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Uniform-scale assessment of role minimization in bipartite networks and its application to access control☆

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HIGHLIGHTS

- This study reveals the features of bipartite network relevant to role minimization.
- This study proposes the metrics to evaluate role minimization on a uniform scale.
- The proposed metrics is based on relative values but not absolute values.
- The approach is independent of any specific role mining algorithms and datasets.

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ABSTRACT

As an important kind of complex network models, bipartite network is widely used in many applications such as access control. The process of finding a set of structural communities in a bipartite network is called role mining, which has been extensively used to automatically generate roles for structural communities. Role minimization, aiming to get the fewest roles to reduce the administrative complexity of the access control, is the simplest and most popular form of role mining. Current assessment metrics of role minimization results are based on the absolute values, and cannot measure or compare the results from different algorithms and different datasets on a uniform scale. To address this problem, this study proposes a framework of *mark-based evaluation for role minimization (MERM)* to provide a normalized measure for different role minimization results on a uniform scale. According to MERM, for each dataset, three quantitative *reference marks* are established to mirror the level of role minimization results. The marks are entirely determined by the inherent features of a dataset but have nothing to do with any role mining algorithm. Based on the marks, a normalized *score vector* is constructed to estimate the performance of results, independent of the size of any dataset. MERM can assess varieties of role minimization results on a uniform scale. The experimental results show the effectiveness of MERM: the different results generated from nine algorithms on six datasets can be measured on a uniform scale.

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Nomenclature

$\mathcal{R}_b$	The base-mark of role minimization.
$\mathcal{R}_l$	The full-mark of role minimization.
$\mathcal{R}_u$	The medium-mark of role minimization.
$\mathcal{R}_{opt}$	The optimum result of role minimization.
$deg(v)$	The degree of vertex v.
k_e	The degree of edge e.
$\Xi(v)$	The indirect-neighbor set of vertex v.
$\Gamma(v)$	The neighbor set of vertex v.
$TN(e)$	The tied neighbor set of an edge e.
$Ver(G)$	The vertex set of graph G.
$Edg(G)$	The edge set of graph G.
$B(V_L, V_R)$	A bipartite clique with the left vertex set V_L and the right vertex set V_R.
$G(V_L \cup V_R, E)$	A bipartite graph with the left vertex set V_L, the right vertex set V_R and the edge set E.
$bc(G)$	The biclique cover number of bipartite graph G.
$\mathrm{bp}(G)$	The biclique partition number of bipartite graph G.
$M(X)$	The reduced adjacency matrix of relation set X, $X = UA, PA, UPA$.
$\vec{\mathcal{S}}$	Score vector.
U	The set of users.
P	The set of permissions.
UPA	The set of user-permission relations.
R	The set of roles.
UA	The set of user-role assignments.
PA	The set of role-permission assignments.
MERM	Mark-based Evaluation for Role Minimization.
MBC	The minimum biclique cover.
MBP	The minimum biclique partition.
ACL	Access control list.
RBAC	Role-based access control.
WSC	The weighted structural complexity.
ε	The small additional value for computing score vector ($\vec{\mathcal{S}}$), with $1 \gg \varepsilon > 0$.

1. Introduction

In the field of complex networks [1–3], bipartite networks have been extensively used to describe the bipartite relations between subjects and objects, such as the buyer–seller relations in recommendation system [4], the task–resource relations in resources scheduling [5], and the user-permission relations in access control [6], etc. In a bipartite network, the process of finding a set of complete bipartite subgraphs[1] to cover[2] the entire network is called *role mining* [7], and each subgraph obtained can be regarded as a role, in which arbitrary two relations have one common vertex. This role indicates a series of similar behaviors, expectations and responsibilities [8]. Without loss of generality, we focus on the bipartite relations in access control in this study.

Access control is the crucial technology in information security management systems. An access control list (ACL) is composed of a set of users, a set of permissions and a set of user-permission relations. ACL is actually a bipartite network in which the user set and the permission set can be seen as two disjoint vertex sets, and the relation set can be seen as the edge set of the network. Correspondingly, the access control implemented by role mining on ACL is *role-based access control* (RBAC) [6]. By role mining, RBAC with fewer roles is easier to be administrated and adopted in the large-size bipartite networks of access control [9]. Now, role mining has become highly desirable, since it can automatically identify roles from the access control list in existing applications and systems [10,11]. In addition, role mining can enforce the existing user-to-permission assignments, leading to a smoother transition from ACL to RBAC [12,13]. Due to the above reasons, the role mining for access control has attracted more and more attention from the academia and industry communities [14,15].

Role minimization, which prefers *the fewest roles* to implement RBAC, has been considered to be the most fundamental role mining [16,17] because fewer roles can greatly reduce the administrative complexity of RBAC[3] [16]. Actually, role

[1] In a bipartite network, a complete bipartite subgraph is a subgraph in which every vertex of the first set is connected to all vertices of the second one.

[2] In a bipartite network, given a series of bipartite subgraphs, if the union of the edge sets of the subgraphs includes all the edges of the bipartite network, and the union of the vertex sets of the subgraphs includes all the vertices of the bipartite network, it is said that the subgraphs cover the bipartite network.

[3] The administrative complexity of RBAC means the workload of managing access control relations, and it is usually measured by the number of roles. It is considered that fewer roles cause lower administrative complexity [11].

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