

# Patterns of Fraud Detection Using Coupled Hidden Markov Model

Kelly R. Sungkono, Riyanarto Sarno

Department of Informatics Engineering  
Institut Teknologi Sepuluh Nopember  
Surabaya, Indonesia

kelsungkono@gmail.com, riyanarto@if.its.ac.id

**Abstract**—The Financial Services Authority does fraud detection through several activities that are recorded in the event logs for detecting fraud. Patterns of Fraud Detection are used to analyze the performances of fraud detection and predict the next fraud detection. Patterns of Fraud Detection can be observed using a map model of fraud detection. On the other hand, modeling fraud detection is difficult because the fraud detection cannot be directly observed through an event log. The event log only records activities triggering by fraud detection. This paper proposes an intention mining method for modeling fraud detection using Coupled Hidden Markov Model. The proposed method determines strategies utilizing the activities and forms a map model of fraud detection using probabilities of Coupled Hidden Markov Model. The experiment outcomes show that the proposed method gets an appropriate map model of fraud detection. This paper also demonstrates that an obtained model using proposed method gets the better validity than an obtained model using Map Miner Method.

**Keywords**—*coupled hidden markov model; fraud detection; intention mining; process discovery; validity*

## I. INTRODUCTION

Fraud in banking is an act of criminal. The fraud creates violations across bank that make the bank as a target and violations via bank that make the bank as an area. To detect the fraud, Financial Services Authority does fraud detections through several activities. The fraud detections are off-site supervision and on-site supervision [1]. The off-site supervision is a fraud detection by utilizing financial details and on-site supervision is a fraud detection by observing the site work.

Observing patterns of fraud detection are useful for analyzing performances of fraud detection and predicting the next fraud detection. This analysis finds gaps between the initial patterns of fraud detection and patterns of fraud detection that are observed based on sequences of activities. In order to facilitate the observation, fraud detection that has been carried out can be presented in a model.

A model becomes an important thing in information systems. It is because the model is a guidance for analyzing performance of processes in the system [2], [3], and finding

complex issues, such as business [4] and fraud [5], [6]. A lot of process mining algorithms, such as [4], [7] - [9], have been proposed for obtaining process model. The similarity between those algorithms is modeled data must be recorded in the event log. In contrast, fraud detections are not recorded in the event log. Activities that are triggered by fraud detections are recorded in the event log. Responding to this condition, intention mining method is chosen to model fraud detection.

Intention mining is an enrichment of process mining that utilizes intention to represent more suitable results for analysis [10]. Intention mining occurs to predict and model intention related to activities that are triggered by the intention and recorded in the event log [11]. Moreover, intention mining is applied to handle several issues in many papers, i.e. user consumption intention from social media or website [12], [13], child care intention [14], and construct a map model of developer behaviors during use Eclipse platform [15]. An intention mining that focuses on discovering a model of intentions is Map Miner Method [15].

Map Miner Method is an algorithm that obtains a map model of intentions and its strategies based on activities in the event log [15]. Strategies are a set of activities that fulfill intentions. Map Miner Method combines Hidden Markov Model (HMM), K-means and several rules. The HMM is used to obtain dependencies between strategies. Afterwards, the outputs of HMM are processed into a map model by K-means and several rules.

Regardless of its success in establishing a model, there is a weakness of Map Miner Method. This method gets adversity in determining a strategy of an activity if the activity is in more than one strategy. This method will assume that the right strategy is the strategy with high probabilities, meanwhile not all strategies with high probabilities are right. Uncertainty determination of strategies gives a major impact on the correctness of the map model.

Responding to this situation, this paper proposes a new method that has several rules to determine the strategies of each activity. In the rules, the connection between an activity and other activities is observed to determine the strategies. It is because most strategies are met by several activities and the

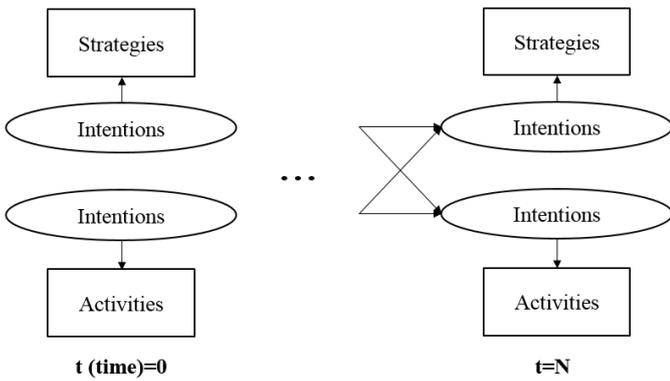


Fig. 1. Coupled hidden markov model to discover a model of fraud detection.

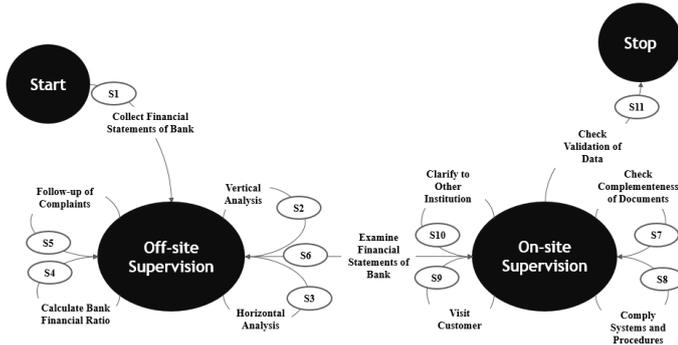


Fig. 2. An actual map model of fraud detection.

combination of activities in one strategy and those in other strategies is different. After determining the strategies, Coupled Hidden Markov Model utilizes the defined strategies and activities to form a map model.

The proposed method utilizes Coupled Hidden Markov Model. The Model has been applied in several issues, i.e. process mining [9], bio signal interaction [16], and bearing fault recognition [17]. The Coupled Hidden Markov Model in the proposed method determines intention and activities as its states and its first observations. The second observations in this Coupled Hidden Markov Model are strategies. Strategies are one or several activities that fulfill the intentions. A model of fraud detection is formed based on state probabilities of this Coupled Hidden Markov Model.

Apart from determining the appropriate model, evaluating the quality of the model is also important. The evaluation is based on the validity that has been used to evaluate a process model [18]. This paper compares the quality of the model obtained by proposed method and those obtained by comparison method, Map Miner Method [15].

This paper is organized into several main sections. The first section explains abstract in more detail. The second section presents Coupled Hidden Markov Model for discovering a map model of fraud detection. Furthermore, the equations for measuring validity of the obtained model is also described in this section. The third section describes the proposed method and the fourth reports the experiment of this paper. The conclusion of this paper is declared in the last section.

## II. PAPER METHOD

### A. Coupled Hidden Markov Model for Map Model

Coupled Hidden Markov Model is a compound of two Hidden Markov Model named chains and those states rely on previous states in all chains of the Model [9]. The initial states, the state transition probability matrix and the emission (observation) matrix of Coupled Hidden Markov Model are described in [9].

Fig. 1 depicts Coupled Hidden Markov Model that this paper proposed for discovering a map model. The states of the Model are intentions. Then, strategies and activities are included in the observations of the Model. It is Baum-Welch method that this paper used to obtain the Model.

### B. Map Model

A map model or an intentional process model is used for modeling output of intention mining [15]. Fig. 2 shows the actual fraud detection and its strategies are illustrated in a map model. There are eleven strategies that can be selected by the Financial Services Authority to fulfill intentions. The intentions are off-site supervision and on-site supervision. Start and Stop are additional intentions to signify the beginning and the end of processes in fraud detection.

Based on Fig. 2, there is one strategy to fulfill off-site supervision if the current position is starting, four strategies to fulfill off-site supervision if the current position is also off-site supervision, one strategy to change intention from off-site supervision to on-site supervision, four strategies to fulfill on-site supervision if the current position is same supervision and one strategy to achieve the stop intention as the end point of the processes.

The Financial Services Authority is not directly applying the strategies, but execute the activities that perform the strategies. Those activities will be recorded in the event logs. There are 25 activities to perform the strategies of fraud supervision. The details of activities and the relations to the strategies will be explained in Section IV.

### C. Quality of a Map Model

Each method can be evaluated based on its output. The proposed method will be evaluated by comparing its quality of obtained model with the quality of obtained model by Map Miner Method. The validity is chosen in this paper to determine the quality of those obtained models and has been applied in evaluating a process model [18].

A model is categorized as valid if all statements in the model are correct [18]. Statements are the data that can be obtained based on the model. In map model, the statements are intentions, dependencies between intentions and strategies. The statements are correct if those are same with the statements of an actual map model.

To define the validity of the map models, this paper uses two measurements. The first measurement is comparing Causal Nets of obtained map models that are constructed by

TABLE I. PSEUDO-CODE OF OBTAINING STRATEGIES

|    |  |
|----|--|
| 1  | <i>Initialize A as list of activities in the event log and S as list of strategies</i> |
| 2  | for a in A do  |
| 3  | if a is first_activity then  |
| 4  | add the first of S in list chosen_strag  |
| 5  | else if a is last_activity then  |
| 6  | add the end of S in list chosen_strag  |
| 7  | else then  |
| 8  | val_temp = 0   |
| 9  | for s in S do  |
| 10 | now_temp = 0   |
| 11 | if a in s then   |
| 12 | now_temp = 1   |
| 13 | if the next activity or the previous activity of a in s then                           |
| 14 | add 1 in variable now_temp   |
| 15 | else then  |
| 16 | add (1/s_length) in variable now_temp  |
| 17 | Endif  |
| 18 | Endif  |
| 19 | if now_temp >= val_temp then   |
| 20 | val_temp ← now_temp and strag_temp ← s   |
| 21 | Endif  |
| 22 | Endfor   |
| 23 | if the next activity of a not in strag_temp then                                       |
| 24 | add strag_temp in list chosen_strag  |
| 25 | Endif  |
| 26 | Endif  |
| 27 | Endfor   |
| 28 | <i>Output is chosen_strag as a list of predictable strategies</i>                      |

proposed method or Map Miner Method with Causal Nets of an actual map model. The usage of Causal Nets in determining valid models refers to [18]. The second measurement is counting the number of the right strategies in the obtained map models. In this case, the right strategies are strategies depicting in the actual map model. The obtained map models are regarded as valid models if all strategies of the actual map model forming in the obtained models.

### III. PROPOSED METHOD

The proposed method for obtaining a map model of fraud detection is divided into 2 steps. The steps are obtaining strategies based on sequences of activities and determining the map model using Coupled Hidden Markov Model.

#### A. Obtaining Strategies Based on Sequences of Activities

The first step is obtaining sequences of strategies as second observations in Coupled Hidden Markov Model for discovering map model of fraud detection. The proposed method for obtaining those strategies is shown in Table I.

The proposed method is obtaining a sequence of strategies based on a case in an event log. This method is conducted repeatedly until it gets sequences of strategies from all cases. Inputs of the method are activities of all cases in the event log and a list of strategies with the related activities. The list is earned from experts. An output of the method is sequences of chosen strategies. The chosen strategy is a strategy which gets the highest interrelation between the activities based on the list of strategies. The correctness of chosen strategies will be decreased if there are missing activities in the event log or fewer used cases.

#### B. Determining Map Model using Coupled Hidden Markov Model

Coupled Hidden Markov Model for discovering map model of fraud detection is trained by Baum-Welch in [9]. In the Model, the states are intentions and the observations are the activities and the strategies. Those strategies are obtained from the method of obtaining strategies.

An initial transition matrix of this Coupled Hidden Markov Model takes values equal to 1/numberofcolumns. An initial emission matrix takes values based on the execution of activities in processes. The first activities are related to starting intention and the last activities are related to stop intention. Each activity which has relation with first activity is related to intention after the start intention and each activity which has relation with last activity is related to intention before the stop intention. If an activity has no relation with first activity and last activity, the activity is related to intentions of previous and next activity. All these provisions also apply to the strategies. The value of each selected element is 1, and another value is 0.1.

## IV. RESULT AND ANALYSIS

#### A. Data

The experiment for this paper is processes of fraud detection. There are two fraud detections that perform several activities according to the related strategies. Fig. 2 is a map of fraud detection, where the edges as the strategies and the nodes (circles) as the intentions. The goal of this paper is obtaining a map model of fraud detection that resembles Fig. 2.

This paper used an event log with 50 cases. The cases were simulation data that were formed according to the actual map model of fraud detection, a list of strategies and related activities from The Financial Services Authority. The list is shown in Table II, the actual map model is shown in Fig. 2, and a piece of the event log is shown in Table III.

#### B. Experiment

This paper applied the proposed method for obtaining the map model of fraud detection. The first step of the proposed method is obtaining strategies. The example of chosen strategies is shown in Table IV. The last step is determining Coupled Hidden Markov Model for Map Model. The probabilities of state transition and probabilities of strategies as observations were used to depict a map model.

TABLE II. STRATEGIES AND RELATED ACTIVITIES

| Strategies |                                      | Related Trace Activities (Activities Code)  |
|------------|--------------------------------------|---|
| S1         | Collect Financial Statements of Bank | Define Bank Financial Report (AFD_1)  |
| S2         | Vertical Analysis                    | Check Trend Transaction (AFD_2), Check Credit Surge (AFD_3), Check Lowering of Interest (AFD_4)   |
| S3         | Horizontal Analysis                  | Check Financial Disbursement (AFD_5), Check Decrease Financial Value (AFD_6)  |
| S4         | Calculate Bank Financial Ratio       | Calculate Liquidity (AFD_7), Calculate Modal Structure and Solvability (AFD_8), Calculate Return on Investment (AFD_9), Calculate Profile Margin (AFD_10), Calculate Assets Utilization (AFD_11), Calculate Market Measure (AFD_12) |
| S5         | Follow-up of Complaints              | Define Follow-up complaints (AFD_13), Specify Actions Related with the Complaints (AFD_14)  |
| S6         | Examine Financial Statements of Bank | Check Company Profit (AFD_15), Check Sales (AFD_16), Check Dividend (AFD_17), Check Equity (AFD_18)   |
| S7         | Check Completeness of Documents      | Check Completeness Bill of Sales (AFD_19), Check Completeness Marketable Securities (AFD_20)  |
| S8         | Comply Systems and Procedures        | Check Conformance Procedures (AFD_21)   |
| S9         | Visit Customer                       | Define Follow-up a Visit to Customer (AFD_22), Define Bank Financial Reports (AFD_1)  |
| S10        | Clarify to Other Institution         | Check Financial History in Other Bank (AFD_23), Check Transaction History with Other Relations (AFD_24)   |
| S11        | Check Validation of Data             | Financial Statements Valid (AFD_25)   |

TABLE III. THE CHOSEN CORRESPONDING STRATEGIES

| Identification of Case | The activities  | The corresponding strategies |
|------------------------|---|------------------------------|
| PP01                   | AFD_1   | S1                           |
|                        | AFD_2 >> AFD_3 >> AFD_4                               | S2                           |
|                        | AFD_5 >> AFD_6  | S3                           |
|                        | AFD_7 >> AFD_8 >> AFD_9 >> AFD_10 >> AFD_11 >> AFD_12 | S4                           |
|                        | AFD_15 >> AFD_16 >> AFD_17 >> AFD_18                  | S6                           |
|                        | AFD_19 >> AFD_20                                      | S7                           |
|                        | AFD_25  | S11                          |

TABLE IV. A PIECE OF EVENT LOG

| Identification of Case | Activities | Beginning Time   | Ending Time      |
|------------------------|------------|------------------|------------------|
| PP01                   | AFD_1      | 11/7/2016 10:00  | 11/7/2016 13:00  |
| PP01                   | AFD_2      | 11/7/2016 13:00  | 11/7/2016 16:00  |
| PP01                   | AFD_3      | 11/7/2016 16:00  | 11/7/2016 19:00  |
| PP01                   | AFD_4      | 11/7/2016 19:00  | 11/7/2016 22:00  |
| PP01                   | AFD_5      | 11/7/2016 22:00  | 11/8/2016 1:00   |
| PP01                   | AFD_6      | 11/8/2016 1:00   | 11/8/2016 4:00   |
| PP01                   | AFD_7      | 11/8/2016 4:00   | 11/8/2016 7:00   |
| PP01                   | AFD_8      | 11/8/2016 7:00   | 11/8/2016 10:00  |
| PP01                   | AFD_9      | 11/8/2016 10:00  | 11/8/2016 13:00  |
| PP01                   | AFD_10     | 11/8/2016 13:00  | 11/8/2016 16:00  |
| PP01                   | AFD_11     | 11/8/2016 16:00  | 11/8/2016 19:00  |
| PP01                   | AFD_12     | 11/8/2016 19:00  | 11/8/2016 22:00  |
| PP01                   | AFD_15     | 11/8/2016 22:00  | 11/9/2016 1:00   |
| PP01                   | AFD_16     | 11/9/2016 1:00   | 11/9/2016 4:00   |
| PP01                   | AFD_17     | 11/9/2016 4:00   | 11/9/2016 7:00   |
| PP01                   | AFD_18     | 11/9/2016 7:00   | 11/9/2016 10:00  |
| PP01                   | AFD_19     | 11/9/2016 10:00  | 11/9/2016 13:00  |
| PP01                   | AFD_20     | 11/9/2016 13:00  | 11/9/2016 16:00  |
| PP01                   | AFD_25     | 11/9/2016 16:00  | 11/9/2016 19:00  |
| PP02                   | AFD_1      | 11/9/2016 19:00  | 11/9/2016 22:00  |
| PP02                   | AFD_2      | 11/9/2016 22:00  | 11/10/2016 1:00  |
| PP02                   | AFD_3      | 11/10/2016 1:00  | 11/10/2016 4:00  |
| PP02                   | AFD_4      | 11/10/2016 4:00  | 11/10/2016 7:00  |
| PP02                   | AFD_5      | 11/10/2016 7:00  | 11/10/2016 10:00 |
| PP02                   | AFD_6      | 11/10/2016 10:00 | 11/10/2016 13:00 |
| PP02                   | AFD_15     | 11/10/2016 13:00 | 11/10/2016 16:00 |
| PP02                   | AFD_16     | 11/10/2016 16:00 | 11/10/2016 19:00 |
| PP02                   | AFD_17     | 11/10/2016 19:00 | 11/10/2016 22:00 |
| PP02                   | AFD_18     | 11/10/2016 22:00 | 11/11/2016 1:00  |
| PP02                   | AFD_19     | 11/11/2016 1:00  | 11/11/2016 4:00  |
| PP02                   | AFD_20     | 11/11/2016 4:00  | 11/11/2016 7:00  |
| PP02                   | AFD_25     | 11/11/2016 7:00  | 11/11/2016 10:00 |

Fig. 3 shows the map model by proposed method utilizing Coupled Hidden Markov Model. As the comparison, Fig. 4 is the discovered map model using a comparison method (Map Miner Method). The strategies with red color indicates the strategies that are different with the strategies in the actual map model or strategies that did not appear in the actual map model.

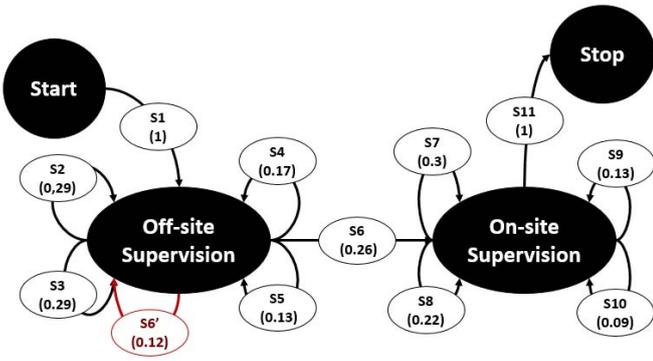


Fig. 3. Discovered map model of fraud detection using proposed method.

TABLE V. THE CAUSAL NET OF ACTUAL MAP MODEL

| Leading intentions   | Intentions | Following intentions |
|----------------------|------------|----------------------|
| {∅}                  | Start      | {{Off-site}}         |
| {{Start,Off-site}}   | Off-site   | {{Off-site,On-site}} |
| {{Off-site,On-site}} | On-site    | {{On-site,Stop}}     |
| {{On-site}}          | Stop       | {{∅}}                |

TABLE VI. THE CAUSAL NET OF MAP MODEL USING PROPOSED METHOD UTILIZING COUPLED HIDDEN MARKOV MODEL

| Leading intentions   | Intentions | Following intentions |
|----------------------|------------|----------------------|
| {∅}                  | Start      | {{Off-site}}         |
| {{Start,Off-site}}   | Off-site   | {{Off-site,On-site}} |
| {{Off-site,On-site}} | On-site    | {{On-site,Stop}}     |
| {{On-site}}          | Stop       | {{∅}}                |

TABLE VII. THE CAUSAL NET OF MAP MODEL USING MAP MINER METHOD

| Leading intentions          | Intentions | Following intentions       |
|-----------------------------|------------|----------------------------|
| {∅}                         | Start      | {{Off-site, On-site}}      |
| {{Start,Off-site, On-site}} | Off-site   | {{Off-site,On-site}}       |
| {{Start,Off-site,On-site}}  | On-site    | {{On-site,Off-site, Stop}} |
| {{On-site}}                 | Stop       | {{∅}}                      |

Based on Table V until Table VII, a map model by proposed method is valid because all of its statements are same with those in the actual map model. Moreover, all of strategies in the actual map model are depicted in the map model, although there is a strategy that should not become up.

On the other hand, a map model of Map Miner Method is not valid because several statements in its Causal Nets are different to those in Causal Nets of the actual map model. Strategy S2 is misplaced and there are several strategies that should not become up.

In addition to constructing a valid map model, the patterns of fraud detection and most-likely patterns can be observed using the map model. Based on probabilities, number of each strategies in Fig. 3, one of likely patterns that can be seen is Start >> Off-site Supervision >> Off-site Supervision >> On-

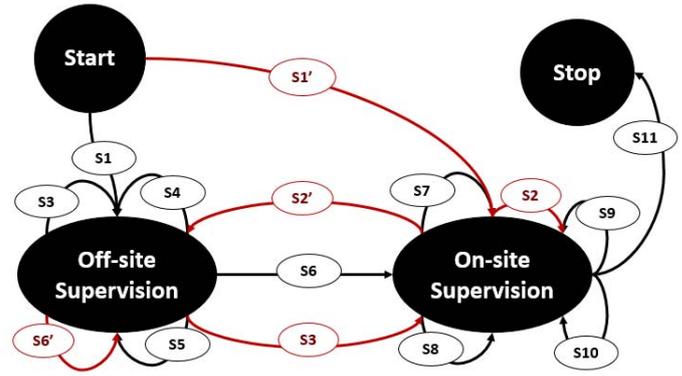


Fig. 4. Discovered map model of fraud detection using map miner method.

site Supervision >> Stop. And then, off-site supervision is more performed than on-site supervision based on total probabilities of strategies that are related to those fraud detection.

### V. CONCLUSION

This paper discovers the map model of fraud detection by the proposed method utilizing activities triggering by fraud detection and Coupled Hidden Markov Model. The proposed method is divided into two steps. The first step is obtaining sequences of strategies based on sequences of activities in the event log. Then, the last step is determining map model using Coupled Hidden Markov Model with utilizing obtained sequences of strategies and sequences of activities from the event log.

Outcomes of experiments showed that the proposed method using Coupled Hidden Markov Model could illustrate the right map model of fraud detection and its strategies. Moreover, using the map model and probabilities of the strategies, patterns of fraud detection and likely patterns can be determined. The outcomes of experiments also showed that an obtained map model by proposed method utilizing Coupled Hidden Markov Model has better validity than the obtained map model by Map Miner Method.

This proposed method is promising because there are only a few papers on determining a map model as an output of intention mining utilized Coupled Hidden Markov Model. Then, the evaluation of validity of a map model will be better if there is the availability of large-scale event logs of fraud detection.

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