Evolutionary Algorithms*

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Abstract

The Clever Algorithms project aims to describe a large number of Artificial Intelligence algorithms in a complete, consistent, and centralized manner, to improve their general accessibility. The project makes use of a standardized algorithm description template that uses well-defined topics that motivate the collection of specific and useful information about each algorithm described. The second batch of ten algorithms for the project have been described, all of which are classified as Evolutionary Algorithms under the adopted algorithm taxonomy. This report provides a point of reflection on the preparation of these algorithms.

Keywords: `Clever, Algorithms, Project, Evolutionary, Optimization, Findings`

1 Introduction

The Clever Algorithms project aims to describe a large number of algorithms from the fields of Computational Intelligence, Biologically Inspired Computation, and Metaheuristics in a complete, consistent and centralized manner [3]. The project requires all algorithms to be described using a standardized template that includes a fixed number of sections, each of which is motivated by the presentation of specific information about the technique [15]. This report provides an overview of the Evolutionary Algorithms in the Clever Algorithms project. Section 2 provides background information and reviews common themes for the general class of algorithm and summarizes those evolutionary algorithms that have been described for the Clever Algorithms Project.

2 Evolutionary Algorithms

2.1 Background

The algorithms to be described in the Clever Algorithms project are drawn from a diverse set of subfields of Artificial Intelligence, such as Computational Intelligence, Biologically Inspired Computation, and Metaheuristics. The majority of the algorithms selected for description in the project are optimization algorithms [4]. The recently completed ten algorithms that have been described for the Clever Algorithms project are referred to as Evolutionary Algorithms.

They are differentiated from the remainder of the algorithms described in the project that have been designated a taxonomy including stochastic, swarm, probabilistic, physical, and immune algorithms [4].

2.1.1 Evolution

Evolutionary Algorithms belong to the Evolutionary Computation field of study concerned with computational methods inspired by the process and mechanisms of biological evolution. The process of evolution by means of natural selection (descent with modification) was proposed by Darwin to account for the variety of life and its suitability (adaptive fit) for its environment. The mechanisms of evolution describe how evolution actually takes place through the modification and propagation of genetic material (proteins). Evolutionary algorithms are concerned with investigating computations that resemble simplified versions of the processes and mechanisms of evolution toward achieving the effects of these processes and mechanisms, namely the development of adaptive systems. Additional subject areas that fall within the realm of Evolutionary Computation are algorithms that seek to exploit the properties from the related fields of Population Genetics, Population Ecology, Coevolutionary Biology, and Developmental Biology.

2.1.2 References

Section 2.2 lists the evolutionary algorithms algorithms that have been described. These algorithms share properties of adaptation through an iterative process of trial and error that accumulates and amplifies beneficial variation. Candidate solutions represent members of a virtual population striving to survive in an environment defined by a problem specific objective function. In each case, the evolutionary process refines the adaptive fit of the population of candidate solutions in the environment, typically using surrogates for the mechanisms of evolution such as genetic recombination and genetic mutation.

There are many excellent texts on the theory of evolution, although Darwin's original source can be an interesting and surprisingly enjoyable read [17]. Huxley's book defined the modern synthesis in evolutionary biology that combined Darwin's natural selection with Mendel's genetic mechanisms [27], although any good textbook on evolution would suffice (such as Futuyma's 'Evolution' [23]). Popular science books on evolution are an easy place to start, such as Dawkins' 'The Selfish Gene' that presents on a gene-centric perspective on evolution [18], and Dennett's 'Darwin's Dangerous Idea' that considers on the algorithmic properties of the process [19].

Goldberg's classic text is still a valuable resource for the Genetic Algorithm [24], and Holland's text is interesting for those looking to learn about the research into adaptive systems that became the Genetic Algorithm [26]. Additionally, the seminal work by Koza should be considered for those interested in Genetic Programming [29], and Schwefel's seminal work should be considered for those with an interest in Evolution Strategies [30]. For an indepth review of the history of research into the use of simulated evolutionary processed for problem solving, see Fogel [22] For a rounded and modern review of the field of Evolutionary Computation Bäck, Fogel, and Michalewicz's two volumes of 'Evolutionary Computation' are an excellent resource covering the major techniques, theory, and application specific concerns [1, 2]. For some additional modern books on the unified field of Evolutionary Computation and Evolutionary Algorithms, see De Jong [28], a recent edition of Fogel [21], and Eiben and Smith [20].

2.2 Described Algorithms

This section lists the evolutionary algorithms currently described for inclusion in the Clever Algorithms project. It is proposed that these algorithms will collectively comprise a chapter on 'Evolutionary Algorithms' in the Clever Algorithms book.

1. **Genetic Algorithm**: [9]

2. **Genetic Programming**: [10]
3. **Evolutionary Programming**: [7]
4. **Evolution Strategies**: [6]
5. **Differential Evolution**: [5]
6. **Grammatical Evolution**: [11]
7. **Gene Expression Programming**: [8]
8. **Learning Classifier System**: [12]
9. **Non-dominated Sorting Genetic Algorithm**: [13]
10. **Strength Pareto Evolutionary Algorithm**: [14]

3 Extensions

There are many algorithms, and even classes of algorithm that were not described given the breadth and size of the field of Evolutionary Computation. Some areas that may be considered for algorithm description in follow up works include:

- **Distributed Evolutionary Computation**: such as Island Population Genetic Algorithms and Diffuse Genetic Algorithms.
- **Niching Genetic Algorithms**: such as Determinist Crowding, Restricted Tournament Selection, and Fitness Sharing Genetic Algorithms.
- **Evolutionary Multiple Objective Optimization Algorithms**: such as Vector-Evaluated Genetic Algorithm, Pareto Archived Evolution Strategy, and the Niched Pareto Genetic Algorithm.
- **Classical Techniques**: such as Genitor, and the CHC Genetic Algorithm.
- **Competent Genetic Algorithms**: (so-called [25]) such as the Messy Genetic Algorithm, Fast Messy Genetic Algorithm, Gene Expression Messy Genetic Algorithm, and the Linkage-Learning Genetic Algorithm.

Additionally, there are Evolutionary Algorithms that have can be considered to have developed beyond the field into the related field of Estimation of Distribution Algorithms (referred to as probabilistic approaches in the adopted taxonomy [4]). These include algorithm such as the Compact Genetic Algorithm and Bayesian Optimization Algorithm (and variations) that are intended to be described as part of the Clever Algorithms project [4].

4 Conclusions

This report provided a point of reflection for the second batch of ten algorithm descriptions prepared for the Clever Algorithms project. All described algorithms were assigned to the 'Evolutionary Algorithms' kingdom in the chosen algorithm taxonomy. This report highlighted the commonality for all described Evolutionary Algorithms and provided a definition suitable for use in the proposed book and website.

References

[1] Thomas Bäck, D.B Fogel, and Z Michalewicz, editors. *Evolutionary Computation 1: Basic Algorithms and Operators*. IoP, 2000.

[2] Thomas Bäck, D.B Fogel, and Z Michalewicz, editors. *Evolutionary Computation 2: Advanced Algorithms and Operations*. IoP, 2000.

[3] Jason Brownlee. The clever algorithms project: Overview. Technical Report CA-TR-20100105-1, The Clever Algorithms Project http://www.CleverAlgorithms.com, January 2010.

[4] Jason Brownlee. Data-driven optimization algorithm selection. Technical Report CA-TR-20100112-1, The Clever Algorithms Project http://www.CleverAlgorithms.com, January 2010.

[5] Jason Brownlee. Differential evolution. Technical Report CA-TR-20100402-1, The Clever Algorithms Project http://www.CleverAlgorithms.com, April 2010.

[6] Jason Brownlee. Evolution strategies. Technical Report CA-TR-20100326-1, The Clever Algorithms Project http://www.CleverAlgorithms.com, March 2010.

[7] Jason Brownlee. Evolutionary programming. Technical Report CA-TR-20100313-1, The Clever Algorithms Project http://www.CleverAlgorithms.com, March 2010.

[8] Jason Brownlee. Gene expression programming. Technical Report CA-TR-20100404-1, The Clever Algorithms Project http://www.CleverAlgorithms.com, April 2010.

[9] Jason Brownlee. Genetic algorithm. Technical Report CA-TR-20100303-1, The Clever Algorithms Project http://www.CleverAlgorithms.com, March 2010.

[10] Jason Brownlee. Genetic programming. Technical Report CA-TR-20100308-1, The Clever Algorithms Project http://www.CleverAlgorithms.com, March 2010.

[11] Jason Brownlee. Grammatical evolution. Technical Report CA-TR-20100403-1, The Clever Algorithms Project http://www.CleverAlgorithms.com, April 2010.

[12] Jason Brownlee. Learning classifier system. Technical Report CA-TR-20100411-1, The Clever Algorithms Project http://www.CleverAlgorithms.com, April 2010.

[13] Jason Brownlee. Non-dominated sorting genetic algorithm. Technical Report CA-TR-20100426-1, The Clever Algorithms Project http://www.CleverAlgorithms.com, April 2010.

[14] Jason Brownlee. Strength pareto evolutionary algorithm. Technical Report CA-TR-20100508-1, The Clever Algorithms Project http://www.CleverAlgorithms.com, May 2010.

[15] Jason Brownlee. A template for standardized algorithm descriptions. Technical Report CA-TR-20100107-1, The Clever Algorithms Project http://www.CleverAlgorithms.com, January 2010.

[16] Jason Brownlee. Unconventional optimization algorithms: An introduction. Technical Report CA-TR-20100118-1, The Clever Algorithms Project http://www.CleverAlgorithms.com, January 2010.

[17] Charles Darwin. *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*. John Murray, 1859.

[18] Richard Dawkins. *The selfish gene*. Oxford University Press, 1976.

[19] Daniel C. Dennett. *Darwin's Dangerous Idea.* Simon & Schuster, 1995.

[20] Agoston E. Eiben and James E. Smith. *Introduction to evolutionary computing.* Springer, 2003.

[21] David B. Fogel. *Evolutionary computation: toward a new philosophy of machine intelligence.* IEEE Press, 1995.

[22] David B. Fogel. *Evolutionary Computation: The Fossil Record.* Wiley-IEEE Press, 1998.

[23] Douglas Futuyma. *Evolution.* Sinauer Associates Inc., 2nd edition, 2009.

[24] David Edward Goldberg. *Genetic algorithms in search, optimization, and machine learning.* Addison-Wesley, 1989.

[25] David Edward Goldberg. *The design of innovation: lessons from and for competent genetic algorithms.* Springer, 2002.

[26] John Henry Holland. *Adaptation in natural and artificial systems: an introductory analysis with applications to biology, control, and artificial intelligence.* University of Michigan Press, 1975.

[27] Julian Huxley. *Evolution: The Modern Synthesis.* Allen & Unwin, 1942.

[28] Kenneth A. De Jong. *Evolutionary computation: a unified approach.* MIT Press, 2006.

[29] John R. Koza. *Genetic programming: on the programming of computers by means of natural selection.* MIT Press, 1992.

[30] Hans-Paul Schwefel. *Numerical Optimization of Computer Models.* John Wiley & Sons, 1981.