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Outbound logistics exception monitoring: A multi-perspective ontologies' approach with intelligent agents

Dongming Xu [a,*], Chinthake Wijesooriya [a], Yong-Gui Wang [a], Ghassan Beydoun [b]

[a] School of Business, University of Queensland, Brisbane, Australia
[b] Faculty of Informatics, University of Wollongong, Australia

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ABSTRACT

Logistics consists of a complex network of organizations and processes where exception monitoring is critical for the success of logistics service. In order to detect exceptions effectively, exception monitoring requires proper understanding of the possible exceptions. However, the extant exception monitoring approaches or systems still lack sufficient emphasis in exceptions understanding. This paper presents a novel outbound logistics exception monitoring approach by incorporating multi-perspective ontologies and intelligent agents. Specially, the multi-perspective ontologies, involving static ontology, social ontology and dynamic ontology, are firstly employed to develop the taxonomy of the logistics exception, to reflect the situation dependencies of logistics exception and to represent the dynamic nature of business processes. From this point forwards, an outbound exception monitoring system is designed by introducing multi-intelligent agents, which can ensure autonomous, flexible, and collaborative exception monitor in logistics service. Finally, the presented approach and designed system are exhibited through a case study of two ubiquitous logistics exceptions, which indicates that the proposed multi-perspective ontologies provide better understanding of exceptions thereby enabling the designed outbound exception monitoring system to perform well.

1. Introduction

Exception management consists of monitoring, diagnosis, and resolution (Wang, Wang, Xu, Wan, & Vogel, 2004b), which respectively concerns the process of keeping track of the activities of the business process, the process of checking the cause of the exception found, and the process of deciding the solution and applying the solution for the exception. For example, a late delivery exception could be detected by monitoring the actual delivery time against the scheduled delivery time. Then by diagnosing the cause of the late delivery (e.g. traffic congestion), a resolution can be presented by assessing all possible options for an effective resolution. Throughout the literature, extant researches place more emphasis on the design of the whole exception management, i.e. how to coordinate every part (e.g. monitoring, diagnosis, resolution) involved in exception management system (Ozkohen & Yolum, 2006; Wang et al., 2004b). Only a few researches focused on the design of particular part – exception monitoring. They deployed such techniques as exception patterns (Russell, Aalst, & Hofstede, 2006), AND/OR trees (Ozkohen & Yolum, 2006), and fishbone diagrams (Wang, Wang, Kit, & Xu, 2004a). However, those techniques are insufficient to provide proper understanding of exception situations, i.e. what, when, where, and how the problems happen, which, as a matter of fact, is critical to exception monitoring since it could help to improve exception monitoring thereby resulting in better exception management.

Therefore, in order to provide a proper understanding of exception situations, this paper firstly introduces multi-perspective ontologies to represent the exception situations, especially for the outbound exception, which refers to the process related to the movement and storage of products from the end of the production line to the end user. Multi-perspective ontologies mean dividing a single ontology into multiple ontologies according to the type of knowledge that is addressed. They are able to avoid ambiguity in single ontology thereby providing better understanding (Kingston, 2008; Wemmerlöv, 1990). Specially, the multi-perspective ontologies in this study include static ontology (using taxonomy), which presents the things that exists along with its attributes and relationships; social ontology (using dependencies), which presents the organizational structures and interdependencies; and dynamic ontology (using business rules), which presents the dynamic nature of the phenomena such as the state in relation to transition and the process (Jurisca, Mylopoulos, & Yu, 2004; Ye, Wang, Yan, Wang, & Miao, 2009). The aforementioned ontologies present the structural nature, interdependencies, and dynamic state of the exception situations respectively.

* Corresponding author.
E-mail address: d.xu@business.uq.edu.au (D. Xu).

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In addition, an effective monitoring system requires to be autonomous (free from human intervention), cooperative (working with other agents/systems effectively), pro-active (taking the initiative in order to achieve the designed objective) and be reactive (responding to the changes in the environment) (Wang et al., 2004a). On the other hand, autonomy, cooperative, pro-activity and reactivity are properties of intelligent agents (Wooldridge, 2001). Hence, considering the complexity of the logistics networks and the properties of intelligent agents, the paper proposes a logistics exception monitoring system using intelligent agents along with reflection of taxonomy, dependencies, and business rules. The proposed system is explained and demonstrated by using two hypothetical cases, by which the ontological views are demonstrated and reflected back to the exception situation.

The remainder of the paper is structured as follows: The next section briefly reviews the relevant literatures in logistics exception monitoring and ontology. Section 3 expatiates the multi-perspective ontologies development, including taxonomy (static ontology), dependency in exception situations (social ontology) and business rules in exception scenarios (dynamic ontology). Subsequently, an exception monitoring prototype system is designed in Section 4. In Section 5, two ubiquitous logistics exceptions are employed to demonstrate how the proposed approach can be applied in logistics management. Finally, Section 6 concludes with some recommendations for future research.

2. Related works

2.1. Logistics exceptions and exception monitoring

Researchers defined exception as anything that deviates from the planned process (Wang et al., 2004a). Some others defined the exception as a violation of a commitment (Ozkohen & Yolum, 2006). In summary, for the purpose of this study we define "the exception as anything that changes the planned process". A process may or may not violate the commitment but it could vary from the plan. Since logistics is an inter-connected and inter-related process, any variation could impact the logistics network. Therefore, it is important to monitor any variations in the logistics process.

Recent research which focuses on exception management systems use violation of commitment (Ozkohen & Yolum, 2006; Russell et al., 2006), task failures or deadline failures (Russell et al., 2006) to identify an exception. These approaches require knowledge of possible exceptions to monitor exceptions, or else the exceptions are unpredictable. However, the existing exception monitoring approaches do not provide the necessary knowledge for effective monitoring, thereby lacking an important aspect of exception management systems. For responding these limitations, some researchers considered alternative approaches, e.g. predicting errors before it occurs (Ozkohen & Yolum, 2006); system-wide exception management rather than localized exception management (Klein, Rodriguez-Aguilar, & Dellarocas, 2003); multi-method approaches such as use of statistical data, rules or cross model information (Bourguet, 2006); and ontology with AND/OR trees (Ozkohen & Yolum, 2006). Further, there were some efforts introducing dynamic and autonomous capability into the exception management systems, particularly using intelligent agents (Wang et al., 2004a; Xu & Wang, 2002).

However, the emphasis of the existing studies was exception management, not exception monitoring. Exception monitoring requires understanding of the exceptions and understanding of the nature of exceptions. Research on understanding the nature of exceptions is still rare. Insufficient understanding the exception situations, limits the ability to identify exceptions effectively and efficiently. Due to the nature of the logistics networks, failure to understand the exceptions could lead to continuous problems in the logistics process. Consequently, it's necessary to develop a novel way to enable appropriate understanding of logistics exceptions.

2.2. Ontology and its applications in exceptions

Ontology is the formal representation of the real world. Ontology is defined as "a specification of some conceptualization, which is an abstract and simplified view of the world" (Wang, 1997; Wijesooriya, Xu, & Gao, 2008). Ontology has been used as a method to design systems to find a solution for real-world problems. Recently, the use of ontology has become more popular (Noy, Kunnatur, Klein, & Musen, 2004b). Ontologies have been classified into static, social, dynamic, and intentional in previous study (Jurisca et al., 2004). Currently, ontology is seldom used in exception monitoring but some closely related studies were found: One of them, looking at predicting exception before it occurs using ontology with AND/OR trees (Ozkohen & Yolum, 2006), recognizes the importance of ontology in exception management and also the importance of hybrid systems. It uses rules along with AND/OR trees to predict exceptions in which it is looking at the dynamic nature of the processes. Another study uses ontology for abstraction where the exception situation is extracted in an abstract form and explained via ontology (Luo, Sheth, Kochut, & Miller, 2000). They use the ontology for categorizing and organizing the exceptions which are useful in retrieving abstract exception cases. The study by Grosof and Poon (2004) uses the ontology in exception situations to address the problems in exception handling provisions in automated e-contracts. It uses ontologies about business processes by including ontology knowledge into e-contracts. During this process it looks at taxonomical/hierarchical aspects and knowledge about exceptions/exception-handling. All of these studies use ontology from an exception management context, rather than exception monitoring. In contrast, our proposed approach emphasizes exception monitoring where it involves three different ontological views concerning the nature of exception situations thereby increasing the understanding of the exceptions.

3. Multi-perspective ontologies development

3.1. Taxonomy development

Taxonomic hierarchies of classes and their relationships are often used to implement ontologies (e.g. Beydoun & Hoffmann, 2001; Beydoun et al., 2005; Noy & Klein, 2004a; Wang, 1997). Taxonomic hierarchies structure a complex field of interest and help develop an understanding (Wemmerlöv, 1990) of it. Understanding the nature of the logistics processes is an essential aspect before understanding the problems of logistics processes. This can be directly applied to the logistics exceptions. Similar scenario was highlighted by previous research as the research found that one of the major problems in the study of service production is of taxonomical nature (Wemmerlöv, 1990). They stressed that it was a problem when dealing with identifying and classifying service systems in a meaningful way. Importance of taxonomy was noted by other researchers too, as it was considered developing a taxonomy is appropriate and relevant in failure or exception situations (Massad & Beachboard, 2008). Further, the use of taxonomy improves the understanding of the environment from the taxonomical perspective, and it could be developed as a decision making tool (Wemmerlöv, 1990), which is particularly useful in system design.