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Business process semantic annotation suggestions in ERP systems

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ABSTRACT

Enterprise resource planning (ERP) systems are usually extremely large and combine various views of the business and the technical implementation perspective. Also, a very specific vocabulary has evolved into ERP systems. This vocabulary is not clearly mapped to business management concepts. The semantic web technology can be used in the context of an ERP to enable the absence of the automation process. The proposed solution exploits the use of the semantic web that significantly contributes to overcome the deficiencies rooting from the heterogeneity of information contents and semantics generated from various sources. In addition, ERP databases should be extended with semantic capabilities, specifically explicit descriptions of relationships and conceptualization of the entities detected in the relational model. In this paper, a core reference ontology (CRO) is built to provide metadata mapping between the various business process modeling notations. Also, domain ontology is constructed to be used in business process alignment. Ontologies include shared concepts about business process and data objects. Semantic similarity functions are applied to business process models and domain ontology concepts to increase the degree of automation of business process semantic annotation. Receiver Operating Characteristic (ROC) Curve analysis is performed between two collaborative business process models having a different level of abstraction. The implementation of the proposed solution results in significant enhancement of the Area under Curve (AUC) from .4 to .8.

1. Introduction

The Enterprise Resource Planning (ERP) system provides basic structures that are embedded in the system, and these need to reflect the structures in the organization. Thus, the problem with the implementation of ERP system is the risk of misalignment between the ERP system and the organization [1]. Lots of ERP implementations do not achieve their estimated benefits and fail to meet expectations due to underestimation of change management [2]. ERPs business process

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integration has traditionally been file-based, or batch oriented and worked well in the past since transactions were primarily inbound integrations. As ERPs expand to become a key data source of business information, there is a need to provide outbound data from the ERP to other systems in the enterprise [3]. ERP systems face challenges results from the need of different modules for different vocabulary and concept hierarchy as they are enormous and combine various views from the business and the technical implementation perspective [4].

To the best of our knowledge, most of ERPs have a weakness to deal with integration with other systems. ERP system may not fulfill all the enterprise requirements which lead companies not to abandon their legacy systems and tend to integrate the functionality from disparate applications into a business infrastructure. Bottom-up efforts are needed to integrate isolated legacy systems; this may imply format conversion efforts, and human intervention because of the lack of compatibility. In addition, ERPs have semantic interoperability problems. Terms are used differently for the same concept in two systems e.g. 'Client', 'purchase' in System A and 'Customer', 'buy' in system B [3]. Sometimes the same term can have different interpretations, which makes it hard to share knowledge. The same words can give different meanings to various cultures and backgrounds e.g. 'Quotation'. There are also conceptualization mismatches, e.g. 'City' is a class in system A, and it is an attribute of another class in system B; 'finish' is an action in system A but it is a state in system B [5].

Apparently, the semantic web technology can be used in a localized context such as ERP for organizations, yet giving an edge for integrating and sharing business as specific web services to outside world. The semantic web is defined as "The Web provides a common framework that allows data to be shared and reused across application, enterprise and community boundaries" [6].In semantic web, the information will have a well-defined meaning and this will enable the computers to know how to process the information. Therefore, we can conclude that ERP system does not offer an integrated solution, but it amplifies the need for integration when they attempted to incorporate other applications with ERP system. In our opinion, most of these challenges can be significantly dealt with by applying SW technology in ERP systems.

Against this background, this paper provides the following contributions. We discuss the strengths of the proposal for utilizing semantic annotation in facilitating integration with ERP systems without the need for standardization. We introduce a method for embedding semantic process modeling in existing enterprise application such as ERP. Also:

A. Introducing semantics-oriented metadata models through building CRO-ontology
B. Proposing Domain-specific semantic business logic layer through building CRM- ontology.
C. Providing business process semantic annotation suggestions through finding semantic similarity between business process activities and concepts in proposed ontologies.
D. Performing ROC Curve to measure profile consistency between business process activities.

The remainder of this article is structured as follows. Section 2 we review related work. Section 3 we illustrate the proposed method based on the semantic annotation to facilitate integration with ERP systems. We report on our results of applying ROC Curve to the data set in section 4. Finally, we conclude and state the future work in Section 5.

2. Related Works

ERP implementation through internal enterprise systems depends on standardization of data, business processes, and re-engineered business logic. Also, ERP systems support generic processes and best practices with organizations attempting to parameterize ERP packages to support better their business processes [7]. Therefore, ERP systems have integration issues and may have failed to achieve application integration because it does not cover all Information Technology (IT) requirements, and they cannot meet all business processes [8], so they are supposed to be customized.

There are existing common approaches to ERP integration, and each provides their unique strengths and weaknesses as illustrated in Figure 1. Point-to-Point Businesses often choose point-to-point integration in which each new application added to the enterprise will require a new integration into the ERP system and each existing application. Over time, this integration method becomes more complex and creates tightly coupled dependencies that can become brittle as the enterprise grows, thus it fails to realize the long-term complications [1].

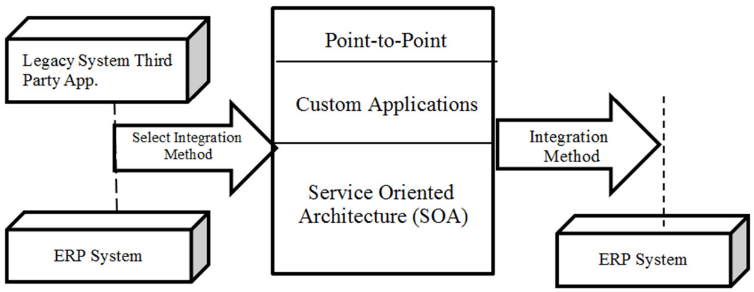

Fig. 1. Existing ERP Integration Approaches

Alternatively, businesses can choose to build their own custom integration applications [9]. These often start as simple data transfer tools, but as organizational requirements expand and they begin to use multiple ERP vendors, companies find that they need to build more and more adaptors which become a large maintenance cost, compounded by the consistent evolution of protocols and complexity in ERP upgrades. The next alternatives for ERP integration are Service Oriented Architecture (SOA) stacks [10]. The primary advantage of utilizing SOA stack is that it creates a relatively robust integration architecture that can address most use cases. Applications are loosely coupled so when changes are needed they can be quickly addressed. However, SOA stacks involve multiple products which all must be deployed and configured. A full SOA implementation utilizing one of these stacks can take multiple years and extraordinary upfront costs. Therefore, there is a need to employ new technology to integrate disparate enterprise business applications with ERP.

Semantic web technology can be used in the context of an ERP system to enable the lacking automation process and overcome the shortages rooting from the heterogeneity of information. A model was proposed for automating enterprise resource planning data semanticization through Formal Concept Analysis (FCA) derivation based on the ERP relational database existing in most companies [11]. Semantic Web ontology principles can contribute in presenting prototype model for the design and development of ERP training material where both the multimedia objects used in training scenarios and the knowledge built into them are captured and fully reusable [12]. Ontologies and automatic annotation of large HTML can be utilized by System Analysis and Program Development (SAP) ERP software documentation in order to improve the usability and accessibility [13]. The role of semantic web technology in Enterprise Application Integration (EAI) considers as a vital role as EAI focuses on the syntactic integration of application interfaces on an implementation technology level [14]. Ontologies can be used to semantically map concepts among information systems formats achieving integration using Service Oriented Architecture-enabled (SOA) workflow automation through ontology-driven approach [15]. In [16], the representational requirements of Semantic Business Process Management (SBPM) were defined as the approach of increasing the level of automation in the translation between business perspective and the systems perspective of enterprises.

To summarize, the listed papers utilize the ability of semantic web in automating ERP data but from different perspectives. There is a lack of having a way to embedded semantic process modeling in existing organizational structures. Our proposed solution is complementary to these works, as by using it, we assume that correspondences of two process models in different ERP systems have been identified and captured seamlessly to convert ERP system to fully integrated system regarding business process and data.

3. Proposed Method

To provide integration between collaborative business process models, objects, and rules we need to find matches between them. Semantic model annotation helps to achieve this target by annotated business process, objects, and regulations to domain ontology. By Annotating business process model for each system to the domain ontology, the problem of integration of systems is reduced to the problem of mapping between the models. Also, the proposed method uses semantic similarity function to provide automatic annotation between business process models and the ontology concepts. It consists of four steps. First, the business workflow is modeled with one of modeling language notation. Second, core reference ontology is built and is used for mapping metadata of different business modeling language. Third, domain ontology is built and is used for mapping the business process behavior; finally, semantic annotation suggestion is used to increase automation. Figure 2 illustrates the semantic annotation process.

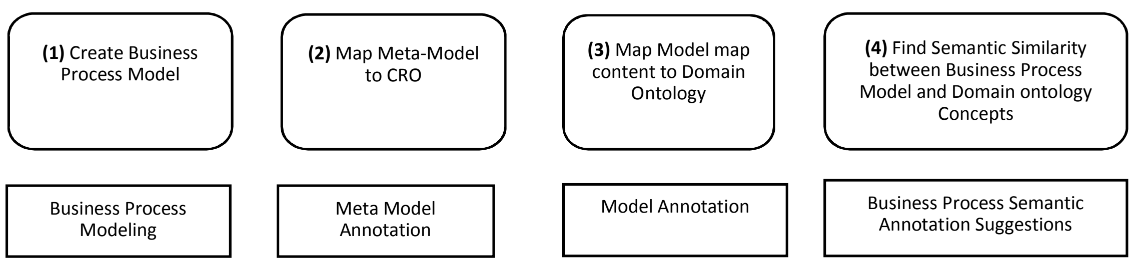

Fig. 2. Semantic annotation process for the proposed method

3.1 Ontology-based Representation of Business Process Model

The ontology-based framework exemplarily contains classes for workflow pattern, actors, activities, events as relevant elements of an enterprise description. In addition to classes, the example ontology contains instances, which symbolizes a member of a class. In the course of the framework, our ontology will be used to specify the model element-specific semantics of the elements of an Event Process Chain model (EPC) [17] and Business Process Management Notation model (BPMN) [18]. To specify the semantics of model elements through relations to ontology concepts, we will use BPMN model as an example. The BPMN first must be represented within the ontology which is referred in the proposed solution as CRO (see figure 3). Regarding the representation of the BPMN in the ontology, one can differentiate between representations of BPMN-language constructs and a representation of BPMN-model elements. BPMN language constructs such as “Task” or “event” but BPMN-model elements are represented as an instance of ontology as "customer approval", as well as the control flow is created in the ontology as classes and properties.

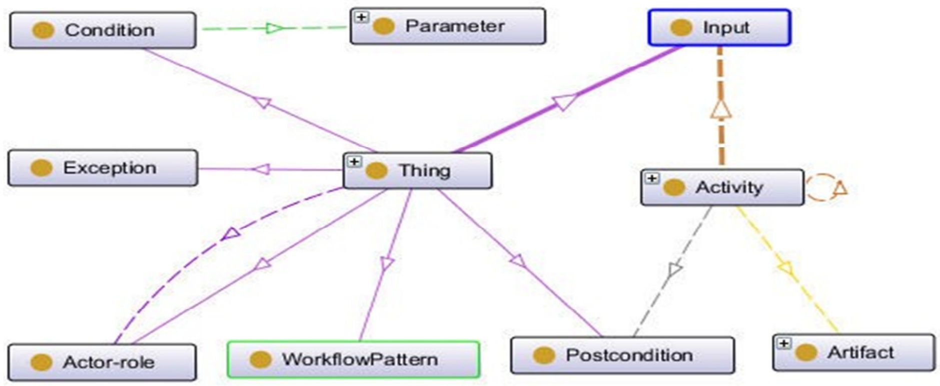

Fig. 3. Core Reference Ontology (CRO)

3.2 CRM Domain Ontology

A CRM reference model has been developed to describe the standard business activities associated with all phases of satisfying a customer's demand in any Customer Relationship Management system (CRM). As standards, the model can be formalized as reference ontology for customer relationship management domain. We are focusing on process element level which is decomposing the process categories into the process elements as clarified in Figure 4.

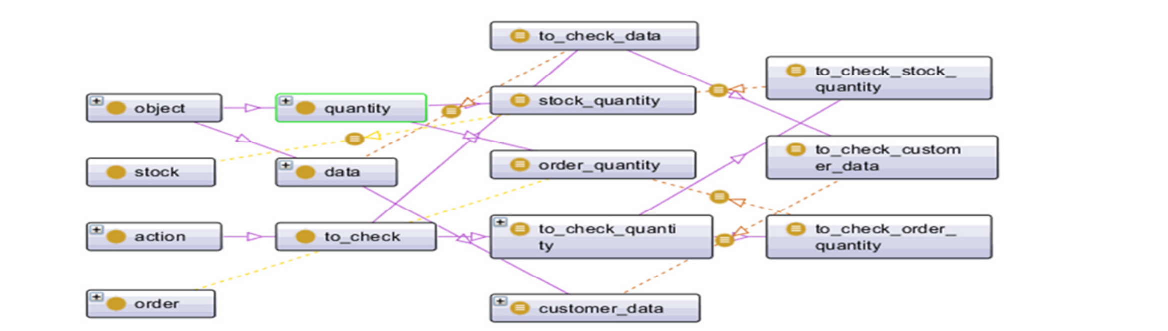

Fig. 4. Part of business domain ontology (CRM Ontology)

3.3 Business Process Semantic Annotation Suggestions

In the case of concepts absence in business domain ontology that relate to specific instances, we need to suggest the closest concept to increase the degree of atomization in the annotation process. The choice of the suggestions is based on the semantic similarity between BPMN element label and ontology concepts: the higher the similarity measure is, the higher the score that will be given to the candidate ontology concept c as a possible semantic annotation for the element label. The matching Candidate Semantic Pair in [19] CSP (W_l, W_c) between the words in label l and the words in concept c is built in the following steps:

A. given V (l) and V (c), the set of verbs in l and c respectively, the pair of verbs (v_l, v_c), with v_l ϵ V (l) and v_c ϵ V (c) located higher in the parsing trees of the sentences in l and c, is added to CSP $(W_{cll};W_{clc})$

B. the pair composed of the respective objects $(o(v_{cll}); o(v_{clc}))$ where o(v_l) $\rightarrow_{obj}$ v_l and o(v_c) $\rightarrow_{obj}$ (v_c) is added to CSP(W_l, W_c) (when both verb objects exist);

C. the pair composed of the object specifiers (s(o(v_l)); s(o(v_c))), where s(o(v_l)) $\rightarrow_{nn}$o(v_l) and s(o(v_c)) $\rightarrow_{nn}$ (o(v_c)) is added to CSP(W_l, W_c) (when both object specifiers exist);

The CSP and the semantic similarity are computed between the two sentences based on the next formula.

$$Semsim_{sentance(l,c)} = \frac{\sum_{i=1}^{t}(\omega_i \times f_{ics(t_l,t_c)})}{\sum_{i=1}^{t}\omega_i} \quad (1)$$

Where ω_i is weights to the semantic similarity measures (i.e., the verb has greater importance than the object, in turn more important than the specifier) and $f_{ics(t_l,t_c)}$ is semantic similarity function [19].

4. Results

The semantic-based framework is applied on a real case study [20]. The case study describes process models (depot repair process [21,22]) which are modeled by different modeling languages. Three business process models are used to describe the different depot repair business case scenarios of two systems SAP reference model and Oracle CRMs.

Receiver Operating Characteristic (ROC) Curve analysis is performed [23]. The ROC Curve is a plot of values of the False Positive Rate (FPR) versus the True Positive Rate (TPR) for all possible cutoff values from 0 to 1. It is a relationship between sensitivity and 1-specificity. Test sensitivity is the ability of a test to correctly identify those with the disease for example (true positive rate), whereas test specificity is the ability of the test to correctly identify those without the disease (true negative rate). ROC curve clarifies the profile consistency for the business process models activities and events in the current ERP system and after applying proposed solution (See Figure 5) is increased. Profile consistency aims to measure how many activities and events with a different level of abstraction are consistent and have same behavior although they have different business activities or events. The green curve represents the case study handled by the proposed solution and the blue curve represents same case handled by existing solution mentioned in the related work. We can observe that area under green curve is more than area under blue curve and therefore, the proposed solution enhances the profile consistency of business process models and increases the ability to discriminate between consistent and inconsistent business process activities.

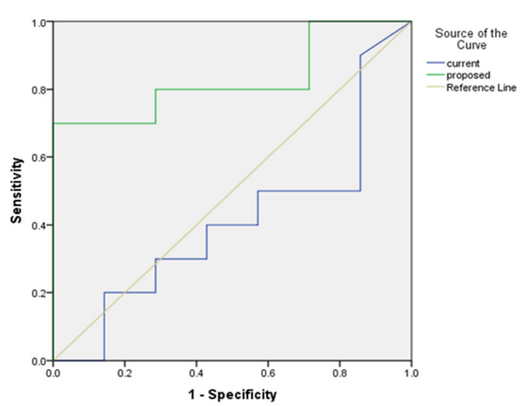

Fig. 5. ROC curve for existing ERP solution and proposed solution for semantic based ERP model

We can observe from Table 1 that higher the ROC curve becomes, the better fit can be achieved. In fact, the area under the curve (AUC) can be used for this purpose. The closer AUC is to 1 (the maximum value) the better the fit. Values close to 0.5 show that the model's ability to discriminate between success and failure. The table clarifies that that AUC for consistency degree after applying proposed method increased from 0.4 to 0.8.

Table 1
Area under curve for ROC (AUC)

Test Result Variable(s)	Area	Std. Error	Asymptotic 95% Confidence Interval	
			Lower Bound	Upper Bound
Existing solution	0.407	0.145	0.122	0.692
Proposed solution	0.829	0.103	0.626	1.000

5. Conclusions

ERP systems need an efficient method to enable systems interconnectivity in order to seamlessly provide system integration. Because each system possesses its own data format and protocols, the challenge rests in adaptation between the systems. The core of this paper is to exploit how vital the semantic interoperability is in exchanging ERP data and process models, integration between ERP and other applications, and knowledge sharing between different enterprises. In this paper, we used semantic technology to formalize ERP data, business process models enriched with semantic annotations into a knowledge base. Two-level semantic interoperability of process templates: meta-model level through using CRO and model level through using CRM_ontology were presented. Semi-automatic techniques are presented to support business designers in the semantic annotation of business process models

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