Requirements for the Functionality and Design of Interfaces in IPS²

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Zusammenfassung

Teilprojekt B4 des SFB/TR29 „Engineering hybrider Leistungsbündel“ (HLB) beschäftigt sich mit dem Einfluss des HLB-Konzeptes auf die Gestaltung von Mensch-Maschine-Interaktion und der Entwicklung von Unterstützungsformen für Benutzer von HLB. Hybride Leistungsbündel zeichnen sich nach Meier et al. (2005) durch deren gleichzeitige Entwicklung von Sach- und Dienstleistungsanteilen, deren gegenseitige Substituierbarkeit und deren Veränderbarkeit über den gesamten Lebenszyklus hinaus aus und unterscheiden sich dadurch von der klassischen Entwicklung von Produkt und Dienstleistung. In diesem Artikel wird kurz der Ansatz zur Herleitung von spezifischen Anforderungen von HLB an die Funktionalität und die Gestaltung von Mensch-Maschine-Schnittstellen vorgestellt. Sowohl die vorläufigen als auch die endgültigen Anforderungen werden an Beispielen erläutert. Als spezifisch für HLB konnten Aspekte der Nutzerqualifikation, der Initiierung von Kommunikation, Koordination und Kooperation sowie die Sicherheit von Daten und der Schutz von Betriebsgeheimnissen gegenüber und zwischen HLB-Anbieter und -Kunde identifiziert werden.

Abstract

Subproject B4 of the collaborative research project “Engineering of industrial product-service systems” (IPS²) focuses on the influence of the IPS²-concept on the design of human-machine interaction and the development of support tools for users of IPS². After Meier et al. (2005) industrial product-service systems are characterised by the simultaneous development of product and service shares, their potential to substitute one another and their convertibility over the full life cycle which makes them different from conventional development of product and service. In this paper the approach for the deduction of IPS²-specific requirements for the functionality and design of human machine interfaces (HMI) is briefly introduced, preliminary and final results are explained. The aspect of the users’ qualification, aspects of the initiation of communication, coordination and cooperation and the aspect of protection of knowledge and data against and between the involved IPS²-provider and -customer were identified as specific for the design of HMI.

Introduction

Constant availability, different qualifications of users and company-spanning cooperation in the field of industry demand a specific support concept during the delivery of services like maintenance and repairing. In the interdisciplinary and collaborative research project TR29 it is the mission of subproject B4, not to discount the role of the human being in the phases of planning, development and delivery of industrial product-service systems (IPS²). In particular the human-machine interaction in the phase of delivery is to the fore.

Hitherto in the research answers were obtained, whether and which specific requirements influenced by the IPS²-concept exist for the interface design. For this purpose, focus-group discussions among colleagues of the TR29 as specialists for IPS² were conducted to detect, which kind of interactions during the operation of IPS² exist between which involved persons and with which kind of tools. Accompanying the discussion, the answers were collected and noted by the semi-formal C3-notation (communication, coordination, cooperation) (Foltz et al, 2000).

Subsequently these results were used to develop specific C3-models. As a result of the different phases of analysis (development of models depending on the IPS²-specific business models, development of scenarios like machine breakdown and maintenance, differences between these scenarios) preliminary requirements were merged thematically to aspects of qualification, C3 and rights of access to data.

These aspects contain the demands for usability for users of different qualification, integration of tools into the human-machine interface (HMI) for coordination and communication, as well as the access to the machine's sensor data and to during operation generated knowledge. Due to the fact that the involved persons in IPS² pursue different interests, a security concept with rights of access to all data is needed which is created during the phases of planning and operation.

Preliminary requirements

Based on the preliminary requirements (Roetting & Hoege, 2008) more steps were necessary, to concretise final requirements for the functionality and design of human-machine interfaces in IPS². After presentation at international conferences and discussions amongst members of the TR29, the preliminary requirements were as follows:

The HMI should be usable for users of different qualification. Due to changing use models over the life cycle of a machine, different users of different qualification will work with the same machine. The interface should match with the user's level of experience and knowledge. But of course there is still the question, how different qualifications can be provided for.

Integration of tools to support communication and coordination in the HMI should minimise unnecessary down time of the machine due to service planning in case of failures and problem definitions. It is still an open research question, how communication and coordination tools can be designed into the HMI.

Especially in micro production facilities it seems to be necessary to make access to the sensor data possible for users. These sensor data could represent the condition of the machine and be used for determination of maintenance and overhauling.

Intelligent algorithms should obtain knowledge out of the collected sensor data. This could be used to analyse repeated failures as well as for obtaining 'best practice' knowledge for recording training procedures or creating instruction manuals. The open research question here is, how automatically obtained knowledge could be utilized by the users.

Finally, all data which is used for programming the machines or which is collected during operation is property and industrial secret by the particular involved company. Therefore, the HMI should contain separated areas with different rights to access data of sensors or programming data. This allows an IPS²-customer for example, to protect specific data against the access by a technician of the IPS²-provider during repairing.

The six preliminary requirements were put into a chart to concretise each requirement in different use cases like production, maintenance, breakdown and re-manufacturing of the machine. Each requirement was analysed under the influence of both customer and manufacturer perspectives and for each use model like function-orientated, availability-orientated and result-orientated. After completing the chart, only those elements were taken as a result, which were specific for the IPS² concept.

Final requirements

Three superordinate groups of the six preliminary requirements were generated: aspects of qualification, C3 aspects and security aspects. In the following, each of the groups will be ex-

plained in detail and deducted requirements for the HMI are shown supplemented with examples.

Qualification

The aspect of qualification contains the requirement for usability of the HMI for users of different qualification. In IPS² use models un-, low- or less skilled workers can be deployed as well as skilled technicians up to highly qualified specialists. Under the constraints of the use models, specific roles can be assigned to personnel (see fig.1).

	IPS²-Provider	IPS²-Customer
Function-orientated	Expert for special problem	Novice – Expert for task and problem
Availabilty-orientated	Expert for problem	Novice – Expert for task
Result-orientated	Expert for task and problem	Not involved

Fig. 1: Assignment of specific roles to IPS²-provider and -customer depending on use models

The IPS²-customer is only involved into the function- and availability-orientated use model since the IPS²-provider is fully operating the production in the result-orientated model. In the function-orientated model, the IPS²-customer can deploy personnel with low skills (novice) up to high skilled technicians (expert). The main responsibility for operation lies with the IPS²-customer. Only in cases of breakdown, when even the skilled technicians cannot solve the problems, experts from the IPS²-provider are requested.

The deployed personnel by the IPS²-customer is not necessarily different in the availability orientated use model. One major difference is the responsibility and guarantee of availability for operation by the IPS²-provider. In the case of a machine breakdown, expert's knowledge needs to be rapidly transferred to the operator on-site to avoid longer breakdowns by waiting for the arrival of an expert. In this use model remote support solutions are necessary to guide the on-site personnel trough repairing procedures.

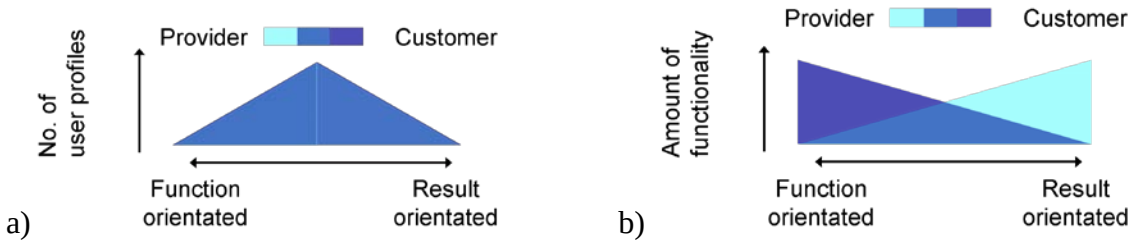

Fig. 2: a) Qualitative graph of the demand for different user profiles in IPS²-specific HMI. b) Qualitative graph of the amount of functionality varying by the constraints of the use models and the personnel.

Due to the described constraints there are consequences for the design of the HMI. One point is the heterogeneity of the personnel which has to interact with the interfaces. Different technicians with different skills, responsibilities and tasks lead to the concept of user profiles for each user or user group. The profiles allow to separate operation functions from maintenance functions and to adapt the functionality to the technician's skills. In Figure 2a) is qualitatively shown that IPS²-provider and -customer could have an equal demand for user profiles in all use models. In the function-orientated model as well as in the result-orientated model according to figure 1, both groups of technicians are experts for problems and tasks. Therefore, a user profile with full functionality for each group could be sufficient. However in the result orientated

model, a user access for the customer is not essential. The highest number of user profiles can be necessary in the availability-orientated use model in-between both others. In this use model the functions for service are separated from operation and the IPS²-provider can access the machine remotely.

In figure 2b) is shown that the amount of functionality is highest in the function-orientated use model for the customer's personnel whereas the functionality for the provider site is limited to the necessary maintenance or service functions. The contrary is shown for the result orientated model since there only the provider's technicians are involved into service and operation.

To summarize the requirements for the HMI regarding the aspects of qualification both IPS²-customer and -provider can access to a similar HMI in work tasks, a special HMI is necessary for service tasks. General functions are the identification of users, a user profile management depending on the use model and the possibility to adapt the functionality to the customer's needs. In the availability-orientated use model the experts for the process operation are responsible for the profile management whereas less-skilled technicians use predefined profiles and service technicians get access by a remote connection. For function and result-orientated use model a complex user management can be optional depending on the customer's or provider's needs. It is from importance to the IPS²-designer of the provider, to take the functionality for the different user groups already in the phase of planning into account, for example while identifying the customer's needs. The user profiles can be generated at the moment of first time access to a machine or are preconfigured for the user groups.

C3

To deduct the requirements for a HMI regarding to aspects of communication, coordination and cooperation, the direction and the initiation of C3 play a decisive role as well as the grade of integration of IPS²-provider and customer. The simplified directions and relations for C3 can be seen in figure 3a). In this figure, the numbers *0* and *1* stand for *is not initiating* and *is initiating*. From left to right, the first number stands for *communication*, second for *coordination* and third one for *cooperation*.

a)

	IPS²-Provider	IPS²-Customer
Function-orientated	0 0 0 ←	1 1 1
Availabilty-orientated	1 1 1 ↔	1 1 1
Result-orientated	1 1 1 →	0 0 0

b)

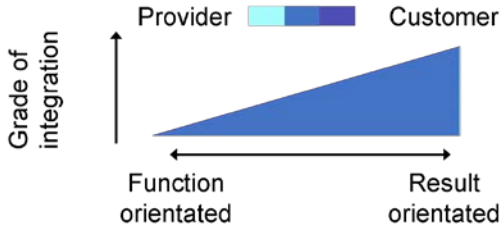

Fig. 3: a) Direction of C3 depending on use model. b) Qualitative graph of the grade of integration.

In the function-orientated use model, the initiation of C3 comes from the IPS²-customer which is shown by an arrow pointing to the provider. The customer is interested in communication when extraordinary problems occur which cannot be solved by the personnel. Coordination for the planning of service and maintenance is the customer's interest as well as the cooperation during conduction of services. Machine data has to be communicated, the production has to be re-planned and the machine has to be prepared for the service. Regarding to the design of the HMI, this means, the customer needs tools for contacting the provider easily and coordinating the production to prepare the cooperation. A communication interface can be integrated directly into the HMI, also a tool for planning and visualisation of production and service intervals.

A contrary intention is obvious in the result-oriented use model. When the operation and service is conducted by the IPS²-provider, it is the interest to communicate, coordinate and cooperate with the customer whenever it is necessary. Nevertheless, the implementation of the functions into the HMI is more provider-orientated since the customer is not involved into any operation or services processes. But in the availability-orientated use model both sides are interested similarly. To prevent downtimes of the machine, also the provider can initiate C3, plan service intervals or guide the customer during repairing.

The more the IPS²-provider takes over functions from the customer, the higher is the grade of integration of customer and provider processes (see fig. 3b). As the grade integration is the lowest in the function-oriented model, the full integration of the provider's personnel and machinery is implemented at the customer's site in the result-orientated model. In this use model, work tasks and manufacturing processes have to be planned by customer and provider. Compatible interfaces to the customers planning, designing and administration software are necessary for the IPS²-provider to guarantee a seamless operation.

To summarize the requirements for the HMI regarding the aspects of C3, communication tools have to be implemented into the HMI as well as tools for the coordination of services. Already in the phase of planning of the IPS², interfaces to the customer's software have to be identified.

Security

One of the main results of the conducted focus-group discussions was the aspect of data and knowledge protection. An IPS² which is configurable and changeable over its lifecycle demands a precise concept of data and knowledge handling to prevent that the customer's or provider's industrial secrets are revealed.

The aspects of security are shown in a matrix of interests for the IPS²-provider and -customer depending to the specific use model. In the figure 4a), the numbers *0* and *1* stand for *is not interested in* and *is interested in*. From left to right, the first number stands for *generated knowledge*, the second for *secrets about the operation* and the last one for *sensor data*.

a)

	IPS²-Provider	IPS²-Customer
Function-orientated	1 0 0	0 1 1
Availabilty-orientated	1 0 1	0 1 0
Result-orientated	1 1 1	0 0 0

b)

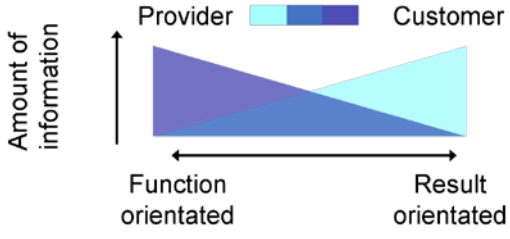

Fig. 4: a) Interests of IPS²-provider and -customer regarding *generated knowledge*, *secrets about the operation* and *sensor data* depending on use model. b) Qualitative graph of the amount of information which can be accessed or obtained by the provider and customer depending on use model.

As well as the IPS²-customer in the function-orientated use model has an interest in protecting the operational secrets and the sensor data against external access, the IPS²-provider has similar interests in the result-orientated use model. In these cases each of both is responsible for the full process of operating the machine by use of expert experience and by full control over the sensor data (see fig. 4b). In particular in the availability-orientated use model where IPS²-provider and -customer have access to the machine but also in the function-orientated model whenever a service technician is requested, functions have to be implemented into the HMI to prevent loss of data and secrets about the operation.

As a solution, a concept is required which separates and saves the different types of data into secure areas. For example in the function-orientated use model, the IPS²-customer saves the programming data for the machine operation into a secure memory which cannot be accessed by a service technician. The service technician can only access a failure log with specific measurements regarding aspects of warranty.

In the availability-orientated use model the IPS²-customer still has interest in protecting the secrets of operation but the IPS²-providers needs access to the sensor data to guarantee the availability and to prevent machine downtimes. In this case, the sensor data should be saved in a way which prevents that the IPS²-provider can restore or deduce operational secrets about the manufacturing processes.

The aspect of knowledge generation by usage of special algorithms becomes more relevant, the more the IPS²-provider is integrated into the customer's processes. The provider can use this knowledge to compare, optimise and redesign the installed IPS².

In summary, the separation of data is crucial depending on the specific use model. Parameters and measured values of machine components can be directly accessed by service technicians, however target values and characteristic data for configuration and operation can only be accessed by the particular operators.

Summary and outlook

The general concept of IPS² in the TR29 was used to deduce the specific requirements for the functionality and the design of human-machine interfaces which are introduced in this article. Especially the use models function- and result-orientated lead to similar HMI since the responsibilities of the operating personnel are similar. Nevertheless is the complexity of software, hardware and intelligent sensors which can be implemented into IPS², growing from the function- to the result-orientated use model. As most specific, the availability-orientated use model can be identified.

The aspect of support tools for the machine users who are working in the specific use models was not focus of this work but the development of support tools is based on the knowledge which was obtained in the background while deducing the introduced requirements.

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