An Approach for Modelling the Micro-Macro Link

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Abstract. Socionic is a recently established research area, bringing together computer- and social-science. Both disciplines meet at the investigation of multi-agent systems. In our project "ASKO" we analyse decision processes in public administrations. The project is based on empirical studies as well as on theoretical work. The theoretical work is based on a reconstruction of established social theories and their integration into a middle-range-theory. This reconstruction is supported by a modelling process using formal techniques from computer-science. The resulting model is used as a basis for the "social" elements of our multi-agent system architecture SAM.

Central questions arising in this trans-disciplary work concern the modelling of an aspect of social systems, known as the micro-macro link: The micro-macro link addresses the emergent aggregation of micro processes – like group interactions – into macro ones – like the establishment of dominance.

In this article we present a model which links the micro with the macro level. This model is one of our major results of the analysis of social theories concerning their commonness. A main advantage of the model is the simultaneous description of the micro and the macro level in one model. This is a great benefit over models which are based on a refinement from the macro towards the micro level, and also over models which are formed by an abstraction process starting at the micro level. So, we can analyse both levels and their linkage in an integrated way.

The model can be exploited in two directions: First, it is possible to investigate existing social theories using our micro-macro-model as an evaluation frame. Theories can be investigated by contrasting the processes of our micro-macro-model with the processes described by the theory.

Second, the model acts as the core design for the social layer in our agent system architecture SAM. Our model is formulated in terms of Petri nets, an advancement of the model of finite state machines. Since the architecture SAM is also designed and implemented in terms of Petri nets, the problems arising while switching the base formalism does not occur.

1 Introduction

This contribution has been developed in the context of the socionics-project "Acting in social contexts" (ASKO). Socionics is a trans-disciplinary research area between computer- and social-science in the area of multi-agent systems.[1] The ASKO-project [vLMV01] analyses the relationship of actors, social acts, and actor constellations under the consideration of social process and structural elements. This analysis is validated empirically in the context of decision processes in public administrations, especially in universities.

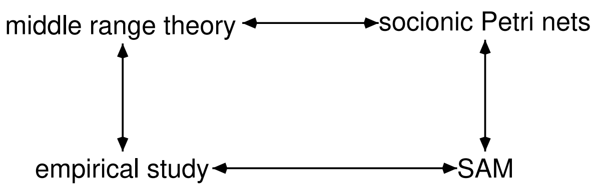

Fig. 1. Research areas of the ASKO-project

The social-science part of our project is connected with the reconstruction of social organisation theories as well as general theories of society. This analysis is combined into in a *middle-range-theory* (MRT) for decision processes. The theoretical work is accompanied by *empirical studies.*[2]

The computer-science part is integrated in the development of the middle-range-theory, since the theory reconstruction is done by using formal models. These models are *socionic Petri nets*[3]. These socionic Petri nets have an exact semantics. So, an direct integration into the SAM-architecture [KMR01] is possible, since SAM is designed by the use of reference Petri nets, an improved Petri net formalism of Valk (cf. [Val98]) implemented by the RENEW-tool [KW98].

[1] Socionics is a research program sponsored by the Deutsche Forschungsgemeinschaft. For an overview on the research program cf. [Soz98]. For an introduction into the research area addressed by socionics cf. [Mal96].

[2] For a preliminary version of the combination of empirical and theoretical analysis cf. [HKL$^+$01c].

[3] For an introduction into the use of Petri nets in the context of socionics cf. [KR01].

So, both disciplines can integrate their theoretical research investigation in the design of socionic Petri nets, expressing the middle-range-theory. Also on practical level the research meets, since empirical studies can be expressed using the agent system SAM (cf. [HKL+01a]). These research areas are presented in Fig. 1.

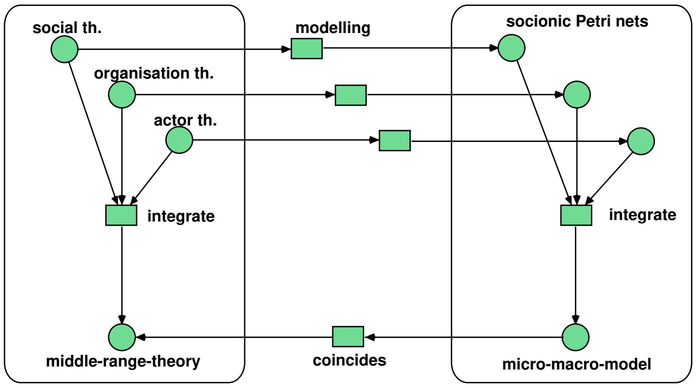

Fig. 2. Integration of different social theories

In this work we concentrate on the development of a middle-range-theory using socionic Petri nets. This development is an ongoing evolutionary process between theory-reconstruction and -modelling. Central aim of this modelling process is an integration of the different perspectives, which are used by organisation-, actor- or society-theories.[4] One cycle of this process is depicted in Fig. 2: Each theory is used for the formulation of the middle-range-theory which is contrasted with the model integration of the models for each theory.[5]

After some iterations of this modelling cycle, a first version of the integrated model can be identified. The integration results in a Δ-pattern, illustrated in Fig. 3, which is based on three elements, and their relationships: actor, acting processes, and social structures. The relationships are formed by dialectic pairs: individual versus society, actor versus acting, and acting versus structure.

[4] For our current work we have chosen [CMO72] and [CF93] for the organisational field, [Sch00] for general actor theories an actor constellation, and [Eli39,Eli87] as well as [Bou87,Bou93] for general society theories.

[5] The models are published as [HKMM00], [HKL+00,HKL+02b], and [KLMR00] as well as [HKL+01b].

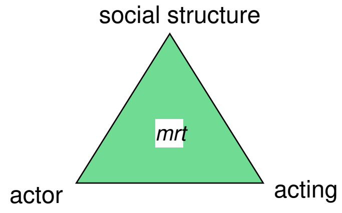

Fig. 3. Integrated views of the middle-range-theory

From an analytical point of view all these views – actor, acting, and structure – are relevant, depending on the phenomena one wants to explain. So, a social theory can be developed starting from any view point. Any view can be considered as dominant while the others are subsidiary. But, the use of one favoured view is risky because of the likely “white areas” in the theory; the theory might be inconsistent or incomplete.

For the social pre-structuring of our multi-agent system architecture Sam [KMR01] a theory which integrates all these viewpoints is necessary. Our micro-macro-model has this desired property, since it is based on the dialectic processes between actor, acting, and structure. As the micro-macro-model is formulated in the same formalism it can be integrated into the Sam-architecture directly.

The following presentation is structured as follows: Section 2 gives a short introduction into the concepts of Petri nets. Ordinary Petri nets are described as well as the advanced formalism of reference nets, also known as “nets within nets”. In section 3 we describe some socionic Petri net models which addresses the micro-macro link in the theory of Bourdieu, Elias, and Schimank. Using the paradigm of reference nets the socionic models are separated in section 4 at the micro-macro-borderline. The general structure which becomes visible is expressed into the generalised micro-macro-model. The work closes with an outlook.

2 Socionic Modelling with Petri Nets

Petri nets are based in the thesis of Carl Adam Petri [Pet62]. They are used for theoretical as well as for practical issues for the description of discrete systems – discrete with respect to states and events. The model of a Petri net is an advancement of the finite state machine, since it naturally describes concurrent actions and independent states of a system. Several formalism are derived from the Petri net model. Here, we restrict ourselves to the presentation of elementary Petri nets and Reference nets.

2.1 Elementary Petri Nets

The graphical representation of a Petri net is a bipartite, directed graph with two types of nodes: *places* and *transitions*. Places are drawn as ellipses, transitions as rectangles. Places can be considered as passive entities while transitions are active. Places are only connected with transitions and vice versa.[6]

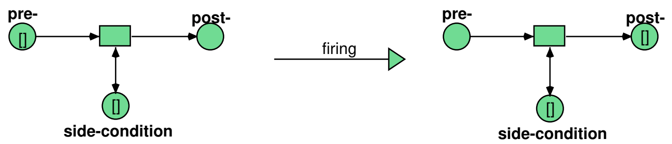

Fig. 4. Firing of a transition

On top of this static structure the dynamic behaviour is achieved by providing *tokens* on the places. A place s having an arc leading to the transition t is called pre-condition for t. A place s having an arc leading from t to s is called post-condition for t. Places being pre- as well as post-conditions are called side-conditions. A transition t can *"fired"* if all pre-condition-places of t are marked with tokens. These tokens are deleted and fresh tokens on the post-conditions are generated. Figure 4 illustrates this firing.

An extension of this model is the formalism of coloured Petri nets [Jen92], which allows typed tokens. So, tokens of one place can be differentiated. Firing of transitions is then dependent on a binding of variables, which are denoted as inscriptions of arcs.

[6] For a formal introduction cf. [Rei85].

2.2 Reference Nets – Nets as Tokens

A special situation arises if tokens can be Petri nets itself again. This idea of "nets within nets" has been developed by Valk [Val98,Val00]. The idea of *nets within nets* is that tokens of a so-called *system net* correspond to Petri nets on a lower level, called *object nets* (cf. Fig. 5). This approach is especially well suited for hierarchically structured systems.

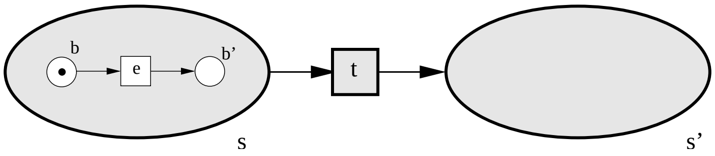

Fig. 5. A Petri net as a token

Reference nets [Kum01] 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. Channels are denoted by inscriptions : $ch()$ of transitions in the system and in the object net, with the meaning that both transitions can only fire synchronously.

3 Micro-Macro-Borderlines

In the following we present some results of the reconstruction and modelling process of social theories. Here, the theories of Pierre Bourdieu, Norbert Elias, and Uwe Schimank are chosen as exemplary examples, since these theories address the micro-macro-link. Due to the limited space we cannot describe step by step how the models were derived. For a detailed explanation we refer to the original presentation in [HKL$^+$01b], [HKL$^+$02a], and [HKL$^+$02b].

3.1 The Habitus-Field-Theory – Pierre Bourdieu

As a first example the habitus-field-theory of Pierre Bourdieu is considered. The micro-macro link is addressed in this theory by the relationship of habitus and the logic of the practice, illustrated in Fig. 6. Following Bourdieu the logic of the practice is incorporated by the individuals as their habitus. The habitus is the central mechanism: it controls what the actor will observe, how he reasons, and how he acts. Doing so each actor provides a practical acceptance of the practical logic. This acceptance, which is an unintentional process, reproduces the practical logics; the field thus controls the actions of the individuals. So, we can conclude that by this process the habitus stabilises its field, e.g. the field that has produced the habitus.

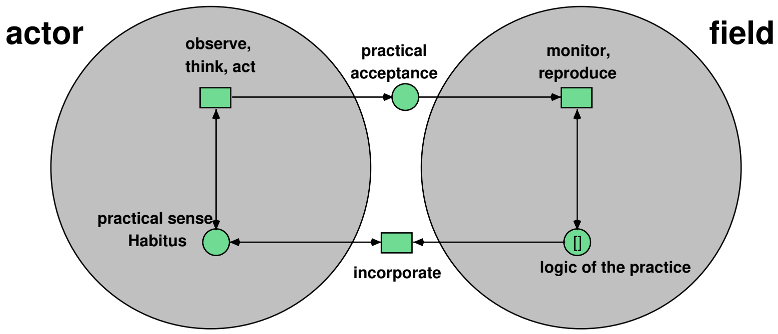

Fig. 6. The habitus stabilises its field (taken from [HKL+02a])

3.2 Social Control – Norbert Elias

One aspect of Elias' theory covers the reproduction of social norms illustrated in Fig. 7: Following Elias, the sense of shame is the central reason for groups to control their members. Control results in social bondage, which is transformed in a self bondage, because their fear of loosing the groups sympathy. This internalisation results also in the sense for embarrassment. The self bondage of actors result in behaviour, that is in accordance with the social norms. So, the norm is exerted, which reproduces the existence of the norm.

Also the sense of shame, the fear of loosing sympathy, and the sense for embarrassment is reproduced, which cannot be illustrated here – cf. [HKL+01b] for the complete model.

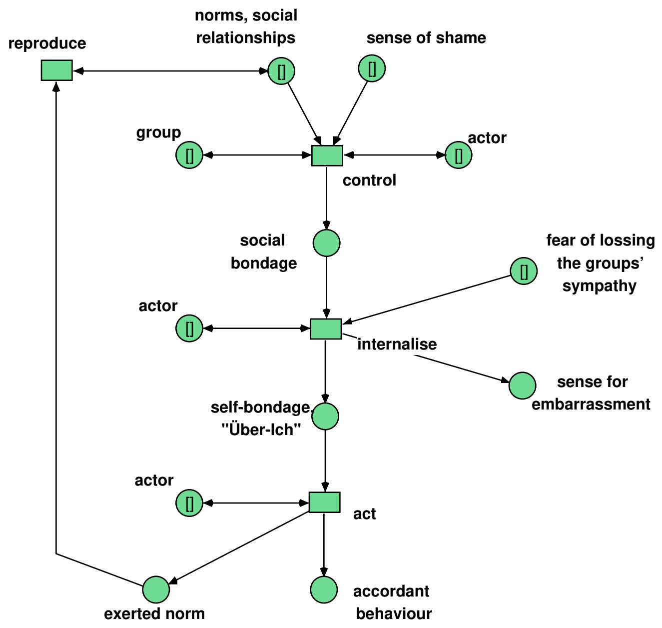

Fig. 7. Reproduction of social norms (taken from [HKL+01b])

3.3 Actor and Structure

As a third modelling sample we provide an example of the relationship of actors and their social environment – based on the social work of Uwe Schimank [Sch00]. Here, we concentrate on the actor model, known as the “homo sociologicus”. The acting of a homo sociologicus is aligned on the established norms, which are bundled into a social role. If the expectations towards the actor's role are conflicting, an inter-role-conflict is present. For example consider a teacher, who is member of a political party and teaches political science. Then a conflict is present, since the party usually expects its party member behaving in accordance with the party's political goals while the school usually aspects the teacher being political neutral (cf. Fig. 8).

The actor can modify the role, so the conflict is resolved (“role-making”). This can be done by yielding to the stronger group or to the role, which is controlled more intesive. Figure 8 provides the twofold aspects of a social role, since a role can be seen as expectations from the environment and also as the internalised role of the actor.

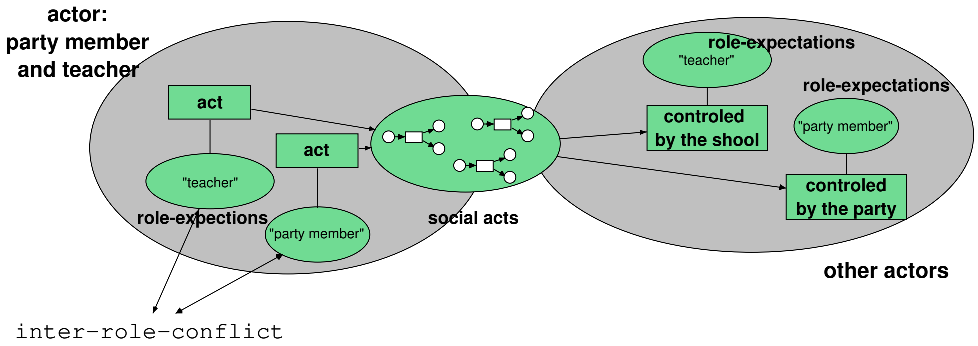

Fig. 8. Inter-role-conflict (taken from [HKL+02b])

4 The Micro-Macro-Model

In the following, we develop a model, which provides the micro- as well as the macro-viewpoint directly. So, our model contains both levels of abstractions but has neither the disadvantages of refining the macro- towards the micro-level nor those of abstracting the macro level from the micro one.

The resulting model is no longer expressible as an elementary Petri net – instead reference nets will be used. The paradigm of nets within nets allows to describe micro processes by a micro net which is embedded into the macro net, that describes the macro structures. The resulting model has an inherent vertical structure. Along this vertical dimension the micro-macro link builds the relation of the two processes.

4.1 Separation of the Micro- and the Macro-Level

For a vertical structuring of the micro-macro-model it is necessary to make an analytical distinction of social concepts which are used to describe processes of elements on the micro as well as on the macro level, like the concept of “social structure”. In general, these concepts link dependent concepts on both levels. But without a clear distinction the description of their inner micro-macro linkage will remain vague.

We will illustrate this separation for the model in Fig. 6, which describes the relationship of a micro concept – the habitus of an

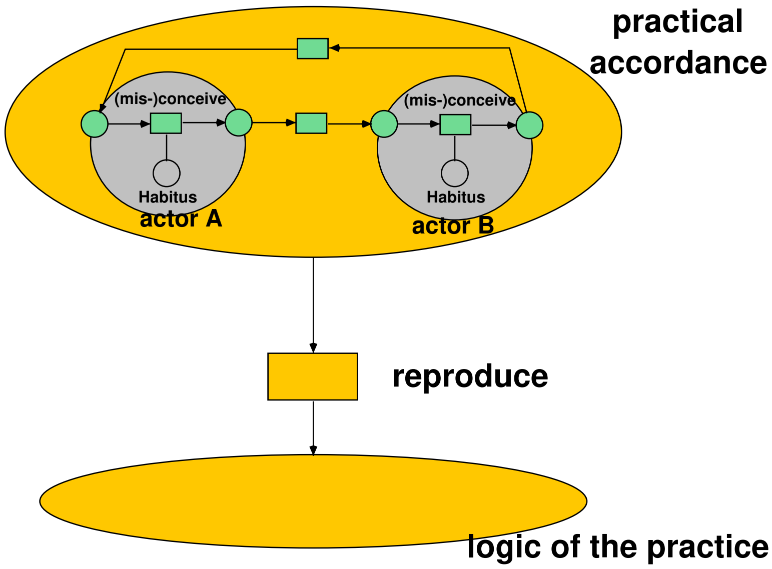

Fig. 9. The habitus stabilises its field (cf. Fig. 6)

actor – with an macro construct – the logic of the practice/field. The same separation has to be done for the processes: Reproduction of the field is a macro process which is based on the micro processes of practical acceptance. The processes have a different quality. This hierarchy of concepts and processes is modelled as a reference net system given in Fig. 9: The micro process – here formed by actor A and B – describes practical accordance, which reproduces the logics of the practice in the field at the macro level.

Similarly, the reproduction of social norms due to Elias pictured in Fig. 7 should be modelled in a hierarchical way: The reproduction process is constructed by the embedded process of control and internalisation. The same for the role aspects for the homo sociologicus sketched in Fig. 8: Here a separation of the internalised role and the role expectation of the social environment has to be undertaken. The internalised role builds the inside view, which can only be observed indirectly. This concrete role is different from the more abstract concept of role expectations. This abstract role is detached from the actor itself. It is part of the social system, which has to be modelled as the system net for the embedded actor net model. Unfortunately, these aspects and all the others from [HKL$^+$01b], [HKL$^+$02a], and

[HKL+02b] cannot be presented in this presentation. Instead, we present the micro-macro-model, which is the result obtained by an integration the central, common aspects of all models.

4.2 The Abstract Micro-Macro-Model

The micro-macro-model has two central aspects: First, it is formulated in a generalised way, since it describes the results of a reconstruction and comparison of social theories resulting in a middle-range-theory. So, all the processes described by the single models in [HKL+01b], [HKL+02a], and [HKL+02b] are part of the processes of the micro-macro-model, but will be expressed in the generalised terminology. Second, the model will integrate the micro- as well as the macro-viewpoint, thus making the micro-macro link a "first-class" element of the model.

The model consist 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. 10.

Social structure The top level describes the dialectic 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 due to social processes.

Social processes So, structuring consists of social processes, which are modelled by the subordinated net, describing the social processes. The two levels are connected by two channels: one named $gen()$ linking the process of generation of actions, and one named $rep()$ for the processes of reproduction of social structure. Central element of this net is the string of actions. This string is extended by individual actions resulting in an extended string of actions. Whenever this extension is observed the string is updated. This updating is linked by the channel $gen()$ with the upper net.

A process that can be considered as separated from the individual is the extraction of structure out of the string of actions, either as a

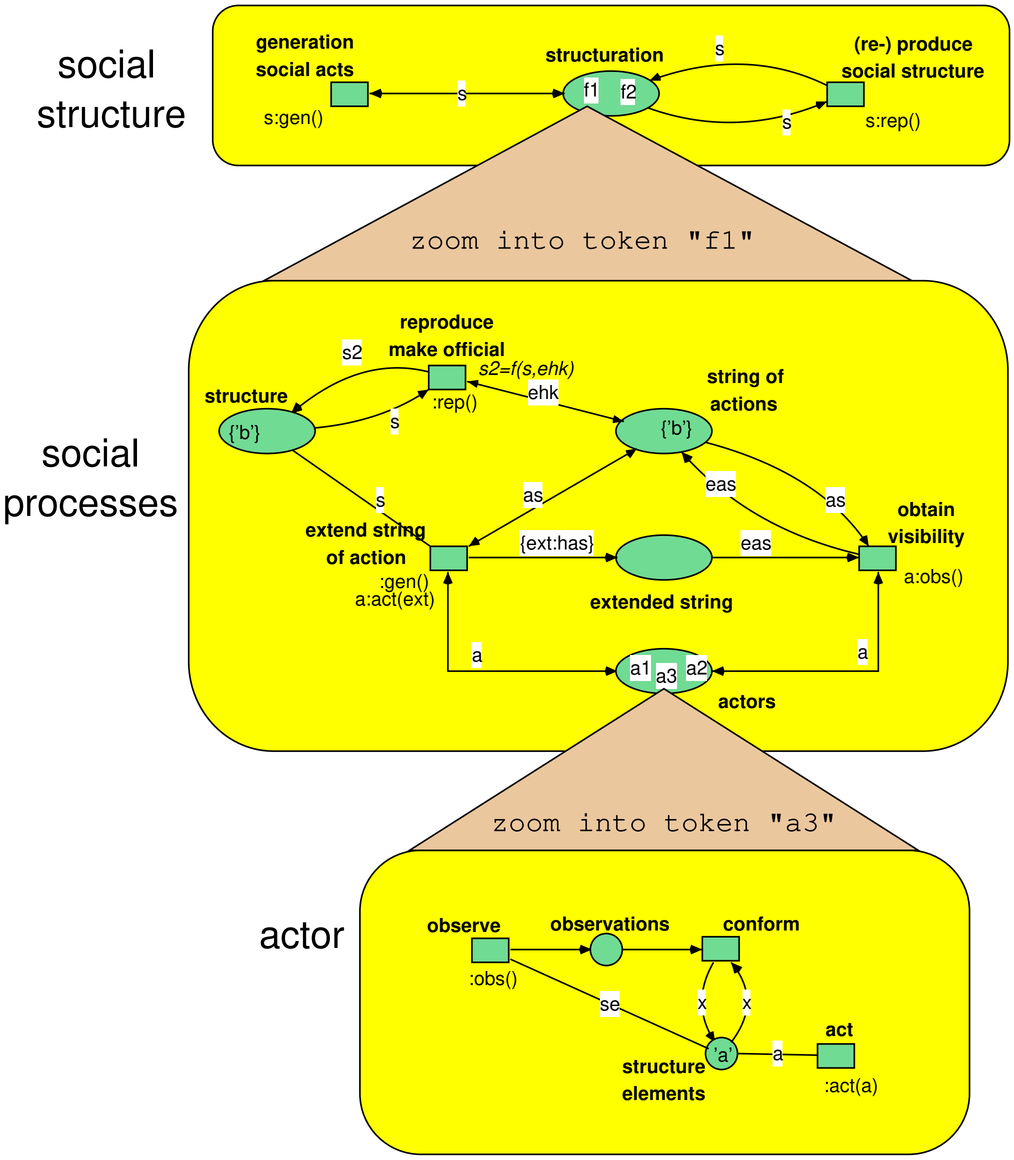

Fig. 10. The abstract micro-macro-model

reproduction of structure or as an making new elements official. This process is a central element on Elias' as well as Bourdieu's theory. It is linked by the channel $rep()$ with the reproduction of the upper level net.

Social actors The two processes of extending and observing are generated by actors. Each actor net has also a linkage with the medium net, describing the social processes. This linkage is provided by the two channels $act()$ which connects the processes of extending the string of actions with the individual choice of actions, and $obs()$ which connects the update of the string with the actor's observation process. Actors can observe the action of others. 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 make his choice for an action. These elements can be social norms for a homo sociologicus or a optimising function for a rational choice actor.

4.3 Benefits of the micro-macro-model

An remarkable point of this model is the analytical separation of concepts, which are present at two or more levels. For example, each theory operates with the term *structure*. General theories in the sense of the top level net, use it for something more or less fix. Also, the term structure is used in the sense of the middle net, where structure is more connected to the process view. And for actor theories the term structure is used for the inner conceptions of the generation principles of actions.

A second relevant aspect is the explicit description of the micro-macro link, which is realised in the model by channels. These channels link the behaviour of one net level with the upper (or the lower) one. So, this model is well suited to study the effect of emergent processes and the interconnections of the several viewpoints taken by the social theories.

The technical details of the special Renew-syntax of the model cannot be deepened at full length, so we finally stress an important point. The presented model of Fig. 10 is more than a diagram. It is executable by the Renew tool, which provides an interactive animation of the markings and the firing processes of the net system. This is possible due to the exact semantics of reference nets. So, the processes of the micro-macro-model can be visualised and inspected also by social scientist, which are not part of the socionics community.

Despite the simple appearing of the model it has several interesting elements. For example, the structure net contains several net tokens for social processes . Since it is possible that one actor is present in several process nets at the same time, there is an interference of all social process nets. The high degree of complexity, that is described by the model, arises by the use of channels which link the different levels. So, a great amount of synchronisation possibilities provides a very complex behaviour.

5 Outlook

As a central result of this presentation we obtain a model, that integrates relevant aspects of social theories into a hierarchical description. This hierarchy naturally covers the micro-macro link, so extensions of the model can be undertaken independently at each level.

For social-science this model is a valuable starting point for further comparison of theories, since it can be used as a reference scheme, as one can analyse which parts of a theory are well develop while others remains vague.

For computer-science the micro-macro-model can directly be used for the design of multi-agent systems. The micro macro link is also present here, especially at the interface of the agent and the agent platform. The design of such an interface is topic of current standardisations of the FIPA [FIP].

For the design of our multi-agent system architecture Sam, we identified several interesting architectural elements derived from the model. For the agent itself, we can conclude, that an observation module is needed, which must be combined with an adaption module. Since an agent has to adapt his structure, the behaviour must be defined in terms of dynamic reconfigurable behaviour descriptions. This is handled by the protocol mechanism of Sam.

For the design of the agent platform it is necessary to identify structures in the string of interactions. Such dynamically built structures can be provided for mobile agents, that enter this platform. So, foreign agents can be supported for interaction in an unknown environment.

The connections from the model to the agent system architecture are more than only conceptual as the micro-macro-model is expressed in terms of reference nets. Since reference nets are the formalism for the SAM-architecture a direct integration is possible without the problems of a change in the formalism.

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