Comparison of meta-heuristic algorithms for fuzzy modelling of COVID-19 illness' severity classification

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Article Info

ABSTRACT

The world health organization (WHO) proclaimed the COVID-19, commonly known as the coronavirus disease 2019, was a pandemic in March 2020. When people are in close proximity to one another, the virus spreads mostly through the air. It causes some symptoms in the affected person. COVID-19 symptoms are quite variable, ranging from none to severe sickness. As a result, the fuzzy method is seen favourably as a tool for determining the severity of a person's COVID-19 sickness. However, when applied to a large situation, manually generating a fuzzy parameter is challenging. This could be because of the identification of a large number of fuzzy parameters. A mechanism, such as an automatic procedure, is consequently required to identify the right fuzzy parameters. The meta-heuristic algorithm is regarded as a viable strategy. Five meta-heuristic algorithms were analyzed and utilized in this article to classify the severity of COVID-19 sickness data. The performance of the five meta-heuristic algorithms was evaluated using the COVID-19 symptoms dataset. The COVID-19 symptom dataset was created in accordance with WHO and the Indian ministry of health and family welfare criteria. The findings provide the average classification accuracy for each approach.

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1. INTRODUCTION

A newly found coronavirus, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has triggered a global pandemic of respiratory sickness dubbed coronavirus disease 2019 (COVID-19) [1]–[24]. COVID-19 appears to be more contagious than influenza and results in more serious diseases in certain people [5], [11], [15]. COVID-19 has a variable effect on individuals. COVID-19 infection has been associated with a wide variety of symptoms, ranging from mild to severe illness. Symptoms often manifest 2-14 days following viral contact. Fever, fatigue, a dry cough, difficulty breathing, sore throat, nasal congestion, runny nose, and diarrhoea are just a few of the pre-defined typical symptoms. These symptoms are based on world health organization (WHO) regulations [3], [12], [13], [19], [20], [25]. The severity of the sickness assists the medical team in isolating patients and providing appropriate health care.

It was found that using the fuzzy system is a suitable approach in identifying to identify the severity of the COVID-19 illness as it implements fuzzy logic and approximate reasoning [26], [27]. In addition, the fuzzy system also uses expert knowledge to ensure the system performs better. Fuzzy parameters are required to ensure the system able to work, and this process is called fuzzy modelling [26], [28]–[36]. Regrettably, when used to sophisticated problems such as engineering or medicine, the fuzzy systems architecture becomes complicated [26], [37]–[44]. This could occur as a result of the detection of numerous fuzzy parameters. A method for determining the suitable fuzzy parameters is required to address this issue [26], [33], [36], [45]–[61]. As a result, an automated procedure for identifying fuzzy parameters was developed [33], [36], [46], [62]–[66].

Fuzzy modelling is possible to be automated using metaheuristic algorithms. Metaheuristic algorithms are a type of computational intelligence paradigm that is particularly well-suited for solving complex optimization problems [29], [67]–[75]. Metaheuristic algorithms is potential to construct an automated method for determining the severity of a COVID-19 infection infected person based their symptoms [76]. Five metaheuristic algorithms were employed in this work to assess the severity of people's COVID-19 illness: differential evolution (DE), teaching-learning-based optimization (TLBO), particle swarm optimization (PSO), genetic algorithm (GA), and bat algorithm (BA). The next section describes these methods and illustrates them using their existing implementations.

2. META-HEURISTIC ALGORITHMS
2.1. Differential evolution
Differential evolution (DE) is a form of evolutionary algorithm invented by Storn and Price [77]. DE is a fast evolutionary algorithm (EA) that was developed for the purpose of solving optimization problems with real-valued parameters [73], [78]–[96]. DE enables the resolution of optimization problems by maintaining a population of candidate solutions. It generates new candidate solutions by merging existing solutions in the current generation to solve the optimization problem and retaining the candidate solution with the highest quality in the subsequent generation. DE is a three-step process that includes mutation crossover and selection [86], [97]–[100]. The flowchart in Figure 1 depicts the DE process.
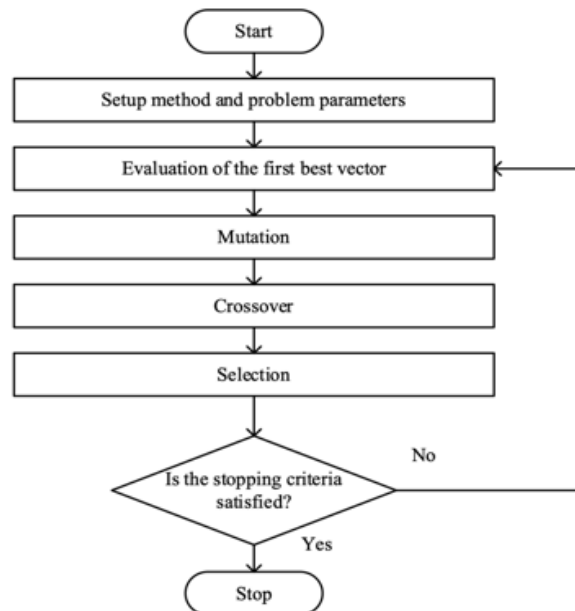

Figure 1. Flowchart of DE

2.2. Genetic algorithm
Genetic algorithm (GA) was introduced by John Holland in 1975 [101] mimics the natural concepts, which are genetic to represent the solution and selection, crossover, mutation to perform its operation. At each phase, GAs employ three distinct sorts of rules to generate the next generation from the present population: selection, crossover, and mutation [93], [95], [102]–[113]. Selection rules determine which individuals, referred to as parents, contribute to the population in the following generation. Crossover rules

create the subsequent generation by combining the offspring of two parents. Individual parents are subjected to random mutations in order to produce children. The process of GA is depicted in flowchart form in Figure 2.
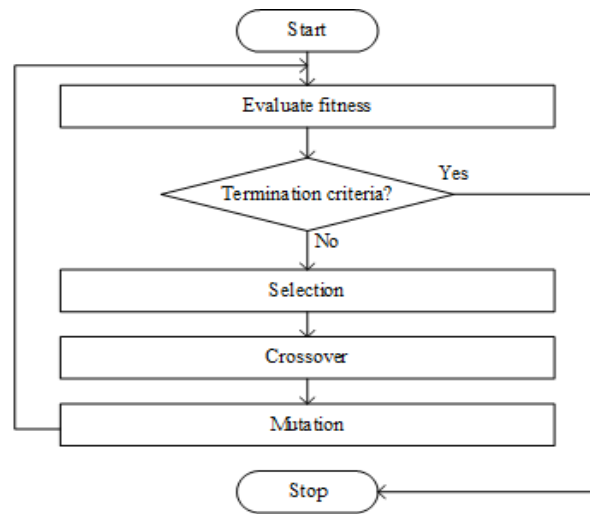

Figure 2. Flowchart of GA

2.3. Particle swarm optimization

Particle swarm optimization (PSO) is a form of swarm intelligence and swarm search that evolved from artificial life and evolutionary computation [114]–[124]. It is modelled after the social behaviour of flocking birds or schooling fish [124]. Since its inception in 1995, PSO has been successfully employed as a solution to a variety of function optimization problems or problems that able to be turned into function optimization problems [116]. Due to its lower memory needs and superior performance in offering solutions that are closer to the optimal for a variety of benchmarks and technical challenges such as computer vision [72], [93], [114], [120], [125]–[158]. PSO has become one of the most popular methods for tackling optimization problems [116][159]–[161]. The operation of PSO is depicted in flowchart form in Figure 3.
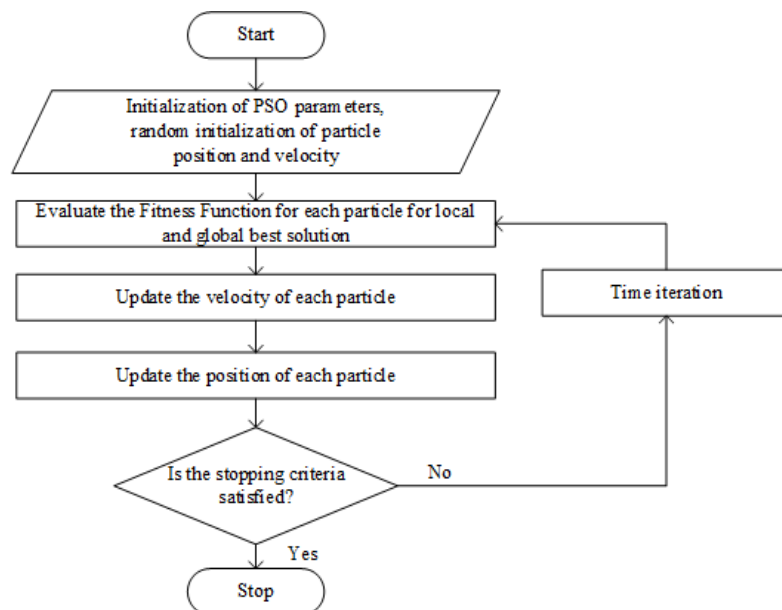

Figure 3. Flowchart of PSO algorithm

2.4. Teaching-learning-based optimization

The teacher-learning-based optimization (TLBO) algorithm is a novel form of metaheuristic algorithm motivated by the teaching-learning process. The TLBO method is a population-based optimization technique in which a group or class of students is considered a population. Each student is an embodiment of a potential solution to the problem. The numerous courses offered in class are interpreted as diverse design variables for the optimization problem, and students performance is interpreted as the fitness value of probable solutions to the optimization problem. The TLBO algorithm is separated into two phases: teacher and student [79], [162]–[170].

The teacher phase is the stage during which pupils learn directly from the teacher. According to the teaching-learning concept, the teacher is defined as the most experienced, knowledgeable, and highly educated member of society. The teacher makes an effort to increase pupils knowledge and to assist students in achieving high grades. Pupils, on the other hand, acquire knowledge and earn grades based on the quality of their teachers instruction and the quality of their classmates. Students acquire information throughout the student phase through mutual engagement. To improve knowledge, a student interacts randomly with other students in the class. If another student in the class has more knowledge than the former, the latter will teach the former something new. Thus, if the latter student is superior to the former, the former student is relegated to the latter. Otherwise, the former student will be separated from the latter. TLBO operates and processes in the manner depicted in Figure 4.
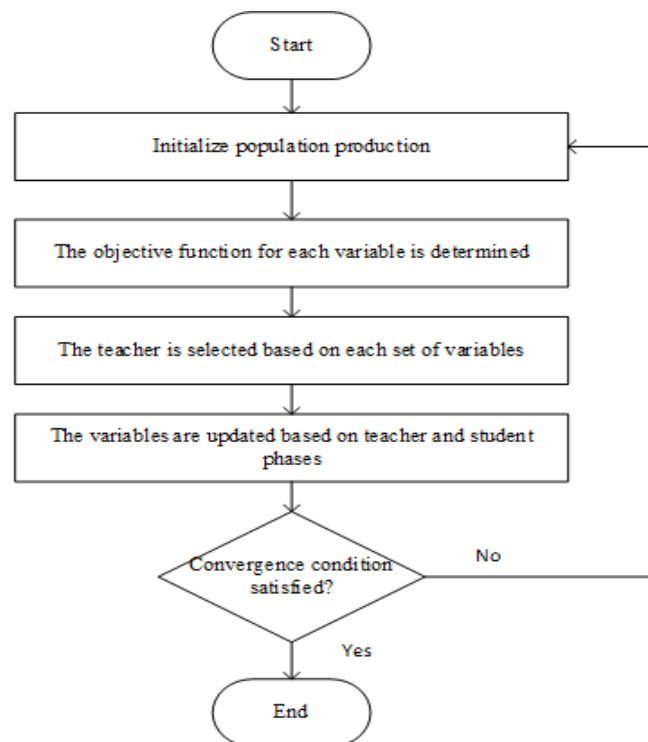

Figure 4. Flowchart of TLBO algorithm

2.5. Bat algorithm

The bat algorithm (BA) was introduced by Yang [171] in 2010 as a way for searching for global optimal solutions. BA has gained increased attention due to its simplicity, a small number of parameters, high robustness, and ease of implementation [144], [172]–[177]. The BA is designed to replicate bats echolocation activity. Bats generate a very loud sound pulse and listen for echoes in their environment. This signal varies according to the species of bat [178]. BA is founded on two tenets: i) all bats utilize echolocation and fly randomly in search of prey; and ii) all bats use echolocation. They distinguish between victim or food and impediment or background barriers; iii) bats utilize echolocation to determine distance. Bats able to automatically alter the wavelength of their outgoing pulses in response to their target. Figure 5 illustrates the steps required in BA.
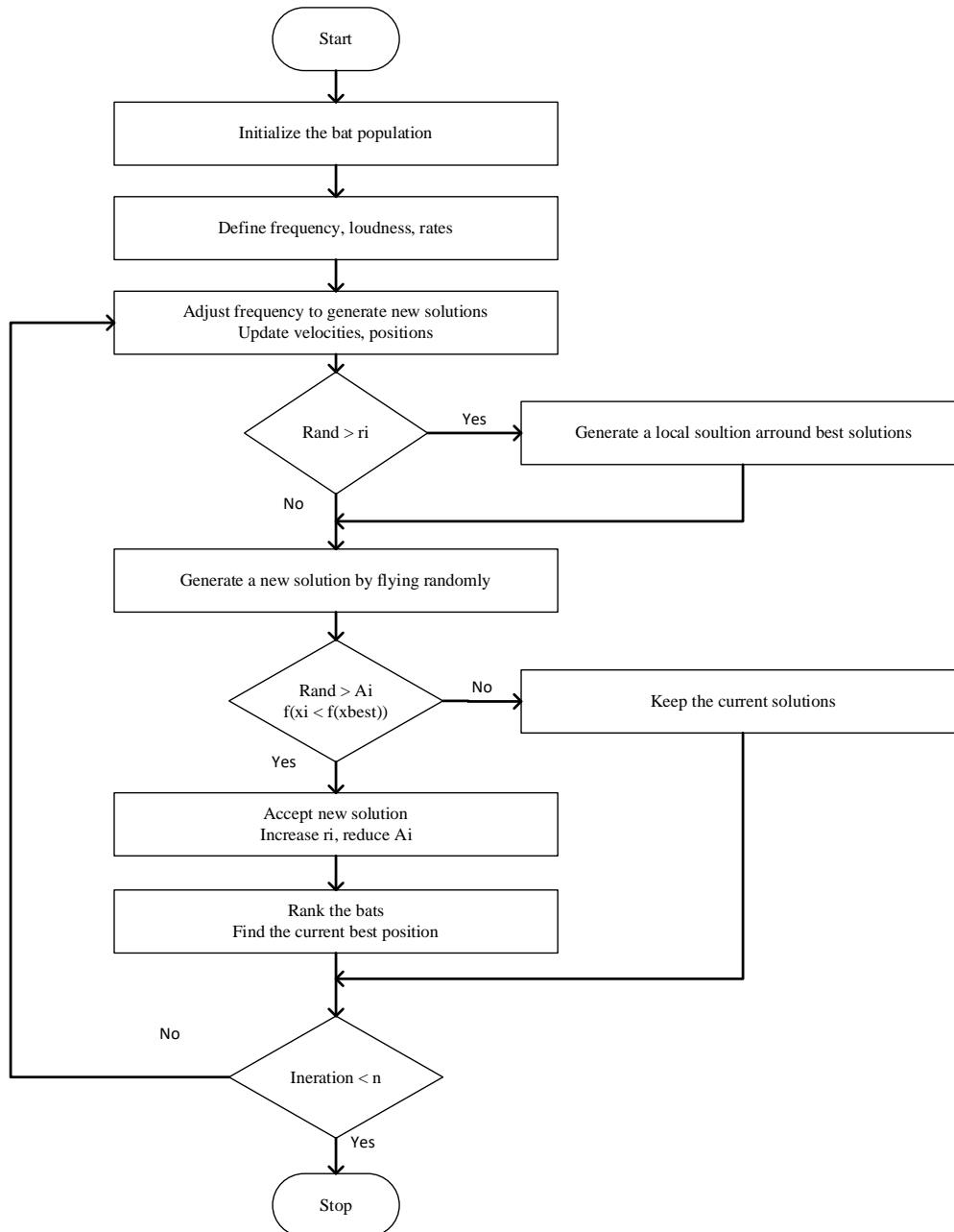
Figure 5. Flowchart of BAT algorithm

3.   FUZZY META-HEURISTIC ALGORITHMS

This section discusses how meta-heuristic algorithms [29], [67]–[70], [73]–[75], [82], [90], [95], [109], [119], [160], [163], [176], [179]–[188] are included in the fuzzy modelling process. The implementation of fuzzy meta-heuristic algorithms is depicted in Figure 6. The initialization of the first population is the first process. The fuzzy parameters, including the fuzzy rules and fuzzy membership function, were produced randomly and represented by candidate solutions during this process. Figure 7 illustrates the representation of fuzzy rules and the fuzzy membership functions. Following that, the fuzzy rules and fuzzy membership functions are evaluated [189]. The fuzzy system classified data using fuzzy rules and the fuzzy membership functions. At this stage, proposed solutions were reviewed to see if they satisfied the termination requirement or not. If the termination requirement is met, the process terminates, and the optimal solution is found; and the process will continue when the termination condition is not achieved. The reproduction procedure seeks to increase the candidate solutions quality. The replication procedure is dependent on the meta-heuristic algorithm utilized in the fuzzy modelling process [29], [88], [180].
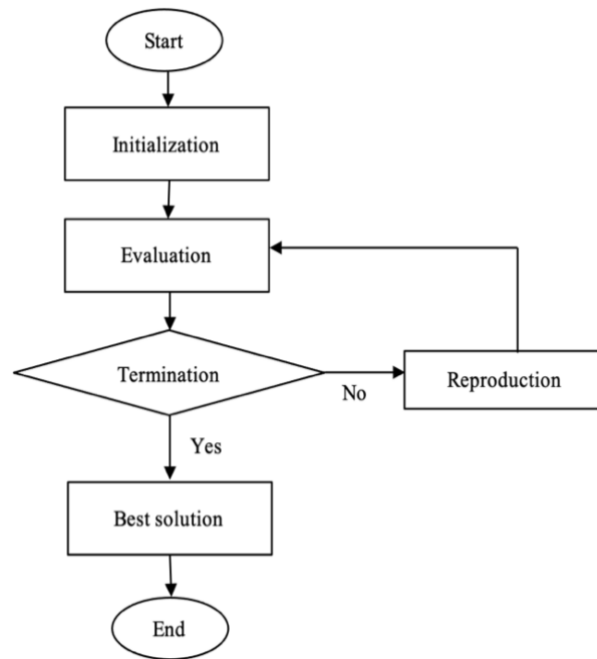
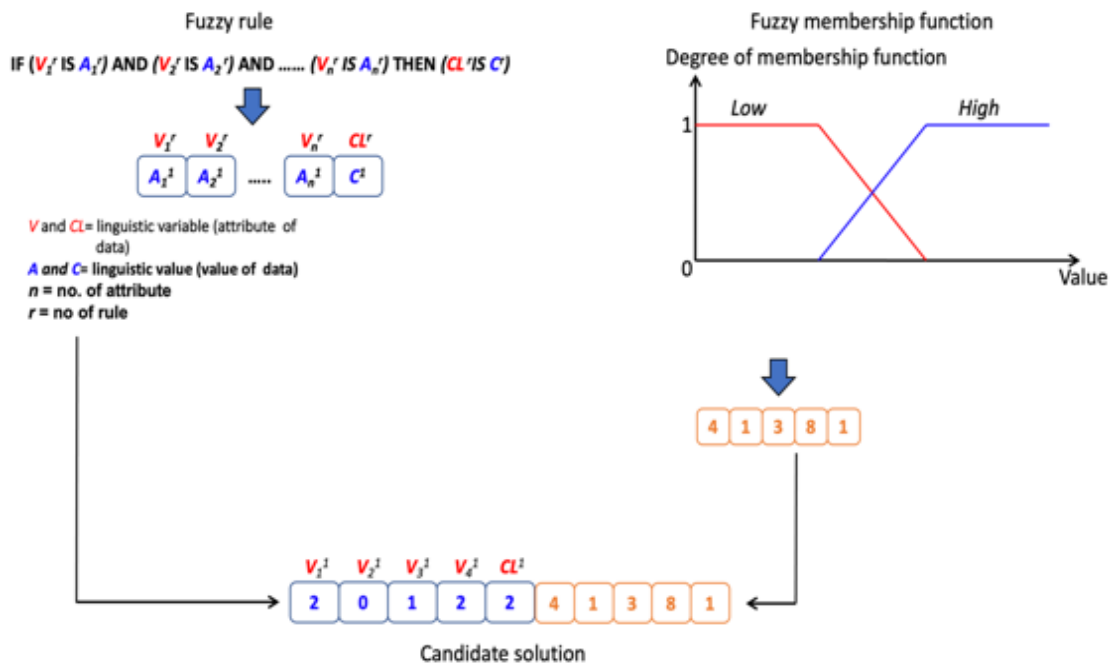Figure 6. Flowchart of fuzzy meta-heuristic algorithm

Figure 7. The representation of fuzzy rules and fuzzy membership function

4. EXPERIMENTAL DATA

In evaluating the performance of metaheuristic algorithms, the COVID-19 symptoms checker dataset was utilized. This dataset is available for download on the Kaggle website at https://www.kaggle.com/iamhungundji/covid19-symptoms-checker. This dataset contains information on COVID-19 classification (whether or not a person has the disease) based on a set of pre-defined standard symptoms. These symptoms are based on WHO and the Indian Ministry of Health and Family Welfare recommendations. The dataset contains significant variables that is utilized to determine whether or not someone has coronavirus illness. There are 316801 instances in the dataset.

5.   RESULTS AND DISCUSSION

Following the collection of data, the performance of each machine-learning technique was examined. The various experiments results were presented and contrasted. The results revealed disparate values for various variables, including the number of correctly identified occurrences and the time required to execute the experiment. Table 1 gives the experiment's results. From the table, the fuzzy DE and fuzzy PSO algorithms performed well, with an average accuracy of 74.9 percent, followed by the fuzzy GA at 25.6 percent. Fuzzy TLBO and fuzzy BA had the lowest average accuracies at 25.1 percent each.

Table 1. The result of the meta-heuristic algorithm for fuzzy modelling in the classification of COVID-19

Method	Average accuracy (%)
Fuzzy DE	74.9
Fuzzy GA	25.6
Fuzzy PSO	74.9
Fuzzy TLBO	25.1
Fuzzy BA	25.1

Along with average accuracy, computational time was considered. Table 2 summarises the time required (in minutes) for each machine-learning approach to handle both datasets. According to the table, fuzzy DE outperformed the other approaches for both datasets. This could be due to the speed with which fuzzy DE performed the classification process, as it worked with the maximum margin, allowing for extremely low classification error [190]. It is robust and quick in classifying objects [191], [192]. Meanwhile, fuzzy TLBO required the most time to classify all datasets. This could be because the fuzzy TLBO's slow training procedure utilized a large amount of computer memory, making it time demanding [193]–[195]. The comparison of time expresses in Table 2.

Table 2. The comparison of time

Method	Computational time (sec)
Fuzzy DE	5.9771
Fuzzy GA	11.4683
Fuzzy PSO	6.5285
Fuzzy TLBO	146.7146
Fuzzy BA	14.5643

6.   CONCLUSION

Machine learning is one of the methods that is suitable to be applied for classifying the severity of peoples COVID-19 illnesses. Five machine-learning algorithms were evaluated in this study: fuzzy DE, fuzzy GA, fuzzy PSO, fuzzy TLBO, and fuzzy BA. The benchmark dataset was created in accordance with WHO requirements. The data set included pre-defined standard symptoms such as fever, fatigue, dry coughing, trouble breathing, sore throat, nasal congestion, runny nose, and diarrhoea. Numerous experiments were conducted to show the ability of the methods. The performance criteria included the precision with which the data were classified correctly and the time required to conduct the experiment. As a result of the data, it is clear that fuzzy DE performs admirably in terms of average accuracy and classification time. As a result, the fuzzy DE fared the best in classifying the COVID-19 Symptoms Checker dataset.

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