



A new hybrid method based on Particle Swarm Optimization, Ant Colony Optimization and 3-Opt algorithms for Traveling Salesman Problem



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ABSTRACT

The Traveling Salesman Problem (TSP) is one of the standard test problems used in performance analysis of discrete optimization algorithms. The Ant Colony Optimization (ACO) algorithm appears among heuristic algorithms used for solving discrete optimization problems. In this study, a new hybrid method is proposed to optimize parameters that affect performance of the ACO algorithm using Particle Swarm Optimization (PSO). In addition, 3-Opt heuristic method is added to proposed method in order to improve local solutions. The PSO algorithm is used for detecting optimum values of parameters α and β which are used for city selection operations in the ACO algorithm and determines significance of inter-city pheromone and distances. The 3-Opt algorithm is used for the purpose of improving city selection operations, which could not be improved due to falling in local minimums by the ACO algorithm. The performance of proposed hybrid method is investigated on ten different benchmark problems taken from literature and it is compared to the performance of some well-known algorithms. Experimental results show that the performance of proposed method by using fewer ants than the number of cities for the TSPs is better than the performance of compared methods in most cases in terms of solution quality and robustness.

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1. Introduction

The Traveling Salesman Problem (TSP) is a well-known combinatorial discrete optimization problem where the salesman attempts to find the shortest tour through cities. This problem has been used in many engineering applications such as the design of hardware devices and radio electronic systems, and computer networks [1,2].

In the theory of computational complexity, the decision version of the TSP (where, given a length L , the task is to decide whether the graph has any tour shorter than L) belongs to the class of NP-complete problems. Thus, it is possible that the worst-case running time for any algorithm for the TSP increases exponentially with the number of cities [2]. For this reason, in recent years some heuristic algorithms have been proposed to solve this problem, which have achieved better results in terms of computational and time complexity. Grefenstette et al. presented some approaches to the application of Genetic Algorithms (GA) to the TSP [3]. Shi et al. presented a Particle Swarm Optimization (PSO) based

algorithm for the TSP [4]. Geng et al. proposed an effective local search algorithm based on Simulated Annealing (SA) and greedy search techniques to solve the TSP [5]. In order to obtain more accuracy solutions, the proposed algorithm based on the standard SA algorithm adopted the combination of three kinds of mutations with different probabilities during its search. Jolai and Ghanbari presented an improved Artificial Neural Network (ANN) approach for solving the TSP [6]. They employed Hopfield Neural Network and data transformation techniques together to improve accuracy of the results and reach to the optimal tours with less total distances. Pedro et al. proposed a Tabu Search algorithm to solve the TSP [7]. Dorigo et al. proposed an Ant System to solve the TSP [8]. Dorigo and Gambardella described an artificial ant colony (ACO) capable of solving the TSP [9]. They demonstrated that the ACO was capable of generating good solutions to both symmetric and asymmetric instances of the TSP. Mavrouniotis and Yang proposed an ACO framework for dynamic environments [10]. Their framework contains different immigrants schemes, including random immigrants, elitism-based immigrants, and memory based immigrants. Karaboga and Gorkemli proposed a new Artificial Bee Colony (ABC) algorithm called Combinatorial ABC for the TSP [11]. They showed that the ABC algorithm can be used for combinatorial optimization problems.

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To solve this problem, hybrid heuristic methods based on Simulated Annealing, PSO, ACO, ABC, ANN, etc. were used. Bountoux and Feillet proposed a hybrid algorithm to solve the TSP [12]. Their algorithm consists of the ACO algorithm hybridized with local search procedures. They called Dynamic Multi-Dimensional Anamorphic Travelling Ants (DMD-ATA). Tsai et al. presented a metaheuristic approach called ACOMAC algorithm for solving the TSP [13]. They introduced multiple ant clans' concept from parallel genetic algorithm to search solution space utilizing various islands to avoid local minima and thus can yield global minimum for solving the TSP. Also, they presented two approaches named the multiple nearest neighbor (NN) and the dual nearest neighbor (DNN) to ACOMAC to enhance large TSPs. Pasti and Castro proposed a meta-heuristics for solving the TSP based on a neural network trained using ideas from the immune system [14]. The network was self-organized and the learning algorithm aims at locating one network cell at each position of a city of the TSP instance to be solved. Their network based on a Real-valued Antibody Network (RABNET). Masutti and Castro proposed some modifications on the RABNET-TSP, an immune-inspired self-organizing neural network, for the solution of the TSP [15]. Beam-ACO algorithm, which is a hybrid method combining ACO with beam search was used to solve TSP [16]. Cheng and Mao developed a modified ant algorithm, named Ant Colony System-Traveling Salesman Problem with Time Windows (ACS-TSPW), based on the ACO technique to solve the TSP [17]. Krohling and Coelho presented an approach based on co-evolutionary PSO for solving the constrained optimization problems as min–max problems [18]. Lin et al. presented an evolutionary neural fuzzy network, designed using the functional-link-based neural fuzzy network and an evolutionary learning algorithm [19]. Their evolutionary learning algorithm was based on a hybrid cooperative PSO and cultural algorithms for prediction problems. Chen and Chien presented a method, called the genetic simulated annealing ant colony system with Particle Swarm Optimization techniques, for solving the TSP [20]. Junqiang and Aijia proposed a Hybrid Ant Colony Algorithm (HACO) which is containing ACO and delete-cross method which is used to speed the convergence of local search is presented for the shortcoming that the convergence speed of ACO is a bit slow [21]. Dong et al. presented an approach, called Cooperative Genetic Ant System (CGAS), combines both GA and ACO together in a cooperative manner to improve the performance of ACO for solving TSP [22]. Peker et al. proposed for the TSP using the ant colony system and parameter optimization was taken from the Taguchi method [23]. Gunduz and Kiran presented a new hierarchic method based swarm intelligence algorithms for solving well-known TSP [24]. The swarm intelligence algorithms implemented in their study were divided into two types as path construction and path improvement based methods. The path construction based method (Ant Colony Optimization-ACO) that produced good solutions have taken more time to achieve a good solution and also, the path improvement based technique (Artificial Bee Colony – ABC) that quickly produced results have not achieved a good solution in a reasonable time. Therefore, their hierarchic method which consists of ACO-ABC was proposed to achieve a good solution in a reasonable time. ACO was used to provide better initial solution for ABC that use path improvement technique in order to achieve to optimal or near optimal solution.

In this study, a new hybrid method was suggested, which optimizes parameters that affect performance of the ACO algorithm through PSO and reduces the probability of falling in local minimum with the 3-Opt algorithm. Better results were achieved with the suggested method compared to other studies in the literature by using fewer ants than the number of cities for the TSPs.

The rest of the paper is organized as follows: In Section 2, Materials and methods gives the background information including PSO, ACO and 3-Opt algorithms. The proposed method is presented in

Section 3. The results obtained in the application are given in Section 4. Consequently, in Section 5, we conclude the paper with a summarization of results by emphasizing the importance of this study.

2. Materials and methods

In this section, information is provided on the PSO, ACO and 3-Opt algorithms.

2.1. Particle Swarm Optimization (PSO) algorithm

PSO is a population-based optimization algorithm developed by Kennedy and Eberhart and inspired by bird flocks' behavior when searching for food [25]. Each individual in the swarm is called a particle and points to a solution in search space. Particles have dimensions similar to the number of parameters whose values are desired to be found in a problem. Particles are randomly distributed in search space at first. Each particle generates a fitness value depending on the objective function of the problem. Locations of particles are updated as in Eqs. (1) and (2) [25].

$$v_i^{t+1} = v_i^t + c_1 r_1^t (Pbest_i^t - X_i^t) + c_2 r_2^t (gbest - X_i^t) \quad (1)$$

$$X_i^{t+1} = X_i^t + v_i^{t+1} \quad (2)$$

where X_i^t indicates i th particle's location in t iteration, X_i^{t+1} indicates i th particle's location in $t+1$ iteration and v_i^{t+1} indicates velocity vector of i th particle. c_1 and c_2 determine impact of the particle's own best solution ($Pbest_i$) and the system's best solution ($gbest$) on velocity vector and r_1 and r_2 are random numbers at interval [0–1]. In improved versions of the PSO, the parameter of inertia weight w , which determines impact of old velocity vector on new velocity vector, was added to Eq. (1) [25]. Algorithm is operated until the designated number of iterations or error value has been achieved.

2.2. Ant Colony Optimization (ACO) algorithm

The ACO algorithm was developed by Dorigo et al. as inspired by actual ant colony behaviors [8]. Having examined behaviors of ants in real life, it is observed that ants have the ability to find the shortest route between their nest and food source. The most important feature in finding the shortest route is the volatile, chemical matter of pheromone that ants leave on the path they use. Ants in a colony generally choose a path where pheromone matter is concentrated. The amount of pheromone increases on a frequently used route [26]. The algorithm that suggests a solution to the TSP, which is a discrete (combinatorial) test problem, by utilizing this attribute of ants was proposed by Dorigo et al. [27]. In the TSPs, the traveling salesman aims to form a closed tour of minimum length provided that it visits every city once. In this proposed method, it is accepted that ants leave pheromones on inter-city routes that they use and this pheromone becomes volatile in a certain ration. Selection of the cities to which ants will go is greedily performed depending on the distance and the amount of pheromones between cities. This algorithm is operated iteratively and the shortest route found is regarded as the best solution. Selection of city j , to which an ant in city i in iteration t will go, is made according to Eq. (3).

$$P_{ij}^k = \begin{cases} \frac{[\tau_{ij}(t)]^\alpha [\eta_{ij}]^\beta}{\sum [\tau_{ij}(t)]^\alpha [\eta_{ij}]^\beta}, & \text{if } j \text{ is allowed city} \\ 0, & \text{otherwise} \end{cases} \quad (3)$$

In Eq. (3), τ_{ij} indicates the amount of pheromones between i and j cities, η_{ij} indicates information ($1/d_{ij}$) pertaining to distance between i and j cities, and j display cities where k th ant can go. An

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