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Visualizing Workflow-Supported Social Networks and Their Degree Centrality Measures

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Abstract

The purpose of this paper[1] is to implement a visualization framework and system for workflow-supported social networking knowledge and its analysis measures of degree centrality. The workflow-supported social networking knowledge is formally represented by the workflow-supported social network model, and it is discovered from a XPDL[2]-based workflow model or a group of workflow models in a workflow-supported organization. The visualization framework is pipe-lining from the XPDL-formatted workflow model to the GraphML[3]-formatted graph, and it is eventually implemented by adopting the open sources of information visualization toolkits, such as Prefuse, JFreeChart, and Log4j. Additionally, the system is able to visualize the degree-centrality measurements for each of the workflow performers making up of a workflow-supported social network.

Keywords: *workflow & business process, workflow-supported social network, XPDL, GraphML, degree centrality, knowledge visualization.*

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[1]This paper is fully refurbished and extended from the conference paper [20] published in the ICONI 2013, Pattaya, Thailand.
[2]XPDL stands for XML Process Definition Language released by WfMC.
[3]GraphML stands for Graphical Markup Language.

1 Introduction

Recently, the workflow literature just started being focused on "People," which begins from the strong belief that social relationships and collaborative behaviors among people in a workflow-supported organization affect the overall performance and being crowned with great successes in real businesses and working productivity as well. Consequently, research and development issues of adopting the social network concept by the workflow intelligence have been emerging in the literature, and one of those issues is surely "the workflow-supported social networking knowledge discovery." There are two main branches in terms of the research approaches in the issue. One is the discovery approach, and the other is the rediscovery approach. The latter is concerned about mining workflow-supported social networking knowledge from workflow enactment event logs, which was firstly issued by Aalst, *et al.* [10]. The former is to discover the knowledge by exploring the human perspectives (performers and roles) from the workflow models and packages, which was issued at first by the authors' research group *via* Song, *et al.* [2].

More specifically we have differentiated the discovery approach from the rediscovery approach in exploring workflow-supported social networking knowledge in the workflow literature. The discovery implies to explore planned (or defined) workflow-supported social networking (abbreviated as pWSSN) knowledge from a workflow model itself, whereas the rediscovery is to mine enacted workflow-supported social networking (abbreviated as eWSSN) knowledge from the execution event logs of a workflow model. In terms of visualizing the workflow-supported social networking knowledge, we try to differentiate the planned from the enacted, too. In this paper, we develop a systematic way of visualizing the planned workflow-supported social networking knowledge. That is, we device a systematic framework for implementing a knowledge visualization system that is able to effectively visualize and beautifully display not only the planned social networking knowledge but also its degree centrality analysis measures.

In terms of making up the paper, the next section describes the literature survey focusing on discovering and visualizing workflow-supported social networking knowledge. And the next consecutive sections describes the details of the systematic framework and its implemented knowledge visualization system with a couple of screen-captures. Finally, we give some concluding remarks including future works.

2 Related Works

In recent, we have been interested in social and collaborative work analysis among employees in a workflow-driven organization. Our work of workflow-supported social networking knowledge is directly related with a converged issue [3] of the information model-log comparison issue [1] and social networks generation and analysis issue [4, 18]. This converged issue stems from the actor-oriented workflow model [5], in which the authors suggested an algorithm transforming an ICN-based workflow model [6] into an actor-oriented workflow model. Unfortunately, it was interpreted not as social or collaborative behaviors among actors but as control flows among actor-objects in implementing an actor-oriented workflow engine. Also, there have been several research approaches, so far, that can be classified into the social network discovery issue [2, 16] and the social network re-discovery issue [10, 19], as sated in the previous section.

However, almost all of those approaches are concerning about how to represent [8, 21], discover [7, 17, 21, 22], and analyze [7, 9] workflow-supported social networking knowledge, whereas they are rarely interested in how to effectively, efficiently, and even beautifully visualize the corresponding knowledge. The only one emphasizing visualization of the knowledge was published by Jeon, *et al.* [9], in which the authors developed a display function to visualize workload-centrality measurements of performers engaged in enacting a specific workflow model. However, because the display function is visualizing the graphical objects on a fixed-size window and it doesnt adopt any graphical toolkits or libraries, it always needs a certain amount of additional manual-operations, such as repositioning, resizing, or rearranging operations, to gracefully and properly visualize graphical objects making up the displayed workflow-supported social networking knowledge.

As an upgraded version of the visualization system, the conference paper, authored by Jeong, *et al.* [20], proposed a systematic approach to dramatically improve the quality of beautification as well as the quality of efficiency in visualizing the workflow-supported social networking knowledge, and this paper is an extended version of this conference paper for the special issue of this journal. The systematic framework proposed in this paper is pipelining from XPDL-based workflow model [14, 15] to GraphML-based workflow social networking knowledge [11, 12, 13], and it is designated for the planned workflow-supported social networking knowledge, and adopts the famous information visualization toolkits like Prefuse, JFreeChart, and Log4j.

3 A Systematic Framework

In this section, we start from defining a systematic framework for visualizing the planned workflow-supported social networking knowledge, and it is used to implement the knowledge visualization system that is the main purpose of the paper. We describe a series of concepts related with the framework pipelining an XPDL-based workflow model (or package) to visualizing its workflow-

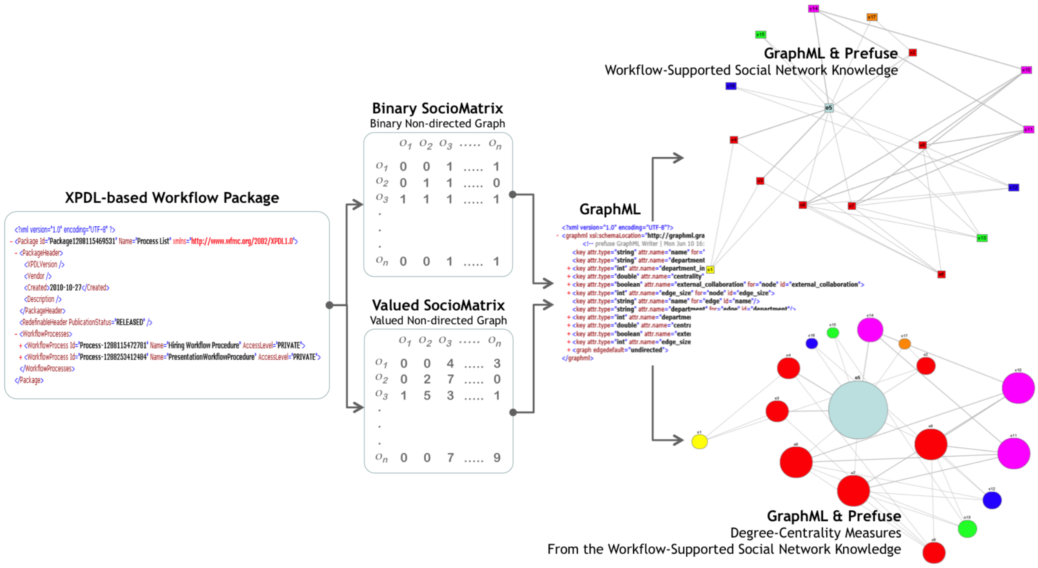

Figure 1: A Planned WSSN Knowledge Visualization Framework

supported social networking knowledge with the degree centrality measures of the performers.

Figure 1 illustrates a systematic framework for implementing the knowledge visualization system that copes from dissolving an XPDL-based workflow package into a workflow-supported social network in a mathematical form of SocioMatrix to visualizing the discovered knowledge via a graphical format of GraphML. The framework is realized through three procedural functionalities—SocioMatrix generating functionality, GraphML formatting functionality, and knowledge visualizing functionality. The SocioMatrix generating functionality is in charge of discovering the planned workflow-supported social networking (pWSSN) knowledge from an XPDL-based workflow model (or package), and it can be implemented by extensively applying the algorithm proposed in Song, *et al.* [2]. The final result of this functionality is represented by a binary (or valued) SocioMatrix. The GraphML formatting functionality produces a GraphML-based pWSSN document and its GraphML-based centrality measurement document for defining a pWSSN graph and centrality measurement graph, respectively. Finally, the knowledge visualization functionality is for colorfully and gracefully visualizing the pWSSN knowledge and its centrality measures through compiling the GraphML-based pWSSN and centrality measurement documents.

At the last phase, as shown in the righthand side of Figure 1, the framework is able to visualize the pWSSN knowledge through two forms of colorful graphs. One is to represent the pWSSN knowledge itself by a colored graph with the performer-nodes of small rectangles, the other is to depict the degree centrality measures of the performers in a colored graph with colorful and different-sized circles, where the size of circle implies the magnitude of the performer's degree centrality. In particular, we would expatiate on the degree centrality measurements. Suppose that the pWSSN is represented in a binary and non-directed graph [2] and its mathematical form is so a binary SocioMatrix [4].

The degree centrality measures can be applied to the individual performer (*individual degree centrality*) as well as the performers group (*group degree centrality*) of the planned workflow-supported social network. The individual degree centrality is to quantify the utmost extent to which a performer connects to all others in a planned workflow-supported social network. For an instance, on a binary non-directed SocioMatrix with g performers, the degree centrality for a performer N_i is the sum of N_i's adjacent ties to the $g-1$ other performers, and its equation is given in the Equation (1) [4]; where $C_d(N_i)$ denotes the degree centrality for the performer N_i and $\sum_{j=1}^{g} x_{ij} (i \neq j)$ counts the number of adjacent ties that the performer N_i has direct-connections to the $g-1$ other N_j performers.

- Individual Degree Centrality Analysis Equation:

$$C_d(N_i) = \sum_{j=1}^{g} x_{ij} \tag{1}$$

- Normalized Individual Degree Centrality Analysis Equation:

$$C_n(N_i) = \frac{C_d(N_i)}{g} \tag{2}$$

As you see, the individual degree centrality reflects each performer's connectivity to others. However, its value depends on g, the size of the planned workflow-supported social network; in other words, the larger the network is, the higher the maximum of possible degree centrality value is. It means that it needs to be normalized in order to eliminate the effect of variation in the network size on the degree centrality measures. So, [4] gives the Equation (2) [4] for the standardized measures, and then its value is becoming between 0.0 and 1.0, which is independent to the sizes of the planned workflow-supported social networks. In the colored graph with a set of different-sized circles, the sizes of circles are calculated from the normalized individual degree centrality analysis equation.

4 A Visualization System

The authors' research group implements a pWSSN knowledge visualization system that is able to explore, analyze, and visualize the planned workflow-supported social networking knowledge discovered from a workflow model or a group of workflow models (or packages) formatted in XPDL. In this section, we describe about the system architecture and a series of systemic components through describing the detailed functionalities and their captured-screens.

4.1 System Architecture

The implemented knowledge visualization system is composed of the following essential functional components coping with the visual-transformation phases:

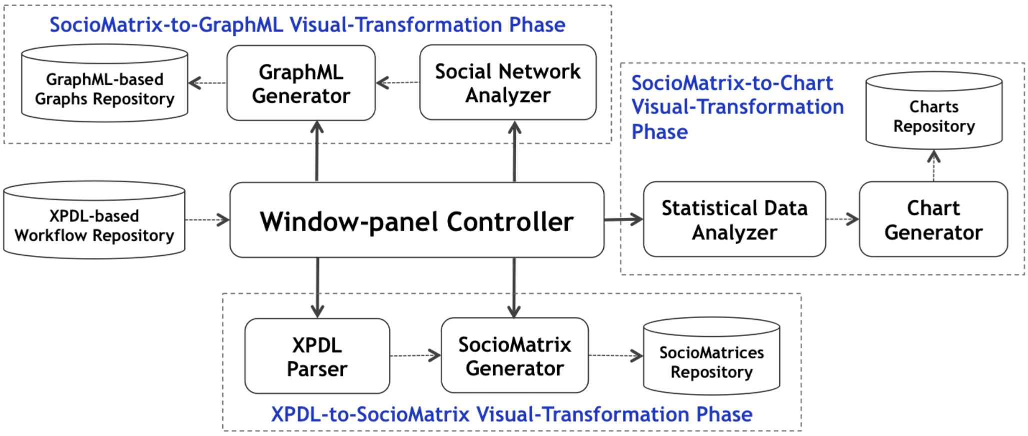

Figure 2: The System Architecture of the Planned WSSN Knowledge Visualization System

Figure 2 depicts the system architecture of the pWSSN knowledge visualization system that is implemented by using the Java programming language, and it is made up of seven architectural components—Window-panel controller, XPDL parser, SocioMatrix Generator, GraphML generator, Social Network Analyzer, Charts generator, and Statistical Data Analyzer—that are functionally associated with the XPDL-to-SocioMatrix, SocioMatrix-to-GraphML, and SocioMatrix-to-Chart visual-transformation phases. The XPDL parser using the Xpdl-parser supports the XPDL1.0 version of WfMC, and the SocioMatrix generator takes charge of generating the binary and valued SocioMatrices from an XPDL-based workflow package. The social network analyzer and the GraphML generator are able to visualize discovered pWSSN knowledge as well as analyzed pWSSN knowledge as non-directed graphs that are transformed from binary and valued SocioMatrices and graphically displayed by the Prefuse graphic library. Figure 3 is to draw the GraphML schema of pWSSN, which is used by the GraphML generator. In terms of the pWSSN knowledge analysis aspect, the system is theoretically backed up by the extended versions

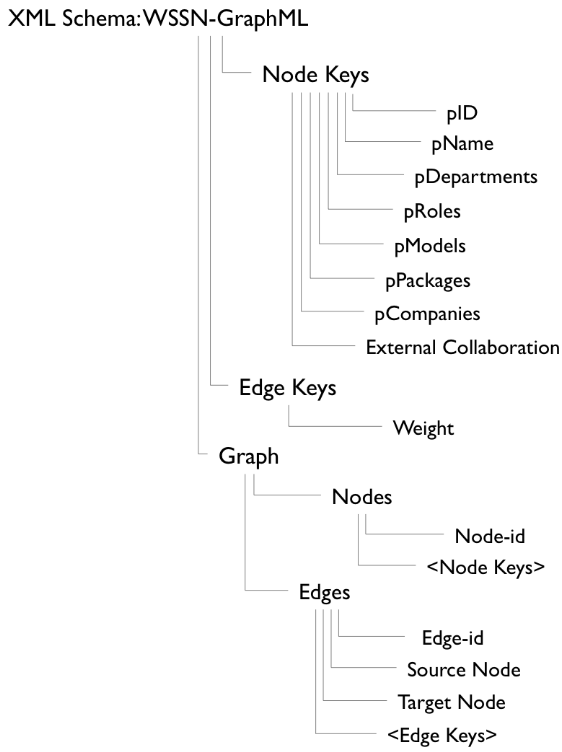

Figure 3: The GraphML Schema of pWSSN

of the workload-centrality analysis equations [4, 8], such as individual degree centrality analysis equations, group-degree centrality analysis equations, closeness centrality analysis equations, betweenness centrality analysis equations, and so on. Finally, the statistical data analyzer and the Charts generator are able to visualize a variety of charts to the pWSSN knowledge by using the JFreeChart library.

- XPDL-to-SocioMatrix visual-transformation phase: SocioMatrix Generating Functionality
  - XPDL-to-Binary SocioMatrix: Binary SocioMatrix
  - XPDL-to-Valued SocioMatrix: Valued SocioMatrix
- SocioMatrix-to-GraphML visual-transformation phase: pWSSN Knowledge Visualizing Functionality
- SocioMatrix-to-Chart visual-transformation phase: pWSSN Knowledge Analysis & Visualization Functionality
  - Degree Centrality Analysis Function
  - Prestige Analysis Function

Summarily, the systems development and operation environments are listed in the following. Note that the input XPDL workflow packages release version is XPDL 1.0, as mentioned before, and so, it is necessary to be extended to support the recently released version of XPDL 2.0 or more, which reflects the BPMN[4] graphical constructs.

- Display: NVIDIA Geforce GTS 450
- Operating System: Microsoft Windows 8 Pro K 32bits
- Programming Language: Java Development Toolkit v.7.0
- XPDL Version: XPDL 1.0
- Development Tool: Eclipse Indigo Release 2
- Libraries: Awt/Swing, Prefuse, Xpdl-parser, Junit4, Log4j, JFreeChart

4.2 An Operational Example

As an operational example, we try to visualize the pWSSN knowledge from a typical ICN-based workflow model, which is the Hiring workflow model rigorously described in the book chapter by Kim & Ellis [6]. That is, we apply the XPDL-formatted Hiring workflow model to the implemented knowledge visualization system, and the visualized results from the system are Figure 4 and Figure 5. The captured screen in Figure 4 is to visualize the Hiring pWSSN knowledge discovered through the binary SocioMatrix-to-Discovery GraphML visual-transformation phase of the system, and the captured screen in Figure 5 shows the Degree-centrality measurements of the performers, who are planned to be involved in enacting the Hiring workflow model, through the binary SocioMatrix-to-Analysis GraphML visual-transformation phase of the system, too. In Figure 5, the sizes of the circles imply the normalized values (between 0 and 1) of the degree-centrality of each performer, and the bigger the circle is, the larger number of in/out connections with others it has. Furthermore, in the case of the valued SocioMatrix, the different values can be visualized by the different levels of weights (thickness) of the corresponding edges in the graphical visual of the pWSSN knowledge, and otherwise the values themselves may be directly put on the corresponding edges. Eventually, these figures show the graphical view of the Hiring workflow model illustrating the performers work-sharing relationships (or collaborative behaviors) with others in order to emphasize the performer-centered social aspect.

At this moment, lets remind the question raised in Song, *et al.* [2] and Kim [7]. From two the figures of the visualized Hiring pWSSN knowledge, we can easily answer to the following question:

[4]BPMN stands for Business Process Model & Notation, released by the OMG's BMI-DTF

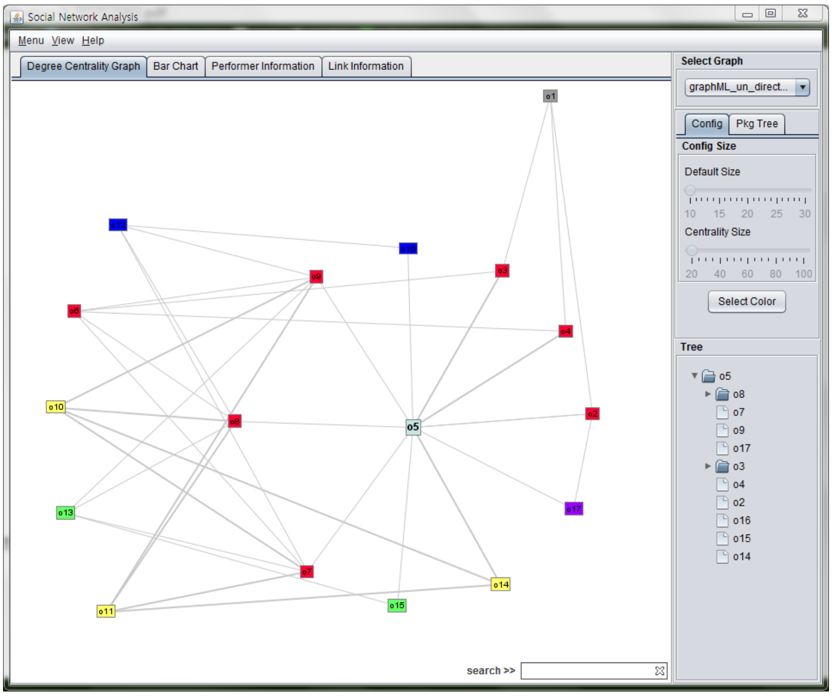

Figure 4: Visualization of the Planned WSSN Knowledge

– Question: Who is the most important or prominent performer in the planned Hiring workflow procedure?

– Answer: We can easily recognize and visually interpret that the workflow performer, o_5, is the most influential performer out of the workflow performers in the planned Hiring workflow procedure.

Through the operational example, we were able to verify that the implemented knowledge visualization system works perfectly in terms of visualizing not only planned workflow-supported social networking knowledge discovered from an XPDL based workflow model, but also the analyzed (degree-centrality) results of the discovered workflow-supported social networking knowledge. Likewise, the implemented system is able to deal with a group of workflow models (or workflow packages) so that it is properly applied to organization-wide large scale workflow models and packages, although we do not describe the visualization results in this paper.

5 Conclusion

The recent big-trends in working environments are undoubtedly large-scale workflow management systems with increasingly large and complex workflow applications. The large-scale workflow management systems ought to be re-

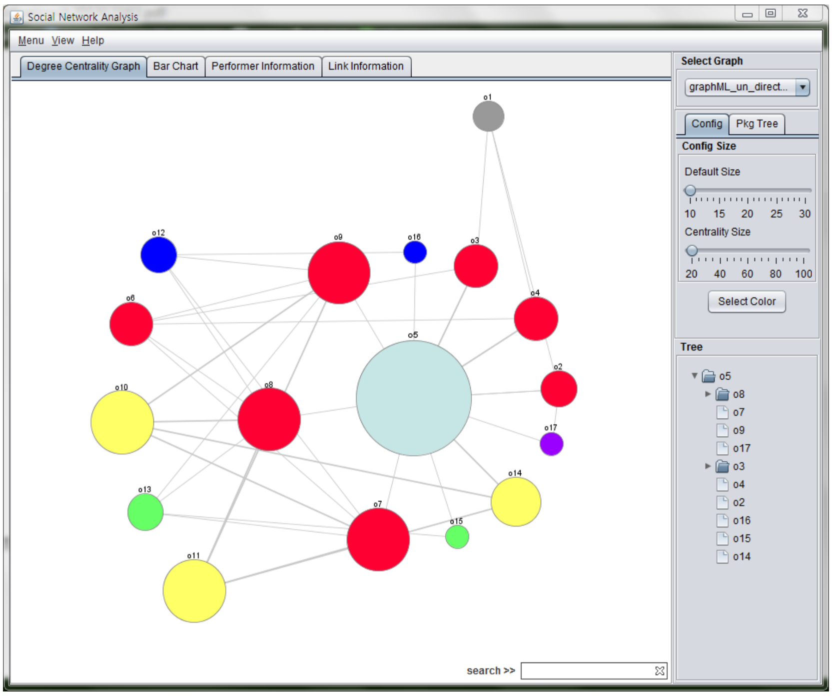

Figure 5: Visualization of the Degree Centrality Measures

flecting the typical organization-wide perspectives like behavioral, social, informational, collaborative, and historical perspectives, and accordingly the visualization capability of the large-scale information ought to become a much more important feature in those large-scale systems. In this paper, we suggested a tangible way of discovering and visualizing a special type of social networking knowledge, the planned workflow-supported social networking knowledge that is effectively exhibiting work-sharing relationships and collaborative behaviors among workflow performers. Finally, we have verified the applicability and operational correctness of the implemented system through an operational example. As future works, we need to extend the pWSSN knowledge visualization system not only to develop much more advanced functionalities but also to visualize the enacted workflow-supported social networking knowledge, which is abbreviated as eWSSN knowledge, rediscovered from the workflow enactment event logs, and accordingly we have a plan to implement an eWSSN knowledge visualization system in the similar way of this paper.

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