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A WEIGHTED WORK TRANSFERENCE NETWORK MODEL FOR WORKFLOW-SUPPORTED ORGANIZATIONS

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Abstract. *The purpose of this paper is to define an extended model of the work transference networks, which is named as a weight work transference network model. The formal concept of "weighted" denotes the number of work-transference occurrences among the workers and connotes the degrees of work-sharing and work-relevancy among the workers in a workflow-supported work transference network model. We formally define the weighted work transference network model and describe its implications in a workflow-supported organization. Finally, we show a discovered model of the weighted work transference network that is rediscovered from an experimental analytics on a workflow enactment event log dataset by the mining framework and system theoretically supported by the weight work transference network model and systematically implemented by the authors' research group.*
Keywords: Workflow-supported organization, Organizational knowledge discovery, Work transference network, Work transference occurrence, Work-sharing and work-relevancy

1. **Introduction.** In recent years, the workflow literature just started being focused on "People" working on workflow-supported organizations and also it is widely accepted for the workflow management systems to be the people systems. Therefore, we are able to analyze the social relationships and collaborative behaviors among the workers who are involved in enacting workflow models and accordingly we are able to measure and estimate their overall performances in performing their activities in the corresponding workflow models. The authors' research group is recently carrying out a research and development project of applying the concept of social networks and its analysis methods into human-centered workflow knowledge discovery [1, 2, 3, 4] and analysis [5, 6, 7]. As a partial outcome of the project, we are particularly interested in the work transference relationships among the performers who are planned to participate in the enactment of a specific workflow procedure and we proposed the model of work transference networks and its discovery algorithm [1]. In this paper, we extend the work transference network model [1] so as to append the concept of weight and rename as the weighted work transference network model with redefining formally and graphically.

2. **Background and Motivation.** The theoretical background is the information control net methodology [8] that is a typical workflow modeling approach supporting graphical and formal representations. In defining a workflow procedure, the methodology uses the basic workflow entity types – activity, role, actor/performer, invoked application and transition condition – to represent the procedural properties of workflow, such as control-flow and data-flow, as well as the associative properties of workflow such as activity-to-role, role-to-performer, activity-to-condition/rule, and activity-to-application associations. In

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this section, we assume that the formal representation of the information control net of a workflow model is based upon the formal definition previously introduced in [8], and will not describe all the details of the formal definition due to the page limitation. However, we need the activity-to-role and the role-to-performer associations in the information control net model to form a work transference network model, which is the main topic of this paper.

- Activity-to-Role Association: for any activity α, $\varepsilon_r(\alpha) = \{\eta\}$ means that an activity α is associated with the role, η; also, $\varepsilon_a(\eta) = \{\alpha_1, \alpha_2, \ldots, \alpha_m\}$, where m is the number of activities being associated with the role, means that a role η can be associated with several activities in a workflow procedure.
- Role-to-Performer Association:
  - For any role η, $\pi_p(\eta) = \{p_1, p_2, \ldots, p_n\}$, where n is the number of performers being assigned into the role, means that one or more performers (participants) are assigned to perform each activity via a role. A role is a named designator for one or more participants which conveniently acts as the basis for partitioning of work skills, access controls, execution controls, and authority/responsibility.
  - Also, for any performer p, $\pi_r(p) = \{\eta_1, \eta_2, \ldots, \eta_m\}$, where m is the number of roles being assigned into the performer, means that a performer can be assigned into several different roles at the same time, and he/she fulfills the roles via their associated activities in a workflow procedure.

3. **A Formal Model of Weighted Work Transference Networks.** In this section, we formally describe the basic concept and definition of weighted work transference networks that are formed from an information control net model of a workflow model. We know that the procedural activities on a workflow model eventually trigger off the work transferences [1] among the performers who are involved in the corresponding workflow model. Analyzing work transferences among the performers is one of the essential planning activities in the human resource management and decision-making support management [11], in general. Especially, the work transference relationships in performing a workflow model turn also out the essential knowledge and criteria for evaluating and validating the human resource performance of the corresponding workflow model.

As a representation formalism of such knowledge of the work transferences and their weights, we formally define a weighted work transference network model as Definition 3.1. A weighted work transference network is the formal and graphical structure of a directed graph (or digraph) model to represent the relationship of work (activity) transferences and their associated occurrences among the performers who are involved in a corresponding workflow procedure. Each vertex represents a performer, each ordered pair of vertices (or a directed edge) represents a work transference relationship, and the integer number on each of the ordered pairs represents a weight (or occurrence) of the corresponding work transference. Through the formal notation of σ ($= \sigma_i \cup \sigma_o$), we define the work transference relationships and their weights, in which the initial and terminal vertices of a directed edge represent the transferrer and receiver of works. Also, we define the formal notation of ψ ($= \psi_i \cup \psi_o$) for the work association relationships with their weights by labeling each directed edge with the number of work-transferences that are transferred to the terminal and received from the initialization of the corresponding work transference relationship, at the same time.

Definition 3.1. *Weighted Work Transference Network Model. A weighted work transference network model is formally defined as* $\Lambda^W = \left(\sigma, \psi, F_r^W, T_o^W\right)$*, over a set* $\boldsymbol{P}$ *of performers, and a set* $\boldsymbol{A}$ *of activities in a workflow model, where*

- F_r^W *is a finite set of coordinators or coordinator-groups connected from an external buildtime model of the work transference network;*

- T_o^W *is a finite set of coordinators or coordinator-groups connected to an external buildtime model of the work transference network;*
- $\sigma = \sigma_i \cup \sigma_o$ */* Work (Activity) Transferences */*
  - $\sigma_o : \boldsymbol{P} \longrightarrow \wp(\boldsymbol{P})$ *is a multi-valued function mapping a performer to its set of (immediate) work (activity) transferrers;*
  - $\sigma_i : \boldsymbol{P} \longrightarrow \wp(\boldsymbol{P})$ *is a multi-valued function mapping a performer to its set of (immediate) work (activity) receivers;*
- $\psi = \psi_i \cup \psi_o$ */* Work (Activity) Associations */*
  - $\psi_i : (\boldsymbol{P} \times \boldsymbol{P}) \longrightarrow \wp(\boldsymbol{A})$ *is a multi-valued function returning a set of receiving works (activities) on ordered pairs of performers,* $(\sigma_i(o), o)$*,* $o \in \boldsymbol{P}$*, from* $\sigma_i(o)$ *to* o*;*
  - $\psi_o : (\boldsymbol{P} \times \boldsymbol{P}) \longrightarrow \wp(\boldsymbol{A})$ *is a multi-valued function returning a set of transferring works (activities) on ordered pairs of performers,* $(o, \sigma_o(o))$*,* $o \in \boldsymbol{P}$*, from* o *to* $\sigma_o(o)$*;*
- $\omega = \omega_i \cup \omega_o$ */* Weights */*
  - $\omega_i : (\boldsymbol{P} \times \boldsymbol{P}) \longrightarrow N_{weight}$ *is a single-valued function returning a weight on each of the ordered pairs of performers,* $(\sigma_i(o), o)$*,* $o \in \boldsymbol{P}$*, from* $\sigma_i(o)$ *to* o*;*
  - $\omega_o : (\boldsymbol{P} \times \boldsymbol{P}) \longrightarrow N_{weight}$ *is a single-valued function returning a weight on each of the ordered pairs of performers,* $(o, \sigma_o(o))$*,* $o \in \boldsymbol{P}$*, from* o *to* $\sigma_o(o)$*.*

4. **Implications of the Weighted Work Transference Networks.** Recently, the workflow literature has been interested in repositioning the workflow management systems as a supporting tool of business and organizational knowledge and intelligence by reinforcing the knowledge discovery and analysis functionalities. The work transference network model and its extended models ought to be one of those reinforcement efforts. In particular, the weighted work transference network model begins from the strong belief that by overtly revealing, measuring, quantifying and visualizing the work-transferring relationships and collaborative behaviors among workflow-performers in enacting workflow models, we expect and eventually achieve the dramatic performance enhancement and being crowned with great successes in the real businesses and the working productivity as well. The typical outcomes of those repositioning works ought to be [1, 2, 4, 7, 9], in which the authors formalized models, discovery algorithms and their analysis techniques for several different shapes of human-centered networking knowledge, like workflow-supported social networking knowledge [2, 3, 9] and workflow-supported affiliation networking knowledge [4, 5, 6, 7], in workflow models and their enactment event histories.

In the previous paper [1], we focused on a new shape of human-centered networking knowledge hidden inside the workflow models, which is so-called the work transference networking knowledge. Through discovering the work transference networking knowledge, we were able to analyze and visualize the work-transferring relationships in enacting workflow models. Now, in this paper we focus on quantitatively measure and quantify the degrees of work-transferring and work-closeness among the workers, and we are able to ultimately control and estimate the degree of work-intensity of workers in a workflow-supported organization. Based upon the weighted work transference networking knowledge, we can represent the two types of weights as follows and Figure 1 represents these two types of weights:

- Work-transference occurrences between the workflow-performers in enacting a workflow procedure;
- Stochastic [13] and probabilistic [15] work-transferences between the workflow performers in enacting a workflow procedure.

Based upon those formal models proposed in the paper, the authors' research group has developed a mining framework and system that is able to rediscover a weighted work transference network from a workflow enactment event log dataset recorded and

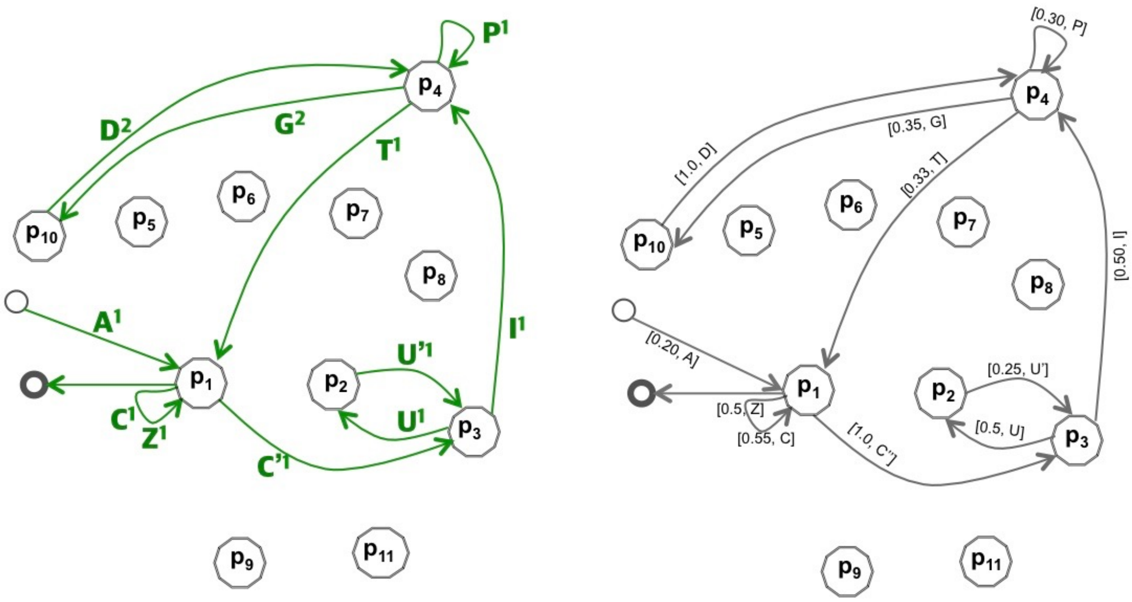

FIGURE 1. Two types of weights: Graphical representations of the weighted work transference networks from a control-path of the library book acquisition workflow model [1]

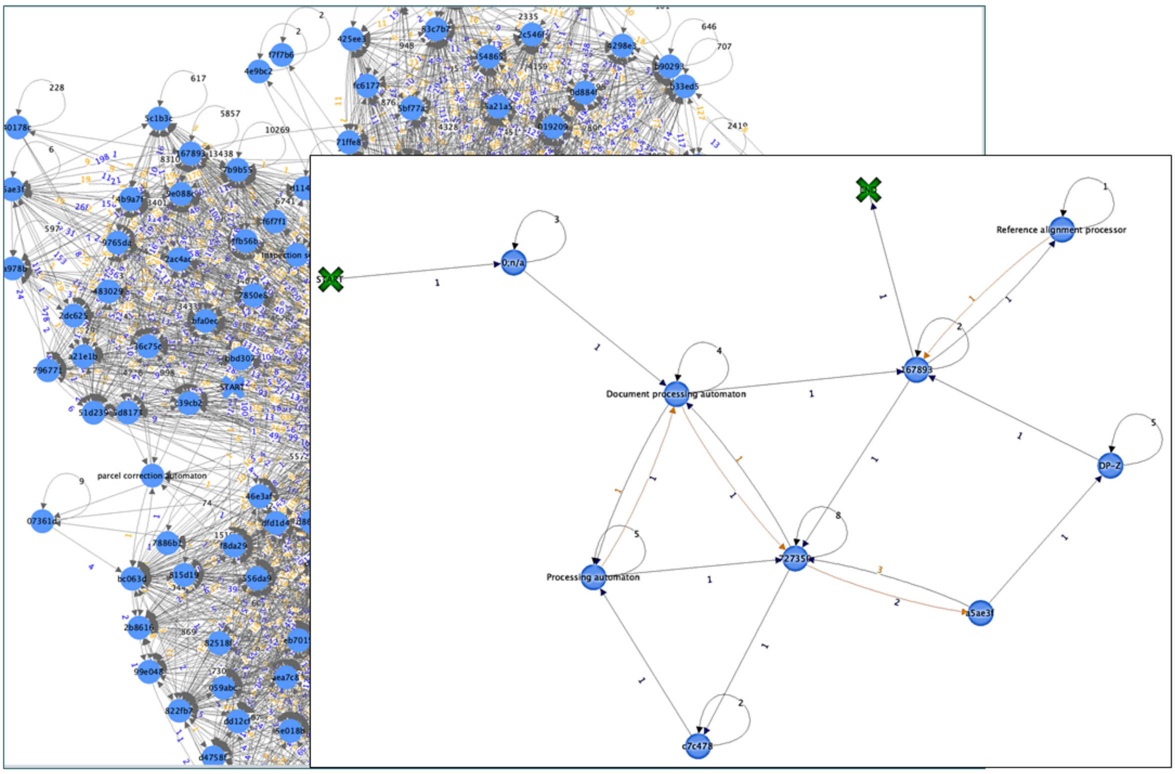

FIGURE 2. A weighted work transference network discovered from an experimental analytics

formatted in the IEEE XES [14] standardized event stream format. Also, by using the mining framework and system, we carried out an experimental analytics on a workflow enactment event log dataset that is provided to the public as the BPI 2018 Challenges dataset of 4TU.Centre for Research Data [12]. Figure 2 shows two captured-screens of the system: one visualizes the graphical representation of a weighted work transference network and the other enlarges a weighted work transference network of a specific workflow instance. These are discovered from the dataset logged from enacting a specific workflow process model that covers the handling of applications for EU direct payments for German farmers from the European Agricultural Guarantee Fund.

Especially, the dataset used in the experimental analytics was provisioned for the 2018 BPI (Business Process Intelligence) Challenge sponsored by the BPM conference organization. In the experimental analytics, we found out that the event log contains 2,514,266 events for 43,809 payment applications (workflow instances) over a period of three years. The shortest case contains 24 events, the longest 2,973 and on average there are 57 events per case referring to 14 activities. In total, the numbers of workflow-activities and workflow-performers in the dataset are 41 activities and 165 performers, respectively. The captured-screen on the main screen of Figure 2 shows all the work transference relationships with their occurrences among 165 workflow-performers.

5. **Conclusion.** In this paper, we proposed a formal representation of a model of weighted work transference network model that can be discovered from an information control net of a workflow model. A concept of weight can be discovered from the informational artifacts and the behavioral histories at the buildtime as well as at the runtime of a workflow procedure, respectively. Accordingly, we need two ways of the formal discovery approach. One is a way of discovering a weighted work transference network of buildtime from an information control net of a workflow procedure, the other is a way of discovering a weighted work transference network of runtime from a bunch of workflow instance event traces. Particularly, we developed a formal model of weighted work transference networks and its graphical representation. Even we showed a weighted work transference network model discovered from an experimental analytics, our eventual goal of the research and development on the weighted work transference network model ought to cover all the series of the discovering, analyzing, measuring and visualizing issue in workflow modeling and workflow mining research fields. We leave these issues to the future work of this paper.

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