Computational Intelligence based QoS-aware Web Service Composition: A Systematic Literature Review

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Abstract—Web service composition concerns the building of new value added services by integrating the sets of existing web services. Due to the seamless proliferation of web services, it becomes difficult to find a suitable web service that satisfies the requirements of users. Till date, there is no systematic literature review (SLR) on computational intelligence based Quality of Service (QoS)-aware web service composition. The focus of this paper is to systematically classify and compare the existing research methods and techniques on computational intelligence based QoS-aware web service composition (published between 2005 and 2015).

Index Terms—Web service composition, Systematic literature review, Quality of Service (QoS), Computational Intelligence Methods, Meta heuristic algorithms.

1 Introduction

WEB service composition is a process by which existing web services can be integrated together to create value added composite web services. A single web service may not necessarily fulfill the requirements of users. Hence, several web services are combined to create composite web services. However, there are three challenges in web service composition: (i) Specification of requirements for composite services, (ii) Selection of candidate web services, that are provided by different service providers that vary in quality of service (QoS) parameters, and (iii) Execution of composite web services [1], [2]. Addressing these challenges is seen as a multi-objective optimization problem [3].

Computational intelligence (CI) addresses adaptive mechanisms to facilitate intelligent behavior in complex and real world problems. Computational intelligence techniques are used for solving complex problems such as NP-hard for which there are no effective algorithms [4], [5], [6], [7], [8]. QoS-aware web service composition can be seen as a NP-hard problem and resolved by several techniques including statistical modeling, operational research, and computational intelligence techniques [9], [10], [11], [12]. This paper focuses research works on solving QoS-aware web service composition using computational intelligence techniques that are nature inspired computational methodologies.

A systematic literature review (SLR) identifies, classifies, and synthesizes a comparative overview of state-of-the-research and transfers knowledge in the research community [13], [14]. Till date, to the best of our knowledge, there is no systematic literature review (SLR) on QoS-aware web service composition using computational intelligence techniques, making it difficult to evaluate the research gaps and the latest research trends in computational intelligence (CI) based QoS-aware web service composition. We conduct a SLR on computational intelligence (CI) based QoS-aware web service composition to identify, taxonomically classify, and systematically compare existing research methods and techniques. Our main aim is to answer the following research questions using the guidelines of SLR [13], [14]:

1. What are the main research motivations behind CI based QoS-aware web service composition?
2. What are the QoS parameters generally used in CI based QoS-aware web service composition?
3. What are the existing methods and techniques that support CI based QoS-aware web service composition?
4. What are the existing research issues and future areas in CI based QoS-aware web service composition?

This paper presents a systematic literature review on state-of-the art approaches and techniques for CI based QoS-aware web service composition and describes future research directions in this area. The major contributions of this SLR includes identifying the different objectives of CI based QoS-aware web service composition and classifying the different existing computational intelligence approaches.

This SLR gives a systematic description for researchers in software engineering, cloud computing, and service oriented computing, and helps to gain on research implications, solutions, and future directions. Further, this SLR presents available methods, techniques, and their constraints for the understanding purpose of the practitioners in this domain.

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The rest of the paper is organized as follows. Research methodology for CI based QoS-aware web service composition is illustrated in Section 2. The classification of current approaches for web service composition is described in Section 3. The results of SLR on CI based QoS-aware web service composition are discussed and analyzed in Section 4. Research implications and future directions including threats to validity are presented in Section 5 followed by concluding remarks in Section 6.

2 Research Methodology

Research methodology is a process of taxonomical and metaphysical analysis of the methods which are applied to a field of study[1]. A systematic literature review (SLR) is a research methodology which includes critical assessment, evaluation and interpretation of all available research studies, topics or phenomenon of interest that address a particular research problem [14] in contrast to a non-structured review process. SLR reduces bias and follows a precise and strictly sequential methodological steps to research literature. SLR relies on well-defined studies, and extraction of results [15] as shown in Fig 1. We followed a three step review process which includes planning, conducting, and documenting [14], [16].

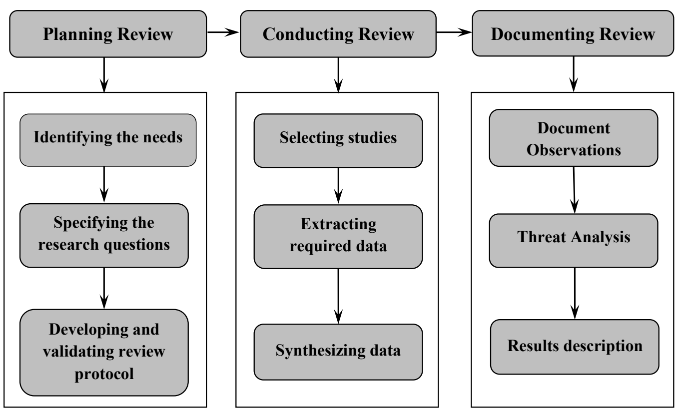

Fig. 1: Overview of research methodology (Based on [14], [16])

2.1 Planning Review

Planning starts with identifying the needs for a systematic literature review and ends with developing and validating the review protocol.

2.1.1 Identifying the Needs

The need for a SLR is to identify, classify, and compare existing researches in CI based QoS-aware web service composition through a characterization framework. This process aims to demonstrate that a similar systematic literature review has not been already reported. We searched Compendex, ACM, Science direct, Springer link, IEEE Xplore, Google Scholar digital libraries with the following search string.

(Computational Intelligence)

AND

(Web service composition OR QoS-aware web service OR Web service OR QoS-aware web service composition OR Web service composition environment)

AND

(Systematic Literature Review OR Systematic Review OR SLR OR Systematic Mapping OR Research Review OR Research synthesis)

2.1.2 Specifying the Research Questions

We define the research questions and their motivations (See Table 1). We define the scope and goals of our systematic literature review through population, intervention, comparison, outcomes and context (PICOC) criteria [15] as shown in Table 2.

Research Questions	Motivations
RQ1-What are the main research motivations for Computational Intelligence (CI) based QoS-aware web service composition?	To get insight on CI based QoS-aware web service composition satisfying functional requirements and non-functional requirements.
RQ2-What are the QoS parameters generally used in CI based QoS-aware web service composition?	To identify the QoS parameters that are used in CI based QoS-aware web service composition.
RQ3-What are the existing methods and techniques that support CI based QoS-aware web service composition?	To identify, compare, and classify the existing methods and techniques that are used in CI based QoS-aware web service composition.
RQ4-What are the existing research issues and what are the future areas in CI based QoS-aware web service composition?	To understand the research gap that needs to be addressed and to find the future directions in this field.

TABLE 1: Research Questions and Their Motivations

2.1.3 Developing and Validating the Review Protocol

Based on the objectives, we define the review scope to explicate the search strings for literature extraction. Here, we developed a protocol for the systematic literature review following the guidelines of [13], [16], [17]. We have consulted with two external experts for feedback, who had experience in conducting SLRs in the domain of web services and computational intelligence, in order to evaluate the proposed protocol. We refined our review protocol based on the feedbacks by the external experts. Further, we performed a pilot study (approximately 20 percent) of systematic literature review of our studies. The main objective of conducting the pilot study was to reduce the bias between researchers. We also improve the review scope, search strategies, and refined the inclusion / exclusion criteria.

1. http://en.wikipedia.org/wiki/Methodology

Criteria	RQ1	RQ2	RQ3	RQ4
Population	Motivation	QoS parameters	Methods & Techniques	Research Challenges & Future dimensions
Intervention	Characterization, Internal/External validation, Extracting data and synthesis.			
Comparison	A comparison study by mapping the primary studies in the field of web service composition.			
Outcome	Classification and comparison of CI based QoS-aware web service composition, Hypotheses for future research and directions.			
Context	A systematic investigation to consolidate the peer reviewed research in CI based QoS-aware web service composition.			

TABLE 2: Scope and Goals of the SLR Criteria (PICOC)

2.2 Conducting Review

Conducting phase consists of selecting the studies, extracting the results and synthesizing information.

2.2.1 Selecting studies

We determined the search terms as guided by [13] following our research questions and motivations as described in Section 2.1. We extracted 438 peer reviewed research papers that were published between 2005 and 2015 (till May 2015) via the following query:

(Web service composition OR QoS-aware web service OR web service OR QoS-aware web service composition OR web service composition environment)

AND

(Heuristic search OR Meta-heuristic search OR Genetic programming OR A* search algorithm OR Ant colony optimization algorithm OR Particle swarm optimization OR Artificial Ant colony optimization algorithm OR Bee colony optimization OR OA* search algorithm OR Cuckoo search OR Tabu search OR Hill-climbing OR Constraint satisfaction OR Pruning algorithm OR Simulated annealing OR ABC algorithm OR Harmony search OR Immune algorithm OR Min-Max algorithm OR Win-Win Strategy OR firefly algorithm OR Grey wolf optimization OR Bat algorithm OR bacterial colony optimization OR Gravitational search algorithm OR Glowworm optimization OR Ant lion algorithm)

The year 2005 was chosen as no earlier research was found related to the specified research questions.

2.2.1.1 Initial selection

The extracted 438 articles cover the research topic of CI based QoS-aware web service composition across the search databases (as shown in Table 3). We explore the title and abstract of prospective primary studies and apply inclusion/exclusion criteria (shown in Table 4).

S.No	Search Databases	Results
1	ACM Digital Library	92
2	Science Direct	60
3	Springer Link	74
4	IEEE Xplore Digital Library	116
5	Google Scholar	96
	Total	**438**

TABLE 3: Number of retrieved studies

Criteria		Prenominal
Inclusion	I.Research articles that are in the form of peer reviewed papers (CI based QoS-aware web service composition).	Scientific papers generate quality through a peer review and contain significant content.
	II.Research articles that explicitly propose methods, solutions, experiences, evaluations to facilitate CI based QoS-aware web service composition.	We aim to study solutions for CI based QoS-aware web service composition.
Exclusion	I.Books, Book Chapters, and Thesis.	These studies are generally published in journals and conferences. We included the relevant papers of the corresponding authors of books/ book chapters from their conference/ journal articles.
	II.Non-peer-reviewed research articles, white papers, or non-English scripts.	There are lots of white papers and other kind of technical reports for CI based QoS-aware web service composition. However, we decided to exclude them because they are situational.
	III.Editorials, Abstracts or Short papers (less than 4 pages).	These studies do not present any reasonable significant solutions and information.
	IV.Research articles that do not explicitly propose methods, techniques, and tools to facilitate CI Based QoS-aware web service composition.	These studies do not directly describe decision making solutions and methods for CI based QoS-aware web service composition.

TABLE 4: Criteria for Inclusion and Exclusion

2.2.1.2 Final selection

We focused specifically on meta-heuristics among the research articles in initial selection and selected 85 studies using the following query.

(Title: (web service composition OR QoS-aware web service OR web service OR QoS-aware web service composition OR web service composition environment) OR Abstract: (web service composition OR QoS-aware web service OR web service OR QoS-aware web service composition OR web service composition environment))

OR

(key words: web service composition OR keywords: QoS-aware web service OR keywords: QoS-aware web service

composition OR keywords: web service composition environment)

AND

(Title: (Meta-heuristic search OR Genetic programming OR Ant colony optimization algorithm OR Particle swarm optimization OR Artificial Ant colony optimization algorithm OR Bee colony optimization OR Simulated annealing OR ABC algorithm OR Cuckoo search OR NSGA-II OR Harmony search OR Immune algorithm OR firefly algorithm OR Grey wolf optimization OR Bat algorithm OR bacterial colony optimization OR Gravitational search algorithm OR Glowworm optimization OR Ant lion algorithm))

OR

(key words: Meta-heuristic search OR key words: Genetic programming OR key words: Ant colony optimization algorithm OR key words: Particle swarm optimization OR key words: Artificial Ant colony optimization algorithm OR Bee colony optimization key words: ABC algorithm OR key words: GRASP and Path-relinking algorithm OR key words: NSGA-II OR key words: Tabu search OR key words: Simulated annealing OR key words: Cuckoo search OR key words: Harmony search OR key words: Immune algorithm OR key words: firefly algorithm OR key words: Grey wolf optimization OR key words: Bat algorithm OR key words: bacterial colony optimization OR key words: Gravitational search algorithm OR key words: Glowworm optimization OR key words: Ant lion algorithm OR key words: Fruit fly algorithm)

The list of 85 research articles with the algorithms and QoS parameters used by these articles is presented in Table 13.

2.2.2 Data Extraction and Synthesis

We extracted data from the list of five search databases (mentioned in Table 3) and designed a structural format based on characterization aspects using the guidelines provided by [13]. We compare and analyze the approaches for QoS-aware web service composition in Section 3. Further, we analyze merits and demerits of the existing research and future directions.

3 Classification and Approaches in QoS-aware Web service composition

This section proposes a classification of current approaches in CI based QoS-aware web service composition that includes non-heuristic (exact), heuristic, and meta-heuristic methods, their algorithms and metrics. The classification of research approaches is shown in Figure 2.

3.1 Non-heuristic (Exact) Algorithms

Non-heuristic (Exact) algorithms solve optimization problems optimally. Every optimization problem can be solved using exhaustive search but as the size of the instances grows it takes forbiddingly large amount of time to find the optimal solution. Exact algorithms are significantly faster than exhaustive search [18]. Generally, the problem of web service composition is considered as a single objective problem with local/global QoS maximization or a multi-objective problem with global QoS maximization. Zeng et al. [19] used local and global optimization algorithms for QoS aware web service composition. The local optimization algorithm selects the optimal service for each given tasks in the composite web service application. The global optimization algorithm selects the optimal execution plan for all possible paths based on integer programming. Yu et al. [20] proposed methods to maximize the prenominal function and to satisfy the global constraints, designed as a multidimensional, multi objective, multi choice knapsack problem.

Yu et al. [21] presented a method considering the multiple QoS constraints and used different work-flows for different business processes. Zeng et al. [22] proposed a method of quality driven composition, evaluating QoS of web services and selecting web services by using local optimization and global constraints. Huang et al. [23] adopted filtering algorithms to reduce the search space to compute optimal QoS. Gao et al. [24] proposed two different types of service selection approaches including local optimal selection and global optimal selection. Wang et al. [25] discussed an efficient divide-and-conquer algorithm for QoS service selection based on a high-level conceptual model for web service composition. Alrifai et al. [26] adopted a hybrid methodology by applying mixed integer programming (MIP) to seek out the best decomposition of QoS constraints into native constraints and to the simplest web service that satisfy all these constraints. Jaeger et al. [27] discussed a novel model for service selection and evaluation of quality of service for QoS aware web service composition. Jaeger et al. [28] proposed a method based on computational and resource-values for finding optimal solution for web service selection. Gabrel et al. [29] presented a method to find optimal solution for transactional web service composition using dependency graph and 0-1 linear programming. Liu et al. [30] proposed methods based on mathematical programming and convex-hull method for finding the optimal solution and applied multiple criteria decision making (MCDM) to merge the multiple dimensional resources for global and local constraints in web service composition.

Some authors discussed an end-to-end QoS maximization to maximize the end-to-end availability and to choose local maximization for each task for each implementation [12] for selecting an optimal execution plan. Many other researchers proposed several exact algorithms to reduce the time complexity for global and local constraints related to web service composition [31], [32], [33], [34], [35], [36], [37]. The classification of current approaches in exact algorithms and their metrics are shown in Table 5.

3.2 Heuristic Algorithms

Heuristic algorithms are algorithms which are generally created by ”experience” for specific optimization problems and they intend to find a good solution to the problem by ”trail-and-error” in a acceptable amount of time. The solutions may not be the best or optimal solution but they might be better than an educated guess [39]. Heuristic algorithms

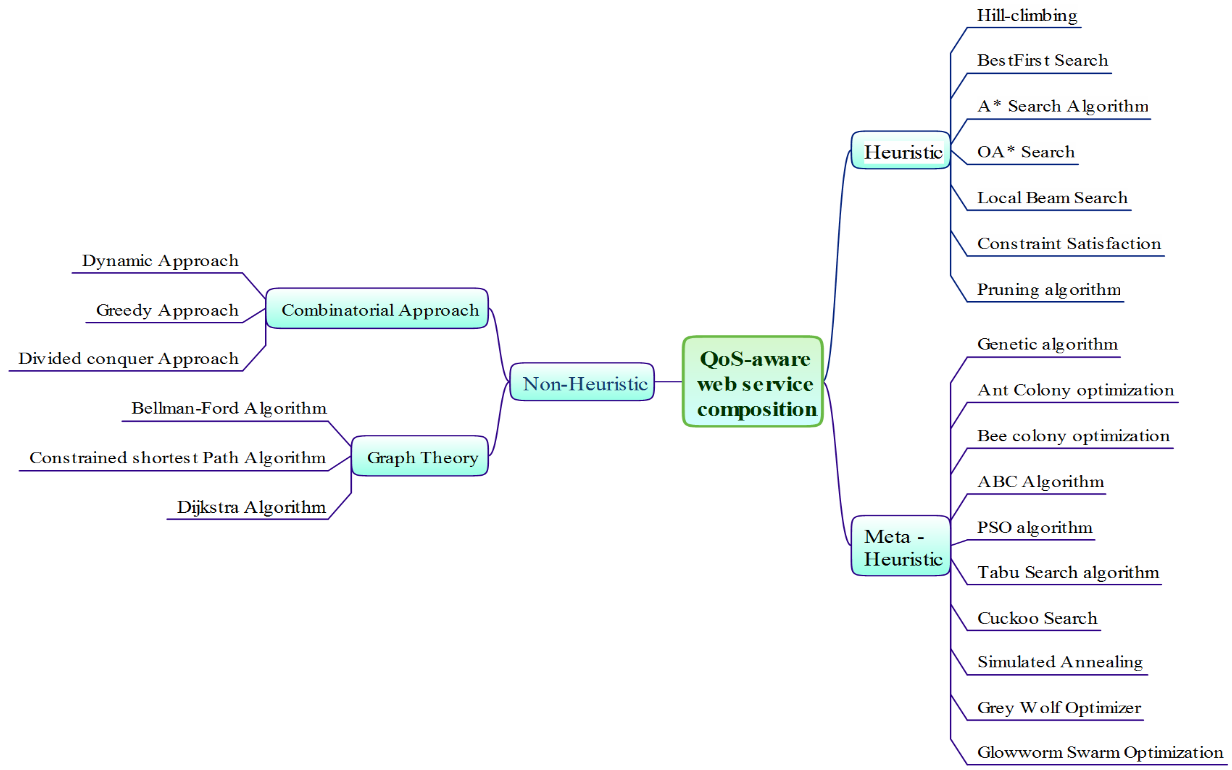

Fig. 2: Classification of Research Approaches

Approach	Optimization mode	QoS Specification Constraints	Multi objective optimization	Algorithm
Ardagna et al. [12]	global	Supported	Supported	Mixed integer programming
Marco et al. [31]	global	Not supported	Not Supported	Backward breadth first
Liangzhao et al. [19]	global	Supported	Supported	Linear integer programming
Changlin et al. [25]	global	Supported	Supported	Divide-and-Conquer
Tao et al. [21]	global	Supported	Supported	MMKP & MCOP
Tai et al. [32]	local	Supported	Supported	MCOP Algorithm
Cardellini et al. [33]	global	Supported	Supported	Linear programming
Mohabey et al. [34]	global	Supported	Supported	Integer Programming
Yang et al. [35]	local	Not Supported	Supported	MCOP Algorithm
Huang et al. [23]	local	Not Supported	Not Supported	Mod.Dynamic Programming
Gao et al. [24]	local	Not Supported	Supported	Mod. Dy.Programming
Yu et al. [20]	global	Supported	Not Supported	MCKP & CSPP
Zeng et al. [22]	local	Supported	Supported	Linear integer programming
Alrifai et al. [26]	global	Supported	Supported	Mixed integer programming
Jaeger et al. [27]	global	Supported	Supported	Knapsack problem & Constraint project scheduling problem (RCPSP)
Jaeger et al. [28]	global	Supported	Supported	Knapsack problem & Multi-Mode RCPSP
Gabrel et al. [29]	global	Supported	Supported	dependency graph and 0-1 linear programming
Min et al. [37]	global	Supported	Supported	BB4EPS
Yang et al. [38]	global	Supported	Supported	Greedy Quick-hull

TABLE 5: Some non-heuristic (exact) algorithms for QoS-aware web service composition

take the full advantage of the particularities of the problem. Since exact algorithms take forbiddingly large amount of time to obtain the optimal solution, heuristic algorithms are preferred which obtain near-optimal solutions in acceptable amount of time. Berbnar et al. [40] proposed H1 RELAX IP, H2 SWAP, and H3 ANNEAL methods for finding an optimal solution and improving the efficiency in QoS-aware web service composition. Klein et al. [41] proposed a method using hill-climbing algorithm and compared with linear integer programming to reduce the time complexity to find the near-optimal solution. Qi et al. [42] presented a local optimization and enumeration method to find the local candidates and then combine them to find the optimal solution. Diana et al. [43] proposed a novel heuristic search model for service selection and evaluation of quality-of-service for service composition. Jun et al. [44] discussed an efficient and reliable approach for selection of trustworthy services in a QoS-aware web service composition to obtain

the near-optimal solution.
Luo et al. [45] proposed a heuristic HCE algorithm for QoS aware web service composition which satisfy the end-to end QoS constraints. Pedro et al. [46] presented a heuristic algorithm QoS-aware web service composition within the minimal search space and realistic deadline. Moustafa et al. [47] and Liang et al. [48] discussed reinforcement learning algorithm to solve multi-objective quality of service problem and find a set of Pareto optimal solutions which satisfy the multiple QoS factors and user requirements. Feng et al. [49] presented a relaxable QoS-aware service selection algorithm to find the optimal solution by using complex local and global constraints which satisfy the user requirements.
Many other researches proposed several heuristic algorithms for web service composition to reduce the time complexity for global and local constraints [50], [51], [52], [53], [54], [55], [56]. The classification of current approaches in heuristic algorithms and their metrics are shown in Table 6.

3.3 Meta-Heuristic Algorithms

A meta-heuristic algorithm is a higher-level heuristic algorithm which is problem independent and applicable to a broad range of problems. Recently ”meta-heuristics” refers to all modern higher-level algorithms [39]. Some of the well known meta-heuristics are Particle Swarm Optimization (PSO), Simulated Annealing (SA), Evolutionary Algorithms (EA) including Genetic Algorithms (GA), Tabu Search (TS), Ant Colony Optimization (ACO), Bee Algorithms (BA), Firefly Algorithms (FA), and, Harmony Search (HS). There are two important components in modern meta-heuristics: intensification and diversification [58]. A balance between intensification and diversification is important for an effective and efficient meta-heuristic algorithm. A meta-heuristic algorithm searches the entire solution space a diverse set of solutions are to be generated and search needs to be intensified around the neighborhood of the optimal or near-optimal solutions.
The first genetic algorithm for web service composition was proposed by Canfora et al. [9]. Several researchers proposed web service composition using genetic algorithm methods with global constraints [9], [59], [60], [61], [62], [63], [64], [65], [66], [67]. Yu et al. [68] proposed a tree based genetic algorithm to solve QoS aware web service composition. Liu et al. [69] adopted an improved genetic algorithm using ant colony optimization to select the initial population antibodies for better efficiency and convergence speed. Ma et al. [70] presented a convergent population diversity handling genetic algorithm for web service selection.
Xiangbing et al. [71] proposed a web service modeling ontology (WSMO) based web service composition method to solve QoS aware service composition and applied a genetic algorithm which minimizes the search time to find the near-optimal solution. Some researchers adopted tabu search for finding optimal QoS-aware web service composition [72], [73]. In [74], [75], [76], authors proposed harmony search algorithms to find near-optimal solution by using local and global constraints which satisfy the user requirements.
Another efficient meta heuristic technique for web service composition is particle swarm optimization (PSO). Many researchers [77], [78], [79], [80], [81], [82] adopted particle swarm optimization algorithms for QoS-aware web service composition.
In many scientific and engineering problems, we require to find more than one optimal solutions. Original PSO technique focuses on finding one solution. The evolutionary algorithms which find multiple solutions are generally referred to niching or specification algorithms [83]. NichePSO algorithm is a technique which locates and refines multiple solutions to multi-modal problems. Liao et al. [84] developed a niching particle swarm optimization supporting multiple global constraints and load balancing for web service composition. Liu et al. [85] presented a hybrid quantum particle swarm optimization algorithm to solve combinatorial optimization problem for web service composition. Xiangwei et al. [86] proposed discrete particle swarm optimization algorithms and color petri nets (CPN) for solving web service composition. Zhao et al. [87] adopted an improved discrete immune optimization method based on PSO for QoS-aware web service composition. some researchers used Immune algorithms for QoS-aware web service composition [88], [89], [90], [91] to find the near-optimal solution as multi-objective problems.
Another efficient meta-heuristic technique for QoS-aware web service composition is Ant colony optimization. Various researchers adopted ant colony optimization (ACO) algorithm for web service composition [92], [93], [94], [95]. While solving web service composition using ant colony optimization, the problem is modeled as a weighted directed acyclic graph with the starting point denoting the nest of ants, target point denoting food sources, and the QoS constraints denoting weights of the edges.
Li et al. [96] selected a web service model with QoS global optimization and converted it into multi-objective optimization problem. Further, they used a multi-objective chaos ant colony optimization (MOCACO) algorithm to select the services, optimize QoS, and satisfy the user requirements. Mao et al. [97] presented different meta-heuristic algorithms (particle swarm optimization, estimation of distribution algorithm, genetic algorithm) for efficient performance in web service composition. Pop et al. [94] proposed a hybrid method (ant colony optimization, and graph model) with improved accuracy and efficiency for web service composition.
Some researchers adopted bee colony optimization (BCO) for web service composition [98], [99], [100] to find near-optimal solutions as multi-objective problems. The classification of current approaches for QoS-aware web service composition using meta-heuristic algorithms and their metrics are presented in Table 7.

4 Analysis of SLR Results

This section analyses the results of this study addressing the research questions RQ1, RQ2, and RQ3 (shown in Table 1).

4.1 Overview of primary studies

During the analysis of state-of-the-art literature in QoS-aware web service composition, we consider the following research questions:

Approach	Optimization mode	Algorithm
Berbner et al. [57]	global	MIP heuristic
Simone et al. [53]	global	Memetic Algorithm
Lianyong et al. [42]	local	Local optimization and enumeration method
Ying et al. [52]	global	Win-Win strategy algorithm
Yuan-Sheng et al. [50]	global	Heuristic algorithm
Adrian et al. [41]	global	Hill climbing
Jun et al. [44]	global	Global Heuristic algorithm
Liu et al. [30]	global	Heuristic algorithm
Luo et al. [45]	global	Heuristic algorithm
Jing et al. [51]	global	Heuristic algorithm
Diana et al. [43]	global	Heuristic search
Pedro et al. [46]	global	Heuristic algorithm
Moustafa et al. [47]	global	Reinforcement Learning
Liang et al. [48]	global	Improved Reinforcement Learning
Feng et al. [49]	global	Relaxable service selection algorithm
Chan et al. [55]	global	BF* algorithm
Rodriguez et al. [56]	global	A* algorithm

TABLE 6: Some Heuristic search algorithms for QoS-aware service composition (supporting multiple QoS constraints and multi-objective optimization)

Approach	Algorithm
de campos et al. [101]	Multi-objective evolutionary optimization algorithm
Xianzhi et al. [102]	Improved artificial bee colony
Yang et al. [68]	Adaptive genetic algorithm
Anqui et al [103]	Genetic algorithm, Greedy Search
Parejo et al. [104]	GRASP and Path-relinking
Canfora et al. [3], [9], [105], Lifeng et al. [106], Wada et al. [107], Gao et al. [108], Tang et al. [62], Susen et al. [63], Junli et al. [65], Li et al. [67], Hongbing et al. [109], Liang et al. [110], Xiangbing et al. [71]	Genetic algorithm
Gao et al. [89], Jiuyun et al. [88], Zhao et al. [87], Pop et al. [91], [111]	Immune Algorithm
Rosenberg et al. [112]	Simulated Annealing
Zongkai et al. [92]	Genetic algorithm, Ant colony optimization
Shanshan et al. [113], Pop et al. [94], Ya-mei et al. [95]	Ant colony optimization
Wang et al. [93]	Chaos ant colony optimization
Li et al. [96]	Multi-objective chaos ant colony optimization
Sondos et al. [72]	Hybrid Genetic algorithm, Tabu search
Jiuxin et al. [114], Li et al. [78], LongJun et al. [77], Ludwig et al. [80]	Particle swarm optimization
Susen et al. [61]	Improved genetic algorithm
Chunming et al. [64]	Tree coded genetic algorithm
Huan et al. [69]	Improved Genetic Algorithm
Yue et al. [70]	Diversity Genetic algorithm
Jose et al. [73]	Tabu search, Hybrid genetic algorithm
Liu et al. [79]	Hybrid genetic algorithm, PSO
Jianxin et al. [84]	Niching particle swarm optimization
YangLiu et al. [85]	Hybrid particle swarm optimization
Xiangwei et al. [86]	Discrete Particle swarm optimization
Chifu et al. [98]	Bee colony optimization
Zhou et al. [99]	Chaotic Artificial bee colony optimization
Jafarpour et al. [74], [76], Mohammed et al. [75]	Harmony search
Kousalya et al. [100]	Bee algorithm
Fan et al. [115]	Co-evolution Algorithm
Rezaie et al. [116]	Multi-objective PSO
Wenbin et al. [81]	Improved PSO

TABLE 7: Some(meta)-heuristic search algorithms for QoS-aware service composition (supporting global optimization, multiple QoS constraints, and multi-objective optimization)

1. What is the status of research on CI based web service composition?
2. What are the fora in which the researchers published their results related to CI based QoS-aware web service composition?
3. What are the active research communities for CI based QoS-aware web service composition?

The number of research papers on CI based QoS-aware web service composition and their year of publication are shown in Figure 3. From Figure 3, we observe that the first set of papers on meta-heuristic based web service composition was published in 2005. Further, we observed that the number of papers significantly increased in 2010. Also, we observe that a consisting increase is seen in the last 3 years.

Most of the papers in CI Based QoS-aware web service composition are published in ICWS, ICSOC, WWW, CEC,

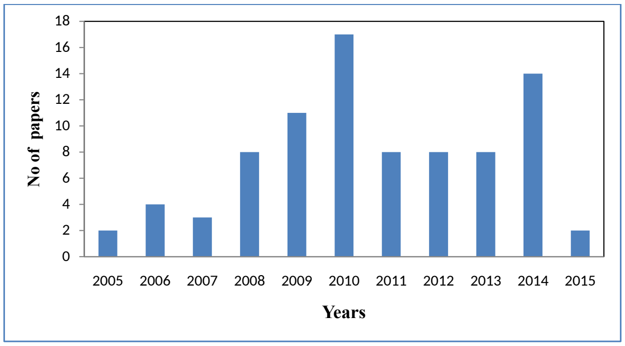

Fig. 3: No of papers in each year (upto May 2015)

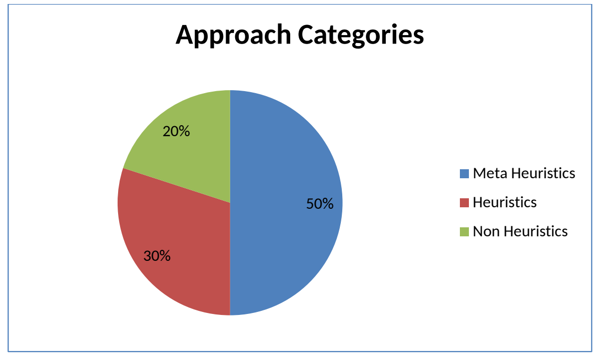

Fig. 4: Importance of Approaches

SSC, IST, ICCP, APCC, and other major conferences (as shown in Table 8). Among 85 studied papers, 24 papers were published in major journals including Expert Systems with Applications, Applied Soft Computing, Future Generation Computer Systems, SOCA, International Journal of Computational Intelligence Systems, and Evolutionary Intelligence. A list of distribution of studies per publication channel is shown in Table 8.

After the selection of papers and synthesis, we looked at affiliation of authors. We considered a research group in a particular University / Institute to be an active research group which had at least two included studies. The list of the active research communities and their research focus are shown in Table 9. A significant number of research papers on QoS-aware web service composition were published by researchers from Wuhan University, Vienna University of Technology, Beijing university of post and telecommunications, University of Seville, Victoria University of Wellington, University of Sannio, Queensland University of Technology, Technical University of Cluj-Napoca, University of Isfahan, and Zhejiang Normal University.

4.2 Research objectives, Approaches, and QoS parameters

Based on our literature survey, we identified 3 major approaches in QoS-aware web service composition (see Fig. 4). It can be observed that 20 percent of studies focus on exact, 30 percent of studies focus on heuristic, and 50 percent of studies focus on meta-heuristic approaches. Exact algorithm approach has the following limitations: low user satisfaction, assessment of QoS parameters, and high time complexity. Most of the researchers used heuristic methods to solve QoS-aware web service composition problems with global constraints. However, these algorithms support limited workflow and do not give optimal solution. Meta-heuristic methods support large workflow sizes with global constraints and have less computation time. Thus, meta-heuristics methods appear as a premier solution for QoS-aware web service composition.

Considering RQ3, the proposed approaches are classified into three categories as mentioned in Section 3. These categories and their statistics are shown in Figures 5 and 6. From Figure 5, it is clear that the highest percentage of research is done in genetic algorithms.

Considering RQ2, most researchers focus on the following QoS parameters: Availability (A), Reliability (Re), Response time (Rt), Cost (C), Reputation (R), Throughput (Th), Security (S). Table 10 lists QoS Parameters commonly used in the algorithms of various computational intelligence based web service composition. Based on the said parameters, we calculate the importance percentage of each parameter as the ration of the number of occurrence of each parameter to the sum of the number of occurrences of all parameters [17]. The list of occurrence of QoS parameters and their percentage are shown in Figure 7 and 8. Table 11, 12, and 13 illustrate the selected studies and their QoS parameters for exact, heuristics, and Meta-heuristics respectively.

5 Research Implications and Future Directions

In this section, we address the research question RQ4 and discuss the benefits and drawbacks of this SLR.

5.1 Research Challenges and Future Directions

After analyzing the data collected through this SLR for CI based QoS-aware web service composition, we observe that the following research challenges are not addressed by the research communities.

5.1.1 Meta-heuristics

In existing literature, researchers did comparisons among exacts, heuristics, and meta-heuristics algorithms [9], [11], [85]. From these comparisons, we observe that meta-heuristic algorithms obtain near-optimal execution plan in a reasonable amount of time. Section 3.3 presents a list of related research using meta-heuristics. However, appropriate web service composition methods using Artificial Bee Colony (based on intelligent behavior of honey bee swarm [132], [133]), Grey Wolf Optimizer (inspired by grey wolves [134]), Firefly Algorithm (based on flashing characteristics of fireflies [135]), Bat Algorithm (based on echo location capabilities of bats [136]), Bacterial colony optimization (inspired by behaviors of E. coli bacteria [137]), Gravitational search algorithm (based on law of gravity and notion of mass interaction [138]), Glowworm swarm optimization (inspired by behaviors of glowworms [139]), and Ant lion optimizer (inspired by imitating the hunting mechanism of ant-lions [140]) are still missing. These meta-heuristic algorithms could find near-optimal solutions for QoS-aware web service composition in a more effective and efficient way.

Publication Channel	Abbreviations	Count
Expert systems with Applications	ESWA	3
Applied Soft Computing	APPL SOFT COMPUT	2
Service Oriented Computing and Applications	SOCA	2
International Journal of Computational Intelligence Systems	IJCIS	2
Evolutionary Intelligence	EI	1
Future Generation Computer Systems	FGCS	1
Knowledge and Information Systems	KIS	1
Journal of System Software	JOSS	1
Journal of Theoretical & Applied Inf. Tech.	JATIT	1
Chinese Journal of Computers	CJOC	1
Computer Networks	JCN	1
Journal of Networks	JNW	2
Transactions on Large-Scale Data & Knowledge Centered Syst.	TLDKS	1
Tsinghua Science & Technology	Tsinghua Sci Technol	1
Information Technology Journal	ITJ	1
Mathematical Problems in Engineering	MPE	1
International Journal of Advanced Manufacturing Technology	IJAMT	1
Wuhan University Journal of Natural science	WUJNS	1
IEEE Congress on Evolu. Computation	CEC	4
Inter. Conf. on Ser. Oriented Comp.	ICSOC	2
IEEE Inter. Conf. on Ser. Comp.	SCC	2
Inter. Conf. on Web Services	ICWS	5
Inter. Conf. on World Wide Web	WWW	1
Inter. Conf. on Eng. and Business Eng.	ICEBE	1
Inter. Conf. on Web Inf. Sys. and Mining	ICWiSM	1
Inter. Joint Conf. on AI	IJCAI	1
Inter. Conf. on Advanced Inf. Networking and Applications	ICAINA	1
IEEE Inter. Conf. on Global Telecommunication	IEEE GLOBECOM	1
IEEE Inter. Conf. on Inf. Integration and web based appl. and services	IIWAS	1
IEEE Inter. Conf. on Intelligent computer communication and processing	ICCP	3
Asia-Pacific conf. on Communications	APCC	1
Pacific-Asia conf. on web mining and web based appl.	WMWA	1
IEEE Asia-Pacific conf. on service computing	APSCC	1
Inter. Conf. on Dependable, Automatic, and secure computing	DASC	1
Inter. Conf. on Computational Inte. for Modeling, Control and Automation	CIMCA	1
Annual Conf. on genetic and evolu. comp.	GECCO	1
Annual Inter. Computers, Software & Appli. Conf.	COMPSAC	2
IEEE Inter. Conf. on Algorithms and Architecture for Parallel Processing	ICA3PP	2
Inter. Sym. on Symbolic and Numeric Algorithms for Scientific Computing	SYNASC	1
Inter. Conf. on Computers, Networks, Systems, and Industrial Eng.	CNSI	1
Inter. Conf. on Interaction Sciences:Information Technology, culture & Human	ICIS	1
Inter. Conf. on Informatics, Cybernetics, and Computer Engineering	ICCE	1
Inter. Sym. on Parallel and Distributed Processing with Appli.	ISPA	1
Inter. Conf. on Mobile Web Inf. Sys.	MobiWIS	1
Inter. Conf. on Swarm Intelligence	ICSI	1
Inter. Conf. on Advanced Communication Technology	ICACT	1
IEEE Inter. Sym. on Web Systems Evolution	ISWSE	1
Inter. Workshop on Resource Discovery	RED	1
Actas de los Talleres de las Jornadas de Ingeniera del Software y Bases de Datos	SISTEDES	1
Inter. Conf. on Wireless Communi.,Networking and Mobile Comp.	WiCOM	1
Brazilian Sym. on Neural Networks	SBRN	1
Inter. Sym. on Telecommunications	IST	3
Inter. Forum on information technology and applications	IFITA	1
Inter. Conf. on Database and Expert Systems Applications	DESA	1
Inter. Conf. on Advanced Language Processing and Web Inf. Tech.	ALPIT	1
Inter. Conf. on e Sciences	ICeS	1
IEEE Congress on services	SERVICES	1
Inter. Sym. on ISKO-Maghreb: Concepts and Tools for knowledge Management	ISKO-Maghreb	1
Inter. Sym. on Computational Intelligence and Design	ISCID	1
Inter. Conf. on Industrial Control and Electronics Eng.	ICICEE	1
Inter. Conf. on Simulated Evolution and Learning (SEAL 2014)	SEAL	2
Inter. Conf. on Knowledge Science, Engineering and Management	KSEM	1
Inter. Conf. on Networked Digital Technologies	NDT	1

TABLE 8: List of distribution of studies (Papers) per Publication Channel

5.1.2 Inter service dependencies and conflicts

Inter service dependencies and conflicts are one of the most promising challenges in QoS-aware web service composition. In the literature survey, we observe that exact algorithm methods do not incorporate inter service dependencies and conflicts between web service compositions. In few web service composition scenarios, service implementations for each task could be selected independently from the other tasks. However, there are several business, technological or partnership related constraints in web service composition scenarios. During modeling of a service composition, the selection of a service is highly dependent on constraints like time and place. This problem was first identified by Ai and Tang in 2008 [117] and solved by [106] using genetic

	Studies	Research Focus
Queensland University of Technology	[62] [106] [117]	Web service composition, Genetic algorithm
Wuhan University	[118] [96] [78]	QoS-aware web service composition, Chao PSO, ACO
Vienna University of Technology	[112] [119]	Web service composition
Beijing University of Posts and Telecommunications	[120] [121] [84] [87] [90] [70] [81]	QoS-aware web service composition, MOCACO, PSO
Victoria University of Wellington	[68] [122] [123] [103] [124] [125] [126]	QoS-aware web service composition, Genetic algorithm, PSO
University of Seville	[73] [104]	QoS-aware web service composition, Genetic algorithm, GRASP
University of Sannio	[9] [105] [3]	QoS-aware web service composition, Genetic algorithm
Technical University of Cluj-Napoca	[94] [127] [91] [98] [128] [111]	Web service composition, Immune inspired, PSO, Cuckoo search algorithms
Zhejiang Normal University	[69] [93] [129]	Web service composition, genetic algorithm, PSO
University of Isfahan	[74] [76] [72] [116] [130]	QoS-aware web service composition, Harmony search, GA

TABLE 9: Active Communities and Their Research Focus

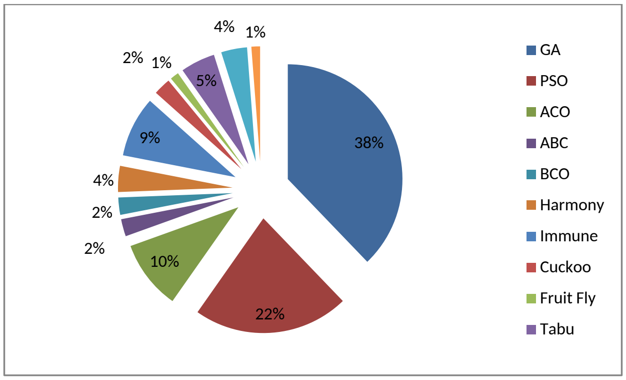

Fig. 5: Importance of each approach and their percentage

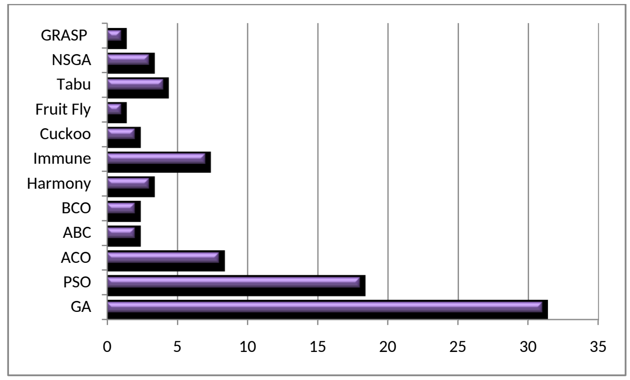

Fig. 6: No of papers in each approach categories

Parameter Name	Description
Availability (A)	The probability that a service is available during the request.
Reliability (Re)	The probability that a request is correctly responded within the maximum expected time.
Response time (Rt)	The time interval between the moments when a user requests the service and when the user receives the response.
Cost (C) / Price (P)	The price that a service requester has to pay for invoking the service.
Reputation (R)	The average ranking given to the service by end users according to their own experiences.
Throughput (Th)	The number of web service requests served at a given time period.
Security (S)	The quality aspect of a web service providing confidentiality and non-repudiation by authenticating the parties involved and encrypting messages.

TABLE 10: List of QoS Parameters and their description [131] commonly used in the algorithms of various computational intelligence based web service composition

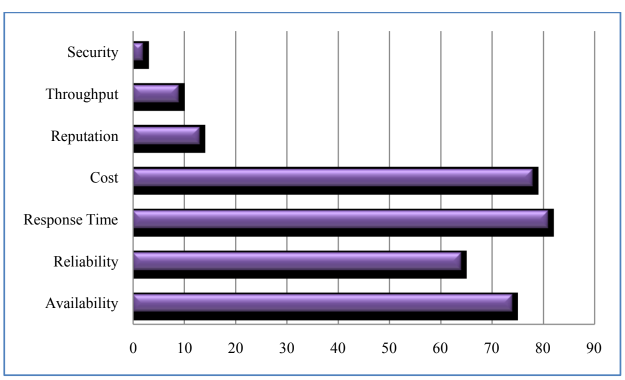

Fig. 7: Repetition of QoS parameters in literature

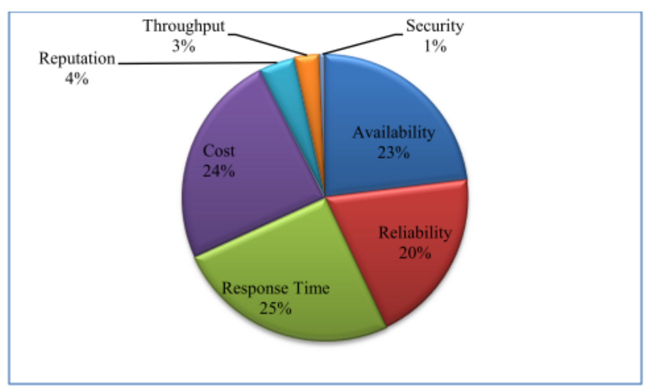

Fig. 8: Percentage of QoS parameters in literature

algorithm. Unfortunately, inter service dependencies and conflicts still remain unexplored by other meta-heuristic algorithms.

5.1.3 QoS-aware cloud service composition

QoS-aware approaches are emerging as a challenging research topic in cloud service composition [17], [141], [142], [143]. In SaaS model, the challenges include monitoring and managing QoS requirements and resource allocation optimization [144], [145], [146], [147]. Further, there are no tools and metrics to develop and deploy SaaS applications based on QoS requirements [148], [149].

In IaaS model, the challenges include resource management and scalability [150] and performance monitoring [151]. Though several approaches have been proposed for IaaS resource management, determining the minimum cost for cloud service composition remains a challenge [152]. Managing service level agreements (SLA) and mapping of SLAs with QoS requirements remains a challenges in IaaS [150], [153].

Meta-heuristic methods for cloud service composition are addressed in [141], [154], [155]. However, cloud service composition using several other Meta-heuristic approaches are still missing.

5.2 Benefits for Researchers and Practitioners

This SLR provides classification, approaches, and comparisons of QoS aware web service composition. The classification and comparisons of this SLR study contains the 85 most relevant papers and provides a reasonable amount of information. By using this SLR, researchers and practitioners get relevant studies and related information that support CI based QoS web service composition quickly. For example, if the researchers use the following query:

Title: (QoS-aware web service composition) OR **Abstract: (web service composition)** AND **Title: (meta-heuristics)**, then they will get a variety of relevant studies based on QoS-aware web service composition using meta-heuristics. By using this SLR, we can reduce time and complexity for searching studies and solutions.

5.3 Threats To Validity

The main threats to the validity of this SLR are as follows.

Threats to completeness:

The most important factor in design phase of SLR is the construction and evaluation of the search string. The search string enables researchers to focus on examining a small cluster of related findings instead of spending a lot of time to refine unrelated studies [14]. The search was enhanced by using a combination of a general search string and a final selection (secondary) string. In our search strategy, we used five search databases from which we have extracted relevant studies using the constructed search string. The obtained studies were filtered using the inclusion and exclusion criteria defined earlier in Section 2.2.1. The search string was constructed to include maximum number of relevant articles, but some article might have been missed due to linguistic barriers and limitation of defined inclusion and exclusion criteria.

Threats to method of identifying primary studies:

In our search strategy, the key idea is to retrieve the most relevant and available literature without any bias. Our scope of the study is to determine CI based QoS-aware web service composition that may relate to different heuristic, meta-heuristic and exact algorithms. To avoid bias, we searched common terms and combined them in our search string for identifying the most relevant studies. Due to different perspectives and understanding of inclusion and exclusion criteria by each researcher, we obtained different findings from each researcher. To minimize the bias and increase the reliability, in this work, two researchers worked together. In case of disagreement among the researchers, other researchers were called for help to achieve consensus of the selection of studies.

Threats to data extraction:

In this SLR, we extracted the data relevant for computational intelligence based QoS-aware web service composition. By using general query, we got 438 relevant studies. By secondary search, we found 85 most relevant studies to answer our research questions.

6 Concluding Remarks

The objective of this study is to systematically review the literature and develop a classification on CI based QoS-aware web service composition. During this study, we got a complete insight into QoS-aware web service composition and reflections on future research challenges on QoS-aware web service composition by synthesizing the collected data. In this paper, we applied the search query on five databases and extracted 438 studies that were published between 2005 and 2015. From these studies, we analyzed 85 papers that focused on meta-heuristic algorithms for QoS-aware web service composition. This SLR has provided a complete description of computational intelligence based QoS-aware web service composition with the analysis of different algorithms, mechanisms, and techniques. During the SLR we observed that the most commonly used approach for solving QoS-aware web service composition was meta-heuristic (50%). 30% of studies focussed on heuristic approaches and 20 % of studies focussed on non-heuristic (exact) approaches. This is justified by the fact that QoS-aware web service composition is NP-hard and it needs to be solved in an acceptable amount of time. With respect to RQ2, we observed that the most widely considered QoS attributes were response time (25%), cost (24%), availability (23%), and reliability (20%). With respect to RQ3, we find that the most widely used meta-heuristic techniques were genetic algorithm (38%), PSO (22%) and ACO (10%). The increased power of meta-analysis can be a disadvantage of this SLR since it is possible to detect small biases and true effects. Since it takes a lot of effort and time to conduct a SLR, this SLR aims to save time and effort of other researchers by giving a thorough review of state-of-the-art techniques for CI based QoS-aware web service composition. We observed that new meta-heuristic algorithms have not yet been used for solving QoS-aware web service composition. We also observed that there is a lack of tools supporting for CI based QoS-aware web service composition. We believe that researchers of data mining and service oriented computing need to collaborate together for exploring and progressing this field further, developing a joint research agenda.

Authors Name	Algorithm used	QoS Parameters Considered
Zeng et al. [19]	Linear integer programming	Cost (C), Response time (Rt) , Reputation (R), Availability (A)
Yu et al. [20]	MMMKP	Response time (Rt) , Cost (C) , Availability (A), Reliability (Re)
Tao et al. [21]	Branch-and-Bound	Response time (Rt) , Cost (C), Reliability (Re), Availability (A)
Zeng et al. [22]	Linear integer programming	Cost (C) , Response time (Rt), Reputation (R), Reliability (Re) , Availability (A)
Huang et al. [23]	Mod.Dynamic Programming	Response time (Rt), Throughput (Th)
Gao et al. [24]	Dynamic Programming	Response time (Rt), Throughput (Th)
Changlin et al. [25]	Divide-and-Conquer	Cost (C), Response time (Rt), Reliability (Re), Availability (A)
Alrifai et al. [26]	Linear integer programming	Availability (A), Response time (Rt) , Reputation (R), Cost (C)
Yuan-sheng et al. [45]	Heuristic-enhanced cross entropy	Cost (C), Response time (Rt), Reputation (R) , Availability (A), Security (S) (S), Throughput (Th)
Ardagna et al. [12]	Mixed integer programming	Response time (Rt), Throughput (Th), Availability (A), Price (P)
Marco et al. [31]	Backward breadth first	Response time (Rt), Availability (A), Reputation (R), Price (P)
Tai et al. [32]	MCOP Algorithm	Response time (Rt), Cost (C), Availability
Cardellini et al [33]	Linear programming	Response time (Rt), Cost (C), Availability (A)
Mohabey et al. [34]	Integer Programming	Response time (Rt), Reputation (R), Availability (A), Response time (Rt)
Gabrel et al. [29]	Dependency Graph and 0-1 Linear Programming	Availability (A), Cost (C), Response time (Rt)
Jaeger et al. [27]	Knapsack problem & Constraint project scheduling problem (RCPSP)	Response time (Et), Cost (C), Reputation (R), Availability (A)
Jaeger et al. [28]	Knapsack problem & Multi-Mode RCPSP	Response time (Rt), Cost (C), Reputation (R), Availability (A)
Min et al. [37]	BB4EPS	Reputation (R), Availability (A), Response time (Rt), Reliability (Re)
Yang et al. [38]	Greedy Quick-hull	Cost (C), Availability (A), Reliability (Re), Reputation (R), Response time (Rt)
Yang et al. [35]	MCOP Algorithm	Cost (C), Reputation (R)

TABLE 11: List of studies and their QoS parameters (Exact Algorithms)

Authors Name	Algorithm used	QoS Parameters Considered
Liu et al. [30]	Heuristic algorithm	Cost (C), Response time (Rt), Reputation (R), Availability (A)
Klein et al. [41]	Hill climbing	Response time (Rt), Cost (C), Availability (A), Reliability (Re)
Qi et al. [42]	Local optimization and enumeration method	Response time (Rt), Reputation (R), Availability (A), Cost (C)
Yuan-Sheng et al. [50]	Heuristic algorithm	Reputation (R), Availability (A), Cost (C), Security (S)
Jing et al. [51]	Distributed Heuristic algorithm	Cost (C), Availability (A), Reliability (Re)
Ying et al. [52]	Win-Win strategy algorithm	Response time (Rt), Reliability (Re), Availability (A)
Simone et al. [53]	Memetic Algorithm	Response time (Rt), Reliability (Re), Availability (A), Cost (C)
Berbner et al. [57]	MIP heuristic	Cost (C), Response time (Rt), Reliability (Re), Availability (A)
Jun et al. [44]	Global heuristic algorithm	Cost (C), Reliability (Re), Availability (A), Response time (Rt)
Diana et al. [43]	Heuristic search	Availability (A), Cost (C), Response time (Rt), Reliability (Re)
Pedro et al. [46]	Heuristic algorithm	Availability (A), Cost (C), Response time (Rt), Reputation (R)
Moustafa et al. [47]	Reinforcement Learning	Availability (A), Cost (C), Response time (Rt)
Liang et al. [48]	Improved Reinforcement Learning	Availability (A), Cost (C), Response time (Rt)
Lin et al. [49]	Relaxable service selection algorithm	Availability (A), Cost (C), Response time (Rt), Reliability (Re)
Chan et al. [55]	BF* algorithm	Availability (A), Cost (C), Response time (Rt)
Rodriguez et al. [56]	A* algorithm	Availability (A), Cost (C), Response time (Rt), Reliability (Re)
Luo et al. [45]	Heuristic algorithm	Availability (A), Cost (C), Response time (Rt), Throughput (Th), Security (S)

TABLE 12: List of studies and their QoS parameters (Heuristic)

S.No	Authors Name	Algorithm used	QoS Parameters Considered
1.	Parejo et al. [104]	GRASP and Path Relinking	Cost (C), Response time (Rt), Reliability (Re), Availability (A), Security (S)
2.	Yu et al. [68]	Adaptive genetic algorithm	Response time (Rt), Cost (C), Reliability (Re), Availability (A)
3.	Amiri et al. [156]	Genetic algorithm	Cost (C), Response time (Rt), Availability (A), Reputation (R)
4.	Tang et al. [62]	Hybrid Genetic algorithm	Response time (Rt), Cost (C), Reputation (R), Reliability (Re), Availability (A)
5.	Zhao et al. [87]	Discrete immune optimization, PSO	Cost (C), Response time (Rt), Availability (A), Reliability (Re)
6.	Liu et al. [69]	Improved GA	Response time (Rt), Cost (C), Reliability (Re), Availability (A)
7.	Amiri et al. [82]	PSO	Cost (C), Response time (Rt), Availability (A), Reputation (R)
8.	Canfora et al. [9]	Genetic algorithm	Cost (C), Response time (Rt), Availability (A), Reliability (Re)
9.	Chen et al. [157]	MMGA	Cost (C), Response time (Rt), Availability (A)
10.	Chengying et al. [97]	GA, PSO	Response time (Rt), Cost (C), Reliability (Re), Availability (A)
11.	Xiangbing et al. [71]	Genetic algorithm	Price, Response time (Rt), Availability (A), Reliability (Re)
12.	Yunwu et al. [93]	Chaos ACO	Cost (C), Response time (Rt)
13.	Ludwig et al. [80]	PSO	Reliability (Re), Availability (A), Reputation (R), Response time (Rt), Price (P)
14.	Anqui et al. [103]	GA, Greedy Approach	Response time (Rt)
15.	Rodriguez-mier et al. [158]	Genetic algorithm	Response time (Rt)
16.	Roseberg et al. [112]	GA,SA,TA	Cost (C), Availability (A), Throughput (Th), Response time (Rt)
17.	de Campos et al. [101]	MESOA	Cost (C), Reliability (Re), Availability (A), Reputation (R)
18.	Chifu et al. [98]	Bee colony optimization algorithm	Availability (A), Reliability (Re), Response time (Rt), Cost (C)
19.	Chifu et al. [128]	PSO, Graph	Response time (Rt), Availability (A), Reliability (Re), Throughput (Th), Cost (C).
20.	Xiangwei et al. [86]	Discrete PSO	Not mentioned
21.	Xia et al. [159]	PSO	Availability (A), Reliability (Re), Response time (Rt), Cost (C)
22.	Berbner et al. [40]	GA	Cost (C), Reliability (Re), Availability (A), Response time (Rt)
23.	Quanwang et al. [160]	Ant colony optimization	Cost (C), Response time (Rt), Reliability (Re) , Availability (A)
24.	Jian et al. [79]	GA,PSO	Cost (C), Reliability (Re), Availability (A), Response time (Rt)
25.	Jianxin et al. [120]	Multi-objective PSO	Cost (C), Reliability (Re), Availability (A), Response time (Rt)
26.	Tian et al. [161]	Genetic algorithm	Throughput (Th), Availability (A), Response time (Rt)
27.	Xinfeng et al. [162]	Hybrid GA	Response time (Rt), Availability (A), Cost (C)
28.	Lifeng et al. [106]	Penalty GA	Response time (Rt), Cost (C), Reputation (R), Reliability (Re), Availability (A)
29.	Lifeng et al. [117]	GA and Hill climbing	Response time (Rt), Cost (C), Reputation (R), Reliability (Re), Availability (A)
30.	Chunming et al. [64]	TGA	Cost (C), Response time (Rt), Reliability (Re), Availability (A)
31.	Yujie et al. [163]	NSGA-II	Cost (C), Response time (Rt), Availability (A), Reputation (R), Throughput (Th)
32.	Yang et al. [85]	HQPSO	Cost (C), Response time (Rt), Availability (A)
33.	Wang et al. [78]	Choa PSO	Cost (C), Response time (Rt), Availability (A), Reliability (Re)
34.	Wang et al. [96]	MOCACO	Cost (C), Response Time, Reliability (Re)
35.	Jianxin et al. [121]	ASPSO	Cost (C), Response time (Rt), Availability (A), Reliability (Re)
36.	Jafarpour et al. [74]	Harmony search	Cost (C), Response time (Rt), Availability (A), Reliability (Re)
37.	Pop et al. [94]	Ant-Inspired	Availability (A), Reliability (Re), Response time (Rt), Cost (C)
38.	Wang et al. [118]	MOCACO	Response time (Rt), Availability (A), Reputation (R), Price (P)
39.	Kousalya et al. [100]	Multi-objective Bees Algo	Availability (A), Reliability (Re), Response time (Rt), Cost (C)
40.	Junli et al. [65]	Multi-Objective Genetic Algo	Cost (C), Response time (Rt), Reliability (Re)
41.	Pop et al. [91]	Immune-inspired algorithm	Not mentioned
42.	Sondos et al. [72]	Hybrid GA, Tabu search	Availability (A), Reliability (Re), Response time (Rt), Cost (C)
43.	Parejo et al. [73]	Hybrid GA, Tabu search	Availability (A), Reliability (Re), Response time (Rt), Cost (C)
44.	Jafarpour et al. [76]	Harmony search	Availability (A), Reliability (Re), Response time (Rt), Cost (C)
45.	Jiuyun et al. [164]	Immune Algo,GA	Availability (A), Reliability (Re), Response time (Rt), Cost (C)
46.	Xinchao et al. [90]	Negative selection immune algo	Cost (C), Availability (A), Response time (Rt), Reliability (Re)
47.	Shanshan et al. [113]	Improved ACO	Availability (A), Reliability (Re), Response time (Rt), Cost (C), Throughput (Th)
48.	Zhang et al. [165]	ACO	Availability (A), Reliability (Re), Response time (Rt), Cost (C)
49.	Jiuxin et al. [114]	PSO	Response time (Rt), Reliability (Re), Availability (A), Cost (C)
50.	Wada et al. [107]	MOGA	Response time (Rt), Cost (C), Availability (A), Reliability (Re)
51.	Su et al. [63]	GA	Availability (A), Reliability (Re), Response time (Rt)
52.	Yue et al. [70]	Convergence GA	Availability (A), Reliability (Re), Response time (Rt), Cost (C)
53.	Xia et al. [99]	Chaotic ABC	Availability (A), Reliability (Re), Response time (Rt), Cost (C)
54.	Zhang et al. [166]	PSO	Cost (C), Availability (A), Reliability (Re), Response time (Rt)
55.	Jun at el. [167]	Improved ABC	Response time (Rt), Cost (C), Availability (A), Reliability (Re)
56.	Pop et al. [127]	Cuckoo-inspired search	Availability (A), Reliability (Re), Response time (Rt), Cost (C)
57.	Yang et al. [124]	Genetic algorithm	Availability (A), Reliability (Re), Response time (Rt), Cost (C)
58.	Silva et al. [123]	Graph based PSO	Availability (A), Reliability (Re), Response time (Rt), Cost (C)
59.	Serial et al. [168]	Quantum Inspired Cuckoo Search	Availability (A), Reliability (Re), Response time (Rt), Cost (C)
60.	Jian et al. [169]	culture minimax ant system (C-MMAS)	Availability (A), Reliability (Re), Response time (Rt), Cost (C)
61.	Silva et al. [126]	Genetic algorithm	Availability (A), Reliability (Re), Response time (Rt), Cost (C)
62.	Yang et al. [125]	Hybrid GP and Tabu search	Availability (A), Reliability (Re), Response time (Rt), Cost (C)
63.	Hao et al. [170]	Hybrid Multi-objective Discrete Particle Swarm Optimization Algorithm	Throughput (Th), Latency (L), Cost (C)
64.	Jiang et al. [129]	Variable length chromosome genetic algorithm	Throughput (Th), Availability (A), Reliability (Re), Response time (Rt), Cost (C)
65.	Ying et al. [171]	Distributed Partial Selection Algorithm (DPSA)	Throughput (Th), Response time (Rt)
66.	Sharifara et al. [172]	NSGA-II	Availability (A), Reliability (Re), Response time (Rt), Cost (C)
67.	Yiwen et al. [173]	Improved Fruit Fly Optimization Algorithm	Availability (A), Response time (Rt), Cost (C), Reputation (R)
68.	Qian et al. [174]	Multi-population Genetic Algorithm (MGA)	Availability (A), Response time (Rt), Cost (C)
69.	Mu et al. [54]	GOS: a global optimal selection algorithm	Availability (A), Response time (Rt), Cost (C), Reputation (R)
70.	Surianarayanan et al. [175]	Global optimization selection algorithm	Availability (A), Response time (Rt), Cost (C), Reliability (Re)
71.	Denghui et al. [176]	Adaptive ACO	Cost (C), Response time (Rt), Reliability (Re), Availability (A), Reputation (R)
72.	Jiuyun et al. [88]	Immune Algorithm	Response time (Rt), Cost (C), Availability (A), Reliability (Re)
73.	Gao et al. [89]	Immune Algorithm	Cost (C), Response time (Rt), Reliability (Re), Availability (A)
74.	Jianxin et al. [84]	Niching particle swarm optimization	Availability (A), Reliability (Re), Response time (Rt), Cost (C)
75.	Pop et al. [111]	Immune Algorithm	Availability (A), Reliability (Re), Response time (Rt), Cost (C)
76.	Li et al. [67]	Genetic algorithm	Availability (A), Reliability (Re), Response time (Rt), Cost (C)
77.	Canfora et al. [3]	Genetic algorithm	Availability (A), Reliability (Re), Response time (Rt), Cost (C)
78.	Fan et al. [115]	PSO,SA Algorithm	Availability (A), Reliability (Re), Response time (Rt), Cost (C)
79.	Liang et al. [110]	Genetic algorithm	Availability (A), Reliability (Re), Response time (Rt), Cost (C)
80.	Rezaie et al. [116]	Multi-objective PSO	Availability (A), Reliability (Re), Response time (Rt), Cost (C)
81.	Hongbing et al. [109]	Genetic algorithm	Availability (A), Reliability (Re), Response time (Rt), Cost (C)
82.	Wenbin et al. [81]	Improved PSO	Availability (A), Reliability (Re), Response time (Rt), Cost (C)
83.	Mardukhi et al. [130]	Genetic algorithm	Availability (A), Reliability (Re), Response time (Rt), Cost (C)
84.	Mohammed et al. [75]	Harmony search	Availability (A), Reliability (Re), Response time (Rt), Cost (C)
85.	Yang et al. [122]	Genetic algorithm	Availability (A), Reliability (Re), Response time (Rt), Cost (C)

TABLE 13: List of selected studies and their QoS parameters (Meta-heuristic)

REFERENCES

[1] J. El Hadad, M. Manouvrier, and M. Rukoz, "Tqos: Transactional and qos-aware selection algorithm for automatic web service composition," *IEEE Trans. on Services Computing*, vol. 3, no. 1, pp. 73–85, Jan 2010.

[2] R. Anane, K.-M. Chao, and Y. Li, "Hybrid composition of web services and grid services," in *Proceedings of the IEEE Intl. Conf. on e-Technology, e-Commerce & e-Service (EEE)*, March 2005, pp. 426–431.

[3] G. Canfora, M. Di Penta, R. Esposito, and M. L. Villani, "A lightweight approach for qos-aware service composition," in *Proceedings of the 2nd intl. conf. on serv. ori. comp. (ICSOC)*. ACM, 2004, pp. 36–47.

[4] A. P. Engelbrecht, *Computational intelligence: an introduction*. John Wiley & Sons, 2007.

[5] A. Konar, "An introduction to computational intelligence," *Computational Intelligence: Principles, Techniques and Applications*, pp. 1–35, 2005.

[6] W. Duch, "What is computational intelligence and what could it become," *Computational Intelligence, Methods and Applications Lecture Notes NTU, Singapour*, 2003.

[7] A. Konar, *Computational intelligence: principles, techniques and applications*. Springer, 2006.

[8] R. Kruse, C. Borgelt, F. Klawonn, C. Moewes, M. Steinbrecher, and P. Held, *Computational intelligence: a methodological introduction*. Springer Science & Business Media, 2013.

[9] G. Canfora, M. Di Penta, R. Esposito, and M. L. Villani, "An approach for qos-aware service composition based on genetic algorithms," in *Proceedings of the 7th Annual Conf. on Genetic & Evolutionary Computation (GECCO)*, 2005, pp. 1069–1075.

[10] M. Alrifai and T. Risse, "Combining global optimization with local selection for efficient qos-aware service composition," in *Proceedings of the 18th Intl. Conf. on World Wide Web*, 2009, pp. 881–890.

[11] A. Strunk, "Qos-aware service composition: A survey," in *Proceedings of the IEEE 8th European Conf. on Web Services (ECOWS)*, Dec 2010, pp. 67–74.

[12] D. Ardagna and B. Pernici, "Adaptive service composition in flexible processes," *IEEE Trans. on Software Engineering*, vol. 33, no. 6, pp. 369–384, June 2007.

[13] P. Brereton, B. A. Kitchenham, D. Budgen, M. Turner, and M. Khalil, "Lessons from applying the systematic literature review process within the software engineering domain," *Journal of Systems & Software*, vol. 80, no. 4, pp. 571–583, April 2007.

[14] B. Kitchenham and S. Charters, "Guidelines for performing systematic literature reviews in software engineering," Technical report, EBSE Technical Report EBSE-2007-01, Tech. Rep., 2007.

[15] P. Jamshidi, A. Ahmad, and C. Pahl, "Cloud migration research: A systematic review," *IEEE Transactions on Cloud Computing*, vol. 1, no. 2, pp. 142–157, July 2013.

[16] C. Calero, M. Bertoa, and M. Angeles Moraga, "A systematic literature review for software sustainability measures," in *Proceedings of the 2nd Intl. Workshop on Green & Sustainable Software (GREENS)*, May 2013, pp. 46–53.

[17] A. Jula, E. Sundararajan, and Z. Othman, "Cloud computing service composition: A systematic literature review," *Expert Systems with Applications*, vol. 41, no. 8, pp. 3809 – 3824, June 2014.

[18] G. Woeginger, "Exact algorithms for np-hard problems: A survey," in *Combinatorial Optimization Eureka, You Shrink*, vol. 2570. Springer, 2003, pp. 185–207.

[19] L. Zeng, B. Benatallah, A. H. H. Ngu, M. Dumas, J. Kalagnanam, and H. Chang, "Qos-aware middleware for web services composition," *IEEE Trans. on Software Engineering*, vol. 30, no. 5, pp. 311–327, May 2004.

[20] T. Yu and K. J. Lin, "Service selection algorithms for web services with end-to-end qos constraints," in *Proceedings of the IEEE Intl. Conf. on e-Commerce Tech. (CEC)*, July 2004, pp. 129–136.

[21] T. Yu and K. Lin, "Service selection algorithms for composing complex services with multiple qos constraints," in *Proceedings of the Intl. Conf. on Ser. Ori. Comp. (ICSOC)*, 2005, vol. 3826, pp. 130–143.

[22] L. Zeng, B. Benatallah, M. Dumas, J. Kalagnanam, and Q. Z. Sheng, "Quality driven web services composition," in *Proceedings of the 12th Intl. Conf. on World Wide Web*, 2003, pp. 411–421.

[23] Z. Huang, W. Jiang, S. Hu, and Z. Liu, "Effective pruning algorithm for qos-aware service composition," in *Proceedings of the IEEE Conf. on Commerce & Enterprise Computing (CEC)*, July 2009, pp. 519–522.

[24] Y. Gao, J. Na, B. Zhang, L. Yang, and Q. Gong, "Optimal web services selection using dynamic programming," in *Proceedings of the 11th IEEE Sym. on Computers & Communications (ISCC)*, June 2006, pp. 365–370.

[25] C. Wan, C. Ullrich, L. Chen, R. Huang, J. Luo, and Z. Shi, "On solving qos-aware service selection problem with service composition," in *Proceedings of the 7th Intl. Conf. on Grid & Cooperative Computing (GCC)*, Oct 2008, pp. 467–474.

[26] M. Alrifai, T. Risse, and W. Nejdl, "A hybrid approach for efficient web service composition with end-to-end qos constraints," *ACM Trans. Web*, vol. 6, no. 2, pp. 1–31, May 2012.

[27] M. C. Jaeger, G. Muhl, and S. Golze, "Qos-aware composition of web services: An evaluation of selection algorithms," in *Proceedings of the Intl. Conf. on CoopIS, DOA, and ODBASE on the Move to Meaningful Internet Systems*, 2005, pp. 646–661.

[28] M. Jaeger, G. Muhl, and S. Golze, "Qos-aware composition of web services: a look at selection algorithms," in *Proceedings of the IEEE Intl. Conf. on Web Services (ICWS)*, July 2005, pp. 807–808.

[29] V. Gabrel, M. Manouvrier, and C. Murat, "Optimal and automatic transactional web service composition with dependency graph and 0-1 linear programming," in *Proceedings of the 12th Intl.Conf. on Serv. Ori. Comp.* Springer, 2014, pp. 108–122.

[30] D. Liu, Z. Shao, C. Yu, and G. Fan, "A heuristic qos-aware service selection approach to web service composition," in *Proceedings of the Eighth IEEE/ACIS Intl. Conf. on Computer and Information Science (ICIS)*, June 2009, pp. 1184–1189.

[31] M. Aiello, E. El Khoury, A. Lazovik, and P. Ratelband, "Optimal qos-aware web service composition," in *Proceedings of the 7th IEEE Intl. Conf. on E-Commerce Tech. (CEC)*, July 2009, pp. 491–494.

[32] T. Yu, Y. Zhang, and K.-J. Lin, "Efficient algorithms for web services selection with end-to-end qos constraints," *ACM Trans. Web*, vol. 1, no. 1, may 2007.

[33] V. Cardellini, E. Casalicchio, V. Grassi, and F. Lo Presti, "Flow-based service selection forweb service composition supporting multiple qos classes," in *Proceedings of the IEEE Intl. Conf. on Web Services (ICWS)*, July 2007, pp. 743–750.

[34] M. Mohabey, Y. Narahari, S. Mallick, P. Suresh, and S. V. Subrahmanya, "A combinatorial procurement auction for qos-aware web services composition," in *Proceedings of the IEEE Intl. Conf. on Automation Science & Engineering (CASE)*, Sept 2007, pp. 716–721.

[35] Y. Li, J. Huai, T. Deng, H. Sun, H. Guo, and Z. Du, "Qos-aware service composition in service overlay networks," in *Proceedings of the IEEE Intl. Conf. on Web Services (ICWS)*, July 2007, pp. 703–710.

[36] M. Chen and Y. Yan, "Qos-aware service composition over graphplan through graph reachability," in *Proceedings of the 2014 IEEE Intl. Conf. on Services Computing (SCC)*. IEEE, 2014, pp. 544–551.

[37] M. Liu, M. Wang, W. Shen, N. Luo, and J. Yan, "A quality of service (qos)-aware execution plan selection approach for a service composition process," *Future Generation Computer Systems*, vol. 28, no. 7, pp. 1080–1089, July 2012.

[38] Y. Yang, S. Tang, Y. Xu, W. Zhang, and L. Fang, "An approach to qos-aware service selection in dynamic web service composition," in *Proceedings of the 3rd Intl. Conf. on Networking & Services (ICNS)*, June 2007, pp. 18–23.

[39] X.-S. Yang, "Harmony search as a metaheuristic algorithm," in *Music-Inspired Harmony Search Algorithm*, vol. 191. Springer, 2009, pp. 1–14.

[40] R. Berbner, M. Spahn, N. Repp, O. Heckmann, and R. Steinmetz, "Heuristics for qos-aware web service composition," in *Proceedings of the Intl. Conf. on Web Service*, Sept 2006, pp. 72–82.

[41] A. Klein, F. Ishikawa, and S. Honiden, "Efficient heuristic approach with improved time complexity for qos-aware service composition," in *Proceedings of the IEEE Intl. Conf. on Web Services (ICWS)*, July 2011, pp. 436–443.

[42] L. Qi, Y. Tang, W. Dou, and J. Chen, "Combining local optimization and enumeration for qos-aware web service composition," in *Proceedings of the IEEE Intl. Conf. on Web Services (ICWS)*, July 2010, pp. 34–41.

[43] D. Comes, H. Baraki, R. Reichle, M. Zapf, and K. Geihs, "Heuristic approaches for qos-based service selection," in *Proceedings of the 8th Intl. Conf. on Serv. Ori. Comp.*, vol. 6470. Springer, 2010, pp. 441–455.

[44] J. Li, X. Zheng, S. Chen, W. Song, and D. Chen, "An efficient and reliable approach for quality-of-service-aware service composition," *Information Sciences*, vol. 269, pp. 238 – 254, June 2014.

[45] Y. Luo, Y. Qi, D. Hou, L. feng Shen, Y. Chen, and X. Zhong, "A novel heuristic algorithm for qos-aware end-to-end service composition," *Computer Communications*, vol. 34, no. 9, pp. 1137–1144, June 2011.

[46] P. F. do Prado, L. H. V. Nakamura, J. C. Estrella, M. J. Santana, and R. H. C. Santana, "A performance evaluation study for qos-aware web services composition using heuristic algorithms," in *Proceedings of the 7th Intl. Conf. on Digital Society (ICDS 2013)*, 2013, pp. 53–58.

[47] A. Moustafa and M. Zhang, "Multi-objective service composition using reinforcement learning," in *Proceedings of the 11th Intl. Conf. on Serv. Ori. Comp. (ICSOC)*. Springer, 2013, pp. 298–312.

[48] L.-i. Feng, M. Obayashi, T. Kuremoto, K. Kobayashi, and S. Watanabe, "Qos optimization for web services composition based on reinforcement learning," *Intl. Jour. Innov. comp., Inf. and Control*.

[49] C.-F. Lin, R.-K. Sheu, Y.-S. Chang, and S.-M. Yuan, "A relaxable service selection algorithm for qos-based web service composition," *Information and Software Technology*, vol. 53, no. 12, pp. 1370–1381, 2011.

[50] Y.-s. Luo, Y. Qi, L.-f. Shen, D. Hou, C. Sapa, and Y. Chen, "An improved heuristic for qos-aware service composition framework," in *Proceedings of the 10th IEEE Intl. Conf. on High Performance Computing & Communications*, Sept 2008, pp. 360–367.

[51] J. Li, Y. Zhao, M. Liu, H. Sun, and D. Ma, "An adaptive heuristic approach for distributed qos-based service composition," in *Proceedings of the IEEE Sym. on Computers & Communications (ISCC)*, June 2010, pp. 687–694.

[52] Y. Li and T. Wen, "An approach of qos-guaranteed web service composition based on a win-win strategy," in *Proceedings of the IEEE 19th Intl.Conf. on Web Services (ICWS)*, June 2012, pp. 628–630.

[53] S. A. Ludwig, "Memetic algorithm for web service selection," in *Proceedings of the 3rd Workshop on Biologically Inspired Algorithms for Distributed Systems*. ACM, 2011, pp. 1–8.

[54] M. Li, D. Zhu, T. Deng, H. Sun, H. Guo, and X. Liu, "Gos: a global optimal selection strategies for qos-aware web services composition," *Service Oriented Computing & Applications*, vol. 7, no. 3, pp. 181–197, 2013.

[55] S.-C. Oh, B.-W. On, E. J. Larson, and D. Lee, "Bf*: Web services discovery and composition as graph search problem," in *Proceedings of the IEEE Intl. Conf. on e-Technology, e-Commerce & e-Service.*, 2005, pp. 784–786.

[56] P. Rodriguez-Mier, M. Mucientes, and M. Lama, "Automatic web service composition with a heuristic-based search algorithm," in *Proceedings of the IEEE Intl. Conf. on Web Services (ICWS)*, 2011, pp. 81–88.

[57] R. Berbner, M. Spahn, N. Repp, O. Heckmann, and R. Steinmetz, "Dynamic replanning of web service workflows," in *Proceedings of the Inaugural IEEE-IES Digital EcoSystems & Technologies Conf.*, Feb 2007, pp. 211–216.

[58] F. Glover and M. Laguna, *Tabu Search*. Kluwer Academic Publishers, 1997.

[59] M. C. Jaeger and G. Muehl, "Qos-based selection of services: The implementation of a genetic algorithm," in *Proceedings of the 2007 ITG-GI Conf. Communication in Distributed Systems (KiVS)*, Feb 2007, pp. 1–12.

[60] I. Rojas, J. Gonzalez, H. Pomares, J. J. Merelo, P. A. Castillo, and G. Romero, "Statistical analysis of the main parameters involved in the design of a genetic algorithm," *Systems, Man, and Cybernetics, Part C: Applications and Reviews, IEEE Transactions on*, vol. 32, no. 1, pp. 31–37, Feb 2002.

[61] S. Su, C. Zhang, and J. Chen, "An improved genetic algorithm for web services selection," in *Proceedings of the Distributed Applications & Interoperable Systems*, vol. 4531. Springer, 2007, pp. 284–295.

[62] M. Tang and L. Ai, "A hybrid genetic algorithm for the optimal constrained web service selection problem in web service composition," in *Proceedings of the IEEE Cong. on Evolu. Computation (CEC)*, July 2010, pp. 1–8.

[63] Z. Chengwen, S. Sen, and C. Junliang, "Genetic algorithm on web services selection supporting qos," *Chinese Journal of Computers*, vol. 29, no. 7, pp. 1029–1037, 2006.

[64] C. Gao, M. Cai, and H. Chen, "Qos-aware service composition based on tree-coded genetic algorithm," in *Proceedings of the 31st Annual Intl. Conf. Computer Software & Applications (COMPSAC)*, vol. 1, July 2007, pp. 361–367.

[65] J. Wang and Y. Hou, "Optimal web service selection based on multi-objective genetic algorithm," in *Proceedings of the Intl. Symposium on Computational Intelligence & Design*, vol. 1, Oct 2008, pp. 553–556.

[66] A. E. Yilmaz and P. Karagoz, "Improved genetic algorithm based approach for qos aware web service composition," in *Proceedings of the 2014 IEEE Intl. Conf. on Web Services (ICWS)*. IEEE, June 2014, pp. 463–470.

[67] L. Li, P. Yang, L. Ou, Z. Zhang, and P. Cheng, "Genetic algorithm-based multi-objective optimisation for qos-aware web services composition," in *Proceedings of the 4th Intl. Conf. on Knowledge Science, Engineering & Management*, vol. 6291. Springer, 2010, pp. 549–554.

[68] Y. Yu, H. Ma, and M. Zhang, "An adaptive genetic programming approach to qos-aware web services composition," in *Proceedings of the IEEE Cong. on Evolu. Comp.(CEC)*, June 2013, pp. 1740–1747.

[69] H. Liu, F. Zhong, B. Ouyang, and J. Wu, "An approach for qos-aware web service composition based on improved genetic algorithm," in *Proceedings of the Intl. Conf. on Web Information Systems & Mining (WISM)*, vol. 1, Oct 2010, pp. 123–128.

[70] Y. Ma and C. Zhang, "Quick convergence of genetic algorithm for qos-driven web service selection," *Computer Networks*, vol. 52, no. 5, pp. 1093 – 1104, 2008.

[71] Z. Xiangbing, M. Hongjiang, and M. Fang, "An optimal approach to the qos-based wsmo web service composition using genetic algorithm," in *Proceedings of the Intl. Conf. on Ser. Ori. Comp. (ICSOC)*, 2013, vol. 7759, pp. 127–139.

[72] S. Bahadori, S. Kafi, K. Far, and M. Khayyambashi, "Optimal web service composition using hybrid ga-tabu search," *Journal of Theoretical & Applied Inf. Tech.*, vol. 9, no. 1, pp. 10–15, 2009.

[73] J. A. Parejo, P. Fernandez, and A. R. Cortes, "Qos-aware services composition using tabu search and hybrid genetic algorithms," *Actas de Talleres de Ingeniera del Software y Bases de Datos*, vol. 2, no. 1, pp. 55–66, 2008.

[74] N. Jafarpour and M. Khayyambashi, "A new approach for qos-aware web service composition based on harmony search algorithm," in *Proceedings of the 11th IEEE Intl. Sym. on Web Systems Evolution (WSE)*, Sept 2009, pp. 75–78.

[75] M. Mohammed, M. Chikh, and H. Fethallah, "Qos-aware web service selection based on harmony search," in *Proceedings of the 4th Intl. Sym. on ISKO-Maghreb: Concepts & Tools for knowledge Management (ISKO-Maghreb)*, Nov 2014, pp. 1–6.

[76] N. Jafarpour and M. Khayyambashi, "Qos-aware selection of web service composition based on harmony search algorithm," in *Proceedings of the 12th Intl. Conf. on Advanced Communication Technology (ICACT)*, feb 2010, pp. 1345–1350.

[77] L. Jun and G. Weihua, "An environment-aware particle swarm optimization algorithm for services composition," in *Proceedings of the Intl. Conf. on Computational Intelligence and Software Engineering (CiSE)*, Dec 2009, pp. 1–4.

[78] W. Li and H. Yan-xiang, "Web service composition based on qos with chaos particle swarm optimization," in *Proceedings of the 6th Intl. Conf. on Wireless Communications Networking & Mobile Comp. (WiCOM)*, Sept 2010, pp. 1–4.

[79] J. Liu, J. Li, K. Liu, and W. Wei, "A hybrid genetic and particle swarm algorithm for service composition," in *Proceedings of the 6th Intl. Conf. on Advanced Language Processing & Web Information Technology (ALPIT)*, 2007, pp. 564–567.

[80] S. A. Ludwig, "Applying particle swarm optimization to quality-of-service-driven web service composition," in *Proceedings of the IEEE 26th Intl. Conf. on Advanced Information Networking & Applications (AINA)*, March 2012, pp. 613–620.

[81] W. Wenbin, Z. Qibo Sunb, Xinchao, and Y. Fangchun, "An improved particle swarm optimization algorithm for qos-aware web service selection in service oriented communication," *Intl. Journal of Computational Intel. Syst.*, vol. 3, no. 1, pp. 18–30, 2012.

[82] M. Amiri and H. Serajzadeh, "Effective web service composition using particle swarm optimization algorithm," in *Proceedings of the 6th Intl. Sym. on Telecommunications (IST)*, Nov 2012, pp. 1190–1194.

[83] R. Brits, A. P. Engelbrecht, and F. van den Bergh, "Locating multiple optima using particle swarm optimization," *Applied Mathematics & Computation*, vol. 189, no. 2, pp. 1859–1883, 2007.

[84] J. Liao, Y. Liu, X. Zhu, T. Xu, and J. Wang, "Niching particle swarm optimization algorithm for service composition," in *Proceedings of the IEEE Global Telecommunications Conf. (GLOBECOM)*, 2011, pp. 1–6.

[85] Y. Liu, H. Miao, Z. Li, and H. Gao, "Qos-aware web services composition based on hqpso algorithm," in *Proceedings of the First ACIS/JNU Intl. Conf. on Computers, Networks, Systems and Industrial Engineering (CNSI)*, May 2011, pp. 400–405.

[86] L. Xiangwei and Z. Yin, "Web service composition with global constraint based on discrete particle swarm optimization," in *Proceedings of the 2nd Pacific-Asia Conf. on Web Mining and Web-based Application*, June 2009, pp. 183–186.

[87] X. Zhao, B. Song, P. Huang, Z. Wen, J. Weng, and Y. Fan, "An improved discrete immune optimization algorithm based on pso for qos-driven web service composition," *Applied Soft Computing*, vol. 12, no. 8, pp. 2208–2216, 2012.

[88] J. Xu and S. Reiff-Marganiec, "Towards heuristic web services composition using immune algorithm," in *Proceedings of the IEEE Intl. Conf. on Web Services (ICWS)*, Sept 2008, pp. 238–245.

[89] G. Yan, N. Jun, Z. Bin, Y. Lei, G. Qiang, and D. Yu, "Immune algorithm for selecting optimum services in web services composition," *Wuhan University Journal of Natural Sciences*, vol. 11, no. 1, pp. 221–225, Jan 2006.

[90] X. Zhao, Z. Wen, and X. Li, "Qos-aware web service selection with negative selection algorithm," *Knowledge and Information Systems*, vol. 40, no. 2, pp. 349–373, 2014.

[91] C. Pop, V. Chifu, I. Salomie, and M. Dinsoreanu, "Optimal web service composition method based on an enhanced planning graph and using an immune-inspired algorithm," in *Proceedings of the IEEE 5th Intl. Conf. on Intelligent Computer Communication & Processing*, Aug 2009, pp. 291–298.

[92] Z. Yang, C. Shang, Q. Liu, and C. Zhao, "A dynamic web services composition algorithm based on the combination of ant colony algorithm and genetic algorithm," *Journal of Computational Inf. Syst.*, vol. 6, no. 8, pp. 2617–2622, may 2010.

[93] W. Yunwu, "Application of chaos ant colony algorithm in web service composition based on qos," in *Proceedings of the Intl. Forum on Inf. Tech. & Applications (IFITA)*, vol. 2, May 2009, pp. 225–227.

[94] C. Pop, V. Chifu, I. Salomie, M. Dinsoreanu, T. David, and V. Acretoaie, "Ant-inspired technique for automatic web service composition and selection," in *Proceedings of the 12th Intl. Sym. on Symbolic & Numeric Algorithms for Scientific Computing (SYNASC)*, Sept 2010, pp. 449–455.

[95] Y. Xia, J. Chen, and X. Meng, "On the dynamic ant colony algorithm optimization based on multi-pheromones," in *Proceedings of the 7th IEEE/ACIS Intl. Conf. on Computer & Information Science (ICIS)*, May 2008, pp. 630–635.

[96] W. Li and H. Yan-xiang, "A web service composition algorithm based on global qos optimizing with mocaco," in *Proceedings of the Algorithms & Architectures for Parallel Processing*, 2010, vol. 6082, pp. 218–224.

[97] C. Mao, J. Chen, and X. Yu, "An empirical study on meta-heuristic search-based web service composition," in *Proceedings of the IEEE 9th Intl. Conf. on e-Business Engineering (ICEBE)*, Sept 2012, pp. 117–122.

[98] V. R. Chifu, C. B. Pop, I. Salomie, M. Dinsoreanu, A. N. Niculici, and D. S. Suia, "Selecting the optimal web service composition based on a multi-criteria bee-inspired method," in *Proceedings of the 12th Intl. Conf. on Information Integration and Web-based Applications & Services*, 2010, pp. 40–47.

[99] X. Zhou, J. Shen, and Y. Li, "Immune based chaotic artificial bee colony multiobjective optimization algorithm," in *Proceedings of the 4th Intl. Conf. on Swarm Intelligence*, vol. 7928, 2013, pp. 387–395.

[100] G. Kousalya, D. Palanikkumar, and P. R. Piriyankaa, "Optimal web service selection and composition using multi-objective bees algorithm," in *Proceedings of the 9th IEEE Intl. Sym. on Parallel & Distributed Processing with Applications Workshops (ISPAW)*, May 2011, pp. 193–196.

[101] A. de Campos, A. T. R. Pozo, S. Vergilio, and T. Savegnago, "Many-objective evolutionary algorithms in the composition of web services," in *Proceedings of the 11th Brazilian Sym. on Neural Networks (SBRN)*, Oct 2010, pp. 152–157.

[102] X. Wang, Z. Wang, and X. Xu, "An improved artificial bee colony approach to qos-aware service selection," in *Proceedings of the 20th Intl. Conf. on Web Services (ICWS)*, June 2013, pp. 395–402.

[103] A. Wang, H. Ma, and M. Zhang, "Genetic programming with greedy search for web service composition," in *Proceedings of the Database & Expert Systems Applications*, 2013, vol. 8056, pp. 9–17.

[104] J. A. Parejo, S. Segura, P. Fernandez, and A. Ruiz-Cortes, "Qos-aware web services composition using grasp with path relinking," *Expert Sys. with Applications*, vol. 41, no. 9, pp. 4211 – 4223, 2014.

[105] G. Canfora, M. Di Penta, R. Esposito, and M. L. Villani, "A framework for qos-aware binding and re-binding of composite web services," *journal System Software*, vol. 81, no. 10, pp. 1754–1769, oct 2008.

[106] L. Ai and M. Tang, "A penalty-based genetic algorithm for qos-aware web service composition with inter-service dependencies and conflicts," in *Proceedings of the Intl. Conf. on Comp. Int. for Modelling Control Automation*, Dec 2008, pp. 738–743.

[107] H. Wada, P. Champrasert, J. Suzuki, and K. Oba, "Multiobjective optimization of sla-aware service composition," in *Proceedings of the IEEE Cong. on Services*, July 2008, pp. 368–375.

[108] B. Z. Gao, Yan, J. Na, L. Yang, and Dai, "Optimal selection of web services for composition based on interface-matching and weighted multistage graph," in *Proceedings of the 6th Intl. Conf. on Parallel & Distributed Computing, Applications and Technologies*, 2005, pp. 336–338.

[109] H. Wang, P. Ma, and X. Zhou, "A quantitative and qualitative approach for nfp-aware web service composition," in *Proceedings of IEEE 9th Intl. Conf. on Services Computing (SCC)*. IEEE, June 2012, pp. 202–209.

[110] W.-Y. Liang and C.-C. Huang, "The generic genetic algorithm incorporates with rough set theory-an application of the web services composition," *Expert Syst. with Applications*, vol. 36, no. 3, pp. 5549–5556, 2009.

[111] C. Pop, V. Chifu, I. Salomie, and M. Dinsoreanu, "Immune-inspired method for selecting the optimal solution in web service composition," in *Proceedings of the Resource Discovery*, vol. 6162, 2010, pp. 1–17.

[112] F. Rosenberg, M. Muller, P. Leitner, A. Michlmayr, A. Bouguettaya, and S. Dustdar, "Metaheuristic optimization of large-scale qos-aware service compositions," in *Proceedings of the IEEE Intl. Conf. on Services Computing (SCC)*, July 2010, pp. 97–104.

[113] Z. Shanshan, W. Lei, M. Lin, and W. Zepeng, "An improved ant colony optimization algorithm for qos-aware dynamic web service composition," in *Proceedings of the 2012 Intl. Conf. on Industrial Control & Electronics Eng. (ICICEE)*, Aug 2012, pp. 1998–2001.

[114] C. Jiuxin, S. Xuesheng, Z. Xiao, L. Bo, and M. Bo, "Efficient multi-objective services selection algorithm based on particle swarm optimization," in *Proceedings of the IEEE Asia-Pacific Serv. Comp. Conf. (APSCC)*, Dec 2010, pp. 603–608.

[115] X.-Q. Fan, X.-W. Fang, and C.-J. Jiang, "Research on web service selection based on cooperative evolution," *Expert Syst. with Applications*, vol. 38, no. 8, pp. 9736–9743, 2011.

[116] H. Rezaie, N. NematBaksh, and F. Mardukhi, "A multi-objective particle swarm optimization for web service composition," in *Proceedings of 2nd Intl. Conf. on Networked Digital Technologies*, vol. 88. Springer, 2010, pp. 112–122.

[117] L. Ai and M. Tang, "Qos-based web service composition accommodating inter-service dependencies using minimal-conflict hill-climbing repair genetic algorithm," in *Proceedings of the 4th Intl. Conf. on eScience*, Dec 2008, pp. 119–126.

[118] W. Li and H. Yan-xiang, "A web service composition algorithm based on global qos optimizing with mocaco," in *Proceedings of the Intl. Conf. on Informatics, Cybernetics, & Computer Eng.*, November 2012, vol. 111, pp. 79–86.

[119] P. Leitner, W. Hummer, and S. Dustdar, "Cost-based optimization of service compositions," *IEEE Transactions on Services Computing*, vol. 6, no. 2, pp. 239–251, 2013.

[120] J. Liao, Y. Liu, X. Zhu, J. Wang, and Q. Qi, "A multi-objective service selection algorithm for service composition," in *Proceedings of the 19th Asia-Pacific Conf. on Communications (APCC)*, Aug 2013, pp. 75–80.

[121] J. Liao, Y. Liu, X. Zhu, and J. Wang, "Accurate sub swarms particle swarm optimization algorithm for service composition," *Journal of Systems and Software*, vol. 90, pp. 191–203, 2014.

[122] Y. Yu, H. Ma, and M. Zhang, "A genetic programming approach to distributed qos-aware web service composition," in *Proceedings of the IEEE Cong. on Evolu. Computation (CEC)*, July 2014, pp. 1840–1846.

[123] A. S. da Silva, H. Ma, and M. Zhang, "A graph-based particle swarm optimisation approach toqos-aware web service composition and selection," in *Proceedings of the IEEE Cong. on Evolu. Computation (CEC)*, July 2014, pp. 3127–3134.

[124] H. Ma, A. Wang, and M. Zhang, "A hybrid approach using genetic programming and greedy search for qos-aware web service composition," in *Proceedings of Trans. on Large-Scale Data & Knowledge-Centered Systems XVIII*. Springer, 2015, pp. 180–205.

[125] Y. Yu, H. Ma, and M. Zhang, "A hybrid gp-tabu approach to qos-aware data intensive web service composition," in *Proceedings of the 10th Intl. Conf. on Simulated Evolution & Learning (SEAL 2014)*. Springer, 2014, pp. 106–118.

[126] A. S. d. S. Alexandre, M. Hui, and Z. Mengjie, "A gp approach to qos-aware web service composition and selection," in *Proceedings of the 10th Intl. Conf. on Simulated Evolution & Learning (SEAL 2014)*. Springer, 2014, pp. 180 – 191.

[127] C. Pop, V. Chifu, I. Salomie, and M. Vlad, "Cuckoo-inspired hybrid algorithm for selecting the optimal web service composition," in *Proceedings of the IEEE Intl. Conf. on Intelligent Computer Communication & Processing (ICCP)*, Aug 2011, pp. 33–40.

[128] V. Chifu, C. Pop, I. Salomie, M. Dinsoreanu, A. kover, and R. Vachter, "Web service composition technique based on a service graph and particle swarm optimization," in *Proceedings of the IEEE Intl. Conf. on Intelligent Computer Communication & Processing (ICCP)*, Aug 2010, pp. 265–272.

[129] H. Jiang, X. Yang, K. Yin, S. Zhang, and J. A. Cristoforo, "Multipath qos-aware web service composition using variable length chromosome genetic algorithm," *Information Technology Journal*, vol. 10, no. 1, pp. 113–119, 2011.

[130] F. Mardukhi, N. NematBakhsh, K. Zamanifar, and A. Barati, "Qos decomposition for service composition using genetic algorithm," *Applied Soft Computing*, vol. 13, no. 7, pp. 3409–3421, 2013.

[131] D. Edmond, J. OSullivan, and A. ter Hofstede, "Whats in a service? towards accurate description of non-functional service properties," *Distributed and Parallel Databases Journal*, vol. 12, pp. 117–133, 2002.

[132] D. Karaboga and B. Basturk, "On the performance of artificial bee colony (abc) algorithm," *Applied Soft Computing*, vol. 8, no. 1, pp. 687 – 697, 2008.

[133] R. Akbari, R. Hedayatzadeh, K. Ziarati, and B. Hassanizadeh, "A multi-objective artificial bee colony algorithm," *Swarm and Evolutionary Computation*, vol. 2, pp. 39 – 52, 2012.

[134] S. Mirjalili, S. M. Mirjalili, and A. Lewis, "Grey wolf optimizer," *Advances in Engineering Software*, vol. 69, pp. 46 – 61, 2014.

[135] X.-S. Yang, "Firefly algorithm," *Engineering Optimization*, pp. 221–230, 2010.

[136] ——, "A new metaheuristic bat-inspired algorithm," in *Nature Inspired Cooperative Strategies for Optimization (NICSO 2010)*, vol. 284. Springer Berlin Heidelberg, 2010, pp. 65–74.

[137] B. Niu and H. Wang, "Bacterial colony optimization," *Discrete Dynamics in Nature and Society*, vol. 2012, 2012.

[138] E. Rashedi, H. Nezamabadi-pour, and S. Saryazdi, "Gsa: A gravitational search algorithm," *Information Sciences*, vol. 179, no. 13, pp. 2232 – 2248, 2009.

[139] K. Krishnanand and D. Ghose, "Glowworm swarm optimization for simultaneous capture of multiple local optima of multimodal functions," *Swarm Intelligence*, vol. 3, no. 2, pp. 87–124, 2009.

[140] S. Mirjalili, "The ant lion optimizer," *Advances in Engineering Software*, vol. 83, no. 0, pp. 80 – 98, 2015.

[141] Q. Yu, L. Chen, and B. Li, "Ant colony optimization applied to web service compositions in cloud computing," *Computers & Electrical Engineering*, vol. 41, pp. 18–27, 2015.

[142] A. Abdelmaboud, D. N. Jawawi, I. Ghani, A. Elsafi, and B. Kitchenham, "Quality of service approaches in cloud computing: A systematic mapping study," *Journal of Systems & Software*, vol. 101, pp. 159–179, 2015.

[143] S. Wang, Z. Zheng, Q. Sun, H. Zou, and F. Yang, "Cloud model for service selection," in *2011 IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS)*. IEEE, 2011, pp. 666–671.

[144] S. Yau and H. An, "Software engineering meets services and cloud computing," *Computer*, no. 10, pp. 47–53, 2011.

[145] M. Godse and S. Mulik, "An approach for selecting software-as-a-service (saas) product," in *IEEE International Conference on Cloud Computing*. IEEE, 2009, pp. 155–158.

[146] L. Braubach, K. Jander, and A. Pokahr, "A middleware for managing non-functional requirements in cloud paas," in *2014 Intl. Conf. on Cloud and Autonomic Computing (ICCAC)*. IEEE, 2014, pp. 83–92.

[147] E. Elghoneimy, O. Bouhali, and H. Alnuweiri, "Resource allocation and scheduling in cloud computing," in *2012 Intl. Conf. on Computing, Networking and Communications*, Jan 2012, pp. 309–314.

[148] J. L. Vazquez-Poletti, R. Moreno-Vozmediano, R. S. Montero, E. Huedo, and I. M. Llorente, "Solidifying the foundations of the cloud for the next generation software engineering," *Journal of Systems & Software*, vol. 86, no. 9, pp. 2321–2326, 2013.

[149] R. Buyya, C. S. Yeo, S. Venugopal, J. Broberg, and I. Brandic, "Cloud computing and emerging it platforms: Vision, hype, and reality for delivering computing as the 5th utility," *Future Generation comp. syst.*, vol. 25, no. 6, pp. 599–616, 2009.

[150] T. Dillon, C. Wu, and E. Chang, "Cloud computing: Issues and challenges," in *Proceedings of the 24th IEEE Intl. Conf. on the Advanced Information Networking & Applications (AINA)*, April 2010, pp. 27–33.

[151] D. Armstrong and K. Djemame, "Towards quality of service in the cloud," in *Proceedings of the 25th UK Performance Eng. Workshop*, 2009.

[152] J. Ge, B. Zhang, and Y. Fang, "Research on the resource monitoring model under cloud computing environment," in *Proceedings of the Web Inf. Syst. and Mining*, 2010, pp. 111–118.

[153] M. Armbrust, A. Fox, R. Griffith, A. D. Joseph, R. Katz, A. Konwinski, G. Lee, D. Patterson, A. Rabkin, I. Stoica *et al.*, "A view of cloud computing," *Communications of the ACM*, vol. 53, no. 4, pp. 50–58, 2010.

[154] L. Zhao, S. Sakr, A. Liu, and A. Bouguettaya, "Qos-aware service compositions in cloud computing," in *Proceedings of the Cloud Data Management*, 2014, pp. 119–133.

[155] H. Kurdi, A. Al-Anazi, C. Campbell, and A. Al Faries, "A combinatorial optimization algorithm for multiple cloud service composition," *Computers & Electrical Engineering*, 2014.

[156] M. Amiri and H. Serajzadeh, "Qos aware web service composition based on genetic algorithm," in *Proceedings of the 5th Intl. Sym.on Telecommunications (IST)*, Dec 2010, pp. 502–507.

[157] Z. Chen, H. Wang, and P. Pan, "An approach to optimal web service composition based on qos and user preferences," in *Proceedings of the Intl. Joint Conf. on Artificial Intelligence (JCAI)*, April 2009, pp. 96–101.

[158] P. Rodriguez-mier, M. Mucientes, M. Lama, and M. Couto, "Composition of web services through genetic programming," *Evolutionary Intelligence*, vol. 3, pp. 171–186, 2010.

[159] H. Xia, Y. Chen, Z. Li, H. Gao, and Y. Chen, "Web service selection algorithm based on particle swarm optimization," in *Proceedings of the Eighth IEEE Intl. Conf.on Dependable, Autonomic and Secure Computing*, Dec 2009, pp. 467–472.

[160] Q. Wu and Q. Zhu, "Transactional and qos-aware dynamic service composition based on ant colony optimization," *Future Generation Computer Syst.*, vol. 29, no. 5, pp. 1112 – 1119, 2013.

[161] T. H. Tan, M. Chen, E. Andre, J. Sun, Y. Liu, and J. S. Dong, "Automated runtime recovery for qos-based service composition," in *Proceedings of the 23rd Intl. Conf. on World Wide Web*, 2014, pp. 563–574.

[162] X. Ye and R. Mounla, "A hybrid approach to qos-aware service composition," in *Proceedings of the IEEE Intl. Conf. on Web Services (ICWS)*, 2008, pp. 62–69.

[163] Y. Yao and H. Chen, "Qos-aware service composition using nsga-ii," in *Proceedings of the 2nd Intl. Conf. on Interaction Sciences: Information Technology, Culture and Human*, 2009, pp. 358–363.

[164] J. Xu and S. Reiff-Marganiec, "Towards heuristic web services composition using mmune algorithm," in *Proceedings of the IEEE Intl. Conf. on Web Services (ICWS)*, Sept 2008, pp. 238–245.

[165] W. Zhang, C. Chang, T. Feng, and H. yi Jiang, "Qos-based dynamic web service composition with ant colony optimization," in *Proceedings of the IEEE 34th Annual Computer Software & Applications Conf. (COMPSAC)*, July 2010, pp. 493–502.

[166] T. Zhang, "Qos-aware web service selection based on particle swarm optimization," *Journal of Networks*, vol. 9, no. 3, pp. 565–570, 2014.

[167] J. He, L. Chen, X. Wang, and Y. Li, "Web service composition optimization based on improved artificial bee colony algorithm," *Journal of Networks*, vol. 8, no. 9, pp. 2143–2149, 2013.

[168] S. Boussalia and A. Chaoui, "Optimizing qos-based web services composition by using quantum inspired cuckoo search algorithm," in *Proceedings of the Mobile Web Inf. Syst.*, vol. 8640, 2014, pp. 41–55.

[169] Z.-J. Wang, Z.-Z. Liu, X.-F. Zhou, and Y.-S. Lou, "An approach for composite web service selection based on dgqos," *The Intl. Journal of Advanced Manufacturing Technology*, vol. 56, pp. 1167–1179, 2011.

[170] H. Yin, C. Zhang, B. Zhang, Y. Guo, and T. Liu, "A hybrid multiobjective discrete particle swarm optimization algorithm for a sla-aware service composition problem," *Mathematical Problems in Engineering*, vol. 2014, 2014.

[171] Y. Chen, J. Huang, and C. Lin, "Partial selection: An efficient approach for qos-aware web service composition," in *Proceedings of the IEEE Intl. Conf. on Web Services (ICWS)*, 2014, pp. 1–8.

[172] P. Sharifara, A. Yari, and M. M. R. Kashani, "An evolutionary algorithmic based web service composition with quality of service," in *7th Intl. Sym. on Telecommunications (IST)*, 2014, pp. 61–65.

[173] Y. Zhang, G. Cui, Y. Wang, X. Guo, and S. Zhao, "An optimization algorithm for service composition based on an improved foa," *Tsinghua Science & Technology*, vol. 20, no. 1, pp. 90–99, 2015.

[174] Q. Li, R. Dou, F. Chen, and G. Nan, "A qos-oriented web service composition approach based on multi-population genetic algorithm for internet of things," *Intl. Journal of Computational Intelligence Syst.*, vol. 7, pp. 26–34, 2014.

[175] C. Surianarayanan, G. Ganapathy, and M. S. Ramasamy, "An approach for selecting best available services through a new method of decomposing qos constraints," *Service Oriented Computing & Applications*, pp. 1–32, 2014.

[176] D. Wang, H. Huang, and C. Xie, "A novel adaptive web service selection algorithm based on ant colony optimization for dynamic web service composition," in *Algorithms and Architectures for Parallel Processing*, 2014, pp. 391–399.

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