Solving Job Shop Scheduling problem using multiple meta heuristic algorithms (Ant colony optimization, Tabu search, Genetic Algorithm)

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1. Introduction

In this project, we aim to address the **Job Shop Scheduling problem (JSSP)** using multiple meta-heuristic algorithms, specifically Ant Colony Optimization, Tabu Search, and Genetic Algorithm. The Job Shop Scheduling problem holds great significance in the fields of operations research and production planning, as it plays a vital role in optimizing the allocation of machines to tasks in manufacturing processes. The computational complexity of such problems is predominantly NP-hard.

This project is relevant to Search-Based Software Engineering (SBSE) and Software Modeling and Testing (SMT/SAT) solvers for Software Testing (ST) or Software Engineering (SE) as it demonstrates the applicability of advanced optimization techniques to real-world scheduling problems, which can be applied in various domains.

We will analyze the performance, time complexity, and space complexity of these three different algorithms to determine the most optimized search algorithm for the target problem.

2. Related Work

Our project is built upon key papers in the field of meta-heuristics for job shop scheduling. Notable works include [1] which presents a comprehensive review of Cuckoo Search Algorithm for job shop scheduling. Another relevant paper [2] proposes a hybrid approach that combines GA with Tabu Search for solving job shop scheduling problems. Our project extends by applying the ACO algorithm, GA with Tabu Search and combines the approaches mentioned in these papers to address the problem more comprehensively.

3. Research Questions

Our research questions are as follows:

1. What is the research goal?
   - Understanding the working of the chosen meta-heuristic algorithms (Ant Colony Optimization, Tabu Search, and Genetic Algorithm will) on the selected Dataset and compare their results to identify which algorithm is the most suitable for this specific scheduling challenge.
   - We also aim to understand the similarities between them.

2. Can a hybrid approach that combines these meta-heuristic algorithms improve the quality of solutions and convergence speed?
   - Combining these meta-heuristic algorithms into a hybrid approach has the potential to improve the quality of solutions and the convergence speed. This will enhance the overall efficiency of solving the Job Shop Scheduling problem.

4. Data Set and Replication plan (if your project is about replication or if you plan to use any existing or new data sets)

We plan to use publicly available benchmark data sets for the Job Shop Scheduling problem. These data sets are widely used in literature and will ensure the replicability of our results.

SOURCE: http://mistic.heig-vd.ch/taillard/problemes.dir/ordonnancement.dir/ordonnancement.html

The much-detailed information/explanation about the selected data set will be updated towards the end of final reporting.

5. Overview

In the context of metaheuristic algorithms like Ant Colony Optimization (ACO), Tabu Search, and Genetic Algorithms (GAs) applied to the Job Shop Scheduling Problem, the fitness function is a crucial component that measures the quality of a particular solution or schedule. The goal of these algorithms is to optimize the scheduling of jobs on machines to minimize certain objective criteria. The fitness function quantifies how well a solution performs with respect to these criteria.

For the Job Shop Scheduling Problem, the common objective is to minimize one or more of the following criteria:

- **Makespan**: This is the total time required to complete all jobs. The fitness function could be defined as the makespan, where shorter makespans represent better schedules.
- **Total Flow Time**: The total time that all jobs spend in the system, which includes the waiting time and processing time. The fitness function could aim to minimize this total flow time.
- **Total Completion Time**: The sum of completion times for all jobs. A good schedule minimizes this value.
- **Maximum Lateness**: The maximum amount by which a job finishes late. The fitness function can aim to minimize the maximum lateness.

The choice of fitness function is a critical aspect of adapting these metaheuristic algorithms to solve the Job Shop Scheduling Problem effectively.

6. Analysis or implementation Procedure

To answer our research questions, we will follow these steps:

Step1: Implement Ant Colony Optimization, Tabu Search, and Genetic Algorithm for the Job Shop Scheduling problem.
Step2: Configure and fine-tune the algorithms using a set of parameters. (Detailed explanation on parameters will be provided in final report).
Step3: Apply the algorithms to benchmark data instances.
Step4: Evaluate the solutions in terms of makespan, solution quality, and convergence speed.
Step5: Develop a hybrid algorithm by combining the best-performing components.
Step6: Conduct experiments to compare the hybrid approach with individual algorithms.
Step7: Analyze the results and draw conclusions regarding the effectiveness of each algorithm and the hybrid approach.

7. Teamwork Plan (applies only to teams)

This project is conducted by a team of two individuals. The work will be divided as follows:

Ahmed: Responsible for implementing and fine-tuning Ant Colony Optimization.
Aishwarya: Responsible for implementing and fine-tuning Tabu Search and Genetic Algorithm.

Both team members will collaborate on the analysis, experiments, and report writing.

References

[1] Aziz Ouaarab, Bela¨ıd Ahiod, Xin-She Yang, Mohammed Abbad, “Discrete Cuckoo Search Algorithm for Job Shop Scheduling Problem”, 2014 IEEE International Symposium on Intelligent Control (ISIC).

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[3] Mohamed Ahmed Awad, Hend Mohamed Abd-Elaziz, “An Efficient Modified Genetic Algorithm for Integrated Process Planning-Job Scheduling”, 2021 International Mobile, Intelligent, and Ubiquitous Computing Conference (MIUCC).

[4] Matrenin P.V., Manusov V.Z., “The Cyclic Job-Shop Scheduling Problem, The New Subclass of the Job-Shop Problem and Applying the Simulated Annealing to Solve It”, 2016 2nd International Conference on Industrial Engineering, Applications and Manufacturing (ICIEAM).