Report on Recent Scientific Applications of Self-Organizing Migration Algorithm

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Abstract: Self-Organizing Migration Algorithm was developed by prof. Zelinka in 1999 as a powerful tool of evolutionary optimization. Since then it has found many successful implementations. This paper summarizes recent applications of the algorithm by the scientific team of the department where it was created. Applications can be divided into three main areas: chaotic system control, Neural Network Synthesis and electricity-related optimization. These applications are described considering current SCOPUS database indexation. The paper also contains basic description of the algorithm itself.

Key-Words: Self-Organizing Migration Algorithm, SOMA, chaotic system control, Hénon map, Neural Network Synthesis, optimization, evolutionary algorithm

1 Introduction

In recent years, a broad class of algorithms was developed for stochastic optimization, i.e. for optimizing systems where the functional relationship between the independent input variables *x* and output (objective function) *y* of a system *S* is not known. Using stochastic optimization algorithms such as Genetic Algorithms, Simulated Annealing, Differential Evolution (DE) and Particle Swarm Optimization, a system is confronted with a random input vector and its response is measured. This response is then used by the algorithm to tune the input vector in such a way that the system produces desired output or target value in an iterative process.

SOMA – **S**elf-**O**rganizing **M**igration **A**lgorithm, is based on self-organizing behavior of groups of individuals in "social environment". It can also be classified as evolutionary algorithm despite the fact that no new generations of individuals are created during search process (philosophy of this algorithm). Only positions of the individuals in the searched space are changed during generation called "migration loop". The algorithm, developed by prof. Zelinka in 1999 [1], has been published in various journals, books and has been presented at international conferences, symposiums as well as during many invited lectures.

This paper summarizes recent applications of the algorithm by the scientific team of the department where it was created. In the second chapter, main principles of the algorithm are explained.

Chapter three then contains description of various SOMA applications in three main areas of interest: chaotic system control, Neural Network Synthesis and electricity connected optimization. These applications are described considering current SCOPUS database indexation.

2 SOMA

Several different versions of SOMA exist. This chapter presents the most common **All-to-One** version. All basic All-to-One SOMA principles important for correct understanding of the algorithm are described below.

1) Parameter definition

Before starting the algorithm, SOMA's parameters Step, PathLength, PopSize, PRT and the Cost Function need to be defined. The Cost Function is simply a function which returns a scalar that can directly serve as a measure of fitness.

2) Creation of Population

Population of individuals is generated randomly. Each parameter for each individual has to be chosen randomly from the given range <Low, High>.

ISBN: 978-1-61804-113-5

3) Migration loop

Each individual from population (PopSize) is evaluated by the Cost Function and the Leader (individual with the highest fitness) is chosen for the current migration loop. Then all other individuals begin to jump, (according to Step parameter definition) towards the Leader. Each individual is evaluated after each jump using the Cost Function. Jumping continues until a new position defined by PathLength has been reached. The new position $x_{i,j}$ after each jump is calculated by (1). This is shown graphically in Fig. 1. The individual then returns to the position where it found the best fitness on its trajectory.

$$x_{i,j}^{MLnew} = x_{i,j,start}^{ML} + (x_{L,j}^{ML} - x_{i,j,start}^{ML})tPRTVector_j \quad (1)$$

where $t \in$ <0, *by Step to, PathLegth*>
and ML is actual migration loop

Before an individual begins jumping towards the Leader, a random number *rnd* is generated (for each individual's component) and then compared with PRT. If the generated random number is larger than PRT, then the associated component of the individual is set to 0 by means of PRTVector.

$$\text{if } rnd_j < \textbf{PRT} \text{ then } PRTVector_j = 0 \text{ else } 1 \quad (2)$$

where $rnd \in$ <0, 1>
and $j = 1, \ldots n_{param}$

j	rnd_j	PRTVector
1	0.234	1
2	0,545	0
3	0,865	0
4	0,012	1

Table 1, An example of PRTVector for 4 parameters individual with PRT = 0.3

Hence, the individual moves in the N-k dimensional subspace, which is perpendicular to the original space. This fact establishes higher robustness of the algorithm. Earlier experiments have demonstrated that without the use of PRT SOMA tends to find only local optimum rather than the global one.

4) Test for stopping condition

If the maximum number of migration loops has been reached, algorithm stops and recalls the best solution(s) found during search process.

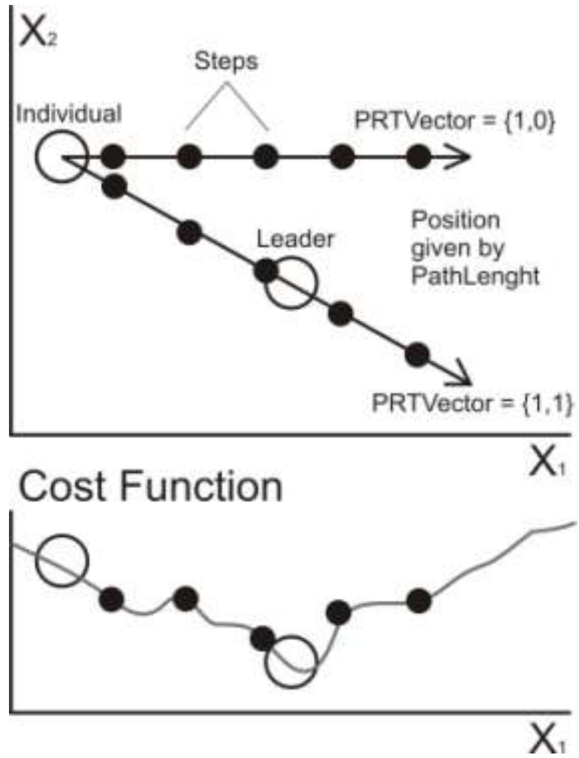

Fig. 1, PRTVector and its action on individual movement

3 Report on SOMA applications in the years 2011 and 2012

Recent scientific activities of the members of Faculty of Applied Informatics of Tomas Bata University in Zlín (the department where the algorithm was originally created) can be divided into three following subchapters. As it can be seen, SOMA implementation on chaotic system control is clearly dominant.

3.1 Chaotic System Control

Chaotic system control has been the most common application of SOMA by the researchers from FAI within the last two years.

Dr. Roman Šenkeřík, et. al., in his paper "Synthesis of feedback controller for chaotic systems by means of evolutionary techniques" deals with a synthesis of control law for three selected discrete chaotic systems by means of analytic

ISBN: 978-1-61804-113-5

programming. The novelty of this approach is that a tool for symbolic regression - analytic programming (AP) - is used for such kind of difficult problem. The paper consists of analytic programming description as well as descriptions of chaotic systems and used Cost Function. For experimental part, SOMA with AP was used. [2]

Prof. Zelinka, the founder of SOMA as well as AP algorithms, together with his team published a paper titled “An investigation on evolutionary identification of continuous chaotic systems’. This paper discusses possibility of using evolutionary algorithms for reconstruction of chaotic systems. The main aim of this paper is to show that evolutionary algorithms are capable of reconstruction of chaotic systems without any partial knowledge of internal structure, i.e. they work based only on measured data. SOMA was used in several experiments. Systems selected for numerical experiments is the well-known Lorenz system. For each algorithm and its variants, repeated simulations were done totaling 20 simulations. According to obtained results it can be stated that evolutionary reconstruction is an alternative and promising way to identify chaotic systems. [3]

Dr. Oplatková and her colleagues wrote a paper titled “Comparison of two cost functions for evolutionary synthesis of control law for higher periodic chaotic logistic equation”. In the paper they deal with a synthesis of control law for chaotic logistic equation by means of analytic programming. The novelty of their approach is that the tool for symbolic regression - analytic programming - is used for the purpose of stabilization of higher periodic orbits - oscillations between several values of a chaotic system. The paper consists of AP and chaotic system descriptions and comparison between the two used Cost Functions - black box type and standard type - where the difference between required and actual state is calculated. For experimental part, SOMA with AP and DE as a second tested algorithm for meta-evolution, were used. [4]

Dr. Šenkeřík, Dr. Oplatková and prof. Zelinka published a paper titled “Investigation on evolutionary chaos controller synthesis for Hénon map stabilization”. Their research deals with a synthesis of control law by means of AP for the Hénon Map, which is a discrete chaotic system. The tool for symbolic regression (AP) is used for the purpose of stabilization of a stable state and higher periodic orbits, which represent oscillations between several values of a chaotic system. For practical part, SOMA with AP and DE as second tested algorithm for meta-evolution, were used similarly as in the previously mentioned paper. [5]

The same team together with prof. Jašek published a paper titled “Evolutionary synthesis of control law for higher periodic orbits of chaotic logistic equation”. It deals with a synthesis of control law for selected discrete chaotic system by means of analytic programming. The novelty of the approach is that a tool for symbolic regression - analytic programming - is used for the purpose of stabilization of higher periodic orbits - oscillations between several values of a chaotic system. The paper consists of the descriptions of analytic programming as well as chaotic system and the used black box type Cost Function. For experimental part, the same algorithms were used as in the two previously discussed papers. [6]

In 2012, Dr. Šenkeřík, et. al., published a paper titled “Evolutionary optimization of Hénon map control: A black box approach”. This paper deals with the use of heuristics for chaotic system control optimization. The main aim of his paper is to show a new approach of solving this problem and constructing new Cost Functions (CFs) operating in 'black box mode' without any previous exact mathematical analysis of the system, thus without any knowledge of the stabilized target state. Three proposals of 'black box' mode CFs were tested and presented in this paper. As a model of deterministic chaotic system, the two-dimensional Hénon map was used. The optimizations were done in several ways and one for each desired state of the system. Evolutionary algorithms (EAs) SOMA and DE were used. For each variant, repeated simulations were conducted to outline effectiveness and robustness of the used method and CF. [7]

The same team of authors also published a paper titled “Evolutionary and meta-evolutionary approach for the optimization of chaos control”. This paper deals with optimization of Hénon Map, which is a discrete chaotic system. This paper introduces and compares evolutionary approach representing tuning of parameters for an existing control method as well as meta-evolutionary approach representing synthesis of whole control law by means of AP. These two approaches are used for the purpose of stabilization of the stable state and higher periodic orbits that stand for oscillations between several values of a chaotic system. For experimental part, SOMA and DE were used as was the case in previously introduced papers. [8]

The last and the most actual paper, considering the topic and SCOPUS indexation, is also work of Dr. Šenkeřík and his team of researchers. His paper with the title “Application of analytic programming for evolutionary synthesis of control law-introduction of two approaches" deals with evolutionary synthesis of control law for Logistic equation, which is a discrete chaotic system. The novelty of the approach is that AP, which is a tool for symbolic regression, is used for synthesis of a feedback controller for a chaotic system. This work introduces and compares two approaches representing black-box type Cost Function as well as non-black-box type Cost Function. These two approaches are used for the purpose of stabilization of the higher periodic orbits that stand for oscillations between several values of a chaotic system. The paper consists of AP, chaotic system and used Cost Functions descriptions. [9]

3.2 Neural Network Synthesis

In 2011, two papers dealing with application of SOMA within Neural Network Synthesis method of neural network optimization were indexed by SCOPUS.

Dr. Vařacha published a paper titled: "Neural Network Synthesis Dealing with classification problem". It deals with AP which was proven to be highly effective tool for Artificial Neural Network (ANN) synthesis and optimization. AP is used here to obtain optimal ANN that satisfactorily solves given classification problem. The algorithm is theoretically explained and successfully used to perform classification upon real-life data of breast cancer diagnosis. Very simple, but effective, ANN is acquired as a result. [10]

The same author together with prof. Jašek published a paper titled „ANN synthesis for an agglomeration heating power consumption approximation". AP is successfully applied here to evolve ANN able to approximate heating power consumption of an agglomeration, depending on time and atmospheric temperature, more accurately than conventional methods. Experiment described in this paper was performed using real life data from Most agglomeration and heating plant situated in Komořany, Czech Republic. Acquired ANN allowed 19% approximation accuracy increase. [11]

3.3 Optimization tasks connected with electricity

This subchapter includes two papers which are dealing with electricity-related optimization.

Mr. Posíšilík, et al., published a paper titled "Single and double layer spiral planar inductors optimization with the aid of Self-Organizing Migrating Algorithm". Planar inductors made on printed circuit boards are rather commonly employed today and there are various software applications to help their designers. In this paper authors describe optimization of single and double layer spiral inductors made with the help of evolutionary SOMA in order to achieve required inductance while resistance of the inductor's conductor was kept as low as possible. Primarily, these inductors are of large extent, supposed to be utilized in low-frequency applications such as proximity sensors or metal detectors, but the results stated in this paper can be generalized for various applications. A simple Maple algorithm was created so the results obtained from the evolutionary algorithm could be verified. [12]

The last (but not least) paper of this short report titled "Optimal dispatch of ancillary services via self-organizing migration algorithm" was written by Dr. Novák, Dr. Chalupa and prof. Bobál. It deals with modern electric power systems, which are large-scale systems with a complex structure comprised of interconnected networks. Balance between generation and consumption of electricity has to be maintained at any moment. Transmission System Operator (TSO) uses auxiliary services for keeping domestic power balance. Selection of services can be viewed as an optimization problem here. The optimization problem is solved by SOMA, which belongs to the class of evolutionary algorithms. The comparison with historical activations of auxiliary services showed improved performance in terms of reduced costs for auxiliary services. [13]

4 Conclusion

This paper describes all papers indexed by SCOPUS database that are dealing with SOMA in the year 2011 and the first half of 2012.

It shows that SOMA optimization clearly dominates chaotic system control; from 12 indexed papers in total there are 8 that deal with this topic, which makes 66% of all SOMA implementations. Two papers address Neural Network Synthesis, which makes 17% of all SOMA implementations. Remaining two papers solve electricity-related optimization.

This paper proves that SOMA is still commonly used algorithm even after more than ten years since its development. It is highly effective especially when applied on chaotic system control.

References:

[1] NOLLE, L., ZELINKA, I., HOPGOOD, A.A. and GOODYEAR, A., 2005. Comparison of an self-organizing migration algorithm with simulated annealing and differential evolution for automated waveform tuning. Advances in Engineering Software, 36(10), pp. 645-653.

[2] SENKERIK, R., OPLATKOVA, Z., ZELINKA, I., DAVENDRA, D. and JASEK, R., 2011. Synthesis of feedback controller for chaotic systems by means of evolutionary techniques, AIP Conference Proceedings 2011, pp. 273-279.

[3] ZELINKA, I., DAVENDRA, D., SENKERIK, R. and JASEK, R., 2011. An investigation on evolutionary identification of continuous chaotic systems, AIP Conference Proceedings 2011, pp. 280-284.

[4] OPLATKOV, Z., SENKERIK, R., ZELINKA, I. and JASEK, R., 2011. Comparison of two cost functions for evolutionary synthesis of control law for higher periodic chaotic logistic equation, Proceedings - AMS 2011: Asia Modelling Symposium 2011 - 5th Asia International Conference on Mathematical Modelling and Computer Simulation 2011, pp. 26-31.

[5] SENKERIK, R., OPLATKOVA, Z. and ZELINKA, I., 2011. Investigation on evolutionary chaos controller synthesis for Hénon map stabilization, AIP Conference Proceedings 2011, pp. 1027-1030.

[6] SENKERIK, R., OPLATKOVA, Z., ZELINKA, I. and JASEK, R., 2011. Evolutionary synthesis of control law for higher periodic orbits of chaotic logistic equation, Proceedings - 25th European Conference on Modelling and Simulation, ECMS 2011 2011, pp. 452-458.

[7] SENKERIK, R., ZELINKA, I., DAVENDRA, D. and OPLATKOVA, Z., 2012. Evolutionary optimisation of Hénon map control: A black box approach. International Journal of Operational Research, 13(2), pp. 129-146.

[8] SENKERIK, R., OPLATKOVA, Z., DAVENDRA, D. and ZELINKA, I., 2012. Evolutionary and meta-evolutionary approach for the optimization of chaos control.

[9] ŠENKEŘÍK, R., OPLATKOVÁ, Z., ZELINKA, I. and JAŠEK, R., 2012. Application of analytic programming for evolutionary synthesis of control law- introduction of two approaches.

[10] VAŘACHA, P., 2011. Neural Network Synthesis Dealing with classification problem, Recent Researches in Automatic Control - 13th WSEAS International Conference on Automatic Control, Modelling and Simulation, ACMOS'11 2011, pp. 377-382.

[11] VAŘACHA, P. and JAŠEK, R., 2011. ANN synthesis for an agglomeration heating power consumption approximation, Recent Researches in Automatic Control - 13th WSEAS International Conference on Automatic Control, Modelling and Simulation, ACMOS'11 2011, pp. 239-244.

[12] POSPISILIK, M., KOURIL, L., MOTYL, I. and ADAMEK, M., 2011. Single and double layer spiral planar inductors optimisation with the aid of Self-Organising Migrating Algorithm, Recent Advances in Signal Processing, Computational Geometry and Systems Theory - ISCGAV'11, ISTASC'11 2011, pp. 272-277.

[13] NOVÁK, J., CHALUPA, P. and BOBÁL, V., 2011. Optimal dispatch of ancillary services via self-organizing migration algorithm. Journal of Electrical Engineering, 62(6), pp. 342-348.