Report
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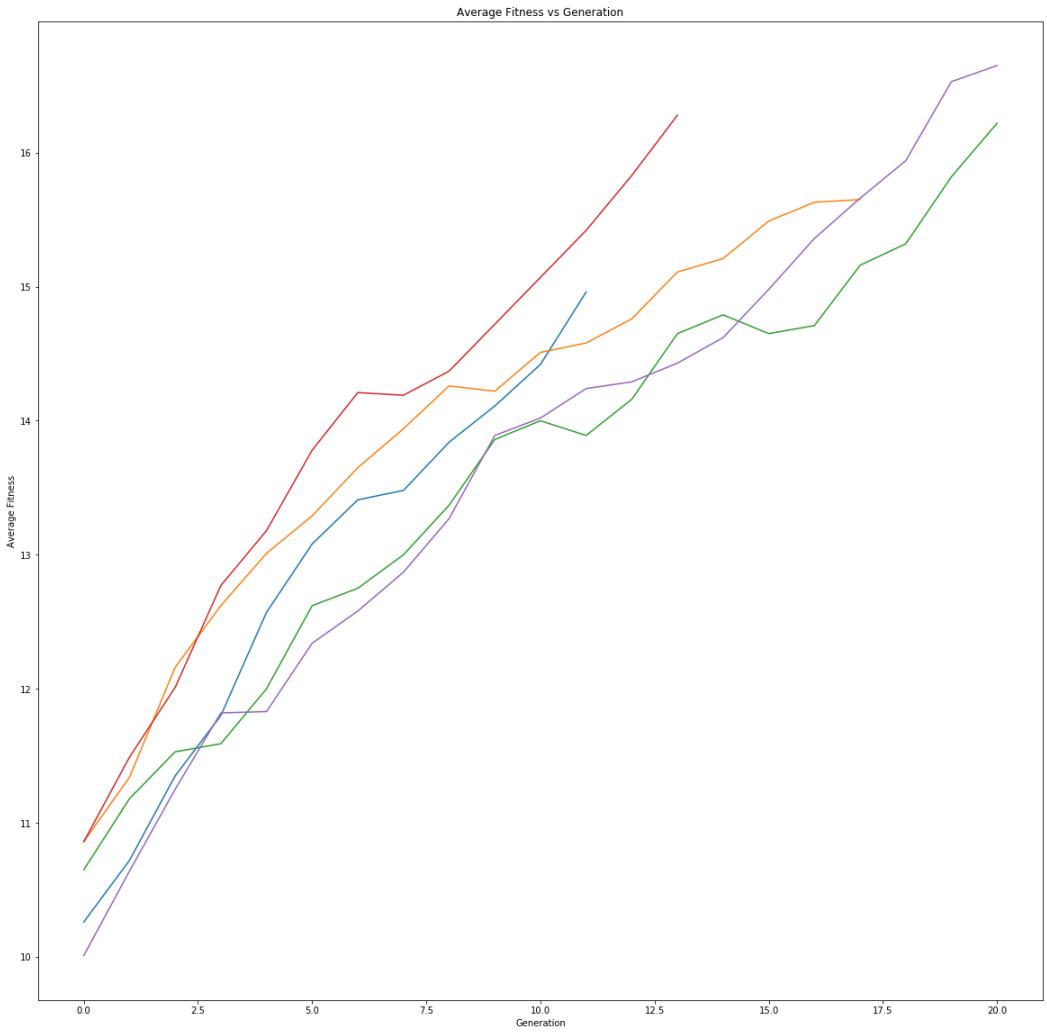
Part 1

1.

```
Average is: 23.38
Maximum is: 49
Minimum is: 6
```

After we run 50 times of runGA function, we calculate the average final generation and the maximum generation and minimum generation as above.

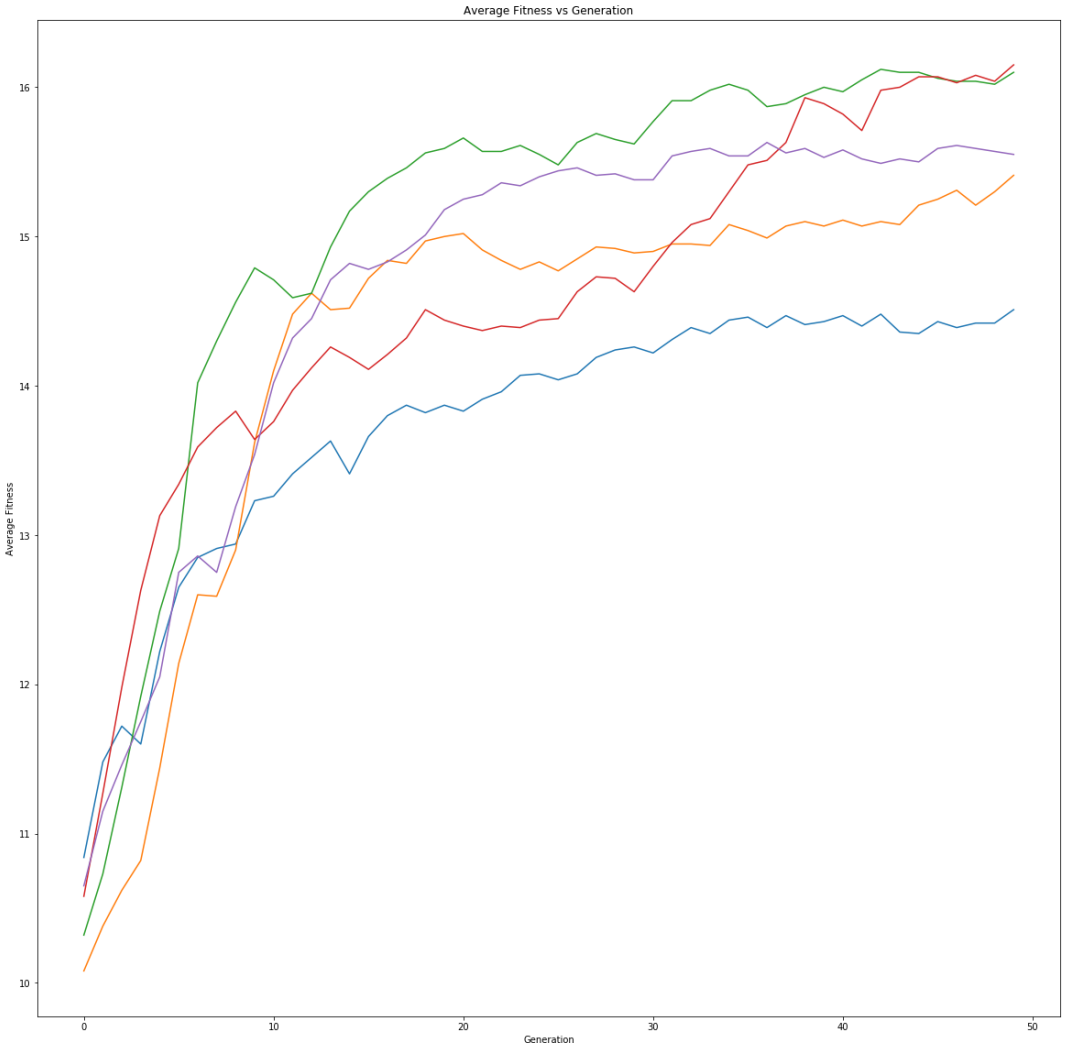
2. We choose randomly 5 result from above and plot the result as below:



In these five instances, the average fitness increases as the generation increases in general. And they have similar increasing rate.
The first difference of these is the initial average fitness since when we generate the initial data randomly.
The second difference of these is the length of each line because the generation which can be find the optimal genome is different (randomly) for each time of run.

3. Pc = 0

```
Average is: 49.0
Maximum is: 49
Minimum is: 49
```



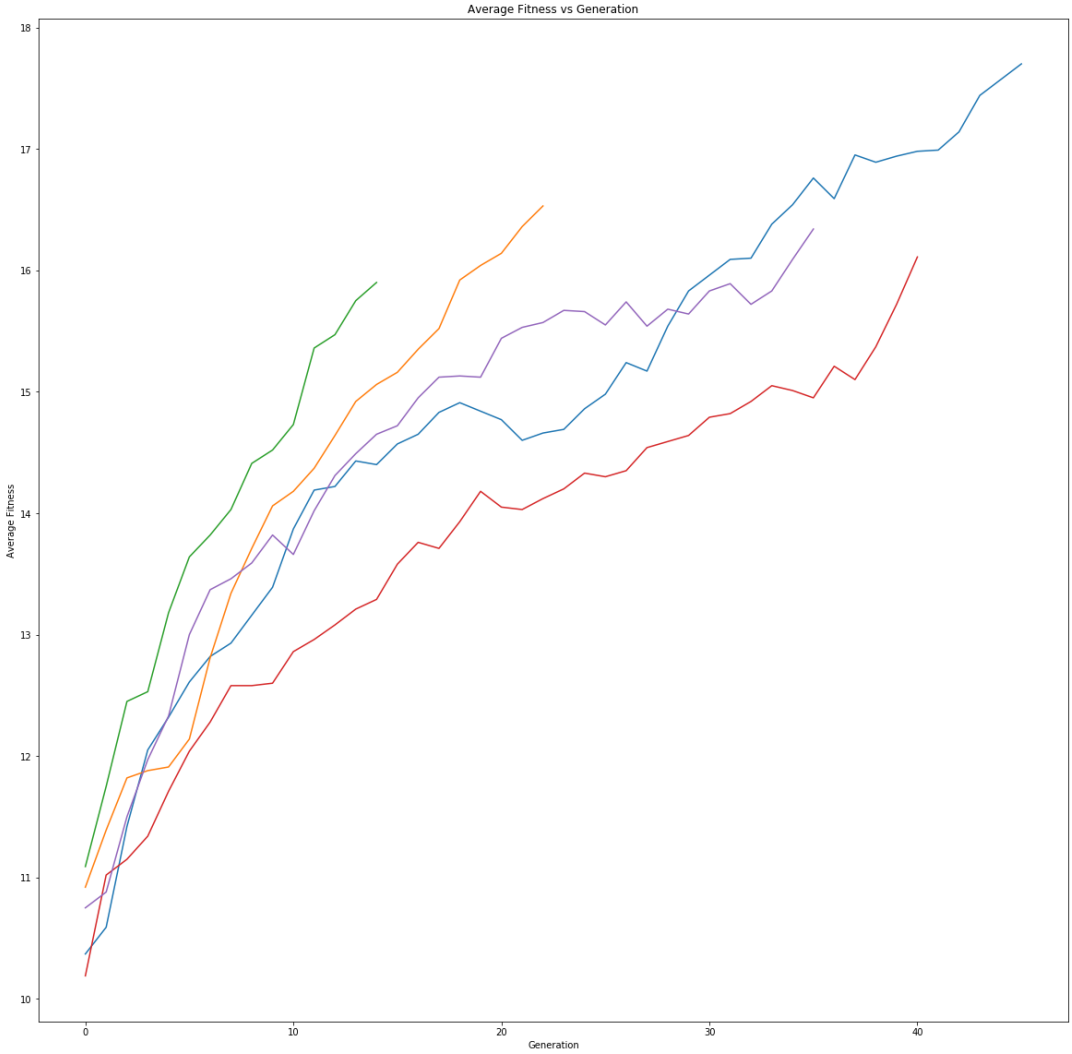
The efficiency of the algorithm to get the optimal solution decreases a lot. And the average fitness increases very slowly. We cannot find the optimal string within 50 generations if we let Pc = 0.

It happens because there is no crossover for our algorithm. But crossover is the main way to improve the average fitness.

4. Pc = 0.5

If we decrease the crossover rate. We may need much more generations to find the optimal string. The maximum, minimum and average of fitness are larger than the result in Part1.1.

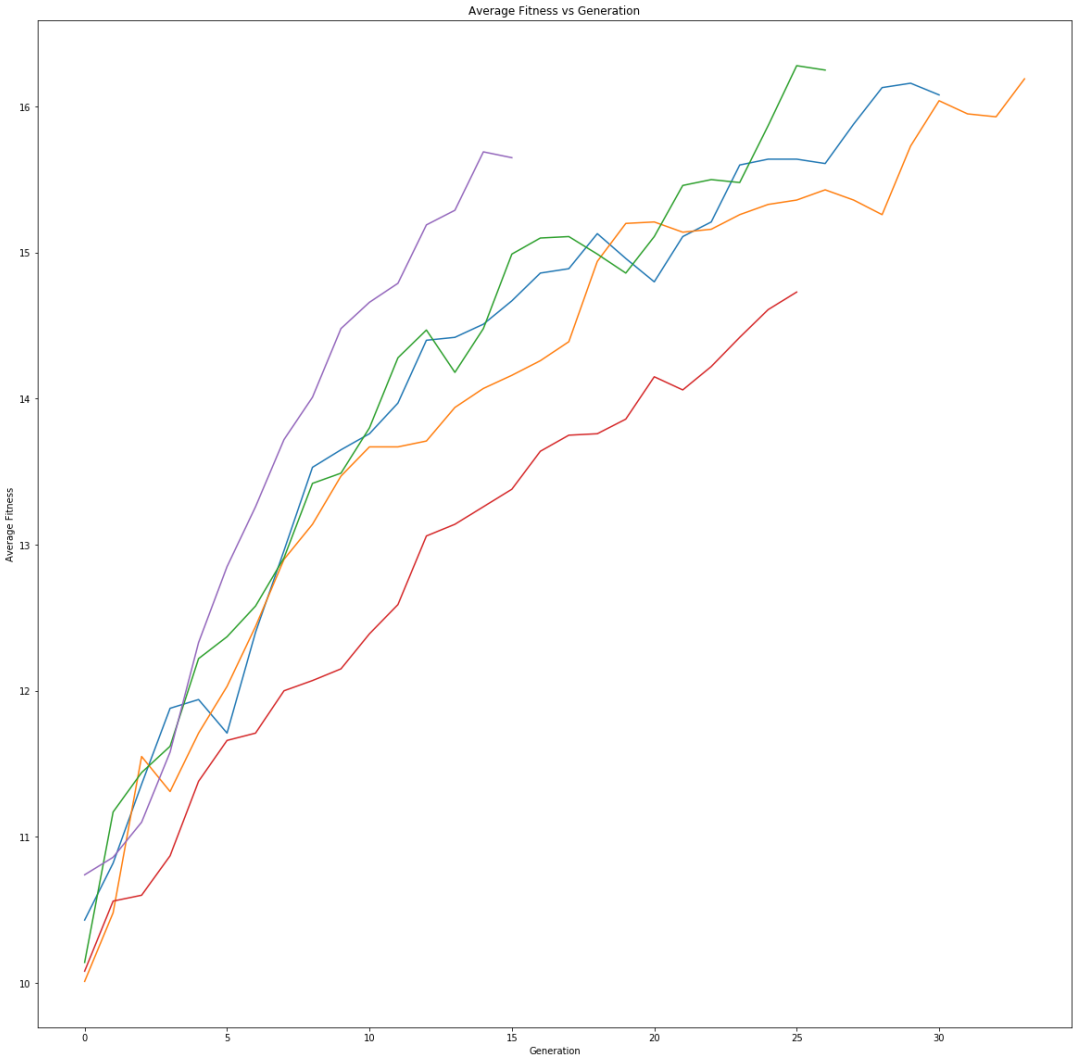
```
Average is: 30.52
Maximum is: 49
Minimum is: 4
```



Pm = 0.005

If we increase the mutation rate, it does not effect the efficiency of algorithm a lot. The maximum, minimum and average of fitness are closed to the result in Part1.1.

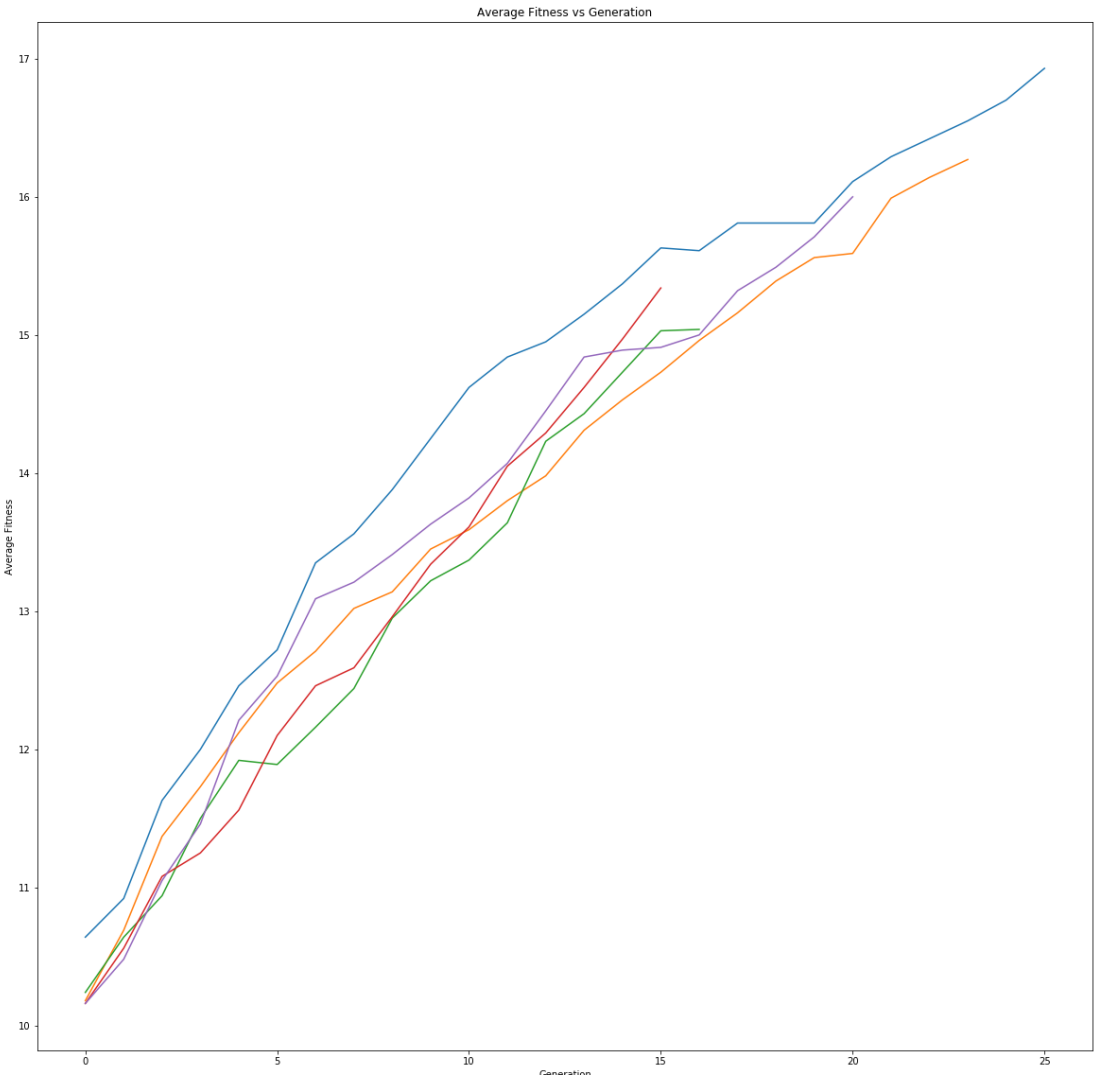
```
Average is: 25.94
Maximum is: 49
Minimum is: 9
```



Population = 200

When we doubled the population of the algorithm. We only need less generations to find the optimal genome. The maximum, minimum and average of fitness are less than the result in Part1.1.

```
Average is: 18.68
Maximum is: 34
Minimum is: 6
```



In total, as population increases, the number of generation at which the string of all ones are discovered will decrease.

As crossover rate increases, the number of generation at which the string of all ones are discovered will decrease.

As mutation rate increases, the number of generation at which the string of all ones are discovered does not change a lot.

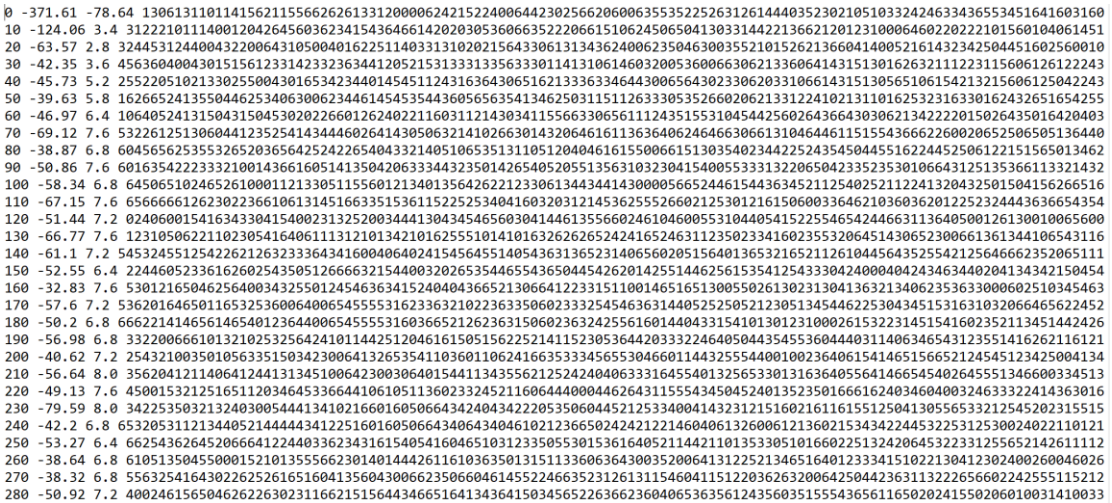
Part 2

Since we do not have enough time to run our algorithm, we can't get a very good strategy like strategy. But if we increase the total generations and populations, we can finally get a really good strategy even better than strategyM.

For runGA, we have 4 parameters. The first parameter is population. We need to make population as large as possible to get the optimal strategy. As we increase the population, we may more likely to get a good strategy.

In the first test, we used 100 population (runGA(100, 1.0, 0.05, "GAoutput.txt")).

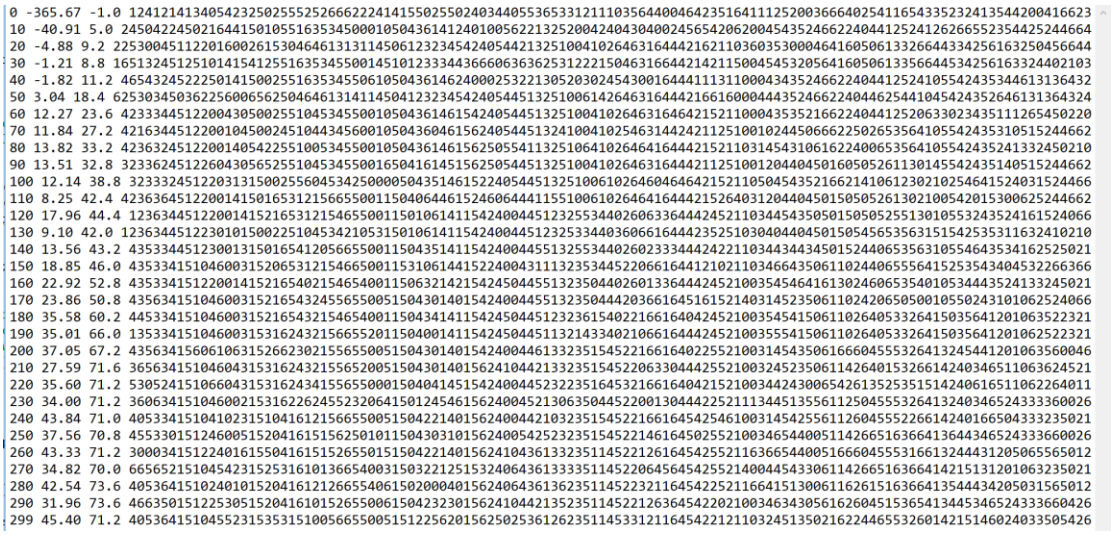
Then the output file is like this:



```
0 -371.61 -78.64 13061311011415621155662626213312000062421522400644230256620600635535225263126144403523021051033242463343655345164160316010 -124.06 3.4 31222101114001204264560362341543646614202030536066352220661510624506504130331442213662120123100064602202221015601040614512
20 -63.57 2.8 32445312440043220064310500401622511403313102021564330613134362400623504630035521015262136604140052161432342504451602560010
30 -42.35 3.6 45636040043015156123314233236344120521513333133563330114131061460320053600663062133606414315130162632111223115606126122243
40 -45.73 5.2 25522051021330255004301653423440145451124316364306516213336334644300656430233062033106614315130565106154213215606125042243
50 -39.63 5.8 16266524135504462534063006234461454535443605656354134625031151126333053526602062133122410213110162532316330162432651654255
60 -46.97 6.4 10640524131504315045302022660126240221160311214303411556633065611124351553104544256026436643030621342222015026435016420403
70 -69.12 7.6 53226125130604412352541434446026414305063214102663014320646161136364062464663066131046446115155436662260020652506505136440
80 -38.87 6.8 60456562535532652036564252422654043321405106535131105120404616155006615130354023442252435450445516224452506122151565013462
90 -50.86 7.6 60163542223332100143661605141350420633344323501426540520551356310323041540055333132206504233523530106643125135366113321432
100 -58.34 6.8 64506510246526100011213305115560121340135642622123306134434414300005665244615443634521125402521122413204325015046156266516
110 -67.15 7.6 65666661262302236610613145166335153611522525340416032031214536255526602125301216150600336462103603620122523244436656345 4
120 -51.44 7.2 02406001541634330415400231325200344413043454656030414461355660246104600553104405415225546524466311364050012613001006560 0
130 -66.77 7.6 12310506221102305416406111312101342101625551014101632626265242416524631123502334160235532064514306523006613634410654311 6
140 -61.1 7.2 54532455125422621263233364341600406402415456455140543631365231406560205156401365321652112610445643525542125646662352065111
150 -52.55 6.4 22446052336162602543505126666321544003202653544655436504542620142551446256153541254333042400004243463440204134342150454
160 -32.83 7.6 53012165046256400343255012456363415240404366521306641223315110014651651300550261302313041363213406235363000602510345463
170 -57.6 7.2 53620164650116532536006400654555553162336321022363350602333254546363144052525052123051345446225304345153163103206646562452
180 -50.2 6.8 66622141465614654012336440065455553160366521262363150602363242556160144043315410130123100026153223145154160235211345144242 6
190 -56.98 6.8 33220066610132102532564241011442512046161505156225214115230536442033322464050443545536044403114063465431235514162621161121
200 -40.62 7.2 25432100350105633515034230064132653541103601106241663533456553046601144325554400010023640615414651566521245451234250041 4
210 -56.64 8.0 35620412114064124413134510064230036401544113435562125242404063331645540132565330131636405564146654502645551346600334513
220 -49.13 7.6 45001532125165112034645336644106105113602332452116064440004462643115554345045240135235016666162403460400324633322413630 6
230 -79.59 8.0 34225350321324030054441341021660160506643424043422205350604452125334004143231215160216116155125041305565332125452023155 5
240 -42.2 6.8 65320531121344052144444341225160160506643406434046102123665024242122146040613260061213602153434224453225312530024022110121
250 -53.27 6.4 66254362645206664122440336234316154054160465103123350553015361640521144211013533051016602251324206453223312556521426111 2
260 -38.64 6.8 61051350455000152101355566230140144426116103635013151133606364300352006413122521346516401233341510221304123024330260046026
270 -38.32 6.8 55632541643022625261651604135604300662350660461455224663523126131154604115122036263200642504423631132226566022455511521 2
280 -50.92 7.2 40024615650462622630231166215156443466516413436415034565226366236040653635612435603515554365611650202415502060103141003 3
290 -26.96 7.2 00616351005522525151155550411053506606101042411425324224635400035100016546443322155536355204614232440364266423443500512 3
```

Then we enlarged the population to 200 (runGA(200, 1.0, 0.05, "GAoutput1.txt")).

And the output file is like this:



```
0 -365.67 -1.0 12412141340542325025552566622241415502550240344055365331211103564400464235164111252003666402541165433523241354420041662 3
10 -40.91 5.0 24504224502164415010551635345000105043614124010056221325200424043040024565420620045435246622404412524126266552354425244664
20 -4.88 9.2 22530045112201600261530464613131145061232345424054421325100410264631644421621103603530004641605061332664433425616325045664 4
30 -1.21 8.8 16513245125101415412551635345500145101233344366606363625312221504631664421421150045453205641605061335664453425616332440210 3
40 -1.82 11.2 46543245222501415002551635345506105043614624000253221305203024543001644411131100043435246622404412524105542435344613136432
50 3.04 18.4 62530345036225600656250464613141145041232345424054451325100614264631644421661600044435246622404462544104542435264613136432 4
60 12.27 23.6 42333445122004305002551045345500105043614615424054451325100410264631646421521100043535216622404412520633023435111265450220
70 11.84 27.2 42163445122001045002451044345600105043604615624054451324100410254631442421125100102445066225026535641055424353105152446662
80 13.82 33.2 42363245122001405422551005345500105043614615625055411325106410264641644421521103145431061622400653564105542435241332450210
90 13.51 32.8 32336245122604305652551045345500165041614515625054451325100410264631644421125100120440450160505261130145542435140515244662
100 12.14 38.8 32333245122031315002556045342500005043514615224054451325100610264604646421521105045435216621410612302102546415240315244666
110 8.25 42.4 42363645122001415016531215665500115040644615246064441155100610264641644421526403120440450150505261302100542015300625244662
120 17.96 44.4 12363445122001415216531215465500115010614115424004451232553440260633644424521103445435050150505255130105532435241615240666
130 9.10 42.0 12363445122301015002251045342105315010614115424004451232533440360661644423525103040044045015054565356315145235314632410210
140 13.56 43.2 43533445123001315016541205665500115043514115424004455132553440260233344424221103443443450152440653563105546435341625250221
150 18.85 46.0 43533415104600315206531215466500115310614415224004311323534452206616441210211034664350611024406555641525354340453226636 6
160 22.92 52.8 43533415122001415216540215465400115063214215424504455132350440260133644424521003545464161302460653540105344435241332450221
170 23.86 50.8 43563415104600315216543245565500515043014015424004455132350444203661645161521403145235061102420650500105502431010625240666
180 35.58 60.2 44533415104600315216543215465400115043414115424504451232361540221661644245210035454150611026405332641503564120106352321
190 35.01 66.0 13533415104600315316243215665520115040041115424504451132143340210661644424521003555415061102640533264150356412010625223221
200 37.05 67.2 43563415606106315266230215565500515043014015424004461332351545221661640225521003145435061666045553264132454412010635600046
210 27.59 71.6 36563415104604315316243215565200515043014015624104421332351545220633044425521003245235061142640153266142403465110636245211
220 35.60 71.2 53052415106604315316243415565500015040414515424004452322351645321661640421521003442430065426135253515142406165110622640111
230 34.00 71.2 36063415104600215316226245523206415012454615624004523206135034452220013044422521113445135561125045555326413240346524333360026
240 43.84 71.0 40533415104102315104161215665500515042214015624004421032351545221661645425461003145425561126045552266142401665043333235021
250 37.56 70.8 45533015124600515204161515625010115043031015624005425232351545221461645025521003465440051142665163664136443465243336600026
260 43.33 71.2 30003415122401615504161515265501515042214015624104361332351145221261645425521163665440051666045553166132444312050655651 2
270 34.82 70.0 66565215104542315253161013665400315032212515324064361333351145220645645425521400445433061142665163664142151312010632350211
280 42.54 73.6 40536415102401015204161212665540615020004015624064361362351145223211645422521166415130061162615163664135444342050315651 2
290 31.96 73.6 46635015122530515204161015265500615042323015624104421352351145221263645422021003463430561626045153654134453465243336660426
299 45.40 71.2 40536415104552315353151005665500515122562015625025361262351145331211645422121103245135021622446553260142151460240335054 6
```

The best fitness of 100 population is 7.2 while the best fitness of 200 population is 73.6. So we find that increasing the population will largely increase the efficiency of our algorithm.

The second parameter is crossover rate. We need to set it as 1 to avoid decrease the efficiency of the algorithm.

The third parameter is mutation rate, it does not affect the result a lot.

As the generation increases, the fitness of the best strategy so far will increase. It may start at very low fitness (like -400) and increases very quickly when the generation increases. After the fitness reaches around 0, it will increase very slowly as the generation increases.
It happens because it is easy to train the Robby to avoid crushing to the wall, but it is hard to train him to pick up the cans on the ground. We need much more generations to increase the fitness from 0 to 500. The graph "Generation vs fitness" will similar to the below one.