Fraud detection using process mining and analytical hierarchy process with verification rules on erp business process

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Abstract. Today many corporate run their business process by applying Enterprise Resource Planning (ERP). A corporate which has a well-defined business process will run its business process effectively and efficiently. In practice, the executed business process is not always complied with Standard Operational Procedure (SOP). The deviations of the business process can be identified by analyzing event logs from the business process activities using process mining method. The various kinds of deviation are skip activity, wrong throughput time, wrong actor, wrong duty, and wrong decision. But not all deviations are frauds. Hence, Analytical Hierarchy Process and verification rules are employed to analyze the deviations to determine the fraud status. The proposed method successfully detected frauds conducted in the business processes of the bank credit application and procurement process. The proposed method achieved up to 95% accuracy.

1. Introduction

Fraud is viewed as a threatening issue in the world. There have been 2690 fraud cases that have made a loss of US$7 billion from 125 countries in 23 industry categories [1]. On average, organization has lost a gross profit of 7% in a year. In fraud cases, 20% of people in company never do any fraud, 60% highly relies on the opportunity to do a fraud and 20% of the rest really does [2]. This is a fact which forced company to have policies in term to detect fraud. Fraud has a definition of a misuse of the system organization without breaking the law [3]. According to [4] fraud is a criminal act in using false information to gain an unfair advantage.

This research focuses on process-based fraud that is a fraud which occurs in business processes [5]. Deviation is defined as the occurrence of fraud criterions. Process mining is designed to identify, monitor, and improve the actual process of event logs data resulted by system. It uses event logs data to extract information and knowledge. Process mining has three main excellences which are discovery, conformance, and enhancement [6]. Discovery refers to an actual model shaping on how a business process occurs by using event logs data. Conformance refers to comparing event logs with SOP. It is also referred to one of capabilities of process mining to detect any deviated process in accordance with the event logs data. Analytical Hierarchy Process and verification rules are employed to analyse the deviations for determine the fraud status.

2. Basic Concepts

2.1. Event Logs

Event logs contain a record of an event executed when a business process is being run. Event Logs also frequently called as history, audit trail, or transaction log [6]. Event logs are used as a data to gain information from a business process that has been run. Event logs contain information about the actor who execute the event, length of event execution time, and another data which is needed to execute event. For example, in a case study of bank credit application in which a make decision activity has been done by a manager in certain time and the manager who making decision must considers the

credit submission requirements. Such requirements are in the form of attribute data as recorded in event logs. Event logs must comprise case id, events, start time, complete time, and actor who execute. Case id shows the ID of one instant process from the beginning to the end. Events refers to what activity is executed in a one process. Furthermore, start time is to show the beginning of an activity execution. Complete time refers to the end time of an executed events and actor refers to the actors who execute events. Table 1 shows the example of event logs.

2.2. ProM

ProM is a tool to run the process mining method. ProM was developed by lecturers and professors from the University of Mon Netherland [6]. ProM has more than 200 plugins and has the advantage of a very extensive approach to the analysis, such as the Discovery Process, Social Network, Conformance Checking. Other Prom excellence which can convert a variety of models such as Petri Net, EPC, BPMN, BPEL, YAWL. Prom is also able to read the event logs in XES or MXML format.

2.3. Process-based Fraud

Process-based Fraud (PBF) is a fraud which occurs in business processes [5]. Therefore, internal controls can be performed as a counter measure against fraud [7]. One of internal control is defining a Standard Operational Procedure (SOP). Fraud occurs due to a mismatch between the SOP against real events recorded in the event logs. Based on the research that has been done [8], there are six kind of deviations which we will use them as attributes to determine the fraud status which are skipped event [4], wrong throughput time, wrong actor, wrong duty, wrong pattern, wrong duty, wrong pattern, wrong decision.

2.4. Process Mining for Fraud Detection

Process mining is used to recognize the sequence of processes that exist in the event logs. According to [6] the goal of process mining is to extract knowledge from event logs recorded by the system. Process mining has three main objectives, namely process discovery, conformance check, and enhancement. Process, case, activity, and event logs is a common term in the process mining. A process consists of several case, activity, and events. A case is a collection of activity sequentially from beginning to end by the time of execution. An event is a representation of the activity that aims to differentiate based on execution time and case. Process mining can be used for fraud detection by performing four types of analysis, namely control flow analysis, resource analysis, throughput time analysis, and decision point analysis [4].

2.5. Analytical Hierarchy Process

Analytical Hierarchy Process (AHP) is a structured technique for organizing and analysing complex decisions based on mathematical calculations [12]. The primary method of AHP is to compare the importance weights of criteria that influence for decision-making. Value will be stored in the table comparison matrix with n x n criteria dimensions. Every criterion, it is possible to have sub-criteria and will also do a comparison between the other weight of the sub-criteria in one level. The results of the comparison of each element are between 1 to 9, which shows a comparison of the importance rate criteria. If criteria in the matrix compared with itself the result of the comparison value is 1. Criteria assessment in comparing one with the other criteria are independent of each other, and this can lead to

inconsistencies. Saaty [12] has shown that the *Consistency Index (CI)* of *n x n* criteria matrix can be obtained by the formula:

$$CI = (\lambda maks-n) / (n-1) \quad (1)$$

λmaks means the Largest eigen value of *n x n* matrix. Largest eigen value is obtained by adding up the results of multiplying the value of each columns with the eigen vector (final weight criterions at a certain level). Inconsistencies limit in measurement is calculated by using *Consistency Ratio (CR)*, i.e ratio of *Consistency Index (CI)* with *Random Index (RI)*. This value depends on the order of matrix n. When the value of *CR* is smaller than 10%, criteria assessment is still acceptable. Consistency ratio can be formulated:

$$CR = CI / RI \quad (2)$$

The reason of using AHP is fraud detection needs subjective assessment from the expert for predicting the severity of each fraud criterions.

3. Proposed Method

In this research we proposed deviation analysis in event logs. The kind of deviations analysis are skip activity analysis, wrong throughput time analysis, wrong resource analysis, wrong duty analysis, wrong pattern analysis, and wrong decision analysis. Process Mining method is employed to analyze the deviation and calculate the occurrences of that deviation. We call each deviation as a fraud attribute to determine the fraud status of a process. The method is presented in the grey box of Figure 1, which shows the steps to identify the deviations from event logs and analyze the deviations using AHP to determine the fraud status. This method was implemented as a ProM Plugin in order to make easier for the users to use.

3.1. Skipped Event Analysis

This part is to analyse event logs to find out the presence of skipped event which unfit with SOP. This analysis was conducted using ProM Plugin which name is conformance checking in order to present the number of skipped events. The input of this analysis are SOP and Event logs.

3.2. Wrong Pattern Analysis

nalyse patterns in event logs by comparing the sequence of events in event logs with SOP. If there was a case in which the activity inside runs with the sequence not in line with event logs, it would be detected as a wrong pattern. The inputs of this analysis are SOP and event logs.

3.3. Wrong Actor Analysis

This part is to analyze on each actor who execute each activity recorded in event logs. If there was an event which is executed by an actor who was not authorized execute it based on SOP model, it would be detected as Wrong Actor.

3.4. Wrong Duty Analysis

In this part, an analysis would be done to find out whether there was an actor execute two events in a process simultaneously. This could be suspected as a fraud in a business process.

3.5. Wrong Throughput Time Analysis

An analysis on time execution from all event logs was done in this part by comparing the time standard existing in the SOP. If time execution was not in line with SOP model in term of it was too fast or slow, it would be suspected as a fraud.

3.6. Wrong Decision Analysis

An analysis in this part concerned with the decision events or branching events. The decision events had an attribute that was influential on the event that must be executed next. To do Wrong Decision Analysis, event logs were firstly transformed into Ontology-based event logs to facilitate ontology

query using SPARQL [11]. Figure 2 illustrates the decision event which is "check plafond" that had a plafond attribute that would have an effect on the activity that will be executed next. The essence of wrong decision analysis using query SPARQL was to identify the event that had plafond amount of 500.000.000 but the event that was done next was not director authorization.

3.7. Fraud Weighting using AHP

Analytical Hierarchy Process (AHP) is a technique to support the decision-making process aimed to determine the best choice from several alternatives taken. The excellence of AHP is its capability to provide an alternative weight in a decision-making. In this case, AHP can be used to give a weight in the case suspected as a fraud based on fraud criterions. The fraud weighting of each fraud criterions was performed by experts after the process mining analysis was done. The final weight of each criterions has been obtained in Table 2. For sub-criteria, the final weight would be multiplied with its weight of main criteria. For example, skip sequence as a sub-criteria of skip had a weight of 0.33 x 0.27 = 0.09. In weighting a case suspected as a fraud, the number of deviation in each criterion would be multiplied with the final weight and divided with the maximum number of deviation that might occur in each criterion.

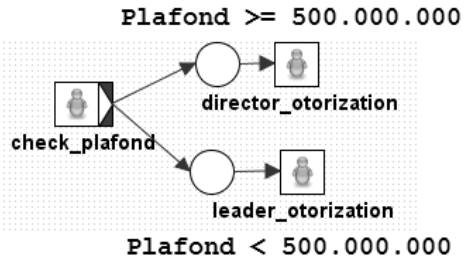

Figure 2. Sample of decision event

3.8. Training and Determining Verification Rules

There are X^{10} deviation combinations in a business process. The integer X indicates the number of events in business process and 10 indicates the number of deviations. The training dataset is developed based on the fraud weights which represent all combinations of frauds. In this phase, the system

determine the threshold or the weight limit used to differentiate whether a case is fraud or normal. The threshold limit must have the most maximal accuracy value. The accuracy value would be measured using Receiver Operating Characteristic (ROC) method. However, the weight of the threshold was often not able to differentiate whether a case was a fraud or not. Thus, a rule is necessary to cope with it. By determining the threshold limit, it was possible to identify if a case truly was as a fraud detected by system (True Positive), a case as truly normal not detected by the system (True Negative), a case truly as a fraud but not detected by system (False Negative) which can occur when there is a fraud but has a low weight of fraud deviation, or a case truly normal but detected as a fraud by system (False Positive) which can occur when there is a normal case but has a high weight of fraud deviation.

Verification is an effort to accommodate the rules aimed to minimize the False-Negative and False-Positive values. The resulted rules were used in doing a dataset test consisting of fraud and normal case. By so doing, if there was a case with the weight of fraud under the threshold limit but in fact, it was a fraud, the system would determine that the case was a fraud in accordance with the verification rules that has been resulted in training. It was also similar with the case that was truly normal but had a fraud weight above the threshold. To illustrate, from a fraud case with one infraction of wrong decision from the maximum eight infractions, the case would have a weight of 0.26 x 1 / 8 = 0.035. Meanwhile, the threshold limit with the best accuracy was 0.014. Based on the threshold limit, the case is considered as fraud by system. That deviation here can be considered as Wdecision Low as the number of deviations in divided by the maximal number of deviation is 1 / 8 <= 0.3. Thus, a verification rules was used in which any deviation of Wdecision Low, it would not be considered as a fraud although the weight of the fraud was above the threshold limit. Similarly, it was also valid in any other deviation.

4. Results

4.1. Case Study of Credit Bank Application

For the case study of credit application, 130 cases of training data comprising 100 fraud cases and 30 normal cases were used. From the result of the training, threshold was generated from 0.001 up to 1 and resulting the maximal threshold of 0.033. The threshold limit was then used as the base of the threshold limit for the next data testing. But if we depend only on threshold limits there are 6 false negative cases. Furthermore the verification rules are utilized to analyse fraud in the case of this false negative cases. Table 3 shows verification rules of this Credit Bank Application and Procurement case study. After the training was complete, the threshold limit and verification rules were used to perform a test. There were 100 cases of testing data comprise 70 fraud cases and 30 normal cases. Table 4 shows the result of testing.

Table 2. Final weight of each fraud criterions

Final Weights									
Skip Seq	0.1	**TT Min**	0.07	**Wrong Resource**	0.1	**Wrong Duty Dec**	0.07	**Wrong Pattern**	0.07
Skip Dec	0.2	**TT Max**	0.07	**Wrong Duty Seq**	0.02	**Wrong Duty Com**	0.04	**Wrong Decision**	0.25

4.2. Case Study of Procurement

For the case study of procurement, 100 cases of training data comprising 70 fraud cases and 30 normal cases were used. From the result of the training, threshold was generated from 0.001 up to 1 and resulting the maximal threshold of 0.014. The threshold limit was then used as the base of the threshold limit for the next data testing. But if we depend only on threshold limits there are 14 false positive cases. Furthermore, the verification rules are utilized to analyse fraud in the case of this false positive cases. There were 100 cases of testing data comprise 40 fraud cases and 60 normal cases were used. Table 5 shows the result of testing.

5. Conclusion

The fraud detections in the business processes of bank credit application and procurement have been studied. It can be concluded that the deviations in business processes can be identified using the process mining method. Then, the AHP method was successfully utilized to determine the fraud status. The AHP achieved the accuracy of 90%. Furthermore, the AHP method could be improved by adding verification rules to detect fraud cases with low weight of deviations and to detect normal cases with high weight of deviations. The computational studies show that the AHP with the verification rules increase the accuracy to 93.5%. Thus, it can be concluded that the AHP with the additional rules achieved high accuracy in detecting frauds in business processes.

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Preface

Welcome Remarks,
Chair of the Steering Committee

It is a great pleasure to welcome all of you to Bali and to the International Conference on Informatics, Technology, and Engineering 2019 (InCITE 2019) held by the Faculty of Engineering, University of Surabaya (UBAYA) in collaboration with The University of Adelaide, Australia and Sirindhorn International Institute of Technology (Thammasat University), Thailand. The first InCITE has been successfully held in Bali, Indonesia in 2017. We are very delighted to host the second InCITE here in Bali, Indonesia again.

There are more than 75 presentations in this conference. We welcome leading experts not only from Indonesia, but also from different parts of the world. The experts will share the knowledge and experiences in the fields of informatics, technology, science, and engineering. The main theme of this conference is **Enhancing Engineering Innovation Towards A Greener Future** in response to several world challenges including sustainable development, global convergence of information and communications technologies, climate change and global warming as well as the depletion of unrenewable natural resources. We hope this conference will provide you a good opportunity to get to know each other better and consolidate bonds of friendship and mutual trust.

We would like to express our sincere gratitude to the Keynote and Plenary speakers, International Scientific Committee, Steering Committee, and Organising Committee for their huge efforts to make this conference successful.

Thank you all for your support and attendance at InCITE 2019. Please enjoy the conference and Bali !

Asst. Prof. Djuwari, Ph.D.

Preface

Welcome Remarks,
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Welcome to Bali, Indonesia to all delegates and presenters. It is my pleasure and privilege to welcome all of you to the 2nd (second) International Conference on Informatics, Technology, and Engineering 2019 (InCITE 2019) held by the Faculty of Engineering, University of Surabaya (UBAYA) in collaboration with The University of Adelaide, Australia and Sirindhorn International Institute of Technology (Thammasat University), Thailand.

InCITE 2019 has received more than 75 papers to be presented in this conference. All papers represent four following parallel clusters: Green Design and Innovation, Green Manufacturing and Green Processes, Power System and Green Energy Management, and The Role of IT in Innovation Enhancement. Each cluster supports the main theme of the conference, which is **Enhancing Engineering Innovation Towards A Greener Future.** The engineering innovation is the key to increase our awareness in maintaining the sustainable growth and development in the world.

The Organising Committee of InCITE 2019 would like to express our sincere gratitude for the tremendous supports and contributions from many parties. The supports from The Faculty of Engineering of UBAYA, keynote and plenary speakers, our International Scientific Committee, the Steering and Organising Committees are really acknowledged.

The last but not the least, thank you for your supports, enjoy the conference and we hope through this meeting all of you can extend your networks and collaborations.

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