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Agent-based monitoring service for management of disruptive events in supply chains

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ABSTRACT

Schedules of supply chains are generated with buffers to absorb the effect of disruptive events that could occur during their execution. Schedules can be systematically repaired through specific modifications within buffers by using appropriate decision models that consider the distributed nature of a supply chain. To this aim, information of disruptive events at occurrence or in advance allows decision models to make better decisions. To detect and predict disruptive events along a schedule execution, a service-oriented monitoring subsystem that uses a reference model for defining monitoring models was proposed. This subsystem offers services for collecting execution data of a schedule and environment data, and assessing them to detect/anticipate disruptive events. Because of the distributed nature and the complexity of these services functionalities, this paper presents an agent-based approach for their implementation. This technology allows dealing with supply chain monitoring by structuring monitoring subsystem functionalities as a set of autonomous entities. These entities are able to perform tailored plans created at execution time to concurrently monitor different schedules. A case study is described to try out the implemented prototype system.

1. Introduction

In an integrated supply chain, the overall performance largely depends on keeping the coordination of the schedules for producing and distributing the goods. These schedules are typically represented by production and distribution orders, where each order represents a particular instance of a generic supply process.

During the execution of the scheduled orders, significant changes may occur either in the specification of the orders or in the availability of the involved resources. These unplanned changes, called disruptive events, can produce negative effects that are propagated throughout the supply chain affecting schedules and their coordination [1–3].

The robust planning paradigm advises the definition of schedules with buffers (material, resource capacity, or time) that are capable to absorb the effect of disruptive events [4]. Some decision models were proposed to systematise the use of these buffers [5]. These models consider the distributed nature of a supply chain for repairing schedules through limited and specific modifications within the provided buffers [6]. To perform these modifications, the mentioned decision models require being notified on the occurrence or alerted about the possible occurrence of disruptive events by performing a continuous monitoring of the schedule execution.

Predictive monitoring is able to anticipate a disruptive event when there is enough evidence of its occurrence [7]. By collecting environment data (such as weather conditions or port congestion) and changes in the expected availability of resources (such as equipment breakdowns or breakage of materials), the predictive monitoring should be able to anticipate a possible change in an order specification. *Reactive monitoring* is able to detect a disruptive event when it has occurred. To this aim, it collects observed information on changes in resource availability and order specifications, assessing those changes to detect disruptive events.

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Several approaches for reactive monitoring [8–13], for predictive monitoring [14,15] and for both reactive and predictive monitoring [5,16–19] were proposed. From the point of view of data collecting capability, they can be classified into approaches for order monitoring [5,11,16], approaches for resource monitoring [9,14,15,18] and approaches for both order and resource monitoring [8,9,12,13,19].

Monitoring systems are conceived as an extension of traditional tracking and tracing systems [20,21] with capability to collect data and to process these data in order to detect and/or anticipate disruptive events. Monitoring system capabilities rely on the monitoring process that defines the set of task to be performed for anticipating/detecting disruptive events [22].

Given the diverse nature of supply chain operations, monitoring processes are usually domain-specific and quite dependent on the type of resources and supply processes being monitored. To address this diversity in a systematic way, Fernández et al. [22] proposes a domain-independent metamodel as a reference model to generate monitoring processes for any kind of resources or supply processes. This reference model defines an abstract language that, unlike [13], allows the specification of models for reactive and predictive monitoring based on orders, resources, and environment data. By a set of transformation rules, monitoring models can be automatically transformed into monitoring processes to be performed by a monitoring system.

By using the proposed abstract language, users can represent the monitoring process of a supply process without being aware of the implementation technology. Each monitoring model, represented in terms of the reference model, could be also automatically transformed into different technological languages. However, the development of a monitoring system that implements this approach is still an unresolved issue which involves a complex challenge.

Based on the reference model proposed by [22], this paper presents an approach for implementing a monitoring subsystem as a part of an integral service-oriented architecture [23,24] for a Collaborative Management of Disruptive Events in Supply Chains system [25]. The monitoring subsystem can be hired by any enterprise involved in the supply chain. To this aim this subsystem provides a monitoring service with two main functionalities: collection of data could affect supply process executions; and collected data processing to detect and/or anticipate disruptive events.

This proposal introduces three novel aspects not addressed in previous works. First, the monitoring system is conceived as a multiagent system composed of autonomous agents with the ability to concurrently monitor a set of orders and resources involved in a schedule. Since agent-oriented paradigm provides suitable support for distributed systems and web service implementation [26,27], the proposed agents are able to work remotely collecting execution and environment data. Second, the proposed monitoring system allows the definition of new processes by just designing high-level models based on the reference model abstract language and dynamically generate, using a model-driven development approach, the executable instance of the monitoring process. That is, agents, plans, and assessment functions are created by transformations of a high-level conceptual model. Third, by further using transformation rules, the system is able to translate the predictive models declared at the high level language, into implementations with a specific tool (for instance, Bayesian network).

The remainder of this paper is structured as follows: Section 2 discusses related works. The multi-agent based architecture proposed for monitoring subsystem is presented in Section 3. Section 4 describes the implementation of monitoring subsystem. Section 5 describes a case study used for trying out the prototype system, and, finally, conclusions and future work are presented in Section 6.

2. Approaches for monitoring systems

The research related to supply chain monitoring still has not a body of disciplinary knowledge. It is supported by contributions from various disciplines and applied to different domains, which hinders to arrange an historical development of community awareness. In addition, recent works do not imply a necessary evolution of monitoring features, but rather they frequently refer to particular applications with different decision tools to detect/anticipate disruptive events in a domain.

With the purpose of reviewing related research work in a systematic way, we classify monitoring approaches taking into account their prediction ability (reactive/predictive) and the scope of event sources they are observing (orders/resources). Another aspect that this classification takes into account is the generality of approaches considering their capability for using different monitoring models that belong to different application domains. Based on this classification, relevant literature related to monitoring systems is reviewed. A summary of approach features is presented in Table 1.

Winkelmann et al. [8], Basal et al. [9], Liu et al. [10], Oztemel and Tekez [11], and Mahdavi et al. [12] present approaches focused on reactive monitoring. Winkelmann et al. [8] present a conceptual language for modelling monitoring processes by a set of rules based on arithmetic ratios of order specifications and material resource parameters. Basal et al. [9] present an approach based on key performance indicators assessed at regular intervals to detect material resource changes by monitoring the crude oil inventory. Liu et al. [10] present an approach that distinguishes task status-related events, events produced by a task, and external events, and define a set of rules relating them. Each rule is associated to a coloured Petri Net pattern in order to generate the monitoring process to detect disruptive events. Oztemel and Tekez [11] define several software agents responsible for performing different activities for monitoring manufacturing orders. For each activity, these agents can have different monitoring models that use information collected through a predefined network of sensors. Mahdavi et al. [12] develop an agent-based system for quality control of cement production processes. The system implements a model that receives the result of quality tests at each state of the supply process and uses a rule-based control mechanism for detecting disruptive events and correcting the process.

Table 1
Approach comparative.

Monitoring features	[8]	[9]	[10]	[11]	[12]	[14]	[15]	[16]	[17]	[5]	[18]	[19]	[13]
Reactive monitoring	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Predictive monitoring						✓	✓	✓	✓	✓	✓	✓	
Monitoring orders	✓		✓	✓	✓			✓	✓	✓		✓	✓
Monitoring resources	✓	✓	✓		✓	✓	✓				✓	✓	✓
Generality of the approach													✓