Modelling Social Behaviour with Petri net based Multi-Agent Systems

Michael Köhler, Marcel Martens, and Heiko Rölke

University of Hamburg,
Department for Computer Science
Vogt-Kölln-Str. 30, D-22527 Hamburg
{koehler,martens,roelke}@informatik.uni-hamburg.de

Abstract. An important issue regarding the deeper understanding of social and organisational phenomena is the interaction and the linkage between micro and macro layers. The micro-macro-link deals with the emergent aggregation of processes and actions on the micro-level and with structures, rules and roles on the macro-level. This paper presents recent results of the "socionics" project ASKO[1], which is a fusion of sociology and computer science[2]. Due to the interdisciplinary character of our project we use a graphical representation of our models: a special dialect of high-level Petri nets, namely reference nets, has been chosen, since it offers a simple and executable representation with a clear mathematical foundation.
Keywords: micro-macro-link, modelling, multi-agent systems, organisations, Petri nets, reference nets, socionics

1 Introduction

This paper presents basic concepts of modelling sociological phenomena by means of Petri nets considering micro and macro layers. An abstract model of a social theory (cf. subsection 3.2) is used as a guideline to model an empirical case study: the *decision problem of recruiting new employees in universities*. Following the ideas of Cohen et al. [5], universities are huge public organisations ("organized anarchies") which have to deal with problematic preferences, unclear technology, and fluid participation. Their ability of "good" decision making is an essential criterion and assures their survival. In order to accomplish their tasks (educate students, produce knowledge), universities have to care about a certain number of new academic members (namely PhD students). The problem is the corresponding decision process which is characterised by inefficiencies and decision failures[3]. We will demonstrate that our multi-agent system architecture Mulan combined with extensions for social modelling provides an attractive framework for modelling such case studies.

Former results in linking sociology and computer science in the "socionics" research area are used as a basis for this paper. The project "Acting in social

[1] "Acting in social contexts" (ASKO): cf. [24]
[2] A research program that has been funded by the Deutsche Forschungsgemeinschaft (DFG) cf. [23].
[3] As found out in the empirical study of the ASKO project.

contexts" (ASKO) intends to analyse *decision processes* in public administrations, since this area is characterised by inefficiencies and decision failures. This analysis is validated empirically in the context of decision processes in public administrations, especially in universities. The goal of ASKO is to combine sociological theories of organisations and theories of agent-oriented Petri nets to derive a notion of flexible software systems.

The problem of modelling sociological phenomena is the complexity of such systems: on the one hand social actors, actions and processes (micro-level) do have implications on the macro-level which consists of (social) structures, rules and roles. On the other hand the macro-level is "structuring" and controlling all embedded actions and actors (cf. [10]). Many sociological theories concentrate mainly on one perspective, either the micro or the macro view (cf. [7] resp. [5]). In our opinion the linkage between those two views has to be taken into account to improve the understanding of social behaviour.

A common way to model complex systems is to use diagrams of the UML [22] or workflows [1]. Since UML models incorporate many different, inconsistent and semi-formal diagram types of a system they are not suitable as a modelling technique for a socionical MAS. Petri net based workflows do have precise semantics but their structure is fixed and they have no means to express the micro-macro-link which is necessary for a dynamical MAS. A modelling technique which can handle processes, structures, *and* their interactions is needed. Furthermore it should offer a mathematical foundation for a formal analysis of the models and it should be executable. To model social processes appropriately we use results achieved in [20] and have adjusted our general agent Petri nets to socionic-oriented ones (cf. [15]). First results of our group regarding the modelling of organisational theories can be found in [11, 12]. These models are described in terms of our reference nets formalism [18], modelled with the Renew-tool [19].

The paper is structured the following way: Section 2 gives a short introduction into our basic modelling formalisms: reference nets and multi-agent systems. Section 3 introduces the sociological background theory which is needed to connect structures and processes. This theory is used to model the case study in an adequate way. The work closes with a conclusion.

2 Modelling Concepts

Before we present the sociological case study of decision processes in the context of universities in Section 3, reference nets are introduced in Subsection 2.1 and a description of the Petri net based multi-agent system Mulan is presented in Subsection 2.2.

2.1 Reference Nets

Reference nets are a so-called "high-level" variant of Petri nets. The reader is assumed to be familiar with the static and dynamic aspects of Petri nets. This subsection only explains the differences between the formalism of reference nets and other high-level nets like coloured Petri nets [13]. Detailed information on Petri nets can be found in [21], while reference nets are described in [18].

Basically, reference nets look like other Petri nets, but they offer two important additional features: communication by means of synchronous channels and net instances together with net references ("nets within nets").

Synchronous channels were first considered for coloured Petri nets by Christensen and Hansen [4]. They synchronise two or more transitions which all fire atomically at the same time. All transitions must agree on the name of the channel and on an (optional) set of parameters before they can synchronise. Reference nets generalise this concept by allowing transitions in different net instances to fire. However, the channel itself has a direction, while parameter passing is bidirectional.

The idea of *nets within nets* [25] is that tokens of a so-called *system net* correspond to Petri nets on a lower level, called *object nets* (cf. Fig. 1).

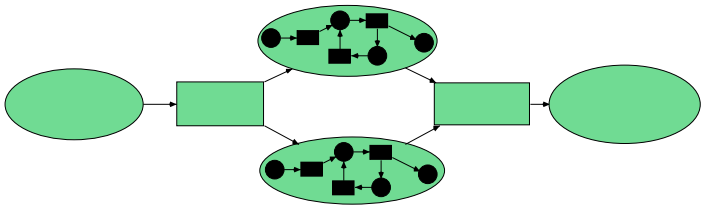

Fig. 1. Nets within nets

Reference nets put this idea into practice by creating tokens that reference other Petri nets. When a reference net is constructed, it is specified as a static structure that serves as a template. During simulation an arbitrary number of copies can be created using this template. These copies are net instances. As mentioned above, the different net instances (system and object nets) communicate by means of synchronous channels. The type system of reference nets is closely related to that of the Java language.

2.2 The Multi-Agent System Mulan

This section gives a short introduction to our multi-agent system MULAN ("**Mul**ti-**a**gent **n**ets") modelled in terms of "nets within nets" (cf. [14, 8]).[4] Take a look at Figure 2: The grey rounded boxes enclose net instances of their own right. The ZOOM lines enlarge object nets that are tokens in the respective system net[5]. The upper left net of the Figure is an arbitrary agent system with places containing agent platforms and transitions modelling communication channels between the

[4] It is neither an introduction to multi-agent systems nor are the assets and drawbacks of dividing the system into platforms discussed here. For a broad introduction see for example [27], the special view taken in our work is a standard proposal of the "Foundation for Intelligent Physical Agents" (FIPA) [9].

[5] Beware not to confuse this net-to-token relationship with place refinement.

platforms[6]. Platforms (the upper left net) offer services as internal or external communication.

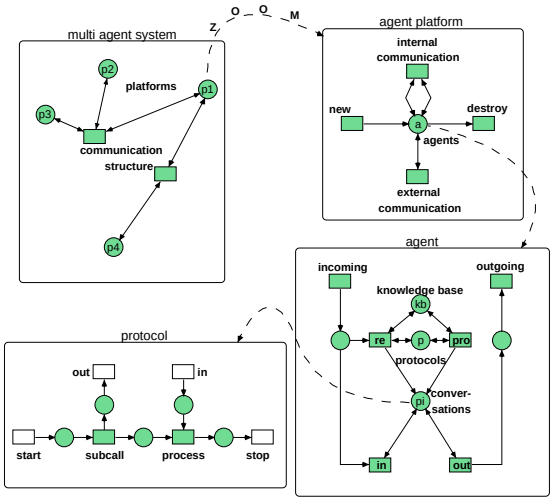

Fig. 2. MAS as nets within nets

This leads to the most simplified (but nevertheless meaningful) view on an agent, which is presented as a reference net in the lower right corner of Figure 2. The communication interface of this abstract agent consists of the transitions input and output. The agents communicate to other agents via synchronous channels that are not represented in the Figure.

The agent's behaviour and functionality is hidden in object nets that are called *protocols* (lower left corner of Figure 2). A protocol controls the flow of messages and internal actions of one agent. If an (abstract) action involves more than one agent the appropriate protocols form a *conversation* [6].

The main idea behind the approach to model an agent's behaviour by means of protocols and to model the dynamic aspect of a multi-agent system with conversations (both presented as reference nets) is the following (cf. [3]): It is often easy to give an abstract "message flow" between agents to achieve a desired action. In this approach, this flow of messages can be directly used to specify the behaviour of the agents that participate in the action.

[6] This is just an illustrating example, the number of places and the form of interconnection has no further meaning.

3 Case Study: Decision Making Processes in Universities

The main focus of this case study is the investigation and analysis of decision inefficiencies and failures regarding the employment of new academic staff, namely PhD students. Usually such employments are a clearly defined administrative act, described in the universities' administrative laws. But there are differences between the "ideal" process of employment and the "real" process, which are shown in the following subsections.

3.1 Empirical Scenario

According to our empirical study the process of employing new academic staff is described briefly as follows: a PhD position is vacant and has to be occupied. Therefore a professor fills out an application form and discusses this issue with the managing director. Then a committee called *department council*[7] (consisting of seven professors, three PhD students, two regular students and one technical staff) debates about the PhD-candidates with the dean. The women's representative and the staff council check the application again.

In fact it should be in the university's interest to optimise this process and ensure that it always produces the desired result[8], but there are some hidden qualities of this process: (1) the more assistants a professor has, the greater his reputation and his efficiency of labour. This is the reason for discussions in the department council; (2) the women's representative position in the department council is not taken seriously, so she tries to stand up to others by using her right to veto.

3.2 The Middle Range Theory (Mrt)

The modelling of our social case study is based on the micro-macro-model [16, 17]. The model integrates the micro- as well as the macro-viewpoint, thus making the micro-macro-link a crucial element of the model.

The model consists of a three level hierarchy connected by synchronous channels: The social structure builds the top-level. Tokens of this net are again nets, which describe the processes of social interaction. Each interaction is produced by actors, being tokens of this middle level. Actors, the base level, are again nets. This model, denoted in RENEW-syntax, is illustrated in Fig. 3. The Figure illustrates only parts of the model, since only one net token of each level is zoomed.

The top level describes the dialectics of the social structure, consisting of the relationship of structure and action, which are coupled in the concept of structuring. Structuring can be seen as an active element since it generates social acts. But it can also be seen as an passive element since, the social structure is (re-)produced by social processes.

Structuring consists of *social processes*, which are modelled by the subordinated nets. The two levels are connected by two channels. Central element of this net is

[7] In german: "Fachbereichsrat" (FBR). The FBR has a right to *veto*.
[8] Which is the employment of academic assistants (PhD students).

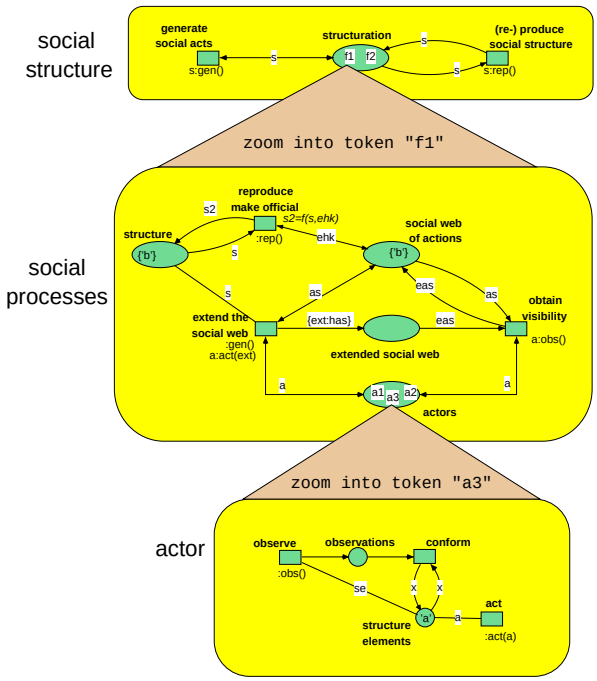

Fig. 3. The abstract micro-macro-model

the string of actions and its extension by individual actions.Whenever this extension is observed the string is updated.[9]

The two processes of extending and observing are generated by actors. Each actor-net also has a linkage with the medium net, describing the social processes. How this is done depends on the inner structure elements of the actor. The structure elements are the interpretation frame for each actor. Under special conditions (e.g. in the context of role-conflicts) observations can cause actors to conform to external demands. At each time the structure elements describe how the actor makes his choice for an action. The structure elements can be social norms for a homo sociologicus or a utility function for a rational choice actor.

The model acts as a conceptual starting point for the modelling of the case study (for a detailed presentation cf. [17]).

3.3 Social Structures (Macro View)

The Petri net in Fig. 4 represents a macro view in our case study. One can see the underlying social structure and the basic relationships between the agents[10] and the causally determined order of actions. An ideal and desired workflow would

[9] This process is a central element of Elias' as well as Bourdieu's theory.
[10] Which are the actors described in subsection 3.1.

terminate in the place vacancy filled, which means that the debate of the department council would have a result and the women's representative would accept the PhD-candidate. As analysed in our empirical study the debating of the department council results in a constant postponing of the final decision and the women's representative uses her veto very often. The consequence of this "real life" workflow is represented by the place vacancy not filled.

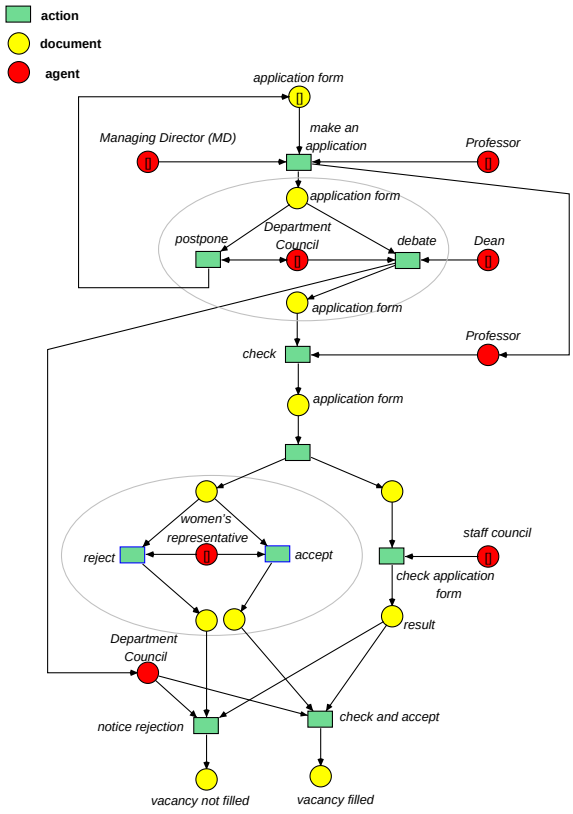

Fig. 4. Macro view on decision process

Obviously this is not a desired outcome for the university, since a lack of new academical staff leads to severe problems regarding the quality of teaching and research activities. What are the reasons for this behaviour? The explanation can not be found on the macro level, so we have to analyse the agents on the micro level in the following subsection.

3.4 Empirical Processes (Micro View)

Since we can not show all aspects of the decision making process, we concentrate on the behaviour of the women's representative. An abstract view of her behaviour

is shown in Fig. 5. Basically, she tries to enhance her prestige by using her veto and thus rejecting incoming applications. As soon as her position is strengthened[11] and she is accounted as a serious member by the professors, she is willing to accept applications. This micro-behaviour of the women's representative is one reason for decision making failures on the macro level.

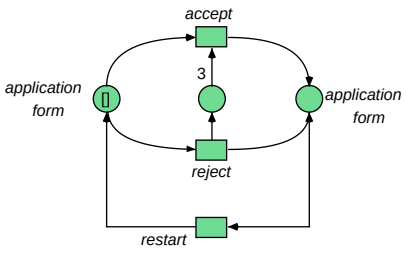

Fig. 5. Abstract view on actor "women's representative"

Fig. 6 shows the behaviour of the women's representative modelled as a MULAN protocol. One can see the same behaviour as shown in Fig. 5. Each agent has a knowledge base which represents the agent's mental state. In our case this is done by invoking the method wb:ask(mental_state, x) before she decides whether to accept or reject the candidate. By sending corresponding messages she informs other agents about her decision by using a speech act (action p2=new AclMessage). So actions inside the protocols (on the micro level) do have implications on the macro level and thus meet the requirements of socionical modelling and do explicitly feature the micro-macro-link. Furthermore this modelling style is similar to the MRT described in section 3.2. In MULAN the user only has to care about the modelling of the protocols as the structure of the agents and the platforms is part of the MULAN-framework.

4 Summary and outlook

This paper demonstrates the possibility to model aspects of a sociological theory by means of Petri nets. The need to consider both – micro and macro perspectives – is shown and explicitly modelled. Furthermore the similarity is shown between the abstract micro-macro-model (MRT) and our empirical case study regarding decision processes in universities. We have presented a model which takes micro *and* macro perspectives into account. The empirical model and the MRT are structured similar and thus are capable of handling micro and macro phenomena. We have shown that on the macro level a social structure can be represented by means of workflows, and a step further, as a conglomeration of agents which are organised by a socionical MAS (MULAN). On the micro level social actors can be represented by their logic of actions and thus be modelled by MULAN-protocols. Our proposed technique in this

[11] Modelled by three tokens as a precondition before the transition accept can fire.

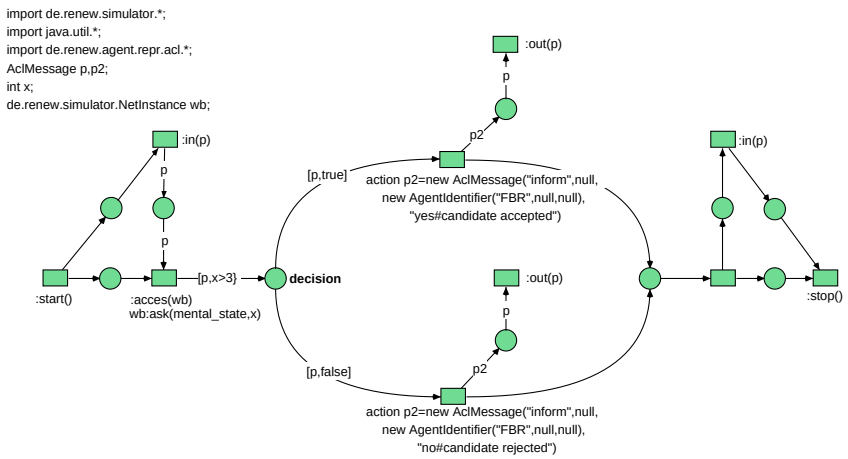

Fig. 6. Multi-agent system protocol "women's representative"

paper are agent-reference nets, which explicitly support an executable multi-level model.

We concentrate on the modelling of emergent processes that support dynamic structures. Current modelling techniques focus either on processes *or* on structures which is not suitable for social phenomena. By using concepts of the Mrt we are able to model the micro-macro-link explicitly.

Our goal is to combine these and following models to a Petri net framework called Sam for a description and analysis of processes in public administrations.

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