Interoperability and Integration in Future Production Systems

Discussion Panel at the 20th IEEE International Conference of Business Informatics (CBI2018)

Christian Huemer, Gerti Kappel, Manuel Wimmer
Business Informatics Group, TU Vienna & Centre of Digital Production (CDP)
Vienna, Austria
{huemer,gerti,wimmer}@big.tuwien.ac.at

Henderik A. Proper
Luxembourg Institute of Science and Technology,
Luxembourg, Luxembourg
e.proper@acm.org

Siegfried Reich, Wernher Behrendt
Salzburg Research
Salzburg, Austria
siegfried.reich@salzburgresearch.at

Stefan Thalmann
Institute for Interactive Systems and Data Science, Graz University of Technology & Pro2Future Graz
Graz, Austria
stefan.thalmann@tugraz.at

Georg Weichhart
Flexible Production Systems
PROFACTOR
Pro2Future
Steyr-Gleink, Austria
georg.weichhart@profactor.at

Alois Zoitl
LIT Cyber-Physical Systems for Engineering and Production Lab
Johannes Kepler University
Linz, Austria
alois.zoitl@jku.at

***Abstract*—This panel discussion in the context of the IEEE International Conference of Business Informatics (CBI2018) focuses on topics that allow systems to interact and exchange information. Every system in this context has its own world model. Interactions between two systems will involve a partially shared model (including e.g. standard interfaces), and two detailed, private models.**

Keywords—Enterprise Application Integration, Enterprise Modeling, Business Process Modeling, Enterprise Integration, Enterprise Interoperability, Model-driven Control.

I. Introduction

Research in areas of Internet of Things (IoT), Industry 4.0 (I4.0), Cyber Physical Systems (CPS), consider system-of-systems composed of hardware and software systems that seamless work together. Interoperability ranges from compatibility (systems do not disturb other systems, but no interaction between systems) to integration (systems that share a common model / worldview). Between these extremes a continuum of interoperability exists.

In any case, interoperability is a model-driven approach – in contrast to data-driven or machine-learning approaches, for example. In general, models contain modules, connections, and behavior descriptions of different types.

Integration and interoperability may not only be seen as (goal) states but also as processes. Changes in one system might trigger adaptation in other systems. However, in loose integration and interoperability settings there is more support for the evolution of models.

II. Scope

Taking the viewpoint of enterprise interoperability research, future, modular production systems consider multiple levels. These levels are shown below, giving some examples.

- Business level: Enterprise interaction concerning e.g. business values (performance indicators), legal constraints.
- Process level: Ranging from Business Processes to Production Processes, and interoperability of activities / functions along the common and expected process behavior.
- Service level: Interoperability with respect to syntax and semantic of service descriptions. This includes e.g. service granularity on conceptual level.
- Data level: Interoperability on syntax as well as semantics of information. Also interoperability with respect to data organization and management, like privacy, classified information, etc.

III. Panelists

This panel is organized by Georg Weichhart and is moderated by Christian Huemer. All other authors serve as panelists who have provided position statements that are outlined in the following sections.

IV. Position Statement of Gerti Kappel

Information integration challenges have not newly emerged with cyber-physical production systems (CPPS), but are as old as the data management field as a whole ranging back to the seventies. What we can learn from them is a structured process supporting interoperability and integration. This includes among other things multi-view modeling, loss-less and distortion-free transformation between these views, and model transformations handled as transformation models, thus reifying the integration process. Next to data management, the seamless integration of design time models and runtime models will be an important precursor in the successful implementation of smart CPPS. Concerning the latter, we can learn from the

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Model-driven Software Engineering community with liquid models as first class entities. The results of both communities will be paramount in building up digital twins, the "heart and soul" of any smart CPPS.

V. Position Statement of Hend*erik* A. Proper

Production systems involve a hybrid mix of human and IT-based actors, supported my mechanical means. More often than not, these hybrid mixes cut across business units / domains, across organizations and even across countries. This makes interoperation and integration between these hybrid mix of actors rather challenging.

Key to interoperation and integration is the ability for the actors involved to understand each other. In other words, they need to "speak" (at least actor-to-actor) the same language. Of course, IT-based actors "speak" in terms of a different language to each other than human actors do. Nevertheless, where there is communication, there is essentially a language.

The natural strategy to achieve the use of a common language is to e.g. use a pre-defined ontology, a controlled language (among human actors), or even a (formal) specification language (among IT-based actors), to frame the communication. This results in a so-called "frozen language" in the sense that in these cases, the set of concepts / things one can "talk about" is a-priori fixed; i.e. frozen. At the same time, when following this approach, there is an implied assumption that all actors involved share the same understanding of the underlying ontology / language definition. When using a formally specified language, and an error free implementation (...), IT-based actors might indeed share the same interpretation. However, when dealing with human actors this is not likely to be the case.

Furthermore, when applying Stafford Beer's law of requisite variety, this would seem to suggest that if we are to develop an ontology / language definition, then this should necessarily reflect the expected variety (complexity and evolution) of the domain of communication. Given the variety in terms of different (unforeseen) environmental circumstances in which a production system will need to operate, different (unforeseen) misunderstandings, different (unforeseen) changes in production processes, regulations, etc., it is highly debatable if one can define a-priori ontologies / languages. Maybe for some well-scoped domains we are "lucky enough" to know all possible circumstances and parameters beforehand.

As such, it might be a better approach to ensure interoperation and integration at a higher level. The hybrid actors in future production systems (especially when they are extending into space, as planned by Luxembourg and NASA), would need the ability to engage in meta-communication. In other words, they need the ability to detect (possible) miscommunications as they occur, the ability to exchange their understandings of concepts, actions to be taken, etc, and even be able to negotiate about finding a common understanding.

VI. Position Statement of Siegfried Reich

For any two computational systems to interoperate, it is necessary that statements produced in one system and sent to the other system, get interpreted there in a way that is compliant with an agreed standard that is established outside the two systems. Industrie 4.0 and IoT in particular (thinking e.g. smart cities) face this fundamental problem in a multitude of dimensions: sensor measurements need to be normalized, contextualized, and aggregated into agreed performance metrics. Several standards from SensorThings to oneM2M or SensorML offer highly complex data structures that need to be interpreted by automated business processes. High-level business processes as defined by UBL2.2 need to be automated to support flexible supply chains e.g. on a B2B internet platform. Each product offered in global platforms needs to be structured according to some taxonomy e.g. ecl@ss. And if we want to monitor a supplier’s production according to PPAP then we need interfaces between local manufacturing systems, shared Internet platforms and above all, our data exchanges need to be compliant with IPR protection rules at established between the two parties. In a current H2020 FoF project establishing a European B2B platform for manufacturing SMEs we are facing several of these challenges. One particularly hard engineering problem is the separation of concerns, i.e. the scope of standards or ontologies. If I have a business process ontology, then I do not need a domain taxonomy for wood articles to also contain “half an ontology” about business processes “as usually done” in the wood trade. Interoperability has also the dimension of licenses: for example, the ecl@ss taxonomy – while being available for free in research projects – is a licensed standard costing several thousand Euros per company using it for real business. This becomes prohibitive if we want to offer a relatively simple B2B platform for smaller SMEs where each SME would only use a fraction of the taxonomy. This is why there is a strong tendency towards new developments of standards and software, under permissive open source licenses, because this reduces cost and friction caused by proprietary technology and standardization stacks.

VII. Position Statement of Stefan Thalmann

Integration in future production systems in inter-organizational settings faces not only technical but also business-related challenges. In this regard risk management and in particular knowledge protection concerns are important. Following the idea of “industry 4.0” requires an intensive sharing of data along the value chain. Sharing of data is useful to improve quality of products and also for predictive maintenance in supply chains. However, sensitive information or sensitive knowledge can be extracted by data analytics from the shared data. Many companies experienced a fear of unwanted knowledge spillover, especially of critical knowledge. So far it is very difficult to predict what others can extract out of the shared data, especially if data can be linked to other data.

Such perceived risks are a major barrier for introduce and scale data analytics in supply chains and thus also for integration in future production systems. Knowledge risks and benefits of data sharing need to be traceable so that organizations can make an informed decision by balancing the risks and benefits of data sharing. Additionally, traceability about the knowledge risks included in a data set is also needed for risk and compliance management.

Hence, in analogy to privacy-aware analytics, approaches for risk aware analytics are needed. Such technologies should provide decision support in the planning phase of a data integration project and lead to more transparent data sharing in future production systems.

VIII. Position Statement of Georg Weichhart

Production machines get more modular supporting re-configuration on the spot. Business process systems get also more adaptive. Information technology (IT) and organizational technology (OT) support flexible process execution.

The flexibility on all levels of granularity (data to business) results in increased complexity that needs to be handled. Complex (adaptive) systems are hard to control. Several research approaches suggest distributed and decentralized cyber physical systems to handle this complexity. Distributed artificial intelligence approaches, like multi-agent-systems and holonic control systems, have been proposed for manufacturing control. These systems are based on symbolic AI and deductive reasoning (in contrast to sub-symbolic AI like neural networks and inductive reasoning using machine learning algorithms).

One of the major challenges from a manufacturing process point of view is the required physical realization of a single process. At the end of the day, this process has to span multiple systems. Neither a pure decentralized system, nor a pure process based system is capable to realize flexible execution of a single (physical) process.

However, because basic technologies are researched in isolation, interoperability of the approaches is not given. Applied research is required to bring together OT and IT to support adaptability of manufacturing processes. This includes not only execution but also the design, management and communication to human and artificial agents.

IX. POsition Statement of Manuel Wimmer

Standards are important for providing sustainable interoperability and integration solutions in general and specifically in the production system domain. In this context, the main challenges (among others) are the technical, syntactic, and semantic heterogeneities which have to be dealt with as well as the challenging pragmatics of vertical and horizontal integration as well as integration in time.

The AutomationML initiative started in 2006 is exactly working on these challenges by providing a neutral, free, open, XML-based, and standardized data exchange format which focusses on the engineering processes of production systems. Recent developments in this initiative focus not only on engineering, but also on the operation phases as well as on how to connect the shop floor to the top floor. Now the question arises what is a meaningful selection of standards for the smart production area and how to realize their interoperability and integration?

X. Position Statement of Alois Zoitl

Future production systems will have a much greater modularity. Machines will be constantly added and removed. We already see now that some manufactures need to change their production in the range from two to four weeks. These pace will be increasing. Changes like these can hardly be anticipated and considered during initial system design. However for optimal system operation machines need to interact with each other and also with higher level systems. This requires at first for technical interoperability at the communication system level. With OPC UA it seems that we get the first time in the history of production automation a standard that can at the one hand full-fill most of our communication requirements and on the other hand gets a broad support from suppliers as well as machine-builders and users.

To utilize these communication mechanisms machines need to provide semantic-self descriptions of their capabilities, boundary and operation conditions as well as descriptions of their interaction interfaces. OPC UA can serve here as medium for providing this information however currently no models exist serving our needs.

In the recent time we see to further trends requiring the same interoperability:

1. Also machines themselves get more modular and therefore machine parts are exchanged during the machines life-time, requiring to work together
2. With Industrie 4.0 interaction along the supply-chain requires interaction from machines, logistic systems to supplier and customer machines and software systems.

For this interoperability and interaction requires also that programs in machines and machine parts may change or are extended like installing a new app on a mobile phone. For this hardware abstracting real-time execution environments, like the one provided by the Eclipse 4diac project and vendor neutral control software modeling languages like IEC 61499 can help to reduce this burden.

XI. Date / Time

This panel will be held during the IEEE International Conference of Business Informatics (CBI2018) at TU Vienna.

The panel will take place on July 12th 2018.

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