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Teaching-learning-based artificial bee colony

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1 Introduction

- **Problem**: continue function optimization

$$\min \quad f(x)$$
$$s.t. \quad x_{min} \le x \le x_{max}$$

- **Metaheuristic algorithms**
  - nature inspired optimization strategies
  - received much attention regarding their potential as global optimization techniques

2 TLBO and ABC

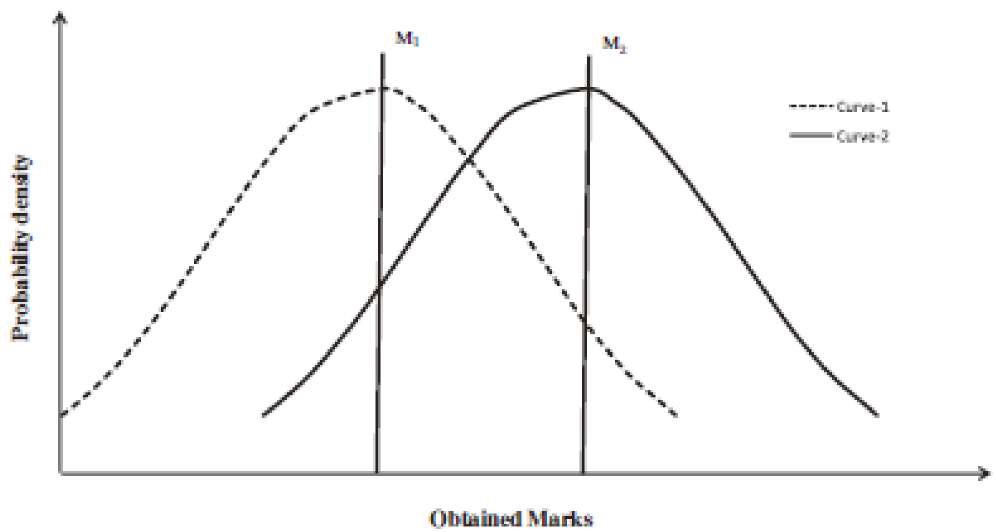
- Our paper focuses on two metaheuristic algorithms
  - **Teaching-learning-based optimization (TLBO)**
  - Inspired by the teaching and learning process of a class
  - Two operators: teacher phase and learner phase

  - **Artificial bee colony (ABC)**
  - Inspired by the intelligent foraging behavior of honey bees
  - Three kinds of bees: employed bees, onlooker bees, and scout bees

2.1 TLBO

- **Teaching-learning-based optimization (TLBO)**
  - **Two operators**: teacher phase and learner phase
  - **Teacher phase**: the teacher provides knowledge to the learners to increase the mean result of the class.

$$\boldsymbol{x}_i^{new} = \boldsymbol{x}_i^{old} + \boldsymbol{rand} \cdot (\boldsymbol{x}_{teacher} - T_F \cdot \boldsymbol{x}_{mean})$$



2.1 TLBO

- **Teaching-learning-based optimization (TLBO)**
  - **Two operators**: teacher phase and learner phase
  - **Learner phase**: each learner randomly interacts with other different learners to further improve his result

$$\boldsymbol{x}_i^{new} = \begin{cases} \boldsymbol{x}_i^{old} + \boldsymbol{rand} \cdot (\boldsymbol{x}_i - \boldsymbol{x}_j), & if \quad f(\boldsymbol{x}_i) \le f(\boldsymbol{x}_j) \\ \boldsymbol{x}_i^{old} + \boldsymbol{rand} \cdot (\boldsymbol{x}_j - \boldsymbol{x}_i), & if \quad f(\boldsymbol{x}_j) > f(\boldsymbol{x}_i) \end{cases}$$

Remark: In both teacher phase and learner phase, if $\boldsymbol{x}_i^{new}$ is better than $\boldsymbol{x}_i^{old}$, then use $\boldsymbol{x}_i^{new}$ to replace $\boldsymbol{x}_i^{old}$.

2.2 ABC

- **Artificial bee colony (ABC)**
  - Inspired by the intelligent foraging behavior of honey bees
  - Three kinds of bees: employed bees, onlooker bees, and scout bees
  - **Employed bees:** responsible for seeking out better food sources and passing quality information of the food sources to onlooker bees by dancing.
  - **Onlooker bees:** select good food sources found by employed bees to further search for better food source.
  - **Scout bees**: abandon the exhausted food sources, and regenerate a new food source.

3 Proposed Teaching-learning-based Artificial Bee Colony

- **Motivation**
  - **TLBO**: Good exploitation, poor exploration
  - **ABC**: Good exploration, poor exploitation
  - Design a hybrid metaheuristic algorithm based on TLBO and ABC.

- **Question**
  - How to effectively combine TLBO and ABC?

3 Proposed Teaching-learning-based Artificial Bee Colony

- **Teaching-learning-based Artificial Bee Colony (TLABC)**
  - **Method**: Combine the search equations of TLBO with the search framework of ABC
  - Three hybrid search phases

    (1) **Exploration**: teaching-based employed bee phase

    (2) **Exploitation**: learning-based onlooker bee phase

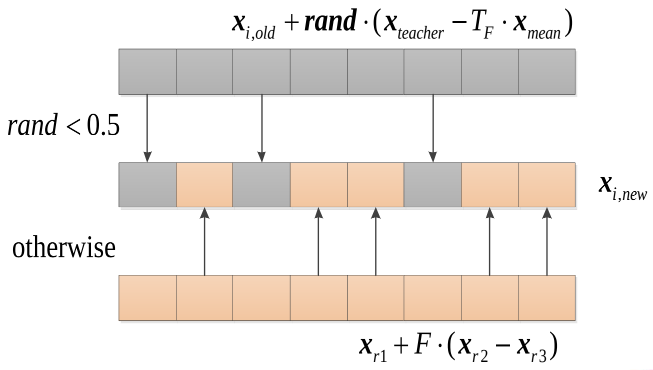
    (3) **Restart**: generalized oppositional scout bee phase

3 Proposed Teaching-learning-based Artificial Bee Colony

- **Teaching-based employed bee phase**
  - Exploration phase
  - Each employed bee use an hybrid TLBO teaching strategy to update the position

$$u_{i,d} = \begin{cases} x_{i,d}^{old} + rand_2 \cdot (x_{teacher,d} - T_F \cdot x_{mean,d}) & if\ rand_1 < 0.5 \\ x_{r1,d} + F \cdot (x_{r2,d} - x_{r3,d}) & else \end{cases}$$

Remark: The hybrid TLBO teaching strategy can improve the **exploration** of the original TLBO teaching strategy.



3 Proposed Teaching-learning-based Artificial Bee Colony

- **Learning-based onlooker bee phase**
  - Exploitation phase
  - Each onlooker bee select a solution based on the fitness

$$fit(\boldsymbol{x}_i) = \begin{cases} \frac{1}{1+f(\boldsymbol{x}_i)} & if \;\; f(\boldsymbol{x}_i) \geq 0 \\ 1 + |f(\boldsymbol{x}_i)| & otherwise \end{cases}$$

  - Use the TLBO learning strategy to update the position

$$\boldsymbol{x}_i^{new} = \begin{cases} \boldsymbol{x}_i^{old} + \boldsymbol{rand} \cdot (\boldsymbol{x}_i - \boldsymbol{x}_j), & if \;\; f(\boldsymbol{x}_i) \leq f(\boldsymbol{x}_j) \\ \boldsymbol{x}_i^{old} + \boldsymbol{rand} \cdot (\boldsymbol{x}_j - \boldsymbol{x}_i), & if \;\; f(\boldsymbol{x}_j) > f(\boldsymbol{x}_i) \end{cases}$$

3 Proposed Teaching-learning-based Artificial Bee Colony

- **Generalized oppositional scout bee phase**
  - Restart phase
  - Each exhausted solution re-initializes using a generalized opposition based learning (GOBL)

$$\boldsymbol{x}_i = \begin{cases} \boldsymbol{x}_i, & if \quad f(\boldsymbol{x}_i) \le f(\boldsymbol{x}_i^{GO}) \\ \boldsymbol{x}_i^{GO}, & if \quad f(\boldsymbol{x}_i) > f(\boldsymbol{x}_i^{GO}) \end{cases}$$

where $\boldsymbol{x}_i = (x_{i1}, \cdots, x_{ij}, \cdots, x_{iD})$, $\boldsymbol{x}_i^{GO} = (x_{i1}^{GO}, x_{i2}^{GO}, \cdots, x_{iD}^{GO})$

$$x_{ij}^{GO} = k \cdot (x_{min,j} + b_{max,j}) - x_{ij}$$

3 Proposed Teaching-learning-based Artificial Bee Colony

- **Framework of TLABC**

Algorithm 1. Teaching-learning artificial bee colony algorithm

Initialization	
While the stop criterion is not satisfied	
Teaching-based employed bee phase;	Exploration
Learning-based onlooker bee phase;	Exploitation
Generalized oppositional scout bee phase;	Restart
End While	
Output the best solution.	

4 Experimental Results and Analysis

- **Benchmarks**
  - CEC2014 test functions
  - G1: unimodal functions (F01–F03);
  - G2: simple multimodal functions (F04–F16);
  - G3: hybrid functions (F17–F22);
  - G4: composition functions (F23–F30).
- **Comparisons**
  - Four TLBO : TLBO, NIWTLBO, LETLBO and GOTLBO
  - Four ABC: ABC, GABC, MABC and GBABC

4 Experimental Results and Analysis

- **Compared with TLBO algorithms**

Table The win-draw-loss statistics results between TLABC and the compared TLBO algorithms based on Wilcoxon rank-sum test

TLABC vs	TLBO	NIWTLBO	LETLBO	GOTLBO
G1	3-0-0	3-0-0	3-0-0	2-1-0
G2	9-2-2	9-2-2	7-3-3	8-3-2
G3	3-2-1	3-0-3	3-1-2	2-3-1
G4	5-2-1	3-2-3	6-2-0	1-2-5
Total	20-6-4	18-4-8	19-6-5	13-9-8

(i) TLABC shows the best performance on the unimodal functions, simple multimodal functions and hybrid functions.

(ii) On composition functions, GOTLBO shows the best performance, TLABC the second.

4 Experimental Results and Analysis

- **Compared with ABC algorithms**

Table The win-draw-loss statistics results between TLABC and the compared ABC algorithms based on Wilcoxon rank-sum test

TLABC vs	ABC	GABC	MABC	GBABC
G1	3-0-0	3-0-0	2-1-0	3-0-0
G2	3-2-8	3-2-8	5-2-6	3-2-8
G3	5-0-1	5-0-1	3-0-3	3-3-0
G4	7-0-1	6-2-0	5-2-1	4-3-1
Total	18-2-10	17-4-9	15-4-11	13-8-9

(i) TLABC shows the best performance on the unimodal functions, hybrid functions, and composition functions.

(ii) For the simple multimodal functions, the performance of TLABC is not very satisfactory, but it also gets the best results on some multimodal functions.

4 Experimental Results and Analysis

- **Multiple-problem statistical comparison**

Table Results of Multiple-problem Wilcoxon test between TLABC and the compared TLBO and ABC algorithms

Algorithm	R+	R-	p-value	α=0.05	α=0.1
TLABC vs TLBO	375	60	3.32E-04	Yes	Yes
TLABC vs NIWTLBO	318	117	2.91E-02	Yes	Yes
TLABC vs LETLBO	331	104	1.29E-02	Yes	Yes
TLABC vs GOTLBO	328	107	1.57E-02	Yes	Yes
TLABC vs ABC	331	134	4.27E-02	Yes	Yes
TLABC vs GABC	311	154	1.09E-01	No	No
TLABC vs MABC	284	181	≥0.2	No	No
TLABC vs GBABC	256	209	≥0.2	No	No

4 Experimental Results and Analysis

- **Multiple-problem statistical comparison**

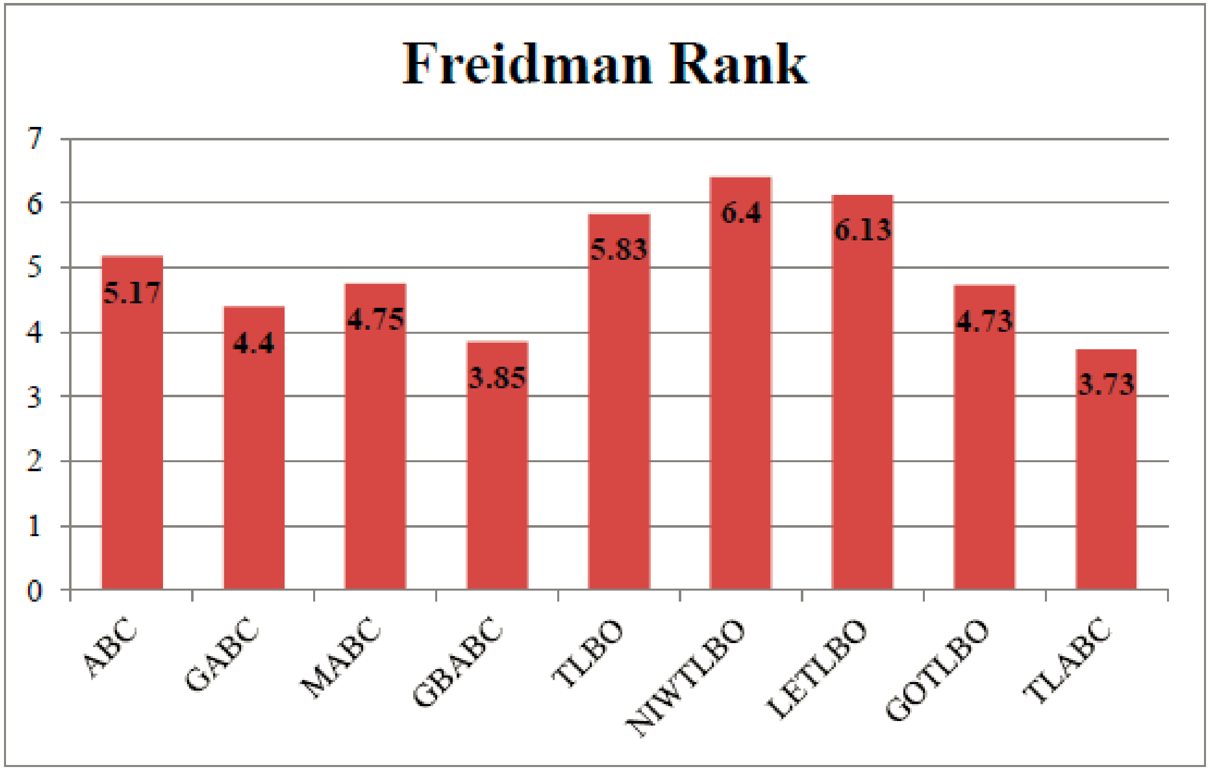


Figure Friedman rank of TLABC and the compared algorithms.

4 Experimental Results and Analysis

Convergence graphs

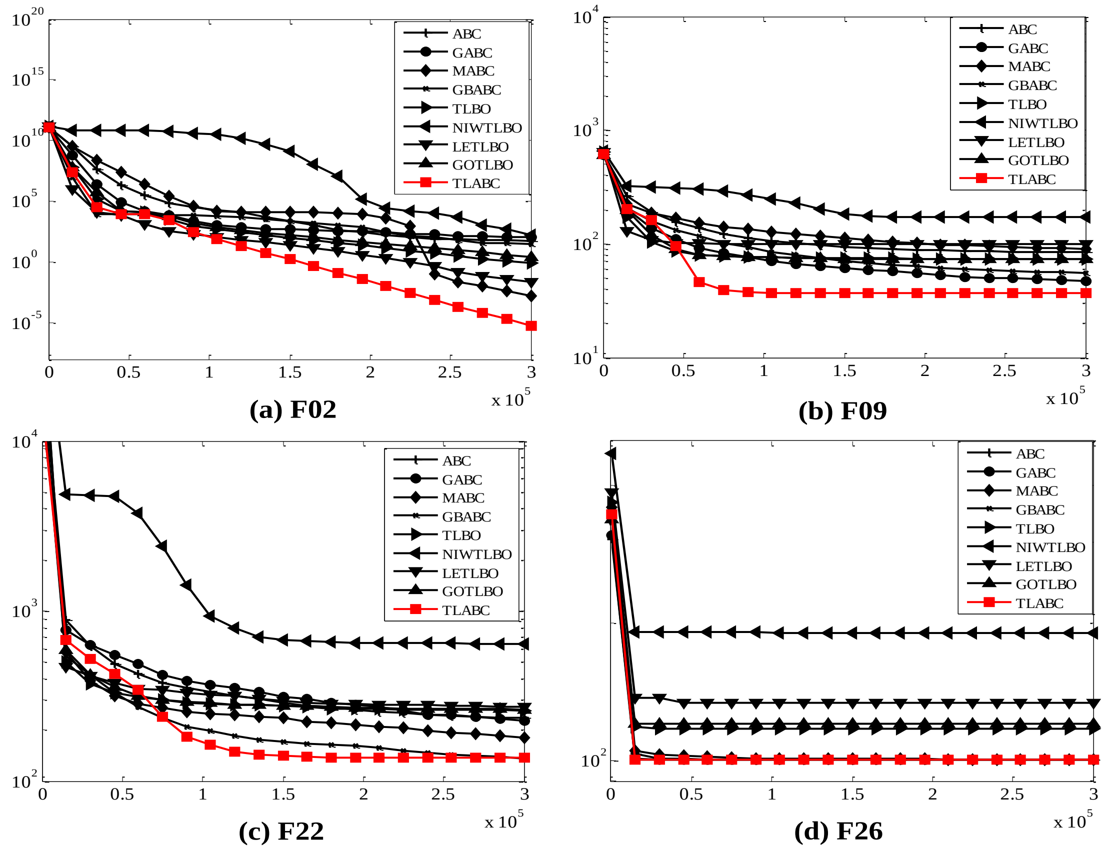


Figure Convergence graphs of TLABC and the compared algorithms on four typical functions

5 Conclusion

- A hybrid TLABC algorithm based on TLBO and ABC is proposed.
- TLABC combines good exploitation of TLBO and good exploration of ABC.
- TLABC provides a better balance between exploration and exploitation compared with the previous TLBO and ABC algorithms.
- TLABC is better than the compared TLBO and ABC algorithms on most of CEC2014 benchmark functions.

The End.

Thanks for Your Attentions.