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Aleksandra Popovska Mitrovikj
Biljana Tojtovska
Kire Trivodaliev

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Aleksandra Popovska Mitrovikj
Biljana Tojtovska
Kire Trivodaliev

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Preface

This volume contains the papers presented at CIIT 2017: the 14th International Conference on Informatics and Information Technologies held on April 07-09, 2017 in Mavrovo, Macedonia. The conference was organized by the Faculty of Computer Science and Engineering (FCSE), within the Ss. Cyril and Methodius University in Skopje, Republic of Macedonia.

In the fourteenth edition, the key CIIT conference mission remained to provide an opportunity for young researchers to present their work to a wider research community, but also facilitate multidisciplinary and regional colaboration. Building on the success of the past thirteen conferences, this year conference attracted a large number of submissions resulting in presentations of 48 short and full papers. The conference was comprised of nine sessions. Traditionally, the conference included two student sessions presenting the work of the best undergraduate students, selected on the basis of their submitted projects, prepared during the previous year. The format of the conference allowed the participants to attend most of the talks that covered a diverse spectrum of research areas.

Three distinguished key note lecturers gave plenary sessions covering the different areas of the conference. Prof. Smile Markovski, retired professor at the Faculty of Computer Science and Engineering, UKIM, Skopje, gave a talk on Probabilistic Quasigroups, Vesna Prchkovska, PhD, co-founder & CSO of Mint Labs, Barcelona, Spain, gave a talk on Seeing the brain: How neuroimaging transforms the diagnosis and treatment of patients with brain disorders, and Ognjen eki, PhD, postdoc researcher at the Distributed Systems Group, Institute of Information Systems, TU Wien, gave a talk on Cyber-Human Smart Cities: The Internet of Things, People and Systems. The conference also welcomed a guest student speaker, Ana Tanevska, MSc, PhD student at the Robotics, Brain and Cognitive Sciences Unit, Istituto Italiano di Tecnologia (IIT), Italy, on the topic of Autonomous and cognitive human-robot interaction.

Part of the conference success is owed to the support received from partners and sponsors: Ss. Cyril and Methodius University, Makedonski Telekom, Nextsense, Sorsix, Software4Insurance, Macedonian Winemakers and Pivara Skopje.

All in all, this year the CIIT conference has outgrown the role of being an excellent opportunity for young researchers to present their scientific growth, to a more premier role, that is to bring researchers together for establishing collaborative links between disciplines, for testing the ground for innovative ideas and for engaging the wider academic community.

September, 2017
Skopje

Aleksandra Popovska Mitrovikj
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Agent-based solution of caregiver scheduling problem in home-care context

Aleksandra Stojanova, Natasha Stojkovikj, Mirjana Kocaleva, Saso Koceski
Faculty of Computer Science
"Goce Delcev" University
Shtip, Macedonia
{aleksandra.stojanova, natasa.maksimova, mirjana.kocaleva, saso.koceski}@ugd.edu.mk

***Abstract*—The increased number of elderly, the prolongation of life and the urge of costs reduction have changed the way of how the healthcare services are provided. Nowadays, home care service model has rising popularity. Main challenges of this model are the problems of caregivers' scheduling, their geo-routing, people management etc.**

Despite various technological advances, especially in the fields of Internet services, sensors and Internet Of Things, the problem of caregivers' scheduling is still open and demands for practical solutions. The process of the scheduling of caregivers to elderly people can be considered as Job Shop Scheduling problem, which is NP-hard for solving.

In this paper, we are making analogy of the problem to job shop scheduling problem and we propose agent-bases approach, where corresponding entities are caregivers and elderly people, and they will be represented as agents. The paper proposes a simulation for the problem based on agents using the Anylogic software

Keywords*— *agent-bases model; job shop scheduling; caregiver; elderly.

I. INTRODUCTION

The number of elderly people today is rapidly increasing. This is due to increasing average life age. Demographic aging at first, after the Second World War, was noticed at more developed countries, but nowadays this situation is typical for developing countries too.

According to estimations of the United Nations, every tenth person in the world is an elderly person over the age of 60 years. According to the same data, by 2050 is expected, every fifth person to be an old person over the age of 60 years, and in 2150, every third person to be over the age of 60 years.

The social systems in the countries make an effort helping these people and trying to answer to a larger demand, meeting the needs of elderlies.

Republic of Macedonia is not excluded in this trend of demographic aging. According to population census of 1994, the elderly population over 60 years in Macedonia is 13%, and according to the population census of 2002 elderly population is 15%, and according to population census for 2008, 16.6%. These people have their rights for normal life, but in Macedonia as a developing country, elderly people are a strong risk of poverty and socially isolated group. Therefore, Macedonia is working on National strategy to help these persons with mobile care services, social support and institutional support. However, these services are hardly available because of limited number of caregivers and nursing homes from one side and increasing number of elderly people, from the other.

In order to satisfy the needs of elderly and to provide service of appropriate care, especially healthcare, is necessary to make optimisation of service, taking into account available limited resources and number of elderly.

Therefore, we are trying to offer an optimization method to handle the increasing demand of supplying healthcare services to elderly. That means, by using the limited number of caregivers and making proper scheduling, as more as possible, elder patients to be serviced.

The main problem here is scheduling patients (elderly people) to the available caregivers. Scheduling is the allocation of shared resources over time to competing activities. Our problem is similar to a well-known job shop scheduling problem (JSSP) [1]. Therefore, we are making analogy of this problem to job shop scheduling problem. In addition, we propose new agent-bases approach, where caregivers and elderly people are corresponding entities.

II. JOB SHOP SCHEDULING PROBLEM (JSSP)

The n×m minimum-makespan general job-shop scheduling problem, referred to as the JSSP, can be described by a set of n jobs J_j, where $1 \leq j \leq n$, and each job has to be processed on a set of m machines M_r, where $1 \leq r \leq m$. Each job has a sequence of machines that must be processed. The processing of job J_j on machine M_r is called the operation O_{jr}. Operation O_{jr} requires the exclusive use of M_r for an uninterrupted duration p_{jr}, where p_{jr} is its processing time. A schedule is a set of completion times for each operation MS_{jr}, where $1 \leq j \leq n$ and $1 \leq r \leq m$ that satisfies those constraints. The time required to complete all the jobs is called the makespan *MS*. The scheduling objective is makespan minimization, which means to minimize the completion time of the last operation of any job.

This problem is not only NP-hard, but it, also, is considered as being one of the most computationally stubborn combinatorial problems.

There are different approaches and methods for solving JSSP. Brucker and Schile [1] were the first authors to describe this problem in 1990. They developed a polynomial graphical algorithm for a two-job problem. Several heuristic procedures have been developed in recent years for the JSSP. The methods in this category include dynamic programming and the branch-and-bound method, simulated annealing (SA) and genetic algorithm (GA) [2] [3]. Tabu search [4], and Particle swarm optimization problem [5] [6] are another group of metaheuristic methods used for solving the flexible job shop scheduling problem. Meta-heuristics usually take less time than algorithmic methods to find a good solution for larger problems. However, they do not guarantee optimality.

For better representation of the solution of the problem simulation-based scheduling (SBS) approaches is proposed. Discrete-event simulation is a highly effective tool for modeling complex systems, understanding their behavior over time, and discovering the impact of changes to their configuration. In [7] classical deterministic job shop operations are modelled as a discrete-event simulation model. In this paper, iterative simulation with an optimization approach for solving problem of job shop scheduling is developed. The authors use Linear Programming method for solving scheduling problem. In the simulation model, each machine in the shop is modelled as a unit resource of capacity with an infinite capacity queue in front of it and each job is modelled as an entity, associated with the sequence of machines, which has to visit, and the process time of the job on the machines. If a job arrives to find machine busy, it is placed in a queue. This is a deterministic model with exactly one entity created per job. The entity which successfully seizes the machine begins processing and the rest are put in a queue before the machine, ordered in first-come order. Once the job finishes processing at a machine it proceeds to the next machine as per its sequence. If the job finds the required machine busy, it joins the queue for that machine. Every job proceeds in this manner through the job shop until all the machines in it's sequence are visited. The simulation ends when the last job or entity completes processing at the last machine in it's sequence and the end time indicates the makespan.

In [8] the CHESS algorithm is presented. Here, a series of brief simulation "look-aheads" are used to predict the future impact of scheduling in a particular operation. This approach can be viewed as an advanced application of the dispatch heuristic, where the dispatching rule is to schedule the operation that might be a cause for the some future resource conflicts.

The experimental results of this study offer makespan performance improvements of over 20 percent as opposed to fixed heuristic algorithms. Another simulation approach similar to this is given in [9], where monitoring scheduling performance are improved and also, dynamically adjusting local dispatch parameters are added.

III. Problem Scheduling Caregivers' Services to Patients (Elderly)

Our problem can be mapped to a job shop scheduling problem, where corresponding entities are as follows: Jobs are Patients (elderly people) and Machines are Caregivers (nurses, doctors). There is some similar mapping in [10]. There, an approach for determining a tour for caregiver in a given working day is proposed. In order to optimize multiple criteria, as optimizing caregivers' tours and limiting patients' waited time between two different visits, this new approach is proposed, similar to the problem of finding routes for vehicles, to satisfy all the customers with a minimal travel time, without violating customers' time windows. Where corresponding mappings are customers - patients, vehicles -caregivers, and a warehouse -HCS.

A. Mathematical representation of the problem

Considering job shop scheduling problem, we can formulate scheduling problem of caregivers to patients. Here, scheduling problem consists of m caregivers, which need to serve n elderly people. Let $C = \{C_1, C_2, \ldots, C_m\}$ is a finite set of caregivers and $E = \{E_1, E_2, \ldots\ldots E_n\}$ is a finite set of elderlies. Let x denote the set of all sequential assignments of elderly to caregivers, such that every elderly people is served by each caregiver exactly once. The element $x \in X$, may be written as m x n matrices, in which row i lists the elderly people that caregiver C_i will serve, in order. For example, the matrix

$$x = \begin{bmatrix} 1 & 2 & 3 \\ 3 & 1 & 2 \end{bmatrix},$$

Means that caregiver C_1 will serve the three elderly people E_1, E_2, E_3, in the order E_1, E_2, E_3 while caregiver C_2 will serve the elderly people in the order E_3, E_1, E_2. Suppose also that there is some cost function MS: $X \rightarrow [0, \infty]$. The cost function, might be interpreted as a total processing time or makespan, and may have some expression in terms of time. MS_{ij}: E x $C \rightarrow [0, \infty]$ is the cost /time for caregiver C_i to serve elderly people E_j. The job-shop problem is to find an assignment of elderly people $x \in X$ such that $MS(x)$ is a minimum, that is, there is no $y \in X$ such that $MS(x) > MS(y)$.

The MIP formulation is often used to model the classical deterministic JSSP [11], i.e. to minimize total processing time MS. MIP model for our problem is as follows:

1) Parameters:

r_{ilk} has a value one, if elderly i requires task l from caregiver k , and zero otherwise.

p_{ik} is servicing time in which an elderly i has to be serviced from caregiver k.

2) Decision variables:

s_{ik} is start time of servicing an elderly i by caregiver k.

y_{ijk} has a value 1 when an elderly j precedes elderly i for caregiver k.

3) MIP model:

The goal is to minimize makespan (to obtain min MS)

$$\sum_{k-1}^{m} r_{imk}(s_{ik} + p_{ik}) \le MS \qquad i = 1,2,\ldots,n \tag{1}$$

$$\sum_{k=1}^{m} r_{ilk}(s_{ik} + p_{ik}) - \sum_{k=1}^{m} r_{i,l+1,k}s_{ik} \le 0,$$
$$i = 1,2,\ldots,m; \tag{2}$$
$$l = 1,2,\ldots,m-1;$$

$$K(1 - y_{ijk}) + s_{jk} - s_{ik} \ge p_{ik},$$
$$k = 1,2,\ldots m; 1 \le i < j \le n \tag{3}$$

$$Ky_{ijk} + s_{ik} - s_{jk} \ge p_{jk}, \quad k = 1,2,\ldots m; 1 \le i < j \le n \tag{4}$$

Constraint 1 gives the lower bound for the function *MS*. Constraint 2 ensures that the starting time of servicing an elderly *i* with task *l* + 1 is not earlier than its finish time in its predecessor, task *l*. Constraints 3 and 4 ensure that only one elderly is served from caregiver at any given time. The parameter *K* is a large number, sometimes taken as the sum of all processing times.

The MIP model yields optimum solutions for small problem instances, but it's not good model for large problem size.

IV. AGENT BASED APPROACH OF THE PROBLEM

Agent-based models (ABMs) consist of a set of elements (agents) characterized by some attributes, which interact each other through the definition of appropriate rules in a given environment. ABMs can be useful to reproduce many systems related to economics and social sciences, where the structure can be designed through a network. Through ABMs, it is possible implementing an environment with its features, forecasting and exploring its future scenarios, experimenting possible alternative decisions, setting different values for the decision variables and analyzing the effects of these changes [12].

Agents have to interact and communicate among each other. Communication capabilities include the abilities to receive and send messages. This is necessary to ensure a coordination mechanism among agents themselves, in order to prevent and avoid conflicts among agents. In the most general context, agents are both adaptive and autonomous entities who are able to assess their situation, make decisions, compete or cooperate with one another on the basis of a set of rules, and adapt future behaviors on the basis of past interactions [13].

In [14] and [15] is presented another hybrid form of solving job shop scheduling problem combining agent based modeling with heuristic methods like genetic algorithms. Here they parallelizing the genetic algorithms, using agent based modeling, to enhance the performance of these algorithms. Also in [16] Lin and Solberg, proposed an autonomous multi-agent architecture for shop floor dynamic scheduling. Their model represents jobs, resources, and parts by agents. Job agents negotiate with resource agents via a contract net.

Our agent based approach of the problem is consist of two types of agents. One group of agents are elderly people (patients) and another group of agents is caregivers (doctors, nurses). They communicate among each other in a manner that caregivers can provide different services to elderlies. This approach is applied in combination with discrete event simulations mentioned earlier.

There is a similar approach in [17] where integration of discrete event and agent-based simulation is used in order to enhance outpatient service quality in an orthopedic department.

Because we are focusing on job shop scheduling problem and making analogies to our problem, for our needs there is simulation in AnyLogic, solving JSSP problem [18]. This simulation is combinations of discrete event and agent based simulation, which exactly meets our needs.

In this simulation, because it deals with job shop scheduling problem, two types of agents are machines and jobs. Jobs are distributing on the machines and that makes communication between agents. In our case, corresponding agents are caregivers instead of machines and elderly people instead of jobs.

The user interface of the simulation is given in Fig. 1. At first, user can choose the number of caregivers, the number of elderlies and can change service time. The user also can choose which scheduling algorithm to be used in simulation.

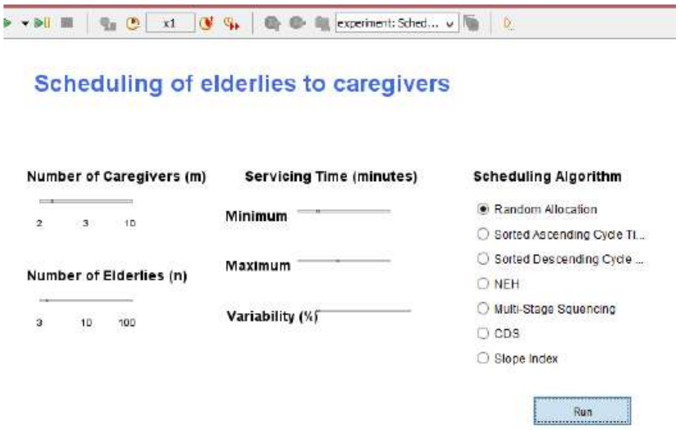

Fig.1. Part of user interface of simulation in AnyLogic.

Here is presented simulator of scheduling n elderlies and m caregivers testing different scheduling strategies. The Caregivers and Elderly people are modeled as agents and can react to changes on the planed schedule.

In Fig 2 is given a screenshot from simulation. Each caregiver is marked by red color if there is elderly in service in the moment, and is marked by green if he/she is free, which means there isn't elderly serviced by him/her in the moment. Each serviced elderly is presented in front of caregiver, in different color. Each caregiver can give service to one elderly in the moment. Simulation ends when all elderly people finished with all services. At the end of simulation, all caregivers are colored green. How much time each caregiver is busy or free can be noticed in time plot colored chart.

There is also indicators presented in the table of simulation, which changes every moment according to a current situation. There, easily can be seen how much elderlies are in service in the moment, haw much of them finished, and how much are waiting to be served. Total makespan during the whole simulation is 0 and is changed at the end of simulation, representing total time spent for all elderlies to be serviced by caregivers.

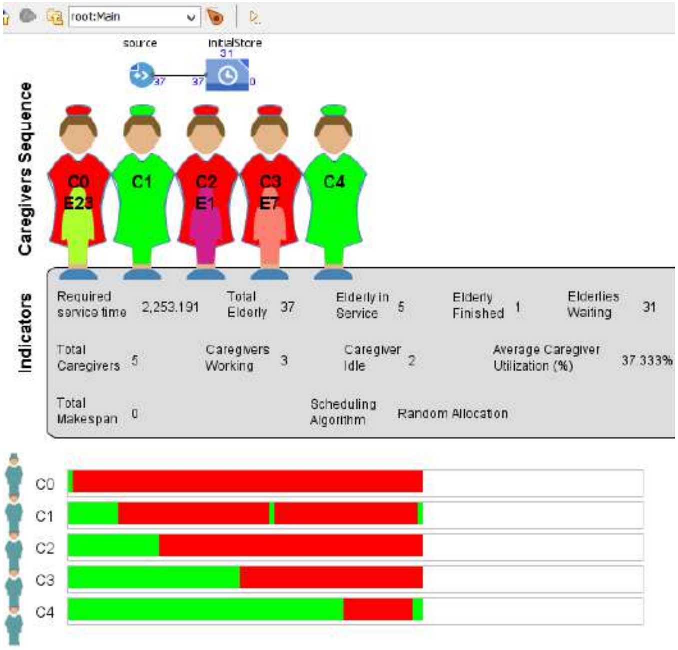

Fig. 2. Screenshot from simulation of scheduling elderlies to caregivers in AnyLogic using agent-based approach and discrete events.

V. Conclusions and Future Work

In this paper, we presented a problem of health care supply to the elderly people. Because of the limited number of caregivers and rapidly increasing number of elderly population, this problem is much more evident. Therefore, finding an optimal solution of the problem is real and necessary need. This problem has many similarities with job shop scheduling problem, therefore we focused on reviewing of different existing solutions of the problem. In addition, we are giving a new approach to the problem using agent based modeling simulation and we demonstrate simulation in AnyLogic.

This presented simulation is adaptation of simulation for job scheduling problem, according to needs of our problem. Our future work will be improving visualizations and functionalities of simulation, and making some improvements in mathematical models in order to obtain better optimization of scheduling. In addition, we are going to add priorities of services and constraints according to the real-life problem needs. We also foresee parallelization of the algorithm in order to be able to cope with large-scale environments.

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