

```
In [2]: import sys
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from scipy.stats import cauchy
sys.path.insert(0, './utils')
from utils.BenchmarkFunctions import Ackley, DeJong3, DeJong5, Michalewicz,
sys.path.insert(0, './algorithms')
from algorithms import *
sys.path.insert(0, './ge')
from ge import *
```

Housekeeping

```
In [6]: numDimensions = 20
populationSize = 40
numGenerations = 1000
sphere = Sphere(numDimensions=numDimensions)
schwefel = Schwefel(numDimensions=numDimensions)
#rastrigin = Rastrigin(numDimensions=numDimensions)
```

Implementação do PSO

PSO é um algoritmo relativamente simples. Existe uma população de agentes (partículas) que passa por um processo iterativo (gerações) em que, a cada geração, todas as partículas atualizam suas posições (update):

```
In [7]: def PSO(agentImpl, fitnessFunction, numGenerations, ndims, populationSize, c
    bounds = fitnessFunction.bounds()
    generations = []
    particles = [agentImpl(fitnessFunction, bounds.min, bounds.max, ndims, c
    best = min(particles, key = lambda p : p.fitness)
    for i in range(numGenerations):
        for p in particles:
            p.update(best)
            best = min(particles, key = lambda p : p.fitness)
            generations.append(best.fitness)
    return {
        "best": best,
        "generations": generations
    }
```

Seguindo esta estrutura base, a implementação da partícula pode variar consoante a estratégia utilizada para a atualização da posição no espaço de procura....

PSO Canônico

```
In [8]: class Particle:
    def __init__(self,
        fitnessFunction,
        lowerBound,
        upperBound,
```

```

        nDims,
        options
    ):
        self.fitnessFunction = fitnessFunction
        self.minval = lowerBound
        self.maxval = upperBound
        self.ndims = nDims
        self.inertiaFactor = options["inertiaFactor"] if "inertiaFactor" in
        self.selfConfidence = options["selfConfidence"] if "selfConfidence"
        self.swarmConfidence = options["swarmConfidence"] if "swarmConfidence"
        self.speed = np.array([0.0] * self.ndims)
        self.pos = np.random.uniform(low=self.minval, high = self.maxval, si
        self.best = self.pos
        self.fitness = fitnessFunction.evaluate(self.pos)

    def update(self, best):
        self.speed = (
            self.inertiaFactor * self.speed +
            self.selfConfidence * np.random.rand(self.ndims) * (self.best -
            self.swarmConfidence * np.random.rand(self.ndims) * (best.best
        )
        self.pos = np.clip(self.pos + self.speed, self.minval, self.maxval)
        fit = self.fitnessFunction.evaluate(self.pos)
        if(fit < self.fitness):
            self.fitness = fit
            self.best = self.pos

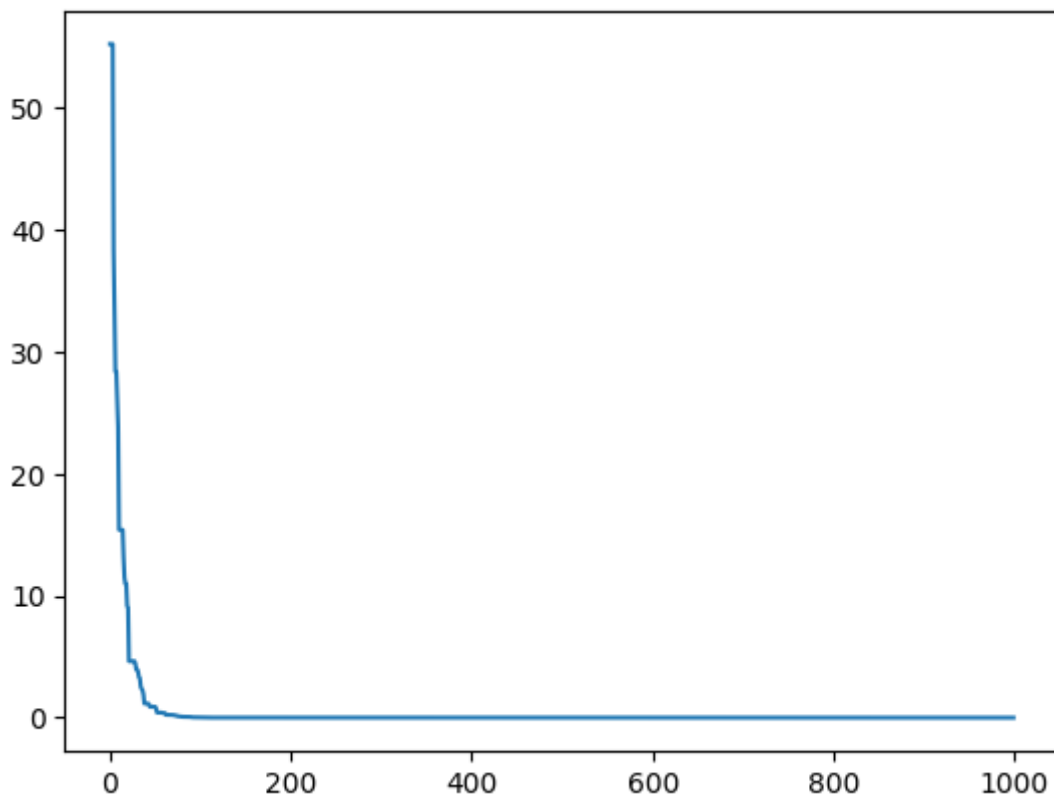
```

Resultados do PSO Canônico para o Sphere

```

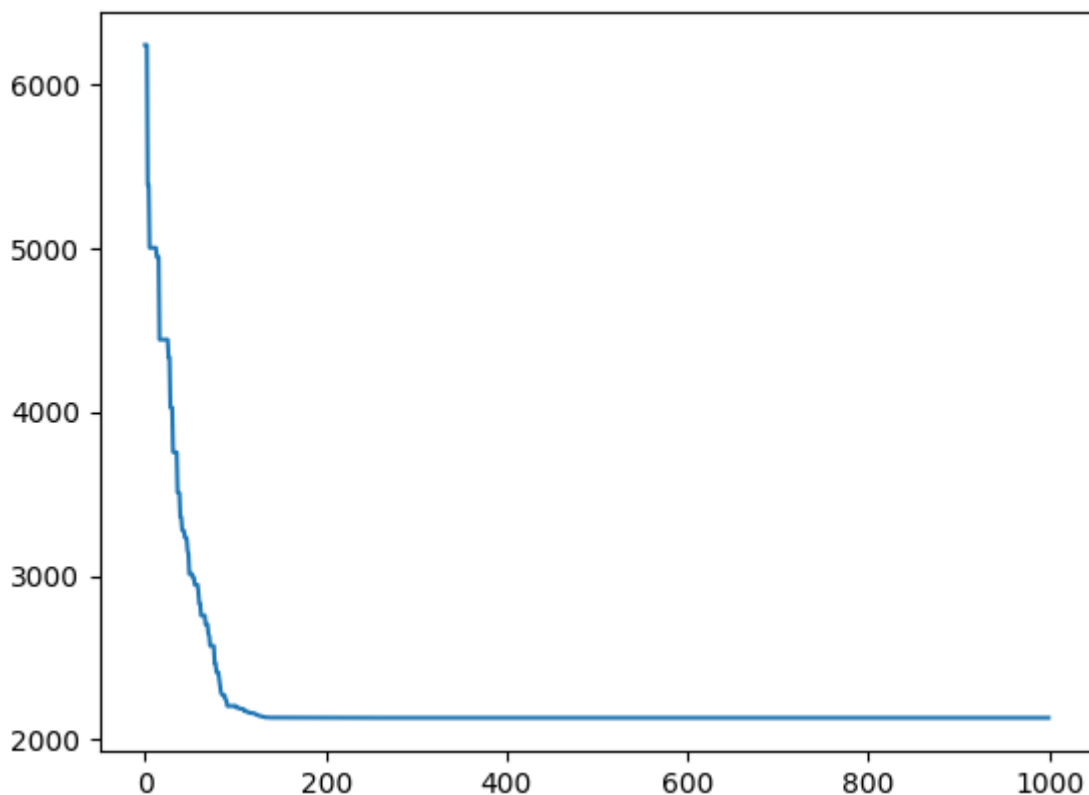
In [10]: sphereCPSO = PSO(Particle, sphere, numGenerations, numDimensions, population
plt.plot(sphereCPSO["generations"])
plt.show()

```



Resultados do PSO Canônico para o Schwefel

```
In [11]: schwefelCPSO = PSO(Particle, schwefel, numGenerations, numDimensions, popula
plt.plot(schwefelCPSO["generations"])
plt.show()
```



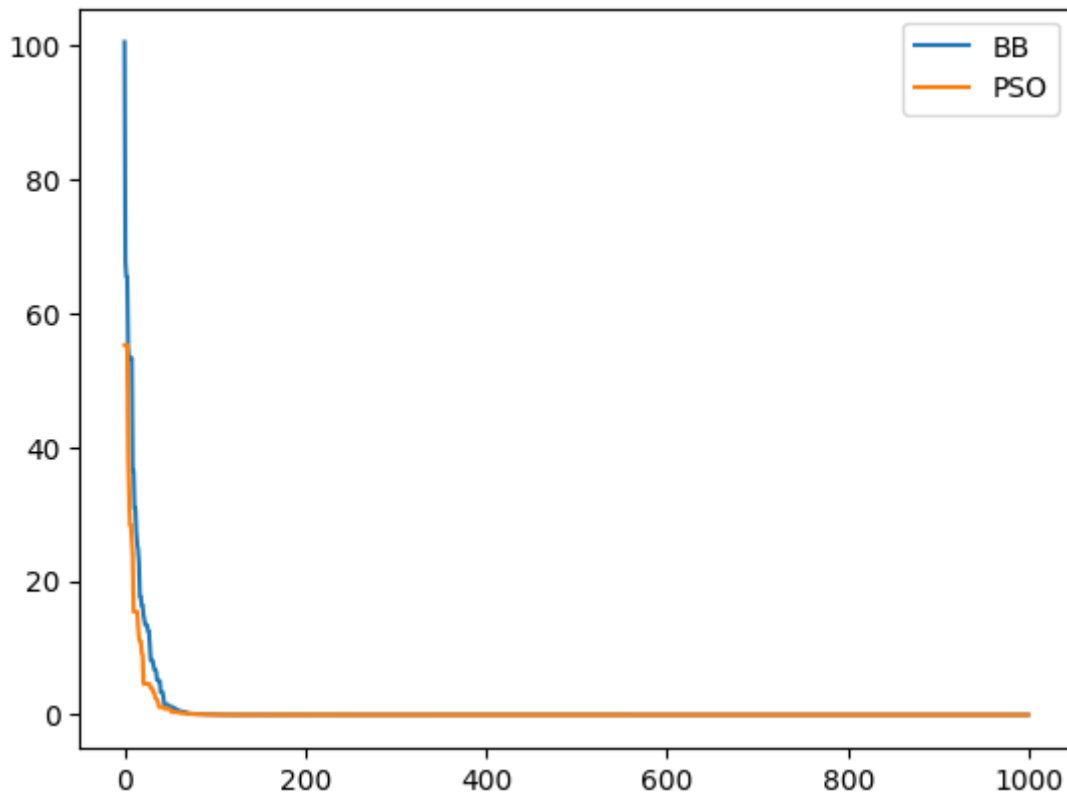
Barebones PSO

```
In [12]: class BBParticle:
    def __init__(self, fitnessFunction, lowerBound, upperBound, nDims, optio
        self.fitnessFunction = fitnessFunction
        self.minval = lowerBound
        self.maxval = upperBound
        self.ndims = nDims
        self.pos = np.random.uniform(low=self.minval, high = self.maxval, si
        self.best = self.pos
        self.fitness = fitnessFunction.evaluate(self.pos)

    def update(self, best):
        posMean = np.add(self.best, best.best) / 2
        posSd = np.abs(np.subtract(self.best, best.best))
        self.pos = np.clip(np.random.normal(posMean, posSd) , self.minval,
        fit = self.fitnessFunction.evaluate(self.pos)
        if(fit < self.fitness):
            self.fitness = fit
            self.best = self.pos
```

Resultados do BB vs PSO para o Sphere

```
In [13]: sphereBB = PSO(BBParticle, sphere, numGenerations, numDimensions, population
plt.plot(sphereBB["generations"], label="BB")
plt.plot(sphereCPSO["generations"], label="PSO")
plt.legend(["BB", "PSO"], loc='upper right')
plt.show()
```

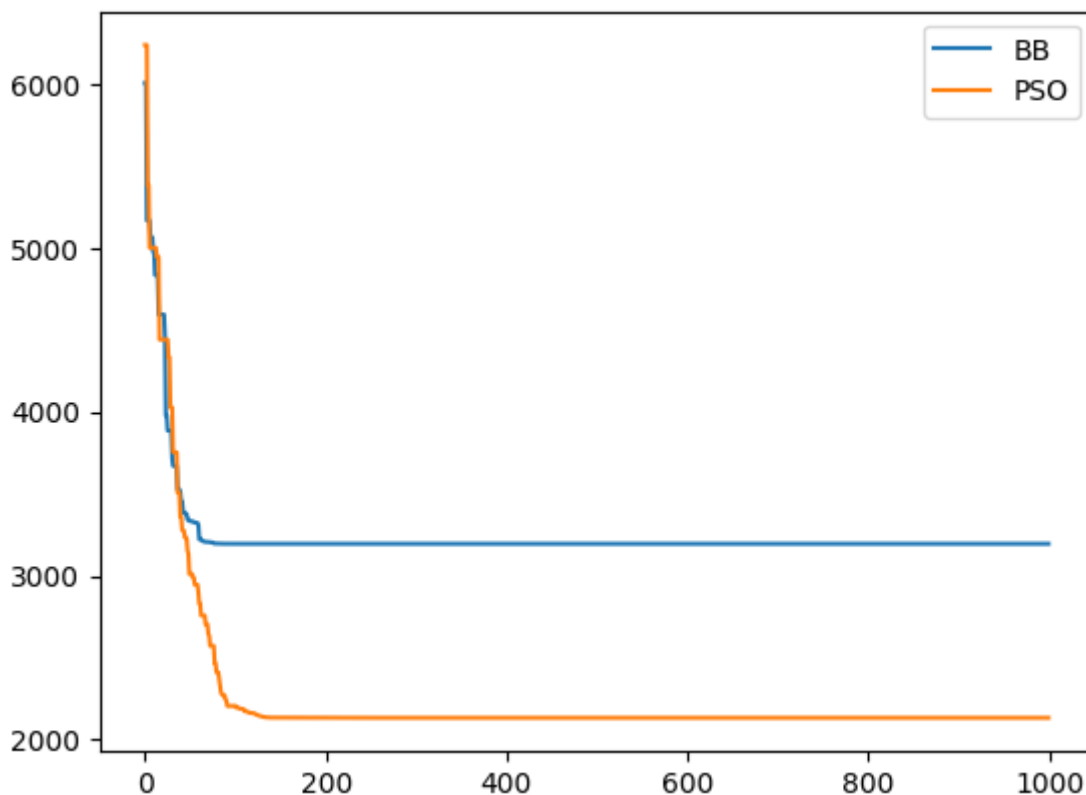


```
In [17]: df = pd.DataFrame({
    "PSO": [sphereCPS0["best"].fitness],
    "BB": [sphereBB["best"].fitness],
})
print(df)
```

```
      PSO      BB
0  1.793353e-31  2.732798e-33
```

Resultados do BB vs PSO para o Schwefel

```
In [18]: schwefelBB = PSO(BBParticle, schwefel, numGenerations, numDimensions, popula
plt.plot(schwefelBB["generations"], label="BB")
plt.plot(schwefelCPS0["generations"], label="PSO")
plt.legend(["BB", "PSO"], loc='upper right')
plt.show()
```



```
In [19]: df = pd.DataFrame({
    "PSO": [schwefelCPSO["best"].fitness],
    "BB": [schwefelBB["best"].fitness],
})
print(df)
```

```
      PSO      BB
0  2133.551162  3194.785944
```

```
In [20]: grammar = """
<expr> ::= <canonicalPso>

<canonicalPso> ::= PSO(Particle, fitnessFunc, numGenerations, numDimensions,
<inertiaFactor> ::= 0.<int><int> | 1
<selfConfidence> ::= 0.<int><int> | 1.<int><int> | 2
<swarmConfidence> ::= 0.<int><int> | 1.<int><int> | 2
<populationSize> ::= 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100
<int> ::= 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9
"""
```

```
In [22]: def siSphere(phenotype):
    fitnessFunc = sphere
    res = eval(phenotype)
    return res["best"].fitness

optPSOSphere = GE(
    grammar=grammar,
    fitnessFunction=siSphere,
    populationSize=50,
    numGenerations=50,
    mutationProbability=0.1,
```

```

        crossoverProbability=0.5,
        genotypeLength=10
    ).evolve("<expr>")

df = pd.DataFrame({
    "PSO": [sphereCPSO["best"].fitness],
    "BB": [sphereBB["best"].fitness],
    "PSO OPT": [optPSOSphere[0].fitness],
})
print(df)

```

| | PSO | BB | PSO OPT |
|---|--------------|--------------|--------------|
| 0 | 1.793353e-31 | 2.732798e-33 | 1.967296e-60 |

In [23]: `print(optPSOSphere[0].phenotype)`

```
PSO(Particle, fitnessFunc, numGenerations, numDimensions, 90, {"inertiaFactor":0.77, "selfConfidence":1.22, "swarmConfidence":1.00})
```

In [30]: `def siSchwefel(phenotype):`
 `fitnessFunc = schwefel`
 `res = eval(phenotype)`
 `return res["best"].fitness`

```

optPSOSchwefel = GE(
    grammar=grammar,
    fitnessFunction=siSchwefel,
    populationSize=50,
    numGenerations=50,
    mutationProbability=0.1,
    crossoverProbability=0.5,
    genotypeLength=10
).evolve("<expr>")

df = pd.DataFrame({
    "PSO": [schwefelCPSO["best"].fitness],
    "BB": [schwefelBB["best"].fitness],
    "PSO OPT": [optPSOSchwefel[0].fitness],
})
print(df)

```

| | PSO | BB | PSO OPT |
|---|-------------|-------------|-------------|
| 0 | 2133.551162 | 3194.785944 | 1817.582669 |

In [31]: `print(optPSOSchwefel[0].phenotype)`

```
PSO(Particle, fitnessFunc, numGenerations, numDimensions, 60, {"inertiaFactor":0.11, "selfConfidence":2, "swarmConfidence":2})
```

In [46]: `autoGrammar = """`
`<expr> ::= <bbPso> | <canonicalPso>`
`<bbPso> ::= PSO(BBParticle, fitnessFunc, numGenerations, numDimensions, <pop`
`<canonicalPso> ::= PSO(Particle, fitnessFunc, numGenerations, numDimensions,`
`<inertiaFactor> ::= 0.<int><int> | 1`
`<selfConfidence> ::= 0.<int><int> | 1.<int><int> | 2`
`<swarmConfidence> ::= 0.<int><int> | 1.<int><int> | 2`
`<populationSize> ::= 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100`

```
<int> ::= 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9
'''''
```

```
In [50]: optPSOBBSchwefel = GE(
    grammar=autoGrammar,
    fitnessFunction=siSchwefel,
    populationSize=50,
    numGenerations=50,
    mutationProbability=0.1,
    crossoverProbability=0.5,
    genotypeLength=10
).evolve("<expr>")

df = pd.DataFrame({
    "PSO": [schwefelCPS0["best"].fitness],
    "BB": [schwefelBB["best"].fitness],
    "AUTO": [optPSOBBSchwefel[0].fitness],
})
print(df)
```

| | PSO | BB | AUTO |
|---|-------------|-------------|-------------|
| 0 | 2133.551162 | 3194.785944 | 1190.451839 |

```
In [51]: print(optPSOBBSchwefel[0].phenotype)

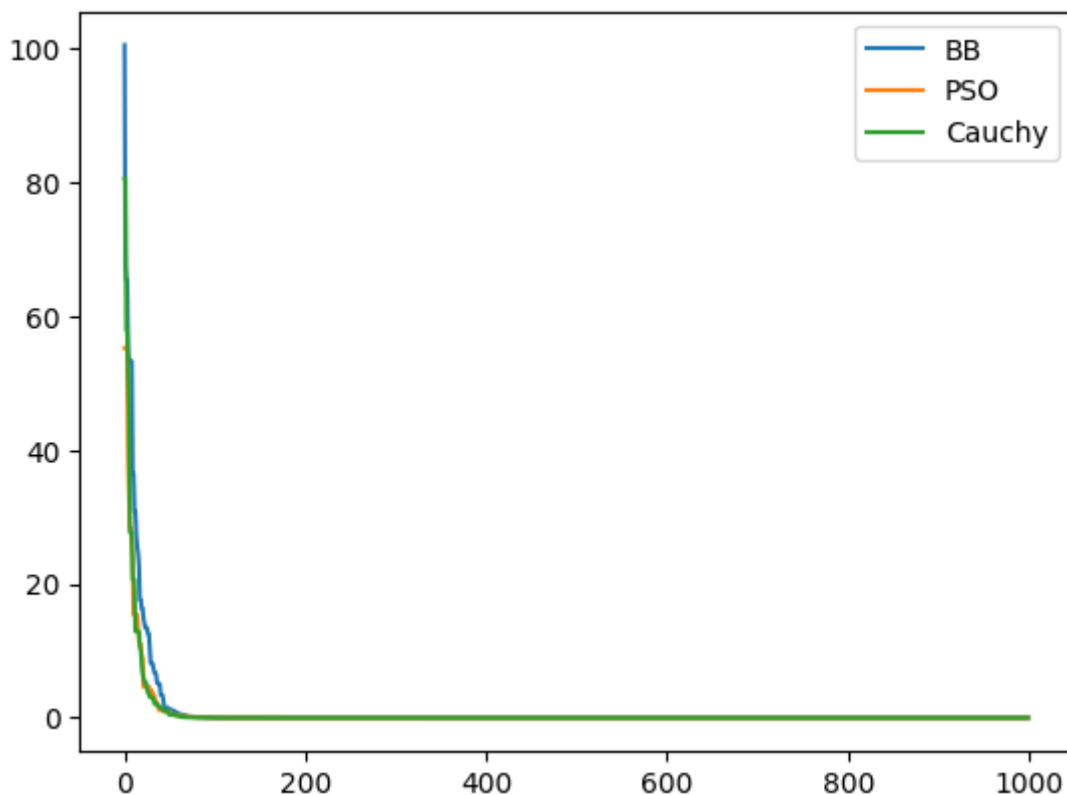
PSO(BBParticle, fitnessFunc, numGenerations, numDimensions, 90)
```

Cauchy PSO

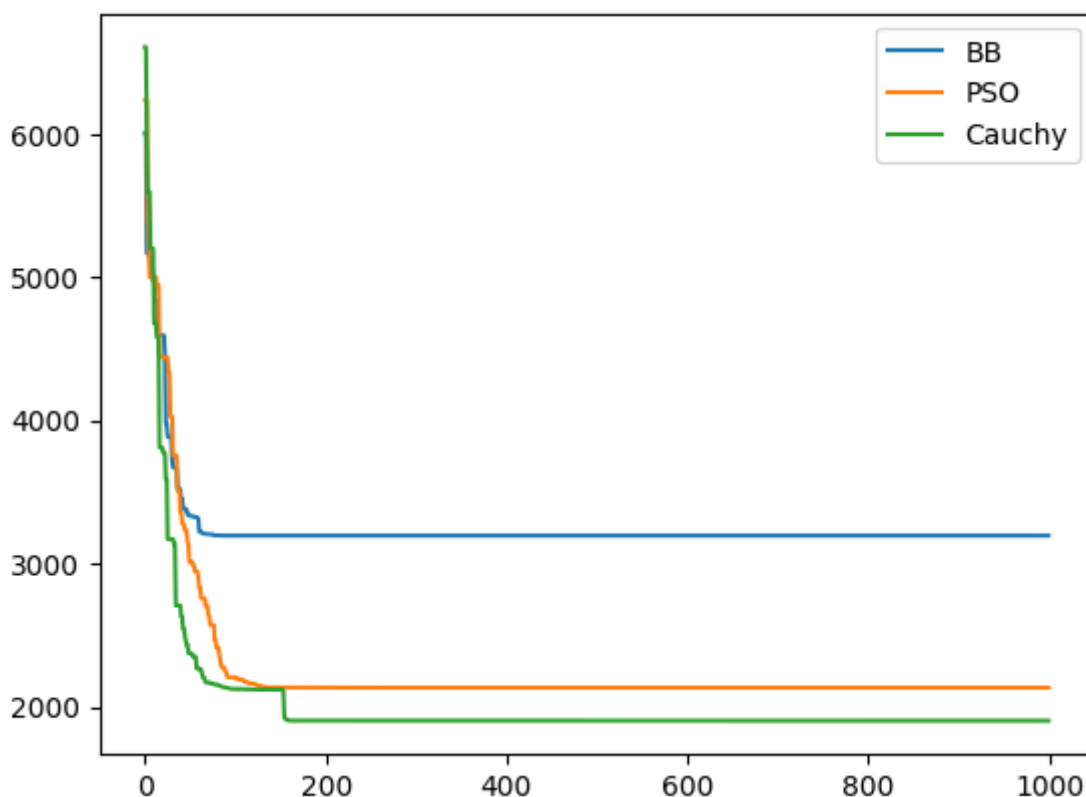
```
In [52]: class CauchyParticle:
    def __init__(self, fitnessFunction, lowerBound, upperBound, nDims, options):
        self.fitnessFunction = fitnessFunction
        self.minval = lowerBound
        self.maxval = upperBound
        self.ndims = nDims
        self.pos = np.random.uniform(low=self.minval, high = self.maxval, size=self.ndims)
        self.best = self.pos
        self.fitness = fitnessFunction.evaluate(self.pos)
        self.coolingFactor = options["coolingFactor"] if "coolingFactor" in options else 1

    def update(self, best):
        posMean = np.add(self.best, best.best) / 2
        posSd = np.abs(np.subtract(self.best, best.best))
        pos = cauchy.rvs(loc=posMean, scale=posSd*self.coolingFactor, size=self.ndims)
        self.pos = np.clip(pos, self.minval, self.maxval)
        fit = self.fitnessFunction.evaluate(self.pos)
        if(fit < self.fitness):
            self.fitness = fit
            self.best = self.pos
```

```
In [55]: sphereCauchy = PSO(CauchyParticle, sphere, numGenerations, numDimensions, options)
plt.plot(sphereBB["generations"], label="BB")
plt.plot(sphereCPS0["generations"], label="PSO")
plt.plot(sphereCauchy["generations"], label="Cauchy")
plt.legend(["BB", "PSO", "Cauchy"], loc='upper right')
plt.show()
```



```
In [56]: schwefelCauchy = PSO(CauchyParticle, schwefel, numGenerations, numDimensions)
plt.plot(schwefelBB["generations"], label="BB")
plt.plot(schwefelCPSO["generations"], label="PSO")
plt.plot(schwefelCauchy["generations"], label="Cauchy")
plt.legend(["BB", "PSO", "Cauchy"], loc='upper right')
plt.show()
```



```
In [57]: autoGrammar = """
<expr> ::= <bbPso> | <cauchyPso> | <canonicalPso>

<bbPso> ::= PSO(BBParticle, fitnessFunc, numGenerations, numDimensions, <pop>
```



```

<cauchyPso> ::= PSO(CauchyParticle, fitnessFunc, numGenerations, numDimensions,
<canonicalPso> ::= PSO(Particle, fitnessFunc, numGenerations, numDimensions,
<inertiaFactor> ::= 0.<int><int> | 1
<selfConfidence> ::= 0.<int><int> | 1.<int><int> | 2
<swarmConfidence> ::= 0.<int><int> | 1.<int><int> | 2
<populationSize> ::= 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100
<int> ::= 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9
,,,,,

```

```

In [58]: optAutoPSOSchwefel = GE(
    grammar=autoGrammar,
    fitnessFunction=siSchwefel,
    populationSize=50,
    numGenerations=50,
    mutationProbability=0.1,
    crossoverProbability=0.5,
    genotypeLength=10
).evolve("<expr>")

df = pd.DataFrame({
    "PSO": [schwefelCPSO["best"].fitness],
    "BB": [schwefelBB["best"].fitness],
    "Cauchy": [schwefelCauchy["best"].fitness],
    "AUTO W/ BB": [optPSOBBSchwefel[0].fitness],
    "AUTO ALL": [optAutoPSOSchwefel[0].fitness],
})
print(df)

```

| | PSO | BB | Cauchy | AUTO W/ BB | AUTO ALL |
|---|-------------|-------------|-------------|-------------|-------------|
| 0 | 2133.551162 | 3194.785944 | 1902.598906 | 1190.451839 | 1068.979385 |

```

In [59]: print(optAutoPSOSchwefel[0].phenotype)

PSO(CauchyParticle, fitnessFunc, numGenerations, numDimensions, 10, {"cool
ingFactor":0.44})

```

```

In [ ]:

```