CENTRO DE INVESTIGACION Y DE ESTUDIOS AVANZADOS DEL I.P.N.

Review of the Habilitation Thesis entitled "Evolutionary Algorithms for Expensive Optimization" by Martin Pilàt

This habilitation thesis focuses on the use of evolutionary algorithms for dealing with expensive (in terms of computational time) objective functions. The thesis consists of 10 chapters, including a short introduction (Chapter 1). Next, I will briefly describe the contents of each of other chapters.

Chapter 2 provides a short and nice introduction to evolutionary algorithms, which includes differential evolution, genetic programming and multi-objective optimization. All of these topics are relevant to the actual contributions reported in this thesis. The final part of the chapter provides a short section on challenges in evolutionary computation, in which the focus is the use of evolutionary algorithms for dealing with expensive objectives. The author correctly indicates that the two main approaches that have been traditionally adopted in this case are: the use of fitness approximation methods (including surrogate methods) and parallelism.

Chapter 3 deals with parallelization and focuses on classical parallelization models, asynchronous computing and GPU implementations of evolutionary algorithms.

Chapter 4 focuses on surrogate models, and provides a short description on how to build and use a surrogate model. Also, there is an interesting section on the use of surrogate models in combinatorial optimization and genetic programming, since such models have been traditionally used in continuous optimization. The final section in this chapter deals with surrogate models and neural architecture search, since, as the author indicates, predicting the quality of individuals in evolutionary algorithms is closely related to the problem of performance estimation in the area of neural architecture search.

In Chapter 5, Dr. Pilàt describes a set of selected papers and the contributions that he made in each of them. First, he indicates that Chapter 6 focuses on two papers that deal with parallelization of evolutionary algorithms. The first of them deals with interleaving generations. In this case, the author deals with problems having slow objective funcions whose evaluation takes variable amounts of time. This makes evident the use of asynchronous computing and the author proposes the use of interleaving generations as a way of dealing with the bias produced by this parallelism scheme. The second paper deals with heterogenous island models. The idea in this case is to use different optimization algorithms in each island and to change dynamically the optimization algorithm adopted during the execution of the algorithm. The implementation adopts migration and a central planner that monitors the performance of each optimization algorithm adopted in each of the islands and then decides which one should be changed (the aim is to improve the overall convergence speed of the algorithm).

Chapter 7 deals with surrogate modelling and it includes two papers that focus on surrogate modelling in genetic programming which is, indeed, an uncommon research area. In the first paper, the author proposes to extract some features of the trees adopted in genetic programming to buld the surrogate model.

The features extracted include: the size of the tree, the frequency of use of each of the terminals and non-terminals, the values of constants and the fitness of parents. The author adopted random forests to predict the quality of the individuals, obtaining good results.

In the second paper, the author adopts graph neural networks instead of extracting features. Graph neural networks also capture the structure of a tree while allowing more accurate predictions.

Chapter 8 refers to the incorporation of user's preferences on a specific multi-objective evolutionary algorithm: MOEA/D. In this case, there is only one paper in which the author uses co-evolution to change the weights of MOEA/D using the preference information provided by the user. This seems to be the first attempt to incorporate user's preferences into MOEA/D, which makes this work very relevant (user's preferences are very common in real-world applications).

Chapter 9 contains 3 papers that focus on applications. The first paper deals with the use of genetic programming to design machine learning workflows (combinations of preprocessing, classification and ensembles). The journal paper included in the thesis is a refined version of a work that was originally presented at two international conferences.

The second paper focuses on the coordination of charging of electric vehicles. This is basically a scheduling problem in which the goal is to avoid an overload in the electrical grid caused by the simultaneous charge of too many electric vehicles. The approach adopted in this case is very interesting, since it's based on the use of a small neural network that gets information about the current electricity consumption (either in the household or in the neighborhood) rather than adopting a central planner that requires communicating with third parties. The weights of the neural network are set using either a gradient-based method or an evolutionary algorithm and the goal was to minimize the variance of the consumtpion of electricity (e.g., in the whole neighborhood). An interesting aspect of this work is that it was presented both at an evolutionary computation and at a neural networks conference, which clearly shows that it makes contributions in both areas.

The last paper focuses on the use of differential evolution to find adversarial examples for image classification. The author focused on finding adversarial examples for models that already adopted some form of defense to the so-called white-box attacks (which use of the knowledge of the complete structure of the neural network, including its parameters, to find an adversarial example). The author used a black-box attach, which means that he relied only on the outputs of the network and was able to create adversarial attacks that went undetected.

Chapter 10 provides the conclusions of the thesis, highlighting the main contributions presented and providing some possible paths for future research.

The work reported in this habilitation thesis is original. I checked the report generated by Turnitin and all the relevant similarities detected correspond to the fact that the thesis contains papers that had been previously published. However, none of the original ideas reported in the thesis were taken from other sources.

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The document is well written and the papers were published in high-quality conferences (e.g., GECCO, PPSN and IJCNN) and journals (International Journal of Artificial Intelligence Tools). The contributions made to the different areas covered by this research (parallelization, surrogate models and incorporation of user's preferences) are significant and relevant within evolutionary computation. I found particularly relevant and significant the contributions made on genetic programming (i.e., surrogate models for it, as well as applications such as its use to design machine learning pipelines) and on incorporation of user's preferences into MOEA/D.

Overall, I consider the research reported in this thesis to be of very good quality and clearly reflects a well-established research agenda as well as research maturity from its author.

Sincerely,

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