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Hybrid evolutionary fuzzy learning scheme in the applications of traveling salesman problems

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ABSTRACT

This study develops a hybrid evolutionary fuzzy learning algorithm that automatically determines the near optimal traveling path in large-scale traveling salesman problems (LSTSPs). Identifying solutions for LSTSPs is one of the most complicated topics in the field of global combinatorial optimization problems. The proposed hybrid evolutionary fuzzy learning scheme combines the advantages of the adaptive fuzzy C-means (FCM), simple MAX–MIN merging concept, simulated annealing (SA) learning algorithm and an efficient table transform-based particle swarm optimization (TPSO). This study uses the proposed method to deal with the large-size TSP routing system.

The evolutionary TPSO learning algorithm is applied to optimize the traveling table, which in turn extracts the appropriate traveling table sequence codes for approaching the shorter traveling path. The SA local optimal learning algorithm works after the TPSO learning scheme, using three operators to acquire the optimal traveling solution, inversion, translation and switching. The other considerable notation is to divide the large-scale cities into suitable subgroup cities to improve the efficiency of training machine. The popular FCM algorithm is a valid unsupervised clustering method that identifies the relational grades of a given traveling city dataset, separating them into popular categories. Based on the critical issue in maximal city number to break the city nodes of the traveling loop, and reconnect suitable nodes again with the minimal distance searching procedure, the proposed simple but powerful MAX–MIN merging algorithm to rebuild the new traveling path. Various sizes of TSP testing instances reveal that the developed hybrid evolutionary fuzzy learning algorithm achieves better results than other learning methods in both the quality of routing and computing time.

1. Introduction

The traveling salesman problem (TSP) is a well-known NP Complete (Non-Deterministic Polynomial) path planning and routing problem [8]. The term NP Complete means that no polynomial time algorithm is actually obtained for its best solution. Therefore, this problem requires a great powerful heuristics learning machine to find the near optimal solution in a reasonable amount of time. In the TSP, a salesman must visit one and only one city before returning to the starting point. The primary objective of the proposed algorithm in solving the TSP combinational optimization problem is to identify the shortest routing length that passes through each city one and only one time in every traveling cycle. The formula for finding the possible traveling paths for n number cities is $(n-1)!/2$. For example, the number of all possible routing combinations is

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181,440 when the number of cities to be visited is 10. The possible solutions grow factorially with the number of cities [28]. Clearly, the closed tour path-routing procedure becomes more complex as the number of cities increases. Researchers proposed a parallel immune algorithm to solve the TSP problems and applied it on the cold rolling scheduling application [43]. The novel homogeneous multi-colony ACO algorithms are also applied to solve the TSP problems in the other study [35] for the highest performance.

The large scale TSP (LSTSP) is becoming an important issue in many scientific and engineering applications. In transportation systems, the TSP simulates passengers travelling from one location to many other targets. An efficient TSP algorithm is also required in similar path planning or routing applications, such as airlines, delivery truck/bus routes, goods/postal carrier deliveries, and computer networks [11,37]. Several learning machines use graph-based methodologies to approach typical discrete scheduling, assigning, and routing applications [5,19,21]. The heuristic biogeography-based optimization and genetic algorithms are proposed to solve the TSP-based combinational optimization problems [33]. Researchers have recently utilized the TSP concept to develop a routing order picker for a warehouse [34]. Faigl used the self-organizing maps (SOMs) to improve the performance in the non-Euclidean TSP problems [15]. Even with the rapid growth in current computation abilities, it is necessary to develop efficient learning technology to deal with LSTSP problems.

Researchers have recently developed several biological and natural learning modes, particularly for swarm intelligent-based machines, that direct the methodologies in computer science and technology. Since Eberhart and Kennedy introduced the nature-inspired PSO learning algorithm in 1995 [22], it has become increasingly popular. This algorithm simulates the ability of bird flocking and fish schooling, organizing a heuristic learning mechanism to achieve various goals [6,7,12–14,40]. The PSO algorithm involves a simple learning stratagem that efficiently selects the best solution from particle position values. A well-defined fitness function is a self-evaluated criterion that obtains the global best solution from the whole swarm and the personal best solution from each particle's developmental solutions. When combined with a simple learning scheme, the heuristic PSO algorithm becomes an efficient engine for acquiring optimal or near-optimal solutions from huge, complex search spaces in various optimization problems. However, the standard PSO leaning algorithm is generally used to derive continuous optimal solutions. This study develops a novel table transformed PSO (TPSO) algorithm to address this drawback. The proposed TPSO finds the proper table value and transforms it into traveling city sequences. Based on this simple concept, TPSO uses swarm intelligent based learning behaviors to approach the global discrete solution of TSP problems efficiently.

Solving the whole traveling path becomes too complex when the TSP number value is large. Zadeh introduced fuzzy logic theory in 1965 [41]. A fuzzy-based information system with available membership functions can be viewed as a soft computational machine for estimating the similarity from the training data. Based on the adaption of fuzzy inference theory, Bezdek proposed the fuzzy C-means (FCM) algorithm. This algorithm combines several membership functions through distributable shapes and flexible grads to select proper city points into desired subgroups [4]. Based on the manual definition of the clustering number, the fuzzy C-means (FCM) algorithm can directly evaluate the entire training samples of city's positions using the adaptable membership function to extract the required city nodes for forming sub-groups. The smaller city number in every sub-group form easy TSP problems, and greatly reduce the searching space. Thus, the TPSO algorithm is more likely to achieve the near optimal solution with a faster computation time.

The simulated annealing (SA) algorithm is a great way to solve the optimization problem in a wide range of applications. The SA algorithm emulates the solid annealing process, which first heats a solid to its melting point, and then slowly cools the material [29]. The SA algorithm is a stochastic optimization technique that converges on the global optimal solution. A major disadvantage of SA algorithm is its relatively slow convergence [3]. To avoid getting trapped in a local minimum during a short training cycle, the efficient SA-based local search scheme tunes each subgroup's adjustable traveling paths using three additional operators: inversion, translation, and switching. However, this method only approaches the local optimal routing path in the individual sub-grouping city by the proposed SA-based local search scheme. This paper derives the simple MAX–MIN merging algorithm to rapidly make a shorter connection between well-trained subgroups and completely restructure them into the whole traveling city path.

The proposed TPSO learning algorithm can efficiently derive the optimal city tours in each sub-group city. The other major contribution of the proposed method is that it employs simple but efficient fuzzy type separating and intuitive merging to greatly reduce the search space. This study provides several TSP examples to demonstrate the efficiency of the proposed learning algorithm.

The rest of this article is organized as follows:

The rest of this article is organized as follows. Section 2 discusses the TSP common background and related research. Section 3 presents a detailed introduction to the FCM clustering, MAX–MIN merging, TPSO, and SA local optimal algorithms included in the hybrid evolutionary fuzzy learning scheme. Section 4 considers several TSP instances to illustrate the efficiency of the generated hybrid evolutionary fuzzy learning algorithm. Finally, Section 5 concludes with a summary of the contributions of this research and discusses directions for future research.

2. Backgrounds and related research

The TSP is the typical NP Complete problem of designing the shortest routing path in a city's traveling sequence. This section first introduces the basic concepts TSP formulation, and the following section discusses the details of fuzzy evolutionary based TSP learning scheme.