Three metaheuristics solving a scheduling problem in a RIA environment

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Abstract. Scheduling decides how to commit resources between a variety of tasks and it is used in different areas as schools, factories, even hospitals; in surgery area of an hospital their main resources are surgery rooms and surgeries, where our objective is maximize number surgeries with respective emergency through metaheuristics like Ant Colony System, Genetic Algorithm, Memetic Algorithm; however to user is not enough the optimize resources in scheduling, also the user wish to get a fast solution and from anyplace, the option is the use of Rich Internet Applications, where the user can see his results of the surgery rooms scheduling in smartphones, tablets and laptops.

Keywords: Scheduling, Rich Internet Application, Ant Colony System, Genetic Algorithm, Memetic Algorithm.

1 Introduction

Scheduling is a process decision-making to use manufacture and services industry, bussiness, and university environment [1] [2]. Between the typical goals of scheduling problems, maximizing resource utilization is not only a measure of academic interest, but also useful and important in practice.

Job shop [3] is combination problem and this is NP-Hard problem. Actually the metaheuristics has been a good way to solve this kind of problems, as Ant Colony System (ACS), Particle Swarm Optimization (PSO), Genetic Algorithms (GA), Memetic Algorithm (MA) etc. [3] [1] [4].

Scheduling problems plays a central role in Ant System System (ACS) research, and many different types of scheduling problems have been attacked with ACS algorithms, one them is Job Scheduling [1], [5]. ACS is inspired by the trail following behavior of ant colonies. Ants, when moving along path to find food, leave along their path a chemical called pheromone as a signal for other ants to follow. Each ant build a solution, the best solutions is marked with more attenuacion from the colony to a food source. [6].

However GA have been applied successfully in many optimization problems. When applied GA to scheduling, view sequences or schedules as individuals or member of a

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population can be observed. Each individual has fitness, and each iteration best individuals survive to next iteration (generation), also commonly a individue is mutated, this way the population preserve genetic diversity, avoiding a local optimum [2].

Memetic Algorithm has many research about scheduling problem where its results are acceptable, as [7], [8], due MA worked combinatorial optimization enviroments, as GA, although GA and MA have many similar processes, MA represent a algorithm with desirable characteristics [8].

Floren Devin [9] use Rich Internet Applications (RIA) to show results from timetabling, says Rich Internet Applications (RIA) can address many users without any requirement because they are run on a web browser, also applications that RIAs' popularity owes much to their powerful presentation and interaction capabilities.

Actually at Social Security Institute by its acronym in spanish (IMSS) does scheduling of surgeries manually through a excel program, they have problems, sometimes, the surgeries are overlap in a surgery room and other surgery room isn't used at the same time. In this work, a program to scheduling the surgery, maximizing the use surgery rooms and number emergency surgeries is proposed.

The analized algorithms find an optimal solution, but this solution must be obtained as soon as posible and in any place, where the user remains. To solve this problem the RIA are used in that way that the surgeon can reach the information if a change in the schedule has occurred.

2 Scheduling of Surgeries

Scheduling is concerned with allocating limited resources to tasks to optimize the performance, such as completion time or production cost.[3]

The models studied in schedule are known as static where the activities, resources, process times are predefined, in other words this are not modified during the process. The automation of the timetable hospital in medical has a database with information about medical, surgical rooms, and patients [10] [11]. In this work, we are going to optimize the use of surgery rooms with scheduling.

To schedule the surgeries in medical unit should observe the following:

- Service hours.
- Duration of service.
- Patient's importance criterion.

It's important to say that every surgery has medical area, every medical area have it surgery hours with itself surgery rooms, time for morning service is *360 min* according to data of Instituto Mexicano del Seguro Social.

In figure 1 shows the representation elements of surgeries, where e is the medical area, C is scheduling's surgery, in this case, it is considered that all patients are equally important. The user will give to system a file with surgeries to scheduling, the structure of file cointains a id surgery, the medical area, time slot and grade emergency

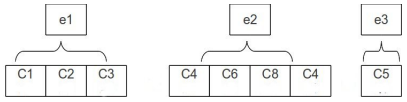

Fig. 1. Representation elements of surgeries

Formally, given *n* of independent surgeries $S = \{s_1, s_2, ..., s_n\}$, *l* surgeries rooms $G = \{g_1, g_2, ..., g_l\}$.

And each $s = \{e_i, ts_j, u_k\}$ where ts_j is time slot and u_k is emergency $u_k = \{1, 2\}$, e_i is the medical area where $e_i \in E$ being E the set of medical areas, then $E = \{e_1, e_2, ..., e_m\}$ and each e contains $\overline{r}$ an a $\overline{d}$

$$e = \{\overline{g}, \overline{d}\} \tag{1}$$

where

- $\overline{g}$ = vector assigned rooms
- $\overline{d}$ = vector assigned days
- $\overline{r} \subseteq R$
- $|\overline{r}| \leq m$
- m = number of rooms
- $|\overline{r}| \leq 7$ (days of the week)

The objective function 2 is maximize the number surgeries to schedule taking in account the emergency grade. Where the grade one is the most importance.

$$\sum_{i=0}^{n} w(ts_i) \leq \texttt{service time} \tag{2}$$

if $w = 1$
where

$$w = \begin{cases} -1 & \texttt{not scheduled} \\ 1 & \texttt{scheduled} \end{cases} \tag{3}$$

The objective function have account that really every day there are patients that should have surgery as soon as possible, and if we consider only time slot surgeries, it should not schedule surgeries with emergency grade one.

When we have more pending scheduling surgeries, the objetive function will be negative number. Also in case we have a few surgeries but with time-slot more high than scheduling surgeries maybe the objetive function will be negative too.

3 Ant Colony System

Ant Colony System (ACS) is an algorithm inspired from the foraging behavior of ant species. The ants deposit pheromone on the ground in order to mark some favorable path that should be followed by other ants.[6]

To find a solution, the surgeries are organizated, given a path, it means a sequence of task to do, then the goal is to travel greatest number surgeries, with time restriction (See figure 2).

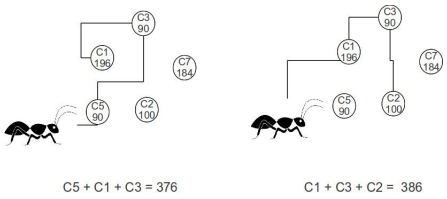

Fig. 2. Representation the ants search the solution

In Ant System each (artificial) ant is placed on a randomly chosen surgery, Setting off from its starting surgery an ant builds a complete tour by probabilistically selecting surgery to move to next until all surgeries have been visited. There are two way to select the next surgery

If *q (random number [0,1]) $\leq q_0$ (probability of exploitation)* then (see equation 4)

$$j = \arg\max_{j \in LT_k} = [\tau_{ij}]^{\alpha}[\eta_{ij}]^{\beta} \tag{4}$$

otherwise do equation 5

$$p_{ij}^{k} = \begin{cases} \frac{[\tau_{ij}]^{\alpha}[\eta_{ij}]^{\beta}}{\sum_{l \varepsilon N_i^k}[\tau_{ij}]^{\alpha}[\eta_{ij}]^{\beta}} \\ 0 \text{ otherwise} \end{cases} \tag{5}$$

where α is the constant importance pheromone, β is the constant importance distance, η is $\frac{1}{d(i,j)}$, τ the matrix of values asociate to pheromone and LT_k ant's (k) list tabu.

The value's matrix pheromones(τ_{ij}) continue preserve it concept according to [2][5], [12]; where there is more pheromone, there will are probability to better solution, however, η_{ij} changes it concept to η_i, because there aren't distance matrix ($d(i,j)$), this variable is calculate heuristic by authors as $\eta_i = \frac{1}{time-slot}$ [13].

After tour, each ant update matrix asociate to pheromone (τ). [14]. That is to say they search a local solution through the equation 6.

$$\tau(i,j) = (1-\rho)[\tau(i,j)] + \tau_0 \tag{6}$$

where ρ is constant evaporation, τ is the matrix of values asociates to pheromone and τ_0 = pheromone.
When get tour every ant, the next step is update pheromone (global search) as show in equation 7.

$$\tau(i,j) = (1-\sigma)[\tau(i,j)] + \Delta\tau_{i,j} \tag{7}$$

where σ is global search's factor, τ is a value's matrix asociate to pheromone, and $\Delta\tau_{i,j}$ is represented by equation 8.

$$\Delta\tau_{i,j} \begin{cases} \frac{1}{d_{i,j}} \text{if it is the best} \\ 0 \text{ otherwise} \end{cases} \tag{8}$$

4 Genetic Algorithm

GA are search algorithm, where main objective is find a parameter set that maximize the function 2, through the algorithm 1

Algorithm 1 Genetic Algorithm

Require: (numPopulation, totalCall, percentageElitism, percentageMutation)
1: Choose the initial population of individuals
2: **repeat**
3: Evaluate the fitness of each individual in that population
4: Do process elitism
5: Selec individuals for 3 tournament
6: Do cross of individual selected
7: Do mutation
8: Update population
9: Do process intensifier
10: Add countcall
11: **until** totalCall $\leq$ countCall

The population is represented id surgery, where it is sequence surgeries. Initial population is generated randomly, in select better individuals, ensure don't lose the the best. Through tournament selection where subgroups of individuals are chosen from larger population, possible schedule, the best of subgroup is chosen, then the parents are reproduced, the method used is annular cross where the parents do interchange of information like as figure 3. In case mutation is select a bit, a id surgery, and it is moved from its place.

During reproduction process, sometimes offspring are like as parents, then individual hasn't changes when the new individuals do reproduction process again, so solution is local optimum, then there is percentage of clones and percentage of scouts, where if

population exceed the percentage of scouts, the population get n worst individual and regenerate them (See figure 3).

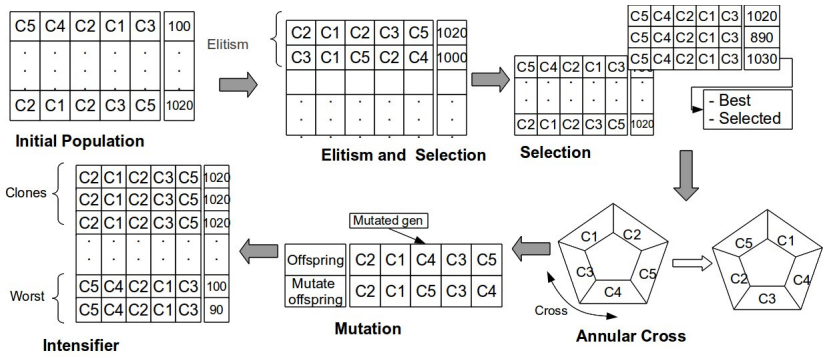

Fig. 3. Genetics algorithm's process

5 Memetic Algorithm

Dawkins in his book propound the idea called *meme* [15], which it means unit of cultural transmission or a unit of imitation. This idea, meme, was accepted and tranforming itself [8], [4].

A memetic algorithm have agent wich is each posible solution. Making a analogy in genetic algorithm is like individual. The memetic algorithm begins like as genetic algorithm (see algorithm 2), building a population of a sequences surgeries, get a subset of better population, and select agents to cross. After creating a new population, we obtain an agent to mutate, like as the mutation in section 4. Is easy to see memetic algorithm is like genetic algorithm, but it has small changes to help it, the transformation and finally the intesifier.

The transformation updates population, makes a small mutation in which a new solution can potentially replace any existing solution [4], that to say, the algorithm select a small subset of population of surgeries, make mutation moving from place an id surgery, and get a new fitness, it is compared with previous fitness to select the best between the new agent and the selected.

6 Rich Internet Applications

Interactive, dynamic interfaces are produced by Rich Internet Applications (RIAs), wich can be used like traditional desktop application, enable moving part of the computation to the client. This mean, every investigation has applications, then, the purpose is to apply the above algorithms to a hospital, were given a list of surgeries with their

Algorithm 2 Memetic Algorithm

Require: (numPopulation, totalCall, percentageElitism, percentageMutation)

```
Choose the initial population of individuals
repeat
    Evaluate the fitness of each individual in that population
    Do process elitism
    Do the method of selection call three tournament
    Do cross of individual selected
    Do mutation
    Do transformation
    Update population
    Do process intensifier
    Add countcall
until totalCall ≤ countCall
```

propieties are scheduled through ACS, GA or MA; it shows surgeries scheduled through interfaz friendly.

Interface user must be clear, that is to say, the user don't know if ACS or GA is used, but the answer must be fast and efficient. When used Rich Internet Applications, we talk about ajax. because Ajax applications can add or retrieve new data for a page it working, therefore the page will be update inmediatly.

Framework ZK is an event-driven, component-based framework to enable rich user interfaces for web applications [16]. The main mechanism of ZK is Ajax, however, the framework ZK is diferent for other frameworks because not require you to have any knowledge of JavaScript to develop Ajax-based web applications. There are three important parts in architecture framework Zk, the ZK loader, ZK AU (asynchronous update) engine, and ZK client engine (see Figure 4).

When an user make an activity (*click*), this event, "upload" for example, is bubbled up to the ZK Client Engine; ZK Client Engine decides whether and when to send the event back to the server in an Ajax request to the ZK Update Engine on the server. ZK Update Engine will invoke for handling an AU request and send a collection of commands back to the client; the ZK Client Engine evaluates each of these commands to update the widgets accordingly. Each activity is represented in figure 4

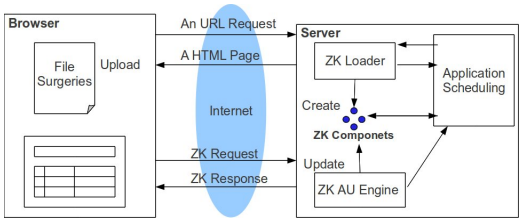

Fig. 4. Architecture of Framework ZK applied to the scheduling of surgery rooms.

7 Results

The instances used for test mentioned metaheuristics was generated initially real data from a series of surgeries done during six weeks in Instituto Mexicano del Seguro Social (IMSS), however the data showed are random continued variables by Poisson process. Those data being sorted by creating two kind of files:

.dat file : This file contains surgeries will be to schedule
.cld file : This file contains the medical area with each days and assigned surgery rooms.

The initial data for methods of ACS, GA and MA can show in table 1 where we have ten thousand function call, and diferent kind population, because each algorithm has its characteristics, strengths and weaknesses, in case ACS used few population, because if we use a lot population there aren't enought iterations to share it better local solution. In case GA and MA the mutation is least to hasn't a lot change in poputation.

Table 1. Initial data for metaheuristics Anto Colony System (ACS), Genetic Algorithm (GA), Memetic Algorithm (MA)

Item	**ACS**	**Item**	**GA**	**Item**	**MA**
Population	10	Population	50	Population	100
Function calls	10,000	Function calls	10,000	Function calls	10,000
α	5	Elitism	0.3	Elitism	0.20
β	2	Mutation	0.2	Mutation	0.01
ρ	0.9	scouts	0.4	scouts	0.10
σ	0.9				
q_0	0.5				

The table 2 show the results according objetive function, where we can observe, six intances was evaluated with ACS, GA and MA, a standart desviation mixed because in case instance textit1-5 ACS and MA show less dispersion than GA, however in case instance *6* ACS shows less dispersion than MA, a low standard deviation indicates that the data points tend to be very close to the mean, then we try to find algorithms that show results acceptables with standard deviation low.

Table 2. Instances results of metaheuristics ACS and GA

Instance	**Median**			**Standar Deviation**			**Best**		
-	**ACS**	**GA**	**MA**	**ACS**	**GA**	**MA**	**ACS**	**GA**	**MA**
1	10,136.01	9,542.82	9,414.91	287.40	346.15	184.34	10,629.50	10,126.75	9,834.50
2	3,300.00	-667.50	-1,342.50	119.21	310.81	290.62	3,420.00	-255.00	-1,800.00
3	17,100.00	17,820.00	17,520.00	310.42	345.24	173.95	17,580.00	18,375.00	17,280.00
4	14,295.00	14,857.50	14,505.00	280.37	236.88	177.63	14,805.00	15,195.00	14,250.00
5	12,450.00	12,375.00	12,195.00	179.00	404.00	236.09	12,810.00	13,365.00	11,700.00
6	15,225.00	16,785.00	16,230.00	439.95	330.23	296.77	15,810.00	17,460.00	15,630.00

The test instances selected have a set of medical areas, surgeries, times. this items are organized through the metaheuristics before mentioned obtained finally the table 3, it shows total number surgeries has each instance, and the median of surgeries scheduled; it should be emphasized every surgery is different size, therefore in time t is possible to have two surgeries inside this time t or only surgery inside this time t.

Table 3. Median of surgeries scheduled

Instance	ACS	GA	MA	Total
1	106.5	106	105	158
2	61	69	67	144
3	116	122	118.5	151
4	118.5	121	112.5	162
5	117	121.5	118.5	175
6	137	142	133	187

The user need know when the patient will be make the surgery, then the Rich Internet Applications begins to work, the next figure show a result after run anything metaheuritics before cited.

In figure 5 the results of the RIA and application of the algorithms are showed, the first combobox is medical area, and two buttons to upload or schedule but it doesn't show which algorithm is used, because this process is clear for user, then the user get a viable solution, and fast answer, recharge only the table when is changed the medical area.

When the user touch the button *calendarizar* the datas are collected, and send to metaheuristics, the user doesn't know the algorithm used, but he wait a valid response, surgeries with it day and surgery room appropiate with a scheduling that optimize the surgery rooms. Then the user can see the id surgery when and where will be. In case *N/A* means unallocated, there isn't surgery rooms available.

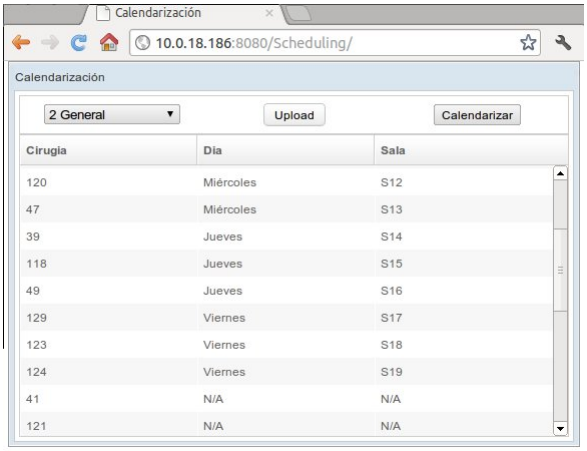

Fig. 5. GUI of scheduling for user

8 Conclusion

The scheduling of surgeries can reduce the effort of scheduling surgeries and avoid overlapping them, besides that can be optimize the resources available to the hospital, because it reduces dead-time, so adding the easy access to schedule representing the surgery.

The objetive function presents maximize the time, however sometimes the fitness is different but the result is the same, the best solution is just as equals as the worst solution, but both solutions are differents itself, because each solution has a sequence different.

Ant Colony Optimization has presented acceptable results to solution, because this algorithm build a solution itself. Additionally other advantage is to use resouces computer during it execution, because Ant Colony Optimization is provided to use threads, take some resorces togther.

However Genetic Algorithm is a algorithm make to combinatorial problems, because their results are viables how solution to problem of scheduling, also, GA is easy to understand and transfer for his simulation.

Both algorithms were comparated, however their performace was similar, through Wilcoxons Signed Sum Ranking Test can see there isn't enough statistical evidence to say which has a better performance.

On the other hand Memetic Algorithm has had a good performance, but comparing through Wilcoxons Signed Sum Ranking Test, is possible to observe that the Genetic Algorithm have a better performance than Memetic Algorithm, however comparing ACS with MA, we can observe that there isn't enough statistical evidence to say which has a better performance.

Moreover, the RIA is a good tool to show result to the user, because is better responsiveness and information flow, it has better interactivity than the tradidional web pages also this system can be seen online from any smartphone in any place.

How future job is to compare with other algorithms. To make a most appropiate interface with their respective data base. On the other hand generate new instances that cause stress in this algorithms.

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