TechTalk on Artificial Intelligence
— A practical approach to Genetic Algorithm —

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Goal of today

Give an introduction to what genetic algorithm is

Show what can be done in plain Pharo related to genetic algorithm
These slides…

... are a support for the TechTalk

... are not meant to be understandable when read offline

... are a summary of a lecture given at the University of Chile

... incremental in their content
"The fact that life evolved out of nearly nothing, some 10 billion years after the universe evolved out of literally nothing, is a fact so staggering that I would be mad to attempt words to do it justice."

— Richard Dawkins
“One general law, leading to the advancement of all organic beings, namely, vary, let the strongest live and the weakest die”

— Charles Darwin
Flow - chart of an evolution algorithm

Population → Selection → Parents

Parents → Reproduction → Offspring

Offspring → Replacement → Population
Flow - chart of an evolution algorithm

Many EAs are around: Ant colony optimization, Artificial immune system, Cultural algorithms, Genetic Algorithm, Genetic Programming, Grammatical evolution, …
Evolution algorithm

May be written as:

\[ x[t + 1] = v( s( x[t] ) ) \]

where:

- \( x[t] \) is the population at time \( t \) under a representation \( x \)
- \( s \) is the selection operator
- \( v \) is a random variation operator
Evolutionary algorithms have many advantages, including:

- Offer a framework such that it is comparably easy to incorporate prior knowledge about the problem.

- May be combined with other optimization techniques. For example, could be used to tuning weights in a neural networks
Genetic Algorithm in a Nutshell

*Evolutionary computation technique* that automatically solves problems without specifying the form or structure of the solution in advance

Generally speaking, *genetic algorithms are simulations of evolution*, using biological genetic operations.
Genetic Algorithm in a Nutshell


Since then, this field has witnessed a tremendous development.

Often considered as an optimization method

ie. finding $x$ such as $f : X \rightarrow R$ is maximal, $x$ belonging to $X$, a multidimensional space.
Flow - chart of a genetic algorithm

- Initialize population
- Evaluate fitness
- Selection
- Reproduction
- Solution found?
- Yes: End
- No: Reproduction
The algorithm

Compute initial population $B_0$;

WHILE stopping condition not fulfilled DO
BEGIN
select individuals for reproduction;
create offsprings by crossing individuals;
eventually mutate some individuals;
compute new generation
END
A friend asks you to solve a challenge:

He secretly wrote a word of 3 letters, and challenge you to find it

Your friend can help you that way:

He can tell you how many letters are actually correct.
Canonical example

You have made 3 words: w1, w2, w3

Your friend tells you that 3 letters are different in w1, 2 in w2, and 1 in w3.

The sequences w2 and w3 are closer to the solution than w1

You can forget w1 as it is too far from your friend secret

You have several options:

- You can randomly create a new sequence
- You can randomly modify some letters in w2 or w3
- You can combine w2 and w3 in the hope to produce a better sequence
Step 1 - Initialize Population

This step is rather easy. It simply consists in creating $N$ words of 3 letters.

$N$ is a parameter of your algorithm.

Let’s say $N = 10$

We call a sequence that belongs to our population as \textit{individual} or \textit{member}
Step 2 - Evaluate fitness

The fitness function produce a number score to describe the fitness of a given member of the population.

GA is used to evolve a population to an optimal solution to a problem, so we need to numerically evaluate any given possible solution.
Step 2 - Evaluate fitness

For example, if the secret sequence is: “cat”

We have:

\[ f(“cow”) = 1 \]
\[ f(“cak”) = 2 \]
\[ f(“cat”) = 3 \]

Assuming that none of our 10 sequences exactly match the secret sequence, we need to create a new generation of sequences.

We therefore have to enter the selection process.
Darwinian Natural Selection

In order to have a natural selection, we need to have:

**Heredity**: a child receives properties of its parents. In particular, if the parents are robust and can live long enough, then the child should too.

**Variation**: some variation may be introduced in children. Children should not be identical copy of their parents.

**Selection**: some members of a population must have the opportunity to be parents and have offsprings in order to pass their genetic information. Typically referred to as “survival of the fittest”
Step 3 - Selection

Once the fitness is computed for each individual (i.e., sequence of our population) we need to select which individuals are fit enough to become parent

Several strategies are possible:

Pick the fittest 25%

The probability to pick a parent depends on its fitness (e.g., if i1 has a fitness of 5 and i2 a fitness of 10, then i2 has 2 times more probability to be picked)

This step result in a mating pool, in which parent will be picked in the following step
Step 3 - Selection

A generic selection procedure may be implemented as follows:

1. The **fitness function** is evaluated for each individual, providing fitness values, which are then normalized. Normalization means dividing the fitness value of each individual by the sum of all fitness values, so that the sum of all resulting fitness values equals 1.
2. The population is sorted by descending fitness values.
3. Accumulated normalized fitness values are computed (the accumulated fitness value of an individual is the sum of its own fitness value plus the fitness values of all the previous individuals). The accumulated fitness of the last individual should be 1 (otherwise something went wrong in the normalization step).
4. A random number $R$ between 0 and 1 is chosen.
5. The selected individual is the last one whose accumulated normalized value is smaller than $R$. 
Step 4 - Reproduction

This step builds a new population (with the same size)

Individuals composing this new populations are “babies” of two parents individuals (from the previous population)

Each baby is created using two genetic operations: cross-over and mutation
Step 4 - Reproduction

Pick two parents from the mating pool

Create a new individual, for which its genes is the result of mixing the parents’ genes
Step 4 - Reproduction

Pick two parents from the mating pool

Create a new individual, for which its genes is the result of mixing the parents’ genes

Mixing point randomly picked
Step 4 - Reproduction

Go over each gene of the child if replace the gene using a mutationRate probability
Configuring the algorithm

*Mutation rate*: % to change a gene when creating a child

*Population size*: number of individual to consider each time

*Number of genes*: how many genes contains each individual

*Fitness function*: Function that tells how good / far an individual is from the (ideal) solution
Result of the algorithm

Once the algorithm is run, we need to know how good we did

Two metrics are usually enough:

- Number of generations until the solution is found
- Total time until the solution is found
The Fitness Function

The real hard work of doing some genetic algorithm is to write the fitness function.

The function describes the goal and how well an individual...
Demo

```smalltalk
Gofer it
smalltalkhubUser: 'abergel' project: 'GeneticAlgo';
configurationOf: 'GeneticAlgo';
loadDevelopment
```
Applications:
Software Performance
What is the performance of this car?
What is the performance of this source code?
Problem description

A benchmark is a representative execution of a software system.

Essential to measure performance evolution.

A benchmark requires a workload.

However, defining such workload is not trivial.
public class CSVImporter {
    private ArrayList<ArrayList<Double>> content
            = new ArrayList<>();

    private void importFrom(BufferedReader r)
            throws IOException {
        String row;
        while((row = r.readLine()) != null) {
            ArrayList<Double> fs = new ArrayList<Double>();
            for(String value : row.split(",",))
                fs.add(Double.parseDouble(value));
            content.add(fs);
        }
    }

    public void importFrom(String filename)
            throws IOException {
        FileReader fr = new FileReader(filename);
        this.importFrom(new BufferedReader(fr));
    }
}
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    }
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    }
}

7.398087255376432,3.076587022783508,3.088394050993209
9.982048943630442,4.77719718982212,0.23295837931007068
0.07317507642934801,0.8468390353242117,0.9063179655495648
5.257870939214654,2.126741512737582,1.9651785408915852

Measuring the performance of this class requires a workload
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    public void importFrom(String filename)
        throws IOException {
        FileReader fr = new FileReader(filename);
        this.importFrom(new BufferedReader(fr));
    }
}

//input1.csv
1.1,3.0
3.2,2.0

//input2.csv
1.123232,3.000001
3.21231,2.0000001
public class CSVImporter {
    private ArrayList<ArrayList<Double>> content
        = new ArrayList<>();

    private void importFrom(BufferedReader r)
        throws IOException {
        String row;
        while((row = r.readLine()) != null) {
            ArrayList<Double> fs = new ArrayList<Double>();
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                fs.add(Double.parseDouble(value));
            content.add(fs);
        }
    }

    public void importFrom(String filename)
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        FileReader fr = new FileReader(filename);
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    }
}

//input1.csv
1.1,3.0
3.2,2.0

//input2.csv
1.123232,3.000001
3.21231,2.0000001

These two files do not take the same time to be parsed
<table>
<thead>
<tr>
<th>//input1.csv</th>
<th>//input2.csv</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1, 3.0</td>
<td>1.123232, 3.000001</td>
</tr>
<tr>
<td>3.2, 2.0</td>
<td>3.21231, 2.0000001</td>
</tr>
</tbody>
</table>

Around 5 millions numbers per second

Around 3 millions numbers per second
Case study

RTUMLClassBuilder is a tool to draw UML class diagrams

SourceCode.java

How many classes per seconds can it render?
Finding the upper bound
Fitness function = time to render 100 genes
Gene = 1 class (randomly picked)
Finding the lower bound
Fitness function = negated time to render 100 genes
Gene = 1 class (randomly picked)
We identified the spectrum performance for RTUMLClassBuilder. In particular, we found:

100 classes that maximize the performance
100 other classes that minimize the performance
Applications:
Organic living systems
Unsupervised learning
Making a random car drive a road

http://boxcar2d.com/about.html
Join segmented Line creatures

https://www.youtube.com/watch?v=GOFws_hhZs8
https://www.openprocessing.org/sketch/377698
Unsupervised learning

“Evolving Neural Networks through Augmenting Topologies”
by Kenneth O. Stanley and Risto Miikkulainen

Identifying weights and bias using Genetic Algorithm

Some application

https://www.youtube.com/watch?v=BBLJFYr7zB8
Unsupervised learning

“Evolving Neural Networks through Augmenting Topologies”

by Kenneth O. Stanley and Risto Miikkulainen

The idea is to find the optimal configuration of the network. Topology is variable
Unsupervised learning

“Neural Network Weight Selection Using Genetic Algorithms”
by David J. Montana

“Parameter Tuning of MLP Neural Network Using Genetic Algorithms”
By Meng Joo Er and Fan Liu

Topology is fixed, and the idea is to find the best weights and bias