Advance Teaching–Learning Based Optimization for Global Function Optimization

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Abstract Teaching–Learning based optimization (TLBO) is an evolutionary powerful algorithm in optimal solutions search space that is inspired from teaching learning phenomenon of a classroom. It is a novel population based algorithm with faster convergence speed and without any algorithm specific parameters. The present work proposes an improved version of TLBO called the Advance Teaching–Learning Based Optimization (ATLBO). In this algorithm introduced a new weight parameter for more accuracy and faster convergence rate. The effectiveness of the method is compare against original TLBO on many benchmark problems with different characteristics and shows the improvement in performance of ATLBO over traditional TLBO.

Keywords Global function optimization · Teaching-learning based optimization (TLBO) · Population based algorithms · Convergence speed

1 Introduction

To solve complex optimization problems such as mathematical optimization, multimodality, dimensionality and numeric optimization problems, several modern heuristic algorithms have been introduced. In a recent time a new optimization

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technique Teaching–Learning Based Optimization (TLBO) gaining popularity for their reliability, accuracy and faster convergence rate. It has not required any algorithm-specific parameters so TLBO can also be called as an algorithm-specific parameter-less algorithm [1, 2]. TLBO is based on the effect of the influence of a teacher on the outcome of learners in a classroom and output is considered in terms of grades.

In this proposed work, includes a weight parameter 'W' in both phases and team leader concept with original TLBO that is known as Advance Teaching–Learning Based Optimization (ATLBO). The inclusive parameter gives a better convergence rate and accuracy. ATLBO compared with original TLBO for solving global function optimization problems and the performance characteristic are provided to show that ATLBO has better results than basic TLBO.

Rest of this paper is organized as follows. Section 2 presents the concept of basic TLBO. Section 3 describes the proposed Advance TLBO. Section 4 discusses results and comparison with basic TLBO. Section 5 gives conclusion. The detailed explanation of TLBO is given in next section.

2 Teaching Learning Based Optimization (TLBO)

Teaching–Learning Based Optimization (TLBO) is a newly introduced an efficient optimization algorithm, inspired by the teaching—learning process in the classroom. It is a population-based evolutionary computer algorithm that modeled on transferring knowledge in the classroom and use student result to proceed on global solution. TLBO does not need any specific parameters, it only requires common controlling parameters like population size and number of generations, so it is called parameter less optimization algorithm [3]. TLBO is divided into two phases: 'Teacher Phase' and 'Learner Phase'. In Teacher phase learners gain knowledge from teacher and then Learner also gain knowledge from their classmates by mutual interaction, group-discussion etc. [4–6] in 'Learning phase'.

2.1 Initialization

Following notation is used to describing TLBO

MAXIT: maximum number of allowable iterations.
N: number of learners in a class i.e. "class size";
D: number of courses offered to the learners;

The X is randomly initialized population by a search space bounded by matrix of N rows and D columns.

$$X_{new,i} = X_{min,i} + ri\left(X_{maxi} - X_{min,j}\right) \tag{1}$$

where ri is a uniformly distributed random variable within the range (0, 1), $X_{max,i}$ and $X_{min,j}$ represent the minimum and maximum parameter value [3, 7].

2.2 Teacher Phase

In human society teachers are seen as best learner and have more knowledge than learners. Teachers always tries to improve the knowledge of learners by which knowledge level of classroom in turn increase and help to get better grades and marks. But a teacher only improves the knowledge mean among students according to their ability and effectiveness. Merely it is unacceptable for a teacher that it can improve the knowledge mean of classroom towards specific degree [3, 8].

Let a teacher Ti is try to improve classroom mean Mi upward own knowledge level. Ti is denoted by "M_{new}" as new mean. The result is changed by the inequality between current [7, 9, 10] and new mean expressed by

$$\text{Difference\_Mean}_i = ri(M_{new} - T_f M_i) \tag{2}$$

where ri denotes for a random number in the range of [0, 1] and Tf is denominated as a teaching factor which determines the students mean value that is changed either select 1 or 2 with equivalent probability [9]

$$T_f = \text{round}[1 + \text{rand}(0, 1)\{2 - 1\}] \tag{3}$$

where termed rand denotes a random values between 0 and 1. This difference updates the current solution by following expression.

$$X_{new,i} = X_{old,i} + \text{Difference\_Mean}_i \tag{4}$$

2.3 Learner Phase

In Learner phase, Learners try to increases their knowledge from their classmates in the form of group discussion, mutual interaction and tutorial etc. A learner randomly interacts with each other's in the form of presentation, formal communication and group discussion, etc. If any learner has better knowledge than others, learners improve their knowledge form whom. For a population size Pn, learner improves their knowledge from following algorithm [7, 9, 10].

For i = 1 :Pn
Xi and Xj are two randomly selected learners
Where i<> j
if f (Xi) < f (Xj)
$X_{new,i}$= $X_{old,i}$+ ri (Xi – Xj)……………..................................5
Else
$X_{new,i}$= $X_{old,i}$+ ri(Xj – Xi)………………….........................6
End if
End for
Accept Xnew if gives a better function value.

2.4 Algorithm Termination

The algorithm is terminated when maximum iteration MAXIT is reached.

3 Proposed Advance Teaching–Learning Based Optimization

The proposed ATLBO is the improved version of traditional TLBO algorithm. In basic TLBO learn improves their knowledge by a single teacher or by interaction of other learners. In classroom environment some student gains knowledge during tutorial hours, group discussion or by self-motivation learning. TLBO algorithm tries to shift the mean of learners towards the teacher of class. In ATLBO algorithm a new weight factor W are included in teacher phase (in Eq. 1) of basic TLBO and in the part of learning phase (in Eqs. 5 and 6) includes a team leader concept that provides the global position of best learner. In learning phase of ATLBO previous best learner are act as a team leader, team leader are change during every iteration until result is not reached on global solution. Weight factor is linearly decreases with time.

$$\text{Weight factor}(w) = \text{Wmax} - \Delta\text{w} \tag{7}$$

$$\Delta\omega = [(\text{Wmax} - \text{Wmin}) * (\text{Tmax} - \text{t})/\text{Tmax})] \tag{8}$$

where W_{max} and W_{min} are the maximum and minimum values of weight factor w, iteration is the current iteration number and max iteration is the maximum number of allowable iterations. W_{max} and W_{min} are selected to be 0.9 and 0.1, respectively.

So the improved teacher phase express following

$$X_{new,i} = w * X_{old,i} + ri(M_{new} - T_f M_i) \tag{9}$$

In contrast of Learning phase of basic TLBO, ATLBO improves its learning phase by concept of best learner that act as a team-leader, In every iteration previously best learner treat as a team-leader. A team-leader has always has the more knowledge than their classmate [9, 10].

Hence in the learning phase the new set of improved learns can be

For i = 1 : Pn
Xi and Xj are two randomly selected learners
Where I <> j
if f (Xi) < f (Xj)
$X_{new,i}$=W*$X_{old,i}$+ ri (Xi – Xj)+ri(Xbest-Xi)...............................10
Else
$X_{new,i}$= W*$X_{old,i}$+ ri(Xj – Xi)+ri(Xbest-Xi)...............................11
End if
End for

where r_i denotes for a random number in the range of 0–1.

Xbest is best learner act as team leader.

Accept X_{new} if gives a better function value.

4 Experimental Results

In this section, we have an exhaustive comparison of our proposed algorithm (ATLBO) with basic TLBO. For all the experiments population size was set to 20 and the maximum number fitness function evaluation was set to 100. Table 1 shown

Table 1 List of benchmark functions have been used in experiment

No	Function	n	C	Range	Formulation value (f_{min}) = 0
f1	Step	30	US	[−100, 100]	$f(x) = \sum_{i=1}^{n} (x_i + 0.5)^2$
f2	Sphere	30	US	[−100,100]	$f(x) = \sum_{i=1}^{n} (x_i)^2$
f3	Sum Squares	30	US	[−100, 100]	$f(x) = \sum_{i=1}^{n} (ix_i)^2$
f4	Schwefel 2.22	30	UN	[−10, 10]	$f(x) = \sum_{i=1}^{n} \lvert x_i \rvert + \Pi_{i=1}^{n} \lvert x_i \rvert$
f5	Bohachevsky1	2	MS	[−100,100]	$f(x) = X_1^2 + X_2^2 - 3\cos(3\Pi x_1) - 0.4\cos(4\Pi x_2) + 0.7$
f6	Bohachevsky2	2	MS	[−100, 100]	$f(x) = x_1^2 + x_2^2 - 3\cos(3\Pi x_1) \times \cos(4\Pi x_2) + 0.7$
f7	Bohachevsky3	2	MS	[−100, 100]	$f(x) = x_1 + x_2 - 3\cos(3\Pi x_1 + 4\Pi x_2) + 0.7$
f8	Rastrigin	30	MS	[−5.12, 5.12]	$f(x) = [x_1^2 - 10\cos(2\Pi x_i) + 10]$
f9	Griewank	30	MN	[−600, 600]	$f(x) = \frac{1}{4000}\sum_{i=1}^{n} (x_i)^2 - \Pi_i^n = 1\cos(xi/\sqrt{i}) + 1$

Table 2 Fitness evaluation of TLBO and ATLBO (mean and standard deviation)

No	Function	Mean (TLBO)	Sd (TLBO)	Mean (TLBO)	Sd (TLBO)
f1	Step	6.99E+01	64.99796	5.599362	13.34852
f2	Sphere	142.0809	174.0369	4.10E+00	7.557908
f3	Sum squares	591.9211	799.6606	4.53E+00	5.717949
f4	Schwefel 2.22	4.464452	3.663719	1.72E−01	0.224143
f5	Bohachevsky1	158.2136	155.8383	2.79E+00	3.477812
f6	Bohachevsky2	230.8089	254.7465	3.20E+00	4.672983
f7	Bohachevsky3	116.5454	178.0865	−2.4217	26.36527
f8	Rastrigin	5.06E+00	2.188272	6.32E−01	0.490737
f9	Griewank	0.023156	0.026999	1.48E−02	0.013463

below gives the description of all the nine benchmark functions that was used for experimentation.

4.1 Performance Metrics

To check the performance of proposed algorithm (ATLBO), Mean and standard deviation of different benchmarks is calculated for determining the quality of solution and the convergence rate is plotted and the resultant performance is compared to basic TLBO.

a. **Quality of Solution**: To determine the quality of solution, mean and standard deviation of 30 independent runs on nine different benchmark functions is calculated and recorded in Table 2. In all the cases ATLBO performs better than TLBO. To further verify the result, a two tailed t-test is performed and results are shown in Table 3. The result of t-test proves that the quality of ATLBO's solution is better than TLBO solution quality.
b. **Convergence Rate of Proposed Algorithm**: To determine the convergence rate, Both algorithms (ATLBO and TLBO) are tested on 10 independent sets with 100 iteration on 10 independent run over different benchmarks and draw graphs for comparing the convergence rate follows (Fig. 1):

Table 3 t-Test Result of benchmark functions

Function	f1	f2	f3	f4	f5	f6	f7	f8	f9
TLBO/ATLBO	Sign	Sign	Sign	Sign	Ex. Sign	Sign	Sign	Ex. Sign	Sign

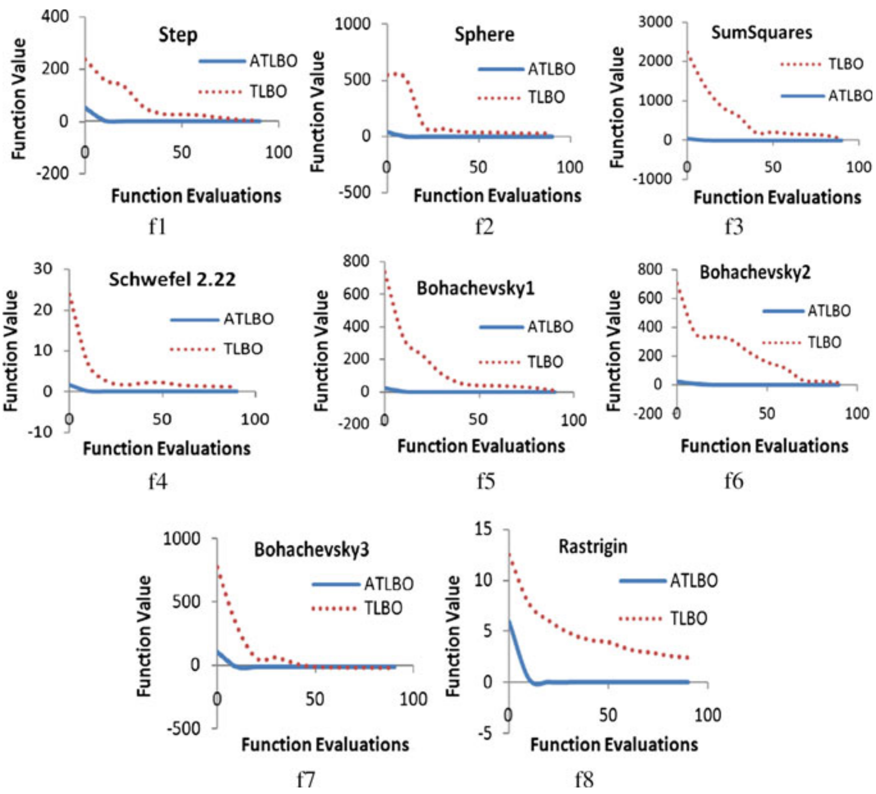

Fig. 1 Convergence curve for different benchmarks using ATLBO against TLBO

5 Conclusion and Further Research

A new algorithm Advance Teaching–Learning Based Optimization (ATLBO) is suggested. It is an improved version of basic Teacher Learning Based Optimization (TLBO). In ATLBO algorithm a new weight factor is introduced in both teaching and learning phase also with a new concept of team leader. Team leader which was the best learner in the previous phase will act as a teacher in learning phase. The ATLBO algorithm provides better results compared to basic TLBO algorithm on several benchmark functions. The proposed ATLBO algorithm is able to find the global optimum values more accurately with faster convergence rate. The experiment results have shown satisfactory performance of the ATLBO algorithm. In future performance of ATLBO may be enhanced with new parameter tuning strategy and adapts for multi-objective optimization and also its the practical application areas like clustering, data mining, design and optimization of communication, networks would be worth studying.

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