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Integration von Gamification in ein digitales Assistenzsystem für die industrielle Instandhaltung

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Patrick Kokoll, BSc.
Matrikelnummer 01427764

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der Technischen Universität Wien
Betreuung: Univ.-Prof. Dr.-Ing. Sebastian Schlund

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Patrick Kokoll

Sebastian Schlund

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Patrick Kokoll, BSc.
Registration Number 01427764

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Patrick Kokoll | Sebastian Schlund

Technische Universität Wien
A-1040 Wien ▪ Karlsplatz 13 ▪ Tel. +43-1-58801-0 ▪ www.tuwien.at

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Patrick Kokoll, BSc.

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Wien, 29. März 2024

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Kurzfassung

Im Bereich der industriellen Wartung und Inbetriebnahme führen Monotonie und mangelnde Motivation zu einer hohen Fehlerquote, und die Techniker verbringen viel Zeit mit dem Sammeln von Informationen. Um diese Probleme zu verbessern, wurde ein digitales Assistenzsystem mit integrierten Gamification Elementen entwickelt.
Das digitale Assistenzsystem wurde von Fachleuten aus dem Bereich der industriellen Wartung und Inbetriebnahme in einem Laborexperiment getestet. Das Laborexperiment gliederte sich in zwei Teile; es begann mit einer entspannten Thinking-Aloud- Studie, bei der die Teilnehmer mit verschiedenen Aufgaben konfrontiert wurden, gefolgt von einem semistrukturierten Interview.
Die Studie zeigte, dass das digitale Assistenzsystem in der Lage wäre, die Arbeitssituation zu verbessern, indem es die Funktionen eines Smartphones oder Tablets, wie z. B. die Kamera, nutzt. Das digitale Assistenzsystem wurde als nützlich eingestuft, weil es Aspekte der täglichen Arbeit vereinfacht. Während des Laborexperimentes wurden Gamification-Funktionen wie Leaderboards, Punkte, Levels, Erfolge und Avatare eingeführt. Die Gamification-Elemente wurden gut angenommen, mit Ausnahme des Avatars, da dieser während des Laborexperiments optional war und nur von einem Teilnehmer ausgewählt wurde. Das Leaderboard erwies sich als das nützlichste Gamification-Element, da es den Wettbewerbsgeist der Teilnehmer weckte und sie motivierte, ihre Kollegen zu übertreffen.

Abstract

In the field of industrial maintenance and commissioning, monotony and lack of motivation lead to a considerable amount of errors, and technicians spend a lot of time gathering information.
In order to improve these problems, a digital assistant system with integrated gamification elements was developed. The digital assistant system was tested by professionals from the field of industrial maintenance and commissioning in a lab experiment.
The lab experiment was divided into two parts, it started with a relaxed thinking-aloud study during which the participants had to encounter different tasks and was followed by a semi-structured interview.
The study showed that the digital assistant system would be able to improve the work situation by using the features of a smartphone or tablet, such as the camera. The digital assistant system was valued for simplifying aspects of the daily job. During the lab experiment, gamification features such as leaderboards, points, levels, achievements, and avatars were introduced. The gamification elements were well accepted, except for the avatar, because it was optional during the lab experiment and only selected by one participant. The leaderboard proved to be the most beneficial gamification element, as it awakened the competitive spirit in the participants and motivated them to outperform their colleagues.

Contents

CHAPTER 1

Introduction

1.1 Problem Statement and Motivation

One of the biggest challenges in the field of industrial maintenance is the knowledge transfer. Often there is just a small group of people or even just a single person within the company, who is familiar with the needed know-how and the needed documentation is either non-existent, incomplete or hard to understand.
Studies have shown that during the shift of a maintenance worker, 45% of his working time is used to search for and to study the found documentation.
Furthermore, most industrial accidents are caused by incorrect manipulation of the process by the operator, which clearly points out the importance of good process visualizations in order to mitigate risks and enhance safety [44].
Hossayni et al. are showing that the sharing of knowledge in the field of industrial maintenance has many obstacles to overcome in order to improve process. Automated data anonymization and knowledge graphs are proposed approaches to improve the knowledge sharing between industries and to optimize maintenance [28][29].

Another challenge is that motivation is an important factor for the final outcome of a task, and it is needed in industries to reduce the error rate, because motivation and boredom are causing most of the errors in some industries [31]. Gamification can be a useful tool to improve the motivation of the personnel and is already widely spread and well accepted in areas like education and health. However, gamification in the industry is still in its early stages and the industry still needs time to adopt to include gamification [36]. Jacob et al. demonstrated the effectiveness of gamification in an industrial setting, resulting in measurable improvements in work performance and enhanced motivation. The study provides evidence for the benefits of gamification in the workplace [30].

When errors occur in a production line, workers often lack the necessary skills and expertise to resolve the issue, emphasizing the need for digital assistant systems to

upskill workers and provide essential information for problem-solving. The digitization of maintenance work management can significantly alter the nature of technician work, impacting their skill variety, task identity, and autonomy, among other aspects. However, maintenance technicians usually are not focused on the development of new digital assistant systems [65]. Visualization techniques in a digital tool can enhance the efficiency in maintenance tasks and guide low-skilled workers through errors [33].

Research is being conducted on assistance systems to determine their impact on the motivation of service technicians. By incorporating these systems into maintenance tasks, there is potential to greatly influence worker motivation and enhance the quality of service provided [22]. In the context of Maintenance 4.0, the role of skilled workers is evolving. There is a greater emphasis on the interaction between humans and digital assistant systems to increase efficiency and reduce downtime [64]. The integration of service workers into modern production facilities and the improvement of their task-specific skills are greatly influenced by the design of assistant systems for industrial maintenance tasks [54].

The integration of digital assistant systems in industrial maintenance has been further elaborated through the development of platforms like Smartool, which use machine learning for Condition-Based Maintenance, demonstrating the potential to lower maintenance costs and improve equipment management[41]. Maintenance digitalization frameworks propose transformation strategies that include digital tools and stakeholder collaboration to revolutionize maintenance management for a competitive advantage [2]. Digital assistant systems have a transformative impact on the maintenance sector. Remote monitoring and maintenance systems, AI-enabled Digital Twins for predictive maintenance, and IoT platforms like TIP4.0 for predictive maintenance offer insights into reducing downtime and maintenance costs [66][59][50].

Therefore, addressing both, skill deficiencies and motivational factors through digital assistant systems is essential for empowering workers to tackle errors independently. This approach reduces the need to report unresolved problems to the maintenance team, potentially decreasing the overall downtime of the production line.

Hence, the thesis will tackle the following research questions:

Research Question 1:
What requirements have to be considered in the context of industrial maintenance and commissioning for a digital assistant systems and gamification?

Research Question 2:
Which gamification elements can increase the motivation in the field of industrial maintenance and commissioning?

1.2 Methodology

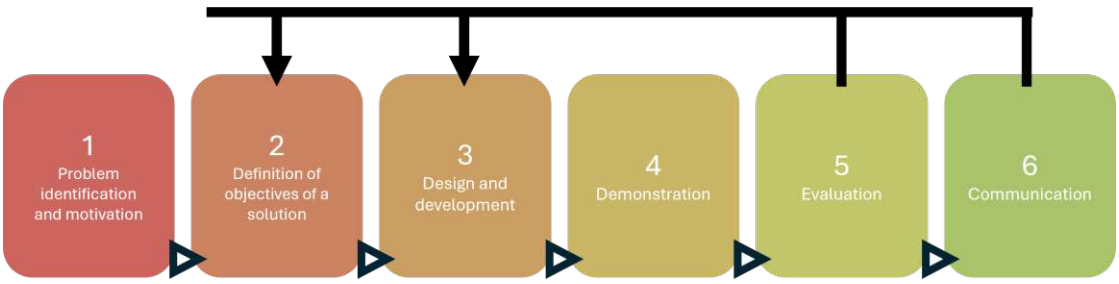

Figure 1.1: Steps of Design Science Research Process[53]

In this master thesis the chosen methodology will be Design Science, in order to be able to develop an artifact. These artifacts can be categorized into 4 products: constructs, models, methods, and instantiations. In order to bring science to building artifacts, evaluation has to be added.

Design science is used to extend the capabilities of humans and organizations with the help of newly developed artifacts. The research is motivated by the application domain to improve the environment through these new and innovative artifacts [27].

The design science research process of Peffers et al. [45] will be used as a guide to fulfill the design science methodology. Figure 1.1 shows the six steps of the design science research process.

1.2.1 Problem identification and motivation

In the first step the currently existing problem will be explained and the state of the art will be researched by using a narrative literature review. The narrative review was chosen for its flexibility in gathering the current state of research and for getting a broad understanding of the field. The problem statement and motivation for this work can be found in chapter 1.1. The findings of the narrative literature review are presented in chapter 2 and combined into thematic sections [21].

1.2.2 Objectives of a solution

Peffers et al.[45] stated that these objectives can be quantitative or qualitative. In this step, we define qualitative objectives about the digital assistant system that later will be evaluated. Furthermore, the needed resources will be defined like the needed hardware to test the possible situations. For the Master thesis, the functional requirements will be modeled with Unified Modeling Language (UML). Benfell[6] showed that UML is a typical approach to functional requirement modeling. The Use cases are then split into user stories for a clearer understanding and contain the functional requirements and the requirements to the gamification elements.

1.2.3 Design and development

During this phase, an artifact will be built. Hevner et al.[27] defined that artifacts in design science can be either constructs, models, methods, or instantiations. In the master thesis, a digital assistant system for industrial maintenance and commissioning will be implemented in the form of a mobile application. The application will be developed with the requirements of step 2 in mind. During the design and development of the gamification elements, the requirements defined by Dale [12] will be taken into consideration.

1.2.4 Demonstration

Step 4 shows that the artifact produced actually solves the problem defined in the first step of the design science research process. For this demonstration, experiments, simulations, case studies, proof or other appropriate ways can be used[45]. We will use a simulation to show that the problem can be solved with the use of the two corresponding artifacts. During this simulation the users will face errors that they will have to solve with the help of the digital assistant system.

1.2.5 Evaluation

Hevner et al. [27] mentions the importance of the evaluation for design science and hints that evaluation brings science into design science. This fifth step checks if the requirements from the second step are met, if this is not the case, the researchers can either go back to step 3 and improve the artifact or document it and leave it for future projects[45]. Venable et al. [63] offer a framework for using the correct evaluation method. A visual representation of the framework can be seen in Figure 1.2. Ex Ante evaluation can be used if no artifact is needed, and it is possible to evaluate the outcomes without an artifact. Ex Post evaluation is the evaluation of the build artifact against its requirements. Naturalistic evaluation is testing in the field versus artificial evaluation is testing in laboratory settings. In the master thesis the ex-post evaluation method will be used, because the built artifacts should be evaluated. The participants of step 4 took part in the evaluation of the artifact. The evaluation was a combination of two qualitative evaluation methods. During step 4 a relaxed thinking-aloud study took place and after the completion of all tasks a semi-structured interview was conducted.

DSR Evaluation Method Selection Framework	Ex Ante	Ex Post
Naturalistic	•Action Research •Focus Group	•Action Research •Case Study •Focus Group •Participant Observation •Ethnography •Phenomenology •Survey (qualitative or quantitative)
Artificial	•Mathematical or Logical Proof •Criteria-Based Evaluation •Lab Experiment •Computer Simulation	•Mathematical or Logical Proof •Lab Experiment •Role Playing Simulation •Computer Simulation •Field Experiment

Figure 1.2: A DSR Evaluation Method Selection Framework[63]

1.2.5.1 Thinking-Aloud Protocols

Thinking-aloud or Think-aloud protocols are one of the most widely used evaluation methods in usability testing and are based on the theoretic basis of Ericsson and Simon [14].

This technique is most often used in psychological and educational research, but also in other fields, like for example in the development of knowledge-based computer systems. In many cases, this method is a unique source of information to understanding how cognitive processes work [60]. The method involves users verbalizing their thoughts while interacting with a system. The users are seen as quasi-researchers, and the verbalized thoughts are recorded on paper, audio, or video for further analysis and give insight into the cognitive processes of the users.
There are two types of Thinking-Aloud Protocols:

- Concurrent/Introspective Think Aloud
- Retrospective Think Aloud

A concurrent/introspective thinking-aloud method means, that the users verbalize their thoughts while solving the tasks while in a retrospective thinking-aloud study, the users first complete the tasks silently and afterwards expresses their thoughts [9] [23].

Literature reviews have shown that thinking-aloud research methods provide a valid source of data about participant thinking [9].

The original approach from Ericsson and Simon requests that the participant has to verbalize all of his thoughts, and the researchers only interaction option with the participant is to prompt the participant to continue talking, if the participant is quite for a period of about 15-60 seconds. The researcher is not allowed to interact in any other way. This interaction should be short and not influence the thoughts of the participant. Boren et al. highlight, that the original approach from Ericsson and Simon is very strict and that the practice does not align with it. Usability tests often deviate from those strict rules as they are of an unpredictable nature and due to lack of guidance Field observations have shown that participants can feel irritated through the quick prompts and often apologize for not talking as well as they feeling interrupted in their task flow. This makes the researcher seem controlling and authoritarian, while the participant feels inferior[7].

For these reasons, a weakened version of the Thinking Aloud method was invented, the so called "Relaxed Thinking Aloud". It is a more relaxed and less structured approach compared to the original one as it allows the participants to not only verbalize what they are doing, but also why they are doing it. In comparison, Simon and Ericsson did not allow the participant to reflect about their actions, as they saw this as a distraction. The study of Hertzum et al. shows, that the relaxed approach, which is also the way such usability tests are conducted in practice, leads to a broader range of insights into how users interact with a system due to their feedback, emotions and reactions [26].

For this thesis, the method of concurrent relaxed thinking aloud is used, which means the participants were thinking aloud parallel to solving the tasks.

1.2.5.2 Semi-structured Interview

Semi-structured interviews are like guided conversations between the researcher and the participant. The researcher has a clear understanding of what topics should be covered and can have a prepared list of questions that can be used as a guideline. In contrast, structured interviews have a predefined set of questions that are asked in the same order and are like verbalized questionnaires. Each semi-structured interview can vary between participants, because the order of the questions / topics is not predefined and can be adapted to the situation [51].
The questions should be adapted to the research questions and can contain more structure if the answer is coded. Semi-structured interviews are well-suited to answer 'why' questions rather than 'how many' or 'how much' questions. Participants must have the option to not answer questions that are too personal or that they do not want to answer to protect them from unnecessary stress [17]. Open-ended discussion in a semi-structured interview can provide interesting details and insights that a planned interview might not cover [9]. The schedule from the semi-structured interview must be defined beforehand and should be done thoroughly. This interview schedule is only for the interviewer and should never be shown to the participant [55]. The prepared question should be brief, and not more

than five broad questions should exist in order to be able to keep track of covered topics. The participants should answer the following. What they thought, how they felt, and What they did? The interviewer has the option to help the participant with probes, when the participant is having problem with talking freely or when the interviewer wants to go deeper.
Typical prompt for semi-structured interviews is short and open and should help the participant to explain him/herself further. Flyan [17] defined typical prompts, like "Really?", "Tell me more about that“, "How did you feel about that?" and many other prompts. Body language is also a kind of prompting, and the interview should engage and make the participant feel comfortable with their body language. After all topics are covered the interviewer should summarize the answers of the participant in order to debrief the interview. During this debrief the participant can check if his/her answers are interpreted correctly and if they have anything left to say [17].

1.2.5.3 Coding

Coding is the process of extracting information for quantitative values from qualitative data, which can come from the thinking-aloud protocol or interviews. These quantitative values can then be used to perform a quantitative or statistical analysis of the qualitative data. This process turns the spoken words into values, that can be used in quantitative analysis, without changing the subjectivity or objectivity of the collected data [55]. At the beginning of the coding process the qualitative data is examined and phrases or sentences are labeled with a code, that could be a word or a short phrase. This makes the data more accessible and easier to analyze. For the coding process, the researchers can use markers to color code the different codes or use software that marks the passages with the correct code and records where the passages were found. There are two kinds of coding processes: inductive and deductive coding.
Inductive coding involves developing codes directly from the data using phrases or terms used by participants, rather than the vocabulary of the researcher. This approach is most useful in exploratory studies or when theoretical concepts are not immediately available. In the first round of coding a large number of codes can emerge and in the following rounds the researcher can reduce the number of codes by combining them together to reduce complexity.
Deductive coding involves creating a pre-defined list of codes in a coding frame before coding the data, which helps to focus on issues that are important for the research question. Codes in deductive coding are often theoretical concepts or themes drawn from the existing literature, with a relatively limited number of codes, typically five to ten. The coding frame can be adjusted during coding if interesting differences emerge within a given code or if new and interesting things arise that are not captured by existing codes [37].
The two types of coding can be combined during the research, which can be called the blended approach [20]. The coding of the data should occur in cycles of coding. The first cycle should concentrate on collecting and labeling all the data, and the second cycle is more focused on interpreting the collected labels. The collected data can then be visually

displayed to make it easier for the reader to comprehend .

1.2.6 Communication

Peffers et al.[45] define the last step as the communication of the research in scholarly research publications. This project will be published as a master's thesis and will be available for future research. Hevner et al.[27] defined the seventh guideline as the communication of the research and mention the importance that the research must be presented to technology oriented as well as management-oriented audiences. This thesis will be written at the Institute of Management Science of the Technische Universität Wien and in collaboration with a development department of Festo GmbH. Therefore, both audiences are taken into consideration.

CHAPTER 2

State of the Art

2.1 Maintenance

Maintenance plays a significant role in the industry as it ensures optimal performance, reliability and longevity of machines, devices and infrastructure. The aim is to have a continuous production that is as error-free as possible, with minimal losses and maintenance costs [11].
Currently, there are two distinct approaches used in the industry: preventive maintenance and predictive maintenance.

2.1.1 Preventive Maintenance

Preventive maintenance (PM) is performed at predetermined intervals. The aim is to prevent any downtime or failure of the system, by replacing the component or equipment after a certain period of time, regardless of its condition. On the one hand, this approach can be effective and reduce downtime, as well as being time efficient, but on the other hand it can lead to unnecessary maintenance actions and to a wastage of resources, which could have been avoided [15].

2.1.2 Predictive Maintenance

In contrast to Preventive Maintenance, Predictive Maintenance (PDM) focuses on the condition of the equipment. It includes continuous monitoring to detect an error or any signs of an error as soon as possible, in order to perform maintenance just in time and to avoid any downtime. This approach focuses on the use of different diagnostic tools and techniques, to estimate possible machine downtime by predicting potential failures even before they occur, as well as avoiding unnecessary equipment wastage [56].

The current trend in industrial maintenance, particularly within the context of Industry 4.0, is to shift towards these predictive maintenance models. This is achieved by leveraging advancements in digital technologies to optimize maintenance processes and enhance equipment life cycle management. This approach uses digital technologies to monitor the equipment condition for the prediction algorithms to improve production quality and efficiency. The workflow for predictive maintenance usually starts with understanding the project and collecting data. It then progresses to analysis and decision-making. Common models in this field include condition-based maintenance, prognostics and health management, and estimating the remaining useful life of machinery [1].
Maintenance management systems with Industry 4.0 technologies play a crucial role in achieving improvements in operations and productivity. Artificial Intelligence, machine learning, the Internet of Things and cloud computing have revolutionized maintenance processes. These advancements allow for real-time monitoring, efficient data management, and improved coordination among maintenance tasks, which leads to reduced unplanned shutdowns and lowers costs [57].
Even though Industry 4.0 brings many benefits to maintenance strategies, companies still need to overcome significant challenges. These include the high cost of implementation, the complexity of data analysis, and the need for skilled personnel. Future research should concentrate on developing cost-effective solutions, improving data analytics capabilities, and training personnel to bridge the skills gap in this rapidly evolving field.

2.2 Commissioning

Industrial commissioning is a phase in the life cycle of manufacturing and automation systems. This process involves testing and verifying equipment and systems to ensure they meet the specified requirements and are ready to operate at the expected capacity. The aim of commissioning is to improve the efficiency and reliability, minimizing downtime and optimizing performance.In this phase, the planned system is made operational, and possible issues are identified and addressed to minimize the potential for failures.
The rise of Industry 4.0 has resulted in a significant increase in data generation caused by for example the Industrial Internet of Things (IIoT). IIoT presents opportunities for remote monitoring, intelligent analytics, and control of industrial processes. However, it also comes with challenges such as scalability, interoperability, security, privacy, reliability, and low latency. These challenges need to be addressed for an effective integration of IIoT systems in the commissioning process [42]. The IIoT creates heaps of data, which create a need for effective data management strategies. This requires a comprehensive understanding of data properties and the development of architectures that facilitate data presence, coordination, and computation [49].

Virtual commissioning is using simulation to test and validate the design and functionality of manufacturing systems before they are physically built or modified. By doing so, design errors can be identified, the system performance can be optimized, and it can be proved that the system works as intended before any investment costs occur and any setup time is lost [58].

Digital twins are detailed digital models that mirror the physical characteristics and behavior of real-world systems. They are created using data collected from sensors installed on physical objects, allowing these digital replicas to update and change in real-time based on their physical counterparts. This concept is part of the digital transformation initiatives of Industry 4.0, utilizing advanced technologies such as the Internet of Things (IoT), artificial intelligence (AI), machine learning, and big data analytics. The integration of digital twins in the commissioning process can improve operation readiness and during system runtime it enables ongoing performance improvements [39][10].

2.3 Assistant Systems

An assistant system is a technological solution to help humans complete their tasks more efficiently. Advanced technologies such as artificial intelligence, machine learning, augmented reality, virtual reality, and handheld computers are used in assistant systems. These systems automate tasks, support decision making, and are tailored to the user's needs to assist them with various tasks. Assistant systems are used in various fields ranging from healthcare to product facilities up to the private sector. For example, in healthcare, handheld computers provide information, improve workflows, and support physicians [40].

In the field of industrial commissioning and maintenance, assistant systems are significantly influenced by Industry 4.0 technologies. These technologies, such as artificial intelligence, machine learning, the Internet of Things (IoT), big data analytics, and cloud computing, enable one to create predictive maintenance models and increase system efficiency. Integration of assistant systems can reduce unplanned shutdowns and machine downtimes by improving data management and coordination [57]. Maintenance costs can affect overall production costs from about 15% to 40%, and with the use of assistant systems, costs can be reduced.
Another trend from Industry 4.0 is technologies such as virtual reality (VR) and augmented reality (AR). VR is an enabling technology in the field of training that allows the trainee to use a virtual environment to interact with the work item. Studies showed that VR can reduce the time used for training and improve the overall gain in skill of the trainee. AR can support the maintenance operator through a mobile or wearable device, which can be used to plan and perform the maintenance task. These technologies enable maintenance operators to reduce both the time spent and errors made during maintenance tasks. Research also focuses on improving the quality of work, in addition to reducing the error rate and the time to completion. The business benefits are measurable with KPIs (productivity, quality, costs, safety, efficiency, and sustainability), if the operators workflows are improved and supported with enabling technologies[61].

Nowadays, a trend towards smart factories can be seen that include digital assistance systems for industrial environments. These smart factories are context-aware and can assist people and machines with their different tasks[48]. Currently, there are multiple assistant systems for factories in the field of assembly, logistics, maintenance, and

training[8]. Heinz et al. [24] recognized that the number of assistant systems for maintenance tasks is lower compared to the number of assistant systems for assembly tasks. One problem of the maintenance assistant system is the high variability required between the different repair tasks. Aromaa et al.[4] showed that maintenance workers found multiple benefits in their daily tasks while using assistance systems. Dale[12] showed the potential of gamification in businesses and how gamification can motivate employees to perform better. However, Korn et al.[35] recognized that there is almost no research on the usage of gamification in assistive systems in industrial production.

In industrial commissioning, assistant systems play an important role in improving the efficiency of the commissioning process. Alavikia and Shabro (2019) conducted a study to showcase the capabilities of augmented reality (AR) tools in virtualizing essential information for workers. The use of AR enables workers to access crucial data in real time and at the appropriate location, potentially revolutionizing industrial maintenance and commissioning practices [3].

2.4 Gamification

"The opposite of play is not work. It is depression" is a provocative statement by Stuart Brown, which shows that work and play are not opposing each other [5]. The term 'gamification' is used since around 2003 and describes the usage of game mechanics in non-game contexts, i.e. education, health and enterprises. Dale listed the most common game mechanics used in gamification:

- achievements
- exercise
- synchronizing with the community
- result transparency
- time
- luck

The goal of gamification is to influence users, whether they realize it or not. Real-life examples of gamification are loyalty cards or trophies. A definition for gamification from Dale is 'the use of game mechanics and experience design to digitally engage and motivate people to achieve their goals'[12].
Dale mentions all the good features of gamification, but also mentions that 80% of gamifications will fail due to bad design. His concerns are that the implementation focuses more on the needs and goals of the companies and stakeholders and not the users. First, the needs and goals of the end user must be researched before the first prototype

can be created and tested [12]. In general, gamification can be an effective way to engage and motivate people to achieve their goals in a wide range of contexts [13].

The use of gamification can range from education to healthcare, industrial context, fitness and many more. The main focus is to increase motivation and participation. A study by Gangolells et al. [18] used a game-based solution to improve domestic energy savings. The participants of the study had to play a serious game that simulated real life and had real-life energy consumption data. The goal was to minimize energy consumption without losing any comfort levels in the game. Through the game the participants adapted the learned findings into their own real life and the energy consumption of the households went down. Through the study the authors were able to quantify, that with the usage of gamification the energy consumption of a household can be reduced [18].

In his work, Kifetew studied the influence of gamification elements, especially points-based elements, also called "pointsification", on the overall user experience and user engagement in a decision making game (DMGame). The DMGame was used to facilitate the prioritization of requirements, which the software development team should address. Two opposing requirements had to be be evaluated and each user gave a preference score. The study was conducted in 3 companies and the teams got the DMGame either with pointsification or without pointsification. The research found that the engagement and activity flow were marginally higher with the pointsification system in use. However, they also point out, that the effectiveness of those elements is based on how they are designed and how clear they are described to the user [32].

Korn et al. presented two different gamification implementations in a sheltered work organization and compared them after making an evaluation. The results showed that the design in the context of gamification plays an important role for the employees, as they preferred to work with certain designs more likely than with others. They also point out, that there are some requirements which need to be fulfilled, in order to make the gamification elements useful, such as a low cognitive workload, which means avoiding to distract the user from his work focus, as well as projecting the gamification elements close to the workers place. In conclusion, they point out that there is potential to increase employee engagement and motivation in production environments with the use of gamification [34].

Jacob et al. explored the impact of gamification on work performance in a real industrial setting with the focus on monotonous and repetitive tasks. They designed a basic gamification application within the existing information system. For a month they tracked the performance of the participants, who were split into two groups, a gamified group and a control group. The results showed, that thanks to gamification, the motivation of the workers increased, the work performance increased and there was an overall positive emotional reaction [30].

In the field of industrial maintenance and commissioning, the literature regarding gamification is scarce. However, in other fields there are promising results.

For example, in software engineering, gamification techniques have been effectively used

to motivate and engage users and to support the overall success of software development projects. The findings show that the most commonly used gamification element is the point system, followed by levels, badges, social engagement, challenges-quests, leaderboards, voting, and betting. The paper from Priyadi et al. points out that there is no standard methodology or framework for developing gamification systems, and that there is a great need for one [46].

Gamification methods in combination with augmented reality are showing promising results in the training of assembly work, especially in view of the increasing demands in terms of complexity and precision that are required in industrial assembly. Furthermore, the review suggests that gamification elements such as points, badges, leaderboards and feedback mechanisms can improve user engagement and satisfaction, and potentially the overall effectiveness of training programs as they make the training process more fun and exciting for participants [62].

In the study of Gerdenitsch et al. they designed a habit-tracking app, which should support the user in self-organization, in managing and structuring their tasks as well as in monitoring the progress of them. They discovered a positive correlation between productivity and job satisfaction when using the gamified app, especially for employees with leadership responsibilities. The results validate the hypothesis that gamification activates the hedonic system, which is responsible for enjoyment and playfulness, resulting in increased satisfaction and increasing efficiency [19].

These examples show that gamification can also be used in the field of industrial maintenance and commissioning to improve motivation and engagement.

2.5 Motivation

Hense et al. summarized the importance of motivation with a simplifying formula "(ability + skill) * motivation = outcome". This shows that motivation enables people to use their abilities and skills in any work situation. In motivation research, it is differentiated between intrinsic and extrinsic motivation. Extrinsic motivation is triggered by the environment and is based on incentives. Intrinsic motivation is used to satisfy the person himself/ herself with completion of a task. Hense et al. mention five principal perspectives of motivation research that can be useful in the perspective of gamification.

1. The *trait perspective* focuses on individual sources of motivation, such as the motivation for achievement, the need for recognition, the search for sensations or the need for affiliation. These stable traits can be used in gamification to generate intrinsic motivation. Game elements like badges and achievements can illustrate recognition and affiliation by being virtual status symbols. These game elements show in a group which experiences a user had.
2. The *behaviorist learning perspective* is the motivation of past experiences, which can be positive or negative. In gamification, this is an often-used practice to motivate users by leveling up or by losing a virtual life. The great advantage is that the user can get

immediate reinforcing feedback with the usage of gamification.
3. The *cognitive perspective* is the motivational aspect that creates motivation through expectations, estimation, and assessment of specific goals. The consequences are understood, and the motivation comes from the subjective value of task completion. A common game element for this type of motivation are quests. Through quests, the users get a direct goal, and the consequences are clearly shown in the form of badges, virtual items, or other benefits. The user gets awarded for problem solving and task completion.
4. The *self-determination theory* focuses on three universal psychological needs for competence, autonomy, and social relatedness. Motivation comes from the feeling of being able to learn and master a new skill, from having the opportunity to decide themselves, and from having peers in the same community. In gamification, different choices can be offered to the player to solve tasks and different opportunities to experience and learn new skills. These options give the player autonomy and through badges and awards, the competences of the player are shown. The need for social relatedness can be achieved through cooperation between players or by offering to generate communities in which they can take part.
5. The *perspective of interest* is motivation from the relation between the person and the contents of a task. In gamification, players should be able to customize their experience to their preferences to fully immerse themselves and get a feeling of flow. From this perspective, the context is the main motivation factor for the player [25].

In the paper from Sailer et al. they point out the importance of understanding the relationship between different motivational mechanisms and game elements when designing gamification tools. They identify elements such as points, badges, and leaderboards, progress bars, quests and avatars and match them with several psychological perspectives, including the trait perspective, the behaviorist learning perspective, the cognitive perspective, the perspective of self-determination, the perspective of interest and the perspective of emotion. They highlight the potential of gamification when it comes to foster the work motivation [52].

The research from Pura et al. investigated the potential of gamification in order to enhance motivation and engagement, especially among remote teams. In conclusion, they show that gamification has a high potential to improve motivation and engagement and emphasize the value of collaborative design elements in gamification to create a sense of community among geographically dispersed teams [47].

CHAPTER 3

Requirements

The definition of requirements is a crucial part of gamification, multiple researchers have stated that this is the first obstacle where the whole process of gamification of a product can fail. Morschheuser defined 13 design principles (DP) based on the literature about gamification and validated them in interviews with gamification experts. These are the 13 design principles:

- DP 1. Understand the user needs, motivations, and behavior, as well as the characteristics of the context
- DP 2. Identify project objectives and define them clearly
- DP 3. Test gamification design ideas as early as possible
- DP 4. Follow an iterative design process
- DP 5. Profound knowledge in game-design and human psychology
- DP 6. Assess if gamification is the right choice to achieve the objectives
- DP 7. Stakeholders and organizations must understand and support gamification
- DP 8. Focus on user needs during the ideation phase
- DP 9. Define and use metrics for the evaluation and monitoring of the success, as well as the psychological and behavioral effects of a gamification approach
- DP 10. Control for cheating / gaming-the-system
- DP 11. Manage and monitor to continuously optimize the gamification design
- DP 12. Consider legal and ethical constraints in the design phase

- DP 13. Involve users in the ideation and design phase

These 13 design principles can give guidelines during the design phase of gamification[43]. The design principles were considered in the generation of the requirements, and an association to the corresponding design principle is given by referencing the number of the design principle. For the generation of requirements, the users' needs and goals are the main topic to focus on. The design method should be a user-centered design approach. The focus should be first on the people, what they want to achieve and how they are motivated. Therefore, the two main tasks of users are defined to better understand their needs and to be able to generate the correct requirements (DP 1):

3.1 Use Cases

3.1.1 Commissioning of new devices

The current process for commissioning Festo devices is to connect them to the network and then open the Festo Automation Suite to perform the initial configuration of the devices. During initial commissioning, the device name, network settings, or firmware can be changed and adjusted to the required values via the Festo Automation Suite. In this scenario, several devices of the same type may need to be commissioned, and it can be difficult for the user to differentiate between the devices. The user can investigate the device details and compare the information displayed in the Festo Automation Suite to the information printed on the devices. The possible identifications of a specific device could be the MAC Address of the device or the serial number. This manual comparison is tedious and error-prone. Therefore, the Festo Automation Suite offers the option to turn on the identification feature of a device. When this feature is turned on, the device flashes all of its status LEDs to differentiate itself from the other blinking LEDs. In figure 3.1, a CPX-E-CEC can be seen with its normal status LEDs on the left and on the right when the identify feature is turned on. With the help of the blinking LEDs, the user knows which device is currently selected and can adapt the settings of the device. The mobile app should make this selection of a specific device even easier. The app should be able to scan the Data Matrix code, which is printed on the housing, and give the user the direct connection to the device. When the device is scanned, the user should be able to change all the necessary settings to the desired values. This new requirement is modeled in figure 3.4.

3.1.2 Maintaining existing configurations

The other main use case is to check whether a servo drive is configured correctly and see which motor is connected and what is moved by the motor. For example, a machine that wants to move in 3 dimensions needs at least 3 servo drives, 3 corresponding motors, and 3 axes. During maintenance or commissioning, it can be critical to check which servo drive is controlling what and if everything is working as expected. In the Festo Automation Suite the 3 servo drives are represented in a project, and they can have names that could

Figure 3.1: CPX-E-CEC with normal status LED (left) - CPX-E-CEC with identifying feature on(right)

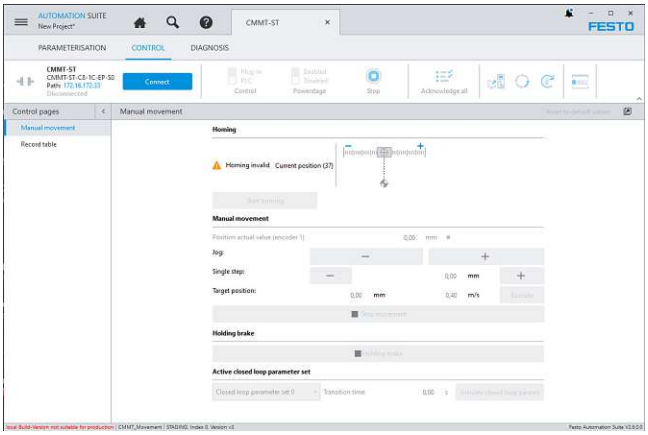

Figure 3.2: Manual Movement Page from the Festo Automation Suite

reveal their purpose like 'Servo Drive X Axis'. However, these names do not ensure that the drives are configured correctly or during commissioning these names have to be given to the servo drives. The user has the option to directly connect to the servo drive via its IP address and manually move the connected motor and axis. Figure 3.2 shows the Festo Automation Suite interface that provides the ability to manually move the motor for testing. The current problem with the Festo Automation Suite is that there could be no direct line of sight between the moving parts and where the notebook with the Festo Automation Suite is. Therefore, the mobile app should solve 2 inconveniences for this type of task. The first is the correct selection of the servo drive by offering the option of scanning the Data Matrix code on the device and adding it directly to the project and naming it accordingly. The second inconvenience is the possibility of not having a direct view of the moving parts, which can be solved by the cable-free experience of using a smartphone with the mobile application. Figure 3.5 represents this new workflow with the help of the mobile app.

3.2 Functional Requirements

The mobile application should help users to commission and maintain Festo devices. The mobile application should be an extension of the Festo Automation Suite and enhance the user experience by adding new features and gamification elements. Festo devices can be controllers or servo drives used in industry to automate processes. They can be connected to a network using Ethernet cables and can then be scanned within the same network. The main functional use cases for the mobile application are modeled in the use case diagram shown in figure 3.3 and defined in the user stories below.

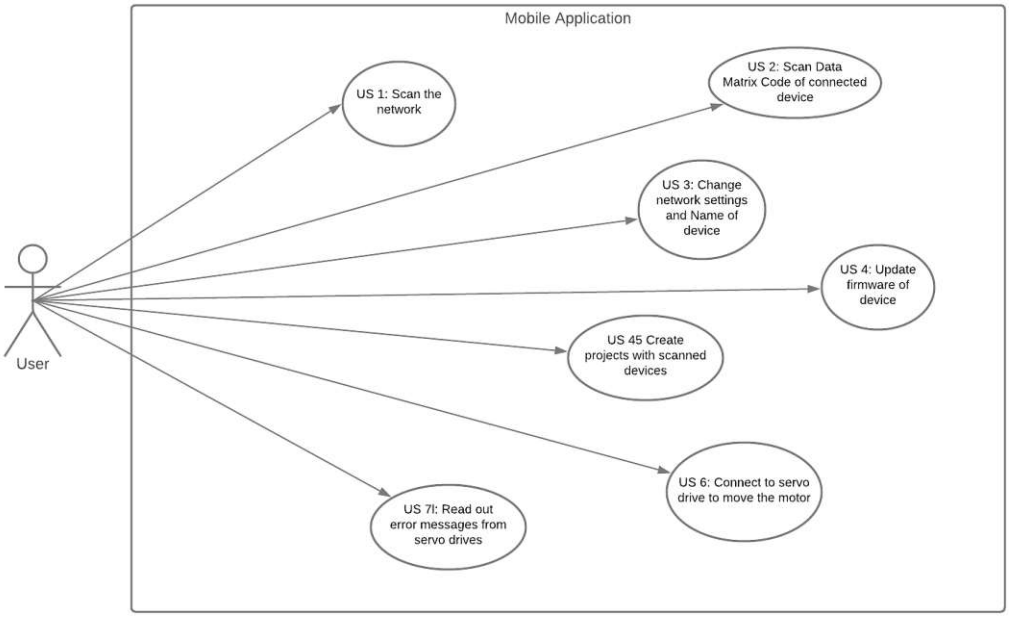

Figure 3.3: Use Case Diagram

The application should be developed using the Scrum process to have an agile and iterative process (DP 4). In the Scrum process, requirements are written down in user stories (DP 8) and collected in the product backlog. Sprints are fixed length time periods, in which the development team has time to develop and complete user stories. At the end of a sprint, a new sprint release is created, and this is a new increment of the developed product. In this case, a sprint is 3 weeks long, and in the beginning the sprint planning defines which user stories should be tackled in the next 3 weeks. After each sprint, there is a sprint review, where the current state of the mobile app is presented to the stakeholders and feedback is taken in (DP 3). User Stories define who the beneficiary is and what this person/ role wants to achieve, i.e., "As x, I want to y in order z". (DP 2) The user stories are then used to create tasks and guide the development of the app. The researcher defined the user stories and were then refined with the development lead

of the Festo Automation Suite to take their year-long experience and knowledge into consideration.

- ***US 1*** *As the user, I want to scan the network for devices in order to modify or control them.*
  Festo devices are reachable over the network with proprietary protocols. When the network is scanned for devices, the devices correspond with their current state. The sent information is their current name, IP address, firmware version, and MAC address. The user can then select a scanned device and alter the name, IP address, or firmware version.

- ***US 2*** *As the user, I want to scan the Data Matrix code on the physical device in order to get the exact device.*
  On the device, there is a Data Matrix code, when the user scans it with the included scanner, the device information should open. This helps the user to get to the device page quicker and make his life easier.

- ***US 3*** *As the user, I want to change the network settings and the name of the device in order to organize the network.*
  To avoid errors the user wants to organize the network and check that each device has its own network address and is reachable. The name can be used to organize the network or to better identify the devices in the network.

- ***US 4*** *As the user, I want to update the firmware of devices to get the newest features and bug-fixes for a device.*
  Firmware updates can unlock new features for the user or solve bugs. The user should be able to update the firmware of a scanned device and want to select the firmware from a list offered specifically for a certain device type.

- ***US 5*** *As the user, I want to create projects with the devices in order to revisit them later.*
  The devices can be organized in projects, which should then be usable over the PC where the Festo Automation Suite is running.

- ***US 6*** *As the user, I want to connect to a servo drive in order to manually test the movements of the motor.*
  The user wants to connect to a servo drive that has a connected motor and axle and move the corresponding axle to check if everything is connected properly and that no errors occur when it is moved around.

- ***US 7*** *As the user, I want to connect to a servo drive in order to read out the error messages and reset the device.*
  Sometimes the drive can throw an error, which can be solved by resetting the device and deleting the error memory of the device. On the other hand, the user wants to connect to a device and see what errors are currently displayed.

3.3 Gamification Requirements

The mobile application should have gamification elements to increase the motivation of the users. The gamification elements that will be used are Points, badges, leaderboards, quests, progress indicators, and level. Pointsification is the usage of point-based game elements, such as leaderboards, badges, level, and progress indicators [32]. Pointsification can be a useful approach for gamifying software if the point gaining rules are transparent to the user. For the usage of pointsification, the following game elements should be used:

- Progress indicator, which informs the user of the progress made and when the next achievement will be reached after completing a task and gaining points.
- Overall standings/ leaderboard, which is a game element, in which the points are represented via icons or pictures of medals or trophies. These visual elements can give the users psychological gratification.
- Total Points/ level, which offers the possibility to the users to compare their progress with other users in the team using their achieved points.

To achieve higher user satisfaction and acceptance, the game elements must be clear and understandable [32]. It is important to avoid giving users too many points when rewarding them for appropriate behavior. Users should not get an achievement every time they do something desirable [12].

The two main tasks are also used to identify the possible situation where points can be awarded. The first task **Commissioning of new devices** 3.1.1 is modeled as an activity diagram in the figure 3.4 and the point system is also modeled. The user gets points for setting up a device by changing the network settings and perhaps changing the name of the device. It should be a one-time point award per device and to prevent users from cheating by always changing the same device to get points. Therefore, the MAC address of the devices must be stored to prevent exploitation and abuse of this game mechanic (DP 10). This mechanism must be global, not per user, to prevent users from cheating and earning points by using devices already configured.

The second task **Maintain existing configurations** is also modeled in an activity diagram in figure 3.5. In this task there are two different options to gather points modeled. The first way to earn points is to check the diagnostic state of the drive. If an error is displayed, the user is awarded points when the error is resolved, and the state of the servo drive is back to normal. The other point-earning task is to move the device manually. These points should motivate the user to manually check that the axis is moving freely and that there are no errors. Both point-reward actions should have a built-in timer to avoid exploitation of point collection (DP 10). After the points are awarded, it should take some time for the same drive to award the points again.

In order to support the point rewarding system and other mentioned features, gamification requirements are needed. Like the functional requirements, the requirements for the

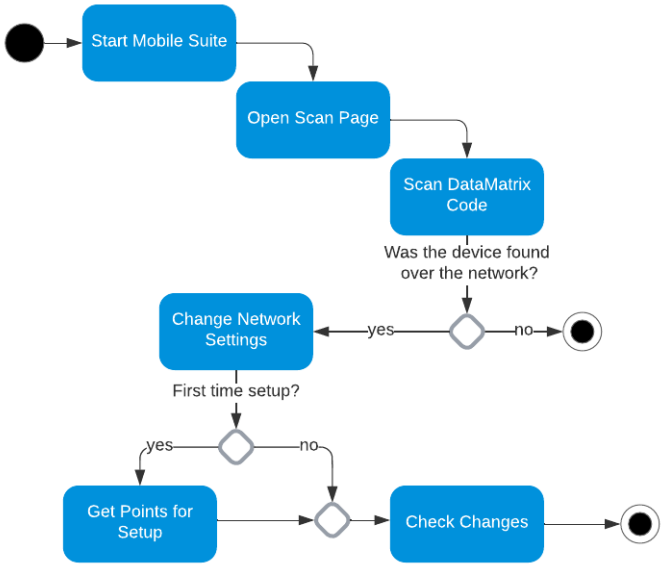

Figure 3.4: Activity diagram of changing network settings

gamification features are written in user stories. The following user stories are defining what features need to be implemented:

- ***US 8*** *As the user, I want to register myself in order to choose if I want to share personal information or arbitrary information.*
  In the production sector, the employees are not used to real-time monitoring of their tasks. By registering, the user's actions will be tracked for the progress indication until getting the next award and to award users for task completion. This tracking could lead to problems with working councils in Europe, Japan and the USA (DP 12) [36]. One solution could be the option of letting users choose whether to use information that could identify them or use a random nickname.
- ***US 9*** *As the user, I want to log in in order to get my personalized experience.*
  In case the application is used on a shared smartphone, the users want to log themselves in to work on their own progress and skills. To differentiate between users, they need accounts they can log into. The personalized experience motivates the user through the perspective of interest [25].
- ***US 10*** *As the user, I want to check my user statistics compared to other users.*
  Part of gamification involves competing elements; therefore, users need an option to compare themselves. The users should be able to compare their accomplished skill levels and their overall level. The usage of Smart leader boards shows customized rankings based on the users' best achievements. This ensures that only positive information is shared between users and prevents shaming and disappointment [38].

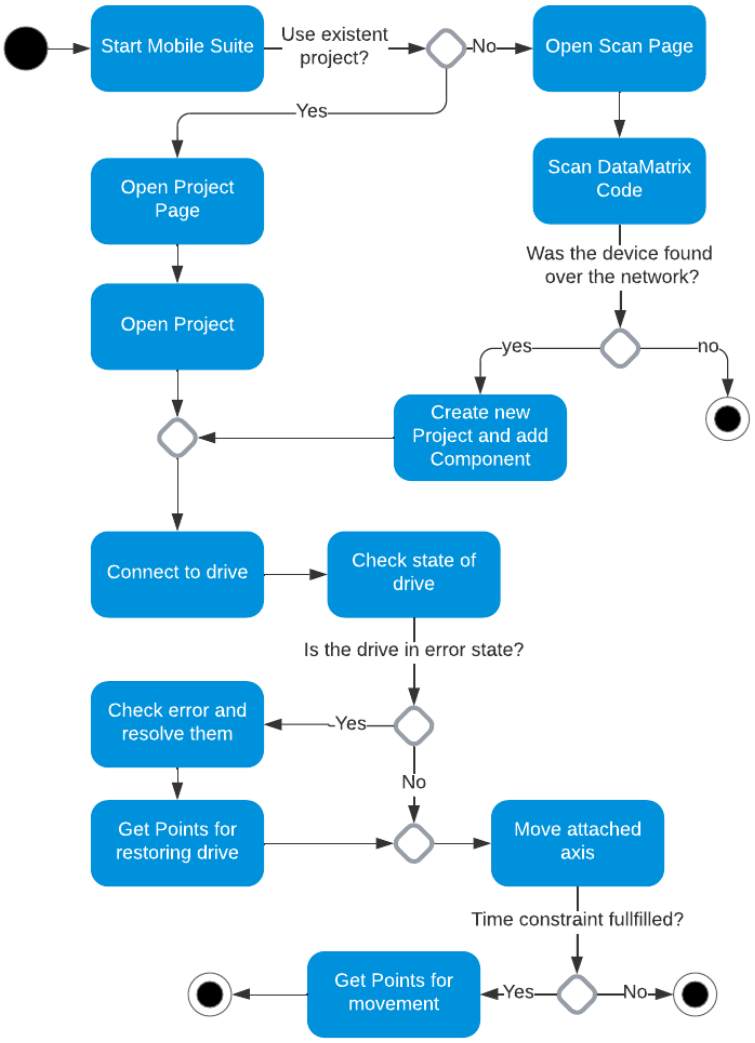

Figure 3.5: Activity diagram of maintaining servo drive

- ***US 11*** *As the user, I want to gather points in order to complete quests and reach new levels and get new achievements.*
  The user wants to have tasks to achieve awards and new levels. This user story uses motivation through the cognitive perspective. The defined quests give the user a direct goal to achieve, and the results from each quest are known. On the other hand, the user gets its motivation through the rewards in the form of badges, which is the motivation through the trait perspective [25].

- ***US 12*** *As the user, I want to have a page for my current quests in order to see my next objectives.*
  The cognitive perspective of motivation builds on the foundation that the user knows which current quests are open and what needs to be done to complete the quests [25]. The current quests should be highlighted, and the upcoming quest can be displayed. The page should consist of a graph with different quests grouped corresponding to their main topic. The icons for the quest should be clickable to gather more information on the specific tasks to achieve the goal of the quest.

- ***US 13*** *As the user, I want to understand how points can be achieved and understand what the different point systems mean.*
  In order to increase acceptance and understanding, the users should either get an introduction or a page where they can get information about the pointsification system [16].

- ***US 14*** *As the user, I want to know which data is collected and what is happening with the data.*
  Users could believe that their scores can be used to evaluate their skills or judge their work by the management. The problem is that the collected data are not complete enough for a real evaluation, and this incomplete evaluation could be harmful to the users. Foucault et al. had to overcome the concerns of developers in their case studies. The developers had concerns about the collected data and were worried that they will be evaluated with the tool of the study. After the explanation by the researchers, the concerns were settled, and the developers were willing to use the Themis tool. However, the researchers were concerned that the user that joined later and did not get the explanation from the researchers could dislike the tool because of the before-mentioned concern. Therefore, they implemented a data usage policy that is directly visible to the users of Themis [16].

- ***US 15*** *As the user, I want the option to opt-out of the gamification features*
  Not all users who are using the app are motivated by the gamification features and can find it irritating in their work tasks. In order to avoid frustration in the work environment, the user should have the option to decide whether they want to use the included gamification elements. Foucault et al. recognized in their studies that not all people want to use gamification or take part in their study. In their first case study, only eight out of 14 developers took part in the survey. In the second study, only 6 out of 40 developers took part in their interviews [16].

CHAPTER 4

Prototype

This chapter explains the prototype, the development method, and the functionality of the finished prototype. The goal was to generate an artifact to evaluate whether gamification can be used to motivate users of an industrial maintenance and commissioning application. The application was developed for use with Festo industrial controllers. Currently, these controllers are commissioned and configured with the Windows application Festo Automation Suite. The mobile application should improve the user experience for workers making them more mobile and freeing them from the tethered to a computer. With the app, they can move freely and have all the necessary information and basic functionalities to commission and maintain the controllers.

The prototype was developed using the agile method SCRUM. Each sprint was 3 weeks long, and after these sprints, the progress was presented in a review with the stakeholders. The user stories and sprint planning were done by the researcher and head developer of the Festo Automation Suite. The prototype uses the REST API from the Festo Automation Suite to communicate with the devices that are in the local network. The devices are only reachable over wired connections, due to the used communication protocols between the devices and the PC that runs the Festo Automation Suite. Therefore, a host PC is needed that has the Festo Automation Suite installed and is able to communicate with the devices over a wired connection. The host PC and the smartphone have to be in the same network, so that the mobile application can access the locally hosted REST API from the Festo Automation Suite. The mobile application is a digital assistant system that should improve the user experience. The gamification features use a Rest API hosted on the Azure Cloud. The gamification REST API handles the user data and gamification features such as points, progress, levels, and achievements. The gamification REST API has an underlying database that keeps track of the users' progress and achievements and enables the mobile app to access this information over the network.

4.1 App Pages

4.1.1 Login Page

When opening the app the first time, the user is greeted on the login page, see figure 4.1. On the page, the user can either log in if an account already exists or go to the registration page and register himself/herself. The user will not be greeted each time by the login page, because the account will be remembered, and the user will be automatically logged out after 24 hours. This page fulfills **US 9**, because it allows one to have personalized experiences based on the logged in user.

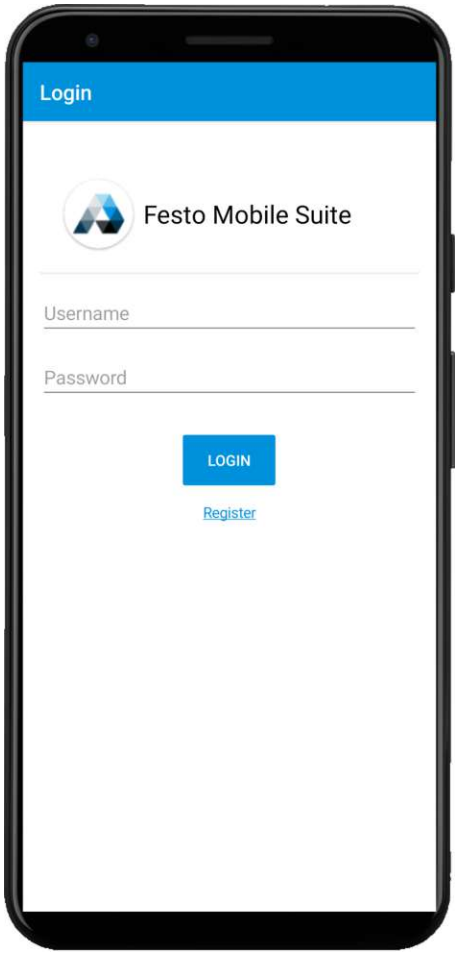

Figure 4.1: Login page

4.1.2 Register Page

On the register page, see figure 4.2 on the left, the users the user is able to register himself/herself. The first text field is the username, which can be artificial to hide

your own identity or the name of the user. This was chosen to comply with the **US 8** to give the user the option to choose by themselves. The password must be entered twice to confirm that the user knows his password and hasn't made a typo. The email will not be shown to other users but is visible to the researchers in case they need to message a user in any scenario. The image on the top is clickable and opens the Image Selection Popup, see figure 4.2 on the right. The user has the option to choose between 50 funny avatars to represent their interest or self. The avatars are from Laua Reen and are free to download on iconfinder(https://www.iconfinder.com/iconsets/avatars-xmas-giveaway). When the registration is successful, the user is logged in and the project page 4.1.3 is opened.

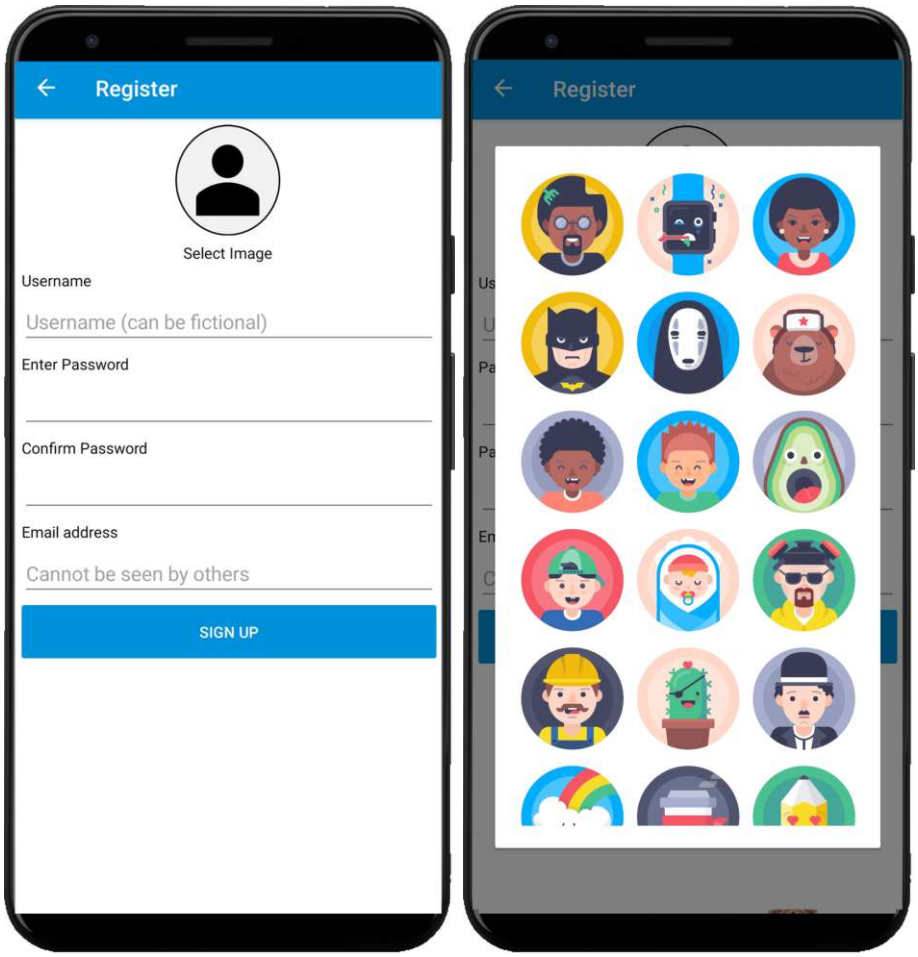

Figure 4.2: Register Page (left)- Image Selection Popup (right)

4.1.3 Project Page

After logging in, the first page is the projects page and can be seen in figure 4.3. On appearing, the mobile application sends a HTTP Get request to the host PC to load

all projects that are found on the host PC. The loaded projects are then presented in a list view, where each entry can be expanded to show further details beside the name of the project. The expanded project shows following additional information: project file location, description, component count, creation date, created by, last modified date, and last modified by. The projects list is part of **US 5** since it is needed for the organization of projects that are found on the host PC. In the top left corner, the 3 bars are a button to get to the navigation menu 4.1.6.

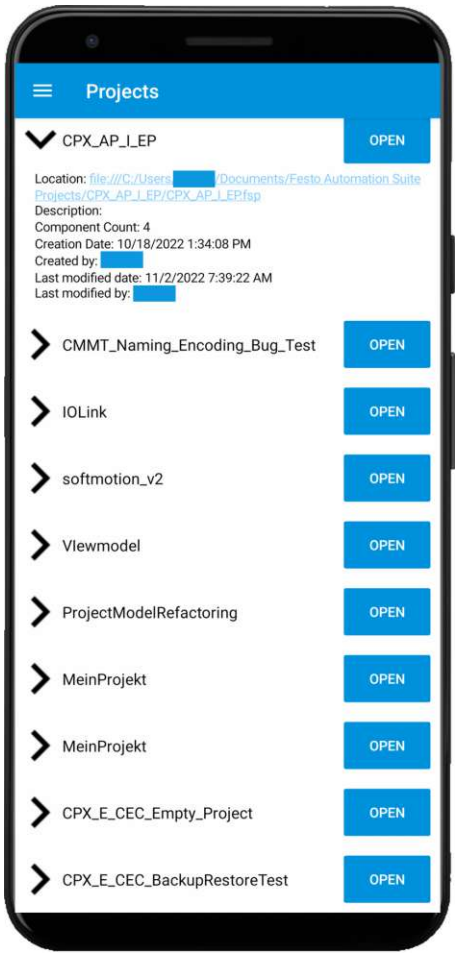

Figure 4.3: Projects page

4.1.4 Project Detail Page

After pressing the "open" button on one project, it opens itself and the project detail page, see figure 4.4, is shown and is used to show details of the mentioned projects of **US 5**. In the top left corner is the back button to go back to the projects page 4.1.3. In the header, the title is the name of the opened project. The page shows detailed information on all components that are currently in the project. Each component shows

its own information: The name of the component, the device list of the component, the connection route and the connection status and the connectors of the device. The open button opens the component, and the app changes to the component page.

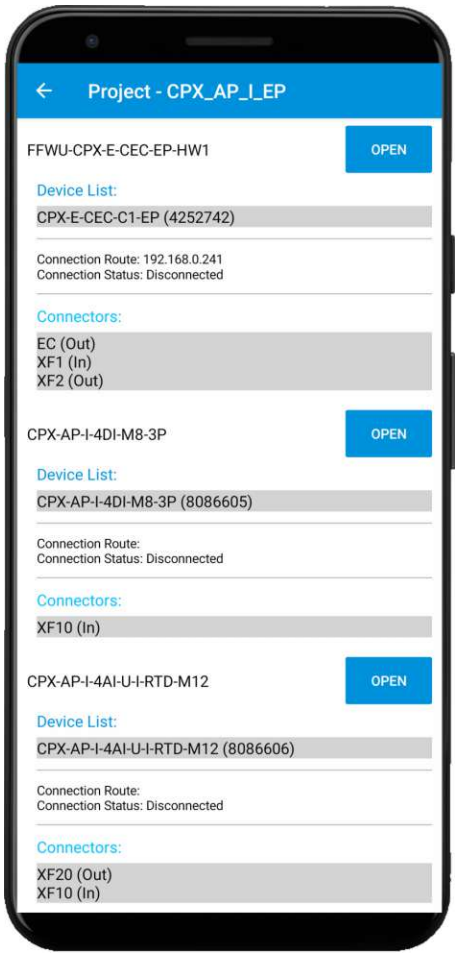

Figure 4.4: Project Detail Page

4.1.5 Component Pages

In the top left corner there is the back button to go back to the project detail page 4.1.4 to see the other components again. Below the header, the component information, see Figure 4.5 (left), is shown to check if the correct component was selected. Next to the component information, the page the Connect button is placed, when pressed the mobile app sends a REST call to the Festo Automation Suite and the host PC establishes a connection with the selected component. Below the component information, a navigation menu for the 3 options, parameterization, control, and diagnosis, exists and the selected option is shown by highlighting the text color in blue. This page is needed as a starting

point for **US 6** and **US 7**, as it is the page on which the connection to the servo drive is established.

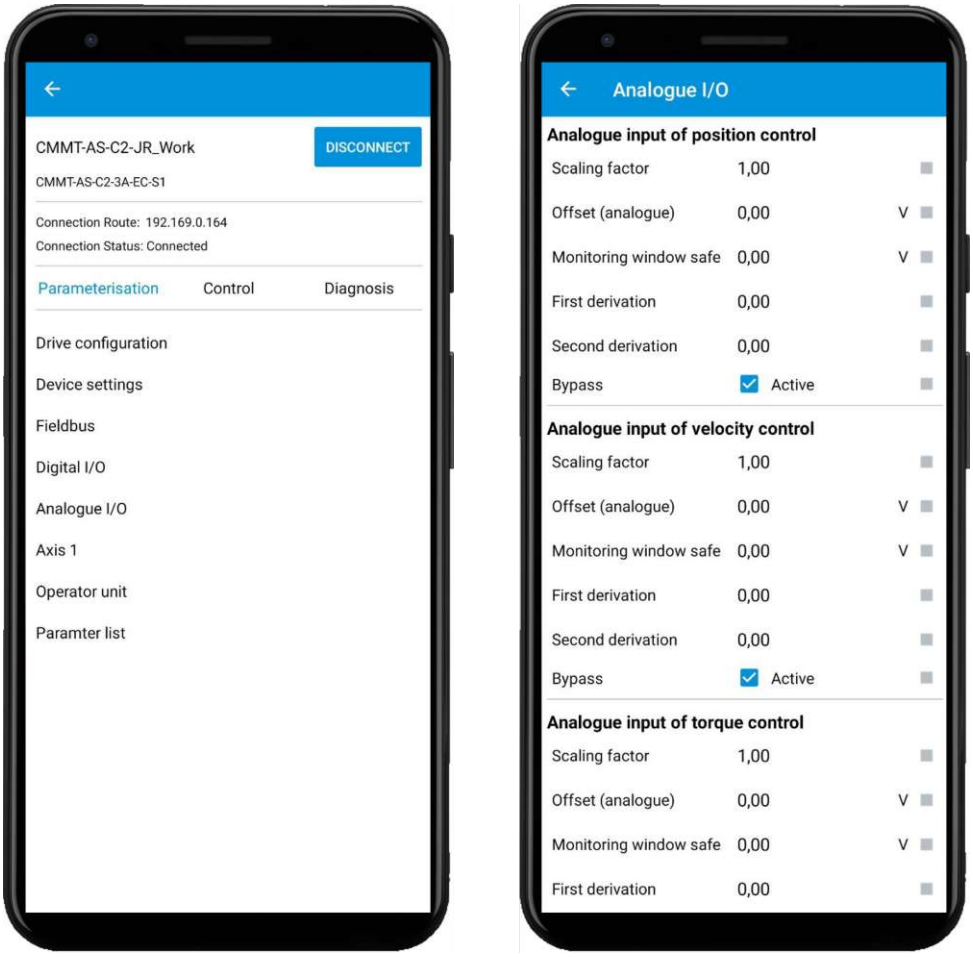

Figure 4.5: Component Main Page (left) - Parameter Page (right)

4.1.5.1 Parameter Page

In the top left corner, the back button goes back to the component main page 4.1.5. The parameter pages are divided into multiple subpages and each page has its own parameter and parameter groups. The changing of parameters could be needed to solve issues that were read out before and could be one of the solving steps referred to in **US 7**. The parameters are the parameters of the chosen component and are used to configure a servo drive. The mobile app stores the parameter groups and IDs per page and requests the parameter information from the Festo Automation Suite REST API by sending the ID. The response includes the name, type, current value, and much more information for each sent parameter ID. Then the app can dynamically build up the parameter page, see figure 4.5 (right). The parameter group name is displayed as the bold text, and each

parameter gets corresponding fields. Next to the parameter, a gray square is shown and when clicked it opens the parameter info page 4.1.5.2.The parameters can have string content, Boolean content, or enumeration content. When an enumeration parameter is clicked, a pop-up with the list of select-able items is shown.

4.1.5.2 Parameter Info Popup

The popup is opened by clicking the gray square next to the parameter. In the top, the name of the parameter is shown. The address and parameter type are in bold. Below that, the description of the parameter is shown. If the parameter has a default minimum or maximum, the value is shown and clickable. If a value is clicked, the popup closes itself, sends the new value to the REST API, and the page reloads itself.

4.1.5.3 Control Page (Manual Movement)

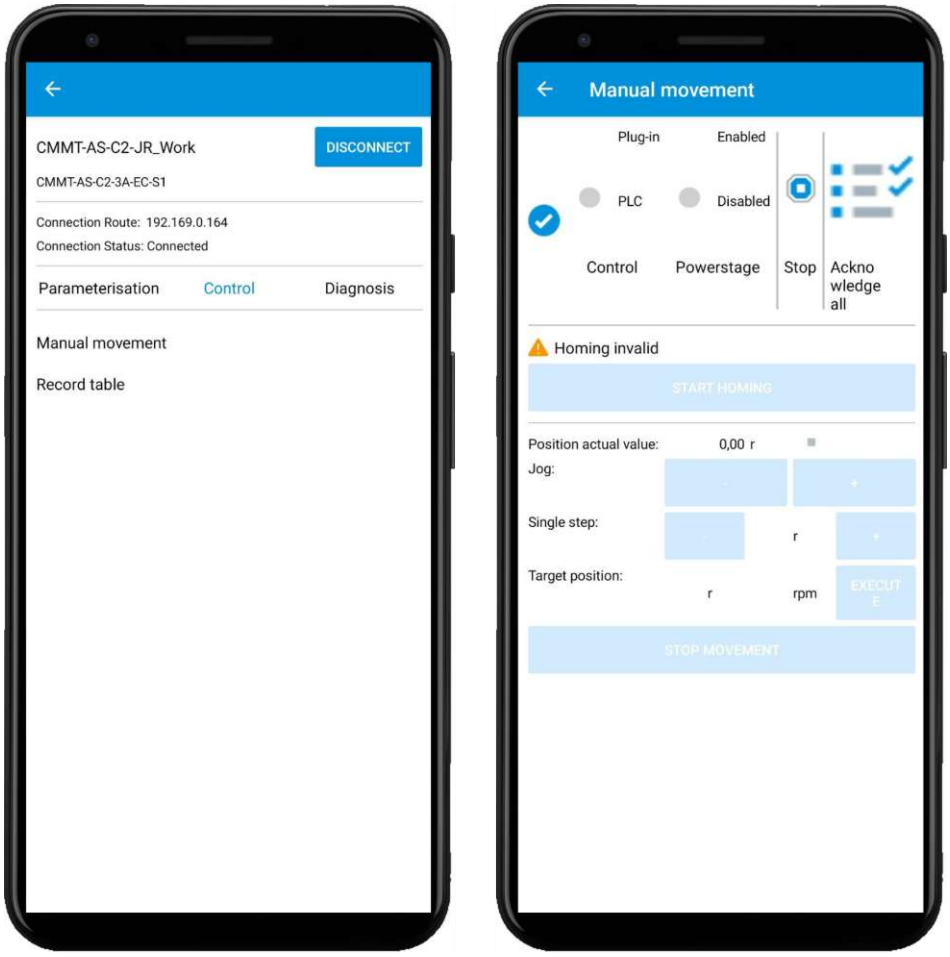

Figure 4.6: Component Page on Control option(left) - Manual Movement Page(right)

On the component main page, the user can change to the control option to see the subpage "manual movement", see figure 4.6 (left). The manual movement page, see figure 4.6 (right), can be used to move the motor and axis of the connected servo drive and was implemented for the **US 6**. The back button goes back to the component main page 4.1.5. The device state icon shows the current diagnosis state of the servo drive and is clickable to reach the device state page 4.1.5.4. With the acknowledge button, the device state can be reset to delete an old error. The homing text shows if the axis has a valid homing point, if it does not, the start homing command can be sent via the start homing button. The current position of the axis is shown and can be altered in 3 ways. The jog is moving the axis as long as the button is pressed. The single step moves the axis by the defined step side in either direction. The last option is to move the axis by setting the exact position. In case of an error or emergency, any movement can be stopped via the stop movement button.

4.1.5.4 Device State Page

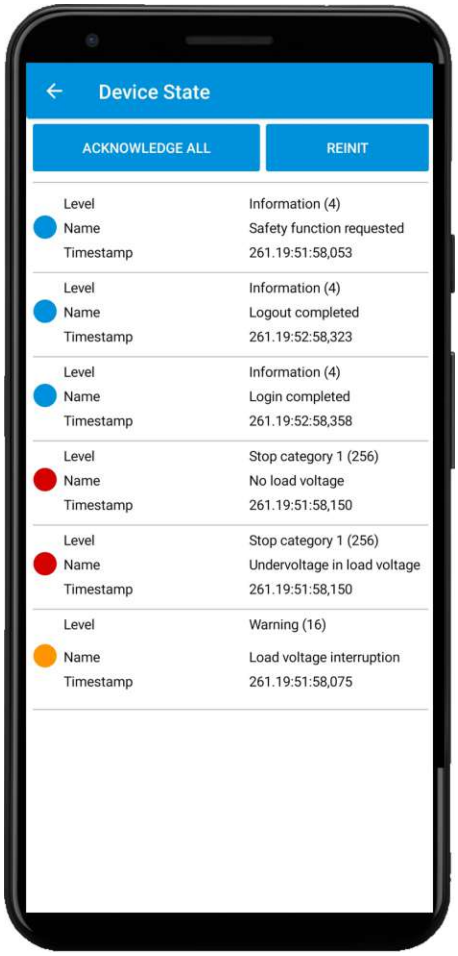

Figure 4.7: Device State Page

The Device state page, see figure 4.7, show the diagnosis information of the connected servo drive and is used to read out error messages and to reset the device state as described in **US 7**. This page is accessible over the device status icon on the manual movement page 4.1.5.3 or over the diagnosis option on the component main page 4.1.5. The acknowledge all button on the top of the page deletes all messages and rests the device and reloads the current state of the connected component. The colored circle shows the type of diagnosis information. Blue is information, orange is warning, and red is error. Each entry shows the level, the name and the timestamp. By dragging the list down, the device state is reloaded.

4.1.6 Navigation Menu

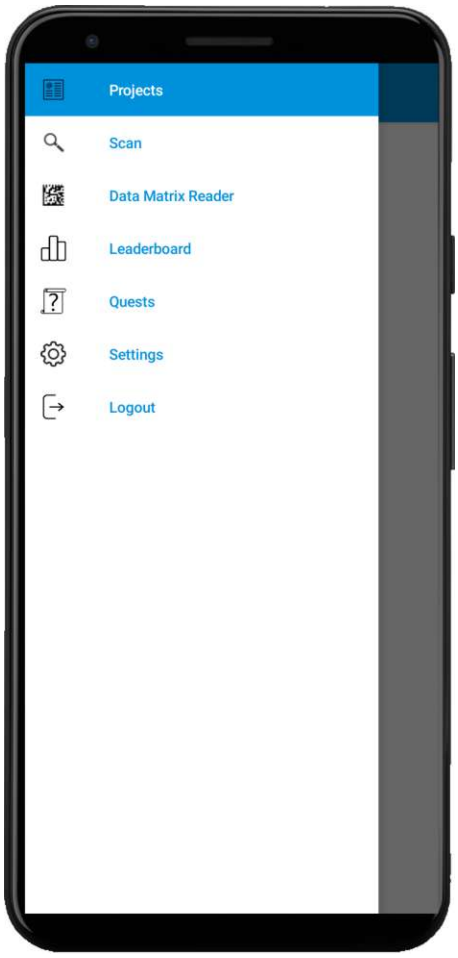

Figure 4.8: Navigation Menu

The navigation menu, see figure 4.8, can be reached over the three bars icon. The different app pages can be reached over the corresponding menu items. The last item of the menu is the logout button; this logs the user out and returns him/her to the login page 4.1.1.

4.1.7 Scan Page

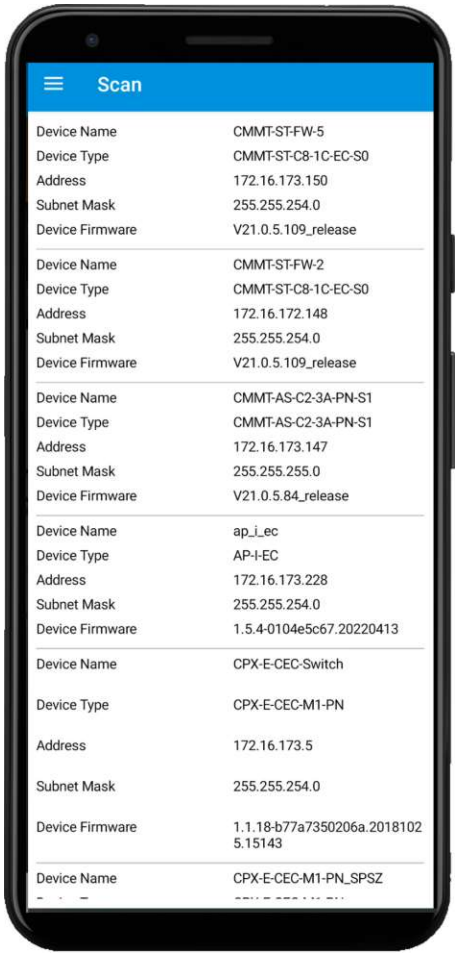

Figure 4.9: Scan Page

The scan page, see figure 4.9, can be reached over the Navigation Menu 4.1.6. This feature enables the user to scan the network as mentioned in **US 1** and find the devices they want to modify. When opening the page, the mobile app triggers the scan job of the Festo Automation Suite REST API, which starts a network scan on the host PC. After triggering, the app continuously checks the state of the scan job and once the job is completed, the result can be received. The job result is a list of all available Festo devices. Each device has its own entry and the device name, device type, address, subnet mask, and firmware are shown. Each entry is clickable, and the scanned device page is shown.

4.1.8 Scanned Device Page

The scanned device page, see figure 4.10, shows the device information: device name, device type, address, subnet mask, and firmware. This page represents the device and its

functions such as changing the network settings or the device name, which was defined in **US 3**. Below the information, the available device functions are shown. When the "Identify Device" function is pressed, the device starts to blink its LEDs to identify it among the other devices.

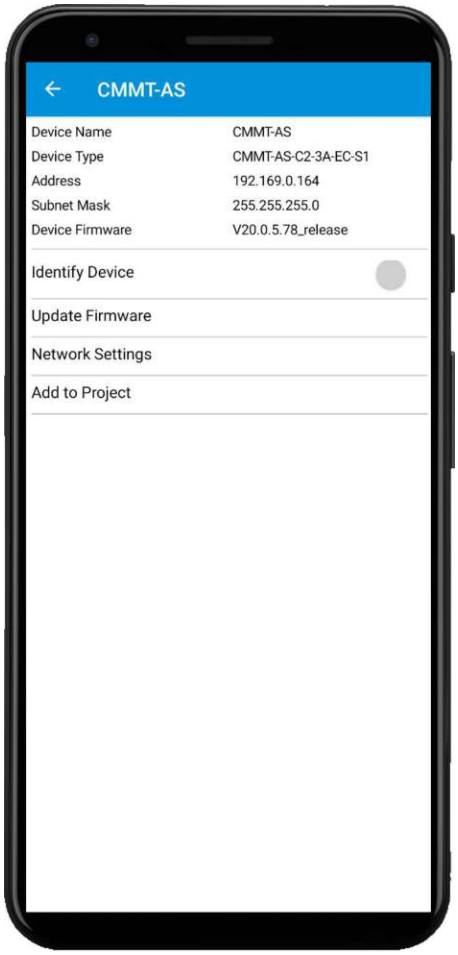

Figure 4.10: Scanned Device Page

4.1.8.1 Network Settings Page

The network setting page, see figure 4.11, can be reached over the scanned device page 4.1.8. This page meets the requirements of **US 3**. On the page, the name of the device and the network configuration of the device can be changed. After pressing the "activate new settings" button, the updated information is sent to the device, and the app will return to the scanned device page.

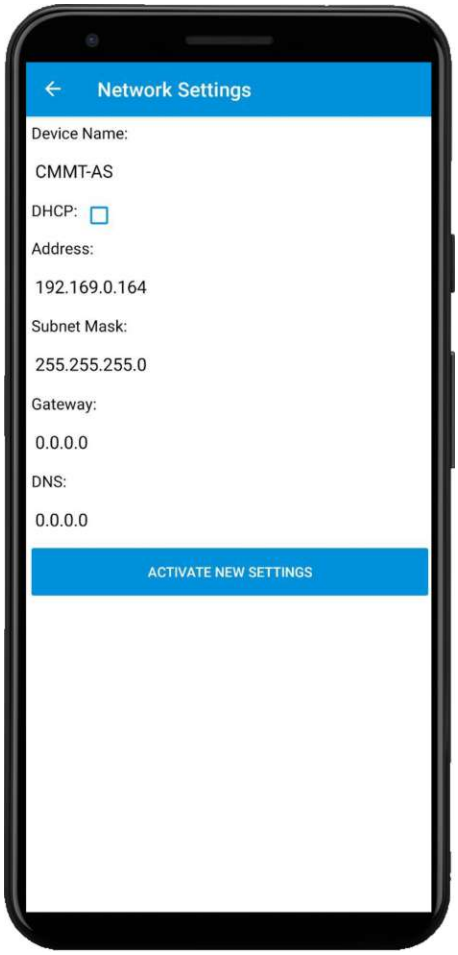

Figure 4.11: Network Setting Page

4.1.8.2 Firmware Update Page

The firmware update page, see figure 4.12, is another device function that can be reached over scanned device page 4.1.8. The page gives the user the option to update the firmware of the selected device in order to get the latest features and bug fixes, which was requested from **US 5**. The list of available firmware updates is shown to the user. The offered firmware are specific to the selected device and each entry is clickable. When a firmware is selected, the user is asked if he/she really wants to update the firmware and if accepted the app shows a progress bar is displayed until the firmware download is finished. This process can take up to several minutes and the application is blocking any user input to avoid any interaction with the device. This is done to secure that the device isn't altered during the update process, which could lead to a failed firmware update and the failed firmware update could brick the device in the worst case.

Figure 4.12: Firmware Update Page

4.1.9 Data Matrix Reader

The data matrix reader, see figure 4.13, can be reached through the navigation menu 4.1.6 and is part of the **US 2**. The mobile application needs access to the camera to be able to scan for data matrix codes. A data matrix code is a special type of QR code. The user has the option to turn on the flash of the smartphone if needed. When the data matrix reader is opened, the scan job is triggered in the background, like the scan job on the scan page 4.1.7. When a data matrix code is successfully scanned, the scan result is shown in a popup, see figure 4.13 (right). The popup contains the scanned serial number, which is also written on the housing of the device, and below the corresponding scanned device of the scan job is shown and can be opened. When clicking "Open device", the scanned device page 4.1.8 is shown. When no device with the corresponding serial number is found in the scan job result, only the scanned serial number is shown in the popup.

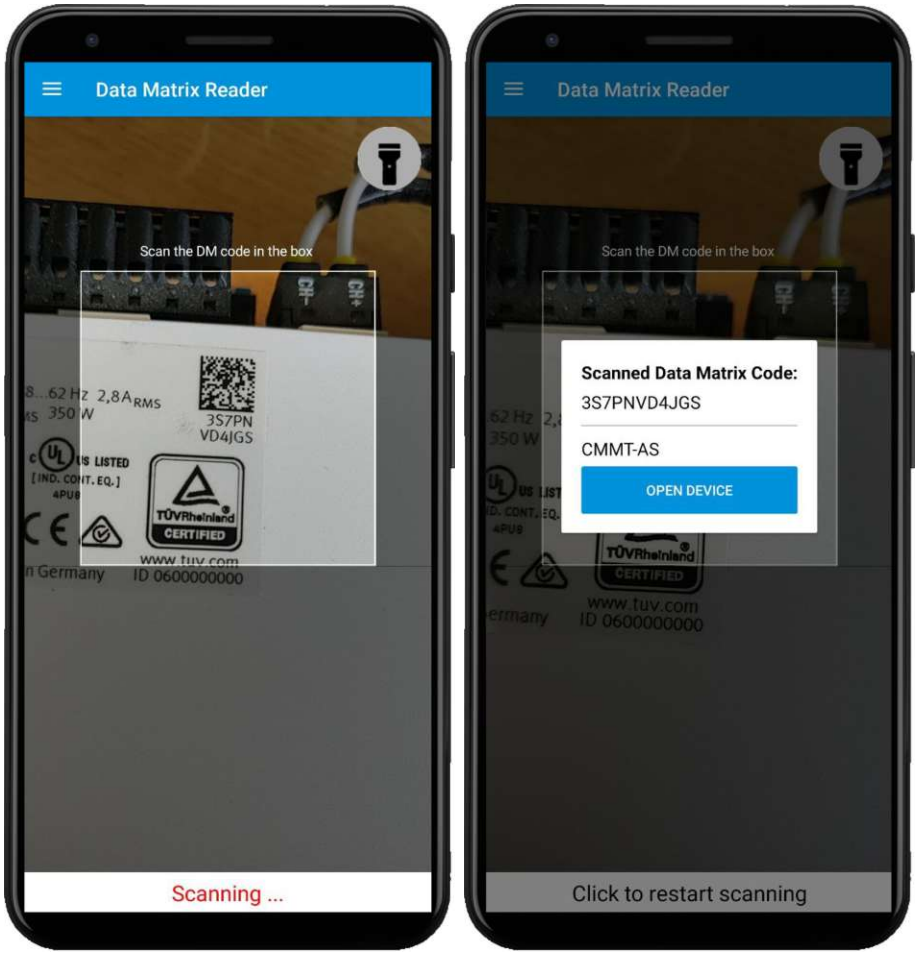

Figure 4.13: Data Matrix Reader (left) - Data Matrix Result (right)

4.1.10 Leaderboard Page

The Leaderboard Page, see figure 4.14, can be reached over the navigation menu 4.1.6, when the gamification features are enabled. The **US 10** was implemented as this leaderboard. At the top of the page, the user information is shown. The user image is displayed and can be clicked to be changed, when clicked the image selection popup as in figure 4.2 (left) is opened. Next to the user avatar, the username is displayed. Underneath the username, the current level is shown, and a progress bar indicates the current progress until the next level is reached. Then there is space to show the highest achieved rank per achievement type. Under the user information, a list of other users is shown. The other users are described with the chosen avatar, username, current level, and a display of their highest achieved rank per achievement type.

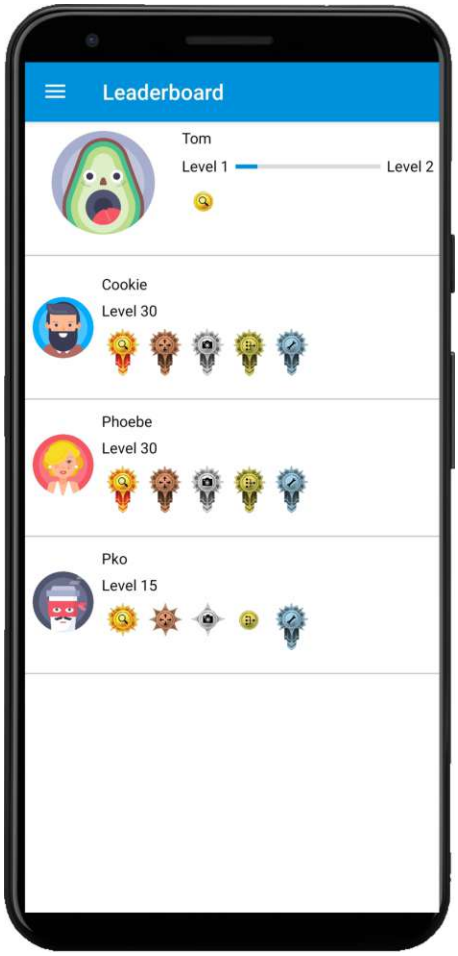

Figure 4.14: Leaderboard Page

4.1.11 Quests Page

The quest page, see Figure 4.15, is reachable over the navigation menu, when the gamification features are enabled. The quest page is a zoom-able page in which the user can see the current progress on different quests to fulfill the **US 12**. The middle of the quest tree is the user avatar. From there, 5 different achievement types are shown. Each type consists of five ranks and ranks that are not yet achieved are grayed out. Each rank is clickable and opens the achievement popup 4.1.12 and shows the current progress and information about the achievement type.

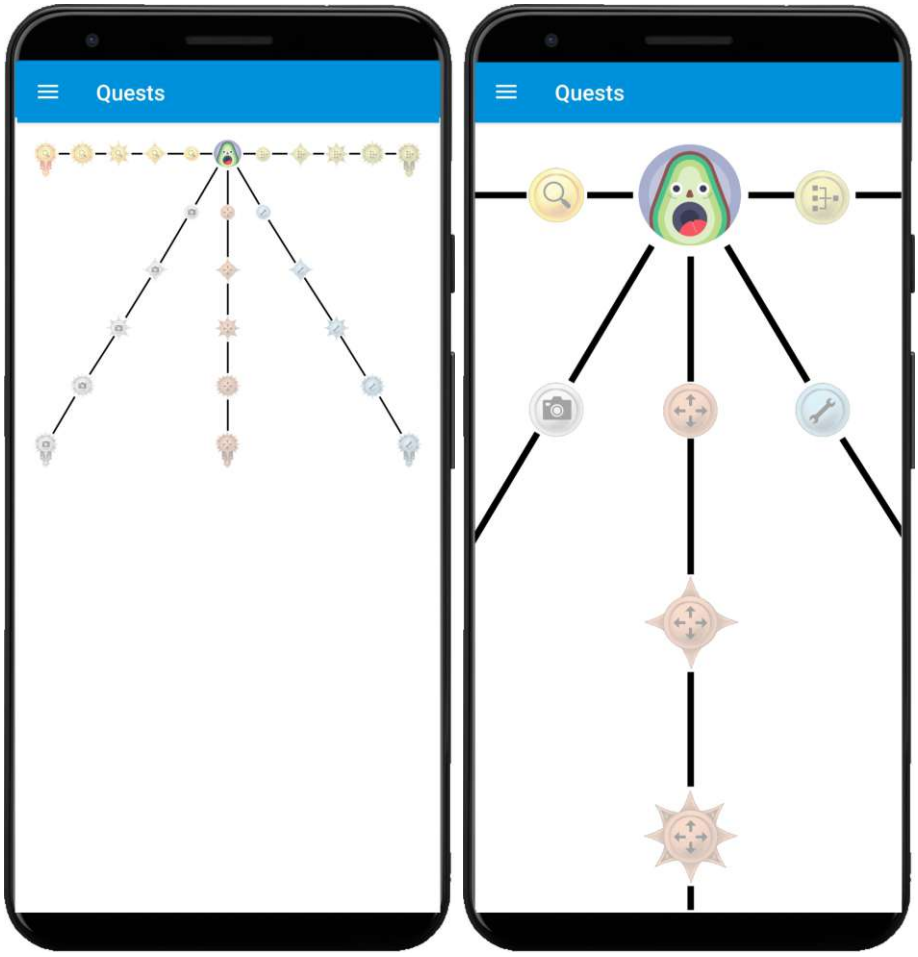

Figure 4.15: Quest Paged Zoomed Out (left) - Quest Paged Zoomed In (right)

4.1.12 Achievement Popup

The achievement popup, as seen in figure 4.16, has two appearances. The first is the information pop-up, in which the name, rank, and description of the achievement are shown. Through the popup the gained points and progress are shown to the user, which was requested from **US 11**. Below this information, the specific user progress is displayed. The second type is the completed achievement type, which is shown when the user reaches this new rank and consists out of a congratulation message.

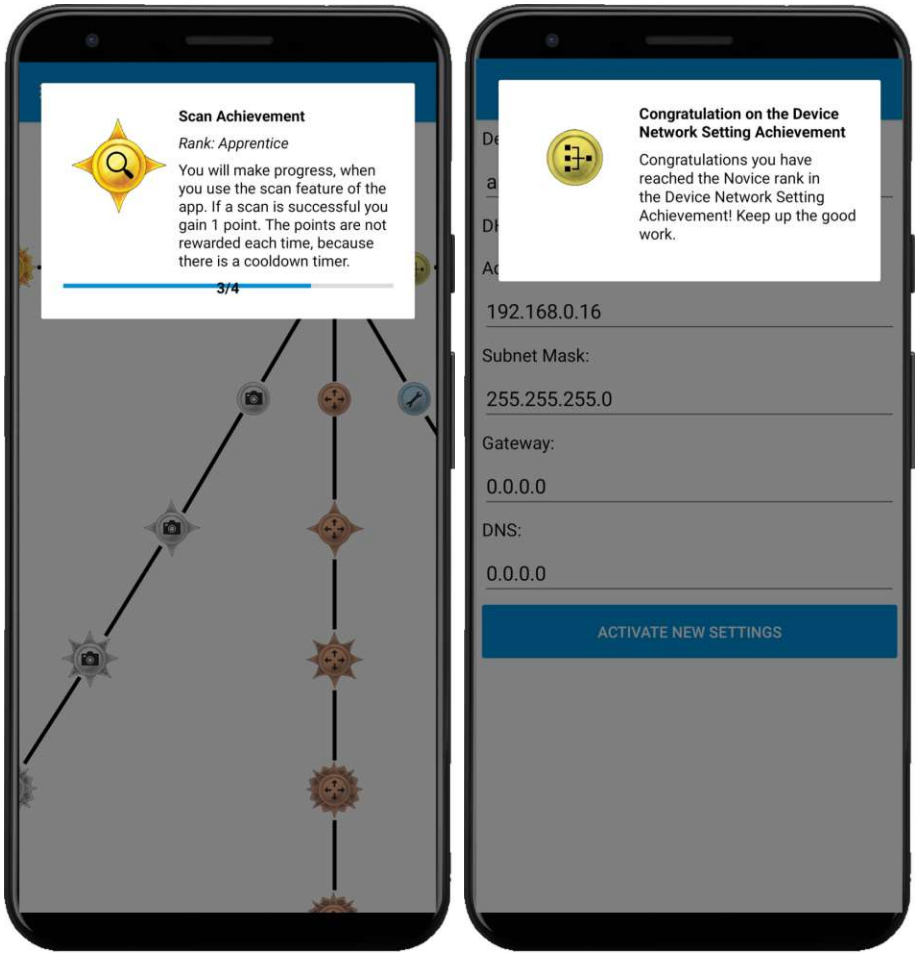

Figure 4.16: Achievement Information Popup (left) - Achievement Completed Popup (right)

4.1.13 Settings Page

The settings page, see figure 4.17, can be reached over the navigation menu 4.1.6. At the top of the settings page, the user can disable or enable the gamification features defined in **US 15**. If disabled, the user cannot gain any achievements and has no access to the leaderboard page 4.1.10 and the quests page 4.1.11. The base URL is the URL used to make ReST calls to the Festo Automation Suite hosted on a PC on the same network. This can be changed if there are some issues. The "Open Wi-Fi Settings" button brings the user to the Wi-Fi settings of the smartphone to make it easier to be on the same network as the PC with the Festo Automation Suite running. Below the Wi-Fi Button, a list of pingable IPs is shown. The device pings every IP of the network (i.e., 192.168.0.X, where X is 1-255). If an IP returns the ping request, it is added to the list. The IP list is clickable and when an IP is clicked, it is automatically exchanged in the Base URL.

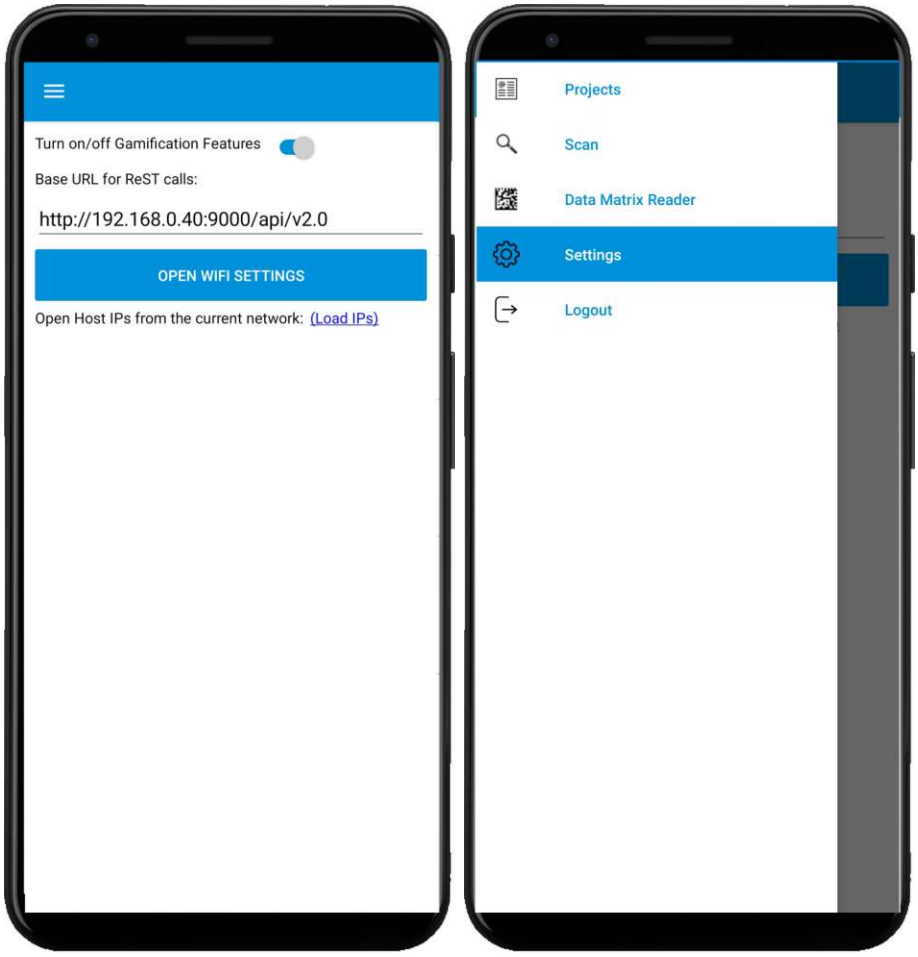

Figure 4.17: Settings Page (left) - Navigation Menu without Gamification Features (right)

4.2 Achievement System

There are 5 different achievement paths, in which the user can progress. The 5 different paths are called:

- **Scan Achievement**
  Progress can be made by using the scan page 4.1.7 and conducting a successful network scan.
- **Data Matrix Scan Achievement**
  The user is awarded with progress, if the user scans a new device by using the data matrix scanner 4.1.9.
- **Movement Achievement**
  When manually moving an axis of a connected servo controller in order to check, if

it is correctly set up and no errors occur, the user will gain points for the movement achievement. (See section 4.1.5.3)

- **Fix Achievement**
  If an servo controller is having issues and the user is able to resolve these issues by re-configuring or resetting the device, they will be awarded with points. (see section 4.1.5.4)

- **Network Setting Achievement**
  The first setup of a device network configuration will reward the user with points. (See section 4.1.8.1)

Each achievement path consists of the following 5 ranks: Novice, Apprentice, Specialist, Master, and Grandmaster. Each achievement path expects certain user actions to progress to a new rank. When the user registers himself/herself, there is no progress in any achievement path. After the first successful action, the user is awarded to the Novice rank in the corresponding achievement path. The higher ranks have higher thresholds until they are achieved and differ between the different paths. The user uses the app normally and when one of the predefined actions is completed successfully, a request to the gamification server is sent. The server then checks if it is a valid action to avoid exploitation and cheating. To prevent users from exploiting the system and gaining too much progress too quickly, the achievement system includes a timeout feature. This means that even if a user completes an action that would normally help them progress to the next rank, they must wait a certain amount of time before they can advance. This helps to ensure that users are engaging with the app in a meaningful way and are not simply completing tasks in an attempt to game the system. In addition, the achievement system includes an anti-cheat feature that checks that users are only performing one action for each device. This is controlled using the MAC address of the device to ensure that users do not attempt to cheat the system.

CHAPTER 5

Evaluation

In this chapter, the goal is to clarify and check whether the prototype developed is a useful assistant system and if the gamification elements are motivating the users. For this, a lab experiment with predefined tasks was conducted by experts in the field of industrial commissioning and maintenance. The lab experiment and the following questionnaire were used to evaluate the prototype for usability and how the gamification features are perceived. (DP 9)

5.1 Study design

The study was a lab experiment conducted at Festo Austria. Participants had to solve multiple tasks with the help of the mobile application, in which they encountered the implemented game elements. The participants were informed about the recordings of the study and a clear explanation about the usage of the collected data was given in advance. It was made clear that participation was voluntary, and the participants have the right to withdraw from the study at any time. The participants gave their informed consent and agreement about the collection of their data by taking part in the lab experiment. First, they filled out a small questionnaire to gather their demographic information. Then the participants took part in a relaxed thinking-aloud study while solving the tasks, following a task list, and verbalizing their thoughts and impressions. After all tasks were completed, a semi-structured interview was conducted by the researcher, who was also supervising the experiment and the thinking-aloud study. The smartphone with the app installed and the PC with the Festo Automation Suite Host application recorded the whole process to ensure redundancy in case one of the recordings fails.

5.1.1 Hypotheses

The evaluation aimed to clarify if the functional and gamification requirements of Chapter 3 were suitable in this field of industrial commissioning and maintenance. The goal was

to create a digital assistant system with gamification elements that makes the work tasks for the user easier and more fun to challenge the different tasks. Therefore, the following null hypotheses were created to be tested:

Hypothesis 1: Achievements do not increase the motivation and engagement of the user
Hypothesis 2: Leaderboards do not increase the motivation and engagement of the user
Hypothesis 3: Avatars do not increase the motivation and engagement of the user
Hypothesis 4: Quests do not indicate the knowledge about the digital assistant system

5.1.2 Demographic questionnaire

At the beginning of the lab experiment, the participants filled out a questionnaire to gather their demographic data. The following data were collected from the participants:

- School education
- Gender
- Age
- Work experience
- Experience with assistant systems
- Experience with gamification

5.1.3 Thinking-Aloud

After the demographic questions were answered by the participants, the researcher gave an explanation about the thinking aloud protocol, as described in chapter 1.2.5.1. During the initial explanation, the researchers explained to the participants what to do and which data would be collected. It was explained that the data were only collected for the study and this was done to meet **US 14** from section 3.3. The next step was to start the recordings and hand out the task list and the smartphone containing the prototype to evaluate. The participants had to solve nine tasks and voice their thoughts throughout. The tasks guided the participants through the app and the thinking-aloud protocol was chosen to capture how the users interacted with the app and what their thoughts were about the gamification features and if it was intuitive for them. The following tasks had to be completed by the participants:

1. Register
2. Open the prepared project "CMMT-Movement"
3. Connect to the CMMT-ST-...

4. Check error log and delete any logs
5. Move the connected axis manually
6. Scan the network
7. Select a CPX-E-CEC-C1-EP
8. Run "Identify"
9. Reboot the device
10. Check Quest page and click on the achievements
11. Use Data Matrix Reader to scan CPX-AP-I-EP
12. Update firmware of the device
13. Scan for CPX-AP-I-PN
14. Set IP Address to specified values
15. Scan other CPX-AP-I-EP
16. Set the device to DHCP mode
17. Open Leaderboard

The task list was handed out to the participants in German and can be found in the Appendix A. The first task was to create a new user for a participant and the first gamification feature was interacted with. The participants could choose an avatar to represent themselves. Tasks 2-5 represent the defined task "Maintain existing configuration" from chapter 3 and gave the participant the possibility to interact with the servo controller and the connected axis. During the execution, the benefit of using a smartphone was shown and the participants experienced the cable-free solution. The tasks 6-9 and 11-16 were commissioning tasks and represent the "Commissioning of new devices" from chapter 3. The tasks showed the participants how the usage of the digital assistant system can assist them in their daily tasks by making the identification of devices easier. Throughout the tasks, the participants encountered the different achievements. Tasks 10 and 17 let the participants go to the gamification features quests and the leaderboard.

5.1.4 Semi-structured interview questions

For the semi-structured interview, 5 broad questions were defined beforehand. The questions were chosen to be broad and open to allow the interview to be more like a conversation. This style of interview was chosen to find insights into the opinion and feelings of the participants and to find unplanned information through the style of a semi-structured interview. The main topics that needed to be discussed are defined below.

1. Was the app intuitive for you?

2. Can this digital assistant/app improve your work?

3. How did you find the gamification features?

4. Do you have any concerns about being tracked?

5. What features are you missing?

5.2 Results

5.2.1 Participants

For conducting the study, experienced technicians in the field of industrial maintenance and commissioning were selected to obtain valuable feedback and information on this field. Six male Festo employees took part in the lab experiment with the relaxed thinking-aloud study and the semi-structured interview. They had different levels of experience in that field and had a deep understanding of the Festo Automation Suite, which the mobile application enhances and extends. These criteria were needed to get an insight on how such a digital assistant system can improve daily tasks and if gamification can be useful in the field of industrial maintenance and commissioning. The six participants were male, and their educational backgrounds vary, including trade school, high school, bachelor's, and master's degrees (see Figure 5.1). The age range of the participants falls within 25-44 years (see Figure 5.2). Their experience in the field ranges from 2 to 20 years, indicating a diverse level of professional knowledge (see Figure 5.3).

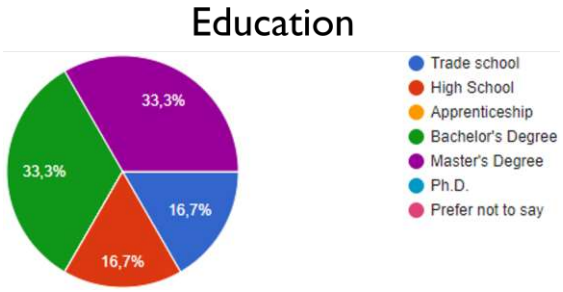

Figure 5.1: Education

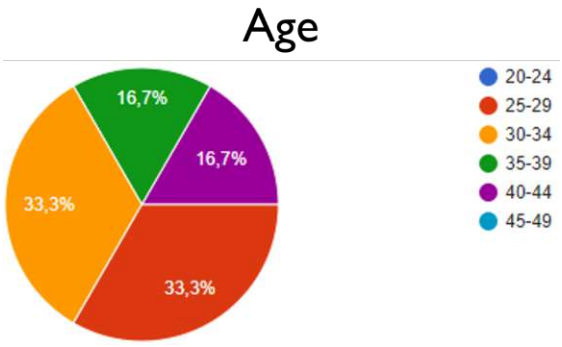

Figure 5.2: Age

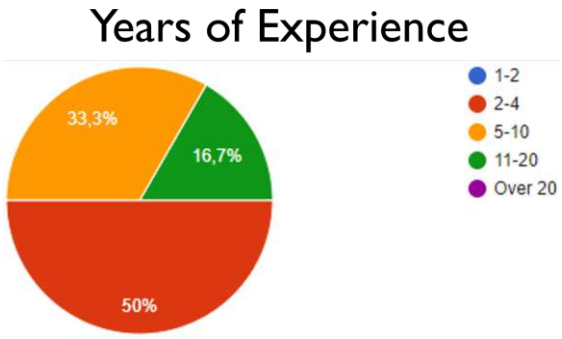

Figure 5.3: Years of Experience

The participants rated their familiarity with assistant systems on average with 3.167 and with gamification on average with 2.83. One third of the participants answered that they are very unfamiliar with gamification, however another third were very familiar with gamification (see Figure 5.4).

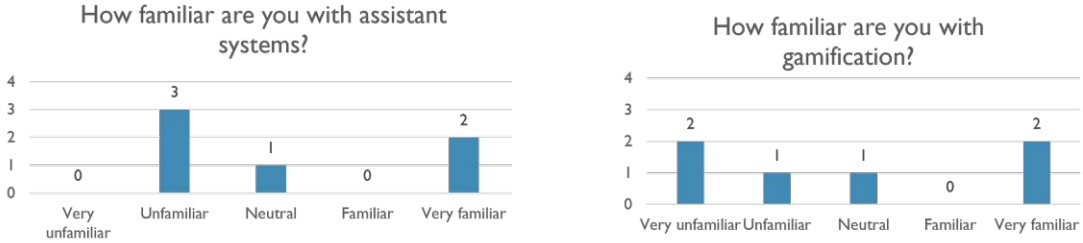

Figure 5.4: Assistant System and Gamification Familiarity Graphs

	P1	P2	P3	P4	P5	P6
Work Enhancements	X	X	X	X	X	X
Immediate Feedback				X	X	X
Ease of Use	X	X		X	X	
Missing Feature	X				X	

Table 5.1: Digital Assistant System Codes per User

5.2.2 Thinking-Aloud Result

The data from the thinking-aloud study were evaluated by using the coding framework as described in chapter 1.2.5.3. First, the data were examined to get a general understanding and from that the first codes were generated. After the first round of exploring the data, 79 codes were created. The codes were created with the exploratory approach and by generating them based on the phrases and terms of the participants. After the first generation, of codes the codes were reviewed and filtered. Then they were combined to reduce the number of codes and complexity and the number of codes was reduced to 11 different codes. During this process, the codes were grouped with respect to their relation to the digital assistant system and the gamification elements. For the digital assistant system, 4 codes were used, and for the gamification elements, 7 codes were identified.

5.2.2.1 Digital Assistant System Codes

Work Enhancements: Participants showed positive reactions to the features of the digital assistant system (e.g., *"ok wow that is a very cool feature"*, *"jogging works very well and is already responsive"*). These statements indicate that the features of the digital assistant system are useful to the participants and could improve their daily work.

Immediate Feedback: Participants appreciated the immediate feedback provided by the digital assistant system, as indicated by expressions such as *"cool also recognized directly that the IP address had changed"* or *"yay there is also progress. Feedback that something is happening"*. The indication that an action of the user changed properties of the device or that something loading was seen as valuable.

Ease of Use: Statements like *"that is really easy and cool, really fool proof"* show that the participants found it easy to use the digital assistant system and were not afraid of misusing it.

Missing Feature: During the lab experiment, the participants wished for more functionality than offered by the prototype with expression like *"I would like to change the reference run"* or *"Where is the homing method? It would be interesting to know"*. This shows that the participants could imagine using the digital assistant system and thought about which features they were missing for their work.

In table 5.1 the distribution of codes per participant is displayed. The X means that the participant has at least one expression that was coded with the corresponding code. Each

participant noticed the useful functionality of the digital assistant system and commented on it during the relaxed thinking-aloud study. For the code Immediate Feedback 50% of the participants mentioned that they appreciated the immediate feedback of the digital assistant system. Four out of the six participants found the app easy to use, and 2 had additional feature request during the lab experiment to do more than needed due to their curiosity.

5.2.2.2 Gamification Element Codes

Achievement: Statements like *"silver trophy, very good"* indicate a positive reaction to the gamification element of achievements. The participants received them for their interaction with the system and had positive reactions to them.

Leaderboard: Participants had as their last step to look at the gamification element leaderboard. Comments, such as *"Oh God, I'm right at the back, what else could I do?"* or *"Level 4- boah golden star, very good, I like that, so how do i reach level 5"*, about their ranking and their rank compared to their colleagues were marked with this code.

Avatars: The participant had the option to select an avatar and the reactions to the avatar selection and setting are gathered in this code.

Quests: Participants mentioned that the quests can give an overview of their accomplishments and also show what features they know and where they are missing experience. Statements like *"that tells you how well you can handle the app"*, *"I still have something to learn"* or *"Ah the things I have achieved, they are all milestones"* were categorized with this code.

Game References: Some participants were able to recognize the gamification elements and made connections to a game. One of the comments, for example, was *"looks like Age of Empire"*.

Usability Difficulties: For some participants, it was difficult to use the two-finger operations required to navigate the quest page. This was indicated by statements like *"if you don't know how to use your cell phone, it's a bit difficult"*.

Positive Reactions: During the lab experiment, the participants laughed and had positive reactions when encountering the gamification elements. Expressions such as laughing, or positive comments such as *"very good"* or *"nice"* are coded with this.

The distribution of codes for the gamification elements is displayed in table 5.2 and the X do not indicate how often a participant had a corresponding comment. All participants had a positive reaction to the achievements. Each participant showed a positive reaction to the leaderboard and the comparison with their colleagues. Participants that used the app more out of curiosity had a higher rank and this had a positive impact on their motivation. On the other hand, the participants with a lower score, asked how they could gain more points to beat their colleagues, also showing an increase in their motivation. Only one participant chose to select an avatar and he had a positive reaction regarding

	P1	P2	P3	P4	P5	P6
Achievement	X	X	X	X	X	X
Leaderboard	X	X	X	X	X	X
Avatars					X	
Quests		X	X	X		X
Game References	X	X			X	
Usability Difficulties			X			X
Positive Reactions	X	X	X		X	X

Table 5.2: Gamification Codes per User

the avatar. Four out of six participants understood the quest page as a tool to see and track their understanding of the digital assistant system. Half of the participants saw the connection to other games or to other gamification solutions of their daily life. One third had issues with the usability of the quest page and its interactions. Every participant had at least one positive reaction to one of the gamification elements.

5.2.3 Semi-structured Interview Results

The recordings of the semi-structured interview were evaluated with the coding framework as described in chapter 1.2.5.3. After familiarization with the data, codes were generated, and the following codes were used to identify themes:

Tool Efficiency: Statements regarding the digital assistant begin a smartphone app and highlighting the benefits were categorized with this code. Expression like *"It has a charm. We've already discussed an app, but once you've seen it now, you can already see the advantages of it."* or *"I think it's cool that you don't need the laptop to look at something or change something."* were coded with this.

Ease of Use: The participants said that the mobile app was responsive and easy to use with statements such as *"With one click you can always move on and I think that is a good solution."* or *"Very intuitive - easy to use. There are no major visual flaws, I don't have to search for long."*

User tracking: The opinions about the collection of data and user actions were coded with this code and expression such as *"I don't see tracking the actions as a problem."* or *"I don't see a disruptive factor here. I don't see it as extremely sensitive. There is no extremely sensitive data in the app"*. The code gives an insight about their views on the data collection, which was needed for the gamification elements.

Competitiveness: Participants mentioned the leaderboard and beating their colleagues when asked about gamification. Expressions like *"The ranking among your colleagues makes you want to be better. You have the same thing when you are gaming. That is certainly an incentive. I think it's good", "Comparison between individuals is interesting."* or *"I would like to have a higher level than my colleagues and would like to do something*

for it." have been marked with this code and show that this gamification element was well accepted.

Positive Reception: The positive statements about gamification, such as *"Collecting points during planning and project planning is fun because there is time. Then the whole thing would be a lot of fun to operate."* and *"It surprised me and I thought it was fun."*, were categorized with this code. It shows that gamification elements, in general, were considered beneficial and had a positive impact on user engagement.

Technical Concerns: The participants had some concern regarding the limits of using a smartphone for the commissioning and maintenance. Comments like *"but there could be problems because you also have to handle files"* and *"I wouldn't trust the cell phone to react correctly in tricky situations, because I can always click stop on the PC"* show that there are underlying uncertainties and possible problems by only relying on a smartphone.

Action History: During the interview participants mentioned that the tracking of user actions could be beneficial to recap what was done in case of errors. Statements such as *"You could see that as a positive thing if you could track your mistakes."* were marked with this code.

Missing Feature: The participants mentioned what features were missing for a better experience. The wishes were stated as *"Trace would be cool."* and *"what I am missing is the diagram so that I can discuss it with my colleague and check it with them."*

Opt Out: Regarding the gamification elements, the participants mentioned that during stressful situations they wanted to have the option to opt out of the gamification elements to not get distracted. The following comments were made in this regard *"Under time pressure, I would ignore it or even find it annoying"* and *"but if you are under stress, it would be good to have the option of deactivating it so that you are not distracted by it"*.

Gamification Doubts: Statements, such as *"But I don't quite see the point of it in the Festo Automation Suite, because you have to deal with it either way."*, show that the participants don't fully see the benefits of gamification and have a neutral standing to it.

Learning Progress: The benefit of the quests and the achievement system was understood, and comments about the progress tracking and understanding of the app were such as *"but otherwise it is cool for learning and an incentive to get more involved with the app."* and *"But I think it is cool when you are there, it also shows that you have already learned how to use the app completely."*.

Gamification Request: The wish (i.e. *"when can I unlock skins?"*) for further gamification elements were tracked with this code.

In table 5.3 the distribution of codes between the participants is shown. A "X" for a participant indicates that he has statements, that were coded with that code, but it does not display how many statements were coded with the specific code. Each participant saw the benefits of using a smartphone for the digital assistant system and experienced that the features could help them in their daily tasks. All participants found the digital

	P1	P2	P3	P4	P5	P6
Tool Efficiency	X	X	X	X	X	X
Ease of Use	X	X	X	X	X	X
User tracking	X	X	X	X	X	X
Competitiveness	X	X		X		X
Positive Reception			X	X	X	
Technical Concerns			X	X	X	
Action History		X				X
Missing Feature	X	X	X	X	X	X
Opt Out				X	X	X
Gamification Doubts	X		X		X	
Learning Progress		X			X	X
Gamification Request					X	

Table 5.3: Semi-structured Interview Codes

assistant intuitive and found the user interface easy to use. All six participants talked about the collection of user action and personal data. However, they were not concerned about the data collection since they did not view it as sensitive data. The leaderboard and the competition between the colleagues were mentioned by four participants and were seen as motivating aspect. 50% of the participants mentioned that the achievement of points and achievements made them fun and surprised them positively. The same 50% was concerned that the smartphone can be used in all situations during commissioning and maintenance and mentioned that in some cases they will probably need to use a notebook. Two participants saw tracking of their actions in the app as an opportunity to understand how errors occur by looking at their past steps. All participants had more ideas about how they could use the digital assistant system and the features they would need every day to solve their tasks. Three out of six said that during stressful times they would like to disable the gamification features in order to not get distracted. Half of the participants were not sure whether gamification really motivates them. However, they did not see it as annoying or negative. The quests and achievements were seen by 50% as a tool to see in which field they have gained knowledge and in which fields they need to further investigate their time to better understand the app. One participant concluded the interview by asking when he is able to get skins.

CHAPTER 6

Conclusion & Outlook

6.1 Conclusion

The main problem in industrial maintenance and commissioning is that there are not many digital assistant systems with gamification elements. To generate an artifact, the requirements were defined in Chapter 3 and used to develop the prototype. The prototype was developed using the iterative development approach Scrum and presented to the Festo Automation Suite team, a software for industrial commissioning and maintenance, every 3 weeks. The gamification elements were chosen based on the literature and the context in which it was applied. The artifact was then tested by six Festo technicians in a lab experiment. They are experts in the field of industrial maintenance and commissioning and have many years of experience. During the lab experiment, a relaxed thinking-aloud study was conducted, followed by a semi-structured interview. The semi-structured interview covers 5 topics, including intuitivity, work improvements, gamification features, tracking concerns and missing features. The collected data were then evaluated using a coding framework, and with the data, the following two research questions were answered.

Research Question 1: What requirements have to be considered in the context of industrial maintenance and commissioning for a digital assistant systems and gamification?

With the requirements from chapter 3 and the evaluation in mind the most important requirements can be defined. The user needs have to be understood and the characteristics of the context must influence the design of the digital assistant system and the gamification elements. For the user needs, the expertise of the development team of the Festo Automation Suite, a commissioning and maintenance software, was used to create user stories to fulfill all functional and nonfunctional requirements. Due to the context, it was chosen to develop a smartphone application to better fulfill the user needs and behaviors. The smartphone gave the users freedom to move around freely and removed the need of setting up a workspace for a notebook. The evaluation has shown that these

requirements and decision lead to a good prototype. The functionality of the app got positive reactions from the participants during the lab experiment, which is marked with the Work Enhancements code from Section 5.2.2.2. During the interview, the decision of using a smartphone application was welcomed and the benefit of not needing a setup for a notebook was mentioned by the participants.

What data are collected and how the data is collected are requirements from the user stories 13 and 14 from Section 3.3. These requirements should protect the user regarding their personalized data and give them the right to device by themselves, if the participate or not. The collection of data can cause fears in users that they will be evaluated based on incomplete data. During the semi-structured interview this topic was covered, and no participant was concerned that their steps in the application were tracked to enable the gamification features. One participant talked about the fear of being evaluated based on the collected data, but concluded by himself that any manager that rates him based on these data alone would be a bad manager anyway. Two participants understood what data were collected and saw it as a benefit to have their steps documented in case of errors or for learning purposes.

The requirement User Story 15 from Section 3.3 states that the user needs an option to opt-out of the gamification features. During the interviews, the overall opinion about the gamification elements was positive. However, participants had concerns that during stressful times the gamification elements can distract them and hinder them in their work. Those concern were stated as *"but if you are under stress, it would be good to have the option of deactivating it so that you are not distracted by it"*. Therefore, there should always be the option to opt out from gamification to give the user the choice by themselves.

Research Question 2: Which gamification elements can increase the motivation in the field of industrial maintenance and commissioning?

After evaluation the collected data, the null hypotheses from Section 5.1.1 can now be tested to answer research question 2.

Hypothesis 1: Achievements do not increase the motivation and engagement of the user
This null hypothesis is rejected since all of participants had a reaction to the achievements. The reactions were positive and comments such as *"silver trophy, very good"* have been made during the relaxed thinking-aloud study. In the semi-structured interview, the achievements were seen as motivating and as a benefit during less stressful times.

Hypothesis 2: Leaderboards do not increase the motivation and engagement of the user
With the collected data this hypothesis is rejected. The participants showed a clear increase in motivation and engagement as soon as they saw the leaderboard and their score. Comparison with colleagues was the most beneficial gamification element regarding the motivation of the participants. The increase in motivation was seen during the lab experiment and in the semi-structured interview. The comments from the thinking-aloud study show and immediate wish to gain extra points to beat the colleagues. This first

reaction was then also observed during the semi-structured interview by comments such as *"The ranking among your colleagues makes you want to be better"* .

Hypothesis 3: Avatars do not increase the motivation and engagement of the user
The data did not provide sufficient evidence to reject this hypothesis.. Only one of the participants actively used this gamification element and had no explicit reaction to avatars. This is probably caused by a bad user interface, because most of the participants did not come to the avatar selection page, as seen in Figure 4.2 on the right, and did not interact with this feature. Therefore, there is not enough evidence to reject this null hypothesis.

Hypothesis 4: Quests do not indicate the knowledge about the digital assistant system
This null hypothesis is rejected, since the participants understood the quests as an indication about their knowledge about the app. The participants mentioned the benefit of seeing in which parts of the application they have already learned and in which fields they need to improve. An interesting idea from the study was that the actions that lead to an achievement can be useful during work, since it can show how errors occur, because it is a history of user actions. Four out of the six participants found the quest page useful during the lab experiment and 3 participants during the interview. In total 5 out of the 6 participants commented on the usefulness of this gamification element.

6.2 Outlook

Due to the scope of the master's thesis, the digital assistant system was only a prototype, lacking features for the daily challenges faced by technicians. Enhancing the prototype with additional features to better meet the needs of users would be a good next step to further test user engagement and satisfaction with a more complete product. It would be interesting to evaluate the effects of a longer usage period on the opinions of the gamification elements and the duration of competitiveness between colleagues. One limitation of the study is that it included only male technicians. It would be valuable to investigate how individuals of other genders perceive the digital assistant system and whether the gamification elements motivate them.

Another interesting aspect is to validate whether the team size changes the motivational gain from the leaderboard or other aspects of the user experience. A possible next step would be to adopt a department-based approach. In this regard, it is important to consider how gamification should handle department-based leaderboards and how department comparison should be designed and implemented. It is also important to assess to what extent this inter-departmental approach would influence the experience of individual users.

APPENDIX A

Questionnaire

Demografische Umfrage:

Was ist Ihr höchster Schul- oder Hochschulabschluss?

- ☐ Matura
- ☐ Lehre
- ☐ HTL oder ähnliches
- ☐ Bachelor-Abschluss
- ☐ Master-Abschluss
- ☐ Doktor-Grad

Zu welcher der nachfolgenden Alterskategorien gehören Sie?

- ☐ Unter 18
- ☐ 18-24
- ☐ 25-34
- ☐ 35-44
- ☐ 45-54
- ☐ 55-64
- ☐ Über 65

Bitte geben Sie Ihr Geschlecht an.

- ☐ Weiblich
- ☐ Männlich
- ☐ Divers

Wie viele Jahre Erfahrung haben Sie in Ihrem Beruf?

- ☐ 1-2
- ☐ 2-4
- ☐ 5-10
- ☐ 11-20
- ☐ Über 20

Wie vertraut sind Sie mit dem Begriff Assistenzsystemen?

- ☐ Nicht vertraut
- ☐ Teilweise vertraut
- ☐ Neutral
- ☐ Mäßig vertraut
- ☐ Sehr vertraut

Wie vertraut sind Sie mit dem Begriff Gamification?

- ☐ Nicht vertraut
- ☐ Teilweise vertraut
- ☐ Neutral
- ☐ Mäßig vertraut
- ☐ Sehr vertraut

Aufgaben:

- ☐ Neuen User registrieren
  - Das User Bild wird den anderen Usern gezeigt
  - Username kann beliebig gewählt werden
  - E-Mail wird anderen Usern nicht angezeigt

- ☐ Projekt „CMMT_Movement“ öffnen
- ☐ Mit „CMMT-ST-AT0IM“ eine Connection aufbauen
- ☐ Unter Diagnose den Geräte Status überprüfen und alle anerkennen
- ☐ Die verbundene Achse manuell bewegen
  - Um die Achse manuell zu bewegen, muss die „Control“ auf „Plugin“ und die „Powerstage“ auf Enabled gesetzt werden
- ☐ Powerstage und Control deaktivieren.

- ☐ “Scan” öffnen und Geräte-Scan durchführen
- ☐ CPX-E-CEC-C1-EP (“CPX-E-CEC-MA”) auswählen
- ☐ Identify ausführen zur Überprüfung ausführen
- ☐ Gerät rebooten

- ☐ „Quests“ öffnen und Achievements anschauen

- ☐ „Data Matrix Reader“ öffnen und linken CPX-AP-I-**EP** scannen.
- ☐ CPX-AP-I-**EP** Firmware auf Version 1.2.2 updaten

- ☐ CPX-AP-I-**PN** (“ERTEC200P”) scannen
- ☐ IP-Adresse umstellen
  - IP-Adresse 172.16.173.45
  - Subnet Mask: 255.255.254.0

- ☐ Rechten CPX-AP-I-**EP** (“AP-I-EP-at0bf3”) scannen
- ☐ Netzwerkeinstellungen auf DHCP(172.16.172.XXX) setzen

- ☐ Leader Board öffnen

List of Figures

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