Business Process Model Annotation Techniques: Identification, Classification and Analysis

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Abstract
Enterprises have to maintain a large collection of business process models. These models are annotated with additional semantic information to enhance the searching, comprehension and understanding of the models. However, such enhancement of the models is an time-consuming, error-prone and labor-intensive task. Therefore, several attempts have been made to develop techniques for annotating these models with additional semantic information. To the best of our knowledge, no attempt has been made for the identification and analysis of these annotation techniques which has thwarted the advancement of these techniques. To that end, this study has employed a systematic approach to identify a comprehensive set of annotation techniques. Secondly, a taxonomy of these annotation techniques is developed to classify these techniques based on their underlying annotation mechanism. Finally, an analysis and comparison of the automated and semi-automated techniques is performed. The study concludes that there is a need for developing the next generation of techniques that can automatically annotate process models with the semantic information.

Keywords
Software engineering, Business process modeling, Semantic annotation, Annotation techniques, Classification, Taxonomy

1. Introduction

Business organizations are continuously evolving as new business use cases are regularly defined and the existing ones are modified to fulfill the customer needs. Consequently, the underlying business processes are changing and new processes are also added [1]. The effective management of business process, which includes designing, implementation and improving business processes, has unleashed the Business Process Management (BPM) discipline. Formally, a business process is the collection or sequence of steps that are performed in a certain order to achieve a business goals. The formal representation of business process is called business process model which are designed using process modeling languages.

A majority of the stakeholders cannot search, comprehend and use process models due to the intricacies of process modeling languages. To address that challenge, process models are enriched with some additional semantic information. A considerable number of studies have been conducted on the annotation of process models with semantic information and the development of annotation techniques. However, little attempts have been made to classify and analyse the techniques used for the annotation of business process models which has thwarted the advancement of these techniques. To that end, this study has made the following key contributions:

- A systematic literature review protocol is employed to identify a comprehensive set of process model annotation techniques.
- An iterative and bottom-up approach is used to develop a taxonomy of the annotation techniques.
- Finally, analysis of the automated and semi-automated techniques is performed to identify the strengths and weaknesses of the techniques.

This study has the following key research questions.

- RQ1. What research studies have been conduction on the development of process model annotation techniques?

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- RQ2. What are the different types of techniques used for the annotation of process models?
- RQ3. What are the strengths and weaknesses of process model annotation techniques?

The rest of the study is organized as follows: Section 2 discusses the systematic approach used for searching and screening of relevant literature along with extraction and coding of annotation techniques. Section 3 presents the taxonomy of the annotation techniques that is proposed in this study. An analysis of the techniques is presented in Section 4. Finally, Section 5 concluded this study.

2. Identification of annotation techniques

This section presents the first contribution, identification of annotation techniques. It is a three-phase procedure that is inspired by the Kitchenham's guidelines for conducting a systematic literature review [2]. In particular, it includes searching for literature, and employing relevance screening for identifying the relevant studies, and extracting and coding of the relevant annotation techniques for the development of an artifact. The details of of the procedure are as follows.

2.1. Literature search

For the comprehensiveness of search, we have performed searching through multiple digital libraries, which includes IEEE Xplore, ACM Digital Library, SpringerLink, Sciencedirect, Taylor Francis Online and Emerald Insight. The primary search is limited to peer-reviewed journal articles, conference and workshop proceedings. That is, white papers, newspaper articles and posters, are excluded from the search. Furthermore, the search is limited to the English articles published since the year 2002.

For the searching, relevant search terms and their combinations are used. The search terms are, business, process, model, and annotation. Additionally, query expansion is performed by adding synonyms and other related words. Table 1 presents complete Boolean search string. For performing the search, advance-searching features of electronic databases are used. In some cases, search strings are customised to fulfill the specific requirements of the target database. As search string query provides results in large quantity therefore only the top 1000 relevant references are considered. All electronic databases, except Taylor and Francis, provide the facility to export all the search results to a spreadsheet. The search results of the electronic databases were exported in a single go, whereas the search results of Taylor and Francis were exported one-by-one.

Table 1
The boolean expression used for the literature search.

The Boolean expression
("Process" OR "Business Process" OR "Process Model" OR "Business Process Model") AND ("Annotation" OR "Tagging" OR "Taxonomy" OR "Repository" OR "Classification" OR "Categorization" OR "Categorisation" OR "Labelling" OR "Grouping")

2.2. Relevance screening

For the relevance assessment of the searched studies, Inclusion (I) and Exclusion (E) criteria and a screening procedure are defined. The criteria are as follows.

- Does the study discuss the mechanism of annotating of process models or its elements? (I)
- Does study annotate models or its elements with predefined labels? (I)
- Does it annotate models with run-time generated categories? (I)
- Does study annotate with domain ontologies with predefined concepts? (I)
- Does study annotate with semantic similarity measurement? (I)
- Does study discuss any mechanism regarding business process models except their annotation like business process model verification, similarity and generation etc.? (E)
- Does study conducted survey or interview only regarding business process model annotation? (E)

2.3. Screening procedure

Screening procedure is composed of three steps. In the first step, a single team member performed screening based on title and keyword of each study and marked it as relevant, irrelevant or ambiguous. During this screening step, a study was marked as relevant or irrelevant based on a sound reasons. For the quality assurance, the second team evaluated the correctness of relevant and irrelevant studies based on a random selection. In the second step,

relevance screening was performed in the same manner based on the abstract, summary or conclusion of the studies. In third step, full text of the shortlisted studies was identified and the relevance assessment step was repeated based on the complete content. Any disagreement between the decisions of both team members were resolved with the consensus. As a result of the literature search and screening procedure 56 relevant studies were identified that are used in the rest of the study.

2.4. Data extraction and coding

To collect the details about annotation techniques, we extracted some specific details about the annotation techniques in order to understand their mechanism. These following nuggets of information were extracted.

- The mechanism used for annotation of process models, clustering based, rule-based, etc.
- The level at which the annotation is performed, process model level, elements level or both.
- The mechanism used for defining the annotation concepts, predefined or runtime.
- The annotation concepts used by the technique, generic annotation concepts, domain-specific or both.
- The level of automation of the annotation technique, automatic, semi-automatic or manual.
- Implementation of the proposed artifacts, if available.

Two researchers independently extracted the information discussed above. The results of the data extraction were recorded and conflicts were resolved by the consensus approach. In some cases, the results were retraced back to full-text to develop consensus. Accordingly, the generated information was generated for use in the rest of the study.

3. Taxonomy of the Annotation Techniques

Figure 1 presents the taxonomy of annotation techniques for process model annotation that we have developed. It can be observed from the figure that annotation techniques are firstly classified based on the level of automation, Automatic, Semi-automatic and Manual. A techniques that annotates process models without any human involvement are classified as Automatic annotation techniques. For instance, [3] proposed a technique that takes input labels of a process model element as input and assigns it a labelling style without any human intervention. In contrast, the techniques that provide a list of recommendations for annotating process models, and requires human experts to select the most appropriate annotation value are categorized as semi-automatic annotation techniques. The cases in which humans are required to perform the annotation manually are classified as Manual annotation techniques.

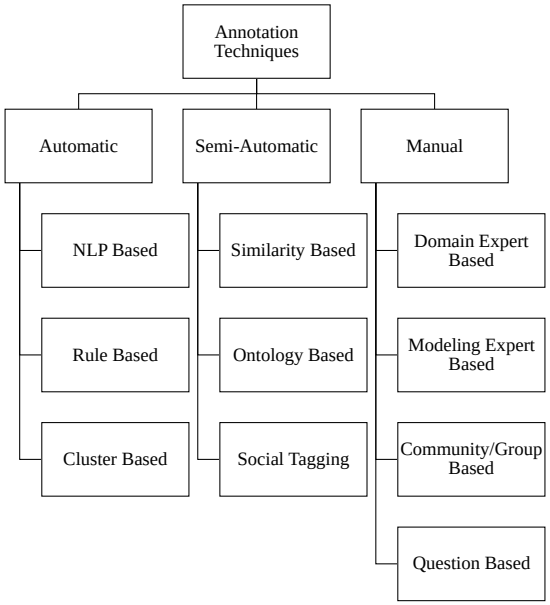

Figure 1: Taxonomy of the annotation techniques.

For the second-level classification, the automatic annotation techniques are categorized into three sub-categories, Natural Language Processing (NLP) based, Rule based and Clustering based. The techniques that automatically annotate process models using the text processing tools are categorized as NLP based annotation techniques. The techniques that automatically annotate the different parts of process models based on predefined rules are categorized as rule based annotation techniques. The annotation techniques that use clustering to group process models for the annotation are referred to as clustering techniques.

The semi-automatic annotation techniques are further classified into three sub-categories: similarity based, ontology based and social tagging based annotation techniques. The techniques that automatically generate recommendations using textual

Table 2
Distribution of the annotation techniques.

Level 1	Level 2	Count
Automatic	Cluster based	3
	NLP based	11
	Rule based	4
	Total	**18**
Semi-Automatic	Ontology based	5
	Similarity based	15
	Social Tagging	4
	Total	**24**
Manual	Community/Group Based	11
	Domain Expert	71
	Modeling Expert	38
	Question Based	6
	Total	**126**
	Grand Total	**168**

similarity techniques are categorized as similarity based techniques. The annotation techniques that automatically generate ranking list of most related ontology concept are categorized as ontology based semi-automatic annotation techniques. Whereas, the annotation techniques that provide a social platform to the users for assigning tags to process model using their knowledge, and afterwards uses machine learning techniques to automatically annotate process models are categorized as social tagging based semi-automatic annotation techniques.

The manual annotation techniques are further classified into four sub-categories: Domain Expert based, Modeling Expert based, Community based annotation and Question Based annotation. The annotation techniques in which domain experts manually annotate process models are categorized as domain expert based techniques. While, the techniques in which modeling experts manually annotate process models are grouped into modeling expert based annotation techniques. The annotation techniques in which a community or a group of people annotate process models in a controlled environment are classified as community based annotation techniques. Whereas, the annotation techniques in which an ordinary person can annotate process models by answering the predefined questions are categorized as question based annotation techniques.

Table 2 presents the distribution of the annotation techniques. It can be observed from the table that a vast majority of the annotation techniques falls in the Manual category, whereas there is scarcity of Semi-automatic and Automatic annotation techniques. This indicates that there is a need for development of Semi-automatic and Automatic annotation techniques. From the distribution of Semi-Automatic category it can be observed that most of the techniques use Similarity based annotation techniques, whereas for the Automatic techniques, researchers mainly focused on NLP based annotation techniques which merely annotates process model elements.

4. Analysis of the Annotation Techniques

The third contribution of this study is analysis of the annotation techniques. In particular, we focus on two types of techniques, automated techniques and semi-automated techniques. The analysis and comparison is based on the five criteria, Annotation Mechanism, Level of Annotation, Annotation Concepts, Type of technique and Implementation of the proposed solution. Where, Mechanism represents that the proposed technique belongs to in which sub-category of taxonomy. Level of Annotation represents that the proposed technique performs annotations to a process model or elements of the process model. Concepts list represents that the proposed technique uses a predefined list of annotation concepts or it generates new labels at run-time. The fourth criterion, type of technique, represents whether the proposed approach uses a supervised approach or not, whereas the fifth criterion represents whether a prototype/tool is developed to demonstrate the annotation of process models.

4.1. Automatic Techniques

Table 3 presents the analysis and comparison of automatic process model annotation techniques. The first notable observation is that a majority of techniques employs an NLP based mechanism for the annotation, whereas little attention has been paid to the development of Clustering and Rule based techniques. One possible reason stems from the maturity of NLP discipline. The second notable observation is that a majority of the annotation techniques perform annotations at repository level, meaning that an annotation is assigned to a complete process model. Furthermore, it can be observed that all the Clustering and Rule based techniques propose repository level annotations. In contrast, NLP based techniques perform annotation at repository level as well as at the model level. It is pertinent to mention that no effort has been made to propose such technique that performs both model and repository level annotations.

Table 3
Analysis of the automatic annotation techniques.

Ref.	Mechanism	Annotation Level	Concepts list	Supervised	Prototype
[4]	Clustering	Repository	Runtime	✘	✔
[5]	Clustering	Repository	Runtime	✘	✔
[6]	Clustering	Repository	Runtime	✘	✘
[7]	Clustering	Repository	Runtime	✘	✘
[3]	NLP based	Model	Predefined	✘	✘
[3]	NLP based	Model	Predefined	✘	✘
[3]	NLP based	Model	Predefined	✘	✘
[8]	NLP based	Model	Predefined	✘	✔
[3]	NLP based	Model	Predefined	✘	✘
[9]	NLP based	Repository	Predefined	✘	✔
[10]	NLP based	Model	Predefined	✘	✔
[10]	NLP based	Repository	Predefined	✘	✔
[11]	NLP based	Model	Predefined	✘	✘
[11]	NLP based	Model	Predefined	✘	✘
[12]	NLP based	Repository	Predefined	✘	✘
[13]	Rule based	Repository	Runtime	✘	✘
[14]	Rule based	Repository	Runtime	✘	✔
[15]	Rule based	Repository	Runtime	✘	✘
[16]	Rule based	Repository	Predefined	✘	✔

The third notable observation is that a large majority of automatic annotation techniques use predefined classes for the annotation, whereas some techniques generates annotation information at the runtime. A further analysis of the techniques revealed that all the NLP based techniques use predefined concepts for the annotation, whereas the Clustering techniques used runtime generated concepts for the annotation. It can also be observed from the table that none of the annotation techniques employ supervised learning techniques for the annotation, although several research domains have benefited from the supervised learning techniques. Therefore, we recommended to propose supervised learning techniques for the annotation. Finally, it can be observed that merely seven automatic annotation techniques are evaluated practically by developing a prototype applications, whereas, all the remaining eleven automatic annotation techniques merely demonstrated the effectiveness using illustration.

4.2. Semi-automatic Techniques

Table 4 presents the analysis and comparison of semi-automatic process model annotation techniques. The first notable observation is that a majority of techniques employs Similarity based mechanism for the annotation, whereas little focus has been placed to the development of Ontology and Social Tagging based techniques. It shows the maturity of Similarity domain for the semi-automatic annotation of process models. The second notable observation is that a small majority of the annotation techniques perform annotations at model level, i.e. annotations are performed with the element of process model. Furthermore, majority of Ontology based techniques perform annotations at the model level. Whereas, Similarity based techniques performs annotation at repository level, as well as at the model level. It is also pertinent to mention that no effort has been made to propose a semi-automatic technique that performs element and model level annotations.

The third notable observation is that a large majority of semi-automatic annotation techniques use predefined classes for the annotation, whereas some techniques generates annotation information at the runtime. In contrast to automatic annotation techniques, there are three semi-automatic techniques that deals with both predefined and run-time generated annotation concepts. A further analysis of the techniques revealed that all Ontology based techniques have used predefined concepts for the annotation, whereas the majority of Social Tagging based techniques have used runtime generated.

It can also be observed from the table that none of the semi-automatic annotation technique employs supervised learning approach for the annotation. Moreover, it can be observed that in contrast to automatic annotation techniques, a large majority of semi-automatic annotation techniques are evaluated practically by developing a prototype, whereas,

Table 4
Analysis of the semi-automatic annotation techniques.

Ref.	Mechanism	Annotation Level	Concepts list	Supervised	Prototype
[17]	Ontology	Model	Predefined	✘	✔
[18]	Ontology	Model	Predefined	✘	✔
[19]	Ontology	Model	Predefined	✘	✔
[20]	Ontology	Model	Predefined	✘	✘
[17]	Ontology	Model	Predefined	✘	✔
[18]	Ontology	Model	Predefined	✘	✔
[21]	Ontology	Model	Predefined	✘	✔
[21]	Ontology	Repository	Predefined	✘	✔
[22]	Similarity	Model	Predefined	✘	✔
[23]	Similarity	Model	Predefined	✘	✔
[24]	Similarity	Model	Predefined	✘	✔
[25]	Similarity	Repository	Predefined	✘	✘
[25]	Similarity	Model	Predefined	✘	✘
[26]	Similarity	Model	Predefined	✘	✔
[27]	Similarity	Model	Predefined	✘	✘
[19]	Similarity	Model	Both	✘	✔
[19]	Similarity	Repository	Both	✘	✔
[28]	Similarity	Repository	Predefined	✘	✘
[29]	Similarity	Repository	Predefined	✘	✘
[28]	Similarity	Model	Predefined	✘	✘
[29]	Similarity	Model	Predefined	✘	✘
[30]	Similarity	Model	Predefined	✘	✔
[31]	Similarity	Model	Predefined	✘	✔
[32]	Similarity	Model	Predefined	✘	✔
[33]	Similarity	Repository	Runtime	✘	✘
[34]	Similarity	Repository	Runtime	✘	✔
[35]	Similarity	Repository	Runtime	✘	✔
[36]	Social Tagging	Repository	Both	✘	✔
[37]	Social Tagging	Repository	Runtime	✘	✔
[38]	Social Tagging	Repository	Runtime	✘	✘
[39]	Social Tagging	Repository	Runtime	✘	✘
[40]	Social Tagging	Repository	Runtime	✘	✔

eight semi-automatic annotation techniques merely illustrated the use of the proposed techniques. It shows the maturity of semi-automatic annotation techniques regarding their practical evaluation. Finally, further analysis of Similarity based annotation techniques revealed that recommendation based semi-automatic annotation techniques can be automated by employing a ranking or other statistical procedures.

5. Conclusion

In this study, we have employed a systematic procedure to identify 56 studies that proposed techniques for the annotation of process models. Subsequently, a taxonomy of the annotation techniques has been developed by employing a bottom up approach. The taxonomy can serve as a reference for research community of this domain. Lastly, an analysis of automated and semi-automated techniques is presented. The analysis of the results revealed the existence of research gap for the partial or fully automation of annotation techniques. One notable gap is that little attention has been paid on the development of an automated or even semi-automated techniques. Secondly, there are vast opportunities to benefit from the advancements of machine learning techniques to develop fully automated techniques. Also, there is a need for developing next generation of annotation techniques that can perform annotation at model level, as well as at the element level.

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