Achievements and New Research Trends in Evolutionary Computation
Habilitation Thesis
- Abstract-

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This habilitation thesis presents the scientific, managerial and educational achievements of the candidate, after receiving the PhD title in 2012.

Part I of the thesis highlights the general achievements. Seven articles have been published since PhD thesis defense, some of them in ones of the best journals in the field, such as *Neurocomputing* (Impact Factor 2.005), *Optimization* (Impact Factor 2.158) and *Applied Mathematical Modelling* (Impact factor 0.771).

The candidate has coordinated 6 teams within several European funded projects, with more than 25 people and a total budget of about 500,000 EUR (see section 1.2). The projects have been funded through FP7 (at the European level), respectively by UEFISCDI and POR at the national level.

Another significant research project is the one run for Electrolux, which is the most important home appliances producers in the world. In 2013, the candidate negotiated with Electrolux a research framework agreement between Technical University of Cluj-Napoca (UT Cluj) and Electrolux Italy. It was the starting point for a very good cooperation. That contract has been extended with a new one, for minimum three years, according to which Electrolux will start a research centre within the UT Cluj.

The academic career was quite fast, yet well founded. The candidate became an assistant professor in 2009. In 2012 he defended his PhD thesis ("*Theoretical and practical applications of evolutionary computation in solving combinatorial optimization problems*") and in 2013, he already became a lecturer and only one year later (2014), he became an associate professor. His entire career is centered on artificial intelligence. He is the responsible for the courses "Artificial Intelligence" and "Intelligent Systems", both based on our research experience.

Part II of the thesis focuses on the scientific achievements. Briefly, he published 12 ISI articles, out of which 6 in journals and 6 at conferences with ISI proceedings, such as *Lecture Note in Artificial Intelligence, Lecture Notes in Computer Science* (both Springer), *Hybrid Artificial Intelligence Systems* (Springer). Other 19 articles have been published in BDI journals. The applied research activities have led to 1 international patent and 3 national patents. Google Scholar reports 95 citations, out of which 23 are citations in ISI journal and proceedings. Moreover, three publications have been awarded by UEFISCDI in 2013 and 2014 (within "Research Results Awards").

The results of all these research activities are summarized within habilitation thesis. We start with two works very well accepted by the scientific community and published in journals with high impact factor. Chapter 3 presents a memetic algorithm approach for solving the multidimensional multi-way number partitioning problem. This work has been validated within *Applied Mathematical Modelling* journal. The next step was to apply evolutionary computation for another combinatorial optimization problem, namely for reducing the bandwidth of a sparse matrix. The results have been published in *Optimization*.

Based on all our experience with the evolutionary computation, we reached an important conclusion: the genetic algorithms alone are hardly capable of solving complex optimization problems. Therefore extra techniques are needed. We have investigated the influence of inserting immigrant individuals into the evolutionary population, which brings diversity and new information. Of course, the convergence is slower, but the solutions are better. The results, concluded in chapter 5, have been also published in *Neurocomputing*.

Being part of sub-symbolic intelligence, evolutionary computation is a powerful technique for optimization, but it lacks expressiveness and semantics. Therefore we decided to combine it with ontologies and we have come up with a totally new concept, called *evolutionary ontologies (EO)*, introduced in chapter 6. This concept successfully blends genetic algorithms and ontologies. And this approach appears for the first time in our research. Due to their particularities, EO's require specific operators, such as crossover and mutation, detailed in chapter 7. Moreover, new genetic operators, especially at a relational level, are introduced in chapter 8, such as union, composition and intersection.

And, finally, part III presents the development plans of the candidate on the same three coordinates: research, project management and education. The number of publications is already significant, given the very reduced period (of less than three years). This is because the research during the PhD was seriously conducted and opened several opportunities and questions. Based on all this research, two aspects have arisen, namely:

- the evolutionary algorithms fail in finding the optimum optimorum in many cases. We have investigated the possibility of using immigrants for diversifying the population. The results have been already disseminated in *Neurocomputing* journal. Other techniques to be investigated are:
  - bi-chromozomal genetic algorithms, which means using individuals carrying two solutions rather than only one. This way, the quantity of information within a population is twice as much as in classical genetic algorithms. And this is a good premise for diversification.
  - avoidance of cosanguinity, which means that binary genetic operators, such as crossover, may be applied only on sufficiently different individuals.
  - seclusion, which means keeping apart a group of genes, with outstanding results. This group of genes does not undergo the genetic operators.
- the evolutionary algorithms lack of expressiveness. We have introduced the concept of evolutionary ontologies and they have been researched only a little. We want to deepen the knowledge on this field.

The projects already implemented allow us to be partners with important international industrial players, such as Electrolux, Volkswagen, IBM, Siemens, Citroen, Airbus and Open Group. We target on developing these relationships for other research projects, funded by the European Comission (e.g. within Horizon 2020) as well as financed by the companies themselves, as is the case of Electrolux, which already invested in four research projects.

From an educational point of view, the target is to develop academic and research teams, mainly focused on evolutionary computation. Of course, one achievement would be PhD supervision.