AN IMPROVED BAT ALGORITHM FOR THE DYNAMIC TRAVELLING SALESMAN
PROBLEM WITH TRAFFIC FACTORS

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Abstract :*In recent times, there has been an increasing consideration to use evolutionary algorithms (EAs) in solving dynamic optimisation problems (DOPs) in line for its importance in the physical world implementations. Dynamic travelling salesman problems (DTSPs) are classified in DOPs. In the Travelling Salesman Problem (TSP), a salesman needs to dispense stuffs retailed in dissimilar towns beginning from his home town and returning once he stayed all the towns to his home town again by efficiently utilising his period and trip. On the other hand, in the DTSPs, it is more problematic to consider the traffic interruptions that may disturb the path of the salesman and alter the time scheduled earlier. Therefore, the salesman will improve his time once more and discover a new substitute path to escape long traffic interruptions. In this thesis, the current study work targets to rely on the most recent research approaches for the DTSPs with traffic features, where with a view to handle the dynamic behaviour. This thesis studies a based metaheuristic algorithm called Bat algorithm (BA) is a recently developed nature stimulated metaheuristic optimization algorithm for DTSP issues. this thesis presents the hybridization of BA with local search algorithms such as Simulated Annealing (SA) was investigated. This algorithm is utilised to resolve different continuous optimization complications with extending bat-inspired algorithm to resolve the DTSP. Though many algorithms have been adopted to resolve DTSP, the key goal of the current study was to examine this discrete version to attain important developments, in addition to compare the customary algorithms but also to a different metaheuristic. The performance of the suggested BA algorithm was confirmed on two variants of DTSPs with traffic features, random and cyclic traffic delays. On the basis of the different DTSP test circumstances, the experimental outcomes display that the suggested method is capable to find modest results when compared to the best known results in the scientific literatures.*
Keyword: *Bat algorithm BA, Dynamic Traveling Salesman Problem DTSP, traffic factor*

INTRODUCTION

The travelling salesman problem (TSP) is one of the well-known and extensively studied problems in discrete or classical combinatorial optimization. The goal of this problem is to find the shortest tour that visits each city in a given list exactly once and then returns to the starting city. TSP is known to be a NP-hard problem, it is easy to describe but very difficult to solve. A dynamic optimization problem (DOP) can be defined as a series of some static problem instances that are connected under several dynamic rules. Dynamic optimization

refers to the process of minimizing or maximizing the costs or the benefits of some objective function over a period of time. Dynamic optimization is important due to the similarities of its problems to many real-world applications. Many functional optimization problems are dynamic in nature since the optimal solution changes over time. Therefore, the optimization algorithm has to find the optimum and then to track the changing optimum. An example is the arrival of new jobs in scheduling as well as in many routing problems, e.g., TSP and vehicle routing problems, were there is the probability of changes in the properties of the input graph over time (Talbi 2009).The dynamism's major sides can be categorized as follows:

a. **The frequency of environmental changes:** This aspect identifies the speed in which environmental changes are executed.

b. **The magnitude of environmental changes:** Identifies the degree of environmental changes.

The environmental change may include some factors, i.e., the problem instance, objective function, input variables, the constraints, etc.

The DOP can be defined formally as follows:

$$\Pi = (X(t), \Omega(t), f(t))_{t \in T} \qquad \qquad \text{...(1)}$$

where Π is the dynamic optimization problem, $X(t)$ is assigned to the search space, $\Omega(t)$ is used to represent a set of constraints and $f(t)$ is the objective function. The objective function specifies an objective value to every solution in the search space. The search space, constraints and the objective function are all assigned with a time value t, which belongs to a set of T time values (Mavrovouniotis and Yang 2013).

The Dynamic Travelling Salesman Problem (DTSP) is an extension of TSP, which has the following supplementary features (Kang et al. 2004; Li et al. 2006):

– Real-time The weights of the links between nodes may change probabilistically with time;
– Robustness Allows for unexpected situations which require a timely response (e.g. nodes may randomly join or quit the system);
– Efficiency DSTP requires an optimal or sub-optimum solution in a finite time.

Typical algorithms for solving DTSP mainly include ant colony algorithms (ACA) (Mavrovouniotis and Yang 2013; Melo et al. 2013) and genetic algorithms (GA) (Falcon and Nayak 2010), which generally make appropriate adjustments based on changes in the environment, such as varying traveling cost between cities. However, in this case, it is often computationally expensive to identify the optimal solution in a short time, due to the numerous sudden changes in parameter values. Obviously, each of the DTSP sub-problems can be solved separately using one of the methods developed for the TSP. Nevertheless, if the differences between consecutive DTSP sub-problems are small, it is possible that the optimal solutions differ only slightly. In such a case, it is possible to use the knowledge gathered while solving the previous sub-problem to speed up solving the current one. A summary of recent research on solving the DTSP .

Literature Review

Meta-heuristic algorithms can be divided into two classes, single-solution based meta-heuristics and population-based meta-heuristics (Talbi 2009). The efficiency of meta-heuristics algorithms in addressing any optimization problems like DTSP depends on two

important factors which are exploitation and exploration (Talbi 2009). Optimisation is the process of finding the best solution(s) for a specified problem among all available solutions. Optimisation occurs in the minimisation or maximisation of the given objective function. It is encountered in many fields such as science, engineering, medicine, business and economics (Talbi 2009).

Optimisation problems can either be classified as static or dynamic. Conventionally, researchers have focused on addressing static optimisation problems (SOPs) where the environment stays stable during the algorithms' execution. On the other hand, researchers still have to deal with many real-life issues in dynamic environments (Jin and Branke 2005).Problem optimisation in dynamic environments has attracted increasing attention because of its significance in real world problems (Yang et al. 2007). In dynamic optimisation problems (DOPs), there is a probability to change the problem through the execution of an algorithm (Talbi 2009). These changes include the objective function, problem instance, and decision variables. These values make the problem more realistic, challenging and pragmatic

Bat algorithm is an innovative technique proving to give better solution than many popular traditional and heuristic algorithms for solving complex engineering problems. Bat algorithm is based on the echolocation of micro bats. Echolocation (echolocation) is a fascinating sonar wave emitted by the micro bats; it helps them find prey and, in some magical ways, they are able to discriminate the different kinds of obstacles or danger on the way towards the prey in complete darkness. The bats emit loud ultrasonic sound waves and listen to the echo that reflects back from the surrounding objects. The bat algorithm uses some idolized rules for simplicity

(1) Bats use echolocation to sense prey, predator, or any barriers in the path and distance.
(2) Bats fly with a velocity v_i and position xi. They have frequency f and loudness a_i to reach their prey. They can adjust the frequency of pulse emission r.
(3) As they get close to the prey, pulse increases and loudness decreases.

The Bat algorithm (BA) is one of the newest swarm-intelligence-based algorithms proposed by Yang in 2010, based on the intelligent echolocation behavior of bats when catching their prey. In recent years, the BA has become a popular bio-inspired algorithm and one can easily understand that the BA is applied to solve a large variety of optimization problems, while many researchers have provided a wide range of contributions to the literature. Gandomi et al. focused on solving constrained optimization tasks by using BA. Khan et al. .proposed a fuzzy modification of BA for the clustering of company workplaces. Tamiru and Hashim used fuzzy systems for modeling energy destructions in the components of an industrial gas turbine Yilmaz and   Kucksille suggested three different methods to enhance the local and global search of BA, and they employed both standard test functions and constrained real-world problems to validate the performance of their approaches. Nguyen et al. hybridized BA with the ABC algorithm and four benchmark functions are used to test the convergence of the proposed method. Pan et al. applied the concepts of parallel processing and communication strategy to hybrid PSO with BA and six benchmark functions are tested to validate the approached method. Wang et al. employed a Gaussian walk with BA to improve the local search capability, and they modified the velocity equation to assure good exploitation. Gandomi and Yang introduced chaos mechanism into BA to improve the global search mobility of BA and optimized a set of benchmark problems with different chaotic maps.

Using this behavior bats find insects the size of mosquitoes that they like to eat. Bats fly randomly using frequency, velocity and position to search for prey. In the BA, the frequency, velocity and position of each bat in the population is updated for further movements. The algorithm is formulated to imitate the ability of bats to find their prey. The BA follows many simplifications and idealization rules of bat behavior that were considered and proposed by Yang (2010).

The results for BA are weighed against ACO, GA, and hybrid ACO-GA [9, 10]. Figure 8 shows the best solution for the algorithms. BA establishes the best results compared to the other three for 12, 16, and 20 nodes, but for 24 nodes and 28 nodes ACO and Hybrid algorithm outperform BA. It was observed that the hybrid algorithm performs the best among the algorithms. In most of the cases BA gives the worst solution in comparison to the other 3 algorithms. Figure 10 presents the average solution for ACO, GA, hybrid ACO-GA, and BA. It was observed that the hybrid ACO-GA outperforms ACO, GA, and BA. The average wait time for BA is found to be higher than the other techniques despite the fact that it gave the best solutions in comparison to the rest of the techniques in many cases. The ranges of all the four algorithms, ACO, GA, hybrid ACO-GA, and BA. It can be observed that BA explores the highest range of solution sets.

Applications of Bat Algorithm

i.   Classification, Clustering and Data Mining:

Komarasamy and Wahi (2012) analyzed k-means clustering using bat algorithm additionally they concluded that the composition of each ok-way and additionally BA can acquire more efficiency and therefore better than various different algorithms. Khan et al. (2011) supplied studies of a clustering trouble for workplace workplaces the use of a fuzzy bat algorithm Khan and Sahari (2012a) as properly offered a comparison study of bat set of rules with PSO, GA, in conjunction with different algorithms inside the attitude for e-learning, and for that reason recommended that bat set of rules has really some blessings over different algorithms. Then, they (Khan and Sahari, 2012b) also counselled a observe of clustering issues the use of bat algorithm and its enlargement like a bi-sonar optimization variant with fantastic outcomes. On the other side, Mishra et al. (2012) carried out bat set of rules to categorize microarray records, even as Natarajan et al. (2012) supplied a evaluation look at of cuckoo search and also bat algorithm for Bloom filter optimization. Damodaram and Valarmathi (2012) studied phishing website detection applying changed bat algorithm and also attained superb final results. Marichelvam together with Prabaharan (2012) carried out bat algorithm to study fusion glide store scheduling troubles with a view to lessen the makespan and suggest flow time. Their effects advocated that BA, an efficient technique for solving hybrid waft shop scheduling problems. Faritha Banu and Chandrasekar (2013) used a revised bat algorithm to document deduplication as an optimization method and records

compression method. Their research advises that the revised bat algorithm can do a good deal higher than genetic programming.

ii.Image processing

Abdel-Rahman et al. (2012) supplied a record for entire frame human reason estimation the usage of bat algorithm, and that they got here to the belief that BA carries out loads better than particle swarm optimization (PSO), particle filter out (PF) and annealed particle clear out (APF). Du and Liu (2012) offered a variation of bat algorithm with mutation for photograph matching, so they indicated that their bat-based totally system is greater efficient and viable in consider matching than other models inclusive of differential evolution and genetic algorithms.

FUZZY LOGIC AND OTHER APPLICATIONS

Reddy and Manoj (2012) advised a study of surest capacitor positioning for loss reduction in distribution techniques utilizing bat algorithm. It incorporates with fuzzy good judgment to discover top of the line capacitor sizes to be able to reduce the losses. Their effects endorsed that the real strength loss may be reduced substantially. Moreover, Lemma et al. (2011) used fuzzy systems and bat set of rules for power modelling, and in a while Tamiru and Hashim (2013) hired bat set of rules to analyze fuzzy systems to be able to layout exergy changes in a gas turbine. At the duration of writing while we researched the Google scholar and other databases, we located different papers on bat algorithm that were both just truely normal or conference shows. However, there isn't sufficient detail to be involved on this evaluate. In fact, because the literature is extending, increasingly papers on bat set of rules are emerging, a similarly timely review will be needed in the the subsequent couple of years.
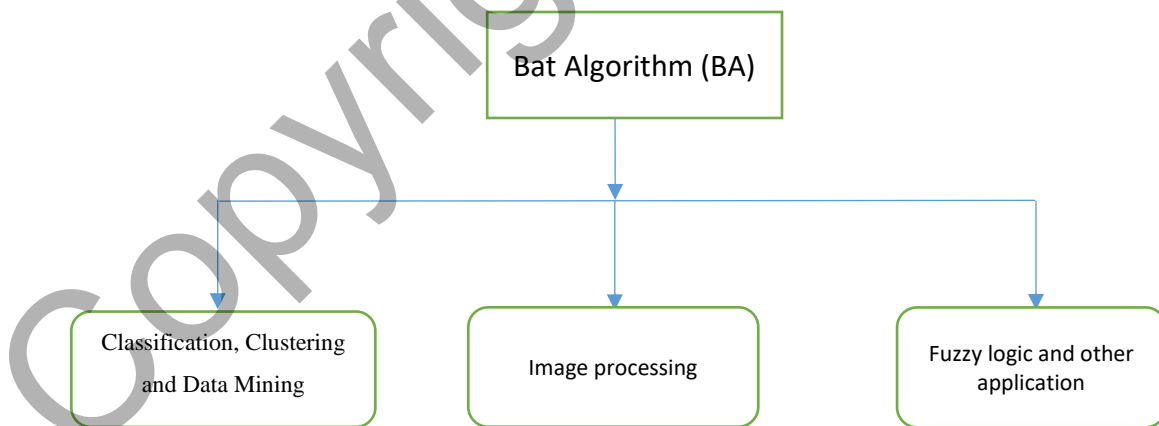
Bat Algorithm (BA)

Classification, Clustering and Data Mining

Image processing

Fuzzy logic and other application

Figure 2 A summary of applications of the BA

Benefits Bat Algorithms (BAs)

Based on the literature review the main advantage of the BA is that it combines the benefits of population-based and single-based algorithms to improve the quality of convergence. The other benefits of the BA that motivate researchers to adopt it to solve classification and time series prediction problems are as follows(Yang & He 2013):

   i. Frequency tuning: The BA employs echolocation and frequency tuning during the process of problem solving. Although echolocation is not directly used to imitate the right function in the real world, frequency alterations are used.
  ii. Automatic zooming: The BA has the ability to automatically zoom into an area where potentially better solutions have been found. This zooming is performed by the automatic shifting from explorative movement to local intensive exploitation. Therefore, the BA has a fast convergence rate in the early stages of the iteration process.
 iii. Parameter control: Most metaheuristic algorithms employ fixed parameters which need to be tuned in advance. In contrast, the BA uses parameter control, whereby the values of the parameters (A and r) are differed as the iterations progress. This helps to automatically direct the BA to move from exploration to exploitation when the best solution is searching.

1.2   RESEARCH MODEL AND RESEARCH QUESTIONS

There has been an increased interest over static travelling salesman problems (STSPs) within the past several years, but according to Mavrovouniotis and Yang (2013), considering the potential of traffic jams in impacting the tour, TSP could be further realistic if subjected to dynamic environments.

Within the various actual implementations, dynamic optimisation problems (DOPs) are considerably challenging (Talbi, 2009) considering that the objectives are to efficiently attain the optimal solution and follow the optimum over the environmental variations (Branke et al., 2005). The successful use of certain algorithms in the resolution of DTSPs has been reported in several studies including Mavrovouniotis and Yang (2011a) and Gharehchopogh et al. (2012).

BA simulates the echolocation process through the highly voluble sound waves and echoes to identify the specific location of the objects within space. Hence, BA has been used in solving the diverse problems associated with optimisation within continuous and discrete space. To improve the performance of BA, ways to improve the basic BA algorithm steps are adhered to.

Hence, the present research will address the following research questions:

   i. What are the ways to adapt and develop the basic Bat algorithm for DTSP with traffic factors?
  ii. How to control the solution diversity in the proposed method when addressing DTSP?

RESULTS & DISCUSSION

In the current study, two types of DTSPs, random and cyclic traffic factors, were generated with the lesser bound representing possible traffic blockages ($f_L = 1$) and the upper bound ($f_U = 5$). The worth of the random number, (R), denoted the traffic congestions $\in [1, 5]$. Furthermore, three cyclic conditions were employed in cyclic DTSPs. For random and cyclic kinds, the frequency parameter, (f), for the environmental variations was fixed to 5 and 100 to specify fast and slow dynamic variations, correspondingly. The value of the magnitude factor of the dynamic changes, (M), was fixed to 0.1, 0.25, 0.5, and 0.75 to show the degree of dynamic changes from small to medium and large respectively (Mavrovouniotis and Yang 2013). As a result, 8 dynamic test DTSP instances were produced from each dataset, such as, 4 values of $M \times 2$ values of 'f'. Thus, 24 dynamic test cases were utilized to examine the adaptation experiences of the offered algorithm on the DTSP with traffic features for individual kind of DTSPs, such as, 3 TSP instances $\times$ 8 cases each. the investigations of the adjusting competences of the hybridization BA algorithm on the DTSP with the simple BA algorithm, 56 dynamic test situations were employed for random and cyclic kinds, such as, 7 TSP cases $\times$ 8 cases individually. For the proposed hybridization BA algorithm with SA on a DTSP instance, $N = 30$ turns were implemented on the identical environmental variations. The algorithm was performed for $g =$ one thousand iterations. The simple experimental outcomes in DTSP with random traffic factors with fast environmental fluctuations ($f = 5$) are specified in Table 1.

Statistical investigation consequences about the off-line presentation of BA, BASA-1L and BASA -3Ls on random and cyclic DTSPs that verified on kroA100, kroA150 and kroA200 The results show that the hybridization BA algorithm with Simulated annealing SA with multiple Ls strategy is capable to attain superior outcomes than the standard BA and the hybridization BA algorithm with simulated annealing SA with one L in all of the 7 verified datasets with random and cyclic traffic features, and in all of the distinct situations.

Table 1: Experimental result of basic BA , BASA-1L & BASA -3Ls in

DTSP with random traffic factors in case of fast environmental changes ($f = 5$)

algorithm	$M = 0.1$	$M = 0.25$	$M = 0.5$	$M = 0.75$
kroA100				
BA	30371.7	40428.0	58708.4	80121.5
BASA-1L	29958.5	39858.0	55817.6	73317.2
BASA-3Ls	**23537.0**	**30191.0**	**42464.1**	**57245.1**
kroA150				
BA	39048.5	45710.3	62188.3	96331.7
BASA-1L	35462.2	44067.0	62287.5	89733.4
BASA-3Ls	**31425.4**	**36926.1**	**58196.2**	**74280.3**
kroA200				
BA	40013.4	50148.0	74883.0	99551.7

BASA-1L	38144.8	52335.0	69472.5	96283.2
BASA-3Ls	**35562.2**	**42003.8**	**65754.5**	**90203.7**
eil51				
BA	561.4	703.7	1130.0	1425.3
BASA-1L	493.8	699.5	1105.0	1449.3
BASA-3Ls	**460.8**	**669.4**	**939.0**	**1308.7**
lin318				
BA	54307.7	76439.0	106703.7	144720.3
BASA-1L	52947.0	73914.0	97658.7	135009.2
BASA-3Ls	**50217.3**	**69008.7**	**89797.7**	**134427.3**
pr439				
BA	152098.0	193559.7	284835.3	357031.6
BASA-1L	138105.4	184221.6	280173.5	355169.3
BASA-3Ls	**130323.4**	**172824.4**	**260783.0**	**329740.3**
rat783				
BA	12424.0	16220.0	22695.3	28838.7
BASA-1L	11692.0	14690.7	21906.0	28485.0
BASA-3Ls	**11621.0**	**14662.7**	**21604.7**	**28404.0**

CONCLUSION

This study explores the usage of BA algorithm for resolving the DTSP. Experimental outcomes displayed that this methodology has been positively improved for resolving the DTSP by means of traffic issues because of its adaptation proficiency to fix the distinct variables seeing that its procedure for generating new solutions. The hybridization of the typical BA algorithm with local search (SA) was presented with the intention of keeping the solution diversity and improving the efficiency for the DTSP. Since BA algorithm is more flexible, it is more adaptable for the hybridization mechanism to be embedded within BA algorithm to keep the solution diversity. The current study established that the suggested hybridization is capable of overtaking the simple BA algorithm and formed among the finest outcomes while employed on the DTSP with traffic elements.

ACKNOWLEDGEMENT

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