PROPOSING A FRAMEWORK FOR BUILDING HUMAN–BASED AGENTS FOR DISCRETE EVENT SIMULATION:

A CASE STUDY IN SCREENING PROGRAMS

Nasim GhanbarTehrani and Mohammad Aghdasi

Tarbiat Modares University

Industrial Engineering Department

Tehran - Iran P.O.Box:14115-111

Email: nasim.tehrani@modares.ac.ir

KEY WORDS

Simulating human behavior, Human-Based Agents, Reference Model, Health Belief Model (HBM)

ABSTRACT

By knowing more about the special characteristics of human behavior in complex environment, especially understanding the communication processes, social interactions and their role in forming human behaviors, the need for capturing these attributes in problem solving techniques will be increased. The ability of implementing complex computational models, calls for a trade-off between the complexity of representing personal attributes from one side, and the complexity of model structure from the other side. One of the main ideas for solving this problem is using object-oriented techniques in order to create Human-Based Agents, and substitute these agents as the human representatives in the simulation.

In this article, some of the main theories that describe the human behavior – especially decision making in the health–care context, are explained and a simulation model of the implementation of the screening process is structured.

The case refers to a real situation of blood–pressure screening in Iranian villages. For this purpose, a reference framework and the related mathematical equation are developed in two categories: internal structure of the agents and the external structure, that is the environment that agents live and behave in. Finally, the model is simulated by using a Delphi-based computer program.

1-INTRODUCTION

Simulation is a suitable tool for problem solving in the different contexts, researches and evaluation of new theories and also training. The ability of simulation practices in building and developing simplified replicas of the real world has been appreciated by many researchers. As the main objective of the most health care processes is serving customers, there are lots of benefits for the use of simulation in this context. (Standbridge, 1999). Most problems in this area are related to the human behavior (Brailsford, 2003). As an example, in most epidemic models, not only biologic and physiologic factors are important, but also behavioral elements (such as tendency to do risk) are really dominants. Prevention and dermatological models in most disease contain the factors that affect the decision makings about using drugs and doing the prescribed treatments. In screening programs, the factors affecting the patient's acceptance are really critical.

In the most simulation models, human behaviors encountered by the model are limited to the statistical data gathered from the real world experiments. Obviously, this could not be done in every case. In the proposed framework, human behavior is produced by the human-based agents; due to the external factors affect their behavior. A simple schema of these approaches is shown in figure 1.

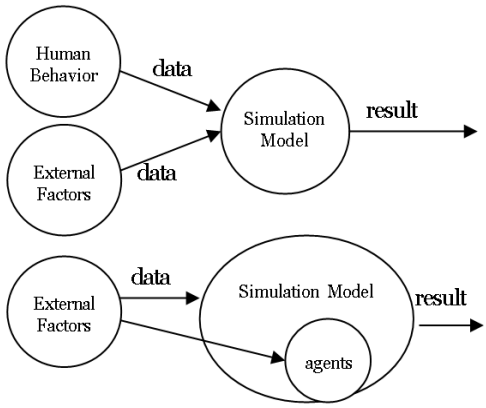

Figure 1: Comparing Simulation Models, with and without Human-Based Agents

Proceedings 22nd European Conference on Modelling and Simulation ©ECMS Loucas S. Louca, Yiorgos Chrysanthou, Zuzana Oplatková, Khalid Al-Begain (Editors)
ISBN: 978-0-9553018-5-8 / ISBN: 978-0-9553018-6-5 (CD)

The disease patterns are usually different with what observed in the society means the major part of the iceberg is hidden and just special cases (in terms of the patient's accessibility, the severity of disease and etc.) are recorded. Screening programs are proposed to estimate the real situation of infection. As the costs of implementing these overall programs are really high, there should be a great focus on planning and designing phases of these programs in order to gain more acceptance, as the result of the program is dictated by the human behaviors. In this research, a screening program is selected as a basis for developing the context of simulation. A descriptive scheme of screening program is shown in figure 2.

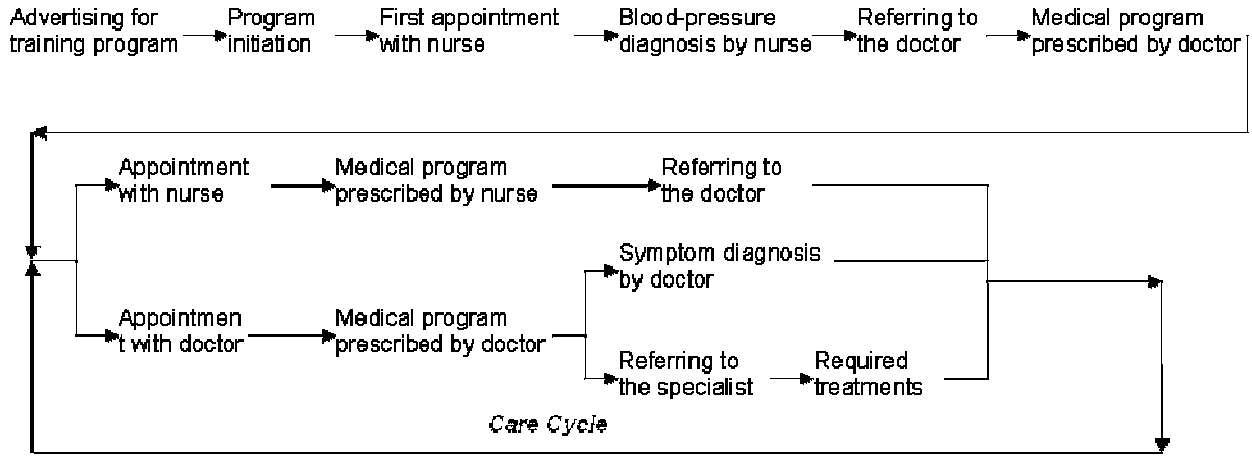

Figure 2: Screening Process

Human beings commonly are a part of complex systems. For describing these systems in details, they should be modeled by the same details as non-human parts.

A human has the ability to behave diversely in a social context. As different Physical, cognitive, sensitive, psychological, cultural, historical and social factors affect it; the description of human behavior is really complicated. When considering the complexity of the environment together with the complexity of the behavior of people with interaction together, the modeling seems to be impossible.

In the most problem–solving models, human and human characteristics are modeled by adding some extra variables, constraints, figures or simple entities. (Klugl, 98). Searching the literature revealed that the more detailed organizational structures, results in the more simple modeled humans. (Moss,nd)

The Human Agents Applications in simulation are extending their context (Urban, 2000). In recent years, agents have been had a critical role in modeling and simulation. (Schmidt, 2000). Agents have been used for modeling social structures in organization by Moss (Moss, nd). Klugl uses SeSAm software for simulating social behavior of Ants and bees, and also for simulating some human behaviors such as fire fighting and robbing the supermarkets. (Klugl, 98).Urban uses this method for simulating group learning (Urban, 2000), forming supportive networks, Prad and Predator model (Urban, 2001)

Sibbel implies a model for Hospital management (Sibbel,2001). Schmidt uses an agent named Adam for investigating the instinctive behaviors (Schmidt, 2000), and screening program. (Ohler & Roger)

Some mathematical structures are designed for simulating human behaviors, such as PECS(Schmidth,2000), and BDI (Pokahr et al, 2003)

Many Human behavior models have been developed in different disciplines. Some researchers use simulation models in conjunction with these descriptive models for examining new theories and understanding the existing ones.

The applicability of simulation in analyzing Health care systems has been experimented many times. The simulation models have been used for patient scheduling and other problems in operations management in hospitals. (Fether & Thompson, 98) (Robinson, 95) (Wing & David, 98)

Simulation systems used in Health care, are very similar to the Manufacturing simulation models.

The main problem in these systems is the ignorance of the human behavior – which has a great effect on the system performance. Physicians, nurses and other personnel decide upon their experiences and personalities and change the process by their decisions. The personal attributes of patients affects their caring and working Processes. (Sibbel and Urban, 2001)

2-DESCRIPTIVE HUMAN BEHAVIOR MODELS IN HEALTH CARE-Literature Review

Human behavior models are generally derived from the behavioral science and Psychology. They provide a

framework for prediction, policy evaluation and help decision makers to describe the reason of human behavior. Based on the literature review performed by authors, the most used models in the health care are Ajzen's planned behavior theory, HBM models and HLC model.

Although these models have been developed widely, they have limited ability to understand, predict and control human behavior. The purpose of these behavioral models is to describe why people do/ don't do health-related behaviors (such as using drugs, doing the prescribed behavior, stop smoking and etc.). They also explain the relationship between the encountered variables. These relations could be evaluated by various tests and the new variables and relationships could be added respectively.

2-1-HBM Model

HBM (Health Belief Model) is one of the most applicable conceptual frameworks in health-related behaviors. Proposed in 1950s, HBM has a successful career in promoting health care behaviors (like using seat belt, medical acceptance, participation in the screening programs, and etc.). A schematic view of this model is described in figure 3.

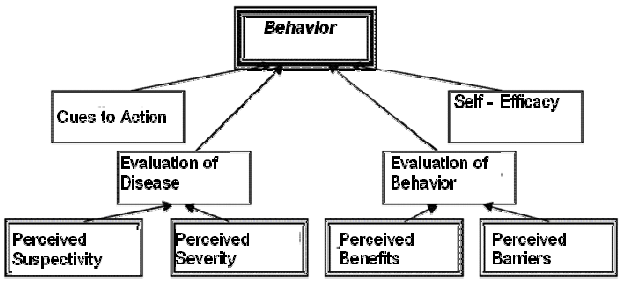

Figure 3: HBM Model

A brief definition of main concepts is given in table 1.

Table 1: Main concepts of HBM

Concept	*Definition*
Perceived susceptibility	One's belief of the changes of getting a condition
Perceived severity	One's belief of how serious a condition and its consequences are
Perceived Benefits	One's belief in the efficacy of the advised action to reduce risk or seriousness of impact
Perceived Barriers	One's belief in the tangible and psychological costs of the advised behavior
Cues to Action	Strategies to activate readiness
Self - Efficacy	Confidence in one's ability to take action

This model is really simple and reasonable, and the main concepts could be understood by non-expert users. This model has been used widely, and has high validity.

2-2-Stages of Change Transtheorical Model

This theory has been developed by Caro Diclemente and James O. Prochaska in 1979. They proposed the change of human behavior (changing undesired to desired behavior) has general stages that could be formulated in a model. In this theory, people are modeled by their decision making process. This theory claims that the change is a process consisting of many general stages. Change, means doing the right thing at the same time. These stages of change have been conceptualized for a variety of problem behaviors:

- Pre-contemplation ; is the stage at which there is no intention to change behavior in the foreseeable future (about 6 months)
- Contemplation is the stage in which people are aware that a problem exists and seriously think about overcoming it but have not yet made a commitment to take action.
- Preparation is the stage that combines intention and behavioral criteria. Individuals in this stage are intending to take action in the next month and have unsuccessfully take action in the past year.
- Action is the stage in which individuals modify their behavior, experiences or environment in order to overcome their problem.
- Maintenance is the stage in which people work to prevent relapse and consolidate the gains attained during action.
- Termination: change has been occurred and the new behavior is now one of the ordinary procedures of the person.

2-3-Social Learning Theory (SLT) & Health Locus of Control (HLC)

Social learning theory focuses on the learning that occurs within a social context. It considers that people learn behaviors from each other. They observe other's behavior and the outcomes of these behaviors, and could learn to accept or reject these behaviors. Learning may occur, but the behavior could be fixed. Although Behaviorist imply that learning means changing the behavior, SLT theorists insist on learning may not necessarily be shown in the behavior. They also focus on "cognition" as a key issue in learning. Awareness and expectations of future reinforcements/punishments may have a major effect on this concept.

Health locus control (HLC) has been developed on SLT concept. HLC has a set of statements that could

measure the belief of Individuals to control their behaviors internally and externally; these statements are evaluated by scores and the sum of these scores determines the level of person's health belief. Due to many problems in prediction, this theory has been developed, and multi–dimensional HLC introduced by Wallston and Kaplan. In this model, by standardizing measures, researches could repeat their survey, and compare the results.

2-4-Theory of Reasoned Action (TRA) / Theory of Planned Behavior (TPB)

TRA developed in 1967 by Martin Fishbein and Icek Ajzen. It has been revised in 1970s, and has been used for studying human behavior and design of experiments since 1980s. In 1988, the concept of TPB has been added to TRA to overcome its inefficiencies.

This theory is developed to predict and understand the effect of motivations on behaviors, analyzing the strategies for changing behavior and embedding human behavior in virtual environments. A schematic view of this model is shown in figure 4. In this theory, the main determinant of human behavior is behavior intention. Intention is a combination of Individual's attitude to implementation of behavior and mental norms.

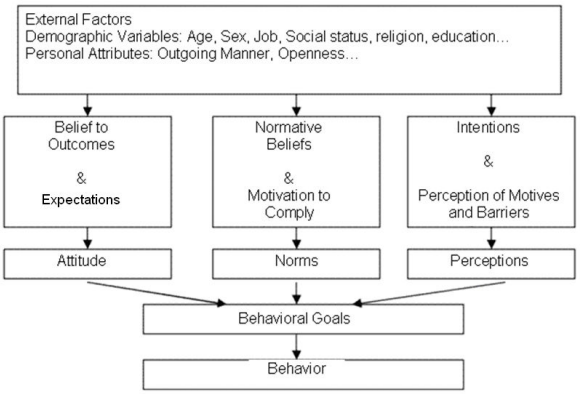

Figure 4 : Theory of Planned Behavior

2-5-Social Cognition Theory (SCT)

Behaviorists insist that a specific boundary exist between stimuli and response and believe that human behavior is just a response to the external stimulus. SCT implies cognition as a medium between stimuli and response, which adjusts control on the Individual behavior.

SCT considers human behavior as the result of dynamic interaction between personal, behavioral and contextual factors. It also implies that people could learn most behaviors and reality means interaction of environment and Individual cognition. SCT has been used to investigate a wide range of health–related issues such as medical acceptance, alcohol abuse, vaccination, and etc. Most STC techniques are used in modeling and skills training in many interventions, but complexity of this model makes it unsuitable in various contexts.

3-HUMAN – BASED AGENTS IN SIMULATION

Simulation is a suitable tool to solve most problems and has been used in various contexts of application, research and also to assess and train new theories. The ability to build and run a simplified replica of real world situations and evaluate the methods and solutions without implementation is the main source of interests to this technique.

Human beings, are the most important part of most systems for describing these systems, these element should be modeled at least as the other elements. A human lives in a social context and does the various behaviors. The human behavior is a complex system, influenced by several physical, cognitive, sensual, cultural, and social factors. This complexity is more evident when studying the behavior in a complex context, considering human interactions. In most problem solving methods, such as OR modeling, or discrete event Simulation, usually the characteristics of human behavior are ignored, or simply modeled by a few parameters, variables, or some constraints. There should be a trade–off between the complexity of modeled human, and the complexity of modeled environment (Klugl, 98). In the literature, the more detailed organizational structure has been resulted in the more simplified persons. (Moss,nd). One of the most popular techniques to resolve this paradox is using object oriented programming to create human-based agents and to put them in the Simulated environment, as representatives of human beings. (Sibbel, 2001).Using human based Agents is spreading in Simulation experiments (Urban, 2000a). In the recent years, agents have been had a critical role in Simulation models (Schmidt, 2000).

The first matter in Agent–Based Simulation is the internal structure of agents. This structure, named "Reference Model", (Schmidt, 2001) is built upon the theory describing human behavior, describing the behavior in the specified context.

In health care, the theories explained in the second part of this article could be used for designing the reference model. By examining more, the HBM model has been selected, because of its many applications in the literature, and also having the capability to be represented by the mathematical equations.

In the next section, the proposed structure of agent used in the Simulation of screening process is proposed. In this model, the human behavior is modeled by different decision points in the screening process, including the decision to reject or continue the process. Despite the PECS model (described by Urban (Urban, 2000)) in these agents the internal psychological mechanism for making behavior is not

modeled, but like the BDI agents (Pokahr et al, 2003), the decision making process, and the different effecting factors have been modeled. As a result, the psychological details are less included, but the decision making process in the complex context is mentioned.

3-1-THE INTERNAL STRUCTURE

The internal structure of agents is consisted of some types of variables, as described below:

- Personal variables: Indicates the variables that are not related to the other variables which are quantified by a random distribution. These variables are of different types:

- Constants; which does not change in a Simulation run. (12 steps, each one is a month) These include age, sex, marital status, number of children, job and income.

- The next variables are behavioral variables, indicating some behavior like smoking, doing exercise, diets and drug use. These are aggregated in a single variable indicating the overall status of a person.

- The third type of personal variables includes the effects of disease aggregated in a single variable showing the heart stroke, headaches, visual inefficiencies and other results of blood– pressure.

- The fourth type indicates the blood–pressure and results from the distribution of blood–pressure in the selected community.

- Social variables: Indicating the characteristics of the specified society (mainly concerning the attitudes) and also the health care system. These variables include social attitude to disease, (fear of others to know about the disease), time schedule (the ability of being present and having appointment), and drug accessibility.

- Internal variables: these variables, indicate the result on the decision variables. These are mainly resulted from the HBM model, including self–efficacy, perception about infection, the ability to perform, awareness about the blood–pressure, perception of Benefits and Barriers and perception about severity.

- Decision variables: these variables indicate the decisions model by the agent, and directly influence the progress of screening. These variables include having appointment with. Nurse or doctor, performing care and drug–consumption.

- External variables: The external variables, which refer to the health care system, affect the internal and social variable.

- Program Progress variables, which will be explained in 3-3.

3-2-The causal effects

The casual relationships between the variables have been shown in the diagrams by some lines (such as figure number 5). 3 key decisions have been entered in the model:

- Decision for drug–consumption, which is influenced by drug accessibility to construct drug–consumption by the person.

- Decision to perform prescribed care by the doctor or nurse (such as not smoking, having diet and etc…) that cause the gradual (not radical) change of behavior.

- Decision for having appointment with doctor or nurse, by considering the ability to go (presence of Doctor in conjunction with the presence of patient), shows the incidence of appointment.

One of these decisions (having appointment with doctor) is shown in figure 5 as an example. As shown, the personal variables lead the social variable, which in turn shape the internal variables and by interacting

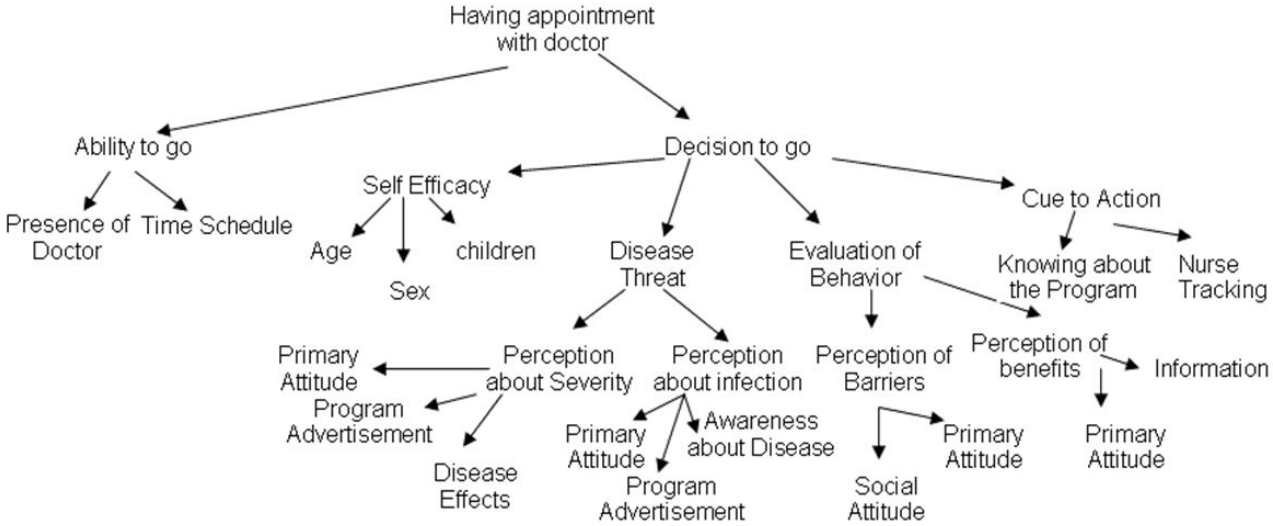

Figure 5- decision tree related to make decisions about having appointment with doctor

these variable, the decision variables are formed, which influence the health–status of the agent.

3-3-Program process

The screening Program consists of four stages which are indicated by Program process variable. These variables are defined as the program process (also presented in figure 2) as follows:

- Program Announcement
- Appointment with nurse: in this stage, persons who decide to have an appointment with nurse could be examined by nurse. If the nurse diagnoses the blood-pressure is more than normal, the person goes to the next stage.
- Appointment with doctor: in this stage, some of agents that have high blood-pressure, decide to go to the doctor, and the ones who could be examined by the doctor (if both are present at the time), are examined. If doctor diagnoses the high blood-pressure, the agent goes to the periodic care cycle. In this stage, doctor prescribes some drugs, as well as physical exercises and diet.

The agents that pass this stage go to the care cycle. There are two stages in this cycle:

- Appointment with nurse (monthly) that includes decision- making about having appointment again.
- Appointment with doctor (once in 3 months): in this stage: patient could decide again about having appointment. Doctor could change his prescription, and also could refer him to the hospital, if necessary.

After each appointment, agent could decide again about drug-consumption and performing the medical care.

4-Model execution and results

A Delphi Program has been used to simulate the designed structure described in the previous session. By executing this Program, user could assign the initial value of variables and could see the characteristics of agents in the right-side box. Then simulation runs and the results are available via an excel file. So, the information could be drilled down to diagnosis the causes of observed behavior.

The main screen of the software program, as shown in figure 6, consists of some places for entering value of parameters and also buttons for run the model. The right-hand side refers to the main variables that should be fed to the program by user. Executing the simulation program using the right button in the bottom of page would show the agents in the text box. By accepting the agents and running the program, results would be shown in an excel file.

The program has been used as a pre-test for blood-pressure screening program which performed in Iranian villages in winter 2004. This program gave decision makers and managers of health-care divisions in the related areas some insights about the program inefficiencies prior to the real execution. As the result, some refinements especially about the announcement and also about the time-frame of the related health-care personnel were performed.

5-CONCLUSION

As this method focuses on the Program progress (not the illness progress), could be used as a suitable tool for professional managers to conduct more suitable decisions.

This view to simulate as a decision-aiding tool is a new approach. Most simulation models concerning analysis

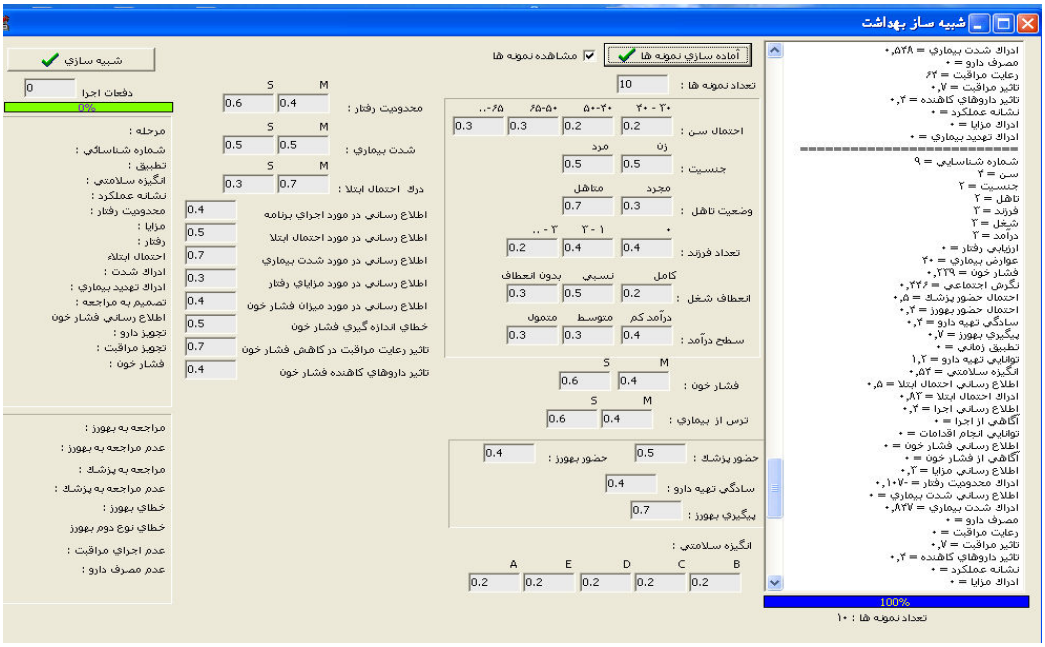

Figure 6- screen shot of the program

of organizational problems, just consider balancing and time-delays in resource (man, material and machine) utilization. In this research, behavioral characteristics interactions are considered. Using simulation for assessing health-care policies is a new idea that has been used in few models for the cancer screening assessment focusing on the physiologic aspects related to the illness progress. But this model is focused on health-care service, in order to design more effective programs.

This model, by ignoring waiting time and available resources, simulates the target group behavior, without system service consideration. So, this agent-based simulation could be used to design a policy for improving the quality of problem solving and decision making in health-care. In human-based agents, by limiting the complexity of human behavior to the internal structure of agents, modeler could use the simulation to anticipate the success and main bottlenecks in the implementation of any program for increasing the efficiency and effectiveness.

In the application of human based agents, the irrelevant research (such as examining the relationship between self–efficacy and the personal characteristics – such as age, sex, marital status and the number of children) could help in building and validating the reference model that could be used for Simulating complex situations. As this method is focused on the progress of program (not on the progress of disease); it could be used as a tool in decision–making for Generalist Managers in the health care. As this model lacks these experiments, it limits the utility of this model, which could be considered in the next studies.

REFERENCES

Brailsford, Sally; Schmidt, Bernd; (2003) Towards incorporating human behavior in models of health care systems: An approach using discrete event simulation, European Journal of Operational Research 150 (2003) 19–31, available from elsevier

Klügl, F., Puppe, F.(1998) The Multi-Agent Simulation Environment SeSAm, Available from Elsevier

Moss, S. (nd), Gaylard, H., Wallis, S., Edmonds, B., SDML: A Multi-Agent Language for Organizational Modelling , Available from : Elsevier

Ohler,P.P;Reger,K.(1999),Emotional Cooperating Agents, In Modeling and Simulation-A tool for the next Millenium, 13th European Simulation Multiconference (proceedings),Available from Elsevier

Pokahr, A., Braubach,L.,Lamersdorf,W. ,2003,Jadex: Implementing a BDI-Infrastructure for JADE Agents, in: EXP - In Search of Innovation (Special Issue on JADE), Vol 3, Nr. 3, Telecom Italia Lab, Turin, Italy, September 2003, pp. 76-85., available from http://vsis-www.informatik.uni-hamburg.de/projects/jadex/papers/jadex-exp03_final_revised.pdf [last accessed feb 2007]

Robinson G.H, P. Wing, L. E. Davis. 1965. Computer simulation of hospital patient scheduling systems. *Health Services Research* 3:130-141.

Schmidt, B.,(2000) Modeling of Human Behavior [online], available from web site of Passau University , URL: www.or.uni-passau.de/5/Publik/Scmidt [Last Accessed 1th May 2003]

Schmidt, B.,(2001) Human Factors in Simulation Models ,available from www.or.unipassau.de/2/Human_Factors.pdf [Last Accessed 21th Feb 2003]

Sibbel , R., Urban , C.(2001) Agent-Based Modeling and Simulation for Hospital Management, [online] available from www.or.uni-passau.de/5/publik/urban /Artikel_Agents_in_Hospital_Management.pdf [Last Accessed 1th March 2003]

Standridge ,Charles R.,1999, A TUTORIAL ON SIMULATION IN HEALTH CARE: APPLICATIONS AND ISSUES, Proceedings of the 1999 Winter Simulation Conference, P. A. Farrington, H. B. Nembhard, D. T. Sturrock, and G. W. Evans, eds.

Urban, C, (2000) PECS:A Reference Model for Human-Like Agents, [online] available from : www.or.uni-passau.de/5/publik/urban /Artikel_Avatars_2000.pdf [Last Accessed 2nd Nov 2003]

Urban, C, (2001) PECS:A Reference Model for Human-Like Agents, [online] available from : www.or.uni-passau.de/5/publik/urban /Artikel_Avatars_2000.pdf [Last Accessed 22th Jan 2003]

Urban, C., (2000) PECS: A Reference Model for the Simulation of Multi-Agent Systems. [online] Available from :Author's HomePage on University of Passau

Urban, C., Schmidt B.(2000) PECS – Agent-Based Modelling of Human Behaviour , [online] available from : www.or.uni-passau.de/5/publik/urban/CUrban01.pdf [Last Accessed 20th June 2003]

AUTHOR BIOGRAPHIES

NASIM GHANBARTEHRANI was born in Tehran, Iran. Now she is a PhD student in Tarbiat Modares University, where she studies Industrial Engineering. She has worked on Simulating Human Behavior as her MS thesis in 2004 in Tarbiat Modares University with Dr Aghdasi. Her Email Address is: Nasim.Tehrani@modares.ac.ir

MOHAMMAD AGHDASI,PhD. has studied Industrial Engineering and gained his Phd from tsuioka university, Japan, in 1988. He is now Professor of Industrial Engineering Faculty at Tarbiat Modares University. He has been worked in Simulation , Productivity ,and Quality area. His Email Address is: Aghdasim@modares.ac.ir