CaRE – A Framework for a Multimedia Assistance System for Singletons
"Does IT help?"

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Abstract

In contrast to the increasing degree of automation in the production industry, commissioning and maintenance activities will essentially be limited to manual activities. Production involves repetitive actions that are manageable and clearly defined as a process. Unlike this, commissioning and maintenance have to deal with uncontrollable, undefined, and non - standardized processes. The paper provides a framework for a multimedia assistance system for singletons. It was found that the paradigm has to consist of five key components to provide tailored assistance to customers. These key components are Expertise, Infrastructure, Application & Platforms, Security & Privacy and Business Process & Business Model. The resulting stack and the overlaying business model are called "CaRE – Custom Assistance for Remote Employees". With a user-centered approach, the needs of the target group were identified. Based on this, the framework was implemented in the form of a prototypical application. To check, whether the assumptions regarding a Multimedia Assistance System are correct, the prototypical developed application was tested with aremote-usability test.

Keywords

Multimedia, Assistance, CaRE, Software.

1. Introduction

During the last decades, many processes and workflows, especially in production environments, changed significantly. Thereby some of the processes are getting more and more complex and sophisticated. With the help of new information systems, it is tried to meet these challenges. The fourth industrial revolution and the fusion of humans and machines to form cyber-physical systems (CPS) are revolutionizing processes and procedures, especially in production-related companies. One of the consequences is that maintenance and service activities are becoming more and more complex and time-consuming. "Smart Maintenance" results in entirely new interconnection, qualification, and support requirements for people involved. Where maintenance-relevant data previously had to be entered manually, these can also be recorded automatically in the future.

In contrast to the increasing degree of automation in production, maintenance and servicing will also in the future be essentially limited to manual activities. Production involves repetitive activities that are manageable and clearly defined as a process. [1] In contrast, maintenance and servicing have to deal with "uncontrollable," undefined, and, above all, non-standardized processes. Furthermore, this is of utmost importance whenever commissioning or maintenance has to be done at singletons in electrical environments. To help users during their tasks, a multimedia assistance system can be used.

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Structure

In chapter 2, some delimitations and state-of-the-art systems are presented. The next chapter describes the CaRE pyramid and the items. In chapter 4, the design guidelines for a multimedia assistance system are presented. The implementation and field-test of the pyramid are described in chapter 5. Finally, the conclusion and future work is represented in chapter 6.

Related Work

With products and singletons becoming more and more complex, it is logistically and for cost reasons, not always possible to send a specialist to the site. As a result, maintenance personnel often have no previous experience with a product to be commissioned or serviced. Nevertheless, implicit knowledge is necessary to carry out most of the work which has to be done on-site. (see [2]). In literature, many possible solutions in terms of "Smart Factory" ([3], [4], [5]), "Cognitive Assistance" ([6], [7]) or "Industry 4.0" ([8], [9])are mentioned. However, there are no examples of how employees can be supported if they are

1. not in a factory,
2. do not have a basic knowledge of the product to be maintained and
3. dealing with singletons

Especially in the energy sector, long-living singletons are common. Parts of an energy network may last for an entire generation in a company. Since such substations are often located outside inhabited areas, the cellular Network might be insufficient. Furthermore, with the help of mobile phones and email, important information might get lost. Multimedia Assistance Systems partially support non-verbal communication, which means that information can be made available more efficiently.

2. MULTIMEDIA ASSISTANCE SYSTEM

According to Tay Vaughan, Multimedia is defined as [10]

"Multimedia is any combination of text, graphic art, sound, animation, and video that is delivered by computer."

This means that multimedia refers to an electronically delivered combination of media, like videos, images, and text. Furthermore, this data can be accessed interactively and on-demand.
Assistance Systems are widely used in daily life and can be seen as indications of an increasing connection between humans and technology. A few examples are stated below:

- Consumer Industry: Cellphones, Laptops, Wearables
- Medical Technology: Implants, Exoskeleton
- Communication Technology: Intelligent Home and Wireless Networks
- Production Technology: Human-Robotics Interaction
- ...

In all of those mentioned examples, it can be distinguished between those two types of technical assistance systems [11]

- Technical systems that substitute a person and thereby relieve the burden lead (technology carries out the task for humans)

- Technical systems that support people in performing their tasks without replacing them (people retain sovereignty and are supported by the technology appropriately)

Taking into account the previous arguments, this paper is based on the following definition of assistance systems:

A technical system is a Multimedia Assistance System if

1. it supports people in activities without substituting them in whole or in part,
2. it leaves the sovereignty over the execution to humans (target value specification by an operator, no mandatory specifications) and
3. the system interactively provides multimedia data.

2.1. State of the Art

In the literature, there are some approaches on how assistance systems can be developed in connection with "Smart Factories" and which advantages companies can achieve from it.

As an example, the maintenance strategy can be changed from reactive maintenance (in case of an error) to preventive maintenance (based on historical values) or even predictive maintenance (based on real-time values). Based on a survey, 57% of companies in Germany do not have any data basis on which maintenance activities are planned, 39% are using historical data [12].

Knowledge management is known as one key factor for a company's success since it protects a company from losing its most important asset called "know-how". The loss of know-how results from rapid changes in personnel, as a consequence of not only demographic change and fixed-term employment contracts, but also data loss because of individual stress on employees. Knowledge management thus ensures that necessary knowledge and skills to achieve strategic and operational goals exist. [13]

The processes and activities in maintenance are characteristic due to a high (technical) complexity and an increased uniqueness compared to production processes. With this background, (multimedia) assistance systems that support employees in complex tasks and thus improve the effectiveness and quality of work are becoming more interesting for companies. [14]

Spare parts management is the basis for solving all tasks effectively and sustainably. It is ensured that necessary work materials are available sufficiently so that maintenance and repair tasks are carried out in a reasonable and – if possible – optimal time. The spare part management influences the stock costs, availability of spare parts, and thus the related expenditure of time during maintenance. [15]

When focusing on commissioning and maintenance for singletons, the following problems may occur:

- Important data (like types or serial numbers) are inserted into multiple systems multiple times. If parts are changed, this leads to inconsistencies among those systems and it is not clear which serial number is the actual one.
- Help with the telephone is hard or nearly impossible because the expert cannot see the problems on-site. Describing sometimes works, but especially when dealing with different languages or jargon, complications may occur.

- Drawings are printed and handed over to supervisors. If changes are made during commissioning or maintenance, those changes are marked directly at the drawing. It takes up to months till the drawings in the factory are updated.
- Damages (either during transport, commissioning or during lifetime) are documented with cellphones or cameras. Emails are sent back and forth, or the pictures are stored on a supervisor's computer.
- The entire lifetime of singletons in electrical environments may last up to 40 years. Unfortunately, this means that hardly any person knows about the changes which were made during their lifetime.

It could be seen that some approaches might be helpful both in an industrial context, smart maintenance, or knowledge management. Nevertheless, non of them fit entirely into the site requirements because of a different context of use.

Furthermore, only parts of the problems above are solved. To eliminate all those problems, the CaRE pyramid was implemented, which can be seen as a framework for Multimedia Assistance Systems for singletons.

3. CaRE Pyramid

A system that users should accept has to be developed together with users. With this in mind, several workshops and interviews were conducted. It could be seen that the two primary needs have to be fulfilled:

- More accessible emergency help: If the expert needs to be called, most of the time, an emergency occurred and immediate help is required (later called Remote Assistance)
- More accessible documentation: The documentation at the site is of utmost importance and takes a lot of time (later called Multimedia Assistance)

It could be seen that for multimedia assistance systems (both remote assistance and multimedia assistance), a holistic approach must be considered. Five key components are necessary to come over those needs. Those components can be visualized in the form of a pyramid. Those five components can be seen as parts of the pyramid which rely on each other:

- Expertise
- Infrastructure
- Applications and Platforms
- Security and Privacy
- Business Processes and Model

The pyramid itself cannot be inverted. Those five components can be applied to both multimedia assistance and remote assistance, where an expert is assisting through telephone or "I see what you see" application. In both cases, those five components have to be fulfilled to provide successful assistance:

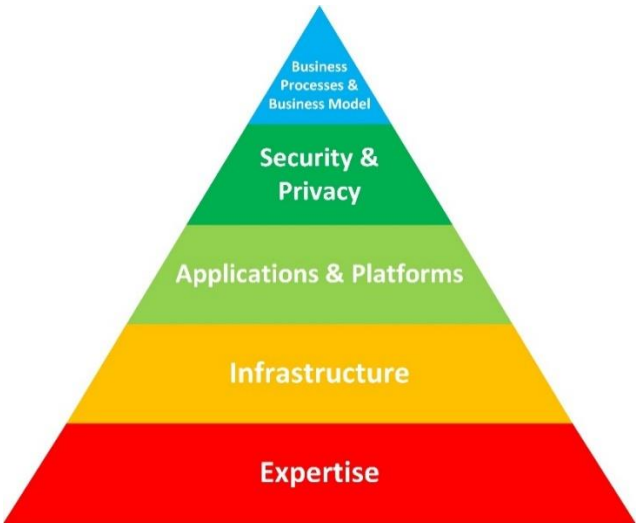

Figure 1: CaRE Pyramid

3.1. Expertise

Expertise describes the basis of the stack, as seen in Figure *1*. Without domain knowledge, assistance is meaningless and not applicable. With remote assistance, it is likelier that the desired expert is available immediately. For example, field engineers have to wait more than one week to get working permissions in some cases. Furthermore, the daily fees for field engineers are expensive, which means that customers have to pay thousands of euros for unproductive dwell times. In this case, it would be possibly cheaper to send engineers from the customer to the site and help them via remote assistance. Furthermore, a single expert can work on more than one site in parallel, even if these sites are located in different places. Another benefit is that there is the possibility to accomplish a group conference call if more than one expert is needed.

When assisting with multimedia assistance applications, the users at the site need to have at least basic domain knowledge. If, for example, a specific jargon is used during maintenance or commissioning, the workers at the site need to at least have a basic understanding.

Moreover, the work on-site must be done in any case. The work which needs to be done is manual and cannot be done by robots or artificial intelligence: Traditional work will not go extinct.

3.2. Infrastructure

The infrastructure part can be divided into a network and hardware part.

3.2.1. Network

A comprehensive availability of broadband internet is necessary for both parties. This is both important for video- and audio conferring, as well as for sending data over the Network. According to recent studies, in more than 80 countries, more than half of the area is covered by 4G [16]. In the US, for example, the coverage is more than 90%. However, poor network quality and low bandwidth remote assistance will lead to dissatisfaction.

Since substations may be in regions that are not entirely inhabited, the internet connection might not be sufficient. Therefore a small box with an embedded router was implemented. The so-called “Remote Access Box” consists of a switch-mode power supply that allows AC/DC and different voltage levels. The power supply cable is connected with so-called bayonet connectors, which are also safe against water intrusion and minor impacts. Whenever the power supply is connected, the box starts automatically. In closed operation, without any connected periphery, the box reaches IP protection class 64.

Inside the box, an LTE router is mounted. Two antennas are located inside the case; for the other two antennas, ducts in the surface are available. These two antennas do have a five-meter cable and can be placed at windows or doors. To connect to the wireless Network, the QR Code on the surface can be scanned.

The SIM card slot is also available with a duct at the surface. In addition, two RJ 45 Ethernet connectors are available for connections with LAN cables. With those cables, it is also possible to supply a wired internet connection.

After booting, the router automatically connects with the VPN Server inside the company network. Thus a secure communication is guaranteed.

3.2.2. Hardware

In terms of Hardware, it must be distinguished between remote assistance and multimedia assistance.

3.2.2.1. Remote Assistance

In maintenance, the service technicians often need both hands free and have to be mobile. Due to that fact, the first evaluation mainly focused on wearables. Four types of wearables are available. [17]

- binocular and non-see-through
- binocular and see-through
- monocular and non-see-through
- monocular and see-though

A literature review has shown that some key criteria have to be met to provide a useful wearable in a maintenance context. ([17], [18], [19]) Those criteria are:

- Wearing Comfort
- Battery Lifetime
- Field of View
- Navigation

Wearing Comfort

In the case of service activities, the device may be worn over a more extended period. The musculature in the neck area is stressed, even if the wearable itself is not heavy. Some devices use nose bridges, brackets for ears, or some sort of neck holder. The device should not be too heavy, but it should be rugged if it falls to the ground. The device should offer the possibility of individual wearing settings. It has to sit well because the wearing feeling is mainly influenced by

the mounting method. Users have to trust that the device is seated well and won't come off suddenly.

Battery Lifetime

The time assistance is needed during maintenance may be between some minutes or hours. Even if the device is not required during the entire working process, the battery shall be durable and have a battery life of approximately one working day. It is worse if the device battery is getting empty when assistance is needed. Therefore, the battery of the device should be fast loading or replaceable.

Field of View (FOV)

The standard FOV of humans is 200° horizontally and 135° vertically. [20]The user sight should not be limited significantly and the users should not lose their situational perception. With a limited field of view, the eyes are stressed, which leads to eye strain and dry eyes. [17] A wide field of view is desirable and also linked to improved user acceptance. It should furthermore be possible to wear eyeglasses beyond the wearable.

Navigation

It must be easy to navigate inside the operating system of the wearable. Therefore, these three input methods are available:

- Buttons directly at the device
- Speech
- Gestures

All of these three types are not useful during maintenance operations. Therefore, a companion app should be available. With these apps, it is possible to interact with the devices. For example, they may offer a keyboard that makes entering text more accessible.

Tests were conducted with the Microsoft Hololens (binocular and see-through), the Daqri Smart Glass (binocular and see-through) and the Realwear HMT-1 (monocular and non-see-through). Binoculars which are non-see-through are not suitable for maintenance activities. Also, Augmented Reality is not necessarily needed. Additionally, it has to be clarified if a full-face display is required. If not, wearable with a microdisplay or a tablet may also fulfill the needs during remote assistance.

It could be seen that situational perception suffers when full-face displays are used. For example, test persons could not see harmful items, even though they occur in their standard field of view. The Realwear HMT-1 has a microdisplay mounted on a small arm. Due to that, it is possible to move the display out of the field of view whenever it is not needed.

Furthermore, it could be seen that the Hololens and the Daqri Smart Glass are becoming heavy, although their weight is only around 370g. Wearing the Hololens or the Daqri Smart Glass underneath a helmet is physically exhausting over a more extended period. Therefore, a device is required which is comfortable to wear for the user. It is often necessary to wear personal safety equipment such as safety glasses or safety helmets in production environments. If engineers wear the Hololens, it is essential to wear safety glasses underneath. In contrast to that, Daqri Smart Glass would count as personal safety equipment (PSE).

Additionally, the Hololens is heating up at the processing unit located right above the ear. The Daqri Smart Glass computing unit is an external device, which can be mounted on a belt. In the case of menu navigation during usage, both Hololens and Daqri Smart Glass are using gestures. It takes some time to learn those gestures, but users got more and more experienced with these gestures after a short time. In contrast to that, the Realwear HMT-1 uses speech recognition for navigation. However, in environments with high sound intensity, speech recognition is not suitable.

Based on the evaluation results, it was decided to use the Realware HMT-1 for remote assistance activities. Despite having the smallest display has the best wearing comfort of all tested devices. Furthermore, it offers the possibility to replace the battery if needed and uses an Android operating system which is standard on many devices.

3.2.2.2. Multimedia Assistance

During commissioning and maintenance, supervisors must be mobile. This means that only a part of devices is suitable as the basis for multimedia assistance applications. Thus the following types were used during the tests:

- Tablet Computer (Vendor Samsung)
- Cell Phone (Vendor Apple)
- Laptop Computer (Vendor HP)
- 2-in-1 Computer Convertible (Vendor Microsoft)

It could be seen that the display of a cellphone is too small for usage. Even if the application is responsive and fits itself to the available screen size, the user interface is no more user friendly. Even if users are familiar with scrolling inside apps, the lists are becoming too long, and searching for specific items is hard. Usage of a tablet computer solves the issue with the screen size. Also, the interaction with fingers in different parts of the application (like annotating) is working well. As a drawback, it must be mentioned that the input of long character sequences is not easy since the ten-finger typing is hardly possible: The heel of the hand cannot be placed in the same way as on usual keyboards, which leads to an unfamiliar posture.

Furthermore, the feedback of the screen keyboard is also unfamiliar in terms of the ten-finger system. As a result of those two drawbacks, only a Laptop computer or 2-in-1 convertible seems suitable for those actions. Since it is sometimes necessary to climb on top of the workpiece, Laptop computers might be impractical. Furthermore, Laptop computers sometimes only have one camera, which is located in front of the screen. With this location, it is nearly impossible to take pictures. If no desk or position is available where the Laptop computer can be placed, it is also impractical to hold the Laptop computer with one hand, whereas the other hand is used to navigate. Even if the Laptop computer weighs only 1.74kg, the device becomes heavy immediately.

Based on the results of the evaluation, it was decided to use the convertible. Despite having the worst battery, it has the best features and characteristics of all tested devices.

To summarize, the following Hardware was selected as appropriate for an assistance system:

- The Realwear HMT-1 for remote assistance calls. Even if some advertisements show the benefits of apps running on such wearables, it could be seen that this is impractical in real life. As stated above, the perception is suffering, and it is exhausting. Therefore, those devices should only be used if needed for remote assistance calls.

- A 2-in-1 convertible for the usage of the Multimedia Assistance System. Since these kinds of devices are both laptop and tablet, they are flexible in many cases. For multimedia assistance, they can be used to take pictures and make quick notes and documentation in the site office.

3.3. Application and Platform

A supporting application or platform is necessary for sharing knowledge and providing help during commissioning and maintenance activities. In terms of Applications and Platforms, it can be distinguished between remote assistance and multimedia assistance.

3.3.1. Remote Assistance

There are many possible solutions for remote assistance which are already in place. Some of them are listed below:

- Librestream (https://librestream.com/)
- Fieldbit (https://www.fieldbit.net/)
- Stream (https://www.streem.com/)
- Skype for Business (https://www.skype.com/de/business/)
- Teamviewer Frontline (https://www.teamviewer.com/de/loesungen/frontline/)
- and many more.

All of the mentioned systems have their unique selling proposition. After deciding to go along with Realwear HMT-1 for remote assistance, the application Skype for Business, Librestream and Teamviewer was evaluated because licenses were available for further researches. It was decided to use an existing one since all the required features below are already in place in all of the mentioned ones. It would make no sense to develop an own one in this case.

After discussions and interviews with the target group, criteria for a software platform that is usable in maintenance activities were identified:

- Usability & User Acceptance
- Annotations or Pointer Functionality
- Mutliconferencing
- Chat Function
- Reporting

Usability & User Acceptance

The key factor of the software is that it has to be accepted by the users both in the field as well as in the office (experts). Therefore, the user interface has to provide the most important functionalities at a glance so that service technicians can navigate quickly. For example, it should be easy to select the desired expert. The web interface of all systems is user-friendly. Even though Teamviewer and Librestream have more possibilities and features than Skype, the user interface appears to be tidy and well-structured. Depending on the bandwidth and the selected device, the video and audio quality is equal on all systems.

Annotation or Pointing Functionality

The expert should have the possibility to point or annotate certain things in the video. In the field tests, it could be seen that some field engineers – if they are non-native speakers of the language spoken by the expert – have problems understanding what the expert intends. This helps the field engineers to identify objects and makes it easier to understand what the expert is talking about. According [21], visual annotations are a key factor for successful remote assistance. But the usage of annotations on static images is dangerous, especially when using head-mounted devices. They may cause a loss of orientation for a short period, which may become hazardous in industrial environments.

Furthermore, annotations onto a live video stream may limit one's sight. This means that annotations are helpful, but they must be used carefully. Additionally, it should be possible to send documents or drawings, which also might be annotated.

Multi-conferencing

In some cases, one expert alone is not capable of resolving the issues at the site. Therefore the possibility of conference calls should be available. With this feature, a group of people can help one or more engineers at the site.

Chat Function

In some cases – especially in noisy environments – some of the commands to the field engineers are not understandable. In this case, a chat function where an expert can write down requests is necessary. Furthermore, it is imaginable that engineers at the site have to change some parameters of the software. Therefore, it is easier to send text messages with the desired parameter than to describe the values.

Reporting

After finalizing a remote assistance session, it should be easily possible to create a report. So it should, for example, be possible to create a PDF document with all participants written down, the period of the conference, or the text messages sent. This report can be used for internal documentation or as a prove for the customers.

As mentioned above, all of the three systems do have some features and characteristics which are helpful. Thus it cannot be said which of the systems above is the best and which suits most. Skype for Business has the advantage of seamlessly integrating into the Windows environment, which makes it easier to select an appropriate expert. Teamviewer has the advantage of sharing the screen with other participants who can also interact with the remote computer. Librestream has the advantage of providing end-to-end communication with no server in between, which makes it the best in terms of security and Privacy. Unfortunately, there is no mixture of all three systems, selecting the best of all three solutions.

3.3.2. Multimedia Assistance

As already stated, some multimedia assistance applications are already in place. Examples of systems that are already in place are:

- Reportheld (https://www.reportheld.com/)
- Workheld (https://tabletsolutions.at/)

- Evoassist (https://evoassist.evolaris.net/)
- ProWorkFlow (https://www.proworkflow.com/)

Unfortunately, non of them fitted to the needs of the users due to:

- Different contexts of use
- No offline availability
- No spare part management
- No interface for external systems or sources
- Drawings cannot be integrated

So it was decided to create a flexible multimedia assistance application as a prove of concept. Therefore, the CaRE lifecycle shown in

Figure *2* was used:

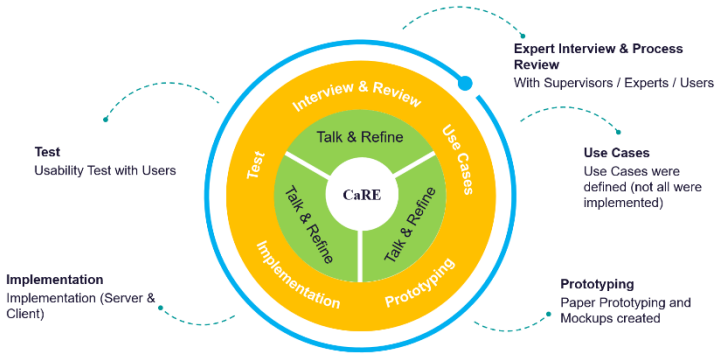

Figure 2: CaRE Lifecycle

As it can be seen, the CaRE lifecycle has its basis in the Deming PDCA (plan-do-check-act) cycle [22] and has the following items:

- Interview and Review
- Criteria Catalogue
- Prototyping
- Implementation
- Test

Above everything, "Talk and Refine" needs to be mentioned, which means that it was communicated with the target group during the entire lifecycle. During the mentioned interview and review part, it was found out that the following topics should be met:

- The application should lower the cognitive workload of the users
- The user interface should only show the topics which are of relevance (parts which are not applicable should be invisible)
- It should be user-friendly and supervisors should get a friendly frontend. If possible, the look and feel of the paper should be indicated.
- Data should be shown in real-time.
- The application should have the same look and feel as it is already known to the supervisors.

- It should work offline without an internet connection.
- New and revised drawings should be available automatically. Furthermore, it should be possible to mark changes on the drawings.
- Serial numbers should be detected automatically.
- It should be able to create markers not to forget work-items
- Data should be already inserted if it is available in another system.

Based on this criteria catalog, a paper prototype was created together with the target group. This prototype was implemented in the form of a prove of concept. Due to Covid-19, no face-to-face usability test was possible. Instead, a remote usability test was done. Therefore an Microsoft Teams session was started. The interviewer launched the application and shared the screen with the participant. The participant turned on the camera and got control over the interviewers' computer. The participant was asked to fulfill the tasks and think loudly. With the camera turned on, the facial expressions and gesturing could be seen.

3.4. Security and Privacy

applications like CaRE provide new challenges regarding time-sensitive networking (TSN) [23]as well as for real-time networks [24]. Security and Privacy have to be met at all levels all the time. Companies must provide security measures to protect their data, Business, and reputation. Security breaches often lead to loss of reputation and monetary loss. In addition to that, data protection regulations, like the GDPR, force business to protect their data. That means that security is mostly driven from top to down, which also means that the usability of these security measures suffers. In former times, the security measures were often bypassed, which should not happen now.

According to Gartner, 124 Billion Dollars were spent on information security from enterprises in 2019 [25]. Not only enterprise security has a high significance. According to Eurostat, approximately 1 in 3 EU citizens reported security-related incidents in 2019. Especially in the electrical industry, security is essential to ensure an undisturbed power supply. In North America, NERC is responsible for highly reliable and secure power systems.

Furthermore, the NIS Regulation (Measures for the high common security of network and information systems) also enforces high-level security and usability. Therefore security tools should be as flexible as possible to allow the best user experience possible. Unfortunately, high security often leads to non-user-friendly systems. One way to achieve usable security is to use the "Security by default" approach. The GDPR encourages that security by default is the fundamental factor in achieving usability and secure products. For example, it should be easily possible to remove personal data from a webpage.

Security and Privacy by default

Security by default is a fundamental factor whenever a high level of usability and security want to be achieved. It means that the default configuration is the most secure configuration which is possible. This should also be the case for Privacy. The principles of "Security by default" enhanced with Privacy are listed below [26].

- Security and Privacy mechanisms should be built into products starting from the beginning.
- The root cause of a threat should be handled, not the symptoms.
- Security must be continued through the entire lifetime of a product.

- Security should not require extensive configuration to work – it should work reliably where implemented.
- Security and Privacy should never compromise usability
- It should defeat the latest threats
- Security through obscurity should be avoided
- Special technical knowledge should not be required

Therefore security tools should be as flexible as possible to allow the best user experience possible. To achieve this goal, it is essential to incorporate users during the design process to improve the user experience.

Security Controls

Users always want to work in a manner they are comfortable with. For example, a system – even a security system – should not hinder users during their day-to-day tasks. [27]. Often there are multiple ways to achieve a task, and security itself should be accommodating of this. When designing user interfaces, considerations in terms of varying levels of security or risk-based features should be taken into account. For example, user interfaces should use new technologies like biometrics (face recognition or fingerprints) or smart cards. If this is not possible, two-factor authentication and authorization (like SMS PINs) would also be possible. To create secure user interfaces on the web, captcha is visible on more and more systems. On the one hand, captchas are perfect if automated access from robots needs to be prohibited. On the other hand, captchas are not ideal in terms of usability and accessibility. [28]

The world-wide-web consortium defined alternatives for captcha like temporary tokens or multi-factor authentication. For users themselves, it is hindering if authorization and authentication must be done for every transaction. This leads to frustration and a cutoff of security mechanisms.

To gain the utmost level of security that users accept, the following topics should be addressed:

- Security must not be hindering: If users feel that the security measured are slowing them during their daily work, the security measures won't be accepted by them.
- Disabled Security measures during commissioning & re established in production: Security measures should not be disabled during commissioning. This could be a backdoor for cybersecurity attacks and also be forgotten.
- Use Best Practices from other companies with more experience: Companies with less experience in cybersecurity should get help from companies with more experience. Furthermore, best practices should be established.
- Use of Multifactor Authentication or Biometrics: Standard Login mechanisms often lead to cybersecurity holes. Enabling multi-factor authentication or biometrics may address this.
- Amount of login processes: the number of login processes should be kept as low as possible. Users will not accept systems where it is necessary to log in for each transaction.
- Disabling of default users: Default users should be disabled or deleted.

3.5. Business Process and Business Model

A business model for revenue strategy needs to be implemented. Even though remote assistance is faster and cheaper than sending people directly to the site, it must be accounted for. So it might be possible to offer remote assistance over a defined period for free. If more time is needed, the

billing is at cost, which might be cheaper than a flight, daily allowance and other fees. The time of assistance can be recorded and accounted minute-wise. With video recording, it is easy to document the work done and these videos may then be used during training. Another advantage is that customer satisfaction may increase due to the quickness of the service. This may also lead to a long-term partnership between the vendor and the customer.

4. DESIGN GUIDELINES

Based on the CaRE Pyramid design guidelines for a Multimedia Assistance System for singletons was developed.

Therefore, based on the Visual Information Seeking Mantra by Ben Shneiderman [29], first, give an overview of the current status on the site (overview first). Then, upon request, it should be possible to provide more precise information about individual sections (zoom and filter). For example, it should be possible to see only data from one specific workpiece. On-demand, users could also be shown more detailed information such as parts (details on demand). Finally, it should be possible to show historical values (maintenance activities or recent changes) and, if desired, also export that information (history and extract).

Based on the “Eight Golden Rules” according to Ben Shneiderman [30] and the “Ten Usability Heuristics” according to Jakob Nielsen [31] seven guidelines are defined below for the design of a user-friendly assistance system for singletons:

Consistency

A Multimedia Assistance System for singletons must be consistent throughout the entire system. For example, the background color, navigation, type of feedback during interactions, or the basic arrangement of the elements should not change within the visualization platform. Since the assistance can affect several parts of the workpiece, a uniform design must be used here.

Feedback

Since delays are typical in data transfer from the backend system to the frontend application, users should get feedback. In this way, users should be made aware of active loading processes. Furthermore, users need to know what is happening and whether an input is being processed or not.

Overwhelm users

When creating the user interface for a Multimedia Assistance System, it has to ensure that the users are not distracted from the actual content for no reason. According to Steve Krug, it is also essential to ensure that the representation is on the human receptivity is adapted ("Don't make me think") (see [#Krug]): For this reason, there should not be too much information which is presented at once. For example, only a few notifications should be shown.

System status

At all times, users must be aware of the state in which Multimedia Assistance System currently is. If there is no connection to the backend system, this must be indicated. Furthermore, it must be shown if there is data available that is not yet synced to the backend services. This point can also be linked back to "feedback" because it has to be shown if the user interface is still responsive when it is loading.

Help

Within a Multimedia Assistance System, it must be ensured that help is provided if it is needed. Context-sensitive help must be offered. For example, only support for a specific part of the workpiece is presented.

Coloring

The coloring schema within a Multimedia Assistance System plays an important role and must be consistent. For example, it can be tried to create awareness of specific inputs for users: Delete buttons, for example, should be red. Furthermore, successful actions can be displayed with a simple change of the respective background.

Another critical point in terms of coloring is the background color of the application. Although neutral colors should be used, background images, animations and decorative graphics should be avoided since it distracts from the actual content.

Elements that belong together

As discussed in the Gestalt laws, elements that belong together should be grouped. This can take the form of lines, differences in brightness, or color. Subsequently, parts that are disconnected from each other should be separated from each other. For example, in CaRE, all points which are of relevance for commissioning should be grouped.

4.1. Interaction

The navigation of a Multimedia Assistance System must be as easy and quick as possible. Users must be able to orient themselves immediately and find any information needed without any problems. It is essential that users only have one obvious option of where content belongs to or where content can be found. Additionally, users need to know where they are in the menu tree. This can be achieved with so-called breadcrumbs.

It must be apparent to every user at which point in the application they are. To guarantee this, the background of the currently active menu item can be changed. In addition, all links and menu items must be marked as such to be recognizable for users. There is no need for a further orientation aid, such as the path specification, since no more than two levels are available.

While CaRE loads data or after a user has made interaction with fields user should receive feedback. This feedback should be visible until the backend has processed the changes made. After that, a success or error message should be presented. If no connection to the backend is available, this should also be recognizable in the application.

4.2. Content

Within the application, loading processes must take less than five seconds. However, it is essential that during the loading process, information is shown that the system is working. A loading time of fewer than five seconds is usually no issue for desktop applications. However, with mobile devices, longer loading occurs since a fast network is not available everywhere.
The content should be provided in a way users are familiar with. Since some supervisors are traveling to the site for years, the look and feel of the former PDF document should be available as good as possible. In this case, the system has to adapt to users' needs and not vice versa. This is of utmost importance since users should accept the application. Applications that are driven

top-down by the management will hardly be accepted. Users are using such systems because of instructions, not because of their free will.

4.3. Error Handling

As stated by Ben Shneiderman and Jakob Nielsen, a Multimedia Assistance System should be error-resistant. This means that no incorrect entries should be possible and that entries must be checked against plausibility. For example, it should only be possible to enter numerical values for threshold value settings. The entered values should be checked in the best-case scenario while they are entered or the input forms should only allow certain data types. Understandable feedback should be presented to users with examples of what the input should look like. In addition, it must be possible to undo changes and default values should be available.

4.4. Criteria for Mobile Devices

The same design criteria can be assumed both for mobile devices and desktop PCs. However, in any case, the changed size of the user interface and the changed context of use must not be forgotten. This results in the following additional criteria:

Building on the usability of mobile applications, the available space on those devices has to be used for the essentials. When creating native apps, the design guidelines of the respective operating system should be consulted, as these already provide an excellent basis. If platform-independent applications are created, the look and feel on all platforms should be the same since devices can change from time to time.

In mobile applications, the use of "responsive design" or "adaptive design" is one way of reacting to the changed screen size. Thus, the layout of the application automatically adapts to the size of the screen. Furthermore, for mobile variants, attention should be paid to the contrast, and transparent feedback should be presented.

Due to the changed context of use and the smaller screen size, it is essential to ensure that the most critical information can be seen immediately. Furthermore, it must be guaranteed that the interaction elements are the right size for operation with a mobile device and can also be identified as interactive elements. Finally, since mobile devices are often used in places with no ideal lighting conditions, a high level of contrast should be ensured. This applies to all interaction elements, fonts, and graphics.

5. IMPLEMENTATION AND TEST

In order to test the proposed pyramid, a prototypical application was implemented. This application can be divided into a Backend System and a Frontend System.

5.1. Backend System

For users, the most crucial part is, of course, the front end of the assistance system. Nevertheless, the central part of the system is running behind, with interfaces to other systems. Therefore, a software architecture was defined, which will be described in this part. It was decided to implement this architecture in terms of a Microservice Architecture because the system should be flexible and capable of dealing with different other systems.

The Architecture, therefore, consisted of ten Microservices and three additional external services, which were used. Microservices overcome the limitations of traditional monolithic architecture [32]. During the implementation of this proof of concept, refactoring was necessary to meet all the desired quality attributes. First of all, it is hard to find the correct granularity for the Microservices. The first approach was more or less a monolith, which was caused due to an implementation start without a clear big-picture, no strategy and no structure. Without those, the implementation will undoubtedly lead to anti-pattern and architectural smells, according to [33].
After the final definition of the entire working process of the supervisors at the site, those process steps were meant to be a single Microservice. This process was identified with the user-centered design approach and interviews with the users, later working with the system. To ensure proper code quality, test-driven development with NUnit was used for both the model and RESTful interface.

With all those Microservices in place, it could be seen that Logging into files was not the best solution to debug. Therefore the interface to the Elastic Stack was implemented. After that, it could be seen that Identity Management should be taken into account from the beginning of the programming. The integration of Identity Management into already existing Microservices took a lot of work and refactoring. If it is integrated from scratch, the work which needs to spend will decrease significantly.

Since the CaRE System is a prove of concept, Scalability, Availability and Performance (see [34]) were not taken into account in terms of the Microservices. Sometimes it makes sense to make use of already existing services rather than implementing them again. As an example, in the CaRE architecture, the TextAnalysis needs to be mentioned. If – for example – a system requires natural language processing, it also makes sense to use already existing services.

To summarize, it needs to be mentioned that a clear understanding of the big picture is necessary before starting with implementation. Otherwise, a lot of refactoring needs to be done. Furthermore, the best solution must be found for each individual project. Solutions of big players like Netflix, Facebook and so on sometimes do not fit for small applications and vice versa. Even if Microservice architecture is emerging, it is not always the best choice and needs to be investigated carefully.

5.2. Frontend System

The frontend application should be platform-independent. Thus the application was implemented as a Xamarin Forms application.

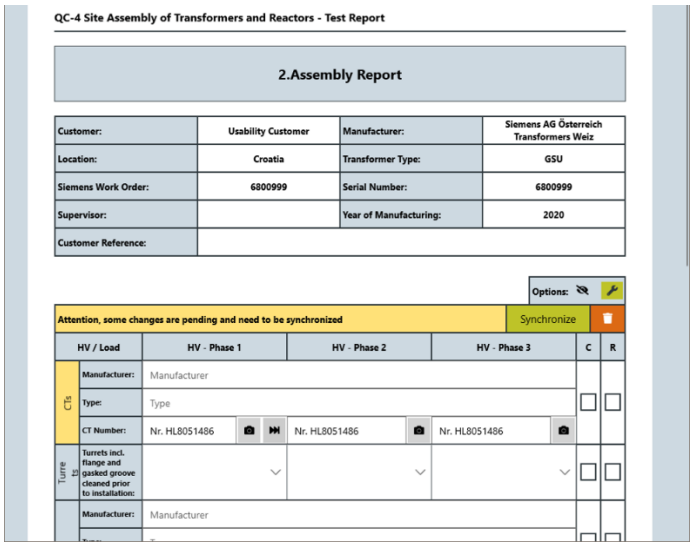

Figure 3: Report View

Figure *3* shows a report which is about to be filled out. It has the same structure and looks and feels like a PDF document, making it easy for users to navigate. In the shown case, the report was filled without connection to the backend system. A hint is shown that the current information, which is filled in, is not yet synchronized with the backend. This can be achieved by clicking on "Synchronize". A click on the red trash bin deletes all offline changes.

5.3. Field-Test and Evaluation

To check whether the assumptions regarding a Multimedia Assistance System are correct, the prototypical developed application was tested with a usability test. With this test, an attempt is made to determine which forms of visualization are suitable for the user-friendly display of data. Furthermore, the interaction methods are tested.

Unfortunately, a lock-down due to Covid-19 occurred and it was not possible to execute the test face to face as planned. Instead of this, a “Remote Usability Test” was conducted. In total, seven Microsoft Teams Sessions took place. Users were asked to turn on the camera on their end to see their gestures and facial expressions. With desktop and mouse sharing, users were able to control the application on the interviewer's computer. It could be seen that users implicitly moved the mouse where they were looking at. With this, it could be tested whether the planned menu navigation is also user-friendly.

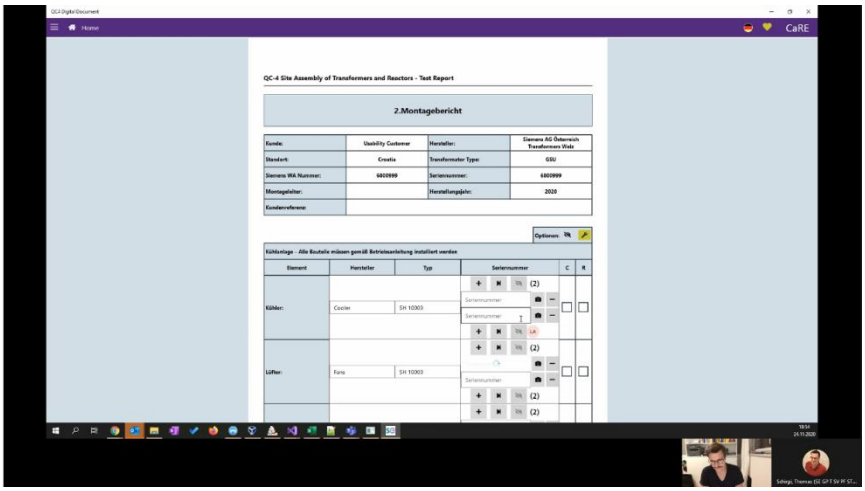

Figure 4: Remote Usability Test

It can be said that most of the tasks could be completed without any problems. With 14 tasks, only minor issues occurred; nine tasks out of 98 possible could not be completed without the interviewer's help, which is effectiveness of 90.8%. In some cases, the jargon was not clear or buttons were not found. The results regarding the general opinion about the application were almost identical. All test subjects described the application as clear, intuitive and visually appealing. It was also emphasized that the application does not appear too overloaded and that the users are not overwhelmed. Those users who found the automatic serial number recognition liked this feature very much since it is sometimes hard to enter such long serial numbers. Some users said that the font size is sometimes too small and that there should be an introduction during first use. One also stated that help text is missing. All those users who were used to the PDF version of the documentation said that it nearly looks the same and that it is for sure faster than before. Furthermore, the following statements were given:

- Buttons with special functions should be emphasized
- A tip of the day should be included
- Rework the wording and jargon. Some texts might not be apparent to supervisors. (e.g., Annotation)
- Datasets should be locked if one user is currently working on them. This prevents already inserted data is overwritten.
- An export into Microsoft Word, a PDF format or the possibility to print should be implemented.
- A back button or restore button should be added to the application.

During interaction with the application, no real problems occurred. The menu points were seen as self-explaining. As stated above, buttons with special functions should be emphasized and highlighted. For actions that finalize something (like signing), a confirmation (“Do you really want to do this?”) should be shown. For signing, an interactive pen is more suitable than using the computer's mouse. This is also the case for the annotation service since it is nearly impossible to mark something with a finger precisely. Annotating with the computer's mouse works, but it is also not user-friendly.

It could be seen that the interaction with the system accelerated with time. As soon as users understood the navigation concept and how certain features were emphasized, they were explicitly looking at it. On average, a goal was achieved in approximately 84 seconds. Therefore

the overall relative efficiency was calculated according to [35] and is 76.5%. The relative time-based efficiency was also calculated according to [35] and is 55,6%. One drawback was that the interaction was sometimes lacked due to Xamarin Forms, which is a bit slower than other frameworks. With this in mind, feedback right after a click onto an item is of utmost importance. It could be seen that the users became more and more familiar the longer the usability test lasted. As soon as the users understood the interaction concept and the navigation strategy, it became more and more intuitive.

6. CONCLUSIONS

The developed prototype is moving in the right direction, which can be seen in the results of the usability tests. The application adjusts to the needs of the users and thus is well accepted by them. It helps users during their work and they can see the current status at the site. With the help of the user-centered design approach, the needs and wishes of users could be identified quickly. The feedback cycles during implementation also helped in this regard.

Additionally, criteria were developed which are necessary to create an assistance system. The usability test showed that the requirements could be confirmed. To be able to exploit the full potential of CaRE, additional functions such as the selection of a power plant based on the GPS position or the operating diary and a native app might have to be implemented. For the annotation functionality also features with augmented reality can be implemented. This, however, is only possible if the selected Hardware is capable of rendering those features. Nevertheless, the usage of Microsoft Hololens or others is not intended. Even if advertisements are showing good-looking features, those functions are not helpful in daily life.

The presented CaRE pyramid helps to ensure a better process during assistance combined with smart devices. Thus, better and tailored commissioning and maintenance can be offered to the customer, and service can be made faster and cheaper. Due to that, higher availability of energy plants can be reached. Furthermore, the failure rate and the number of incorrect assemblies during commissioning and maintenance can be decreased. In addition, both parties may save a significant amount of money. The framework can also be used for other singletons, which are about the be commissioned or maintained. Therefore, the structure and logic behind it should be helpful for all types of singletons.

In some cases, it may be prohibited to use devices with cameras at the site – such as nuclear power plants or military zones – which makes such assistance applications not applicable. Then engineers at the site have to work on their own. Due to that fact, "traditional" service will also remain a critical factor in the future.

The sub-header of this paper is "Does IT help?". This question is freely based on the book "Does IT matter?" by Nicholas Carr. In this book, the question is raised if IT brings a competitive advantage. The answer in the book is no since IT is seen as an enabler, but companies do not have any competitive advantage of using IT. It is also stated that IT might hinder daily Business.

To answer the question in the sub-header, it can be said, "Yes, IT helps, but...". IT during daily work of supervisors might for sure help them if the assistance is not hindering. There are examples where supervisors had to document every step with tools, which impede their daily work. Most of the time, such tools were driven top-down from management. IT helps if, e.g., it accelerates, supports, or takes over some work. A Multimedia Assistance System – regardless of the scope – should assist users and not add additional work.

6.1. Future Work

There is also room for improvement in some areas, which would also provide further assistance to users. For example, context-sensitive help with recommendations would be appreciated, where the application automatically detects desires. Such features have to be handled with care since false positives would lead to disturbances. Another topic would be auditory checklists: With this, the checklist can be spoken to a device and the system is behind automatically detects the part in the checklist. A further possibility would be the detection of emotions with an analysis of the spoken texts. This must also be handled with care since this might be hard in a noisy environment. In terms of the user interface, some research must be done within adaptive user interfaces. Only one application needs to be developed, which adapts itself according to the current device and the available features.

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