Development and Investigation of Biologically Inspired Algorithms Cooperation Metaheuristic

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ABSTRACT
Cooperation of biologically inspired algorithms as an optimization meta-heuristic is considered. Its performance evaluation and comparison with component algorithms performance on benchmark optimization problems is fulfilled. Workability of the meta-heuristic is demonstrated with artificial neural networks based classifiers tuned to two real world problems.

Categories and Subject Descriptors
G.4 [**Mathematical Software**]: – *Algorithm design and analysis, Efficiency.*

I.2.8 [**Artificial intelligence**]: Problem Solving, Control Methods and Search – *Heuristic methods*.

General Terms
Algorithms, Performance, Design, Experimentation.

Keywords
Self-tuning, swarm intelligence, population size, real-parameter optimization, classification.

1. INTRODUCTION
Particle Swarm Optimization (PSO), Wolf Pack Search (WPS), Firefly Algorithm (FFA), Cuckoo Search Algorithm (CSA) and Bat Algorithm (BA) are instances of biology related optimization algorithms originally developed for continuous variables space [1-5]. These algorithms mimic collective behavior of corresponding animal group.

Performance of above-listed five heuristics was investigated and compared on six known test functions: sphere, hyper-ellipsoid, Griewank's, Rosenbrock's, Ackley's and Rastrigin's functions [6]. Results show that all these algorithms are effective enough for solving real-parameter optimization problems, but we can't say which of them is the most appropriate for solving current problem. The best results were obtained for different problems with different dimensions by different algorithms. The best algorithm differs even for the same test problem if the dimension varies.

It brings researchers to the idea of formulating a new meta-heuristic approach that combines major advantages of above-listed algorithms. So we investigate the optimization method based on cooperation of PSO, WPS, CSA, FFA and BA and called Co-Operation of Biology Related Algorithms (COBRA). Investigation was conducted on 28 benchmark optimization functions from [7] and results allowed us to conclude that COBRA outperforms each component algorithm and the higher problem dimension is the bigger advantage could be observed. Additional confirmation of the approach usefulness and workability was confirmed after solving two classification problems with artificial neural network based classifiers where weight coefficients were tuned by COBRA.

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2. CO-OPERATION OF BIOLOGY RELATED ALGORITHMS (COBRA)
So investigation (and comparison of obtained results) of PSO, WPS, CSA, FFA and BA bring one to the idea of a new approach based on combination of these five algorithms. This approach has to automate choice of appropriate algorithm for the problem in hand. The basic idea consists in generating five populations (one population for each algorithm) which are then executed in parallel but cooperating with each other.

Proposed method is a self-tuning meta-heuristic: we don't have to choose the population size for each algorithm. Number of individuals in each algorithm's population can increase or decrease depending on changes of fitness value. If the fitness value wasn't improved during a given number of generations, then the size of all populations increases. Conversely, if fitness value was constantly improved, then size of all populations decreases.

At the same time, each population can "grow" by accepting individuals removed from other populations. Population "grows" only if its average fitness is better than the average fitness of all other populations. Thereby we can determine "winner algorithm" on each iteration/generation. Such a kind of competition allows presenting the biggest resource (population size) to the most appropriate (in the current situation) algorithm. This property can be very useful in case of hard optimization problem when, as it is known, there is no single best algorithm on all stages of optimization process execution.

The most important driving force of the suggested meta-heuristic is the migration operator that creates a cooperation environment for component algorithms. All populations communicate with each other: they exchange individuals in such a way that part of the worst individuals of each population is replaced by the best individuals of other populations. It brings up to date information on the best achievements to all component algorithms and prevents their preliminary convergence to its own local optimum that improves group performance of all algorithms.

3. NUMERICAL EXPERIMENTS

First, we solved the same six test problems by proposed approach and observed that it demonstrates comparable performance. Besides, COBRA outperformed other algorithms on a number of test problems. Additionally, with increasing of the problem dimension the proposed approach showed best results.

Then all five algorithms were compared with a new meta-heuristic on 28 benchmark functions submitted for CEC 2013 Special Session on Real-Parameter Optimization [7], following experiment settings described there. Problem dimensions used for comparing were 2, 5, 10 and 30. All these functions are shifted and scalable. The same search ranges are defined for all test functions: $[-100, 100]^D$. So, algorithms were tested by using 5 unimodal functions, 15 basic multimodal functions and 8 composition functions. Error values achieved after maximal function evaluations in 51 runs were sorted from the smallest (best) to the largest (worst**)** and then the best, worst, mean, median and standard variance values of function error values over 51 runs were recorded and analyzed. For each problem we established "winner algorithm" by the best and mean results averaged over 51 program runs. Considering mean results, COBRA had 19 wins on the test problems of dimension D=2, 24 wins when D=5, 26 wins when D=10 and 28 wins when dimension was equal to 30. Considering the best results, COBRA had 7, 11, 18 and 26 wins, correspondingly. As one can observe number of "wins" for COBRA increases with the problem dimension. So results of these experiments show that suggested approach is workable and useful for solving real-parameter optimization problems.

Table 1. Classifiers' performance comparison

Classifier	Scoring in Australia	Scoring in Germany
2SGP	0.9027	0.8015
C4.5	0.8986	0.7773
Fuzzy	0.8910	0.7940
ANN (5)	0,8907	0,7829
ANN (3)	0,8898	0,7809
GP	0.8889	0.7834
CART	0.8744	0.7565
LR	0.8696	0.7837
CCEL	0.8660	0.7460
RSM	0,8520	0,6770
Bagging	0.8470	0.6840
Bayesian	0.8470	0.6790
Boosting	0.7600	0.7000
k-NN	0.7150	0.7151

That is why we used proposed algorithm for adjustment of neural network's weight coefficients for solving real world classification problems. Structure of neural networks was fixed as a single hidden layer perceptron with 3 or 5 neurons, each having bipolar sigmoid as an activation function.

Two applied problems were solved with neural networks: bank scoring in Germany (20 attributes, 2 classes, 700 records of the creditworthy customers and 300 records for the non-creditworthy customers) and in Australia (14 attributes, 2 classes, 307 examples of the creditworthy customers and 383 examples for the non-creditworthy customers). Benchmark data were taken from [8]. From optimization view point, these problems have from 45 till 105 real-valued variables. Obtained results are presented in Table 2 below where portion of correctly classified instances from validation sets is presented. There are also results of other researchers used other approaches (found in scientific literature).

4. CONCLUSION

New meta-heuristic algorithm (COBRA) based on five known optimization methods has been suggested and tested. Although many successful modifications of component algorithms are known, the original design of these algorithms was used because of having in mind the examination of idea as such. Numerical experiments showed that this idea is useful; so using of further modifications of component algorithms will give also positive effect. Additionally, the migration process can be modified that also can improve proposed algorithm. These modifications are the subject of further research.

5. REFERENCES

[1] Kennedy, J., Eberhart, R., 1995. Particle Swarm Optimization. In *Proceedings of IEEE International Conference on Neural networks.* IV., 1942–1948.

[2] Chenguang Yang, Xuyan Tu and Jie Chen, 2007. Algorithm of Marriage in Honey Bees Optimization Based on the Wolf Pack Search. In *Proceedings of the International Conference on Intelligent Pervasive Computing.* IPC2007, 462-467.

[3] Yang, X. S., 2009. Firefly algorithms for multimodal optimization. In *Proceedings of the 5th Symposium on Stochastic Algorithms, Foundations and Applications.* SAGA 2009, 169–178.

[4] Yang, X. S. and Deb, S., 2009. Cuckoo Search via Levy flights. In *Proceedings of the World Congress on Nature & Biologically Inspired Computing.* NaBic 2009, IEEE Publications, USA, 210-214.

[5] Yang, X. S., 2010. A new metaheuristic bat-inspired algorithm. In *Nature Inspired Cooperative Strategies for Optimization.* (NICSO 2010), Springer, SCI 284, 65-74.

[6] Molga, M., Smutnicki, Cz., 2005. Test functions for optimization need. 3 kwietnia.

[7] Liang, J. J., Qu, B. Y., Suganthan, P. N. and Hernandez-Diaz, A. G., 2012. Problem Definitions and Evaluation Criteria for the CEC 2013 Special Session on Real-Parameter Optimization. Technical Report. Zhengzhou University, Computational Intelligence Laboratory, Zhengzhou China, and Nanyang Technological University, Singapore.

[8] Frank, A. and Asuncion, A., 2010. UCI Machine Learning Repository. Irvine, CA: University of California, School of Information and Computer Science. http://archive.ics.uci.edu/ml.