Simulations of Highly Complex Social Systems as a Tool for Designing Information Systems

MSc. Joel Palmius, MSc. Gunilla Egonsdotter, PhD Viveca Asproth,
Department of Information Technology and Media
Mid Sweden University, S-83125 Östersund, Sweden,
Email: joel.palmius@mh.se, gunilla.egonsdotter@mh.se, viveca.asproth@mh.se
http://www.itm.mh.se

Abstract
When designing information systems, it would be good to be able to compare alternatives. However, information systems are complex phenomena as they encompass the humans involved in distributing the information. One possible way of making comparisons would be through simulation. Having constructed a prototype for such a simulation we have seen that the traditional approaches, such as Cellular Automata, utilized within the social simulations field are usable but not sufficient. However, the newer agent-based approaches show more promise. We conclude that in order to make simulations of our kind possible, the new technologies, such as multi-agent systems, need be adapted and extended. One of the pieces missing is an agent-based infrastructure building on anticipatory principles for agent information behavior.
Keywords: Information System, Simulation, Social System, Multi-agent Systems, Social Simulation

1 Introduction

When developing information systems, there is a multitude of available systems development methods to use. In these, there is often functionality provided for ascertaining the systemic desirability of possible actions before they are taken. However, while being based on structured and proven approaches, these methods can only provide an indicator of whether the direction of the development is likely to be good. These predictions often fail, which is shown by the number of systems development projects which have failed on the border of implementation, because it was then realized they were not systemically desirable. Most systems development methods have in common that they are prescriptive and normative; they do not contain prognostic or predictive capabilities.

One possible reason why these predictions do not work as well as one would want is the overwhelming complexity of even small information systems. An information system does not only include cables connecting a collection of more or less intelligent boxes stuffed with electronics, but also the humans using the technical infrastructure. An information system should be seen as the sum total of all that contributes to the propagation of information and all that has an effect on that propagation, within an organization: Humans, routines, policies, geographical locations and technological artefacts to mention a few examples. In order to handle this complexity, a computer-based tool such as a simulation is useful. In combination with the traditional strengths systems development methods provide, simulation could provide capabilities for prognosis and comparison.

For clarity, it should here be pointed out that the kind of simulation we are talking about here is indicative, a study of patterns and probabilities. While sharing the same roots, this simulation is in its approach often very different from simulations of, say, electronic circuits.

Simulation as method is well known and used in social science. In different ways and techniques, simulations had been made to describe phenomenon in the field of social science since early 60's. The simulations are different and include the whole area from macro sociological theories to simulation about human ability to learn. (Halpin, 1999; Morreti, 2002).

Another argument in favor of simulation as a method for the study of societies is the expanded number of studies which use simulation as method. Further another argument is that the number of disciplines involved in simulation as method has grown to encompass fields like cognitive science, biology, and neuroscience. Still another argument is the increase of number of theoretical perspectives involved. (Conte and Gilbert, 1995)

Of course there are also opponents against simulation as a method for studying social systems. One of the critics is Byrne (1997) who discussed one of the main problems with simulation of complex system, namely that of setting up the initial parameters. Because of the difficulties with this, he claimed that the result of a simulation is uncertain. Gilbert and Troitzsch (1999) maintain that simulation is an acceptable experimental methodology and that it is possible to change parameters and execute the simulation many times.

Another problem with simulation as a method is to isolate specific phenomena. However, Goldspink (2002) claims that even if there are problems with isolating specific phenomena from its environment, simulation can show interesting results. Therefore it is important to not view simulation as a single method. It should rather be seen as a complement to other methods. (Goldspink, 2002)

The basic idea is so far that simulation is a useful method, perhaps combined with other methods, to study a complex phenomenon, in this case information propagation in an organization.

The field of social simulations is well-developed and contains many useful methods for studying well-defined and well-delimited phenomena. We shall in the following examine a few of these methods, compare them with our experience of trying to construct a simulation of the above mentioned kind, and suggest areas where development need be conducted.

2 The Historical Development of Simulating Social Systems

"Social systems" can be defined in many ways, for example through the definition by Luhmann (1995). In his work he maintains that social system is characterized by autopoiesis and have clear and definite boundary. Our definition of "Social system" in this paper is a system with a clearly defined boundary, an input and an output, and it includes individuals together and other elements (such as computers) that interact to form a whole.

As mentioned above, simulation as a method to study social systems has been used for at least 40 years. In the beginning the simulations were not computer based, but rather a kind of social game. Further, statistics and simulation has a long tradition of working together, and some of that kind of simulations had been used to study sociological problems (Halpin, 1999). One example of that are Monte Carlo Simulations (Miller, 1978).

2.1 Different Approaches in Simulation of Social Systems.

When studying the different sorts of simulations and techniques it is possible to see two main streams. These two main streams came from different research fields: different researchers have approached various phenomena in social science from different angles. One way to attack social phenomena was through the top-down approach. Researchers have studied macro-sociological phenomena through a couple of parameters. These kinds of simulations produce a comprehensive result from an overview and do not focus on the particular parts: they try to represent the reality through a few important aspects.

The other approach is the bottom-up approach, which in practice implements the simulation through different sorts of agents that often include some sort of artificial intelligence. This kind of simulation tries to represent some sort of human behavior or part of behavior and those qualities are implemented in the agents. The result of the simulation is the aggregated result from the agents' interactions. This sort of simulation has lately become more in use and is now a functional complement to the macro-sociological perspective.

2.2 Macro-Perspective Social Simulation

One example of a macro approach is System Dynamics, with its roots in cybernetics and system theory, an approach which has been useful for describing macro-sociological theories. Forrester (1973) worked in the field System Dynamics, and one of his first works was a model about worldwide growth, pollution and population. Another example of this kind of simulations is Jacobsen and Vanki (1996) who study norms through the use of System Dynamics.

Some critics against models and simulation in System Dynamics claim that such models often have a high level of aggregation, some subjective assumptions and a weak empirical base. System Dynamics is still a common way of creating simulations, even though it is not living up to its initial promise. It is a possible way to study sociological phenomena if there is a very stylized model and a careful manipulation of parameters. Then it can be possible to draw some interesting relationship. (Halpin, 1999)

Another major tradition in social science is Game Theory, which has been used as base for simulations. One common example of game theory is the "prisoner's dilemma", which has been used to simulate to study the emergence of cooperation phenomena. In Game Theory, techniques like cellular automata and genetic algorithm have been used. With these techniques, it has been possible to study individual-level parameters and their effects on the overall outcome.

These kinds of simulations do not attempt to include a complete picture of human behavior; they do rather aim at studying a specific phenomenon, like cooperation, and the effects of parameters on the agents or automata. (Axelrod, 1987; Epstein, 1997; Hegselmann, 1996; Kirchkamp, 1996).

2.3 Micro-Perspective Social Simulations

The other extreme approach for creating social simulation is to create every individual as an agent and from that point of view study the emergence of a pattern. This approach has gained acceptance during the later part of the 90's. Within this approach, the challenge of modeling human behavior is inherent. Even if there are a lot of problems with representing human behavior in a simulation, many researches aim to construct such models. (Schmidt 2000; Moffat 1997; Sloman 1997).

In the discussion about whether it is possible to model human behavior, it is important to distinguish between a model and a replica. "*A replica is an identical copy of an original. A replica is completely indistinguishable from the original. It appears to be impossible, at least for the foreseeable future, to produce an artificial replica of a human being.*" (Schmidt 2000)

It is not necessary, probably not even possible, that a model of human behavior includes everything in the human nature. Even a quite simple model with focus on the dominant facts concerning the problem could give excellent result. (Schmidt, 2000)

In the bottom-up approach, techniques like Distributed Artificial Intelligence and Multi Agent Systems are very important. According to Sen (1997) there is ongoing research about problem solving in the context of a group of agents using these techniques. He describes how cooperative agents work jointly on achieving a common goal. According to him the most important parts in the construction of the simulation are:

- How agents decompose goal into sub goal.
- How to solve the organization of the agent and the agent's problem solving protocol that gives the agents the ability to share results and knowledge.
- How do agents keep coherence and problem solving focus?

A lot of research is conducted within the area of agent system. Wooldridge and Jennings (1995) for example describe an agent as hardware or software- based computer system with these properties:

- "*autonomy: agents operate without the direct intervention of humans or others, and have some kind of control over their actions and internal state;*

- *social ability: agents interact with other agents(and possibly humans) via some kind of agent-communication language;*
- *reactivity: agents perceive their environment, (which may be the physical world, a user via a graphical user interface, a collection of other agents, the INTERNET, or perhaps all of these combined), and respond in a timely fashion to changes that occurs in it;*
- *pro-activeness: agents do not simply act in response to their environment; they are able to exhibit goal-directed behavior by taking the initiative."*

Wooldridge and Jennings (1995) points out that there are researchers who include more in the agent term. Especially researchers within the field Artificial Intelligence use concepts that are more applied to humans, such as knowledge, beliefs, intention obligation and emotion.

2.4 The Span Between the Different Approaches

The above shows that there are many different ways of representing phenomena in a simulation today. We identify the main difference between the various approaches as that of either describing the phenomenon on an overall level with a top-down approach or through implement the behavior in every single part and let the pattern grow from the parts with an bottom-up approach. We further conclude that there is a significant span between the two perspectives and that a researcher should consider which technique he is using, as it will implicitly place him within one of the streams.

2.5 Things Done in Agent-Based Simulations Relevant for Simulations of IS

Research close to one of our questions has been done by Lepperhoff (2002), who has studied negotiations via email as communication media. In his simulation he demonstrates which parameters are important during such a negotiation. He created his simulation using Multi Agent technology and bases his models upon theories such as Herrmann's negotiation principle.

An import aspect in an information system is the communication and interaction between individuals. Models hereof include some sort of interaction between agents or at least some form of interaction between the agent and his environment. This interaction could involve some sort of passing information to each other like in the case of negotiation of contracts. Agents representing humans also need some sort of 'language' to be able to communicate. There is a considerable amount of literature in the field computer languages for communication between agents but it is also obvious that it is a very difficult and problematic area. One way to avoid this problem is to take for granted that messages pass straight between agents. This could be a possible way to solve the problem dependent on the object of the simulation (Gilbert and Troitzsch,1999).

Loyall (1997) has earlier built simulations and created agents that could both act and generate language. This is an ongoing work for development of what he thinks is a key question for creating believable agents.

"Human language provides, among other things, a mechanism for distinguishing between relevant objects in the natural environment. This mechanism is made up of two components –forms and meanings- which must be shared by the community of language users." (Hutchins and Hazlehurst, 1995)

Hutchins and Hazlehurst (1995) have developed a sort of language for interaction between agents. They use a model based on interacting artificial neural networks. This language consists of shared symbols of form and meaning pairs.

3 Experiences of Tying to Simulate an Information System

During the last two years the AMSIDO project[1], aiming at constructing better methods for comparing different potential information systems, has been working on a framework for the simulation of information systems.

3.1 The Case Scenario

The project has so far been conducted as joint project between the Mid Sweden University (MSU) and the Swedish National Defense College (SwNDC), with the bulk of the financing coming from the latter. The incitement for the study from the view of SwNDC has been the evaluation of their "AQUA lab", a laboratory built for the purpose of developing a new technology-aided form for Command and Control (C2).

SwNDC annually conducts exercises, OBS/OPS (Operative Strategic Decision game), as a part of a course in applied war science. The exercise is a decision game for students at the school for experts in political science and students in strategic command, and is a part of the Program for Advanced Command.

The purpose of the decision game exercise is that two "states" (North and South) are confronted in a conflict situation. The decision-making within the "states" are organized in three levels: the political, the military strategic and the operative. Different decisions have to be made by the participants depending on the information they receive. The calculated intention of the opponent has to be taken into account and compared to the own "state's" goals and resources in every specific situation.

As a way to measure the projected efficiency of the AQUA lab, the AMSIDO project has been trying to build a simulation of the exercise situation. It has been intended that the simulation should be able to quantify and compare the information distribution efficiency of the two "states", or in other words compare two information systems organized slightly differently.

---

[1] The AMSIDO project, "Agent-based Micro-world Simulation of Information Distribution in Organizations".

3.2 Things That were Given But Which had to be Rejected

Before the project even begun, there were a few things that were considered as given. The most important of these was that the simulation was to be constructed using a cellular automata (CA) approach and perspective. The project was even initially called "Cellular Automata Simulation...". The reason that this was given was that SwNDC had previously constructed battle simulations using CA, and thus had experience with the approach.

The CA way of thinking implies a drastic reductionist view of the phenomena to simulate. In consequence, the components of the information distribution phenomenon were initially reduced to consist of transference of an inherently abstract token ("information") without any properties, between homogenous "actors" viewed as automatons without will or intention.

It soon became apparent that a model as reduced as this could have no use whatsoever in order to describe a concrete phenomenon: It became too abstract to be possible to map back on the reality which was supposed to be modeled and simulated.

Eventually, the CA view had to be dropped in favor of a more iso-morphic agent-based approach. This was one of the major shifts within the projects. These are described in more detail later in the article.

3.3 Tangible Results so Far

A functional prototype for the simulation software has been developed, consisting of 20000 lines of Java code. This software is capable of interpreting and run a simulation of a model of an organization, consisting of humans ("agents"), information points, information and physical/geographical constraints ("arena").

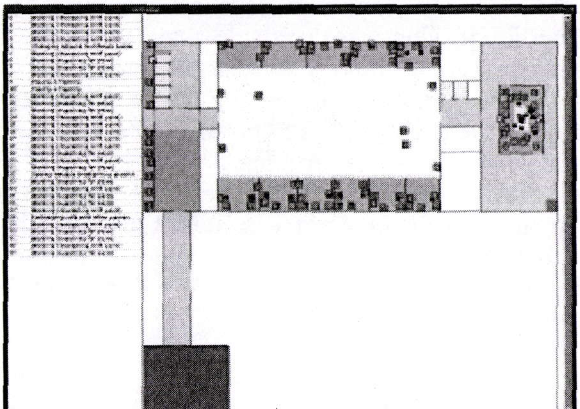

Figure 1: Screenshot of a concept prototype of the IS simulator. A model of a building is visible with humans (the black dots) walking around searching for information.

It should be noted that this is the results after having dropped the CA approach. The prototype is thus built using an agent-approach with intentions and goals, something which became quite different from what a CA approach would have looked like.

In the simulation it is possible to inject information through an information point (such as a computer, a telephone or an information screen) and watch it propagate through the organization via mouth-to-mouth distribution and transmissions between information points.

While this is possible, the simulation has so far not undergone a validation above the level of face validity. In other words, it shows internal consistency and experts of the modeled activity say the underlying models look believable[2].

4 Experienced Paradigmatic Shifts

The work during the project cannot be said to have been completely straight-forward. During several periods of the work, the crew has been forced to rethink fundamental concepts. The below is a summary of four of the major shifts in underlying assumptions.

4.1 Cellular Automata to Multi Agent System

The project started with the explicit intention to utilize a Cellular Automata (CA) approach for the simulation. The project was even named "Cellular Automata Simulation of...". The CA base was taken as a given, since much previous work on battle simulation had been successfully conducted with a CA perspective.

However, after the first survey of literature, and after the first exploratory modeling of the system to be simulated, it became quite obvious that CA is too limited to describe such a complex phenomenon as an information system. First and foremost, the CA technology implies homogeneity over the whole grid. This was not feasible since our actors were of several different kinds: Human agents with different tasks and goals, and technological agents in various forms such as computers, phones and bulletin boards. To forcibly reduce all this variety into a synthetic form characterized by a few quantitative or logical parameters would simply completely remove the phenomenon we wanted to study.

Secondly, CA implies geographical immobility. Simulations such as Conway's Game of Life does not really exhibit movement, the "moving" patterns are rather propagation of grid cell properties. This was contradictory to out design goals. One of the things we intended as different in our simulation was that information should be allowed to propagate through chance encounters between humans in corridors and lunch rooms. This would not be possible if the entity that represented the humans was geographically static.

---

[2] While the results of the project has not yet been formally published, work material in the form of reports and code can be acquired through http://gathering.itm.mh.se/amsido

Thirdly and somewhat related to the first point, we found it difficult to represent our most important entity in the simulation. The most important aspect of information propagation is the information that propagates. In a classical CA model, this would be on/off property of the grid cells, and not a traceable entity in itself. We felt this was unsatisfactory.

In the end, it was decided that the focus should be directed towards the construction of a simulation utilizing Multi Agent technology. Instead of trying to fit all entities into a cell grid matrix model, the entities were modeled as entities. The perspective now became that of a game arena on which various agent entities were placed with the task of shuffling packets of the information entity between them.

To summarize this, our experience was that in a simulation of an inherently heterogeneous collection of active objects, a CA approach with its implication of reductive forced homogeneity does not function well. The solution is to move away from CA to a model more supportive of heterogeneity: Multi-agent simulations.

4.2 Mechanic to Teleological

Partly caused by the initial focus on CA, the components of the information system were seen as automatons, or in other words completely deterministic and mechanical. This included the "human" components.

It was, however, soon discovered that the attempt to represent the human as a passive information shuffler, somewhat akin to a network switch, was not feasible. Information in an organization is not directed through static routes.

First and foremost, this view would implement a strict "push" approach to information distribution. Individual A pushes information to B who pushes it to C. In practice things do not work this way. The humans do not only sit silently waiting for an information packet to arrive, they also go about searching for wanted information.

Secondly, and as a consequence of the first point, the humans must have a goal with their information collecting behavior. If a "pull" approach is to be used for describing information collection, it must be known which information it is that the human searches for.

Because of the above it was necessary to start searching for a way to describe a limited teleology in the human agents. It should be noted that the produced code has so far not succeeded in implementing this, mainly because of the lack of a structured model for containing it.

The experienced problem here was that in a heterogeneous collection of supposedly active objects, a way to describe intentionality is required. The solution to this is, again, to move away from CA's forced passivity and aim at a form of teleology implemented in the agent structure.

4.3 Information to Decision

In the beginning, information was viewed as something static that floated around in the information system without any inherent properties. It was then never question where the information came from, something which is partly a problem of the selected case scenario. In the case scenario, the information gathering took place outside the system in focus and arrived to be processed and sent upwards in the organization.

With the base in the CA approach, information was implemented as a serial number without any other properties. The agents in the system either had the information, or they did not. It was, however, discovered that this was not a feasible model of information, and that it could not be used to represent information flows.

Firstly, information is not a collection of opaque homogenous building blocks. Information has properties which determine what will happen with it. As an example, it is difficult to model an information flow without knowing the sender and the intended recipient of the information.

Secondly, information is simply not just distributed and collected. The purpose of the information system is to enable humans to acquire information so they can do something with it. In the case scenario, it soon became apparent that it was not feasible to model the system as simply a shuffling of information upwards in the organization.

To solve these problems, a model for aggregation was implemented. The view now became that humans look for different pieces of information in order to puzzle it together into other pieces of information, something we took to be a good emulation of "decision". This further led to the expansion of the information concept. Information now had to have a few properties to enable humans to decide if it fit with the other information they had, and whether they were a recipient at all.

The problem here is the decision what information actually symbolizes in an organization: What is it there to do? In essence this is a problem of operationalization. The solution, one solution, is to implement the information as a *decision* rather than as a somewhat abstract token. A decision here is an action leading to a difference in behavior. In other words, the information should be *noticed* in the sense that it makes a difference somewhere.

5 Discussion

So far this project has suffered from a conflict which is central to all simulations of complex systems, namely that of richness, validatability and usefulness. To phrase the conflict drastically, we can summarize the options as:

The richness option - we can include pretty much everything relevant in the model, and thus capture the richness which is inherent in a social system. With this approach, the human behavior should be modeled fully with, for example, language, teleology and perception. However, such a model would be almost impossible to validate since there are too many independent variables. Further the simulation would be rendered more or less useless, since the cost of filling it with input data would be greater then the gain with the result of the study.

The validity option - we can reduce the model to only include a very limited number of independent variables, so that we can ensure that those variables are correctly described and simulated. With this approach, we should not model a human teleology, and information should probably not be more than a serial number, a homogenous building block. This would, however, be rendered useless since such few variables cannot describe a social system in a satisfactory way. The richness inherent in the system would have been cut off.

The tricky part would be to find a usefulness option. To simply aim at somewhere in between richness and validatability is not likely to be a success since chances are both would become unsatisfactorily handled that way.

As a parenthesis we can also mention that the paraphrased triangular model (Klir, 1988) for the trade-off is not very fair. It implies that as long as the model is neither complex nor exact, it must be useful, which is of course not the case.

Another problem so far has been the staticness of human behavior in the simulation. So far the teleological parts have not been satisfactorily modeled. So far the model has been completely build on mechanical reaction patterns. Events occur which makes the agents change their behavior.

Real humans plan their work in advance and decide on a procedure for reaching a personal goal. They *anticipate* their needs and act accordingly. This planning occurs both in the long-term perspective (when formulating a strategy for, in this case, acquiring information) and in the short-term perspective (when doing immediate choices about what the next course of action should optimally be).

During the later part of the 90's, much has happened within the field of social simulation. New tools have been made available, drastically extending the scope of what simulations are possible to construct and validate. The social scientist now has access to approaches such as multi-agent simulations, multi-level simulations, BDI architectures and easy-to-use toolsets and APIs for very rich simulations.

We believe that our experiences with trying to apply both CA and agent-based approaches to a complex social system demonstrate that these new tools can extend and better formulate models of social systems, of systems that should encompass a heterogeneity of agents and organizational levels.

The CA approaches are useful and sufficient for many simulations, of course also for quite complex social systems. However, by adopting a more iso-morphic approach, a closer connection to "reality" can be achieved: It is simply easier to compare results between model and reality when the model encompassed the recognizable elements of the modeled reality.

The newer agent-based technologies, as seen in the overview of recent method development, are very useful, but for simulations of highly complex social systems, of clusters of heterogeneous and teleological components, some additions need to be made.

In order to do truly iso-morphic simulations of social systems, the agent architectures would need to be extended with, among other things, weak anticipation. The anticipatory subsystems would drive human behavior in order more closely resemble how humans act in a work situation.

6 Conclusions

In the above, we have seen that the field of social simulation has developed new interesting technologies lately. It is our experience that in simulations of highly complex social systems, such as the simulation of how information is distributed as a base for decisions within an organization, the older technologies, such as CA, do not function well since they are too reductive. The newer technologies, such as multi-agent systems, can provide a more iso-morphic simulatory approach. These new technologies do, however, have to be extended further, for example with weak anticipation. The agent technologies fit well for such extensions, as anticipation and teleology can then be encapsulated in a collection of more intelligent objects, rather than being a subroutine of a complex whole.

We suggest that a coherent framework for anticipation-based iso-morphic simulations be developed. This framework, a framework for Simulations of Highly Complex Social Systems, would need to include models for validation and comparisons with the object reality. In practise this would mean developing not only theories and models, but also collecting consistent APIs and class hierarchies building on validated and reliable models. Such APIs exist to some extent, but the real work would be fitting them all together into a larger whole and adding the pieces missing for the real possibility of simulating highly complex social systems.

7 References

Axelrod R.(1987), *The evolution of strategies in iterated prisoner's dilemma*. In Davis L. (Ed.) Genetic algorithms and simulated annealing pp. 32-41 Morgan Kaufman. London

Byrne D. (1997), '*Simulation –A way Forward?*' Sociological Research online, vol. 2 no.2. [http://www.socresonline.org.uk/2/2/4.html] 2002-07-26

Conte R., Gilbert N. (1995), *Computer simulation for social theory*. In Gilbert N. and Conte R. (Ed.) *Artificial societies: the Computer simulation of social life*. pp.1- 15. UCL press. London.

Epstein J. M. (1997), *Zones of cooperation in demographic prisoner's dilemma*. [http://www.santafe.edu/sfi/publications/wplist/1997] 2002-07-18

Forrester J. W. (1973), *World Dynamics*. Wright-Allen, Cambridge, MA.

Gilbert N., Troitzsch K. G. (1999), *Simulation for the Social Scientist*. Biddles Limited, Guildford.

Goldspink C. 2002. *Methodological Implications of Complex Systems Approaches to Sociality: Simulation as a foundation for knowledge*. Journal of Artifical Societies and Social Simulation vol.5 no.1

Halpin B. (1999), *Simulation in Sociology*. American behavioral scientist. Vol. 42 No. 10 pp. 1488-1508

Hegselmann R. (1996), *Understanding social dynamics: the cellular automata approach*. In: Troitzsch K. G., Mueller U., Gilbert G.N. Doran J. E. (Ed.) Social science microsimulation. pp.282-306. Springer. Berlin.

Hutchins E., Hazlehurst B. (1995), *How to invent a lexicon: the development of shared symbols in interaction*. In Gilbert N. and Conte R. (Ed.) *Artificial societies: the Computer simulation of social life*. pp.157-189. UCL press. London.

Jacobsen C., Vanki T. (1996), *Violating an occupational sex-stereotype: Israeli women earning engineering degrees*. Sociological research [http://www.socresonline.org.uk

/1/4/3.html] 2002-07-20

Kirchkamp O. (1996), *Spatial evolution of automata in the prisoner's dilemma*. In: Troitzsch K. G., Mueller U., Gilbert G.N. Doran J. E. (Ed.) Social science microsimulation .pp.307-358 Springer. Berlin.

Klir G. J. (1988), *Fuzzy sets, uncertainty, and information*. Prentice Hall, New York.

Lepperhoff N. (2002), *SAM - Simulation of Computer-mediated Negotiations*. Journal of Artificial Societies and Social Simulation vol. 5 no. 4

Luhmann N. (1995), *Social Systems*. Stanfords University Press. Stanford, California

Loyall A.B. (1997), *Some Requirements and Approaches for natural Language in a believable Agent.* In Trappl R., Petta P. (Ed.) *Creating personalities for synthetic actors*. pp. 113 -119 Springer-Verlag, Berlin Heidlberg; Germany

Miller J.G.(1978), *Living Systems*. McGraw-Hill. United States

Moffat D. (1997), *Personality Parameters and Programs.* In Trappl R., Petta P. (Ed.) *Creating personalities for synthetic actors*. pp.120 – 165 Springer-Verlag, Berlin Heidlberg; Germany

Morreti S. (2002), *Computer Simulation in Sociology*. Social Science Computer Review. Vol. 20 no.1 pp.43-57

Schmidt B. (2000), *The Modelling of Human Behaviour*. Gruner Druck GmbH. Erlang.

Sen S. (1997), *Multiagent systems: milestones and new horizons*. Trends in Cognitive Sciences vol. 1 no. 9.

Sloman A. (1997), *What Sort of Control System Is Able to Have a Personality?* In Trappl R., Petta P. (Eds*) Creating personalities for Synthetic Actors*. Springer-Verlag, Berlin Heidlberg; Germany

Wooldrige M., Jennings N. R. (1995), *Agent Theories, Architectures, and Languages. A Survey.* In Wooldrige M. and Jennings N. R (Ed.) *Intelligent Agents*. pp. 1-39 Springer- Verlag Berlin, Heidelberg.