21.neuro-evolution-agent

September 29, 2021

```
[1]: import numpy as np
     import pandas as pd
     import tensorflow as tf
     import matplotlib.pyplot as plt
     import seaborn as sns
     sns.set()
```

```
[2]: df = pd.read_csv('../dataset/GOOG-year.csv')
     df.head()
```

```
[2]:         Date        Open        High         Low       Close   Adj Close  \
     0  2016-11-02  778.200012  781.650024  763.450012  768.700012  768.700012
     1  2016-11-03  767.250000  769.950012  759.030029  762.130005  762.130005
     2  2016-11-04  750.659973  770.359985  750.560974  762.020020  762.020020
     3  2016-11-07  774.500000  785.190002  772.549988  782.520020  782.520020
     4  2016-11-08  783.400024  795.632996  780.190002  790.510010  790.510010

         Volume
     0  1872400
     1  1943200
     2  2134800
     3  1585100
     4  1350800
```

```
[3]: close = df.Close.values.tolist()
     initial_money = 10000
     window_size = 30
     skip = 1
```

```
[4]: class neuralnetwork:
         def __init__(self, id_, hidden_size = 128):
             self.W1 = np.random.randn(window_size, hidden_size) / np.
      ↪sqrt(window_size)
             self.W2 = np.random.randn(hidden_size, 3) / np.sqrt(hidden_size)
             self.fitness = 0
             self.id = id_
```

```python
def relu(X):
    return np.maximum(X, 0)

def softmax(X):
    e_x = np.exp(X - np.max(X, axis=-1, keepdims=True))
    return e_x / np.sum(e_x, axis=-1, keepdims=True)

def feed_forward(X, nets):
    a1 = np.dot(X, nets.W1)
    z1 = relu(a1)
    a2 = np.dot(z1, nets.W2)
    return softmax(a2)
```

```python
[5]: class NeuroEvolution:
    def __init__(self, population_size, mutation_rate, model_generator,
                 state_size, window_size, trend, skip, initial_money):
        self.population_size = population_size
        self.mutation_rate = mutation_rate
        self.model_generator = model_generator
        self.state_size = state_size
        self.window_size = window_size
        self.half_window = window_size // 2
        self.trend = trend
        self.skip = skip
        self.initial_money = initial_money

    def _initialize_population(self):
        self.population = []
        for i in range(self.population_size):
            self.population.append(self.model_generator(i))

    def mutate(self, individual, scale=1.0):
        mutation_mask = np.random.binomial(1, p=self.mutation_rate,␣
 ↪size=individual.W1.shape)
        individual.W1 += np.random.normal(loc=0, scale=scale, size=individual.
 ↪W1.shape) * mutation_mask
        mutation_mask = np.random.binomial(1, p=self.mutation_rate,␣
 ↪size=individual.W2.shape)
        individual.W2 += np.random.normal(loc=0, scale=scale, size=individual.
 ↪W2.shape) * mutation_mask
        return individual

    def inherit_weights(self, parent, child):
        child.W1 = parent.W1.copy()
        child.W2 = parent.W2.copy()
        return child
```

```python
    def crossover(self, parent1, parent2):
        child1 = self.model_generator((parent1.id+1)*10)
        child1 = self.inherit_weights(parent1, child1)
        child2 = self.model_generator((parent2.id+1)*10)
        child2 = self.inherit_weights(parent2, child2)
        # first W
        n_neurons = child1.W1.shape[1]
        cutoff = np.random.randint(0, n_neurons)
        child1.W1[:, cutoff:] = parent2.W1[:, cutoff:].copy()
        child2.W1[:, cutoff:] = parent1.W1[:, cutoff:].copy()
        # second W
        n_neurons = child1.W2.shape[1]
        cutoff = np.random.randint(0, n_neurons)
        child1.W2[:, cutoff:] = parent2.W2[:, cutoff:].copy()
        child2.W2[:, cutoff:] = parent1.W2[:, cutoff:].copy()
        return child1, child2

    def get_state(self, t):
        window_size = self.window_size + 1
        d = t - window_size + 1
        block = self.trend[d : t + 1] if d >= 0 else -d * [self.trend[0]] +␣
↪self.trend[0 : t + 1]
        res = []
        for i in range(window_size - 1):
            res.append(block[i + 1] - block[i])
        return np.array([res])

    def act(self, p, state):
        logits = feed_forward(state, p)
        return np.argmax(logits, 1)[0]

    def buy(self, individual):
        initial_money = self.initial_money
        starting_money = initial_money
        state = self.get_state(0)
        inventory = []
        states_sell = []
        states_buy = []

        for t in range(0, len(self.trend) - 1, self.skip):
            action = self.act(individual, state)
            next_state = self.get_state(t + 1)

            if action == 1 and starting_money >= self.trend[t]:
                inventory.append(self.trend[t])
                initial_money -= self.trend[t]
                states_buy.append(t)
```

```python
                print('day %d: buy 1 unit at price %f, total balance %f'% (t,
→self.trend[t], initial_money))

            elif action == 2 and len(inventory):
                bought_price = inventory.pop(0)
                initial_money += self.trend[t]
                states_sell.append(t)
                try:
                    invest = ((self.trend[t] - bought_price) / bought_price) *
→100
                except:
                    invest = 0
                print(
                    'day %d, sell 1 unit at price %f, investment %f %%, total
→balance %f,'
                    % (t, self.trend[t], invest, initial_money)
                )
            state = next_state

        invest = ((initial_money - starting_money) / starting_money) * 100
        total_gains = initial_money - starting_money
        return states_buy, states_sell, total_gains, invest

    def calculate_fitness(self):
        for i in range(self.population_size):
            initial_money = self.initial_money
            starting_money = initial_money
            state = self.get_state(0)
            inventory = []

            for t in range(0, len(self.trend) - 1, self.skip):
                action = self.act(self.population[i], state)
                next_state = self.get_state(t + 1)

                if action == 1 and starting_money >= self.trend[t]:
                    inventory.append(self.trend[t])
                    starting_money -= self.trend[t]

                elif action == 2 and len(inventory):
                    bought_price = inventory.pop(0)
                    starting_money += self.trend[t]

                state = next_state
            invest = ((starting_money - initial_money) / initial_money) * 100
            self.population[i].fitness = invest

    def evolve(self, generations=20, checkpoint= 5):
```

```python
        self._initialize_population()
        n_winners = int(self.population_size * 0.4)
        n_parents = self.population_size - n_winners
        for epoch in range(generations):
            self.calculate_fitness()
            fitnesses = [i.fitness for i in self.population]
            sort_fitness = np.argsort(fitnesses)[::-1]
            self.population = [self.population[i] for i in sort_fitness]
            fittest_individual = self.population[0]
            if (epoch+1) % checkpoint == 0:
                print('epoch %d, fittest individual %d with accuracy␣
 ↪%f'%(epoch+1, sort_fitness[0],

                                                                    ␣
 ↪fittest_individual.fitness))
            next_population = [self.population[i] for i in range(n_winners)]
            total_fitness = np.sum([np.abs(i.fitness) for i in self.population])
            parent_probabilities = [np.abs(i.fitness / total_fitness) for i in␣
 ↪self.population]
            parents = np.random.choice(self.population, size=n_parents,␣
 ↪p=parent_probabilities, replace=False)
            for i in np.arange(0, len(parents), 2):
                child1, child2 = self.crossover(parents[i], parents[i+1])
                next_population += [self.mutate(child1), self.mutate(child2)]
            self.population = next_population
        return fittest_individual
```

```python
[6]: population_size = 100
     generations = 100
     mutation_rate = 0.1
     neural_evolve = NeuroEvolution(population_size, mutation_rate, neuralnetwork,
                             window_size, window_size, close, skip,␣
      ↪initial_money)
```

```python
[7]: fittest_nets = neural_evolve.evolve(50)
```

```
epoch 5, fittest individual 0 with accuracy 10.849749
epoch 10, fittest individual 0 with accuracy 11.095000
epoch 15, fittest individual 0 with accuracy 11.095000
epoch 20, fittest individual 93 with accuracy 13.756802
epoch 25, fittest individual 95 with accuracy 23.728605
epoch 30, fittest individual 0 with accuracy 23.728605
epoch 35, fittest individual 0 with accuracy 23.728605
epoch 40, fittest individual 0 with accuracy 23.728605
epoch 45, fittest individual 0 with accuracy 23.728605
epoch 50, fittest individual 0 with accuracy 23.728605
```

```python
[8]: states_buy, states_sell, total_gains, invest = neural_evolve.buy(fittest_nets)
```

day 1: buy 1 unit at price 762.130005, total balance 9237.869995
day 2: buy 1 unit at price 762.020020, total balance 8475.849975
day 3, sell 1 unit at price 782.520020, investment 2.675399 %, total balance 9258.369995,
day 5, sell 1 unit at price 785.309998, investment 3.056347 %, total balance 10043.679993,
day 6: buy 1 unit at price 762.559998, total balance 9281.119995
day 7: buy 1 unit at price 754.020020, total balance 8527.099975
day 8: buy 1 unit at price 736.080017, total balance 7791.019958
day 9: buy 1 unit at price 758.489990, total balance 7032.529968
day 10, sell 1 unit at price 764.479980, investment 0.251781 %, total balance 7797.009948,
day 12: buy 1 unit at price 760.539978, total balance 7036.469970
day 14: buy 1 unit at price 768.270020, total balance 6268.199950
day 15: buy 1 unit at price 760.989990, total balance 5507.209960
day 16: buy 1 unit at price 761.679993, total balance 4745.529967
day 17, sell 1 unit at price 768.239990, investment 1.885888 %, total balance 5513.769957,
day 18, sell 1 unit at price 770.840027, investment 4.722314 %, total balance 6284.609984,
day 20: buy 1 unit at price 747.919983, total balance 5536.690001
day 21: buy 1 unit at price 750.500000, total balance 4786.190001
day 22: buy 1 unit at price 762.520020, total balance 4023.669981
day 24, sell 1 unit at price 771.190002, investment 1.674381 %, total balance 4794.859983,
day 25, sell 1 unit at price 776.419983, investment 2.087991 %, total balance 5571.279966,
day 26, sell 1 unit at price 789.289978, investment 2.736012 %, total balance 6360.569944,
day 27: buy 1 unit at price 789.270020, total balance 5571.299924
day 28: buy 1 unit at price 796.099976, total balance 4775.199948
day 29: buy 1 unit at price 797.070007, total balance 3978.129941
day 31: buy 1 unit at price 790.799988, total balance 3187.329953
day 32, sell 1 unit at price 794.200012, investment 4.364055 %, total balance 3981.529965,
day 33: buy 1 unit at price 796.419983, total balance 3185.109982
day 34, sell 1 unit at price 794.559998, investment 4.316774 %, total balance 3979.669980,
day 35, sell 1 unit at price 791.260010, investment 5.794741 %, total balance 4770.929990,
day 37: buy 1 unit at price 791.549988, total balance 3979.380002
day 38, sell 1 unit at price 785.049988, investment 4.603596 %, total balance 4764.429990,
day 39: buy 1 unit at price 782.789978, total balance 3981.640012
day 40: buy 1 unit at price 771.820007, total balance 3209.820005
day 41: buy 1 unit at price 786.140015, total balance 2423.679990
day 42, sell 1 unit at price 786.900024, investment 3.197294 %, total balance 3210.580014,

day 43: buy 1 unit at price 794.020020, total balance 2416.559994
day 44: buy 1 unit at price 806.150024, total balance 1610.409970
day 46, sell 1 unit at price 804.789978, investment 1.966369 %, total balance 2415.199948,
day 47, sell 1 unit at price 807.909973, investment 1.483482 %, total balance 3223.109921,
day 48: buy 1 unit at price 806.359985, total balance 2416.749936
day 49, sell 1 unit at price 807.880005, investment 1.356217 %, total balance 3224.629941,
day 50, sell 1 unit at price 804.609985, investment 1.746332 %, total balance 4029.239926,
day 51, sell 1 unit at price 806.070007, investment 1.211675 %, total balance 4835.309933,
day 52: buy 1 unit at price 802.174988, total balance 4033.134945
day 53: buy 1 unit at price 805.020020, total balance 3228.114925
day 54, sell 1 unit at price 819.309998, investment 3.507044 %, total balance 4047.424923,
day 55, sell 1 unit at price 823.869995, investment 5.247898 %, total balance 4871.294918,
day 56, sell 1 unit at price 835.669983, investment 8.272651 %, total balance 5706.964901,
day 57, sell 1 unit at price 832.150024, investment 5.852648 %, total balance 6539.114925,
day 58: buy 1 unit at price 823.309998, total balance 5715.804927
day 59: buy 1 unit at price 802.320007, total balance 4913.484920
day 60: buy 1 unit at price 796.789978, total balance 4116.694942
day 61: buy 1 unit at price 795.695007, total balance 3320.999935
day 63: buy 1 unit at price 801.489990, total balance 2519.509945
day 65: buy 1 unit at price 806.969971, total balance 1712.539974
day 66, sell 1 unit at price 808.380005, investment 1.808517 %, total balance 2520.919979,
day 67: buy 1 unit at price 809.559998, total balance 1711.359981
day 68, sell 1 unit at price 813.669983, investment 0.932824 %, total balance 2525.029964,
day 69, sell 1 unit at price 819.239990, investment 1.597302 %, total balance 3344.269954,
day 70, sell 1 unit at price 820.450012, investment 2.278184 %, total balance 4164.719966,
day 71: buy 1 unit at price 818.979980, total balance 3345.739986
day 72: buy 1 unit at price 824.159973, total balance 2521.580013
day 73: buy 1 unit at price 828.070007, total balance 1693.510006
day 75, sell 1 unit at price 830.760010, investment 3.197435 %, total balance 2524.270016,
day 76, sell 1 unit at price 831.330017, investment 0.974119 %, total balance 3355.600033,
day 77, sell 1 unit at price 828.640015, investment 3.280488 %, total balance 4184.240048,
day 78, sell 1 unit at price 829.280029, investment 4.077618 %, total balance

5013.520077,
day 79, sell 1 unit at price 823.210022, investment 3.457985 %, total balance 5836.730099,
day 80: buy 1 unit at price 835.239990, total balance 5001.490109
day 81, sell 1 unit at price 830.630005, investment 3.635730 %, total balance 5832.120114,
day 83: buy 1 unit at price 827.780029, total balance 5004.340085
day 84: buy 1 unit at price 831.909973, total balance 4172.430112
day 85: buy 1 unit at price 835.369995, total balance 3337.060117
day 86, sell 1 unit at price 838.679993, investment 3.929517 %, total balance 4175.740110,
day 87, sell 1 unit at price 843.250000, investment 4.161520 %, total balance 5018.990110,
day 88, sell 1 unit at price 845.539978, investment 3.243058 %, total balance 5864.530088,
day 89: buy 1 unit at price 845.619995, total balance 5018.910093
day 90, sell 1 unit at price 847.200012, investment 2.795578 %, total balance 5866.110105,
day 91: buy 1 unit at price 848.780029, total balance 5017.330076
day 92: buy 1 unit at price 852.119995, total balance 4165.210081
day 93, sell 1 unit at price 848.400024, investment 2.455108 %, total balance 5013.610105,
day 95: buy 1 unit at price 829.590027, total balance 4184.020078
day 97: buy 1 unit at price 814.429993, total balance 3369.590085
day 98, sell 1 unit at price 819.510010, investment -1.883289 %, total balance 4189.100095,
day 100: buy 1 unit at price 831.409973, total balance 3357.690122
day 101, sell 1 unit at price 831.500000, investment 0.449391 %, total balance 4189.190122,
day 102: buy 1 unit at price 829.559998, total balance 3359.630124
day 103: buy 1 unit at price 838.549988, total balance 2521.080136
day 104: buy 1 unit at price 834.570007, total balance 1686.510129
day 105, sell 1 unit at price 831.409973, investment -0.060103 %, total balance 2517.920102,
day 106: buy 1 unit at price 827.880005, total balance 1690.040097
day 108: buy 1 unit at price 824.729980, total balance 865.310117
day 109: buy 1 unit at price 823.349976, total balance 41.960141
day 110: buy 1 unit at price 824.320007, total balance -782.359866
day 112, sell 1 unit at price 837.169983, investment 0.215472 %, total balance 54.810117,
day 113, sell 1 unit at price 836.820007, investment -1.040655 %, total balance 891.630124,
day 114, sell 1 unit at price 838.210022, investment -1.245318 %, total balance 1729.840146,
day 115: buy 1 unit at price 841.650024, total balance 888.190122
day 117: buy 1 unit at price 862.760010, total balance 25.430112
day 118, sell 1 unit at price 872.299988, investment 2.368210 %, total balance 897.730100,

day 119: buy 1 unit at price 871.729980, total balance 26.000120
day 120, sell 1 unit at price 874.250000, investment 5.383379 %, total balance 900.250120,
day 121, sell 1 unit at price 905.960022, investment 11.238539 %, total balance 1806.210142,
day 122, sell 1 unit at price 912.570007, investment 9.761734 %, total balance 2718.780149,
day 123, sell 1 unit at price 916.440002, investment 10.473022 %, total balance 3635.220151,
day 124, sell 1 unit at price 927.039978, investment 10.552739 %, total balance 4562.260129,
day 125, sell 1 unit at price 931.659973, investment 11.633532 %, total balance 5493.920102,
day 126, sell 1 unit at price 927.130005, investment 11.988452 %, total balance 6421.050107,
day 127, sell 1 unit at price 934.299988, investment 13.285561 %, total balance 7355.350095,
day 128, sell 1 unit at price 932.169983, investment 13.216738 %, total balance 8287.520078,
day 129: buy 1 unit at price 928.780029, total balance 7358.740049
day 130, sell 1 unit at price 930.599976, investment 12.893047 %, total balance 8289.340025,
day 132: buy 1 unit at price 937.080017, total balance 7352.260008
day 133, sell 1 unit at price 943.000000, investment 12.041819 %, total balance 8295.260008,
day 134: buy 1 unit at price 919.619995, total balance 7375.640013
day 135: buy 1 unit at price 930.239990, total balance 6445.400023
day 136: buy 1 unit at price 934.010010, total balance 5511.390013
day 138: buy 1 unit at price 948.820007, total balance 4562.570006
day 140: buy 1 unit at price 969.539978, total balance 3593.030028
day 142, sell 1 unit at price 975.880005, investment 13.111409 %, total balance 4568.910033,
day 143, sell 1 unit at price 964.859985, investment 10.683355 %, total balance 5533.770018,
day 144, sell 1 unit at price 966.950012, investment 4.109690 %, total balance 6500.720030,
day 146, sell 1 unit at price 983.679993, investment 4.972892 %, total balance 7484.400023,
day 147: buy 1 unit at price 976.570007, total balance 6507.830016
day 148, sell 1 unit at price 980.940002, investment 6.667972 %, total balance 7488.770018,
day 149: buy 1 unit at price 983.409973, total balance 6505.360045
day 150, sell 1 unit at price 949.830017, investment 2.105911 %, total balance 7455.190062,
day 151: buy 1 unit at price 942.900024, total balance 6512.290038
day 152, sell 1 unit at price 953.400024, investment 2.075996 %, total balance 7465.690062,
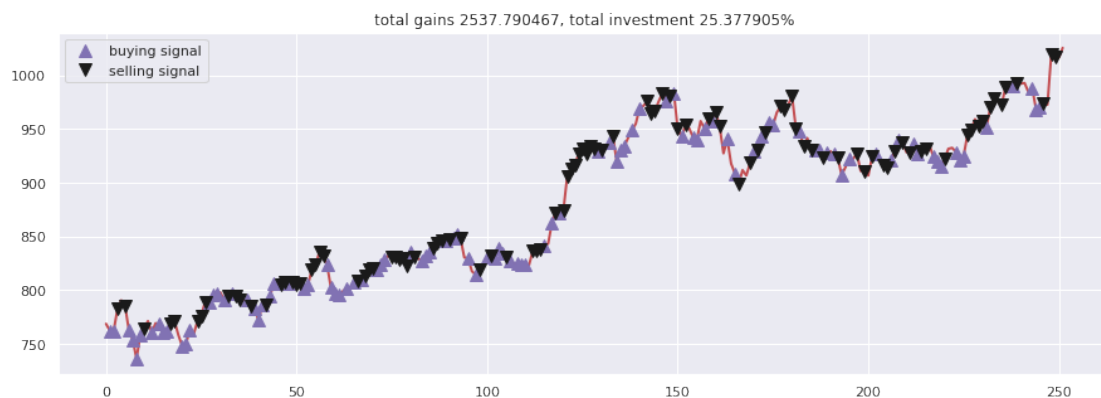day 154: buy 1 unit at price 942.309998, total balance 6523.380064

day 155: buy 1 unit at price 939.780029, total balance 5583.600035
day 157: buy 1 unit at price 950.630005, total balance 4632.970030
day 158, sell 1 unit at price 959.450012, investment 1.120339 %, total balance 5592.420042,
day 159: buy 1 unit at price 957.090027, total balance 4635.330015
day 160, sell 1 unit at price 965.590027, investment -0.407405 %, total balance 5600.920042,
day 161, sell 1 unit at price 952.270020, investment -2.488300 %, total balance 6553.190062,
day 163: buy 1 unit at price 940.489990, total balance 5612.700072
day 165: buy 1 unit at price 908.729980, total balance 4703.970092
day 166, sell 1 unit at price 898.700012, investment -8.613901 %, total balance 5602.670104,
day 169, sell 1 unit at price 918.590027, investment -2.578216 %, total balance 6521.260131,
day 170: buy 1 unit at price 928.799988, total balance 5592.460143
day 171, sell 1 unit at price 930.090027, investment -1.296810 %, total balance 6522.550170,
day 172: buy 1 unit at price 943.830017, total balance 5578.720153
day 173, sell 1 unit at price 947.159973, investment 0.785284 %, total balance 6525.880126,
day 174: buy 1 unit at price 955.989990, total balance 5569.890136
day 175: buy 1 unit at price 953.419983, total balance 4616.470153
day 177, sell 1 unit at price 970.890015, investment 2.131219 %, total balance 5587.360168,
day 178, sell 1 unit at price 968.150024, investment 1.155586 %, total balance 6555.510192,
day 180, sell 1 unit at price 980.340027, investment 4.237157 %, total balance 7535.850219,
day 181, sell 1 unit at price 950.700012, investment 4.618537 %, total balance 8486.550231,
day 182: buy 1 unit at price 947.799988, total balance 7538.750243
day 183, sell 1 unit at price 934.090027, investment 0.569556 %, total balance 8472.840270,
day 185, sell 1 unit at price 930.500000, investment -1.412332 %, total balance 9403.340270,
day 186: buy 1 unit at price 930.830017, total balance 8472.510253
day 187: buy 1 unit at price 930.390015, total balance 7542.120238
day 188, sell 1 unit at price 923.650024, investment -3.382877 %, total balance 8465.770262,
day 189: buy 1 unit at price 927.960022, total balance 7537.810240
day 191: buy 1 unit at price 926.789978, total balance 6611.020262
day 192, sell 1 unit at price 922.900024, investment -3.201103 %, total balance 7533.920286,
day 193: buy 1 unit at price 907.239990, total balance 6626.680296
day 195: buy 1 unit at price 922.669983, total balance 5704.010313
day 197, sell 1 unit at price 926.960022, investment -2.198773 %, total balance 6630.970335,

day 199, sell 1 unit at price 910.669983, investment -2.165813 %, total balance 7541.640318,
day 201, sell 1 unit at price 924.690002, investment -0.612648 %, total balance 8466.330320,
day 202: buy 1 unit at price 927.000000, total balance 7539.330320
day 204, sell 1 unit at price 915.890015, investment -1.300703 %, total balance 8455.220335,
day 205, sell 1 unit at price 913.809998, investment -1.400531 %, total balance 9369.030333,
day 206: buy 1 unit at price 921.289978, total balance 8447.740355
day 207, sell 1 unit at price 929.570007, investment 2.461313 %, total balance 9377.310362,
day 208: buy 1 unit at price 939.330017, total balance 8437.980345
day 209, sell 1 unit at price 937.340027, investment 1.589956 %, total balance 9375.320372,
day 211, sell 1 unit at price 927.809998, investment 0.087378 %, total balance 10303.130370,
day 212: buy 1 unit at price 935.950012, total balance 9367.180358
day 213: buy 1 unit at price 926.500000, total balance 8440.680358
day 214, sell 1 unit at price 929.080017, investment 0.845558 %, total balance 9369.760375,
day 215, sell 1 unit at price 932.070007, investment -0.772892 %, total balance 10301.830382,
day 217: buy 1 unit at price 925.109985, total balance 9376.720397
day 218: buy 1 unit at price 920.289978, total balance 8456.430419
day 219: buy 1 unit at price 915.000000, total balance 7541.430419
day 220, sell 1 unit at price 921.809998, investment -1.510766 %, total balance 8463.240417,
day 223: buy 1 unit at price 928.530029, total balance 7534.710388
day 224: buy 1 unit at price 920.969971, total balance 6613.740417
day 225: buy 1 unit at price 924.859985, total balance 5688.880432
day 226, sell 1 unit at price 944.489990, investment 1.941715 %, total balance 6633.370422,
day 227, sell 1 unit at price 949.500000, investment 2.636445 %, total balance 7582.870422,
day 229, sell 1 unit at price 953.270020, investment 3.583658 %, total balance 8536.140442,
day 230, sell 1 unit at price 957.789978, investment 4.676500 %, total balance 9493.930420,
day 231: buy 1 unit at price 951.679993, total balance 8542.250427
day 232, sell 1 unit at price 969.960022, investment 4.461890 %, total balance 9512.210449,
day 233, sell 1 unit at price 978.890015, investment 6.289026 %, total balance 10491.100464,
day 235, sell 1 unit at price 972.599976, investment 5.161861 %, total balance 11463.700440,
day 236, sell 1 unit at price 989.250000, investment 3.947756 %, total balance 12452.950440,

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day 238: buy 1 unit at price 989.679993, total balance 11463.270447
day 239, sell 1 unit at price 992.000000, investment 0.234420 %, total balance
12455.270447,
day 243: buy 1 unit at price 988.200012, total balance 11467.070435
day 244: buy 1 unit at price 968.450012, total balance 10498.620423
day 245: buy 1 unit at price 970.539978, total balance 9528.080445
day 246, sell 1 unit at price 973.330017, investment -1.504756 %, total balance
10501.410462,
day 248, sell 1 unit at price 1019.270020, investment 5.247561 %, total balance
11520.680482,
day 249, sell 1 unit at price 1017.109985, investment 4.798361 %, total balance
12537.790467,
```

[9]:
```python
fig = plt.figure(figsize = (15,5))
plt.plot(close, color='r', lw=2.)
plt.plot(close, '^', markersize=10, color='m', label = 'buying signal',␣
 ↪markevery = states_buy)
plt.plot(close, 'v', markersize=10, color='k', label = 'selling signal',␣
 ↪markevery = states_sell)
plt.title('total gains %f, total investment %f%%'%(total_gains, invest))
plt.legend()
plt.show()
```


[ ]: