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**PyGAD**

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().

```
pip3 install pygad
```

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```
import pygad
```

```
y = f(w1:w6) = w1x1 + w2x2 + w3x3 + w4x4 + w5x5 + w6x6  
where (x1,x2,x3,x4,x5,x6)=(4,-2,3.5,5,-11,-4.7) and y=44
```

```
function_inputs = [4,-2,3.5,5,-11,-4.7]  
desired_output = 44
```

```
listtuple(numpy.ndarray()).
```

```
def fitness_func(ga_instance, solution, solution_idx):  
    output = numpy.sum(solution*function_inputs)  
    fitness = 1.0 / numpy.abs(output - desired_output)  
    return fitness
```

```
fitness_function = fitness_func  
  
num_generations = 50  
num_parents_mating = 4  
  
sol_per_pop = 8  
num_genes = len(function_inputs)  
  
init_range_low = -2  
init_range_high = 5  
  
parent_selection_type = "sss"  
keep_parents = 1  
  
crossover_type = "single_point"  
  
mutation_type = "random"  
mutation_percent_genes = 10
```

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```
ga_instance = pygad.GA(num_generations=num_generations,
                       num_parents_mating=num_parents_mating,
                       fitness_func=fitness_function,
                       sol_per_pop=sol_per_pop,
                       num_genes=num_genes,
                       init_range_low=init_range_low,
                       init_range_high=init_range_high,
                       parent_selection_type=parent_selection_type,
                       keep_parents=keep_parents,
                       crossover_type=crossover_type,
                       mutation_type=mutation_type,
                       mutation_percent_genes=mutation_percent_genes)
```

```
run()
```

```
ga_instance.run()
```

```
run()
```

```
solution, solution_fitness, solution_idx = ga_instance.best_solution()
print("Parameters of the best solution : {solution}".format(solution=solution))
print("Fitness value of the best solution = {solution_fitness}".format(solution_
↪fitness=solution_fitness))

prediction = numpy.sum(numpy.array(function_inputs)*solution)
print("Predicted output based on the best solution : {prediction}".
↪format(prediction=prediction))
```

```
Parameters of the best solution : [3.92692328 -0.11554946 2.39873381 3.29579039 -0.
↪74091476 1.05468517]
Fitness value of the best solution = 157.37320042925006
Predicted output based on the best solution : 44.00635432206546
```

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pygad  
nn  
gann()  
cnn  
gacnn  
kerasga  
torchga  
visualize  
utils()  
helper

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```
@article{gad2023pygad,  
  title={Pygad: An intuitive genetic algorithm python library},  
  author={Gad, Ahmed Fawzy},  
  journal={Multimedia Tools and Applications},  
  pages={1--14},  
  year={2023},  
  publisher={Springer}  
}
```

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## pygad

```
' pygad
pygad
```

## pygad.GA

```
pygadGA
```

## \_\_init\_\_()

```
pygad.GA
pygad.GA
    num_generations
    num_parents_mating
    fitness_func() (pygad.GA). ' listtuplenumpy.ndarray
    fitness_batch_size=Nonefitness_batch_size1None(), fitness_batch_size1 < fitness_batch_size <= sol_per_popfitness_batch_size
    initial_populationNonesol_per_popnum_genesinitial_populationNone
    (sol_per_pop num_genes) None
    sol_per_pop() initial_population
    num_genesinitial_population
    gene_type=floatfloatfloatgene_typeintfloatnumpy.int/uint/float (8-64)
    listtuplenumpy.ndarray(gene_type=[int, float, numpy.int8]). float(
    gene_type=[float, 2]
    init_range_low=-4init_range_low-4initial_population
    init_range_high=4init_range_high+4initial_population
    parent_selection_type="sss"sss(), rws (), sus (), rank (), random (), tournament().
    keep_parents=-1-1() 0greater than 0keep_parents< - 1sol_per_popkeep_elitism0
    ' keep_parents=0
```

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---

```

keep_elitism=10(0 <= keep_elitism <= sol_per_pop). 10Ksol_per_pop0
keep_parents

K_tournament=3tournamentK_tournament3

crossover_type="single_point"single_point(), two_points (), uniform (), scattered
(). single_pointcrossover_type=None

crossover_probability=Nonecrossover_probability

mutation_type="random"random(), swap (), inversion (), scramble (), adaptive(). random
mutation_type=NoneAdaptive

mutation_probability=Nonemutation_probabilitymutation_percent_genesmuta-
tion_num_genes

mutation_by_replacement=False(mutation_type="random").          muta-
tion_by_replacement=True

mutation_percent_genes="default""default"10>0<=100mutation_num_genesmu-
tation_percent_genesmutation_probabilitymutation_num_genesmutation_type
None

mutation_num_genes=NoneNonemutation_num_genesmutation_probabilitymuta-
tion_typeNone

random_mutation_min_val=-1.0randomrandom_mutation_min_val-1mutation_type
None

random_mutation_max_val=1.0randomrandom_mutation_max_val+1mutation_type
None

gene_space=NoneListrangenumPy.ndarrayListtuplerrangenumPy.ndarraygene_space
= [0.3, 5.2, -4, 8]gene_space[[0.4, -5], [0.5, -3.2, 8.2, -9],
...]None' init_range_lowinit_range_highrandom_mutation_min_valran-
dom_mutation_max_valgene_spacegene_spacegene_space{'low': 2, 'high':
4}"step""low""high"

on_start=None'

on_fitness=None)' )'

on_parents=None)' )'

on_crossover=None

on_mutation=None

on_generation=Nonestoprun ()

on_stop=None'

delay_after_gen=0.00.0

save_best_solutions=FalseTruebest_solutionsFalse(), best_solutions

save_solutions=FalseTruesolutions

suppress_warnings=FalseFalse

allow_duplicate_genes=TrueTrueFalse

stop_criteria=Nonestrreachsaturationreachrun () reach"reach_40">saturatesatu-
rate"saturate_7"run ()

```

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---

```

parallel_processing=NoneNone(),          []          'process''thread')          ]parallel_
lel_processing=['process',                  10]parallel_processing=5parallel_
lel_processing=["thread", 5]

random_seed=None(). (random_seed=2). None

logger=Nonelogging.Loggerprint () logger=NoneStreamHandler

' fitness_func

init_range_lowinit_range_high(init_range_lowinit_range_high).          ran-
dom_mutation_min_valrandom_mutation_max_val

mutation_typecrossover_typeNone

```

## pygad.GA

```

plot_fitness ()
plot_genes ()
plot_new_solution_rate ()

supported_int_types
supported_float_types
supported_int_float_types

```

```
pygad.GApygad.GApygad.GA
```

```

generations_completed
population
valid_parametersTrueGA
run_completedTruerun ()
pop_size
best_solutions_fitness
best_solution_generationrun ()
best_solutionssave_best_solutionspygad.GATrue
last_generation_fitness

```

---

```
previous_generation_fitnesslast_generation_fitnesslast_generation_fitness
previous_generation_fitness

last_generation_parents

last_generation_offspring_crossover

last_generation_offspring_mutation

gene_type_singleTruegene_typegene_typelisttuplenumpy.ndarray
gene_type_singleFalse

last_generation_parents_indices

last_generation_elitismkeep_elitism

last_generation_elitism_indiceskeep_elitism

loggerlogging

gene_space_unpackedgene_spacerange(1, 5)[1, 2, 3, 4]{'low': 2, 'high': 4}(
).

pareto_frontspareto_frontspygad.GA

last_generation_
```

```
cal_pop_fitness()fitness_func

crossover()crossover_type

mutation()mutation_type

select_parents()parent_selection_type

adaptive_mutation_population_fitness()

summary()

run_run()run_run()

    run_select_parents(call_on_parents=True)on_parents()call_on_parents
    Trueon_parents()Falserrun_select_parents()run()

    run_crossover()on_crossover()

    run_mutation()on_mutation()

    run_update_population()population

pygad.GA
```

---

---

## **initialize\_population()**

population

low

high

pop\_size

population

initial\_population

## **cal\_pop\_fitness()**

cal\_pop\_fitness()

save\_solutionsTrue  
solutionssolutions\_fitness

save\_solutionsFalseTrue  
cal\_pop\_fitness()keep\_elitism  
last\_generation\_elitism  
previous\_generation\_fitness

(save\_solutionsFalseTruekeep\_elitism), cal\_pop\_fitness()keep\_parents-1  
last\_generation\_parentsprevious\_generation\_fitness  
fitness\_func

parallel\_processing

fitness\_batch\_size

,

## **run()**

cal\_pop\_fitness()fitness\_funcpygad.GA

select\_parents()parent\_selection\_typepygad.GA

crossover()mutation()crossover\_type  
mutation\_typepygad.GA

population

generations\_completed

on\_generation

run()

best\_solution\_generation

run\_completedTrue

---

```
ParentSelectionpygad.utils.parent_selection
    fitness
    num_parents
```

```
steady_state_selection()
```

```
rank_selection()
```

```
random_selection()
```

```
tournament_selection()
```

```
roulette_wheel_selection()
```

```
stochastic_universal_selection()
```

```
nsga2_selection()
```

```
tournament_selection_nsga2()
```

---

---

```
Crossoverpygad.utils.crossover
    parents
    offspring_size
```

```
single_point_crossover()
```

```
two_points_crossover()
```

```
uniform_crossover()
```

```
scattered_crossover()
```

```
Mutationpygad.utils.mutation
    offspring
```

```
random_mutation()
```

```
mutation_num_genesmutation_percent_genes
random_mutation_min_valrandom_mutation_max_val
```

---

```
swap_mutation()
```

```
inversion_mutation()
```

```
scramble_mutation()
```

```
adaptive_mutation()
```

```
best_solution()
```

```
pop_fitness=NoneNonecal_pop_fitness()
```

```
best_solution
```

```
best_solution_fitness
```

```
best_match_idx
```

```
plot_fitness()
```

```
plot_result()
```

```
(),
```

```
plot_new_solution_rate()
```

```
plot_new_solution_rate() save_solutions=Truepygad.GA
```

```
(),
```

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## **plot\_genes()**

plot\_genes()

graph\_type  
(),

## **save()**

filename

## **pygad**

pygad.GApygadload()

## **pygad.load()**

pygadpygad.load(filename)

filename

## **pygad**

pygad  
fitness\_func

pygad  
pygad.GA

,

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## fitness\_func

fitness\_func

supported\_int\_float\_typespygad.GA

listtuplenumpy.ndarray

,

()

()()

()?

W1W6y=44' y=44

```
function_inputs = [4, -2, 3.5, 5, -11, -4.7] # Function inputs.
desired_output = 44 # Function output.
```

```
def fitness_func(ga_instance, solution, solution_idx):
    output = numpy.sum(solution*function_inputs)
    fitness = 1.0 / numpy.abs(output - desired_output)
    return fitness
```

pygad.GA

()(). fitness\_batch\_size

fitness\_batch\_size

fitness\_func'

\_\_code\_\_

```
num_generations = 50
num_parents_mating = 4

fitness_function = fitness_func

sol_per_pop = 8
num_genes = len(function_inputs)

init_range_low = -2
init_range_high = 5
```

---

)

```
parent_selection_type = "sss"
keep_parents = 1

crossover_type = "single_point"

mutation_type = "random"
mutation_percent_genes = 10
```

## on\_generation

on\_generation() generations\_completed

```
def on_gen(ga_instance):
    print("Generation : ", ga_instance.generations_completed)
    print("Fitness of the best solution :", ga_instance.best_solution()[1])
```

on\_generationon\_gen()

```
ga_instance = pygad.GA(...,
                       on_generation=on_gen,
                       ...)
```

pygad.GA

## pygad

```
import pygad
```

pygad.GA

## pygad.GA

pygad.GA

```
ga_instance = pygad.GA(num_generations=num_generations,
                       num_parents_mating=num_parents_mating,
                       fitness_func=fitness_function,
                       sol_per_pop=sol_per_pop,
                       num_genes=num_genes,
                       init_range_low=init_range_low,
                       init_range_high=init_range_high,
                       parent_selection_type=parent_selection_type,
                       keep_parents=keep_parents,
                       crossover_type=crossover_type,
                       mutation_type=mutation_type,
                       mutation_percent_genes=mutation_percent_genes)
```

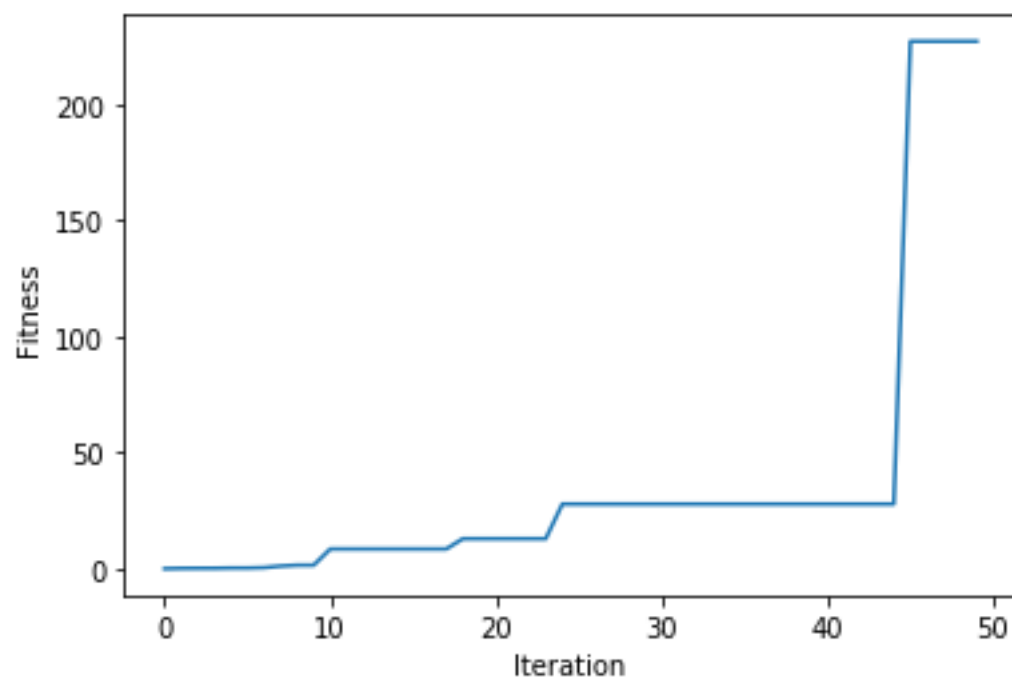
---

```
pygad.GArun()
```

```
ga_instance.run()
```

```
plot_fitness()
```

```
ga_instance.plot_fitness()
```



```
best_solution()
```

---

---

```
solution, solution_fitness, solution_idx = ga_instance.best_solution()
print(f"Parameters of the best solution : {solution}")
print(f"Fitness value of the best solution = {solution_fitness}")
print(f"Index of the best solution : {solution_idx}")
```

best\_solution\_generationpygad.GAbest fitness

```
if ga_instance.best_solution_generation != -1:
    print(f"Best fitness value reached after {ga_instance.best_solution_generation} generations.")
```

run() save() genetic.pkl

```
filename = 'genetic'
ga_instance.save(filename=filename)
```

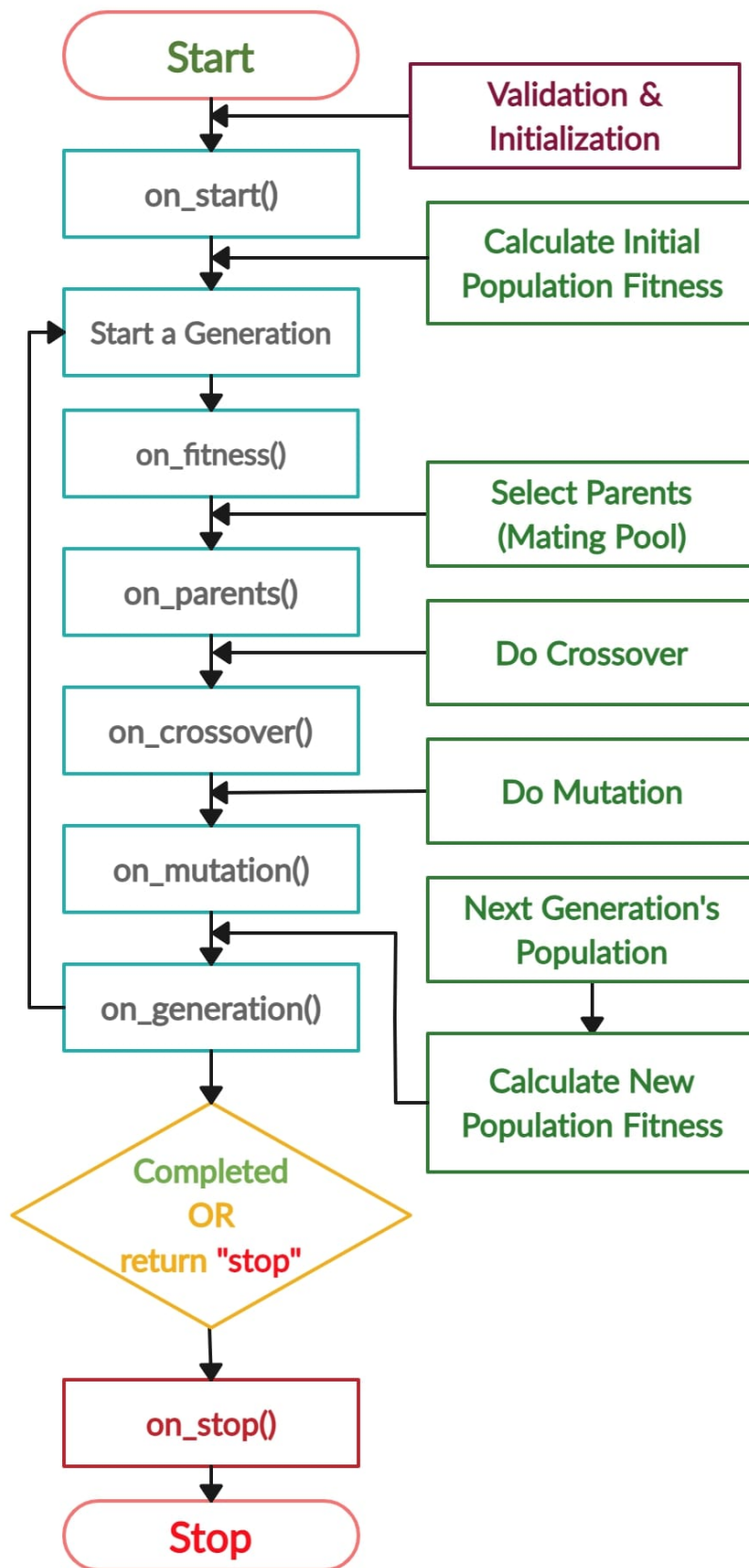
load() save() load() run()

```
loaded_ga_instance = pygad.load(filename=filename)
```

```
print(loaded_ga_instance.best_solution())
```

pygad.GAon\_generationstop

---



---

```

import pygad
import numpy

function_inputs = [4,-2,3.5,5,-11,-4.7]
desired_output = 44

def fitness_func(ga_instance, solution, solution_idx):
    output = numpy.sum(solution*function_inputs)
    fitness = 1.0 / (numpy.abs(output - desired_output) + 0.000001)
    return fitness

fitness_function = fitness_func

def on_start(ga_instance):
    print("on_start()")

def on_fitness(ga_instance, population_fitness):
    print("on_fitness()")

def on_parents(ga_instance, selected_parents):
    print("on_parents()")

def on_crossover(ga_instance, offspring_crossover):
    print("on_crossover()")

def on_mutation(ga_instance, offspring_mutation):
    print("on_mutation()")

def on_generation(ga_instance):
    print("on_generation()")

def on_stop(ga_instance, last_population_fitness):
    print("on_stop()")

ga_instance = pygad.GA(num_generations=3,
                       num_parents_mating=5,
                       fitness_func=fitness_function,
                       sol_per_pop=10,
                       num_genes=len(function_inputs),
                       on_start=on_start,
                       on_fitness=on_fitness,
                       on_parents=on_parents,
                       on_crossover=on_crossover,
                       on_mutation=on_mutation,
                       on_generation=on_generation,
                       on_stop=on_stop)

ga_instance.run()

```

num\_generations

```

on_start()

on_fitness()
on_parents()
on_crossover()

```

0

```
on_mutation()
on_generation()

on_fitness()
on_parents()
on_crossover()
on_mutation()
on_generation()

on_fitness()
on_parents()
on_crossover()
on_mutation()
on_generation()

on_stop()
```

pygad

```
import pygad
import numpy

"""
Given the following function:
     $y = f(w1:w6) = w1x1 + w2x2 + w3x3 + w4x4 + w5x5 + 6wx6$ 
    where  $(x1,x2,x3,x4,x5,x6)=(4,-2,3.5,5,-11,-4.7)$  and  $y=44$ 
What are the best values for the 6 weights (w1 to w6)? We are going to use the
↳ genetic algorithm to optimize this function.
"""

function_inputs = [4,-2,3.5,5,-11,-4.7] # Function inputs.
desired_output = 44 # Function output.

def fitness_func(ga_instance, solution, solution_idx):
    output = numpy.sum(solution*function_inputs)
    fitness = 1.0 / (numpy.abs(output - desired_output) + 0.000001)
    return fitness

num_generations = 100 # Number of generations.
num_parents_mating = 10 # Number of solutions to be selected as parents in the mating
↳ pool.

sol_per_pop = 20 # Number of solutions in the population.
num_genes = len(function_inputs)

last_fitness = 0
def on_generation(ga_instance):
```

0



```

    global last_fitness
    print(f"Generation = {ga_instance.generations_completed}")
    print(f"Fitness      = {ga_instance.best_solution(pop_fitness=ga_instance.last_
↪generation_fitness)[1]}")
    print(f"Change      = {ga_instance.best_solution(pop_fitness=ga_instance.last_
↪generation_fitness)[1] - last_fitness}")
    last_fitness = ga_instance.best_solution(pop_fitness=ga_instance.last_generation_
↪fitness)[1]

ga_instance = pygad.GA(num_generations=num_generations,
                       num_parents_mating=num_parents_mating,
                       sol_per_pop=sol_per_pop,
                       num_genes=num_genes,
                       fitness_func=fitness_func,
                       on_generation=on_generation)

# Running the GA to optimize the parameters of the function.
ga_instance.run()

ga_instance.plot_fitness()

# Returning the details of the best solution.
solution, solution_fitness, solution_idx = ga_instance.best_solution(ga_instance.last_
↪generation_fitness)
print(f"Parameters of the best solution : {solution}")
print(f"Fitness value of the best solution = {solution_fitness}")
print(f"Index of the best solution : {solution_idx}")

prediction = numpy.sum(numpy.array(function_inputs)*solution)
print(f"Predicted output based on the best solution : {prediction}")

if ga_instance.best_solution_generation != -1:
    print(f"Best fitness value reached after {ga_instance.best_solution_generation}
↪generations.")

# Saving the GA instance.
filename = 'genetic' # The filename to which the instance is saved. The name is
↪without extension.
ga_instance.save(filename=filename)

# Loading the saved GA instance.
loaded_ga_instance = pygad.load(filename=filename)
loaded_ga_instance.plot_fitness()

```

$$y_1 = f(w_1:w_6) = w_1x_1 + w_2x_2 + w_3x_3 + w_4x_4 + w_5x_5 + 6wx_6$$

$$y_2 = f(w_1:w_6) = w_1x_7 + w_2x_8 + w_3x_9 + w_4x_{10} + w_5x_{11} + 6wx_{12}$$

$$(x_1, x_2, x_3, x_4, x_5, x_6) = (4, -2, 3.5, 5, -11, -4.7) y = 50$$

$$(x_7, x_8, x_9, x_{10}, x_{11}, x_{12}) = (-2, 0.7, -9, 1.4, 3, 5) y = 30$$

```
() w1 w6
y1y2
listtuplenumpy.ndarray
```

```
import pygad
import numpy

"""
Given these 2 functions:
    y1 = f(w1:w6) = w1x1 + w2x2 + w3x3 + w4x4 + w5x5 + 6wx6
    y2 = f(w1:w6) = w1x7 + w2x8 + w3x9 + w4x10 + w5x11 + 6wx12
    where (x1,x2,x3,x4,x5,x6)=(4,-2,3.5,5,-11,-4.7) and y=50
    and   (x7,x8,x9,x10,x11,x12)=(-2,0.7,-9,1.4,3,5) and y=30
What are the best values for the 6 weights (w1 to w6)? We are going to use the
↳ genetic algorithm to optimize these 2 functions.
This is a multi-objective optimization problem.

PyGAD considers the problem as multi-objective if the fitness function returns:
    1) List.
    2) Or tuple.
    3) Or numpy.ndarray.
"""

function_inputs1 = [4,-2,3.5,5,-11,-4.7] # Function 1 inputs.
function_inputs2 = [-2,0.7,-9,1.4,3,5] # Function 2 inputs.
desired_output1 = 50 # Function 1 output.
desired_output2 = 30 # Function 2 output.

def fitness_func(ga_instance, solution, solution_idx):
    output1 = numpy.sum(solution*function_inputs1)
    output2 = numpy.sum(solution*function_inputs2)
    fitness1 = 1.0 / (numpy.abs(output1 - desired_output1) + 0.000001)
    fitness2 = 1.0 / (numpy.abs(output2 - desired_output2) + 0.000001)
    return [fitness1, fitness2]

num_generations = 100
num_parents_mating = 10

sol_per_pop = 20
num_genes = len(function_inputs1)

ga_instance = pygad.GA(num_generations=num_generations,
                       num_parents_mating=num_parents_mating,
                       sol_per_pop=sol_per_pop,
                       num_genes=num_genes,
                       fitness_func=fitness_func,
                       parent_selection_type='nsga2')

ga_instance.run()

ga_instance.plot_fitness(label=['Obj 1', 'Obj 2'])

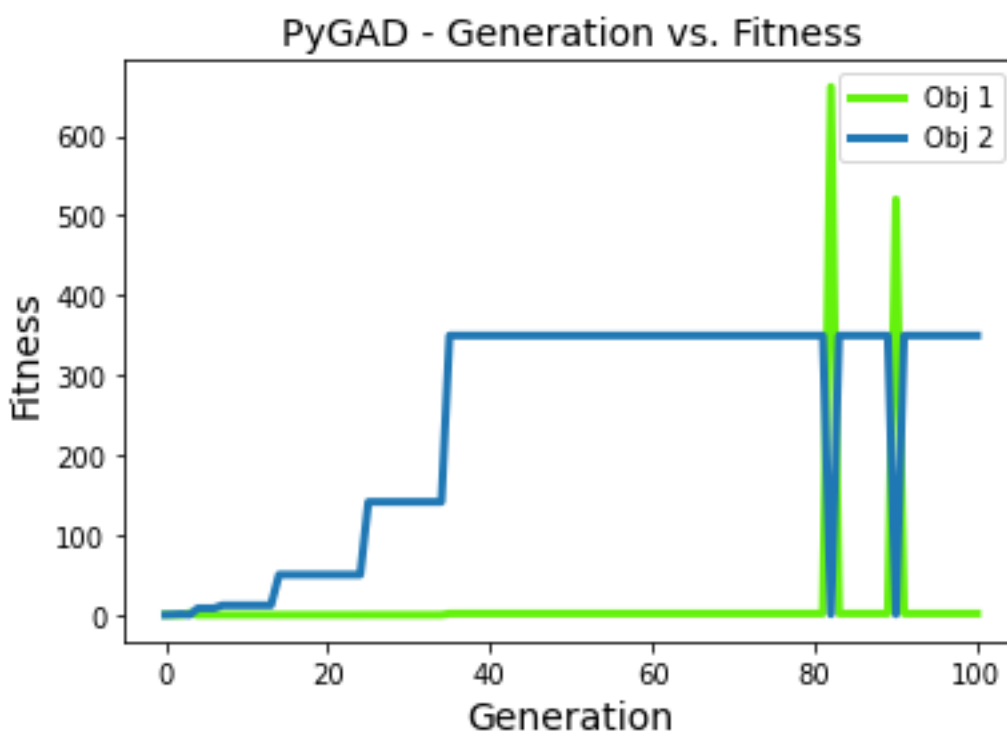
solution, solution_fitness, solution_idx = ga_instance.best_solution(ga_instance.last_
↳ generation_fitness)
print(f"Parameters of the best solution : {solution}")
print(f"Fitness value of the best solution = {solution_fitness}")
```

0

```
prediction = numpy.sum(numpy.array(function_inputs1)*solution)
print(f"Predicted output 1 based on the best solution : {prediction}")
prediction = numpy.sum(numpy.array(function_inputs2)*solution)
print(f"Predicted output 2 based on the best solution : {prediction}")
```

```
Parameters of the best solution : [ 0.79676439 -2.98823386 -4.12677662  5.70539445 -2.
↪02797016 -1.07243922]
Fitness value of the best solution = [ 1.68090829 349.8591915 ]
Predicted output 1 based on the best solution : 50.59491545442283
Predicted output 2 based on the best solution : 29.99714270722312
```

plot\_fitness()



---

fruit.jpg

```
import imageio
import numpy

target_im = imageio.imread('fruit.jpg')
target_im = numpy.asarray(target_im/255, dtype=float)
```



pygad.GA

```
import gari

target_chromosome = gari.img2chromosome(target_im)

def fitness_fun(ga_instance, solution, solution_idx):
    fitness = numpy.sum(numpy.abs(target_chromosome-solution))

    # Negating the fitness value to make it increasing rather than decreasing.
    fitness = numpy.sum(target_chromosome) - fitness
    return fitness
```

gari.img2chromosome()

gari

---

```
import numpy
import functools
import operator

def img2chromosome(img_arr):
    return numpy.reshape(a=img_arr, newshape=(functools.reduce(operator.mul, img_arr.
↵shape)))

def chromosome2img(vector, shape):
    if len(vector) != functools.reduce(operator.mul, shape):
        raise ValueError(f"A vector of length {len(vector)} into an array of shape
↵{shape}.")

    return numpy.reshape(a=vector, newshape=shape)
```

## pygad.GA

```
mutation_by_replacement=True,init_range_low=init_range_high=ran-
dom_mutation_min_val=random_mutation_max_val

init_range_low=random_mutation_min_val,init_range_high=random_mutation_max_val
,
```

```
import pygad

ga_instance = pygad.GA(num_generations=20000,
                        num_parents_mating=10,
                        fitness_func=fitness_fun,
                        sol_per_pop=20,
                        num_genes=target_im.size,
                        init_range_low=0.0,
                        init_range_high=1.0,
                        mutation_percent_genes=0.01,
                        mutation_type="random",
                        mutation_by_replacement=True,
                        random_mutation_min_val=0.0,
                        random_mutation_max_val=1.0)
```

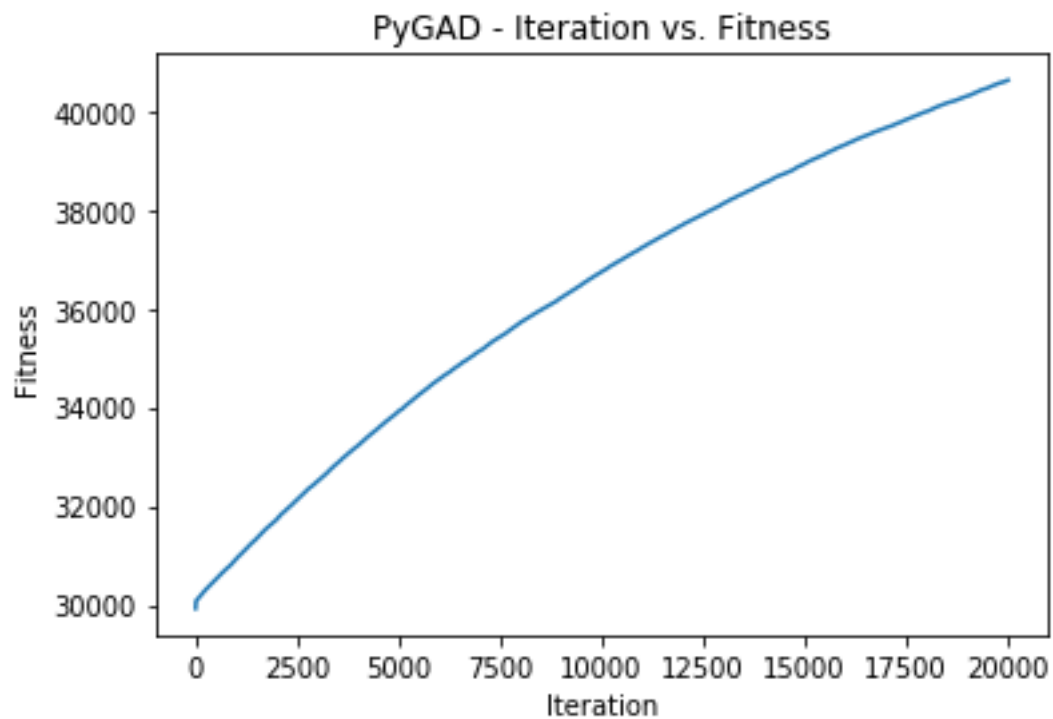
---

```
run()
```

```
ga_instance.run()
```

```
run()plot_fitness()
```

```
ga_instance.plot_fitness()
```



```
# Returning the details of the best solution.
solution, solution_fitness, solution_idx = ga_instance.best_solution()
print(f"Fitness value of the best solution = {solution_fitness}")
print(f"Index of the best solution : {solution_idx}")

if ga_instance.best_solution_generation != -1:
    print(f"Best fitness value reached after {ga_instance.best_solution_generation} ↵
    ↵generations.")

result = gari.chromosome2img(solution, target_im.shape)
matplotlib.pyplot.imshow(result)
```

```
matplotlib.pyplot.title("PyGAD & GARI for Reproducing Images")  
matplotlib.pyplot.show()
```



pygad.GA









---

---

---

().

fitness

```
def fitness_func(ga_instance, solution, solution_idx):  
    ...  
    return fitness
```

list

tuple

numpy.ndarray

```
def fitness_func(ga_instance, solution, solution_idx):  
    ...  
    return [fitness1, fitness2, ..., fitnessN]
```

nsga2

tournament\_nsga2

$y_1 = f(w_1:w_6) = w_1x_1 + w_2x_2 + w_3x_3 + w_4x_4 + w_5x_5 + 6w_6x_6$

$y_2 = f(w_1:w_6) = w_1x_7 + w_2x_8 + w_3x_9 + w_4x_{10} + w_5x_{11} + 6w_6x_{12}$

$(x_1, x_2, x_3, x_4, x_5, x_6) = (4, -2, 3.5, 5, -11, -4.7)$   $y=50$

$(x_7, x_8, x_9, x_{10}, x_{11}, x_{12}) = (-2, 0.7, -9, 1.4, 3, 5)$   $y=30$

---

---

() w1 w6

y1y2

```
import pygad
import numpy

"""
Given these 2 functions:
    y1 = f(w1:w6) = w1x1 + w2x2 + w3x3 + w4x4 + w5x5 + 6wx6
    y2 = f(w1:w6) = w1x7 + w2x8 + w3x9 + w4x10 + w5x11 + 6wx12
    where (x1,x2,x3,x4,x5,x6)=(4,-2,3.5,5,-11,-4.7) and y=50
    and   (x7,x8,x9,x10,x11,x12)=(-2,0.7,-9,1.4,3,5) and y=30
What are the best values for the 6 weights (w1 to w6)? We are going to use the
↳genetic algorithm to optimize these 2 functions.
This is a multi-objective optimization problem.

PyGAD considers the problem as multi-objective if the fitness function returns:
    1) List.
    2) Or tuple.
    3) Or numpy.ndarray.
"""

function_inputs1 = [4,-2,3.5,5,-11,-4.7] # Function 1 inputs.
function_inputs2 = [-2,0.7,-9,1.4,3,5] # Function 2 inputs.
desired_output1 = 50 # Function 1 output.
desired_output2 = 30 # Function 2 output.

def fitness_func(ga_instance, solution, solution_idx):
    output1 = numpy.sum(solution*function_inputs1)
    output2 = numpy.sum(solution*function_inputs2)
    fitness1 = 1.0 / (numpy.abs(output1 - desired_output1) + 0.000001)
    fitness2 = 1.0 / (numpy.abs(output2 - desired_output2) + 0.000001)
    return [fitness1, fitness2]

num_generations = 100
num_parents_mating = 10

sol_per_pop = 20
num_genes = len(function_inputs1)

ga_instance = pygad.GA(num_generations=num_generations,
                       num_parents_mating=num_parents_mating,
                       sol_per_pop=sol_per_pop,
                       num_genes=num_genes,
                       fitness_func=fitness_func,
                       parent_selection_type='nsga2')

ga_instance.run()

ga_instance.plot_fitness(label=['Obj 1', 'Obj 2'])

solution, solution_fitness, solution_idx = ga_instance.best_solution(ga_instance.last_
↳generation_fitness)
print(f"Parameters of the best solution : {solution}")
print(f"Fitness value of the best solution = {solution_fitness}")

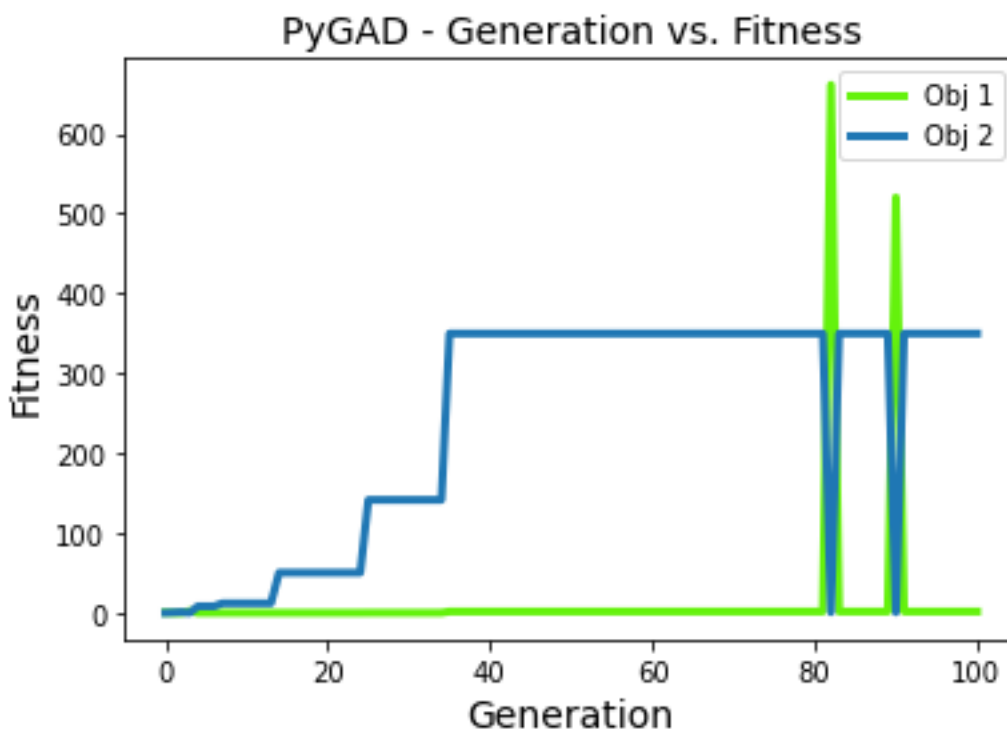
prediction = numpy.sum(numpy.array(function_inputs1)*solution)
```

0

```
print(f"Predicted output 1 based on the best solution : {prediction}")
prediction = numpy.sum(numpy.array(function_inputs2)*solution)
print(f"Predicted output 2 based on the best solution : {prediction}")
```

```
Parameters of the best solution : [ 0.79676439 -2.98823386 -4.12677662  5.70539445 -2.
→02797016 -1.07243922]
Fitness value of the best solution = [ 1.68090829 349.8591915 ]
Predicted output 1 based on the best solution : 50.59491545442283
Predicted output 2 based on the best solution : 29.99714270722312
```

plot\_fitness()



## gene\_space

```
gene_space' gene_space
gene_space
[0.4, 12, -5, 21.2]
[-2, 0.3]
[1.2, 63.2, 7.4]
gene_space
```

gene\_space

---

```
gene_space = [[0.4, 12, -5, 21.2],
               [-2, 0.3],
               [1.2, 63.2, 7.4]]
```

```
gene_space
```

```
gene_space = [33, 7, 0.5, 95. 6.3, 0.74]
```

```
range()range(1, 7)1, 2, 3, 4, 5, and 6numpy.arange()numpy.linspace()
```

```
gene_space
```

```
()
```

```
    'low'
```

```
    'high'
```

```
{'low': 1,
  'high': 5}
```

```
'low''high'
```

```
()().
```

```
gene_space = [{'low': 1, 'high': 5}, {'low': 0.3, 'high': 1.4}, {'low': -0.2, 'high': -4.5}]
```

## gene\_space

```
gene_space
```

```
gene_spacegene_space
```

```
gene_space = [0.3, 5.2, -4, 8]
```

```
gene_space
```

```
    (intfloatNumPy):
```

```
    listtuplenumpy.ndarrayrangenumPy.arange()numpy.linspace
```

```
    dict"low""high""step""low""high""step"().
```

```
    None:          Noneinit_range_lowinit_range_highrandom_mutation_min_valran-
    dom_mutation_max_valgene_spaceNone
```

```
gene_space
```

```
[0.4, -5][0.5, -3.2, 8.8, -9]
```

```
gene_space = [[0.4, -5], [0.5, -3.2, 8.2, -9]]
```

```
gene_space = [range(5), range(10, 20)]
```

```
gene_space
```

---

---

```
gene_space = numpy.arange(15)
```

```
gene_space
```

```
gene_space = {"low": 4, "high": 30}
```

```
gene_space = {"low": 4, "high": 30, "step": 2.5}
```

```
dict{"low": 0, "high": 10}gene_space() 010109.9999[float, 2]
Noneinit_range_lowinit_range_highpygad.GA' random_mutation_min_valran-
dom_mutation_max_valNone
```

```
gene_space = [range(5), None, numpy.linspace(10, 20, 300)]
```

```
initial_populationgene_space
```

## gene\_space

```
gene_space
```

```
gene_spaceintfloat
```

```
gene_space[1, 2, 3]
```

```
Gene space: [[1, 2, 3],
              None]
Solution: [1, 5]
```

```
[1, 5]().
```

```
None
```

```
random_mutation_min_valrandom_mutation_max_val
,
```

```
-0.5
```

```
gene_space
```

```
gene_space{'low': 1, 'high': 5}
```

```
Gene space: {'low': 1, 'high': 5}
Solution: [1.5, 3.4]
```

```
random_mutation_min_val=-1random_mutation_max_val=10.3() 1.51.5+0.3=1.8
```

```
Gene space: {'low': 1, 'high': 5, 'step': 0.5}
```

---

## gene\_space

---

```
"stop"on_generationnon_generationpygad.GA'
num_generationspygad.GA
"stop"
```

```
def func_generation(ga_instance):
    if ga_instance.best_solution()[1] >= 70:
        return "stop"
```

```
stop_criteriapygad.GA
str
```

```
"word_num"
```

```
reachsaturnate
reachrun() reach"reach_40">
saturatesaturate"saturate_7"run()
127.415
```

```
import pygad
import numpy

equation_inputs = [4, -2, 3.5, 8, 9, 4]
desired_output = 44

def fitness_func(ga_instance, solution, solution_idx):
    output = numpy.sum(solution * equation_inputs)

    fitness = 1.0 / (numpy.abs(output - desired_output) + 0.000001)

    return fitness

ga_instance = pygad.GA(num_generations=200,
                       sol_per_pop=10,
                       num_parents_mating=4,
                       num_genes=len(equation_inputs),
                       fitness_func=fitness_func,
                       stop_criteria=["reach_127.4", "saturate_15"])

ga_instance.run()
print(f"Number of generations passed is {ga_instance.generations_completed}")
```

---



---

```
keep_elitism() 1
keep_elitismpygad.GA
```

```
import numpy
import pygad

function_inputs = [4,-2,3.5,5,-11,-4.7]
desired_output = 44

def fitness_func(ga_instance, solution, solution_idx):
    output = numpy.sum(solution*function_inputs)
    fitness = 1.0 / numpy.abs(output - desired_output)
    return fitness

ga_instance = pygad.GA(num_generations=2,
                       num_parents_mating=3,
                       fitness_func=fitness_func,
                       num_genes=6,
                       sol_per_pop=5,
                       keep_elitism=2)

ga_instance.run()
```

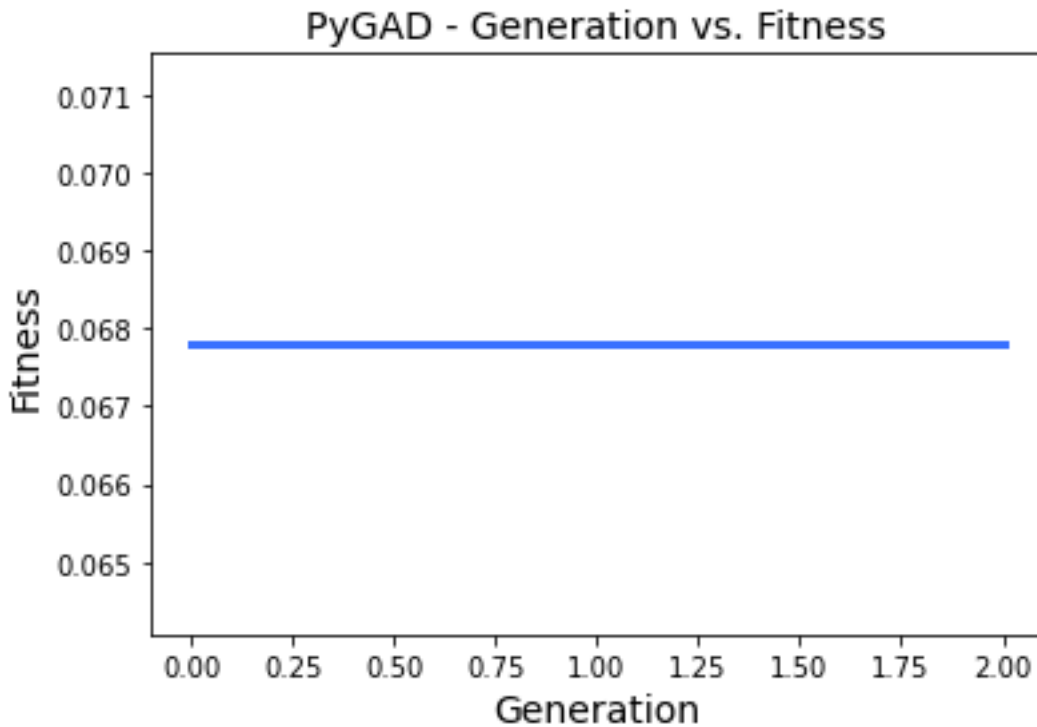
```
keep_elitism
    >= 0
    <= sol_per_pop
keep_elitismsol_per_pop
```

```
...

ga_instance = pygad.GA(...,
                       sol_per_pop=5,
                       keep_elitism=5)

ga_instance.run()
```

---



`keep_elitism(), keep_parentskeep_elitismkeep_parentskeep_parentskeep_elitism=0`

`random_seed`

`random_seedNone`

```
import numpy
import pygad

function_inputs = [4,-2,3.5,5,-11,-4.7]
desired_output = 44

def fitness_func(ga_instance, solution, solution_idx):
    output = numpy.sum(solution*function_inputs)
    fitness = 1.0 / numpy.abs(output - desired_output)
    return fitness

ga_instance = pygad.GA(num_generations=2,
                       num_parents_mating=3,
                       fitness_func=fitness_func,
                       sol_per_pop=5,
```

---

()

```
num_genes=6,
random_seed=2)

ga_instance.run()
best_solution, best_solution_fitness, best_match_idx = ga_instance.best_solution()
print(best_solution)
print(best_solution_fitness)
```

```
[ 2.77249188 -4.06570662  0.04196872 -3.47770796 -0.57502138 -3.22775267]
0.04872203136549972
```

```
[ 2.77249188 -4.06570662  0.04196872 -3.47770796 -0.57502138 -3.22775267]
0.04872203136549972
```

```
run()

self.best_solutions
self.best_solutions_fitness
self.solutions
self.solutions_fitness
```

```
save()
```

```
import pygad

def fitness_func(ga_instance, solution, solution_idx):
    ...
    return fitness

ga_instance = pygad.GA(...)
ga_instance.run()
ga_instance.plot_fitness()
ga_instance.save("pygad_GA")
```

```
load() run()
```

```
import pygad

def fitness_func(ga_instance, solution, solution_idx):
    ...
    return fitness

loaded_ga_instance = pygad.load("pygad_GA")
loaded_ga_instance.run()
```

()

---

---

)

```
loaded_ga_instance.plot_fitness()
```

```
plot_fitness()
```

```
(self.best_solutions self.best_solutions_fitness) save_best_solutionsTrue(self.  
solutions self.solutions_fitness) save_solutionsTrue
```

```
population
```

```
num_offspring
```

```
num_parents_mating
```

```
fitness_func
```

```
sol_per_poppopulation
```

```
last_generation_*
```

```
    last_generation_fitness
```

```
    last_generation_parentslast_generation_parents_indices
```

```
    last_generation_elitismlast_generation_elitism_indiceskeep_elitism != 0
```

```
    keep_elitism
```

```
pop_size
```

```
allow_duplicate_genes
```

```
allow_duplicate_genes=True(), allow_duplicate_genes=False
```

```
allow_duplicate_genes
```

```
import pygad
```

```
def fitness_func(ga_instance, solution, solution_idx):  
    return 0
```

```
def on_generation(ga):  
    print("Generation", ga.generations_completed)  
    print(ga.population)
```

)

---

()

```
ga_instance = pygad.GA(num_generations=5,
                        sol_per_pop=5,
                        num_genes=4,
                        mutation_num_genes=3,
                        random_mutation_min_val=-5,
                        random_mutation_max_val=5,
                        num_parents_mating=2,
                        fitness_func=fitness_func,
                        gene_type=int,
                        on_generation=on_generation,
                        allow_duplicate_genes=False)

ga_instance.run()
```

```
Generation 1
[[ 2 -2 -3  3]
 [ 0  1  2  3]
 [ 5 -3  6  3]
 [-3  1 -2  4]
 [-1  0 -2  3]]
Generation 2
[[-1  0 -2  3]
 [-3  1 -2  4]
 [ 0 -3 -2  6]
 [-3  0 -2  3]
 [ 1 -4  2  4]]
Generation 3
[[ 1 -4  2  4]
 [-3  0 -2  3]
 [ 4  0 -2  1]
 [-4  0 -2 -3]
 [-4  2  0  3]]
Generation 4
[[-4  2  0  3]
 [-4  0 -2 -3]
 [-2  5  4 -3]
 [-1  2 -4  4]
 [-4  2  0 -3]]
Generation 5
[[-4  2  0 -3]
 [-1  2 -4  4]
 [ 3  4 -4  0]
 [-1  0  2 -2]
 [-4  2 -1  1]]
```

allow\_duplicate\_genesgene\_space().

```
import pygad

def fitness_func(ga_instance, solution, solution_idx):
    return 0

def on_generation(ga):
    print("Generation", ga.generations_completed)
    print(ga.population)
```

()

---

)

```
ga_instance = pygad.GA(num_generations=1,
                        sol_per_pop=5,
                        num_genes=4,
                        num_parents_mating=2,
                        fitness_func=fitness_func,
                        gene_type=int,
                        gene_space=[[1, 2, 3, 4], [1, 2, 3, 4], [1, 2, 3, 4], [1, 2, 3,
→ 4]],
                        on_generation=on_generation,
                        allow_duplicate_genes=False)
ga_instance.run()
```

Generation 1

```
[[2 3 1 4]
 [2 3 1 4]
 [2 4 1 3]
 [2 3 1 4]
 [1 3 2 4]]
```

Generation 2

```
[[1 3 2 4]
 [2 3 1 4]
 [1 3 2 4]
 [2 3 4 1]
 [1 3 4 2]]
```

Generation 3

```
[[1 3 4 2]
 [2 3 4 1]
 [1 3 4 2]
 [3 1 4 2]
 [3 2 4 1]]
```

Generation 4

```
[[3 2 4 1]
 [3 1 4 2]
 [3 2 4 1]
 [1 2 4 3]
 [1 3 4 2]]
```

Generation 5

```
[[1 3 4 2]
 [1 2 4 3]
 [2 1 4 3]
 [1 2 4 3]
 [1 2 4 3]]
```

```
gene_space=[[3, 0, 1], [4, 1, 2], [0, 2], [3, 2, 0]][3 2 0 0]
[3 4 2 0]
```

---

---

```
allow_duplicate_genes=Falsegene_space
```

```
,
```

```
Gene space: [[2, 3],  
             [3, 4],  
             [4, 5],  
             [5, 6]]  
Solution: [3, 4, 4, 5]
```

```
[3, 4][4, 5]
```

```
[3, 4, 4, 5]
```

```
' [3, 4]
```

```
[]
```

```
[]
```

---

---

```
Gene space: [[0, 1],
             [1, 2],
             [2, 3],
             [3, 4]]
Solution: [1, 2, 2, 3]
```

```
[]
[]
```

## gene\_type

gene\_typegene\_typefloatgene\_type

,

gene\_typeint

```
gene_type=int
```

'intfloatNumPygene\_type

float

int

```
import pygad
import numpy

equation_inputs = [4, -2, 3.5, 8, -2]
desired_output = 2671.1234

def fitness_func(ga_instance, solution, solution_idx):
    output = numpy.sum(solution * equation_inputs)
    fitness = 1.0 / (numpy.abs(output - desired_output) + 0.000001)
    return fitness

ga_instance = pygad.GA(num_generations=10,
                       sol_per_pop=5,
                       num_parents_mating=2,
                       num_genes=len(equation_inputs),
                       fitness_func=fitness_func,
                       gene_type=int)

print("Initial Population")
print(ga_instance.initial_population)

ga_instance.run()
```

()

---



0

```
print("Final Population")
print(ga_instance.population)
```

Initial Population

```
[[ 1 -1  2  0 -3]
 [ 0 -2  0 -3 -1]
 [ 0 -1 -1  2  0]
 [-2  3 -2  3  3]
 [ 0  0  2 -2 -2]]
```

Final Population

```
[[ 1 -1  2  2  0]
 [ 1 -1  2  2  0]
 [ 1 -1  2  2  0]
 [ 1 -1  2  2  0]
 [ 1 -1  2  2  0]]
```

floatfloatfloat

```
gene_type=[float, 3]
```

float

```
import pygad
import numpy
```

```
equation_inputs = [4, -2, 3.5, 8, -2]
desired_output = 2671.1234
```

```
def fitness_func(ga_instance, solution, solution_idx):
    output = numpy.sum(solution * equation_inputs)
    fitness = 1.0 / (numpy.abs(output - desired_output) + 0.000001)

    return fitness
```

```
ga_instance = pygad.GA(num_generations=10,
                        sol_per_pop=5,
                        num_parents_mating=2,
                        num_genes=len(equation_inputs),
                        fitness_func=fitness_func,
                        gene_type=[float, 3])
```

```
print("Initial Population")
print(ga_instance.initial_population)
```

```
ga_instance.run()
```

```
print("Final Population")
print(ga_instance.population)
```

**gene\_type**

```
Initial Population
[[-2.417 -0.487  3.623  2.457 -2.362]
 [-1.231  0.079 -1.63  1.629 -2.637]
 [ 0.692 -2.098  0.705  0.914 -3.633]
 [ 2.637 -1.339 -1.107 -0.781 -3.896]
 [-1.495  1.378 -1.026  3.522  2.379]]
```

```
Final Population
[[ 1.714 -1.024  3.623  3.185 -2.362]
 [ 0.692 -1.024  3.623  3.185 -2.362]
 [ 0.692 -1.024  3.623  3.375 -2.362]
 [ 0.692 -1.024  4.041  3.185 -2.362]
 [ 1.714 -0.644  3.623  3.185 -2.362]]
```

gene\_type=listtuple(numpy.ndarray

```
gene_type=[int, float, numpy.float16, numpy.int8, float]
```

```
import pygad
import numpy

equation_inputs = [4, -2, 3.5, 8, -2]
desired_output = 2671.1234

def fitness_func(ga_instance, solution, solution_idx):
    output = numpy.sum(solution * equation_inputs)
    fitness = 1.0 / (numpy.abs(output - desired_output) + 0.000001)
    return fitness

ga_instance = pygad.GA(num_generations=10,
                        sol_per_pop=5,
                        num_parents_mating=2,
                        num_genes=len(equation_inputs),
                        fitness_func=fitness_func,
                        gene_type=[int, float, numpy.float16, numpy.int8, float])

print("Initial Population")
print(ga_instance.initial_population)

ga_instance.run()

print("Final Population")
print(ga_instance.population)
```

```
Initial Population
[[0 0.8615522360026828 0.7021484375 -2 3.5301821368185866]
 [-3 2.648189378595294 -3.830078125 1 -0.9586271572917742]
 [3 3.7729827570110714 1.2529296875 -3 1.395741994211889]
 [0 1.0490687178053282 1.51953125 -2 0.7243617940450235]
 [0 -0.6550158436937226 -2.861328125 -2 1.8212734549263097]]
```

()

```
Final Population
[[3 3.7729827570110714 2.055 0 0.7243617940450235]
 [3 3.7729827570110714 1.458 0 -0.14638754050305036]
 [3 3.7729827570110714 1.458 0 0.0869406120516778]
 [3 3.7729827570110714 1.458 0 0.7243617940450235]
 [3 3.7729827570110714 1.458 0 -0.14638754050305036]]
```

float

```
gene_type=[int, [float, 2], numpy.float16, numpy.int8, [float, 1]]
```

```
import pygad
import numpy

equation_inputs = [4, -2, 3.5, 8, -2]
desired_output = 2671.1234

def fitness_func(ga_instance, solution, solution_idx):
    output = numpy.sum(solution * equation_inputs)
    fitness = 1.0 / (numpy.abs(output - desired_output) + 0.000001)
    return fitness

ga_instance = pygad.GA(num_generations=10,
                       sol_per_pop=5,
                       num_parents_mating=2,
                       num_genes=len(equation_inputs),
                       fitness_func=fitness_func,
                       gene_type=[int, [float, 2], numpy.float16, numpy.int8, [float, 1]]))

print("Initial Population")
print(ga_instance.initial_population)

ga_instance.run()

print("Final Population")
print(ga_instance.population)
```

```
Initial Population
[[-2 -1.22 1.716796875 -1 0.2]
 [-1 -1.58 -3.091796875 0 -1.3]
 [3 3.35 -0.107421875 1 -3.3]
 [-2 -3.58 -1.779296875 0 0.6]
 [2 -3.73 2.65234375 3 -0.5]]

Final Population
[[2 -4.22 3.47 3 -1.3]
 [2 -3.73 3.47 3 -1.3]
 [2 -4.22 3.47 2 -1.3]]
```

()

**gene\_type**

---

()

```
[2 -4.58 3.47 3 -1.3]
[2 -3.73 3.47 3 -1.3]]
```

()

parallel\_processingpygad.GA

```
import pygad
...
ga_instance = pygad.GA(...,
                        parallel_processing=...)
...
```

parallel\_processing

None()

(

listtuple

'process' 'thread'

0parallel\_processing=None

Noneconcurrent.futures module

parallel\_processing

parallel\_processing=4

---

---

```
parallel_processing=["thread", 5]parallel_processing=5
parallel_processing=["process", 8]
parallel_processing=["process", 0]parallel_processing=None
```

```
forpygad.GAparallel_processing=None
```

```
import pygad
import time

def fitness_func(ga_instance, solution, solution_idx):
    for _ in range(99):
        pass
    return 0

ga_instance = pygad.GA(num_generations=9999,
                       num_parents_mating=3,
                       sol_per_pop=5,
                       num_genes=10,
                       fitness_func=fitness_func,
                       suppress_warnings=True,
                       parallel_processing=None)

if __name__ == '__main__':
    t1 = time.time()

    ga_instance.run()

    t2 = time.time()
    print("Time is", t2-t1)
```

```
1.5
```

```
' 5
```

```
...
ga_instance = pygad.GA(...,
                       parallel_processing=5)
...
```

```
99
```

```
...
ga_instance = pygad.GA(num_generations=99,
                       ...,
                       parallel_processing=["process", 5])
...
```

---

---

```
import pygad
import time

def fitness_func(ga_instance, solution, solution_idx):
    for _ in range(99999999):
        pass
    return 0

ga_instance = pygad.GA(num_generations=5,
                       num_parents_mating=3,
                       sol_per_pop=5,
                       num_genes=10,
                       fitness_func=fitness_func,
                       suppress_warnings=True,
                       parallel_processing=None)

if __name__ == '__main__':
    t1 = time.time()
    ga_instance.run()
    t2 = time.time()
    print("Time is", t2-t1)
```

```
...
ga_instance = pygad.GA(...,
                       parallel_processing=["process", 10])
...
```

```
...
ga_instance = pygad.GA(...,
                       parallel_processing=["thread", 10])
...
```

summary()

```
line_length=70
fill_character=" "
line_character="-"
line_character2="="
columns_equal_len=False
```

---

```

print_step_parameters=Trueprint_step_parameters=False
print_parameters_summary=True

print_parameters_summary=Trueprint_step_parameters=False

```

```

import pygad
import numpy

function_inputs = [4,-2,3.5,5,-11,-4.7]
desired_output = 44

def genetic_fitness(solution, solution_idx):
    output = numpy.sum(solution*function_inputs)
    fitness = 1.0 / (numpy.abs(output - desired_output) + 0.000001)
    return fitness

def on_gen(ga):
    pass

def on_crossover_callback(a, b):
    pass

ga_instance = pygad.GA(num_generations=100,
                       num_parents_mating=10,
                       sol_per_pop=20,
                       num_genes=len(function_inputs),
                       on_crossover=on_crossover_callback,
                       on_generation=on_gen,
                       parallel_processing=2,
                       stop_criteria="reach_10",
                       fitness_batch_size=4,
                       crossover_probability=0.4,
                       fitness_func=genetic_fitness)

```

```
summary()on_crossover_callback()on_gen()
```

```
ga_instance.summary()
```

```

-----
                        PyGAD Lifecycle
=====
Step                        Handler                        Output Shape
=====
Fitness Function            genetic_fitness()            (1)
Fitness batch size: 4
-----
Parent Selection            steady_state_selection()      (10, 6)
Number of Parents: 10
-----
Crossover                   single_point_crossover()      (10, 6)
Crossover probability: 0.4
-----
On Crossover                on_crossover_callback()       None
-----
Mutation                    random_mutation()             (10, 6)
Mutation Genes: 1

```

0

```
Random Mutation Range: (-1.0, 1.0)
Mutation by Replacement: False
Allow Duplicated Genes: True
```

```
-----
On Generation          on_gen()                      None
Stop Criteria: [['reach', 10.0]]
-----
```

```
=====
Population Size: (20, 6)
Number of Generations: 100
Initial Population Range: (-4, 4)
Keep Elitism: 1
Gene DType: [<class 'float'>, None]
Parallel Processing: ['thread', 2]
Save Best Solutions: False
Save Solutions: False
=====
```

```
print_step_parametersprint_parameters_summaryFalse
```

```
ga_instance.summary(print_step_parameters=False,
                    print_parameters_summary=False)
```

PyGAD Lifecycle		
Step	Handler	Output Shape
Fitness Function	genetic_fitness()	(1)
Parent Selection	steady_state_selection()	(10, 6)
Crossover	single_point_crossover()	(10, 6)
On Crossover	on_crossover_callback()	None
Mutation	random_mutation()	(10, 6)
On Generation	on_gen()	None

```
print() logger
```

```
import logging

logger = ...

ga_instance = pygad.GA(...,
                      logger=logger,
                      ...)
```



---

```
None(logger=None), print ()  
print ()
```

```
    Handler  
    Formatter  
logging
```

```
import logging  
  
# Create a logger  
logger = logging.getLogger(__name__)  
  
# Set the logger level to debug so that all the messages are printed.  
logger.setLevel(logging.DEBUG)  
  
# Create a stream handler to log the messages to the console.  
stream_handler = logging.StreamHandler()  
  
# Set the handler level to debug.  
stream_handler.setLevel(logging.DEBUG)  
  
# Create a formatter  
formatter = logging.Formatter('%(message)s')  
  
# Add the formatter to handler.  
stream_handler.setFormatter(formatter)  
  
# Add the stream handler to the logger  
logger.addHandler(stream_handler)
```

```
Formatter
```

```
logger.debug('Debug message.')  
logger.info('Info message.')  
logger.warning('Warn message.')  
logger.error('Error message.')  
logger.critical('Critical message.')
```

```
print ()
```

```
Debug message.  
Info message.  
Warn message.  
Error message.  
Critical message.
```

```
formatter = logging.Formatter('%(asctime)s %(levelname)s: %(message)s', datefmt='%Y-  
↪%m-%d %H:%M:%S')
```

---

---

```
2023-04-03 18:46:27 DEBUG: Debug message.
2023-04-03 18:46:27 INFO: Info message.
2023-04-03 18:46:27 WARNING: Warn message.
2023-04-03 18:46:27 ERROR: Error message.
2023-04-03 18:46:27 CRITICAL: Critical message.
```

```
logger.handlers.clear()
```

logfile.txt

```
import logging

level = logging.DEBUG
name = 'logfile.txt'

logger = logging.getLogger(name)
logger.setLevel(level)

file_handler = logging.FileHandler(name, 'a+', 'utf-8')
file_handler.setLevel(logging.DEBUG)
file_format = logging.Formatter('%(asctime)s %(levelname)s: %(message)s -
↳ %(pathname)s: %(lineno)d', datefmt='%Y-%m-%d %H:%M:%S')
file_handler.setFormatter(file_format)
logger.addHandler(file_handler)
```

```
2023-04-03 18:54:03 DEBUG: Debug message. - c:\users\agad069\desktop\logger\example2.
↳ py:46
2023-04-03 18:54:03 INFO: Info message. - c:\users\agad069\desktop\logger\example2.
↳ py:47
2023-04-03 18:54:03 WARNING: Warn message. - c:\users\agad069\desktop\logger\example2.
↳ py:48
2023-04-03 18:54:03 ERROR: Error message. - c:\users\agad069\desktop\logger\example2.
↳ py:49
2023-04-03 18:54:03 CRITICAL: Critical message. - c:\users\agad069\desktop\logger\
↳ example2.py:50
```

```
logger.handlers.clear()
```

---

---

```
import logging

level = logging.DEBUG
name = 'logfile.txt'

logger = logging.getLogger(name)
logger.setLevel(level)

file_handler = logging.FileHandler(name, 'a+', 'utf-8')
file_handler.setLevel(logging.DEBUG)
file_format = logging.Formatter('%(asctime)s %(levelname)s: %(message)s -
↳ %(pathname)s: %(lineno)d', datefmt='%Y-%m-%d %H:%M:%S')
file_handler.setFormatter(file_format)
logger.addHandler(file_handler)

console_handler = logging.StreamHandler()
console_handler.setLevel(logging.INFO)
console_format = logging.Formatter('%(message)s')
console_handler.setFormatter(console_format)
logger.addHandler(console_handler)
```

logfile.txt

```
logger.handlers.clear()
```

logger

```
import logging
import pygad
import numpy

level = logging.DEBUG
name = 'logfile.txt'

logger = logging.getLogger(name)
logger.setLevel(level)

file_handler = logging.FileHandler(name, 'a+', 'utf-8')
file_handler.setLevel(logging.DEBUG)
file_format = logging.Formatter('%(asctime)s %(levelname)s: %(message)s', datefmt='%Y-
↳ %m-%d %H:%M:%S')
file_handler.setFormatter(file_format)
logger.addHandler(file_handler)

console_handler = logging.StreamHandler()
```

)

```
console_handler.setLevel(logging.INFO)
console_format = logging.Formatter('%(message)s')
console_handler.setFormatter(console_format)
logger.addHandler(console_handler)

equation_inputs = [4, -2, 8]
desired_output = 2671.1234

def fitness_func(ga_instance, solution, solution_idx):
    output = numpy.sum(solution * equation_inputs)
    fitness = 1.0 / (numpy.abs(output - desired_output) + 0.000001)
    return fitness

def on_generation(ga_instance):
    ga_instance.logger.info(f"Generation = {ga_instance.generations_completed}")
    ga_instance.logger.info(f"Fitness      = {ga_instance.best_solution(pop_fitness=ga_
→instance.last_generation_fitness)[1]}")

ga_instance = pygad.GA(num_generations=10,
                       sol_per_pop=40,
                       num_parents_mating=2,
                       keep_parents=2,
                       num_genes=len(equation_inputs),
                       fitness_func=fitness_func,
                       on_generation=on_generation,
                       logger=logger)

ga_instance.run()

logger.handlers.clear()
```

```
2023-04-03 19:04:27 INFO: Generation = 1
2023-04-03 19:04:27 INFO: Fitness      = 0.00038086960368076276
2023-04-03 19:04:27 INFO: Generation = 2
2023-04-03 19:04:27 INFO: Fitness      = 0.00038214871408010853
2023-04-03 19:04:27 INFO: Generation = 3
2023-04-03 19:04:27 INFO: Fitness      = 0.0003832795907974678
2023-04-03 19:04:27 INFO: Generation = 4
2023-04-03 19:04:27 INFO: Fitness      = 0.00038398612055017196
2023-04-03 19:04:27 INFO: Generation = 5
2023-04-03 19:04:27 INFO: Fitness      = 0.00038442348890867516
2023-04-03 19:04:27 INFO: Generation = 6
2023-04-03 19:04:27 INFO: Fitness      = 0.0003854406039137763
2023-04-03 19:04:27 INFO: Generation = 7
2023-04-03 19:04:27 INFO: Fitness      = 0.00038646083174063284
2023-04-03 19:04:27 INFO: Generation = 8
2023-04-03 19:04:27 INFO: Fitness      = 0.0003875169193024936
2023-04-03 19:04:27 INFO: Generation = 9
2023-04-03 19:04:27 INFO: Fitness      = 0.0003888816727311021
2023-04-03 19:04:27 INFO: Generation = 10
2023-04-03 19:04:27 INFO: Fitness      = 0.000389832593101348
```

---

```
solutionssave_solutions=True
best_solutionssave_best_solutions=True
last_generation_elitismkeep_elitism>
last_generation_parentskeep_parents> keep_parents=-1

keep_elisitm=0
keep_parents=0
keep_solutions=False
keep_best_solutions=False
```

```
import pygad
...
ga_instance = pygad.GA(...,
                        keep_elitism=0,
                        keep_parents=0,
                        save_solutions=False,
                        save_best_solutions=False,
                        ...)
```

(> ).

```
pygad.GA
cal_pop_fitness()pygad.GA
```

### **save\_solutions**

```
FalseTruesolutionspygad.GAsolutions
```

---

---

## save\_best\_solutions

FalseTrue

## keep\_elitism

## keep\_parents

-1

keep\_elitism

```
ga_instance = pygad.GA(...,
                        keep_elitism=1,
                        ...)
```

keep\_elitism=1keep\_elitism=2

()).

keep\_elitismkeep\_parentssave\_solutionssave\_best\_solutionsFalse

```
ga_instance = pygad.GA(...,
                        keep_elitism=0,
                        keep_parents=0,
                        save_solutions=False,
                        save_best_solutions=False,
                        ...)
```

fitness\_batch\_sizefitness\_batch\_size

1Nonefitness\_batch\_size1None(),

1 < fitness\_batch\_size <= sol\_per\_popfitness\_batch\_size1 < fitness\_batch\_size <= sol\_per\_popfitness\_batch\_size

---

---

## fitness\_batch\_size

fitness\_batch\_sizeNone().1fitness\_func

```
solution: [ 2.52860734, -0.94178795, 2.97545704, 0.84131987, -3.78447118, 2.41008358]
solution_idx: 3
```

$2020 \times 5 = 10020 \times 5 + 20 = 120$

keep\_elitismkeep\_parents0

```
import pygad
import numpy

function_inputs = [4,-2,3.5,5,-11,-4.7]
desired_output = 44

number_of_calls = 0

def fitness_func(ga_instance, solution, solution_idx):
    global number_of_calls
    number_of_calls = number_of_calls + 1
    output = numpy.sum(solution*function_inputs)
    fitness = 1.0 / (numpy.abs(output - desired_output) + 0.000001)
    return fitness

ga_instance = pygad.GA(num_generations=5,
                       num_parents_mating=10,
                       sol_per_pop=20,
                       fitness_func=fitness_func,
                       fitness_batch_size=None,
                       # fitness_batch_size=1,
                       num_genes=len(function_inputs),
                       keep_elitism=0,
                       keep_parents=0)

ga_instance.run()
print(number_of_calls)
```

120

## fitness\_batch\_size

fitness\_batch\_size44().

```
solutions:
[[ 3.1129432 -0.69123589  1.93792414  2.23772968 -1.54616001 -0.53930799]
 [ 3.38508121  0.19890812  1.93792414  2.23095014 -3.08955597  3.10194128]
 [ 2.37079504 -0.88819803  2.97545704  1.41742256 -3.95594055  2.45028256]
 [ 2.52860734 -0.94178795  2.97545704  0.84131987 -3.78447118  2.41008358]]
solutions_indices:
[16, 17, 18, 19]
```

---

---

$$20/4 = 5$$

$$5*5 = 255*5 + 5 = 30$$

```
import pygad
import numpy

function_inputs = [4,-2,3.5,5,-11,-4.7]
desired_output = 44

number_of_calls = 0

def fitness_func_batch(ga_instance, solutions, solutions_indices):
    global number_of_calls
    number_of_calls = number_of_calls + 1
    batch_fitness = []
    for solution in solutions:
        output = numpy.sum(solution*function_inputs)
        fitness = 1.0 / (numpy.abs(output - desired_output) + 0.000001)
        batch_fitness.append(fitness)
    return batch_fitness

ga_instance = pygad.GA(num_generations=5,
                       num_parents_mating=10,
                       sol_per_pop=20,
                       fitness_func=fitness_func_batch,
                       fitness_batch_size=4,
                       num_genes=len(function_inputs),
                       keep_elitism=0,
                       keep_parents=0)

ga_instance.run()
print(number_of_calls)
```

30

$$120 - 30 = 90$$

```
fitness_func
on_start
on_fitness
on_parents
on_crossover
on_mutation
on_generation
on_stop
```

---



---

pygad.GA

```
import pygad
import numpy

def fitness_func(ga_instanse, solution, solution_idx):
    return numpy.random.rand()

def on_start(ga_instanse):
    print("on_start")

def on_fitness(ga_instanse, last_gen_fitness):
    print("on_fitness")

def on_parents(ga_instanse, last_gen_parents):
    print("on_parents")

def on_crossover(ga_instanse, last_gen_offspring):
    print("on_crossover")

def on_mutation(ga_instanse, last_gen_offspring):
    print("on_mutation")

def on_generation(ga_instanse):
    print("on_generation\n")

def on_stop(ga_instanse, last_gen_fitness):
    print("on_stop")

ga_instance = pygad.GA(num_generations=5,
                       num_parents_mating=4,
                       sol_per_pop=10,
                       num_genes=2,
                       on_start=on_start,
                       on_fitness=on_fitness,
                       on_parents=on_parents,
                       on_crossover=on_crossover,
                       on_mutation=on_mutation,
                       on_generation=on_generation,
                       on_stop=on_stop,
                       fitness_func=fitness_func)

ga_instance.run()
```

---

Test' Test

selfpygad.GA

```
import pygad
import numpy

class Test:
    def fitness_func(self, ga_instanse, solution, solution_idx):
        return numpy.random.rand()

    def on_start(self, ga_instanse):
        print("on_start")

    def on_fitness(self, ga_instanse, last_gen_fitness):
        print("on_fitness")

    def on_parents(self, ga_instanse, last_gen_parents):
        print("on_parents")

    def on_crossover(self, ga_instanse, last_gen_offspring):
        print("on_crossover")

    def on_mutation(self, ga_instanse, last_gen_offspring):
        print("on_mutation")

    def on_generation(self, ga_instanse):
        print("on_generation\n")

    def on_stop(self, ga_instanse, last_gen_fitness):
        print("on_stop")

ga_instance = pygad.GA(num_generations=5,
                        num_parents_mating=4,
                        sol_per_pop=10,
                        num_genes=2,
                        on_start=Test().on_start,
                        on_fitness=Test().on_fitness,
                        on_parents=Test().on_parents,
                        on_crossover=Test().on_crossover,
                        on_mutation=Test().on_mutation,
                        on_generation=Test().on_generation,
                        on_stop=Test().on_stop,
                        fitness_func=Test().fitness_func)

ga_instance.run()
```

---

---

## **pygad.torchga**

,

```
pygad.utils
    crossoverCrossover
    mutationMutation
    parent_selectionParentSelection
    nsga2NSGA2().
pygad.GApygad.GA
```

## **pygad.utils.crossover**

```
pygad.utils.crossoverCrossover
    single_point_crossover()
    two_points_crossover()
    uniform_crossover()
    scattered_crossover()

    parents
    offspring_size
```

---

---

## pygad.utils.mutation

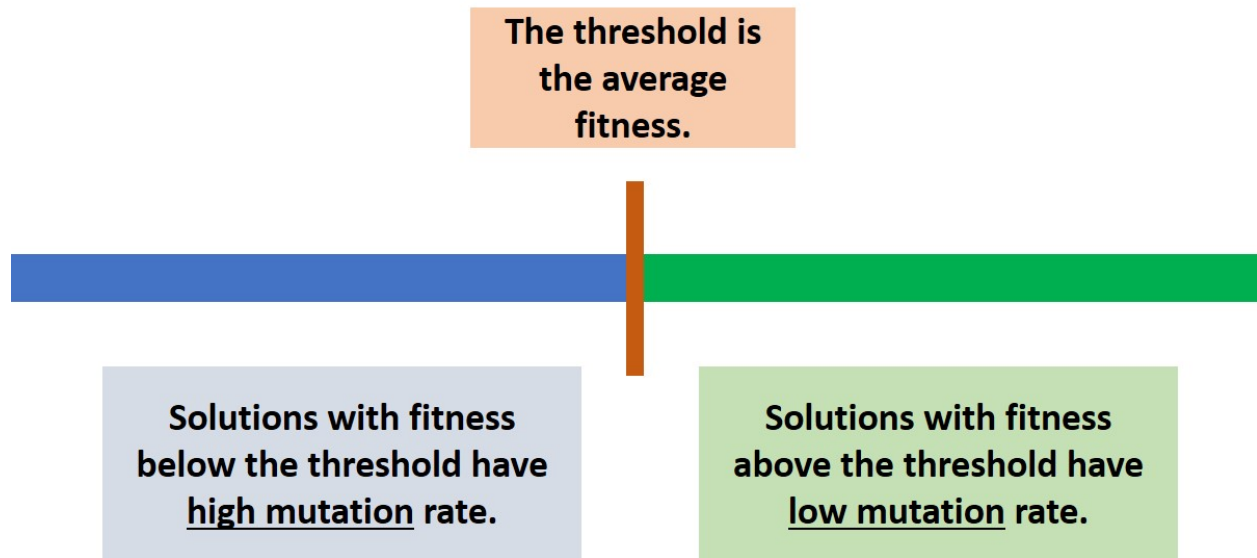
pygad.utils.mutationMutation

```
random_mutation()  
swap_mutation()  
inversion_mutation()  
scramble_mutation()  
adaptive_mutation()
```

```
offspring
```

```
""" ():  
    """
```

```
(f_avg).  
(f).  
f<f_avg  
f>f_avg  
f=f_avg
```



```
pygad.GAmutation_type="adaptive"
```

```
mutation_probabilitymutation_num_genesmutation_percent_genes
```

```
list
```

```
tuple
```

```
numpy.ndarray
```

```
listtuplenumpy.ndarray
```

```
# mutation_probability
mutation_probability = [0.25, 0.1]
mutation_probability = (0.35, 0.17)
mutation_probability = numpy.array([0.15, 0.05])

# mutation_num_genes
mutation_num_genes = [4, 2]
mutation_num_genes = (3, 1)
mutation_num_genes = numpy.array([7, 2])

# mutation_percent_genes
mutation_percent_genes = [25, 12]
```

---

)

```
mutation_percent_genes = (15, 8)
mutation_percent_genes = numpy.array([21, 13])
```

```
mutation_probability = [0.25, 0.1]
```

```
import pygad
import numpy

function_inputs = [4,-2,3.5,5,-11,-4.7] # Function inputs.
desired_output = 44 # Function output.

def fitness_func(ga_instance, solution, solution_idx):
    # The fitness function calculates the sum of products between each input and its_
    ↳corresponding weight.
    output = numpy.sum(solution*function_inputs)
    # The value 0.000001 is used to avoid the Inf value when the denominator numpy.
    ↳abs(output - desired_output) is 0.0.
    fitness = 1.0 / (numpy.abs(output - desired_output) + 0.000001)
    return fitness

# Creating an instance of the GA class inside the ga module. Some parameters are_
    ↳initialized within the constructor.
ga_instance = pygad.GA(num_generations=200,
                       fitness_func=fitness_func,
                       num_parents_mating=10,
                       sol_per_pop=20,
                       num_genes=len(function_inputs),
                       mutation_type="adaptive",
                       mutation_num_genes=(3, 1))

# Running the GA to optimize the parameters of the function.
ga_instance.run()

ga_instance.plot_fitness(title="PyGAD with Adaptive Mutation", linewidth=5)
```

## pygad.utils.parent\_selection

```
pygad.utils.parent_selectionParentSelection
    steady_state_selection()
    roulette_wheel_selection()
    stochastic_universal_selection()
    rank_selection()
    random_selection()
    tournament_selection()
    nsga2_selection()
```

---

---

```
tournament_nsga2_selection()
```

```
fitness
```

```
num_parents
```

## **pygad.utils.nsga2**

```
pygad.utils.nsga2NSGA2
```

```
non_dominated_sorting()
```

```
get_non_dominated_set()
```

```
crowding_distance()
```

```
sort_solutions_nsga2()
```

```
pygad.GA'
```

```
crossover_type
```

```
mutation_type
```

```
parent_selection_type
```

```
import pygad
import numpy

equation_inputs = [4,-2,3.5]
desired_output = 44

def fitness_func(ga_instance, solution, solution_idx):
    output = numpy.sum(solution * equation_inputs)
    fitness = 1.0 / (numpy.abs(output - desired_output) + 0.000001)
    return fitness

ga_instance = pygad.GA(num_generations=10,
                       sol_per_pop=5,
                       num_parents_mating=2,
                       num_genes=len(equation_inputs),
                       fitness_func=fitness_func)

ga_instance.run()
ga_instance.plot_fitness()
```

```
pygad.GA
```

---

().

pygad.GA(population\_size=10, gene\_type=1, gene\_space=1)

```
def crossover_func(parents, offspring_size, ga_instance):
    offspring = []
    ...
    return numpy.array(offspring)
```

()),

```
def crossover_func(parents, offspring_size, ga_instance):
    offspring = []
    idx = 0
    while len(offspring) != offspring_size[0]:
        parent1 = parents[idx % parents.shape[0], :].copy()
        parent2 = parents[(idx + 1) % parents.shape[0], :].copy()

        random_split_point = numpy.random.choice(range(offspring_size[1]))

        parent1[random_split_point:] = parent2[random_split_point:]

        offspring.append(parent1)

        idx += 1

    return numpy.array(offspring)
```

crossover\_type=pygad.CrossoverType.CrossoverTypeOnePoint

```
ga_instance = pygad.GA(num_generations=10,
                        sol_per_pop=5,
                        num_parents_mating=2,
                        num_genes=len(equation_inputs),
                        fitness_func=fitness_func,
                        crossover_type=crossover_func)
```

pygad.GA(population\_size=10, gene\_type=1, gene\_space=1)

---



---

```
def mutation_func(offspring, ga_instance):  
    ...  
    return offspring
```

```
def mutation_func(offspring, ga_instance):  
  
    for chromosome_idx in range(offspring.shape[0]):  
        random_gene_idx = numpy.random.choice(range(offspring.shape[1]))  
  
        offspring[chromosome_idx, random_gene_idx] += numpy.random.random()  
  
    return offspring
```

mutation\_type

```
ga_instance = pygad.GA(num_generations=10,  
                       sol_per_pop=5,  
                       num_parents_mating=2,  
                       num_genes=len(equation_inputs),  
                       fitness_func=fitness_func,  
                       crossover_type=crossover_func,  
                       mutation_type=mutation_func)
```

() gene\_type

gene\_space

mutation\_percent\_genesmutation\_probabilitymutation\_num\_genes

mutation\_by\_replacement

random\_mutation\_min\_valrandom\_mutation\_max\_val

allow\_duplicate\_genes

pygad.GApopulationgene\_typegene\_space

(num\_genes).

numpy.ndarray

---

---

```
def parent_selection_func(fitness, num_parents, ga_instance):
    ...
    return parents, fitness_sorted[:num_parents]
```

num\_parents

```
def parent_selection_func(fitness, num_parents, ga_instance):

    fitness_sorted = sorted(range(len(fitness)), key=lambda k: fitness[k])
    fitness_sorted.reverse()

    parents = numpy.empty((num_parents, ga_instance.population.shape[1]))

    for parent_num in range(num_parents):
        parents[parent_num, :] = ga_instance.population[fitness_sorted[parent_num], :]
        ↪:].copy()

    return parents, numpy.array(fitness_sorted[:num_parents])
```

parent\_selection\_type

```
ga_instance = pygad.GA(num_generations=10,
                        sol_per_pop=5,
                        num_parents_mating=2,
                        num_genes=len(equation_inputs),
                        fitness_func=fitness_func,
                        crossover_type=crossover_func,
                        mutation_type=mutation_func,
                        parent_selection_type=parent_selection_func)
```

```
import pygad
import numpy

equation_inputs = [4,-2,3.5]
desired_output = 44

def fitness_func(ga_instance, solution, solution_idx):
    output = numpy.sum(solution * equation_inputs)

    fitness = 1.0 / (numpy.abs(output - desired_output) + 0.000001)

    return fitness

def parent_selection_func(fitness, num_parents, ga_instance):

    fitness_sorted = sorted(range(len(fitness)), key=lambda k: fitness[k])
    fitness_sorted.reverse()

    parents = numpy.empty((num_parents, ga_instance.population.shape[1]))

    for parent_num in range(num_parents):
        parents[parent_num, :] = ga_instance.population[fitness_sorted[parent_num], ↪
```

0)

---

0

```
→:].copy()

    return parents, numpy.array(fitness_sorted[:num_parents])

def crossover_func(parents, offspring_size, ga_instance):

    offspring = []
    idx = 0
    while len(offspring) != offspring_size[0]:
        parent1 = parents[idx % parents.shape[0], :].copy()
        parent2 = parents[(idx + 1) % parents.shape[0], :].copy()

        random_split_point = numpy.random.choice(range(offspring_size[1]))

        parent1[random_split_point:] = parent2[random_split_point:]

        offspring.append(parent1)

        idx += 1

    return numpy.array(offspring)

def mutation_func(offspring, ga_instance):

    for chromosome_idx in range(offspring.shape[0]):
        random_gene_idx = numpy.random.choice(range(offspring.shape[0]))

        offspring[chromosome_idx, random_gene_idx] += numpy.random.random()

    return offspring

ga_instance = pygad.GA(num_generations=10,
                       sol_per_pop=5,
                       num_parents_mating=2,
                       num_genes=len(equation_inputs),
                       fitness_func=fitness_func,
                       crossover_type=crossover_func,
                       mutation_type=mutation_func,
                       parent_selection_type=parent_selection_func)

ga_instance.run()
ga_instance.plot_fitness()
```

```
import pygad
import numpy

equation_inputs = [4,-2,3.5]
desired_output = 44

class Test:
    def fitness_func(self, ga_instance, solution, solution_idx):
        output = numpy.sum(solution * equation_inputs)

        fitness = 1.0 / (numpy.abs(output - desired_output) + 0.000001)
```

0

```

    return fitness

def parent_selection_func(self, fitness, num_parents, ga_instance):

    fitness_sorted = sorted(range(len(fitness)), key=lambda k: fitness[k])
    fitness_sorted.reverse()

    parents = numpy.empty((num_parents, ga_instance.population.shape[1]))

    for parent_num in range(num_parents):
        parents[parent_num, :] = ga_instance.population[fitness_sorted[parent_
↪num], :].copy()

    return parents, numpy.array(fitness_sorted[:num_parents])

def crossover_func(self, parents, offspring_size, ga_instance):

    offspring = []
    idx = 0
    while len(offspring) != offspring_size[0]:
        parent1 = parents[idx % parents.shape[0], :].copy()
        parent2 = parents[(idx + 1) % parents.shape[0], :].copy()

        random_split_point = numpy.random.choice(range(offspring_size[0]))

        parent1[random_split_point:] = parent2[random_split_point:]

        offspring.append(parent1)

        idx += 1

    return numpy.array(offspring)

def mutation_func(self, offspring, ga_instance):

    for chromosome_idx in range(offspring.shape[0]):
        random_gene_idx = numpy.random.choice(range(offspring.shape[1]))

        offspring[chromosome_idx, random_gene_idx] += numpy.random.random()

    return offspring

ga_instance = pygad.GA(num_generations=10,
                       sol_per_pop=5,
                       num_parents_mating=2,
                       num_genes=len(equation_inputs),
                       fitness_func=Test().fitness_func,
                       parent_selection_type=Test().parent_selection_func,
                       crossover_type=Test().crossover_func,
                       mutation_type=Test().mutation_func)

ga_instance.run()
ga_instance.plot_fitness()

```

---

## pygad.visualize

,

```
plot_fitness()
```

```
plot_genes()
```

```
plot_new_solution_rate()
```

```
save_solutions=True
```

```
import pygad
import numpy

equation_inputs = [4, -2, 3.5, 8, -2, 3.5, 8]
desired_output = 2671.1234

def fitness_func(ga_instance, solution, solution_idx):
    output = numpy.sum(solution * equation_inputs)
    fitness = 1.0 / (numpy.abs(output - desired_output) + 0.000001)
    return fitness

ga_instance = pygad.GA(num_generations=10,
                        sol_per_pop=10,
                        num_parents_mating=5,
                        num_genes=len(equation_inputs),
                        fitness_func=fitness_func,
                        gene_space=[range(1, 10), range(10, 20), range(15, 30),
→range(20, 40), range(25, 50), range(10, 30), range(20, 50)],
                        gene_type=int,
                        save_solutions=True)

ga_instance.run()
```

,

---

---

## **plot\_fitness()**

```
plot_fitness()()
```

```
(),
```

```
    title
```

```
    xlabel
```

```
    ylabel
```

```
    linewidth3
```

```
    font_size14
```

```
    plot_type"plot"(), "scatter", "bar"
```

```
    color"#64f20c"
```

```
    labelNone
```

```
    save_dir
```

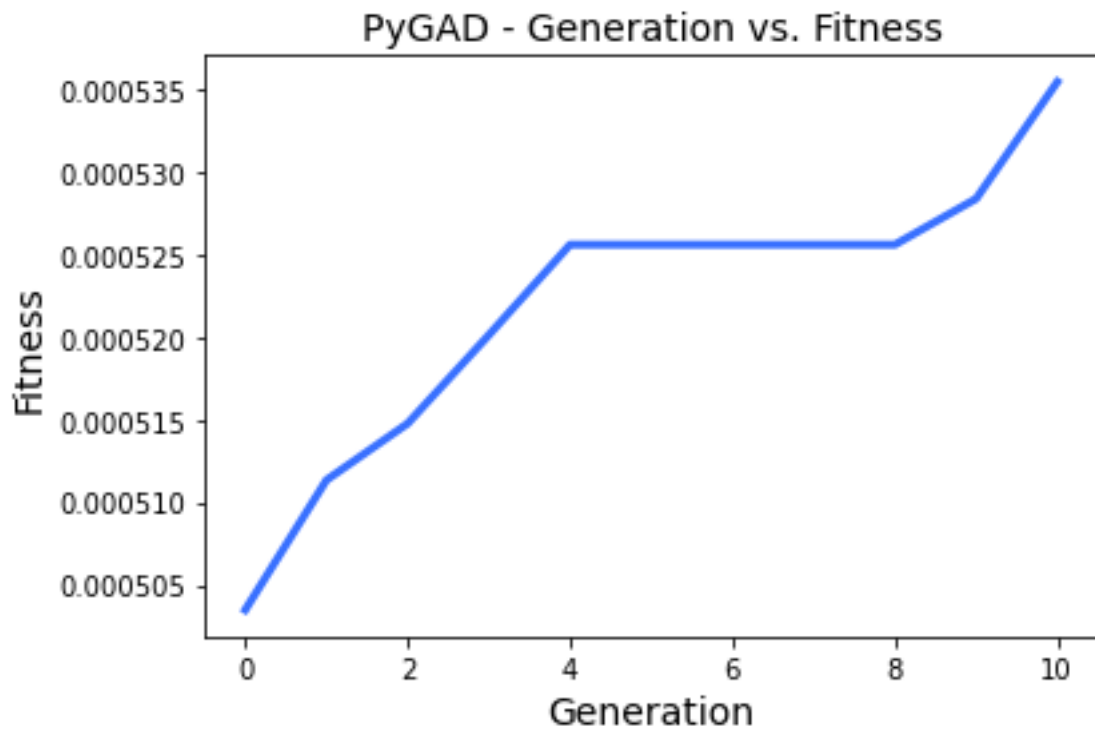
**plot\_type="plot"**

```
plot_type"plot"
```

```
ga_instance.plot_fitness()
```

```
# ga_instance.plot_fitness(plot_type="plot")
```

---

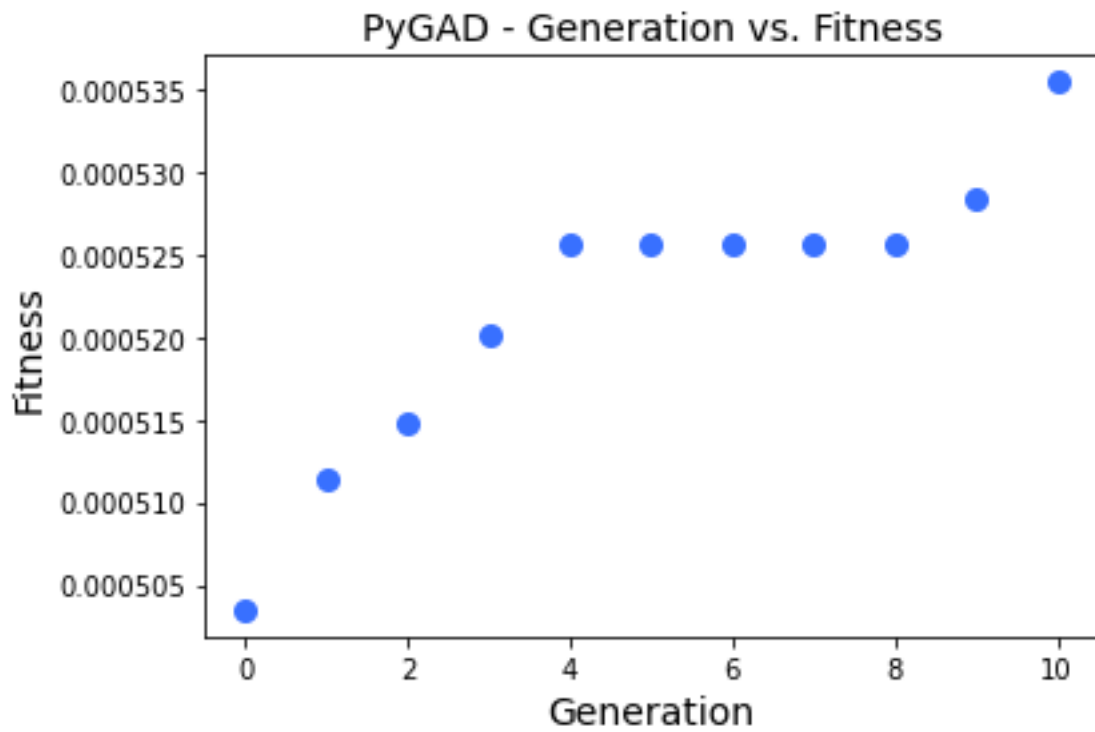


```
plot_type="scatter"
```

```
plot_type"scatter"linewidth
```

```
ga_instance.plot_fitness(plot_type="scatter")
```

---



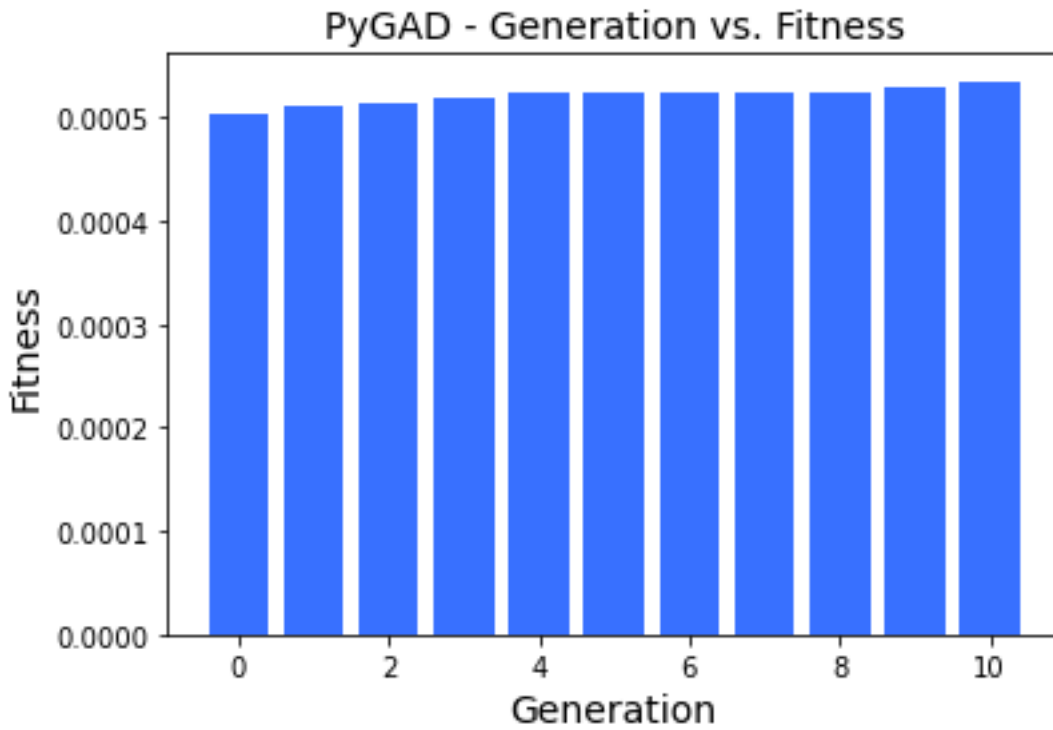
`plot_type="bar"`

`plot_type"bar"`

```
ga_instance.plot_fitness(plot_type="bar")
```

---





**plot\_new\_solution\_rate()**

plot\_new\_solution\_rate()

(),

plot\_new\_solution\_rate()plot\_fitness()(plot\_type).

title

xlabel

ylabel

linewidth3

font\_size14

plot\_type"plot()", "scatter", "bar"

color"#3870FF"

save\_dir

---

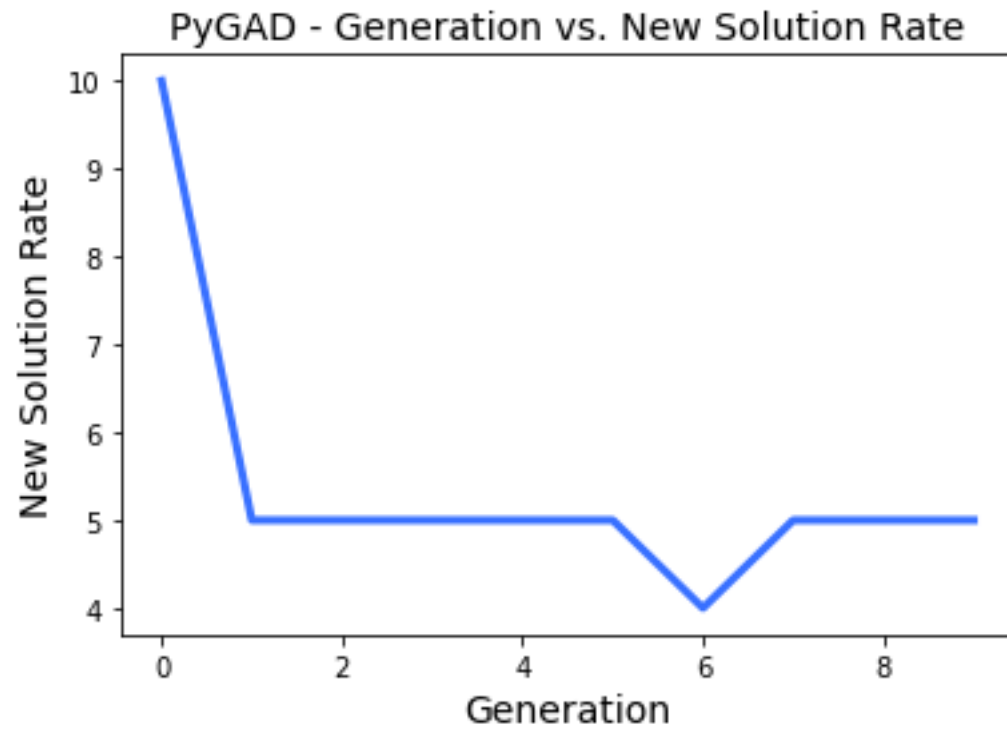
---

```
plot_type="plot"
```

```
plot_type="plot"
```

```
ga_instance.plot_new_solution_rate()  
# ga_instance.plot_new_solution_rate(plot_type="plot")
```

```
(sol_per_poppygad.GA)
```

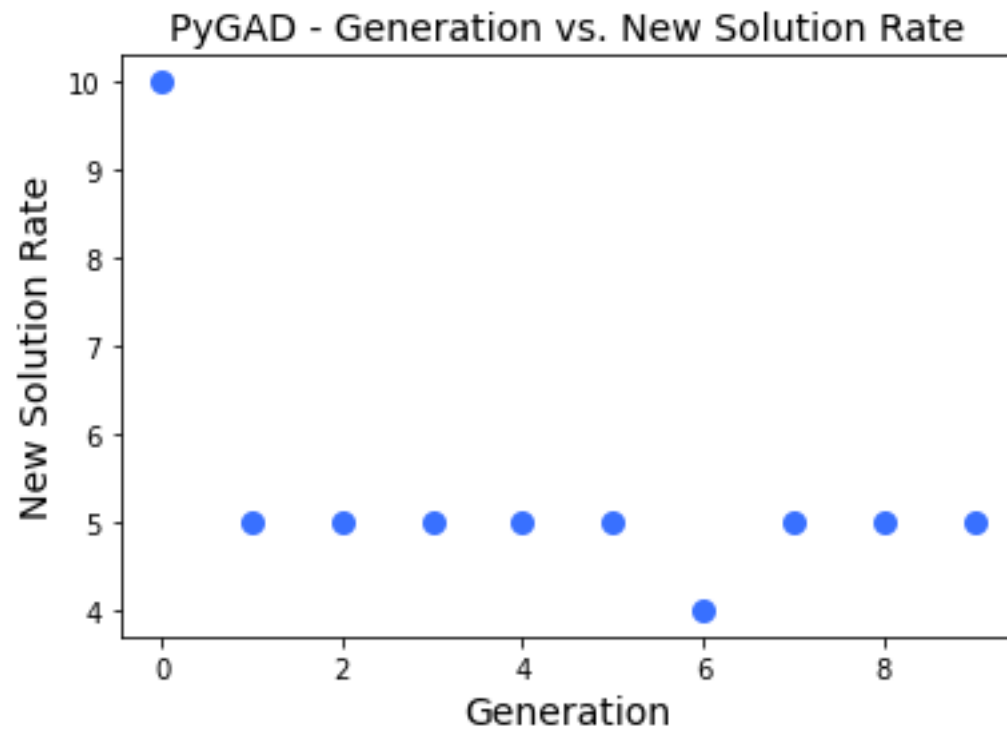


```
plot_type="scatter"
```

```
plot_type="scatter"
```

```
ga_instance.plot_new_solution_rate(plot_type="scatter")
```

---

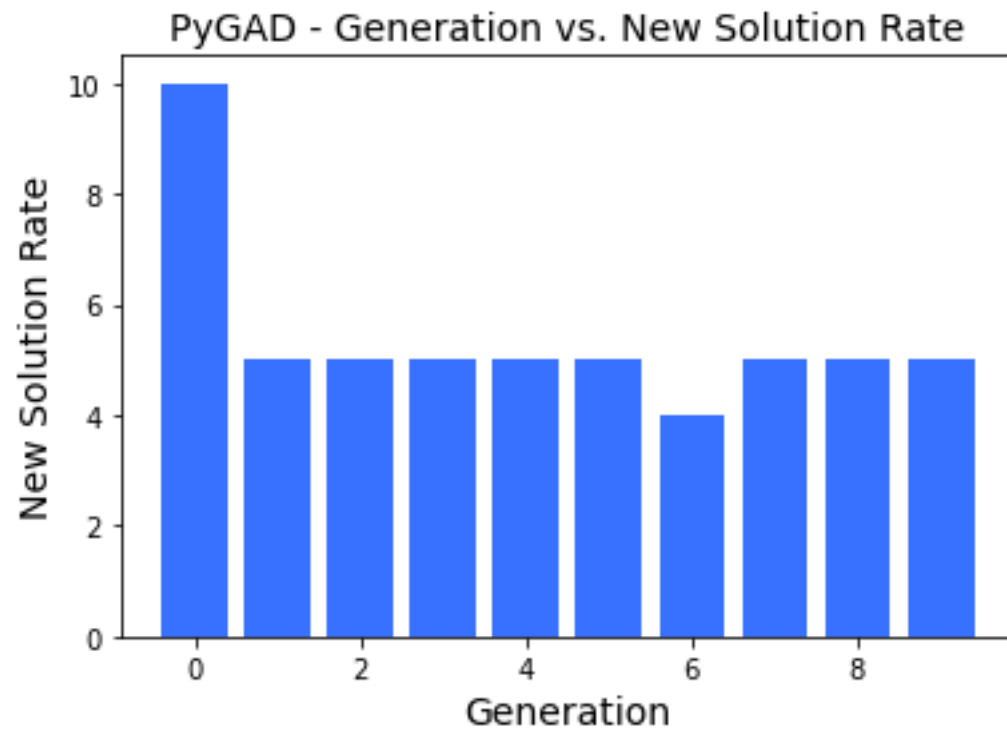


```
plot_type="bar"
```

```
plot_type="scatter"
```

```
ga_instance.plot_new_solution_rate(plot_type="bar")
```

---



**plot\_genes()**

plot\_genes()plot\_genes()

()),

```
title
xlabel
ylabel
linewidth3
font_size14
plot_type"plot()", "scatter", "bar"
graph_type"plot()", "boxplot", "histogram"
fill_color"#3870FF"graph_type="plot"
color"#3870FF"
```

---

---

```
solutions="all" "best"
```

```
save_dir
```

```
graph_type="plot" "plot"(), "boxplot", "histogram"
```

```
plot_type="plot" plot_typeplot_fitness()plot_new_solution_rate()
```

```
solutions="all" "all"() "best"
```

```
graph_type
```

```
plot_type"plot"
```

```
solutions
```

```
solutions="all"save_solutions=Falsepygad.GA
```

```
solutions="best"save_best_solutions=Falsepygad.GA
```

```
graph_type="plot"
```

```
graph_type="plot"
```

```
plot_type="plot"
```

```
graph_typeplot_type"plot"()
```

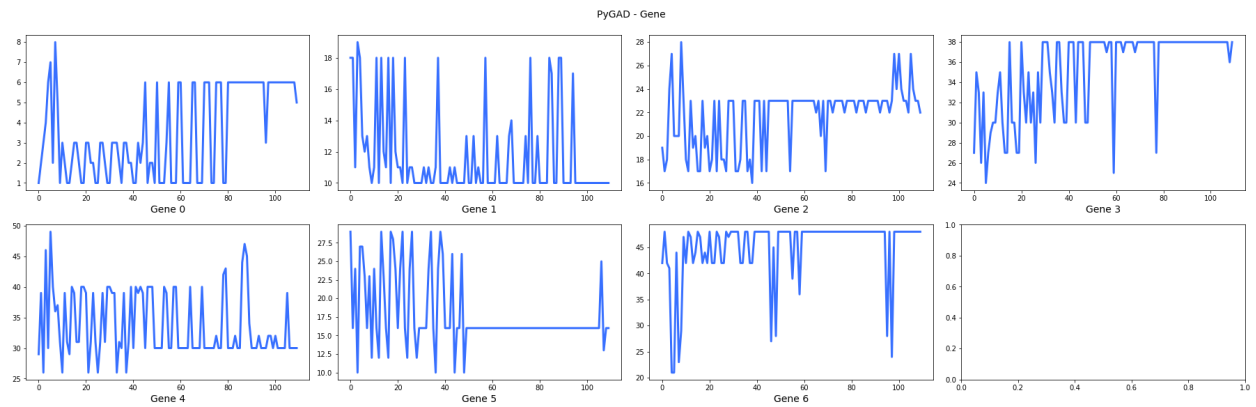
```
ga_instance.plot_genes()
```

```
ga_instance.plot_genes(graph_type="plot")
```

```
ga_instance.plot_genes(plot_type="plot")
```

```
ga_instance.plot_genes(graph_type="plot",  
                        plot_type="plot")
```

---



`solutions="all"`

```
ga_instance.plot_genes(solutions="all")

ga_instance.plot_genes(graph_type="plot",
                       solutions="all")

ga_instance.plot_genes(plot_type="plot",
                       solutions="all")

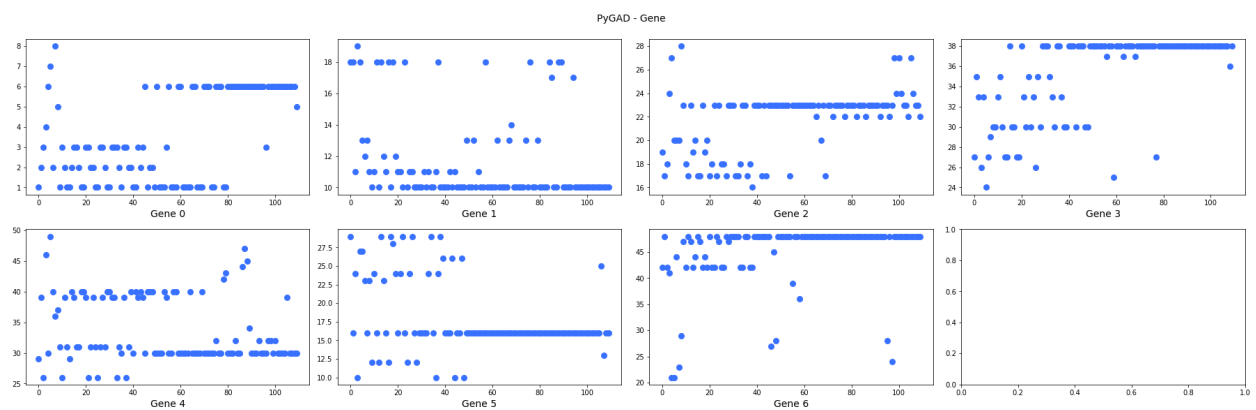
ga_instance.plot_genes(graph_type="plot",
                       plot_type="plot",
                       solutions="all")
```

`plot_type="scatter"`

`plot_genes()`

```
ga_instance.plot_genes(plot_type="scatter")

ga_instance.plot_genes(graph_type="plot",
                       plot_type="scatter",
                       solutions='all')
```

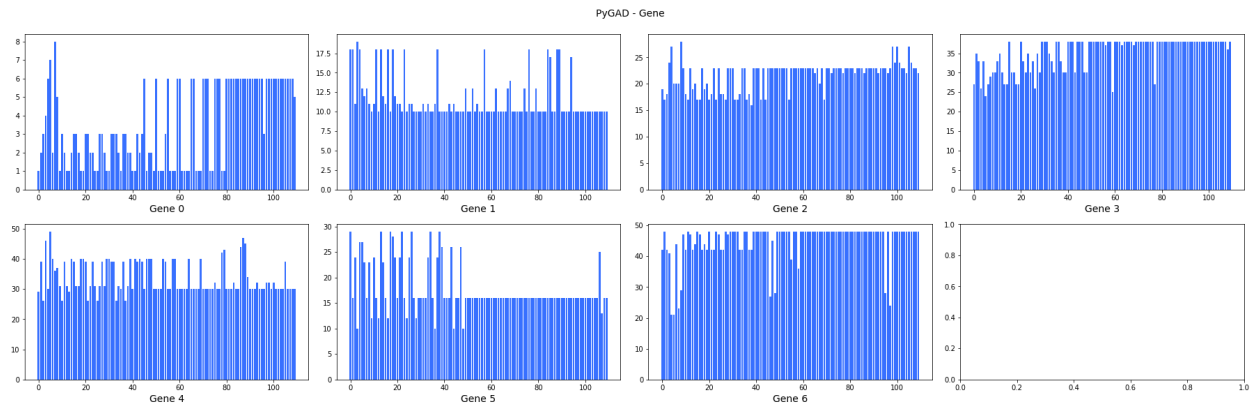


---

`plot_type="bar"`

```
ga_instance.plot_genes(plot_type="bar")

ga_instance.plot_genes(graph_type="plot",
                       plot_type="bar",
                       solutions='all')
```

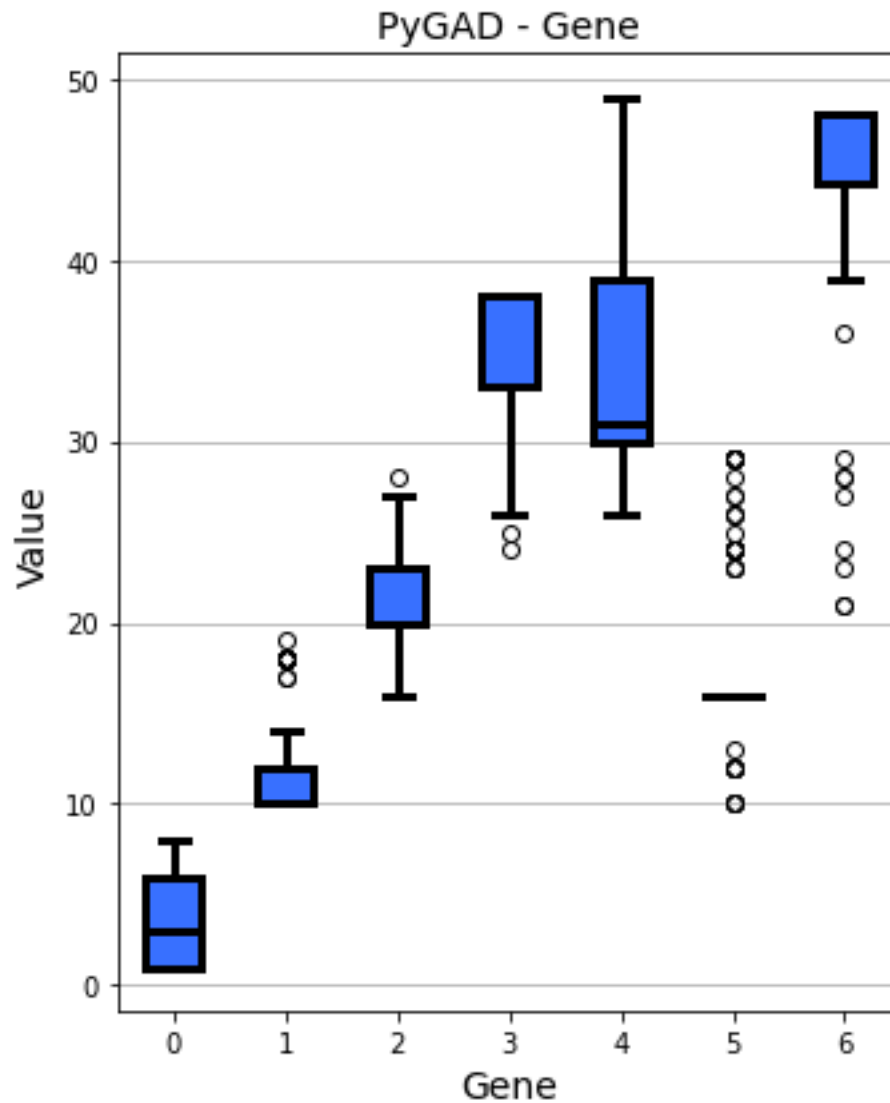


`graph_type="boxplot"`

```
graph_type="boxplot"plot_type
plot_genes()solutions="all"
```

```
ga_instance.plot_genes(graph_type="boxplot")

ga_instance.plot_genes(graph_type="boxplot",
                       solutions='all')
```



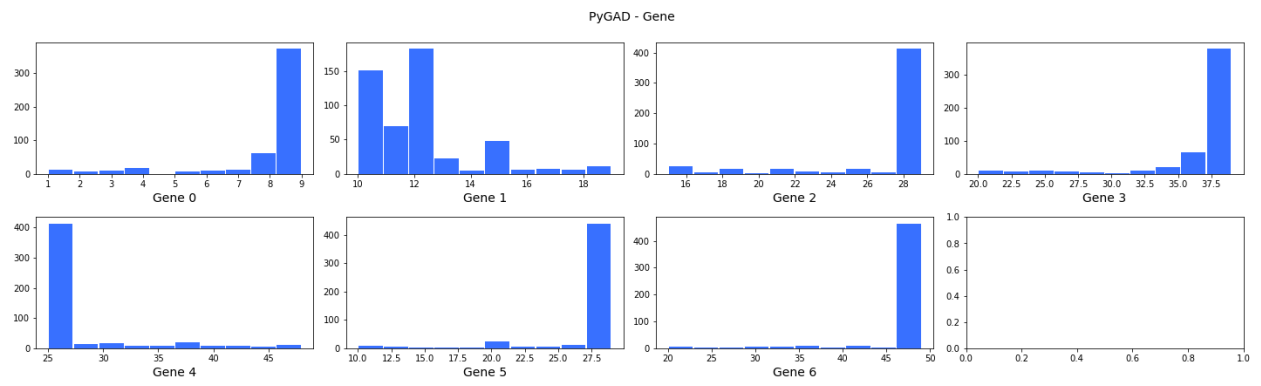
`graph_type="histogram"`

`graph_type="boxplot"graph_type="boxplot"plot_type`  
`plot_genes()solutions"all"`

```
ga_instance.plot_genes(graph_type="histogram")
```

```
ga_instance.plot_genes(graph_type="histogram",  
                        solutions='all')
```





solutions="best "

---

---

---

## pygad.helper

,

uniqueUnique

    solve\_duplicate\_genes\_randomly()

    solve\_duplicate\_genes\_by\_space()

    unique\_int\_gene\_from\_range()

    unique\_genes\_by\_space()unique\_gene\_by\_space()

    unique\_gene\_by\_space()

---

---

---

---

## pygad.nn

,

problem\_typepygad.nn.train()pygad.nn.predict()

```
pygad.nn.InputLayer  
(): pygad.nn.DenseLayer
```

### pygad.nn.InputLayer

```
pygad.nn.InputLayer  
num_neurons  
num_neurons
```

```
input_layer = pygad.nn.InputLayer(num_neurons=20)
```

```
num_neuronspygad.nn.InputLayer
```

```
num_input_neurons = input_layer.num_neurons  
print("Number of input neurons =", num_input_neurons)
```

---

---

## pygad.nn.DenseLayer

```
pygad.nn.DenseLayer()  
    num_neurons  
    previous_layerprevious_layer  
    activation_function"sigmoid""sigmoid""relu""softmax"(), "None"(). "None"()  
    "None"
```

```
    initial_weights  
    trained_weightsinitial_weights
```

```
previous_layerinput_layer
```

```
dense_layer = pygad.nn.DenseLayer(num_neurons=12,  
                                   previous_layer=input_layer,  
                                   activation_function="relu")
```

```
num_dense_neurons = dense_layer.num_neurons  
dense_initail_weights = dense_layer.initial_weights  
  
print("Number of dense layer attributes =", num_dense_neurons)  
print("Initial weights of the dense layer :", dense_initail_weights)
```

```
dense_layer
```

```
input_layer = dense_layer.previous_layer  
num_input_neurons = input_layer.num_neurons  
  
print("Number of input neurons =", num_input_neurons)
```

```
'previous_layer
```

```
dense_layer2 = pygad.nn.DenseLayer(num_neurons=5,  
                                   previous_layer=dense_layer,  
                                   activation_function="relu")
```

```
dense_layer2dense_layerprevious_layerdense_layer
```

```
dense_layer = dense_layer2.previous_layer  
dense_layer_neurons = dense_layer.num_neurons  
  
print("Number of dense neurons =", num_input_neurons)
```

```
dense_layer
```

```
dense_layer = dense_layer2.previous_layer  
input_layer = dense_layer.previous_layer  
num_input_neurons = input_layer.num_neurons  
  
print("Number of input neurons =", num_input_neurons)
```

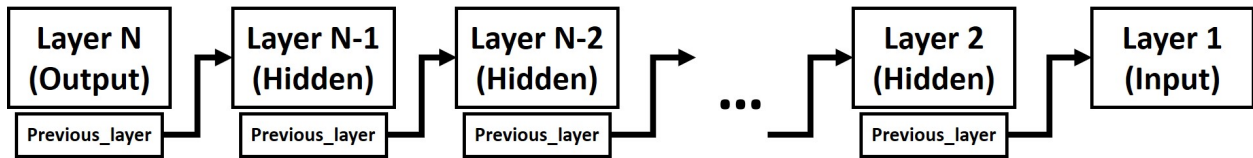
```
dense_layer2
```

---

---

**previous\_layer**

```
previous_layerpygad.nn.DenseLayer  
( ).
```



```
previous_layerprevious_layerprevious_layer().  
( ),whilewhileprevious_layer
```

```
layer = dense_layer2  
  
while "previous_layer" in layer.__init__.__code__.co_varnames:  
    print("Number of neurons =", layer.num_neurons)  
  
    # Go to the previous layer.  
    layer = layer.previous_layer
```

pygad.nn

**pygad.nn.layers\_weights()**

```
last_layer()  
initialTrue(), ' initial_weights False' trained_weights  
whileprevious_layerinitialTrueFalse
```

**pygad.nn.layers\_weights\_as\_vector()**

```
layers_weights()  
  
last_layer()  
initialTrue(), ' initial_weights False' trained_weights  
whileprevious_layerinitialTrueFalse
```

---

---

## **pygad.nn.layers\_weights\_as\_matrix()**

```
layers_weights_as_vectors()
```

```
    last_layer()  
    vector_weights  
whileprevious_layer
```

## **pygad.nn.layers\_activations()**

```
    last_layer()  
whileprevious_layer' activation_function
```

## **pygad.nn.sigmoid()**

```
sop
```

## **pygad.nn.relu()**

```
()
```

```
sop
```

## **pygad.nn.softmax()**

```
sop
```

---



---

## **pygad.nn.train()**

```
num_epochs
last_layer()
data_inputs
data_outputs
problem_type"classification""regression"
learning_rate
```

## **pygad.nn.update\_weights()**

```
weights
network_error
learning_rate
```

## **pygad.nn.update\_layers\_trained\_weights()**

```
trained_weights(final_weights)
() trained_weights

last_layer()
final_weights
whileprevious_layertrained_weightsfinal_weights
```

## **pygad.nn.predict()**

```
,
```

```
last_layer()
data_inputs
problem_type"classification""regression"
```

---

---

pygad.nn

**pygad.nn.to\_vector()**

() array

array

**pygad.nn.to\_array()**

vector

vector

shape

pygad.nn.sigmoid()

(): pygad.nn.relu()

pygad.nn.softmax()

pygad.nn

---

---

```

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,
,
,
,

import numpy
import skimage.io, skimage.color, skimage.feature
import os

fruits = ["apple", "raspberry", "mango", "lemon"]
# Number of samples in the dataset used = 492+490+490+490=1,962
# 360 is the length of the feature vector.
dataset_features = numpy.zeros(shape=(1962, 360))
outputs = numpy.zeros(shape=(1962))

idx = 0
class_label = 0
for fruit_dir in fruits:
    curr_dir = os.path.join(os.path.sep, fruit_dir)
    all_imgs = os.listdir(os.getcwd()+curr_dir)
    for img_file in all_imgs:
        if img_file.endswith(".jpg"): # Ensures reading only JPG files.
            fruit_data = skimage.io.imread(fname=os.path.sep.join([os.getcwd(), curr_
→dir, img_file]), as_gray=False)
            fruit_data_hsv = skimage.color.rgb2hsv(rgb=fruit_data)
            hist = numpy.histogram(a=fruit_data_hsv[:, :, 0], bins=360)
            dataset_features[idx, :] = hist[0]
            outputs[idx] = class_label
            idx = idx + 1
    class_label = class_label + 1

# Saving the extracted features and the outputs as NumPy files.
numpy.save("dataset_features.npy", dataset_features)
numpy.save("outputs.npy", outputs)

```

---

---

```
data_inputs = numpy.load("dataset_features.npy")
data_outputs = numpy.load("outputs.npy")
```

pygad.nn.InputLayer

```
import pygad.nn
num_inputs = data_inputs.shape[1]

input_layer = pygad.nn.InputLayer(num_inputs)
```

```
hidden_layer = pygad.nn.DenseLayer(num_neurons=HL2_neurons, previous_layer=input_
↳layer, activation_function="relu")
output_layer = pygad.nn.DenseLayer(num_neurons=4, previous_layer=hidden_layer2, ↵
↳activation_function="softmax")
```

pygad.nn.train()

```
pygad.nn.train(num_epochs=10,
                last_layer=output_layer,
                data_inputs=data_inputs,
                data_outputs=data_outputs,
                learning_rate=0.01)
```

pygad.nn.predict()

```
predictions = pygad.nn.predict(last_layer=output_layer, data_inputs=data_inputs)
```

---

---

```
num_wrong = numpy.where(predictions != data_outputs)[0]
num_correct = data_outputs.size - num_wrong.size
accuracy = 100 * (num_correct/data_outputs.size)
print(f"Number of correct classifications : {num_correct}.")
print(f"Number of wrong classifications : {num_wrong.size}.")
print(f"Classification accuracy : {accuracy}.")
```

pygad.gann

pygad.nn

(),

```
import numpy
import pygad.nn

# Preparing the NumPy array of the inputs.
data_inputs = numpy.array([[1, 1],
                           [1, 0],
                           [0, 1],
                           [0, 0]])

# Preparing the NumPy array of the outputs.
data_outputs = numpy.array([0,
                             1,
                             1,
                             0])

# The number of inputs (i.e. feature vector length) per sample
num_inputs = data_inputs.shape[1]
# Number of outputs per sample
num_outputs = 2

HL1_neurons = 2

# Building the network architecture.
input_layer = pygad.nn.InputLayer(num_inputs)
hidden_layer1 = pygad.nn.DenseLayer(num_neurons=HL1_neurons, previous_layer=input_
→layer, activation_function="relu")
output_layer = pygad.nn.DenseLayer(num_neurons=num_outputs, previous_layer=hidden_
→layer1, activation_function="softmax")

# Training the network.
pygad.nn.train(num_epochs=10,
               last_layer=output_layer,
               data_inputs=data_inputs,
```

0

```
        data_outputs=data_outputs,
        learning_rate=0.01)

# Using the trained network for predictions.
predictions = pygad.nn.predict(last_layer=output_layer, data_inputs=data_inputs)

# Calculating some statistics
num_wrong = numpy.where(predictions != data_outputs)[0]
num_correct = data_outputs.size - num_wrong.size
accuracy = 100 * (num_correct/data_outputs.size)
print(f"Number of correct classifications : {num_correct}.")
print(f"Number of wrong classifications : {num_wrong.size}.")
print(f"Classification accuracy : {accuracy}.")
```

```
import numpy
import pygad.nn

# Reading the data features. Check the 'extract_features.py' script for extracting
↳ the features & preparing the outputs of the dataset.
data_inputs = numpy.load("dataset_features.npy") # Download from https://github.com/
↳ ahmedfgad/NumPyANN/blob/master/dataset_features.npy

# Optional step for filtering the features using the standard deviation.
features_STDs = numpy.std(a=data_inputs, axis=0)
data_inputs = data_inputs[:, features_STDs > 50]

# Reading the data outputs. Check the 'extract_features.py' script for extracting the
↳ features & preparing the outputs of the dataset.
data_outputs = numpy.load("outputs.npy") # Download from https://github.com/ahmedfgad/
↳ NumPyANN/blob/master/outputs.npy

# The number of inputs (i.e. feature vector length) per sample
num_inputs = data_inputs.shape[1]
# Number of outputs per sample
num_outputs = 4

HL1_neurons = 150
HL2_neurons = 60

# Building the network architecture.
input_layer = pygad.nn.InputLayer(num_inputs)
hidden_layer1 = pygad.nn.DenseLayer(num_neurons=HL1_neurons, previous_layer=input_
↳ layer, activation_function="relu")
hidden_layer2 = pygad.nn.DenseLayer(num_neurons=HL2_neurons, previous_layer=hidden_
↳ layer1, activation_function="relu")
output_layer = pygad.nn.DenseLayer(num_neurons=num_outputs, previous_layer=hidden_
↳ layer2, activation_function="softmax")

# Training the network.
```

0

()

```
pygad.nn.train(num_epochs=10,
                last_layer=output_layer,
                data_inputs=data_inputs,
                data_outputs=data_outputs,
                learning_rate=0.01)

# Using the trained network for predictions.
predictions = pygad.nn.predict(last_layer=output_layer, data_inputs=data_inputs)

# Calculating some statistics
num_wrong = numpy.where(predictions != data_outputs)[0]
num_correct = data_outputs.size - num_wrong.size
accuracy = 100 * (num_correct/data_outputs.size)
print(f"Number of correct classifications : {num_correct}.")
print(f"Number of wrong classifications : {num_wrong.size}.")
print(f"Classification accuracy : {accuracy}.")
```

problem\_typepygad.nn.train()pygad.nn.predict()"regression"

```
pygad.nn.train(...,
                problem_type="regression")

predictions = pygad.nn.predict(...,
                                problem_type="regression")
```

"None"

```
output_layer = pygad.nn.DenseLayer(num_neurons=num_outputs, previous_layer=hidden_
→layer1, activation_function="None")
```

```
abs_error = numpy.mean(numpy.abs(predictions - data_outputs))
print(f"Absolute error : {abs_error}.")
```

pygad.gann

```
import numpy
import pygad.nn

# Preparing the NumPy array of the inputs.
data_inputs = numpy.array([[2, 5, -3, 0.1],
                           [8, 15, 20, 13]])

# Preparing the NumPy array of the outputs.
data_outputs = numpy.array([0.1,
                             1.5])

# The number of inputs (i.e. feature vector length) per sample
num_inputs = data_inputs.shape[1]
# Number of outputs per sample
```

()

)

```
num_outputs = 1

HL1_neurons = 2

# Building the network architecture.
input_layer = pygad.nn.InputLayer(num_inputs)
hidden_layer1 = pygad.nn.DenseLayer(num_neurons=HL1_neurons, previous_layer=input_
↳layer, activation_function="relu")
output_layer = pygad.nn.DenseLayer(num_neurons=num_outputs, previous_layer=hidden_
↳layer1, activation_function="None")

# Training the network.
pygad.nn.train(num_epochs=100,
                last_layer=output_layer,
                data_inputs=data_inputs,
                data_outputs=data_outputs,
                learning_rate=0.01,
                problem_type="regression")

# Using the trained network for predictions.
predictions = pygad.nn.predict(last_layer=output_layer,
                               data_inputs=data_inputs,
                               problem_type="regression")

# Calculating some statistics
abs_error = numpy.mean(numpy.abs(predictions - data_outputs))
print(f"Absolute error : {abs_error}.")
```

(<https://www.kaggle.com/aungpyaeap/fish-market>). (<https://www.kaggle.com/aungpyaeap/fish-market/download>).

```
read_csv()
```

```
data = numpy.array(pandas.read_csv("Fish.csv"))
```

```
# Preparing the NumPy array of the inputs.
data_inputs = numpy.asarray(data[:, 2:], dtype=numpy.float32)

# Preparing the NumPy array of the outputs.
data_outputs = numpy.asarray(data[:, 1], dtype=numpy.float32) # Fish Weight
```

```
"None"problem_typepygad.nn.train()pygad.nn.predict()"regression"
pygad.nn.train()
```

```
abs_error = numpy.mean(numpy.abs(predictions - data_outputs))
print(f"Absolute error : {abs_error}.")
```



---

```
import numpy
import pygad.nn
import pandas

data = numpy.array(pandas.read_csv("Fish.csv"))

# Preparing the NumPy array of the inputs.
data_inputs = numpy.asarray(data[:, 2:], dtype=numpy.float32)

# Preparing the NumPy array of the outputs.
data_outputs = numpy.asarray(data[:, 1], dtype=numpy.float32) # Fish Weight

# The number of inputs (i.e. feature vector length) per sample
num_inputs = data_inputs.shape[1]
# Number of outputs per sample
num_outputs = 1

HL1_neurons = 2

# Building the network architecture.
input_layer = pygad.nn.InputLayer(num_inputs)
hidden_layer1 = pygad.nn.DenseLayer(num_neurons=HL1_neurons, previous_layer=input_
↳layer, activation_function="relu")
output_layer = pygad.nn.DenseLayer(num_neurons=num_outputs, previous_layer=hidden_
↳layer1, activation_function="None")

# Training the network.
pygad.nn.train(num_epochs=100,
               last_layer=output_layer,
               data_inputs=data_inputs,
               data_outputs=data_outputs,
               learning_rate=0.01,
               problem_type="regression")

# Using the trained network for predictions.
predictions = pygad.nn.predict(last_layer=output_layer,
                               data_inputs=data_inputs,
                               problem_type="regression")

# Calculating some statistics
abs_error = numpy.mean(numpy.abs(predictions - data_outputs))
print(f"Absolute error : {abs_error}.")
```

---

---

---

---

## pygad.gann

,  
pygad.gann() pygadpygad.nn

## pygad.gann.GANN

pygad.gannpygad.gann.GANN

### \_\_init\_\_()

```
pygad.gann.GANN
pygad.gann.GANN
    num_solutions()
    num_neurons_input
    num_neurons_output
    num_neurons_hidden_layers=[]().          []intintnum_neurons_hidden_layers=[10]
    num_neurons_hidden_layers=[10, 5]
    output_activation="softmax""softmax"
    hidden_activations="relu"() () ().          "relu"num_neurons_hidden_layersshid-
    den_activationsnum_neurons_hidden_layershidden_activations
pygad.gann.GANNpygad.gann.validate_network_parameters()
```

---

---

```
pygad.gann.GANNpygad.gann.GANN
    parameters_validatedTrueFalse
    population_networks()
```

```
pygad.gann.GANN
```

### **create\_population()**

```
create_population()(). pygad.gann.create_network()
() pygad.gann.GANN
population_networks
```

### **update\_population\_trained\_weights()**

```
update_population_trained_weights()trained_weights() population_trained_weights

    population_trained_weightstrained_weights
```

## **pygad.gann**

```
pygad.gann
```

### **pygad.gann.validate\_network\_parameters()**

```
pygad.gann.GANN
pygad.gann.GANN
num_solutionsNoneNone
hidden_activations(num_neurons_hidden_layers).
() ()().
```

---

## **pygad.gann.create\_network()**

()()

parameters\_validatedpygad.gann.GANNnum\_solutionscreate\_network()

parameters\_validatedFalsevalidate\_network\_parameters()

## **pygad.gann.population\_as\_vectors()**

()

(), ().

population\_networks()

().

## **pygad.gann.population\_as\_matrices()**

()

(),

population\_networks()

population\_vectors

().

pygad.gann.GANN

pygad.GA

pygad.GA

---

---

()

() (200, 50) num\_inputs

```
data_inputs = numpy.array([[1, 1],
                           [1, 0],
                           [0, 1],
                           [0, 0]])

data_outputs = numpy.array([0,
                             1,
                             1,
                             0])

num_inputs = data_inputs.shape[1]
```

0 (200) 0N-1N

num\_classes

## pygad.gann.GANN

pygad.gann.GANN

num\_solutions().

().

```
import pygad.gann
import pygad.nn

num_solutions = 6
GANN_instance = pygad.gann.GANN(num_solutions=num_solutions,
                                num_neurons_input=num_inputs,
                                num_neurons_hidden_layers=[2],
                                num_neurons_output=2,
                                hidden_activations=["relu"],
                                output_activation="softmax")
```

()

().

(number inputs x number of hidden neurons) = (2x2)

(number of hidden neurons x number of outputs) = (2x2)

---

---

```
softmaxrelu
pygad.gann.GANN
```

```
()
```

```
pygad.gann.population_as_vectors()
```

```
population_vectors = pygad.gann.population_as_vectors(population_networks=GANN_
↪instance.population_networks)
```

```
pygad.nn.predict()' pygad.nn.predict()trained_weights
```

```
def fitness_func(ga_instance, solution, sol_idx):
    global GANN_instance, data_inputs, data_outputs

    predictions = pygad.nn.predict(last_layer=GANN_instance.population_networks[sol_
↪idx],
                                   data_inputs=data_inputs)
    correct_predictions = numpy.where(predictions == data_outputs)[0].size
    solution_fitness = (correct_predictions/data_outputs.size)*100

    return solution_fitness
```

```
pygad.nn.predict()' trained_weights
```

```
pygad.GAon_generationpygad.GA
```

```
trained_weights
```

```
trained_weights
```

```
pygad.gann.population_as_matrices()
```

```
update_population_trained_weights()pygad.ganntrained_weights
```

---

---

```
def callback_generation(ga_instance):
    global GANN_instance

    population_matrices = pygad.gann.population_as_matrices(population_networks=GANN_
↪instance.population_networks, population_vectors=ga_instance.population)
    GANN_instance.update_population_trained_weights(population_trained_
↪weights=population_matrices)

    print(f"Generation = {ga_instance.generations_completed}")
    print(f"Fitness      = {ga_instance.best_solution()[1]}")
```

pygad.GA

## pygad.GA

pygad.GA

```
initial_population = population_vectors.copy()

num_parents_mating = 4

num_generations = 500

mutation_percent_genes = 5

parent_selection_type = "sss"

crossover_type = "single_point"

mutation_type = "random"

keep_parents = 1

init_range_low = -2
init_range_high = 5

ga_instance = pygad.GA(num_generations=num_generations,
                        num_parents_mating=num_parents_mating,
                        initial_population=initial_population,
                        fitness_func=fitness_func,
                        mutation_percent_genes=mutation_percent_genes,
                        init_range_low=init_range_low,
                        init_range_high=init_range_high,
                        parent_selection_type=parent_selection_type,
                        crossover_type=crossover_type,
                        mutation_type=mutation_type,
                        keep_parents=keep_parents,
                        on_generation=callback_generation)
```

run()

---



---

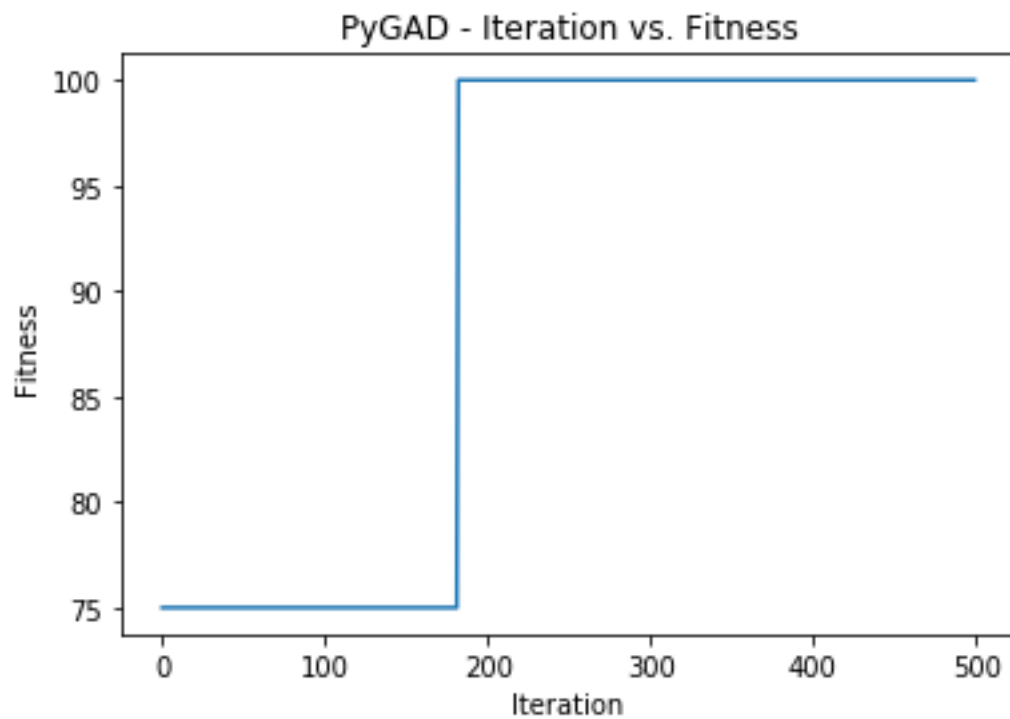
## pygad.GA

run()pygad.GA.num\_generations

```
ga_instance.run()
```

run()plot\_fitness()

```
ga_instance.plot_fitness()
```



best\_solution()pygad.GA

()

```
solution, solution_fitness, solution_idx = ga_instance.best_solution()
print(f"Parameters of the best solution : {solution}")
print(f"Fitness value of the best solution = {solution_fitness}")
print(f"Index of the best solution : {solution_idx}")
```

---

---

```
Parameters of the best solution : [3.55081391 -3.21562011 -14.2617784 0.68044231 -1.
↪41258145 -3.2979315 1.58136006 -7.83726169]
Fitness value of the best solution = 100.0
Index of the best solution : 0
```

```
best_solution_generationpygad.GA
```

```
if ga_instance.best_solution_generation != -1:
    print(f"Best fitness value reached after {ga_instance.best_solution_generation}↪
↪generations.")
```

```
Best solution reached after 182 generations.
```

```
pygad.nn.predict()
```

```
predictions = pygad.nn.predict(last_layer=GANN_instance.population_networks[solution_
↪idx], data_inputs=data_inputs)
print(f"Predictions of the trained network : {predictions}")
```

```
Predictions of the trained network : [0. 1. 1. 0.]
```

```
num_wrong = numpy.where(predictions != data_outputs)[0]
num_correct = data_outputs.size - num_wrong.size
accuracy = 100 * (num_correct/data_outputs.size)
print(f"Number of correct classifications : {num_correct}.")
print(f"Number of wrong classifications : {num_wrong.size}.")
print(f"Classification accuracy : {accuracy}.")
```

```
Number of correct classifications : 4
print("Number of wrong classifications : 0
Classification accuracy : 100
```

---

---

```

import numpy
import pygad
import pygad.nn
import pygad.gann

def fitness_func(ga_instance, solution, sol_idx):
    global GANN_instance, data_inputs, data_outputs

    # If adaptive mutation is used, sometimes sol_idx is None.
    if sol_idx == None:
        sol_idx = 1

    predictions = pygad.nn.predict(last_layer=GANN_instance.population_networks[sol_
↪idx],
                                data_inputs=data_inputs)
    correct_predictions = numpy.where(predictions == data_outputs)[0].size
    solution_fitness = (correct_predictions/data_outputs.size)*100

    return solution_fitness

def callback_generation(ga_instance):
    global GANN_instance, last_fitness

    population_matrices = pygad.gann.population_as_matrices(population_networks=GANN_
↪instance.population_networks,
                                                            population_vectors=ga_
↪instance.population)

    GANN_instance.update_population_trained_weights(population_trained_
↪weights=population_matrices)

    print(f"Generation = {ga_instance.generations_completed}")
    print(f"Fitness    = {ga_instance.best_solution()[1]}")
    print(f"Change     = {ga_instance.best_solution()[1] - last_fitness}")

    last_fitness = ga_instance.best_solution()[1].copy()

# Holds the fitness value of the previous generation.
last_fitness = 0

# Preparing the NumPy array of the inputs.
data_inputs = numpy.array([[1, 1],
                           [1, 0],
                           [0, 1],
                           [0, 0]])

# Preparing the NumPy array of the outputs.
data_outputs = numpy.array([0,
                             1,
                             1,
                             0])

# The length of the input vector for each sample (i.e. number of neurons in the input_
↪layer).

```

```

num_inputs = data_inputs.shape[1]
# The number of neurons in the output layer (i.e. number of classes).
num_classes = 2

# Creating an initial population of neural networks. The return of the initial_
→population() function holds references to the networks, not their weights. Using
→such references, the weights of all networks can be fetched.
num_solutions = 6 # A solution or a network can be used interchangeably.
GANN_instance = pygad.gann.GANN(num_solutions=num_solutions,
                                num_neurons_input=num_inputs,
                                num_neurons_hidden_layers=[2],
                                num_neurons_output=num_classes,
                                hidden_activations=["relu"],
                                output_activation="softmax")

# population does not hold the numerical weights of the network instead it holds a
→list of references to each last layer of each network (i.e. solution) in the
→population. A solution or a network can be used interchangeably.
# If there is a population with 3 solutions (i.e. networks), then the population is a
→list with 3 elements. Each element is a reference to the last layer of each network.
→ Using such a reference, all details of the network can be accessed.
population_vectors = pygad.gann.population_as_vectors(population_networks=GANN_
→instance.population_networks)

# To prepare the initial population, there are 2 ways:
# 1) Prepare it yourself and pass it to the initial_population parameter. This way is
→useful when the user wants to start the genetic algorithm with a custom initial
→population.
# 2) Assign valid integer values to the sol_per_pop and num_genes parameters. If the
→initial_population parameter exists, then the sol_per_pop and num_genes parameters
→are useless.
initial_population = population_vectors.copy()

num_parents_mating = 4 # Number of solutions to be selected as parents in the mating
→pool.

num_generations = 500 # Number of generations.

mutation_percent_genes = [5, 10] # Percentage of genes to mutate. This parameter has
→no action if the parameter mutation_num_genes exists.

parent_selection_type = "sss" # Type of parent selection.

crossover_type = "single_point" # Type of the crossover operator.

mutation_type = "adaptive" # Type of the mutation operator.

keep_parents = 1 # Number of parents to keep in the next population. -1 means keep
→all parents and 0 means keep nothing.

init_range_low = -2
init_range_high = 5

ga_instance = pygad.GA(num_generations=num_generations,
                       num_parents_mating=num_parents_mating,
                       initial_population=initial_population,
                       fitness_func=fitness_func,

```

)

```
        mutation_percent_genes=mutation_percent_genes,
        init_range_low=init_range_low,
        init_range_high=init_range_high,
        parent_selection_type=parent_selection_type,
        crossover_type=crossover_type,
        mutation_type=mutation_type,
        keep_parents=keep_parents,
        suppress_warnings=True,
        on_generation=callback_generation)

ga_instance.run()

# After the generations complete, some plots are showed that summarize how the
# outputs/fitness values evolve over generations.
ga_instance.plot_fitness()

# Returning the details of the best solution.
solution, solution_fitness, solution_idx = ga_instance.best_solution()
print(f"Parameters of the best solution : {solution}")
print(f"Fitness value of the best solution = {solution_fitness}")
print(f"Index of the best solution : {solution_idx}")

if ga_instance.best_solution_generation != -1:
    print(f"Best fitness value reached after {ga_instance.best_solution_generation}
    # generations.")

# Predicting the outputs of the data using the best solution.
predictions = pygad.nn.predict(last_layer=GANN_instance.population_networks[solution_
    # idx],
                                data_inputs=data_inputs)
print(f"Predictions of the trained network : {predictions}")

# Calculating some statistics
num_wrong = numpy.where(predictions != data_outputs)[0]
num_correct = data_outputs.size - num_wrong.size
accuracy = 100 * (num_correct/data_outputs.size)
print(f"Number of correct classifications : {num_correct}.")
print(f"Number of wrong classifications : {num_wrong.size}.")
print(f"Classification accuracy : {accuracy}.")
```

pygad.nnpygad.gann

num\_neurons\_outputpygad.gann.GANN

```
import numpy
import pygad
import pygad.nn
```

)

0

```
import pygad.gann

def fitness_func(ga_instance, solution, sol_idx):
    global GANN_instance, data_inputs, data_outputs

    predictions = pygad.nn.predict(last_layer=GANN_instance.population_networks[sol_
    ↪idx],
                                data_inputs=data_inputs)
    correct_predictions = numpy.where(predictions == data_outputs)[0].size
    solution_fitness = (correct_predictions/data_outputs.size)*100

    return solution_fitness

def callback_generation(ga_instance):
    global GANN_instance, last_fitness

    population_matrices = pygad.gann.population_as_matrices(population_networks=GANN_
    ↪instance.population_networks,
                                                         population_vectors=ga_
    ↪instance.population)

    GANN_instance.update_population_trained_weights(population_trained_
    ↪weights=population_matrices)

    print(f"Generation = {ga_instance.generations_completed}")
    print(f"Fitness     = {ga_instance.best_solution()[1]}")
    print(f"Change      = {ga_instance.best_solution()[1] - last_fitness}")

    last_fitness = ga_instance.best_solution()[1].copy()

# Holds the fitness value of the previous generation.
last_fitness = 0

# Reading the input data.
data_inputs = numpy.load("dataset_features.npy") # Download from https://github.com/
    ↪ahmedfgad/NumPyANN/blob/master/dataset_features.npy

# Optional step of filtering the input data using the standard deviation.
features_STDs = numpy.std(a=data_inputs, axis=0)
data_inputs = data_inputs[:, features_STDs>50]

# Reading the output data.
data_outputs = numpy.load("outputs.npy") # Download from https://github.com/ahmedfgad/
    ↪NumPyANN/blob/master/outputs.npy

# The length of the input vector for each sample (i.e. number of neurons in the input_
    ↪layer).
num_inputs = data_inputs.shape[1]
# The number of neurons in the output layer (i.e. number of classes).
num_classes = 4

# Creating an initial population of neural networks. The return of the initial_
    ↪population() function holds references to the networks, not their weights. Using_
    ↪such references, the weights of all networks can be fetched.
num_solutions = 8 # A solution or a network can be used interchangeably.
GANN_instance = pygad.gann.GANN(num_solutions=num_solutions,
                                num_neurons_input=num_inputs,
```

0

```

        num_neurons_hidden_layers=[150, 50],
        num_neurons_output=num_classes,
        hidden_activations=["relu", "relu"],
        output_activation="softmax")

# population does not hold the numerical weights of the network instead it holds a
→list of references to each last layer of each network (i.e. solution) in the
→population. A solution or a network can be used interchangeably.
# If there is a population with 3 solutions (i.e. networks), then the population is a
→list with 3 elements. Each element is a reference to the last layer of each network.
→ Using such a reference, all details of the network can be accessed.
population_vectors = pygad.gann.population_as_vectors(population_networks=GANN_
→instance.population_networks)

# To prepare the initial population, there are 2 ways:
# 1) Prepare it yourself and pass it to the initial_population parameter. This way is
→useful when the user wants to start the genetic algorithm with a custom initial
→population.
# 2) Assign valid integer values to the sol_per_pop and num_genes parameters. If the
→initial_population parameter exists, then the sol_per_pop and num_genes parameters
→are useless.
initial_population = population_vectors.copy()

num_parents_mating = 4 # Number of solutions to be selected as parents in the mating
→pool.

num_generations = 500 # Number of generations.

mutation_percent_genes = 10 # Percentage of genes to mutate. This parameter has no
→action if the parameter mutation_num_genes exists.

parent_selection_type = "sss" # Type of parent selection.

crossover_type = "single_point" # Type of the crossover operator.

mutation_type = "random" # Type of the mutation operator.

keep_parents = -1 # Number of parents to keep in the next population. -1 means keep
→all parents and 0 means keep nothing.

ga_instance = pygad.GA(num_generations=num_generations,
                       num_parents_mating=num_parents_mating,
                       initial_population=initial_population,
                       fitness_func=fitness_func,
                       mutation_percent_genes=mutation_percent_genes,
                       parent_selection_type=parent_selection_type,
                       crossover_type=crossover_type,
                       mutation_type=mutation_type,
                       keep_parents=keep_parents,
                       on_generation=callback_generation)

ga_instance.run()

# After the generations complete, some plots are showed that summarize how the
→outputs/fitness values evolve over generations.
ga_instance.plot_fitness()

```

```
# Returning the details of the best solution.
solution, solution_fitness, solution_idx = ga_instance.best_solution()
print(f"Parameters of the best solution : {solution}")
print(f"Fitness value of the best solution = {solution_fitness}")
print(f"Index of the best solution : {solution_idx}")

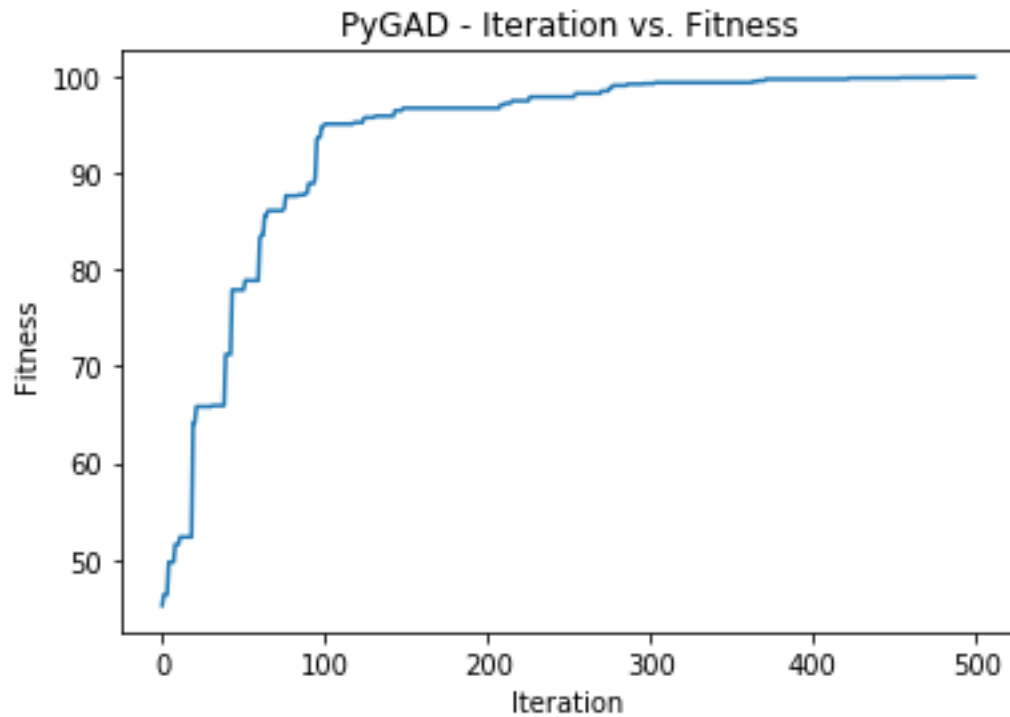
if ga_instance.best_solution_generation != -1:
    print(f"Best fitness value reached after {ga_instance.best_solution_generation} ↪
    ↪generations.")

# Predicting the outputs of the data using the best solution.
predictions = pygad.nn.predict(last_layer=GANN_instance.population_networks[solution_
    ↪idx],
                                data_inputs=data_inputs)
print(f"Predictions of the trained network : {predictions}")

# Calculating some statistics
num_wrong = numpy.where(predictions != data_outputs)[0]
num_correct = data_outputs.size - num_wrong.size
accuracy = 100 * (num_correct/data_outputs.size)
print(f"Number of correct classifications : {num_correct}.")
print(f"Number of wrong classifications : {num_wrong.size}.")
print(f"Classification accuracy : {accuracy}.")
```

```
Fitness value of the best solution = 99.94903160040775
Index of the best solution : 0
Best fitness value reached after 482 generations.
Number of correct classifications : 1961.
Number of wrong classifications : 1.
Classification accuracy : 99.94903160040775.
```





```
output_activation=pygad.gann.GANN("None")
```

```
GANN_instance = pygad.gann.GANN(...  
                                output_activation="None")
```

```
pygad.nn.predict(problem_type="regression")
```

```
predictions = pygad.nn.predict(...,  
                               problem_type="regression")
```

```
()
```

```
def fitness_func(ga_instance, solution, sol_idx):  
    ...  
  
    predictions = pygad.nn.predict(...,  
                                   problem_type="regression")  
  
    solution_fitness = 1.0/numpy.mean(numpy.abs(predictions - data_outputs))  
  
    return solution_fitness
```

```
import numpy  
import pygad
```

0

```
import pygad.nn
import pygad.gann

def fitness_func(ga_instance, solution, sol_idx):
    global GANN_instance, data_inputs, data_outputs

    predictions = pygad.nn.predict(last_layer=GANN_instance.population_networks[sol_
    ↪idx],
                                data_inputs=data_inputs, problem_type="regression")
    solution_fitness = 1.0/numpy.mean(numpy.abs(predictions - data_outputs))

    return solution_fitness

def callback_generation(ga_instance):
    global GANN_instance, last_fitness

    population_matrices = pygad.gann.population_as_matrices(population_networks=GANN_
    ↪instance.population_networks,
                                                         population_vectors=ga_
    ↪instance.population)

    GANN_instance.update_population_trained_weights(population_trained_
    ↪weights=population_matrices)

    print(f"Generation = {ga_instance.generations_completed}")
    print(f"Fitness    = {ga_instance.best_solution(pop_fitness=ga_instance.last_
    ↪generation_fitness)[1]}")
    print(f"Change     = {ga_instance.best_solution(pop_fitness=ga_instance.last_
    ↪generation_fitness)[1] - last_fitness}")

    last_fitness = ga_instance.best_solution(pop_fitness=ga_instance.last_generation_
    ↪fitness)[1].copy()

# Holds the fitness value of the previous generation.
last_fitness = 0

# Preparing the NumPy array of the inputs.
data_inputs = numpy.array([[2, 5, -3, 0.1],
                           [8, 15, 20, 13]])

# Preparing the NumPy array of the outputs.
data_outputs = numpy.array([[0.1, 0.2],
                             [1.8, 1.5]])

# The length of the input vector for each sample (i.e. number of neurons in the input_
    ↪layer).
num_inputs = data_inputs.shape[1]

# Creating an initial population of neural networks. The return of the initial_
    ↪population() function holds references to the networks, not their weights. Using_
    ↪such references, the weights of all networks can be fetched.
num_solutions = 6 # A solution or a network can be used interchangeably.
GANN_instance = pygad.gann.GANN(num_solutions=num_solutions,
                                num_neurons_input=num_inputs,
                                num_neurons_hidden_layers=[2],
                                num_neurons_output=2,
                                hidden_activations=["relu"],
```

0

```

        output_activation="None")

# population does not hold the numerical weights of the network instead it holds a
↳ list of references to each last layer of each network (i.e. solution) in the
↳ population. A solution or a network can be used interchangeably.
# If there is a population with 3 solutions (i.e. networks), then the population is a
↳ list with 3 elements. Each element is a reference to the last layer of each network.
↳ Using such a reference, all details of the network can be accessed.
population_vectors = pygad.gann.population_as_vectors(population_networks=GANN_
↳ instance.population_networks)

# To prepare the initial population, there are 2 ways:
# 1) Prepare it yourself and pass it to the initial_population parameter. This way is
↳ useful when the user wants to start the genetic algorithm with a custom initial
↳ population.
# 2) Assign valid integer values to the sol_per_pop and num_genes parameters. If the
↳ initial_population parameter exists, then the sol_per_pop and num_genes parameters
↳ are useless.
initial_population = population_vectors.copy()

num_parents_mating = 4 # Number of solutions to be selected as parents in the mating
↳ pool.

num_generations = 500 # Number of generations.

mutation_percent_genes = 5 # Percentage of genes to mutate. This parameter has no
↳ action if the parameter mutation_num_genes exists.

parent_selection_type = "sss" # Type of parent selection.

crossover_type = "single_point" # Type of the crossover operator.

mutation_type = "random" # Type of the mutation operator.

keep_parents = 1 # Number of parents to keep in the next population. -1 means keep
↳ all parents and 0 means keep nothing.

init_range_low = -1
init_range_high = 1

ga_instance = pygad.GA(num_generations=num_generations,
                        num_parents_mating=num_parents_mating,
                        initial_population=initial_population,
                        fitness_func=fitness_func,
                        mutation_percent_genes=mutation_percent_genes,
                        init_range_low=init_range_low,
                        init_range_high=init_range_high,
                        parent_selection_type=parent_selection_type,
                        crossover_type=crossover_type,
                        mutation_type=mutation_type,
                        keep_parents=keep_parents,
                        on_generation=callback_generation)

ga_instance.run()

# After the generations complete, some plots are showed that summarize how the
↳ outputs/fitness values evolve over generations.

```

```

ga_instance.plot_fitness()

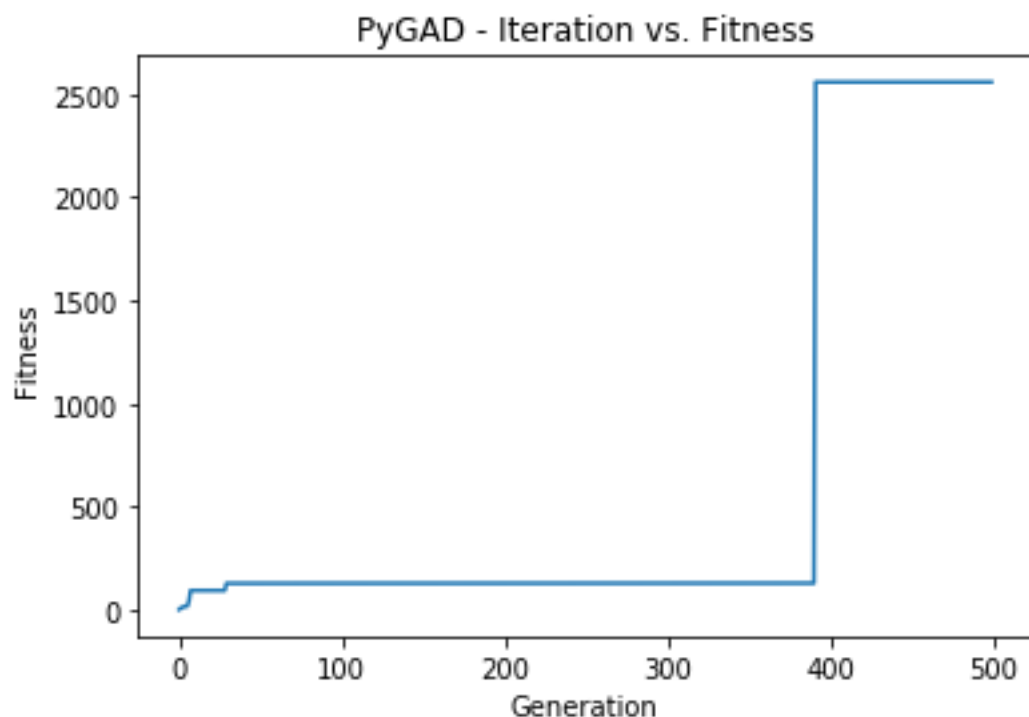
# Returning the details of the best solution.
solution, solution_fitness, solution_idx = ga_instance.best_solution(pop_fitness=ga_
↪instance.last_generation_fitness)
print(f"Parameters of the best solution : {solution}")
print(f"Fitness value of the best solution = {solution_fitness}")
print(f"Index of the best solution : {solution_idx}")

if ga_instance.best_solution_generation != -1:
    print(f"Best fitness value reached after {ga_instance.best_solution_generation}↪
↪generations.")

# Predicting the outputs of the data using the best solution.
predictions = pygad.nn.predict(last_layer=GANN_instance.population_networks[solution_
↪idx],
                                data_inputs=data_inputs,
                                problem_type="regression")
print(f"Predictions of the trained network : {predictions}")

# Calculating some statistics
abs_error = numpy.mean(numpy.abs(predictions - data_outputs))
print(f"Absolute error : {abs_error}.")

```



---

(<https://www.kaggle.com/aungpyaeap/fish-market>). (<https://www.kaggle.com/aungpyaeap/fish-market/download>).

```
read_csv()
```

```
data = numpy.array(pandas.read_csv("Fish.csv"))
```

```
# Preparing the NumPy array of the inputs.
data_inputs = numpy.asarray(data[:, 2:], dtype=numpy.float32)

# Preparing the NumPy array of the outputs.
data_outputs = numpy.asarray(data[:, 1], dtype=numpy.float32) # Fish Weight
```

```
"None"problem_typepygad.nn.train()pygad.nn.predict() "regression"
```

```
solution_fitness = 1.0/numpy.mean(numpy.abs(predictions - data_outputs))
```

```
import numpy
import pygad
import pygad.nn
import pygad.gann
import pandas

def fitness_func(ga_instance, solution, sol_idx):
    global GANN_instance, data_inputs, data_outputs

    predictions = pygad.nn.predict(last_layer=GANN_instance.population_networks[sol_
↪idx],
                                   data_inputs=data_inputs, problem_type="regression")
    solution_fitness = 1.0/numpy.mean(numpy.abs(predictions - data_outputs))

    return solution_fitness

def callback_generation(ga_instance):
    global GANN_instance, last_fitness

    population_matrices = pygad.gann.population_as_matrices(population_networks=GANN_
↪instance.population_networks,
                                                            population_vectors=ga_
↪instance.population)

    GANN_instance.update_population_trained_weights(population_trained_
↪weights=population_matrices)

    print(f"Generation = {ga_instance.generations_completed}")
    print(f"Fitness     = {ga_instance.best_solution(pop_fitness=ga_instance.last_
↪generation_fitness)[1]}")
    print(f"Change     = {ga_instance.best_solution(pop_fitness=ga_instance.last_
↪generation_fitness)[1] - last_fitness}")

    last_fitness = ga_instance.best_solution(pop_fitness=ga_instance.last_generation_
↪fitness)[1].copy()
```

0

---

```

# Holds the fitness value of the previous generation.
last_fitness = 0

data = numpy.array(pandas.read_csv("../data/Fish.csv"))

# Preparing the NumPy array of the inputs.
data_inputs = numpy.asarray(data[:, 2:], dtype=numpy.float32)

# Preparing the NumPy array of the outputs.
data_outputs = numpy.asarray(data[:, 1], dtype=numpy.float32)

# The length of the input vector for each sample (i.e. number of neurons in the input_
↳ layer).
num_inputs = data_inputs.shape[1]

# Creating an initial population of neural networks. The return of the initial_
↳ population() function holds references to the networks, not their weights. Using_
↳ such references, the weights of all networks can be fetched.
num_solutions = 6 # A solution or a network can be used interchangeably.
GANN_instance = pygad.gann.GANN(num_solutions=num_solutions,
                                num_neurons_input=num_inputs,
                                num_neurons_hidden_layers=[2],
                                num_neurons_output=1,
                                hidden_activations=["relu"],
                                output_activation="None")

# population does not hold the numerical weights of the network instead it holds a_
↳ list of references to each last layer of each network (i.e. solution) in the_
↳ population. A solution or a network can be used interchangeably.
# If there is a population with 3 solutions (i.e. networks), then the population is a_
↳ list with 3 elements. Each element is a reference to the last layer of each network.
↳ Using such a reference, all details of the network can be accessed.
population_vectors = pygad.gann.population_as_vectors(population_networks=GANN_
↳ instance.population_networks)

# To prepare the initial population, there are 2 ways:
# 1) Prepare it yourself and pass it to the initial_population parameter. This way is_
↳ useful when the user wants to start the genetic algorithm with a custom initial_
↳ population.
# 2) Assign valid integer values to the sol_per_pop and num_genes parameters. If the_
↳ initial_population parameter exists, then the sol_per_pop and num_genes parameters_
↳ are useless.
initial_population = population_vectors.copy()

num_parents_mating = 4 # Number of solutions to be selected as parents in the mating_
↳ pool.

num_generations = 500 # Number of generations.

mutation_percent_genes = 5 # Percentage of genes to mutate. This parameter has no_
↳ action if the parameter mutation_num_genes exists.

parent_selection_type = "sss" # Type of parent selection.

crossover_type = "single_point" # Type of the crossover operator.

```

```
mutation_type = "random" # Type of the mutation operator.

keep_parents = 1 # Number of parents to keep in the next population. -1 means keep_
↳all parents and 0 means keep nothing.

init_range_low = -1
init_range_high = 1

ga_instance = pygad.GA(num_generations=num_generations,
                       num_parents_mating=num_parents_mating,
                       initial_population=initial_population,
                       fitness_func=fitness_func,
                       mutation_percent_genes=mutation_percent_genes,
                       init_range_low=init_range_low,
                       init_range_high=init_range_high,
                       parent_selection_type=parent_selection_type,
                       crossover_type=crossover_type,
                       mutation_type=mutation_type,
                       keep_parents=keep_parents,
                       on_generation=callback_generation)

ga_instance.run()

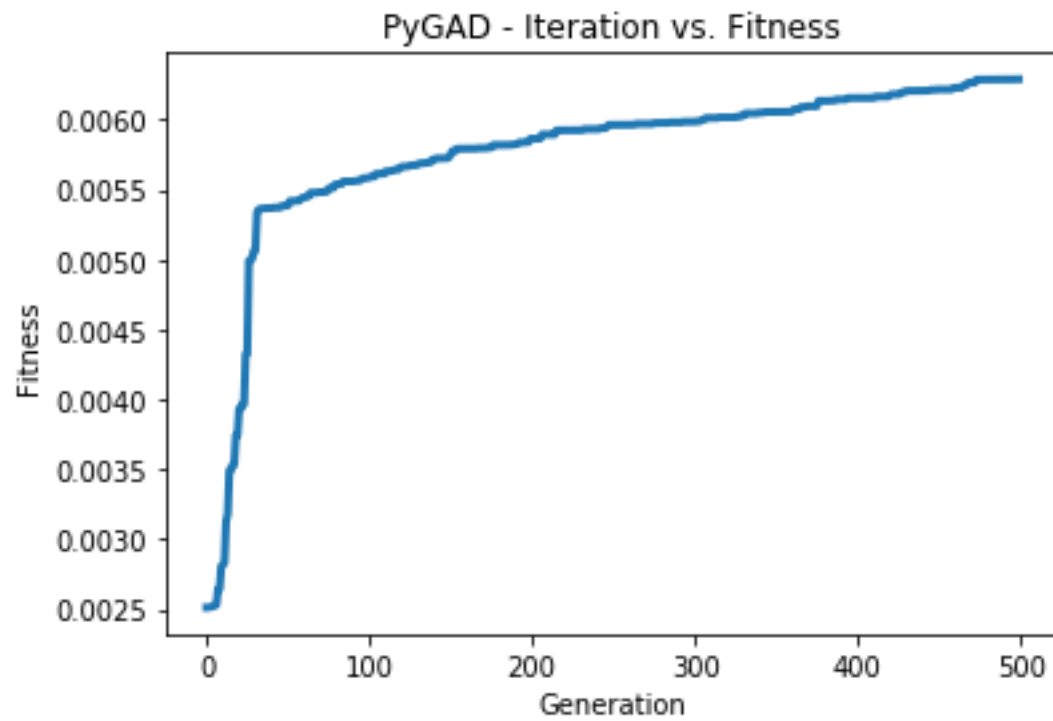
# After the generations complete, some plots are showed that summarize how the_
↳outputs/fitness values evolve over generations.
ga_instance.plot_fitness()

# Returning the details of the best solution.
solution, solution_fitness, solution_idx = ga_instance.best_solution(pop_fitness=ga_
↳instance.last_generation_fitness)
print(f"Parameters of the best solution : {solution}")
print(f"Fitness value of the best solution = {solution_fitness}")
print(f"Index of the best solution : {solution_idx}")

if ga_instance.best_solution_generation != -1:
    print(f"Best fitness value reached after {ga_instance.best_solution_generation}_
↳generations.")

# Predicting the outputs of the data using the best solution.
predictions = pygad.nn.predict(last_layer=GANN_instance.population_networks[solution_
↳idx],
                                data_inputs=data_inputs,
                                problem_type="regression")
print(f"Predictions of the trained network : {predictions}")

# Calculating some statistics
abs_error = numpy.mean(numpy.abs(predictions - data_outputs))
print(f"Absolute error : {abs_error}.")
```





---

## `pygad.cnn`

,

()

```
pygad.cnn.Input2D
pygad.cnn.Conv2D
pygad.cnn.MaxPooling2D
pygad.cnn.AveragePooling2D
pygad.cnn.Flatten
pygad.cnn.ReLU
pygad.cnn.Sigmoid
(): pygad.cnn.Dense
```

```
previous_layer
layer_input_size
layer_output_size
layer_outputNone
```

---



---

```
filter_bank_size = conv_layer.filter_bank_size
conv_initail_weights = conv_layer.initial_weights

print("Filter bank size attributes =", filter_bank_size)
print("Initial weights of the conv layer :", conv_initail_weights)
```

conv\_layer

```
input_layer = conv_layer.previous_layer
input_shape = input_layer.num_neurons

print("Input shape =", input_shape)
```

previous\_layerReLU

```
conv_layer2 = pygad.cnn.Conv2D(num_filters=2,
                                kernel_size=3,
                                previous_layer=conv_layer,
                                activation_function="relu")
```

conv\_layer2conv\_layerprevious\_layerconv\_layer

```
conv_layer = conv_layer2.previous_layer
filter_bank_size = conv_layer.filter_bank_size

print("Filter bank size attributes =", filter_bank_size)
```

conv\_layer

```
conv_layer = conv_layer2.previous_layer
input_layer = conv_layer.previous_layer
input_shape = input_layer.num_neurons

print("Input shape =", input_shape)
```

## **pygad.cnn.MaxPooling2D**

pygad.cnn.MaxPooling2D

```
pool_size
previous_layer
stride=2
```

```
layer_input_size
layer_output_size
layer_output
```

---

---

## **pygad.cnn.AveragePooling2D**

pygad.cnn.AveragePooling2Dpygad.cnn.MaxPooling2D

## **pygad.cnn.Flatten**

pygad.cnn.Flattenprevious\_layer

```
previous_layer
layer_input_size
layer_output_size
layer_output
```

## **pygad.cnn.ReLU**

pygad.cnn.ReLU

previous\_layer

```
previous_layer
layer_input_size
layer_output_size
layer_output
```

## **pygad.cnn.Sigmoid**

pygad.cnn.Sigmoidpygad.cnn.ReLU

## **pygad.cnn.Dense**

pygad.cnn.Dense

```
num_neurons
previous_layer
activation_function"sigmoid""sigmoid""relu"softmax

initial_weights
trained_weightsinitial_weights
layer_input_size
layer_output_size
layer_output
```

---

---

## **pygad.cnn.Model**

```
pygad.cnn.Model
    last_layer().
    epochs=10:
    learning_rate=0.01
network_layersget_layers()pygad.cnn.Model
pygad.cnn.Model
```

### **get\_layers()**

### **train()**

```
    train_inputs
    train_outputs
pygad.cnn.Model
```

### **feed\_sample()**

### **update\_weights()**

### **predict()**

```
    data_inputs
```

---

## **summary()**

```
pygad.cnn.sigmoid()  
(): pygad.cnn.relu()  
softmaxpygad.cnn.softmax()
```

```
pygad.cnn
```

```
,  
,  
,  
,
```

```
(80, 100, 100, 3) (100, 100, 3)
```

```
(https://github.com/ahmedfgad/NumPyCNN/blob/master/dataset\_outputs.npy)
```

---

```
train_inputs = numpy.load("dataset_inputs.npy")
train_outputs = numpy.load("dataset_outputs.npy")
```

pygad.cnn.Input2D

```
import pygad.cnn
sample_shape = train_inputs.shape[1:]

input_layer = pygad.cnn.Input2D(input_shape=sample_shape)
```

[illegible]

---

pygad.cnn.Model

```
model = pygad.cnn.Model(last_layer=dense_layer2,  
                        epochs=5,  
                        learning_rate=0.01)
```

summary() pygad.cnn.Model

```
model.summary()
```

```
-----Network Architecture-----  
<class 'pygad.cnn.Conv2D'>  
<class 'pygad.cnn.Sigmoid'>  
<class 'pygad.cnn.AveragePooling2D'>  
<class 'pygad.cnn.Conv2D'>  
<class 'pygad.cnn.ReLU'>  
<class 'pygad.cnn.MaxPooling2D'>  
<class 'pygad.cnn.Conv2D'>  
<class 'pygad.cnn.ReLU'>  
<class 'pygad.cnn.AveragePooling2D'>  
<class 'pygad.cnn.Flatten'>  
<class 'pygad.cnn.Dense'>  
<class 'pygad.cnn.Dense'>  
-----
```

pygad.cnn.train()

```
model.train(train_inputs=train_inputs,  
            train_outputs=train_outputs)
```

pygad.cnn.predict()

```
predictions = model.predict(data_inputs=train_inputs)
```

---



---

```

num_wrong = numpy.where(predictions != train_outputs)[0]
num_correct = train_outputs.size - num_wrong.size
accuracy = 100 * (num_correct/train_outputs.size)
print(f"Number of correct classifications : {num_correct}.")
print(f"Number of wrong classifications : {num_wrong.size}.")
print(f"Classification accuracy : {accuracy}.")

```

pygad.gacnn

pygad.cnn

```

import numpy
import pygad.cnn

"""
Convolutional neural network implementation using NumPy
A tutorial that helps to get started (Building Convolutional Neural Network using
↳ NumPy from Scratch) available in these links:
    https://www.linkedin.com/pulse/building-convolutional-neural-network-using-numpy-
↳ from-ahmed-gad
    https://towardsdatascience.com/building-convolutional-neural-network-using-numpy-
↳ from-scratch-b30aac50e50a
    https://www.kdnuggets.com/2018/04/building-convolutional-neural-network-numpy-
↳ scratch.html
It is also translated into Chinese: http://m.aliyun.com/yunqi/articles/585741
"""

train_inputs = numpy.load("dataset_inputs.npy")
train_outputs = numpy.load("dataset_outputs.npy")

sample_shape = train_inputs.shape[1:]
num_classes = 4

input_layer = pygad.cnn.Input2D(input_shape=sample_shape)
conv_layer1 = pygad.cnn.Conv2D(num_filters=2,
                                kernel_size=3,
                                previous_layer=input_layer,
                                activation_function=None)
relu_layer1 = pygad.cnn.Sigmoid(previous_layer=conv_layer1)
average_pooling_layer = pygad.cnn.AveragePooling2D(pool_size=2,
                                                       previous_layer=relu_layer1,
                                                       stride=2)

```

```
conv_layer2 = pygad.cnn.Conv2D(num_filters=3,
                                kernel_size=3,
                                previous_layer=average_pooling_layer,
                                activation_function=None)
relu_layer2 = pygad.cnn.ReLU(previous_layer=conv_layer2)
max_pooling_layer = pygad.cnn.MaxPooling2D(pool_size=2,
                                             previous_layer=relu_layer2,
                                             stride=2)

conv_layer3 = pygad.cnn.Conv2D(num_filters=1,
                                kernel_size=3,
                                previous_layer=max_pooling_layer,
                                activation_function=None)
relu_layer3 = pygad.cnn.ReLU(previous_layer=conv_layer3)
pooling_layer = pygad.cnn.AveragePooling2D(pool_size=2,
                                             previous_layer=relu_layer3,
                                             stride=2)

flatten_layer = pygad.cnn.Flatten(previous_layer=pooling_layer)
dense_layer1 = pygad.cnn.Dense(num_neurons=100,
                                previous_layer=flatten_layer,
                                activation_function="relu")
dense_layer2 = pygad.cnn.Dense(num_neurons=num_classes,
                                previous_layer=dense_layer1,
                                activation_function="softmax")

model = pygad.cnn.Model(last_layer=dense_layer2,
                        epochs=1,
                        learning_rate=0.01)

model.summary()

model.train(train_inputs=train_inputs,
            train_outputs=train_outputs)

predictions = model.predict(data_inputs=train_inputs)
print(predictions)

num_wrong = numpy.where(predictions != train_outputs)[0]
num_correct = train_outputs.size - num_wrong.size
accuracy = 100 * (num_correct/train_outputs.size)
print(f"Number of correct classifications : {num_correct}.")
print(f"Number of wrong classifications : {num_wrong.size}.")
print(f"Classification accuracy : {accuracy}.")
```

---

## **pygad.gacnn**

,

pygad.gacnnpygadpygad.cnn

## **pygad.gacnn.GACNN**

pygad.gacnnpygad.gacnn.GACNN()

## **\_\_init\_\_()**

pygad.gacnn.GACNN

pygad.gacnn.GACNN

model

num\_solutions()

pygad.gacnn.GACNNpygad.gacnn.GACNN

population\_networks()

pygad.gacnn.GACNN

---

---

### **create\_population()**

```
create_population().  
population_networks
```

### **update\_population\_trained\_weights()**

```
update_population_trained_weights(trained_weights(pygad.cnn) ) popula-  
tion_trained_weights  
  
population_trained_weightstrained_weights
```

## **pygad.gacnn**

```
pygad.gacnn
```

### **pygad.gacnn.population\_as\_vectors()**

```
pygad.cnn.Model()  
( ), ().  
  
population_networkspygad.cnn.Model  
( ).
```

### **pygad.gacnn.population\_as\_matrices()**

```
()  
( ),  
  
population_networkspygad.cnn.Model  
population_vectors  
( ).
```

```
pygad.gacnn.GACNN
```

---



---

pygad.cnn.Model

```
model = pygad.cnn.Model(last_layer=dense_layer,
                        epochs=5,
                        learning_rate=0.01)
```

summary() pygad.cnn.Model

```
model.summary()
```

```
-----Network Architecture-----
<class 'cnn.Conv2D'>
<class 'cnn.AveragePooling2D'>
<class 'cnn.Flatten'>
<class 'cnn.Dense'>
-----
```

pygad.gacnn.GACNN

**pygad.gacnn.GACNN**

pygad.gacnn.GACNN

num\_solutions(). model

```
import pygad.gacnn

GACNN_instance = pygad.gacnn.GACNN(model=model,
                                   num_solutions=4)
```

pygad.gacnn.GACNN

()

pygad.gacnn.population\_as\_vectors()

```
population_vectors = gacnn.population_as_vectors(population_networks=GACNN_instance.
→population_networks)
```

```
initial_population = population_vectors.copy()
```

---

---

```
pygad.cnn.predict()' pygad.cnn.predict()trained_weights
```

```
def fitness_func(ga_instance, solution, sol_idx):
    global GACNN_instance, data_inputs, data_outputs

    predictions = GACNN_instance.population_networks[sol_idx].predict(data_
    ↪inputs=data_inputs)
    correct_predictions = numpy.where(predictions == data_outputs)[0].size
    solution_fitness = (correct_predictions/data_outputs.size)*100

    return solution_fitness
```

```
pygad.cnn.predict()' trained_weights
pygad.GAon_generationpygad.GA
trained_weights
trained_weights
pygad.gacnn.population_as_matrices()
update_population_trained_weights()pygad.gacnntrained_weights
```

```
def callback_generation(ga_instance):
    global GACNN_instance, last_fitness

    population_matrices = gacnn.population_as_matrices(population_networks=GACNN_
    ↪instance.population_networks, population_vectors=ga_instance.population)
    GACNN_instance.update_population_trained_weights(population_trained_
    ↪weights=population_matrices)

    print(f"Generation = {ga_instance.generations_completed}")
```

```
pygad.GA
```

---

---

## pygad.GA

pygad.GA

```
import pygad

num_parents_mating = 4

num_generations = 10

mutation_percent_genes = 5

ga_instance = pygad.GA(num_generations=num_generations,
                        num_parents_mating=num_parents_mating,
                        initial_population=initial_population,
                        fitness_func=fitness_func,
                        mutation_percent_genes=mutation_percent_genes,
                        on_generation=callback_generation)
```

run()

## pygad.GA

run() pygad.GA num\_generations

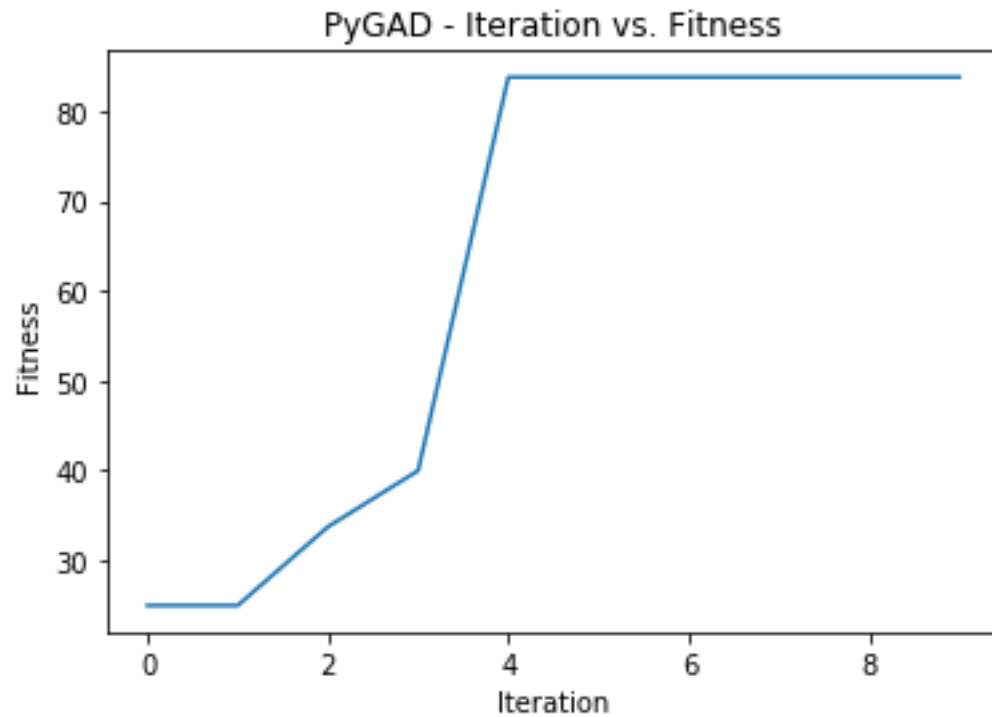
```
ga_instance.run()
```

run() plot\_fitness()

```
ga_instance.plot_fitness()
```

---





`best_solution()` pygad.GA

```
solution, solution_fitness, solution_idx = ga_instance.best_solution()
print(f"Parameters of the best solution : {solution}")
print(f"Fitness value of the best solution = {solution_fitness}")
print(f"Index of the best solution : {solution_idx}")
```

```
...
Fitness value of the best solution = 83.75
Index of the best solution : 0
Best fitness value reached after 4 generations.
```

---

---

```
pygad.cnn.predict()
```

```
predictions = pygad.cnn.predict(last_layer=GANN_instance.population_networks[solution_
↪idx], data_inputs=data_inputs)
print(f"Predictions of the trained network : {predictions}")
```

```
num_wrong = numpy.where(predictions != data_outputs)[0]
num_correct = data_outputs.size - num_wrong.size
accuracy = 100 * (num_correct/data_outputs.size)
print(f"Number of correct classifications : {num_correct}.")
print(f"Number of wrong classifications : {num_wrong.size}.")
print(f"Classification accuracy : {accuracy}.")
```

```
Number of correct classifications : 67.
Number of wrong classifications : 13.
Classification accuracy : 83.75.
```

```
import numpy
import pygad.cnn
import pygad.gacnn
import pygad

"""
Convolutional neural network implementation using NumPy
A tutorial that helps to get started (Building Convolutional Neural Network using
↪NumPy from Scratch) available in these links:
    https://www.linkedin.com/pulse/building-convolutional-neural-network-using-numpy-
↪from-ahmed-gad
    https://towardsdatascience.com/building-convolutional-neural-network-using-numpy-
↪from-scratch-b30aac50e50a
    https://www.kdnuggets.com/2018/04/building-convolutional-neural-network-numpy-
↪scratch.html
It is also translated into Chinese: http://m.aliyun.com/yunqi/articles/585741
"""

def fitness_func(ga_instance, solution, sol_idx):
    global GACNN_instance, data_inputs, data_outputs
```

0

```
    predictions = GACNN_instance.population_networks[sol_idx].predict(data_
↳ inputs=data_inputs)
    correct_predictions = numpy.where(predictions == data_outputs)[0].size
    solution_fitness = (correct_predictions/data_outputs.size)*100

    return solution_fitness

def callback_generation(ga_instance):
    global GACNN_instance, last_fitness

    population_matrices = pygad.gacnn.population_as_matrices(population_
↳ networks=GACNN_instance.population_networks,
                                                    population_vectors=ga_instance.
↳ population)

    GACNN_instance.update_population_trained_weights(population_trained_
↳ weights=population_matrices)

    print(f"Generation = {ga_instance.generations_completed}")
    print(f"Fitness      = {ga_instance.best_solutions_fitness}")

data_inputs = numpy.load("dataset_inputs.npy")
data_outputs = numpy.load("dataset_outputs.npy")

sample_shape = data_inputs.shape[1:]
num_classes = 4

data_inputs = data_inputs
data_outputs = data_outputs

input_layer = pygad.cnn.Input2D(input_shape=sample_shape)
conv_layer1 = pygad.cnn.Conv2D(num_filters=2,
                               kernel_size=3,
                               previous_layer=input_layer,
                               activation_function="relu")
average_pooling_layer = pygad.cnn.AveragePooling2D(pool_size=5,
                                                    previous_layer=conv_layer1,
                                                    stride=3)

flatten_layer = pygad.cnn.Flatten(previous_layer=average_pooling_layer)
dense_layer2 = pygad.cnn.Dense(num_neurons=num_classes,
                               previous_layer=flatten_layer,
                               activation_function="softmax")

model = pygad.cnn.Model(last_layer=dense_layer2,
                        epochs=1,
                        learning_rate=0.01)

model.summary()

GACNN_instance = pygad.gacnn.GACNN(model=model,
                                   num_solutions=4)

# GACNN_instance.update_population_trained_weights(population_trained_
↳ weights=population_matrices)
```

0

```

# population does not hold the numerical weights of the network instead it holds a
↳ list of references to each last layer of each network (i.e. solution) in the
↳ population. A solution or a network can be used interchangeably.
# If there is a population with 3 solutions (i.e. networks), then the population is a
↳ list with 3 elements. Each element is a reference to the last layer of each network.
↳ Using such a reference, all details of the network can be accessed.
population_vectors = pygad.gacnn.population_as_vectors(population_networks=GACNN_
↳ instance.population_networks)

# To prepare the initial population, there are 2 ways:
# 1) Prepare it yourself and pass it to the initial_population parameter. This way is
↳ useful when the user wants to start the genetic algorithm with a custom initial
↳ population.
# 2) Assign valid integer values to the sol_per_pop and num_genes parameters. If the
↳ initial_population parameter exists, then the sol_per_pop and num_genes parameters
↳ are useless.
initial_population = population_vectors.copy()

num_parents_mating = 2 # Number of solutions to be selected as parents in the mating
↳ pool.

num_generations = 10 # Number of generations.

mutation_percent_genes = 0.1 # Percentage of genes to mutate. This parameter has no
↳ action if the parameter mutation_num_genes exists.

ga_instance = pygad.GA(num_generations=num_generations,
                        num_parents_mating=num_parents_mating,
                        initial_population=initial_population,
                        fitness_func=fitness_func,
                        mutation_percent_genes=mutation_percent_genes,
                        on_generation=callback_generation)

ga_instance.run()

# After the generations complete, some plots are showed that summarize how the
↳ outputs/fitness values evolve over generations.
ga_instance.plot_fitness()

# Returning the details of the best solution.
solution, solution_fitness, solution_idx = ga_instance.best_solution()
print(f"Parameters of the best solution : {solution}")
print(f"Fitness value of the best solution = {solution_fitness}")
print(f"Index of the best solution : {solution_idx}")

if ga_instance.best_solution_generation != -1:
    print(f"Best fitness value reached after {ga_instance.best_solution_generation}
↳ generations.")

# Predicting the outputs of the data using the best solution.
predictions = GACNN_instance.population_networks[solution_idx].predict(data_
↳ inputs=data_inputs)
print(f"Predictions of the trained network : {predictions}")

# Calculating some statistics
num_wrong = numpy.where(predictions != data_outputs)[0]
num_correct = data_outputs.size - num_wrong.size

```

---

)

```
accuracy = 100 * (num_correct/data_outputs.size)
print(f"Number of correct classifications : {num_correct}.")
print(f"Number of wrong classifications : {num_wrong.size}.")
print(f"Classification accuracy : {accuracy}.")
```

---

---

---

## **pygad.kerasga**

,

pygad.kerasga().

KerasGA

model\_weights\_as\_vector()

model\_weights\_as\_matrix()

predict()

pygad.kerasga.KerasGA

pygad.GA

---

---

```
import tensorflow.keras

input_layer = tensorflow.keras.layers.Input(3)
dense_layer1 = tensorflow.keras.layers.Dense(5, activation="relu")
output_layer = tensorflow.keras.layers.Dense(1, activation="linear")

model = tensorflow.keras.Sequential()
model.add(input_layer)
model.add(dense_layer1)
model.add(output_layer)
```

```
input_layer = tensorflow.keras.layers.Input(3)
dense_layer1 = tensorflow.keras.layers.Dense(5, activation="relu")(input_layer)
output_layer = tensorflow.keras.layers.Dense(1, activation="linear")(dense_layer1)

model = tensorflow.keras.Model(inputs=input_layer, outputs=output_layer)
```

## **pygad.kerasga.KerasGA**

pygad.kerasgaKerasGA

### **`__init__()`**

pygad.kerasga.KerasGA

model  
num\_solutions

pygad.kerasga.KerasGApopulation\_weights

model  
num\_solutions  
population\_weights

---



---

## KerasGA

pygad.kerasga.KerasGA

### create\_population()

create\_population()population\_weights

## pygad.kerasga

pygad.kerasga

### pygad.kerasga.model\_weights\_as\_vector()

model\_weights\_as\_vector()model  
trainabletrainable=False

model

### pygad.kerasga.model\_weights\_as\_matrix()

model\_weights\_as\_matrix()  
model  
weights\_vector

### pygad.kerasga.predict()

predict()  
model  
solution  
data  
batch\_size=None().  
verbose=None:  
steps=None().  
()batch\_sizeverbosesteps

---

```
import tensorflow.keras
import pygad.kerasga
import numpy
import pygad

def fitness_func(ga_instance, solution, sol_idx):
    global data_inputs, data_outputs, keras_ga, model

    predictions = pygad.kerasga.predict(model=model,
                                         solution=solution,
                                         data=data_inputs)

    mae = tensorflow.keras.losses.MeanAbsoluteError()
    abs_error = mae(data_outputs, predictions).numpy() + 0.00000001
    solution_fitness = 1.0/abs_error

    return solution_fitness

def on_generation(ga_instance):
    print(f"Generation = {ga_instance.generations_completed}")
    print(f"Fitness      = {ga_instance.best_solution()[1]}")

input_layer = tensorflow.keras.layers.Input(3)
dense_layer1 = tensorflow.keras.layers.Dense(5, activation="relu")(input_layer)
output_layer = tensorflow.keras.layers.Dense(1, activation="linear")(dense_layer1)

model = tensorflow.keras.Model(inputs=input_layer, outputs=output_layer)

keras_ga = pygad.kerasga.KerasGA(model=model,
                                 num_solutions=10)

# Data inputs
data_inputs = numpy.array([[0.02, 0.1, 0.15],
                           [0.7, 0.6, 0.8],
                           [1.5, 1.2, 1.7],
                           [3.2, 2.9, 3.1]])

# Data outputs
data_outputs = numpy.array([[0.1],
                             [0.6],
                             [1.3],
                             [2.5]])

# Prepare the PyGAD parameters. Check the documentation for more information: https://pygad.readthedocs.io/en/latest/pygad.html#pygad-ga-class
num_generations = 250 # Number of generations.
num_parents_mating = 5 # Number of solutions to be selected as parents in the mating_
↳pool.
```

)

```
initial_population = keras_ga.population_weights # Initial population of network_
↳weights

ga_instance = pygad.GA(num_generations=num_generations,
                       num_parents_mating=num_parents_mating,
                       initial_population=initial_population,
                       fitness_func=fitness_func,
                       on_generation=on_generation)

ga_instance.run()

# After the generations complete, some plots are showed that summarize how the_
↳outputs/fitness values evolve over generations.
ga_instance.plot_fitness(title="PyGAD & Keras - Iteration vs. Fitness", linewidth=4)

# Returning the details of the best solution.
solution, solution_fitness, solution_idx = ga_instance.best_solution()
print(f"Fitness value of the best solution = {solution_fitness}")
print(f"Index of the best solution : {solution_idx}")

# Make prediction based on the best solution.
predictions = pygad.kerasga.predict(model=model,
                                     solution=solution,
                                     data=data_inputs)

print(f"Predictions : \n{predictions}")

mae = tensorflow.keras.losses.MeanAbsoluteError()
abs_error = mae(data_outputs, predictions).numpy()
print(f"Absolute Error : {abs_error}")
```

```
import tensorflow.keras

input_layer = tensorflow.keras.layers.Input(3)
dense_layer1 = tensorflow.keras.layers.Dense(5, activation="relu")(input_layer)
output_layer = tensorflow.keras.layers.Dense(1, activation="linear")(dense_layer1)

model = tensorflow.keras.Model(inputs=input_layer, outputs=output_layer)
```

```
input_layer = tensorflow.keras.layers.Input(3)
dense_layer1 = tensorflow.keras.layers.Dense(5, activation="relu")
output_layer = tensorflow.keras.layers.Dense(1, activation="linear")

model = tensorflow.keras.Sequential()
model.add(input_layer)
model.add(dense_layer1)
model.add(output_layer)
```

---

## pygad.kerasga.KerasGA

pygad.kerasga.KerasGA

```
import pygad.kerasga

keras_ga = pygad.kerasga.KerasGA(model=model,
                                   num_solutions=10)
```

```
import numpy

# Data inputs
data_inputs = numpy.array([[0.02, 0.1, 0.15],
                           [0.7, 0.6, 0.8],
                           [1.5, 1.2, 1.7],
                           [3.2, 2.9, 3.1]])

# Data outputs
data_outputs = numpy.array([[0.1],
                             [0.6],
                             [1.3],
                             [2.5]])
```

predict()

```
def fitness_func(ga_instance, solution, sol_idx):
    global data_inputs, data_outputs, keras_ga, model

    predictions = pygad.kerasga.predict(model=model,
                                          solution=solution,
                                          data=data_inputs)

    mae = tensorflow.keras.losses.MeanAbsoluteError()
    abs_error = mae(data_outputs, predictions).numpy() + 0.00000001
    solution_fitness = 1.0/abs_error

    return solution_fitness
```

---

---

## pygad.GA

pygad.GAinitial\_population

```
# Prepare the PyGAD parameters. Check the documentation for more information: https://pygad.readthedocs.io/en/latest/pygad.html#pygad-ga-class
↳pygad.readthedocs.io/en/latest/pygad.html#pygad-ga-class
num_generations = 250 # Number of generations.
num_parents_mating = 5 # Number of solutions to be selected as parents in the mating_
↳pool.
initial_population = keras_ga.population_weights # Initial population of network_
↳weights

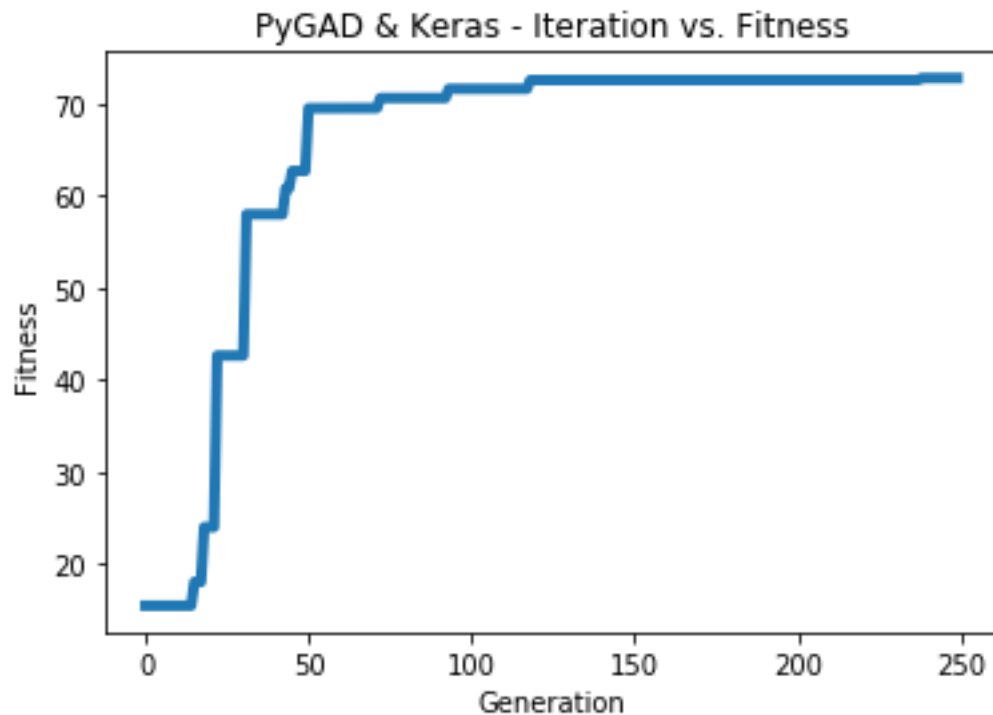
ga_instance = pygad.GA(num_generations=num_generations,
                        num_parents_mating=num_parents_mating,
                        initial_population=initial_population,
                        fitness_func=fitness_func,
                        on_generation=on_generation)
```

run()

```
ga_instance.run()
```

plot\_fitness()

```
ga_instance.plot_fitness(title="PyGAD & Keras - Iteration vs. Fitness", linewidth=4)
```



---

best\_solution()

```
# Returning the details of the best solution.
solution, solution_fitness, solution_idx = ga_instance.best_solution()
print(f"Fitness value of the best solution = {solution_fitness}")
print(f"Index of the best solution : {solution_idx}")
```

```
Fitness value of the best solution = 72.77768757825352
Index of the best solution : 0
```

predict()

```
# Fetch the parameters of the best solution.
predictions = pygad.kerasga.predict(model=model,
                                     solution=solution,
                                     data=data_inputs)
print(f"Predictions : \n{predictions}")
```

```
Predictions :
[[0.09935353]
 [0.63082725]
 [1.2765523 ]
 [2.4999595 ]]
```

```
mae = tensorflow.keras.losses.MeanAbsoluteError()
abs_error = mae(data_outputs, predictions).numpy()
print(f"Absolute Error : {abs_error}")
```

```
Absolute Error : 0.013740465
```

,

```
import tensorflow.keras
import pygad.kerasga
import numpy
import pygad

def fitness_func(ga_instance, solution, sol_idx):
    global data_inputs, data_outputs, keras_ga, model

    predictions = pygad.kerasga.predict(model=model,
                                       solution=solution,
                                       data=data_inputs)

    bce = tensorflow.keras.losses.BinaryCrossentropy()
    solution_fitness = 1.0 / (bce(data_outputs, predictions).numpy() + 0.00000001)

    return solution_fitness

def on_generation(ga_instance):
    print(f"Generation = {ga_instance.generations_completed}")
```

()

---

)

```
print(f"Fitness      = {ga_instance.best_solution()[1]}")

# Build the keras model using the functional API.
input_layer  = tensorflow.keras.layers.Input(2)
dense_layer  = tensorflow.keras.layers.Dense(4, activation="relu")(input_layer)
output_layer = tensorflow.keras.layers.Dense(2, activation="softmax")(dense_layer)

model = tensorflow.keras.Model(inputs=input_layer, outputs=output_layer)

# Create an instance of the pygad.kerasga.KerasGA class to build the initial_
↳population.
keras_ga = pygad.kerasga.KerasGA(model=model,
                                num_solutions=10)

# XOR problem inputs
data_inputs = numpy.array([[0, 0],
                           [0, 1],
                           [1, 0],
                           [1, 1]])

# XOR problem outputs
data_outputs = numpy.array([[1, 0],
                           [0, 1],
                           [0, 1],
                           [1, 0]])

# Prepare the PyGAD parameters. Check the documentation for more information: https://
↳pygad.readthedocs.io/en/latest/pygad.html#pygad-ga-class
num_generations = 250 # Number of generations.
num_parents_mating = 5 # Number of solutions to be selected as parents in the mating_
↳pool.
initial_population = keras_ga.population_weights # Initial population of network_
↳weights.

# Create an instance of the pygad.GA class
ga_instance = pygad.GA(num_generations=num_generations,
                      num_parents_mating=num_parents_mating,
                      initial_population=initial_population,
                      fitness_func=fitness_func,
                      on_generation=on_generation)

# Start the genetic algorithm evolution.
ga_instance.run()

# After the generations complete, some plots are showed that summarize how the_
↳outputs/fitness values evolve over generations.
ga_instance.plot_fitness(title="PyGAD & Keras - Iteration vs. Fitness", linewidth=4)

# Returning the details of the best solution.
solution, solution_fitness, solution_idx = ga_instance.best_solution()
print(f"Fitness value of the best solution = {solution_fitness}")
print(f"Index of the best solution : {solution_idx}")

# Make predictions based on the best solution.
predictions = pygad.kerasga.predict(model=model,
                                    solution=solution,
                                    data=data_inputs)
```

)

---

)

```
print(f"Predictions : \n{predictions}")

# Calculate the binary crossentropy for the trained model.
bce = tensorflow.keras.losses.BinaryCrossentropy()
print("Binary Crossentropy : ", bce(data_outputs, predictions).numpy())

# Calculate the classification accuracy for the trained model.
ba = tensorflow.keras.metrics.BinaryAccuracy()
ba.update_state(data_outputs, predictions)
accuracy = ba.result().numpy()
print(f"Accuracy : {accuracy}")
```

```
# Build the keras model using the functional API.
input_layer = tensorflow.keras.layers.Input(2)
dense_layer = tensorflow.keras.layers.Dense(4, activation="relu")(input_layer)
output_layer = tensorflow.keras.layers.Dense(2, activation="softmax")(dense_layer)

model = tensorflow.keras.Model(inputs=input_layer, outputs=output_layer)
```

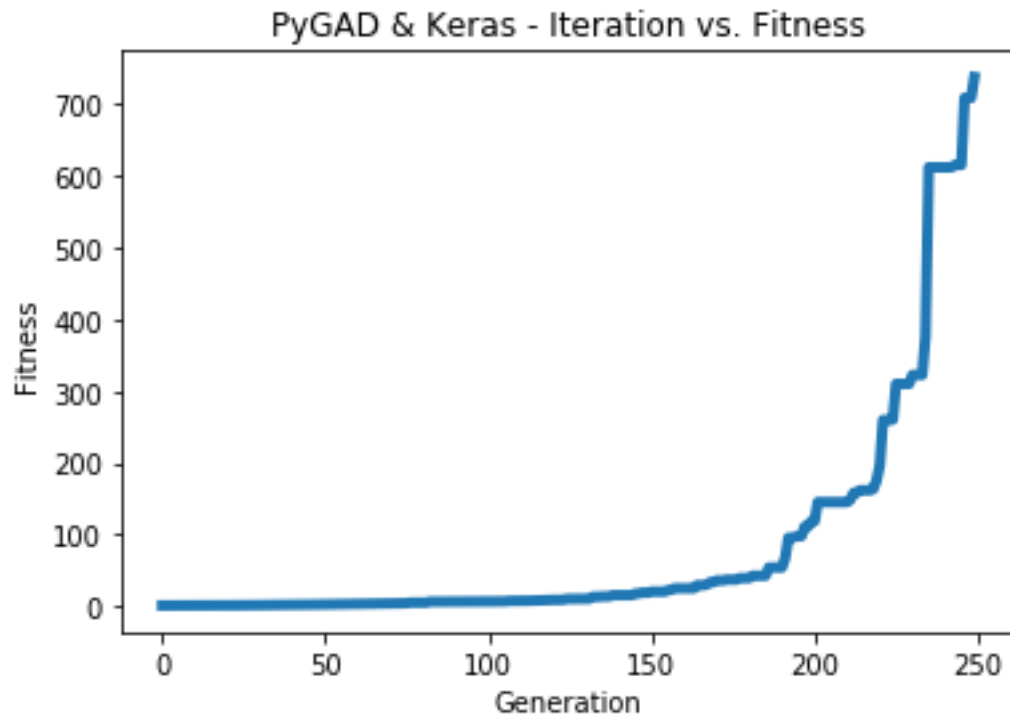
```
# XOR problem inputs
data_inputs = numpy.array([[0, 0],
                           [0, 1],
                           [1, 0],
                           [1, 1]])

# XOR problem outputs
data_outputs = numpy.array([[1, 0],
                            [0, 1],
                            [0, 1],
                            [1, 0]])
```

```
bce = tensorflow.keras.losses.BinaryCrossentropy()
solution_fitness = 1.0 / (bce(data_outputs, predictions).numpy() + 0.00000001)
```

---





739.240.0013527311

Fitness value of the best solution = 739.2397344644013

Index of the best solution : 7

Predictions :

```
[9.9694413e-01 3.0558957e-03]
[5.0176249e-04 9.9949825e-01]
[1.8470541e-03 9.9815291e-01]
[9.9999976e-01 2.0538971e-07]]
```

Binary Crossentropy : 0.0013527311

Accuracy : 1.0

()

```
import tensorflow.keras
import pygad.kerasga
import numpy
import pygad

def fitness_func(ga_instance, solution, sol_idx):
    global data_inputs, data_outputs, keras_ga, model

    predictions = pygad.kerasga.predict(model=model,
                                         solution=solution,
                                         data=data_inputs)
```

()

---

```

cce = tensorflow.keras.losses.CategoricalCrossentropy()
solution_fitness = 1.0 / (cce(data_outputs, predictions).numpy() + 0.00000001)

return solution_fitness

def on_generation(ga_instance):
    print(f"Generation = {ga_instance.generations_completed}")
    print(f"Fitness      = {ga_instance.best_solution()[1]}")

# Build the keras model using the functional API.
input_layer = tensorflow.keras.layers.Input(360)
dense_layer = tensorflow.keras.layers.Dense(50, activation="relu")(input_layer)
output_layer = tensorflow.keras.layers.Dense(4, activation="softmax")(dense_layer)

model = tensorflow.keras.Model(inputs=input_layer, outputs=output_layer)

# Create an instance of the pygad.kerasga.KerasGA class to build the initial_
↳population.
keras_ga = pygad.kerasga.KerasGA(model=model,
                                num_solutions=10)

# Data inputs
data_inputs = numpy.load("../data/dataset_features.npy")

# Data outputs
data_outputs = numpy.load("../data/outputs.npy")
data_outputs = tensorflow.keras.utils.to_categorical(data_outputs)

# Prepare the PyGAD parameters. Check the documentation for more information: https://
↳pygad.readthedocs.io/en/latest/pygad.html#pygad-ga-class
num_generations = 100 # Number of generations.
num_parents_mating = 5 # Number of solutions to be selected as parents in the mating_
↳pool.
initial_population = keras_ga.population_weights # Initial population of network_
↳weights.

# Create an instance of the pygad.GA class
ga_instance = pygad.GA(num_generations=num_generations,
                      num_parents_mating=num_parents_mating,
                      initial_population=initial_population,
                      fitness_func=fitness_func,
                      on_generation=on_generation)

# Start the genetic algorithm evolution.
ga_instance.run()

# After the generations complete, some plots are showed that summarize how the_
↳outputs/fitness values evolve over generations.
ga_instance.plot_fitness(title="PyGAD & Keras - Iteration vs. Fitness", linewidth=4)

# Returning the details of the best solution.
solution, solution_fitness, solution_idx = ga_instance.best_solution()
print(f"Fitness value of the best solution = {solution_fitness}")
print(f"Index of the best solution : {solution_idx}")

# Make predictions based on the best solution.

```

---

()

```
predictions = pygad.kerasga.predict(model=model,
                                     solution=solution,
                                     data=data_inputs)
# print(f"Predictions : \n{predictions}")

# Calculate the categorical crossentropy for the trained model.
cce = tensorflow.keras.losses.CategoricalCrossentropy()
print(f"Categorical Crossentropy : {cce(data_outputs, predictions).numpy()}")

# Calculate the classification accuracy for the trained model.
ca = tensorflow.keras.metrics.CategoricalAccuracy()
ca.update_state(data_outputs, predictions)
accuracy = ca.result().numpy()
print(f"Accuracy : {accuracy}")
```

()

```
cce = tensorflow.keras.losses.CategoricalCrossentropy()
solution_fitness = 1.0 / (cce(data_outputs, predictions).numpy() + 0.00000001)
```

()

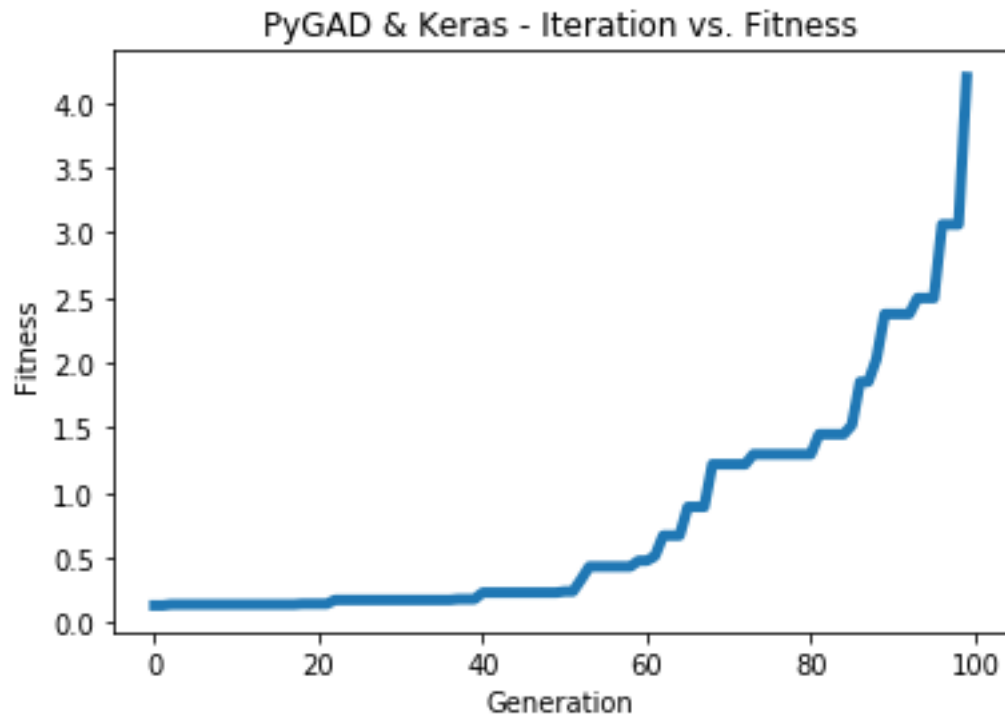
(100, 100, 3)

tensorflow.keras.utils.to\_categorical()

```
import numpy

data_inputs = numpy.load("../data/dataset_features.npy")

data_outputs = numpy.load("../data/outputs.npy")
data_outputs = tensorflow.keras.utils.to_categorical(data_outputs)
```



```
Fitness value of the best solution = 4.197464252185969
Index of the best solution : 0
Categorical Crossentropy : 0.23823906
Accuracy : 0.9852192
```

()

```
import tensorflow.keras
import pygad.kerasga
import numpy
import pygad

def fitness_func(ga_instance, solution, sol_idx):
    global data_inputs, data_outputs, keras_ga, model

    predictions = pygad.kerasga.predict(model=model,
                                         solution=solution,
                                         data=data_inputs)

    cce = tensorflow.keras.losses.CategoricalCrossentropy()
    solution_fitness = 1.0 / (cce(data_outputs, predictions).numpy() + 0.00000001)

    return solution_fitness

def on_generation(ga_instance):
```

()

```

    print(f"Generation = {ga_instance.generations_completed}")
    print(f"Fitness      = {ga_instance.best_solution()[1]}")

# Build the keras model using the functional API.
input_layer = tensorflow.keras.layers.Input(shape=(100, 100, 3))
conv_layer1 = tensorflow.keras.layers.Conv2D(filters=5,
                                              kernel_size=7,
                                              activation="relu")(input_layer)
max_pool1 = tensorflow.keras.layers.MaxPooling2D(pool_size=(5,5),
                                                  strides=5)(conv_layer1)
conv_layer2 = tensorflow.keras.layers.Conv2D(filters=3,
                                              kernel_size=3,
                                              activation="relu")(max_pool1)
flatten_layer = tensorflow.keras.layers.Flatten()(conv_layer2)
dense_layer = tensorflow.keras.layers.Dense(15, activation="relu")(flatten_layer)
output_layer = tensorflow.keras.layers.Dense(4, activation="softmax")(dense_layer)

model = tensorflow.keras.Model(inputs=input_layer, outputs=output_layer)

# Create an instance of the pygad.kerasga.KerasGA class to build the initial_
↳population.
keras_ga = pygad.kerasga.KerasGA(model=model,
                                num_solutions=10)

# Data inputs
data_inputs = numpy.load("../data/dataset_inputs.npy")

# Data outputs
data_outputs = numpy.load("../data/dataset_outputs.npy")
data_outputs = tensorflow.keras.utils.to_categorical(data_outputs)

# Prepare the PyGAD parameters. Check the documentation for more information: https://
↳pygad.readthedocs.io/en/latest/pygad.html#pygad-ga-class
num_generations = 200 # Number of generations.
num_parents_mating = 5 # Number of solutions to be selected as parents in the mating_
↳pool.
initial_population = keras_ga.population_weights # Initial population of network_
↳weights.

# Create an instance of the pygad.GA class
ga_instance = pygad.GA(num_generations=num_generations,
                      num_parents_mating=num_parents_mating,
                      initial_population=initial_population,
                      fitness_func=fitness_func,
                      on_generation=on_generation)

# Start the genetic algorithm evolution.
ga_instance.run()

# After the generations complete, some plots are showed that summarize how the_
↳outputs/fitness values evolve over generations.
ga_instance.plot_fitness(title="PyGAD & Keras - Iteration vs. Fitness", linewidth=4)

# Returning the details of the best solution.
solution, solution_fitness, solution_idx = ga_instance.best_solution()
print(f"Fitness value of the best solution = {solution_fitness}")
print(f"Index of the best solution : {solution_idx}")

```

```

# Make predictions based on the best solution.
predictions = pygad.kerasga.predict(model=model,
                                     solution=solution,
                                     data=data_inputs)

# print(f"Predictions : \n{predictions}")

# Calculate the categorical crossentropy for the trained model.
cce = tensorflow.keras.losses.CategoricalCrossentropy()
print(f"Categorical Crossentropy : {cce(data_outputs, predictions).numpy()}")

# Calculate the classification accuracy for the trained model.
ca = tensorflow.keras.metrics.CategoricalAccuracy()
ca.update_state(data_outputs, predictions)
accuracy = ca.result().numpy()
print(f"Accuracy : {accuracy}")

```

```

# Build the keras model using the functional API.
input_layer = tensorflow.keras.layers.Input(shape=(100, 100, 3))
conv_layer1 = tensorflow.keras.layers.Conv2D(filters=5,
                                              kernel_size=7,
                                              activation="relu")(input_layer)
max_pool1 = tensorflow.keras.layers.MaxPooling2D(pool_size=(5, 5),
                                                  strides=5)(conv_layer1)
conv_layer2 = tensorflow.keras.layers.Conv2D(filters=3,
                                              kernel_size=3,
                                              activation="relu")(max_pool1)
flatten_layer = tensorflow.keras.layers.Flatten()(conv_layer2)
dense_layer = tensorflow.keras.layers.Dense(15, activation="relu")(flatten_layer)
output_layer = tensorflow.keras.layers.Dense(4, activation="softmax")(dense_layer)

model = tensorflow.keras.Model(inputs=input_layer, outputs=output_layer)

```

(100, 100, 3)pygad.cnn

tensorflow.keras.utils.to\_categorical()

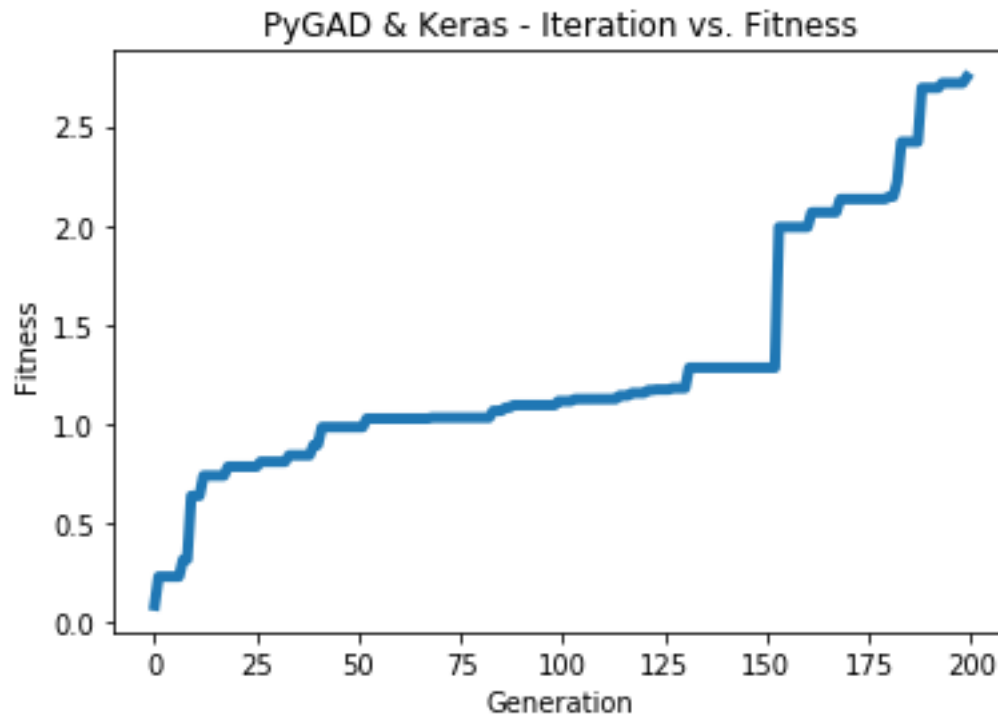
```

import numpy

data_inputs = numpy.load("../data/dataset_inputs.npy")

data_outputs = numpy.load("../data/dataset_outputs.npy")
data_outputs = tensorflow.keras.utils.to_categorical(data_outputs)

```



```
Fitness value of the best solution = 2.7462310258668805
Index of the best solution : 0
Categorical Crossentropy : 0.3641354
Accuracy : 0.75
```

()

tensorflow.keras.preprocessing.image.ImageDataGenerator

```
import tensorflow as tf
import tensorflow.keras
import pygad.kerasga
import pygad

def fitness_func(ga_instanse, solution, sol_idx):
    global train_generator, data_outputs, keras_ga, model

    predictions = pygad.kerasga.predict(model=model,
                                         solution=solution,
                                         data=train_generator)
```

()

---

```

cce = tensorflow.keras.losses.CategoricalCrossentropy()
solution_fitness = 1.0 / (cce(data_outputs, predictions).numpy() + 0.00000001)

return solution_fitness

def on_generation(ga_instance):
    print("Generation = {ga_instance.generations_completed}")
    print("Fitness      = {ga_instance.best_solution(ga_instance.last_generation_
↪fitness) [1]}")

# The dataset path.
dataset_path = r'../data/Skin_Cancer_Dataset'

num_classes = 2
img_size = 224

# Create a simple CNN. This does not gurantee high classification accuracy.
model = tf.keras.models.Sequential()
model.add(tf.keras.layers.Input(shape=(img_size, img_size, 3)))
model.add(tf.keras.layers.Conv2D(32, (3,3), activation="relu", padding="same"))
model.add(tf.keras.layers.MaxPooling2D((2, 2)))
model.add(tf.keras.layers.Flatten())
model.add(tf.keras.layers.Dropout(rate=0.2))
model.add(tf.keras.layers.Dense(num_classes, activation="softmax"))

# Create an instance of the pygad.kerasga.KerasGA class to build the initial_
↪population.
keras_ga = pygad.kerasga.KerasGA(model=model,
                                num_solutions=10)

data_generator = tf.keras.preprocessing.image.ImageDataGenerator()
train_generator = data_generator.flow_from_directory(dataset_path,
                                                    class_mode='categorical',
                                                    target_size=(224, 224),
                                                    batch_size=32,
                                                    shuffle=False)

# train_generator.class_indices
data_outputs = tf.keras.utils.to_categorical(train_generator.labels)

# Check the documentation for more information about the parameters: https://pygad.
↪readthedocs.io/en/latest/pygad.html#pygad-ga-class
initial_population = keras_ga.population_weights # Initial population of network_
↪weights.

# Create an instance of the pygad.GA class
ga_instance = pygad.GA(num_generations=10,
                      num_parents_mating=5,
                      initial_population=initial_population,
                      fitness_func=fitness_func,
                      on_generation=on_generation)

# Start the genetic algorithm evolution.
ga_instance.run()

# After the generations complete, some plots are showed that summarize how the_
↪outputs/fitness values evolve over generations.

```



---

)

```
ga_instance.plot_fitness(title="PyGAD & Keras - Iteration vs. Fitness", linewidth=4)

# Returning the details of the best solution.
solution, solution_fitness, solution_idx = ga_instance.best_solution(ga_instance.last_
    ↳ generation_fitness)
print(f"Fitness value of the best solution = {solution_fitness}")
print(f"Index of the best solution : {solution_idx}")

predictions = pygad.kerasga.predict(model=model,
                                     solution=solution,
                                     data=train_generator)
# print(f"Predictions : \n{predictions}")

# Calculate the categorical crossentropy for the trained model.
cce = tensorflow.keras.losses.CategoricalCrossentropy()
print(f"Categorical Crossentropy : {cce(data_outputs, predictions).numpy()}")

# Calculate the classification accuracy for the trained model.
ca = tensorflow.keras.metrics.CategoricalAccuracy()
ca.update_state(data_outputs, predictions)
accuracy = ca.result().numpy()
print(f"Accuracy : {accuracy}")
```

---

---

---

---

## **pygad.torchga**

,

pygad.torchga().

TorchGA

model\_weights\_as\_vector()

model\_weights\_as\_dict()

predict()

pygad.torchga.TorchGA

pygad.GA

---

---

```
import torch

input_layer = torch.nn.Linear(3, 5)
relu_layer = torch.nn.ReLU()
output_layer = torch.nn.Linear(5, 1)

model = torch.nn.Sequential(input_layer,
                             relu_layer,
                             output_layer)
```

## **pygad.torchga.TorchGA**

pygad.torchgaTorchGA

### **\_\_init\_\_()**

pygad.torchga.TorchGA

```
    model
    num_solutions
```

pygad.torchga.TorchGApopulation\_weights

```
    model
    num_solutions
    population_weights
```

### **TorchGA**

pygad.torchga.TorchGA

### **create\_population()**

create\_population()population\_weights

---

---

## pygad.torchga

pygad.torchga

### pygad.torchga.model\_weights\_as\_vector()

model\_weights\_as\_vector()model

model

### pygad.torch.model\_weights\_as\_dict()

model\_weights\_as\_dict()

model

weights\_vector

state\_dict()load\_state\_dict()'

### pygad.torchga.predict()

predict()

model

solution

data

```
import torch
import torchga
import pygad

def fitness_func(ga_instance, solution, sol_idx):
    global data_inputs, data_outputs, torch_ga, model, loss_function

    predictions = pygad.torchga.predict(model=model,
                                         solution=solution,
```

()

0

```

                                data=data_inputs)

    abs_error = loss_function(predictions, data_outputs).detach().numpy() + 0.00000001

    solution_fitness = 1.0 / abs_error

    return solution_fitness

def on_generation(ga_instance):
    print(f"Generation = {ga_instance.generations_completed}")
    print(f"Fitness      = {ga_instance.best_solution()[1]}")

# Create the PyTorch model.
input_layer = torch.nn.Linear(3, 5)
relu_layer = torch.nn.ReLU()
output_layer = torch.nn.Linear(5, 1)

model = torch.nn.Sequential(input_layer,
                             relu_layer,
                             output_layer)

# print(model)

# Create an instance of the pygad.torchga.TorchGA class to build the initial_
↳population.
torch_ga = torchga.TorchGA(model=model,
                           num_solutions=10)

loss_function = torch.nn.L1Loss()

# Data inputs
data_inputs = torch.tensor([[0.02, 0.1, 0.15],
                             [0.7, 0.6, 0.8],
                             [1.5, 1.2, 1.7],
                             [3.2, 2.9, 3.1]])

# Data outputs
data_outputs = torch.tensor([[0.1],
                              [0.6],
                              [1.3],
                              [2.5]])

# Prepare the PyGAD parameters. Check the documentation for more information: https://
↳pygad.readthedocs.io/en/latest/pygad.html#pygad-ga-class
num_generations = 250 # Number of generations.
num_parents_mating = 5 # Number of solutions to be selected as parents in the mating_
↳pool.
initial_population = torch_ga.population_weights # Initial population of network_
↳weights

ga_instance = pygad.GA(num_generations=num_generations,
                      num_parents_mating=num_parents_mating,
                      initial_population=initial_population,
                      fitness_func=fitness_func,
                      on_generation=on_generation)

ga_instance.run()
```

0

0

```
# After the generations complete, some plots are showed that summarize how the
↳ outputs/fitness values evolve over generations.
ga_instance.plot_fitness(title="PyGAD & PyTorch - Iteration vs. Fitness", linewidth=4)

# Returning the details of the best solution.
solution, solution_fitness, solution_idx = ga_instance.best_solution()
print(f"Fitness value of the best solution = {solution_fitness}")
print(f"Index of the best solution : {solution_idx}")

# Make predictions based on the best solution.
predictions = pygad.torchga.predict(model=model,
                                     solution=solution,
                                     data=data_inputs)
print("Predictions : \n", predictions.detach().numpy())

abs_error = loss_function(predictions, data_outputs)
print("Absolute Error : ", abs_error.detach().numpy())
```

```
import torch

input_layer = torch.nn.Linear(3, 5)
relu_layer = torch.nn.ReLU()
output_layer = torch.nn.Linear(5, 1)

model = torch.nn.Sequential(input_layer,
                             relu_layer,
                             output_layer)
```

### **pygad.torchga.TorchGA**

pygad.torchga.TorchGA

```
import pygad.torchga

torch_ga = torchga.TorchGA(model=model,
                             num_solutions=10)
```

```
import numpy

# Data inputs
data_inputs = numpy.array([[0.02, 0.1, 0.15],
                           [0.7, 0.6, 0.8],
                           [1.5, 1.2, 1.7],
                           [3.2, 2.9, 3.1]])
```

0

---

)

```
# Data outputs
data_outputs = numpy.array([[0.1],
                             [0.6],
                             [1.3],
                             [2.5]])
```

()

```
loss_function = torch.nn.L1Loss()

def fitness_func(ga_instance, solution, sol_idx):
    global data_inputs, data_outputs, torch_ga, model, loss_function

    predictions = pygad.torchga.predict(model=model,
                                         solution=solution,
                                         data=data_inputs)

    abs_error = loss_function(predictions, data_outputs).detach().numpy() + 0.00000001

    solution_fitness = 1.0 / abs_error

    return solution_fitness
```

## pygad.GA

pygad.GAinitial\_population

```
# Prepare the PyGAD parameters. Check the documentation for more information: https://pygad.readthedocs.io/en/latest/pygad.html#pygad-ga-class
num_generations = 250 # Number of generations.
num_parents_mating = 5 # Number of solutions to be selected as parents in the mating_
                        ↳pool.
initial_population = torch_ga.population_weights # Initial population of network_
                        ↳weights

ga_instance = pygad.GA(num_generations=num_generations,
                       num_parents_mating=num_parents_mating,
                       initial_population=initial_population,
                       fitness_func=fitness_func,
                       on_generation=on_generation)
```



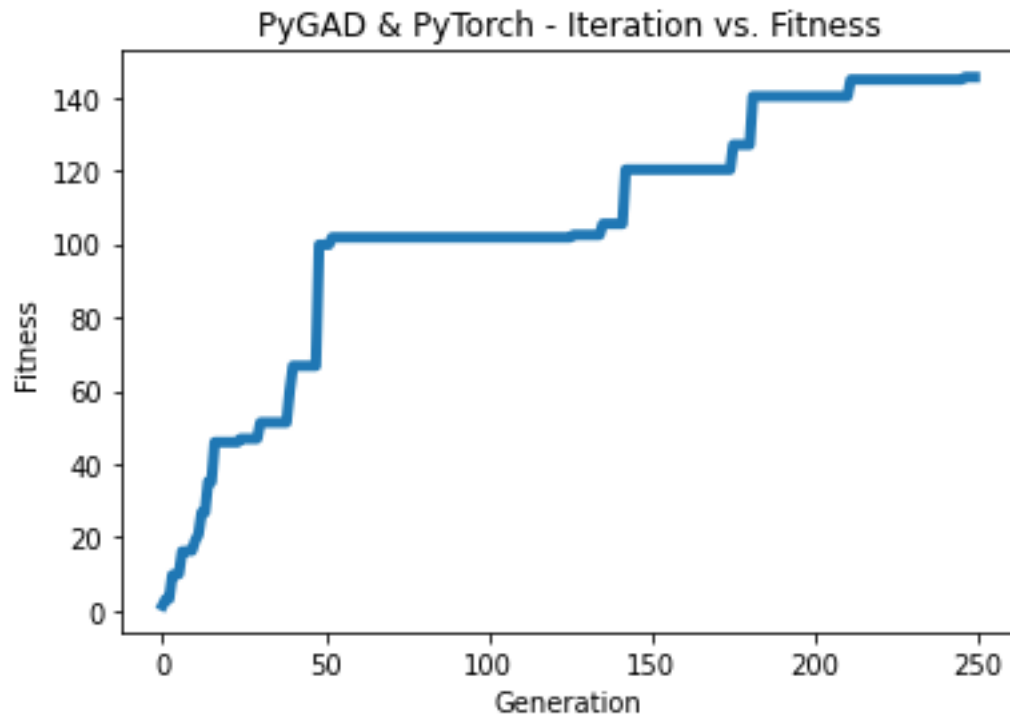
---

```
run()
```

```
ga_instance.run()
```

```
plot_fitness()
```

```
ga_instance.plot_fitness(title="PyGAD & PyTorch - Iteration vs. Fitness", linewidth=4)
```



```
best_solution()
```

```
# Returning the details of the best solution.  
solution, solution_fitness, solution_idx = ga_instance.best_solution()  
print(f"Fitness value of the best solution = {solution_fitness}")  
print(f"Index of the best solution : {solution_idx}")
```

```
Fitness value of the best solution = 145.42425295191546  
Index of the best solution : 0
```

```
model_weights_as_dict()
```

```
predictions = pygad.torchga.predict(model=model,  
                                     solution=solution,  
                                     data=data_inputs)  
print("Predictions : \n", predictions.detach().numpy())
```

```
Predictions :  
[[0.08401088]
```

0

```
[0.60939324]
[1.3010881 ]
[2.5010352 ]]
```

```
abs_error = loss_function(predictions, data_outputs)
print("Absolute Error : ", abs_error.detach().numpy())
```

```
Absolute Error : 0.006876422
```

,

```
import torch
import torchga
import pygad

def fitness_func(ga_instance, solution, sol_idx):
    global data_inputs, data_outputs, torch_ga, model, loss_function

    predictions = pygad.torchga.predict(model=model,
                                         solution=solution,
                                         data=data_inputs)

    solution_fitness = 1.0 / (loss_function(predictions, data_outputs).detach().
    ↪numpy() + 0.00000001)

    return solution_fitness

def on_generation(ga_instance):
    print(f"Generation = {ga_instance.generations_completed}")
    print(f"Fitness      = {ga_instance.best_solution()[1]}")

# Create the PyTorch model.
input_layer = torch.nn.Linear(2, 4)
relu_layer = torch.nn.ReLU()
dense_layer = torch.nn.Linear(4, 2)
output_layer = torch.nn.Softmax(1)

model = torch.nn.Sequential(input_layer,
                             relu_layer,
                             dense_layer,
                             output_layer)

# print(model)

# Create an instance of the pygad.torchga.TorchGA class to build the initial_
↪population.
torch_ga = torchga.TorchGA(model=model,
                           num_solutions=10)

loss_function = torch.nn.BCELoss()

# XOR problem inputs
```

0

```

data_inputs = torch.tensor([[0.0, 0.0],
                             [0.0, 1.0],
                             [1.0, 0.0],
                             [1.0, 1.0]])

# XOR problem outputs
data_outputs = torch.tensor([[1.0, 0.0],
                              [0.0, 1.0],
                              [0.0, 1.0],
                              [1.0, 0.0]])

# Prepare the PyGAD parameters. Check the documentation for more information: https://
↳pygad.readthedocs.io/en/latest/pygad.html#pygad-ga-class
num_generations = 250 # Number of generations.
num_parents_mating = 5 # Number of solutions to be selected as parents in the mating_
↳pool.
initial_population = torch_ga.population_weights # Initial population of network_
↳weights.

# Create an instance of the pygad.GA class
ga_instance = pygad.GA(num_generations=num_generations,
                       num_parents_mating=num_parents_mating,
                       initial_population=initial_population,
                       fitness_func=fitness_func,
                       on_generation=on_generation)

# Start the genetic algorithm evolution.
ga_instance.run()

# After the generations complete, some plots are showed that summarize how the_
↳outputs/fitness values evolve over generations.
ga_instance.plot_fitness(title="PyGAD & PyTorch - Iteration vs. Fitness", linewidth=4)

# Returning the details of the best solution.
solution, solution_fitness, solution_idx = ga_instance.best_solution()
print(f"Fitness value of the best solution = {solution_fitness}")
print(f"Index of the best solution : {solution_idx}")

# Make predictions based on the best solution.
predictions = pygad.torchga.predict(model=model,
                                     solution=solution,
                                     data=data_inputs)
print("Predictions : \n", predictions.detach().numpy())

# Calculate the binary crossentropy for the trained model.
print("Binary Crossentropy : ", loss_function(predictions, data_outputs).detach().
↳numpy())

# Calculate the classification accuracy of the trained model.
a = torch.max(predictions, axis=1)
b = torch.max(data_outputs, axis=1)
accuracy = torch.sum(a.indices == b.indices) / len(data_outputs)
print("Accuracy : ", accuracy.detach().numpy())

```

```

input_layer = torch.nn.Linear(2, 4)
relu_layer = torch.nn.ReLU()
dense_layer = torch.nn.Linear(4, 2)
output_layer = torch.nn.Softmax(1)

model = torch.nn.Sequential(input_layer,
                             relu_layer,
                             dense_layer,
                             output_layer)

```

```

# XOR problem inputs
data_inputs = torch.tensor([[0.0, 0.0],
                             [0.0, 1.0],
                             [1.0, 0.0],
                             [1.0, 1.0]])

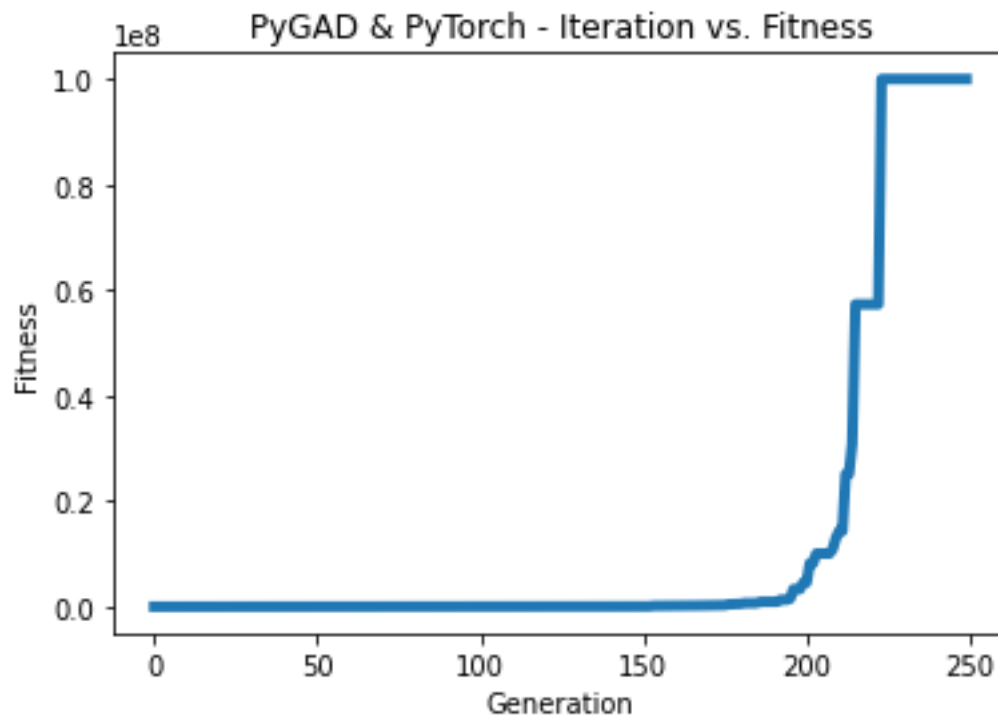
# XOR problem outputs
data_outputs = torch.tensor([[1.0, 0.0],
                              [0.0, 1.0],
                              [0.0, 1.0],
                              [1.0, 0.0]])

```

```

loss_function = torch.nn.BCELoss()

```



100000000.00.0

---

```
Fitness value of the best solution = 100000000.0
```

```
Index of the best solution : 0
```

```
Predictions :
```

```
[[1.0000000e+00 1.3627675e-10]
 [3.8521746e-09 1.0000000e+00]
 [4.2789325e-10 1.0000000e+00]
 [1.0000000e+00 3.3668417e-09]]
```

```
Binary Crossentropy : 0.0
```

```
Accuracy : 1.0
```

()

```
import torch
import torchga
import pygad
import numpy

def fitness_func(ga_instance, solution, sol_idx):
    global data_inputs, data_outputs, torch_ga, model, loss_function

    predictions = pygad.torchga.predict(model=model,
                                         solution=solution,
                                         data=data_inputs)

    solution_fitness = 1.0 / (loss_function(predictions, data_outputs).detach().
    ↪numpy() + 0.00000001)

    return solution_fitness

def on_generation(ga_instance):
    print(f"Generation = {ga_instance.generations_completed}")
    print(f"Fitness    = {ga_instance.best_solution()[1]}")

# Build the PyTorch model using the functional API.
input_layer = torch.nn.Linear(360, 50)
relu_layer = torch.nn.ReLU()
dense_layer = torch.nn.Linear(50, 4)
output_layer = torch.nn.Softmax(1)

model = torch.nn.Sequential(input_layer,
                             relu_layer,
                             dense_layer,
                             output_layer)

# Create an instance of the pygad.torchga.TorchGA class to build the initial_
↪population.
torch_ga = torchga.TorchGA(model=model,
                           num_solutions=10)

loss_function = torch.nn.CrossEntropyLoss()
```

()

---

```

# Data inputs
data_inputs = torch.from_numpy(numpy.load("dataset_features.npy")).float()

# Data outputs
data_outputs = torch.from_numpy(numpy.load("outputs.npy")).long()
# The next 2 lines are equivalent to this Keras function to perform 1-hot encoding:
↳ tensorflow.keras.utils.to_categorical(data_outputs)
# temp_outs = numpy.zeros((data_outputs.shape[0], numpy.unique(data_outputs).size),
↳ dtype=numpy.uint8)
# temp_outs[numpy.arange(data_outputs.shape[0]), numpy.uint8(data_outputs)] = 1

# Prepare the PyGAD parameters. Check the documentation for more information: https://
↳ pygad.readthedocs.io/en/latest/pygad.html#pygad-ga-class
num_generations = 200 # Number of generations.
num_parents_mating = 5 # Number of solutions to be selected as parents in the mating
↳ pool.
initial_population = torch_ga.population_weights # Initial population of network
↳ weights.

# Create an instance of the pygad.GA class
ga_instance = pygad.GA(num_generations=num_generations,
                       num_parents_mating=num_parents_mating,
                       initial_population=initial_population,
                       fitness_func=fitness_func,
                       on_generation=on_generation)

# Start the genetic algorithm evolution.
ga_instance.run()

# After the generations complete, some plots are showed that summarize how the
↳ outputs/fitness values evolve over generations.
ga_instance.plot_fitness(title="PyGAD & PyTorch - Iteration vs. Fitness", linewidth=4)

# Returning the details of the best solution.
solution, solution_fitness, solution_idx = ga_instance.best_solution()
print(f"Fitness value of the best solution = {solution_fitness}")
print(f"Index of the best solution : {solution_idx}")

# Fetch the parameters of the best solution.
best_solution_weights = torchga.model_weights_as_dict(model=model,
                                                         weights_vector=solution)
model.load_state_dict(best_solution_weights)
predictions = model(data_inputs)
# print("Predictions : \n", predictions)

# Calculate the crossentropy loss of the trained model.
print("Crossentropy : ", loss_function(predictions, data_outputs).detach().numpy())

# Calculate the classification accuracy for the trained model.
accuracy = torch.sum(torch.max(predictions, axis=1).indices == data_outputs) /
↳ len(data_outputs)
print("Accuracy : ", accuracy.detach().numpy())

```

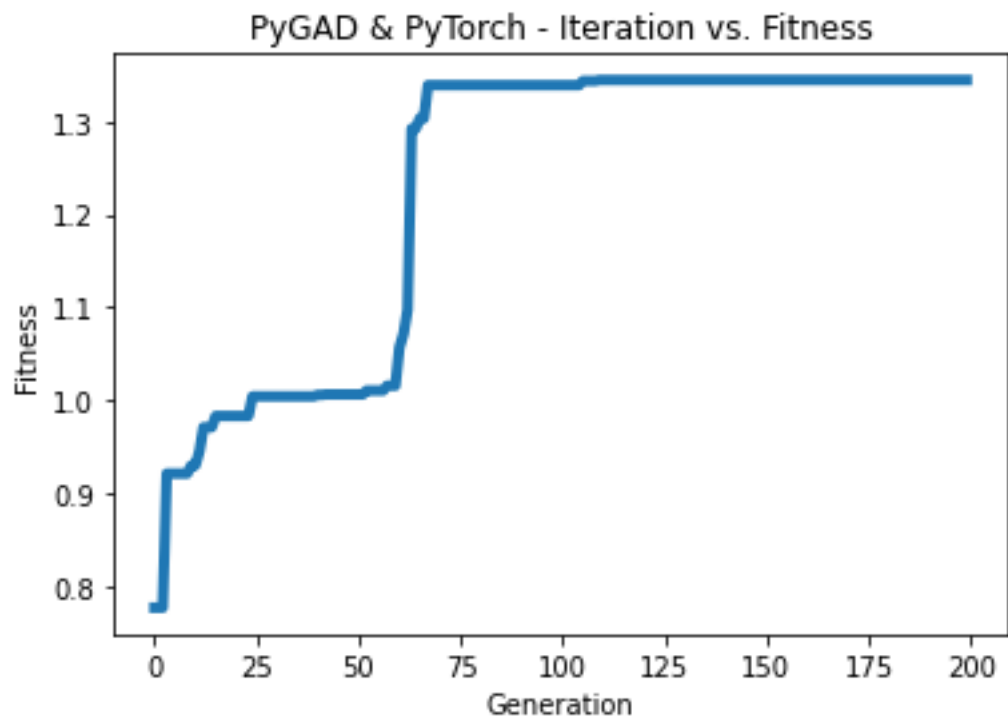
---

```
loss_function = torch.nn.CrossEntropyLoss()
```

```
()
```

```
(100, 100, 3)
```

```
import numpy  
data_inputs = numpy.load("dataset_features.npy")  
data_outputs = numpy.load("outputs.npy")
```



```
Fitness value of the best solution = 1.3446997034434534  
Index of the best solution : 0  
Crossentropy : 0.74366045  
Accuracy : 1.0
```

---

()

```
import torch
import torchga
import pygad
import numpy

def fitness_func(ga_instance, solution, sol_idx):
    global data_inputs, data_outputs, torch_ga, model, loss_function

    predictions = pygad.torchga.predict(model=model,
                                         solution=solution,
                                         data=data_inputs)

    solution_fitness = 1.0 / (loss_function(predictions, data_outputs).detach().
    ↪numpy() + 0.00000001)

    return solution_fitness

def on_generation(ga_instance):
    print(f"Generation = {ga_instance.generations_completed}")
    print(f"Fitness      = {ga_instance.best_solution()[1]}")

# Build the PyTorch model.
input_layer = torch.nn.Conv2d(in_channels=3, out_channels=5, kernel_size=7)
relu_layer1 = torch.nn.ReLU()
max_pool1 = torch.nn.MaxPool2d(kernel_size=5, stride=5)

conv_layer2 = torch.nn.Conv2d(in_channels=5, out_channels=3, kernel_size=3)
relu_layer2 = torch.nn.ReLU()

flatten_layer1 = torch.nn.Flatten()
# The value 768 is pre-computed by tracing the sizes of the layers' outputs.
dense_layer1 = torch.nn.Linear(in_features=768, out_features=15)
relu_layer3 = torch.nn.ReLU()

dense_layer2 = torch.nn.Linear(in_features=15, out_features=4)
output_layer = torch.nn.Softmax(1)

model = torch.nn.Sequential(input_layer,
                             relu_layer1,
                             max_pool1,
                             conv_layer2,
                             relu_layer2,
                             flatten_layer1,
                             dense_layer1,
                             relu_layer3,
                             dense_layer2,
                             output_layer)

# Create an instance of the pygad.torchga.TorchGA class to build the initial_
    ↪population.
torch_ga = torchga.TorchGA(model=model,
                           num_solutions=10)
```

()



```

loss_function = torch.nn.CrossEntropyLoss()

# Data inputs
data_inputs = torch.from_numpy(numpy.load("dataset_inputs.npy")).float()
data_inputs = data_inputs.reshape((data_inputs.shape[0], data_inputs.shape[3], data_
↳inputs.shape[1], data_inputs.shape[2]))

# Data outputs
data_outputs = torch.from_numpy(numpy.load("dataset_outputs.npy")).long()

# Prepare the PyGAD parameters. Check the documentation for more information: https://
↳pygad.readthedocs.io/en/latest/pygad.html#pygad-ga-class
num_generations = 200 # Number of generations.
num_parents_mating = 5 # Number of solutions to be selected as parents in the mating_
↳pool.
initial_population = torch_ga.population_weights # Initial population of network_
↳weights.

# Create an instance of the pygad.GA class
ga_instance = pygad.GA(num_generations=num_generations,
                        num_parents_mating=num_parents_mating,
                        initial_population=initial_population,
                        fitness_func=fitness_func,
                        on_generation=on_generation)

# Start the genetic algorithm evolution.
ga_instance.run()

# After the generations complete, some plots are showed that summarize how the_
↳outputs/fitness values evolve over generations.
ga_instance.plot_fitness(title="PyGAD & PyTorch - Iteration vs. Fitness", linewidth=4)

# Returning the details of the best solution.
solution, solution_fitness, solution_idx = ga_instance.best_solution()
print(f"Fitness value of the best solution = {solution_fitness}")
print(f"Index of the best solution : {solution_idx}")

# Make predictions based on the best solution.
predictions = pygad.torchga.predict(model=model,
                                     solution=solution,
                                     data=data_inputs)

# print("Predictions : \n", predictions)

# Calculate the crossentropy for the trained model.
print("Crossentropy : ", loss_function(predictions, data_outputs).detach().numpy())

# Calculate the classification accuracy for the trained model.
accuracy = torch.sum(torch.max(predictions, axis=1).indices == data_outputs) /_
↳len(data_outputs)
print("Accuracy : ", accuracy.detach().numpy())

```

```

input_layer = torch.nn.Conv2d(in_channels=3, out_channels=5, kernel_size=7)
relu_layer1 = torch.nn.ReLU()
max_pool1 = torch.nn.MaxPool2d(kernel_size=5, stride=5)

```

---

)

```
conv_layer2 = torch.nn.Conv2d(in_channels=5, out_channels=3, kernel_size=3)
relu_layer2 = torch.nn.ReLU()

flatten_layer1 = torch.nn.Flatten()
# The value 768 is pre-computed by tracing the sizes of the layers' outputs.
dense_layer1 = torch.nn.Linear(in_features=768, out_features=15)
relu_layer3 = torch.nn.ReLU()

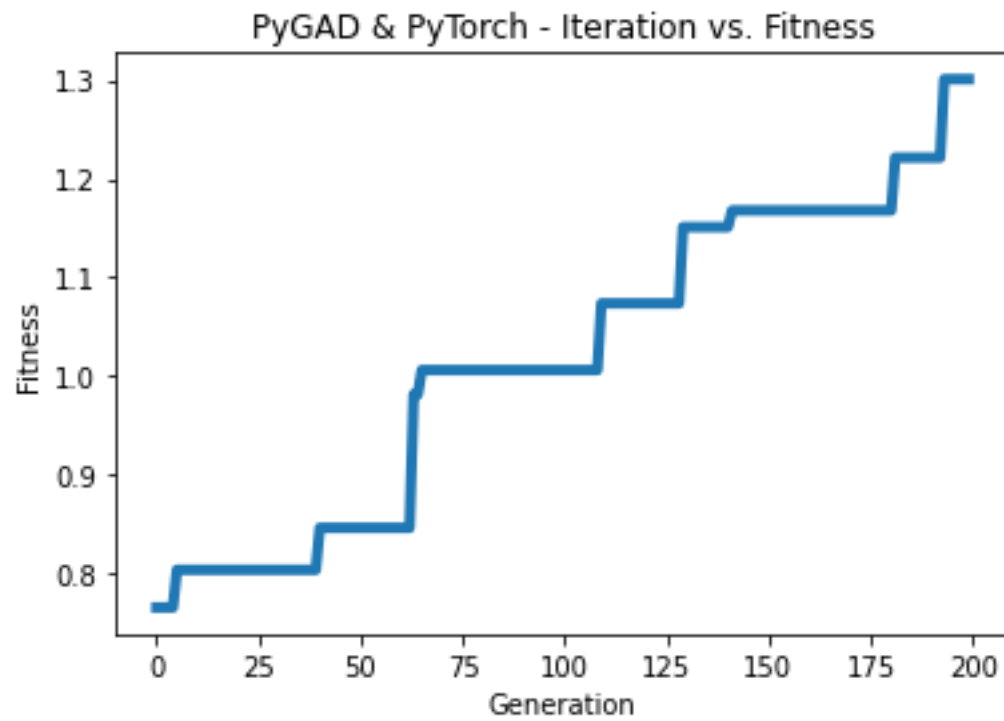
dense_layer2 = torch.nn.Linear(in_features=15, out_features=4)
output_layer = torch.nn.Softmax(1)

model = torch.nn.Sequential(input_layer,
                             relu_layer1,
                             max_pool1,
                             conv_layer2,
                             relu_layer2,
                             flatten_layer1,
                             dense_layer1,
                             relu_layer3,
                             dense_layer2,
                             output_layer)
```

(100, 100, 3)pygad.cnn

```
import numpy

data_inputs = numpy.load("dataset_inputs.npy")
data_outputs = numpy.load("dataset_outputs.npy")
```



Fitness value of the best solution = 1.3009520689219258  
Index of the best solution : 0  
Crossentropy : 0.7686678  
Accuracy : 0.975

---

---

---



**PyGAD**

---

---

fitness\_func

(init\_range\_low init\_range\_high)  
\_\_code\_\_

sol\_idx  
initial\_populationNonesol\_per\_popnum\_genes  
sol\_per\_popnum\_genesNone  
callback\_generation

best\_solution()

```
solution, solution_fitness, solution_idx = ga_instance.best_solution()
print("Parameters of the best solution :", solution)
print("Fitness value of the best solution :", solution_fitness, "\n")
print("Index of the best solution :", solution_idx, "\n")
```

best\_solution\_generationrun()

```
print("Best solution reached after {best_solution_generation} generations.").
↪format(best_solution_generation=ga_instance.best_solution_generation())
```

best\_solution\_fitnessbest\_solutions\_fitness().

---

---

()

generations\_completed0None

mutation\_by\_replacement(mutation\_type="random").  
tion\_by\_replacement=TrueFalse

muta-

mutation\_type="random"mutation\_by\_replacement=False()

mutation\_type="random"mutation\_by\_replacement=True()

Nonemutation\_typecrossover\_typeNone

pygad.cnn

pygad.gacnn

pygad.plot\_result()titlexlabelylabel

pygad.nn

pygad.nn.predict\_outputs()pygad.nn.predict()

pygad.nn.train\_network()pygad.nn.train()

delay\_after\_gen0.0

callback\_generationstoprun()

num\_generationscallback\_generationstop

callback\_generation

```
def func_generation(ga_instance):  
    if ga_instance.best_solution()[1] >= 70:  
        return "stop"
```

---

```
pygad.GA(crossover_probability, mutation_probability,
crossover_probability,
mutation_probability,
linewidth, plot_result(),
,
)()()()()()
gene_spacepygad.GA("<https://pygad.readthedocs.io/en/latest/pygad\_more.html#more-about-the-gene-space-parameter>")
```

```
initial_population
gene_typeintfloatgene_spaceNone
on_starton_fitnesson_parentson_crossoveron_mutationon_generationon_stop
```

```
learning_ratepygad.nn.train()
problem_typepygad.nn.train()pygad.nn.predict()
"None""sigmoid""relu""softmax""None"
pygad.nn
problem_typepygad.nn.train()pygad.nn.predict()"regression"
"None"-infinity+infinity
pygad.nn
pygad.gann
problem_typepygad.nn.train()pygad.nn.predict()"regression"
output_activationpygad.gann.GANN"None"
pygad.gann
problem_type"classification"(). ().
```

---



---

problem\_type: regression

kerasga

crossover\_probability

best\_solutions\_fitness

save\_best\_solutions: False True best\_solutions: False best\_solutions

crossover\_type: "scattered"

gene\_space

(gene\_type, crossover\_probability, mutation\_probability, delay\_after\_gen)  
int float numpy.int numpy.int8 numpy.int16 numpy.int32 numpy.int64 numpy.float  
numpy.float16 numpy.float32 numpy.float64

pygad.torchga

"""():

run() best\_solution\_fitness

parent\_selection\_type: ss(), keep\_parents

mutation\_percent\_genes: "default" mutation\_percent\_genes: "default"

mutation\_percent\_genes > 0 <= 100

---

---

```
warningsprint()
boolsuppress_warningspygad.GAFalse
adaptive_mutation_population_fitness()
best_solution()pop_fitnessNonecal_pop_fitness()
```

```
gene_spaceNone(), init_range_lowinit_range_highgene_typeNone[... , None, ...]
[... , [... , None, ...], ...]
gene_spacegene_type
numpy.uint
pygad.kerasgamodel_weights_as_vector()trainable' trainableTrue(train-
able=True), trainableFalse(trainable=False)
```

```
save_best_solutions=True
```

```
gene_spacelowhighgene_space=[{'low': 1, 'high': 5}, {'low': 0.2, 'high':
0.81}]]() () () ().
plot_result()
```

```
() gene_space[0, 1]
```

```
last_generation_fitnesslast_generation_parentslast_generation_offspring_crossover
last_generation_offspring_mutationon_generation()
initial_populationinitial_populationgene_typeinitial_population((1, 1),
(3, 3), (5, 5), (7, 7))intgene_typefloatintintinitial_populationgene_type
```

```
[]
(),
```

---

---

```
boolallow_duplicate_genesTrueFalse
last_generation_fitnesslast_generation_fitness
```

```
Nonecrossover_typemutation_type
gene_typelist/tuple/numpy.ndarraygene_type"<https://pygad.readthedocs.io/en/latest/pygad\_more.html#more-about-the-gene-type-parameter>'
boolgene_type_singlepygad.GATruegene_typegene_typelist/tuple/numpy.ndarray
gene_type_singleFalse
mutation_by_replacementgene_spaceNonegene_space=[None, [5, 6]]mutation_by_replacementNone
Nonegene_space(gene_space=[None, [5, 6]]), Nonegene_space
```

```
gene_type
```

```
save_best_solutionsTrueibest_solutionsi+1best_solutions
```

```
last_generation_parents_indices
last_generation_fitnesslast_generation_parents_indices
Nonegene_space(gene_space=[[1, 2, 3], [5, 6, None]]), Nonegene_space
gene_space"step""low""high"{ "low": 0, "high": 30, "step": 2}() "<https://pygad.readthedocs.io/en/latest/pygad\_more.html#more-about-the-gene-space-parameter>'
predict()pygad.kerasgapygad.torchga
```

---

---

```

stop_criteriastrreachesaturatereachrun() reach"reach_40">saturatesaturate
"saturate_7"run()

Falsesave_solutionspygad.GATruesolutions

plot_result()plot_fitness()

plot_fitness()pygad.GAfont_size=14save_dir=Nonecolor="#3870FF"
plot_type="plot"font_sizesave_dirNonecolorplot_type"plot()", "scatter", "bar"

titleplot_fitness()"PyGAD - Generation vs. Fitness"PyGAD - Iteration vs.
Fitness"

plot_new_solution_rate()plot_fitness() save_solutions=Truepygad.GA'

plot_genes()plot_fitness()graph_typefill_colorssolutionsgraph_type"plot"
(), "boxplot", "histogram"fill_colorgraph_type"boxplot""histogram"solutions
"all""best"

gene_typefloatfloatlisttuplennumpy.ndarray[float, 2]0.12340.12"<https://pygad.readthedocs.io/en/latest/pygad\_more.html#more-about-the-gene-type-parameter>'

```

```
keep_parents
```

```
kerasgatorchga
```

```
mutation_typecrossover_typeparent_selection_typepygad.GA
```

```
tqdm
```

```

import pygad
import numpy
import tqdm

equation_inputs = [4,-2,3.5]
desired_output = 44

def fitness_func(ga_instance, solution, solution_idx):
    output = numpy.sum(solution * equation_inputs)
    fitness = 1.0 / (numpy.abs(output - desired_output) + 0.000001)

```

()

---

---

)

```
    return fitness

num_generations = 10000
with tqdm.tqdm(total=num_generations) as pbar:
    ga_instance = pygad.GA(num_generations=num_generations,
                           sol_per_pop=5,
                           num_parents_mating=2,
                           num_genes=len(equation_inputs),
                           fitness_func=fitness_func,
                           on_generation=lambda _: pbar.update(1))

    ga_instance.run()

ga_instance.plot_result()
```

```
ga_instance.save()
```

```
ga_instance.save("test")
```

```
on_generationon_generation_progress()
```

```
import pygad
import numpy
import tqdm

equation_inputs = [4,-2,3.5]
desired_output = 44

def fitness_func(ga_instance, solution, solution_idx):
    output = numpy.sum(solution * equation_inputs)
    fitness = 1.0 / (numpy.abs(output - desired_output) + 0.000001)
    return fitness

def on_generation_progress(ga):
    pbar.update(1)

num_generations = 100
with tqdm.tqdm(total=num_generations) as pbar:
    ga_instance = pygad.GA(num_generations=num_generations,
                           sol_per_pop=5,
                           num_parents_mating=2,
                           num_genes=len(equation_inputs),
                           fitness_func=fitness_func,
                           on_generation=on_generation_progress)

    ga_instance.run()

ga_instance.plot_result()

ga_instance.save("test")
```

```
solutionsfitnesssave_solutionsTruesolutions_fitness
```

```
(solutions, solutions_fitness, best_solutions, best_solutions_fitness) run()
run()
```

```
(mutation_type="adaptive"). https://github.com/ahmedfgad/GeneticAlgorithmPython/issues/65
```

---

---

```
previous_generation_fitnesspygad.GAlast_generation_fitness
cal_pop_fitness()'previous_generation_fitness'()
```

```
gene_space[(), ]()
allow_duplicate_genes(mutation_type=None).
tournament_selection()
save_solutions=True
parallel_processingpygad.GA
```

```
run_completedFalse
run()self.best_solutions, self.best_solutions_fitness, self.solutions,
self.solutions_fitnessrun()run()
()
crossover_type=None
keep_elitism
last_generation_elitism
random_seed
pygad.TorchGA
```

---