Indian Journal of Science and Technology, Vol 9(21), DOI: 10.17485/ijst/2016/v9i21/85379, June 2016
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Comparison of Genetic Algorithm with Particle Swarm Optimisation, Ant Colony Optimisation and Tabu Search based on University Course Scheduling System

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Abstract

Objectives: Planning and allocation of the various resources according to the constraints is a hilarious task. The paper aims to find a suitable method to solve the university course scheduling problem. **Methods and Statistical Analysis:** This paper compares the usage of Particle Swarm Optimisation (PSO), Ant Colony Optimisation (ACO), Tabu Search and Genetic Algorithm (GA) in the preparation of University Course Scheduling System. Certain hard constraints, which has to be satisfied and some soft constraints that can be satisfied are considered. **Findings:** The algorithm should check for the satisfaction of the hard constraints and the possibility of satisfying the soft constraints. **Application/Improvements:** The performance of the suitable method is found by comparing with the other methods based on various parameters.

Keywords: Ant Colony Optimisation, Genetic Algorithm, Hard Constraint, Particle Swarm Optimisation, Soft Constraint, Tabu Search

1. Introduction

By the epoch of globalization, the need of in sequence expertise in an organisation is growing very rapidly[1].

Various study in University Course Scheduling used different techniques to solve it. Course scheduling process is carried out for a month or two with the increasing complexity of hard and soft constraints. It is an optimisation problem faced by all universities and colleges irrespective of their size. Different research is going on in this wide area like PATAT, ITC, etc. The study was conducted to produce an optimal schedule within less time, to overcome the hard and to some level soft constraints. The results of this study could provide a stepping stone to the development of Genetic Algorithm in various fields.

2. Literature Review

University Course scheduling has been done manually, by the human intelligence, as it changes to the era of intelligent systems. Different organisations use different methodologies with different set of hard constraints and soft constraints. Various approaches are given by different people to approach the University Course Scheduling problem. They can be:

3. Genetic Algorithm (GA)

It is popular in all places for its intuitiveness, experimentation, easiness and the capability to crack high nonlinear, optimization problems, typically hard mechanical cases.

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John Holland invented Genetic Algorithm in 1970s from Michigan University. It is motivated with the philosophy of inheritance and imbibes the reproduction behaviour of ecological process. It uses "survival of the fittest" in its investigation process to select and generate chromosomes that are adapted to the environment. Number of generations, enviable constraints will be evolved and remain in the iteration of the population over chromosomes with weaker characteristics. It is generally used to solve complex optimization problem as it can handle both detached and incessant variable, and nonlinear objective and constraint function without requiring the minute information.

Simple genetic algorithm is given by:

Generate the population randomly
By using the fitness function, select parents
Apply crossover on the parent chromosomes
Mutate the offspring chromosomes
Append the offspring to the pool
Perform Elitism
(Select parents)

The strength of GA is in the analogous investigation. Even the weak solutions can be part of the future candidate solutions. GA operators like selection, mutation and crossover are used for the successful search. Crossover is the chief GA operator, where mutation is used less commonly[2].

4. Particle Swarm Optimisation (PSO)

PSO, a heuristic search technique is inspired from the collaboration behaviour of biological population or collective intelligence in biological population. PSO is similar to GA as they are evolutionary in nature and population based methods[3].

The basic set of steps of PSO is given by:

- The swarm is initialise from the solution space
- The fitness value of the individual particles is estimated
- Modify gbest, pbest and velocity
- Individual particles are moved to a new position
- Goto Step 2, and repeat till the agreement or a stopping condition is satisfied

PSO compared with GA, the in sequence partaking method in PSO is significantly dissimilar. In GA, Chromosome shares in sequence with each other. The whole population goes like a group toward the optimal area. In PSO, only gbest gives out the information to others. It is a one way information sharing mechanism. The evolution only looks for the best solution. Unlike GA, all the particles tend to converge to the best solution quickly even in the local version.

All the evolutionary techniques begins with a set of random solution generated, all use a fitness value to estimate the population. They will update the population and search the optimum solution with the help of random techniques[4].

The main dissimilarity within the other evolutionary techniques is that, it does not have Genetic operators, such as mutation, crossover and selection. Particles update themselves with the internal velocity; and the memory which is imperative to the algorithm. The procedure followed to share the information is different in PSO. In EC, information is shared between the chromosomes, as the whole population moves towards an optimal area. Here the information is given to others by the best particle, which is a one-way of information sharing mechanism; but the result should be a best solution compared to others. Compared with ECs, all the particles tend to converge to the best solution quickly even in the local version[4]. The PSO has only a few parameters to adjust.

5. Ant Colony Optimisation (ACO)

It is a population based general search technique which is used for difficult combinatorial problem, which is inspired by the pheromone trial laying behaviour of real ant colonies. The ants, which are the search agents, search for a good solution to a given optimisation problem[4]. The problem finds the best solution by moving on a weighted graph[5]. The solution development process is stochastic and is biased by a pheromone model, which is a set of parameters associated with graph components whose values can be modified at runtime by the ants.

The basic steps in ACO are:

- Represent the development of the solution by a construction graph
- The parameters are initialised
- From, each ant's random walk, a random solution is generated

- Update pheromone intensities
- Goto step 3, and repeat until stopping condition is satisfied

6. Tabu Search (TS)

It is a kind of heuristic search and iterative method for solving optimisation problems[6]. It uses memory structures to guide a hill-descending heuristic to continue exploration. This technique was proposed by [**7**] and [**8**].

The General framework of TS algorithm is given as follows:

```
1 s ← s0
2 sBest ← s
3 tabuList ← []
4 while (not stoppingCondition())
5 candidateList ← []
6 bestCandidate ← null
7 for (sCandidate in sNeighborhood)
8 if ( (not tabuList.contains(sCandidate)) and
(fitness(sCandidate) > fitness(bestCandidate)) )
 9 bestCandidate ← sCandidate
10 end
11 end
12 s ← bestCandidate
13 if (fitness(bestCandidate) > fitness(sBest))
14 sBest ← bestCandidate
15 end
16 tabuList.push(bestCandidate);
17 if (tabuList.size > maxTabuSize)
18 tabuList.removeFirst()
19 end
20 end
21 return sBest
```

The main benefit of TS over other methods is the ability of the memory to prevent searching the previously seen areas. It can easily leave the local optimum and attain the global optimum in a shorter time.

6. Methodology

This paper goes through four different methods like GA, TS, ACO, PSA for solving the University Course Scheduling System. The case study of the department of Computer Science, Christ University, was taken into consideration. The process of Scheduling is done in the department yearly twice during the beginning of the semester for the programmes. Strategies used for designing the solution includes PSO, ACO, TS and GA to satisfy the hard constraints and to some level the soft constraints. Based on the above said methods, University course schedule is prepared to solve the timetabling issues in the department.

7. Results

The information is populated from the core committee of the department, who are responsible to prepare the schedule. Christ University, Department of Computer Science has 5 programmes spread across various semesters. The data consist of the course details with the respective hard constraints, room allotments, faculty member's availability, Lab availability and other activities of the University at prescribed time span.

8. Hard Constraints

The schedule is feasible if and only if the following hard constraints are satisfied:

- At a point of time, the student, faculty, resources should be utilised by a single occurrence.
- Only the available classrooms, faculty and resources should be utilised at a point of time.
- Strict time restrictions on the starting time, ending time, Lunch time should be followed.
- Theory and practical class schedule should not be overlapped.
- Lab sessions have to run on two parallel timeslots.
- Class timings are 9 am to 4 pm on all days except Saturday while Saturday with 9 am to 1 pm and a break of one slot (1 pm to 2 pm) for lunch on all days.

9. Soft Constraints

The soft constraints that can be satisfied are:

- A timeslot gap can be there for a faculty between the classes.
- Courses are to be spread over throughout the week.

- Theory classes of a program can be scheduled in the same room.
- First hour classes to be evenly distributed to different course faculty of the same class.
- Only once, a course can be permitted for a programme in a day.

10. Experiment

In PSO, it uses a single population of 10 particles, to hold the iteration of the scheduling problems. Each particle that contains the index allocated to the course is concerned with a number of available iterations. The majority of the particle will have a number of iterations. Each particle will have a position that will be arbitrarily arranged in the search space for scheduling problem. This particle also has a random velocity specified initially.

In GA, it uses a population of 43 instances of chromosomes with the time slot as the existing number of transactions. Gene on chromosome initialization finds the random result for generated. The number of generations needed by the system is determined by the number of iterations used. Reproduction operation uses the mutation, crossover and the inversion operations.

Crossover operations are performed by crossing the first gene of parent chromosome and combine it with the genes of the second parent chromosome. The location of the gene from both chromosome and gene number is also considered for randomization. Crossover is performed so that the operation will not be the repeated for each chromosome.

Mutation operation is performed by altering some of the genes to parent chromosome, which evolves as the new generation that may be behaving differently than the parent. It is done to do some reordering of the gene.

Inversion operation is performed by rearranging the parent chromosome gene sequence to produce a new iteration. It is iterated by deciding the locations of the two genes selected randomly.

In TS, similar representation as GA is used to encode the schedule. The solution generated is optimised and the best solution is taken. Randomly pick two solutions and mutate them by exchanging their schedules. The optimised solutions are selected to test the tabu restrictions and aspiration criteria. They are stored in the tabu memory, if they meet the above test. The advantage of tabu search is the memory.

11. Evaluation

On the whole, the ability of the scheduling problem is done by the fitness function that adds the violations of all constraints by testing it with the course schedule. Each constraint has an associated weight or penalty defined[9].
The specific experiment on course scheduling denotes that the GA is an appropriate technique to be used for this. GA produces several different near optimal solutions. It also generates a whole new generations of the chromosomes, which may not originate from the same parents.

12. Conclusion

Based on the survey and comparison, the amount of penalty obtained by the GA method is much negligible than other methods on some iterations. The paper compared the working of ACO, PSO, TS and GA and found that GA is the most appropriate method for the University Course Scheduling system.

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