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Disconnectedness on Workflow-Supported Organizational Social Networks

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Abstract

The concept of workflow-supported organizational social networks has been issued in the literature as a novel technique for discovering and analyzing meaningful organizational knowledge representing work-sharing and collaborating relationships among workflow-performers. In this paper, we analyze the reason why the workflow-performer nodes being made up of a workflow-supported organizational social network can be disconnected. We show, as a consequence, that this phenomenon, disconnectedness, precipitates a fatal mistake in quantifying and interpreting the closeness centrality analysis results, and we try to revise the conventional closeness centrality analysis method so as to reasonably quantify the closeness centrality measures of workflow-performers even over disconnected workflow-supported organizational social networks.

***Keywords*:** Workflow model & package, information control nets, disconnectedness, workflow-supported organizational social network, closeness centrality analysis, business process & workflow intelligence, organizational knowledge

1. Introduction

Recently, research and development issues of applying the concept of human behaviors and its analysis methods to computational systems have been emerging in the literature, which is so-called *social computing*. According to the Wikipedia's definition, the basic concept of social computing implies computational information systems that support the gathering, representation, processing, use, and dissemination of information that is distributed across social collectivities such as teams, communities, organizations, and markets. The concept of workflow-supported organizational social networks ought to be one of those social computing concepts. It comes from the strong belief that the workflow systems be the people systems [1], and that the social relationships and collaborative behaviors among people affect the overall performance and being crowned with great successes in the real businesses as well as the working productivity in workflow-supported organizations. There are two types of workflow-supported organizational social (org-social) networks, like workflow-supported social networks [5] and workflow-supported affiliation networks [17]. Also, there have been existing two main branches of research issues

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concerning about the workflow-supported org-social networks. One is the *discovery* issue, the other is the *rediscovery* issue. The latter is concerned with mining org-social networking knowledge from workflow enactment event logs, which was firstly issued by [2]; the former is to discover org-social networking knowledge through exploring the human behavioral perspective in a group of workflow procedures, which was issued at first by the authors' research group [17].

The research group of the authors has been proposing several formalisms for discovering [6, 17], analyzing [7, 12, 14, 16], and visualizing [13, 18] workflow-supported org-social networks and their related algorithms. These formalisms are based upon not a workflow package (a group of workflow procedures) but a single workflow procedure. Basically, the workflow-supported org-social network is to be discovered from a single workflow procedure, and so its graphical theory and analysis equations are based on a connected network, all nodes of which are linked to each other either directly or indirectly. However, when a workflow-supported org-social network is discovered from a workflow package that consists of a group of workflow procedures, it can be turned out a disconnected network. Then, its analysis results may precipitate a fatal mistake, and ultimately lead to misinterpret the corresponding workflow-supported org-social network. In this paper, we try to analyze the cause of disconnectedness on discovering a workflow-supported org-social network from a workflow package, and the effect leading to a fatal mistake when we apply the conventional closeness centrality analysis equations [3, 7] to the disconnected network, in particular. Finally, we propose a revised closeness centrality method that ought to be able to reasonably quantify the closeness centrality measures over a disconnected workflow-supported org-social network.

2. Cause of Disconnectedness

In principle, a workflow-supported org-social network is discovered from a workflow procedure, or it is rediscovered from the workflow procedure's enactment event logs. In this paper, we concern about the former case of the discovery issues, and suppose that the discovery algorithm proposed by J. Song, *et al.* [5] is used to discover a workflow-supported org-social network from an information control net of a single workflow procedure. In this case of a single workflow procedure, the discovered org-social network ought to be a connected network, where all of the nodes are linked to each other either directly or indirectly. But on the other hand, the discovered org-social network from a workflow package (a group of workflow procedures) can be either a connected network or a disconnected network because of the reasons depicted in Fig. 1. Suppose that we apply the discovery algorithm to a workflow package containing two workflow procedures, Workflow Model 1 and Workflow Model 2, and no one in the workflow-performer group of the workflow package is assigned to both of the workflow models in common. Then, the discovery algorithm will be discovering a disconnected network after all.

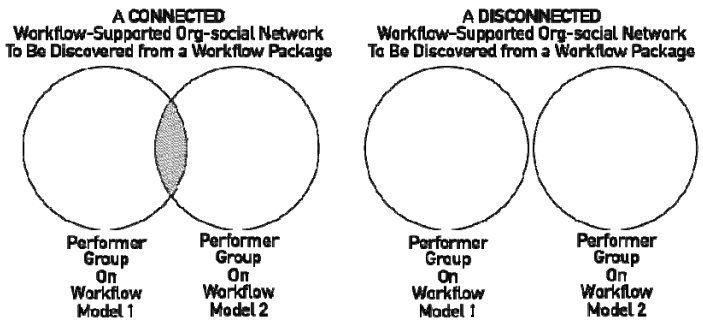

Fig. 1. The Reason Why a Disconnected Workflow-Supported Org-social Network is Discovered from a Workflow Package

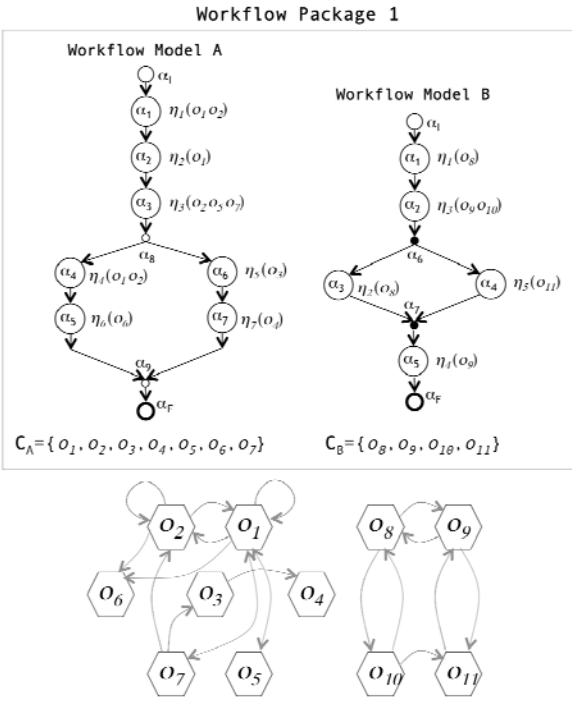

Fig. 2. An Imaginary Workflow Package and Its Discovered Workflow-Supported Org- social Network with Disconnectedness

The authors' research group has been developing the concept of workflow-supported org-social net- works and its analysis methods, such as centrality, prestige, and correspondence analysis methods, in particular. The automatic discovery methodology for workflow-supported org-social networks, published in [5, 6], algorithmically explores the org-social structures from an information control net[1] [4] by using the internal properties of a workflow procedure, such as δ_o(control flow relationships), ε_p(activity-role mapping relationships) and π_c(role-actor mapping relationships).

3. Contradictoriness on Disconnectedness

Once after discovering a workflow-supported org-social network, we transform it to the form of mathematical representation, SocioMatrix, in order to extract a certain structural pattern of human-centered organizational knowledge em- bedded in the corresponding workflow procedures and packages. The typical analytic concepts and measures are centrality and prestige that help to seek a workflow-performer's prominence within the corresponding workflow procedure or package. In particular, we found out a serious semantic contradictory in mea- suring the closeness centralities of workflow-performers within a disconnected workflow-supported org-social network. That is, based upon the SocioMatrix ($Z[g, g]$[2]), we are able to calculate the closeness centrality measures by applying the following equation (1) [3, 7] of the individual workflow-performer's closeness centrality measurement:

$$C_C(N_i) = \frac{1}{\left[\sum_{j=1}^{g} d(N_i, N_j)\right]} (i \neq j) \quad (1)$$

The main term of the equation (1) is the function of geodesic distance, $d(N_i,N_j)$[3], between

[1] The information control net, which is abbreviated as ICN, is a typical mathematical model for formally specifying a workflow procedure.

[2] g is the total number of workflow-performers within a corresponding workflow- supported org-social network.

[3] The geodesic distance implies the length of the

dyadic workflow-performers on a workflow-supported org- social network. This function basically assumes that its underlying workflow-supported org-social network ought to be a connected network. However, when we apply the function to a disconnected workflow-supported org-social network, the following contradictories are occurred in measuring the closeness centralities of individual workflow-performers:

- Mathematical Contradictory: The return value of the function might possibly be zero, because of the disconnectedness. Then, the equation can possibly produce an incompatible value, division by zero, which is mathemati- cally undefined. Without revising the denominator of the equation (1), the mathematical incompatibility can always occur in quantifying the closeness centralities of workflow-performers. For a disconnected workflow-supported org-social network with g performers, the equation of individual closeness centrality is computed as the inverse of the sum of the geodesic distances between performer Ni and the (g − 1) other performers.

– Semantic Contradictory: The conceptual implication of the individual closeness centrality refers to how quickly a workflow-performer can interact with others by communicating directly or through very few intermediaries. Based upon the equation (1), the lowest workflow-performer closeness centrality value, which is meant for the highest sum of the geodesic distances between a focal performer and others, results from a workflow-performer with relatively long distances from others. In a connected workflow-supported org- social network, as a consequence, the higher a workflow-performer's closeness centrality measure is, the closer it is to the other workflow-performers. In this sense, the workflow-performer can reach to all other nodes via shorter geodesic distances, i.e., smaller values of $d(N_i,N_j)$. As you can guess, the semantic contradictory is lying on this point. On a disconnected network, $d(N_i,N_j)$ is zero as its returning value if N_i and N_j are not linked to each other either directly or indirectly. However, the zero value is the smallest value, and it semantically implies the closest relationship even though they are not connected at all.

shortest possible path between two nodes on a network. So, $d(N_i,N_j)$ represents the geodesic distance between two performers, N_i and N_j.

4. Remedies for Disconnectedness

In order to reasonably resolve the contradictories caused by the disconnectedness on the workflow-supported org-social network, we need to revise the closeness centrality method so as to be a remedy for the disconnectedness problem. Conclusively speaking, a disconnected workflow-supported org-social network is to be transformed into a from of the SocioMatrix, Z[g, g], and we are able to quantify the closeness centrality measures by applying the revised equations to be elaborated in this section. That is, through the revised closeness centrality con- cept and its measurements we can obtain a reasonable level of analysis results. These revisions on the closeness centrality measures can be applied to the indi- vidual performer's index of closeness centrality as well as its normalized measure as standardized index of closeness centrality.

An individual performer's closeness centrality is based upon a function of its geodesic distance to all other performers. The conceptual implication of the in- dividual closeness centrality refers to how quickly a performer can interact with others by communicating directly or through very few intermediaries. As the remedy for curing both the mathematical contradictory and the semantic contra- dictory from the disconnectedness phenomenon, we try to revise the conventional closeness centrality method [3, 5], the index of individual closeness centrality, in particular. Assume that a disconnected workflow-supported org-social network is transformed into a mathematical form of a binary non-directed SocioMatrix with g workflow-performers. Then, as shown in the Equation (2), the index of individual closeness cen- trality, $C_C(N_i)$, is computed as the sum of the inverse of the geodesic distances between workflow-performer N_i and the (g − 1) others,

– The Index of Individual Closeness Centrality

$$C_C(N_i) = \left[\sum_{j=1}^{g} \left\{ \begin{array}{ll} 0 & \text{if } d(N_i, N_j) = 0 \\ \frac{1}{d(N_i, N_j)} & \text{if } d(N_i, N_j) \neq 0 \end{array} \right\} \right] (i \neq j) \quad (2)$$

– The Standardized Index of Individual Closeness Centrality

$$C_C^S(N_i) = \left[\frac{C_C(N_i)}{(g-1)} \right] \quad (3)$$

where $d(N_i,N_j)$ represents the geodesic distance between two performers, N_i and N_j. As you can see, the highest measures computed from the Equation (2) ought to be less than or equal to (g − 1), ≤ (g − 1), in the case of which the workflow-performer, Ni, is directly connected to all the (g − 1) others. Thus, closeness centrality scores cannot be computed for isolated performer, which is the case of that only a single performer is assigned to enacting the corresponding workflow procedure, for an example. The Equation (3) is for standardizing the index of individual closeness centrality by dividing by (g − 1). Suppose that an individual workflow-performer is directly close to all others, which means that the workflow-performer has a direct tie to everyone in a binary non-directed org-social network. Then, the computed index values will be vary according to their org-social network sizes. In order to control the size of the org-social network, it is necessary for the individual index to be standardized so as to allow meaningful comparisons of workflow-performers across different org-social networks.

5. Conclusions

Recently, the workflow literature just starts being focused on social and col- laborative work analysis on workflow-supported organizations. Particularly, our work, the disconnectedness phenomenon on a workflow-supported org-social network and its closeness centrality analysis method, is directly related with the knowledge discovery and analysis issues, which we need to dig into more specif- ically and profoundly as the future works of this research results. Based upon the results of this paper, we have a plan to extend the revised closeness centrality method by developing the closeness centrality analysis algorithm in the near future.

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