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SCRUTINIZING THE DESIGN SPECIFICATIONS OF SMART PRODUCTS: A PRACTICAL EVALUATION IN YACHTING

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Research paper

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Abstract

The collection and use of data are of increasing importance not only in virtual worlds but also for real goods. New products operationalize this principle and integrate sensors, actuators and microcomputers into analog products to enable sophisticated features such as context-awareness or connectivity with other devices. The underlying concept is being discussed as "Smart Product" and aims for the automation of activities, right up to autonomization of entire products. This article raises design specifications from existing literature and instantiates Smart Products in sailing. We discuss the application of the design specifications with sailing professionals in order to evaluate its practical value and to identify further benefits. The results affirmed that sailboats can be transformed into Smart Products by the integration of information technology. However, it also turned out that additional benefits can only be tapped by the integration of further stakeholders in a systemic perspective.

Keywords: Smart Product; Design Specifications; Smart Service System; Expert Interview.

1 Motivation

The advent of digitalized products and services is accompanied by an increasing interest in the exchange and use of data to develop new forms of value creation (Kölmel et al., 2017). This manifests in different, partly competing, partly complementary visions, which provide for the IT-based linking of products to an "Internet of Things" (IoT) and, in addition to the consumer goods sector, also aim at the transformation of industrial production in the sense of an "Industry 4.0" (Lasi et al., 2014). A further concept for the implementation of these visions is the "Smart Product", which, in addition to the pure recording and transmission of data, also includes data processing and the ability to make independent decisions and take independent action (Beverungen et al., 2017; Mühlhäuser, 2007). This can take place either purely autonomously, which is already extensively researched in many applications, such as "autonomous driving" (Porter and Heppelmann, 2014), or partially autonomously, which makes the Smart Product an element of a Cyber-Physical System (CPS), in which man and machine jointly contribute to the fulfillment of a task. In this case, the "symbiosis" in the sense of a socio-technical system is focused, whereby activities previously carried out manually by humans are increasingly transferred into the functional spectrum of the machine.

While this development is seen from a purely technical perspective as an exciting opportunity to extend the limits of automation (Porter and Heppelmann, 2014), it is unclear if the technically feasible developments are needed or desired from the perspective of people involved (Ghazizadeh et al., 2012). Given the fact that especially in the field of consumer goods the people involved often bear the costs, the question remains whether the benefit opened up by the use of technology is also understood and wanted as such. In this article we evaluate the concept of the "Smart Product" with regard to its concrete applicability in such a socio-technical context. We transform a conventional sailing boat into a Smart Product on a conceptual level with the help of experts. We chose this example because the sailing sport offers a suitable environment for the application of Smart Products due to its complex and dynamic system context. For evaluation purposes, we extract six design specifications from existing literature and develop them into guidelines for an interview with sailing experts. Based on their personal experience, the experts extend the sailboat by digital functions and thereby evaluate the principles of the Smart Product.

Our overall results show that a transformation has central goals and limitations: The majority of the functions developed aim to improve the capturing of relevant information and the link to other smart products. While many characteristics were met with interest, the automation and autonomization of the product encountered limits: The experts missed their own active involvement in the system, which resulted in the rejection of "over-engineering". What was surprising was that almost half of the raised functions were much more complex services, not aimed at physically changing the product, but generating benefits from the automated exchange of information within the "ecosystem" of the sailboat.

2 Study Design

Our study follows the principles of Design Science Research, which offer a broad range of multi-phased development methods for the structured engineering of information systems. Such methods guide researchers and practitioners through a holistic engineering process, from the identification of a certain problem or idea to the effective implementation and use. Although these methods range from simpler, to more detailed and sophisticated approaches, all of them regard the theoretical *Build-Evaluate-Pattern* as an epistemological building block. In this way, developed artifacts are being investigated and evaluated in order to ensure their usefulness and to identify optimization potentials. Sonnenberg and vom Brocke (2012) extend this principle and propose the repetitive application of the Build-Evaluate-Pattern to identify changing and additional requirements during the development process. The authors therefore distinguish four phases, namely *Identify Problems, Design, Construct* and *Use*, whereby an evaluation step is positioned between each phase. While the problem identification and characterization of smart products have already been addressed in research and their results have been condensed into initial concepts, there is so far little knowledge about their practical feasibility. This paper deals with the development of design specifications which practically validates the feasibility of the characteristics known in the literature. In order to practically validate the design specifications developed from the literature, we first looked for a suitable object of investigation, in which we could concretize the transformation to a Smart Product.

In order to ensure the basic transformability, we followed application cases of relevant literature, which locate Smart Products in an overall system, in order to recognize state and environmental changes by means of sensor technology (Beverungen et al., 2017). The added value results from the communication of the gained information within the system as well as from the automation of decisions and actions (Porter and Heppelmann, 2014). Against this background, our evaluation application case should fulfil three premises: First, the transformed product should be placed in a systemic context. Secondly, it is a dynamic scenario, in which changes of environmental conditions as well as of the product state occur frequently and so that changes can be perceived by integrated sensors. As a third premise, we chose the complexity of the information, which should be high enough to add value through automated data processing. Taking these criteria into account, our choice was to transform a sailboat since it met all premises and additionally was a suitable object of evaluation. The sailboat is a complex entity, which has to be controlled under any conditions (e.g. in emergency situations, in storms, in regattas and various sailing areas) due to the not insignificant safety risk. It can be regarded as a complete system with other boats, territorial conditions and landmarks. With the help of the application case, we examined two central research questions in this article:

RQ1: What design specifications must a Smart Product meet from a scientific point of view?

RQ2: Do the design specifications apply in the practical domain of Yachting?

In order to answer RQ1 and to build on the current prevailing understanding of smart products, essential design specifications are worked out within the framework of a literature search. We then conducted expert interviews with nine experienced sailors to test the specifications against a practical use case and validate the concept in this way. We investigate RQ2 by applying the specifications in the interviews and present a consolidated list of developed functions in chapter 3. Finally, the expert group discusses the benefit contribution of the transformed product.

3 Fundamentals

Related Research on Digitalization in Yachting

Sailing is understood as a knowledge-intensive activity, the management of which requires the constant observation of environmental factors as well as experience and knowledge of the physical properties of the boat and weather conditions (Deutscher Hochseesportverband "Hansa" e.V., 2011). For example, there is a need for current information regarding wind direction, wind force and the prognosis of its development. In addition, there are more special requirements in the case of more complex basic conditions, which occur among other things with sailing in difficult terrain or in regattas. This applies, for example, to hydrodynamics prevailing under water, which are expressed in wave height, frequency and current direction. In order to guarantee boat safety, it is important to obtain information about the area and to check that the boat is in perfect condition. It must also be ensured that the boat is at any time firmly moored, that the engine is ready for operation and that the water filter, fuel and oil supply are working properly. The inspection for moisture ingress as well as the inspection of the standing goods and the mast for damage can be supplemented.

The current state of the digital information supply was described differently by the experts interviewed by us. Thus, for the gain of information often mobile weather apps or own weather stations are used. For navigation tasks during the journey additional mobile terminals were called (e.g. a tablet computer), which were replaced on larger yachts by digital map plotters, a GPS equipment with way points and a radar for the observation of the traffic participants at night. Apart from navigation tasks the experts already used Smartphones to monitor the mooring position ("anchoring alarm") or Regatta clocks, on which wind direction, course, position and speed are indicated.

Within science, there are few articles that deal with the degree of digitalization of sailboats. Currently many manufacturers rather focus on interconnected systems in the production and design process (Liu et al., 2017) than on the development of sailboats to digitalized products. Further contributions identify the use case of developing a sailboat into a Smart Product, but only describe very abstractly how such a concept can look like. "Our last use case addresses mainly the exchange of information between yachts and ports or port authorities, including preparations for refitting and maintenance of the boats (Gojmerac et al., 2016)." Other scientists go further and outline operating systems with the aim to increase security on sailboats. Here the approach of support systems and the integration of terminal devices into the control of ships is being investigated. However, there are only very few Smart Products in sailing so far.

Smart Products

The combination of physical and digital objects has been discussed for several years under the term "Internet of Things" (Wortmann and Flüchter, 2015). A central aspect in this context is the networking of objects that cooperate with each other (Atzori et al., 2010). Smart products, which extend conventional physical products, consisting of mechanical and electronic components, with information technology components such as sensors, processors and data storage, fit into this paradigm (Beverungen et al., 2017). These components are complemented by interface technologies, such as BUS-systems and transmission protocols, which, in addition to human-to-machine communication, are also intended to enable machine-to-machine communication (Porter and Heppelmann, 2014). The "Smart Products Consortium" has made a much-noticed approach to a definition:

> *“A smart product is an autonomous object which is designed for self-organized embedding into different environments in the course of its life-cycle and which allows for a natural product-to-human interaction. Smart products are able to proactively approach the user by using sensing, input, and output capabilities of the environment thus being self-, situational-, and context-aware. The related knowledge and functionality can be shared by and distributed among multiple smart products and emerges over time." (Sabou et al., 2009)*

The term "Smart Product" thus extends the classical understanding of the product by digital properties that enable the product to integrate extended activities and to carry them out independently. Still, smart products have already been processed by a large number of research contributions that attribute varying characteristics to the extended, digitized product. Thus, Beverungen et al. in their analysis of central characteristics state that a "Smart Product" does not have to fulfill all identified aspects completely (Beverungen et al., 2017). The aspect of connectedness is explicitly emphasized by some authors (Porter and Heppelmann, 2014), while others regard it as an immanent component. For example, authors associate "smartness" with the ability to recognize and predict deviations from error-free operation (Allmendinger and Lombreglia, 2005; Tien, 2015). Mühlhäuser defines "Smart Products" as an object (in the sense of a concrete product, service or software) which adapts to its environment (Mühlhäuser, 2007). Mühlhäuser focuses on simplifying the exchange between products and their users or other products. This simplification opens up the "Smart Product" by offering product functions that are selected context-adaptively on the basis of their situational relevance (Mühlhäuser, 2007). In order to map such functions in a product, Smart Products must be able to perceive their environment, identify situational patterns with the help of the collected data in the sense of an "adaptive system" and finally proactively make relevant information available on the basis of the identified context (Mühlhäuser, 2007). Regardless of the fact that the nature of Smart Products and possible characteristics are already largely agreed upon, it is not yet clear which capabilities a Smart Product must fulfill in order to be considered as such, which is why a concrete design specification does not yet exist.

4 Analysis of Design Specifications for Smart Products

Smart Products thus understand their purpose and are able to evaluate the outline conditions, adapt to the individual needs of the user and derive alternative courses of action from past scenarios. Conversely, this means that ideally suited scenarios for the use of smart products must be complex in terms of the number and heterogeneity of relevant outline conditions and that these must change dynamically in order to generate added value from the learning ability and adaptivity. Against this background, this paper analyses key design specifications of the concept in order to derive an application in yachting. In order to identify the key design specification, we conducted a systematic literature reviews by following the method of Webster and Watson (2002). Our initial literature review identified 26 relevant contributions in the databases *AISeL*, *SpringerLink*, *EBSCOhost*, *Web of Science* with the search terms "Smart Product" and "Smart Connected Product". Within our literature research it was noticeable that, in addition to the terms "Smart (Connected) Products", other terms were also used for products with similar characteristics. For example, Smart Objects (Fleisch and Thiesse, 2007; Sabou, 2010), Digitized Products (Herterich et al., 2016), Intelligent Products (Holler et al., 2016) or ServGoods (Tien, 2015) can be named that were similar in characteristics. Even though current studies are leading to a common understanding of the concept, it becomes clear that for Smart Products so far, no conceptual exactness exists, and the clear demarcation remains open. This also concerns superordinate concepts such as "Cyber-Physical-Systems" or the "Internet of Things", which describe systemic approaches. A condensation of the results found in the literature search led to 6 generalizing concepts. Therefore, we followed the classification principle of Webster and Watson (2002), which is methodically comparable to more detailed approaches such as qualitative content analysis according to Mayring (2014). During the elicitation of general concepts, we passed through multiple stages of refinement leading to the results presented in table 1.

		Year	*Context-Awareness*	*Personalization*	*Connectivity*	*Embeddedness*	*Service Bundling*	*Systemic Design*	**Total**
Smart Product	Zheng et al.	2018	x	x	x	x	x	x	**6**
	Abramovici et al.	2017	x	x	x	x	x	x	**6**
	Dawid et al.	2017	x		x	x	x	x	**5**
	Roecker et al.	2017	x		x	x		x	**4**
	Mohelska and Sokolova	2016	x		x	x	x		**4**
	Mayer et al.	2011	x		x	x	x	x	**5**
	Fleisch and Thiesse	2007	x		x	x	x	x	**5**
	Maass et al.	2007	x		x			x	**3**
	Maass and Janzen	2007	x		x			x	**3**
	Mühlhäuser	2007	x			x		x	**3**
	Lee	2003	x			x	x		**3**
	Subtotal		**11**	**2**	**9**	**9**	**7**	**9**	
Smart Connected Product	Mikusz	2018	x	x	x	x	x	X	**6**
	Wang et al.	2018	x	x	x	x	x	x	**6**
	Zheng	2018	x	x	x	x	x	x	**6**
	Beverungen et al.	2017	x	x	x	x	x	x	**6**
	Zimmermann et al.	2017	x			x	x		**3**
	Herterich et al.	2016	x		x				**2**
	Holler et al.	2016	x		x				**2**
	Novales et al.	2016	x		x	x	x	x	**5**
	Herterich et al.	2015	x	x	x	x	x	x	**6**
	Porter and Heppelmann	2015	x	x	x	x	x	x	**6**
	Tien	2015	x		x	x		x	**4**
	Porter and Heppelmann	2014	x	x	x	x	x	x	**6**
	Ahram et al.	2012	x	x		x	x	x	**5**
	Sabou	2010	x		x	x	x	x	**5**
	Rijsdijk and Hultink	2009	x	x		x			**3**
	Subtotal		**15**	**9**	**12**	**13**	**11**	**11**	
	Total (both terms)		**26**	**11**	**21**	**22**	**18**	**20**	

Table 1. Results from the literature review

Specification 1: Context-Awareness

The "smartness" of products is attributed to context awareness in all examined publications. Mühlhäuser (2007) emphasizes the acquisition of information through sensor technology from the direct environment of a product in order to encompass different properties of a smart product. Rijsdijk and Hultink (2013) define a series of properties that rely on sensory context information: "autonomy, adaptability, reactivity, ability to cooperate". Porter and Heppelmann (2014) depict these using the four levels "monitoring, control, optimization and autonomy" and differentiate more strongly between the purposes of use of the data accessed. All stages represent different manifestations of context-awareness, from pure data acquisition to the independent recognition of relevant state changes.

Specification 2: Personalization

Ahram et al. (2012) see personalization as a "customization of products according to buyers and consumer needs" and thus as an adaptability of the product to the individual buyer or user perspective. For Porter and Heppelmann (2014), personalization is already represented by the Control property, in which the user influences product behavior. Software components in the products enable users to adapt the technology to their needs. The customer thus interacts with the Smart Product and actively influences it. Personalization complements the context awareness of a product, which can rather be understood as a passive aspect of a product by means of which the environment is perceived by sensors.

Specification 3: Connectivity

Connectivity describes the ability of products to communicate with other products, systems and users (Novales et al., 2016). Porter and Heppelmann (2014) distinguish three types of connectivity: 1:1, 1:N and N:M assignments. In the case of 1:1 assignment, the product is directly connected to a user or another product. In the case of 1:N assignments, a system is in phases or continuously connected to several products and in the case of M:N assignments, several "sending" products are connected to several receivers (products and actors). Connectivity has two objectives: The exchange of information between a product and its environment and the contribution to cross-product functions.

Specification 4: Embeddedness

"Classical" products with embedded IT (sensors, microprocessors, hard disks, software, etc.) are described by Novales as "hybrid components" (Novales et al., 2016). The specification is also named by other authors as an essential part of the concept (Dawid et al., 2017; Mühlhäuser, 2007; Porter and Heppelmann, 2014). Classic products open up the basic product function through mechatronic components, whereas IT components are able to add logical processing to the product. Embedded IT consists of physical (e.g. sensors) and virtual components (e.g. software) that are used for linking and control (Novales et al., 2016). In this way, embedded IT systems serve as the basis for Smart Connected Products, since the functional structure of the product is supplemented by a digital "product logic", which is fundamental for opening up further properties.

Specification 5: Service Bundeling

Service bundling refers to the marketing of service packages consisting of customer-related combinations of physical goods, services, support, self-service and knowledge (Bonnemeier and Reichwald, 2012). Such service bundles consist of interconnected products in combination with value-enhancing services with the aim of optimizing the overall result (Mohelska and Sokolova, 2016). Services associated with the product extend the range of solutions from one-off product functions to a continuous value creation mechanism between manufacturer and customer. The conclusion is that a product is no longer sold "completed". But is offered continuously on the market as a bundle of services and solutions for existing customer needs.

Specification 6: Systemic Design

Novales regards the ecosystem in which smart products are used as an interacting network (Novales et al., 2016). In this network, individuals and organizations cooperate in order to create added value from the bundling of products and services. Products that exist in a system without mutual reference points are seen as untapped synergy potential (Dawid et al., 2017). According to Novales, other subsystems can also appear within a system and form a "system of systems": The systemic perspective thus represents an essential concept of smart products due to the claim to connectivity, since the resulting links with other products and services are made visible (Novales et al., 2016). At the same time, however, the systemic understanding also complicates the design of necessary interfaces, since important aspects such as data protection for users, conventions and access authorizations must also be considered (Novales et al., 2016).

5 Applying the Design Specifications in Yachting

In this section, the results of the expert interviews are presented and transferred into an operationalizable functional structure. The results are condensed in the sense of qualitative content analysis and differentiated into physical functions of the product and virtual functions that are represented by software or services. The interviews were pre-structured according to Bogner et al. (2014) and Kaiser (2014) by using a guideline and evaluated according to the qualitative content analysis (Mayring, 2010). During the interviews the 6 generalized concepts were presented to the experts and the experts were explicitly asked to identify application areas for transforming a sailboat into a Smart Connected Product. The experts were chosen as diverse as possible in order to consider different degrees of experience and professionalization as well as IT affinities. Table 2 introduces the sailing professionals we interviewed.

No.	*Expertise (Years)*	*Expertise (Graded)*	*Profession*	*Age*	*IT Affinity*
1	>30	Hobbyist	Chemist	62	Intermediate
2	20	Professional	CEO of a Sailing Center	42	Low
3	6	Racing Sailor	IT-Consultant	27	High
4	20	Hobbyist	Electrical Engineer	34	High
5	20	Professional	Sailing Advisor	44	Intermediate
6	7	Hobbyist	Mechanical Engineer	34	High
7	18	Hobbyist	Software Engineer	35	High
8	>35	Hobbyist	Business-IT-Analyst	64	High
9	>20	Hobbyist	Teacher Physical Education	27	Intermediate

Table 2. Overview of the Interviewees

Several experts saw potential in context awareness for the sailboat. Expert 7 outlined his idea of the function with reference to sensory parking distance control. He suggests that "the direct surroundings of the boat should be detected by means of sensors such as optical sensors or cameras or [any] distance sensors such as ultrasonics". As a consequence, skippers are to be supported by automatically issued warnings. The benefits arise, for example, in dangerous situations when the sailor is not on deck and a collision with other objects is imminent. Expert 7 sees further possibilities for sensory context awareness in the measurement of the inflow of sails: "With the help of pressure sensors, one can certainly consider [measurements] to determine [...] the load center of the sail and [whether] [...] it is optimally [located]". Expert 4 adds information requirements in case of moisture ingress in the bilge, water ingress at the sea valves, gas discharge within the piping system, up to warnings of ground contact. A further connecting factor mentioned by several interviewees is the anchor alarm, which is to be extended by information on fluctuations in tension or sudden movements. Expert 4 suggests a definite procedure to check the anchor chain for wear when weighting the anchor: "So I measure the contact resistance between the tensioning point and the water. Then I have a defined length of my chain and then I know [...if] all chain elements are intact". The expert emphasizes the context awareness in the sense of a data-processing product, "that [...] all information would be digital and not just "tank is filled now"". The expert outlined a function that the sailboat uses to automatically generate a forecast of the traveling range from digital information of the filling level and current consumption. The embedding of IT systems also met with positive reactions among the experts. The autopilot was the central topic of discussion in most of the interviews. The autopilot is an automated hydraulic control of the steering wheel, by which the course is automatically calculated and set using information from a compass function. Expert 3 emphasized the already existing importance of the autopilot for the active support of boat navigation, for example in a "double-handed regatta, where you sail pairwise and set a spinnaker [sail], you don't have much time to steer". The primitive control logic was criticized due to the lack of integration of further sources of information. For example, the autopilot usually does not receive any data about the current wave pattern and can therefore not adjust to it. This results in a safety hazard, because "if the [autopilot] does not see the next wave coming, it gets dangerous very quickly". It became clear that embedded IT systems were often seen as functionally dependent on sensory context awareness. For Expert 5, port handbooks are also a central information medium: "But that could be integrated. Another aspect would be to [indicate] free berths in ports, so that one does not have to think about it beforehand".

With regard to user-related personalization, experts 5 and 7 saw digitization as "an opportunity to differentiate between chartering and regatta sailors" in order to meet the different requirements of information. Expert 7 also distinguishes cruising yachtsmen who have a particularly high need for information on the safety status of the boat. The essential design spaces would result from the adaptability of the information supply and representation to the user needs and in the automated reconfiguration of the information system according to the individual boat operation. In this way, different sail sizes can be recognized and in consequence, individual parameters of the sail dimensions can be fed into the system and used to optimize the sail characteristics. The majority of the experts described the connectivity aspect as "already existing": "A lot of things are already given by the AIS system. In other words, I have information about what kind of ship it is, how fast is it, on what course is the ship, what is my distance, do we cross [etc.]" (Expert 2). "Networking the navigational components with each other is already standard today. The GPS automatically sends the correct position with the DSC message via the radio, which the nervous radio operator could do wrong" (Expert 1).

Expert 5 extends this by proposing to "start the engine for proactive collision prevention [...]". The majority of respondents also mentioned the signal feedback of buoys and landmarks: "In the past it was regulated by lighthouses and nowadays it makes sense that other things send messages when they are in the way" (Expert 5). In ports, a "gas alarm" could also be forwarded to neighbouring berths, making the boat a "supplier of information" (Expert 4). An undervoltage detection could also inform the owner via SMS if a defect occurs in the boat's batteries (Expert 4). In this sense, the systemic perspective integrates all the resources of the Smart Product into a cross-product design space of individuals and organizations involved. Expert 4 saw potential in maintenance and repair services for bundling services and designing value-added systems and explained that "a charter base has a maintenance contract with, for example, *Yanmar* [...] [from which] [I] procure all engines". As a service provider, the charter company can obtain information on the condition of the engines while they are entering the port and thus obtain information on wear parts to be replaced or defects to be repaired.

The limits of the transformation from sailboats to smart products were identified at different points. For Expert 8, the limit for Smart Products is economic feasibility. Expert 6 focuses on the protection of personal data, as well as the influence of digitalization on sailing operations and the acceptance of sailors, he notes: "On the other hand, [...] I actually like the simplicity and abundance of technology and look forward to every sailing day where I am not constantly connected to the digital world ". At the technical level, experts believe that there will also be limitations, such as in the assessment of faults in the Smart Product. "You won't be able to measure every defect accurately. This means you won't be able to avoid normal service intervals. Thus, there will be "a lot of physical limitations that you may not be able to detect properly. Especially when I think of the structure in the hull, there are certainly approaches and concepts, but checking each fiber individually will not work" (Expert 4). Table 3 summarizes the functions that were described by the experts in the evaluation.

Two researchers aggregated the results independently according to Mayring's guidelines (2010) and discussed their results. The transcript was translated after the analysis, in order to provide insight into our data to the reader. A distinction was made between *feature-based functions*, i.e. those that are implemented as product functionality, and *collaboration-based* functions. Collaboration-based functions generate benefits from the informational link with other system elements (e.g. marinas, supermarkets or landmarks).

Nr.	*Function*	*Context-Awareness*	*Embeddedness*	*Personalization*	*Connectivity*	*Service Bundeling*	*Systemic Design*	*Mentions*	*Importance (relative to Mentions)*
Feature-based functions									54%
1	Monitoring of Sailing Parameters	x	x	x			x	9	18%
2	Gas Detection	x	x					2	4%
3	Detection of Moisture Ingress	x	x					2	4%
4	Monitoring of Keel Bolts	x	x					3	6%
5	Battery Monitoring (Low Voltage)	x	x					1	2%
6	Preventive Detection of Grounding	x	x		x	x	x	2	4%
7	Localization and Analysis of Grounding	x	x			x	x	2	4%
8	Collision Warning	x	x		x	x	x	6	12%
Collaboration-based functions									46%
9	Analysis of Operating Data	x	x	x	x	x	x	4	8%
10	Deterioration Analysis of Components	x	x	x	x	x	x	4	8%
11	Mooring Guidance				x	x	x	4	8%
12	Proactive Information on Service Stations	x		x	x	x	x	3	6%
13	Proactive Mooring Management	x			x	x	x	4	8%
14	Proactive Supply of Inventories	x		x	x	x	x	4	8%
	Total	13	10	5	8	9	10	33	100%
	Importance (relative to total of functions)	93%	71%	36%	57%	64%	71%	-	-

Table 3. Functional Instantiation of the Design Specifications in Yachting

6 Insights from our Evaluation of the Design Specifications

The study showed that the participants saw a benefit in the transformation of the sailboat into a smart product. This was, however, less seen in the light of autonomization as formulated by Porter, but resulted primarily from the improved informational support of the sailor through real-time data processing and transmission. In the first step, the experts focused on developing "smartness" for a conventional mechanical product by integrating sensor technology and data processing technologies. In the second step, the experts found the information link with other elements of the system beneficial ("connectivity"). On the basis of the connectivity gained, corresponding third party services were added that benefit users from the sensor-generated data and in this way open up new forms of added value. Our observation here is in line with the approach of Nakajima et al., who advocate the sequential development of product functionalities and service offerings based on them due to many direct dependencies (Nakajima et al., 2010). This can be illustrated by the transformation of the anchor, which as a safetycritical component of the sailboat causes a need for information regarding mooring stability and position. The integration of sensors, which record anchor and boat movements, paired with a function that recognizes if the boat is "drifting", could be used here to inform the sailor about threats and the need for immediate action. The digitization of the components, however, also creates a potential follow-up for the implementation of further specifications. For example, "connectivity" and "systemic perspective" could be used to transmit the position of the "digital" anchor, including the anchor chain, to nearby boats, thus helping to prevent the twisting of anchor chains or proactively inform about unsafe grounds. The fact that significant added value can be tapped in this way can also be seen in the quantitative comparison of the developed functions: 46% of the applications addressed the development of system-based functions that can be implemented as data-driven services. From our perspective, the resulting systems made of Smart Products and Services correspond to the conceptual understanding of Smart Service Systems developed by Beverungen et al., according to which the Smart Product can be used as a boundary object between service providers and consumers (Beverungen et al., 2017). Further, we found that a broad range of service providers with different offerings could contribute to such a Smart Service System. Besides the provision of product optimization and remote-control functions, we added “third party suppliers” which respond to demands that were identified through the sensor-based context-awareness of the boat.

Figure 1 outlines our findings following the Smart Service System approach by Beverungen et al. (2017) In the instantiation, we extended the figure by third-party services, that turned out as an important aspect for the interviewees. Functions we did not find during our study were flagged with a “*”, in order to visualize the divergence between the conceptual model and the practice-driven perspective of our results.

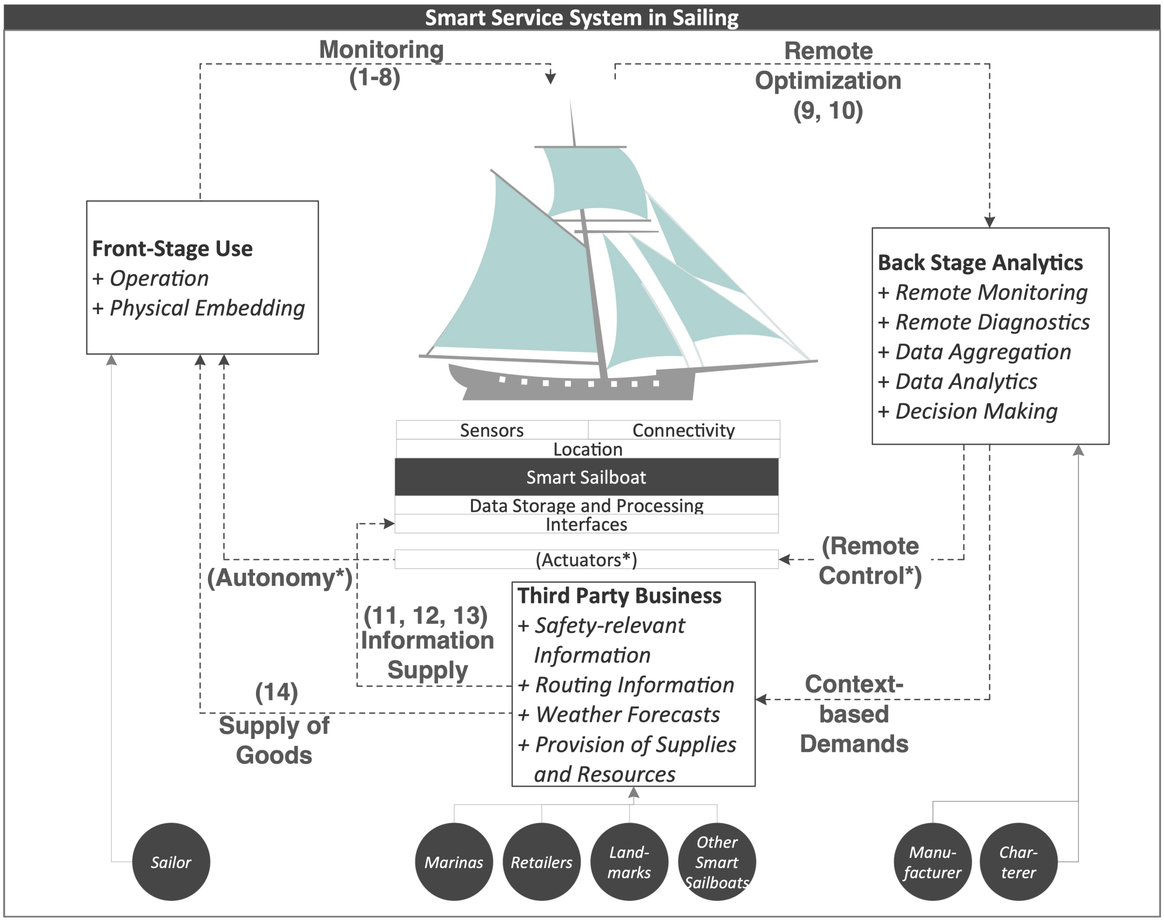

Figure 1. Exemplary Instantiation of a Smart Product in Yachting referring to Beverungen et al. (2017)

It was surprising for us that the development stages of automation and autonomization (which play a central role in the scientific concept) were discussed very controversially and up to a (partly) disagreement between the general concept and the practical instantiation. In the course of the study, we gained initial insights into the domain-specific reasons for and requirements on Smart Products. The application of autonomous functions was a central turning point in the discussion. If one focuses on operational safety, the autonomous intervention of the product in dangerous situations has been positively received. The contribution of the product to the control of very complex situations, such as extreme weather conditions, was also recognized. At the same time, the anxiety of over-automation was addressed, which would be partly triggered by the increasing machine-based execution of previously manual activities, partly already by the need for interaction with technical components and the expectation of a resulting technological stress. Our investigation identifies potential tensions in a defined application case and shares the observation with further studies on the subject. Hence, it should be noted that in a non-private, commercial shipping sector autonomously operating boats could be assessed positively. The general validity as well as the limits and mechanisms of this field of tension have to be further investigated in order to come one step closer to the successful implementation of Smart Products. From our point of view, the step-by-step implementation of the design specifications can offer a first step to further investigate this phenomenon by means of an iterative transformation and to gain knowledge about essential factors for the acceptance of automation and autonomy. We found that the design principles we gathered from literature are of unequal importance for the transformation of a sailboat. However, we argue that their prioritization is depending heavily on the actual use case which hinders the general application of our quantified results. For example, the importance of connectivity and systemic design relies on the existing ecosystem of a product. Following this train of thought, a Smart-Home-application, which heavily relies on the integration of e.g. lamps, heating and ventilation arguably requires more connectivity-functions than a specially designed machine that operates separately. We consequently find that the design principles at hand provide first insights to spark a transformative process. The development of a general design pattern that could be easily applied to any context requires many further applications of the design principles in different industries.

It became clear that the technical realization of "smart" functions is an essential prerequisite, but not the entire design scope for smart products. Within the interviews, it was the "bundling of services" and the "systemic perspective" that had a key role in the design of information links within the "ecosystem" of the sailing boat. In this way, not only a functional extension of the sailboat was designed, but also the interaction between sailor and sailboat, as well as Smart Products among each other and their networking with other things. In conclusion, our investigation reaffirms the scientific differentiation between "smartness" and "connectedness", whereby “smartness” primarily addresses the sensory equipment and processability of the product itself and “connectedness” describes the integration into and active linking with its ecosystem. The result is a series of data-driven functions that can be understood as product-related and cross-product services. These services generate their value proposition from the information of one or more smart products and can thus be understood as part of a data-driven value creation system.

7 Limitations and Outlook

In conducting our study, we learned several new insights into the design and use of Smart Products. From a practical perspective, we show that it is technically possible to transform a sailing boat into a Smart Product and that our domain experts perceive this as useful. The design specifications represent a first starting point for this, which can be used to estimate the implications of a product transformation. The study also indicates, however, that embedding a product in a cross-product value creation system may offer opportunities for added value and thus facilitates further design tasks such as the development of service and cooperation models. Smart Products were recognized during the expert interviews also as contribution to the mastering of very complex product systems by automation. Certainly, "overautomation" was sharply demarcated in the direction of an autonomously driving sailboat. The experts focused on the role of Smart Products as a system that supports people, while the shift towards a “mechanical skipper” was discussed very critically. This was attributed among other things to the understanding of sailing as a leisure activity in which the user seeks active participation.

At present, the work does not yet include the technical implementation, which would require a further evaluation of the concept and the design specifications. While the development of feature-based functions for the "basic" digitization of a boat is conceivable and already planned, the implementation of system-based functions poses the challenge that further stakeholders have to be integrated into a joint value creation system. In order to initiate this process, it must be clarified whether third party business originates from the technical potential of the product, the individual transformation of stakeholder models or the increasing demand on the part of the product owner. Furthermore, it is important to find other feasible practical applications that can contribute to a robust understanding of smart products and their surrounding systems, e.g. in the field of agricultural machinery or cars.

On a theoretical level, we condensed existing literature on Smart Products into Design Specifications and thus answered RQ1. We evaluated the developed Specifications with regard to their operability by discussing them with experts using the application example of a sailing boat. The conducted interviews showed that the specification can be used to guide domain experts to the functional design of a transformed product and thus answer RQ2. The development of a functional spectrum was not intended ex-ante (e.g. by the design of the guideline), but occurred as an intuitive approach of the experts to address the abstract specifications. Due to the novelty and complexity of the topic, the methodical approach proved to be effective in instantiating the application scenario conceptually as well as for the test of its feasibility. In a further level of concretization, however, complementary research methods should be used to evaluate more aspects of a future implementation.

The paper contributes a step forward towards the practical application of smart products and evaluates the concept in the field of sailing. In the next step, these specifications can be used to determine and prototype functions of new Smart Products analogous to our investigation. However, it remains to be added that the purely technical implementation of a Smart Product in the sense of an embedded sensor-based information system does not tap the full potential of the concept. Rather, Smart Products must be seen as one part of a more comprehensive value-added systems.

References

Abramovici, M., J.C. Göbel, P. Savarino and P. Gebus (2017), “Towards Smart Product Lifecycle Management with an Integrated Reconfiguration Management”, in Ríos, J., Bernard, A., Bouras, A. and Foufou, S. (Eds.), *Product Lifecycle Management and the Industry of the Future*, Vol. 517, Springer International Publishing, Cham, pp. 489–498.

Ahram, T.Z., K. Waldemar, and S.M. M (2012), “Embedded systems engineering for products and services design”, *Work*, No. Supplement 1, pp. 941–948.

Allmendinger, G. and R. Lombreglia, (2005), “Four strategies for the age of smart services”, *Harvard Business Review*, Vol. 83 No. 10, pp. 131–145.

Atzori, L., A. Iera and G. Morabito. (2010). “The Internet of Things: A survey.” *Computer Networks*, *54*(15), 2787–2805.

Beverungen, D., O. Müller, M. Matzner, J. Mendling, and J. vom Brocke (2017), “Conceptualizing smart service systems”, *Electronic Markets*, No. 2017, pp. 1–12.

Bogner, A., B. Littig, and W. Menz (2014), *Interviews mit Experten*, Springer Fachmedien Wiesbaden.

Bonnemeier, S. and R. Reichwald (2012), “„Hybride Wertschöpfung“ - vom Industrieproduzenten zum Lösungsanbieter -ein State-of-the-Art Bericht”, *Schmalenbachs Zeitschrift für betriebswirtschaftliche Forschung*, Vol. 64 No. S65, pp. 45–72.

Dawid, H., R. Decker T, Hermann, H. Jahnke, W. Klat, R. König and C. Stummer (2017), “Management science in the era of smart consumer products: challenges and research perspectives”, *Central European Journal of Operations Research*, Vol. 25 No. 1, pp. 203–230.

Deutscher Hochseesportverband “Hansa” e.V. (2011), *Seemannschaft: Handbuch für den Yachtsport*, 29., überarb. und erw. Aufl., Delius Klasing, Bielefeld.

Fleisch, E. and F. Thiesse (2007), "On the Management Implications of Ubiquitous Computing: An IS Perspective.", *Proceedings of the Fifteenth European Conference on Information Systems*, presented at the European Conference on Information Systems, Citeseer, pp. 1929–1940.

Ghazizadeh, M., J.D. Lee and L.N. Boyle (2012), "Extending the Technology Acceptance Model to assess automation", *Cognition, Technology & Work*, Vol. 14 No. 1, pp. 39–49.

Gojmerac, I., P. Reichl, I. Podnar Žarko and S. Soursos (2016), "Bridging IoT islands: the symbIoTe project", *E & i Elektrotechnik Und Informationstechnik*, Vol. 133 No. 7, pp. 315–318.

Herterich, M., A. Eck and F. Uebernickel (2016), "Exploring How Digitized Products Enable Industrial Service Innovation - an Affordance Perspective", *Proceedings of the 24rd European Conference on Information Systems (ECIS)*, presented at the European Conference on Information Systems (ECIS), p. Research Paper 156.

Herterich, M., M. Holler, F. Uebernickel and W. Brenner (2015), "Understanding the business value: towards a taxonomy of industrial use scenarios enabled by cyber-physical systems in the equipment manufacturing industry", *CONF-IRM 2015 Proceedings*, pp. 18–20.

Holler, M., E. Stoeckli, F. Uebernickel and W. Brenner (2016), "Towards Understanding closed-loop PLM: The Role of Product Usage Data for Product Development", pp. 479–491.

Kaiser, R. (2014), *Qualitative Experteninterviews*, Springer Fachmedien Wiesbaden, Wiesbaden.

Kölmel, B., A. Richter, J. Schoblik, U. Dittmann, A. Kühn and A. Schätter (2017), "Customer Centricity von digitalen Produkt-Service-Systemen", in DDV Deutscher Dialogmarketing Verband e.V. (Ed.), *Dialogmarketing Perspektiven 2016/2017*, Springer Fachmedien Wiesbaden, Wiesbaden, pp. 127–138.

Lasi, H., P. Fettke, H.-G. Kemper, T. Feld and M. Hoffmann (2014), "Industry 4.0", *Business & Information Systems Engineering*, Vol. 6 No. 4, pp. 239–242.

Lee, J. (2003), "Smart products and service systems for e-business transformation", *International Journal of Technology Management*, Vol. 26 No. 1, pp. 45–52.

Liu, F., C. Chen, and W. Wu (2017), "Research on Intelligent Design of Luxury Yacht", *Procedia Engineering*, Vol. 174, pp. 927–933.

Maass, W., A. Filler and S. Janzen (2007), "Reasoning on Smart Products in Consumer Good Domains", *European Conference on Ambient Intelligence*, presented at the European Conference on Ambient Intelligence, Springer, Berlin, Heidelberg, pp. 165–173.

Maass, W. and S. Janzen (2007), "Dynamic Product Interfaces: A Key Element for Ambient Shopping Environments", in Markus, M.L. (Ed.), *20th Bled EConference "EMergence: Merging and Emerging Technologies, Processes, and Institutions"*, presented at the 20th Bled eConference "eMergence: Merging and Emerging Technologies, Processes, and Institutions", Faculty of Organizational Sciences, Kranj, pp. 457–470.

Mayer, P., D. Volland, F. Thiesse and E. Fleisch, (2011), "User Acceptance of'Smart Products': An Empirical Investigation", *Wirtschaftinformatik Proceedings 2011*, p. Paper 9.

Mayring, P. (2010), *Qualitative Inhaltsanalyse: Grundlagen und Techniken*, 11., aktualisierte und überarb. Aufl., Beltz, Weinheim.

Mayring, P. (2014), "Qualitative content analysis: theoretical foundation, basic procedures and software solution".

Mikusz, M. (2018), "Channel Multiplicity in Digitized, Connected Products", presented at the International Conference on Information Systems (ICIS).

Mohelska, H. and M. Sokolova (2016), "Smart, connected products change a company's business strategy orientation", *Applied Economics*, Vol. 48 No. 47, pp. 4502–4509.

Mühlhäuser, M. (2007), "Smart Products: An Introduction", *European Conference on Ambient Intelligence*, presented at the European Conference on Ambient Intelligence, Springer, Berlin, Heidelberg, pp. 158–164.

Nakajima, T., Y. Kinebuchi, A. Courbot, H. Shimada, T.H. Lin, and H. Mitake (2010), "Composition kernel: A multi-core processor virtualization layer for rich functional smart products", *IFIP International Workshop on Software Technolgies for Embedded and Ubiquitous Systems*, Springer, pp. 227–238.

Novales, A., M. Mocker, and D. Simonovich, D. (2016), "IT-enriched 'Digitized' Products: Building Blocks and Challenges", *22nd Americas Conference on Information Systems, AMCIS 2016, San Diego, CA, USA, August 11-14, 2016*, presented at the Americas Conference on Information Systems (AMCIS), available at: http://aisel.aisnet.org/amcis2016/SCU/Presentations/23.

Porter, M. and J. Heppelmann (2015), "How Smart, Connected Products Are Transforming Companies", *Harvard Business Review*, Vol. 93 No. 10, pp. 96–114.

Porter, M.E. and J. Heppelmann (2014), "How Smart, Connected Products Are Transforming Competition.", *Harvard Business Review*, Vol. 92 No. 11, pp. 64–88.

Rijsdijk, S.A. and E.J. Hultink (2009), "How Today's Consumers Perceive Tomorrow's Smart Products", *Journal of Product Innovation Management*, Vol. 26 No. 1, pp. 24–42.

Rijsdijk, S.A. and E.J. Hultink (2013), "Developing intelligent products", *The PDMA Handbook of New Product Development. Wiley, Hoboken*, pp. 297–309.

Roecker, J., M. Mocker and A. Novales (2017), "Digitized Products: Challenges and Practices from the Creative Industries", *23rd Americas Conference on Information Systems, AMCIS 2017, Boston, MA, USA*, available at: http://aisel.aisnet.org/amcis2017/StrategicIT/Presentations/16.

Sabou, M. (2010), "Smart Objects: Challenges for Semantic Web Research", *Semantic Web*, Vol. 1 No. 1,2, pp. 127–130.

Sabou, M., J. Kantorovitch, A. Nikolov, A. Tokmakoff, X. Zhou, and E. Motta (2009), "Position paper on realizing smart products: Challenges for semantic web technologies", *Proceedings of the 2nd International Conference on Semantic Sensor Networks-Volume 522*, Vol. 522, presented at the 2nd international workshop on semantic sensor networks 2009 (SSN09) at ISWC 2009, CEUR-WS. org, Washington D.C., USA, pp. 135–147.

Sonnenberg, C. and J. vom Brocke (2012), "Evaluations in the science of the artificial–reconsidering the build-evaluate pattern in design science research", *International Conference on Design Science Research in Information Systems*, Springer, pp. 381–397.

Tien, J.M. (2015), "Internet of connected ServGoods: Considerations, consequences and concerns", *Journal of Systems Science and Systems Engineering*, Vol. 24 No. 2, pp. 130–167.

Wang, N., F.T. Piller and K. Wang (2018), "An Exploratory Study of User Interaction with Smart Products for Customization in the Usage Stage", in Hankammer, S., Nielsen, K., Piller, F.T., Schuh, G. and Wang, N. (Eds.), *Customization 4.0*, Springer International Publishing, Cham, pp. 37–53.

Webster, J. and R.T. Watson (2002), "Analyzing the Past to Prepare for the Future: Writing a Literature Review", *MIS Quarterly*, Vol. 26 No. 2, pp. xiii–xxiii.

Wortmann, F. and K. Flüchter. (2015). "Internet of Things: Technology and Value Added." *Business & Information Systems Engineering*, *57*(3), 221–224.

Zheng, P., T.-J. Lin, C.-H. Chen and X. Xu (2018), "A systematic design approach for service innovation of smart product-service systems", *Journal of Cleaner Production*, Vol. 201, pp. 657–667.

Zheng, P., X. Xu, and C.H. Chen (2018), "A data-driven cyber-physical approach for personalised smart, connected product co-development in a cloud-based environment", *Journal of Intelligent Manufacturing*.

Zimmermann, A., R. Schmidt, K. Sandkuhl, D. Jugel, J. Bogner, J. and M. Möhring (2017), "Multi-perspective Digitization Architecture for the Internet of Things", in Abramowicz, W., Alt, R. and Franczyk, B. (Eds.), *Business Information Systems Workshops*, Vol. 263, Springer International Publishing, Cham, pp. 289–298.