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INTELLIGENT AGENT-BASED MEDICAL SYSTEMS

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Abstract. The development of efficient and flexible agent-based medical diagnosis systems represents a recent research direction. Medical multiagent systems may improve the efficiency of traditionally developed medical computational systems, like the medical expert systems. In our previous researches, a novel cooperative medical diagnosis multiagent system called CMDS (Contract Net Based Medical Diagnosis System) was proposed. CMDS system can flexibly solve a large variety of medical diagnosis problems. In this paper we analyze the increased intelligence of the CMDS system, which motivates its use for different medical problems solving.

1. INTRODUCTION

The development of intelligent systems represents an important research direction [1, 2, 3, 4, 5, 6, 7, 8, 9]. Results described in the literature, prove that the intelligence of a computational system can offer advantages in the problems solving versus a system that does not have intelligence [3,5,10]. Some times a system's intelligence can be measured: how efficiently and flexibly the system can solve problems (intelligence in the problems solving). The purpose of the endowment of an agent with intelligence consists in obtaining improvements in the problems solving. For example solving of problems whose description contains some uncertainties or whose solving is partially known.

Basic proprieties necessary for an intelligent agent consists in the increased autonomy in operation and the capacity of communication and cooperation [1, 5]. These proprieties are necessary in the endowment of the agents with capacities specific to the intelligent systems.

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In the literature, intelligent agents are described [1, 3, 4, 5, 7, 8]. Many times the agents capable to learn autonomously are considered intelligent [3, 5]. Autonomous learning allows the agents to adapt for efficient solving of the problems.

Another propriety that sometimes is associated with the intelligence consists in the capacity to help other agents and humans during the problems solving (some times in the decision support).

Many times the intelligence of the agents should be considered based on the types of the agents, for example [2]: robotic agents' intelligence, static software agents' intelligence and mobile software agents' intelligence. There are many static software agents that could be considered intelligent [3, 5]. Software mobile agents are more limited in intelligence than the software static agents [6, 11, 12]. The limitations of the mobile agents in intelligence have practical motivations [11]. The endowment of a mobile agent with intelligence increases its body size and its behavioral complexity. The transmission of a large number of intelligent mobile agents in a network may overload the network with data transmissions. A large number of intelligent mobile agents at a host may overload the host with data processing.

In a cooperative multiagent system, the intelligence could be considered at the level of the system where the agents operate [1, 5]. If the agents cooperate efficiently, they can solve intelligently difficult problems. The intelligence of an efficiently cooperating multiagent system could be higher than the intelligence of the member agents. In the literature [1, 10], multiagent systems are described, some of them composed from relatively simple agents that could be considered intelligent at the level of the multiagent system in which they operate.

In our previous researches, a novel medical diagnosis system called *CMDS* (*Contract Net Based Medical Diagnosis System*) was developed [13]. In this paper it is analyzed the *CMDS* system's intelligence, which motivates its use for difficult medical problems solving.

The upcoming part of the paper is organized as follows: Section 2 presents agent-based medical diagnosis systems; in Section 3 the *CMDS* system is presented; Section 4 analyses the intelligence of the *CMDS* system; in Section 5 the conclusions of the research are presented.

2. MEDICAL COMPUTATIONAL SYSTEMS

In medical domains, there are proposed and used many medical systems that operate in isolation or cooperate with each other [3, 7, 8, 14, 15, 16, 17]. Medical expert systems represent relatively classical applications used for medical diagnoses elaborations [18, 19, 20, 21, 22, 23, 24, 25, 27, 26]. As examples of developed medical expert systems, we mention: *MYCIN* [19], *Cardiag2* [20], *Gideon* [21], *HDP* [22], *PUFF* [23, 24], *Dimitra* [25], *CASEY* [27] and *Casnet* [26]. Recently, there are developed agent-based medical diagnosis systems that eliminate some disadvantages of the medical expert systems [3]. Motivations of the use of agents for different medical problems solving consist in the proprieties of the agents (increased autonomy in operation, capacity of communication, autonomous learning capacity and capacity to interact with the environment etc.). Intelligent agents used in medicine may increase the accuracy of elaborated diagnostics by the physicians (an agent may help a human medical specialist in the medical decisions elaborations; also, he may verify medical hypothesis elaborated by the human medical specialists) and may improve the solving of medical tasks that must be fulfilled in healthcare processes. As examples of applications of the agents for fulfilling medical tasks, we mention: *patients monitoring* [28], *patients management* [29, 30], *healthcare* [31, 32], *telehealth* [33], *spreads simulation of infectious disease* [34], *web-enabled healthcare computing* [35] and *ubiquitous healthcare* [32].

The paper [14] analyzes different aspects of the multiagent systems specialized in medical diagnosis. Understanding such systems needs a high-level visual view of how the systems operate as a whole to achieve some application related purposes.

As more health-care providers invest on computerized medical records, more clinical data is made accessible. Extracting medical information from huge repositories of data are becoming increasingly important for purposes such as offering better care [36]. The paper [15] describes *intelligent medical diagnosis systems* with built-in functions for knowledge discovery and data mining. The intelligence is considered based on the capacity of the system to learn. Diagnosing rules generated by learning can be used in diagnosis processes.

OnkoNet mobile agents have been successfully used for patient-centric medical problems solving [32]. In the paper [32], it is introduced the notion ubiquitous healthcare, addressing the access of health services by individual consumers using mobile agents. This access requires medical knowledge about the individual health status (relevant recent diseases). The work presented in the paper [32], emerged from a project covering all relevant issues, from empirical process studies in cancer diagnosis/therapy, down to system implementation and validation.

In the paper [10], a medical diagnosis multiagent system that is organized according to the principles of swarm intelligence is proposed. It consists of a large number of agents that interact with each other by simple indirect communication. The proposed multiagent system real power stem from the fact that a large number of simple agents collaborate reliable with the purpose to elaborate diagnostics. The intelligence of the proposed system can be considered based on the agents' capacity to learn.

3. THE CMDS MEDICAL SYSTEM

In our previous researches a novel cooperative medical diagnosis system called *CMDS* (*Contract Net Based Medical Diagnosis System*) was proposed [13]. *CMDS* system is composed from a set $Am \cup Ag$ of members, artificial agents and physicians specialized in different medical domains. In the following, all the members (artificial and human) of the diagnosis system are called agents. Figure 1 presents the *CMDS* system's architecture.

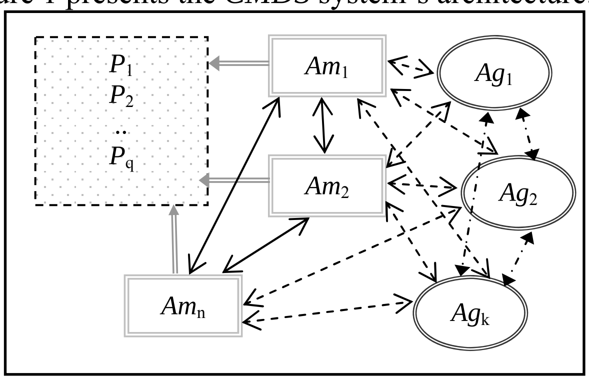

Figure 1. CMDS medical diagnosis system

$Am=\{Am_1, Am_2, \ldots, Am_n\}$ represents agents specialized in medical diagnosis, physicians and medical expert system agents. $Ag=\{Ag_1, Ag_2, \ldots, Ag_k\}$ represents assistant knowledge-based agents. $P=\{P_1, P_2, \ldots, P_q\}$ represents problems that must be solved by the system. The assistant agents are capable to help the medical agents during the problem's solving processes. A *CMDS* system can solve randomly transmitted diagnosis problems for solving. A problem is initially transmitted to a medical agent member of the system; next, the system will handle autonomously the problem solving.

The algorithm *Problem Solving* describes briefly how a medical agent denoted Am_i ($Am_i \in Am$) operates when it receives an initially transmitted medical diagnosis problem or a problem solving statement. The algorithm has been described with details in the paper [13]. In the paper [13] it is presented the medical knowledge detained by the artificial medical agents. An agent is capable [13] to solve a problem, if it has the necessary specialization (problem solving knowledge) and resources for the solving of the problem in the maximum admitted time. The agents from the set *Am* have specializations sets in medical diagnosis. The agents from the set *Ag* have specializations sets that allow the assistance of the agents from the set *Am*. An agent is called capable to processes a problem, if it has the necessary specialization and resources to processes the problem. A problem processing has as objective to obtain a more complete description of the solution (the solution description is completed step by step).

Problem Solving Algorithm

Step 1 - The problem solving.

//the problem overtaking for solving

$St_d \rightarrow Am_i$.

If (Am_i is capable to processes St_d) *then*

//the problem initial processing

$Am_i(St_d) \Rightarrow St_h$.

If (St_h contains the St_d solution) *then*

Goto Step 2.

Else

//establishment of the announcement

$Am_i\ (St_h) \Rightarrow an$.

//announcement transmission

$Am_i\ (an) \rightarrow Ac$.

EndIf

else

//establishment of the St_d announcement

$Am_i\ (St_d) \Rightarrow an$.

//announcement transmission

$Am_i\ (an) \rightarrow Ac$.

EndIf

While (the waiting time to *an* is not expired) *do*

@Am_i evaluates the bids to *an*.

EndWhile

@Am_i awards the problem solving statement to a suitable agent Am_b ($Am_b \in Ac$).

@Am_i receives the St_q problem statement from Am_b.

Step 2 - The problem solution formation.

@The solution sol_d is extracted from the latest problem solving statement.

@The least problem solving statement and sol_d is transmitted to the St_d sender.

EndProblemSolving.

In the *Problem Solving* algorithm the following notations are used: St_d denotes the problem solving statement; Am_i and Am_b denote medical agents; St_h denotes a problem solving statement; *an* denotes an announcement; sol_d denotes the solution of St_d; *Ac* ($Ac \subset Am$) denotes a set of medical agents to whom the announcement *an* can be transmitted; "→" denotes a communication process; "⇒" denotes a problem processing. The solving of a problem is sometimes a recursive process to which more agents can contribute. A problem statement is sent from agent to agent until the problem is solved. The *Problem Solving* algorithm describes a cooperative problem solving by medical agents. During its operation a medical agent may requires the help of assistant agents. The paper [13] describes how an assistant agent helps a medical agent. Each human and artificial medical agent knows at least one assistant agent whose help may require. If it is necessary, an assistant agent may cooperate with other assistant agents to fulfill the requirement.

Formula (1) illustrates a problem solving process.

$$St_a(S_q) \Rightarrow St_b(S_w) \Rightarrow \ldots \Rightarrow St_y(S_r) \Rightarrow St_g. \qquad (1)$$

S_q, S_w,…, S_r represent the specializations used during the St_a solving. Processing St_a using S_q leads to St_b (a new problem solving statement). Processing St_b using S_w leads to St_c. Processing St_y using S_r leads to St_g. St_g is the problem solving statement obtained after all the realized processing (St_g contains the solution of St_a).

A problem solving statement (2) describes medical knowledge $Kg=\{Kg_1, Kg_2, \ldots, Kg_n\}$ obtained during a diagnosis problem solving.

$$< Kg_1 \mid id_1; Kg_2 \mid id_2; \ldots; Kg_n \mid id_n>. \qquad (2)$$

As examples of information that can be contained in a parameter Kg_c from (2), we mention: an illness symptoms, illnesses from the past, a diagnostic etc. Initially a problem solving statement contains information that describes the illness (for example, the history of the patient's illness symptoms specified by the patient). During the solving of the problem, the problem solving statement is changed, by adding new knowledge. The final problem solving statement will contain the established diagnostic. During a problem solving, some parameters' values may not be completed (for example, it is not necessary to retain the history of the diagnosed illness symptoms). Each parameter in (2) has associated as identifier a unique natural number. The identifier of a parameter indicates the type of information that can be retained in that parameter. For example, $type(id_c)$ = *syndromes* specifies that the parameter Kg_c (associated with the identifier id_c) may contains as values the specifications of the syndromes of an illness.

An announcement denoted *an* has the parameters (3).

$$an = < St_j; Dl_j; Elig_j; Emit_j >. \quad (3)$$

St_j represents the announced problem. $Emit_j$, numerical value, specifies the moment of time when *an* is formed. Dl_j, numerical value, specifies the maximum admitted time for the St_j processing. Based on Dl_j and $Emit_j$ values, an agent who receives *an* specify the remaining time for St_j processing. $Elig_j$ value specifies the eligibility criteria of the bid acceptance.

A response R_j of an agent Am_i to the St_j problem solving statement announcement *an* has the parameters (4).

$$R_j = < Of_i; an; Tm_i; Sc_i; Cb_i>. \quad (4)$$

Cb_i values specify the specializations that Am_i can use in the St_j processing. Tm_i (numerical value) specifies the estimated processing time by Am_i. Of_i value specifies the bid to St_j processing, Of_i = '*y*' (acceptance) or Of_i = '*n*' (rejection). When a medical agent receives the bids to an announcement, using the information contained in the responses, he can improve the following decisions about what to do with the announced problem. Sc_i values specify the estimated specializations by Am_i, necessary in the St_j processing. *an* value specifies the announcement identifier.

4. INTELLIGENCE OF THE CMDS SYSTEM

The main proprieties for the artificial agents' members of the *CMDS* system consist in the increased autonomy in operation, communication and cooperation capability. The artificial agents' members of the *CMDS* system can be endowed with autonomous learning capacity. They can learn new knowledge and can improve the detained knowledge accuracy. The agents can learn during the problems transmission for processing. When an agent receives a response to an announcement, he may learn information that can improve the accuracy of the medical decisions that must be made and may improve the efficiency of its following operation. A response to an announcement can contain auxiliary information that may help the agent in the decision elaboration.

From the responses to an announcement, an agent can learn information like:

- what agents can usually overtake problems for processing (this information may limit its future interactions);
- the medical knowledge detained by different agents;
- what agents usually answer fast to the announcements.

In the case of a solved problem, the final problem solving statement contains all the necessary information in a learning process, which consists in the completely obtained problem description and the established diagnostic. The agents (artificial agents and humans) can learn from a final problem solving statement. The information contained in a problem solving statement are understandable to the physicians and artificial agents. Each information contained in a problem solving statement has associated the type of the medical information: illness symptoms, illness syndromes, treatments, etc. The agents can learn new medical diagnosis problems solving or can improve the detained medical diagnosing knowledge accuracy. For example, an artificial medical agent may learn new symptoms of an illness.

A medical agent may require the help of an assistant agent during its operation. For example, it is considered the situation; when the medical agent does not have a specialization; however, he must require the help of an assistant agent, who has the necessary specialization. If an assistant agent cannot solve an overtaken problem, then he can cooperate with other assistant agents in order to solve the problem. For a physician, it is necessary to know a single medical agent, who (if necessary) can cooperate with other assistant agents to fulfill the physician's requirement.

In the *CMDS* system, the intelligence could be considered at the level of multiagent system. The intelligence of a cooperative multiagent system is increased due to the agents' efficient cooperation. The intelligence of the *CMDS* multiagent system is higher than the intelligence of the system's members. An important advantage of the *CMDS* system consists in the flexibility in operation. A diagnosis problem is transmitted to an agent member of the system; next, the system will handle autonomously the problem solving, by transmitting the problem from agent to agent until the problem is solved. The specializations necessary for a diagnosis problem solving are not specified in advance; so, the members of the system must discover cooperatively the problem solving. The specializations necessary to a problem solving may be distributed between more agents. Artificial medical agents and physicians may have only a limited quantity of medical knowledge.

Another motivation that sustains the intelligence of the *CMDS* system consists in the combination of the human thinking and the artificial agents processing advantages during the medical problems solving. The physicians can solve difficult problems using their intelligence specific to the humans (intelligence that cannot be attained by the actual computational systems). The artificial agents can solve problems verifying many conditions that could be ignored by humans, which may have as result the elimination of some mistakes from the physicians' decisions. For example, a physician may forget to take into consideration information from a patient's medical history when diagnoses the patient's illness (for example a known allergy of a patient specified in its medical history).

Agents can find the solutions to hypotheses elaborated by physicians. As an example, we mention the situation when a physician wants to find the answer to a medical issue by consulting more physicians. In order to find the answer, the physician can transmit the issue to an assistant agent, who will search for the physicians capable to answer to the issue. The assistant agent transmits the issue to the physicians, collecting and transmitting their answer to the physician sender of the announcement. The physician sender of the medical issue will establish the answer based on the received answers to the issue. As an example of a medical issue that can be solved, we mention "what is the best-fitted medicine to cure an illness".

5. CONCLUSIONS

The motivations for the use of agents in the medical domain consist in the multitude of aspects that the agents can analyze during the diagnostics elaborations and the realization of different medical tasks. Agent-based approaches may integrate and extend different problem solving technologies. In previous researches, we have proposed a novel cooperative medical diagnosis system called *CMDS* (*Contract Net Based Medical Diagnosis System*). The *CMDS* system has some characteristics of the intelligent systems. The main advantage of the *CMDS* system consists in its autonomy and flexibility in handling medical diagnosis problems. During the diagnosis processes, there are transmitted information that allows to the physicians and artificial agents to improve the detained knowledge accuracy. The accuracy of the elaborated diagnostics by artificial medical agents members of the *CMDS* system, depend on the medical knowledge accuracy detained by them (the initial knowledge of the artificial agents is established by human specialists).

References

[1] J. Ferber, **Multi-Agent Systems: An Introduction to Distributed Artificial Intelligence**, Addison Wesley, 1999.

[2] B. Iantovics, **The Intelligence of the Multiagent Systems**, Scientific Bulletin of the Petru Maior University, vol. XVXVI, 2003, pp.125-129.

[3] B. Iantovics, **A Novel Diagnosis System Specialized in Difficult Medical Diagnosis Problems Solving**, Understanding Complex Systems, Springer-Verlag, Heidelberg, 2006, pp.187-197.

[4] B. Iantovics, C. Chira, and D. Dumitrescu, **Principles of the Intelligent Agents**, Casa Cartii de Stiinta Press, Cluj-Napoca, 2007.

[5] G. Weiss, (Ed.) **Multiagent Systems: A Modern Approach to Distributed Artificial Intelligence**, MIT Press Cambridge, Massachusetts London, 2000.

[6] R. Kowalczyk, P. Braun, I. Mueller, W. Rossak, B. Franczyk, and A. Speck, **Deploying Mobile and Intelligent Agents in Interconnected E-Marketplaces**, Journal of Integrated Design and Process Science, Transactions of the SDPS, vol. 7, no. 3, 2003, pp.109-123.

[7] B. Iantovics, **Cooperative Medical Diagnoses Elaboration by Physicians and Artificial Agents**, Understanding Complex Systems, Springer-Verlag, Berlin/Heidelberg In Press.

[8] B. Iantovics, **Agent-Based Medical Diagnosis Systems**, Computing and Informatics, Slovak Academy of Sciences, Bratislava, vol. 27, no. 4, 2008, pp.593-625.

[9] R. Pfeifer, and C. Scheier, **Understanding Intelligence**, MIT Press, 1999.

[10] R. Unland, **A Holonic Multi-agent System for Robust, Flexible, and Reliable Medical Diagnosis**, OTM Workshops 2003, Meersman, R., Tari, Z., (Eds.), Springer-Verlag, *LNCS*, vol. *2889*, 2003, pp.1017-1030.

[11] B. Iantovics, **A New Intelligent Mobile Multiagent System**, Proceedings of the IEEE International Workshop on Soft Computing Applications. Szeged-Hungary and Arad-Romania, IEEE Computer Society Press, IEEE Hungarian Section, 2005, pp.153-159.

[12] L. Gulyas, L. Kovacs, A. Micsik, B. Pataki, and I. Zsamboki, **An Overview of Mobile Software Systems. Department of Distributed Systems**, Computer and Automation Research Institute of the Hungarian Academy of Sciences, MTA SZTAKI Technical Report TR 2000-1, 2001.

[13] B. Iantovics, **The CMDS Medical Diagnosis System. Symbolic and Numeric Algorithms for Scientific Computing**, IEEE Computer Society Press, 2007, pp.246-253.

[14] T. Abdelaziz, M. Elammari, and R. Unland, **Visualizing a Multiagent-Based Medical Diagnosis System Using a Methodology Based on Use Case Maps**, MATES'04, Lindemann, G. (Ed.), Springer-Verlag, Berlin, Heidelberg, LNAI, vol. 3187, 2004, pp.198-212.

[15] V. Alves, J. Neves, M. Maia, and L. Nelas, **A Computational Environment for Medical Diagnosis Support Systems**, ISMDA 2001, Crespo, J., Maojo, V., Martin, F. (Eds.), Springer-Verlag, LNCS, vol. 2199, 2001, pp.42-47.

[16] H. Myritz, G. Lindemann, G. Zahlmann, and B. Hans-Dieter, **Patient Scheduling in Clinical Studies with Multi-Agent Techniques**, Proceedings

of the 2nd International Workshop on Multi-Agent Systems for Medicine and Computational Biology, Hakodate, Japan, 2006, pp.87-103.

[17] R. Ulieru, and M. Unland, **A Stigmergic Approach to Medical Diagnosis**, Proceedings of the 2nd International Workshop on Multi-Agent Systems for Medicine and Computational Biology, Hakodate, Japan, 2006, pp.87-103.

[18] L.M. Laita, G. Gonzlez-Paez, E. Roanes-Lozano, V. Maojo, L. de Ledesma, and L. Laita, **A Methodology for Constructing Expert Systems for Medical Diagnosis**, ISMDA 2001, In: Crespo J (ed) Springer-Verlag, LNCS 2199, 2001, pp.146-152.

[19] E.H. Shortliffe, **Computer-Based Medical Consultations**, MYCIN Elsevier, New York, 1976.

[20] K. Adlassing, **Cardiag 2 Expert System**, IEEE Transactions on Systems, Man and Cybernetics, vol. 2, no. SMC-16, 1986.

[21] D.M. Bravata, V. Sundaram, K.M. McDonald, W.M. Smith, and H. Szeto, **Evaluating Detection and Diagnostic Decision Support Systems for Bioterrorism Response**, Emerging Infectious Diseases, vol.10, no.1, 2004, pp.100-108.

[22] H.S.F. Fraser, W.J. Long, and S. Naimi, **Differential Diagnoses of the Heart Disease Program have better Sensitivity than Resident Physicians**, Chute CG, ed. Proc AMIA Annu. Fall Symp.,1998, pp.622 -626.

[23] J.S. Aikens, **PUFF: An expert system for interpretation of pulmonary function data**, Computers and Biomedical Research, vol. 16, 1983, pp.199-208.

[24] J.S. Aikins, J.C. Kunz, E.H. Shortliffe, and R.J. Fallat, **PUFF: An Expert System for Interpretation of Pulmonary Function Data**, Comput. Biomed. Res., vol. 16, no. 3, 1983, pp.199-208.

[25] M. Athanasiou, and J.Y. Clark, **DIMITRA: an online expert system for cares of paraplegics and quadriplegics**, International Journal of Healthcare Technology and Management, vol. 7, no. 5, 2006, pp.440-451.

[26] S.M. Kulikowski, and C.A. Weiss, **Representation of Expert Knowledge for Consultation: the CASNET and EXPERT Projects**, Artificial Intelligence in medicine. Szolovits, P. (Ed.), Boulder: Westview Press, 1982, pp.21-56.

[27] J.L. Kolodner (Ed.), **Case-Based Reasoning**, Morgan Kaufmann Publishers: California, 1993.

[28] B. Hayes-Roth, M. Hewett, R. Washington, R. Hewett and A. Seiver, **Distributing intelligence within an individual**, In: Gasser L, Huhns M (eds)

Distributed Artificial Intelligence Volume II. Pitman Publishing: London and Morgan Kaufmann: San Mateo, CA, 1989, pp.385-412

[29] G. Lanzola, S. Falasconi, and M. Stefanelli, **Cooperative Agents Implementing Distributed Patient Management**, Proceedings of the MAAMAW-96 Conference. Berlin, Springer-Verlag, 1996.

[30] G. Lanzola, S. Falasconi, and M. Stefanelli, **Cooperative Software Agents for Patient Management**, Proceedings of the AIME-95 Conference, 1995, pp.173-184

[31] J. Huang, N.R. Jennings, and J. Fox, **An agent-based approach to health care management**, International Journal of Applied Artificial Intelligence, vol. 9, no. 4, 1995, pp.401-420

[32] St. Kirn, **Ubiquitous Healthcare: The OnkoNet Mobile Agents Architecture**, Proceedings of the 3.rd International Conference Netobjectdays. Objects, Components, Architectures, Services, and Applications for a Networked World, Aksit, M., Mezini, M., Unland, R. (Eds.), Springer-Verlag, Germany, LNCS, vol. 2591, 2003.

[33] A. Ulieru, and M. Grabelkovsky, **Telehealth approach for glaucoma progression monitoring**, International Journal: Information Theories and Applications, vol. 10, 2005, pp.326-329

[34] D. Yergens, J. Hiner, J. Denzinger, and T. Noseworthy, **Multi-agent simulation system for rapidly developing infectious disease models in developing countries**, Proceedings of the 2nd International Workshop on Multi-Agent Systems for Medicine and Computational Biology, Hakodate, Japan, 2006, pp.104-116

[35] L. Eder, **Managing Healthcare Information Systems with Web-Enabled Technologies**, Idea group Publishing, 2000

[36] R. Agrawal, H. Mannila, R. Srikant, H. Toivonem, and A.I. Verkamo, **Fast Discovery of Association Rules**, U.M.Fayad, G. Piatetsky, Shapiro and P.Smith, (Eds.), *Advances in Knowledge Discovery and Data Mining*, AAAI/MIT Press, 1995, pp.307-328.

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