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Towards a cost-effective and reusable traceability system. A semantic approach

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ABSTRACT

Industrial processes are not just concerned with efficiency but also with their traceability and accountability. Nowadays, the proper evaluation of parameters in the quality domain is gaining momentum. Even as holistic systems concerned with the provision of these services are a hot topic, there is a gap on the provision of such systems for traceability under the premises of reusability and low deployment costs. The authors of this work were compelled to provide with such system based on the use of semantic technologies. Interested readers can find a thorough description of models and methods leading to the proposed platform. Discussions about worthy features related to the use of semantic technologies are also included along with lessons learned for further attempts.

1. Introduction

Nowadays, the goal of the industrial sector is not limited to maximize production at the lowest cost. In the current trends of industrial processes, the quality control and traceability of products and services is becoming a paramount element. Far from being just an added value feature, the support of these functions is beginning to be considered as mandatory, due both to legal constraints and customers' requirements. Thus, quality and traceability must be addressed in the current industrial framework as a holistic feature.

After a comprehensive literature review (briefly discussed in Section 2), the authors came up with the conclusion that even as there are many solutions for traceability and control of processes in particular scenarios, there is a lack of affordable systems suitable for a wide range of contexts. To fill this gap, a holistic traceability system based on semantic technologies to facilitate the provision of control and monitoring operations was designed. The authors have a broad experience on the use of such technologies, and were compelled to explore the possibility of designing a traceability platform using them as a facilitator for properties relevant to traceability such as manageability of data, extensibility, interoperability or reusability.

The main goal is to exploit these properties to generate a cost-effective and reusable system suitable for almost any use context. To facilitate this task, a conceptual artifact named Control Point (CP) was introduced to identify a specific spot where a monitoring operation is required. The appropriate semantic representation of CPs is a convenient tool for traceability, as illustrated in this paper. Section 3 describes the design of the proposed platform in terms of technical business model, semantic model and reference architecture. The development of a prototype based on these models allows us to conduct an evaluation of the proposal and its requirements, as shown on Section 4. Finally, some comments and conclusions are presented in Section 5.

2. Background

According to ISO 9000:2000, traceability can be defined as the "ability to trace the history, application or location of that which is under consideration". Golan and others [12] describe traceability systems as recordkeeping systems designed to track the flow of products or product attributes through the production process or supply chain. These systems can vary in complexity from simple paper records to complex technological systems [4]. In this regard, the use of software solutions allows collecting much information with little effort. Furthermore, the technology ensures a more

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efficient availability of long-term data and a more frequent, rapid and accurate data collection [33].

The possibility to uniquely identify the entities involved in the processes under study is a key feature in traceability. Relevant entities in a given domain should be identified throughout its entire life cycle to ensure the proper functioning of traceability systems [8]. The most common technologies for identification rely on optical codes printed on a surface (e.g., linear [22] and 2D [30] barcodes) or electromagnetic tags (e.g., RFID [23]). These technologies make possible the electronic reading of tags at an affordable cost; particularly barcodes, which are the most widely used [31].

In general terms, traceability requirements vary depending on the context under consideration. The information to collect is established by the underlying needs and objectives of each organization (e.g., in the food sector, specific legislations must be enforced [5]). In this sense, after a comprehensive review of the scientific literature, it can be stated that there is a huge range of specific solutions to support traceability in different domains. For example, if we focus on the domain of the meat industry, we can find solutions such as the one discussed in [10], addressing the problem of livestock identification and tracking; or that described in [13], aimed to monitor conditions regarding the meat transport. Similarly, in [32] the introduction of RFID tags for tracking the cold chain in the meat industry is discussed. Such proposals are intended to cover specific traceability needs. As the reader may infer, it is not a simple task to directly apply such specific solutions from a certain context to other different context.

There are traceability proposals that address the problem of monitoring entities from a broader perspective. Currently, the EPCglobal Architecture Framework [11] is a collection of standards for hardware, software and data interfaces commonly used for logistic traceability. This solution is based on identifying each entity by a unique serial number etched on an RFID chip. Thus, whenever an identified entity goes through any given point in which an RFID reader is located, a record is automatically generated. The set of records configures a log of traces for the space-time location of all the identified entities.

This type of traceability solutions is specially designed to automate the recording of space-time variables. However, in many contexts, it is required to gather information regarding the environment or the status of the entity [14]. Even, there may be variables that must be manually monitored by a human user [20] (e.g. those that rely on her perception or her decisions). In those cases, the way the user interacts with the traceability system is key to reduce the errors and effort perceived for the task [7].

To the best knowledge of the authors, presently existing solutions in real usage scenarios, i.e. in the business domains of final application, that deal with these issues involve high operational costs and often require specialized equipment. This is especially true for big industries and corporations (e.g. the Cognex solutions for the automotive industry [6]). Besides, these solutions often require highly skilled personnel for its deployment. Additionally, the staff making use of the final system requires a training process for its proper usage. Thus, in many scenarios, organizations seek more direct traceability solutions, such as the deployment of custom modules that can be integrated into their enterprise management systems (e.g. ERPs) [36]. Therefore, it can be stated that the cost and complexity of existing solutions prevent their broad extension.

The conclusion of this succinct review of the state of art tends to suggest the lack of affordable and simple-to-reuse traceability solutions. Even as there are many solutions in the market, to the best knowledge of the authors, the definition and provision of highly customizable, effort-effective and interoperable software platforms for trace-making and data analysis in the industry sector are still a pending issue.

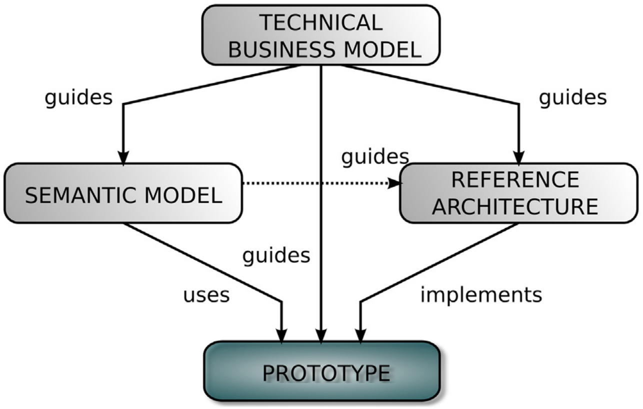

Fig. 1. Relationship among the proposed models.

3. Platform design

The methodology applied to develop the proposed software platform, the artifacts introduced and the materials used were based on a comprehensive approach that combines techniques from software engineering and knowledge engineering. This approach is based on the definition of three major models: Technical Business Model, Semantic Model and Reference Architecture (cf. Fig. 1). The construction of these models is carried out in a sequential way taking into account existing dependences among them. Eventually, derived from these models, it is possible to generate a prototype to evaluate the proposed platform.

This methodology has been proposed, and improved, by the research group to which the authors belong [25]. The methodology has been successfully applied to several projects pursuing the development of semantic-based solutions and systems (e.g. ITEC [2], eGovernment projects [24], and others). Next sub-sections discuss the development of the three models identified above.

3.1. Technical business model

The Technical Business Model is oriented to conveniently characterize the usage setting of the platform, as well as its functionality and the involved stakeholders, actors and generic data flows. Particularly, we start from the fact that in many scenarios, the leaders of organizations tend to plan the working procedures. It is their intention to establish protocols that minimize problems and avoid mistakes in products and services. In this regard, the application of the principles for quality control implicit in the HACCP approach [35] is a suitable mechanism. This approach is focused on the study of processes and their conditions in order to identify Control Points (CPs)[15]. CPs are spatial or temporal spots where it is required to monitor some variables in order to validate certain prerequisites. Logs of events are generated on them for traceability and auditing purposes. To properly handle them, in our platform, CPs (as products and services) are uniquely identified by means of tags, mainly QR codes (a type of 2D barcodes) or NFC tags (an affordable and easy to use alternative to RFID electronic tags).

The starting point for the use of our platform is a set of properly characterized CPs in a given workflow. This characterization defines the monitoring operations to be performed on them and the variables to be registered. Within this scenario, as shown in Fig. 2, an operator uses her smartphone to read a CP tag. The smartphone retrieves the CP information from the server,