Description of an intelligent resource unit for a smart production

Matthias Klein, Markus Leitzgen, Michael Weyrich
University of Stuttgart
Institute of Industrial Automation and Software Engineering
Stuttgart, Germany
ias@ias.uni-stuttgart.de

***Abstract*— Future automated systems are connected to each other in a production network with the goal to manage, schedule and operate the manufacturing process of individual products autonomously. Therefore a semantic language is necessary to empower the systems to fulfil their tasks. In this content eCl@ss is often mentioned as applicable to describe products. In this paper we conduct a study to describe an intelligent barrel with eCl@ss in terms of completeness in objective and functional description to evaluate if it is sufficient for the needs of cyber physical systems (CPS).**

Keywords — cyber physical systems, intelligent resource unit, eCl@ss

I. Introduction

CPS are the basis for visions of connected production systems like Industry 4.0 in Germany. They enable new possibilities for manufacturing in form of connected ad-hoc production networks for individual customer orders. It is difficult for humans to maintain an overview and manage the system e. g. scheduling of the production process in a highly dynamic market. To enable the CPS to fulfill the mentioned tasks, a semantic language for communication between the CPS is necessary. This is needed to manage the production of products with individual requirements like colors or special functionalities [1]. The scope of a semantic language covers the description of the product, the description of automated systems which also includes their functionalities as well as the communication.

The fact that eCl@ss is important in the interaction of Industry 4.0 components, is suggested by many publications e. g. [2], [3], [4], [5] and [6]. Since so many researchers think that eCl@ss is suitable for an Industry 4.0 compliant description, a study was conducted to describe a transportation unit demonstrator in form of an intelligent barrel. The goal is to prove the possibility to describe the whole barrel relating to the classification of products as well as all requirements which are necessary in an Industry 4.0 production network.

This description results in a digital twin in form of a standardized representation of the product which can be described by petri nets, CAD models or even in a semantic description like eCl@ss in a XML file. In addition this representation must also be recognized by machines. Furthermore, it should include the production plan so production units can accomplish production steps autonomously. The link between the digital twin and the real product during manufacturing can be established by Radio-frequency identification (RFID) Tags on the real product.

II. Basis

A. *Industry 4.0 – the vision of smart manufacturing in a connected production*

The term Industry 4.0 describes a vision for manufacturing goods with a higher flexibility and robustness in addition with the highest quality aspects in the field of engineering, planning, production and logistics. Further, it provides the basis for dynamic systems which are able to optimize themselves in value add production networks [7]. In future the customer will define additional requirements which are related to the production conditions like production carbon footprint or resource management.

CPS are seen as the increased networking of microcomputers among each other and with the internet. These small computers have various sensors to perceive their environment, and actuators to influence their environment actively [8]. Their interconnection creates networks which gain a variety of information and share them on the network. In addition, the connected actuators can be controlled due to the available information on the network. This can be done autonomously and in real time. The goal is a merging of the real and the virtual (cyber) aspects. With the available information in the network value-adds can be created. Thus, it is possible for example to react in a variety of ways to deviations to the normal state. CPS used in the industry sector are called cyber physical production systems (CPPS). These systems describe an intelligent network between product, production units and transportation equipment et cetera [7].

Digital twin concepts are also transferred to CPS. This approaches are still used in various fields of technology e. g. in the field of aerospace [9]. Rosen et al. [10] describes a digital twin approach with the focus of production units and Rolle [11] depicts it for the intelligent product. Digital twins have a huge potential to assist the operators and systems. They enable a procedure to simulate the next steps in advance for support, optimization or autonomous decision making. First realizations of the digital twin approaches were already made.

978-1-5090-1314-2/ 16/$31.00 ©2016 IEEE

B. Smart product in the logistics

The smart product as a participant of a CPPS can be located at all times and has to be identified as individual entity during the whole product life cycle. It knows all information about itself. If needed, the information can be reported to other relevant participants in the network [7]. This products actively support the manufacturing process by providing information about their manufacturing steps or completion deadline, communicate parameter changes to production units, or report the final site of operation to the logistics department.

In logistics, especially in the field of transportation of perishable loads like vegetables and fruits, the transportation conditions have an enormous influence on the product quality. According to Zang et al. [12] the product quality depends on the variation of temperature in the transportation (cold) chain and the duration of delivery. Unwanted ripening or the emergent risk of contamination are reasons for the freight owner to be always up to date about the condition of the transported goods. So he can take actions in respect of the goods e. g. additional examinations. The temperature profile along the whole supply chain can be used to determine the quality of fresh products [13]. Integrated sensors in the transportation equipment can inform the operator, if measured parameters reach temperature warning limits in the cold chain early enough to react in respect of the goods. Supermarkets or end users are able to check the temperature of the whole supply chain and can reject the delivery if irregularities or deviations are tracked.

Another example how smart products can be used is the beverage production which is a batch process. If an unacceptable amount of ingredients is detected, a sale stop can be necessary and all barrels and bottles of the same batch have to be identified and demonetized. Intelligent barrels notify the operator about their position in the warehouse and barrels which are in delivery will not be accepted by dealers. This can support the existing systems for traceability e. g. according to the 18 article of the European regulation 178/2002.

To simulate such transportation scenarios in a supply chain an intelligent barrel was developed as a demonstrator. It is divided into two sections. One for the installation of the electronics and one for the simulation of the fluid level (see figure 1). The electronical system is placed on the bottom. It consists of a raspberry pi, a battery pack as an independent power supply, and a temperature sensor. A position transducer for position measurement is also part of the intelligent barrel to track the position (e. g. standing, lying). The battery pack can be extended by wireless changing unit so the electronic components of real smart carrier units can be embedded in the body to achieve high international protection codes e. g. according to DIN EN 60529:2014-09. A Wi-Fi dongle is placed at the top of the barrel to avoid disturbances through the metal of the barrel. It is connected via an USB cable to the raspberry pi.

To facilitate the presentation and to avoid a leakage of the barrel within the ensuring cleaning effort of the surroundings the liquid in this demonstrator is replaced by a mechanism. A flat acryl plate with a magnet as a representative for the fluid level in the barrel can be moved vertically and can be fixed in

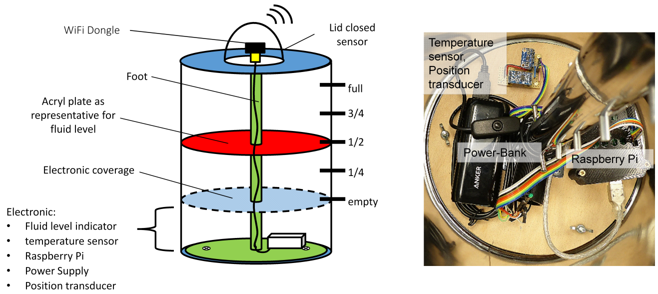

Fig. 1 Intelligent barrel

five different levels. To measure the fluid level and to detect whether the lid of the carrier is closed, reed switches are used. These non-contact operating switches require a magnet on the plate which is located closely to the switch. If this condition is fulfilled, the switch sends a digital signal to a GPIO pin of the Raspberry Pi using a pull-up resistor.

Reed sensors and the lid sensor are connected to the raspberry pi via the GPIOs. The RFID tag and the barcode elements are used for a passive communication and are mounted outside of the barrel. This means that only participants who are close to the barrel can use them to identify and/or locate the barrel. The barrel has the possibility to register on a wireless local area network which is mounted by a warehouse or a truck. Within this network it can push alert messages and other information to the other participants about its status. For example if it has fallen down on the loading area of a truck during transportation, it can inform the truck and the driver immediately. New values for critical temperatures et cetera can be transmitted to the barrel.

C. eCl@ss

For a digital production it is inevitable to define standards that are used equally by all involved companies. In the course of that, machine to machine communication is a crucial aspect of future factories making it necessary to define a common language so that machines can communicate with each other. For this communication to be unambiguous, a unique sematic basis has to be developed, which does not depend on languages. With its variety of product classes and features, eCl@ss as a standard for product data has the ability to describe a product/machine in a detailed way. This description is the foundation for a machine to machine communication.

ECl@ss is an international standard for a consistent classification of products, properties and services along the whole value chain. With its 48.000 product classes and 16.800 properties, eCl@ss is able to cover a variety of traded goods and services [14]. The eCl@ss structure can be divided into two parts. Whereas the first part consists of the classification, the second part represents the product description.

The classification is arranged hierarchically. This hierarchy is composed of the four layers segments, main groups, groups and commodity classes. The bottom layer describes the product with properties and the corresponding values. The eCl@ss-number consists of eight digits. Every pair stands for one classification layer. An apple for instance has the allocated eCl@ss-number 16-04-01-01. It consists of the following layers: 16-00-00-00 (Segment food, beverage, tobacco), 16-04-

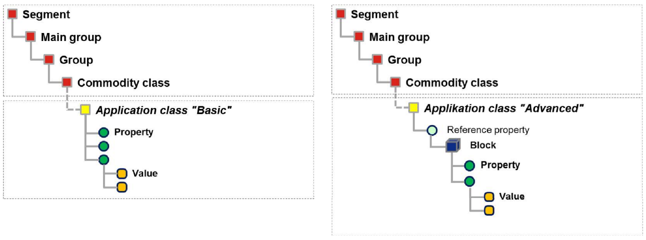

Fig. 2 Structure of eCl@ss BASIC and ADVANCED [according to 18]

00-00 (main group fruit), 16-04-01-00 (group pome fruit), 16-04-01-01 (commodity class apple) [15].

Every eCl@ss property is a so called International Registration Data Identifier (IRDI). The international standards ISO/IEC 11179-6, ISO 29002 and ISO 6532 are the basis for these unique identifiers [16].

Both eCl@ss BASIC and eCl@ss ADVANCED are products published by the eCl@ss e.V. They equally contain classes and properties. However, the biggest difference between eCl@ss BASIC and eCl@ss ADVANCED is the structure. Whereas the BASIC version has a flat structure, eCl@ss ADVANCED provides additional structural elements such as blocks, aspects, cardinalities and polymorphisms [17].

The two crucial reasons why eCl@ss ADVANCED is being preferred instead of eCl@ss BASIC for a future communication in the context of Industry 4.0 are handling and flexibility. Looking at the structural object cardinality clarifies the advantage of eCl@ss ADVANCED immediately. A flat hierarchy as provided by the BASIC version makes it necessary to define every single property unambiguously. Thus, for example an object with more than 100 connection ports needs all ports described in a unique way. If an entire milling machine had to be described, the list of properties would be extremely large which makes it impossible for a user to create and maintain it. Additionally, eCl@ss BASIC cannot offer the necessary flexibility. The number of connection ports of different objects varies strongly which makes it impossible to define the correct number of ports in a flat structure. By using the structural element cardinality in the ADVANCED version, it enables the user to describe the amount of for example connections ports flexibly and precisely. An additional polymorphism can be used to describe the sort of connection port, for example electric or hydraulic. After choosing the appropriate value, other properties are being offered depending on the value picked in the polymorphism. Furthermore, only eCl@ss ADVANCED enables the user to divide a machine into blocks of random size. These example show the necessity to use eCl@ss ADVANCED as a standard for the future Industry 4.0 compliant communication.

Assessing the level of detail of eCl@ss' properties also leads to huge differences among the different commodity classes. On the one hand, this is due to the beginnings of eCl@ss. On the other hand, it is due to the amount of property suggestions as well as on the industrial branch that submits these property suggestions. Both classification and properties of eCl@ss are being changed constantly. It is a matter of fact, that eCl@ss sometimes retrieve classes or properties or add them to the current eCl@ss extent [19]. However there are two aspects:

- Previously not known properties can be added
- Compatibility problems can occur, if there is no downward compatibility.

III. INVESTIGATION OF THE DESCRIPTION'S LEVEL OF DETAIL

To analyze the description of the intelligent barrel the following section is divided into four parts. The first part examines the amount of available classes and thus the possibility to describe the barrel as an object completely. The second part takes a closer look at the delineation of the barrel's functions and to which extend they can be depicted. Since these two parts consider a maximal possible level of detail, the third part deals with a necessary level of detail. An additional paragraph beholds the scope of the classes and properties that are used in eCl@ss version 9.0.

These issues are all established on a common definition of the term completeness. Since the term completeness can be interpreted in various ways, a valid definition is inevitable. Hence, in this study the definition of the term completeness is divided into two parts. The first part addresses the issue that with the use of eCl@ss-numbers all components which are part of the intelligent barrel can be classified.

The additional usage of all available properties leads to the assessment of the functional description. If all functions can be described with the available properties, the description of the intelligent barrel is complete in terms of the functional description.

A. Completeness in terms of the objective description

Judging by the former definition of completeness, the intelligent carrier can be fully described with eCl@ss ADVANCED 9.0 in terms of the objective description. This means that every component of the barrel can be classified and that the intelligent barrel is complete in terms of the objective description.

B. Completeness in terms of the functional description

To examine the completeness in terms of functions all existing use cases of the barrel have to be defined to get all functions. In this survey the following three generic use cases are considered:

- Barrel register / deregister on to the truck
- Barrel has been toppled down
- Temperature is too high.

The eCl@ss version 9.0 does not yet contain dynamic properties that allow the user to describe a dynamic status like one of these three aforementioned use cases. Moreover, these use cases can be divided into two groups. The first use case belongs to the state group »normal operation«. The other two use cases belong to the state group »fault operation«. On top of that, other state groups are imaginable, for example commission operation or maintenance operation. This distinction is necessary, because depending on the use case, different information is needed which leads to the conclusion that different properties have to be used. This means that before every assessment regarding the completeness in terms of the functional description, all possible states of the system and use cases have to be defined. After their definition, the uses cases are being described with the eCl@ss classification system and properties. In case of a complete delineation of all use cases, the description could be assessed as complete in terms of the functional description. As dynamic properties not yet exist, a description of the three use cases cannot take place, therefore the description in terms of the functional description has to be assessed as incomplete.

C. *Analysis of the description's necessary level*

The necessary level of detail is oriented towards the functionality and thus the considerations of the last chapter. Depending on the operation and the machine state the level of detail has to be assessed. In some cases it might be essential to describe every single component. In other cases, the system can be described as a black box model.

D. *Consideration of the classification's and propertie's extent in eCl@ss*

As already assessed in the previous chapter it is not automatically possible to determine whether a class or a property is missing or not. The evaluation of these issues can only be done after all individual use cases have been included. One example to emphasize this fact can be found in the following consideration. For one machine, the property tightening torque of a screw is relevant because of safety issues. The screw cannot be twisted too loose or too tight since otherwise machine damage is going to occur. In this case the eCl@ss property tightening torque is necessary. For a second machine, the screw is used on a part which is not relevant for the work process and thus the property tightening torque does not need to be described. Assuming the property tightening torque does not exist, the description of machine one is incomplete whereas the description of machine two is still complete.

IV. CONCLUSION AND OUTLOOK

To realize the vision of Industry 4.0 a semantic language is required. In this paper eCl@ss was used to find out whether it can be used for an objective and functional description. A demonstrator in form of an intelligent barrel was modeled in ecl@ss and different analyses were undertaken. The completeness in form of the objective description is given. The functional analysis results as incomplete, because dynamic properties do not exist, which are needed for a functional description. It depends on the individual use case to determine whether properties and classes are missing or not. The next versions of eCl@ss should have a downward compatibility, which is relevant for a use in an Industry 4.0 environment. It cannot be assumed that all CPS use the equal version with the same classes and properties. This is needed, however, to guarantee an interoperability between the different versions.

REFERENCES

[1] T. Bauernhansl, M. ten Hompel and B. Vogel-Heuser, Industrie 4.0 in Produktion, Automatisierung und Logistik: Anwendung - Technologien – Migration. Springer, Wiesbaden, 2014.

[2] DIN e.V, DKE, “Deutsche Normierungs-Roadmap,“ 2015, http://www.din.de/blob/95954/42935f7a165f16e341967b8a9f91c026/aktualisierte-roadmap-i40-data.pdf visited on 12th April 2016.

[3] VDI/VDE-Gesellschaft Mess- und Automatisierungstechnik, “Status Report Reference Architecture Model Industrie 4.0 (RAMI4.0),“ 2015, http://www.zvei.org/Downloads/Automation/5305%20Publikation%20GMA%20Status%20Report%20ZVEI%20Reference%20Architecture%20Model.pdf visited on 12th April 2016.

[4] eCl@ss e.V, “eCl@ss - Whitepaper Industrie 4.0,” Köln, 2015.

[5] BITKOM e.V., VDMA e.V., ZVEI e.V., “Umsetzungsstrategie Industrie 4.0 - Ergebnisbericht der Plattform Industrie 4.0,“ Berlin, 2015.

[6] S. Höme, J. Grützner, T. Hadlich, C. Diedrich, D. Schnäpp, S. Arndt and E. Schnieder, “Semantic Industry: Herausforderungen auf dem Weg zur rechnergestützten Informationsverarbeitung der industrie 4.0,” at – Automatisierungstechnik, vol.. 63, no. 2, pp. 74-86, 2015.

[7] Acatech, “Recommendations for implementing the strategic initiative INDUSTRIE 4.0,” 2013. http://www.acatech.de/fileadmin/ user_upload/ Baumstruktur_nach_Website/Acatech/root/de/Material_fuer_Sonderseiten/Industrie_4.0/Final_report__Industrie_4.0_accessible.pdf visited on 12 th April 2016.

[8] Bundesministerium für Bildung und Forschung (BMBF), “Bericht der Bundesregierung – Zukunftsprojekte der Hightech-Strategie (HTS-Aktionsplan),“ Bonn, 2012.

[9] E.H. Glaessgen and D. S. Stargel, “The digital twin paradigm for future NASA and U.S. Air Force vehicles”, in Proceedings of 53rd structures, structural dynamics, and materials conference, Honolulu, HI, pp. 23–26, 2012.

[10] R. Rosen, G. von Wichert, G. Lo and K. D. Bettenhausen, “About The Importance of Autonomy and Digital Twins for the Future of Manufacturing,” in IFAC-PapersOnLine, vol. 48, no. 3, pp. 567–572, 2015.

[11] I. Rolle, “CIM, Industrie 4.0 und der Weg zur Semantik – Parallelen für die Normungsarbeit nutzen,“ in atp-edition - Automatisierungstechnische Praxis, vol. 3, no. 3, pp. 66-72, 2016.

[12] G. Zhang, W. Habenicht, and W. E. L. Spie, “Improving the structure of deep frozen and chilled food chain with tabu search procedure,” in Journal of Food Engineering, vol. 60, no. 1, pp. 67–79, 2003.

[13] M. C. Giannakourou, K. Koutsoumanis, G. J. Nychas, and P. S. Taoukis, “Development and assessment of an intelligent shelf life decision system for quality optimization of the food chill chain,” in Journal of Food Protection, vol. 64, no. 7, pp.1051–1057, 2001.

[14] eCl@ss e.V., “eCl@ss – a summary,” http://www.eclass.eu/eclasscontent/standard/overview.html.en, visited on 12th April 2016.

[15] eCl@ss e.V., “IRDI,” http://wiki.eclass.de/wiki/IRDI, visited on 12th April 2016.

[16] eCl@ss e.V., “Classification Class,” http://wiki.eclass.eu/wiki/Classification_Class#Class_structure, visited on 12th April 2016.

[17] eCl@ss e.V., “Advanced Version,” http://wiki.eclass.eu/wiki/Advanced#Advanced_Version, visited on 12th April 2016.

[18] eCl@ss e.V., “Category:Structure and structural elements,” http://wiki.eclass.eu/wiki/Category:Structure_and_structural_elements visited on 12th April 2016.

[19] eCl@ss e.V., “Change request,” http://wiki.eclass.eu/wiki/Change_Request#Valid_Change_Requests_per_Release_Type visited on 12th April 2016.