Book Review: Evolutionary Computation. A Unified Approach, by Kennet A. De Jong.

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Evolutionary Computation. A Unified Approach, by Kennet A. De Jong (2006, MIT Press) £32.95, $50.00. 256 pages.

Evolutionary computation (EC) is nowadays a very dynamic research field. EC arose as a research area from the union of separate efforts on the 1960's [1, 3, 5]. Even in our time, the necessity to unify concepts, ideas, methods, schemes, paradigms etc. is still one of the key issues in the area, and Kenneth De Jong addresses it in his book: Evolutionary Computation, A Unified Approach.

De Jong proposes to merge those (called by him) "subspecies" like genetic algorithms (GAs), evolution strategies (ES) and evolutionary programming (EP) into one more general class of evolutionary algorithms (EAs).

The book is conveniently organized in such a way that the reader is able to get a concise view of an EA, its main components and their corresponding effects in the algorithm's behavior. Furthermore, some theoretical results complement the knowledge about how an EA works. Finally, some paths of current and future research are examined. In the following, we provide a more detailed review of each Chapter in the book.

Chapter 1 presents the evolutionary process, based on a simple natural-based example, which is immediately translated into a very simple evolutionary system called EV. EV is used through the chapter to show its

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behavior and performance when solving a simple 1-dimensional landscape. Using an incremental approach, a more complicated problem is used to test EV now with additional features.

A chronological set of landmark events in EC history is presented in Chapter 2. The 1960's are presented as the years where the first EAs were proposed, all of them based on a similar biological inspiration, natural evolution. After describing the 1970's as the time where the first empirical and theoretical studies emerged and also the 1980's, where the application of EAs was the main feature of the decade, the book states the 1990's as the time where researchers of different groups started to interact with each other, providing more complete and robust studies about an area known as EC. Finally, the twenty-first Century is seen as the time of maturity and also the time to tackle even more complex problems and to solidify our knowledge about EAs.

Although an EA is based on the idea of natural evolution and the survival of the fittest, three main paradigms are identified, evolutionary programming [1], evolution Strategies [6] and genetic algorithms [2]. Similarities and differences are discussed in Chapter 3. A small performance comparison among these paradigms helps to understand how different the corresponding performance can be. Again, the simplicity of the example leads to a very clear explanation and understanding of each EA.

Chapter 4 focuses on describing the elements of an EA and the way how they interact. The role of the parent and offspring populations is explained. After that, the two types of selection mechanisms (parent and survival selection) are presented and some schemes are enumerated. To end this chapter, two issues are addressed: (1) the influence of the level of representation of solutions (2) the role of recombination and mutation as the way to generate new solutions.

Chapter 5 deals with EAs now as problem solvers. An EA is presented as a problem-independent parallel adaptive search mechanism which has to be designed depending of the problem to be resolved. Then, some decisions have to be made about the way solutions are going to be represented, the model to provide a fitness value for each solution, the number of offspring generated from parents, the termination criterion, etc.

After the review of elements to be defined in an EA, the book shows a set of problems where EAs have been applied successfully: optimization, search, machine learning, automated programming and adaptation.

This chapter emphasizes that EAs have been widely used to solve optimization problems due to two reasons: (1) they can be used to solve problems where analytical methods do not provide competitive results and (2) the clear match between the biological inspiration of the union of the natural evolution and the survival of the fittest with the general objective in an optimization problem (to find the best solutions of all).

This issue is easy to verify in the specialized literature, where there is a huge amount of research reported about optimization with EAs [4].

Among the optimization problems discussed in the chapter, there are the following: Parameter optimization (real-valued, integer-valued, symbolic and non-homogeneous problems), constrained optimization, data structure optimization and multi-objective optimization.

Search problems, where the goal to optimize is not necessarily required, comprise another area where EAs have been applied. Constraint Satisfaction problems and their complexity are used by De Jong to motivate the use of EAs. He also details how EAs are used to solve Machine Learning problems by using a top-down approach, where a model space is explored as to reach the one which provides the best performance and, at the same time, has the lowest complexity. The automated programming is presented as one of the most complex problems solved by EAs. De Jong acknowledges that there are two sources of difficulty: (1) the level where the changes are made to the programs to be optimized and (2) the scheme to evaluate each program. However, some success achieved is reported in languages like Lisp, low level machine and rule-based languages. To end Chapter 5, a discussion about two key issues when solving problems with a changing environment is shown: (1) how fast the environment changes with respect to the evolutionary system behavior and (2) the difference between on-line and off-line evaluation.

Chapter 6 presents a detailed survey related with EC theory. It starts with a discussion about how the gap between theory and practice can be reduced, a description of the main analytical tools used to develop a theoretical framework and a classification of models which divide them in application-independent and application-dependent theories. De Jong remarks that, for sake of simplicity in the theoretical analysis, finite-genotype-size and infinite-population EAs may be recommended, but the gap between theory and practice may increase.

All the chapter is based on a model, where the parent selection, the reproduction and the survival selection are considered separately and, this model is used, first, to focus in selection-only models (without considering reproductive variations). In fact, De Jong describes two sub-categories within it: (1) non-overlapping-generation (parents are eliminated and offspring survive for the next generation) like typical GAs and overlapping-generation models (parents and offspring compete for survival), like typical ES. Uniform and fitness-based selection are discussed in the two sub-categories. Issues like sources of drift and diversity loss are addressed and some mechanisms to deal with them are presented, like increasing the population size, the use of overlapping models and other sampling techniques.

Regarding reproduction-only models, the non-overlapping generation models analysis is divided in two sections: (1) reproduction for fixed-length discrete linear genomes and (2) reproduction for other genome types. For the fixed-length genome case, two-parent, k-parent crossover and discrete mutation are discussed. Furthermore, De Jong presents the interactions between crossover and mutation. An interesting discussion is presented for the reproduction for other genome types. These comments emphasize the significant changes that must be done to the tool for modeling just by assuming that the encoding now is at phenotype-level. This let the reader to easily perceive how complex EA theory can be.

The conclusions regarding that the selection-only EAs may lead to a loss of diversity and that reproduction-only EAs tend to generate populations with considerable diversity get the reader ready to understand the selection and reproduction interactions. The theoretical studies presented in this Section prompt to interesting conclusions about the importance of a balance between the exploitative pressure of selection and the exploratory pressure of reproductive variation. It is important to remark that this issue is still a source of discussion and research in the EC area. Some recommendations are presented in order to promote this balance, like using aggressive reproductive operators coupled with high selection pressure or joining soft operators with low-level selection pressure. Finally, De Jong remarks the importance of using both sexual and asexual operators in order to provide offspring variation in the population.

Chapter 6 also includes some brief ideas about how the encoding selection and their corresponding reproduction operators might impact the performance of an EA when solving a given problem. Besides, the definition of an evolution-friendly landscape and its convenience is also discussed.

De Jong includes in this chapter a Section to argue about some models proposed for an specific EA. Then, he presents a model for an infinite population GA and the GA schema theory. Despite the fact that some interesting questions may be answered by these models, De Jong notices that these models have some drawbacks regarding their prediction capabilities. In this way, other tools, like Markov models and statistical mechanics deserve discussion and inclusion in new proposals. The first provides capabilities for stronger predictions, but adds a considerable mathematical and computational overhead, the second is very dependent of the structure of the fitness landscape and it has been used just in some simple functions.

This chapter ends with some application-dependent approaches, all of them focused on the optimization problem. Some topics are considered, like the definition of convergence for this particular problem, the reasons why it is easier to prove convergence than characterizing convergence rates and also why the last proof is more useful. Finally, two reviews of some theoretical works are provided (e.g. (1+1)ES and simplified

GAs).

The current challenges and "hot" topics in the EC community are addressed in Chapter 7. Self-Adaptive EAs are introduced and a taxonomy is presented with respect to the time when adaptation is applied. The use of EAs to deal with dynamic landscapes is also reviewed; a simple example shows how moving the optimum in a test function may cause a different behavior of an EA. From this example, De Jong points out that there are two key issues to consider when tackling dynamic landscapes: the rate of change of the optimum and mechanisms to maintain enough diversity in the population as to let the EA to recover and look for "new" promising areas in the search space. The use of parallel EAs and their two main types (coarse-grained and fine-grained models) are briefly mentioned. The set of additional parameters and mechanisms which are to be added to a parallel EA and their criteria to be tuned are presented as one of the main challenges in this topic. A summary of previous research about evolving executable objects is also given in this chapter. The review starts with the early attempts to evolve finite-state machines, including the work to optimize the weights and structure of artificial neural networks, the research related with classifier systems and finishes with the arising of genetic programming. In addition to the analysis of EAs used to solve optimization problems, De Jong recalls from Chapter 5 their application to deal with multiobjective problems as an advanced topic in EC. Again, the use of methods to maintain diversity is emphasized because, in the case of multiobjective problems, the EA must find a set of optimal solutions, called Pareto optimal set, instead of searching for a single best solution. To end this chapter, De Jong puts in consideration some topics which may lead to more robust EAs. For example, the combination of different techniques into a hybrid approach and some biological-inspired schemes like non-random mating and speciation, coevolutionary EAs, generative representations and morphogenesis, Lamarkian properties and agent-oriented models.

Chapter 8 ends the book with some final statements about how essential is to establish a unified EC framework. In this way, four positive effects are expected, one to the outside (researchers of other fields will get a clear idea about what is EC) and three to the inside of the area (a common base to compare different EC techniques, an easier way to apply EC to more areas, and a mechanism to detect fertile areas of research within EC).

The most remarkable feature of the book is its unified vision of the evolutionary computation field. The book is well-suited for being used as a text book in basic EC courses. It is also a key reference for practitioners looking for basic information about EAs as to use them to solve different type of problems. It is also useful for research students seeking more knowledge about the area. Furthermore, it is a must-read for researchers

interested on a “back to the basics” process which may be necessary as to get a more deep understanding of the behavior and design of EAs.

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