Modeling Processes for Managing Reputation Information – A Petri Net Approach

Kirsten Lenz[1], Andrijana Mandaric[1], Andreas Oberweis[2]

[1] Institute of Information Systems
J.W. Goethe-University
60054 Frankfurt am Main, Germany

[2] Institute of Applied Informatics and Formal Description Methods
University of Karlsruhe
76187 Karlsruhe, Germany

Abstract. Electronic networks bear various potentials often limited through information asymmetries and opportunism in inter-organizational (business) processes. To reduce uncertainties when selecting trustful partners, qualitative goods, and other objects we propose a concept for a so-called "reputation information management system" that is demand-driven and process-based. Offering decision support by providing reputation information helps reducing uncertainties in virtual environments. However, instead of focusing on technical aspects of generating and managing reputation information we concentrate on modeling the underlying processes. Networked processes and exchange documents (e.g., reputation information reports) are modeled by using a variant of high-level Petri nets, so-called XML nets. XML nets allow for an integrated modeling of the processes and the process relevant XML documents. Due to their formal foundation, XML nets exhibit potentials for analyzing purposes and for the direct execution by a respective workflow engine.

1 Introduction

Electronic networks realized through the Internet bear various potentials for the interaction or transaction between actors who can be natural/legal persons or autonomous software agents. Besides pure technical security risks, behavior and quality uncertainties in a priori choice and decision situations lead to problems, e.g., concerning privacy, authenticity, or fulfillment issues when searching for trustful interaction or transaction partners or qualitative goods and services. Reasons for uncertainties can be widely attributed to the lack of information but also to the physical distance between different actors. Imperfect and uneven distribution of information has the effect that one actor lacks sufficient high-quality information, a problem which is called the "agency dilemma" [7] in agency theory. Opportunism as the failure to comply with implicit and explicit agreements is also a serious problem among actors. Together with the volatility of virtual environments, these are reasons why processes with dif-

Lenz K., Mandaric A. and Oberweis A. (2004).
Modeling Processes for Managing Reputation Information – A Petri Net Approach.
In *Proceedings of the 1st International Workshop on Computer Supported Activity Coordination*, pages 136-148
DOI: 10.5220/0002668901360148

ferent pseudonymous or anonymous actors can be disordered and even may lead to market failure [5].

Existing approaches for reducing uncertainty range from weakly structured concepts of newsgroups or evaluations in online auctions to structured and more formalized mechanisms of institutions like Trusted Third Parties [15]. Concepts and implementations of information systems like recommender systems [19], reputation systems [20], or (collaborative) filtering systems [28] pursuit comparable objectives, but do not meet individual and changing requirements of its different actors. Existing systems for generating "reputation information" (RI) are mostly specialized in particular evaluation objects (e.g., recommender systems in products and reputation systems in behavioral aspects of persons), information resources (e.g., subjective evaluations of users or expert evaluations), specific contexts, and domains and thus do not allow for a versatile use.

Motivated by the lack of integrated concepts for reducing social-economic problems of uncertainties in inter-organizational electronic networks, we propose a so-called "reputation information management system". It is demand-driven, process-based, and flexibly manages evaluations to generate individual "reputation information". A requestor for reputation information can individually determine what object he wants to be evaluated from what information sources (e.g., evaluators) and which evaluation rules shall be used to generate the requested reputation information. Underlying processes of reputation information management are described by using a variant of Petri nets, which allow for integrated modeling of processes and the process relevant documents and data.

The paper is organized as follows: we start with a description of evaluations, reputation information, and the motivation for applying Petri nets to the management of reputation information. Section 3 gives a critical overview of related approaches for reducing uncertainties. Thereupon, we describe the reputation information management system for executing individual reputation information requests and evaluations. In section 5, a part of the evaluation mechanism process is modeled. The paper concludes with a summary and a brief outlook on future work.

2 Reputation Information in Electronic Networks

We start with a short description of evaluations and reputation information. Afterwards, a brief introduction into Petri nets as the appropriate process modeling language for the process of generating reputation information is given.

2.1 Evaluations and Reputation Information in Electronic Networks

Evaluations are equally important for commerce purposes for example within trading communities (like Ebay [11] or Ciao [9]) and for the private use for educational purposes within a knowledge sharing community (like the Reputation Research Network [18]). In multilateral processes of electronic networks evaluations help to actively benefit from any evaluated object in the reputation information generating process,

even from mouth-to-mouth propaganda [10] when made explicit. The evaluator is an actor (human, software-agent) that evaluates an object. Central to an evaluation are the reputation information sources and the evaluation object. The evaluation concerns for example the behavioral aspect of a person (human, software-agent, or institution) or the quality of goods, services, or systems.

Evaluations are the basis for the generation of reputation information by providing (measurable) data. The reputation information management system transforms evaluations of evaluated objects (through algorithms and/or policies) according to individual requirements into reputation information and supports the management of evaluations and reputation information. In accordance to the underlying transformation rules, reputation information can be either a text, a numerical value, a probability, or a complex reputation information value.

The abstract notion of reputation is difficult to understand, but becomes more comprehensible together with its constituent elements (i.e., information source, evaluation, and transformation rule). Reputation with its elusive properties such as multidimensionality, unclear authenticity, non-quantification, and subjective character becomes explicable, understandable, and even measurable (for example in terms of reputation information values). In general, reputation is used in a normative way to express something positive. Within this work, however, reputation information is used to describe either a positive or negative estimate of someone or something generated from multilateral perceptions of other actors. Consequently, reputation information is the result of all perceived attributes imputed into any (reputation-)object from any information source within a specific context of a domain. Reputation information can result from experiences, from implicit knowledge (e.g., intuition) as well as from derivative exogenous experiences and observations of third parties and institutions. Reputation information sources range from intrinsic information cues (e.g., properties of a product) to extrinsic information cues (e.g., product price). Sources can be material objects like medals, immaterial objects like a brand name, or services, like guarantees. An academic title, for instance, can serve as a source of reputation information if brought into an appropriate context. Signaling positive reputation information reduces uncertainty [22, 23] and thus helps to prevent opportunistic behavior. Within electronic networks this can represent an inherent sanction [15] which causes a self-disciplining effect thereby preventing from disregarding explicit or implicit agreements.

2.2 Petri Nets

In the area of process modeling a large number of modeling languages have been discussed. While semi-formal methods such as event-driven process chains [21] are popular because of their easy handling, Petri nets combine the advantages of a graphical language with a formal foundation. They can be also applied for analysis (e.g., verification) and simulation purposes [2].

Petri nets are bipartite directed graphs that consist of two disjunctive classes of nodes: places (depicted by circles) and transitions (depicted by squares). Directed edges are connecting a place and a transition or vice versa. In elementary Petri nets [8] places can either be interpreted as conditions (that can be true or false) or as con-

tainers for (undistinguishable) objects. Transitions represent activities that depend on the respective input and output places connected with the transition. The state of the Petri net is represented by the marking, a set of tokens (depicted by black dots) assigned to the respective places. The marking determines which activities can be executed and changes with the execution of each activity.

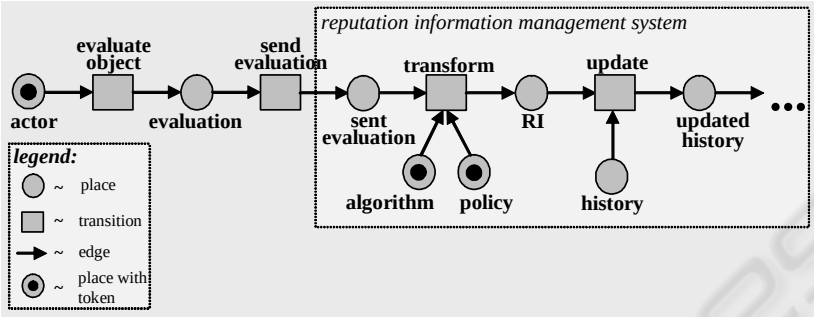

Fig. 1. Petri net for the evaluator's process

Figure 1 shows a simple Petri net. It describes a part of the evaluation process from the evaluator's perspective: An actor evaluates an object. He sends the result of his evaluation to the reputation information management system. The "sent evaluation" is then transformed according to the predefined algorithm and policy. The existing history is finally updated.

While elementary Petri nets are not well suited for the description of individual objects, high-level Petri nets [12] allow for different interpretations of the process relevant objects. In predicate/transition nets [13] places represent relation schemes according to which the marking of the net assigns a relation to each place. A transition represents a class of operations on the relations in the adjacent places. In colored Petri nets [14] individual objects (e.g., resources, goods, or humans) are distinguished by assigning identifying tokens. Motivated by the increasing importance of the XML standard [25] so-called XML nets [16, 17], are proposed. XML nets allow for an integrated modeling of processes and the process relevant XML documents. They are related to SGML nets described in [27], that combine Petri nets with the Standard Generalized Mark-up Language (SGML).

3 Managing Reputation Information

This section gives a critical overview of existing institutions and systems, followed by the derivation of requirements on the reputation information management system.

3.1 Existing Institutions and Systems for Managing Reputation Information

Centralized institutions such as the "Better Business Bureau", "Trustee", and other independent institutions evaluate objects based on available (central) standards for quality criteria thereby providing information based on "objective" evaluations. Certificates and other seals guarantee competence and are supposed to signal trustworthiness according to predefined criteria. The reputation mechanism Sporas [28] which is used for the implementation of the "Better Business Bureau-Service" is based on the principle of an evaluation by pairs of transaction partners. The underlying principle is comparable to that of the reputation database of the online auction Ebay [11]: Both mechanisms provide for centralized reputation services based on "subjective" experiences instead of standardized quality criteria.

The basic principle of decentralized systems is that so-called (external) "reviewer agents" provide their expert knowledge. An example for a decentralized trust-based approach is the internet-based reputation mechanism of Abdul-Rahman and Heiles [4]. It is a personalized system of reputation relationships where every actor maintains his own database of "direct trust relationships" or "recommender trust relationships". Nevertheless, the realization of the mechanisms is not feasible due to the inherent necessity of a globally standardized trust category. Furthermore, the system lacks for assigning temporal information to the recommender and trust values in order to enhance to management of the system accordingly.

3.2 Requirements on a Demand-Driven Reputation Information Management System

The use of centralized service institutions seem to be appropriate only for high-value transactions since it involves high cost. Furthermore, evaluation criteria from independent institutions and centralized or decentralized systems often do not correspond to individual evaluation criteria. A demand-driven and process-based reputation information management system can comprise own evaluations, ("subjective") experiences and observations, and experiences of third parties. Third parties can provide for ("objectified") experiences and standardized ("objective") expert evaluations or even generate reputation information.

A prerequisite for the implementation, use, and maintenance of the reputation information management system is to agree upon common processes within a network. Communication difficulties between heterogeneous actors using different communication standards on the one hand and the reputation information management system on the other hand can thus be prevented. In order to correspond to the variety of requirements of different actors, specific contexts, and domains, the system should be adaptable and flexibly generate and manage reputation information according to individual demands. Additionally, the reputation information management system should be based on a modular technology.

In order to cope with the problem of subjective evaluations of a single person (in contrast to objective or simultaneous evaluations of different actors) weights can be assigned to the respective evaluations. Weights may indicate the importance and usability of the respective evaluations (for example a lower weighting for evaluations

of private actors compared to a high weighting for expert evaluations). However, it is not trivial to agree upon weights and to assure an identical interpretation of the weights by all participating actors.

4 System for Reputation Information Management

In this section, we describe the basic concepts of the reputation information management system, especially the different roles of participating actors and the architecture of the reputation information management system.

4.1 Roles in Reputation Information Management

An actor of the reputation information management can be a human or a legal person or an (autonomous) software agent. Each actor may have different roles such as evaluator, specialized reputation information requestor, and conventional reputation information requestor. The conventional reputation information requestor demands for reputation information that he specifies by interacting with the reputation information management system. For the interactive requirement specification, the reputation information management system provides for adequate functionalities, for example the communication interface. In contrast to the conventional reputation information requestor, the specialized reputation information requestor is able to specify his requirements individually by determining the transformation rules and information sources and thus generates his own reputation information scheme. The reputation information scheme determines the structure, the context, and the domain of the reputation information. Moreover, existing reputation information schemes can also serve as a proposal to a conventional reputation information requestor for his reputation information specification.

The evaluator evaluates objects according to pre-determined instructions. He can also specify the scheme of the evaluation, for example within a so-called initiative evaluation. An evaluation is called "initiative" if the evaluator himself determines the way and the time of evaluating an object and provides this information to the system without being asked for it. Finally, an actor can also have the role of an evaluation object or the reputation information source for other evaluators.

4.2 Architecture of the Reputation Information Management System

In the following section, we describe the basic concept of reputation information management. Figure 2 outlines the interaction of actors in their specific roles with the reputation information management system and their document-based processes (depicted by black arrows). For the exchange, information and data are presented as documents.

The evaluation mechanism of the reputation information management system starts with the reputation information request of an actor. The actor can be either a conven-

tional or a specialized reputation information requestor. The conventional requestor is identified by ID_cR comprising IP-address and his email. He requests reputation information of the target object with an object_ID. The specialized requestor is identified by ID_sR. His reputation request additionally comprises transformation rules, the reputation information scheme, and the information source. The reputation information management system checks if the required reputation information about the evaluation object is already stored in the history database or if the reputation information can be derived from stored evaluations. The history database contains reputation information reports (with temporal information) from which the reputation information itself, reputation information schemes, transformation rules, and meta-information about reputation information reports can be extracted. In the simplest case, the stored reputation information can be sent back to the reputation information requestor straight away as a new reputation information report (as RIMS service). Otherwise, existing evaluations have to be examined by the reputation information management system as to whether or not they can be transformed in order to generate the requested reputation information. If a transformation is possible, the reputation information scheme supports the transformation by serving as a specification base and providing for substantiating rules and methods (algorithms and/or policies). In the most unfavorable case, neither reputation information nor evaluations are stored in the history database and the reputation information management system has to send an evaluation request (comprising the ID of the reputation information management system and the necessary information of the request) to (potential) evaluators.

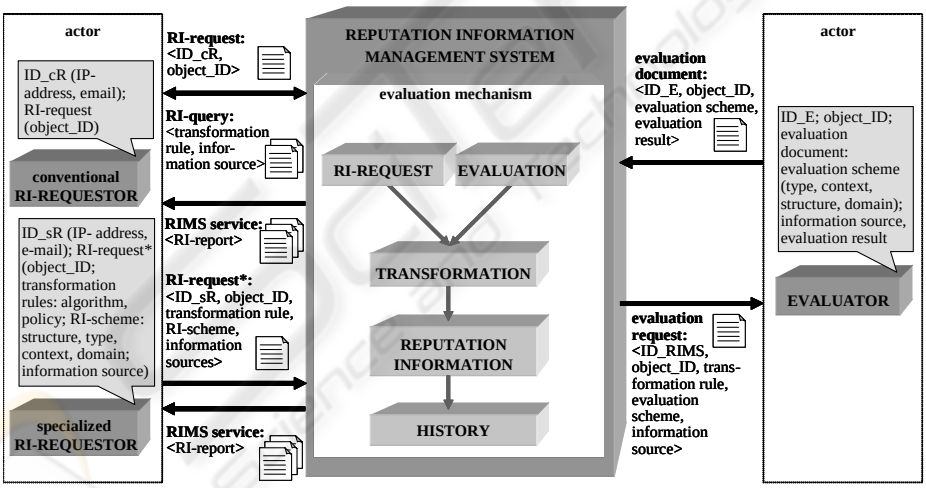

Fig. 2. Interaction between actors and the reputation information management system for the execution of reputation information requests and evaluations

The evaluator can either be an (institutionalized) expert (comparable to a rating agency like Standard & Poor's [24]) or a non-expert that evaluates the required object according to respective instructions. He is identified by ID_E and assigns the evaluation document (comprising information such as evaluation scheme, information

source, and evaluation result) to the target object. Instructions are delivered within the document of an evaluation request. They contain a detailed description of the evaluation process and the evaluation scheme (according to the reputation information scheme of the reputation information requestor by "inverting" the transformation rules). Finally, the generated evaluation document is sent to the reputation information management system. The evaluation mechanism of the reputation information management system in turn transforms the evaluation into the required reputation information and delivers the reputation information report to the reputation information requestor. If evaluations are invoked by other reasons than concrete reputation information requests (e.g., good will of the actor or monetary incentives of the system), the evaluator himself can specify the evaluation scheme. For such an initiative evaluation, the evaluation document includes the evaluation scheme and thus allows for assigning this evaluation to potential reputation information requests in the future.

5 Reputation Information Management Processes

Instead of focusing on technical issues, we will emphasize the process aspects. The example in Figure 1 has illustrated that elementary Petri nets are not well suited for the modeling of document-based processes.

5.1 XML Nets for the Description of Document-Based Processes

All information that is exchanged between actors and the reputation information management system has a structure and thus can be represented as an XML document. XML schemes exactly define the structure of the respective documents and are subject to reputation information management (see [25] for XML and [26] for XML Schema). For an integrated description of evaluation processes and its relevant documents we propose XML nets [17], a variant of high-level Petri nets. In XML nets, schemes of documents can be graphically specified for documents like evaluations or reputation information reports.

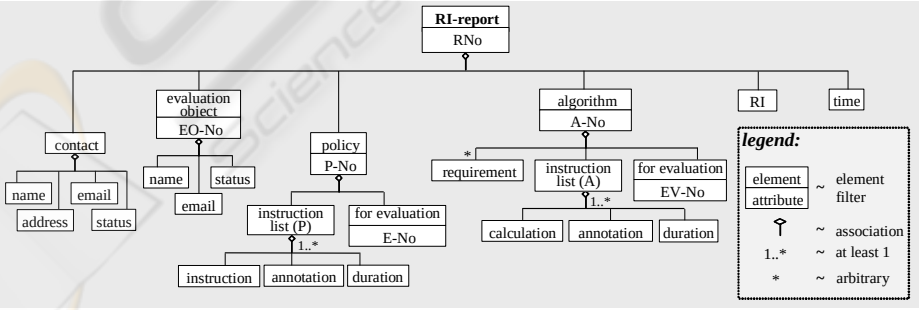

Fig. 3. Graphical XML scheme for the XML documents representing reputation information reports

Figure 3 shows a graphical XML scheme of a reputation information report. In accordance to this scheme, a reputation information report with its identifier "RNo" consists of the following elements: the "contact", the evaluation object, the appropriate transformation rules consisting of the "policy" and the "algorithm", the reputation information, and the date.

In XML nets, XML schemes define the types of the places they are assigned to. As a result, the places can be seen as containers of XML documents according to the respective scheme, e.g., reputation information reports or descriptions of physical objects. The direction of the edge determines whether the relevant documents are input or output documents of the corresponding activity. The edge inscriptions, so-called filter schemes, allow for filtering relevant documents from the set of available documents and for determining how to manipulate documents during the execution of the activity. A filter scheme may contain a manipulation filter, depicted by a black bar on the left side of the element (see Figure 4). The manipulation filter defines the manipulation: for example the deletion of old evaluations, insertion of a new evaluation or updating of the reputation information report. The manipulation operation can be applied either to the whole document or to a part of the document. A filter scheme without manipulation filter expresses that the respective document (e.g., the policy) is only read.

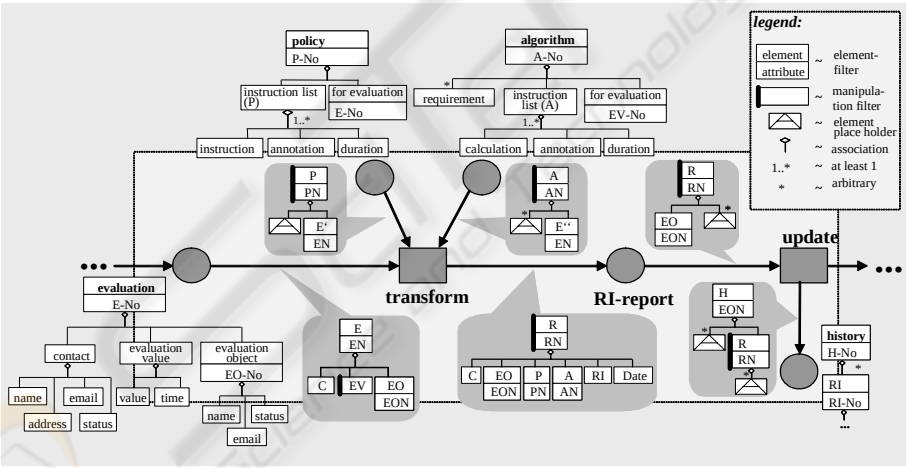

Fig. 4. XML net for the generation of a reputation information report

Figure 4 shows an XML net describing the part of the evaluation mechanism that generates reputation information reports (as a document-based and therefore more detailed description compared to the process in Figure 3). Relevant documents for the execution of the transformation are "evaluation", "policy", "algorithm", and "reputation information report". The respective schemes (except that for the reputation information report which is omitted due to space limitation) are shown in Figure 4. The

activity "transform" describes the transformation of an evaluation and the composition of the document for the reputation information report. For a detailed description of the activities during the transformation, the activity itself can be replaced by an appropriate detailed XML net. An adequate use of variables of the edge inscriptions, especially the one for the identifier of the evaluation object, ensures that only the corresponding policy and algorithm are taken into account for the transformation of the evaluation object.

The example illustrates that XML nets allow for a document-based process modeling. Their expressive power and formal semantics represent the basis for a systematical analysis of the process schemes. XML nets are a suitable means for the visualization and communication of processes (e.g., between experts and other actors), especially since the graphical representation can be adapted to specific skills and requirements. Moreover, XML nets support the execution of processes and therefore allow for a better control of (semi-) automatic process executions.

5.2 Supporting Inter-Organizational Collaboration

An integration of reputation information generating processes of the reputation information management system to the (business) processes of its participating actors allows for a step towards frictionless reputation information management. The exchange of reputation information and evaluation schemes together with a customizable representation results in a seamless collaboration between different actors and the reputation information management system. Especially enterprises with streams of requests and responds (e.g., simultaneous evaluations of several objects or of the same object from different reputation information sources) can benefit from the integration of processes into their own business processes.

Despite the advantages of inter-organizational processes, difficulties can result from integration, access, or execution if complex processes are not controlled. Workflow management systems allow for making complex application logic explicit where processes are modeled in a high-level (typically graphical) language rather than encoded in a programming language. Due to the formal semantics Petri nets are suitable for the graphical specification of workflows [1]. XML nets can be interpreted as workflow descriptions. If an activity that is supposed to be accomplished is initiated, the underlying workflow is automatically triggered by the workflow-engine. For controlling the performance of the respective reputation information processes, so-called fact transitions [13] are a suitable means. Moreover, they allow for the (graphical) declaration of rules that have to be obeyed during the process execution.

Besides the uncertainty reducing signaling effect of reputation information itself there is an inherent sanctioning mechanism within the electronic network. Instead of an explicit sanctioning instance, actors among themselves will prevent other participants to behave in an opportunistic manner within the electronic network. Inter-organizational collaboration, however, also requires that each actor makes his process or parts of it transparent [3] to the reputation information management system. Better comprehension and understanding of each others' processes leads to a better demand-oriented reputation information service. Moreover, the reputation information management system should be able to integrate arbitrary types of reputation information

requestors, consider different reputation information sources and different transformation rules for demand-specific requests.

6 Summary and outlook

The paper describes research work from an ongoing project which aims at developing an architecture of a reputation information management system. In this paper we have proposed a concept for generating and managing reputation information for reducing behavior and quality uncertainties in electronic networks. Rather then coping with the technical aspects of the system, we have concentrated on modeling aspects. We have described evaluations and reputation information and gave a brief introduction into Petri nets. A critical overview of existing concepts and systems for reducing uncertainty led to the development of requirements on the reputation information management. Disadvantages of existing concepts and systems, especially their restriction to specific application domains, have motivated the introduction of a demand-driven, process-based reputation information management system. The reputation information management system is responsible for generating and managing reputation information, e.g., for handling evaluations or reputation information according to user specific requirements. The concept of the reputation information management system, especially the evaluation mechanism and different roles of actors were presented. Processes of the reputation information management were described. Thereafter, a process part and the relevant documents were modeled as an XML net.

Uncertainties in electronic networks that are less a result of technical or environmental but rather of endogenous behavior and quality uncertainties between actors can be reduced by providing indicative reputation information. The reputation information management system helps to generate and manage reputation information in order to deliver individual, demand-specific reputation information reports. It is demand-driven, personalized, and adapts to different domains and contexts of individual requirements of actors in different roles.

It is not necessary that reputation information has to be generated within the evaluation mechanism of reputation information management system. In order to enhance the interchange of relevant documents and data in electronic networks it is necessary to develop appropriate interfaces for the integration of the processes. Spontaneous (especially short run) collaboration can be supported by making available a repository of process fragments to the involved actors. The repository consists of process schemes for relevant process parts that can be delivered to the requesting actor on demand. The implementation of such a repository is facilitated by using a common document-based process modeling language such as XML nets.

A prototype version of the reputation information management system is currently under development.

References

1. van der Aalst, W. M. P.: The Application of Petri Nets to Workflow Management. In: The Journal of Circuits, Systems and Computers, Vol. 8 (1) (1998) 21–66
2. van der Aalst, W. M. P., Desel, J., Oberweis, A. (eds.): Business Process Management – Models, Techniques, and Empirical Studies, Lecture Notes in Computer Science, Vol. 1806, Springer-Verlag, Berlin Heidelberg New York (2000)
3. van der Aalst, W. M. P., Kumar, A.: XML Based Schema Definition for Support of Inter-organizational Workflow. In: Information Systems Research, Vol. 14 (1) (2003) 151–162
4. Abdul-Rahman, A.; Heiles, S.: Using Recommendations for Managing Trust in Distributed Systems. In: Proc. IEEE Malaysia International Conference on Communications, Kuala Lumpur, Malaysia (1997)
5. Akerlof, G.A.: The Market for Lemons: Quality Uncertainty and the Market Mechanism. In: Quarterly Journal of Economics, 84 (3) (1970) 488–500
6. Alonso, G., Casati, F., Kuno, H., Machiraju, V.: Web Services: Concepts, Architectures and Applications. Springer-Verlag, Berlin (2004)
7. Arrow, K.J.: The Economics of Agency. In: Pratt, J., Zeckhauser, R. (eds.), Principles and agents: The structure of business, Harvard University Press, Boston (1985) 37–51
8. Brauer, W., Reisig, W., Rozenberg, G. (eds.): Advances in Petri Nets, Part I, Lecture Notes in Computer Science, Vol. 254, Springer-Verlag, Berlin Heidelberg New York (1986)
9. Ciao, http://www.ciao.com
10. Dasgaputa, P.: Trust as a Commodity. In: Gambetta, D. (ed.): Trust Making and Breaking Cooperative Relations, New York et al. (1988) 49–72
11. Ebay, http://www.ebay.com
12. Ehrig, H., Hoffmann, K., Padberg, J., et al.: High-level Net Processes. In: Brauer, W., Reisig, W., Rozenberg, G. (eds.): Formal and Natural Computing, Lecture Notes in Computer Science, Vol. 2300, Springer-Verlag, Berlin Heidelberg New York (2002) 191–219
13. Genrich, H.J.: Predicate/Transition Nets. In: Brauer, W., Reisig, W., Rozenberg, G. (eds.): Petri Nets: Central Models and Their Properties, Advances in Petri Nets – Part I, Lecture Notes in Computer Science, Vol. 254, Springer-Verlag, Berlin Heidelberg New York (1987) 207–247
14. Jensen, K.: Coloured Petri Nets, Vol. 1 – Basic Concepts, Berlin (1992)
15. Kollock, P.: The Production of Trust in Online Markets. In: Lawler, E.J., Macy, M., Thyne, S., Walker, H.A. (eds.): Advances in Group Processes, Vol. 16 (1999)
16. Lenz, K.: Modellierung und Ausführung von E-Business-Prozessen mit XML-Netzen. Verlag für Wissenschaft und Forschung, Berlin (2003) (in German)
17. Lenz, K., Oberweis, A.: Inter-organizational Business Process Management with XML Nets. In: Ehrig, H., Reisig, W., Rozenberg, G.; Weber, H. (eds.): Petri Net Technology for Communication-Based Systems, Lecture Notes in Computer Science, Vol. 2472, Springer-Verlag, Berlin Heidelberg (2003) 243–263
18. Reputation Research Network, http://databases.si.umich.edu/reputations/
19. Resnick, P.; Varian, H.R.: Recommender Systems. In: Communications of the ACM, 40 (3) (1997) 56–58
20. Resnick, P.; Zeckhauser, R.; Friedman, E.; Kuwabara, K.: Reputation Systems. In: Communications of the ACM, 43 (12) (2000) 45–48
21. Scheer, A.-W.: Business Process Modeling, 2nd edition, Berlin et al. (1999)
22. Shapiro, C.: Premiums for High Quality Products as Returns to Reputations. In: Quarterly Journal of Economics, Vol. 97 (1983) 659–679
23. Spence, M.: Informational Aspects of Market Structure: An Introduction. In: Quarterly Journal of Economics, Vol. 90 (4) (1976) 591–597
24. Standard & Poor's, http://www.standardandpoors.com

25. World Wide Web Consortium: Extensible Markup Language, http://www.w3.org/XML
26. World Wide Web Consortium: XML Schema, http://www.w3.org/XML/Schema
27. Weitz, W.: Combining Structured Documents with High-level Petri-Nets for Workflow Modeling in Internet-based Commerce. In: International Journal of Cooperative Information Systems (IJCIS), Vol. 7 (4) (1998) 275–296
28. Zacharia, G.; Moukas, A.; Maes, P.: Collaborative Reputation Mechanisms in Electronic Marketplaces. In: Proc. 32nd Hawai'i Intl. Conference On System Science (1999) 1–7