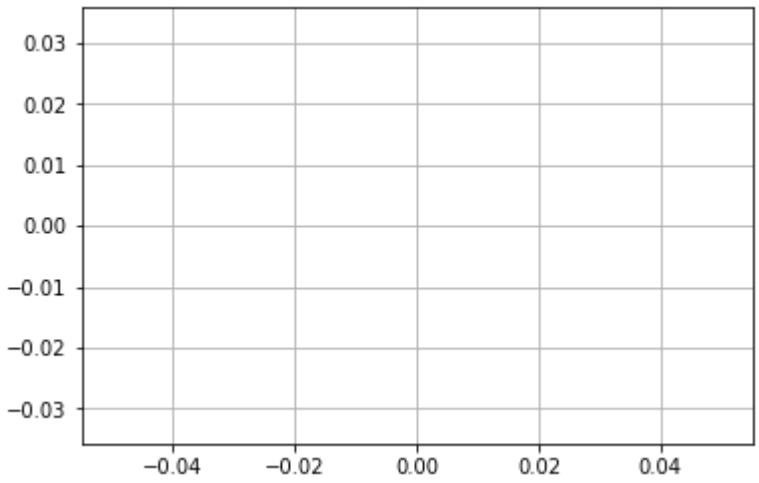
In [2]:

```
# -*- coding: utf-8 -*-


import pandas as pd
import matplotlib.pyplot as plt
from tqdm import tqdm
import copy
from mpl_toolkits.mplot3d import axes3d
import matplotlib.pyplot as plt
import numpy as np
from matplotlib import cm
from matplotlib.animation import FuncAnimation
import scipy.optimize

plt.grid()
plt.axis('equal')
```

Out[2]:

```
(-0.05500000000000001,
 0.05500000000000001,
 -0.05500000000000001,
 0.05500000000000001)
```

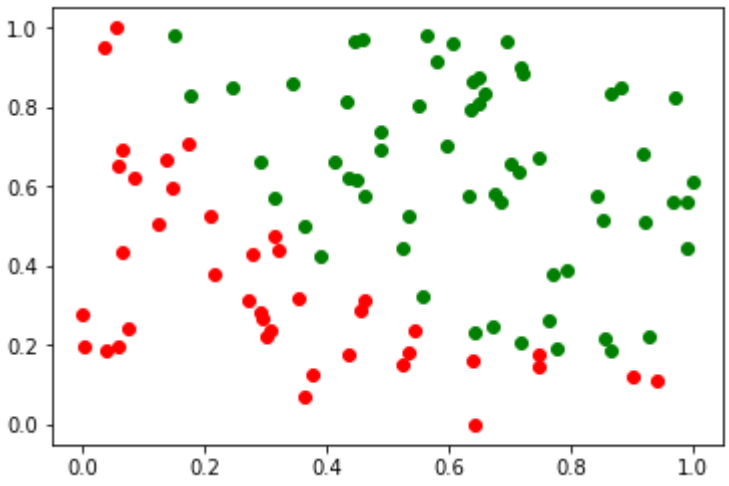


In [4]:

```
# task 1
# Загрузите данные ex2data1.txt из текстового файла.


df = pd.read_csv("G:/Labs/bsuir-labs/11cem/ml/lab02/data/ex2data1.txt", header=None, sep=
normalized_data = (df - df.min()) / (df.max() - df.min())
```

In [5]:

```
# task 2
# Постройте график, где по осям откладываются оценки по предметам, а точки обозначаются д

failedTestResults = normalized_data[normalized_data['IsTestPassed'] == 0]
passedTestResults = normalized_data[normalized_data['IsTestPassed'] == 1]


def ShowData():
    plt.plot(failedTestResults.Test1, failedTestResults.Test2, 'ro')
    plt.plot(passedTestResults.Test1, passedTestResults.Test2, 'go')
    plt.show()


ShowData()
```



In [6]:

```
# tetha = np.array([1, 0])
def InitialApproximation(x, y):
    return np.linalg.inv(x.T.dot(x)).dot(x.T).dot(y)

x = np.array(normalized_data.iloc[:, 0:2])
y = np.array(normalized_data.IsTestPassed)

x_passed = np.array(passedTestResults.iloc[:, 0:2])
y_passed = np.array(passedTestResults.IsTestPassed)

x_failed = np.array(failedTestResults.iloc[:, 0:2])
y_failed = np.array(failedTestResults.IsTestPassed)


# tetha = InitialApproximation(x, y)
tetha = np.array([-2.0,0.0])
print("Initial Approximation: "+str(tetha))
```

```
Initial Approximation: [-2.  0.]
```

In [7]:

```
# task 3
# Реализуйте функции потерь J(ϑ) и градиентного спуска для логистической регрессии с испо

def get_cost(tetha):
    z = tetha.dot(x_passed.T)
    g = 1/(1+np.exp(-z))
    cost_passed = -np.log(g)
    z = tetha.dot(x_failed.T)
    g = 1/(1+np.exp(-z))
    cost_failed = -np.log(1-g)
    return (sum(cost_failed)+sum(cost_passed))/len(x)
print(get_cost(tetha))
```

```
1.1059876480423114
```

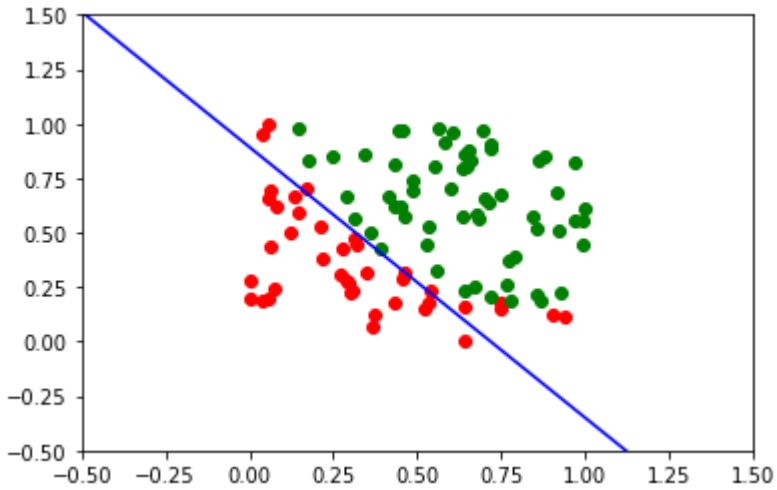
In [8]:

```
def gradientDescent(x, y, theta, alpha=0.5, iterations = 500):
    tetha_history = [copy.deepcopy(theta)]
    cost_history = [get_cost(copy.deepcopy(theta))]
    for _ in range(iterations):
        h = 1 / (1 + np.exp(-(np.dot(x, theta))))
        gradient = x.T.dot(h - y) / len(y)
        theta -= alpha * gradient
        tetha_history.append(copy.deepcopy(theta))
        cost_history.append(get_cost(copy.deepcopy(theta)))
    return tetha_history, cost_history
```

In [10]:

```
# task 6
# Постройте разделяющую прямую, полученную в результате обучения модели. Совместите пряму
def ShowAnimatedGradientResult(tetha_history):
    fig = plt.figure()
    ax = plt.axes(xlim=(-0.5, 1.5), ylim=(-0.5, 1.5))

    plt.plot(failedTestResults.Test1, failedTestResults.Test2, 'ro')
    plt.plot(passedTestResults.Test1, passedTestResults.Test2, 'go')
    x = np.arange(-10, 10, 0.01)
    k = tetha_history[0][0]
    b = tetha_history[0][1]
    y = [-(i * k + b-1.5) for i in x]
    print("result linear function model")
    line, = plt.plot(x, y, 'b-')

    def animate(i):
        x = np.arange(-10, 10, 0.01)
        k = tetha_history[i][0]
        b = tetha_history[i][1]
        y = [-(i * k + b-1.5) for i in x]
        line.set_data(x, y)
        return line,

    anim = FuncAnimation(fig, animate, frames=len(tetha_history), interval=20, blit=True,
    plt.show()
    plt.cla()
    plt.clf()
    plt.close()

tetha_history, cost_history = gradientDescent(x,y,tetha)
ShowAnimatedGradientResult(tetha_history)
print("tetha result"+str(tetha_history[-1]))

print("function y={0:+f}*x{1:+f}".format(-(round(tetha_history[-1][0], 2)),-(round(tetha_
```

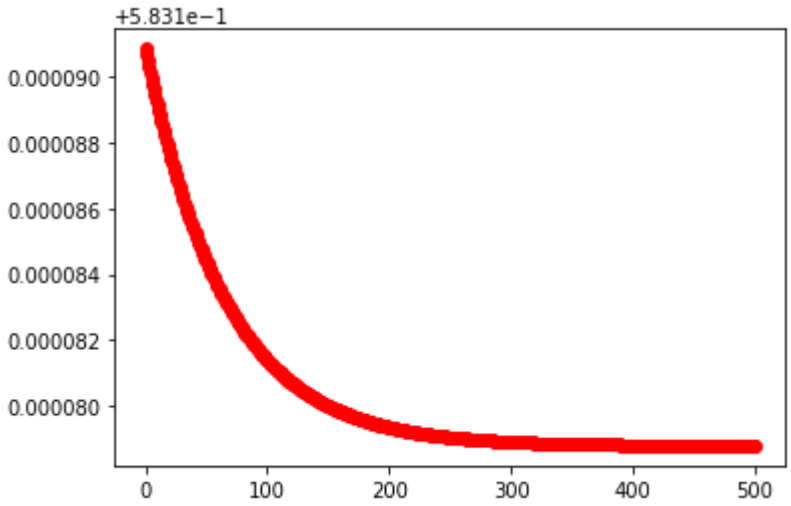
```
result linear function model
```



```
tetha result[1.26891795 0.58032665]
function y=-1.270000*x+0.920000
```

In [11]:

```
def show_linear_plot(data):
    plt.plot(range(len(data)), data, 'ro')
    plt.show()

show_linear_plot(cost_history)
```



In [13]:

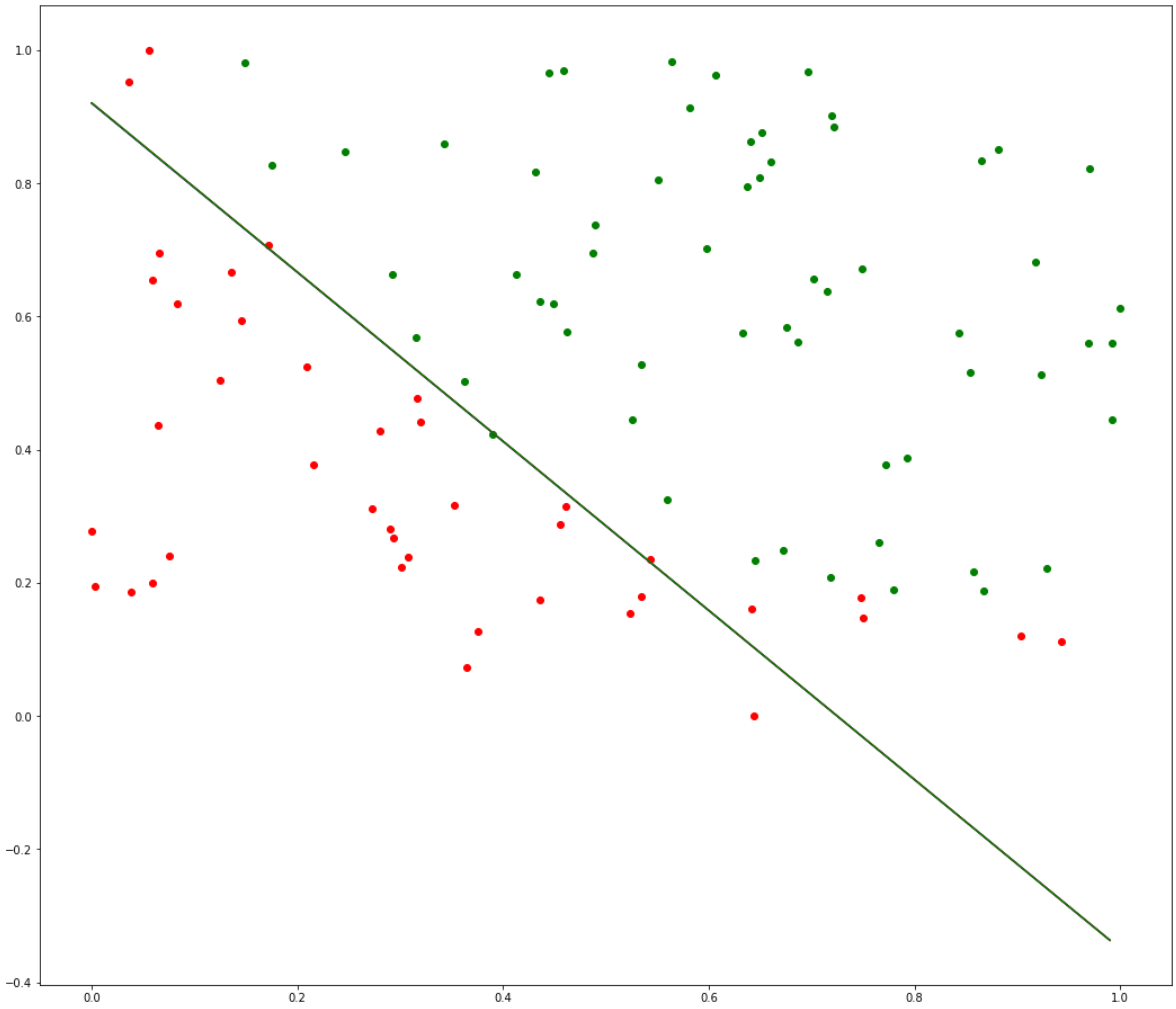
```
# task 5
# Реализуйте функцию предсказания вероятности поступления студента в зависимости от значе

def isTestPassed(tetha, test):
    if test[1]>-(tetha[0]*test[0]+tetha[1] - 1.5):
        print("test passed")
    else:
        print("test failed")


isTestPassed(tetha_history[-1], [0.8, 0.76])
isTestPassed(tetha_history[-1], [0.1, 0.93])
isTestPassed(tetha_history[-1], [0.12, 0.3])
isTestPassed(tetha_history[-1], [0.61, 0.03])

print(1 / (1 + np.exp(-np.dot(tetha_history[-1].copy(), x.copy().T))))
```

```
test passed
test passed
test failed
test failed
[0.61919889 0.5292508  0.61416649 0.73524926 0.78092246 0.62054015
 0.7549078  0.72180044 0.78923963 0.75004276 0.7792972  0.69372919
 0.79253467 0.78337    0.63613681 0.71770203 0.71047702 0.69545351
 0.78044632 0.73059362 0.68624903 0.79955189 0.62891584 0.54765558
 0.76794053 0.71511921 0.73742526 0.77144756 0.6780679  0.61089814
 0.71675404 0.77406942 0.66318154 0.67479804 0.62947122 0.65264579
 0.65711628 0.74042124 0.71234228 0.61169783 0.76813138 0.6292483
 0.81278805 0.73817778 0.62506753 0.6829556  0.767822   0.84665869
 0.7585462  0.83375582 0.78204041 0.82012735 0.77009052 0.58285111
 0.6297438  0.64644222 0.82555704 0.64527272 0.75714996 0.76239806
 0.78472926 0.5583906  0.63414069 0.54027018 0.63886459 0.6798414
 0.6809433  0.6287155  0.80788133 0.71617881 0.53903208 0.73520694
 0.79033927 0.71383839 0.71262842 0.83534166 0.69102038 0.68033454
 0.65792091 0.74112048 0.80276444 0.78690843 0.72781925 0.67701827
 0.80659905 0.76243002 0.65218322 0.79159866 0.80921538 0.65966998
 0.82641195 0.82949934 0.62354269 0.78061328 0.77079433 0.75452269
 0.66868574 0.82978294 0.67953277 0.78821824]
```

In [16]:

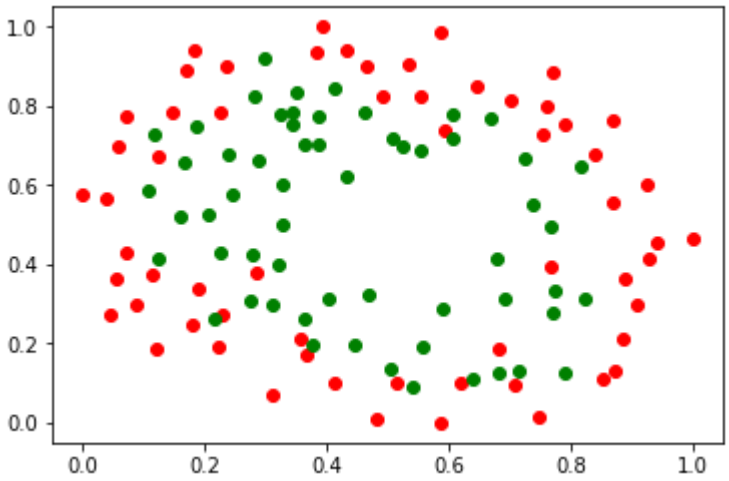
```
# task 4
# Реализуйте другие методы (как минимум 2) оптимизации для реализованной функции стоимост

my_tetha = tetha_history[-1]
print("mead")

mead_theta = scipy.optimize.minimize(get_cost, [1.0, 1.0], method='Nelder-Mead').x
print(mead_theta)
print("Powell")
powell_tetha =scipy.optimize.minimize(get_cost, [1.0, 1.0], method='Powell').x
print(powell_tetha)



def ShowComparedData():
    fig = plt.figure(figsize=(18, 16))
    plt.plot(failedTestResults.Test1, failedTestResults.Test2, 'ro')
    plt.plot(passedTestResults.Test1, passedTestResults.Test2, 'go')

    x = np.arange(0, 1, 0.01)
    k = my_tetha[0]
    b = my_tetha[1]
    y = [-(i * k + b-1.5) for i in x]
    line, = plt.plot(x, y, 'b-')

    x = np.arange(0, 1, 0.01)
    k = mead_theta[0]
    b = mead_theta[1]
    y = [-(i * k + b-1.5) for i in x]
    line, = plt.plot(x, y, 'r-')

    x = np.arange(0, 1, 0.01)
    k = powell_tetha[0]
    b = powell_tetha[1]
    y = [-(i * k + b-1.5) for i in x]
    line, = plt.plot(x, y, 'g-')

    plt.show()

ShowComparedData()
```

```
mead
[1.26951671 0.57975246]
Powell
[1.26955055 0.57973591]
```


1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
0.0
0.2
0.4
0.6
0.8
1.0

In [18]:

```
# task 7
# Загрузите данные ex2data2.txt из текстового файла.

df = pd.read_csv("G:/Labs/bsuir-labs/11cem/ml/lab02/data/ex2data2.txt", header=None, sep=
normalized_data = (df - df.min()) / (df.max() - df.min())


# task 8
# Постройте график, где по осям откладываются результаты тестов, а точки обозначаются дву

def ShowData(data):
    failedTestResults = data[data['IsTestPassed'] == 0]
    passedTestResults = data[data['IsTestPassed'] == 1]
    plt.plot(failedTestResults.Test1, failedTestResults.Test2, 'ro')
    plt.plot(passedTestResults.Test1, passedTestResults.Test2, 'go')
    plt.show()


ShowData(normalized_data) #todo revert before report
```



In [19]:

```
x = np.array(normalized_data.iloc[:, 0:2])
y = np.array(normalized_data.IsTestPassed)


# task 9
# Постройте все возможные комбинации признаков x1 (результат первого теста) и x2 (результ
def GetCombinations(x):
    combination = []
    for entry in x:
        entry_combs = []
        for poly in range(6 + 1):
            for p in range(poly + 1):
                entry_combs.append((entry[0] ** p) * (entry[1] ** poly))
        combination.append(entry_combs)
    return np.array(combination)


combs = GetCombinations(x)
print(x.shape)
```

```
(118, 2)
```

In [20]:

```
def get_sub_cost(tetha, x, y):
    z = tetha.dot(x.T)
    g = 1 / (1 + np.exp(-z))
    return -np.log(1 - g) if y == 0 else -np.log(g)


def get_cost(tetha, data, features_count):
    x_passed = np.array(data[data['IsTestPassed'] == 1].iloc[:, 0:features_count])
    x_failed = np.array(data[data['IsTestPassed'] == 0].iloc[:, 0:features_count])
    z = tetha.dot(np.hstack((x_passed, np.ones((x_passed.shape[0], 1))))).T)
    g = 1 / (1 + np.exp(-z))
    cost_passed = -np.log(g)

    z = tetha.dot(np.hstack((x_failed, np.ones((x_failed.shape[0], 1))))).T)
    g = 1 / (1 + np.exp(-z))
    cost_failed = -np.log(1 - g)
    return (sum(cost_failed) + sum(cost_passed)) / len(x)


def gradientDescent(x, y, theta, data, alpha=-0.5, iterations=500, features_count=2):
    tetha_history = [theta.copy()]
    cost_history = [get_cost(theta, data, features_count)]
    for _ in range(iterations):
        h = 1 / (1 + np.exp(-(np.dot(x, theta))))
        gradient = x.T.dot(h - y) / len(y)
        theta += alpha * gradient
        tetha_history.append(copy.deepcopy(theta))
        cost_history.append(get_cost(theta.copy(), data, features_count))
    return tetha_history, cost_history


# l2-regulariation
def regularization(theta, X, Y, lambda_=0.1):
    particular_costs = []
    for x, y in zip(X, Y):
        cur_sub_cost = get_sub_cost(theta, x, y) + (lambda_ / (2 * len(X))) * np.sum(thet
        particular_costs.append(cur_sub_cost)
    return 1 / len(X) * sum(particular_costs)


X = x
data_count, feature_count = X.shape
X = np.hstack((X, np.ones((data_count, 1))))

Y = y
theta = np.array([0, 0.1, 0.2])

reg = regularization(theta, X, Y)
print("reg standart" + str(reg))
print("answer:" + str(gradientDescent(X, Y, theta, data=normalized_data)[0][-1]))


sample_tetha = np.array([1.0 for _ in range(combs.shape[1])])
reg28 = regularization(sample_tetha, combs, y)

print("reg28 " + str(reg28))
```

```
reg standart0.7031451005359932
answer:[-0.55386963 -0.01685731  0.23141588]
reg28 2.206567021752631
```

In [21]:

```python
# task 10
# Реализуйте L2-регуляризацию для логистической регрессии и обучите ее на расширенном наб

def get_cost28(tetha, x, y, features_count):
    x_passed = x[:58]
    x_failed = x[58:]
    z = tetha.dot(x_passed.T)
    g = 1 / (1 + np.exp(-z))
    cost_passed = -np.log(g)

    z = tetha.dot(x_failed.T)
    g = 1 / (1 + np.exp(-z))
    cost_failed = -np.log(1 - g)
    return (sum(cost_failed) + sum(cost_passed)) / len(x)

alpha=-0.5
iterations=500
features_count=28
tetha = np.array([1.0 for _ in range(combs.shape[1])])

tetha_history = [tetha.copy()]
cost_history = [get_cost28(tetha, combs, y, features_count)]

for _ in range(iterations):
    h = 1 / (1 + np.exp(-(np.dot(combs, tetha))))
    gradient = combs.T.dot(h - y) / len(y)
    tetha += alpha * gradient
    tetha_history.append(tetha.copy())
    cost_history.append(get_cost28(tetha.copy(), combs, y, features_count))

print("polynom tetha")
print(tetha_history[-1], cost_history[-1])
```

```
polynom tetha
[-0.53621477  2.19812697  0.08305599  0.83348743 -0.23741095 -1.12991781
 -0.17881143 -0.40004774 -0.72395555 -0.65588675 -0.81894814 -0.46723714
 -0.46083316 -0.29070682 -0.0889877  -1.19666147 -0.47871677 -0.27388135
 -0.04991339  0.15288446  0.31666876 -1.39904541 -0.45532838 -0.13037591
  0.12079869  0.31778755  0.46621223  0.5767259 ] 0.621370808636357
```

In [22]:

```
# task 11
# Реализуйте другие методы оптимизации.

def optimized_function(x, y, lambda_=0.00000001):
    print(lambda_)
    m, n = x.shape
    tetha = np.zeros((n + 1, 1))
    x = np.hstack((np.ones((m, 1)), x))
    return scipy.optimize.minimize(regularization, tetha, (x, y, lambda_), method='L-BFGS
tetha = optimized_function(combs, y)

print("other functions tetha")
print(tetha)
```

```
1e-08
other functions tetha
[  -2.30189607   -2.19542831  -16.21647127  118.47085301   21.07964011
  -43.05530655 -516.38486019  127.5667733    85.33735485  279.17424558
  149.66575991 -173.32684813  -10.04444054  163.55042268  203.58930984
  121.8977731  -179.71411765  -51.98835235  -65.31441812   -4.13434098
   19.19864255  -30.75415653  212.06299862   38.22481869 -207.72689493
 -183.05183357 -115.96821803  -99.71169406 -127.29098008]
```

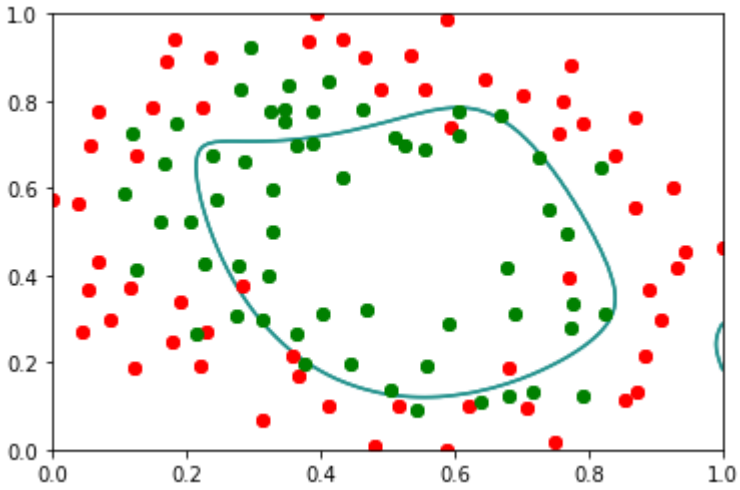
In [23]:

```
# task 12
# Реализуйте функцию предсказания вероятности прохождения контроля изделием в зависимости

print("predictions per record")
print(1 / (1 + np.exp(-np.dot(tetha.copy(), np.hstack((np.ones((combs.shape[0], 1)), comb
```

```
predictions per record
[9.53023719e-01 9.76800708e-01 9.65627433e-01 9.87208427e-01
 9.17170272e-01 9.38739011e-01 9.53359060e-01 7.35686030e-01
 5.75965057e-01 4.03558059e-01 4.57824850e-01 6.59348082e-01
 6.76458823e-01 4.25997411e-01 9.04611375e-01 9.66209817e-01
 9.94693897e-01 6.84706281e-01 9.66726475e-01 7.37150663e-01
 1.90958449e-01 6.60841964e-01 5.17687952e-01 2.86661899e-01
 4.46881305e-01 2.24620405e-01 5.94183795e-01 6.91320933e-01
 9.96718237e-01 7.98348674e-01 3.79213198e-01 8.17221509e-01
 9.85527500e-01 9.96188720e-01 9.94868408e-01 9.78412824e-01
 7.72472543e-01 9.15484687e-01 9.45117172e-01 7.10737955e-01
 8.94468092e-01 8.27765709e-01 5.83850262e-01 9.05216735e-01
 7.27216611e-01 9.02093521e-01 5.41522200e-01 9.93540045e-01
 3.25324620e-01 6.10956772e-01 9.92656793e-01 9.98883912e-01
 9.96752233e-01 9.98523496e-01 9.97022109e-01 9.83186661e-01
 9.78270657e-01 7.42146425e-01 3.54872704e-04 2.06906981e-01
 9.44068081e-01 8.71793968e-04 1.71409213e-04 2.61942640e-01
 1.92338377e-01 6.00359934e-02 2.32487354e-01 1.26278611e-02
 1.86191645e-02 8.16562807e-02 1.61389173e-01 6.24426238e-01
 7.47770855e-01 6.95459031e-01 3.10434149e-02 4.49195205e-01
 7.67030001e-01 3.86519462e-01 1.10160546e-02 1.49727517e-02
 2.47021118e-01 3.01032342e-01 9.73339241e-02 3.80649460e-01
 1.01463135e-02 1.73784490e-01 6.91538206e-02 2.45534550e-03
 7.74609018e-01 2.86392213e-01 4.93239048e-02 1.57061818e-01
 5.99101154e-01 2.49318417e-02 9.44201406e-02 2.07061316e-02
 1.33296434e-12 2.96321253e-04 7.05882630e-14 9.49756795e-06
 9.98365790e-03 1.95451367e-03 1.35936904e-01 3.94415934e-02
 4.80649864e-01 1.32482613e-01 5.65311266e-01 9.44350750e-01
 2.84052849e-01 4.32933932e-02 2.04149860e-02 4.56202739e-02
 5.52524595e-03 1.54118348e-02 5.70377033e-01 1.22324055e-01
 9.26006987e-03 5.80582913e-01]
```

In [24]:

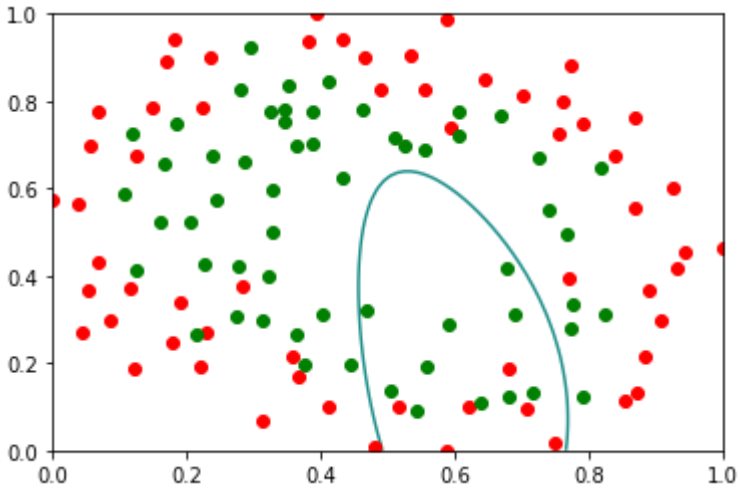
```
# task 13
# Постройте разделяющую кривую, полученную в результате обучения модели. Совместите пряму
def task13( tetha):
    XX = np.linspace(0, 1, 100)
    YY = np.linspace(0, 1, 100)
    ZZ = np.zeros((len(XX), len(YY)))

    for i in range(len(XX)):
        for j in range(len(YY)):
            entry_combs = [1]
            for poly in range(6 + 1):
                for p in range(poly + 1):
                    entry_combs.append((XX[i] ** p) * (YY[j] ** poly))
            ZZ[i, j] = 1 / (1 + np.exp(-tetha.dot(np.array(entry_combs).T)))

    failedTestResults = normalized_data[normalized_data['IsTestPassed'] == 0]
    passedTestResults = normalized_data[normalized_data['IsTestPassed'] == 1]
    plt.plot(failedTestResults.Test1, failedTestResults.Test2, 'ro')
    plt.plot(passedTestResults.Test1, passedTestResults.Test2, 'go')
    plt.contour(XX, YY, ZZ, 0)



task13(tetha) # 0.1
task13(tetha)
plt.show()
```



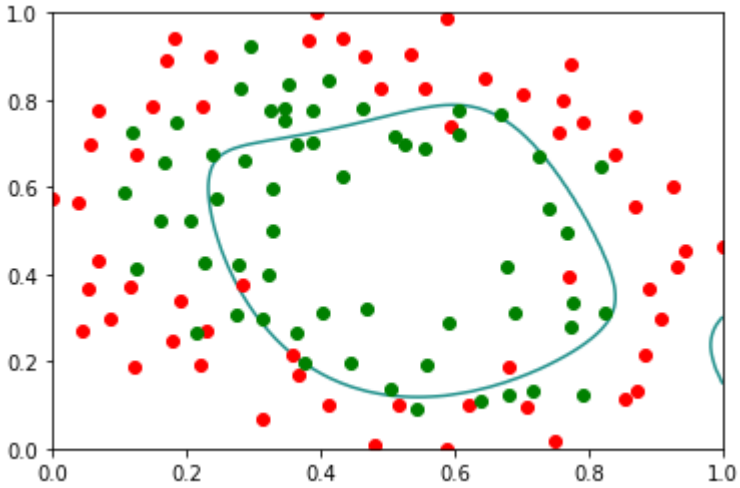
In [25]:

```
# task 14
# Попробуйте различные значения параметра регуляризации λ. Как выбор данного значения вли


tetha = optimized_function(combs, y, lambda_=0.5)
task13(tetha)
plt.show()

tetha = optimized_function(combs, y, lambda_=0.0)
task13(tetha)
plt.show()
```

0.5



0.0



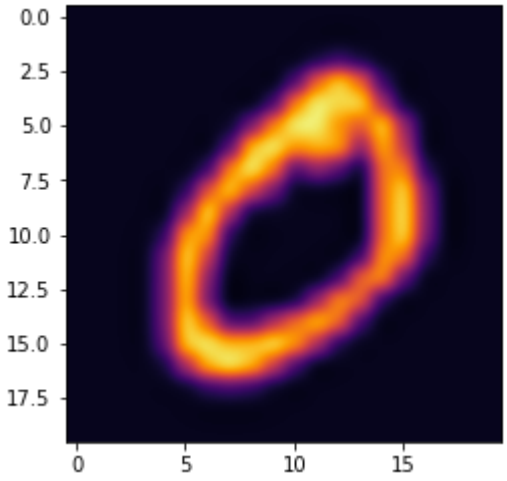
In [27]:

```
from scipy.io import loadmat

# task 15
# Загрузите данные ex2data3.mat из файла.
data = loadmat('G:/Labs/bsuir-labs/11cem/ml/lab02/data/ex2data3.mat')
x = data['X']
y = data['y']
```

In [29]:

```
def show_digit(x):
    plt.imshow(np.array(np.split(x, 20)).T, interpolation='gaussian', cmap='inferno')
    plt.show()


# task 16
# Визуализируйте несколько случайных изображений из набора данных. Визуализация должна со
def show_database(x, y):
    digits = set()
    i = 0
    while len(digits) != 10:
        if y[i][0] not in digits:
            print(y[i][0])
            show_digit(x[i])
            digits.add(int(y[i][0]))
        i += 1
        continue

show_database(x, y) # todo uncomment
X = np.hstack((np.ones((len(x), 1)), x))
_, feature_count = X.shape
l = 0.1
class_count = 10
theta = np.zeros((class_count, feature_count))
```

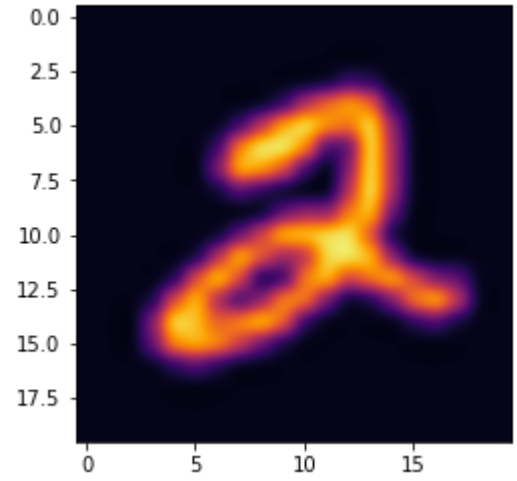
```
10
```



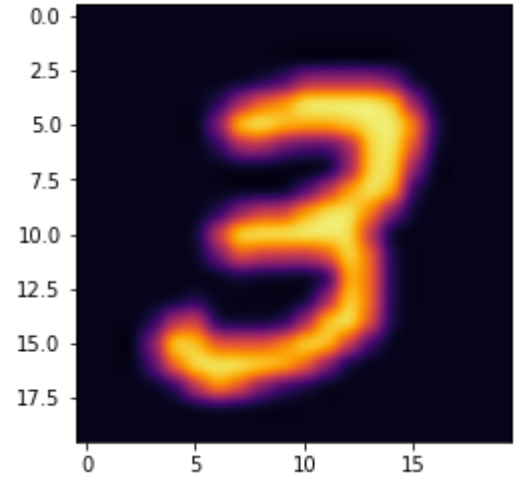

```
1
```


0.0

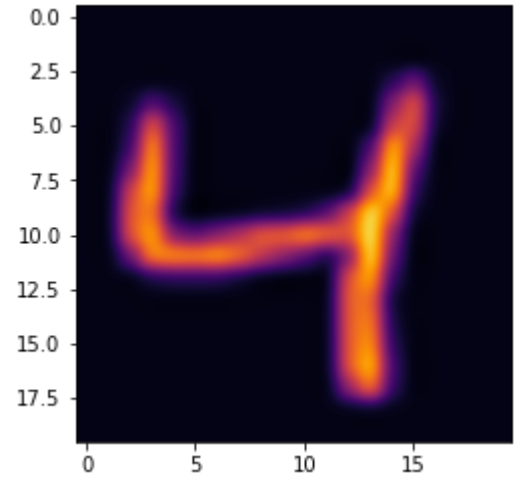
2


0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
0
5
10
15

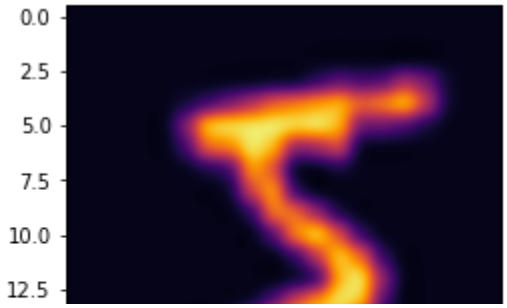
3


0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
0
5
10
15

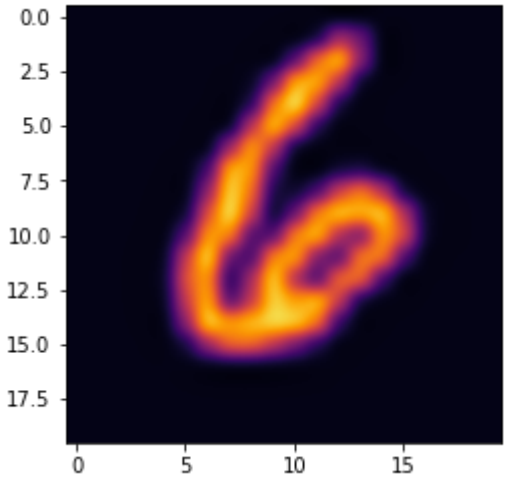
4


0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
0
5
10
15

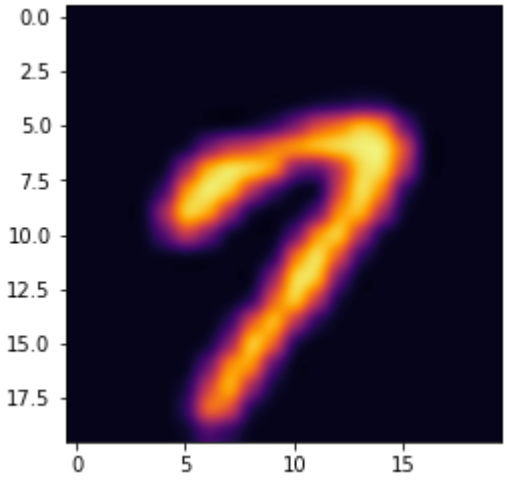
5


0.0
2.5
5.0
7.5
10.0
12.5

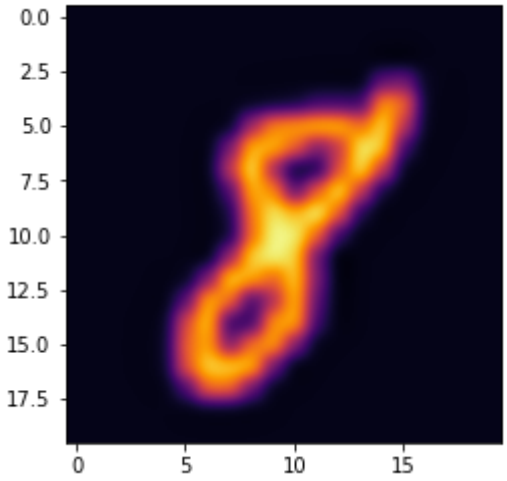
6


0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
0
5
10
15

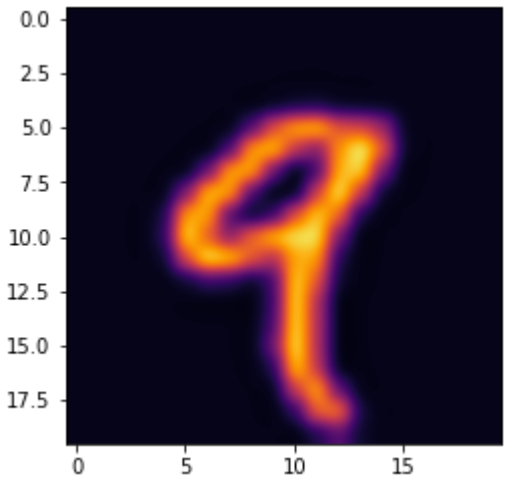
7


0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
0
5
10
15

8


0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
0
5
10
15

9



In [30]:

```
# task 17
# Реализуйте бинарный классификатор с помощью логистической регрессии с использованием ве


def sig(x):
    return 1 / (1 + np.exp(-x))


def h(theta, X):
    return sig(np.dot(theta, X.T))


def cost(theta, X, y, lambda_=0):
    m = len(y)
    h_theta = sig(np.dot(X, theta))
    J = (1.0 / m) * ((np.dot(-y.T, np.log(h_theta))) - np.dot((1 - y).T, np.log(1 - h_the
    return J


def grad(theta, X, Y, lambda_=0):
    record_count = len(Y)
    grad = (1.0 / record_count) * np.dot(X.T, (sig(np.dot(X, theta.T)) - Y))
    return grad.T + ((lambda_ / record_count) * theta) # new tetha


cost(theta[0], X, y)
grad(theta, X, y)
```

Out[30]:

```
array([[-5.00000000e+00,  0.00000000e+00,  0.00000000e+00, ...,
         7.28764624e-06,  6.02839052e-07,  0.00000000e+00],
       [-5.00000000e+00,  0.00000000e+00,  0.00000000e+00, ...,
         7.28764624e-06,  6.02839052e-07,  0.00000000e+00],
       [-5.00000000e+00,  0.00000000e+00,  0.00000000e+00, ...,
         7.28764624e-06,  6.02839052e-07,  0.00000000e+00],
       ...,
       [-5.00000000e+00,  0.00000000e+00,  0.00000000e+00, ...,
         7.28764624e-06,  6.02839052e-07,  0.00000000e+00],
       [-5.00000000e+00,  0.00000000e+00,  0.00000000e+00, ...,
         7.28764624e-06,  6.02839052e-07,  0.00000000e+00],
       [-5.00000000e+00,  0.00000000e+00,  0.00000000e+00, ...,
         7.28764624e-06,  6.02839052e-07,  0.00000000e+00]])
```

In [31]:

```
# task 18
# Добавьте L2-регуляризацию к модели.

l = 0.01
cost(theta[0], X, y, l)
grad(theta[0], X, y, l)
```

Out[31]:

```
array([[-5.00000000e+00,  0.00000000e+00,  0.00000000e+00, ...,
         7.28764624e-06,  6.02839052e-07,  0.00000000e+00],
       [-5.00000000e+00,  0.00000000e+00,  0.00000000e+00, ...,
         7.28764624e-06,  6.02839052e-07,  0.00000000e+00],
       [-5.00000000e+00,  0.00000000e+00,  0.00000000e+00, ...,
         7.28764624e-06,  6.02839052e-07,  0.00000000e+00],
       ...,
       [-5.00000000e+00,  0.00000000e+00,  0.00000000e+00, ...,
         7.28764624e-06,  6.02839052e-07,  0.00000000e+00],
       [-5.00000000e+00,  0.00000000e+00,  0.00000000e+00, ...,
         7.28764624e-06,  6.02839052e-07,  0.00000000e+00],
       [-5.00000000e+00,  0.00000000e+00,  0.00000000e+00, ...,
         7.28764624e-06,  6.02839052e-07,  0.00000000e+00]])
```

In [32]:

```
# task 19
# Реализуйте многоклассовую классификацию по методу “один против всех”.

def classify(theta, k, X, Y, C=0.1):
    for i in range(k):
        digit_class = i if i else 10
        current_y = (Y == digit_class).flatten().astype(np.int)
        theta[i] = scipy.optimize.fmin_cg(f=cost, x0=theta[i], fprime=grad, args=(X, curr
    return theta


theta = classify(theta, class_count, X, y)
print(theta)
```

```
Warning: Maximum number of iterations has been exceeded.
         Current function value: 0.008688
         Iterations: 100
         Function evaluations: 391
         Gradient evaluations: 391
Warning: Maximum number of iterations has been exceeded.
         Current function value: 0.013169
         Iterations: 100
         Function evaluations: 391
         Gradient evaluations: 391
Warning: Maximum number of iterations has been exceeded.
         Current function value: 0.052646
         Iterations: 100
         Function evaluations: 294
         Gradient evaluations: 294
Warning: Maximum number of iterations has been exceeded.
         Current function value: 0.059052
         Iterations: 100
         Function evaluations: 300
         Gradient evaluations: 300
Warning: Maximum number of iterations has been exceeded.
         Current function value: 0.033582
         Iterations: 100
         Function evaluations: 319
         Gradient evaluations: 319
Warning: Maximum number of iterations has been exceeded.
         Current function value: 0.055465
         Iterations: 100
         Function evaluations: 284
         Gradient evaluations: 284
Warning: Maximum number of iterations has been exceeded.
         Current function value: 0.018598
         Iterations: 100
         Function evaluations: 353
         Gradient evaluations: 353
Warning: Maximum number of iterations has been exceeded.
         Current function value: 0.031695
         Iterations: 100
         Function evaluations: 324
         Gradient evaluations: 324
Warning: Maximum number of iterations has been exceeded.
         Current function value: 0.080949
         Iterations: 100
```

```
         Function evaluations: 263
         Gradient evaluations: 263
Warning: Maximum number of iterations has been exceeded.
         Current function value: 0.072690
         Iterations: 100
         Function evaluations: 278
         Gradient evaluations: 278
[[-6.35032288e+00  0.00000000e+00  0.00000000e+00 ... -1.81084534e-04
   8.04871511e-06  0.00000000e+00]
 [-2.67580284e+00  0.00000000e+00  0.00000000e+00 ...  6.10675567e-03
   8.54068126e-08  0.00000000e+00]
 [-3.44037124e+00  0.00000000e+00  0.00000000e+00 ...  8.98749197e-03
  -1.02471336e-03  0.00000000e+00]
 ...
 [-2.07341183e+00  0.00000000e+00  0.00000000e+00 ... -1.93468699e-03
   2.33267158e-04  0.00000000e+00]
 [-8.42146328e+00  0.00000000e+00  0.00000000e+00 ... -2.03511956e-04
   1.83028460e-05  0.00000000e+00]
 [-5.15262110e+00  0.00000000e+00  0.00000000e+00 ... -4.28360186e-03
   3.41324095e-04  0.00000000e+00]]
```

In [34]:

```
# task 20
# Реализуйте функцию предсказания класса по изображению с использованием обученных класси


def show_results(X,x,theta):
    for x_extened, x_regular in zip(X, x):
        predictions = [print(str(index) + ":" + str(class_.T.dot(x_extened))) for index,
        show_digit(x_regular)
        print("___")

#show_results(X,x,theta)
```

In [35]:

```
# task 21
# Процент правильных классификаций на обучающей выборке должен составлять около 95%.

successfull_predictions = 0

for x, y_ in zip(X,y):
    predictions = [class_.T.dot(x) for index, class_ in enumerate(theta)]
    cur_y = 0 if y_[0] == 10 else y_[0]
    successfull_predictions += 1 if predictions.index(max(predictions)) == cur_y else 0

print("prediction: " +str(round(successfull_predictions/len(y)*100,2)))
```

```
prediction: 95.98
```

```
from run at 07/11/2019 - prediction: 95.98
```