A Flexible Peer-to-Peer Production in a Digital Business Ecosystem

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Abstract

The paper proposes a visionary approach aimed at tracing a pathway towards a new production paradigm, positioned among the Flexible Configurable Manufacturing solutions [4]. The proposal is based on the idea that increased flexibility requires the reduction of hierarchical structures, enhanced decentralization with advanced decision-making capabilities to be delegated to the operational level (e.g., shop floor). In parallel, it is necessary to increment the transparency and the peer-to-peer information flow, clear decision-making and operational rules.

Keywords 1

Flexible manufacturing, peer production, service oriented manufacturing

1. Introduction

We believe that in the future it will be necessary to promote new forms of an enterprise characterized by a marked decentralization towards autonomous, but effectively coordinated, production units. Furthermore, production operations will be less directive, with a progressive shift from tight scheduling to a data- and event-driven production paradigm. The goal is a production organization quickly reconfigurable, when needed, where decisions can be made in absence of a centralised management. Then, we need decentralised capabilities to monitor, control, and intervene to guarantee the smooth and lean production flow. Such an innovative production system is composed by a variable number of production units, capable of joining together, agreeing to achieve a common production objective, with a peer-to-peer approach [1]. In case of a substantial change of the production conditions, e.g., due to a major delay in the program or a failure of a production unit, it will be possible to change the composition of the production organization on the fly. We will refer to such a production organization as a Virtual Liquid Enterprise (VLE). The idea of a VLE is positioned in the area of Flexible Configurable Manufacturing and, more specifically, in the Decentralised Autonomous Organization (DAO) and distributed peer-to-peer production paradigm [2].

We know that during the production process there is a high possibility that something goes wrong, e.g., a production unit (PU) fails to respect the agreed production commitments. Then, the VLE is capable of reconfiguring its structure and organization to achieve a new configuration and production plan, e.g., by substituting the faulty PU with one or more new participants to guarantee the business goal [3]. This reconfiguration should take place on the fly without stopping the production process (in case of early detection or, otherwise, with the minimal perturbation). This objective can be achieved since new PUs to be included in the process are selected from within a Digital Business Ecosystem (DBE that will be described below), and therefore they are highly qualified and trusted.

Furthermore, a DBE adopts a Service Oriented Production Architecture (SOPA) [4], where each PU is actually seen as a Production Service Provider (PSP) and its services [5] (together with the production parameters, such as production type, cost, quality, volume capacity, etc.) are described according to a

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common standard (e.g., USDL: Unified Service Description Language[2]) and published in the PSP directory.

Creating and operating a VLE is not an easy job: there are two main phases. Phase 1, the enterprise composition, is activated when a business opportunity materialises, requiring the creation of the suitable VLE to optimally respond to the business opportunity. Then, the Phase 2, the operational one, where the PUs participating in the VLE cooperate to achieve the business objective. The complexity of Phase 1 resides in the selection of the participating PUs, the assignment of tasks and activities, the agreement of the compensations. The complexity of Phase 2 resides in the monitoring of the production progress, the early detection of any possible risk capable of jeopardising the production, and then the adoption of redressing initiatives that may end up with the replanning of the remaining steps of the production plan. One of the major problems in both phases is represented by decision-making. Since the VLE is inherently a democratic organization, all decisions should be made with a consensual approach. This approach is inherently time consuming and therefore incompatible with the fast pace that the business requires. To mitigate this problem, the solution is the consensual pre-definition of a set of business rules capable of driving the decisions in the majority of cases. Such rules should be clearly stated to be easily understood by all participants in the ecosystem and, at the same time, to be easily 'understood' by a computer, to allow an intelligent agent to automatically use them to make a decision.

In this paper, we address the Phase 1 and the very strategic decisions concerning VLE composition. We analysed several proposals for a formal representation of business rules, and finally we decided to adopt the OMG (Object Management Group) standard named Decision Modeling and Notation (DMN) [6]. In essence, DMN represents business rules in a formal way, by using Decision Tables. In our wor, we implemented a test case by using the Low Code platform Camunda[3], that includes a tool supporting the management of DMN Decision Tables.

In the next section, we briefly present a few peer-to-peer production models available in the literature. In Section 3 we introduce a concrete example, presenting the rules that allow for a fast composition of a VLE. Then, in Section 4 we draw some conclusions.

2. Related work on peer-to-peer production

Distributed peer-to-peer production, based on the collaboration of small production units, has a long tradition; however, new opportunities have emerged with the advent of the Internet and the digital flat networking infrastructures. The book *Wikinomics* [7] anticipated the great opportunities that the new digital infrastructures offer in term of unbounded cooperation, openness, transparency, direct access of enterprises (and customers) to worldwide markets, including the opportunity of cooperation within new decentralised organization models based on open digital platforms.

Accordingly, we have seen the growth of a number of initiatives that are introducing innovative production models, in particular in manufacturing, aimed at revamping the true essence of the Internet. Here we briefly list a few of them, with different characteristics but important commonalities, including a strong cooperation attitude, social responsibility, a horizontal organization, an open approach to management strategies, and a democratic decision making attitude. The reported models contributed to characterize the main lines of our VLE proposal.

Collaborative Open Manufacturing. It is a form of flat, horizontal collaborative production model where self-organised communities of small production units, supported by advanced collaboration networks, can get together to engage in the production of goods and services [8], while maintaining their autonomy and independence.

Cloud Manufacturing. This is a manufacturing model, mainly based on full digitalization of the enterprise and its business activities, that fully exploit different cloud computing infrastructures and services [9].

Service-oriented Manufacturing. This enterprise model aims at organising manufacturing capabilities as manufacturing services [5]. It integrates with the previous model by organising the production

[2] https://www.w3.org/2005/Incubator/usdl/charter
[3] www.camunda.org

facilities as a set of Manufacturing Service Providers (MSP) that can be searched on the Cloud [10].

Cyber Manufacturing. This model emphasises the adoption of Cyber-Physical Systems (CPS), a new approach for the tight cooperation of intelligent (typically soft) machines and physical actors, including robots and humans [11]. This model exhibits a high level of smart automation and therefore of reconfigurability.

Commons-Based Peer Production (CBPP). This production model refers to a community-based production of goods and services [12] that relies on open and shared resources [13]. There is a growing number of concrete examples of CBPP, such as *Sensorica*, a hardware development network-organization using the open value network model, and *RepRap*, aimed at creating open-source, low cost, self-copying 3D printers.

The proposal of this paper, based on the above studies and experiences, aims to achieve an original synthesis that leads to the VLE model.

3. An example of peer production in food delivery

In this section, we describe an example positioned in the food production and delivery sector. In this sector, the large majority of business is dominated by companies, such as *Foodora*, *Just Eat*, or *Deliveroo* that essentially play the role of intermediaries, capable of guaranteeing quality, speed, and reliability in the end-to-end process, while cashing a part of the revenue. The challenge is to proceed in the direction of a progressive disintermediation, to free the 'productive' agents, food shops and delivery agents, from the dependence on the food delivery platforms. In order to achieve this objective, it is necessary firstly to create, e.g., a Food Delivery Digital Business Ecosystem (DBE), based on the principles and rules illustrated above, dwelled by different players intended to cooperate in guaranteeing high quality standards. Then, it is necessary to have a DBE platform that manages the incoming orders and dynamically creates a VLE capable of fulfilling such orders. In our example, the VLE will be formed by pizza shops and a delivery agents that, when an order arrives, will be automatically selected, to fulfil the order, according to fair criteria. As anticipated, it is important that the selection criteria, as well as all the main rules governing the operations of the various VLEs, have been previously agreed by all the members of the ecosystem.

We assume that a pizza shop has been already selected and, in order to create the VLE, it needs to recuit a delivery agent. But this VLE is not defined once forever, on the contrary, its structure is highly flexible and it will be reconfigured at each incoming order. Then we concentrate on the dynamic selection of the delivery agent. In the example, there are 3 different delivery agents: drone delivery (DD), bike delivery (BD), motorcycle delivery (MD). All the business actors have agreed on a set of rules and the ecosystem platform applies such rules to complete the VLE composition with the best delivery agent. Below we report a scheme extracted from the Camunda decision-making sub-system[4], the part dedicated to the selection of the delivery agent.

As anticipated, DMN adopts a decision table method to represent in a compact way the rules governing a given decision-making task. In a decision table, the rules are reported on the rows, each of which represent a condition to be satisfied. Then there are columns organized according to two main sections: *input parameters*, modeling the IF part of the rules where the corresponding parameters will be instantiated at runtime, to evaluate which conditions are true. Then there are the *output parameters*, where the THEN part of the rules is represented; it consists of variables that will be returned instantiated according to the fired rules.

[4] Please note that we are dealing here with a decision-making system and not a decision support system (DSS). In fact, the latter is conceived to assist human beings in their decision-making tasks, while the former is fully automatic and does require humans in the loop.

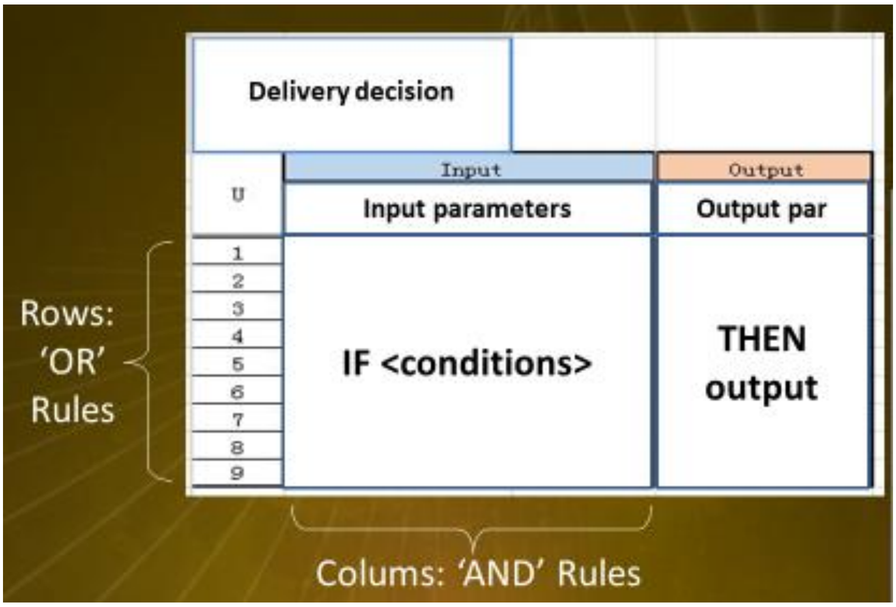

Figure 1: Decision modeling and notation table structure

In our example, the decision criteria are essentially based on the number of pizzas ordered and the distance of the customer from the pizza shop. Then, in a sketchy form, the rules are the following:

- ***drone-delivery***: for orders up to 2 pizzas, to be delivered within 1ml
- ***bike-delivery***: for orders between 3 and 5 pizzas to be delivered within 1ml or orders up to 5 pizzas to be delivered between 1 and 5 miles
- ***motorbike-delivery***: for any order of more than 5 pizzas, or any number of pizzas if requiring a trip of more than a 5 miles;

The above business rules have been translated according to the DMN standard in the following decision table.

Deliver rules			
	Input		Output
U	DistanceFromFood	Order size	Deliver method
	double	integer	string
1	<1	<3	"drone"
2	<1	[3..5]	"bike"
3	<1	>5	"motorcycle"
4	[1..5]	<3	"bike"
5	[1..5]	[3..5]	"bike"
6	[1..5]	>5	"motorcycle"
7	>5	<3	"motorcycle"
8	>5	[3..5]	"motorcycle"
9	>5	>5	"motorcycle"

Figure 2: Decision rules for dynamic pizza delivery

According to the above scheme, the composition of the VLE is not defined until the customer order arrives and the rules are fired.

4. Conclusions

In this paper we presented the main lines of a new enterprise model, referred to as Virtual Liquid Enterprise, characterized by a highly flexible structure. It represents a dynamic aggregation of PUs able to quickly and flexibly respond to an unplanned business opportunity [14]. A VLE requires the availability of various independent production units capable of establishing an impromptu collaboration, achieving an unexpected business objective, in absence of a central authority dedicated to the management and control of the production process. A VLE is characterized by a very flexible and agile organization [15] where its participating units, their roles and tasks are not fixed forever, but can vary over the time depending on the marked conditions and the production capabilities of the PUs. There are three requirements for an effective implementation of a VLE: (i) a Digital Production Ecosystem, capable of guaranteeing the quality and reliability of the participating units; (ii) a knowledge base with the directory of the production units, including their offered production services; (iii) a collaboration platform, with process control and decision-making capabilities; including a set of business rules capable of implementing a smart automation that governs the majority of situations, making the choices that will be necessary during the activities. A first proof of concept has been developed, based on the Camunda platform, in the food delivery business.

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