Turk J Elec Eng & Comp Sci
() : –
◯c TUB¨ ˙ITAK
doi:10.3906/elk

A Taxonomyof Intelligent Algorithms used for Solving Traveling Salesman Problem (TSP) in the Year 2019.

Haroon altarawneh

Al-balqa Applied University

Jordan

Dr.hroon@bau.edu.jo

Abstract

Travel salesman problem (TSP) considered as one of the most important complex optimization problem. The complexity of TSP is due to many reasons, like different types of TSP, the number of visited cities, and the absence of real optimal solution to it. Many intelligent algorithms were proposed and enhanced to solve TSP, but none of them gave the real optimal solution; some solutions were close to the optimal solutions but with special conditions. In our research we reviewed related published articles in the year 2019(Scopus database), to find the state-of-art in Solving Travel Salesman Problem (TSP) by different intelligent algorithms. We reviewed 200 published articles in Scopus database, and found 128 related papers. The reviewed articles showed that; there are 34 types of TSP, 89 proposed and enhanced algorithms.The main type in reviewed articles was the symmetric TSP,where 82 articles from 128 reviewed articles discussed it. This research considered as road map for more research in this filed.

Keywords: travel salesman problem, symmetric TSP, algorithm, optimization.

Introduction

Travel salesman problem (TSP) is a complex computational issue in operational research science and considered as NP-hard problem type (non-deterministic polynomial-time hardness) [129].TSP has in general two main types: symmetric TSP and asymmetric TSP, but there are many sub types like dynamic TSP (DTSP),Multi-commodity Traveling Salesman Problem with Priority Prizes (MTSPPP), angular-metric travelling salesman problem (AngleTSP)…. etc….see table 1.

Solving TSP in general seems to be easy, but it is getting hard when the number of visited cities is increasing [130]. The literature showed that there a huge number of proposed solutions to solve TSP. Different heuristic and meta-heuristic intelligent algorithms were proposed and improved to solve different types of TSP. In this researchwe are going to show the proposed and improved solutions to TSP that published in the year 2019.

doi:10.3906/elk

Methodology:

We are going to show all related published papers in Scopus database in the year 2019, determining the names of proposedalgorithms, improved algorithms, and the different variants of TSP (see figure 1).

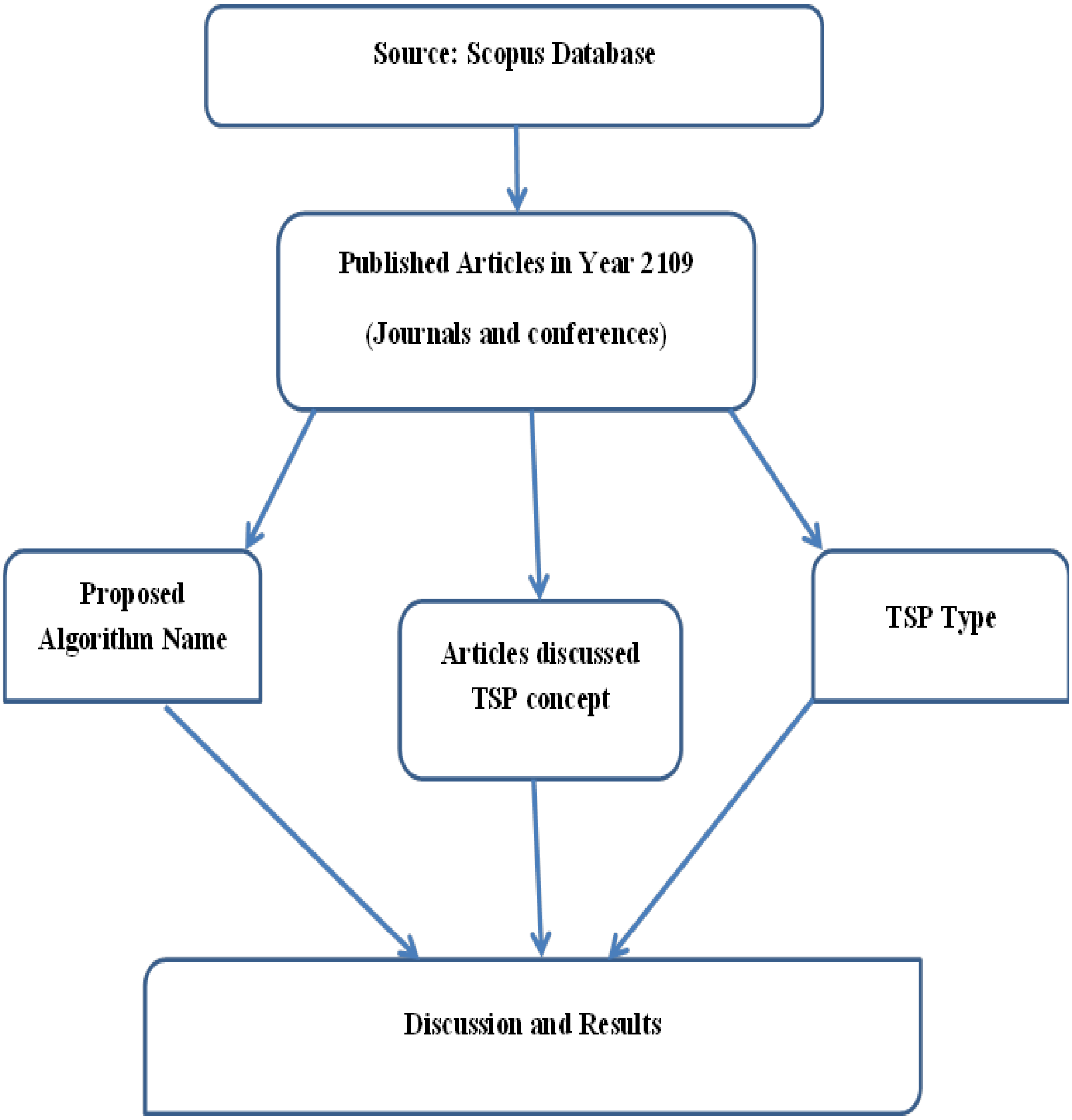

Figure 1: Methodology

Literature Review

Akhand, M.a.h., et al.[1] ,showed a new variant of spider monkey optimization (SMO) called dynamic spider monkey optimization (DSMO) for large symmetric TSP instances. Freitas&Penna[2] , proposed a hybrid heuristic algorithm , to solve a variant of symmetric TSP called , flying sidekick TSP.Bock &Klamroth[3], proposed a hybrid algorithm , called(MOTSRP) ,combined of the Multi-Objective TSP (MOTSP)and Multi-Objective Traveling Repairman Problem (MOTRP), to solve random instances for both problems .Shahmanzari, Masoud, et al.[4] proposed a two-phase matheuristic algorithm to solve Roaming Salesman Problem (RSP). Wang[5] , proposed a heuristic algorithm, with a binomial distribution model based on frequency to solve symmetric TSP. Munapo[6] proposed a network reconstruction technique with minimal spanning tree (MST) for symmetric TSP. Öztürk&Uslu[7] proposed a cantor-set based (CB) method for heuristic algorithms to solve symmetric TSP.Ohira, Ryoma, et al.[8] proposed a genetic algorithm called adaptive and modular genetic algorithm (AMGA) to solve symmetric TSP. Hameed[9], proposed a multi-objective genetic algorithm (MOGA) to find optimal solution for typical symmetric TSP.Ye, Hao, et al[10] proposed a self-exploration strategy added to chicken swarm algorithm to solve symmetric TSP.Halaoui[11] built a virtual graph by using different techniques like algorithm A* and graph Hamilton circuit algorithm to solve symmetric TSP.Silva, Tiago Tiburcio Da, et al.[12]proposed Biased Random-Key Genetic Algorithm (BRKGA) to solve medium and large Multicommodity Traveling Salesman Problem with Priority Prizes (MTSPPP).Moraes&Freitas[13] found that genetic algorithm performance was better than ant colony optimization and simulated annealing performance for Moving Target TSP (MT-TSP).Mohan, Usha, et al[14] discussed path version of the TSP and named it Biased-TSP-Path.Papalitsas, Christos, et al[15] discussed TSP with Time Windows, they anticipated that this method will lead to optimal solution for of small scale TSPTW instances.Ganesan[16] discussed " variance estimates for TSP Cn and prove that if the cities are well-connected in a certain sense, then TSP Cn appropriately centered and scaled converges to zero in probability" for Euclidean TSP.Khan, Indadul, et al. [17] proposed hybrid algorithm , combined of modified particle swarm optimization (PSO) and genetic algorithm (GA) ,used for symmetric and a symmetric TSP instances.Sengupta, Lahari, et al.[18] ,suggested a two new operators ("link swap and 3-permute") for open-loop variant TSP.Cygan, Marek, et al. [19] improved the k-OPT heuristic algorithm for symmetric TSP instances.Kaspi, Moshe, et al. [20] improved classical TSP algorithm by adding an iterative solution method for symmetric TSP instances.Myszkowski, Paweł B., et al. [21] proposed “Non-dominated sorting genetic algorithm II (NSGA-II) “for multi-objective TSP (MOTSP) .Júnior, &, Guimarães, [22] showed a " Greedy Randomized Adaptive Search Procedure (GRASP) metaheuristics" to solve symmetric TSP.Wang & Wu [23], proposed a heuristic model called frequency graph for symmetric TSP.

Sahai, Tuhin, et al. [24] constructed a heuristic strategies based on adding the relaxed discrete optimization into suitable manifolds, for symmetric TSP.Arash, et al [25] improved Christofides algorithm for half-integer TSP.Bonnet, et al. [26] discussed Exponential Time Hypothesis in Hamiltonian cycle for symmetric TSP.Bossek, Jakob, et al. [27] Proposed a new mutation operators for genetic algorithm and used for evolving instances of the symmetric TSP.Azezan, NurArif, et al. [28] showed the initial design of the crow search algorithm for symmetric TSP.Wei, Feng-Feng, et al[29] presented a comprehensive empirical study on GAO, ACO and PSO for symmetric TSP.Divya [30] developed Ant Search method for symmetric TSP.Klug, Nikolas, et al. [31] proposed k-Repetitive-Nearest-Neighbor algorithm which it is an extension of existing Nearest-Neighbor heuristics for symmetric TSP.taněk, Rostislav, et al. [32] proposed a different heuristics improvement for "the angular-metric travelling salesman problem (AngleTSP)".Ramadhan& Imran[33] proposed a two-phased meta-heuristic approach to solve traveling repairman problem(TRP) which is a variant of symmetric TSP.Kumar, Ajendra, et al. [34] proposed a Fuzzy C-Mean Genetic Algorithm (FCMGA) for symmetric TSP.Zhong, Yiwen, et al. [35] proposed a discrete PIO (DPIO) algorithm for large-scale TSP instances .Zouari, Wiem, et al. [36] proposed hybrid ant colony algorithm for Traveling Thief Problem (TTP) which is a variant of symmetric TSP.Varadarajan& Whitley [37] proposed Mixing Genetic Algorithm for symmetric TSP instances.Peake, Joshua, et al. [38] proposed “a restricted variant of the pheromone matrix with linear memory complexity (ACO)" for large-scale symmetric TSP.Luo [39] designed Hopfield network method to solve symmetric TSP. Ban [40] proposed " a two-phase meta-heuristic which combines the Insertion Heuristic (IH), Variable Neighborhood Search (VNS) and the tabu search (TS)" to solve Time Dependent Traveling Salesman Problem (TDTSP) Weise, Thomas, et al[41] proposed a new crossover operator called BBX evolutionary Algorithms (EAs) to solve symmetric TSP instances. Yang, Hongtai, et al. [42] performed experiments to find the shortest path for symmetric TSP by using genetic algorithm (GA). Faigl, Jan, et al [43] proposed two heuristic algorithms , the first one built based on a decoupled approach for symmetric TSP, and the second is the growing self-organizing array method , the combination of tow algorithms used to solve multi-goal path planning which is a variant oftraveling salesman problem with neighborhoods (TSPN) . Herrán, Alberto, et al. [44] proposed "a parallel General Variable Neighborhood Search (GVNS) procedure" to solve Hamiltonian p-Median Problem (HpMP) which is a generalization of symmetric TSP.Caracciolo, Sergio, et al. [45] studied and reviewed Euclidean TSP, with random cities instances. Sahana [46] proposed a hybrid model consisted of genetic algorithm (GA) and heuristics like "remove-sharp" and” local-opt" with ant colony system (ACS) to solve symmetric TSP. Koczy, Laszlo T., et al [47] proposed Triple Fuzzy Time Dependent TravelingSalesmanProblem approach (3FTD TSP) for Time Dependent TSP (TD TSP). Venkatesh, Pandiri, et al. [48] proposed "a multi-start iterated local search algorithm" for maximum scatter travelingsalesmanproblem (MSTSP).Yang &Szeto[49] used a Multi-Agent System method to solve symmetric TSP.Menezes, Breno A. M., et al [50] compared and analyzed the performance of ACO on contemporary high-performance hardware for symmetric TSP. Attarmoghaddam, Narges, et al. [51] proposed a hardware realization of the crossover method in the genetic algorithm for symmetric (TSP). Lupoaie, Vlad-Ioan, et al. [52] developed a self-organizing maps evolutionary algorithms and ACS to handle the Min_Max algorithm for MOTSP instances. Imeson& Smith [53] proposed an algorithm that combined of the state-of-the-art SAT and TSP solvers to solve multi-robot motion planning problem. Hari, S. K. K., et al. [54] Discussed unmanned vehicle routs UAV as symmetric TSP. Bhavana V, et al. [55] applied Cuckoo Search Algorithm on symmetric TSP. RenuJangra and Ramesh Kait [56] proposed modified ant system (MAS) to solve symmetric TSP. Ginting, HagaiNuansa, et al. [57] Discussed Dijkstra algorithm role in solving symmetric TSP. Switrayana, I Nyoman, et al. [58] modeled a Search optimization to find shortest path with genetic algorithms for symmetric STP and MTSP. Jasim and Ali [59] proposed "Branch and Bound technique (BABT)" to solve symmetric TSP. Manopiniwes, Wapee, et al. [60] used symmetric TSP algorithm to solve ecotourism destinations in Chiang Mai, Thailand. Ghasemi-Sardabrud, Mahsa, et al. [61] presented a numerical example to solve draft limit and time windows TSP. Jaradat, Ameera, et al. [62] proposed" Firefly Algorithm (FA) and k-means clustering" to solve symmetric TSP. Al-Omeer, Maha Ata, and ZakirHussain Ahmed [63] developed a genetic algorithm (GA) with six different crossover operators to find the optimal solutions to MOTSP. Duflo, Gabriel, et al.[64] proposed a genetic algorithm called GP hyper-heuristic to solve large scales symmetric TSP. Wang, Y., et al.[65] enhanced the discrete symbiotic organism search (DSOS) and called it the excellence coefficients and self-escape strategy (ECSDSOS) for symmetric TSP. Benavent, Enrique, et al. [66] proposed two mathematical formulations and according to authors, this is the first exact approach to pickup-and-delivery TSP. Vukmirovic, Slavomir, et al.[67] showed how to solve the transport network optimization by using Exhaustive Search Algorithm and Traveling Salesman Problem (TSP). Traub&Vygen [68] showed an improved analysis of the best-of-many Christofides algorithm for s–t-path TSP. Juneja, Sahib Singh, et al. [69] used genetic algorithm (GA) capabilities to solve symmetric TSP. Yelmewad&Talawar [70] showed a GPU-based Parallel Iterative Hill Climbing (PIHC) algorithm to solve large-scale symmetric TSP. Dahan, et al.[71] modified the flying ant colony optimization (FACO) to a new algorithm called dynamic flying ant colony optimization (DFACO)to solve symmetric TSP. Akter, Shamima, et al.[72] proposed a new crossover operator for traditional genetic algorithm to solve symmetric TSP. Ayon, Safial Islam, et al.[73] modified standard spider monkey algorithm (SMO) to solve symmetric TSP. Thenepalle&Singamsetty[74] introduced a new variant of TSP called , open close multiple travelling salesmen problem with single depot (OCMTSP). Miao, Kun, et al.[75] proposed a two-stage approach based on Kernighan–Helsgaun (LKH) algorithm to solve the one-commodity traveling salesman problem with selective pickup and delivery (1-TSP-SELPD). Tawhid&Savsani[76] ,proposed discrete sine-cosine algorithm (DSCA) which is an extension of (SCA)to solve symmetric TSP.Kongzhi[77] proposed An evolutionary multi-objective optimization called non-dominated sorting genetic algorithm II (NSGAII) to solve symmetric TSP. Paul, Victer, et al.[78] discussed new proposed strategies in genetic algorithm (GA) used to solve symmetric TSP.

Jakjoud, Abdeslam, et al. [79] proposed a new heuristic algorithm called, Spores Algorithm (SPA) to solve symmetric TSP. Madani&Ndiaye[80] used the General Algebraic Modeling System to solve a new type of vehicle routing problems(VRP) and a two types of a Discrete Traveling Salesman Problem (TSP) with a Moving Depot (TSP-MD). Mahjoub, A. Ridha, et al. [81] proposed a layered compact ILP formulation to solve Steiner Traveling Salesman Problems. Ahmed, Zied O., et al. [82] proposed the Camels Herd Algorithm (CHA) to solve symmetric TSP. Traub&Vygen [83] used 32 approach to solve s-t-path TSP. Platz [84] discussed and analyzed A multi-depot TSP using graph theory. Dong, Ruyi, et al. [85] proposed new hybrid algorithm based on wolf pack search and local search (WPS-LS) to solve symmetric TSP. Choong, Shin Siang, et al.[86] proposed a hyper-heuristic method, called Modified Choice Function (MCF)based on bee colony algorithm , to solve symmetric TSP. Karaboga&Gorkemli [87] presented new versions of artificial bee colony (ABC) to solve symmetric TSP. Taillard&Helsgaun [88] applied "Partial OPtimizationMetaheuristic under special Intensification Conditions" method called (POPMUSIC) to solve large-scale symmetric TSP. Kaabi&Harrath[89] proposed a new permutation rules for genetic algorithm(GA) to solve symmetric TSP. Ra, N.a., et al.[90] proposed an enhanced algorithm called modernised genetic (MGA-TSP) to solve Symmetric TSP. Hossam, Anass, et al. [91] proposed a meta-heuristic algorithm called Elephant Herding Optimization (EHO) to solve symmetric TSP. Jafari[92] discussed asymmetric travelling salesman problem (ATSP) as a single commodity flow problem. Cooper &Nicolescu[93] discussed (said) algorithm ,and provided a suggested algorithm to solve symmetric TSP. Muchammad&Asep [94] Applied Branch and Bound algorithm on a specific symmetric TSP case study. Wang, Xingyin, et al.[95], improved Steiner Zone Variable Neighborhood Search heuristic algorithm (SZVNS) to solve Close-Enough Traveling Salesman Problem (CETSP). Almahasneh, Ruba, et al. [96] proposed Intuitionistic Fuzzy Time Dependent Traveling Salesman Problem (IFTD TSP) to solve Time Dependent TSP ((TD TSP). X. Chen, Y. Liu, X. Li et al.[97] proposed an improved genetic algorithm to solve multi-objective traveling salesman problem (MOTSP). Li, Hang, et al. [98] proposed an enhanced version of Wolf colony search algorithm to solve symmetric tsp. Rahman&Jinwen [99] proposed a dynamical route construction algorithm to solve symmetric and a symmetric TSP. Othman, Abdoun, et al. [100] proposed a hybrid algorithm combined of ACO and GA to solve MOTSP. Bouzidi& Mohammed [101] proposed an improved Cat Swarm Optimization (CSO) to solve symmetric TSP. Wei & Liu [102] proposed an enhanced particle swarm optimization based on neighborhood searching (NPSO) to solve symmetric TSP. Shi, Jialong, et al [103] showed that methods used in multi-objective optimization can solve single-objective problems like symmetric TSP.Ismail [104] applied a heuristics algorithm called Domino Algorithm and Nearest Neighbor algorithm to solve symmetric TSP.Tinarut&Leksakul [105] solved symmetric TSP by using Self-Organizing Map

(SOM), which is Artificial Neural Networks algorithm (ANN). Soukaina et al [106] proposed mathematical heuristic formulation to solve "The Close Enough Travelling Salesman Problem with Time Window (CETSP-TW)". Salii [107] Revisited dynamic programming method to solve the precedence constrained traveling salesman problem (TSP-PC). Alanzi&Bennaceur [108] proposed "a general platform based on HadoopMapReduce approach for implementing parallel genetic algorithms" to solve symmetric TSP. Naser, Husain, et al [109] used a multi perfect matching and partitioning methods to solve symmetric TSP. Wang, Lijin, et al [110] proposed an enhanced List-based simulated annealing (ELBSA) algorithm for solving large-scale symmetric (TSP). Poikonen, Stefan, et al. [111] used branch and bound algorithm to solve Traveling Salesman Problem with a Drone (TSP-D). Bouziaren&Aghezzaf [112] improved the augmented varepsilon -constraint and a Branch and Cut algorithm (AUGMECON2-BC) to solve traveling salesman problem with profits (TSPP). Othman, Mohamed Rafique, et al. [113] proposed a hybrid algorithm combined of the Water Flow Algorithm (WFA) and Variable Neighbourhood Search (VNS) called WFA-VNS to solve symmetric TSP. Ha, Q.M., Deville, Y., Pham, Q.D. et al. [114] proposed a hybrid genetic search algorithm to solve traveling salesman problem with drone (TSP-D). Waissi&Kaushal [115] proposed a heuristic algorithm to solve symmetric (TSP). Schmitt, João P., et al. [116] evaluated MMAS, US local search and 3-opt local search performance in solving Asymmetric and Dynamic TSP with Moving Vehicle (ADTSPMV). Cacchiani, Valentina, et al. [117] proposed a new Mixed Integer Programming model for Traveling Salesman Problem with Time-dependent Service times (TSP-TS) and developed a multi-operator genetic algorithm and two Branch-and-Cut methods, based on the proposed model. Isoart&Régin [118] corrected the drawbacks of weighted circuit constraint (WCC) by introducing the Hamiltonian cycle constraint associated with propagators to solve symmetric TSP. Alipour&Razavi [119] developed a novel local heuristic search ,based on nearest insertion into the convex hull construction heuristic NICH-LS to solve Euclidean TSP. Chen, Zhixiang, et al. [120] proposed an exponential time approximation scheme for the symmetric (TSP) on undirected graphs. Köhne, Anna, et al. [121] discussed constant integrality ratio in the asymmetric TSP. Jedrzejowicz&Wierzbowska[122] presented a novel application of Apache Spark to solve symmetric TSP. Chlebík&Chlebíková [123] presented the weighted amplifiers and weighted low occurrence methods to solve symmetric TSP. Liu, Qingxue, et al. [124] proposed "a niching particle swarm optimization (PSO)-based Euclidean distance and hierarchical clustering (EDHC) for multimodal optimization" (EDHC-PSO) to solve symmetric TSP. Siemiński [125] discussed the usefulness of Ant Colony Communities (ACC) in solving dynamic TSP (DSTP). Zenklusen, [126] presented 1.5-approximation for the Metric Path Traveling Salesman Problem (Path TSP). Leong, KahHuo, et al [127] presented an optimization algorithm and mathematical model based on the foraging behavior of bees and decision theory to solve a railway traveling salesman problem (RTSP).Khanra, Aditi, et al. [128] proposed a hybrid algorithm combined of ACO and GA to solve discrete multi-objective TSP (MOTSP).

Literature Analysis

We reviewed 200 articles published in year 2019 (Scopus database) related to TSP;from the 200 reviewed papers we found that only 128 papers have a direct relation to TSP.The literature analysis showed the TSP variants that have been discussed in published articles in the year 2019; 34 variants were mentioned see table 1.

Table 1. TSP variants

No	TSP variant	Number of articles
1	Different Symmetric TSP (small , medium and large instances)	82
2	Multi-Objective TSP (MOTSP)	7
3	Roaming Salesman Problem (RSP)	1
4	Multi-commodity Traveling Salesman Problem with Priority Prizes (MTSPPP).	1
5	Moving Target TSP (MT-TSP).	1
6	Biased-TSP-Path	1
7	TSP with Time Windows (TSPTW)	2
8	open-loop variant TSP	1
9	the angular-metric travelling salesman problem (AngleTSP)	1
10	Traveling Thief Problem (TTP) which is a variant of symmetric TSP.	1
11	Time Dependent Traveling Salesman Problem (TDTSP)	1
12	traveling salesman problem with neighborhoods (TSPN)	1
13	Euclidean TSP	4
14	Time Dependent TSP (TD TSP)	2
15	Maximum scatter traveling salesman problem (MSTSP).	1

16	pickup-and-delivery TSP	1
17	s–t-path TSP	1
18	Open close multiple travelling salesmen problem with single depot (OCMTSP).	1
19	One-commodity traveling salesman problem with selective pickup and delivery (1-TSP-SELPD).	1
20	Traveling Salesman Problem (TSP) with a Moving Depot (TSP-MD).	1
21	Steiner Traveling Salesman Problems.	1
22	s-t-path TSP	1
23	multi-depot TSP	1
24	asymmetric travelling salesman(ATSP)	2
25	Close-Enough Traveling Salesman Problems (CETSP).	1
26	precedence constrained traveling salesman problem (TSP-PC)	1
27	Traveling Salesman Problem with a Drone (TSP-D)	2
28	traveling salesman problem with profits (TSPP).	1
29	Asymmetric and Dynamic TSP with Moving Vehicle (ADTSPMV)	1
30	Traveling Salesman Problem with Time-dependent Service times (TSP-TS)	1
31	dynamic TSP (DSTP)	1
32	Metric Path Traveling Salesman Problem (Path TSP).	1
33	railway traveling salesman problem (RTSP)	1
34	half-integer TSP	1

82 articles from 128 were for symmetric TSP with ratio of 64%, and 46 articles were for other different types of TSP with ratio of 36% see figure 2.

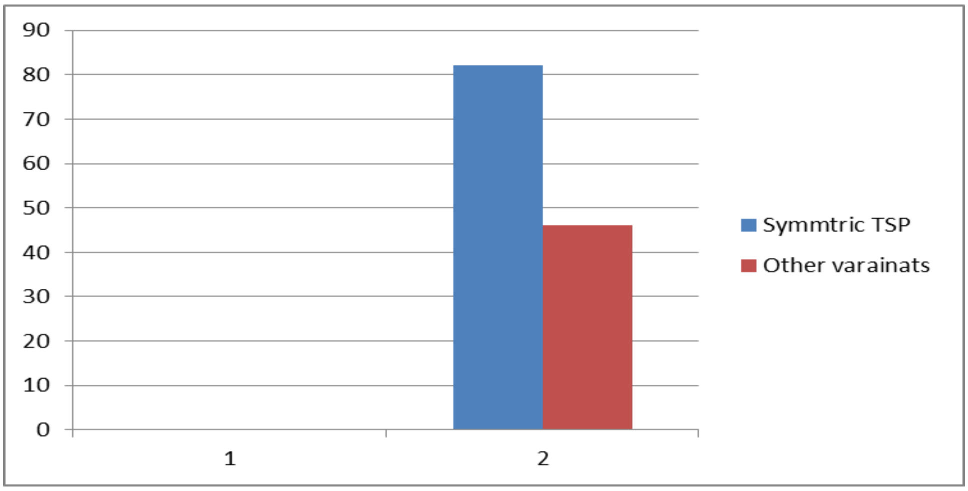

Figure 2: ratio of symmetric TSP to other variants.

The literature analysis showed new proposedalgorithms, improved exiting algorithms and applying exiting algorithms in to different variants. The presented algorithms were used to solve different variants of TSP.The other 72 articles were for other optimization problems and mentioned TSP.

The literature review for 128 articles showed the following proposed and improved algorithms (see table 2.)

Table 2 the proposed /improved algorithms for TSP in the year 2019

No	Algorithm name	Reference	TSP type
1	dynamic spider monkey optimization (DSMO)(new variant)	[1]	large symmetric TSP instances
2	a hybrid heuristic algorithm	[2]	a variant of symmetric TSP called , flying sidekick TSP
3	a hybrid algorithm , called(MOTSRP)	[3]	Multi-Objective Traveling Repairman Problem (MOTRP
4	a two-phase matheuristic algorithm	[4]	Roaming Salesman Problem (RSP).
5	a heuristic algorithm, with a binomial distribution model	[5]	symmetric TSP

6	network reconstruction technique with minimal spanning tree (MST)	[6]	symmetric TSP
7	a cantor-set based (CB) method for heuristic algorithms	[7]	symmetric TSP
8	adaptive and modular genetic algorithm (AMGA)	[8]	symmetric TSP
9	a multi-objective genetic algorithm (MOGA)	[9]	symmetric TSP
10	a self-exploration strategy added to chicken swarm algorithm	[10]	symmetric TSP
11	a virtual graph(algorithm A* and graph Hamilton circuit)	[11]	symmetric TSP
12	Biased Random-Key Genetic Algorithm (BRKGA)	[12]	Medium and large Multi-commodity Traveling Salesman Problem with Priority Prizes (MTSPPP).
13	hybrid algorithm(modified particle swarm optimization (PSO) and genetic algorithm (GA)	[17]	symmetric and asymmetric TSP
14	a two new operators ("link swap and 3-permute")	[18]	open-loop variant TSP.
15	improved k-OPT heuristic algorithm	[19]	symmetric TSP
16	improved classical TSP algorithm[an iterative solution method]	[20]	symmetric TSP
17	Non-dominated sorting genetic algorithm II (NSGA-II)	[21]	multi-objective TSP (MOTSP)
18	Greedy Randomized Adaptive Search Procedure (GRASP)	[22]	symmetric TSP
19	heuristic model (frequency graph)	[23]	symmetric TSP

20	heuristic strategies(discrete optimization)	[24]	symmetric TSP
21	improved Christofides algorithm	[25]	half-integer TSP
22	new mutation operators for genetic algorithm	[27]	evolving instances of the symmetric TSP
23	Improved Ant Search method	[30]	symmetric TSP
24	k-Repetitive-Nearest-Neighbor algorithm	[31]	symmetric TSP
25	different heuristics improvement	[32]	angular-metric travelling salesman problem(AngleTSP)
26	two-phased meta-heuristic approach	[33]	symmetric TSP
27	Fuzzy C-Mean Genetic Algorithm (FCMGA)	[34]	symmetric TSP
28	discrete PIO algorithm(DPIO)	[35]	Large-scale symmetric TSP instances.
29	hybrid ant colony algorithm	[36]	Traveling Thief Problem (TTP)
30	Mixing Genetic Algorithm	[37]	symmetric TSP
31	Improved pheromone matrix with linear memory complexity (ACO)	[38]	large-scale symmetric TSP
32	Hopfield network method	[39]	symmetric TSP
33	two-phase meta-heuristic (Insertion Heuristic (IH), Variable Neighborhood Search (VNS) and the tabu search (TS))	[40]	Time Dependent Traveling Salesman Problem (TDTSP)
34	new crossover operator (BBX evolutionary Algorithms (EAs))	[41]	symmetric TSP
35	Hybrid heuristic algorithm(decoupled approach, growing self-organizing array method)	[43]	traveling salesman problem with neighborhoods (TSPN)

36	parallel General Variable Neighborhood Search (GVNS) procedure	[44]	Hamiltonian p-Median Problem (symmetric TSP)
37	hybrid model (genetic algorithm (GA) , heuristics like "remove-sharp" and" local-opt" with ant colony system (ACS))	[46]	symmetric TSP
38	Triple Fuzzy Time Dependent TSP approach ((3FTD TSP)	[47]	Time Dependent TSP (TD TSP)
39	multi-start iterated local search algorithm	[48]	maximum scatter traveling salesman problem (MSTSP)
40	hardware realization of the crossover method in the genetic algorithm	[51]	symmetric TSP
41	self-organizing maps evolutionary algorithm(ACS to handle the Min_Max algorithm)	[52]	multi-objective TSP MOTSP
42	state-of-the-art SAT and TSP solvers	[53]	Symmetric TSP
43	modified ant system (MAS)	[56]	symmetric TSP
44	Branch and Bound technique (BABT)	[59]	symmetric TSP
45	Firefly Algorithm (FA) and k-means clustering	[62]	symmetric TSP
46	genetic algorithm (GA)(six different crossover operators)	[63]	multi-objective TSP MOTSP
47	GP hyper-heuristic(GA algorthim)	[64]	symmetric TSP (large-scale instances)
48	excellence coefficients and self-escape strategy (ECSDSOS)	[65]	symmetric TSP
49	A two mathematical formulations	[66]	pickup-and-delivery TSP

50	improved analysis of the best-of-many Christofides algorithm	[68]	s–t-path TSP
51	Parallel Iterative Hill Climbing (PIHC) algorithm	[70]	symmetric TSP (large-scale instances)
52	dynamic flying ant colony optimization (DFACO)	[71]	symmetric TSP
53	new crossover operator for traditional genetic algorithm	[72]	symmetric TSP
54	modified standard spider monkey algorithm (SMO)	[73]	symmetric TSP
55	two-stage approach based on Kernighan–Helsgaun (LKH) algorithm	[75]	one-commodity traveling salesman problem with selective pickup and delivery (1-TSP-SELPD).
56	discrete sine-cosine algorithm (DSCA)	[76]	Symmetric TSP
57	non-dominated sorting genetic algorithm II (NSGAII)	[77]	Symmetric TSP
58	new strategies in genetic algorithm (GA)	[78]	Symmetric TSP
59	Spores Algorithm (SPA)	[79]	Symmetric TSP
60	layered compact ILP formulation	[81]	Steiner Traveling Salesman Problems
61	Camels Herd Algorithm (CHA)	[82]	Symmetric TSP
62	new hybrid algorithm(wolf pack search and local search)(WPS-LS)	[85]	Symmetric TSP
63	Modified Choice Function (MCF)based on bee colony algorithm	[86]	Symmetric TSP
64	new versions of artificial bee colony (ABC)	[87]	Symmetric TSP

65	Partial OPtimizationMetaheuristic under special Intensification Conditions((POPMUSIC method)	[88]	symmetric TSP (large-scale instances)
66	new permutation rules for genetic algorithm(GA)	[89]	Symmetric TSP
67	modernised genetic (MGA-TSP)	[90]	Symmetric TSP
68	Elephant Herding Optimization (EHO)	[91]	Symmetric TSP
69	Steiner Zone Variable Neighborhood Search heuristic algorithm (SZVNS)	[95]	Close-Enough Traveling Salesman Problem (CETSP).
70	Intuitionistic Fuzzy Time Dependent Traveling Salesman Problem (IFTD TSP)	[96]	Time Dependent TSP ((TD TSP).
71	an improved genetic algorithm	[97]	multi-objective traveling salesman problem (MOTSP)
72	enhanced version of Wolf colony search algorithm	[98]	Symmetric TSP
73	a dynamical route construction algorithm	[99]	Symmetric and asymmetric TSP
74	hybrid algorithm (ACO and GA)	[100]	multi-objective traveling salesman problem (MOTSP)
75	an improved Cat Swarm Optimization (CSO)	[101]	Symmetric TSP
76	enhanced particle swarm optimization	[102]	Symmetric TSP
77	mathematical heuristic formulation	[106]	The Close Enough Travelling Salesman Problem with Time Window (CETSP-TW)
78	a general platform based on HadoopMapReduce approach for	[108]	Symmetric TSP

	implementing parallel genetic algorithms		
79	enhanced List-based simulated annealing (ELBSA)	[110]	symmetric TSP (large-scale instances)
80	improved augmented varepsilon -constraint and a Branch and Cut algorithm (AUGMECON2-BC)	[112]	traveling salesman problem with profits (TSPP).
81	a hybrid algorithm (WFA-VNS)	[113]	Symmetric TSP
82	hybrid genetic search algorithm	[114]	Traveling salesman problem with drone (TSP-D).
83	heuristic algorithm	[115]	Symmetric TSP
84	new Mixed Integer Programming (multi-operator genetic algorithm and two Branch-and-Cut methods)	[117]	Traveling Salesman Problem with Time-dependent Service times (TSP-TS)
85	a novel local heuristic search(NICH-LS)	[119]	Euclidean TSP
86	an exponential time approximation scheme	[120]	Symmetric TSP
87	novel application of Apache Spark	[122]	Symmetric TSP
88	a niching particle swarm optimization (PSO) (EDHC-PSO)	[124]	Symmetric TSP
89	hybrid algorithm(ACO and GA)	[128]	discrete multi-objective TSP (MOTSP

From 128 related papers, we found that 89articles werefor new proposed and improved algorithms that used to solvedifferent variants of TSP; 58from 89 articles were for symmetric TSP see figure 3.

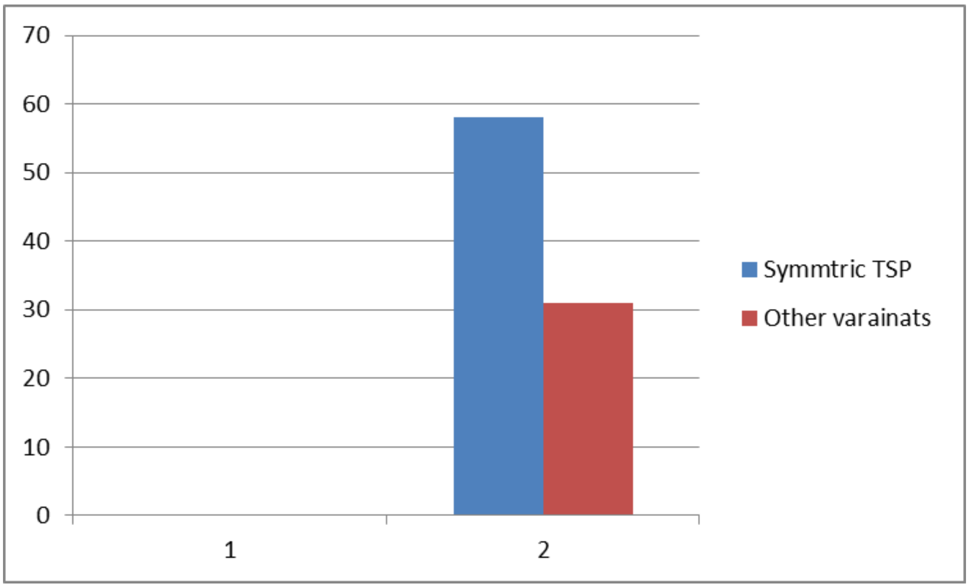

Figure 3: ratio for proposed algorithms for symmetric TSP.

Symmetric TSP got 65.1% ratio from the new proposed and improved algorithms; the other TSP variants got 34.9%. Table 2 also showed that 25 articles proposed genetic (GA) based algorithms with ratio of 28%, proposed Heuristic algorithms in general without determining exact name mentionedin 16 articles, ant colony optimization mentioned in 8 articles, and the rest of articles were for many different types of proposed algorithms. The rest ofrelated Articles (39article)discussed and compared exiting algorithms to find their performance in finding optimal solutions for different TSP see table 3 form more explanations.

Table 3: References discussed TSP in the year 2109

No	Reference no	Objective	Results	TSP variants
1	[13]	Compared GA , ACO and simulated annealingoptimization	genetic algorithm performance was better	Moving Target TSP (MT-TSP).
2	[14]	discussed path version of the TSP	Proved that the Biased-TSP-Path is approximable within a constant factor	Biased-TSP-Path
3	[15]	discussed TSP with Time Windows by applying QUBO formulation	actual execution of small scale TSPTW instances on the D-Wave platform	small scale TSPTW instances
4	[16]	Discussed variance estimates for TSP Cn	“proved that if the cities are well-connected in a	Euclidean TSP

			certain sense, then TSP Cn appropriately centered and scaled converges to zero in probability”	
5	[26]	Discussed Exponential Time Hypothesis in Hamiltonian cycle	improve the 32 best-known bounds for general graphs	symmetric TSP
6	[28]	Discussed initial design of the crow search algorithm	results show the significant and feasible solution	symmetric TSP
7	[29]	a comprehensive empirical study on GAO, ACO and PSO	some guidance for designing efficient evolutionary algorithms to solve TSP	symmetric TSP
8	[42]	experiments to find the shortest path for symmetric TSP	constructed models can be used to estimate the travel time variance and reliability	symmetric TSP
9	[45]	reviewed Euclidean TSP	optimal cost is a self-averaging quantity	Euclidean TSP
10	[49]	used a Multi-Agent System	TSP solver used is based on genetic algorithm	symmetric TSP
11	[50]	compared and analyzed the performance of ACO on contemporary high-performance hardware	there is no overall best parallelization strategy	symmetric TSP
12	[54]	Discussed unmanned vehicle routs UAV as symmetric TSP	the average computation time required to solve the problem	UAV as a Symmetric TSP

doi:10.3906/elk

13	[55]	applied Cuckoo Search Algorithm	"A thorough analysis has been performed to assess the efficacy of this optimization"	symmetric TSP
14	[57]	Discussed Dijkstra algorithm	Dijkstra algorithm must be modified using Dijkstra's priority clustering	symmetric TSP
15	[58]	modeled a Search optimization	find the shortest path with genetic algorithms	symmetric STP , MTSP
16	[60]	used symmetric TSP algorithmto solve ecotourism destinations in Chiang Mai, Thailand	Benefits of TSP technique to the tourism context	symmetric TSP
17	[61]	presented a numerical example	obtained the best possible route	draft limit and time windows TSP
18	[67]	solve the transport network optimization using TSP and Exhaustive Search Algorithm	identify multiple optimal solutions	symmetric TSP
19	[69]	used genetic algorithm (GA)	Obtain convergence of genetic algorithm	symmetric TSP
20	[74]	Presented a new variant of TSP and find optimal route	computational experiments have been carried out on some benchmark	open close multiple travelling salesmen problem with single depot (OCMTSP)
21	[80]	used the General Algebraic Modeling System	a new class of vehicle routing problems	(TSP) with a Moving Depot (TSP-MD).
22	[83]	used 3/2 approach	compute a spanning tree (V, S)	s-t-path TSP
23	[84]	discussed and analyzed A multi-	TS games is analyzed by	A multi-depot TSP

		depot TSP using graph theory	characterizing graphs and digraphs	
24	[92]	Discussed asymmetric travelling salesman problem (ATSP) as a single commodity flow problem.	solving certain real world instances by standard integer programming methods	Asymmetric TSP
25	[93]	discussed (said) algorithm	provides an example application of TSP algorithm	symmetric TSP
26	[94]	Applied Branch and Bound algorithm	small error level with a long calculations	symmetric TSP
27	[103]	showed methods used in multi-objective optimization	solve single-objective problems	symmetric TSP
28	[104]	applied Domino Algorithm and Nearest Neighbor algorithm	finding the optimal results by which the application will be moreover quite simple and easy	symmetric TSP
29	[105]	solve symmetric TSP by using Self-Organizing Map (SOM),	Improve the processing time	symmetric TSP
30	[107]	Discussed dynamic programming method	prove the validity of DP optimality for TSP-PC	Precedence constrained traveling salesman problem (TSP-PC).
31	[109]	used a multi perfect matching and partitioning methods	Get optimum or near-optimum solutions in polynomial execution time	symmetric TSP
32	[111]	used branch and bound algorithm	provide additional variants of heuristic approach	Traveling Salesman Problem with a Drone (TSP-D).
33	[116]	EvaluateMMAS, US local search and 3-opt	MMAS-US is the best algorithm while	Asymmetric and Dynamic TSP with

		local search performance	for ADTSPMV the MMAS-3opt is the most suitable	Moving Vehicle (ADTSPMV).
34	[118]	corrected the drawbacks of weighted circuit constraint (WCC) by introducing the Hamiltonian cycle constraint	a strong reduction of the computation time	symmetric TSP
35	[121]	discussed constant integrality ratio	ATSP node-weighted instances and unweighted digraph instances are almost equivalent	Asymmetric TSP
36	[123]	Discussed the weighted amplifiers and weighted low occurrence methods	show that already slight improvement of known expander values modestly improve the current best approximation hardness value for TSP	symmetric TSP
37	[125]	discussed the usefulness of Ant Colony Communities (ACC)	Showed that the routes are far shorter than in the case of original colonies	Dynamic TSP (DSTP).
38	[126]	Showed 1.5-approximation for the Metric Path Traveling Salesman	progress on the approximability of Path TSP will also lead to an improvement for TSP.	Path Traveling Salesman Problem (Path TSP).
39	[127]	presented an optimization algorithm and mathematical model based on the foraging behavior of bees and decision theory	proved the reliability and capability of the route planning and optimization solutions for RSs	railway traveling salesman problem (RTSP)

Table 3 show that 21 articles from 39 discussed symmetric TSP, where 18 articles discussed other different variants of TSP.

Conclusion

In this research 200 articles were reviewed from Scopus data base, only 128 were having a direct relation to TSP, the other 72 articles were for another optimization problems and mentioned word (TSP). The reviewed literature mentioned 34 different variants of TSP. Symmetric TSP got the highest ratio (64%) from the related (128) reviewed articles. The literature showed that 89 articles proposed or improved new algorithms, Symmetric TSP got 65.1% ratio from the new proposed and improved algorithms, 34.9% for the other TSP variants.The literature also showed that genetic based proposed algorithms got 28% from the reviewed articles.Many exiting heuristic algorithms were improved and enhanced to solve different types of TSP.Finally we conclude that most of published articles were for symmetric TSP and also the proposed and enhanced werealgorithms forsymmetric TSP. We hope that this research considered as a road map for more research in this field in the future

References:

[1] Akhand, M.a.h., et al. "Discrete Spider Monkey Optimization for Travelling Salesman Problem." Applied So, ft Computing, vol. 86, 2020, p. 105887.,

[2] Freitas, JúliaCária De, and PucaHuachiVaz Penna. "A Variable Neighborhood Search for Flying Sidekick Traveling Salesman Problem." International Transactions in Operational Research, 2019, doi:10.1111/itor.12671.

[3] Bock, Stefan, and Kathrin Klamroth. "Combining Traveling Salesman and Traveling Repairman Problems: A Multi-Objective Approach Based on Multiple Scenarios." Computers & Operations Research, vol. 112, 2019, p. 104766., doi:10.1016/j.cor.2019.104766.

[4] Shahmanzari, Masoud, et al. "Formulation and a Two-Phase Matheuristic for the Roaming Salesman Problem: Application to Election Logistics." European Journal of Operational Research, vol. 280, no. 2, 2020, pp. 656–670., doi:10.1016/j.ejor.2019.07.035.

[5] Wang, Yong. "Edges Elimination for Traveling Salesman Problem Based on Frequency $$K_5$$ s." Advances in Intelligent Systems and Computing Optimization of Complex Systems: Theory, Models, Algorithms and Applications, 2019, pp. 1043–1053., doi:10.1007/978-3-030-21803-4_103.

[6] Munapo, Elias. "Network Reconstruction – A New Approach to the Traveling Salesman Problem and Complexity." Advances in Intelligent Systems and Computing Intelligent Computing and Optimization, 2019, pp. 260–272., doi:10.1007/978-3-030-33585-4_26.

[7] Öztürk, Melike, and ÇiğdemAlabaşUslu. “A Novel Neighborhood Generation Method for Heuristics and Application to Traveling Salesman Problem.” Intelligent and Fuzzy Techniques in Big Data Analytics and Decision Making Advances in Intelligent Systems and Computing, June 2019, pp. 1215–1221., doi:10.1007/978-3-030-23756-1_143.

[8] Ohira, Ryoma, et al. “AMGA: An Adaptive and Modular Genetic Algorithm for the Traveling Salesman Problem.” Advances in Intelligent Systems and Computing Intelligent Systems Design and Applications, 2019, pp. 1096–1109., doi:10.1007/978-3-030-16660-1_107.

[9] Hameed, Ibrahim A. “Multi-Objective Solution of Traveling Salesman Problem with Time.” Advances in Intelligent Systems and Computing The International Conference on Advanced Machine Learning Technologies and Applications (AMLTA2019), 2019, pp. 121–132., doi:10.1007/978-3-030-14118-9_13.

[10] Ye, Hao, et al. “An Improved Chicken Swarm Optimization for TSP.” Advances in Intelligent Systems and Computing International Conference on Applications and Techniques in Cyber Intelligence ATCI 2019, 2019, pp. 211–220., doi:10.1007/978-3-030-25128-4_28.

[11] Halaoui, Hatem F. “An Optimal Real-Time Solution for Limited-TSP: Using Smart Algorithms to Find an Optimal TSP Real-Time Solution Over Limited Destinations.” Advances in Intelligent Systems and Computing Human Interaction and Emerging Technologies, 2019, pp. 234–239., doi:10.1007/978-3-030-25629-6_37.

[12] Silva, Tiago Tiburcio Da, et al. “The Multicommodity Traveling Salesman Problem with Priority Prizes: a Mathematical Model and Metaheuristics.” Computational and Applied Mathematics, vol. 38, no. 4, Oct. 2019, doi:10.1007/s40314-019-0976-4.

[13] Moraes, Rodrigo S. De, and Edison P. De Freitas. “Experimental Analysis of Heuristic Solutions for the Moving Target Traveling Salesman Problem Applied to a Moving Targets Monitoring System.” Expert Systems with Applications, vol. 136, 2019, pp. 392–409., doi:10.1016/j.eswa.2019.04.023.

[14] Mohan, Usha, et al. “A 4-Approximation Algorithm for the TSP-Path Satisfying a Biased Triangle Inequality.” Discrete Applied Mathematics, vol. 271, 2019, pp. 108–118., doi:10.1016/j.dam.2019.08.007.

[15] Papalitsas, Christos, et al. “A QUBO Model for the Traveling Salesman Problem with Time Windows.” Algorithms, vol. 12, no. 11, 2019, p. 224., doi:10.3390/a12110224.

[16] Ganesan, Ghurumuruhan. "Traveling Salesman Problem across Well-Connected Cities and with Location-Dependent Edge Lengths." Proceedings - Mathematical Sciences, vol. 129, no. 5, Mar. 2019, doi:10.1007/s12044-019-0517-5.

[17] Khan, Indadul, et al. "A Hybrid PSO-GA Algorithm for Traveling Salesman Problems in Different Environments." International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems, vol. 27, no. 05, 2019, pp. 693–717., doi:10.1142/s0218488519500314.

[18] Sengupta, Lahari, et al. "Which Local Search Operator Works Best for the Open-Loop TSP?" Applied Sciences, vol. 9, no. 19, 2019, p. 3985., doi:10.3390/app9193985.

[19] Cygan, Marek, et al. "Improving TSP Tours Using Dynamic Programming over Tree Decompositions." ACM Transactions on Algorithms, vol. 15, no. 4, Apr. 2019, pp. 1–19., doi:10.1145/3341730.

[20] Kaspi, Moshe, et al. "Maximizing the Profit per Unit Time for the Travelling Salesman Problem." Computers & Industrial Engineering, vol. 135, 2019, pp. 702–710., doi:10.1016/j.cie.2019.06.050.

[21] Myszkowski, Paweł B., et al. "Non-Dominated Sorting Tournament Genetic Algorithm for Multi-Objective Travelling Salesman Problem." Proceedings of the 2019 Federated Conference on Computer Science and Information Systems, 2019, doi:10.15439/2019f192.

[22] Júnior, Alvaro Neuenfeldt, and Lucas RebouçasGuimarães. "A Greedy Randomized Adaptive Search Procedure Application to Solve the Travelling Salesman Problem." International Journal of Industrial Engineering and Management, vol. 10, no. 3, 2019, pp. 238–242., doi:10.24867/ijiem-2019-3-243.

[23] Wang, Yong, and Yiwen Wu. "Frequency Graphs for Travelling Salesman Problem Based on Ant Colony Optimization." International Journal of Computational Intelligence and Applications, vol. 18, no. 03, 2019, p. 1950016., doi:10.1142/s1469026819500160.

[24] Sahai, Tuhin, et al. "Continuous Relaxations for the Traveling Salesman Problem." Nonlinear Dynamics, Vol. 97, Issue 4, 1, PP. 2003-2022 2019, doi:10.1007/s11071-019-05092-5.

[25] Arash, et al. "Towards Improving Christofides Algorithm for Half-Integer TSP." ArXiv.org, 3 July 2019, https://arxiv.org/abs/1907.02120.

[26] Bonnet, et al. "Fine-Grained Complexity of k-OPT in Bounded-Degree Graphs for Solving TSP." ArXiv.org, 25 Aug. 2019, https://arxiv.org/abs/1908.09325v1.

[27] Bossek, Jakob, et al. "Evolving Diverse TSP Instances by Means of Novel and Creative Mutation Operators." Proceedings of the 15th ACM/SIGEVO Conference on Foundations of Genetic Algorithms - FOGA 19, 2019, doi:10.1145/3299904.3340307.

[28] Azezan, NurArif, et al. "Preliminary Design of Crow Search Metaheuristics Algorithm for Travelling Salesman Problem." The 4Th Innovation And Analytics Conference & Exhibition (Iace 2019), 2019, doi:10.1063/1.5121083.

[29] Wei, Feng-Feng, et al. "An Empirical Study on Evolutionary Algorithms for Traveling Salesman Problem." 2019 9th International Conference on Information Science and Technology (ICIST), 2019, doi:10.1109/icist.2019.8836906.

[30] Divya, M. "Solving Travelling Salesman Problem Using Ant Systems: A Programmer's Approach." International Journal of Applied and Computational Mathematics, vol. 5, no. 4, Apr. 2019, doi:10.1007/s40819-019-0662-7.

[31] Klug, Nikolas, et al. "k-RNN: Extending NN-Heuristics for the TSP." Mobile Networks and Applications, vol. 24, no. 4, 2019, pp. 1210–1213., doi:10.1007/s11036-019-01258-y.

[32] taněk, Rostislav, et al. "Geometric and LP-Based Heuristics for Angular Travelling Salesman Problems in the Plane." Computers & Operations Research, vol. 108, 2019, pp. 97–111., doi:10.1016/j.cor.2019.01.016.

[33] Ramadhan, Fadillah, and Arif Imran. "A Two-Phase Metaheuristic Method for Solving Travelling Repairman Problem." 2019 International Conference on Sustainable Engineering and Creative Computing (ICSECC), 2019, doi:10.1109/icsecc.2019.8907032.

[34] Kumar, Ajendra et al. "Travelling Salesman Problem Using Genetic Algorithm And Fuzzy C-Mean Clustering Algorithm." INTERNATIONAL JOURNAL OF SCIENTIFIC & TECHNOLOGY RESEARCH VOLUME 8, ISSUE 08, AUGUST 2019

[35] Zhong, Yiwen, et al. "Discrete Pigeon-Inspired Optimization Algorithm with Metropolis Acceptance Criterion for Large-Scale Traveling Salesman Problem." Swarm and Evolutionary Computation, vol. 48, 2019, pp. 134–144., doi:10.1016/j.swevo.2019.04.002.

[36] Zouari, Wiem, et al. "A New Hybrid Ant Colony Algorithms for the Traveling Thief Problem." Proceedings of the Genetic and Evolutionary Computation Conference Companion on - GECCO 19, 2019, doi:10.1145/3319619.3326785.

[37] Varadarajan, Swetha, and Darrell Whitley. "The Massively Parallel Mixing Genetic Algorithm for the Traveling Salesman Problem." Proceedings of the Genetic

and Evolutionary Computation Conference on - GECCO 19, 2019, doi:10.1145/3321707.3321772.

[38] Peake, Joshua, et al. “Scaling Techniques for Parallel Ant Colony Optimization on Large Problem Instances.” Proceedings of the Genetic and Evolutionary Computation Conference on - GECCO 19, 2019, doi:10.1145/3321707.3321832.

[39] Luo, Yanfen. “Design and Improvement of Hopfield Network for TSP.” Proceedings of the 2019 International Conference on Artificial Intelligence and Computer Science - AICS 2019, 2019, doi:10.1145/3349341.3349372.

[40] Ban, Ha Bang. “An Efficient Two-Phase Metaheuristic Algorithm for the Time Dependent Traveling Salesman Problem.” RAIRO - Operations Research, vol. 53, no. 3, 2019, pp. 917–935., doi:10.1051/ro/2019006.

[41] Weise, Thomas, et al. “A Branch-and-Bound-Based Crossover Operator for the Traveling Salesman Problem.” International Journal of Cognitive Informatics and Natural Intelligence, vol. 13, no. 3, 2019, pp. 1–18., doi:10.4018/ijcini.2019070101.

[42] Yang, Hongtai, et al. “Modeling Quartiles and Variance of Optimal Traveling Salesman Tour Lengths.” 2019 5th International Conference on Transportation Information and Safety (ICTIS), 2019, doi:10.1109/ictis.2019.8883731.

[43] Faigl, Jan, et al. “Fast Heuristics for the 3-D Multi-Goal Path Planning Based on the Generalized Traveling Salesman Problem With Neighborhoods.” IEEE Robotics and Automation Letters, vol. 4, no. 3, 2019, pp. 2439–2446., doi:10.1109/lra.2019.2900507.

[44] Herrán, Alberto, et al. “A Variable Neighborhood Search Approach for the Hamiltonian p-Median Problem.” Applied Soft Computing, vol. 80, 2019, pp. 603–616., doi:10.1016/j.asoc.2019.04.033.

[45] Caracciolo, Sergio, et al. “Average Optimal Cost for the Euclidean TSP in One Dimension.” Journal of Physics A: Mathematical and Theoretical, vol. 52, no. 26, May 2019, p. 264003., doi:10.1088/1751-8121/ab1600.

[46] Sahana, Sudip Kumar. “Hybrid Optimizer for the Travelling Salesman Problem.” Evolutionary Intelligence, vol. 12, no. 2, 2019, pp. 179–188., doi:10.1007/s12065-019-00208-7.

[47] Koczy, Laszlo T., et al. “Modeling of Fuzzy Rule-Base Algorithm for the Time Dependent Traveling Salesman Problem.” 2019 IEEE International Conference on Fuzzy Systems (FUZZ-IEEE), 2019, doi:10.1109/fuzz-ieee.2019.8858853.

[48] Venkatesh, Pandiri, et al. “A Multi-Start Iterated Local Search Algorithm for the Maximum Scatter Traveling Salesman Problem.” 2019 IEEE Congress on Evolutionary Computation (CEC), 2019, doi:10.1109/cec.2019.8790018.

[49] Yang, Chen, and Kwok Yip Szeto. “Solving the Traveling Salesman Problem with a Multi-Agent System.” 2019 IEEE Congress on Evolutionary Computation (CEC), 2019, doi:10.1109/cec.2019.8789895.

[50] Menezes, Breno A. M., et al. “Parallelization Strategies for GPU-Based Ant Colony Optimization Solving the Traveling Salesman Problem.” 2019 IEEE Congress on Evolutionary Computation (CEC), 2019, doi:10.1109/cec.2019.8790073.

[51] Attarmoghaddam, Narges, et al. “FPGA Implementation of Crossover Module of Genetic Algorithm.” Information, vol. 10, no. 6, 2019, p. 184., doi:10.3390/info10060184.

[52] Lupoaie, Vlad-Ioan, et al. “SOM-Guided Evolutionary Search for Solving MinMax Multiple-TSP.” 2019 IEEE Congress on Evolutionary Computation (CEC), 2019, doi:10.1109/cec.2019.8790276

[53] meson, Frank, and Stephen L. Smith. “An SMT-Based Approach to Motion Planning for Multiple Robots With Complex Constraints.” IEEE Transactions on Robotics, vol. 35, no. 3, 2019, pp. 669–684., doi:10.1109/tro.2019.2896401.

[54] Hari, S. K. K., et al. “Efficient Computation of Optimal UAV Routes for Persistent Monitoring of Targets.” 2019 International Conference on Unmanned Aircraft Systems (ICUAS), 2019, doi:10.1109/icuas.2019.8798167.

[55] BhavanaV,Varshini Ramesh, Sivagami M, " Implementing Discrete Cuckoo Search Algorithm for TSP using MPI and Beowulf Cluster" , International Journal of Innovative Technology and Exploring Engineering (IJITEE), Volume-8 Issue-8 June, 2019

[56] RenuJangra, Ramesh Kait," Modified Ant System Solving TSP Problem", International Journal of Innovative Technology and Exploring Engineering (IJITEE) ,Volume-8 Issue-8S3, June 2019.

[57] Ginting, HagaiNuansa, et al. “Item Delivery Simulation Using Dijkstra Algorithm for Solving Traveling Salesman Problem.” Journal of Physics: Conference Series, vol. 1201, 2019, p. 012068., doi:10.1088/1742-6596/1201/1/012068.

[58] Switrayana, I Nyoman, et al. “Item Delivery Simulation Using Genetic Algorithm.” Journal of Physics: Conference Series, vol. 1201, 2019, p. 012060., doi:10.1088/1742-6596/1201/1/012060.

[59] SajjadMajeedJasim ,Faez Hassan Ali " Exact and Local Search Methods for Solving Travelling Salesman Problem with Practical Application" , Iraqi Journal of Science, 2019, Vol. 60, No.5, pp: 1138-1153 DOI: 10.24996/ijs.2019.60.5.22

[60] Manopiniwes, Wapee, et al. “Smart Ecotourism Planning in Chiang Mai Using Traveling Salesman Problem.” Proceedings of the 2019 5th International Conference

on E-Business and Mobile Commerce - ICEMC 2019, 2019, doi:10.1145/3332324.3332334.

[61] Ghasemi-Sardabrud, Mahsa, et al. “A Ship Routing and Scheduling Problem Considering Pickup and Delivery, Time Windows and Draft Limit.” 2019 15th Iran International Industrial Engineering Conference (IIIEC), 2019, doi:10.1109/iiiec.2019.8720627.

[62] Jaradat, Ameera, et al. “Solving Traveling Salesman Problem Using Firefly Algorithm and K-Means Clustering.” 2019 IEEE Jordan International Joint Conference on Electrical Engineering and Information Technology (JEEIT), 2019, doi:10.1109/jeeit.2019.8717463.

[63] Al-Omeer, Maha Ata, and ZakirHussain Ahmed. “Comparative Study of Crossover Operators for the MTSP.” 2019 International Conference on Computer and Information Sciences (ICCIS), 2019, doi:10.1109/iccisci.2019.8716483.

[64] Duflo, Gabriel, et al. “A GP Hyper-Heuristic Approach for Generating TSP Heuristics.” 2019 IEEE International Parallel and Distributed Processing Symposium Workshops (IPDPSW), 2019, doi:10.1109/ipdpsw.2019.00094.

[65] Wang, Y., et al. “Discrete Symbiotic Organism Search with Excellence Coefficients and Self-Escape for Traveling Salesman Problem.” Computers & Industrial Engineering, vol. 131, 2019, pp. 269–281., doi:10.1016/j.cie.2019.04.008.

[66] Benavent, Enrique, et al. “The Probabilistic Pickup-and-Delivery Travelling Salesman Problem.” Expert Systems with Applications, vol. 121, 2019, pp. 313–323., doi:10.1016/j.eswa.2018.12.028.

[67] Vukmirovic, Slavomir, et al. “The Exhaustive Search Algorithm in the Transport Network Optimization on the Example of Urban Agglomeration Rijeka.” 2019 42nd International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO), 2019, doi:10.23919/mipro.2019.8756720.

[68] Traub, Vera, and Jens Vygen. “An Improved Upper Bound on the Integrality Ratio for Thes–t-Path TSP.”Operations Research Letters, vol. 47, no. 3, 2019, pp. 225–228., doi:10.1016/j.orl.2019.02.005.

[69] Juneja, Sahib Singh, et al. “Travelling Salesman Problem Optimization Using Genetic Algorithm.” 2019 Amity International Conference on Artificial Intelligence (AICAI), 2019, doi:10.1109/aicai.2019.8701246.

[70] Yelmewad, Pramod, and BasavarajTalawar. “Parallel Iterative Hill Climbing Algorithm to Solve TSP on GPU.” Concurrency and Computation: Practice and Experience, vol. 31, no. 7, 2018, doi:10.1002/cpe.4974.

[71] Dahan, et al. “Dynamic Flying Ant Colony Optimization (DFACO) for Solving the Traveling Salesman Problem.” Sensors, vol. 19, no. 8, 2019, p. 1837., doi:10.3390/s19081837.

[72] Akter, Shamima, et al. “A New Crossover Technique to Improve Genetic Algorithm and Its Application to TSP.” 2019 International Conference on Electrical, Computer and Communication Engineering (ECCE), 2019, doi:10.1109/ecace.2019.8679367.

[73] Ayon, Safial Islam, et al. “Spider Monkey Optimization to Solve Traveling Salesman Problem.” 2019 International Conference on Electrical, Computer and Communication Engineering (ECCE), 2019, doi:10.1109/ecace.2019.8679221.

[74] Thenepalle, Jayanth Kumar, and PurusothamSingamsetty. “An Open Close Multiple Travelling Salesman Problem with Single Depot.” Decision Science Letters, 2019, pp. 121–136., doi:10.5267/j.dsl.2018.8.002.

[75] Miao, Kun, et al. “A One-Commodity Pickup-and-Delivery Traveling Salesman Problem Solved by a Two-Stage Method: A Sensor Relocation Application.” Plos One, vol. 14, no. 4, 2019, doi:10.1371/journal.pone.0215107.

[76] Tawhid, Mohamed A., and PoonamSavsani. “Discrete Sine-Cosine Algorithm (DSCA) with Local Search for Solving Traveling Salesman Problem.” Arabian Journal for Science and Engineering, vol. 44, no. 4, Nov. 2018, pp. 3669–3679., doi:10.1007/s13369-018-3617-0.

[77] KongzhiyuJuece, “An evolutionary multiobjective optimization method for traveling salesman problems”, Control and Decision. Vol.34 no.4 2019. 775-780. DOI: 10.13195/j.kzyjc.2017.1323

[78] Paul, Victer, et al. “Performance Evaluation of Population Seeding Techniques of Permutation-Coded GA Traveling Salesman Problems Based Assessment.” International Journal of Applied Metaheuristic Computing, vol. 10, no. 2, 2019, pp. 55–92., doi:10.4018/ijamc.2019040103.

[79] Jakjoud, Abdeslam, et al. “SPORES: A New Distributed Heuristic Inspired by Fungi Reproduction.” 2019 6th International Conference on Control, Decision and Information Technologies (CoDIT), 2019, doi:10.1109/codit.2019.8820420.

[80] Madani, B., and M. Ndiaye. “Autonomous Vehicles Delivery Systems Classification: Introducing a TSP With a Moving Depot.” 2019 8th International Conference on Modeling Simulation and Applied Optimization (ICMSAO), 2019, doi:10.1109/icmsao.2019.8880379.

[81] Mahjoub, A. Ridha, et al. "A Layered Compact Formulation for the Multiple Steiner TSP with Order Constraints." 2019 6th International Conference on Control, Decision and Information Technologies (CoDIT), 2019, doi:10.1109/codit.2019.8820661.

[82] Ahmed, Zied O., et al. "Solving the Traveling Salesmans Problem Using Camels Herd Algorithm." 2019 2nd Scientific Conference of Computer Sciences (SCCS), 2019, doi:10.1109/sccs.2019.8852596.

[83] Traub, Vera, and Jens Vygen. "Approaching 3/2 for the s-t-Path TSP." Journal of the ACM, vol. 66, no. 2, July 2019, pp. 1–17., doi:10.1145/3309715.

[84] Platz, Trine Tornøe. "On the Submodularity of Multi-Depot Traveling Salesman Games." Discrete Applied Mathematics, vol. 255, 2019, pp. 75–85., doi:10.1016/j.dam.2018.11.029.

[85] Dong, Ruyi, et al. "Hybrid Optimization Algorithm Based on Wolf Pack Search and Local Search for Solving Traveling Salesman Problem." Journal of Shanghai Jiaotong University (Science), vol. 24, no. 1, 2019, pp. 41–47., doi:10.1007/s12204-019-2039-9.

[86] Choong, Shin Siang, et al. "An Artificial Bee Colony Algorithm with a Modified Choice Function for the Traveling Salesman Problem", Swarm and Evolutionary Computation Volume 44, February 2019, Pages 622-635, doi:10.1016/j.swevo.2018.08.004

[87] Karaboga, Dervis, and BeyzaGorkemli. "Solving Traveling Salesman Problem by Using Combinatorial Artificial Bee Colony Algorithms." International Journal on Artificial Intelligence Tools, vol. 28, no. 01, 2019, p. 1950004., doi:10.1142/s0218213019500040.

[88] Taillard, Éric D., and KeldHelsgaun. "POPMUSIC for the Travelling Salesman Problem." European Journal of Operational Research, vol. 272, no. 2, 2019, pp. 420–429., doi:10.1016/j.ejor.2018.06.039.

[89] Kaabi, Jihene, and Youssef Harrath. "Permutation Rules and Genetic Algorithm to Solve the Traveling Salesman Problem." Arab Journal of Basic and Applied Sciences, vol. 26, no. 1, Feb. 2019, pp. 283–291., doi:10.1080/25765299.2019.1615172.

[90] Ra, N.a., et al. "MGA-TSP: Modernised Genetic Algorithm for the Travelling Salesman Problem." International Journal of Reasoning-Based Intelligent Systems, vol. 11, no. 3, 2019, p. 215., doi:10.1504/ijris.2019.102541.

[91] Hossam, Anass, et al. "Elephants Herding Optimization for Solving the Travelling Salesman Problem." Advances in Intelligent Systems and Computing Advanced

Intelligent Systems for Sustainable Development (AI2SD'2018), 2019, pp. 122–130., doi:10.1007/978-3-030-12065-8_12.

[92] Jafari, Nahid. "A Non-Assignment Problem-Based Formulation for the Asymmetric Travelling Salesman Problem and Its Variation." International Journal of Operational Research, vol. 35, no. 4, 2019, p. 575., doi:10.1504/ijor.2019.101461.

[93] Cooper, James, and RaduNicolescu. "The Hamiltonian Cycle and Travelling Salesman Problems in CP Systems."FundamentaInformaticae, vol. 164, no. 2-3, 2019, pp. 157–180., doi:10.3233/fi-2019-1760.

[94] MuchammadFauzia, AsepAnwarb ," Solving the Travelling SalesmanProblem (TSP) Using Branch andBound Method (Case Study at Company of XYZ)", International Journal of Innovation, Creativity and Change., Volume 6, Issue 6, 2019

[95] Wang, Xingyin, et al. "A Steiner Zone Variable Neighborhood Search Heuristic for the Close-Enough Traveling Salesman Problem." Computers & Operations Research, vol. 101, 2019, pp. 200–219., doi:10.1016/j.cor.2018.07.023.

[96] Almahasneh, Ruba, et al. "Intuitionistic Fuzzy Model of Traffic Jam Regions and Rush Hours for the Time Dependent Traveling Salesman Problem." Advances in Intelligent Systems and Computing Fuzzy Techniques: Theory and Applications, 2019, pp. 123–134., doi:10.1007/978-3-030-21920-8_12.

[97]X. Chen, Y. Liu, X. Li et al. , "A New Evolutionary Multiobjective Model for Traveling Salesman Problem," in IEEE Access, vol. 7, pp. 66964-66979, 2019.doi: 10.1109/ACCESS.2019.2917838

[98] Li, Hang, et al. "A New Wolf Colony Search Algorithm Based on Search Strategy for Solving Travelling Salesman Problem." International Journal of Computational Science and Engineering, vol. 18, no. 1, 2019, p. 1., doi:10.1504/ijcse.2019.10017816.

[99] Rahman, Md. Azizur, and Jinwen Ma. "Solving Symmetric and Asymmetric Traveling Salesman Problems Through Probe Machine with Local Search." Intelligent Computing Theories and Application Lecture Notes in Computer Science, 2019, pp. 1–13., doi:10.1007/978-3-030-26763-6_1.

[100] Othman, Abdoun, et al. "An Effective Parallel Approach to Solve Multiple Traveling Salesmen Problem." Advances in Intelligent Systems and Computing Advanced Intelligent Systems for Sustainable Development (AI2SD'2018), 2019, pp. 647–664., doi:10.1007/978-3-030-11928-7_58.

[101] Bouzidi, Abdelhamid, and Mohammed EssaidRiffi."Improved CSO to Solve the TSP." Advances in Intelligent Systems and Computing Advanced Intelligent Systems for Sustainable Development (AI2SD'2018), 2019, pp. 252–260., doi:10.1007/978-3-030-11928-7_22.

[102] Wei, Yanmeng, and Xiyu Liu. “A Novel PSO Algorithm for Traveling Salesman Problem Based on Dynamic Membrane System.” Green, Pervasive, and Cloud Computing Lecture Notes in Computer Science, 2019, pp. 506–515., doi:10.1007/978-3-030-15093-8_39.

[103] Shi, Jialong, et al. “Multi-Objective Techniques for Single-Objective Local Search: A Case Study on Traveling Salesman Problem.” Lecture Notes in Computer Science Evolutionary Multi-Criterion Optimization, 2019, pp. 114–125., doi:10.1007/978-3-030-12598-1_10.

[104] Ismail, AsrulHarun. “Domino Algorithm: a Novel Constructive Heuristics for Traveling Salesman Problem.” IOP Conference Series: Materials Science and Engineering, vol. 528, Dec. 2019, p. 012043., doi:10.1088/1757-899x/528/1/012043.

[105] Tinarut, Pongpinyo&Leksakul, Komgrit.(2019). Hybrid Self-Organizing Map Approach for Traveling Salesman Problem.Chiang Mai University Journal of Natural Sciences.18. 10.12982/CMUJNS.2019.0003.

[106] SoukainaSemami, HamzaToulni, AbdeltifElByed ,” The close enough traveling salesman problem with time window”, INTERNATIONAL JOURNAL OF CIRCUITS, SYSTEMS AND SIGNAL PROCESSING Volume 13, 2019 pp.579-584

[107] Salii, Yaroslav.“Revisiting Dynamic Programming for Precedence-Constrained Traveling Salesman Problem and Its Time-Dependent Generalization.” European Journal of Operational Research, vol. 272, no. 1, 2019, pp. 32–42., doi:10.1016/j.ejor.2018.06.003.

[108] Alanzi, Entesar, and HachemiBennaceur.“HadoopMapReduce for Parallel Genetic Algorithm to Solve Traveling Salesman Problem.”International Journal of Advanced Computer Science and Applications, vol. 10, no. 8, 2019, doi:10.14569/ijacsa.2019.0100814.

[109] Naser, Husain, et al. “A Multi-Matching Approximation Algorithm for Symmetric Traveling Salesman Problem.” Journal of Intelligent & Fuzzy Systems, vol. 36, no. 3, 2019, pp. 2285–2295., doi:10.3233/jifs169939.

[110] Wang, Lijin, et al. “Enhanced List-Based Simulated Annealing Algorithm for Large-Scale Traveling Salesman Problem.” IEEE Access, vol. 7, 2019, pp. 144366–144380., doi:10.1109/access.2019.2945570.

[111] Poikonen, Stefan, et al. “A Branch-and-Bound Approach to the Traveling Salesman Problem with a Drone.” INFORMS Journal on Computing, vol. 31, no. 2, 2019, pp. 335–346., doi:10.1287/ijoc.2018.0826.

[112] Bouziaren, SoumayaAit, and BrahimAghezzaf. “An Improved Augmented $\Varepsilon$ -Constraint and Branch-and-Cut Method to Solve the TSP With Profits.”

IEEE Transactions on Intelligent Transportation Systems, vol. 20, no. 1, 2019, pp. 195–204., doi:10.1109/tits.2018.2808179.

[113] Othman, Mohamed Rafique, et al. “A Hybrid Water Flow-Like Algorithm and Variable Neighbourhood Search for Traveling Salesman Problem.” International Journal on Advanced Science, Engineering and Information Technology, vol. 9, no. 5, 2019, p. 1505., doi:10.18517/ijaseit.9.5.7957.

[114] Ha, Q.M., Deville, Y., Pham, Q.D. et al.A hybrid genetic algorithm for the traveling salesman problem with drone. J Heuristics (2019) doi:10.1007/s10732-019-09431-y

[115] Waissi, Gary R., and PragyaKaushal.“A Polynomial Matrix Processing Heuristic Algorithm for Finding High Quality Feasible Solutions for the TSP.”Opsearch, 2019, doi:10.1007/s12597-019-00396-x.

[116] Schmitt, João P., et al. “Analysis of Max-Min Ant System with Local Search Applied to the Asymmetric and Dynamic Travelling Salesman Problem with Moving Vehicle.” Lecture Notes in Computer Science Analysis of Experimental Algorithms, 2019, pp. 202–218., doi:10.1007/978-3-030-34029-2_14.

[117] Cacchiani, Valentina, et al. “Models and Algorithms for the Traveling Salesman Problem with Time-Dependent Service Times.” European Journal of Operational Research, 2019, doi:10.1016/j.ejor.2019.11.046.

[118] Isoart, Nicolas, and Jean-Charles Régin.“Integration of Structural Constraints into TSP Models.” Lecture Notes in Computer Science Principles and Practice of Constraint Programming, 2019, pp. 284–299., doi:10.1007/978-3-030-30048-7_17.

[119] Alipour, Mir Mohammad, and SeyedNaserRazavi. “A New Local Search Heuristic Based on Nearest Insertion into the Convex Hull for Solving Euclidean TSP.” International Journal of Operational Research, vol. 34, no. 3, 2019, p. 409., doi:10.1504/ijor.2019.10019739.

[120] Chen, Zhixiang, et al. “Exponential Time Approximation Scheme for TSP.” Algorithmic Aspects in Information and Management Lecture Notes in Computer Science, 2019, pp. 121–128., doi:10.1007/978-3-030-27195-4_11.

[121] Köhne, Anna, et al. “The Asymmetric Traveling Salesman Path LP Has Constant Integrality Ratio.” Mathematical Programming, 2019, doi:10.1007/s10107-019-01450-8.

[122] Jedrzejowicz, Piotr, and IzabelaWierzbowska.“Apache Spark as a Tool for Parallel Population-Based Optimization.” Intelligent Decision Technologies 2019 Smart Innovation, Systems and Technologies, 2019, pp. 181–190., doi:10.1007/978-981-13-8311-3_16.

[123] Chlebík, Miroslav, and JankaChlebíková.“Approximation Hardness of Travelling Salesman via Weighted Amplifiers.” Lecture Notes in Computer Science Computing and Combinatorics, 2019, pp. 115–127., doi:10.1007/978-3-030-26176-4_10.

[124] Liu, Qingxue, et al. “Niching Particle Swarm Optimization Based on Euclidean Distance and Hierarchical Clustering for Multimodal Optimization.” Nonlinear Dynamics, Nov. 2019, doi:10.1007/s11071-019-05414-7.

[125] Siemiński, Andrzej.“Verifying Usefulness of Ant Colony Community for Solving Dynamic TSP.” Intelligent Information and Database Systems Lecture Notes in Computer Science, 2019, pp. 242–253., doi:10.1007/978-3-030-14802-7_21.

[126] Zenklusen, Rico.“A 1.5-Approximation for Path TSP.”Proceedings of the Thirtieth Annual ACM-SIAM Symposium on Discrete Algorithms, 2019, pp. 1539–1549., doi:10.1137/1.9781611975482.93.

[127] Leong, KahHuo, et al. “Application of Decision Theory and Bee-Inspired Method to Railway System Route Optimization.”International Journal of Management Science and Engineering Management, Sept. 2019, pp. 1–11., doi:10.1080/17509653.2019.1604190.

[128] Khanra, Aditi, et al. “Multi-Objective Four Dimensional Imprecise TSP Solved with a Hybrid Multi-Objective Ant Colony Optimization-Genetic Algorithm with Diversity.” Journal of Intelligent & Fuzzy Systems, vol. 36, no. 1, 2019, pp. 47–65., doi:10.3233/jifs-172127.

[129] SapnaKatiyar ,et al, "implementation of Travelling Salesman Problem Using ant Colony Optimization", Int. Journal of Engineering Research and Applications, Vol. 4, Issue 6(Version 3), June 2014, pp.63-67

[130] Valarmathi ,Santhi et al. “Performance Analysis of Genetic Algorithm, Particle Swarm Optimization and Ant Colony Optimization for Solving the Travelling Salesman Problem.” International Journal of Recent Technology and Engineering Special Issue, vol. 8, no. 2S4, 2019, pp. 91–95., doi:10.35940/ijrte.b1016.0782s419.