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A governance metamodel for Industry 4.0 service collaborations

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Abstract—In Industry 4.0 scenarios, the presence of formalized and enforced governance rules helps to clarify how core and external contributors should collaborate to co-design and deliver key subsystems of the finished product. This clarity diminishes the time for establishing collaborations and facilitates tasks execution. However, current governance rules are usually more implicit than explicit and often are subject to time-consuming negotiation before a new collaboration starts. The concept of Industry 4.0 demands higher levels of dynamism; therefore, we present the importance of governance rules in such digital marketplaces. In this short paper, we lay out the foundation for enabling the explicit definition and enforcement of governance rules by proposing a specialized Abstract Syntax Metamodel for specifying governance rules. With such a model, we aim to aid demand-driven production and logistics service collaborations between suppliers towards enabling a quicker and more predictable creation and execution of the tasks involved.

Keywords— Governance rules, Smart Manufacturing

I. INTRODUCTION

Modern collaborative activities involving suppliers of all sizes along supply chains result in building partnerships driven by manufacturer demand and aimed at cooperative order fulfilment [7]. The movement to Industry 4.0 concept [11] such as “lot size of one” and demand-responsive production means these collaborations would be formed “on the fly” to respond to the needs of a fast changing market with shorter product life-cycles. A promising approach to pursue this concept is establishing collaborative marketplaces [3] where demand from manufacturers could be matched with capabilities and capacities of available suppliers, thus accelerating formation of a supplier collaboration that is able to bid for larger business opportunities [5] and reducing supplier switching costs to such formations [7]. Current information technologies can support such demand-driven collaborations (DDC) between suppliers, yet the uptake of this approach is impeded by a number of

factors [7], one of them being lack of formalization and enforcement of governance rules, which results in high switching costs to such partnerships. To significantly reduce the burden of setting up collaborative networks and shorten the time to jointly respond to business opportunities we aim such rules to be enabled for all participants of Industry 4.0 scenarios.

The goal of this paper is to present an abstract syntax of governance rules to underpin demand-driven collaborations.

We use Unified Modelling Language (UML) [1, 2] to create a metamodel that encapsulates collaboration properties, knowledge protection and security rules — in order to shift from ad-hoc case-specific governance rules management to systematic, industry-enforced governance tools for handling production and logistics service partnership formation concerns. This will lay a foundation for a domain specific language (DSL) [4] for Industry 4.0 to increase the speed of DDC formation [9]. We build on the results of the DIGICOR project (<https://www.digicor-project.eu/>) that aims at developing a collaboration platform, tools, and services for the setup and coordination of aerospace production networks.

II. GOVERNANCE RULES IN THE AEROSPACE INDUSTRY

Original Equipment Manufacturers (OEMs) commonly collaborate with hundreds of tier-1 suppliers that handle transactions with multiple SME clusters. Taking into account the presence of sensitive operational data and different attitudes of suppliers to information privacy, we propose a DSL to provide specialised constructs and to explicitly specify governance rules that facilitate demand-driven collaborations and encourage suppliers to join production networks. Table 1 exemplifies three governance rules identified by an aerospace OEM to support interaction with supplier clusters. In the table, the notion of a *meta-rule* refers to an abstract rule template conceivable for different governance modes; it needs to be *instantiated* for a specific mode (called *collaboration regime*).

TABLE I. EXAMPLE OF GOVERNANCE RULES (EXCERPT)

Meta-rule	Instantiation of the meta-rule	Instruction or constraint?	Priority for DDC
1	The partners of a DDC act autonomously regarding legal and economic decisions, but have to come to an agreement regarding the decisions in the name of the DDC.	Instruction	High
2	Every partner company has one vote.	Constraint	High
3	Decisions in the meeting of members have to be recorded, subscribed from auditor and made accessible for all partners.	Instruction	Medium

III. METAMODEL DESCRIPTION

The abstract syntax metamodel restricts the possible structure of collaboration to demand-driven partnerships initiated by the new order (Fig. 1). The model defines the main concepts of a Domain Specific Language, their relationships and includes formalisation of rules (Table 1) [8, 6].

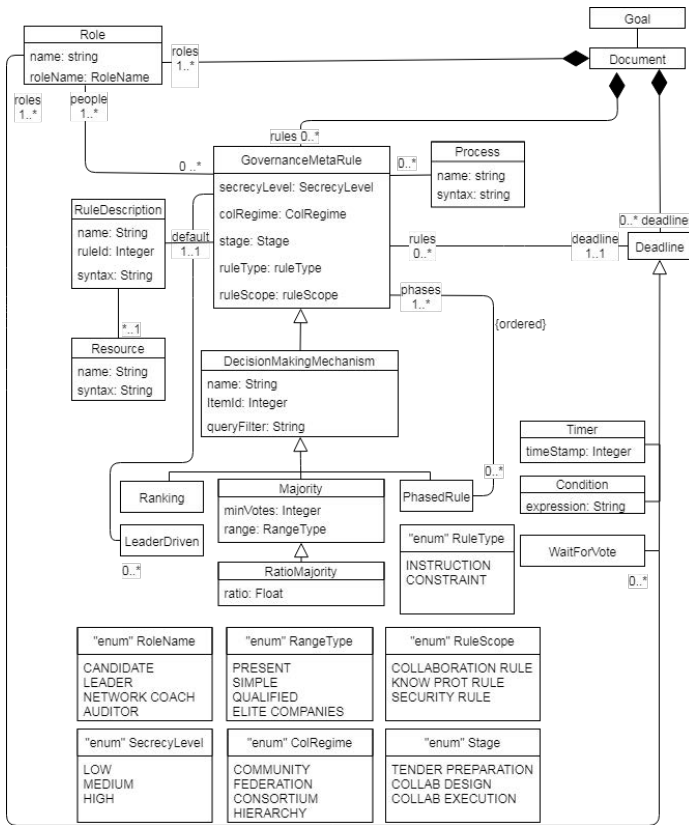


Fig. 1. Abstract syntax of a metamodel [6] to represent governance rules for demand-driven collaborations

The top-level construct in the model is the meta class *Document* (linked with a collaboration *Goal*) that includes: a group of supplier roles (*Role*), rules (*GovernanceMetaRule*) and deadlines (*Deadline*). A *Role* represents any supplier who participates in decision-making (candidate, leader, network coach, and auditor). A governance rule may involve decision making tasks represented in the *DecisionMakingMechanism* class, which also specifies whether a rule is either an additional

instruction or process constraint (*ruleType*) and if it is related to knowledge protection, collaboration or security (*ruleScope*). The actual stage of partnership is encapsulated into *Stage* that could be either a (1) tender preparation, (2) collaborative design or (3) task execution. *GovernanceMetaRules* are linked with *Resource* and *Process* classes. They could be applied to a particular secrecy level (*appliedTo* *SecrecyLevel*) and collaboration regime: community, federation, consortium or hierarchy (*colRegime*) [10]. The scope of the rule can also be defined (*queryFilter* attribute) [5] (e.g., high/low priority). Several types of decision rules are predefined: simple majority, qualified majority, or privileged company’s choice. E.g. under simple majority rule (*Majority* metaclass), to commit a decision, it needs to be supported by over 50% of votes. When a supplier accepts or declines the proposed collaboration, it takes an active position in decision-making that is implemented into *LeaderDriven* metaclass.

The developed metamodel is applicable to enforce the governance rules for OEMs and their suppliers.

IV. FUTURE WORK

This paper describes the first step of development of DSL for Industry 4.0. The next steps include the development of a specific syntax and semantics of DSL, its implementation on a compiler, and its validation in OEM supply chain.

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