



Bucharest University of Economic Studies
Doctoral School of Economic Informatics

Advances in Hybridization of Bioinspired Algorithms - Habilitation Thesis Summary -

Candidate

Conf.dr. Uscatu Cristian Răzvan

Bucharest, 2024

The habilitation thesis entitled *Advances in Hybridization of Bioinspired Algorithms* showcases the main didactic and scientific achievements of the author, conf.dr. Uscatu Cristian Răzvan, from the period after gaining the PhD title in 2007 and also marks the direction of future development of the professional career.

The thesis is structured in 3 parts. Section I presents the main research results, published in representative articles. Section II synthesizes the professional achievements, structured on didactic, professional prestige, publications and research projects directions and indicated the plans for future development of the career on the same directions. The last part consists of bibliographical references.

Section I presents advancements proposed in the hybridization of bioinspired algorithms for solving complex problems in the fields of image processing and neural network optimization. The image processing problem optimized through the use of bioinspired algorithm is the registration (alignment) of images. The registration may involve images captured by diverse sensors, in various spectrums, at different moments in time and or from different angles or other variations of capturing conditions. The concrete problem approached is the registration of images assumed to be perturbed by rigid transformations. The optimizations proposed neural networks are related to improvements of trainable parameters and hyperparameters.

Chapter 1 presents a review of the use of evolutionary algorithms in registration problems, targeted at identifying the trends regarding the use of main evolutionary elements. The goals of the research were: identification of the most recent research papers in the field of evolutionary image registration, published in the last 5 years and indexed in major databases, available either openly from the publisher or the authors, or through the research network of which our university is a member; focus on successful use of evolutionary algorithms for image registration; identification of fields of application where research efforts are focused; main ideas of each reported research are summarized giving a clear view of the approach; identification and comparative analysis of the main (dis)similarity measures used to register images and performance indicators used to assess algorithms' results and to compare them between algorithms; comparative analysis of main elements of evolutionary approaches: basic algorithm and algorithm class and fitness functions. The conclusions are that the field is very dynamic, with new algorithms, variation operators and hybridizations being proposed often, all supported by the rapid evolution of technology that supports faster calculations. This evolution is the background that lead to the spread of population based search algorithms, which are computation-intensive.

In chapter 2 a new hybrid algorithm is proposed for registration of images. The computation take place on binarized versions of the images (which originally can be color or monochrome). The perturbation model considered is geometric, involving rotation, translation and scaling (either with the same factor on both directions or with different scaling factors on each direction). The proposed methodology involves hybridization of the Firefly Algorithm through the use of clustering of current population and local improvements of one individual from each cluster through 2-membered evolution strategy. The number of clusters depends on the current quality of the population (measured as the quality of the best individual), as a mechanism to prevent premature convergence. The proposed methodology was proved through experimentation to produce better results than classic methods, in efficient time (especially considering the stochastic nature of the algorithm). The success rate (correct registration) is 100%, overcoming some problems encountered by classic registration algorithms, including the "upside-down" registration problem of PAT method.

In chapter 2 a further development of evolutionary based image registration is proposed. The new element introduced in the methodology is the use of multiple scales. In order to speed up the process, images are scaled down and used to compute promising initial candidate solutions and identify

search direction that may lead to the global optimum. These initial candidates, which are actually gross approximations of possible solutions, are mixed with randomly generated candidates to form the initial population for the optimization algorithm. Smaller scale is also used to create new individuals that partially replace the current population as a premature convergence mechanism. The experimental results proved that the proposed registration methodology is accurate: 100% success rate, unlike classic algorithms that have problems in cases of extreme perturbations. The methodology also proved to be efficient, speeding the calculations at least 2 times compared to the previously proposed methodology.

In chapter 3 bio-inspired algorithms are used to improve the forecasting based on time series data, through the use of neural networks. Following the exploratory research, a LSTM based neural network was chosen as best prospective network, with the use of NARX model. The target of optimization was the set of learnable parameters of the neural network. The network is trained using the ADAM optimizer to produce the values for the set of learnable parameters. These parameters are then further improved through the use of an evolutionary strategy. The main goal was to improve the F1 score without significantly increasing the error metric, therefore the fitness function of the evolutionary strategy takes into account both a quality measure (F1 score) and an error metric (MAPE). The chosen evolutionary strategy is the 2MES, where an individual is the concatenation of the set of trainable parameters of the neural network. The tests were carried out on notoriously hard to forecast financial data. There were 3 datasets used: exchange rates for BTC-USD, ETH-USD and EUR-USD. The experiments proved that the proposed methodology is better than standard LSTM predictor in terms of both POCID and F1 score, while the MAPE indicator is not significantly degraded, in some case it even registers better values.

Beside forecasting time series data, another application of machine learning algorithms is the classification of data, with application in various fields. On such field is the automated diagnosis of diseases, based on sets of recorded medical values. This can be used to process large amounts of data for early detection of some dangerous diseases, like cardio-vascular ones. In chapter 5 such classifiers are explored and comparatively tested. The two best of them are chosen for hybridization with the purpose of optimization of their hyperparameters. The standard classifiers considered are: logistic regression, random forests, K-Nearest Neighbors (KNN) Classifier, support vector machines (SVM) – specifically soft margin SVM, and deep neural network (DNN) classifiers – specifically LSTM classifier. In the test soft margin SVM and LSTM emerged as the best methods, considering accuracy and generalization capabilities. They were chosen for optimization of hyperparameters. In case of soft margin SVM, an evolutionary strategy was used while for the LSTM the tree-structured Parzen estimation was used. The proposed methods, denominated MES-SVM and TPE-LSTM, were tested using public medical databases. Both proposed methods produced improved results compared to the standard methods in their classes.

The promising tests carried out with the proposed methods entail future exploration of this directions.

Section II consists of two parts. Part A summarizes the previous activity, in over 25 years of academic career, structured on didactic activity, research projects and publications.

On the didactic activity direction, the retrospective reviews the successive steps in the career, with all the courses and seminars held in various structures of the university, on both bachelor and master cycles: Faculty of Economic Cybernetics, Statistics and Informatics (CSIE), University's Economic College of Bucharest (CUEB), University's Economic College of Giurgiu (CUEG), Bulgarian-Romanian Interuniversity Europe (BRIE). Complementary didactic activities are also mentioned here: student guidance and coordination, various types of committees and commissions related to faculty activity, development of course curricula.

The professional prestige is illustrated by various diplomas received during the career, membership in professional associations and editorial boards, invitations to review articles for scientific conferences and journals.

The publications direction summarizes the university manuals, specialty books, articles published in international conference volumes and scientific journals and various seminar communications, highlighting the ISI indexed publications. Also, the account of citations is given, with a special focus on citations in ISI indexed journals.

On the research direction, a summary of research themes is given, covering interdisciplinary fields of interest with high impact in contemporary society, from education and education management, through tele-activities and virtual organizations, digital culture and information systems to new bio-inspired algorithms for optimization and search in the solution space and their application in practical problems.

Part B highlights the development plans, also structured on didactic, research and publication directions. The main points for all directions are: continuation and improvement of current activities, from both curricular point of view as well as regarding the use of modern technologies; continuation of publication activities; opening new opportunities through creation of new or extended courses, exploration of new research opportunities and new publication venues.

The bibliographical references include relevant articles and reference books used in the research and cited in the 5 articles that form the backbone of this thesis. In total, there are 256 titles cited.

The retrospective of didactical, research and publication activities, proves a high professional experience. Together with the objectives for future development of the career, they point to the ability to organize and manage educational activities, support them with publication of manuals and specialty books, approach interdisciplinary research ideas, coordinate research projects, publish the research results in mainstream journals.