

Keen: Kotlin Genetic Algorithms Framework

*Thesis for the degrees of
Civil Engineer in Computer Science
and
Master of Science in Computing*



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Abstract

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Chapter 1

Theoretical Background

1.1 Evolutionary Algorithms

In the field of computational intelligence, evolutionary algorithms (EA) [5] are a family of algorithms inspired by the process of natural selection. They are part of the larger field of evolutionary computation,¹ which is a subfield of metaheuristics.²

EAs are algorithms that perform optimization or learning tasks by evolving solutions to a given problem. These tasks may range from function optimization to machine learning or game AI development. EAs have three main characteristics:

- **Population-based:** These algorithms work with a population of solutions, allowing them to explore the search space in parallel.³
- **Fitness-oriented:** The solutions in the population are evaluated using a fitness function, which is a problem-dependent function that assigns a value to each solution based on its quality. The goal of the algorithm is to find the solution with the highest⁴ fitness.
- **Variation-driven:** The candidate solutions are modified using genetic operators, such as mutation, crossover, and selection, to create new solutions. These operators are usually based on the biological processes of mutation and recombination.

While these principles serve as the foundation for most EAs, it's important to note that some variants may prioritize some principles over others, or introduce new principles. This diversity allows EAs to be adapted to a wide range of problems and scenarios.

1.2 Genetic Algorithms

Genetic Algorithms (GA)⁵ [3, 4, 5, 6] are a kind of EA where a *population of individuals*⁶ representing candidate solutions to an optimization problem evolves towards better solutions. Each individual is defined by its location in the search space, which is called its *genotype*⁷, and its fitness value, which is calculated with a *fitness function*.

¹See definition A.2

²See definition A.6

³Not to be confused with parallelization, which is a technique used to speed up the execution of an algorithm by running it in parallel on multiple processors. “Parallel” in this context means that the algorithm is exploring multiple points in the search space (Def. A.9) simultaneously.

⁴In some cases, the goal is to minimize the fitness function, in which case the algorithm will aim to find the solution with the lowest fitness.

⁵Also known as Simple Genetic Algorithms (SGA) [5], or Traditional Genetic Algorithms (TGA) [6].

⁶See definition A.5.

⁷See definition A.4

Definition 1.1 (Fitness function). A *fitness function* is a function $f : S \rightarrow \mathbb{R}^n$, where S is the search space and n is the number of objectives of the optimization problem, that takes an individual as input and returns a vector of real numbers representing how close the individual is to the global optimum of each objective. The fitness function is usually defined by the user of the algorithm, and it is problem dependent.

A classical GA works as follows:

Algorithm 1 Genetic Algorithm

```

population ← initializePopulation()
evaluate(population)
repeat
    parents ← selectParents(population)
    offspring ← crossover(parents)
    mutate(offspring)
    evaluate(offspring)
    population ← selectSurvivors(population, offspring)
until termination condition is met
return fittest(population)

```

1.3 Genetic Programming

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Chapter 2

Relevant Work (State of the Art)

2.1 Agile Artificial Intelligence in Pharo

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2.2 *DEAP*

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2.4 *ECJ*

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2.5 *GeneticSharp*

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Chapter 3

Introduction

3.1 Motivation

The notion of learning machines has been around since the 1950s, when Alan Turing [1] asked a simple question: “Can machines think?”. Since then, the field of artificial intelligence has grown exponentially, with new applications being developed every day.

The first ideas on programs that simulate natural evolution were proposed by Nils Aall Barricelli [2] in 1954, but was formalized (and popularized) by John Holland [3] in 1975 on his book about genetic algorithms.

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3.2 Hyphotesis and Research Questions

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3.3 Objectives

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Chapter 4

Keen: Kotlin Evolutionary Algorithms Framework

4.1 Introduction

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4.2 Architecture

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4.3 Genetic Algorithms

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4.4 Genetic Programming

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4.5 Parallelism

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4.7 Conclusion

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Chapter 5

Case Study: OneMax

5.1 Introduction

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5.4 Results

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Chapter 6

Case Study: Knapsack Problem

6.1 Introduction

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6.4 Results

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6.5 Conclusion

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Chapter 7

Case Study: Crash Reproduction

7.1 Introduction

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7.2 Problem Description

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7.4 Results

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7.5 Conclusion

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Chapter 8

Conclusions

8.1 Summary

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8.2 Contributions

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Appendix A

Glossary

In this appendix we present a glossary of terms used throughout this document that may not be familiar to the reader, but are not explained in the main text due to their common use in the field.

C

Definition A.1 (Chromosome). Representation of a single column of genetic information of a candidate solution to a given optimization problem.

Formally, a chromosome is a vector $\mathbf{c} = (g_1, g_2, \dots, g_n)$, where g_i is a gene (see definition A.3).

E

Definition A.2 (Evolutionary computation). Family of algorithms for global optimization inspired by the process of natural selection.

This typically involves processes mimicking natural selection, mutation, recombination, and survival of the fittest. The solutions to a problem are encoded as a set of “individuals” in a “population”. Over multiple generations, these individuals are selected and modified (via genetic operators like crossover and mutation) in order to find better solutions.

G

Definition A.3 (Gene). Representation of a single component of a candidate solution to a given optimization problem.

Formally, for a multi-dimensional function f , a gene is an element g in the domain of f .

Definition A.4 (Genotype). Representation of the full genetic information of a candidate solution to a given optimization problem.

Formally, a genotype is a matrix $\mathbf{G} = (\mathbf{c}_1, \mathbf{c}_2, \dots, \mathbf{c}_n)$, where \mathbf{c}_i is a chromosome (see definition A.1).

I

Definition A.5 (Individual). A candidate solution to a given optimization problem.

Formally, an individual is a pair (\mathbf{G}, \mathbf{f}) , where \mathbf{G} is the genotype (see definition A.4) and \mathbf{f} is the fitness value of the individual.

M

Definition A.6 (Metaheuristics). Problem-independent algorithmic method that yields a sufficiently good solution within reasonable time for an optimization problem, especially for complex problems where an exact solution is not crucial.

P

Definition A.7 (Phenotype). Same as definition A.5.

Definition A.8 (Population). Set of candidate solutions to a given optimization problem.

S

Definition A.9 (Search space). Set of all candidate solutions to a given optimization problem.

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