IAES International Journal of Artificial Intelligence (IJ-AI)
Vol. 1, No. 4, Dec 2012, pp. 193~200
ISSN: 2252-8938

A Multi-Agent Architecture for Task Scheduling In University Environment

Tariq Mehmood, M. Shahid Farid
Punjab University College of information Technology, University of the Punjab
Lahore-54000, Pakistan.
Email: tariq.butt, shahid@pucit.edu.pk

Article Info

Article history:

Received Jun 27th, 2012
Revised Oct 1st, 2012
Accepted Oct 10th, 2012

Keyword:

Agent
Task Scheduling
Examination Scheduling
Problem
Approximation algorithms

ABSTRACT

Task scheduling problems are involved in almost every field of life from industry, where scheduling of employees on different machines with different shifts with respect to various constraints, to universities where scheduling involved in time tabling of classes and faculty, in examination scheduling, laboratory scheduling, staff scheduling and so on. Scheduling problem involves scheduling of different resources under various constraints to attain optimal results. In this paper we present a multi-agent based solution to Task Scheduling Problem (TSP) in university environment. It involves two main scheduling problmes; first, time tabling probelm (TTP) and second examination scheduling problem (ESP). In time tabling problem, a time table of classes is consturcted subject to different constraints; like rooms, subjects, teachers, degrees and semester with in a degree program. In examination scheduling problem is central to scheduling issue to every university. In ESP, the schedule of the examination of different courses of different degrees invigilated by different faculty members each with his/her availability constraints, is carried out. The problem is even worse when students of different degrees take a shared course and when there are add-drops students in a course. In this case, the complexity of the scheduling problem doubles, now scheduling has to done with respect to the constraints of faculty, degree and also to decrease the number of clashes in examination. A multi-agent based architecture to TSP is proposed in this paper.

Corresponding Author:

Tariq Mahmood,
Punjab University College of Inofmration Technology,
University of the Punjab, Lahore-54000, Pakistan.
Email: tariq.butt@pucit.edu.pk

1. INTRODUCTION

Intelligent agent *(agent simply)* in artificial intelligence is an entity that monitors the environment for certain parameters and acts as result to obtain its optimal goal. Agents are not a static entity, it's a dynamic thing that can not only monitor its system, can learn from its system and enhance its knowledge base. A multi-agent system contains a number of agents requiring interaction with each other to achieve the goal using appropriate Agent communication language some protocols and particular agent architecture suitable for particular application. In Multiagent system (MAS), each agent has incomplete information of the entire system requiring them to coordinate and collaborate with each other in the society of agents to achieve some goal. This leads to an important property that should be vested in MAS is Social ability. Other properties that MAS have are that they have intelligence to be able to be reactive to the environment and also behave proactively in order to achieve the desired goal.

We come across the problem of scheduling in various situations like duty roaster of doctors and nurses in hospitals, time table in educational institutions, scheduling in transportation companies, scheduling

of sports events, scheduling of employees in world wide departmental stores. Scheduling is difficult task as the objective is to achieve the optimized solution meeting the constraints. Scheduling is the process to allocate the available resources, subject to various constraints, to the various entities. The resources, in general, may be the class rooms, teachers, aero planes, machines, warehouses, employees, etc to name a few. The constraints are the rules that govern the policy for the solution that we are finding. Further some constraints must be followed strictly to obtain the solution while the others may be relaxed. Based upon this, constraints are usually divided into two categories: hard constraints and soft constraints. Hard constraints are the ones that must rigidly be satisfied by our optimal solution whereas the soft constraints are not 100% essential to be fulfilled, though we should try to minimize its violation.

Examination scheduling problems involves scheduling the exams of different courses of different semesters of different degrees and each exam is invigilated by some of the faculty members and courses can be shared across the degrees which increases the complexity of the problem as now the students of different degrees in enrolled in one shared course. The situation is even worse when the add-drop students are also taking a course with regular a student, that is when the sharing of course is across the semesters within a degree and across the degrees. The exams are scheduled in various slots per day, normally three. Scheduling problems of this level are NP hard problems and require exponential time to get an optimal schedule which is practically not difficult but impossible. Many approximation algorithms are developed to solve the scheduling problems with different limitations in terms of time and space complexities as well as the number of constraints under taken.

In this manuscript a novel method to examination scheduling problem is proposed that exploits the power of agents to find an optimal solution, schedule of exams under various constraints from faculty, time slots, and courses across the semesters and across the degrees in such a way that minimizes the total number of clash students. The remaining paper is organized into four sections. Section II describes the existing approaches to scheduling problems and section III describes the proposed approach to ESP. Section IV presents the implementation details of the proposed approach and section V discusses some experiments with their execution times that proves the fitness of use of the proposed algorithm. Section VI concludes the paper.

Scheduling problems exists in almost every environment. In manufacturing industry, scheduling involves efficient utilization of resources like employees and machines in different shifts. In hospitals, scheduling of doctors and paramedical staff in different shifts with various constraints is carried out [1], [2], [3], [4]. In education institutions, scheduling involves scheduling of classes, time table, exam date sheet etc. These are few of the scheduling problems from real world. This section reviews some solutions to scheduling problem proposed during the last couple of decades.

A large number of solutions are proposed in the literature to solve the problem of scheduling. An agent based solution to supply chain management was proposed in [5]. Supply chain management (SCM) deals three major entities, raw material procurement, scheduling of the resources like machines and employees with respect to the date of delivery of the order that is assembly line, warehouse management and product distribution. Their proposed approach used CrocodileAgent in Trading Agent Competition Supply Chain Management (TACSCM) scenario to maximize the profit. Agents are used in business process management (BPM) to reduce the administrative work and minimize the routine processes as described in [6]. The proposed a technique that is used agents to coordinate with and manage the business processes. The basic idea, they presented, was to divide the huge business processes into small tasks and each tasks is governed and managed by an agent and these agents coordinate each other in an intelligent way to carry out the business process successfully.

Agents are also vastly used in semantic web to standardize the data over the Internet and use it make intelligent decisions. The idea of semantic web is to represent the information in a standard way so that one can access and use the information in an easy way. Agent based knowledge management solution is described by Andreea DIOłTEANU and Liviu COTFAS in [7]. They proposed a new framework based on agents for knowledge management using ontologies. Agent based security solution was proposed in [8] for smart environment likes offices and homes that released the human from the routine tasks specially related to the security. Many agent based solutions to health care problems are proposed. An agent based solution is proposed in [9] that is uselful in remote patient monitoring and management in remote areas where health facilities are not availabel. The proposed approach is GPS based and used mltiple agents. A similar solution is also presented in [10], where there is a central agent loacted in some treating site, like hospital and remote agents representing the patients in some remote areas. These mobile agents communicate with the central agent through some communication device, like mobile. A hierarchical approach to patient health monitoring was proposed in [11] that used wireless sensor based mesh network [12]. Yanqing Ji et. al. used intelligent agent for postmarketing and drug safety surveillance [13]. A muliagent framewrok was proposed in [14] for remote health monitoring that used iuntelligent agents to find the symptoms remotely, to diagonise the deasise, to recommend the medication and monitor the patient in mobile environment. An agent based web

health care solution for chronic disasis was proposed in [15] that through web communicates to health care center (HCC). HCC diagonises the disease remotely and using a case based reasoning (CBR) approach based on its knowledge base (KB) suggests the medication. A remote patient monitoring (RPM) system was described in [16] that used Global System for Mobile (GSM) and Global Positioning System (GPS) technologies to monitor the patients remotely. Many other solutions to healthcare problems are also proposed like [17], [18], [19], [20] which used different latest technologies.

Quite a large number of methods have been proposed to solve the problem of Time tabling. A time tabling algorithm for school environment was proposed in [21] that used fuzzy logic to solve the problem. The solution was targeted for Italian schools. Martin Schmidt in his article [22] described a genotype-to-phenotype decoding algorithm fro time tabling problem and also compared the Genetic appraoch to Simulated Annealing approach for optimal solution on different intances of the problem. In [23], the university course scheduling problem is tackled using Evolutionary Programming (EP) that uses a stochastic optimization strategy. The same problem is addressed using tabu search algorithm in [24]. In [25], the authors proposed Genetic Algorithm based university time table solution. The authors used an appropriate encoding scheme coupled with operators to solve the problem. In [26], the author solved the problem with Genetic Algorithm (GA) and followed by the solution using Genetic Artificial Immune network (GAIN) and compared the results obtained from both showing that GAIN is able to find the final solution faster than GA. A casse based approach for time tabling and exam scheduling is described in [27] for a university environment. There are many other approches described in literature for time tabling and course scheduling problem like [28], [29], [30], [31]. A good study of various time tabling approaches is carried out in [32].

These methods are from various disciplines like artificial intelligence, operations research etc. The literature reveals that evolutionary algorithms, most notably Genetic Algorithms (GA), are used widely to solve the problem of scheduling especially time tabling. However, the existing systems (non agent based solutions) have inability to cope with the dynamic changes in the resources. Our paper focuses on the agent based solution for examination schedluling problem.

2. RESEARCH METHOD

Task scheduling problem and examination scheduling problem are two most fundamental scheduling problem in universities, especially in scenarios where there is semester system and multiple degrees are offered and students can share a course across the semesters within a degeree or across the degrees. The problem becomes more complicated when other constraints come in play, like exam slots, staff availability and preferences of the invigilators. This is an NP hard problem and most of the solutions proposed in literature are optimization approaches, that is an optimal solution is not always possible rather solution is approximated. ESP is actualy a minimization problem, where we want to schedule the examination, with all the constraints satisfied, so that the number of clashes in exam of same subject at the same time is be minimized as well as time abling problem.

Efficient solution to task scheduling probelm (TSP) is one that minimizes the number of clashes and satisfies maximum constraints. These constraints are related to the faculty, staff, courses, rooms or halls, exam slots and students. Typical timings of classes are shown in Table I and exam slots per day are shown in Table II. The constraints in TPS are categorized into two categories: hard constraints and soft constraints; explained in the follwing two subsections.

2.1. Hard TSP constraints

Hard constraints are those that must be satisfied for any solution to ESP problem. We observed the following hard constraints in our problem, ESP.

1) A teacher must not be assigned more than one exam duties on the same day and in the same exam slot. Let $D_{i,j,k}$ be:

$$D_{i,j,k} = \begin{cases} 1 \text{ if faculty member i has duty at exam slotj at exam hall k} \\ 0 \text{ if otherwise} \end{cases}$$

So, this constraint means:

$$\sum_{k=1}^{n} D_{i,j,k} \leq 1$$

2) An exam hall must not be assigned to more than one exams in a particular time slot. Let $E_{i,j,s}$ be:

$$E_{i,j,k} = \begin{cases} 1 \text{ if exam hall i for slot j is assigned to subject s} \\ 0 \text{ if otherwise} \end{cases}$$

that is

$$\sum_{k=1}^{n} E_{i,j,s} \leq$$

3) One class has maximum one exam in a day.
4) No student has more than one exam in same time slot.
5) A student can take maximum of exams in a day.
6) A staff member must not be assigned to more than one exam halls in ant exam slot.
7) Particular class must not be assigned more than one subjects in a particular time slot.
8) Number of students in any exam hall must not be more than the capacity of the hall.

Table 1. Class Time Table for a particular university

Sr.	Slot	Class Start Time	Class End Time
1	C1	8:00 am	9:30 am
2	C2	9:30 am	11:00 am
3	C3	11:00 am	12:30 pm

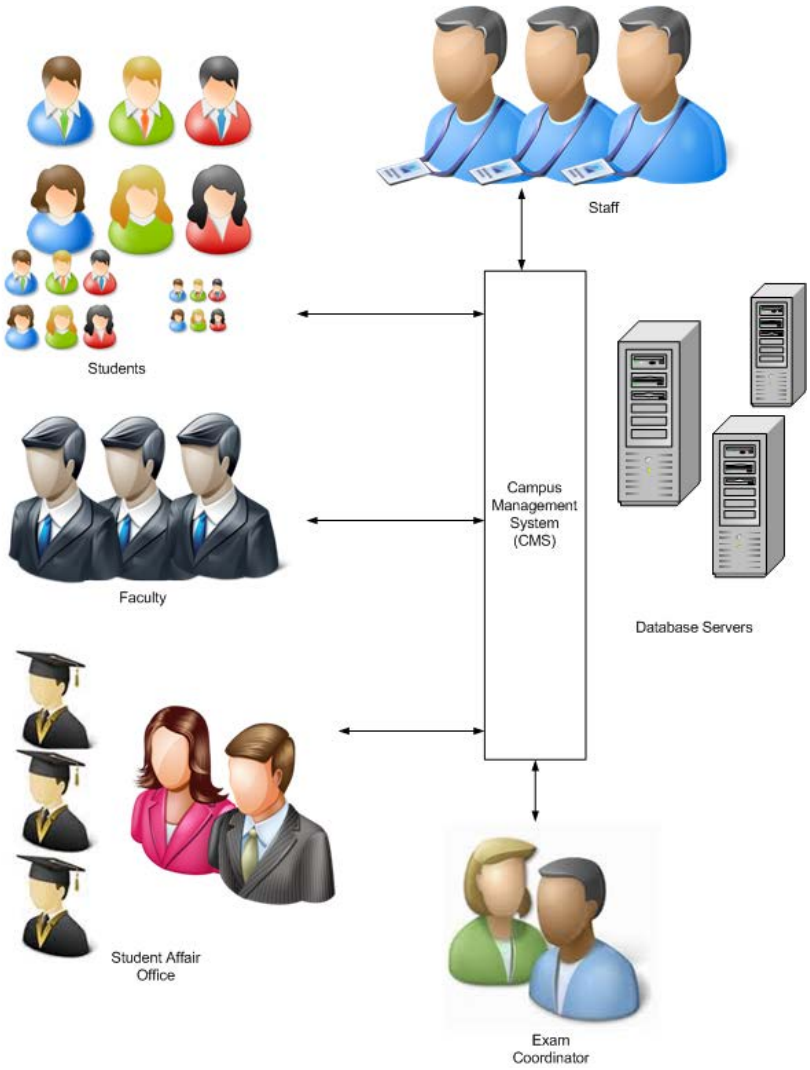

Figure 1. Architecture of task scheduling problem in university environment

Regarding the time tabling problem (TTP), the hard constraints to be taken care of the given below:

1) Particular teacher may not be assigned more than one classes in the same time slot.
2) Particular class room may not be assigned to more than one class in a particular time slot.
3) Particular class must not be assigned more than one subjects in a particular time slot.
4) Class room capacity should not be less than the maximum number of students of the class assigned that particular room.

Table 2. Exam slots in EPS for a particular university.

Sr.	Slot	Time
1	Morning	9:00 am - 11:00 am
2	Noon	12:00 pm - 2:00 pm
3	Afternoon	4:00 pm - 6:00 pm

2.2. Soft TSP constraints

Constraints that are desired to be satisfied but not necessary are soft constraints. We find the following set of soft constraints in ESP problem.

1) No faculty may have more than two exam duties in a day.
2) A faculty member having two duties in a day may have back to back duties.
3) Visiting faculty member may be given three back-toback duties if he/she has three exam duties.
4) The gap between two consective exams of a class may not be more than two days.

Soft constraints to be taken care of regarding time tabling problem (TTP) are the following:

1) Students of a particular class should not have more than three back-to-back classes of one and half hour.
2) Female faculty should not be assigned very late classes.
3) Visiting faculty may be given two back-to-back classes.
4) Permanent faculty should not have more than two classes per day.
5) Teachers should not be given long free time between the classes.

In the next subsection, we describe the architecture for the proposed system and elaborate its main entities. Functional Level Architecture for TSP Task scheduling problem in university environment involves a number of stakeholders and can be decomposed into a number of large scale modules. Figure 1 shows the architecture of the proposed system. The main components of this system are:

- **Students:** are the main actor in any system at universities and perform tasks like enrolling a course, droping a course and course withdrawl etc.
- **Exam Coordinator:** is a person in the examination department who makes the date sheet and duty roster for the faculty and other staff. He is the one who does the imporatnt job of satisfying the faculty hard and soft constraints while designing the date sheet and duty roster.
- **Student Affair Office:** is responsible for designing thetime table and handling the issues regarding students.

3. MULTI-AGENT APPRAOCH TO TSP

There are a number of agent models proposed in the litrature each with its own capabilities. Russell & Norvig [33] described five classes of agent models as briefly described below.

1) Simple reflex agents: take actions on the basis of current environment, called percept, ignoring the previous history. This is simple if condition then action system that is based on simple if then else conditions. This model is successful only when the environment is fully observable, it may go into an infinite loop otherwise.

2) Model-based reflex agents: are extentions of simple reflex agents. These agents can handle environment that is partially observable and store this information about the world in them and take choose the action againts percept on basis of percept and past history.

3) Goal-based agents: are further extention of modelbased reflax agents. These agents, based on the percept

and hsitory information try to choose an action that leads to the goal.

4) Utility-based agents: are goal based agents but the staes of the agents can be between goal states and nongoal states. That is, the desirable state can be measured by using a utility function. This is like a fuzzy logic variable, where it can be 0 or 1 or in between.

5) Learning agents: take decisions or actions not only on the current state of the world but on the history of the world and change the environment parameters with the passage of time, they actually, learn the environment.

We propose a layered architecture for task scheduling problem where the central agent is a Hybrid Agent (vertical layered agent). Figure 2 shows the proposed multi-agent architecture. The following subsections describe each layer in the architecture.

1) Data input layer: The first layer (from bottom to top) is the data input layer, where the data is given to the system. There are two types of data to data input layer; first, the legacy data like student, fculty, classes, halls and staff is provided by the Campus Management System (CMS) which in turns receives data from through the key board, mobile phones and through the web services. The second type of data is the user preferences for certain taks like examination scheduling and time tabling is given to the system preferences interface.

2) Data extraction layer: The data available in the Campus Management System is not in the form required by our proposed system. The central agent requires data in a specified formate to work on. For this purpose, the second layer, data extraction layer, extracts the relevant data from the CMS database and this refined data with the user preferences for a certain task is forwarded to the next layer to work upon.

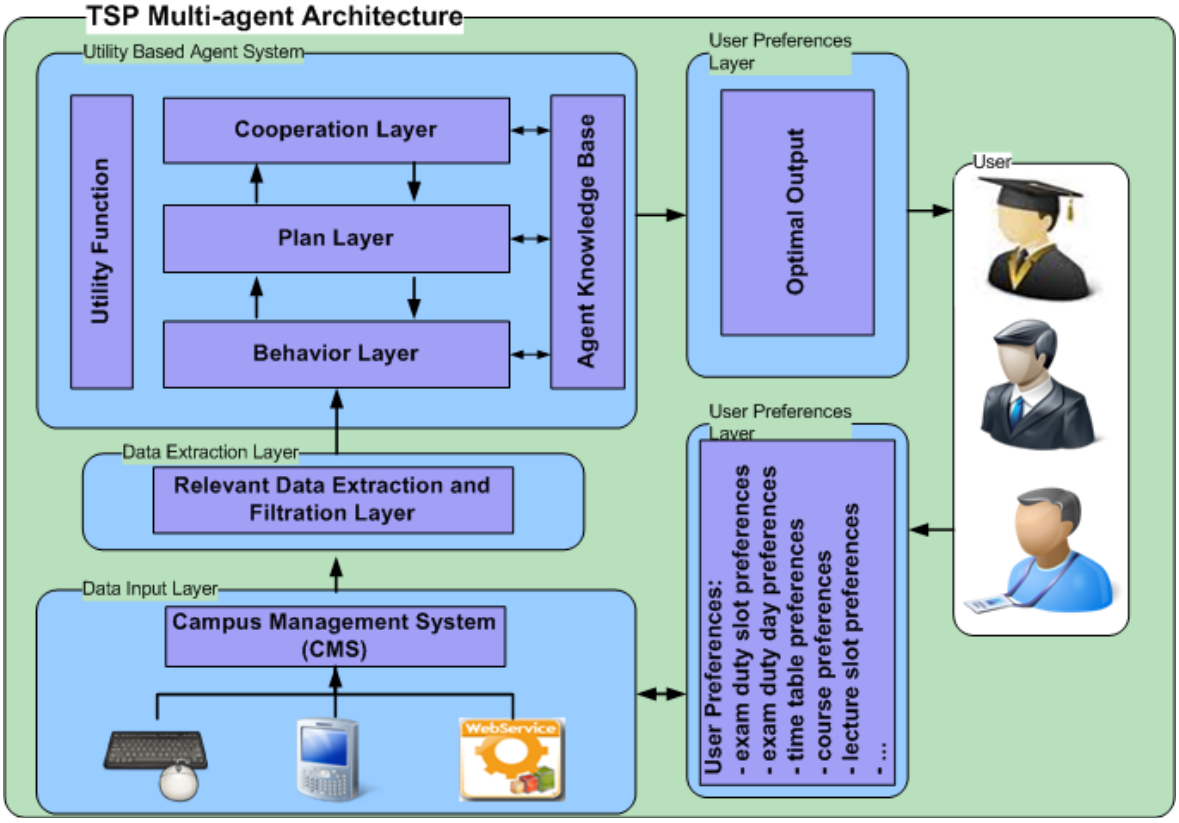

Figure 2. Proposed Utility-based agent model

3) Two-pass vertical layered hybrid agent: The extracted data relevant to a certain task is forwarded to the central agent which is a hybrid agent. There are two types of hybrid agents in the litrature; first Horizontal Layer where all the layers are copnnected to the input and each layer processes the data and proposes action(s). This architecture has a couple of disadvantges as there are actions proposed by each layer so its an

other problem to choose the correct action out of these. The second type of hybrid agents is Vertical layer, where the input data is transferred to only one layer which processes it and forwards the data and or decision to the next layer and so on until a decision with the given utility is made. There are two variants of vertical layer agent, one is one-pass vertical layer and other is two-pass. In once pass data is input to the first layer of the vertical layers, this layer processes the data and forwards it to the second layer and so on upto the last layer that produces the action list. In two-pass vertical layer architecture, the data in the first pass, is forwarded to the first layer, then second layer and so on upto the last layer. In the seond pass the action flow control passes from the last layer to the first layer in that order.

There are three layers in our proposed two-pass vertical layered hybrid agent. Each layer has its own knowledge base. First layer is behavior layer, which makes the first level decisions based on its knowledge base. The second layer is the planning layer that plans to achieve the goal. Finally, the third layer, the cooperation layer, resolves the conflicts. These layers work collectivelly in this sequence and produce an optimal action(s).

4. CONCLUSION

Task schduling is an important problem in our system like supply chain management system where scheduling is done to improve the production at minimal cost, in nuse scheduling problem where the nurses and the doctors are scheduled in different shifts in a hospital and so on. Task scheduling problems are also found in university environment like shceduling the examination and time tabling problems. This paper presented a multi agent approach to task scheduling in university environment. Based on the study of the constraints of the examination scheduling and the time tabling, an agent based solution is prposed. The proposed solution is multi agent based and agent are 3-layered two-pass vertical hybrid agents. Each of the three layers has its knowledge base and based on this processes the data and finally produce the action list.

REFERENCES

[1] Broos Maenhout and Mario Vanhoucke, "An evolutionary approach for the nurse rerostering problem," *Comput. Oper. Res.*, vol. 38, pp. 1400–1411, October 2011.

[2] T. Inoue, T. Furuhashi, H. Maeda, and M. Takaba, "A proposal of combined method of evolutionary algorithm and heuristics for nurse scheduling support system," *Industrial Electronics, IEEE Transactions on*, vol. 50, no. 5, pp. 833 – 838, oct. 2003.

[3] Broos Maenhout and Mario Vanhoucke, "An electromagnetic metaheuristic for the nurse scheduling problem," *Journal of Heuristics*, vol. 13, pp. 359–385, August 2007.

[4] Ruibin Bai, E.K. Burke, G. Kendall, Jingpeng Li, and B. McCollum, "A hybrid evolutionary approach to the nurse rostering problem," *Evolutionary Computation, IEEE Transactions on*, vol. 14, no. 4, pp. 580 –590, aug. 2010.

[5] V. Podobnik, A. Petric, and G. Jezic, "An agent-based solution for dynamic supply chain management," *Journal of Universal Computer Science*, vol. 14, no. 7, pp. 1080–1104, 2008.

[6] Pozdnakovs D. and Grundspenkis J, "An overview of the agent based systems for the business process management," *in Proceedings of International Conference on Computer Systems and Technologies CompSysTech06), 2006*, pp. II.13 –1 – II.13–6.

[7] Andreea DIOSTEANU ; Liviu Adrian COTFAS, "Agent based knowledge management solution using ontology, semantic web services and gis," *Informatica Economica Journal*, vol. 13, no. 4, pp. 90–98, 2009.

[8] Ivan Mars´a-Maestre, Miguel A. L´opez-Carmona, and Juan R. Velasco, "A hierarchical, agent-based service oriented architecture for smart environments," *Service Oriented Computing and Applications*, vol. 2, no. 4, pp. 167–185, 2008.

[9] R.M. Saleem, A. Muhammad, and A.M. Martinez-Enriquez, "Remote patient monitoring and healthcare management using multi-agent based architecture," *in Artificial Intelligence (MICAI), 2010 Ninth Mexican International Conference on, nov. 2010*, pp. 118 –123.

[10] D. Capozzi and G. Lanzola, "An agent-based architecture for home care monitoring and education of chronic patients," *in Complexity in Engineering, 2010. COMPENG '10., feb. 2010*, pp. 138 –140.

[11] K. Miller and S. Sankaranarayanan, "Role of intelligent agents and wireless body sensor mesh networks in patient health monitoring," *in INC, IMS and IDC, 2009. NCM '09. Fifth International Joint Conference on, aug. 2009*, pp. 369 –375.

[12] S. Sankaranarayanan, "Hierarchical intelligent agent based wireless body sensor mesh networks," *in Information Technology: New Generations, 2009. ITNG '09. Sixth International Conference on, april 2009*, pp. 1602 –1603.

[13] Yanqing Ji, Hao Ying, M.S. Farber, J. Yen, P. Dews, R.E. Miller, and R.M. Massanari, "A distributed, collaborative intelligent agent system approach for proactive postmarketing drug safety surveillance," *Information Technology in Biomedicine, IEEE Transactions on*, vol. 14, no. 3, pp. 826 –837, may 2010.

[14] V. Chan, P. Ray, and N. Parameswaran, "Mobile e-health monitoring: an agent-based approach," *Communications, IET*, vol. 2, no. 2, pp. 223–230, february 2008.
[15] Yupeng Zhang, M. Lee, and T.M. Gatton, "Agent-based web healthcare systems for real-time chronic disease," *in Services - I, 2009 World Conference on, july 2009*, pp. 14 –21.
[16] Mudasser F. Wyne, Vamsi K. Vitla, Praneethkar R. Raougari, and Abdul G. Syed, "Remote patient monitoring using gsm and gps technologies," *J. Comput. Small Coll.*, vol. 24, pp. 189–195, April 2009.
[17] Chung-Chih Lin, Ming-Jang Chiu, Chun-Chieh Hsiao, Ren-Guey Lee, and Yuh-Show Tsai, "Wireless health care service system for elderly with dementia," *Information Technology in Biomedicine, IEEE Transactions on*, vol. 10, no. 4, pp. 696 –704, oct. 2006.
[18] Y. Kogure, H. Matsuoka, Y. Kinouchi, and M. Akutagawa, "The development of a remote patient monitoring system using java-enabled mobile phones," *in Engineering in Medicine and Biology Society, 2005. IEEE-EMBS 2005. 27th Annual International Conference of the, jan. 2005*, pp. 2157 –2160.
[19] Pu Zhang, Y. Kogure, H. Matsuoka, M. Akutagawa, Y. Kinouchi, and Qinyu Zhang, "A remote patient monitoring system using a java-enabled 3g mobile phone," *in Engineering in Medicine and Biology Society, 2007. EMBS 2007. 29th Annual International Conference of the IEEE, aug. 2007*, pp. 3713 –3716.
[20] Wei Huang, E. El-Darzi, P. Chountas, and Peng Liu, "Agent-based models for community care systems analysis and design," *in Intelligent Systems, 2006 3rd International IEEE Conference on, sept. 2006*, pp. 278 –283.
[21] Calogero Di Stefano and Andrea Tettamanzi, "An evolutionary algorithm for solving the school time-tabling problem," *in Proceedings of the EvoWorkshops on Applications of Evolutionary Computing, London, UK, UK, 2001, pp. 452–462*, Springer-Verlag.
[22] Martin Schmidt, "Solving real-life time-tabling problems," vol. 1609, pp. 648–656, 1999, 10.1007/BFb0095154.
[23] Salwani Abdullah and Hamza Turabieh, "Generating university course timetable using genetic algorithms and local search," *in Proceedings of the 2008 Third International Conference on Convergence and Hybrid Information Technology* - Volume 01, Washington, DC, USA, 2008, pp.254–260, IEEE Computer Society.
[24] A. Hertz, "Tabu search for large scale timetabling problems," *European Journal of Operational Research*, vol. 54, no. 1, pp. 39–47, September 1991.
[25] V. Sapru, K. Reddy, and B. Sivaselvan, "Time table scheduling using genetic algorithms employing guided mutation," *in Computational Intelligence and Computing Research (ICCIC), 2010 IEEE International Conference on, dec. 2010*, pp. 1 –4.
[26] Antariksha Bhaduri, "University time table scheduling using genetic artificial immune network," *in Proceedings of the 2009 International Conference on Advances in Recent Technologies in Communication and Computing, Washington, DC, USA, 2009, ARTCOM '09*, pp. 289–292, IEEE Computer Society.
[27] Edmund K. Burke, Sanja Petrovic, and Rong Qu, "Case-based heuristic selection for timetabling problems," *J. of Scheduling*, vol. 9, pp. 115– 32, April 2006.
[28] G. Solotorevsky, E. Gudes, and A. Meisels, "Raps: a rule-based language for specifying resource allocation and time-tabling problems," *Knowledge and Data Engineering, IEEE Transactions on*, vol. 6, no. 5, pp. 681 –697, oct 1994.
[29] Michael Eley, "Ant algorithms for the exam timetabling problem," *in Proceedings of the 6th international conference on Practice and theory of automated timetabling VI, Berlin, Heidelberg, 2007, PATAT'06*, pp. 364–382, Springer-Verlag.
[30] A. Bhaduri, "University time table scheduling using genetic artificial immune network," *in Advances in Recent Technologies in Communication and Computing, 2009. ARTCom '09. International Conference on, oct. 2009*, pp. 289 –292.
[31] J. Sheung, A. Fan, and A. Tang, "Time tabling using genetic algorithm and simulated annealing," *in TENCON '93. Proceedings. Computer, Communication, Control and Power Engineering.1993 IEEE Region 10 Conference on, oct 1993*, number 0, pp. 448 –451 vol.1.
[32] A. Schaerf, "A survey of automated timetabling," *Artif. Intell. Rev.*, vol. 13, pp. 87–127, April 1999.
[33] Stuart J. Russell and Peter Norvig, *Artificial Intelligence: A Modern Approach (2nd ed.), Upper Saddle River, New Jersey: Prentice Hall*, ISBN 0-13-790395-2, 2003.