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An Intelligent Graph Edit Distance-Based Approach for Finding Business Process Similarities

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Abstract: There are numerous application areas of computing similarity between process models. It includes finding similar models from a repository, controlling redundancy of process models, and finding corresponding activities between a pair of process models. The similarity between two process models is computed based on their similarity between labels, structures, and execution behaviors. Several attempts have been made to develop similarity techniques between activity labels, as well as their execution behavior. However, a notable problem with the process model similarity is that two process models can also be similar if there is a structural variation between them. However, neither a benchmark dataset exists for the structural similarity between process models nor there exist an effective technique to compute structural similarity. To that end, we have developed a large collection of process models in which structural changes are handcrafted while preserving the semantics of the models. Furthermore, we have used a machine learning-based approach to compute the similarity between a pair of process models having structural and label differences. Finally, we have evaluated the proposed approach using our generated collection of process models.

Keywords: Machine learning; intelligent data management; similarities of process models; structural metrics; dataset; graph edit distance; process matching; artificial intelligence

1 Introduction

Business Process Management (BPM) is composed of different techniques and methods for analysis, enactment, design, and management of business processes [1]. To achieve a competitive edge, business processes and their process models are analyzed to identify the deficiencies. Subsequently, these processes are redesigned to develop effective techniques. The benefits of business process models are manifolds [2]. They are used to support communication, documenting projects, and train employees. Typically, large organizations have hundreds or thousands of process models [3]. To effectively these process models, these organizations maintain repositories of process models. The key features of process model repositories including controlling redundant models and querying process models. The accuracy of these features depends upon the effectiveness of the underlying techniques that compute the similarity between a pair of process models [4].

An established study has proposed that the similarity between a pair of process models can be computed in terms of *label*, *behavioral*, and *structural* similarity [5]. Where *label* similarity relies on the textual labels of process model elements. That is, two process models are considered equivalent if a certain percentage of their activities have similar labels. In contrast, behavioral similarity techniques also take into account the execution behavior of business process models, in addition to the label similarity. As opposed to the first two types, *structural* similarity techniques take into consideration the topology of process models, as well as their activity labels. However, there is no benchmark collection of process models that can be used to evaluate the effectiveness of *structural* similarity techniques. Furthermore, it is desirable to develop techniques for the effective evaluation of structural process similarity.

To that end, in this study, we have developed a large collection of business process models which is composed of a substantial amount of structurally different process model variants. Furthermore, we have developed a graph edit distance-based technique to compute the similarity between a pair of process models. Lastly, we have evaluated the effectiveness of the proposed technique for its ability to detect structural changes. The rest of the paper is organized as follows: Section 2 demonstrates the details of generating our process model collection having a sufficiently large number of process variations. The structural metrics measurements and results are presented in Section 3. Section 4 presents our proposed approach for computing similarity between a pair of process models. Section 5 presents the details of our evaluation, including evaluation measures, and experimental settings. The paper concludes in Section 6.

2 Generating Process Model Collection

The first contribution of this paper is to develop the first-ever and the largest-ever collection of business process models in which the structural changes are manually induced in such a way that the semantics of the process models are not changed significantly. The benefits of the collection are the following: a) the process model collection is freely available for the research community which will be useful for fostering BPM research. And, b) the collection contains multiple variations which stem from the established literature. Hence, we contend that the developed resources will be useful for the evaluation of process similarity techniques.

Below, we discuss the theoretical grounds for structural changes that exist in literature and thereafter use these operations for generating process model variations. In particular, we start with the process model changes from a notable study [6] and the process flexibility patterns presented in [7]. Both the model change operations were synthesized to elicit a key set of change patterns to be used in this study. A key finding of the synthesis is that we shortlisted only those patterns that do not change the semantics of the process. For instance, from the first study [8], if the C and F variants are applied to a process model, it is likely to change the semantics of the model. Similarly, the adaptive patterns referred to as AP1, AP2, and AP4 [7], are likely to transform the semantics of a process model. Therefore, both these patterns were not used for generating process model variants.

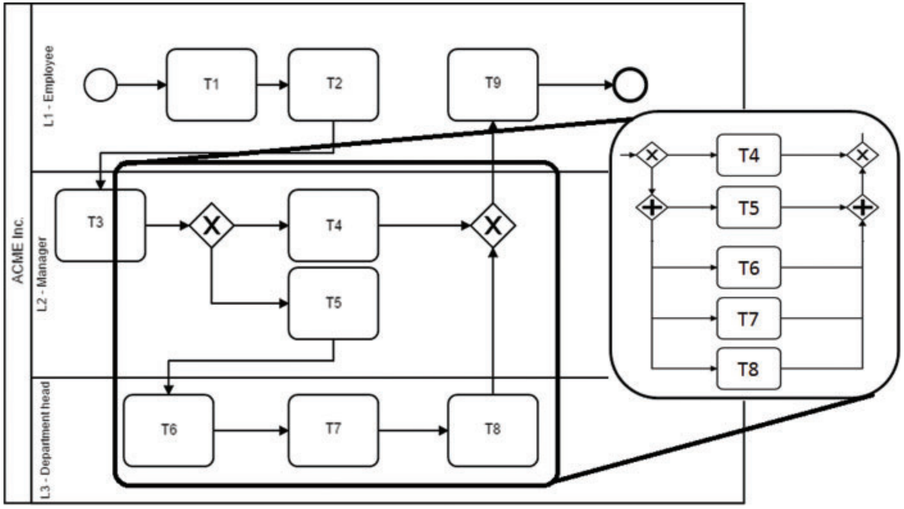
2.1 *Generating Multi-Variant Dataset*

In order to generate a large collection of business process models having structural variations we identified five types of changes based on a comprehensive literature review. The changes are the following: Type-1: Addition of gateways, Type-2: Adjusting trivial activities, Type-3: Inserting control edges, Type-4: Reordering activities, and Type-5: Changing labels of the activities.

2.1.1 Type 1 Change: Addition of Gateways

The '*Type-1*' change was proposed by multiple notable studies [6–11]. For inducing this type of change, the original process model the largest sequence of activities from the model is changed to parallel activities by adding an 'AND' gateway between them. The sequences which were not bounded in sequentially strict order were then converted to parallel. This change pattern is adopted from the Adaptive Pattern 9 *(AP9)* proposed in an existing study [11]. A similar change is also proposed in another study [8]. The details of this type and its implementation rules are explained in Tab. 1.

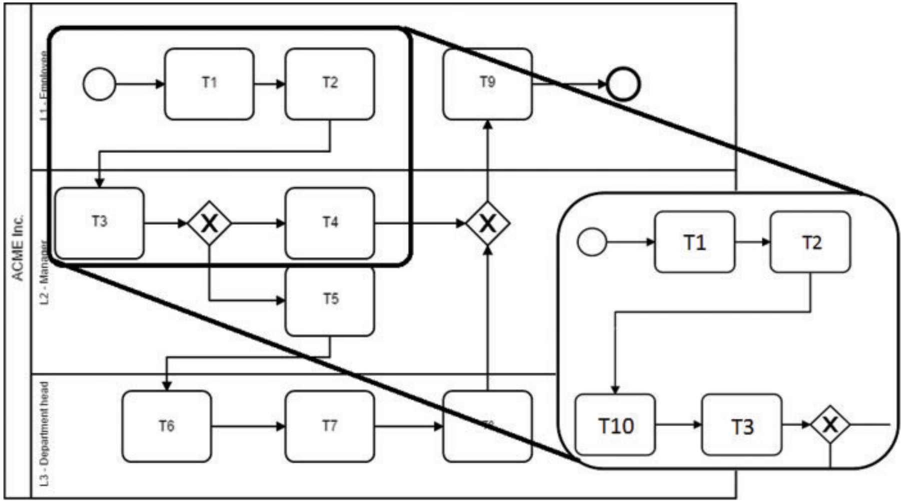
Table 1: Creating structural variation by adding a gateway

Explanation:	Sequential activities are converted into parallel. That is, parallelism is achieved by adding additional gateway(s).
Illustration:	A sample process model is shown below to demonstrate the application of this variation. In the process model the activities labeled as T5, T6, T7, and T8 were changed to parallel activities by adding an 'AND' gateway. Subsequently, the version is labeled as '*ACME Inc. V1'*.
Rooted from:	AP9 [9,11], variant B [8,10].
Rules for implementation:	1) Identify the core sequences in the models. 2) Observe the selected sequences and choose at least one sequence. 3) Convert the selected sequence into parallel by adding either XOR or AND gateway. 4) Observe the semantics of the generated model. If the significant change in semantics observed the generated should not added in repository.
Graphical representation:	 ACME Inc. L1 - Employee L2 - Manager L3 - Department head T1 T2 T9 T3 T4 T5 T6 T7 T8 T4 T5 T6 T7 T8 *T1 fill request form* *T2 send form to manager for approval* *T3 evaluate form* *T4 reject form* *T5 approve form* *T6 receive application form* *T7 review form* *T8 send request to vice principal for approval* *T9 receive approval* *T10 receive form*

2.1.2 Type 2 Change: Adjusting Trivial Activities

The second type of variation is referred to as *"Type-2"* structural variation. This type of change stems from several notable studies [6–11]. A key feature of this change is that it involves inserting or deleting activities from process models. The complete representation of Type-2 change is shown in Tab. 2. At least one activity was deleted or inserted from the model given that the semantics of the original model remained unchanged. Trivial or unimportant activities were first selected and then only one activity was deleted. The Type-2 change pattern was adopted after combing the adaptive patterns AP1, AP2, and variation D proposed by [8,9].

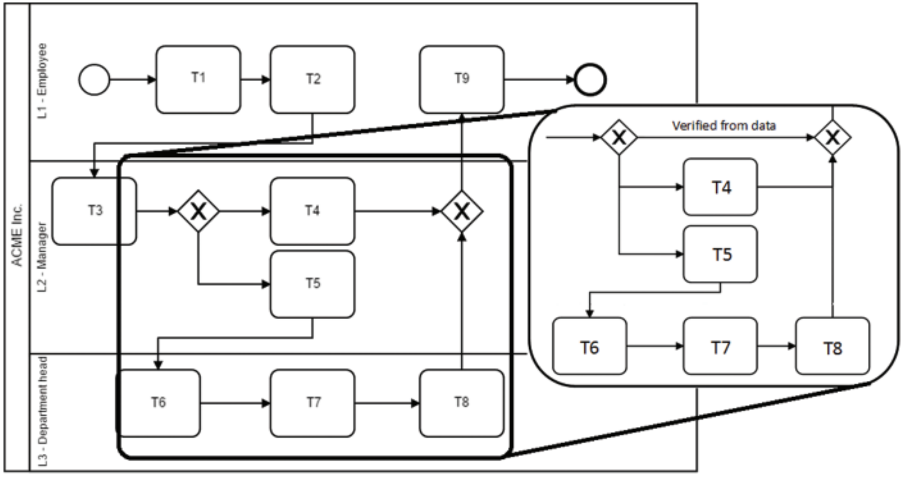
Table 2: Structure variation by adjusting trivial activities

Explanation:	Deletion or insertion of an trivial activity.
Illustration:	In the process model shown below a new activity labeled T10 was added between activity T2 and T3. Whereas, the remaining semantics of process models remain the same. The activity label of T10 '*receive form*' was added before activity T3 '*evaluate form*.'
Rooted from:	AP1, AP2 [7] variant D [10].
Rules for implementation:	1) In the 1st step, two potential activities were selected for insertion or deletion. Based on the analysis of the model, new activities were added. 2) The deletion of trivial activities was also done in the case where the insertion of new activity was not possible.
Graphical representation:	 ACME Inc. L1 - Employee L2 - Manager L3 - Department head T1 T2 T9 T3 T4 T5 T6 T7 T8 T1 T2 T10 T3 *T1 fill request form* *T2 send form to manager for approval* *T3 evaluate form* *T4 reject form* *T5 approve form* *T6 receive application form* *T7 review form* *T8 send request to vice principal for approval* *T9 receive approval* *T10 receive form*

2.1.3 Type 3 Change: Inserting Control Edges

In Type-3 change, a control edge or control flow was inserted into the process model under consideration. This change is rooted in several existing studies [6–11]. More specifically, the AP11, AP12, variant C, variant E, and variant F, proposed in the studies were considered for the Type-3 change. The details of the Type-3 change are shown in Tab. 3.

Table 3: Structure variation by inserting control edge

Explanation:	Insertion of new control edges in the process model.
Illustration:	Inserting a control edge to the process model without changing its semantics was a challenging task. This type of change was performed by adding a control flow edge.
Rooted from:	AP11, AP12 [9], variant C, E, F [10].
Rules for implementation:	1) The edge or flow line exists between two nodes which could be activities or gateways. 2) The potential gateway nodes were selected as a candidate for adding an edge. 3) The inserted edges were also labeled.
Graphical representation:	 ACME Inc. L1 - Employee L2 - Manager L3 - Department head T1 T2 T9 T3 T4 T5 T6 T7 T8 Verified from data T4 T5 T6 T7 T8 *T1 fill request form* *T2 send form to manager for approval* *T3 evaluate form* *T4 reject form* *T5 approve form* *T6 receive application form* *T7 review form* *T8 send request to vice principal for approval* *T9 receive approval* *T10 receive form*

2.1.4 Type-4 Change: Reordering Activities

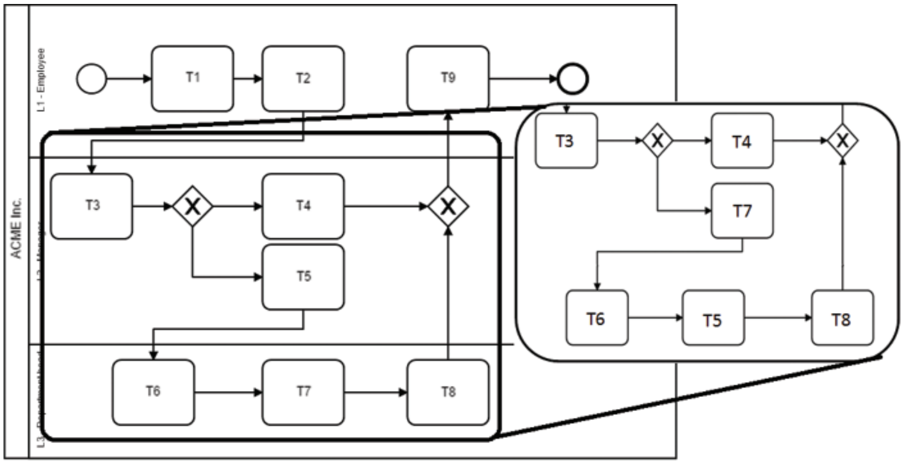
The Type-4 change is also rooted in studies [6–11] by mapping the Weber et. al. [7], adaptive patterns AP5, as well as in the two variants (G and H) proposed in [9]. The overall formation of Type-4 change is shown in Tab. 4. This type of change was achieved by reordering the activities. The Type-4 change was applied to all 150 models.

Table 4: Structure variation via reordering of activities

Explanation:	Reordering of activity/activities.
Illustration:	In the process model shown below, two activities T7 '*review form*' and T5 '*evaluate form*,' were swapped.
Rooted from:	AP5 [9], variant G, H [10].
Rules for implementation:	1) A set of activities that can be swapped, was selected. The order of the process model activities and semantics of the model, were observed. The change was made in such a way that it would not affect the overall semantics. 2) In some cases, where swapping was not possible in the original version, Type-2 variation was performed.

(Continued)

Table 4: Continued

Graphical Representation:	 L1 - Employee ACME Inc. T1 T2 T9 T3 T4 T5 T6 T7 T8 T3 T4 T7 T6 T5 T8 *T1 fill request form* *T2 send form to manager for approval* *T3 evaluate form* *T4 reject form* *T5 approve form* *T6 receive application form* *T7 review form* *T8 send request to vice principal for approval* *T9 receive approval* *T10 receive form*

2.1.5 Type-5 Change: Changing Labels of the Activities

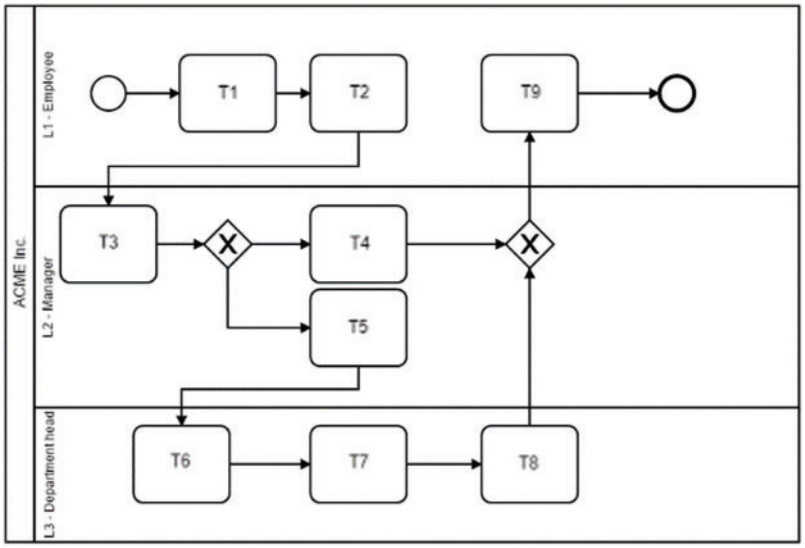
Type-5 involves changing labels for the process activities by replacing them with suitable synonyms in such a way that the meaning of the label remains the same. Change Type-5 which stems from adaptive pattern AP4 [7]. According to [7], the model could be different if its elements are labeled differently. Labels were changed by following some defined rules shown below in Tab. 5. The change was made in the original models while keeping in mind their semantics.

Table 5: Structure variation changing labels of the activities

Explanation:	This variation adopts the changes in the selected labels of activities.
Illustration:	In the example model labels of three activities are changed.
Rooted from:	AP4 [9]
Rules for implementation:	1) The labels of activities were changed, whereas, the trace of the process model remained unchanged. 2) In case there are less than 6 activities in a line, the label of one activity is changed. 3) If there are more than 6 activities in a lane, labels of two activities were changed. 4) The change in the label should be in such a way that the semantics would not change.

(Continued)

Table 5: Continued

Graphical representation:	 ACME Inc. L1 - Employee L2 - Manager L3 - Department head T1 T2 T9 T3 T4 T5 T6 T7 T8 *T1 fill request form* *T2 send form to manager for approval* *T3 evaluate form* *T4 reject form* *T5 approve form* *T6 receive application form* *T7 review form* *T8 send request to vice principal for approval* *T9 receive approval* *T10 receive form*

2.2 Creation of Repository for Process Model Similarities Multi-Variants

As a starting point for the development of the corpus, we used an existing collection of 150 process models [12]. The choice of the collection stems from the following reasons: a) the collection has limited propriety issues as it is freely and publicly available, b) the label-based variants have already been generated and used for the process model matching tasks. Therefore, extending the dataset with structural variants will be a valuable addition to the already usable collection, c) the collection includes process models from diverse genres, hence, providing enough diversity of process models, and d) the models in the collection comply with the widely used process modeling guidelines, which states that the process models in the collection do not contain any errors. For instance, there are no connector mismatches which resulted in no cyclic complexity, and all these models have a single start and an end node, which makes the model more structured.

In the second step of the development, a random sample of 10% of the models was refined by a team of three experts. Specifically, the process model collection was divided into two parts and two researchers were asked to generate variants of models, in such a way that each researcher generate at least two variants of each model. Note, generating these variations was a challenging and resource-intensive task due to several reasons. For instance, generating a process model variant based on Type-4 change was a challenging task as it involves changing the position of the activity which is likely to affect the semantics of the process. All five types of changes were made to create a repository of 900 process models. Where, Type-0 represents an original model, and Type-1, Type-2, Type-3, Type-4, and Type-5 represent the five variants of the original process models. All the models were designed in a widely used process modeling tool and stored in XML format. Also, PNG files of all the models were generated for visualization.

Tab. 6 provides a comparison of the newly developed process model collection with the existing collections that are publicly available. It includes three process model collections from the Process Model Matching Contest (PMMC'15) [13], a state-of-the-art collection of process models, and our newly developed collection. It can be observed from the table that the number of process models in our collection is significantly more than the number of models in any of the existing collections. Furthermore, similar to the existing collections, our collection is also publicly available, and the models are designed in BPMN, which is the de jure for process modeling. Also, our collection includes process models from multiple genres, meaning that the collection contains process models from different domains making it a representative sample of several genres. A notable observation is that most of the existing collections do not include variants of process models. The only exception is a recently developed collection of process models [13]. However, the variations of the models in those collections are limited to the paraphrasing of labels. In contrast to the existing collections, our collection contains variants of process models, including structural and label-based variants, making it the most comprehensive collection that is publicly available. Hence, we contend that the developed collection is a comprehensive resource for the evaluation of the process similarity techniques.

Table 6: Comparison of our process collection with other collections

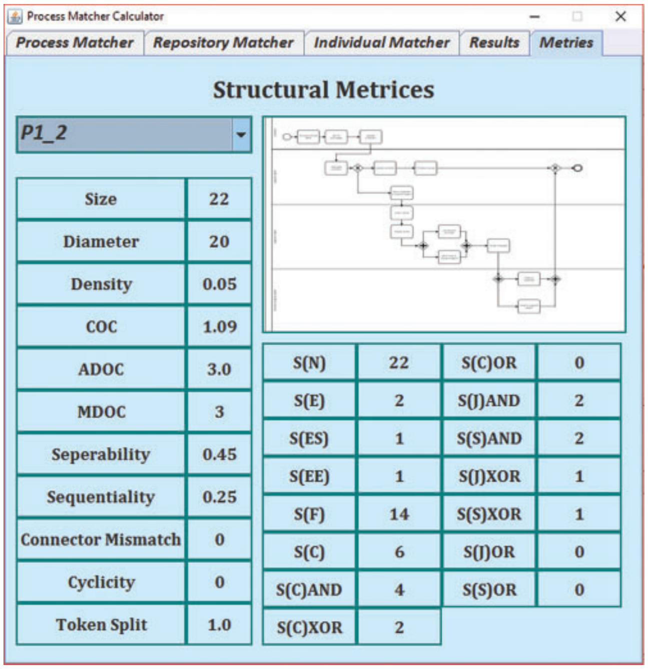
	Process model collection				
Criteria	UA	BR	AM	PMC	Our
No of models	32	8	8	600	900
Public availability	Yes	Yes	Yes	Yes	Yes
Format of models	JSON	JSON	JSON	JSON	JSON
Modelling Language	BPMN	–	Petri net	BPMN	BPMN
Genre wise diversity	No	No	No	Yes	Yes
Compliance of guidelines	–	–	–	Yes	Yes
Variation of models	No	No	No	Yes	Yes
Structural variation	No	No	No	No	Yes
Label variation	No	No	No	Yes	Yes

The models were saved in XML format along with the Portable Network Graphics (PNG) files. The compatible XML format was generated using Camunda, an open-source and established tool for designing process models. The 900 process models were stored after a comprehensive audit of XML codes and graphical models. The models in XML were passed as an input to the developed prototype. The whole collection of process models was passed to our developed prototype and the scores of 26 similarity metrics were computed.

3 Structural Metrics Measurements and Results

To provide an overview of the structural properties of the collection of our process model collection, we use structural metrics. These metrics have been widely used in literature for analyzing the structural properties of the process model collection. The metrics we used to evaluate our process models were extracted from studies [14–18]. The developed prototype is shown in Fig. 1. The 1st module of the developed tool was used to calculate the structural similarities using 26 structural similarity metrics [8].

To provide an overview of the process model collection, we computed the values of structural metrics of each process model and exported them to a CSV file. The standard deviation of all the structural metrics is presented in Fig. 2. In the figure, the blue bars represent the mean score of structural metrics, whereas, the standard deviation is represented by red bars. Furthermore, the 26 metrics are along the x-axis, whereas, the values of these metrics are plotted along the y-axis. It can be observed from Fig. 2 that the mean values of metrics, such as Size, Diameter, S(N), and S(F), are comparatively higher than the other metrics. On the other hand, the mean and standard deviation values of metrics like Density, Connector Mismatch, Cyclicity, S(C)OR, S(J)OR, and S(S)OR is zero, from these values one cannot predict how one model is congruous to the other.



Structural Metrices

P1_2

Size	22
Diameter	20
Density	0.05
COC	1.09
ADOC	3.0
MDOC	3
Seperability	0.45
Sequentiality	0.25
Connector Mismatch	0
Cyclicity	0
Token Split	1.0

S(N)	22	S(C)OR	0
S(E)	2	S(J)AND	2
S(ES)	1	S(S)AND	2
S(EE)	1	S(J)XOR	1
S(F)	14	S(S)XOR	1
S(C)	6	S(J)OR	0
S(C)AND	4	S(S)OR	0
S(C)XOR	2		

Figure 1: Structural metrics calculation tool

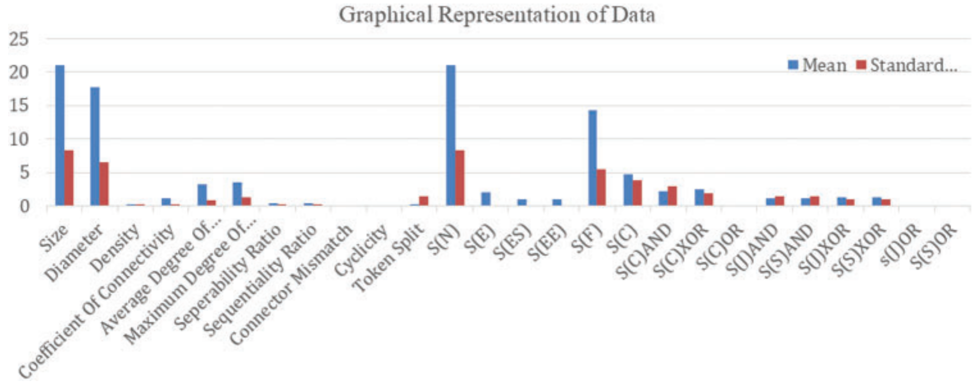


Figure 2: Mean and standard deviation of the results from structural metrics

4 The Proposed Approach for Structural Similarities Measurement

The scores of the structural metrics presented in the preceding section provide an overview of the process collection that we have generated. However, the values of the structural metrics cannot be used to compute the similarity between a pair of process models due to the following reasons: a) these metrics provide a macro view of the process structure and does not provide detailed insights about process models, b) these metrics do not provide a holistic view about the structure of two different process models. For instance, two process models having identical values of size, diameter, and other metrics, but at the same time their semantics can be different, whereas, the two process models having substantially different structural properties can have significantly similar semantics.

In this study, we have proposed a novel approach that relies on structural variation topology, as well as label-content of process models. The proposed approach stems from the notation of Graph Edit Distance (GED) [10]. To elaborate on the approach, firstly, we define a Business Process Graph (BPG) to omit the language-specific details. A BPG is composed of three elements, a finite set of nodes, a finite set of edges between these nodes, and labels associated with them.

4.1 Proposed Algorithm

The pseudocode of the proposed approach is presented below. The algorithm is subdivided into two functions. The first function ‘FUNCTION-1 Maplanes()’ was developed to retrieve the activities, flow line, gateways, and pool lanes, of the model. Whereas, the second function ‘FUNCTION-2 CalculateSimilarity()’ computes the similarities of a model with a single model and with all 899 models from the dataset. The proposed approach is implemented in Java.

```
Start
    List: mappednodes [250][4];
    Variables: Model1 ← InputModel1 Model2 ← InputModel2
    Variables: Lane11 ← Model1.lane Lane2 ← Model2.lane
    Maplanes() *FUNCTION-1
    CalculateSimilarity() *FUNCTION-2
End
```

FUNCTION-1 Maplanes()

```
Start
    Declare variable mappedlanes [50] [4] ml ← 0
    Repeat1 until (End of Lane1)
        Variable: key1 ← Lane1.key Value1 ← Lane1.value
        Repeat2 until (End of Lane2)
            Variable: key2 ← Lane2.key Value2 ← Lane2.value
            if (Value1 == Value2)
                Mappedlanes[ml][0] ← Key1
                Mappedlanes[ml][1] ← Value1
                Mappedlanes[ml][2] ← Key2
                Mappedlanes[ml][3] ← Value2
                ml ← ml + 1
        End Repeat2
    End Repeat1
End
```

FUNCTION-2 CalculateSimilarity()

```
Start
    Variables: $SN \leftarrow 0$ $SE \leftarrow 0$ $SB \leftarrow 0$ $GED \leftarrow 0$ $GEDSim \leftarrow 0$
    Variables: mappednodes [250][4] $SNV \leftarrow 0$ $SEV \leftarrow 0$ $SBV \leftarrow 0$
    If (No mapped Lanes)
        $SN \leftarrow$ Model1.Size + Model2.Size
        $SE \leftarrow$ Model1.Edges + Model2.Edges
        $SN \leftarrow 0$
    Else
        Check Tasks that have same labels in mapped lanes
        Check Gateways that have same types (Exclusive or Parallel which includes
        both split and join)
        Check Events that have same types (Start or End Event) in mapped lanes
        Check Tasks that have different label in mapped lanes based on previous
        and next nodes
        Check Tasks that have different label in mapped lanes based on already
        mapped nodes
        Check Remaining Tasks in mapped lanes and map them
        Check Remaining Gateways in mapped lanes and map them
        Check Remaining Events in mapped lanes and map them
        Remove all the mapped Tasks from the Tasks list of both Models
        Remove all the mapped Gateways (Parallel and Exclusive) from the Gateways
        lists.
        Remove all the mapped Events (Start and End Event) from the Events list of
        both Models
        $SN \leftarrow$ Model1.Tasks + Model1.Events + Model1.Gateways + Model2.Tasks
        + Model2.Events + Model2.Gateways
        Variable: $i \leftarrow 0$ $j \leftarrow 0$ $k \leftarrow 0$ mn1 mn2 mn3 mn4
        $SE \leftarrow$ Model1.Edges+Model2.Edges
    Repeat1 until (i < MappedNodes.Size)
        mn1 $\leftarrow$ MappedNodes[i][0] mn2 $\leftarrow$ MappedNodes[i] [2]
        Repeat2 until (j < MappedNodes.Size)
            mn3 $\leftarrow$ MappedNodes[j][0] mn4 $\leftarrow$ MappedNodes[j] [2]
            Repeat3 until (k < Edges)
                If (Model1.Edge.Start == mn1 AND Model1.Edge.End ==
                mn3 AND
                Model2.Edge.Start == mn2 AND Model2.Edge.END == mn4)
                    $SE \leftarrow SE-2$
            End Repeat3
        End Repeat2
    End Repeat1
    Variable: $i \leftarrow 0$
    Repeat4 until (i<MappedNodes.Size)
        if (MappedNodes[i][1]!=MappedNodes[i][3])
```

```
            Variable: Label1 $\leftarrow$ MappedNodes[i][1]
            Variable: Label2 $\leftarrow$ MappedNodes[i][3]
            Split Labels into array of words
            Variable: max $\leftarrow$ Count(Label with max alphabets)
            Remove the words that are same in both labels
            Variable: tempsb $\leftarrow$ Total letters in both labels
            Map words on their positions with same indexes
            If (same letters are found at some index)
                Tempsb $\leftarrow$ tempsb-2
        SB $\leftarrow$ SB + (tempsb/max)
    End Repeat4
    GED $\leftarrow$ SN + SE + (2 $*$ SB)
    SNV $\leftarrow$ SN/(Model1.Size + Model2.Size) Step 8: SEV $\leftarrow$ SE/(Model1.Edges + Model2.Edges)
    SBV $\leftarrow$ SB/(Model1.Size + Model2.Size-SN)
    GEDSim $\leftarrow$ 1 $-$ [(SNV + SEV + SBV)/3]
End
```

4.2 Implementation

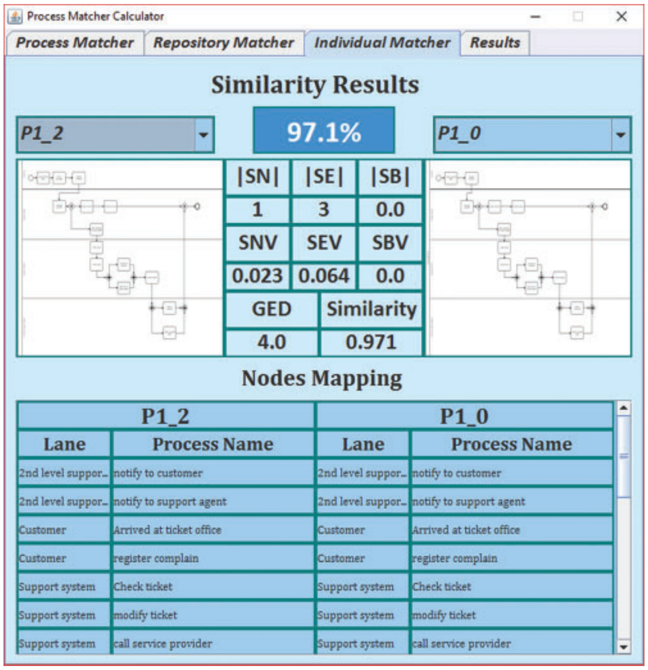
A screenshot of the implemented prototype is presented in Fig. 3. In essence, the lanes in the extracted process model are mapped based on the labels of the two models. Subsequently, the corresponding nodes of the mapped lanes are also be mapped. Finally, the overall similarity between the two process models is computed based on the mapped elements. Consider, while computing the similarity, the unmapped nodes are represented by SN, whereas, unmapped edges are represented SE. Furthermore, the edit distance SB value was computed. Using the three values, SN, SE, and SB, we calculate the SNV, SEV, and SBV. Where, SNV is the ratio between the unmapped nodes SN and the total number of nodes between the two models, and SEV is the ratio between the unmapped edges SE and the total number of edges in the two models. Furthermore, SBV calculates the betweenness of two mapped nodes in the models. A separate module contains the list of models to be used as a query, it provides a preview of the model that is selected. The lower part of the module contains the models that are similar to the query model, as well as the intermediate computation. The Precision and Recall of the selected model show how precise the results are for that specific model. In the following module, the similarity between a pair of process models is provided. The screenshot contains a preview of the pair of process models and the labels of the corresponding elements of the process model. Also, it contains the different scores, SN, SB, SE, SNV, SEV, and SBV, used to compute the similarity between a pair of models.

5 Experimental Results

Fig. 4 shows the module to compute Precision and Recall scores of a proposed technique. The two measures, Precision and Recall, have been widely used for information retrieval, information matching, and similarity computing tasks. Precision is defined as the ratio between the number of process models that are correctly declared similar and the process models that are declared similar by the technique. The Recall is defined as the ratio between the numbers of process models that are correctly declared similar. Formally, the two measures are defined as follows.

$Precision = |(similar\ process\ models) \cap (declared\ similar\ process\ models)|/|(declared\ similar\ process\ models)|$

$Recall = |(similar\ process\ models) \cap (declared\ similar\ process\ models)|/|(similar\ process\ models)|$



Similarity Results

P1_2 | 97.1% | P1_0

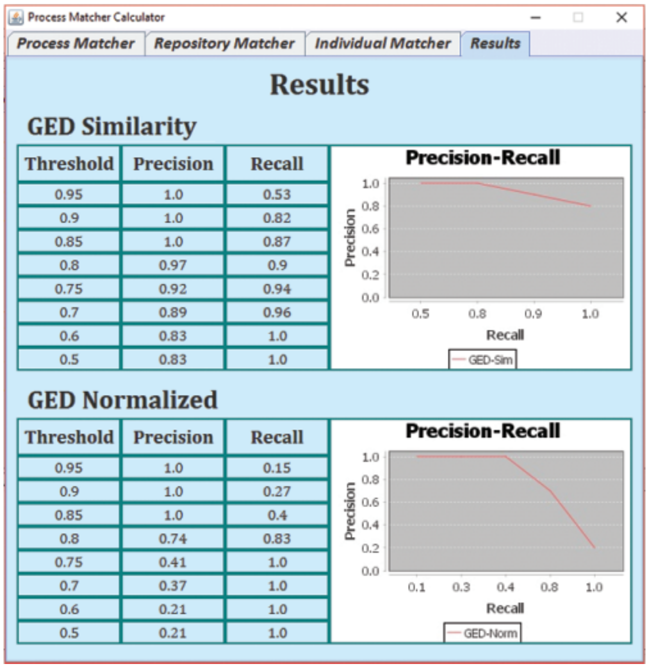
|SN|	|SE|	|SB|
1	3	0.0
SNV	SEV	SBV
0.023	0.064	0.0

GED	Similarity
4.0	0.971

Nodes Mapping

P1_2		P1_0	
Lane	Process Name	Lane	Process Name
2nd level suppor...	notify to customer	2nd level suppor...	notify to customer
2nd level suppor...	notify to support agent	2nd level suppor...	notify to support agent
Customer	Arrived at ticket office	Customer	Arrived at ticket office
Customer	register complain	Customer	register complain
Support system	Check ticket	Support system	Check ticket
Support system	modify ticket	Support system	modify ticket
Support system	call service provider	Support system	call service provider

Figure 3: Individual matcher screen



Results

GED Similarity

Threshold	Precision	Recall
0.95	1.0	0.53
0.9	1.0	0.82
0.85	1.0	0.87
0.8	0.97	0.9
0.75	0.92	0.94
0.7	0.89	0.96
0.6	0.83	1.0
0.5	0.83	1.0

GED Normalized

Threshold	Precision	Recall
0.95	1.0	0.15
0.9	1.0	0.27
0.85	1.0	0.4
0.8	0.74	0.83
0.75	0.41	1.0
0.7	0.37	1.0
0.6	0.21	1.0
0.5	0.21	1.0

Figure 4: Results screen

Experiments were performed using all the 900 process models. Based on the results we observed that as the precision increases the value of recall decreases in both cases (GED normalized and GED similarity). The optimum values for the thresholds are shown in Tab. 7. The higher precision and recall results were observed at the threshold of 0.7. Furthermore, to obtain the optimum value execution of the program was readjusted with different weights for *SNV, SEV, and SEB*, and values were recalculated. The precision results were observed high but the recall values were observed on the lower side in comparison of GED similarity to GED normalized. The weight value 1-1-1 means the variables *SNV, SEV and SEB* were treated equally. The optimal results were found at 2-1-1 where the precision and recall results were observed high for both cases.

Table 7: Results of the implemented algorithms

Optimum threshold for GED similarity				Optimum threshold for GED normalized			
Weights	Threshold	Precision	Recall	Weights	Threshold	Precision	Recall
1-1-1	0.7	0.97	0.88	1-1-1	0.7	0.97	0.41
2-1-1	0.8	0.99	0.85	2-1-1	0.7	1.0	0.41
3-2-1	0.7	0.95	0.91	3-2-1	0.7	0.88	0.41

6 Conclusion

Several attempts have been made to develop techniques for computing similarity between process models. However, a key challenge is that there is a scarcity of process model collections that can be used to evaluate the effectiveness of process similarity techniques. Furthermore, to the best of our knowledge, there is no publicly available collection of process models that can be used to evaluate the effectiveness of process similarity techniques between structurally different process models. To that end, in this study, we have developed a large collection of 900 process models having substantially different structures but at the same time having similar semantics. To demonstrate that we have contributed a valuable resource, we have compared the specification of our developed corpus with the existing collections. The results show that our newly developed collection includes diverse processes, and the specifications of our collection are superior than the existing ones. We have also developed a technique for computing similarity between a pair of process models. The technique relies on the use of graph edit distance and similarity between labels. To demonstrate the applicability of the proposed approach, we have implemented a prototype that is composed of several modules. It includes a module that can parse XML format, import a process model, and compute structural properties of the input model. Another module computes the similarity score between a query process model with all the models in the collection. Also, it computes Precision and Recall scores. Furthermore, a third module provides details of each process model pair i.e., it identifies the corresponding lanes, as well as their corresponding activities. Finally, we evaluated the effectiveness of the proposed approach using the developed collection. The results show that the proposed technique achieved a very high effectiveness score of 0.95.

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