

An Event-based Architecture for Multi-population Optimization Algorithms

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Abstract. In this work, we present a software implementation that follows an event-driven architecture, designed to asynchronously distribute the processing of population-based algorithms. The search algorithm uses a multipopulation approach, creating multiple populations with different parameters of execution, allowing the hybridation of multiple algorithms, in this case Genetic Algorithms (GAs) and Particle Swarm Optimization (PSO). Using a message queue, each population is manipulated by asynchronous serverless functions, taking advantage of functional programming. The cloud-ready javascript implementation, includes a web-based application for the configuration and interaction with algorithms. We executed several experiments in order to validate the system, using benchmark functions and several configurations. Results show ...

Keywords: Multi-population · Asynchronous · Sub-population · Serverless · Distributed.

1 Introduction

A universe of solutions can exist for a single optimization problem and sometimes is too big and complex to solve it traditionally. That is why heuristic, population-based algorithms, and other types of methods can be applied. Population-based algorithms are useful to solve combinatory problems; however, the performance of an algorithm depends on the problem and initial conditions. Usually, an algorithm is suitable for only a specific type of problem, and it is not always easy to know which algorithm is more fitting. Even assuming that we selected an appropriate algorithm, we must also find the appropriate parameters. To deal with these problems, parallel and hybrid architectures have been proposed. The clear advantage of these architectures is the faster execution of the algorithms. However, there is also the ability to change the search dynamically, having multiple algorithms with different parameters interacting with each other at the same time.

In this work, we propose the use of several serverless functions to process small fragments from a population in a distributed way, turning a population into a multi-population. Independent functions, running asynchronously by the use of queues, to process each sub-population. Also, sub-populations use the migration

of data between them, to help each other even if the algorithms or parameters of each sub-population are different. The objective is to prevent the algorithm from falling into optimal local values and increase processing performance.

Distributed and cloud-based architectures are used extensively in the software industry because of their high performance and lower overall cost. Many systems are being created and migrating step by step to microservices and new serverless architectures, which proposes the use of “Function as a Service” (FaaS). Researchers are starting to exploit this type of architectures [References] in heuristic optimization development, and here we take advantage of them to increase the performance of some population-based algorithms.

This document shows what are serverless functions and their spot into the world of software architecture, describing its features and advantages of its implementation compared with others. Once that the concept of Serverless is understood we provide information of the proposed architecture that mix sub-populations to increasing the possibilities to find the best fitness of some benchmark functions by the use of queues and functions. In proposed architecture section every component is described with their role in the algorithm. Followed by several experiments to test if the architecture is giving the expected results, get an easy way to hybridation and a fast convergence, increasing the performance of existing algorithms as Genetic Algorithms and Particle Swarm Optimization making an scalable algorithm. To finalize the document we conclude with the response to the question that if the architecture is useful to be applied on population-based algorithms and future work to remove deficiencies.

1.1 Serverless

Recently, cloud providers such as Amazon Web Services (AWS), IBM Cloud, and Google Cloud, offer a new alternative to programming through interfaces called Serverless Computing [References], this platform consists in an effortless mechanism where developers upload the code into the platform and execute it as many times as it is required, scaling and allowing to do this in parallel. This way, the developers do not worry about servers, connections, and other configurations. In serverless, users pay only for what it is used. There is also the option to install some of these platforms locally; for instance, AWS (Amazon Web Services) [1] or Apache Open Whisk [2]. stall them into your own server to do your own local architecture serverless.

Serverless Function In math, a function is a relation between a set of inputs and an allowed set of outputs, with the idea that each input goes to a single output. However, in computer science a function is defined as a unit of code that has a role into a greater code structure, works on varius inputs that usually are variables and throws a concrete output that are the result of process those variables. One of the main features that belongs to functions is that are stateless, they are focused on inputs and result with a simple process that does not require an state, in the moment the inputs get into the function are already generating

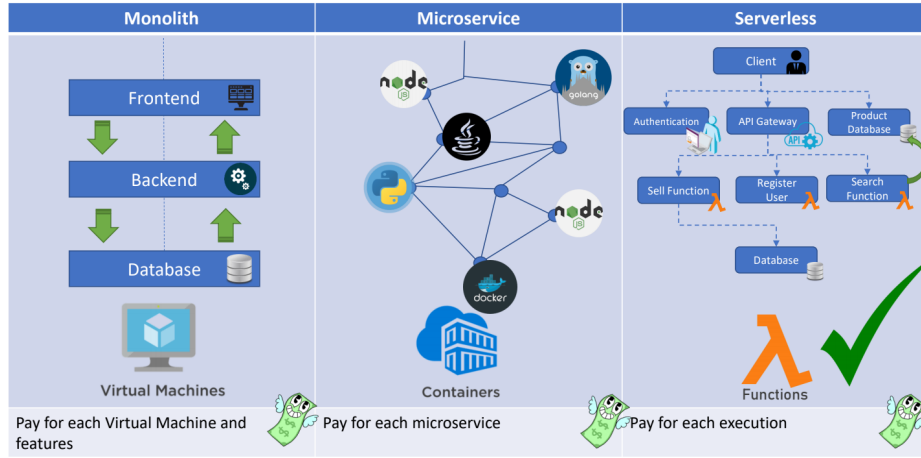


Fig. 1. Software architecture generations.

an output. In serverless, events such as messages or HTTP requests can trigger these functions. Also, each function scales independently and is stateless with a short duration.

2 Proposed architecture

The propose is an architecture that allows to process a simple population that is divided into sub-populations distributing them to process in different ways and then communicating each other with purpose of increase the possibility to find the best fitness of a function. This architecture can accept the use of an indeterminate number of algorithms, allowing an easy hybridation and continuous adaptability for different problems.

This architecture consist in 3 nodes, they are explained on the next points:

- **Manager:** Here a population conformed by sub-populations is created and the architecture initialize parameters to run the algorithm. Every time a sub-population is created triggers an event that sends the subpopulations to be stored in a file JSON of MongoDB (preventing to saturate the memory) and to a message queue that is directed to its subsequent processing in the “Receiver” section that is our cluster of functions (Faas), because each sub-population requires the execution of a different algorithm, there is a different channel in the web sockets for each type of algorithm that triggers its respective serverless function. Once a subpopulation is processed, it is returned and a selection is made for the sub-population migration. The migration selection is made by taking the population attribute of the subpopulation that was returned and the subpopulation that it have been selected among the best 2, it should be noted that the decision to identify the best from the 2 is made

randomly. Once the selection is made, a Splitting Point Uniform crossing will be made. The 2 new subpopulations replace their self and are resent it back to their respective serverless function and this process is repeated until completing the number of assigned migrations for the multi-population. Of course this whole process is performed asynchronously avoiding wait for all responses from serverless functions to perform a crossover or a update of the multi-population status [3, 4]. In the following figure you can see from illustrative way how the multi-population is composed. The mechanism to

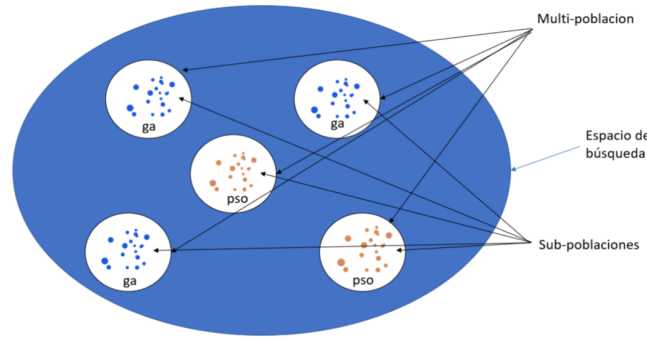


Fig. 2. Multipopulation representation.

send the sub-population to the serverless functions is create a queue with a dimension of 2 positions that allow to communicate in an asynchronous way.

- Message Provider: Its purpose is the creation of a sub-population messages queue which is the communication channel between the sub-population Manager and the Receiver (FaaS), each message is a trigger for the execution of a GA or PSO function. Thanks to the message queue, it is possible to perform the serverless functions asynchronously, avoiding that the algorithm wait for responses independently of their duration and the simultaneous evaluation of different sub-populations independent of its algorithm or characteristics.
- Receiver: The following section contains the Serverless functions of the algorithms to be executed, reduced the best possible using the functional programming paradigm so that they can be converted into FaaS without problems, in addition to achieving a completely clean and fast execution [5]. Each message received on this node is executed in the form of a multi-threaded process in parallel, this allows to having more than one population-based search algorithm running at the same time, and making a copy of itself each algorithm function as required.

To develop this architecture the applied technologies are based in JavaScript using Node JS as it can be see it in the General Architecture Flowchart.

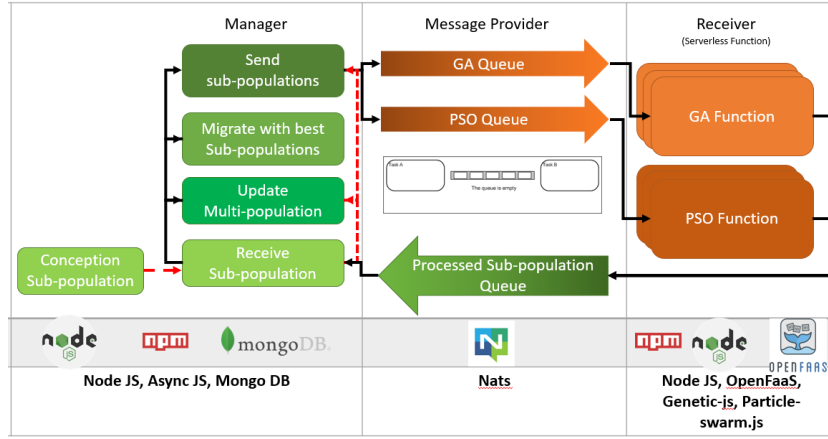


Fig. 3. General Architecture Flowchart.

2.1 Sub-population definition

Individuals are created composed of 2 types of information, the one that is active or useful for crossing and the one that is not. The population contains the series of possible solutions, while the rest contains the information on how the processing for the search of the optimal solutions will be executed, linked directly with their respective algorithms.



Fig. 4. Sub-population composition.

2.2 Splitting Point Uniform Migration

This architecture communicates sub-populations using migrations, taking information from 2 sub-populations and mixing them using a process similar to crossover in Genetic Algorithms, creating 2 completely new sub-populations every time a processed sub-population arrives into the Manager node and replacing them self in the multi-population.

The migration created to this architecture is a method called Splitting Point Uniform that consist in a uniform mask that is created to apply the migration between individuals, vectors or both of them, from 2 sub-populations. The selected

data are combined using the middle point between the active values points by the binary mask generated randomly. This process iterates the 2 sub-populations to randomly swap values and replace some of them with middle points.

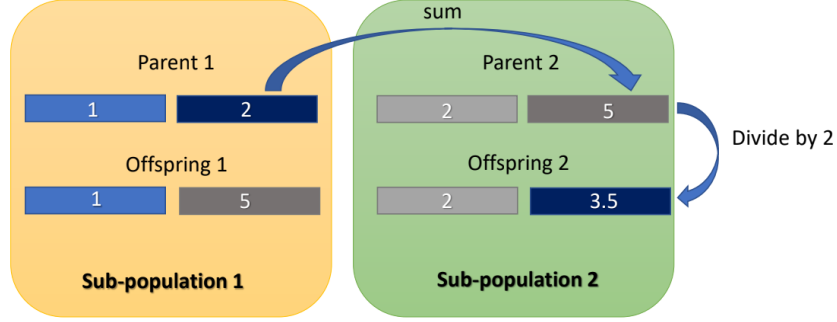


Fig. 5. Splitting Point Uniform process.

2.3 Migration Selection

Using migration selection by tournament keeping up the information of the best sub-population of the multi-population.

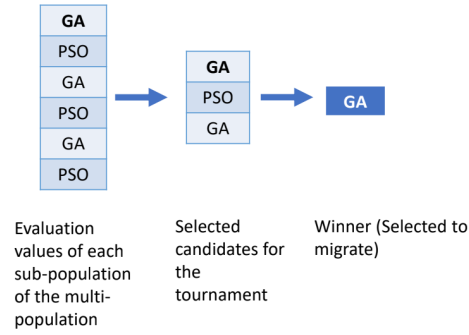


Fig. 6. Selection by tournament.

3 Experiments and Results

3.1 Experiments

Now that an interaction between sub-populations with different algorithms it is working and hybridation have been a success, using until now the added algo-

rithms (GA and PSO) algorithms, all thanks to the developed architecture, lets procede to the experiments. This section is going to be the execution of several experiments from 2 to 40 dimensions, with a stop criterial of an error below $0.5E-8$, without a parameter optimization method, waiting that the architecture by its self would be enough to increase the possibility to find a better optimal result than the traditional methods. All this hoping that the results will probe the needness of this kind of architecture on increasing dimensions. To test if the architecture was useful, several experiments were made to solve benchmark functions, for this case the functions are Sphere, Rastrigin and Rosenbrock. Using 10 sub-population for each experiment and maximum 4 migrations per sub-population with different algorithms and parameters for each sub-population.

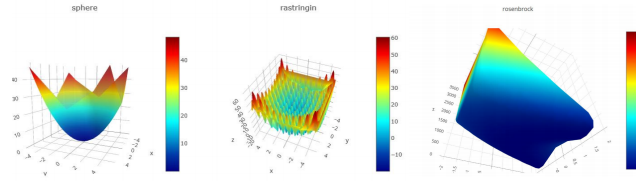


Fig. 7. Benchmark functions for experimentation.

3.2 Parameters Configuration

This architecture modifies the traditional way to work with population based algorithms, then the experiments could not be parameterized as usually are.

Then the experiments are scaled by their number of evaluations and the parameters must be configured to be adjusted to the next criterial, using the next expression:

$$Evaluations = 10^5 Dimensions \quad (1)$$

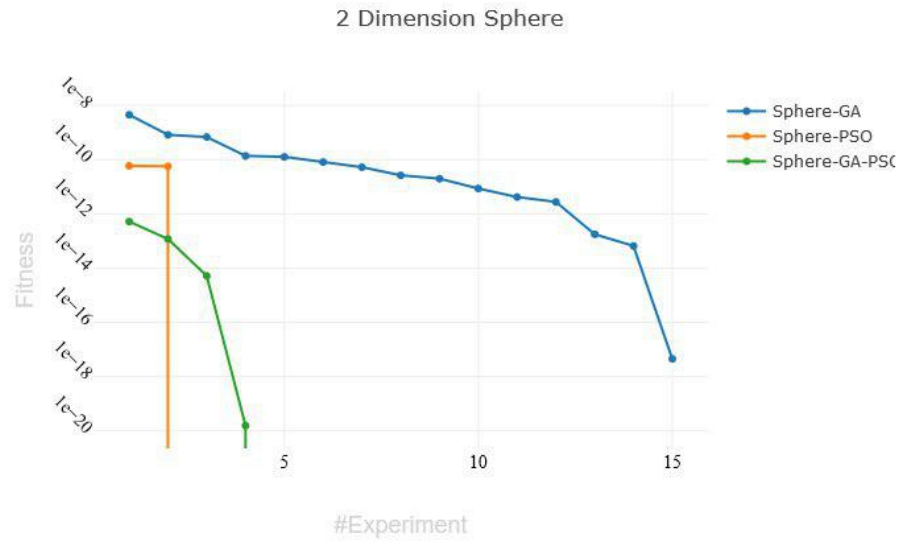
For example, if the experiment has 2 dimensions, the maximum number of evaluations will be 200,000, for 10 dimensions will be 1,000,000 of evaluacions and the same with the others dimensions.

4 Conclusion

This architecture is completely scalable and useful for hybridation of multiple algorithms, until now is only GA and PSO but according with the results with this kind of architecture there is no limit and it works better than multi-populations with only one algorithm, also every experiment executes in short times because serverless functions searching in an asynchronous way getting a fast convergence.

Table 1. 2 dimension parameters

| Parameter | Value |
|-------------------------|--|
| GA Optimization | Minimize |
| GA Generations | 50 |
| GA Dimensions | 2 |
| GA Population size | 100 |
| GA Mutation | Random(Tournament2,Tournament3,Random,RandomLinearRank,Sequential,Fittest) |
| GA Crossover | Tournament3 |
| GA Crossover percentage | Random[10%, 80%] |
| GA Mutation percentage | Random[10%,50%] |
| GA Crossover function | Uniforme de punto medio |
| GA Mutation Function | gaussian |
| PSO Optimization | Minimiza |
| PSO Iterations | 50 |
| PSO Dimensions | 2 |
| PSO Vector size | 100 |
| PSO Social factor | Random[0.5,4.0] |
| PSO Individual factor | Random[0.5,4.0] |
| PSO Inercia factor | Random[0.5,4.0] |

**Fig. 8.** 2 dimension experiments Sphere.

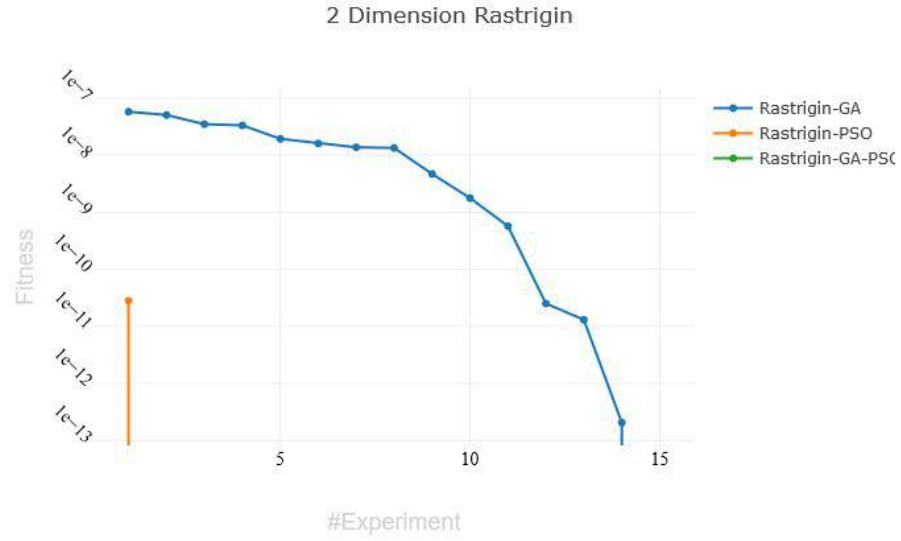
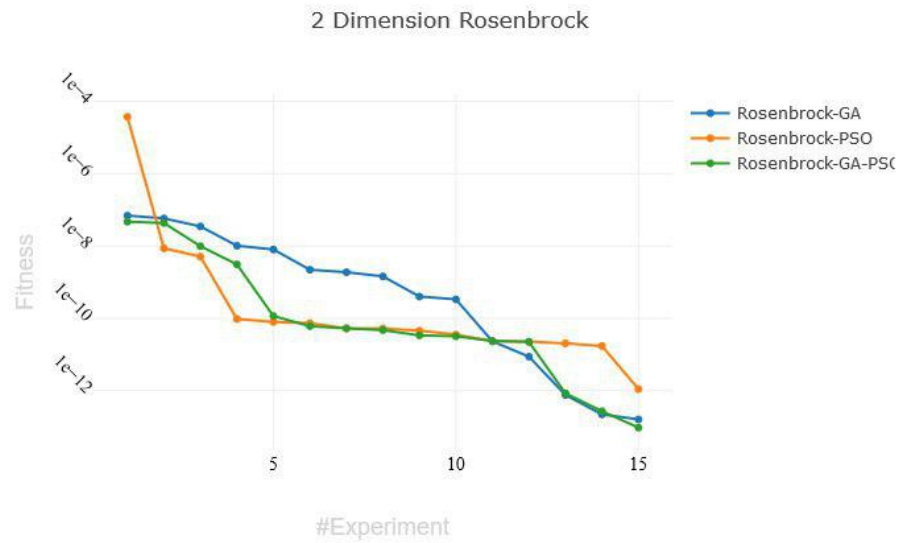
**Fig. 9.** 2 dimension experiments Rastrigin.**Fig. 10.** 2 dimension experiments Rosenbrock.

Table 2. 2 dimensional experiment results

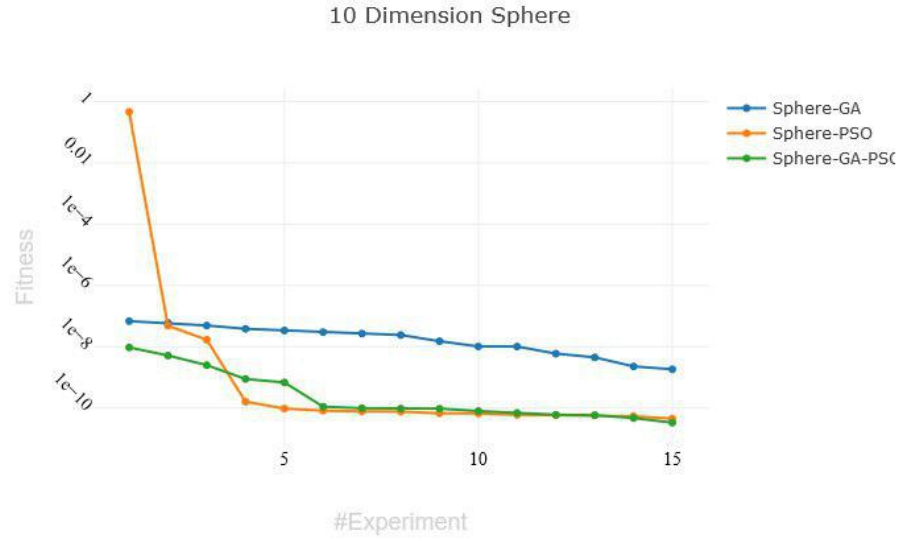
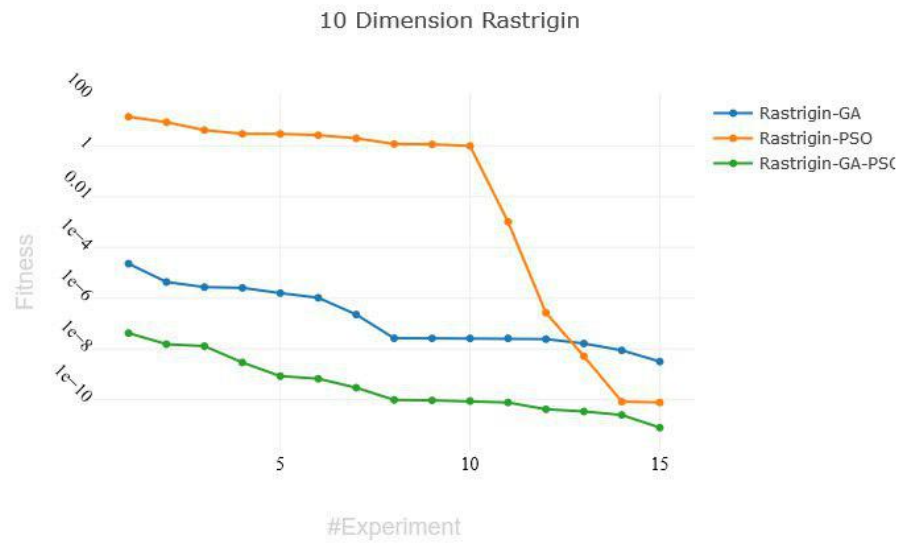
| Fn | Best | AVG | Experiment Number |
|-------------------|-------------|-------------|-------------------|
| Rastrigin GA | 0 | 1.65377E-08 | 15 |
| Rastrigin PSO | 0 | 1.8872E-12 | 15 |
| Rastrigin GA-PSO | 0 | 0 | 15 |
| Sphere GA | 4.53222E-18 | 4.36977E-10 | 15 |
| Sphere PSO | 0 | 7.8012E-12 | 15 |
| Sphere GA-PSO | 0 | 4.33161E-14 | 15 |
| Rosenbrock GA | 1.62335E-13 | 1.24176E-08 | 15 |
| Rosenbrock PSO | 1.11674E-12 | 2.47795E-06 | 15 |
| Rosenbrock GA-PSO | 9.5809E-14 | 6.90695E-09 | 15 |

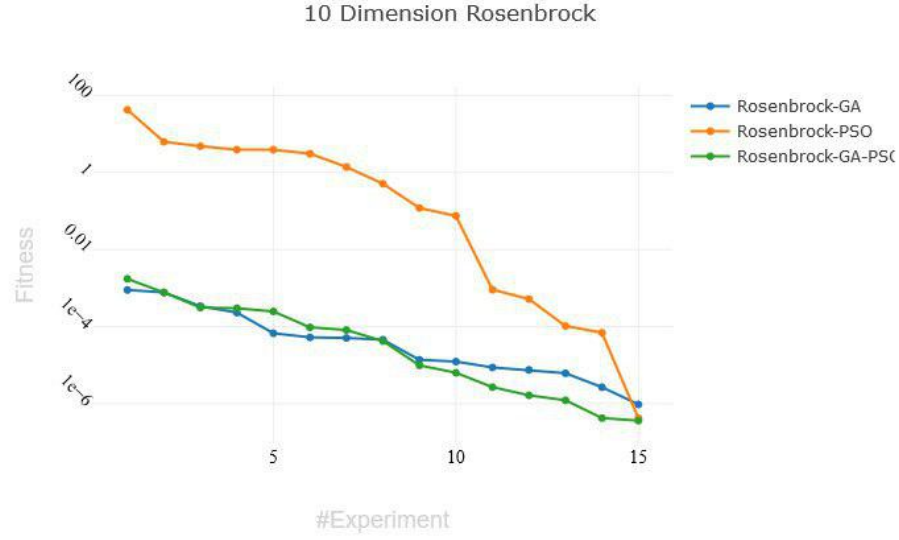
Table 3. 10 dimensions parameters

| Parameter | Value |
|-------------------------|--|
| GA Optimization | Minimiza |
| GA Generations | 70 |
| GA Dimensions | 10 |
| GA Population size | 200 |
| GA Mutation | Random(Tournament2,Tournament3,Random,RandomLinearRank,Sequential,Fittest) |
| GA Crossover | |
| GA Crossover percentage | Random[10%, 80%] |
| GA Mutation percentage | Random[10%,50%] |
| GA Crossover function | Uniforme de punto medio |
| GA Mutation Function | gaussian |
| PSO Optimization | Minimiza |
| PSO Iterations | 70 |
| PSO Dimensions | 10 |
| PSO Vector size | 200 |
| PSO Social factor | Random[0.5,4.0] |
| PSO Individual factor | Random[0.5,4.0] |
| PSO Inercia factor | Random[0.5,4.0] |

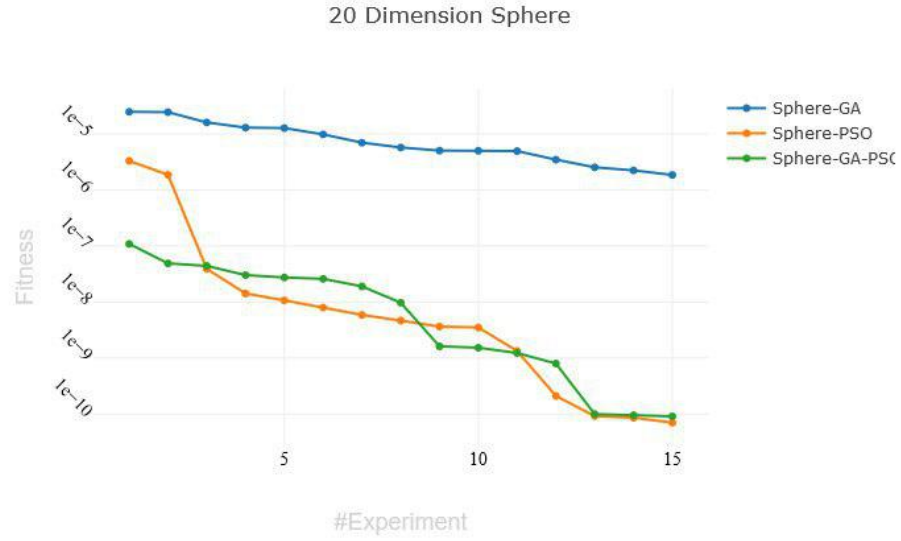
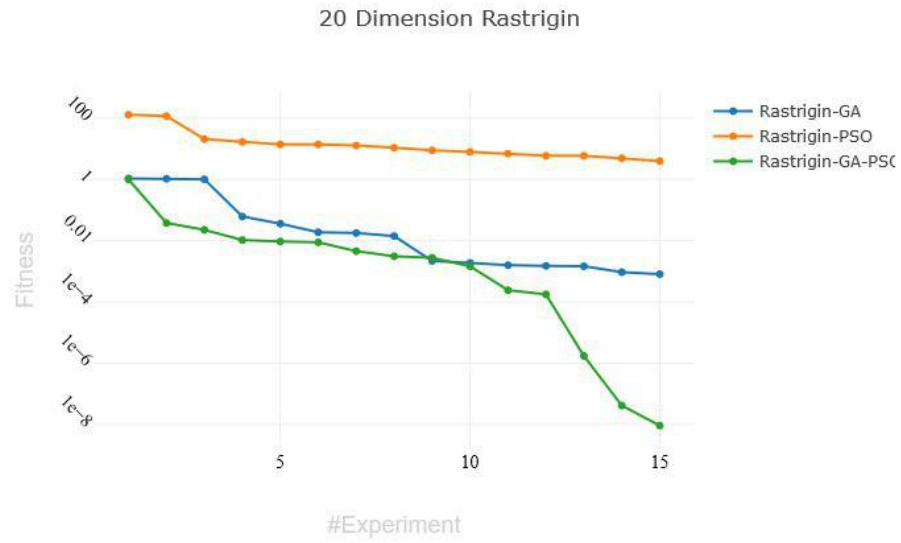
Table 4. 10 dimensional experiment results

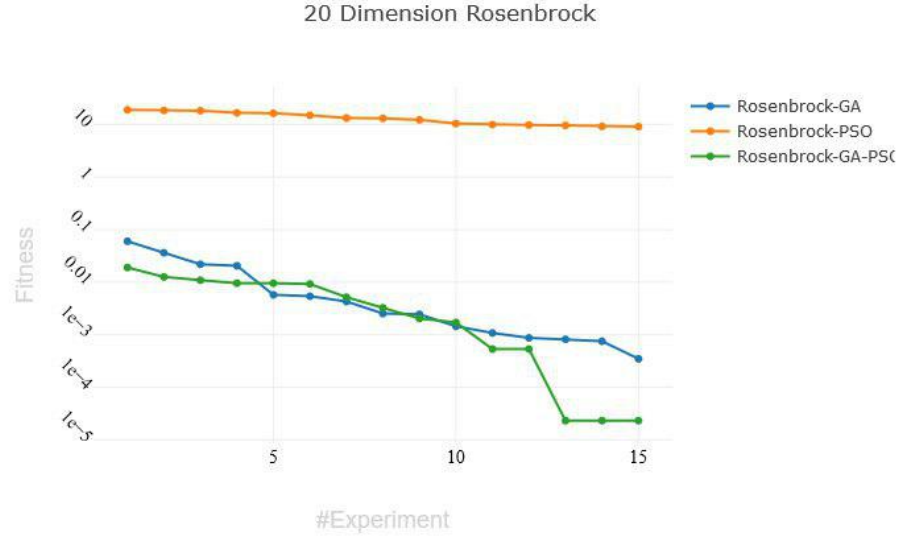
| Fn | Best | Average | Experiment Number |
|-------------------|-------------|-------------|-------------------|
| Rastrigin GA | 3.21768E-09 | 2.38015E-06 | 15 |
| Rastrigin PSO | 7.8586E-11 | 2.715716161 | 15 |
| Rastrigin GA-PSO | 8.01492E-12 | 5.08668E-09 | 15 |
| Sphere GA | 1.84051E-09 | 2.5389E-08 | 15 |
| Sphere PSO | 4.50351E-11 | 4.72855E-09 | 15 |
| Sphere GA-PSO | 3.33851E-11 | 1.30062E-09 | 15 |
| Rosenbrock GA | 9.58323E-07 | 1.24176E-08 | 15 |
| Rosenbrock PSO | 4.16711E-07 | 4.431565444 | 15 |
| Rosenbrock GA-PSO | 3.62472E-07 | 0.000240251 | 15 |

**Fig. 11.** 10 dimensions experiments Sphere.**Fig. 12.** 10 dimensions experiments Rastrigin.

**Fig. 13.** 10 dimensions experiments Rosenbrock.**Table 5.** Parametros experimentos 20 dimensiones

| Parameter | Value |
|-------------------------|--|
| GA Optimization | Minimiza |
| GA Generations | 70 |
| GA Dimensions | 20 |
| GA Population size | 200 |
| GA Mutation | Random(Tournament2,Tournament3,Random,RandomLinearRank,Sequential,Fittest) |
| GA Crossover | Tournament3 |
| GA Crossover percentage | Random[10%, 80%] |
| GA Mutation percentage | Random[10%,50%] |
| GA Crossover function | Uniforme de punto medio |
| GA Mutation Function | gaussian |
| PSO Optimization | Minimiza |
| PSO Iterations | 70 |
| PSO Dimensions | 20 |
| PSO Vector size | 200 |
| PSO Social factor | Random[0.5,4.0] |
| PSO Individual factor | Random[0.5,4.0] |
| PSO Inercia factor | Random[0.5,4.0] |

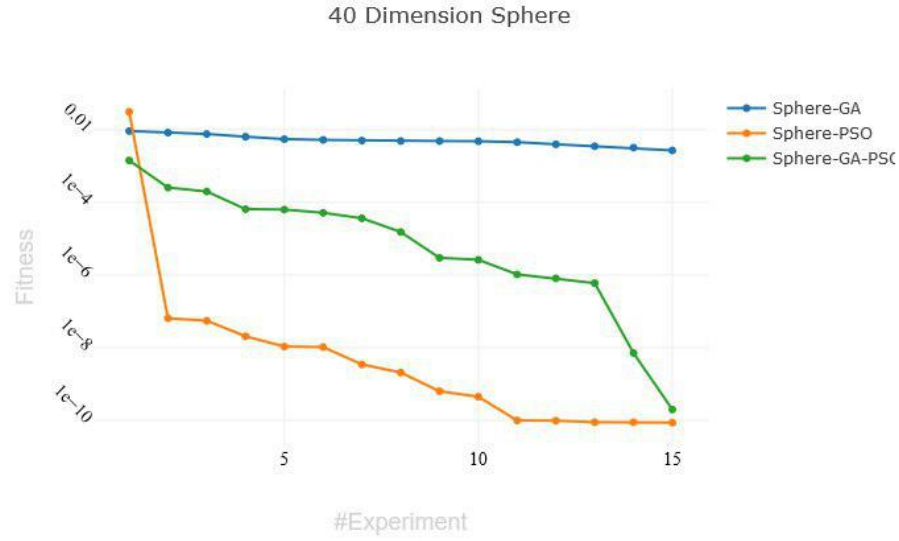
**Fig. 14.** 20 dimensions experiments Sphere.**Fig. 15.** 20 dimensions experiments Rastrigin.

**Fig. 16.** 20 dimensions experiments Rosenbrock.**Table 6.** Resultados 20 dimensiones

| Fn | Best | Average | Experiment Number |
|-------------------|-------------|-------------|-------------------|
| Rastrigin GA | 0.000808633 | 0.220596203 | 15 |
| Rastrigin PSO | 3.988070734 | 25.51777514 | 15 |
| Rastrigin GA-PSO | 9.13E-09 | 7.38E-02 | 15 |
| Sphere GA | 1.84051E-09 | 9.22715E-06 | 15 |
| Sphere PSO | 7.04E-11 | 3.50E-07 | 15 |
| Sphere GA-PSO | 9.11E-11 | 2.13E-08 | 15 |
| Rosenbrock GA | 0.000348015 | 0.010958941 | 15 |
| Rosenbrock PSO | 9.119539342 | 13.37613983 | 15 |
| Rosenbrock GA-PSO | 2.31663E-05 | 0.005608855 | 15 |

Table 7. Parametros experimentos 40 dimensiones

| Parameter | Value |
|-------------------------|--|
| GA Optimization | Minimiza |
| GA Generations | 70 |
| GA Dimensions | 40 |
| GA Population size | 200 |
| GA Mutation | Random(Tournament2,Tournament3,Random,RandomLinearRank,Sequential,Fittest) |
| GA Crossover | |
| GA Crossover percentage | Random[10%, 80%] |
| GA Mutation percentage | Random[10%,50%] |
| GA Crossover function | Uniforme de punto medio |
| GA Mutation Function | gaussian |
| PSO Optimization | Minimiza |
| PSO Iterations | 70 |
| PSO Dimensions | 40 |
| PSO Vector size | 200 |
| PSO Social factor | Random[0.5,4.0] |
| PSO Individual factor | Random[0.5,4.0] |
| PSO Inercia factor | Random[0.5,4.0] |

**Fig. 17.** 40 dimensions experiments Sphere.

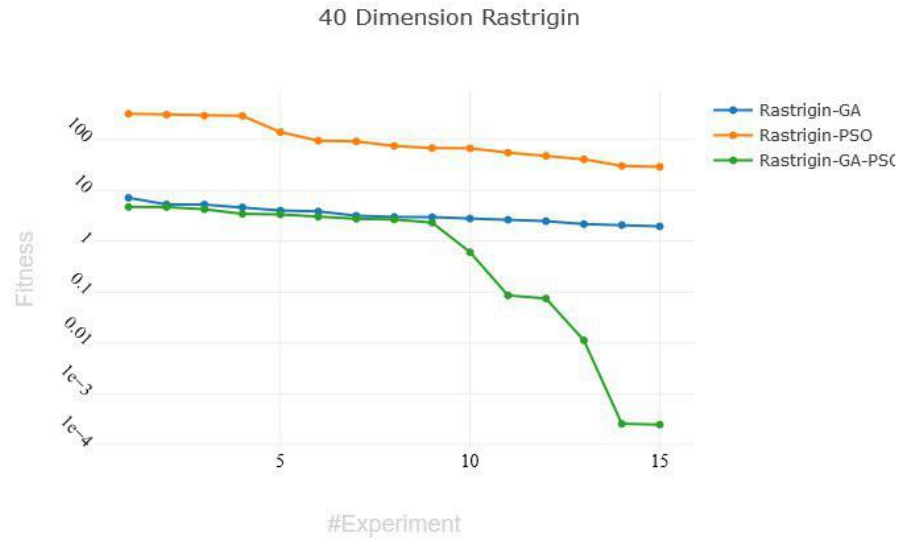


Fig. 18. 40 dimensions experiments Rastrigin.

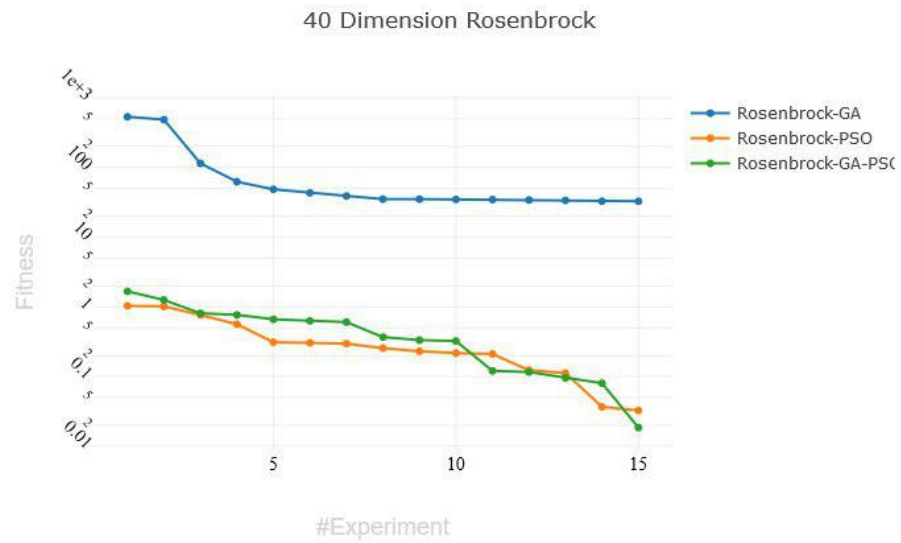


Fig. 19. 40 dimensions experiments Rosenbrock.

Table 8. Resultados 40 dimensiones

| Fn | Best | Average | Experiment Number |
|-------------------|-------------|-------------|-------------------|
| Rastrigin GA | 1.95478879 | 3.560837088 | 15 |
| Rastrigin PSO | 29.06596132 | 130.2865863 | 15 |
| Rastrigin GA-PSO | 2.46E-04 | 2.13E+00 | 15 |
| Sphere GA | 0.002686956 | 0.005302951 | 15 |
| Sphere PSO | 8.68E-11 | 2.07E-03 | 15 |
| Sphere GA-PSO | 2.00E-10 | 1.41E-04 | 15 |
| Rosenbrock GA | 0.000348015 | 106.9287542 | 15 |
| Rosenbrock PSO | 0.032708559 | 0.368395353 | 15 |
| Rosenbrock GA-PSO | 0.018538924 | 0.525086565 | 15 |

5 Future work

To get a continuous improvement it is believed that it is required a sort of mutation applied to the sub-populations. This mutation would be a swapping type, taking the algorithm parameters from the best and the worst sub-populations, increasing the possibilities to get an optimal result, preventing getting stuck into a local optimum. Of course it is expected to use this architecture using more algorithms than GA and PSO.

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