages associated with them. The approach with labels would allow for every part to be completely unique, even if there are many parts that appear to be same, the labels would make the parts distinguishable from each other when scanned by an AR device. This would allow the employees to easily access information, i.e. maintenance records, for that exact part. Further, this could be integrated with ARGUS so that information scanned for a

certain case automatically gets included in the case form. This would also allow for further development options, like allowing ARGUS to have every part mentioned in the description as a link that leads to detailed information on that exact part. Providing detailed information in this fashion could improve the quality of input that the mechanics provide and possibly improve the usability of ARGUS. Another advantage of this approach is that it requires a lot less processing power, since it involves 2D image processing, and could therefore potentially be implemented on a mobile device. An additional advantage of the approach is that it is more accurate and not as susceptible to the tracking problem mentioned in this paper.

However, this has to be tested in the work environment and the work conditions of the workshops in order to get conformational data. A downside of the label approach is that the labels would have to be produced and included on parts and a database of labels would have to be created and maintained. Also, the labels would probably have to be maintained and replaced over time to ensure that they are recognizable by the AR system.

The approach without the labels would not allow every part to be unique since it would scan the shape of the targeted object and compare it against a database of other 3D shapes of truck parts. This means that data provide by the AR system would not apply to that exact part but, rather all of the parts with similar shape. This approach would also require more processing power since it would register objects in 3-dimensional space, in real-time. A benefit of this approach, as observed by Reiners, et al. (1998), is that it is easy to integrate into the existing infrastructure since data (i.e. 3D models) designed for other purposes could be reused, therefore, giving additional value to that data. It is important to mention that, due to dynamic nature and changing conditions of a typical workshop, more testing on the accuracy of the AR technology would have to be done in order to get conformational data.

As described, both approaches have potential to deliver more mobility and allow mechanics to obtain the required information on the site of the truck which could potentially increase the quality of input, to a certain extent. Next, we will discuss different ways that the retrieved information can be used in order to assist the employees in their daily procedure.

### ***5.1.2 More instructive material to improve the quality of input***

Previous studies seem to confirm that maintenance and repair procedures present an exciting application



domain for Augmented Reality. Most of the procedures in the domain involve performing an established number of tasks, while interacting with items in dynamic and complex environments. Tight regulations often call for use of various forms of assistance like manuals, computer documentation and other assisting material. Projects like Tang, et al (2003) and more recently Henderson and Feiner (2011), seem to suggest that by merging the psychomotor phase (physical work) with the cognitive phase (information retrieving) AR has potential to be an effective assistance tool for maintenance and repair procedures. Studies done by Baird and Barfield (1999), and later, Tang, et al. (2003) seem to suggest that AR is faster and better instructional tool, for maintenance and repair tasks, than, other commonly used aids in today's workshops.

Projects like Tang, et al (2003) and more recently Henderson and Feiner (2011), demonstrated that, it was possible to reduce the number of instances and amount of movement in each performed task when using AR as an instructional tool. Feiner, et al. (2003) demonstrated effectively that AR can be used as a simple instruction tool for maintenance procedures.

With this in mind, Volvo Trucks support employees could use AR in order to display various instructions, schematics and maintenance and repair records with a simple action of scanning a certain truck part. The user would be presented with interactive step-by-step instructions in form of 2D and 3D graphics like directing symbols, labels and animated instructional models set out in 3-dimensional space and displayed over the user natural view or the real world scene. Schematics and other material could be overlaid over reality in order to visualize the location of wires, pipes and beams on the truck. Depending on the display technique used for the purpose, there could be several possible approaches for the implementation of such AR system. All approaches have different benefits and drawbacks associated with them. In this discussion we will suggest two approaches.

The HMD (Head-Mounted Display) approach would enable the mechanics to have free hands to do manipulations on the truck while simultaneously receiving instructions. It would also involve less movement since employees would not need to retrieve any instructions manually. Some of the possible downsides connected with this approach are over-reliance, distraction and the fact that it requires the employees to wear a HMD that can be uncomfortable for the head and the eyes after a prolonged use. From the implementation perspective, price of such AR device might present another issue and it might also be hard to teach the mechanics how to use the device correctly. As

studies done by Baird and Barfield (1999) and Tang et al. (2003) seem to indicate, a potential benefit of the HWD approach is that training of new employees on different procedures would be made easier and, thus would not require as much assistance from the experienced employees, which would allow them to do other procedures.

Considering the fact that most of the employees wanted a solution on a mobile device and the perceived familiarity with such devices, a mobile approach might be more suitable for this purpose. The most obvious disadvantage of this approach is that it does not allow for free hands. Although, there are various solutions on the market, which could make this approach a hands-free one. Both the HMD- and the mobile device-approach seem to have potential to increase the mobility of the workshop setup when compared to the current one. Also, 3D models designed for other purpose could be used to design the instruction for different tasks. An additional development option would be to integrate ARGUS and the AR device. This would allow the AR device to display information relevant to a specific case i.e. parts mentioned in the description or the summary, warnings, similar cases etc.

Previous projects where AR has been used as an instructional tool seem to support the proposition that the technology has the potential to reduce the number of instances in maintenance and repair procedures, since it does not require the user to retrieve any instructional material manually. Reducing the number of instances in a task, could consequentially reduce the possibility of mistakes. Studies done by Tang, et al. (2003) suggest that by shortening the number of instances in a task it is also possible to decrease the mental workload on the workers, and therefore, potentially increase the employee satisfaction.

Although, using AR as an instructional tool has many notable advantages, it is almost impossible to predict its effectiveness without an extensive testing of the performance under different scenarios in the environment where it is expected to be used. This is especially true, for dynamic environments like workshops, where constantly changing conditions have potential to provoke inconsistency in AR devices. For this reason, AR devices that use spatial display technique seem to be unsuitable for the work environment of Volvo Trucks mechanics.

### **5.1.3 Testing and design to improve the quality of input**

In the testing and design procedures AR systems can help Volvo Trucks support employees by allowing them to test different scenarios in a semi-virtual world before applying them in the real world. Computer-generated input can be super-imposed on to the user's view of the world, in order to test different configurations, scenarios and compatibility between different parts on a truck. A study done by Thomas (1999) indicates that AR could also enable the mechanics to see what a potential design will look in the real-world context or to visualize a potential redesigns to evaluate their compatibility with existing structure. An AR system with these capabilities would allow the mechanics to confirm the validity of their input data, possibly, from the location of the truck, before progressing it. Likewise, the back-end office employees would be able to confirm the validity of their solutions. Such AR system could possibly improve the quality of the input for an average ARGUS case.

Additionally, AR has potential to improve the design and testing process by increasing productivity by i.e. reducing the training, testing and production time by significantly reducing the amount of work required in these phases. Number of instances in each phase would be reduced since there would be no need to produce and work with physical models, instead it would be done in a semi-virtual environment and a virtual 3D model. This could enable for easier and faster manipulation of the model, when compared to working with a physical model. An advantage of this approach is that all changes can be reversed and there would be no need to produce another model in case of a mistake. Another good thing about working with digital models is that they can be reused for other purposes in the later stages of the development process, like in Reiners et al. (1998) door-assembly example, where models developed in the design and production phase were later reused for creating an AR manual.

The capabilities of such systems lead us to believe that a spatial display technique would be best suited for the purpose. Although, the respondents seem to need more mobility and spatial AR device are, for the most part, not mobile, the fact remains that designed procedures usually do not require any movement, but rather a comfortable way of interacting with the design model. Since there is no movement involved the fact that spatial displays are not mobile should not be considered as a disadvantage, but rather an advantage. Another possible advantage of using this display technique is the fact that spatial AR devices usually implement more realistic interaction techniques.

### **5.1.4 Communicating solutions**

Some participants mentioned that it is sometimes easier to use the phone to explain a certain issue. This is not good because the solution gets passed on to the mechanics directly and does not get saved in any form. The usual communication of the solution is done via activities that are attached to the ARGUS case and that can be accessed by several mechanics. The recurring solutions get saved for future references.

Using AR and working with digital models has another advantage that could address this issue to a certain extent; it allows for easier collaboration between users on remote sites, since the digital models can be automatically and simultaneously modified on all instances. Reiner, et al. (1998) indicated that distributed AR is able to provide an effective and precise way of communicating particulars of the problem and the solution. Project like Ahlers, et al. (2008) lead us to believe that collaboration between the mechanics and the back-end offices (1<sup>st</sup> and 2<sup>nd</sup> line support) can be improved by using distributed Augmented Reality. For example, by manipulating a 3D model from his office, an employee of the 2<sup>nd</sup> line support would be able to communicate a solution to the mechanics in the workshop that is observing the same model and is able to follow the procedure in real-time. The mechanic is able to follow the entire procedure almost like it was done in front of him. This has potential to, not only explain the problem in detail, but also to save the procedure for future references. This has potential to improve the communication on typical ARGUS case as well as the quality of input and the usability of ARGUS system.

## **5.2 Mobility and Accessibility**

Another issue, commonly highlighted, by the respondents was mobility and accessibility. This includes:

- Mobility of the setup in the workshops
- ARGUS on mobile devices
- Mobility and accessibility of the schematics

### **5.2.1 Access to camera to improve the quality of input and mobility**

The mechanics described the procedure of taking a picture to use as an attachment for an ARGUS case. He noted the procedure is cumbersome and requires time that could be used for better purposes. For these reasons, the camera is almost never used. Considering the fact that the 1<sup>st</sup> and 2<sup>nd</sup> line support respondents

desired better input from the mechanics, and that one respondent from the 2<sup>nd</sup> line support explicitly mentioned that they do not get enough attachments, this seems to be an important issue. AR seems to be able to address this issue and improve the procedure needed to create an attachment for an ARGUS case.

Most of AR systems rely on camera for the visual input; this means that the user of an AR system would have easy access to a camera. Thus, picture and video could be taken and later, manipulated, directly from the location of the truck. The mechanic would not need to move as much in order to upload attachments to the ARGUS system. Augmented Reality could also provide additional options when editing the material by providing 3D input so the user would be able to provide further information about the scene before taking the picture. Pointers, guides, video and audio files that explain the problem could be placed onto the real-world scene before capturing it as a picture or a video, that could then be directly attached to an ARGUS case. This has potential to simplify the procedure of creating the material for the attachments and produce more instructive attachments, and thus, improve mobility as well as quality of input. The employees working in the back-end offices (1<sup>st</sup> and 2<sup>nd</sup> line support) would get more descriptive attachments, which could potentially enable them to provide better and faster solutions.

Further, since almost all of the respondents desired some kind of solution on mobile devices, this would be possible to implement on both smartphones and tablets. As emphasized in the literature review, the choice of display technique is always one of the first design decisions that would have to be taken when building AR systems. Further, different display techniques have different advantages and disadvantages that makes some more appropriate for certain problems than others. Considering the limitations and challenges of AR on mobile devices and, in particular, smartphones, care should be taken to study and address the challenges described in this paper before attempting any implementations.

### 5.3 Usability

We were not able to find a good way to address the usability of ARGUS with AR. Although there is no obvious way to address the usability of the ARGUS system with AR, it has to be mentioned that in order to accommodate changes and successfully integrate AR into the current system, ARGUS would have to be developed further. This would include developing support for ARGUS on mobile devices and integrating the AR technology with ARGUS. Though, it may not address the specific needs

highlighted by the respondents in regards to the interface of ARGUS, it will certainly make the system more mobile and information-rich, thus, the usability of the system would improve. Another scenario could be a complete redesign of the interface to accommodate the AR technology.

### 5.4 Methodological Limitations

The researchers are open to the possibility that there may be additional themes that were not addressed by this paper. Kirk and Miller (1986) note that the aim of a qualitative observation is to identify the presence or absence of a something, in contrast to quantitative observation which aims to measure the degree to which something is present. Moreover, qualitative observations are always based on the perception of the researcher and therefore cannot, and do not, aim to answer all of the questions, or give conclusive answers, instead they aim to achieve a step towards discovery of the truth.

## 6 CONCLUSION

This paper set out to investigate how Augmented Reality (AR) can aid Volvo Trucks support employees in their day-to-day work and potential benefits that AR can bring to the company. We interviewed employees working in Volvo Trucks' support network in order to capture their needs and understand how Augmented Reality could address those needs. The analysis revealed three interrelated themes in terms of perceived needs: quality of input, mobility and accessibility and usability of ARGUS. The paper provides insights on the possibilities of AR application in the automotive industry, in particular the area of maintenance and repair. It also provides suggestions for future research in the field of AR in the automotive industry and beyond.

### 6.1 Implications for Research

The study suggests that by using AR to provide mechanics with assistance in their daily work, Volvo Trucks would be able to improve the mobility of their tools and workshop setup as well as the quality of input on a typical ARGUS case. This in turn would maximize the 1<sup>st</sup> and 2<sup>nd</sup> line support's chances of providing better and faster solutions. The main benefits observed in this study include:

- Easier access to information on truck parts
- Instructive material for maintenance and repair procedures
- Better problem-capturing mechanism
- Communicating solutions

- Simplify testing and design procedures
- Training new employees
- Better input when creating ARGUS case
- Better mobility in the workshops
- Faster solutions

Depending on the tasks involved, these benefits could also apply for other industries where maintenance and repair procedures take place.

## 6.2 Implications for Practice

Our data points to a need for better mobility in the workshops and for ARGUS on mobile devices. Further, it seems that better input from the mechanics is required in order to maximize the back-end office's chances of providing good solutions. Lastly, a more optimized and user friendly ARGUS interface is desired. If implemented correctly Augmented Reality has potential to aid Volvo Trucks support employees in several areas and improve upon their current situation by addressing some of their needs to a certain extent.

AR can provide better mobility by addressing the camera issue and making it easier to take pictures from the location of the truck. AR can also be used as simple input and output mechanism for vehicle information. It can be used as an instructional tool when doing maintenance and repair procedures on the truck and for training of new employees. It can be used to overlay wiring schematics over the truck to provide better indication of the wires. It can also be used to locate maintenance records and schematics by scanning various parts. It can be used as a collaboration tool when testing and doing design procedures which would enable the employees to test their solutions before progressing them. Finally, it can be used to communicate the details of the problem or the solution.

## 6.3 Future research

This paper presents important insights that need to be considered before implementing Augmented Reality for maintenance and repair procedures in the automotive industry. Firstly, more research should be done to validate the findings of this research and to investigate whether more themes can be found. Secondly, there should be more research to investigate how AR can address the usability of the ARGUS case-handling system.

Further, using AR has many observed benefits, but it is almost impossible to predict its effectiveness in a certain environment without an extensive testing of the technologies under different scenarios. This is especially

true, for dynamic environments such as Volvo Trucks workshops, where constantly changing conditions have potential to provoke inconsistency in AR devices. Therefore a natural next step for Volvo would be to develop a prototype based on the findings of the report. The prototype should then be tested in the considered work environment under different scenarios involving standard procedures. If the tests validate the perceived benefits of this study, a complete implementation of the system and integration into the work method should be attempted.

As for the future of Augmented Reality, it can be said, with great deal of certainty, that it will infiltrate more areas as the technology matures. The natural evolution would involve more supported devices that, today, would not be necessarily associated with Augmented Reality, so in the not so distant future we might all be living in a very augmented reality.

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# APPENDIX

## A. Terms & Abbreviations

<b>ARGUS</b>	Volvo Case Management System
<b>Augmented</b>	made greater, as in size, extent or quality
<b>Augmented Reality (AR)</b>	Refers to the Augmented Reality technology that includes a number of supporting technologies (Image processing, GPS, 3D manipulations and others...)
<b>CPU</b>	Central Processing Unit
<b>DR</b>	Diminished Reality
<b>GPS</b>	Global Positioning System
<b>HMD</b>	Head-Mounted Display
<b>HWD</b>	Head-Worn Display
<b>IT</b>	Information Technology
<b>OST</b>	Optical See-Through
<b>VIN</b>	Vehicle Identification Number
<b>Volvo IT</b>	The IT division of the Volvo Group
<b>Volvo Truck</b>	Division of the Volvo Group
<b>VR</b>	Virtual Reality
<b>VST</b>	Video See-Through

## B. Keywords

The following keywords used to search for relevant literature:

- Augmented reality technology
- Augmented reality in different applications
  - Designing
  - Testing
  - Manufacturing
  - Assembling
  - Repairing
  - Medical
  - Entertainment

- Education and training
- Augmented reality state-of-the Art (current knowledge)
- Augmented reality specification
- Augmented reality limitations, issues and barriers
- Augmented reality in market
- Augmented reality devices
- Augmented reality surveys
- Augmented reality in industry

### C. Search Engines

- *Chans* <http://chans.lib.chalmers.se/>
- *Libris* <http://libris.kb.se/>
- *Chalmers Library* <http://lib.chalmers.se>
- *ProQuest* <http://search.proquest.com/index?accountid=10041>
- *Chalmers Catalogue* <http://www.lib.chalmers.se/find/eres/db/>
- *Google Scholar* <http://scholar.google.se/>
- *Scirus* <http://scirus.com/>
- *IEEE Explore* <http://ieeexplore.ieee.org/Xplore/dynhome.jsp>

### D. Interview guides

This appendix indicates interview questions which used during the five interviews described in this paper. The first section shows 1<sup>st</sup> and 2<sup>nd</sup> line support interview guide and the second section shows the interview guide for the mechanics.

#### **First and Second line support Interview Guide**

##### *Collection of demographic data*

- Name?
- What type of work do you usually do? Role?
- Fulltime/part-time?
- How long have you been working in this role?

##### *Data collection*

- Describe your typical workday?
- What are the challenges/problems that you encounter on a normal working day?
- What are the most critical tasks?
- What are the most time-consuming tasks? Why?
- What type of technology are you using in your daily work? (OBS! Give examples!)

##### *Case*

- How much of your working time do you spend on cases?
- What's the procedure/process when handling a case?
- What type of information is necessary when handling a case?
- How do you obtain it?
- How is the quality of the received cases?
- From you viewpoint, how would you describe the challenges of handling a case?



- How would you improve to the current process of handling cases?

### **Mechanic Interview Guide**

#### *Mechanics information*

- Name?
- Workshop base?
- Main purpose of dealership (Truck, Buss...)
- How many technicians are working in the dealership?
- Location?

#### *Collection of demographic data*

- Name?
- What type of work do you usually do? Role?
- Age?
- Fulltime/part-time?
- How long have you been working in your current role?

#### *Data collection*

- Describe your typical workday?
- What are the challenges/problems that you encounter on a normal working day?
- What type of technology are you using in your daily work? (If they want clarification on technology; example **tools**)
- What is your experience of using information technology (IT)?
- What is important for you to be able to work effectively?
- From you viewpoint, what would improve your daily work?

#### *Case*

- How often do you create a case?
- Please describe the procedure for creating a case?
- What type information is necessary when creating a case?
- How do you obtain necessary information?
- What is the most time-consuming in this process?
- What are the main challenges in creating a case? Why?
- Is there a procedure to avoid creating a case? How?
- From your perspective, what is needed to improve case-creating process?
- Is it possible to create a fake case?