Towards Unlocking the Potential of the Internet of Things for the Skilled Crafts

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Abstract: The Internet of Things (IoT) enables companies to develop new digital business models or optimize existing processes through digitalization. Since value creation in the skilled crafts is determined by the manufacturing of material products and the provision of associated services, it is predestined for the use of IoT technologies. While these services are increasingly finding their way into the consumer market via industrial providers, the local skilled crafts with its small and medium-sized businesses lacks the knowledge to assess the potential and to adequately develop and operate IoT solutions. Our aim is to develop a manufacturer-independent platform that enables those businesses to implement IoT solutions independently. The platform is intended to support craftsmen in identifying suitable IoT use cases and resulting business models for their trades, products or services. For that, it will provide an overview of the components (e.g., sensors) required for the respective use cases. Based on this, the use cases can be set up without special know-how with the help of the platform, which also collects and manages the accruing data. Each craft business can identify new use cases and make them available to the other users of the platform, thus creating a cross-trade solution from the skilled crafts for the skilled crafts. Potential IoT use cases and their technical requirements were already identified in a pre-study in collaborative hackathons and will be evaluated during the development of the IoT Crafts Portal. The results are intended to assist craft businesses from a wide range of trades to identify and implement new business models in such a way that they can be integrated into the existing processes of the businesses. At the same time, there will be a transfer of knowledge between the craft businesses themselves, since each can use the experience of the other business or offer its own insights.

1 INTRODUCTION

Dealing with digitalization is both an opportunity and a challenge for a wide variety of industries. Modern agriculture, industrial production, and the transportation and logistics sector are examples of how the potential of advanced digitalization can be exploited. Numerous enterprises in these industries have already been able to gain extensive experience with digital and digitized products as well as services, from which a wealth of novel business models have emerged. At the same time, experience has shown that digital transformation cannot be taken for granted and poses a multitude of challenges. The Internet of Things (IoT) (Ashton et al., 2009) plays a key role here and it is rising in different domains, such as smart cities (Gyrard and Serrano, 2015) or the smart home (Zschörnig et al., 2017). The underlying technologies focus in particular on mapping and describing the physical, real world in a digital image by generating digital shadows or even digital twins (Atzori et al., 2010). The basic step in this process is the integration of sensors into products, machines and systems in order to determine a digital image from the collected data by means of various analysis and learning processes. The digital image obtained in this way in turn creates the basis for optimizing existing business processes, services and products, and in many cases also for generating new digital or digitalized business models. The *skilled crafts*, where value creation is determined by the manufacture of material products or the provision of services on demand for the material product, are therefore predestined for the introduction of IoT technologies into everyday working life. The mapping of the physical world in a digital representation opens up numerous areas of application (Sisinni et al., 2018). It is therefore all the more surprising that although IoT technologies are increasingly finding their way into the consumer market, the focus of developments is completely bypassing the

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skilled crafts. As a result, the potential of the IoT has so far been little or not at all widespread among traditional small and medium-sized craft businesses - despite the fact that the technologies are there and the craft businesses are demonstrating their interest in using the IoT, for example, in public workshops and hackathons.

Large industrial companies, on the other hand, which as representatives of industrial mass production are often in direct competition with the skilled crafts, are increasingly equipping their products with IoT-capable sensor and communication technology and providing associated applications for end customers. In doing so, these companies focus on their area of application, which prevents a comprehensive view and correspondingly advanced overarching digitalization. For example, customers can check the operating status of their heating system and contact the manufacturer directly in the event of potential faults, but this does not include regional craftsmen. The resulting fragmented IoT platform landscape of individual industrial providers does not provide a breeding ground from which regional craft businesses can benefit or, due to the lack of access to data, participate. Other key challenges for these craft businesses result, for example, from difficult access to the topic and the great uncertainties associated with it. Accordingly, for regional craft businesses, i) assessing the potential of IoT solutions and their impact on their operations, and ii) acquiring the knowledge and skills to develop and operate adequate IoT solutions are key obstacle factors.

To address these challenges, our goal is to design and implement a vendor-independent end-to-end IoT Crafts Portal, which will be developed from the skilled crafts for the skilled crafts. This portal should enable German craft businesses to i) identify suitable IoT use cases and resulting business models for their trade as well as their products or services and share them with other businesses, ii) get an overview of the required components (e.g. sensors) needed to implement the use cases, iii) set up the identified use cases in a simple and user-friendly way via the portal, and iv) collect, manage and use the resulting data for their own business purposes.

The two most important aspects for the development of the IoT Crafts Portal deal with the identification of suitable IoT use cases and the creation of a corresponding crafts-friendly IoT portal as a prototype, which can be used by the craft businesses for the implementation of their IoT use cases. A large number of different IoT sensors will be used to implement the use cases. The resulting data will be stored in a central data lake and managed via it. The main research focus is on developing ways how the accessibility of IoT technology can be enabled for the craftsmen. In particular, the development of recommendation and search systems based on machine learning methods as well as the design of corresponding visual user interfaces are in focus. Another important aspect is the investigation of approaches on how the IoT technology and its application potential can be didactically prepared for the craft businesses and communicated to them in a target group-oriented or -adaptive way. Based on the IoT Crafts Portal, different participating craft businesses from a wide variety of trades aim to identify and develop IoT-based use cases and prototypes, which either optimize an internal process or enable the implementation of an additional (digital) business model specific to their trade and business.

In this way, craft businesses improve their work organization and design with Digital Transformation technologies. The fact that the data generated on the developed IoT Crafts Portal belongs to the craft businesses itself ensures that they can use it profitably. At the same time, craft businesses can already benefit from implemented IoT use cases of other (craft) businesses. If a new use case is identified and implemented using the developed IoT portal, it also becomes available to other businesses. This enables knowledge transfer both within and across trades, so that the full potential of IoT use cases for the skilled crafts is exploited. In summary, the developed IoT portal enables the strengthening of craft services in Germany by enabling the development of modern IoT-based business models, which is reflected, for example, in new services for the end customer of the respective craft businesses.

The rest of the paper is organized as follows: Section 2 will show related work and discuss the issues of current IoT platforms for technical inexperienced users. Afterwards, we show and discuss in Section 3 potential use cases that we already identified in two different pre-studies using a hackathon concept before we present the methodology and the approach that we follow in order to develop the IoT Crafts Portal in Section 4. Finally, we give a short conclusion in Section 5.

2 RELATED WORK

The related work can essentially be divided into i) the area of technical implementation (IoT platforms and existing IoT solutions) and ii) the area of existing platforms in the Skilled Craft Sector that push the issue of digitalization.

2.1 Technical Implementation and Existing IoT Solutions

Today, IoT platforms are ubiquitous. Well-known technology companies such as Amazon[1], Microsoft[2], Google[3] or Deutsche Telekom[4] already offer scalable IoT platforms that enable the implementation of any IoT use cases - provided the technical programming skills are available and the user already knows exactly which use case might fit his business. In addition, there are a number of other platforms (Bosch[5], Upswift[6], Influxdata[7] or Device Insight[8]) which also offer IoT platforms for customers. The focus of these platforms is on the collection and evaluation of the raw data generated in the IoT. However, these platforms address either users with advanced technical skills or large enterprises with their own IT departments. IoT use cases that produce the required IoT raw data have to be identified and implemented by the users themselves - knowledge transfer between users does not take place and is not focused on by these platforms. In reverse, this means that every craft business itself must acquire the necessary skills, identify its use cases and then either also implement them via an IoT platform in a time-intensive manner or commission IT experts to do so - without knowing a priori the economic benefits. Moreover, there exist also concepts for semantic IoT and data platforms, such as (Palavalli et al., 2016), (Dorsch, 2016), (Cambridge Semantics, 2016) or (Pomp et al., 2021). However, they only deal with semantically describing sensor data and do not focus on IoT use cases.

In addition to the existing IoT platforms, which are mainly aimed at companies from the Industry 4.0 sector, there are already various IoT-based solutions that have been developed for the skilled crafts. Hilti (Hilti, 2020) and Bosch (Bosch, 2020), for example, offer IoT-based solutions that enable craftsmen to track the tools in use. The company Doka (Doka, 2020) offers sensor technology and the associated software to measure and predict the drying time of cement. In the context of monitoring moisture damage in roofs, Saint Gobain has developed Isover GuardSystem (Saint Gobain, 2020), a solution that allows flat roofs to be monitored in real time and alerts the owner in the event of moisture damage. While on the one hand these examples show the potential already inherent in IoT solutions for the skilled crafts, on the other hand, it becomes clear that all these solutions are isolated applications which are offered by one manufacturer and can only be used in this context. So if a craft business now wants to use all these different solutions, it must first learn of their existence (for example, via trade fairs, representatives of the companies or via other craft businesses) and then buy these solutions from the various large companies in each case. At the same time, the craft business loses control over its data, because it usually becomes the property of the large company. On the one hand, this prevents reuse for other IoT use cases. On the other hand, it shows that there is not yet a solution tailored to the needs of the skilled crafts that enables them to have an overview and all-encompassing use of the Internet of Things. There are craft businesses that try out IoT solutions in hackathons or even implement them on their own initiative (e.g. Holzgespür[9]) and offer them to their customers - but this remains more the exception than the rule - even though the IoT offers numerous possibilities.

2.2 Digital Platforms for the Skilled Crafts

In the course of the last few years, numerous platform-based business models have emerged in the digital skilled crafts, which have greatly changed communication between customers, crafts, trade and industry. The current study by the Ludwig Fröhler Institute for Skilled Crafts Sciences (LFI) (Ludwig-Fröhler-Institut für Handwerkswissenschaften, 2019) shows that more than 100 transaction-oriented platforms are active in the craft value chain in Germany. Here, previous platforms can be divided into the categories of partner brokers, franchisers, infrastructure providers, advertising platforms and online stores. Partner mediators, like MyHammer[10] or Blauarbeit[11], focus thereby on the switching of craft businesses for services desired by the final customer. Businesses, which do not co-operate with the respective platforms, remain thereby outside. Franchiser, like Myster[12] or Banovo[13], even go one step further. Here, the local craftsman's business is only used as an executing instance - all offers and contract arrangements run via the respective platform. The consequence of this is, of course, that the local craft business no

[1] https://aws.amazon.com/de/iot/
[2] https://azure.microsoft.com/en-us/overview/iot/
[3] https://cloud.google.com/iot-core
[4] https://iot.telekom.com/en
[5] https://developer.bosch-iot-suite.com/
[6] https://www.upswift.io/
[7] https://www.influxdata.com/influxdb-cloud-iot
[8] https://www.device-insight.com/
[9] https://www.holzgespuer.de/
[10] https://www.my-hammer.de/
[11] https://www.blauarbeit.de/
[12] http://myster.de/
[13] https://www.banovo.de/

longer has the business in its own hands and must therefore submit to the rules of the platform operators. Infrastructure providers, such as Helpling[14] or Caroobi[15], on the other hand, give craft businesses more freedom. Advertising platforms and online stores then already try to win customers via new channels. The LFI study shows that platforms have become an important tool in the skilled crafts for building new business models and simplifying interaction with customers. However, the study only looks at transaction-oriented platforms. Data-centric platforms, which essentially include all Infrastructure-as-a-Service (IAAS), Software-as-a-Service (SAAS), Platform-as-a-Service (PAAS) and other specialized platforms, such as IoT platforms, were not considered. It has already been shown in the previous section that although technical solutions do exist, they are not tailored to the skilled crafts and their needs.

In summary, it can be said that there is no existing IoT platform that enables craft businesses to i) find out about the IoT, ii) identify relevant use cases and associated sensor technology, and iii) subsequently implement and operate the use cases relevant to their own business themselves.

3 POTENTIAL OF THE IoT FOR THE SKILLED CRAFTS

Over the last three years, we conducted together with our partners Kreishandwerkerschaft Rhein-Erft, Handwerkskammer Düsseldorf, Kompetenzzentrum Digitales Handwerk Koblenz and Wirtschaftsförderung Rhein-Erft GmbH two hackathons with altogether 20 different craft businesses from different trades in which we explored potential use cases for either improving processes within the own business or setting up new IoT-based business models. Each hackathon was organized in a two-day workshop format where the craft businesses identified IoT-based use cases on the first day and implemented them as prototypes in conjunction with scientists and developers from our institute on the second day.

The aim of implementing the prototypes together with the craftsmen was to show them, using concrete examples that are relevant to them and that were identified by themselves, (i) which sensors are available, (ii) what they can measure and how they record data, (iii) how the data can then be sent to a backend and can be stored and processed accordingly. For that,

Figure 1: Selection of sensors for the craftsmen.

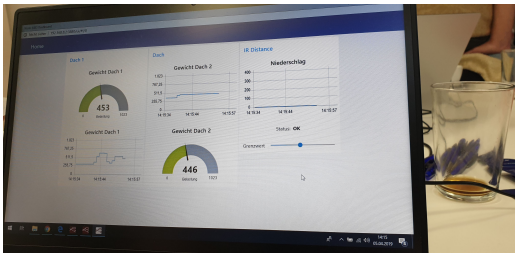

Figure 2: Developed dashboard for one of the IoT use cases.

we provided a large set of different sensors to the craftsmen (cf. Figure 1). After selecting the relevant sensors for their use cases, the craftsmen had to connect the sensors to a Raspberry Pi and the data were recorded using NodeRED[16]. From there, the data was transmitted via an MQTT Broker to a cloud instance on which we then developed visualizations and business logic for the identified use cases (cf. Figure 2). In this way, the craftsmen were able to understand exactly what was happening, how the data was transmitted and how it could then be processed. However, it would not have been possible for the craftsmen to implement the prototypes without the help of the advisors.

A central result of the two hackathons conducted is the large number of different IoT use cases identified by the participants from the various craft businesses from different trades that were assessed as relevant for their business. Altogether, 52 different IoT use cases were identified in various domains. In addition to obvious use cases that are already covered by the state of the art but were not known to the craftsmen (e.g. tracking of tools or moisture penetration on the roof), many interesting new use cases were also identified. For instance, two businesses from the construction trades identified a use case for monitoring the tightness of cellars during and after the construction phase. Trades from the glazing or metal craft came up with use cases for equipping their products with additional sensor technology to, for example, track the use of these products - and thus being able to optimize their products in the future. Businesses

[14]https://www.helpling.de/
[15]https://caroobi.com/
[16]https://nodered.org/

from the electrical, sanitary-heating-air-conditioning or roofer sectors had ideas to offer new services to their customers in the form of "predictive maintenance" through the use of IoT technology. A roofing company, for example, would like to equip gutters with water flow sensors. Based on the amount of rain that has fallen and the flow rate within the gutter, it is possible to calculate whether the gutter is clogged and whether maintenance is required, which can then be offered in advance.

The hackathons have proven to be a useful tool for introducing craftsmen to IoT topics. In particular, the great potential of IoT for the skilled crafts could be experienced by the participants, but it also became obvious that the implementation of own IoT use cases cannot be achieved by the craftsmen themselves. The support of developers and scientists has always been needed.

4 METHODOLOGY AND APPROACH

Figure 3: Adding IoT Platforms as missing Platform for the Skilled Crafts.

As outlined in Section 2, there is, to the best of our knowledge, no platform that focuses on enabling craft businesses to implement IoT use cases (cf. Figure 3), as these i) only add value for technically skilled individuals, ii) do not provide an overview of which IoT use cases are implementable, relevant or already exist, iii) do not enable knowledge transfer between users, and iv) are usually only in English. These disadvantages are flanked by the fact that small and medium-sized craft businesses - in contrast to large enterprises - often do not have the financial means to build up the corresponding required technical staff to identify, set up and manage IoT use cases. This means that relevant IoT use cases, such as, *Monitoring the degree of drying of screed*, cannot be efficiently implemented with the existing solutions on the market, as these solutions do not address the explicit needs of craft businesses. At the same time, however, the experience gained in our conducted pre-studies (cf. Section 3), shows, among other things, that these are precisely the kind of use cases that support craft businesses in their day-to-day work, or in which potential for the digitalization of craft businesses is seen. Accordingly, the goal for the developed IoT Crafts Portal is to show businesses similar scenarios from IoT projects that have already been carried out by other craft businesses and to provide information on sensor technology and information processing. For the above example, the portal could display, for example, *Moisture sensors that can be installed in the screed.* After the required sensors have been acquired by the craftsman's company, they can be directly integrated into the portal and the corresponding analyses or monitoring solutions can be carried out. In the example mentioned, a craftsman's company would be notified when the desired degree of drying has been reached, so that the connection work can be carried out earlier than expected, if necessary.

Compared to the current state of the art, the IoT Crafts Portal presented here fills an important gap. It represents an end-to-end solution that is explicitly adapted and optimized for the skilled crafts and can be used in a wide variety of trades. Through an explicit focus in development of the IoT Crafts Portal on intuitive usability (queries using natural language, simple plug-and-play connection of sensors, automatic recommendation of useful use cases), a complexity of the solution is achieved that is suitable for craftsmen without appropriate technical training and is missing in the current market. Through a continuous expansion of use cases, it should also be ensured that all businesses always have the opportunity to move at the current state of the art. If new use cases arise in a trade, they can be implemented via the IoT Crafts Portal and also made directly available to other craft businesses (knowledge transfer). If a business identifies and implements a new use case, such as the *detection of leaking roofs* via the IoT Crafts Portal, it is possible to make this use case available to other businesses. This means that other businesses can see which sensor technology is needed and get access to the implemented use case. This mechanism allows other businesses to see use cases that have already been successfully implemented. On the one hand, this mechanism thus strengthens confidence in the use of IoT technology. On the other hand, it enables individual craft businesses to independently develop new business models for their own operations. At the same time, the business that provides a use case can also benefit.

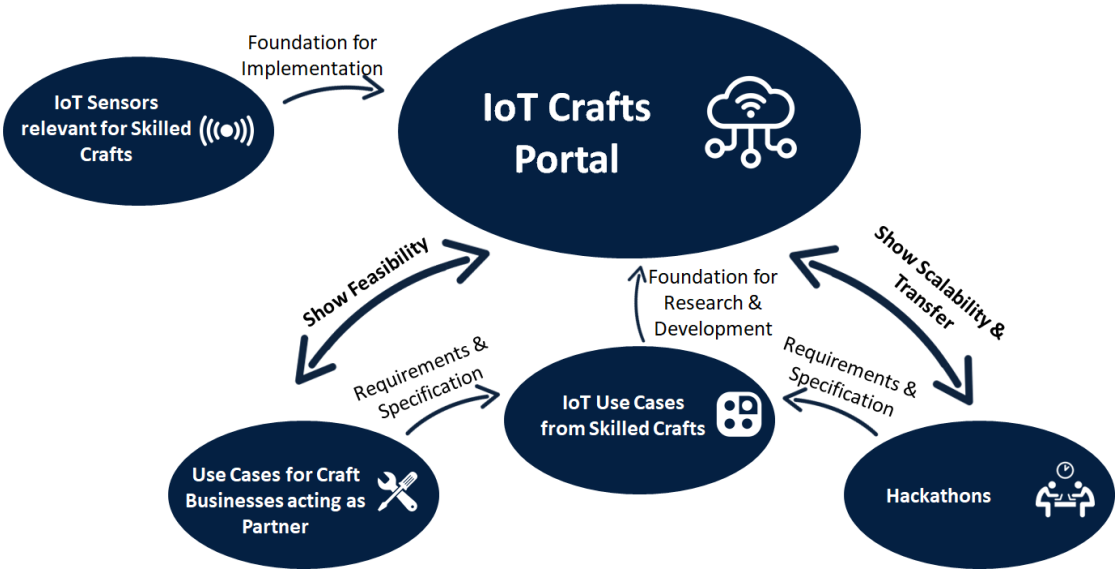

Figure 4: Main Aspects for the development of the IoT Crafts Portal.

4.1 Approach

Figure 4 shows the main aspects for the development of the IoT Crafts Portal and how they are related to each other. All in all, we follow an agile approach for developing the IoT Crafts Portal. This first requires the identification of potential use cases in the skilled crafts that can be implemented with the help of current IoT technology. In order to create a broad coverage of use cases for different trades, the IoT Crafts Portal will be developed in close cooperation with seven application partners from seven different trades. Together we define IoT-based use cases at the beginning of the development phase that are to be implemented with the help of the IoT Crafts Portal. On the one hand, these use cases serve to derive requirements for the technical development of the platform and, on the other hand, they serve as initial use cases that can be used by other crafts businesses. By conducting six different hackathons with a large number of craft businesses that are not involved in the development, it will be evaluated, on the one hand, that already defined use cases are transferable to other businesses and/or trades, and on the other hand, the agility of the further development will be demonstrated, as further use cases will be identified and added to the IoT Crafts Portal. In this context, we also explore in particular which didactic concepts are suitable to bring craft businesses closer to IoT technology. Both the execution of hackathons and the implemented use cases (lighthouse projects) can then be used specifically to promote the dissemination of the IoT Crafts Portal to transfer it to the broad public. In the implementation of the IoT Crafts Portal, technical research is needed in particular on how data processing pipelines for heterogeneous data streams can be implemented for a wide variety of IoT use cases by people who do not deal with IoT solutions in detail in everyday life. For this purpose, setting up IoT use cases by means of intuitive user interfaces is seen as a central building block. In the following, we will elaborate these important aspects in more detail.

4.2 Identification and Evaluation of IoT Use Cases

At the beginning, two hackathons will be conducted with the aim of identifying a broad mass of potentially relevant IoT use cases and establishing an understanding of the necessity as well as the potential of using IoT in the skilled crafts. In doing so, the participants of the hackathons will be supported and accompanied by experienced scientists and developers. In order to ensure target group-adaptive communication, a didactic concept will be developed that will enable craft businesses to gain added value from and access to IoT technology. In addition to the use cases that arise during the hackathons, each craft business of the seven application partners from seven different trades will define at least one further use case relevant to this enterprise in a workshop.

The evaluation of the IoT Crafts Portal is based on four further hackathons. In contrast to the first two hackathons, which serve to identify user cases, these evaluation hackathons will be conducted with less assistance. This will show whether the skilled craftsmen are able to implement their use cases inde-

pendently using the IoT Crafts Portal. At the same time, this will iteratively identify additional requirements and use cases. In this way, the development of the portal will be continuously guided in the right direction and its usability will also be ensured by craft businesses not involved in the development of the IoT Crafts Portal. Based on the experience of hackathons already held (cf. Section 3), it can be assumed that three to four additional previously unknown use cases will be identified in each hackathon.

4.3 IoT-sensor Screening

Based on the identified IoT use cases, an overview will be created of which IoT sensors are relevant for the identified use cases, how they function and to what extent they already have industry approval. In addition, all further sensor technology that might be relevant to the skilled crafts will be identified in a further search and included in the sensor technology catalog so that it can later be included in the IoT Crafts Portal. This systematic approach will ensure that a wide range of use cases for the skilled crafts can be covered by the IoT Crafts Portal. This screening will be continuously updated. The results will be made available to the public in a separate database.

4.4 IoT Crafts Portal

Based on the identified use cases and an overview of relevant sensors, technical requirements for the IoT Crafts Portal are formulated and a technical architecture is designed. This includes the definition of interfaces for data acquisition, decisions on technologies to be used, and the identification of suitable data analysis and AI-based learning methods needed to implement the use cases.

Next, procedures will be developed to connect the identified sensors to the IoT Crafts Portal via plug-and-play solutions. For this purpose, modules are needed that record and read out the data from the sensors and forward it to the IoT Crafts Portal. To solve the problems of heterogeneity in terms of data format and meaning (semantics), the data added to the portal will be annotated with semantics based on a craft IoT ontology that is to be defined before. Based on the semantic annotation, the data will be converted into a syntactically uniform data format and will be stored in a data lake.

In order to be able to flexibly implement the different use cases of the craft businesses on the basis of the data to be collected, modular data processing is implemented. This is based on the semantic information defined when adding the sensors. In addition, generic data processing building blocks are implemented that allow different processing steps, such as converting units or merging data streams. In this way, flexible data processing is created that enables the fusion of different sensor data streams and thus provides a basis to adequately implement a wide range of different IoT crafts use cases.

One of the most important building blocks of the IoT crafts portal will be a recommendation and search engine. This engine is being designed and implemented to enable knowledge transfer between the craft businesses and to encourage them to implement further IoT use cases or identify them for themselves. The search engine provides an efficient way to identify use cases that have already been implemented by other businesses based on a natural query language. The recommendation system, on the other hand, suggests further useful use cases to businesses based on their profile and trade as well as the use cases implemented so far, which have been implemented by other businesses with similar profiles. This ensures that businesses are always kept up to date and are notified when new IoT use cases emerge that are of interest to them. State of the art machine learning techniques will be used to develop the recommendation and search engine.

In order to enable a simple and intuitive operation for the craft businesses, a user interface is implemented that allows to realize own use cases even without technical training. This interface should create the possibility to identify, implement and monitor desired use cases. In addition to the findings from the first two hackathons, the requirements and wishes of the craft businesses for the user interface will be recorded in a workshop. On this basis, a user interface will be developed, which will be continuously adapted with the crafts businesses in an agile approach.

5 CONCLUSION

In this paper, we presented our concept for developing a manufacturer-independent IoT portal that enables small and medium-sized craft businesses from the skilled crafts to implement IoT solutions independently. Through preliminary studies, we showed how craftsmen can be introduced to the topic of IoT and how great the potential of IoT is for the skilled crafts. Subsequently, we presented a concept for the implementation of the IoT Crafts Portal, which should enable craftsmen to implement IoT use cases themselves. The next steps now include conducting further hackathons, identifying more IoT use cases and implementing the IoT Crafts Portal.

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