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Continuous improvement through knowledge-guided analysis in experience feedback

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ABSTRACT

Continuous improvement in industrial processes is increasingly a key element of competitiveness for industrial systems. The management of experience feedback in this framework is designed to build, analyze and facilitate the knowledge sharing among problem solving practitioners of an organization in order to improve processes and products achievement. During Problem Solving Processes, the intellectual investment of experts is often considerable and the opportunities for expert knowledge exploitation are numerous: decision making, problem solving under uncertainty, and expert configuration. In this paper, our contribution relates to the structuring of a cognitive experience feedback framework, which allows a flexible exploitation of expert knowledge during Problem Solving Processes and a reuse such collected experience. To that purpose, the proposed approach uses the general principles of root cause analysis for identifying the root causes of problems or events, the conceptual graphs formalism for the semantic conceptualization of the domain vocabulary and the Transferable Belief Model for the fusion of information from different sources. The underlying formal reasoning mechanisms (logic-based semantics) in conceptual graphs enable intelligent information retrieval for the effective exploitation of lessons learned from past projects. An example will illustrate the application of the proposed approach of experience feedback processes formalization in the transport industry sector.

1. Introduction

Industrial products developed nowadays are more and more complex and involve several technologies at the same time. Moreover, design time is reduced, adding new constraints during pre-industrialization phases. In this context, sharing experience feedback and lessons learned is a key issue to improve the performance of organizations over time. However, sharing this knowledge is made difficult in large organizations for two main reasons:

- the project based management which creates a partitioning of the produced knowledge,
- the distributed structure of nowadays organizations implies virtually space across geographic and temporal boundaries.

In order to overcome these difficulties, building an experience feedback and lessons learned repository can be of major interest to share knowledge through time and space. This is made all the more relevant that, during the past decades, considerable efforts have been made by industrial firms in order to standardize their products and their processes. Therefore, from a representational point of view, the knowledge acquired from previous problem solving experiences should be reused as much as possible to allow the domain experts to find appropriate solutions with minimal effort. After solving one problem (leading to an experience) of many to be solved, experts can transfer lessons learned from one context to another without having to achieve the whole problem solving process. However, in some fuzzy domains, experts may sometimes be more overconfident and they may miss very obvious features without a root cause problem analysis or with a misleading problem analysis. These new constraints are rarely taken into account in traditional problem solving methods. The concern of this work is to address the knowledge capitalization and exploitation for continuous improvement in the resolution of industrial problems. Different tools and approaches for the acquisition, representation and exploitation of knowledge have been proposed especially in knowledge engineering sciences (Hicks, 2004). However, these methods dedicated to model expert knowledge modeling, show some practical difficulties: experts often lack motivation, skills and time to document their expertise, a mediator is often needed to remove semantic distance between the expert and the knowledge-based system, the regular update of the knowledge referential is difficult. Thus, experience feedback, which advocates a capitalization during the activities of

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experts, helps to overcome these disadvantages (Henninger, 2003). Naturally, the captured knowledge remains fragmentary and requires additional efforts if it is to be generalized. Finally, a compromise appears between the quality and generality of knowledge and the effort required to acquire it. In a context of rapidly evolving knowledge (such as encountered in continuous improvement processes), it may be interesting to focus on reducing the effort to obtain knowledge allowing experience feedback (Weber et al., 2001). Besides, in many companies, quality certification requirements have led to standardized problem-solving processes in which experts investigate the causes of the problems and attempt to eradicate them.

In this context, the experience feedback approaches based on standardized problem solving methods can contribute to continuous improvement in business processes. In an experience feedback approach of this kind, the knowledge is generated, on one hand, from the capitalization of knowledge and know-how used in industrial processes and, on the other hand, formalized through the tools and methods used by actors in their work (Jacobsson et al., 2010). For example, in the Swedish Center for Lessons Learned from Incidents and Accidents (NCO), learning from accidents is institutionalized in order to overcome various social barriers and to disseminate information so that new insights in accident prevention are as widely applied as possible (Lindberg et al., 2010).

Historically, experience feedback was mainly based on statistical methods to identify some failure laws. However, this kind of feedback does not allow the extraction of expert knowledge from the technical data. This is made possible by the "cognitive approach" of experience feedback modeling. It models the expert knowledge of the organization and facilitates the enrichment of knowledge repository by using methods from artificial intelligence. The cognitive vision framework of experience feedback provides means of understanding, interpreting, storing and indexing the activities of experts (Weber and Aha, 2003).

This work specifically focuses on issues in the "analysis" activity (mainly oriented towards the search of the root causes of a problem) of experience feedback processes. It uses semantic technologies and reasoning mechanisms to refine indexation and adaptation steps by keeping track of the analysis performed. The analysis model must incorporate the possibility for an expert to appoint the most significant descriptors necessary for the best explanation of factors affecting problem occurrence and severity (Beler, 2008). The resulting analysis would correspond to a combination of relevant pieces of cognitive task analysis on which the domain expertise has associated a degree of belief that takes into account all the available evidence (Shafer, 1990). Indeed, knowledge related to cognitive elements underlying the analysis generation and lessons learned can be produced by tools that enable the formal description of physical tasks and cognitive plans required from a user to accomplish a particular work goal (Militello and Hutton, 1998).

The paper is structured as follows. Section 2 exposes a state of the art concerning knowledge management for experience feedback and a comparison between the potentially relevant semantic technologies is discussed. Section 3 presents the three-layer model proposed for analysis improvement in experience feedback framework. An illustrative application example is exposed in Section 4. Finally, Section 5 concludes and discusses future challenges.

2. Knowledge management for experience feedback: state of the art

2.1. Modeling of cognitive experience feedback

Experience Feedback is a structured process of capitalization and exploitation of information extracted from the analysis of positive and/or negative events. Here, the term "event" is used to generically identify occurrences that may produce safety, health, environmental, quality, reliability or production impacts. Experience Feedback uses a set of human and technological resources that must be managed to reduce the repetition of errors and to promote effective practices (Hermosillo et al., 2005). In all cases, the Experience Feedback process reveals two phases: the capitalization phase which allows the construction of the experience feedback repository and the exploitation phase which consists in the reuse of the capitalized experiences. In cognitive experience feedback, the capitalization phase can rely on problem solving methods commonly used in the industrial field (such as 9S (IAQG, 2010), 8D (Rambaud, 2006), 7-Step (Shiba, 1997), PDCA, Six Sigma-DMAICS (Geoff, 2001)). The main activities in the problem solving process are (Hicks, 2004):

- The composition of a problem solving team.
- The description and assessment of the problem highlighted by events.
- The analysis of events to identify their root causes and the validation of this analysis.
- The formulation of the problem solutions and its application checking (corrective actions).
- The action suggestions to prevent a new occurrence of the problem (preventive actions and lessons learned).

Our work fits into the scheme of the experience feedback framework detailed in Rakoto (2004). In this framework, a structured description of gradual transformation, by actors, of an event into knowledge is proposed. For example, this can be used in a continuous improvement process through a problem solving method use (e.g. 8D or Six Sigma-DMAICS) for the Quality Assurance department assisting a supplier in improving the quality of its products/services. Despite the seeming disparity in purpose and definition among the different problem solving methods, they have some base component features in common (Fig. 1). The four components ("context–analysis–solutions–lessons learned") of cognitive experience feedback process are described as follows:

- The first level leads to the event description: we call it the context level. Context provides a general picture of the problem to solve prior to in depth analysis. It contains for instance the description of a faulty product and its use conditions when the problem occurred (Brézillon, 1999). Context is useful in representing and reasoning about a restricted state space within which a problem can be solved. The identification of critical events is often made by a multidisciplinary committee. In this case, risk criteria are the terms of reference (standards, measures, or expectations) used to make a judgement or a decision on the significance of risk to be assessed (Gouriveau and Noyes, 2004). Risk criteria may include: associated costs and benefits, legal and statutory requirements or stakeholders concerns. Thus, beyond a critical threshold, the experience feedback is recorded systematically.
- The second level leads to the definition and implementation of solutions for the event: we call this the case or experience level. An event must be analyzed according to its context (search of the causes and evaluation of the effects on the system) to propose corrective actions. A Tree Analysis Diagram is often used to list the various potential causes and their weighting factor that characterizes their degree of plausibility (Smets and Kennes, 1994). In a causal tree, the worst thing that happened or almost happened is placed at the top. This formalization is important, since it focuses on the most likely branches (e.g. safety nets) to validate the root causes.
- The "knowledge" level refers to the knowledge of one or several experiences, summarizing the involved analysis (knowledge