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ScienceDirect

Procedia CIRP 57 (2016) 213 – 218

www.elsevier.com/locate/procedia

49th CIRP Conference on Manufacturing Systems (CIRP-CMS 2016)

Towards a Rule-Based Manufacturing Integration Assistant

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Abstract

Recent developments and steadily declining prices in ICT enable an economic application of advanced digital tools in wide areas of manufacturing. Solutions based on concepts and technologies of the "Internet of Things" or "cyber physical systems" can be used to implement monitoring as well as self-organization of production, maintenance or logistics processes. However, integration of new digital tools in existing heterogeneous manufacturing IT systems and integration of machines and devices into manufacturing environments is an expensive and tedious task. Therefore, integration issues on IT and manufacturing level significantly prevent agile manufacturing. Especially small and medium-sized enterprises do not have the expertise or the investment possibilities to realize such an integration. To tackle this issue, we present the approach of the Manufacturing Integration Assistant - MIALinx. The objective is to develop and implement a lightweight and easy-to-use integration solution for small and medium-sized enterprises based on recent web automation technologies. MIALinx aims to simplify the integration using simple programmable, flexible and reusable "IF-THEN" rules that connect occurring situations in manufacturing, such as a machine break down, with corresponding actions, e.g., an automatic maintenance order generation. For this purpose, MIALinx connects sensors and actuators based on defined rules whereas the rule set is defined in a domain-specific, easy-to-use manner to enable rule modeling by domain experts. Through the definition of rule sets, the workers' knowledge can be also externalized. Using manufacturing-approved cloud computing technologies, we enable robustness, security, and a low-effort, low-cost integration of MIALinx into existing manufacturing environments to provide advanced digital tools also for small and medium-sized enterprises.

Peer-review under responsibility of the scientific committee of the 49th CIRP Conference on Manufacturing Systems

Keywords: Rules; Integration; Manufacturing; Smart-Factory; Industrie 4.0

1. Introduction

Today, the use of cyber-physical systems as well as the increasing connectivity of technical devices and machines provide the basis for novel forms of manufacturing operations, especially for self-organization and self-optimization. These aspects are typically subsumed under the term "Industrie 4.0" (I4.0). At this, the flexible linking and integration of heterogeneous manufacturing IT systems and devices, e.g., machines and ERP systems, constitutes a central success factor. Existing integration solutions, such as, workflow systems and manufacturing services busses, represent complex and centrally organized systems, which are costly to adapt and maintain. Thus, they prohibit flexible integration of IT systems and self-organization of manufacturing processes, especially in small and medium-sized manufacturing companies with limited IT budget and IT knowhow.

To address this issue, we present the concept of the Manufacturing Integration Assistant (MIALinx), discuss its implementation in a cloud environment and evaluate its benefits with respect to a real life application scenario in a SME. MIALinx is a lightweight and easy-to-use IT integration solution oriented towards recent web automation platforms and enables rule-based self-organization for manufacturing processes. It supports manufacturers to organize and manage their manufacturing processes using simple, reusable "IF-THEN" rules that link occurring situations in manufacturing environments with corresponding actions.

Peer-review under responsibility of the scientific committee of the 49th CIRP Conference on Manufacturing Systems
doi:10.1016/j.procir.2016.11.037

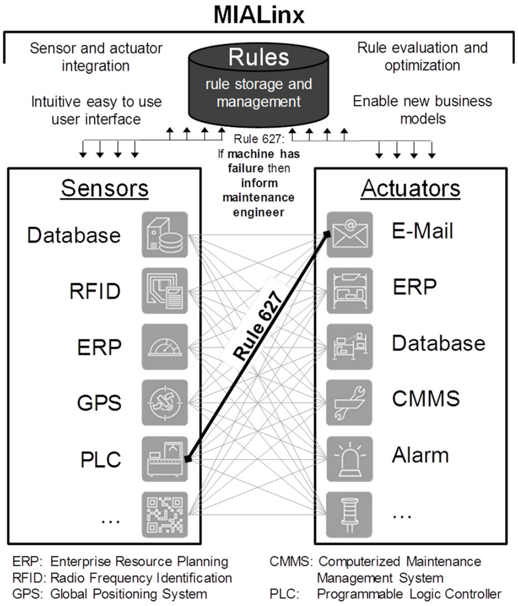

Fig. 1: Concept of MIALinx

Fig. 1 shows the main concept of MIALinx: Rules connect data sources (sensors) and sinks (actuators) based with conditions to model when and if a rule has to be triggered. The rules are stored and managed in a rule database, optimized and rated based on their practical use. Furthermore, MIALinx aims to provide an intuitive user interface for easy modeling of rules.

Fig. 1 shows an example for a rule. A certain machine condition can be defined as a machining break down situation that triggers a notification by sending an e-mail to the responsible maintenance worker. Using this rule, the maintenance worker is automatically informed of any machine failure on the shop floor. Furthermore, it is possible to perform the planning of the maintenance activities in the computerized maintenance management system (CMMS) automatically.

The remainder of the paper is organized as follows: Section 2 details on related work. Section 3 presents the main contribution of the paper and introduces the MIALinx architecture and its components. In Section 4, the two main use-case scenarios are explained – production data acquisition and maintenance. Section 5 gives a summary of the paper and describes future work.

2. Related Work

Existing manufacturing IT environments are coined by a huge heterogeneity of systems and interfaces, ranging from multiple ERP and MES systems of different vendors to various different machine interfaces even in one single factory. To enable data exchange and integration between these systems and interfaces, complex and proprietary point-to-point bridges are typically built in practice [1]. The continuous adaptation of manufacturing processes then leads to significant modification and reimplementation efforts.

A first step towards more simple system integration represent integration middleware approaches, especially the service-oriented architecture (SOA) paradigm using service buses, like the enterprise service bus (ESB) [2], or the manufacturing service bus (MSB) which was especially designed to meet the needs of manufacturing [3]. At this, the Virtual Fort Knox (VFK) approach and implementation deals with running a MSB in a secure cloud environment [4]. In MIALinx, the VFK will be used as to connect to all sensors and actuators available in the production environment with our system. In the SOA context, also workflow technology has become an important tool to connect services. Workflows are commonly used to define and execute business processes. Established standards to define and execute workflows are the Business Process Execution Language [5] (BPEL) and the Business Process Management Notation [6] (BPMN). These standards enable modeling processes and their automatic execution. Workflows ease the integration of different systems, too, but still require strong programming skills to do so. Moreover, they focus on business processes as opposed to manufacturing processes and are thus rarely used on the factory shop floor [7].

Recently, web-automation-platforms like IFTTT [8], or Zapier [9] came up to address easy, simple and flexible system integration. Using these platforms users are able to integrate different IT systems without any programming skills. Nevertheless, this advantage is also one of their biggest drawbacks: to keep up this level of simplicity, these systems only allow users to define rules using simple and predefined conjunctions. Some existing systems, like Zapier, are able to integrate, e.g., Customer Relationship Management Systems. However, they are not able to integrate machines, sensors, or actuators on the factory shop floor as they do not have standardized interfaces. Another disadvantage is that rules are defined independent from each other. For an enterprise system it is necessary to harmonize all rules created by employees and to optimize them. Rule Engines like Jess [10] or Drools [11] are able to do this, but are not designed to operate in an I4.0 environment as they lack manufacturing-specific meta models and interfaces. As we want to use rule engines, another advantage of our approach in contrast to web-automation-platforms is that rule engines support rule definition languages like the Rule Interchange Format (RIF). Using RIF one can easily design a set of rules and deploy them on a rule engine, or export a set of rules from a rule engine and import them in another one.

Some rule engines, e.g., Drools, support also the execution of Complex Event Processing (CEP) queries on a stream of (sensor) data. To cope with a huge number of sensors sending data, a middleware has been developed which is able to distribute the evaluation of CEP queries [12].

There are also other projects who deal with simplifying the modeling of rules: the UC4 Decision System uses a web-based modeling approach similar to the mentioned web-automation-platforms for business users, whereas power users model rules using visual decision graphs and a script language [13]. There is also an approach to use BPMN as a modeling