Using MIP to Solve Military Plane Relocation And Developing a new Algorithm

Ishika Bansal
Chemical Engineering
Indian Institute of Technology, Guwahati
Guwahati, Assam
b.ishika@iitg.ac.in

Samiran Doley
Chemical Engineering
Indian Institute of Technology, Guwahati
Guwahati, Assam
d.samiran@iitg.ac.in

Abstract—**In this paper, we will solve a production planning problem with a new algorithm that is made by the combination of Differential Evolution and Teaching Learning Based Optimization Algorithms. We will also solve a Relocation Analysis problem with the help of mathematical Techniques.**

Index Terms- Optimization, Metaheuristic Techniques, Differential Evolution, Teaching Learning Based Optimization Algorithms, mathematical Technique

I. INTRODUCTION

Problem statement

The term "supply chain management" gained popularity in the middle of the 1990s, yet it is still unclear what it means. In contrast, supply chain management is viewed by the majority of academics and professionals as a broad word that encompasses a variety of activities, such as but not limited to production, warehousing, and transportation, as well as supplier relationship management and inventory management. One such instance would be the reassignment of automobiles among a number of places while utilising optimisation to reduce the cost of reassignment.

Hybrid algorithm

Using combinations of optimization algorithms can be highly advantageous for solving complex optimization problems. By leveraging the strengths of different algorithms, such as improved solution quality, faster convergence, increased robustness, flexibility, and scalability, a combination approach can help achieve better optimization results. Combining algorithms can also allow for better problem-specific adaptation and can mitigate the limitations of individual algorithms.

II. DISCUSSION

Problem statement

Imagine that we installed a mechanism for automatically reassigning vehicles. There are currently a lot of aspects that need to be taken into account when solving this challenge. The distance between the sites we are going to reassign to, the demand at that location, and the number of cars already allocated at that location are just a few of the elements we must take into account. Reassigning can be done while trying to keep the expense of assigning to a minimum. Metaheuristic approaches and built-in mathematical models can thus be used to achieve the aforementioned objectives.

Hybrid algorithm

Combinations of DE and TLBO produced the best results among the available algorithms that we examined. We suggest a hybrid algorithm that combines the differential evolution mutation method and the teaching-learning-based optimization algorithm in order to incorporate the advantages of both algorithms. The method effectively explores the search space and converges to the global optimum because it combines the exploration capability of the differential evolution mutation strategy with the exploitation capability of the teaching-learning-based optimization algorithm. We will use the Production Planning Problem to test our new method.

III. PROBLEM STATEMENT

There is a set of military bases in a country, and each base consists of a number of fighter planes for their protection, at the end of each time period an intelligence survey is done specifying the risk of attack in particular bases and the number or fighter planes required in the base are estimated, and it is decided whether any of the planes need to be reassigned. There is a transportation cost associated with reassigning a plane to a different base. Therefore, the military wants to determine the minimum cost of assignment of fighter planes to bases to satisfy the next period of projected demand for each base.

As an example, consider a fighter plane provider with 5 locations in the Midwest. The military evaluates the need to relocate fighter planes based on the monthly projected demand for each location. The cost of reassigning Fighter planes from site i to site j is $10 per unit distance from the site (i) to site (j).

Input Data

- location: This will require information on the distance between locations where planes are assigned. Note if the number of locations is n then there should be an n*n number of elements in the distance matrix.
- projected demand: the demand for Fighter planes in each site
- units currently assigned: the current number of Fighter planes in each site

- A example of the input is given below.

location	Project demand	currently assigned
1	7	6
2	3	2
3	2	3
4	4	3
5	2	4

Distance matrix	1	2	3	4	5
1	0	16.4012	38.2753	26.4764	34.4384
2	16.4012	0	26	19.8494	30.8058
3	38.2753	26	0	43.0116	54.0833
4	26.4764	19.8494	43.0116	0	11.1803
5	34.4384	30.8058	54.0833	11.1803	0

IV. SOLVING THE MATHEMATICAL FORMULATION

Given the set of locations, the pairwise distances between locations, the number of Fighter planes currently assigned to each location, the projected demand for each location, and the cost per kilometer, the objective of the Military Planes Reassignment Problem is to determine a minimum cost set of reassignments to satisfy projected demand. The problem can be formulated as a linear programming problem because the objective function and the constraints are all linear functions.

MIP formulation on the problem statement

Mixed integer programming is referred to as MIP. A linear objective function must be minimized or maximised while taking into account a number of linear constraints, and some of the variables must only accept integer values. When these integer variables can only accept the values 0 or 1, they are referred to as binary variables. When they can take any integer value within a specified range, they are referred to as general integer variables.

A mathematical technique called MIP (Mixed Integer Programming) is used to tackle problems when some of the variables can only accept integer values. The Military Planes Reassignment Problem can be solved using MIP to determine the lowest cost set of reassignments that would meet the anticipated demand while also accounting for the cost of transportation and the current number of Fighter planes currently stationed at each location.

To solve the problem using MIP, we first need to define the decision variables. Let xi,j be a integer variable. Then, the objective function can be defined as the total cost of reassignments, which is the sum of the transportation costs for each reassignment:

$$\text{minimize } Z = \sum i \in L \ \sum j \in L \ c \times distij \times xi,j$$

The constraints can be formulated as follows:

Case 1: the total demand number of helicopters is larger than the total number of current assigned helicopters:

When this is the case, the flow balance constraint will be:

$$\sum j \in L \ xji+si>=di+\sum j \in Lxij, \forall i \in L$$

Case 2: the total demand number of helicopters is smaller than or equal to the total number of current assigned helicopters.

When this is the case, the flow balance constraint will be:

$$\sum j \in L \ x+si<=di+\sum j \in Lxij, \forall i \in L$$

V. NEW ALGORITHM DISCUSSION

TLBO

In 2011, Rao and Savsani proposed the Teaching Learning Based Optimization (TLBO) metaheuristic optimization method. The teaching and learning process in a classroom, where a teacher guides students to support their learning, served as the model for the algorithm.

The fundamental principle of TLBO is to enhance solutions by simulating the teaching and learning process using a population of candidate solutions. The following steps make up the algorithm:

Initialization: Produce a starting population of potential answers.

Evaluation: Assess the appropriateness of each potential option.

Phase of the teacher: Choose the best solution from the group and help the pupils develop their own solutions based on it. By offering suggestions on how to enhance the solutions, the teacher aids the pupils in learning..

Xnew = X + r*(Xteacher – TF*Xmean)

Learner phase: Every student gets the chance to benefit from the knowledge of their other classmates. Each student is randomly partnered with another student during this phase, and they share ideas to enhance their solutions.

If(F < Fpartner)
Xnew = X + r*(X – Xpartner)
Else
Xnew = X – r*(X – Xpartner)

Update the population with the new potential solutions after the teacher and student phases.

Termination: Continue performing steps 2 through 5 until a stopping requirement is satisfied, such as a set number of iterations or a successful conclusion.

A population-based metaheuristic that can be applied to a variety of optimization issues is the TLBO algorithm. It has been proven to be successful in locating excellent solutions for a variety of situations in the actual world. However, TLBO's efficiency is influenced by the particular problem and its parameters, just like any optimization technique.

Differential evolution

Storn and Price first presented Differential Evolution (DE), a well-liked metaheuristic optimization approach, in 1997. DE is a population-based algorithm that generates and assesses a set of potential solutions in order to find the best one for a particular optimization issue.
The basic steps of the DE algorithm are as follows:

Initialization: Produce a starting population of potential answers.

Mutation: Using a mutation method, randomly disturb the present population to produce a new set of potential solutions. By adding a weighted difference between two candidate solutions that were chosen at random to a third candidate solution, the mutation technique generates a new candidate solution.

Crossover: To create a new population of potential solutions, perform a crossover operation between the existing population and the mutant population. Using the crossover operation, it is decided whether to preserve the values from the original population or swap them out for the equivalent values from the mutant population.

Selection: To create the next generation of candidate solutions, choose the top candidates from the existing and incoming populations.

Termination: Continue performing steps 2-4 until a stopping requirement is satisfied, such as a set number of iterations or a successful conclusion.

DE has been effectively used to solve a variety of optimisation issues because to its famed simplicity and durability. The handling of noisy and non-differentiable objective functions is one of DE's strengths, making it particularly helpful in engineering and scientific applications.

$$V = X_{r_1} + F\left(X_{r_2} - X_{r_3}\right)$$

$$u^j = \begin{cases} v^j & \text{if } r \le p_c \text{ or } j = \delta \\ x^j & \text{if } r > p_c \text{ and } j \ne \delta \end{cases}$$

$$\left.\begin{array}{l} X_i = U_i \\ f_i = f_{U_i} \end{array}\right\} \text{if } f_{U_i} < f_i$$

New Algorithm

Combining Differential Evolution (DE) and Teaching-Learning Based Optimization (TLBO) can be a powerful way to solve optimization problems. Here's one possible algorithm that combines the two methods:

Initialize the population with random solutions.
Evaluate the objective function for each solution in the population.
While the stopping criterion is not met:
a. Sort the population in ascending order based on their fitness values.
b. Calculate the best and the worst solutions in the population.
c. Calculate the teaching vector using TLBO.
d. For each solution in the population, perform DE:
i. Select three random solutions from the population, different from the current solution.
ii. Generate a mutant vector using the differential mutation operator.
iii. Crossover the current solution with the mutant vector to create a trial vector.
iv. If the trial vector has better fitness than the current solution, replace it.
e. Calculate the learner vector using TLBO.

f. Evaluate the objective function for each solution in the population.
Return the best solution found.
In this algorithm, TLBO is used to calculate the teaching vector, which is then used in DE to guide the search toward

promising regions of the search space. The mutation and crossover operators of DE are used to explore the search space and escape from local optima. The population is sorted in ascending order based on their fitness values, which makes it easier to calculate the best and worst solutions for TLBO.

Formulation of new Algorithm on PPP

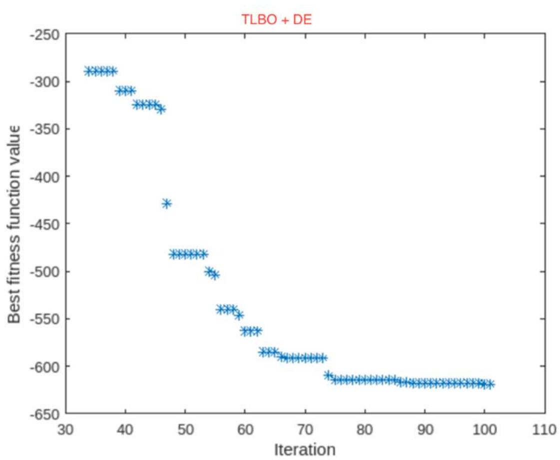
Production planning is a complex problem that involves optimizing the use of resources and meeting demand while minimizing costs. A production planning problem can be formulated as a metaheuristic optimization problem. The objective function is typically to maximize profits or minimize costs, subject to constraints such as capacity constraints, demand constraints, and inventory constraints. We will test our new algorithm on Production Planning Problem. The results we obtain are as we expected. Our new algorithm gave better results than the TLBO algorithm and gives much better results for the first hundred iterations.

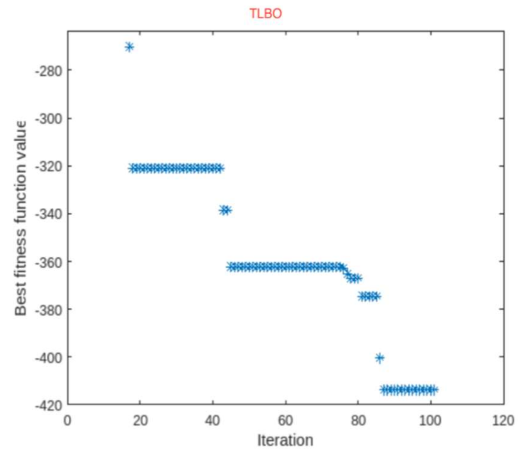
.

VI. RESULTS

Results of the hybrid algorithm

After using the hybrid algorithm and TLBO for 100 iterations to solve the production planning problem we got the following graphs. The following graph is between the Best Fitness function value and iterations

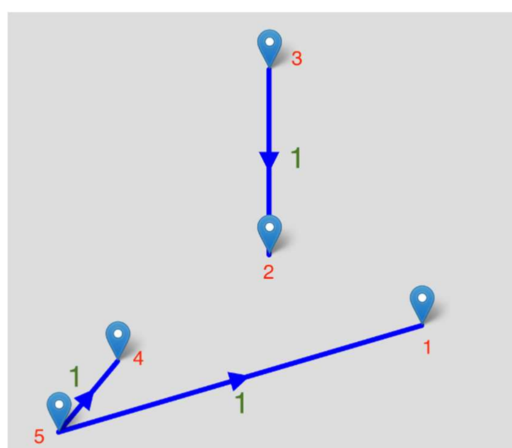




The results we obtain are as we expected. Our new algorithm gave better results than the TLBO algorithm and gives much better results for first hundred iterations. The graph shows that TLBO converges to -483 after 100 iterations and on the other hand, the hybrid algorithm converges to -619 after 100 iterations.

Results and output for problem statement

After using MIP for solving the problem we get the following digraph. The digraph shows the reassignment of Fighter planes among all the sites. The Fighter planes will be reassigned from the head of the arcs to the tail of the arcs. The number of reassigned Fighter planes in this arc is the weight shown on the arc



Relocation matrix	1	2	3	4	5
1	0	0	0	0	0
2	0	0	0	0	0
3	0	1	0	0	0
4	0	0	0	0	0
5	1	0	0	1	0

The above digraph shows that the assignment is done between locations 3→2, 5→1, and 5→4 with the reassignment of 1 plane for each set. So an optimum solution has been found for the problem statement using MIP.

ACKNOWLEDGMENT

We are grateful to Prof. Prakash Kotecha, IIT Guwahati, for teaching us a memorable and interesting course on "Computer-Aided Applied Optimization Techniques". We also thank the teaching assistants, Rajani Kant Baro and Nikhil Anant Purao for guiding us whenever needed.

FUTURE IMPROVEMENTS

- Look for a better combination of algorithms for a more optimum solution.
- Existing formulations can be modified for better coordination between the algorithms.
- The hybrid algorithm does not give a better result compared to others when higher iterations are taken, so a new formulation or combination can be searched for more globally searching.

REFERENCES

[1] Supply Chain Management problems
https://neos-guide.org/case-studies/
[2]A hybrid strategy on combining different optimization algorithms
https://www.sciencedirect.com/science/article/pii/S0957582019322360