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A process ontology based approach to easing semantic ambiguity in business process modeling

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ABSTRACT

Business process modeling continues to increase in complexity, due, in part, to the dynamic business contexts and complicated domain concepts found in today's global economic environment. Although business process modeling is a critical step in workflow automation that powers business around the world, business process modelers often misunderstand domain concepts or relationships due to their lack of precise domain knowledge. Such semantic ambiguity affects the efficiency and quality of business process modeling. To address this problem, a Process Ontology Based Approach is proposed to ease semantic ambiguity by providing a means to capture rich, semantic information on complex business processes through domain specific ontologies. This approach is grounded in the Bunge–Shanks Framework to semantic disambiguation and evaluated using an expert survey as well as a controlled laboratory experiment.

1. Introduction

Business process modeling, which forms the core part of business process management, is challenging because it is a knowledge intensive endeavor, requiring an accurate understanding of both domain knowledge and process logic [21]. Process modeling is “an area where artists meet scientists, internal knowledge workers meet external knowledge owners, and business meets IT (information technology)” [42]. A process model is a conceptual model of how businesses conduct their operations, by specifying relevant activities, events, states, control flow logic, and so forth [39]. Furthermore, a process model is critical for business process optimization and automation and often represented in a standardized graphical notation, such as Petri nets [41], Business Process Model and Notation (BPMN) [57], or Event-driven Process Chain (EPC) [43]. Although formal methodologies and business solutions have been proposed to model business processes, most process models are still designed manually by business analysts or system designers with limited quality control [28,34].

Modeling a business process requires both domain knowledge and technical modeling skills to identify and represent the tasks, activities, and procedures in a particular business domain [33]. However, when the underlying domain becomes larger and more complex, as in today's global business environment, accurately understanding a domain can be difficult, especially for a modeler who is not familiar with that domain. The complexity of a business domain and lack of domain knowledge in a modeler's mind usually lead to semantic ambiguity, which means that a precise (one-to-one) mapping is not easy to identify between domain concepts and their relevant business process model constructs (e.g. roles and activities). Semantic ambiguity, in turn, can lead to high cognitive load for the modeler, resulting in over-specification or under-specification, thus reducing the quality of a process model [18].

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The objective of this research is to develop a process ontology based approach to resolving semantic ambiguity in business process modeling, which we refer to as the *Process Ontology Based Approach* (*POBA*). The approach is based on cognitive load theory and intended to help reduce semantic ambiguity by avoiding problems such as construct overload (one modeling construct stands for two or more ontological constructs) and construct redundancy (more than one modeling construct is used to represent a single ontological construct). The contribution of this research is to create a systematic approach to ontology based modeling in business process management that reduces semantic ambiguity. Classes for a domain process ontology are formally defined to guide business process modeling. The research also attempts to advance and deepen the theoretical explanation of the role of ontologies in conceptual business process modeling from a cognitive load perspective. The potential, real-world impact of this research could be far-reaching because any improvement in the efficiency and quality of business process modeling could help improve business productivity in companies worldwide that run their business via workflow automation.

The next section reviews related research on business process modeling and ontology-based conceptual modeling. Then, the process ontology based approach (POBA) is presented in three phases: domain process ontology construction, model generation, and model validation. POBA is illustrated with an auction domain example and an empirical evaluation of POBA carried out. POBA's effectiveness and usefulness are analyzed, and the research implications and limitations are discussed before concluding the paper.

2. Related research

Business process modeling, which plays a key role in workflow automation that drives worldwide business [27,37], represents enterprise processes via modeling tools. High-quality models help reduce organizational costs and improve efficiency [20]. Process modeling, however, is usually manual and error-prone [28], with the process quality largely dependent upon the level of the domain expertise of the modeler. Workflow technology is a standard solution for business process management because a workflow represents a business process from functional, behavioral, informational, operational, and organizational perspectives [46,48].

2.1. Semantic issues in business process modeling

Design ambiguities in process modeling are structural or semantic [34]. Structural ambiguities arise when a modeling language does not provide a formal definition of modeling constructs. Semantic ambiguity is a phenomenon that occurs when a precise (one-to-one) mapping between two concepts is lacking [13,17,54]. It arises when a business process model does not convey the underlying business logic correctly. In business process modeling, semantic ambiguity arises when one model construct is used to represent multiple domain concepts or vice versa. For example, in a loan approval process of a bank, a loan application must be verified in two steps: 1) the local branch verifies the validness of loan application material; and 2) the credit management department verifies the credit score of the applicant. If the modeler is not clear about the domain knowledge, he or she may simply develop a loan approval process with one step of verification. In this example, two constructs in domain knowledge (verify application material and verify credit score) are mapped to one business process model construct (loan verification). Such issues are referred to as semantic ambiguity in business process modeling. As a result, a modeler may need to iterate with domain experts to understand the precise logic.

Although previous process modeling methods offer different perspectives on the analysis of business processes, they do not address semantic ambiguity problems directly [20]. One reason is the semantic gap between the understanding of business process modelers and the real world phenomena [22]. As shown in Table 1, most formal methods focus only on resolving structural ambiguity. Although some studies [10,28,30,31,55] propose to improve the semantics of business process models by enforcing business rules, the issue of semantic ambiguity remains.

Ambiguity of requirements in natural language is well recognized [9]. However, approaches to solving ambiguity in natural languages cannot be directly applied to business process modeling. First, these approaches assume that all requirements are documented in natural language. In practice, however, requirements may be represented in many formats, such as casual diagrams, data sample, verbal interview, business reports, etc. Second, these approaches use natural language processing techniques and cannot accurately identify all ambiguities [58]. In response, POBA requires domain experts to build or acquire accurate domain

Table 1
Formal business process modeling methods.

Study	Characteristics	Resolve structural ambiguity?	Resolve semantic ambiguity?
[52]	Petri net-based	Yes	No
[3]	Metagraph-based	Yes	No
[27]	Grammar-based	Yes	No
[40]	Criteria-based	No	No
[28]	Business logic-based	Yes	Limited
[6]	Entity-centric	No	No
[51]	Simulation-based	No	No
[48]	Dataflow-based	Yes	No
[55]	Policy-based	Yes	Limited
[49]	Reference-based	Yes	No
[30]	Compliance-based	Yes	Limited
[15]	Declarative modeling	Yes	Limited
[4]	Semantic building block	Yes	Partially