Chapter 14

Socio-cognitive modeling

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14.1 Introduction

Socio-cognitive modeling is a new research area that merges aspects of computer science, social sciences and cognitive science. The basic idea is to model interlinked social and cognitive phenomena. Our focus has traditionally been in modeling individual cognition that learns and uses language, or in building models of language using statistical machine learning methods. Already for a long time, we have been interested in language and its use as a dynamic phenomenon rather than as a static structural object. Thereafter, we have widened our interest to language as a socio-cultural phenomenon that encodes human knowing and further to other socio-cognitive phenomena, however often related to language. In other words, cognition and intelligent activity are not only individual processes but ones which rely on socio-culturally developed cognitive tools. These include physical and conceptual artifacts as well as socially distributed and shared processes of intelligent activity embedded in complex social and cultural environments [5].

At the socio-cultural level, humans create and share conceptual artifacts such as symbols, words and texts. These are used as mediators between different minds. In communicating and sharing knowledge, individuals have to make a transformation between their internal representation into an explicit representation to be communicated and vice versa, as Vygotsky pointed out already in the 1930s. The internalization and externalization processes take place as a continuous activity. In externalization, the internal view is externalized as explicit and shared representations. Vygotsky also investigated child development and how this was guided by the role of culture and interpersonal communication [19]. He observed how higher mental functions develop historically in cultural groups and individually through social interactions. The specific knowledge gained by children represents the shared knowledge of a culture including the social norms, e.g., related to language use. In our research, we are interested how norms emerge, evolve, and disintegrate at a sociocultural level, how the norms are internalized and externalized by individuals, how they are followed or occasionally deliberately not followed, and how they are implicitly represented in linguistic expressions and explicitly represented as externalized rules.

One approach in socio-cognitive modeling is social simulation. It aims at exploring and understanding of social processes by means of computer simulation. Social simulation methods can be used to to support the objective of building a bridge between the qualitative and descriptive approaches used in the social sciences and the quantitative and formal approaches used in the natural sciences. Collections of agents and their interactions are simulated as complex non-linear systems, which are difficult to study in closed form with classical mathematical equation-based models. Social simulation research builds on the distributed AI and multi-agent system research with a specific interest of linking the two areas. The research area of simulating social phenomena is growing steadily (see, e.g., [18]).

In Kulta project, we have been modeling and simulating the changing needs of consumers in collaboration with Helsinki School of Economics (including Prof. Mika Pantzar, Prof. Raimo Lovio and his group, and Aleksi Neuvonen) National Consumer Research Center (Dr. Tanja Kotro, and Mikael Johnson). The project, funded by Tekes, ends during spring 2010 but many results are already available including [10, 11, 15, 13]. Also some other results have been partially based or connected to the Kulta project including [7]. As an interdisciplinary effort, a wide range of methodologies has been developed, refined and/or applied. These have summarized in Fig. 14.1. In addition to the research partners, the network has included collaborators from various sectors: information and communications technology (Nokia), energy (Helsingin Energia), gaming (Finland's Slot Machine Association), and consultancy (Pöyry).

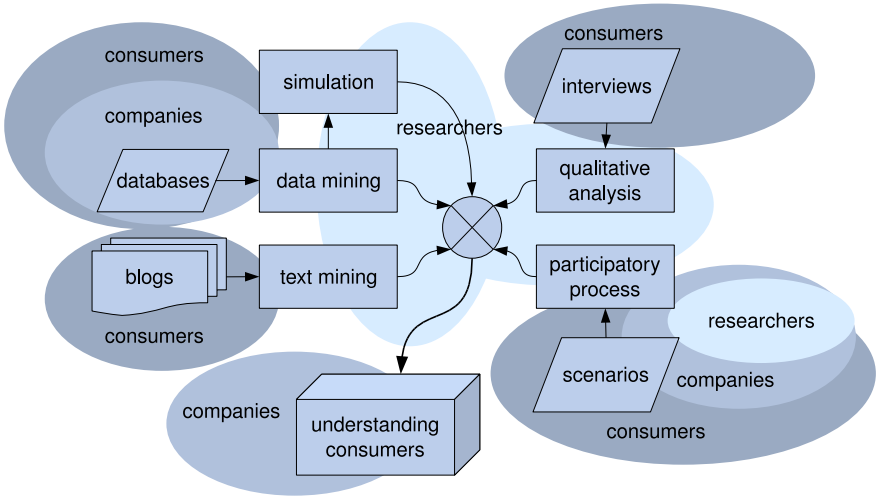

Figure 14.1: A schematic diagrams of the means used in Kulta project for obtaining understanding on changing consumer needs.

A central theoretical starting point in Kulta project has been practice theory as formulated by Prof. Mika Pantzar and Prof. Elisabeth Shove. In their theory, it is assumed that practices consist of three basic elements: material (materials, technologies and tangible, physical entities), image (domain of symbols and meanings), and skill (competence, know-how and techniques) [16, 17]. Practices come into existence, persist and disappear when links between these foundational elements are made, sustained or broken: material, image and skill co-evolve. The disintegration of the links leads into fossilization [16, 17].

In the following, we describe several areas of our research related to socio-cognitive modeling. Modeling expertise is considered both at individual and social level as well as in its implicit and explicit forms. Based on the results of a collaboration effort with Prof. Kai Hakkarainen's group from University of Helsinki, we present how development of knowledge structures in the web can be grounded on evolving knowledge practices and tools supporting them. This area of research is nowadays coined with the term "pragmatic web". The development of a social simulation model based on practice theory is also described. We continue by reporting four results on analyzing complex socio-cognitive phenomena and data. First, we discuss in some detail how text mining based on the self-organizing map can be used to support qualitative research. Second and third, based on the collaboration in Kulta project especially with Dr. Tanja Kotro, we describe means for analyzing consumer data and supporting democratic innovation in organizations by collecting and analyzing observations, ideas and questions. Fourth, we present an analysis of the relationship between the popularity of political parties in parliamentary elections and the socio-economic situation in Finland between 1954 and 2003.

14.2 Modeling expertise at individual and social level

Finding ways in which communities of experts can benefit from each other is a question shared by the machine learning community and social sciences alike. Considerable research in machine learning methods has shown that communities of experts can provide consistently better classifications and decisions than single experts in various tasks and domains.

In our research, we have extended the perspective on communities of experts to cover the wider context of socio-cognitive research. In particular, we consider how the formation and use of expertise relates to the modeling of concept formation, integration and use in human and artificial agents. We have presented a methodological framework for the computational modeling of these phenomena with a specific emphasis on unsupervised statistical machine learning of heterogeneous conceptual spaces in multi-agent systems [7].

We consider different computational models that have been used to represent individual expertise. In particular, we make a distinction between explicit representations (such as rule systems) and implicit representations (such as artificial neural networks [7].

It seems that an individual's rationality is an adaptive tool that does not follow (only) the principles of symbolic logic or probability theory as such, but includes various "cognitive survival strategies", such as a collection of heuristics as pointed out, for instance, by Gerd Gigerenzer and his colleagues [3]. The difference between explicit and implicit knowledge is usually defined by referring to language. If knowledge is represented as interpretable linguistic expressions, it is considered to be explicit, otherwise implicit. Computational intelligence methods such as neural networks and statistical machine learning have provided models of implicit (unconscious, intuitive) understanding [7]. The nature of knowing also depends on the source of experience on the concept or topic (direct versus indirect), illustrated in Fig. 14.2.

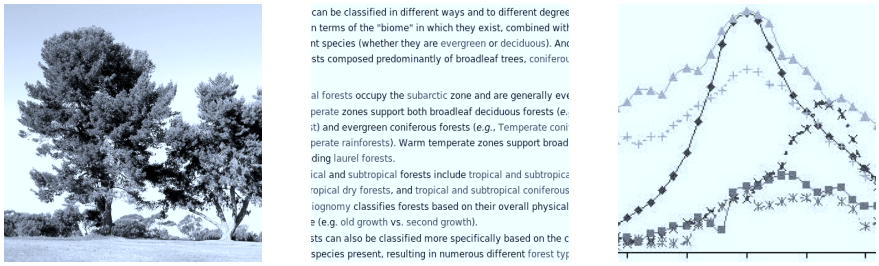

Figure 14.2: An illustration of different sources of knowing i.e., direct experience, written information, and numerical information.

The social level of expertise refers to competencies that arise from social interaction, knowledge sharing, and collective problem solving ([5]. Cognition and intelligent activity rely on socio-culturally developed cognitive tools. These include physical and conceptual artifacts as well as socially distributed and shared processes of intelligent activity embedded in complex social and cultural environments [5]. Expertise at the social level is constituted in interaction between individuals, communities, and larger networks supported by cognitive artifacts.

When a community of conceptually heterogeneous human experts collaborate in order to solve challenging problems, for instance, in the environmental, health or consumer domains, they are likely to encounter a number of knowledge-related challenges [1]. Some of these challenges stem from differences in the conceptual systems of the individual experts. These kinds of situations call for means of highlighting the conceptual differences and

resolving the resulting communication blocks. We present three strategies for this. These three strategies are, in order of increasing complexity, a) clarifying naming conventions, b) visualizing differences in conceptual density, and c) providing augmenting data that mediates between the different conceptual systems [7].

Communication across borders of expertise in collaborative problem solving efforts can, in principle, be achieved in two ways: (1) by bringing forth a combination of the opinions of the experts by, e.g., voting, or (2) by a more involved sharing or integration of expertise and experience at the conceptual level [7]. A particular form of sharing expertise is sharing prototypes. This refers to a process in which an expert communicates prototypical cases to the other expert. In the methodological context of the self-organizing map and other prototype-based conceptual models, prototype sharing means transmitting a collection of model vectors [7].

14.3 Knowledge practices and pragmatic web

We have collaborated with University of Helsinki and the Knowledge-Practices Laboratory project in which 22 organizations from 15 European countries take part. This integrating project (IP), coordinated by Prof. Kai Hakkarainen's research group. The semantic web has been the general foundation of KP-Lab project, but it also addresses practice-based issues extending mere semantic considerations and highlighting the importance of examining the boundaries of the semantic and pragmatic webs. This has been the central area of common interest for Hakkarainen's research group and the computational cognitive systems group [4].

The Pragmatic Web consists of the tools, practices and theories describing why and how people use information. In contrast to the Syntactic Web and Semantic Web the Pragmatic Web is not only about form or meaning of information, but about social interaction which brings about e.g. understanding or commitments.

The transformation of existing information into information relevant to a group of users or an individual user includes the support of how users locate, filter, access, process, synthesize and share information. Social bookmarking is an example of a group tool, end-user programmable agents are examples of individual tools

In the context of the pragmatic web, creating, using, and developing knowledge rather than mere transmission of information or social exchange becomes the central concern. So far, discourses concerning the pragmatic web have, however, mainly addressed contextual aspects of using information by diverse communities of practice. Also highlighted have been various processes of negotiation of meaning which take place in the context of knowledge usage [8].

The pragmatic web may elicit knowledge creation by 1) providing a technological infrastructure for augmenting the functioning of more or less distributed epistemic communities, 2) facilitating automated analysis and interpretation of large bodies of data generated by the users, and 3) adapting to and coevolving with human knowledge practices. Knowledge practice refers to personal and social practices related to working with knowledge. Current theories of social practices highlight both the inseparability of knowing and doing and the creative and improvisational aspect of practice. Here the term "knowledge" is used in the broadest sense, to include explicit official discourses, implicit habits of expert working; and further yet to that which underlies the competencies of experts, for example, so called "procedural knowledge".

An essential factor in pragmatics is context. When the semantic level is dealt with in a context-free manner, investigators tend to focus on prototypical meanings. Resulting models consist of a set of entities and relations connecting those entities. In their actual use at the pragmatic level, meanings are imprecise and changing, biased at any moment by the particular social and external context. The contextual process of meaning attribution is simultaneously both socio-cultural and cognitively subjective [8]. While the semantic web has been preoccupied with standardization of knowledge and systems of knowledge based on ontologies determined mainly by experts beforehand, the envisioned pragmatic web is oriented toward adapting to the special needs of customers and user communities. Rather than simply assimilating to already existing knowledge ontologies, the vision is to engage user communities in active negotiation and interpretation of meaning and to the development of knowledge structures grounded on their evolving practices and epistemic pursuits.

14.4 Social simulation and ensemble models

Agent-based social simulation has provided the scientists a promising tool for analyzing social phenomena without costly real-life experiments. Recently, massive sources of social data have also started to become available. In [13] we explore the possibilities of social simulation in demonstrating the practice theory of social sciences. We present a stochastic multiagent simulation framework for modeling the diffusion of practices among a group of agents. The evolution of the system state in the high-dimensional space of practices is visualized and analyzed using the SOM.

In general, the agents implement stochastic behavior based on their individual representations of beliefs, utilities and context. Ensembles of such agents are simulated for stochastic forecasting of state distributions of the modeled phenomenon. Our goal has been to build a framework that can handle incomplete data and probabilistic interaction models. Based on the framework, we propose a recommender system that combines the traditional collaborative filtering and content-based methods. To evaluate the framework and the recommender system, we applied it to music listening data from the Last.fm service.[13]

In collaboration with Dr. Amaury Lendasse in AIRC and colleagues, we have investigated the application of adaptive ensemble models of Extreme Learning Machines to the problem of one-step ahead prediction in (non)stationary time series [6]. This research is described more in detail elsewhere in this report.

14.5 Text mining in qualitative research

Text mining using the SOM presents an interesting methodological opportunity for qualitative research. Qualitative researchers aim to gather rich understanding of human behavior and the reasons for the behavior. In qualitative research, small but focused samples are therefore more often used, rather than large samples. We have argued that the SOM is particularly efficient in improving inference quality within qualitative research, with regard to both confirmatory and exploratory research [9]. Within the theory-driven or deductive mode of qualitative research, the SOM can be used to test the adequacy of conceptual frameworks created before the analysis of the data. In the data-driven or inductive mode, the SOM can be applied in creating emerging category systems describing and explaining the data.

The SOM (and related methods) can be considered as a quantitative method or research tool that is particularly well suited to the aim of respecting complexity rather than trying to do away with it. The SOM can produce not only one but a multitude of perspectives on some data. In relation to very large data sets of the kind, some of these multiple perspectives might be such that no human would, even in principle, be able to produce them. This follows from the fact that the computational method can be used to process writings or sayings of thousands or even millions of persons, something that is beyond the scope of any individual researcher. Yet applying the SOM allows us access to potentially highly relevant and novel categories and patterns that "really are there," even if we do not as yet know it. This would appear to be particularly true when it comes to various nonconscious categorizations. Thus, it would appear that applying the quantitative method of the SOM could take us even beyond situational analysis in that it is capable of revealing subconscious operations of the human mind, which the consciously operating human mind of the situational analyst will never be able to discover [9]. In general, a cartographer of social life can greatly benefit from taking the text mining results into account.

14.6 Analysis of consumer data

In [10] we present the concept of 'open data': a kind of consumer data produced by the consumers themselves from their perspective and for their own purposes that is not intended to be used primarily as consumer data. It is shared publicly in such a way that it can be used as basis for the business and nonprofit organizations in their quest for novelty and understanding of changing consumer trends, also for the benefit of the consumers themselves. We discuss and analyze three cases of opportunities brought by open data: web enhanced brand communities, the weak signals approach and conceptual mapping, which is in its early phase of development.

14.7 Supporting democratic innovation in organizations

When talking about innovations in organizations, our aim is to put the power to innovate in the hands of the people in organizations. We have developed a concept of a tool to support innovative open practices within organizations and to avoid problems often noticed in organizational practice, such as problems in sharing understanding about consumers and markets, and lack of creating organizational memory. [11] The tool is called Note and it helps with the problems of vanishing organizational memory, disappearing or badly accessible notes, and wide range of ideas that are hard to be organized. Note is a shared electronic noteboard where the employees of a company write down their observations, ideas and questions. The underlying data processing system processes the notes and links similar or related ideas together. The text processing is carried out by statistical text mining methods. The notes are short, about 1–20 words each, and they may be written in any language for which there is also textual background material available. The background material is used as a sample of general language for the clustering methods. [15] A demo version of the tool and its data processing methods has been implemented.

14.8 Analysis of political popularity patterns

The complex phenomena of political science are typically studied using qualitative approach, potentially supported by hypothesis- driven statistical analysis of some numerical data. We have examined the use of the self-organizing map in this area and explored the relationship between parliamentary election results and socio-economic situation in Finland between 1954 and 2003 [14]. In the following, we discuss some of the specific results and findings. The variable maps (or component planes, as they are traditionally called) show the distribution of each separate variable on the map. These are presented in Fig. 14.3.

It is commonly believed that being in the government will cause a popularity reduction in the next election. According to our analysis, this is true for the four largest parties: Centre Party (KESK), Social Democratic Party (SDP), National Coalition Party (KOK) and Left Alliance (LEFT). This observation is not however valid for the other parties. There is a strong negative correlation between the Centre Party (KESK) and inflation (COLI(T), COLI(T-1) and COLI(T-2)). During high unemployment the popularity of the Centre Party has been decreasing and during low unemployment it has been increasing. The Centre Party's position as the largest party that has been many times in the government could cause these findings. Voters have punished it because of unfavorable economic situations or developments. The popularity of the National Coalition Party (KOK) has the same feature as the popularity of the Centre Party. During high unemployment it has been decreasing and during low unemployment it has been increasing. During the existence of the Green League (GREENS) the approval ratings of the Social Democratic Party and the Greens have had negative correlation. The popularity of the Left Alliance (LEFT) has been decreasing within the whole period of the study.[14]

A change that took place in the late 1970s is clearly discernable. Many dependences between variables changed their features. Correlations turned from negative to positive and vice versa. For example, turnout has a positive correlation with the Change of Gross Domestic Product per Capita (CGDP(T), CGDP(T-1) and CGDP(T-2)) in the 1950s and 1960s. In the 1990s and 2000s, there is, on the contrary, a negative correlation. Earlier economic growth has potentially provided possibilities to be politically active and later it has made people negligent.[14]

References

[1] H. Bruun, R. Langlais & N. Janasik (2005) Knowledge networking: A conceptual framework and typology. *VEST*, 18(3-4): 73-104.

[2] B. Castellani & F.W. Hafferty (2009) *Sociology and Complexity Science: A New Field of Inquiry*. Springer.

[3] S. Gigerenzer, P. Todd, and the ABC Research Group (1999) *Simple heuristics that make us smart*. New York: Oxford University Press.

[4] Kai Hakkarainen, Ritva Engeström, Sami Paavola, Pasi Pohjola, and Timo Honkela. Knowledge practices, epistemic technologies, and pragmatic web. In *Proceedings of I-KNOW'09 and I-SEMANTICS'09: the 4th AIS SigPrag International Pragmatic Web Conference Track (ICPW 2009)*, pages 683-694. Verlag der Technischen Universität Graz, 2009.

[5] K. Hakkarainen, T. Palonen, S. Paavola & E. Lehtinen (2004) *Communities of networked expertise: Professional and educational perspectives*. Elsevier, Amsterdam.

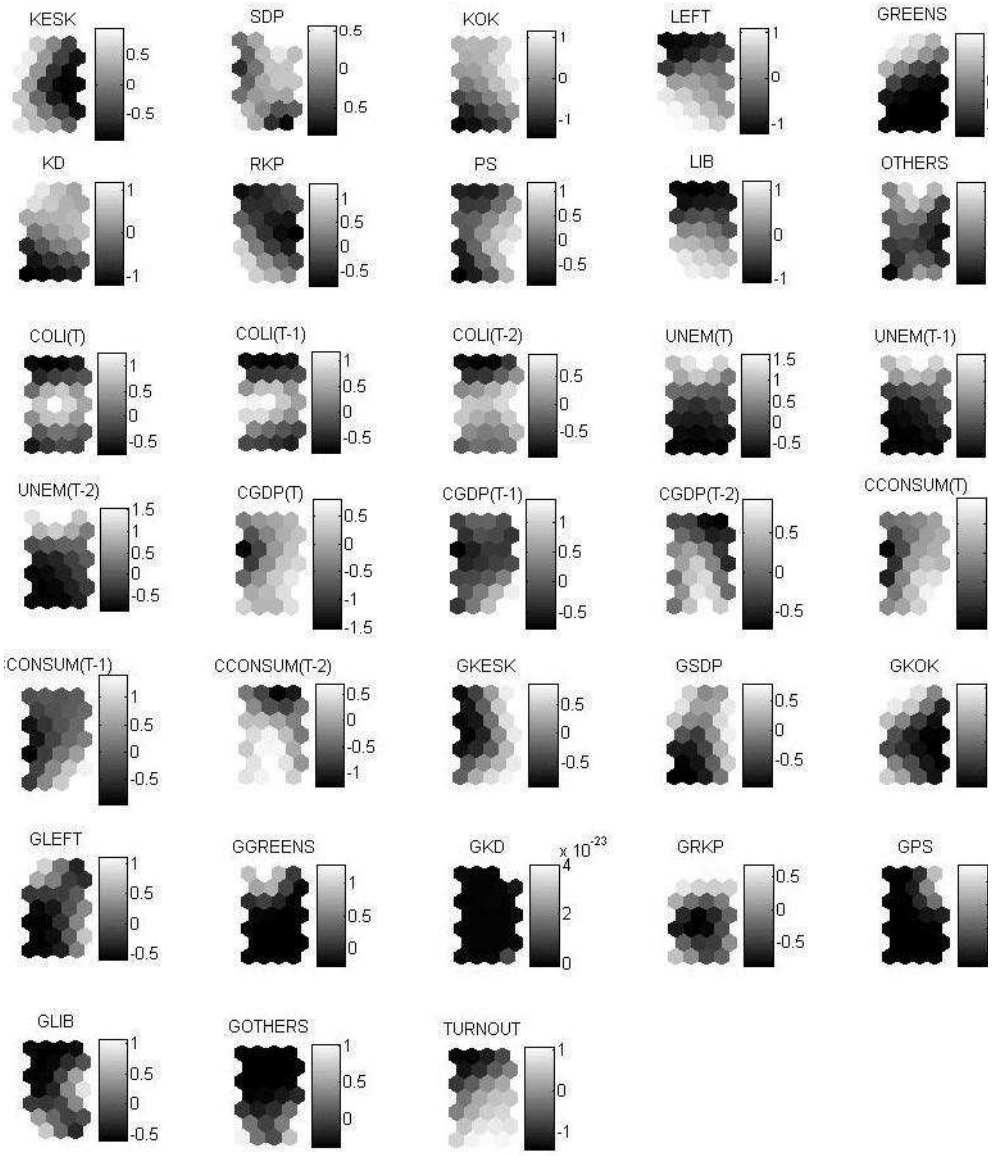

Figure 14.3: The variable maps of all variables used in the study. The acronyms for the political parties are as follows: KESK: Centre Party of Finland, SDP: Social Democratic Party of Finland, KOK: National Coalition Party, VAS: Left Alliance, GREENS: Green League, KD: Christian Democrats in Finland, RKP: Swedish People's Party, PS: True Finns, and LIB: Liberals. National economic conditions are analyzed using four measurements: Change of Cost of Living Index (COLI), Unemployment Rate (UNEM), Change of Gross Domestic Product per Capita (CGDP), and Change of Total Consumption per Capita (CCONSUM). These four monetary values are transformed into constant prices of the year 2000. For each measurement, there are three variables included in the data: the first at elections year (marked with COLI(T), UNEM(T), CGDP(T), and CCONSUM(T)), the second at a year before elections (marked with COLI(T-1), etc.) and the third at two years before elections (marked with COLI(T-2), etc.)

[6] Mark van Heeswijk, Yoan Miche, Tiina Lindh-Knuutila, Peter A. J. Hilbers, Timo Honkela, Erkki Oja, and Amaury Lendasse. Adaptive ensemble models of extreme learning machines for time series prediction. In *Proceedings of ICANN*, Volume 2, pages 305-314, 2009.

[7] Timo Honkela, Nina Janasik, Krista Lagus, Tiina Lindh-Knuutila, Mika Pantzar, and Juha Raitio. Modeling communities of experts - conceptual grounding of expertise. Technical Report TKK-ICS-R24, Helsinki University of Technology, 2009.

[8] Timo Honkela, Ville Könönen, Tiina Lindh-Knuutila, and Mari-Sanna Paukkeri. Simulating processes of concept formation and communication. *Journal of Economic Methodology*, 15(3):245-259, 2008.

[9] Nina Janasik, Timo Honkela, and Henrik Bruun. Text mining in qualitative research: Application of an unsupervised learning method. *Organizational Research Methods*, 12(3):436-460, 2009

[10] Tanja Kotro, Tiina Lindh-Knuutila, and Elina Hiltunen. How to analyze various consumer data in the future? In Marileena Koskela and Markus Vinnari, editors, *Future of the consumer society: Proceedings fo the conference Future of the Consumer Sciety, number 7 in FFRC eBook*, pages 135-143. Finland Future Research Centre, May 2009.

[11] Tanja Kotro and Mari-Sanna Paukkeri (2009) Micro democracy - Enhancing Openness in Innovation in an Organizational Context. *In Proceedings of OPEN 2009*. Helsinki, Finland, October 2009.

[12] Lasse Lindqvist, Timo Honkela, and Mika Pantzar, Visualizing practice theory through a simulation model, Technical Repprt E9, Helsinki University of Technology, Laboratory of Computer and Information Science, 2007.

[13] Eric Malmi, Juha Raitio, and Timo Honkela. Modeling practice diffusion with an agent-based social simulation framework. In *Proceedings of the 6th European Social Simulation Association Conference, ESSA 2009*, page 53, Guildford, U.K., September 2009. Extended abstract.

[14] Pyry Niemelä and Timo Honkela. Analysis of parliamentary election results and socio-economic situation using self-organizing map. In *Proceedings of WSOM'09*, pages 209-218, 2009.

[15] Mari-Sanna Paukkeri and Tanja Kotro (2009) Framework for Analyzing and Clustering Short Message Database of Ideas. In *Proceedings of I-KNOW'09,the 9th International Conference on Knowledge Management and Knowledge Technologies*. Graz, Austria, September 2009.

[16] M. Pantzar, The choreography of everyday life: A missing brick in the general evolution theory, *World Futures, The Journal of General Evolution*, vol. 27, no. 3, pp. 207-226, 1989.

[17] E. Shove and M. Pantzar Consumers, producers and practices: understanding the invention and reinvention of nordic walking, *Journal of Consumer Culture*, vol. 1, pp. 43-64, 2005.

[18] R. Sun (2006) *Cognition and Multi-Agent Interaction: From Cognitive Modeling to Social Simulation*. Cambridge University Press.

[19] L. Vygotski (1962) *Thought and Language*. MIT Press. (Originally published in Russian in 1934.)