

## 20.duel-curiosity-q-learning-agent

September 29, 2021

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[1]: import numpy as np
import pandas as pd
import tensorflow as tf
import matplotlib.pyplot as plt
import seaborn as sns
sns.set()
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[2]: df = pd.read_csv('../dataset/GOOG-year.csv')
df.head()
```

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[2]:
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	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

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[3]: from collections import deque
import random

class Agent:

    LEARNING_RATE = 0.003
    BATCH_SIZE = 32
    LAYER_SIZE = 500
    OUTPUT_SIZE = 3
    EPSILON = 0.5
    DECAY_RATE = 0.005
    MIN_EPSILON = 0.1
    GAMMA = 0.99
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MEMORIES = deque()
COPY = 1000
T_COPY = 0
MEMORY_SIZE = 300

def __init__(self, state_size, window_size, trend, skip):
    self.state_size = state_size
    self.window_size = window_size
    self.half_window = window_size // 2
    self.trend = trend
    self.skip = skip
    tf.reset_default_graph()
    self.X = tf.placeholder(tf.float32, (None, self.state_size))
    self.Y = tf.placeholder(tf.float32, (None, self.state_size))
    self.ACTION = tf.placeholder(tf.float32, (None))
    self.REWARD = tf.placeholder(tf.float32, (None))
    self.batch_size = tf.shape(self.ACTION)[0]

    with tf.variable_scope('curiosity_model'):
        action = tf.reshape(self.ACTION, (-1,1))
        state_action = tf.concat([self.X, action], axis=1)
        save_state = tf.identity(self.Y)

        feed = tf.layers.dense(state_action, 32, activation=tf.nn.relu)
        self.curiosity_logits = tf.layers.dense(feed, self.state_size)
        self.curiosity_cost = tf.reduce_sum(tf.square(save_state - self.
↪curiosity_logits), axis=1)

        self.curiosity_optimizer = tf.train.RMSPropOptimizer(self.
↪LEARNING_RATE)\
            .minimize(tf.reduce_mean(self.curiosity_cost))

    total_reward = tf.add(self.curiosity_cost, self.REWARD)

    with tf.variable_scope("q_model"):
        with tf.variable_scope("eval_net"):
            x_action = tf.layers.dense(self.X, 128, tf.nn.relu)
            tensor_action, tensor_validation = tf.split(x_action,2,1)
            feed_action = tf.layers.dense(tensor_action, self.OUTPUT_SIZE)
            feed_validation = tf.layers.dense(tensor_validation, 1)
            self.logits = feed_validation + \
                tf.subtract(feed_action,tf.
↪reduce_mean(feed_action,axis=1,keep_dims=True))

            with tf.variable_scope("target_net"):
                y_action = tf.layers.dense(self.Y, 128, tf.nn.relu)
                tensor_action, tensor_validation = tf.split(y_action,2,1)

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        feed_action = tf.layers.dense(tensor_action, self.OUTPUT_SIZE)
        feed_validation = tf.layers.dense(tensor_validation, 1)
        y_q = feed_validation + \
            tf.subtract(feed_action,tf.
↪reduce_mean(feed_action,axis=1,keep_dims=True))

        q_target = total_reward + self.GAMMA * tf.reduce_max(y_q, axis=1)
        action = tf.cast(self.ACTION, tf.int32)
        action_indices = tf.stack([tf.range(self.batch_size, dtype=tf.
↪int32), action], axis=1)
        q = tf.gather_nd(params=self.logits, indices=action_indices)
        self.cost = tf.losses.mean_squared_error(labels=q_target,
↪predictions=q)
        self.optimizer = tf.train.RMSPropOptimizer(self.LEARNING_RATE).
↪minimize(
            self.cost, var_list=tf.get_collection(tf.GraphKeys.
↪TRAINABLE_VARIABLES, "q_model/eval_net"))

        t_params = tf.get_collection(tf.GraphKeys.GLOBAL_VARIABLES,
↪scope='q_model/target_net')
        e_params = tf.get_collection(tf.GraphKeys.GLOBAL_VARIABLES,
↪scope='q_model/eval_net')
        self.target_replace_op = [tf.assign(t, e) for t, e in zip(t_params,
↪e_params)]

        self.sess = tf.InteractiveSession()
        self.sess.run(tf.global_variables_initializer())

    def _memorize(self, state, action, reward, new_state, done):
        self.MEMORIES.append((state, action, reward, new_state, done))
        if len(self.MEMORIES) > self.MEMORY_SIZE:
            self.MEMORIES.popleft()

    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 predict(self, inputs):
        return self.sess.run(self.logits, feed_dict={self.X:inputs})

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def get_predicted_action(self, sequence):
    prediction = self.predict(np.array(sequence))[0]
    return np.argmax(prediction)

def _select_action(self, state):
    if np.random.rand() < self.EPSILON:
        action = np.random.randint(self.OUTPUT_SIZE)
    else:
        action = self.get_predicted_action([state])
    return action

def _construct_memories(self, replay):
    states = np.array([a[0] for a in replay])
    actions = np.array([a[1] for a in replay])
    rewards = np.array([a[2] for a in replay])
    new_states = np.array([a[3] for a in replay])
    if (self.T_COPY + 1) % self.COPY == 0:
        self.sess.run(self.target_replace_op)

    cost, _ = self.sess.run([self.cost, self.optimizer], feed_dict = {
        self.X: states, self.Y: new_states, self.ACTION: actions, self.
↪REWARD: rewards
    })

    if (self.T_COPY + 1) % self.COPY == 0:
        self.sess.run(self.curiosity_optimizer, feed_dict = {
            self.X: states, self.Y: new_states, self.ACTION: actions, self.
↪REWARD: rewards
        })
    return cost

def buy(self, initial_money):
    starting_money = initial_money
    states_sell = []
    states_buy = []
    inventory = []
    state = self.get_state(0)
    for t in range(0, len(self.trend) - 1, self.skip):
        action = self._select_action(state)
        next_state = self.get_state(t + 1)

        if action == 1 and initial_money >= self.trend[t]:
            inventory.append(self.trend[t])
            initial_money -= self.trend[t]
            states_buy.append(t)
            print('day %d: buy 1 unit at price %f, total balance %f' % (t,
↪self.trend[t], initial_money))

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        elif action == 2 and len(inventory):
            bought_price = inventory.pop(0)
            initial_money += self.trend[t]
            states_sell.append(t)
            try:
                invest = ((close[t] - bought_price) / bought_price) * 100
            except:
                invest = 0
            print(
                'day %d, sell 1 unit at price %f, investment %f %%, total_
→balance %f,'
                % (t, close[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 train(self, iterations, checkpoint, initial_money):
    for i in range(iterations):
        total_profit = 0
        inventory = []
        state = self.get_state(0)
        starting_money = initial_money
        for t in range(0, len(self.trend) - 1, self.skip):

            action = self._select_action(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) > 0:
                bought_price = inventory.pop(0)
                total_profit += self.trend[t] - bought_price
                starting_money += self.trend[t]

            invest = ((starting_money - initial_money) / initial_money)

            self._memorize(state, action, invest, next_state,
→starting_money < initial_money)
            batch_size = min(len(self.MEMORIES), self.BATCH_SIZE)
            state = next_state
            replay = random.sample(self.MEMORIES, batch_size)

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        cost = self._construct_memories(replay)
        self.T_COPY += 1
        self.EPSILON = self.MIN_EPSILON + (1.0 - self.MIN_EPSILON) * np.
→exp(-self.DECAY_RATE * i)
        if (i+1) % checkpoint == 0:
            print('epoch: %d, total rewards: %f.3, cost: %f, total money:
→%f'%(i + 1, total_profit, cost,
→ starting_money))

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[4]: close = df.Close.values.tolist()
initial_money = 10000
window_size = 30
skip = 1
batch_size = 32
agent = Agent(state_size = window_size,
               window_size = window_size,
               trend = close,
               skip = skip)
agent.train(iterations = 200, checkpoint = 10, initial_money = initial_money)

```

WARNING:tensorflow:From <ipython-input-3-e49b5b607a66>:53: calling reduce\_mean (from tensorflow.python.ops.math\_ops) with keep\_dims is deprecated and will be removed in a future version.

Instructions for updating:

keep\_dims is deprecated, use keepdims instead

epoch: 10, total rewards: 698.460085.3, cost: 596251.000000, total money: 10698.460085

epoch: 20, total rewards: 1683.164917.3, cost: 5890915.500000, total money: 6720.204895

epoch: 30, total rewards: 1686.875004.3, cost: 75077.554688, total money: 6721.424992

epoch: 40, total rewards: 541.999876.3, cost: 2707843.750000, total money: 9525.359861

epoch: 50, total rewards: 1668.824950.3, cost: 32719.388672, total money: 7666.774900

epoch: 60, total rewards: 751.654909.3, cost: 1165742.750000, total money: 8743.134889

epoch: 70, total rewards: 1637.889772.3, cost: 325201.937500, total money: 6669.909730

epoch: 80, total rewards: 587.055053.3, cost: 1527037.250000, total money: 892.705077

epoch: 90, total rewards: 2170.969727.3, cost: 122936.546875, total money: 8204.549683

epoch: 100, total rewards: 1565.850155.3, cost: 844705.187500, total money: 19.270138

epoch: 110, total rewards: 1733.244930.3, cost: 557043.125000, total money:

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6744.174861
epoch: 120, total rewards: 1282.489866.3, cost: 3785043.750000, total money:
8328.149839
epoch: 130, total rewards: 1260.559873.3, cost: 596946.312500, total money:
6319.639890
epoch: 140, total rewards: 1346.769778.3, cost: 26543662.000000, total money:
10330.129763
epoch: 150, total rewards: 2415.594848.3, cost: 851761.625000, total money:
9467.174865
epoch: 160, total rewards: 1033.800112.3, cost: 3596937.500000, total money:
9044.600099
epoch: 170, total rewards: 1597.439823.3, cost: 511038.375000, total money:
93.789859
epoch: 180, total rewards: 1736.860354.3, cost: 3795484.000000, total money:
1011.990359
epoch: 190, total rewards: 1682.540215.3, cost: 657330.250000, total money:
8675.460198
epoch: 200, total rewards: 875.094668.3, cost: 30907612.000000, total money:
10875.094668

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[5]: states_buy, states_sell, total_gains, invest = agent.buy(initial_money =
    ↪initial_money)

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day 3: buy 1 unit at price 782.520020, total balance 9217.479980
day 4: buy 1 unit at price 790.510010, total balance 8426.969970
day 5: buy 1 unit at price 785.309998, total balance 7641.659972
day 6: buy 1 unit at price 762.559998, total balance 6879.099974
day 7: buy 1 unit at price 754.020020, total balance 6125.079954
day 9: buy 1 unit at price 758.489990, total balance 5366.589964
day 10, sell 1 unit at price 764.479980, investment -2.305377 %, total balance
6131.069944,
day 11: buy 1 unit at price 771.229980, total balance 5359.839964
day 13: buy 1 unit at price 769.200012, total balance 4590.639952
day 15: buy 1 unit at price 760.989990, total balance 3829.649962
day 16: buy 1 unit at price 761.679993, total balance 3067.969969
day 17: buy 1 unit at price 768.239990, total balance 2299.729979
day 19: buy 1 unit at price 758.039978, total balance 1541.690001
day 21: buy 1 unit at price 750.500000, total balance 791.190001
day 22, sell 1 unit at price 762.520020, investment -3.540751 %, total balance
1553.710021,
day 23, sell 1 unit at price 759.109985, investment -3.336264 %, total balance
2312.820006,
day 24: buy 1 unit at price 771.190002, total balance 1541.630004
day 25, sell 1 unit at price 776.419983, investment 1.817560 %, total balance
2318.049987,
day 27, sell 1 unit at price 789.270020, investment 4.674942 %, total balance
3107.320007,
day 29, sell 1 unit at price 797.070007, investment 5.086424 %, total balance

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3904.390014,  
 day 30, sell 1 unit at price 797.849976, investment 3.451629 %, total balance  
 4702.239990,  
 day 32: buy 1 unit at price 794.200012, total balance 3908.039978  
 day 33, sell 1 unit at price 796.419983, investment 3.538738 %, total balance  
 4704.459961,  
 day 34, sell 1 unit at price 794.559998, investment 4.411360 %, total balance  
 5499.019959,  
 day 38: buy 1 unit at price 785.049988, total balance 4713.969971  
 day 39, sell 1 unit at price 782.789978, investment 2.771503 %, total balance  
 5496.759949,  
 day 40, sell 1 unit at price 771.820007, investment 0.466002 %, total balance  
 6268.579956,  
 day 41: buy 1 unit at price 786.140015, total balance 5482.439941  
 day 45: buy 1 unit at price 806.650024, total balance 4675.789917  
 day 47, sell 1 unit at price 807.909973, investment 6.578808 %, total balance  
 5483.699890,  
 day 50: buy 1 unit at price 804.609985, total balance 4679.089905  
 day 51, sell 1 unit at price 806.070007, investment 7.404398 %, total balance  
 5485.159912,  
 day 52, sell 1 unit at price 802.174988, investment 4.017815 %, total balance  
 6287.334900,  
 day 53: buy 1 unit at price 805.020020, total balance 5482.314880  
 day 54, sell 1 unit at price 819.309998, investment 3.161670 %, total balance  
 6301.624878,  
 day 56: buy 1 unit at price 835.669983, total balance 5465.954895  
 day 58, sell 1 unit at price 823.309998, investment 4.873576 %, total balance  
 6289.264893,  
 day 59, sell 1 unit at price 802.320007, investment 2.058157 %, total balance  
 7091.584900,  
 day 60: buy 1 unit at price 796.789978, total balance 6294.794922  
 day 61, sell 1 unit at price 795.695007, investment -1.358088 %, total balance  
 7090.489929,  
 day 62, sell 1 unit at price 798.530029, investment -0.755640 %, total balance  
 7889.019958,  
 day 63, sell 1 unit at price 801.489990, investment -0.438502 %, total balance  
 8690.509948,  
 day 66: buy 1 unit at price 808.380005, total balance 7882.129943  
 day 67, sell 1 unit at price 809.559998, investment -3.124437 %, total balance  
 8691.689941,  
 day 68: buy 1 unit at price 813.669983, total balance 7878.019958  
 day 69, sell 1 unit at price 819.239990, investment 2.817557 %, total balance  
 8697.259948,  
 day 70, sell 1 unit at price 820.450012, investment 1.493111 %, total balance  
 9517.709960,  
 day 72, sell 1 unit at price 824.159973, investment 1.289219 %, total balance  
 10341.869933,  
 day 73: buy 1 unit at price 828.070007, total balance 9513.799926



day 74, sell 1 unit at price 831.659973, investment 0.433534 %, total balance 10345.459899,  
 day 75: buy 1 unit at price 830.760010, total balance 9514.699889  
 day 76: buy 1 unit at price 831.330017, total balance 8683.369872  
 day 78: buy 1 unit at price 829.280029, total balance 7854.089843  
 day 79: buy 1 unit at price 823.210022, total balance 7030.879821  
 day 80: buy 1 unit at price 835.239990, total balance 6195.639831  
 day 81, sell 1 unit at price 830.630005, investment -0.015649 %, total balance 7026.269836,  
 day 82, sell 1 unit at price 829.080017, investment -0.270651 %, total balance 7855.349853,  
 day 84, sell 1 unit at price 831.909973, investment 0.317136 %, total balance 8687.259826,  
 day 85: buy 1 unit at price 835.369995, total balance 7851.889831  
 day 86: buy 1 unit at price 838.679993, total balance 7013.209838  
 day 88: buy 1 unit at price 845.539978, total balance 6167.669860  
 day 89: buy 1 unit at price 845.619995, total balance 5322.049865  
 day 90, sell 1 unit at price 847.200012, investment 2.914200 %, total balance 6169.249877,  
 day 91: buy 1 unit at price 848.780029, total balance 5320.469848  
 day 92: buy 1 unit at price 852.119995, total balance 4468.349853  
 day 93, sell 1 unit at price 848.400024, investment 1.575599 %, total balance 5316.749877,  
 day 94: buy 1 unit at price 830.460022, total balance 4486.289855  
 day 95: buy 1 unit at price 829.590027, total balance 3656.699828  
 day 96, sell 1 unit at price 817.580017, investment -2.129593 %, total balance 4474.279845,  
 day 97: buy 1 unit at price 814.429993, total balance 3659.849852  
 day 98, sell 1 unit at price 819.510010, investment -2.285733 %, total balance 4479.359862,  
 day 100: buy 1 unit at price 831.409973, total balance 3647.949889  
 day 101, sell 1 unit at price 831.500000, investment -1.660475 %, total balance 4479.449889,  
 day 103: buy 1 unit at price 838.549988, total balance 3640.899901  
 day 104: buy 1 unit at price 834.570007, total balance 2806.329894  
 day 105, sell 1 unit at price 831.409973, investment -1.680426 %, total balance 3637.739867,  
 day 106: buy 1 unit at price 827.880005, total balance 2809.859862  
 day 108: buy 1 unit at price 824.729980, total balance 1985.129882  
 day 109: buy 1 unit at price 823.349976, total balance 1161.779906  
 day 110: buy 1 unit at price 824.320007, total balance 337.459899  
 day 112, sell 1 unit at price 837.169983, investment -1.367851 %, total balance 1174.629882,  
 day 113: buy 1 unit at price 836.820007, total balance 337.809875  
 day 115, sell 1 unit at price 841.650024, investment -1.228697 %, total balance 1179.459899,  
 day 116, sell 1 unit at price 843.190002, investment 1.532883 %, total balance 2022.649901,

day 117, sell 1 unit at price 862.760010, investment 3.998358 %, total balance 2885.409911,  
 day 118: buy 1 unit at price 872.299988, total balance 2013.109923  
 day 119, sell 1 unit at price 871.729980, investment 7.035594 %, total balance 2884.839903,  
 day 120, sell 1 unit at price 874.250000, investment 5.152696 %, total balance 3759.089903,  
 day 123, sell 1 unit at price 916.440002, investment 9.288655 %, total balance 4675.529905,  
 day 124: buy 1 unit at price 927.039978, total balance 3748.489927  
 day 126, sell 1 unit at price 927.130005, investment 11.090741 %, total balance 4675.619932,  
 day 127, sell 1 unit at price 934.299988, investment 12.854518 %, total balance 5609.919920,  
 day 128, sell 1 unit at price 932.169983, investment 13.027294 %, total balance 6542.089903,  
 day 129: buy 1 unit at price 928.780029, total balance 5613.309874  
 day 133, sell 1 unit at price 943.000000, investment 14.532098 %, total balance 6556.309874,  
 day 137, sell 1 unit at price 941.859985, investment 14.259023 %, total balance 7498.169859,  
 day 140, sell 1 unit at price 969.539978, investment 15.860038 %, total balance 8467.709837,  
 day 141: buy 1 unit at price 971.469971, total balance 7496.239866  
 day 142, sell 1 unit at price 975.880005, investment 11.874357 %, total balance 8472.119871,  
 day 143, sell 1 unit at price 964.859985, investment 4.079652 %, total balance 9436.979856,  
 day 144, sell 1 unit at price 966.950012, investment 4.109690 %, total balance 10403.929868,  
 day 145, sell 1 unit at price 975.599976, investment 0.425129 %, total balance 11379.529844,  
 day 147: buy 1 unit at price 976.570007, total balance 10402.959837  
 day 148: buy 1 unit at price 980.940002, total balance 9422.019835  
 day 149, sell 1 unit at price 983.409973, investment 0.700407 %, total balance 10405.429808,  
 day 150: buy 1 unit at price 949.830017, total balance 9455.599791  
 day 151, sell 1 unit at price 942.900024, investment -3.877911 %, total balance 10398.499815,  
 day 152, sell 1 unit at price 953.400024, investment 0.375857 %, total balance 11351.899839,  
 day 153: buy 1 unit at price 950.760010, total balance 10401.139829  
 day 155, sell 1 unit at price 939.780029, investment -1.154864 %, total balance 11340.919858,  
 day 156: buy 1 unit at price 957.369995, total balance 10383.549863  
 day 157: buy 1 unit at price 950.630005, total balance 9432.919858  
 day 158: buy 1 unit at price 959.450012, total balance 8473.469846  
 day 159, sell 1 unit at price 957.090027, investment -0.029243 %, total balance

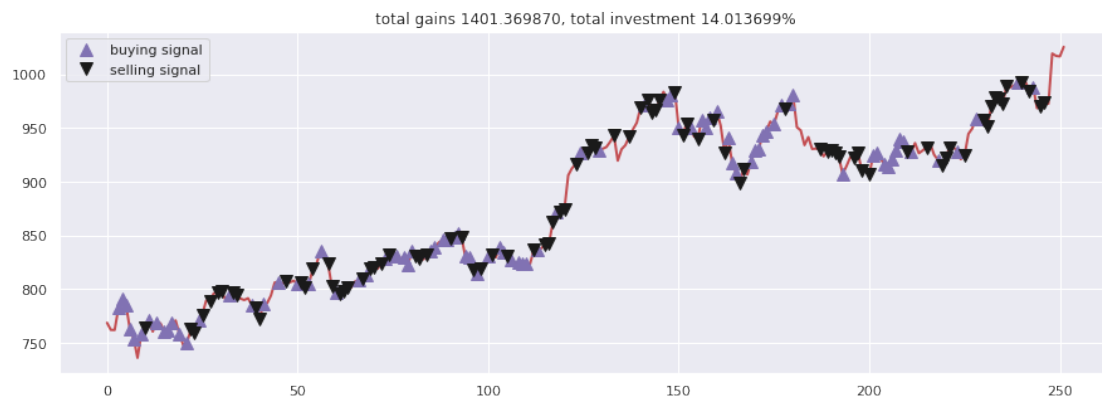
9430.559873,  
 day 160: buy 1 unit at price 965.590027, total balance 8464.969846  
 day 162, sell 1 unit at price 927.330017, investment -2.451005 %, total balance 9392.299863,  
 day 163: buy 1 unit at price 940.489990, total balance 8451.809873  
 day 164: buy 1 unit at price 917.789978, total balance 7534.019895  
 day 165: buy 1 unit at price 908.729980, total balance 6625.289915  
 day 166, sell 1 unit at price 898.700012, investment -6.331752 %, total balance 7523.989927,  
 day 167, sell 1 unit at price 911.710022, investment -5.580008 %, total balance 8435.699949,  
 day 169: buy 1 unit at price 918.590027, total balance 7517.109922  
 day 170: buy 1 unit at price 928.799988, total balance 6588.309934  
 day 171: buy 1 unit at price 930.090027, total balance 5658.219907  
 day 172: buy 1 unit at price 943.830017, total balance 4714.389890  
 day 173: buy 1 unit at price 947.159973, total balance 3767.229917  
 day 175: buy 1 unit at price 953.419983, total balance 2813.809934  
 day 177: buy 1 unit at price 970.890015, total balance 1842.919919  
 day 178, sell 1 unit at price 968.150024, investment 2.941024 %, total balance 2811.069943,  
 day 179: buy 1 unit at price 972.919983, total balance 1838.149960  
 day 180: buy 1 unit at price 980.340027, total balance 857.809933  
 day 187, sell 1 unit at price 930.390015, investment 1.372867 %, total balance 1788.199948,  
 day 189, sell 1 unit at price 927.960022, investment 2.116145 %, total balance 2716.159970,  
 day 190, sell 1 unit at price 929.359985, investment 1.172444 %, total balance 3645.519955,  
 day 191, sell 1 unit at price 926.789978, investment -0.216409 %, total balance 4572.309933,  
 day 192, sell 1 unit at price 922.900024, investment -0.773044 %, total balance 5495.209957,  
 day 193: buy 1 unit at price 907.239990, total balance 4587.969967  
 day 196, sell 1 unit at price 922.219971, investment -2.289612 %, total balance 5510.189938,  
 day 197, sell 1 unit at price 926.960022, investment -2.132686 %, total balance 6437.149960,  
 day 198, sell 1 unit at price 910.979980, investment -4.451344 %, total balance 7348.129940,  
 day 200, sell 1 unit at price 906.659973, investment -6.615584 %, total balance 8254.789913,  
 day 201: buy 1 unit at price 924.690002, total balance 7330.099911  
 day 202: buy 1 unit at price 927.000000, total balance 6403.099911  
 day 204: buy 1 unit at price 915.890015, total balance 5487.209896  
 day 205: buy 1 unit at price 913.809998, total balance 4573.399898  
 day 206: buy 1 unit at price 921.289978, total balance 3652.109920  
 day 207: buy 1 unit at price 929.570007, total balance 2722.539913  
 day 208: buy 1 unit at price 939.330017, total balance 1783.209896

day 209: buy 1 unit at price 937.340027, total balance 845.869869  
 day 210, sell 1 unit at price 928.450012, investment -4.570774 %, total balance 1774.319881,  
 day 211: buy 1 unit at price 927.809998, total balance 846.509883  
 day 215, sell 1 unit at price 932.070007, investment -4.923804 %, total balance 1778.579890,  
 day 218: buy 1 unit at price 920.289978, total balance 858.289912  
 day 219, sell 1 unit at price 915.000000, investment 0.855343 %, total balance 1773.289912,  
 day 220, sell 1 unit at price 921.809998, investment -0.311456 %, total balance 2695.099910,  
 day 221, sell 1 unit at price 931.580017, investment 0.494069 %, total balance 3626.679927,  
 day 223: buy 1 unit at price 928.530029, total balance 2698.149898  
 day 225, sell 1 unit at price 924.859985, investment 0.979372 %, total balance 3623.009883,  
 day 228: buy 1 unit at price 959.109985, total balance 2663.899898  
 day 230, sell 1 unit at price 957.789978, investment 4.812814 %, total balance 3621.689876,  
 day 231, sell 1 unit at price 951.679993, investment 3.298637 %, total balance 4573.369869,  
 day 232, sell 1 unit at price 969.960022, investment 4.345021 %, total balance 5543.329891,  
 day 233, sell 1 unit at price 978.890015, investment 4.211512 %, total balance 6522.219906,  
 day 234, sell 1 unit at price 977.000000, investment 4.231119 %, total balance 7499.219906,  
 day 235, sell 1 unit at price 972.599976, investment 4.827495 %, total balance 8471.819882,  
 day 236, sell 1 unit at price 989.250000, investment 7.493293 %, total balance 9461.069882,  
 day 239: buy 1 unit at price 992.000000, total balance 8469.069882  
 day 240, sell 1 unit at price 992.179993, investment 6.854917 %, total balance 9461.249875,  
 day 242, sell 1 unit at price 984.450012, investment 2.642036 %, total balance 10445.699887,  
 day 243: buy 1 unit at price 988.200012, total balance 9457.499875  
 day 245, sell 1 unit at price 970.539978, investment -2.163309 %, total balance 10428.039853,  
 day 246, sell 1 unit at price 973.330017, investment -1.504756 %, total balance 11401.369870,

```

[6]: 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()
```



[ ]: