

Recent Trends in Role Mining Algorithms for Role-Based Access Control: A Systematic Review

^{1,2}Nazirah Abd Hamid, ¹Rabiah Ahmad and ¹Siti Rahayu Selamat

¹Faculty of Information & Communication Technology, Universiti Teknikal Malaysia Melaka, Malaysia

²Faculty of Informatics and Computing, Universiti Sultan Zainal Abidin, Malaysia

Abstract: Role-based access control (RBAC) has been widely accepted by many organizations due to its security features. RBAC executes based on a role which includes set of permissions built in a matrix form. There are many studies investigated flexibility offered by RBAC. One of them is the ability to modify and reassigned user's roles according to the permissions policy. Public known this process as role mining and various techniques have been designed and developed to improve the process. Up to now, very limited studies provide systematic review of roles mining techniques. This paper, offers conceptual understanding through a systematic review by classifying role mining problem (RMP) and its proposed solution. The results from our study provide clear understanding of approaches reported by previous studies in solving roles mining problem. The analysis offered variety of areas that can be explored in leveraging role mining techniques towards improving roles based access control.

Key words: Role Mining • RBAC • Trends • Review

INTRODUCTION

An access control model (ACM) can be described as a set of criteria to define a user's right on any digital system and these procedures are to ensure that only authorized users can manipulate those resources [1, 2]. There are various types of methods and models available in access control model. The traditional ACMs known as Mandatory Access Control (MAC) and Discretionary Access Control (DAC). However, the models reported by [3] may not effective for a dynamic environment such as cloud computing environment. The main reason is ACM in cloud computing needs to have a special function to support flexibility to allow user control their own resources. In addition, large number of resources invites privacy concern to users [4, 5]. Hence, an improvement of ACM which commonly known as Role Based Access Control (RBAC) was introduced in [6]. The study highlighted concept of relationship between users-roles-permissions.

Sandhu in [7] presented basic framework of RBAC which rely on access decision policy (allow/deny). In [3]

and [8] described that in RBAC, access decisions (allow/deny) are based on the individual's roles and responsibilities within the cloud environment. Roles can be allocated based on the least privilege and can be transferred and used based on the security policies. The big advantage of this feature is the users can be reassigned from one role to another in a simple way. RBAC also applies the separation of roles principle so that the abuse of information can be controlled. Hence RBAC can be reflected as an easy model and the best ACM for the local domain.

This paper is quite similar to the work presented by [9]. The key contribution of this paper is to discuss and conclude the development of role mining. In this paper, firstly we review the different variants of role mining problem (RMP) and secondly, study the solution approaches that consistent with aforementioned RMP. Moreover, we address this following research questions:

- RQ1: What problems are trying to be solved in existing role mining approaches?
- RQ2: Which solutions are employed in existing role mining approaches?

The remainder of the paper is structured as follows. Section 2 presents a background study of the research area. The methodology that constructs this works is shown in Section 3 while Section 4 presents and classifies the general RMP and the proposed solutions for each identified RMP. Lastly, Section 5 gives a conclusion.

Background Study: Role-based access control (RBAC) has been accepted by many organizations especially in commercial sectors such as military and healthcare field because of the security feature that RBAC offers. Generally, RBAC involves a role with a set of permissions and the advantage of RBAC is the flexibility to modify or reassigned the roles of a user if the permissions are changed or any security changes in the company. Therefore, the complexity of managing user-permission assignment (UPA) can be reduced [10]. However, one of the main challenges in designing and executing a RBAC model is to define a complete and correct set of roles and assigning them with permissions. This process is also known as role engineering that can be carried out in three means of approaches namely top-down, bottom-up and hybrid.

According to [11] the top-down approach requires the interference from human expert to understand the business processes and extract relevant roles from the analysis. However, this approach relies in human and can be a slow and costly process. In con-trast the authors explain that the bottom-up approach or often called as role mining exploit the existing user-permission assignment (UPA) to define roles. Role mining has the advantage of being automated by applying certain algorithms.

Definition of the Role Mining Problem: The theory of role mining was introduced by [12] while RMP concepts were proposed by [10]. Role mining main objective is to reveal the appropriate roles from existing UPA [13] and the outputs from the role mining process are set of roles (ROLES), a user-role assignment relation (UA) and

a role-permission assignment relation (PA) [14]. Moreover, Role Mining Problem (RMP) can be defined as a problem to acquire an optimal set of roles from an existing user-permission assignment to build a high quality RBAC system [15]. The basic RMP can be defined as follows:

Definition 1: Given a set of users (U), a set of permissions (PRMS), a user permis-sion assignment (UPA), a set of roles (ROLES), a user-to-role assignment (UA) and a role-to-permission assignment (PA), 0-consistent with UPA and minimizing the number of roles, k.

Methodology: For this work, we implemented the methodology proposed by [9, 16, 17] to address the research questions as Section 1 as illustrated in Figure 1.

Firstly, we carried out a bibliographic database search including the ACM Digital Library, DBLP, IEEE Digital Library and Google Scholar using the keyword “role mining”. Secondly, to achieve a complete catalog of role mining algorithm, the references search for each publication was applied to identify any related works and any publications that did not present role mining techniques were removed from the catalog. Thirdly, we classified the recent role mining publications according to the general role mining problems and lastly, we analyzed the proposed solutions for each problem.

Classification of Role Mining Algorithms: Generally, a role mining problem goals is to find out an optimal role set from a user-permission assignment (UPA) and according to [18] if the same user-permission as-signments are given, with using different role mining algorithms, the different RBAC models or systems can be built. For the rest part of this chapter, we would discourse some of the recent role mining algorithms in the past three years and as abovementioned, this work is addressing two research questions accordingly; we classify the recent role mining

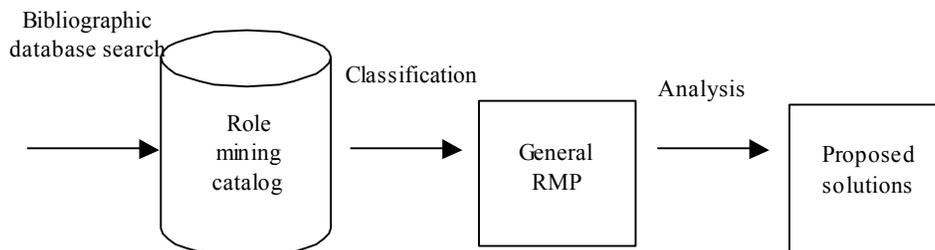


Fig. 1: Research methodology

publications according to the general role mining problems and then highlighting the proposed solutions for each problem. Between 2014 and 2016, a total of 60 publications concerning role development issues have been identified.

Design and Configuration of RBAC Schemes: RBAC scheme design is done at the early stage of an information security system development. Reconfiguration of the scheme should be performed if the RBAC system goes through many changes because changes can lead to uncontrollable role management. But, this reconfiguration can be costly to the administration [19].

Numerous studies have attempted to solve these problems and according to [19], the authors proposed an enhancement of genetic algorithm (GA) with several enhancements that showed high effectiveness. Another study by [13] examined the usage of clustering algorithm to recognize abnormal configurations and then recommend suggestions to fix them and the studies by [20-22] also supported previous work by indicating the usage of clustering algorithm to address abovementioned problem.

Incomplete Knowledge: A common assumption in managing role mining that the security administrator has a complete set of permissions to work with. However, in the real practice this theory is hard to accomplish and sometimes the admin must work with missing or incomplete information. According to [23] studies, one of the techniques that could be implemented to solve this shortcoming was by using a data cleansing method namely k-NN missing value imputation and it worked by replacing the missing values with its nearest neighbor. Moreover, Boolean matrix factorization problem (BMF) algorithm specifically called as Ternary Matrix Factorization (TMF) also could support the problem of the missing information [24].

User Perception: User experience is one of the most important aspect in any information system yet, according to [25] this aspect is often overlooked by many role mining studies so the authors argued that despite the advantage of RBAC that enabled the user to activate the necessary role at each session only, this activating and deactivating process could be a problematic situation from the user perception. So, the authors proposed user-oriented algorithm, a fast heuristic algorithm that is based on a novel dynamic candidate role generation strategy.

Role Management: According to [26], role explosion could be happening if an organizational overdone the process of decoupling subject and permission therefore one of the method to overcome this problem was to apply hierarchical graphing model to enhance the visualization on the subject-permission mappings. Similarly, the authors recommended graph model called k-partite graph approach to provide high quality RBAC system with lower cost [27].

A considerable amount of literature has been published on role system maintenance especially on role optimization. These studies tried to propose models and algorithms to upgrade the quality of role definitions. The most recent studies have proposed a new approach specifically a data-centric approach to produce an optimal role mining results without running any role mining algorithms [28] and a new optimization model based on pairwise dependency for structural roles was suggested to show improvement in role discovery [29].

Multiple Constraints: In recent years, there has been an increasing amount of literature on constraints in RBAC and constraint can be defined as a relationship or condition among roles. However, many existed role mining algorithm in RBAC could not complies with multiple constraints even though multiple constraints are needed to support current security requirements in an organization. This section will discuss numerous developments of role mining algorithms that can fulfill many constraints at one time [18].

Authors identified a new role mining technique that implemented answer set programming (ASP) approach and the main key of this approach was the declarative problem solving that essential to deal with multiple constraints [18]. Moreover, [30] employed Matrix Based Role Assignment (MBRL) algorithm to solve the same problem. Also [31] discovered that the Matrix Based Role Assignment (MBRL) algorithm and the visual approach could enhance the process of mining the roles especially in the present of two cardinality constraints.

Furthermore, the authors consider greedy heuristic solution by modeling the heuristic algorithm using integer linear programming (ILP) that eventually could deliver optimal solution [32] and according to [33] additional constraints may be inflicted when a role was generated from an existing permission assignment relation. To avoid that situation, the authors also presented a heuristic solution by introducing two separate frameworks. Additionally [34] claimed they were the first researcher that initiated the weight of permission notion and this

Table 1: General problems and proposed techniques for role mining

Techniques	Design and Configuration of RBAC Schemes	Incomplete Knowledge	User Perception	Role Management	Multiple Constraints
GA	[19] X				
Clustering	[13] X [20-22]				
k-NN	[23]	X			
BMF	[24]	X			
User-oriented	[25]		X		
Graph / Graphical	[26-27] [35]			X	X
Optimization Model	[29]			X	
Data-centric Approach	[28]			X	
ILP	[32]				X
ASP	[18]				X
MBRL	[30-31]				X
Framework	[33]				X
Weight	[34]				X

notion proved could prioritize the importance on permissions. Moreover, the present study by [35] focused on a visual role mining approach to signify the user-permission assignments to assist better analysis on roles with constraints.

CONCLUSION

This work discoursed the recent role mining algorithms in the past three years and as discussed in Section IV, this work answered two research questions accordingly; we classified the recent role mining publications according to the general role mining problems and then highlighting the proposed solutions for each problem. Table 1 shows the general role mining problems (RMP) and the proposed solutions that we think significant in the role mining developments and moreover Table 1 can suggest different types of solutions or techniques that could be used in to resolve any RMP. One of the future direction is to propose a RBAC system that accommodate the user perception in role decision process. The incentive is because most of the RBAC system only to minimize the admin workloads without considering the users' perception.

ACKNOWLEDGEMENT

This research is fully sponsored by Centre for Research and Innovation Management (CRIM), Universiti Teknikal Malaysia Melaka (UteM) with the Project Code of TRGS/1/2016/FTMK-CACT/01/D00006.

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