User-friendly, requirement-based assistance for production workforce using an asset administration shell design

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Abstract

Future production methods like cyber physical production systems (CPPS), flexibly linked assembly structures and the matrix production are characterized by highly flexible and reconfigurable cyber physical work cells. This leads to frequent job changes and shifting work environments. The resulting complexity within production increases the risk of process failures and therefore requires longer job qualification times for workers, challenging the overall efficiency of production. During operation, cyber physical work cells generate data, which are specific to the individual process and worker. Based on the asset administration shell for Industry 4.0, this paper develops an administration shell for the production workforce, which contains personal data (e.g. qualification level, language skills, machine access, preferred display and interaction settings). Using worker and process specific data as well as personal data, allows supporting, training and instating workers according to their individual capabilities. This matching of machine requirements and worker skills serves to optimize the allocation of workers to workstations regarding the ergonomic workplace setup and the machine efficiency. This paper concludes with a user-friendly, intuitive design approach for a personalized machine user interface. The presented use-cases are developed and tested at the ARENA2036 (Active Research Environment for the Next Generation of Automobiles) research campus.

Keywords: Industry 4.0; Human-centered design; Cyber physical production systems (CPPS); Smart factories

1. Introduction and state of the art

Cyber physical production systems (CPPS) drive the 4th industrial revolution [1, 2]. Future production systems like CPPS and matrix productions, are characterized by highly flexible and reconfigurable workstations [3, 4]. The paradigm of these productions systems includes the holistic connectivity and virtualization of machinery and tools [5, 6]. In order to build a framework for norms and standards, several German research and industrial institutions developed the Reference Architecture Model Industry 4.0 (RAMI4.0), which can be

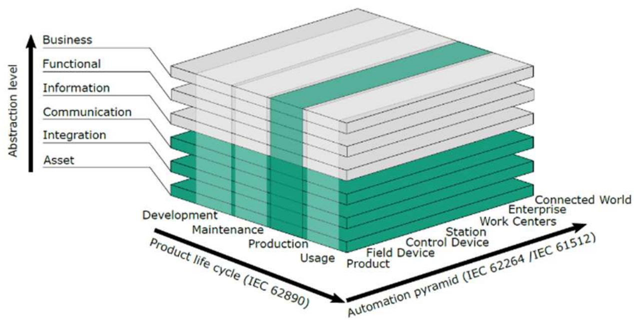

Fig. 1. Reference Architecture Model Industry 4.0, illustration based on [7]

derived by the automation pyramid (1st dimension) and the product life cycle (2nd dimension). The 3rd dimension represents the abstraction level. Figure 1 summarizes the RAMI4.0 model: (For further reference see [7])

Several articles have been published on the Industry 4.0 component model, which is the key element of the RAMI4.0 model [8, 9, 10, 11, 12, 13, 14]. Tantik et al. described the potentials of an asset administrations shell in context of Industry 4.0 [9]. Diedrich et al. presented a semantic approach for smart factories [12]. Wagner et al. considered the life cycle of plants in context of an asset administration shell [13]. However, no author addressed the role of workers in context to the Industry 4.0 component model, the administration shell and the virtual world [15]. According to [8] workers are also part of the asset layer which is connected to the virtual world via the integration layer. According to the industrial associations VDE, VDI and ZVEI, the Industry 4.0 component model is defined as a combination of an asset (e.g. a machine or a machine sensor; the granularity is application-dependent) and an asset administration shell (AAS) [8]. Figure 2 gives a schematic overview of an Industry 4.0 component.

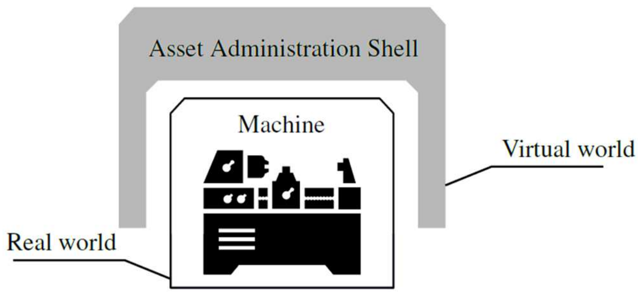

Fig. 2. The Industry 4.0 component model, illustration based on [7]

The AAS serves as interface between the physical and the virtual world and therefore enables both, a virtual representation as well as a technical functionality [19]. Technically, the AAS can be divided in two parts, header and body [10]:

- The header part contains the communication level, which enables the communication of different Industry 4.0 components to each other.
- The body part of the AAS is divided into different sub-models (e.g. data models or functions) [10].

An open-source implementation of the AAS has been published by Palm [20].

2. Related work

Analogous to the AAS which is applied on different assets (e.g. machinery), the introduction of a human administration shell (HAS) is necessary in order to virtualize the capability of production workforce.

2.1 Design

The HAS is applied on smart connected things (e.g. smartphones and smartwatches), serving as interface from the real to the virtual world. Figure 3 depicts exemplary information contained in a HAS. The HAS can be classified into two categories: condition monitoring and service provider:

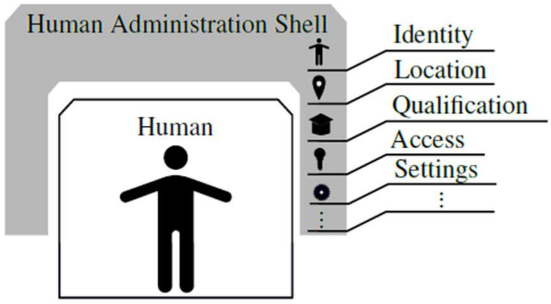

Figure 3: Exemplary information contained in a human administration shell (HAS)

- The condition monitoring contains properties such as availability, identity or location.
- The category of service provider contains properties that give information about the personal skills and knowledge.

For safety and security reasons a sophisticated access rights management is recommended. For the HAS, three different access rights seem feasible: owner properties, bidirectional properties and pushed properties.

- Owner properties include properties such as name or table height. For privacy and security reasons, only the worker can edit and introduce owner properties.
- The bidirectional properties are set by the worker or higher instance (e.g employer or governmental authorities) and include for example information about the workers specific knowledge.
- The pushed properties such as access rights to machines, rooms or IT-Systems can only be set by a higher instance.

Table 1 shows the exemplary content of a HAS and the proposed data structure.

Table 1. Proposed data structure of a human administration shell

Group	Right	Property	Value
Identity	Owner	Name	String
		Age	Integer
		Availability	Boolean
		Preferred Workplace	String
		X-Coordinate	Float
		Y-Coordinate	Float
		Language	String
		Font Size	String
		Table Height	Float
		Light Condition	Float
Knowledge	Bidirectional	Electrical	String
		Mechanical	String
		Social	String
Access	Pushed	Room	String
		Machine	String
		Role	String

2.2 Technical implementation

Technically, the open-standard file format JavaScript Object Notation (Json) is used for the implementation of the human administration shell as well as for the asset administration shell. Listing 1 shows an excerpt of the according Json script.

The lightweight Message Queuing Telemetry Transport (MQTT) is utilized as transfer protocol, which is suitable for devices with limited processing and memory capacity [21]. MQTT is a publisher and subscriber protocol, which uses the top layer of the TCP/IP protocol [22].

Listing 1. Excerpt of Json script for the human administration shell

```
{
  "_comment": "Owner_property",
  "name": "identity",
  "type": "composite",
  "properties": [
    {"name": "name", "type": "string"},
    {"name": "available", "type": "bool"},
        {"name": "age", "type": "int"},
        {"name": "table_height", "type": "float"},
        {"name": "light", "type": "float"},
        {"name": "language", "type": "string"},
        {"name": "fontsize", "type": "string"},
        {"name": "x-coordinate", "type": "float"},
        {"name": "y-coordinate", "type": "float"}
                     ]
}
```

Fig. 4. The interaction of HAS with AAS of an adjustable table

3. Use cases

The presented approach of a human administration shell has been developed and implemented at the ARENA2036 research campus. The following section presents three different use-cases of the human administration shell.

3.1 Adjustable workstation

Typically, for ergonomic reasons the height of worktables is adjustable. In order to save the adjusted height, there are memory buttons on the worktable. According to the DIN ISO 5970 the worktable height depends on the body height. Therefore, our proposed HAS includes a preferred table height. For several reasons dimmable lights are spreading. This results in another control parameter for users. Figure 4 shows our worktable use-case. For this use-case we propose to use a Raspberry Pi or similar single-board computer for the AAS of the worktable. The AAS of the worktable can be classified in two categories: state information and service provider. State information are availability, current height, current location and light condition. The second category (service provider) offers the functions of adjusting height and changing light conditions. The interaction of the HAS and the AAS is processed via a MQTT broker, where HAS and AAS subscribing each other.

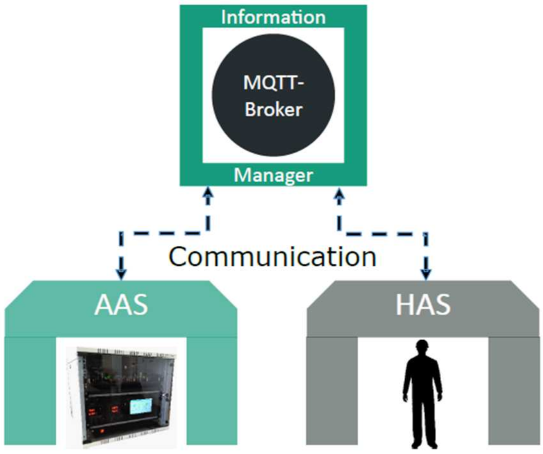

Fig. 5. Asset administration shell of a test bench in interaction with human administration shell (HAS)

3.2 Automatic information and individual rights management based on human administration shell (HAS)

In CPPS, different workers need to have different access levels to different assets based on certain criteria like roles, see Table 1. The management of the access rights ranges from usually highly centralized and digitalized, e.g. in the case of computer access, to oftentimes still being based upon physical barriers and close human monitoring, e.g. for shop floor equipment. In order to automatically and thereby efficiently organize the access rights across all kinds of assets, the HAS can be utilized: By allowing for the specification of rules for the distribution of certain information or the access to certain controls in an asset's AAS and by providing corresponding attributes in HAS, the automatic consideration and employment of comprehensive rights policies becomes possible. This concept was prototypically implemented in the following use-case: A custom-made test bench is managed via communication between its AAS and multiple HAS. The MQTT broker on the test benches' internal computer is wrapped inside an information manager that is able to extract rules from the AAS' information model and to check the available HAS for matching attributes in order to allow or prevent certain communication attempts based on their nature, see Figure 5.

Table 2 provides an excerpt of the information model of the test bench. For every parameter to be accessible via the aforementioned system, a MQTT message topic is defined together with additional restraints regarding the handling of such communication.

Table 2. Information model of the test bench

Message Topics	Possible Subscribers	Possible Publishers
Read asset name	All	Asset
Write asset name	Asset	Owner
Read temperature	All but Guest	Asset
Read update state	Admin	Asset
Read test voltage	All but Guest	Asset
Write test voltage	Asset	Owner, Admin, User

The test bench can be accessed locally via a touch display or remotely via the network. Both paths make use of the same web application based on the system described above, providing the following advantages:

- Locally, the touch display can be activated based on a worker's location. The web application then only gives access to parameters matching the worker's role.
- In case the test bench needs to contact a worker because some human interaction is required, it can notify workers based on their role and location.
- Remotely, workers can access the web application from their preferred location and device. Again, it will give access to parameters matching the workers' respective rights.

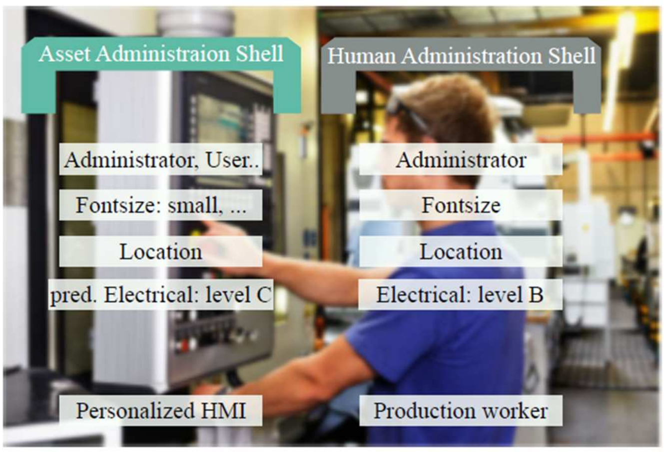

Fig. 6. Asset administration shell of HMI in interaction with production worker

3.3 Personalized human-machine-interface (HMI)

Analogous to consumer products, the individual settings of the Human-Machine-Interface is getting more important. The HAS helps to achieve an automatic setting procedure. The following use-case describes the interaction of an HAS with the AAS of an HMI. As mentioned in Table 1 our propagated HAS contains the location of workers and the preferred settings such as language, font size and role. Those properties are subscribed by the AAS of the HMI to overcome the manual setting procedure. Another aspect is the specific knowledge of the worker (e.g. electrical), which can be according to its shell level B. On the other side a smart HMI can predict with the help of clicking frequency, error generation and the during of setting procedures a electrical level, which can be lower. These results could then be used to support or for re-qualification purposes.

4. Discussion and outlook

The current HAS implementation does not conform with employee rights. Future work will consider encryption methods to protect private data. Moreover, we will address the communication protocol and matching process between the AAS and HAS. The current implementation in MQTT is suitable for pilot design and pilot activity. Future implementation has to cover the large-scale industrial context, which can be based on OPC UA. However, it should be considered that our examples have been implemented on accessible devices, which are not completely matching with large scale industrial equipment. Bidirectional communication will be the key factor for the realization of HAS. The full potential of HAS can be exploited by introducing the HAS beyond companies and institutions. Therefore, the HAS could for example be complemented by a curriculum vita. Due to the use of sensitive and private data, the HAS should be managed by an independent authority.

5. Conclusion

This paper shows a user-friendly, cross-machine and requirements-based approach for production workers using a human administration shell in combination with an asset administration shell for operating equipment. Our results provide a contribution to the design of roles for workers in the virtual world. This new approach of a human administration shell for production workers can optimize the allocation of workers to workstations regarding e.g. ergonomics, skills, workplace setups or machine efficiency, due to optimized operations. We have shown that workers can take a vital and essential role in future production systems. We propose the application of the human administration shell primarily on wearables, which are suitable for industrial usage and comfortable for the workers.

Acknowledgments

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