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A WORKFLOW PERFORMER-ROLE AFFILIATION NETWORKING KNOWLEDGE DISCOVERY ALGORITHM

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Abstract. In recent, we have been focusing on a special type of organizational social networking knowledge, which is dubbed 'workflow-supported affiliation networking knowledge,' that can be extracted from deploying workflow models and packages into large-scale enterprises. Particularly, this paper introduces a focal part of the knowledge, 'workflow performer-role affiliation networking knowledge,' in terms of discovering human resource allotting and collaborating relationships hidden in a group of workflow models or a heap of its enacted logs. We conceive a theoretical algorithm that is able to discover the underlying workflow performer-role affiliation networking knowledge from an ICN(Information Control Net)-based workflow model, and we extend the algorithm so as to operate for a group of workflow models (or packages). The discovered knowledge is represented by a bi-partite graph as well as a bi-partite matrix through the so-called workflow performer-role affiliation network model defined in the paper. Through the discovered knowledge, we are able to analyze, control, and predict the organizational intelligence, like allotments, involvements, participations, and collaborations of human resources, that avails of the affiliated relationships between a group of performers and a group of roles in a workflow model (or a workflow package). Ultimately, the workflow performer-role affiliation networking knowledge ought to be the fate of visualizing and numerically expressing how much the performers and the roles are interrelated and collaboratively affiliated in enacting a specific workflow model (or package).

Keywords: information control net, workflow intelligence and knowledge discovery, workflow-supported affiliation networking knowledge, performer-role affiliation, bi-partite graph and matrix

1. **Introduction.** The logical foundation of a workflow management system is based upon its underlying workflow model, almost all of which commonly employ the five essential entity types[5], such as activity, role, actor, repository and application entity types, to describe organizational works with their procedural collaborations and resource allotments. After all, the workflow model embodies the typical people-oriented organizational

perspectives, such as behavioral, social, informational, collaborative, and historical perspectives. So, workflow management systems are a sort of "people systems" that must be designed, deployed, and understood within their social and organizational contexts.

In recent, the workflow literature brings into being interested in "social networking services." It begins from the strong belief that social relationships and collaborative behaviors among employees affect the overall performance in the real businesses and the working productivities, as well, over workflow-supported enterprises. Therefore, the authors' research group has been doing research on applying the concept of social networking services and its analysis methods to workflows in the names of workflow-supported social networking knowledge[6][7] and workflow-supported affiliation networking knowledge[8][12]. Particularly, this paper is concerned with a special type of workflow-supported affiliation networking knowledge, workflow performer-role affiliation networking knowledge, which is the essential knowledge that can be discovered from a workflow model or a group of workflow models, and it is also called a workflow membership network representing the involvements (or participations)of a set of performers with a set of roles in the corresponding workflow model. That is, workflow performers (or actors) are linked through their joint participation in performing roles; conversely, workflow roles are connected to the extent that they have performers in common. Through the workflow performer-role affiliation networking knowledge, it is possible to visualize how performers and roles are simultaneously interrelated in a workflow model or package. Conclusively, the paper derives a series of concepts and algorithms related to exploring a planned aspect (defined in the workflow build-time) of performer-role affiliation networking knowledge from a group of workflow models based upon the information control net methodology.

In terms of making up the paper, the next section gives the related works that have been done in the workflow literature. And the next consecutive section describes the details of the knowledge discovering procedure for workflow performer-role affiliation networking knowledge, like its representation, discovery, and analytics. Finally, we give a summary with a brief description of conclusions including future works.

2. **Related Work and Scope.** There, of course, exist two main research issues in discovering workflow performer-role affiliation networking knowledge. One is a knowledge *discovery* issue[6][7][8][12], the other has something to do with a knowledge *rediscovery* issue[3]. The latter is concerned with mining an enacted aspect of workflow performer-role affiliation networking knowledge from a mountainous pile of workflow enactment event logs; the former is to explore a planned aspect of workflow performer-role affiliation networking knowledge by extracting a certain type of associations among the entity types of workflow models, such as activity-performer association, activity-application association, activity-role association, role-performer association, and model-performer association. More specifically, the paper would differentiate the former from the latter and be narrowed by scoping out the performer-role entity types of associations.

Firstly, the workflow-supported affiliation networking knowledge was addressed by H. Kim, et al.[8], in which they introduced the basic concept and its related framework for discovery, mathematical abstraction, and visual abstraction of the workflow-supported affiliation networking knowledge. Also, K. Kim[12] dug out a theoretical knowledge exploring framework from representation to visualization by availing of the activity-performer associative relationships in the ICN-based workflow model. This paper is the conceptual and contextual extension of the framework[12] in order to particularly discover a

performer-role affiliative relationships and networking knowledge from a group of ICN-based workflow models and/or packages.

3. **Discovering Performer-Role Affiliation Networking Knowledge.** This section starts from introducing the basic concept of performer-role affiliation networking knowledge, and its graphical and formal representations. Next, it devises a knowledge discovering algorithm and a bipartite matrix generation algorithm to discover performer-role affiliation networking knowledge from an ICN-based workflow model, and to analyze the discovered activity-performer affiliation networking knowledge, respectively.

3.1. **Workflow Meta-Model: Affiliated Relationships.** An ICN-based workflow model is to be instantiated from the workflow meta-model[5] that is constructed from the functional linkages of the following basic conceptual components—activity, relevant data (repository), role, actor (performer), and invoked application including web services. These essential components and their functional linkages become the primitive information to form affiliated relationships as workflow affiliation knowledge. Conversely, the ICN-based workflow model instantiated from the workflow meta-model can be also defined by capturing the affiliated relationships among the primitive entity types, like activities and their precedence of controls, invoked applications, roles, actors, and input/output repositories. In this subsection, we define the basic associations or affiliations embedded in the ICN-based workflow model.

The following [Definition 1] is a formal definition of those affiliated relationships and its functional components to be used for retrieving affiliation knowledge, such as activity-role association, activity-relevant data association, activity-invoked application association, and role-actor association knowledge. Based upon the workflow affiliation knowledge, it is possible to explore several types of workflow-related affiliations, like activity-actor association, relevant data-invoked application association, role complexity, actor complexity information, and so forth.

[**Definition 1**] **Affiliated Relationships** in the formally defined ICN-based workflow model. A basic set of **affiliations** is represented by a 4-tuple formula, $\Gamma = (\rho, \lambda, \varepsilon, \pi)$, over a set of $\mathbf{A}$ activities (including a set of group activities), a set $\mathbf{R}$ of repositories, a set $\mathbf{G}$ of invoked application programs, a set $\mathbf{P}$ of roles, and a set $\mathbf{C}$ of actors (including a set of actor groups). $\wp(\ )$ represents a power set.

- $\rho = \rho_i \cup \rho_o$
  where $\rho_o : \mathbf{A} \longrightarrow \wp(\mathbf{R})$ is a single-valued mapping function from an activity to its set of output repositories, and $\rho_i : \mathbf{A} \longrightarrow \wp(\mathbf{R})$ is a single-valued mapping function from an activity to its set of input repositories;f
- $\lambda = \lambda_a \cup \lambda_g$
  where $\lambda_g : \mathbf{A} \longrightarrow \mathbf{G}$ is a single-valued mapping function from an activity to its invoked application program, and $\lambda_a : \mathbf{G} \longrightarrow \wp(\mathbf{A})$ is a single-valued mapping function from an invoked application program to its set of associated activities;
- $\varepsilon = \varepsilon_a \cup \varepsilon_p$
  where $\varepsilon_p : \mathbf{A} \longrightarrow \mathbf{P}$ is a single-valued mapping function from an activity to a role, and $\varepsilon_a : \mathbf{P} \longrightarrow \wp(\mathbf{A})$ is a single-valued mapping function from a role to its set of associated activities;
- $\pi = \pi_p \cup \pi_c$
  where, $\pi_c : \mathbf{P} \longrightarrow \wp(\mathbf{C})$ is a single-valued mapping function from a role to its set of

associated actors, and $\pi_p : \mathbf{C} \longrightarrow \wp(\mathbf{P})$ is a single-valued mapping function from an actor to its set of associated roles;

3.2. **Knowledge Representation: Performer-Role Affiliation Network Model.** In order to represent the workflow-supported performer-role affiliation knowledge, the paper newly defines a graphical (Bipartite Graph) and formal representation model, which is dubbed the performer-role affiliation network model. A performer-role affiliation network model, which is abbreviated as APANM, consists of two types of nodes—a set of performers and a set of roles—and a set of relations between these two nodal types. Thus, the performer-role affiliation network is a two-mode network, through which it used to accomplish the following dual objectives:

- to uncover the relational structures of workflow-performers through their joint involvement in roles, and
- to reveal the relational structures of workflow-roles through their joint participation of common performers.

Additionally, those relational structures can be weighed to measure the extent of their strengths by assigning a value to each of relations between nodal types. Therefore, there are two types of activity-performer affiliation networks—binary activity-performer affiliation network and valued activity-performer affiliation network. In the binary activity-performer affiliation network, its value (0 or 1) implies a binary relationship of involvement (or participation), while values in the valued activity-performer affiliation network may represent various implications according to their application domains; typical examples of values might be stochastic (or probabilistic) values, strengths, and frequencies. The formal knowledge representation of activity-performer affiliation network model is defined in [Definition 2].

[**Definition 2**] **Performer-Role Affiliation Network Model**. The performer-role affiliation network model is formally defined as a 3-tuple formula, $\Lambda = (\sigma, \psi, \mathbf{S})$, over a set $\mathbf{C}$ of performers (actors), a set $\mathbf{P}$ of roles, a set $\mathbf{V}$ of weight-values, a set $\mathbf{E}_p \subseteq (\mathbf{C} \times \mathbf{P})$ of edges (pairs of performers and roles), and a set $\mathbf{E}_a \subseteq (\mathbf{P} \times \mathbf{C})$ of edges (pairs of roles and performers), where, $\wp(\mathbf{P})$ represents a power set of the role set, $\mathbf{P}$:

- $\mathbf{S}$ is a finite set of work-sharing actors or groups of some external performer-role affiliation network models;
- $\sigma = \sigma_p \cup \sigma_v$ /* Involvement Knowledge */
  where, $\sigma_p : \mathbf{C} \longrightarrow \wp(\mathbf{P})$ is a single-valued mapping function from a performer to its set of involved roles; $\sigma_v : \mathbf{E}_p \longrightarrow \mathbf{V}$ is a single-valued mapping function from an edge ($\in \mathbf{E}_p$) to its weight-value;
- $\psi = \psi_a \cup \psi_v$ /* Participation Knowledge */
  where, $\psi_a : \mathbf{P} \longrightarrow \wp(\mathbf{C})$ is a single-valued mapping function from a role to a set of participated performers; and $\psi_v : \mathbf{E}_a \longrightarrow \mathbf{V}$ is a single-valued function from an edge ($\in \mathbf{E}_a$) to its weight-value;

And the graphical knowledge representation is depicted by an affiliation graph. So, the performer-role affiliation network's graphical model consists of two types of graphical nodes—a set of performers (shaped in hexagon) and a set of roles (shaped in circle)—and a set of non-directed edges between these two nodal types, which means that a workflow affiliation network is a non-directed graph. That is, in a performer-role affiliation graph, non-directed lines connect workflow performers aligned on one side of the diagram to the

roles aligned on the other side. Importantly, a performer-role affiliation graph does not permit lines among the workflow performers nor among the roles. Therefore, a performer-role affiliation graph with g performers and h roles can be transformed into a matrix with 2-dimension of $g \times h$.

3.3. **Knowledge Discovery: Performer-Role Affiliation Knowledge Discovering Algorithm.** At this moment, it is important to emphasize that the performer-role affiliation networking knowledge would not be modeled or designed but be automatically discovered from workflow procedures. So, this paper devises an algorithmic discovery methodology to discover performer-role affiliation knowledge, which is represented by the performer-role affiliation network model, from exploring the simple internal social perspective—π_c (role-actor mapping information)—of the ICN-based workflow model. Likewise, we have to remind that it should not be differentiated the single-actor binding type from the group-actor binding (the realtime groupware activity as an example) type, where all the actors affiliated to a role are simultaneously assigned to cooperatively perform a single activity; almost all the current available workflow models do not support such a realtime groupware activity type. However, as a future work, we need to cope with these social relationships caused from the group-actor binding type in discovering activity-performer affiliation knowledge. The following is the algorithm to automatically discover a performer-role affiliation network model from an ICN-based workflow model:

Performer-Role Affiliation Knowledge Discovering Algorithm:
Input An ICN, $\Gamma = (\delta, \rho, \gamma, \lambda, \varepsilon, \pi, \kappa, \mathbf{I}, \mathbf{O})$;
Output A Binary Performer-Role Affiliation Network Model, $\Lambda = (\sigma, \psi, \mathbf{S})$;

Begin Procedure
  For ($\forall \phi \in$ **C** *(performer-set)*) **Do** /* $\sigma = \sigma_p \cup \sigma_v$: Involvement Knowledge */
    Begin
      Add *all members of* $\pi_p(\phi)$ **To** $\sigma_p(\phi)$;
      Add "$weight\text{-}value \leftarrow 1$" **To** σ_v(*all edges of* $(\phi, \sigma_p(\phi))$;
    End
  For ($\forall p \in$ **P** *(role-set)*) **Do** /* $\psi = \psi_a \cup \psi_v$: Participation Knowledge */
    Begin
      Add *all members of* $\pi_c(p)$ **To** $\psi_a(p)$;
      Add "$weight\text{-}value \leftarrow 1$" **To** ψ_v(*all edges of* $(p, \psi_a(p))$;
    End
End Procedure

As stated in the previous subsection, there are two kinds of performer-role affiliation network models; one is the binary, the other is the valued. The current knowledge discovering algorithm shows only discovering a binary performer-role affiliation network model, because any weighted relationships or any meaningful semantics except existence relationships are not applied to the involvement and participation relations between roles and performers. If each of the relations has something to do with differentiated values or weights except existence relations, the algorithm has to assign the corresponding values greater than 1.0 to the variable, "*weight-value*." Then, it implies that the algorithm is able to discover a valued performer-role affiliation network model.

4. **Conclusion.** In this paper, we suggested a possible way of viewing a special affiliation knowledge of the workflow-supported affiliation relations (involvement and participation behaviors) between workflow-based people and workflow-based roles by converging the social network techniques and the workflow discovering and rediscovering techniques. As a consequence of this suggestion, we newly defined a term, the performer-role affiliation networking knowledge, and proposed an algorithm to discover a performer-role affiliation network model from an ICN-based workflow model. Eventually, the performer-role affiliation network model discovered by the algorithm devised in this paper will be transformed into a performer-role affiliation matrix in order to be analyzed as workflow performer-role affiliation networking knowledge. So, we would leave the development of the performer-role affiliation matrix transformation algorithms to the future work. At the same time, the paper doesn't cover the performer-role affiliation networking knowledge analysis and rediscovery issues, too, because of the page limitation. Especially, the authors' research group, in the near future, would try to extend the basic ideas of the performer-role affiliation networking knowledge discovery issue to the rediscovery issue.

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