Нейроинформатика. Лабораторная работа 1

Перцептроны. Процедура обучения Розенблатта

Целью работы является исследование свойств персептрона Розенблатта и его применение для решения задачи распознавания образов.

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Подключим библиотеки, необходимые для обучения перцептрона.

```
import numpy as np

import tensorflow as tf
from tensorflow import keras
from tensorflow.keras import layers

import matplotlib.pyplot as plt
```

Задание 1

Опишем датасет для первого задания, соответствующий варианту.

```
data1 = np.array([[2.7, 4.3], [-3.8, 0.6], [-0.4, -4.9], [-1.7, -3.4],
[2.9, -1.9], [0.2, -3.4]])
labels1 = np.array([0, 0, 1, 1, 1, 1])
data1, labels1
```

```
(array([[ 2.7,  4.3],
        [-3.8,  0.6],
        [-0.4, -4.9],
        [-1.7, -3.4],
        [ 2.9, -1.9],
        [ 0.2, -3.4]]),
 array([0, 0, 1, 1, 1, 1]))
```

Обучим перцептрон для классификации точек:

```
model1 = keras.Sequential()
model1.add(keras.layers.Dense(1, activation='sigmoid'))
```

В качестве функции потерь использую бинарную кросс-энтропию (что более привычно для задач классификации). Функция активации - сигмоид.

```
model1.compile(loss='bce', optimizer='adam')

train_info1 = model1.fit(data1, labels1, batch_size=1, epochs=500)
```

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Epoch 1/500
6/6 [==============================] - 0s 2ms/step - loss: 1.9264
Epoch 2/500
6/6 [==============================] - 0s 2ms/step - loss: 1.9130
Epoch 3/500
6/6 [==============================] - 0s 2ms/step - loss: 1.9025
Epoch 4/500
6/6 [==============================] - 0s 2ms/step - loss: 1.8906
Epoch 5/500
6/6 [==============================] - 0s 2ms/step - loss: 1.8800
Epoch 6/500
6/6 [==============================] - 0s 1ms/step - loss: 1.8697
Epoch 7/500
6/6 [==============================] - 0s 1ms/step - loss: 1.8584
Epoch 8/500
6/6 [==============================] - 0s 1ms/step - loss: 1.8490
Epoch 9/500
6/6 [==============================] - 0s 3ms/step - loss: 1.8379
Epoch 10/500
6/6 [==============================] - 0s 2ms/step - loss: 1.8273
Epoch 11/500
6/6 [==============================] - 0s 1ms/step - loss: 1.8153
Epoch 12/500
6/6 [==============================] - 0s 1ms/step - loss: 1.8058
Epoch 13/500
6/6 [==============================] - 0s 2ms/step - loss: 1.7956
Epoch 14/500
6/6 [==============================] - 0s 2ms/step - loss: 1.7840
Epoch 15/500
6/6 [==============================] - 0s 1ms/step - loss: 1.7754
Epoch 16/500
6/6 [==============================] - 0s 2ms/step - loss: 1.7635
Epoch 17/500
6/6 [==============================] - 0s 1ms/step - loss: 1.7538
Epoch 18/500
6/6 [==============================] - 0s 2ms/step - loss: 1.7435
Epoch 19/500
6/6 [==============================] - 0s 2ms/step - loss: 1.7325
Epoch 20/500
6/6 [==============================] - 0s 2ms/step - loss: 1.7226
Epoch 21/500
6/6 [==============================] - 0s 3ms/step - loss: 1.7135
Epoch 22/500
6/6 [==============================] - 0s 2ms/step - loss: 1.7039
Epoch 23/500
6/6 [==============================] - 0s 2ms/step - loss: 1.6935
Epoch 24/500
6/6 [==============================] - 0s 2ms/step - loss: 1.6837
Epoch 25/500
6/6 [==============================] - 0s 2ms/step - loss: 1.6745
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Epoch 26/500
6/6 [==============================] - 0s 2ms/step - loss: 1.6642
Epoch 27/500
6/6 [==============================] - 0s 2ms/step - loss: 1.6545
Epoch 28/500
6/6 [==============================] - 0s 2ms/step - loss: 1.6461
Epoch 29/500
6/6 [==============================] - 0s 2ms/step - loss: 1.6352
Epoch 30/500
6/6 [==============================] - 0s 2ms/step - loss: 1.6262
Epoch 31/500
6/6 [==============================] - 0s 2ms/step - loss: 1.6167
Epoch 32/500
6/6 [==============================] - 0s 2ms/step - loss: 1.6092
Epoch 33/500
6/6 [==============================] - 0s 2ms/step - loss: 1.5987
Epoch 34/500
6/6 [==============================] - 0s 2ms/step - loss: 1.5883
Epoch 35/500
6/6 [==============================] - 0s 2ms/step - loss: 1.5808
Epoch 36/500
6/6 [==============================] - 0s 2ms/step - loss: 1.5714
Epoch 37/500
6/6 [==============================] - 0s 2ms/step - loss: 1.5618
Epoch 38/500
6/6 [==============================] - 0s 2ms/step - loss: 1.5542
Epoch 39/500
6/6 [==============================] - 0s 2ms/step - loss: 1.5442
Epoch 40/500
6/6 [==============================] - 0s 2ms/step - loss: 1.5348
Epoch 41/500
6/6 [==============================] - 0s 2ms/step - loss: 1.5267
Epoch 42/500
6/6 [==============================] - 0s 2ms/step - loss: 1.5168
Epoch 43/500
6/6 [==============================] - 0s 2ms/step - loss: 1.5106
Epoch 44/500
6/6 [==============================] - 0s 2ms/step - loss: 1.4998
Epoch 45/500
6/6 [==============================] - 0s 2ms/step - loss: 1.4918
Epoch 46/500
6/6 [==============================] - 0s 2ms/step - loss: 1.4841
Epoch 47/500
6/6 [==============================] - 0s 2ms/step - loss: 1.4760
Epoch 48/500
6/6 [==============================] - 0s 2ms/step - loss: 1.4665
Epoch 49/500
6/6 [==============================] - 0s 2ms/step - loss: 1.4580
Epoch 50/500
6/6 [==============================] - 0s 2ms/step - loss: 1.4508
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Epoch 51/500
6/6 [==============================] - 0s 2ms/step - loss: 1.4425
Epoch 52/500
6/6 [==============================] - 0s 2ms/step - loss: 1.4334
Epoch 53/500
6/6 [==============================] - 0s 2ms/step - loss: 1.4254
Epoch 54/500
6/6 [==============================] - 0s 3ms/step - loss: 1.4168
Epoch 55/500
6/6 [==============================] - 0s 2ms/step - loss: 1.4098
Epoch 56/500
6/6 [==============================] - 0s 2ms/step - loss: 1.4020
Epoch 57/500
6/6 [==============================] - 0s 2ms/step - loss: 1.3937
Epoch 58/500
6/6 [==============================] - 0s 2ms/step - loss: 1.3849
Epoch 59/500
6/6 [==============================] - 0s 2ms/step - loss: 1.3769
Epoch 60/500
6/6 [==============================] - 0s 2ms/step - loss: 1.3708
Epoch 61/500
6/6 [==============================] - 0s 2ms/step - loss: 1.3620
Epoch 62/500
6/6 [==============================] - 0s 2ms/step - loss: 1.3545
Epoch 63/500
6/6 [==============================] - 0s 2ms/step - loss: 1.3467
Epoch 64/500
6/6 [==============================] - 0s 2ms/step - loss: 1.3403
Epoch 65/500
6/6 [==============================] - 0s 2ms/step - loss: 1.3324
Epoch 66/500
6/6 [==============================] - 0s 2ms/step - loss: 1.3237
Epoch 67/500
6/6 [==============================] - 0s 2ms/step - loss: 1.3175
Epoch 68/500
6/6 [==============================] - 0s 2ms/step - loss: 1.3097
Epoch 69/500
6/6 [==============================] - 0s 2ms/step - loss: 1.3012
Epoch 70/500
6/6 [==============================] - 0s 2ms/step - loss: 1.2956
Epoch 71/500
6/6 [==============================] - 0s 3ms/step - loss: 1.2861
Epoch 72/500
6/6 [==============================] - 0s 2ms/step - loss: 1.2800
Epoch 73/500
6/6 [==============================] - 0s 2ms/step - loss: 1.2719
Epoch 74/500
6/6 [==============================] - 0s 2ms/step - loss: 1.2655
Epoch 75/500
6/6 [==============================] - 0s 2ms/step - loss: 1.2585
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Epoch 76/500
6/6 [==============================] - 0s 2ms/step - loss: 1.2512
Epoch 77/500
6/6 [==============================] - 0s 2ms/step - loss: 1.2460
Epoch 78/500
6/6 [==============================] - 0s 2ms/step - loss: 1.2370
Epoch 79/500
6/6 [==============================] - 0s 2ms/step - loss: 1.2301
Epoch 80/500
6/6 [==============================] - 0s 2ms/step - loss: 1.2232
Epoch 81/500
6/6 [==============================] - 0s 2ms/step - loss: 1.2178
Epoch 82/500
6/6 [==============================] - 0s 2ms/step - loss: 1.2092
Epoch 83/500
6/6 [==============================] - 0s 2ms/step - loss: 1.2022
Epoch 84/500
6/6 [==============================] - 0s 2ms/step - loss: 1.1962
Epoch 85/500
6/6 [==============================] - 0s 2ms/step - loss: 1.1898
Epoch 86/500
6/6 [==============================] - 0s 2ms/step - loss: 1.1827
Epoch 87/500
6/6 [==============================] - 0s 2ms/step - loss: 1.1752
Epoch 88/500
6/6 [==============================] - 0s 2ms/step - loss: 1.1702
Epoch 89/500
6/6 [==============================] - 0s 2ms/step - loss: 1.1630
Epoch 90/500
6/6 [==============================] - 0s 2ms/step - loss: 1.1553
Epoch 91/500
6/6 [==============================] - 0s 2ms/step - loss: 1.1504
Epoch 92/500
6/6 [==============================] - 0s 2ms/step - loss: 1.1426
Epoch 93/500
6/6 [==============================] - 0s 2ms/step - loss: 1.1365
Epoch 94/500
6/6 [==============================] - 0s 2ms/step - loss: 1.1299
Epoch 95/500
6/6 [==============================] - 0s 2ms/step - loss: 1.1245
Epoch 96/500
6/6 [==============================] - 0s 2ms/step - loss: 1.1176
Epoch 97/500
6/6 [==============================] - 0s 3ms/step - loss: 1.1111
Epoch 98/500
6/6 [==============================] - 0s 2ms/step - loss: 1.1046
Epoch 99/500
6/6 [==============================] - 0s 3ms/step - loss: 1.0987
Epoch 100/500
6/6 [==============================] - 0s 2ms/step - loss: 1.0927
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Epoch 101/500
6/6 [==============================] - 0s 2ms/step - loss: 1.0865
Epoch 102/500
6/6 [==============================] - 0s 2ms/step - loss: 1.0796
Epoch 103/500
6/6 [==============================] - 0s 2ms/step - loss: 1.0747
Epoch 104/500
6/6 [==============================] - 0s 2ms/step - loss: 1.0671
Epoch 105/500
6/6 [==============================] - 0s 2ms/step - loss: 1.0616
Epoch 106/500
6/6 [==============================] - 0s 2ms/step - loss: 1.0557
Epoch 107/500
6/6 [==============================] - 0s 2ms/step - loss: 1.0497
Epoch 108/500
6/6 [==============================] - 0s 2ms/step - loss: 1.0440
Epoch 109/500
6/6 [==============================] - 0s 3ms/step - loss: 1.0380
Epoch 110/500
6/6 [==============================] - 0s 4ms/step - loss: 1.0319
Epoch 111/500
6/6 [==============================] - 0s 3ms/step - loss: 1.0259
Epoch 112/500
6/6 [==============================] - 0s 3ms/step - loss: 1.0192
Epoch 113/500
6/6 [==============================] - 0s 2ms/step - loss: 1.0142
Epoch 114/500
6/6 [==============================] - 0s 2ms/step - loss: 1.0084
Epoch 115/500
6/6 [==============================] - 0s 3ms/step - loss: 1.0044
Epoch 116/500
6/6 [==============================] - 0s 2ms/step - loss: 0.9960
Epoch 117/500
6/6 [==============================] - 0s 2ms/step - loss: 0.9918
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6/6 [==============================] - 0s 2ms/step - loss: 0.9857
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6/6 [==============================] - 0s 2ms/step - loss: 0.9744
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Epoch 123/500
6/6 [==============================] - 0s 2ms/step - loss: 0.9584
Epoch 124/500
6/6 [==============================] - 0s 2ms/step - loss: 0.9514
Epoch 125/500
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Epoch 126/500
6/6 [==============================] - 0s 2ms/step - loss: 0.9414
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Epoch 129/500
6/6 [==============================] - 0s 2ms/step - loss: 0.9244
Epoch 130/500
6/6 [==============================] - 0s 3ms/step - loss: 0.9198
Epoch 131/500
6/6 [==============================] - 0s 3ms/step - loss: 0.9151
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6/6 [==============================] - 0s 2ms/step - loss: 0.9093
Epoch 133/500
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Epoch 140/500
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Epoch 141/500
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6/6 [==============================] - 0s 2ms/step - loss: 0.8225
Epoch 150/500
6/6 [==============================] - 0s 2ms/step - loss: 0.8176
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Epoch 151/500
6/6 [==============================] - 0s 2ms/step - loss: 0.8122
Epoch 152/500
6/6 [==============================] - 0s 2ms/step - loss: 0.8076
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Epoch 156/500
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Epoch 157/500
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Epoch 159/500
6/6 [==============================] - 0s 2ms/step - loss: 0.7759
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Epoch 161/500
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6/6 [==============================] - 0s 2ms/step - loss: 0.7611
Epoch 163/500
6/6 [==============================] - 0s 2ms/step - loss: 0.7570
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6/6 [==============================] - 0s 2ms/step - loss: 0.7516
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Epoch 167/500
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Epoch 169/500
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6/6 [==============================] - 0s 2ms/step - loss: 0.7242
Epoch 171/500
6/6 [==============================] - 0s 2ms/step - loss: 0.7215
Epoch 172/500
6/6 [==============================] - 0s 2ms/step - loss: 0.7159
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Epoch 174/500
6/6 [==============================] - 0s 2ms/step - loss: 0.7085
Epoch 175/500
6/6 [==============================] - 0s 2ms/step - loss: 0.7030
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Epoch 176/500
6/6 [==============================] - 0s 2ms/step - loss: 0.6992
Epoch 177/500
6/6 [==============================] - 0s 2ms/step - loss: 0.6941
Epoch 178/500
6/6 [==============================] - 0s 2ms/step - loss: 0.6910
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6/6 [==============================] - 0s 2ms/step - loss: 0.6866
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6/6 [==============================] - 0s 2ms/step - loss: 0.6208
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6/6 [==============================] - 0s 2ms/step - loss: 0.6187
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6/6 [==============================] - 0s 2ms/step - loss: 0.6142
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6/6 [==============================] - 0s 3ms/step - loss: 0.6098
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6/6 [==============================] - 0s 2ms/step - loss: 0.6062
Epoch 200/500
6/6 [==============================] - 0s 2ms/step - loss: 0.6018
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Epoch 201/500
6/6 [==============================] - 0s 2ms/step - loss: 0.5988
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6/6 [==============================] - 0s 2ms/step - loss: 0.5946
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6/6 [==============================] - 0s 2ms/step - loss: 0.5915
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6/6 [==============================] - 0s 2ms/step - loss: 0.5654
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6/6 [==============================] - 0s 2ms/step - loss: 0.5622
Epoch 212/500
6/6 [==============================] - 0s 1ms/step - loss: 0.5587
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6/6 [==============================] - 0s 1ms/step - loss: 0.5557
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6/6 [==============================] - 0s 2ms/step - loss: 0.5417
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6/6 [==============================] - 0s 2ms/step - loss: 0.5383
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6/6 [==============================] - 0s 2ms/step - loss: 0.5306
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6/6 [==============================] - 0s 2ms/step - loss: 0.5277
Epoch 222/500
6/6 [==============================] - 0s 2ms/step - loss: 0.5245
Epoch 223/500
6/6 [==============================] - 0s 1ms/step - loss: 0.5206
Epoch 224/500
6/6 [==============================] - 0s 2ms/step - loss: 0.5172
Epoch 225/500
6/6 [==============================] - 0s 2ms/step - loss: 0.5151
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Epoch 226/500
6/6 [==============================] - 0s 1ms/step - loss: 0.5104
Epoch 227/500
6/6 [==============================] - 0s 2ms/step - loss: 0.5081
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6/6 [==============================] - 0s 1ms/step - loss: 0.5014
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6/6 [==============================] - 0s 1ms/step - loss: 0.4976
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6/6 [==============================] - 0s 1ms/step - loss: 0.4961
Epoch 232/500
6/6 [==============================] - 0s 1ms/step - loss: 0.4912
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6/6 [==============================] - 0s 1ms/step - loss: 0.4894
Epoch 234/500
6/6 [==============================] - 0s 2ms/step - loss: 0.4854
Epoch 235/500
6/6 [==============================] - 0s 1ms/step - loss: 0.4828
Epoch 236/500
6/6 [==============================] - 0s 2ms/step - loss: 0.4793
Epoch 237/500
6/6 [==============================] - 0s 2ms/step - loss: 0.4763
Epoch 238/500
6/6 [==============================] - 0s 3ms/step - loss: 0.4726
Epoch 239/500
6/6 [==============================] - 0s 2ms/step - loss: 0.4700
Epoch 240/500
6/6 [==============================] - 0s 2ms/step - loss: 0.4676
Epoch 241/500
6/6 [==============================] - 0s 2ms/step - loss: 0.4638
Epoch 242/500
6/6 [==============================] - 0s 1ms/step - loss: 0.4614
Epoch 243/500
6/6 [==============================] - 0s 2ms/step - loss: 0.4582
Epoch 244/500
6/6 [==============================] - 0s 2ms/step - loss: 0.4552
Epoch 245/500
6/6 [==============================] - 0s 2ms/step - loss: 0.4526
Epoch 246/500
6/6 [==============================] - 0s 2ms/step - loss: 0.4496
Epoch 247/500
6/6 [==============================] - 0s 2ms/step - loss: 0.4462
Epoch 248/500
6/6 [==============================] - 0s 2ms/step - loss: 0.4433
Epoch 249/500
6/6 [==============================] - 0s 3ms/step - loss: 0.4405
Epoch 250/500
6/6 [==============================] - 0s 2ms/step - loss: 0.4382
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Epoch 251/500
6/6 [==============================] - 0s 2ms/step - loss: 0.4350
Epoch 252/500
6/6 [==============================] - 0s 2ms/step - loss: 0.4323
Epoch 253/500
6/6 [==============================] - 0s 2ms/step - loss: 0.4292
Epoch 254/500
6/6 [==============================] - 0s 2ms/step - loss: 0.4271
Epoch 255/500
6/6 [==============================] - 0s 2ms/step - loss: 0.4234
Epoch 256/500
6/6 [==============================] - 0s 2ms/step - loss: 0.4209
Epoch 257/500
6/6 [==============================] - 0s 2ms/step - loss: 0.4186
Epoch 258/500
6/6 [==============================] - 0s 2ms/step - loss: 0.4155
Epoch 259/500
6/6 [==============================] - 0s 2ms/step - loss: 0.4133
Epoch 260/500
6/6 [==============================] - 0s 2ms/step - loss: 0.4112
Epoch 261/500
6/6 [==============================] - 0s 3ms/step - loss: 0.4074
Epoch 262/500
6/6 [==============================] - 0s 3ms/step - loss: 0.4048
Epoch 263/500
6/6 [==============================] - 0s 3ms/step - loss: 0.4021
Epoch 264/500
6/6 [==============================] - 0s 2ms/step - loss: 0.4005
Epoch 265/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3967
Epoch 266/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3945
Epoch 267/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3916
Epoch 268/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3906
Epoch 269/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3872
Epoch 270/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3840
Epoch 271/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3822
Epoch 272/500
6/6 [==============================] - 0s 1ms/step - loss: 0.3790
Epoch 273/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3773
Epoch 274/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3748
Epoch 275/500
6/6 [==============================] - 0s 3ms/step - loss: 0.3725
```

```
Epoch 276/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3692
Epoch 277/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3668
Epoch 278/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3652
Epoch 279/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3622
Epoch 280/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3607
Epoch 281/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3577
Epoch 282/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3555
Epoch 283/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3530
Epoch 284/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3507
Epoch 285/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3484
Epoch 286/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3461
Epoch 287/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3435
Epoch 288/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3417
Epoch 289/500
6/6 [==============================] - 0s 1ms/step - loss: 0.3394
Epoch 290/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3373
Epoch 291/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3359
Epoch 292/500
6/6 [==============================] - 0s 1ms/step - loss: 0.3329
Epoch 293/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3309
Epoch 294/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3285
Epoch 295/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3262
Epoch 296/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3245
Epoch 297/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3226
Epoch 298/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3195
Epoch 299/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3179
Epoch 300/500
```

```
6/6 [==============================] - 0s 2ms/step - loss: 0.3157
Epoch 301/500
6/6 [==============================] - 0s 3ms/step - loss: 0.3144
Epoch 302/500
6/6 [==============================] - 0s 3ms/step - loss: 0.3120
Epoch 303/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3093
Epoch 304/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3081
Epoch 305/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3060
Epoch 306/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3036
Epoch 307/500
6/6 [==============================] - 0s 2ms/step - loss: 0.3017
Epoch 308/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2998
Epoch 309/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2976
Epoch 310/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2960
Epoch 311/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2944
Epoch 312/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2919
Epoch 313/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2905
Epoch 314/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2879
Epoch 315/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2861
Epoch 316/500
6/6 [==============================] - 0s 1ms/step - loss: 0.2845
Epoch 317/500
6/6 [==============================] - 0s 1ms/step - loss: 0.2826
Epoch 318/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2812
Epoch 319/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2793
Epoch 320/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2769
Epoch 321/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2758
Epoch 322/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2732
Epoch 323/500
6/6 [==============================] - 0s 1ms/step - loss: 0.2720
Epoch 324/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2704
```

```
Epoch 325/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2684
Epoch 326/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2664
Epoch 327/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2643
Epoch 328/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2631
Epoch 329/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2612
Epoch 330/500
6/6 [==============================] - 0s 1ms/step - loss: 0.2600
Epoch 331/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2582
Epoch 332/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2562
Epoch 333/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2545
Epoch 334/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2533
Epoch 335/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2512
Epoch 336/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2495
Epoch 337/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2481
Epoch 338/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2467
Epoch 339/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2456
Epoch 340/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2433
Epoch 341/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2422
Epoch 342/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2402
Epoch 343/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2387
Epoch 344/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2372
Epoch 345/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2354
Epoch 346/500
6/6 [==============================] - 0s 3ms/step - loss: 0.2337
Epoch 347/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2327
Epoch 348/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2314
Epoch 349/500
```

```
6/6 [==============================] - 0s 2ms/step - loss: 0.2294
Epoch 350/500
6/6 [==============================] - 0s 3ms/step - loss: 0.2285
Epoch 351/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2264
Epoch 352/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2255
Epoch 353/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2239
Epoch 354/500
6/6 [==============================] - 0s 3ms/step - loss: 0.2220
Epoch 355/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2211
Epoch 356/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2192
Epoch 357/500
6/6 [==============================] - 0s 1ms/step - loss: 0.2184
Epoch 358/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2165
Epoch 359/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2156
Epoch 360/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2139
Epoch 361/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2123
Epoch 362/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2114
Epoch 363/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2099
Epoch 364/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2087
Epoch 365/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2069
Epoch 366/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2061
Epoch 367/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2050
Epoch 368/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2029
Epoch 369/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2024
Epoch 370/500
6/6 [==============================] - 0s 2ms/step - loss: 0.2007
Epoch 371/500
6/6 [==============================] - 0s 3ms/step - loss: 0.1994
Epoch 372/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1982
Epoch 373/500
6/6 [==============================] - 0s 1ms/step - loss: 0.1971
```

```
Epoch 374/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1958
Epoch 375/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1942
Epoch 376/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1932
Epoch 377/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1922
Epoch 378/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1906
Epoch 379/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1897
Epoch 380/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1886
Epoch 381/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1874
Epoch 382/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1861
Epoch 383/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1847
Epoch 384/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1838
Epoch 385/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1824
Epoch 386/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1816
Epoch 387/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1802
Epoch 388/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1792
Epoch 389/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1779
Epoch 390/500
6/6 [==============================] - 0s 3ms/step - loss: 0.1770
Epoch 391/500
6/6 [==============================] - 0s 3ms/step - loss: 0.1764
Epoch 392/500
6/6 [==============================] - 0s 3ms/step - loss: 0.1748
Epoch 393/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1739
Epoch 394/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1723
Epoch 395/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1717
Epoch 396/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1705
Epoch 397/500
6/6 [==============================] - 0s 3ms/step - loss: 0.1694
Epoch 398/500
```

```
6/6 [==============================] - 0s 2ms/step - loss: 0.1686
Epoch 399/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1676
Epoch 400/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1661
Epoch 401/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1654
Epoch 402/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1642
Epoch 403/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1636
Epoch 404/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1621
Epoch 405/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1615
Epoch 406/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1604
Epoch 407/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1593
Epoch 408/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1581
Epoch 409/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1577
Epoch 410/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1567
Epoch 411/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1552
Epoch 412/500
6/6 [==============================] - 0s 3ms/step - loss: 0.1547
Epoch 413/500
6/6 [==============================] - 0s 3ms/step - loss: 0.1534
Epoch 414/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1528
Epoch 415/500
6/6 [==============================] - 0s 3ms/step - loss: 0.1516
Epoch 416/500
6/6 [==============================] - 0s 3ms/step - loss: 0.1511
Epoch 417/500
6/6 [==============================] - 0s 3ms/step - loss: 0.1498
Epoch 418/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1490
Epoch 419/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1480
Epoch 420/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1472
Epoch 421/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1466
Epoch 422/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1456
```

```
Epoch 423/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1445
Epoch 424/500
6/6 [==============================] - 0s 3ms/step - loss: 0.1437
Epoch 425/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1428
Epoch 426/500
6/6 [==============================] - 0s 4ms/step - loss: 0.1418
Epoch 427/500
6/6 [==============================] - 0s 3ms/step - loss: 0.1411
Epoch 428/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1405
Epoch 429/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1394
Epoch 430/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1386
Epoch 431/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1382
Epoch 432/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1371
Epoch 433/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1360
Epoch 434/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1354
Epoch 435/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1347
Epoch 436/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1339
Epoch 437/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1331
Epoch 438/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1320
Epoch 439/500
6/6 [==============================] - 0s 17ms/step - loss: 0.1314
Epoch 440/500
6/6 [==============================] - 0s 12ms/step - loss: 0.1308
Epoch 441/500
6/6 [==============================] - 0s 11ms/step - loss: 0.1299
Epoch 442/500
6/6 [==============================] - 0s 13ms/step - loss: 0.1290
Epoch 443/500
6/6 [==============================] - 0s 8ms/step - loss: 0.1283
Epoch 444/500
6/6 [==============================] - 0s 6ms/step - loss: 0.1277
Epoch 445/500
6/6 [==============================] - 0s 3ms/step - loss: 0.1271
Epoch 446/500
6/6 [==============================] - 0s 4ms/step - loss: 0.1262
Epoch 447/500
```

```
6/6 [==============================] - 0s 4ms/step - loss: 0.1256
Epoch 448/500
6/6 [==============================] - 0s 4ms/step - loss: 0.1247
Epoch 449/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1239
Epoch 450/500
6/6 [==============================] - 0s 3ms/step - loss: 0.1233
Epoch 451/500
6/6 [==============================] - 0s 3ms/step - loss: 0.1224
Epoch 452/500
6/6 [==============================] - 0s 3ms/step - loss: 0.1218
Epoch 453/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1213
Epoch 454/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1204
Epoch 455/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1199
Epoch 456/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1191
Epoch 457/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1184
Epoch 458/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1177
Epoch 459/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1169
Epoch 460/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1164
Epoch 461/500
6/6 [==============================] - 0s 3ms/step - loss: 0.1156
Epoch 462/500
6/6 [==============================] - 0s 3ms/step - loss: 0.1152
Epoch 463/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1145
Epoch 464/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1136
Epoch 465/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1130
Epoch 466/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1124
Epoch 467/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1120
Epoch 468/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1113
Epoch 469/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1106
Epoch 470/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1100
Epoch 471/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1093
```

```
Epoch 472/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1086
Epoch 473/500
6/6 [==============================] - 0s 9ms/step - loss: 0.1080
Epoch 474/500
6/6 [==============================] - 0s 13ms/step - loss: 0.1076
Epoch 475/500
6/6 [==============================] - 0s 14ms/step - loss: 0.1069
Epoch 476/500
6/6 [==============================] - 0s 13ms/step - loss: 0.1063
Epoch 477/500
6/6 [==============================] - 0s 12ms/step - loss: 0.1056
Epoch 478/500
6/6 [==============================] - 0s 12ms/step - loss: 0.1053
Epoch 479/500
6/6 [==============================] - 0s 5ms/step - loss: 0.1045
Epoch 480/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1039
Epoch 481/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1035
Epoch 482/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1027
Epoch 483/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1022
Epoch 484/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1017
Epoch 485/500
6/6 [==============================] - 0s 3ms/step - loss: 0.1012
Epoch 486/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1005
Epoch 487/500
6/6 [==============================] - 0s 2ms/step - loss: 0.1001
Epoch 488/500
6/6 [==============================] - 0s 2ms/step - loss: 0.0994
Epoch 489/500
6/6 [==============================] - 0s 2ms/step - loss: 0.0989
Epoch 490/500
6/6 [==============================] - 0s 2ms/step - loss: 0.0984
Epoch 491/500
6/6 [==============================] - 0s 2ms/step - loss: 0.0979
Epoch 492/500
6/6 [==============================] - 0s 3ms/step - loss: 0.0972
Epoch 493/500
6/6 [==============================] - 0s 2ms/step - loss: 0.0968
Epoch 494/500
6/6 [==============================] - 0s 2ms/step - loss: 0.0964
Epoch 495/500
6/6 [==============================] - 0s 2ms/step - loss: 0.0956
Epoch 496/500
6/6 [==============================] - 0s 2ms/step - loss: 0.0953
```

```
Epoch 497/500
6/6 [==============================] - 0s 2ms/step - loss: 0.0948
Epoch 498/500
6/6 [==============================] - 0s 2ms/step - loss: 0.0942
Epoch 499/500
6/6 [==============================] - 0s 2ms/step - loss: 0.0936
Epoch 500/500
6/6 [==============================] - 0s 2ms/step - loss: 0.0931
```

```python
def plot_loss(train_info):
    plt.figure(figsize=(6, 6))
    loss_history = train_info.history['loss']
    plt.plot(range(1, len(loss_history) + 1), loss_history)
    plt.grid()
    plt.show()

plot_loss(train_info1)
```

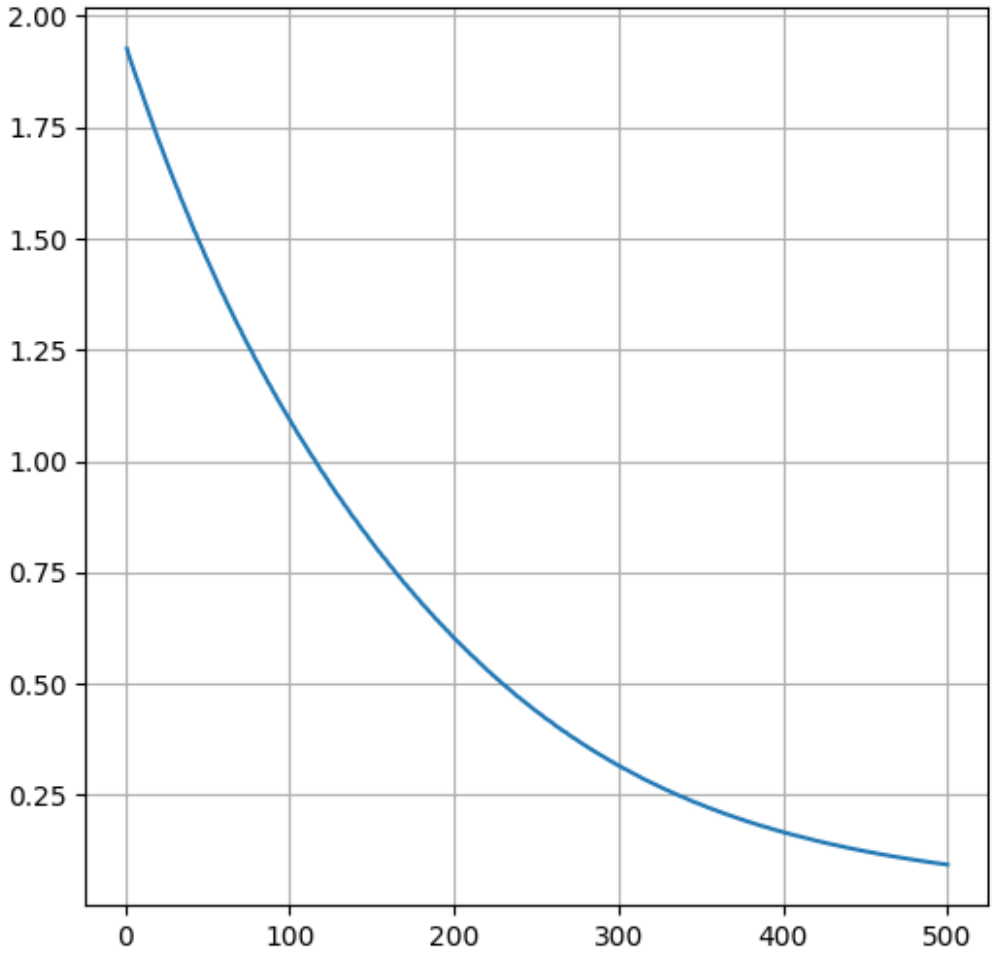


График функции потерь показывает, что обучение происходит правильно: потери уменьшаются, точность возрастает.

Построим разделяющую линию для двумерного случая.

Мы знаем, что однослойный перцептрон - линейный слой, поэтому разделяющая линия будет прямой. Любую прямую можно задать уравнением:

$$a\,x+b\,y+c=0$$

С математической точки зрения перцептрон - это функция вида

$$perceptron(v)=v\,A+b$$

где $v=(x,y)$, $A=(a_0,a_1)^T$

Записывая в скалярном виде:

$$perceptron(x,y)=a_0\,x+a_1\,y+b$$

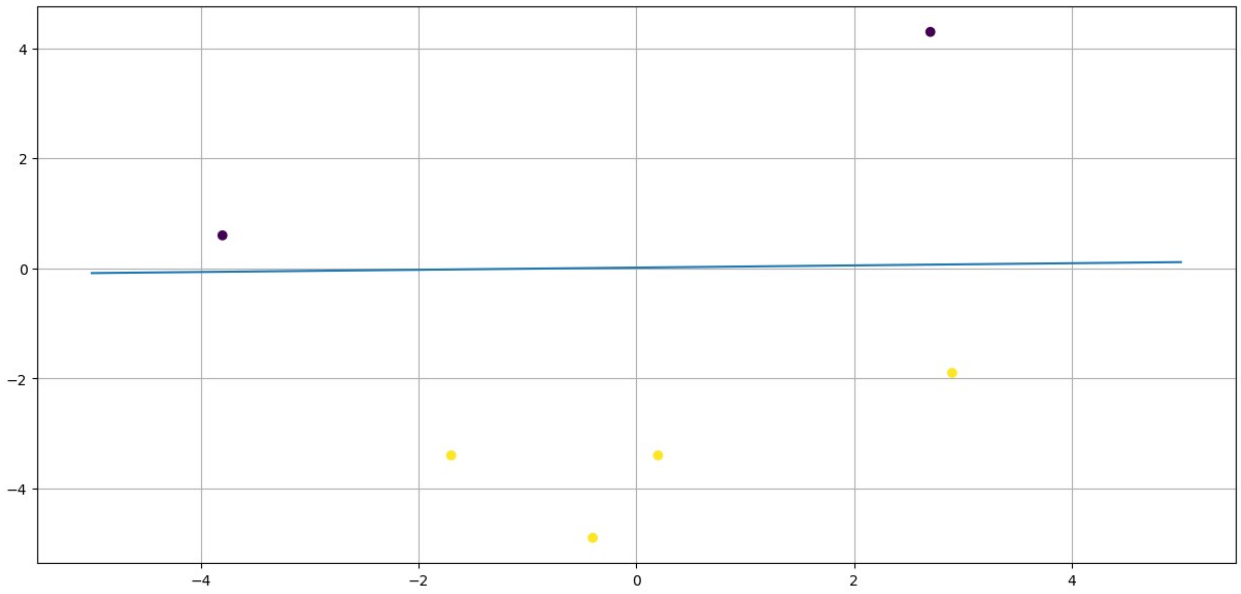
Если значение этой функции больше нуля (сигмоида от результата больше 0.5), то относим точку (x,y) к первому классу, иначе ко второму. Следовательно, искомая разделяющая прямая имеет вид

$$a_0 x+a_1\,y+b=0$$

Коэффициенты a_i, b нам известны.

Для построения прямой возьмем несколько значений x, для каждого из них найдем $y=\frac{(-a_0\,x-b)}{a_1}$

```
def plot_result(data, labels, model, show_result=True):
    plt.figure(figsize=(15,7))

    plt.scatter(data[:, 0], data[:, 1], c=labels)

    A, b = model.layers[0].get_weights()

    x_disc = np.linspace(-5, 5, 5)
    plt.plot(x_disc, (-A[0] * x_disc - b) / A[1])

    plt.grid()
    if show_result:
        plt.show()

plot_result(data1, labels1, model1)
```

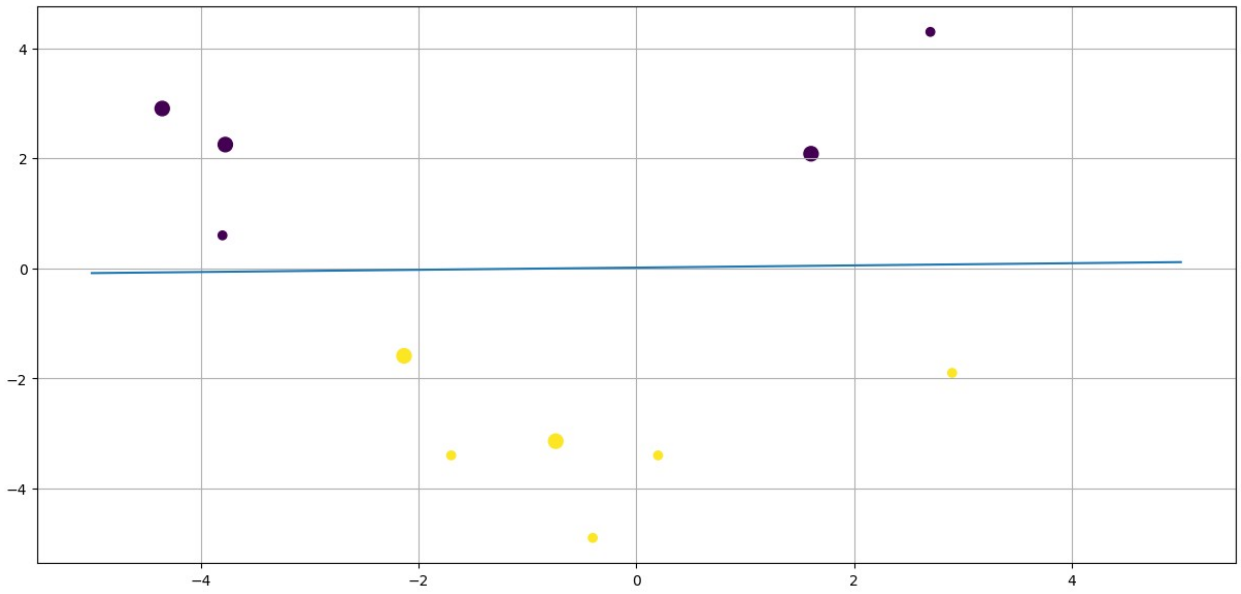


Проверка классификации перцептрона на тестовой выборке

Создадим несколько случайных точек, которые на графике будут большего размера. Получим предсказания модели и отметим их соответствующим цветом на картинке.

```
def check_model(data, labels, model, n=5, threshold=0.5):
    plot_result(data, labels, model, show_result=False) # train data
and line

    test_data = np.random.uniform(-5, 5, (n, 2))
    test_labels = model.predict(test_data) > threshold
    plt.scatter(test_data[:, 0], test_data[:, 1], c=test_labels,
s=100)
    plt.show()

check_model(data1, labels1, model1)
```

```
1/1 [==============================] - 0s 72ms/step
```



Видим, что перцептрон определил классы без ошибок.

Задание 2

Определим датасет для второго задания.

```
data2 = np.array([[-1.5, -0.6], [4.6, -4.6], [4.7, -3.2], [1.6, 0.8],
[1.7, -1.4], [1.2, 3.1], [-4.9, -4.2], [4.7, 1.5]])
labels2 = np.array([[0, 0], [0, 1], [0, 1], [1, 0], [0, 0], [1, 0],
[0, 1], [1, 1]])
data2, labels2
```

```
(array([[-1.5, -0.6],
        [ 4.6, -4.6],
        [ 4.7, -3.2],
        [ 1.6,  0.8],
        [ 1.7, -1.4],
        [ 1.2,  3.1],
        [-4.9, -4.2],
        [ 4.7,  1.5]]),
 array([[0, 0],
        [0, 1],
        [0, 1],
        [1, 0],
        [0, 0],
        [1, 0],
        [0, 1],
        [1, 1]]))
```

```
model2 = keras.Sequential()
model2.add(keras.layers.Dense(2, activation='sigmoid'))
```

```
model2.compile(loss='bce', optimizer='adam')
```

Используем также бинарную кросс-энтропию и сигмоид.

```
train_info2 = model2.fit(data2, labels2, batch_size=1, epochs=500)
```

```
Epoch 1/500
8/8 [==============================] - 1s 3ms/step - loss: 1.0636
Epoch 2/500
8/8 [==============================] - 0s 3ms/step - loss: 1.0556
Epoch 3/500
8/8 [==============================] - 0s 3ms/step - loss: 1.0450
Epoch 4/500
8/8 [==============================] - 0s 4ms/step - loss: 1.0377
Epoch 5/500
8/8 [==============================] - 0s 4ms/step - loss: 1.0278
Epoch 6/500
8/8 [==============================] - 0s 3ms/step - loss: 1.0190
Epoch 7/500
8/8 [==============================] - 0s 3ms/step - loss: 1.0098
Epoch 8/500
8/8 [==============================] - 0s 3ms/step - loss: 1.0026
Epoch 9/500
8/8 [==============================] - 0s 3ms/step - loss: 0.9929
Epoch 10/500
8/8 [==============================] - 0s 3ms/step - loss: 0.9829
Epoch 11/500
8/8 [==============================] - 0s 3ms/step - loss: 0.9756
Epoch 12/500
8/8 [==============================] - 0s 4ms/step - loss: 0.9672
Epoch 13/500
8/8 [==============================] - 0s 3ms/step - loss: 0.9578
Epoch 14/500
8/8 [==============================] - 0s 3ms/step - loss: 0.9495
Epoch 15/500
8/8 [==============================] - 0s 3ms/step - loss: 0.9418
Epoch 16/500
8/8 [==============================] - 0s 2ms/step - loss: 0.9342
Epoch 17/500
8/8 [==============================] - 0s 3ms/step - loss: 0.9252
Epoch 18/500
8/8 [==============================] - 0s 3ms/step - loss: 0.9166
Epoch 19/500
8/8 [==============================] - 0s 3ms/step - loss: 0.9088
Epoch 20/500
8/8 [==============================] - 0s 3ms/step - loss: 0.9005
Epoch 21/500
8/8 [==============================] - 0s 3ms/step - loss: 0.8937
Epoch 22/500
```

```
8/8 [==============================] - 0s 3ms/step - loss: 0.8851
Epoch 23/500
8/8 [==============================] - 0s 3ms/step - loss: 0.8781
Epoch 24/500
8/8 [==============================] - 0s 3ms/step - loss: 0.8693
Epoch 25/500
8/8 [==============================] - 0s 3ms/step - loss: 0.8627
Epoch 26/500
8/8 [==============================] - 0s 3ms/step - loss: 0.8544
Epoch 27/500
8/8 [==============================] - 0s 3ms/step - loss: 0.8483
Epoch 28/500
8/8 [==============================] - 0s 3ms/step - loss: 0.8399
Epoch 29/500
8/8 [==============================] - 0s 3ms/step - loss: 0.8328
Epoch 30/500
8/8 [==============================] - 0s 3ms/step - loss: 0.8246
Epoch 31/500
8/8 [==============================] - 0s 3ms/step - loss: 0.8179
Epoch 32/500
8/8 [==============================] - 0s 3ms/step - loss: 0.8110
Epoch 33/500
8/8 [==============================] - 0s 2ms/step - loss: 0.8036
Epoch 34/500
8/8 [==============================] - 0s 3ms/step - loss: 0.7970
Epoch 35/500
8/8 [==============================] - 0s 3ms/step - loss: 0.7908
Epoch 36/500
8/8 [==============================] - 0s 2ms/step - loss: 0.7833
Epoch 37/500
8/8 [==============================] - 0s 3ms/step - loss: 0.7763
Epoch 38/500
8/8 [==============================] - 0s 3ms/step - loss: 0.7706
Epoch 39/500
8/8 [==============================] - 0s 2ms/step - loss: 0.7638
Epoch 40/500
8/8 [==============================] - 0s 2ms/step - loss: 0.7571
Epoch 41/500
8/8 [==============================] - 0s 3ms/step - loss: 0.7501
Epoch 42/500
8/8 [==============================] - 0s 2ms/step - loss: 0.7449
Epoch 43/500
8/8 [==============================] - 0s 3ms/step - loss: 0.7382
Epoch 44/500
8/8 [==============================] - 0s 2ms/step - loss: 0.7317
Epoch 45/500
8/8 [==============================] - 0s 3ms/step - loss: 0.7253
Epoch 46/500
8/8 [==============================] - 0s 3ms/step - loss: 0.7200
```

```
Epoch 47/500
8/8 [==============================] - 0s 3ms/step - loss: 0.7131
Epoch 48/500
8/8 [==============================] - 0s 3ms/step - loss: 0.7080
Epoch 49/500
8/8 [==============================] - 0s 3ms/step - loss: 0.7017
Epoch 50/500
8/8 [==============================] - 0s 3ms/step - loss: 0.6965
Epoch 51/500
8/8 [==============================] - 0s 3ms/step - loss: 0.6907
Epoch 52/500
8/8 [==============================] - 0s 3ms/step - loss: 0.6845
Epoch 53/500
8/8 [==============================] - 0s 3ms/step - loss: 0.6791
Epoch 54/500
8/8 [==============================] - 0s 3ms/step - loss: 0.6731
Epoch 55/500
8/8 [==============================] - 0s 3ms/step - loss: 0.6673
Epoch 56/500
8/8 [==============================] - 0s 2ms/step - loss: 0.6635
Epoch 57/500
8/8 [==============================] - 0s 3ms/step - loss: 0.6573
Epoch 58/500
8/8 [==============================] - 0s 3ms/step - loss: 0.6521
Epoch 59/500
8/8 [==============================] - 0s 2ms/step - loss: 0.6471
Epoch 60/500
8/8 [==============================] - 0s 3ms/step - loss: 0.6413
Epoch 61/500
8/8 [==============================] - 0s 3ms/step - loss: 0.6360
Epoch 62/500
8/8 [==============================] - 0s 3ms/step - loss: 0.6311
Epoch 63/500
8/8 [==============================] - 0s 2ms/step - loss: 0.6268
Epoch 64/500
8/8 [==============================] - 0s 2ms/step - loss: 0.6212
Epoch 65/500
8/8 [==============================] - 0s 2ms/step - loss: 0.6163
Epoch 66/500
8/8 [==============================] - 0s 3ms/step - loss: 0.6121
Epoch 67/500
8/8 [==============================] - 0s 3ms/step - loss: 0.6069
Epoch 68/500
8/8 [==============================] - 0s 3ms/step - loss: 0.6017
Epoch 69/500
8/8 [==============================] - 0s 3ms/step - loss: 0.5983
Epoch 70/500
8/8 [==============================] - 0s 3ms/step - loss: 0.5928
Epoch 71/500
```

```
8/8 [==============================] - 0s 2ms/step - loss: 0.5887
Epoch 72/500
8/8 [==============================] - 0s 3ms/step - loss: 0.5842
Epoch 73/500
8/8 [==============================] - 0s 2ms/step - loss: 0.5786
Epoch 74/500
8/8 [==============================] - 0s 3ms/step - loss: 0.5748
Epoch 75/500
8/8 [==============================] - 0s 2ms/step - loss: 0.5705
Epoch 76/500
8/8 [==============================] - 0s 3ms/step - loss: 0.5667
Epoch 77/500
8/8 [==============================] - 0s 3ms/step - loss: 0.5619
Epoch 78/500
8/8 [==============================] - 0s 2ms/step - loss: 0.5585
Epoch 79/500
8/8 [==============================] - 0s 3ms/step - loss: 0.5539
Epoch 80/500
8/8 [==============================] - 0s 2ms/step - loss: 0.5489
Epoch 81/500
8/8 [==============================] - 0s 2ms/step - loss: 0.5456
Epoch 82/500
8/8 [==============================] - 0s 3ms/step - loss: 0.5420
Epoch 83/500
8/8 [==============================] - 0s 3ms/step - loss: 0.5377
Epoch 84/500
8/8 [==============================] - 0s 3ms/step - loss: 0.5337
Epoch 85/500
8/8 [==============================] - 0s 3ms/step - loss: 0.5295
Epoch 86/500
8/8 [==============================] - 0s 3ms/step - loss: 0.5255
Epoch 87/500
8/8 [==============================] - 0s 3ms/step - loss: 0.5217
Epoch 88/500
8/8 [==============================] - 0s 3ms/step - loss: 0.5191
Epoch 89/500
8/8 [==============================] - 0s 2ms/step - loss: 0.5145
Epoch 90/500
8/8 [==============================] - 0s 2ms/step - loss: 0.5110
Epoch 91/500
8/8 [==============================] - 0s 2ms/step - loss: 0.5067
Epoch 92/500
8/8 [==============================] - 0s 2ms/step - loss: 0.5033
Epoch 93/500
8/8 [==============================] - 0s 3ms/step - loss: 0.5004
Epoch 94/500
8/8 [==============================] - 0s 2ms/step - loss: 0.4973
Epoch 95/500
8/8 [==============================] - 0s 2ms/step - loss: 0.4933
```

```
Epoch 96/500
8/8 [==============================] - 0s 2ms/step - loss: 0.4899
Epoch 97/500
8/8 [==============================] - 0s 2ms/step - loss: 0.4863
Epoch 98/500
8/8 [==============================] - 0s 2ms/step - loss: 0.4825
Epoch 99/500
8/8 [==============================] - 0s 2ms/step - loss: 0.4797
Epoch 100/500
8/8 [==============================] - 0s 3ms/step - loss: 0.4766
Epoch 101/500
8/8 [==============================] - 0s 2ms/step - loss: 0.4734
Epoch 102/500
8/8 [==============================] - 0s 3ms/step - loss: 0.4694
Epoch 103/500
8/8 [==============================] - 0s 2ms/step - loss: 0.4677
Epoch 104/500
8/8 [==============================] - 0s 3ms/step - loss: 0.4635
Epoch 105/500
8/8 [==============================] - 0s 2ms/step - loss: 0.4602
Epoch 106/500
8/8 [==============================] - 0s 2ms/step - loss: 0.4573
Epoch 107/500
8/8 [==============================] - 0s 2ms/step - loss: 0.4548
Epoch 108/500
8/8 [==============================] - 0s 2ms/step - loss: 0.4519
Epoch 109/500
8/8 [==============================] - 0s 3ms/step - loss: 0.4485
Epoch 110/500
8/8 [==============================] - 0s 3ms/step - loss: 0.4457
Epoch 111/500
8/8 [==============================] - 0s 3ms/step - loss: 0.4428
Epoch 112/500
8/8 [==============================] - 0s 3ms/step - loss: 0.4396
Epoch 113/500
8/8 [==============================] - 0s 3ms/step - loss: 0.4376
Epoch 114/500
8/8 [==============================] - 0s 3ms/step - loss: 0.4347
Epoch 115/500
8/8 [==============================] - 0s 3ms/step - loss: 0.4315
Epoch 116/500
8/8 [==============================] - 0s 3ms/step - loss: 0.4297
Epoch 117/500
8/8 [==============================] - 0s 3ms/step - loss: 0.4262
Epoch 118/500
8/8 [==============================] - 0s 3ms/step - loss: 0.4238
Epoch 119/500
8/8 [==============================] - 0s 3ms/step - loss: 0.4218
Epoch 120/500
```

```
8/8 [==============================] - 0s 2ms/step - loss: 0.4185
Epoch 121/500
8/8 [==============================] - 0s 3ms/step - loss: 0.4163
Epoch 122/500
8/8 [==============================] - 0s 3ms/step - loss: 0.4138
Epoch 123/500
8/8 [==============================] - 0s 3ms/step - loss: 0.4110
Epoch 124/500
8/8 [==============================] - 0s 3ms/step - loss: 0.4086
Epoch 125/500
8/8 [==============================] - 0s 3ms/step - loss: 0.4063
Epoch 126/500
8/8 [==============================] - 0s 3ms/step - loss: 0.4038
Epoch 127/500
8/8 [==============================] - 0s 3ms/step - loss: 0.4015
Epoch 128/500
8/8 [==============================] - 0s 3ms/step - loss: 0.3990
Epoch 129/500
8/8 [==============================] - 0s 3ms/step - loss: 0.3972
Epoch 130/500
8/8 [==============================] - 0s 3ms/step - loss: 0.3947
Epoch 131/500
8/8 [==============================] - 0s 2ms/step - loss: 0.3930
Epoch 132/500
8/8 [==============================] - 0s 3ms/step - loss: 0.3902
Epoch 133/500
8/8 [==============================] - 0s 3ms/step - loss: 0.3881
Epoch 134/500
8/8 [==============================] - 0s 2ms/step - loss: 0.3858
Epoch 135/500
8/8 [==============================] - 0s 2ms/step - loss: 0.3842
Epoch 136/500
8/8 [==============================] - 0s 2ms/step - loss: 0.3817
Epoch 137/500
8/8 [==============================] - 0s 3ms/step - loss: 0.3800
Epoch 138/500
8/8 [==============================] - 0s 3ms/step - loss: 0.3775
Epoch 139/500
8/8 [==============================] - 0s 2ms/step - loss: 0.3757
Epoch 140/500
8/8 [==============================] - 0s 2ms/step - loss: 0.3739
Epoch 141/500
8/8 [==============================] - 0s 3ms/step - loss: 0.3723
Epoch 142/500
8/8 [==============================] - 0s 3ms/step - loss: 0.3701
Epoch 143/500
8/8 [==============================] - 0s 3ms/step - loss: 0.3680
Epoch 144/500
8/8 [==============================] - 0s 4ms/step - loss: 0.3664
```

```
Epoch 145/500
8/8 [==============================] - 0s 3ms/step - loss: 0.3645
Epoch 146/500
8/8 [==============================] - 0s 3ms/step - loss: 0.3622
Epoch 147/500
8/8 [==============================] - 0s 3ms/step - loss: 0.3609
Epoch 148/500
8/8 [==============================] - 0s 3ms/step - loss: 0.3591
Epoch 149/500
8/8 [==============================] - 0s 3ms/step - loss: 0.3573
Epoch 150/500
8/8 [==============================] - 0s 2ms/step - loss: 0.3555
Epoch 151/500
8/8 [==============================] - 0s 3ms/step - loss: 0.3541
Epoch 152/500
8/8 [==============================] - 0s 2ms/step - loss: 0.3524
Epoch 153/500
8/8 [==============================] - 0s 2ms/step - loss: 0.3507
Epoch 154/500
8/8 [==============================] - 0s 2ms/step - loss: 0.3489
Epoch 155/500
8/8 [==============================] - 0s 2ms/step - loss: 0.3477
Epoch 156/500
8/8 [==============================] - 0s 2ms/step - loss: 0.3460
Epoch 157/500
8/8 [==============================] - 0s 2ms/step - loss: 0.3442
Epoch 158/500
8/8 [==============================] - 0s 2ms/step - loss: 0.3429
Epoch 159/500
8/8 [==============================] - 0s 2ms/step - loss: 0.3413
Epoch 160/500
8/8 [==============================] - 0s 3ms/step - loss: 0.3399
Epoch 161/500
8/8 [==============================] - 0s 3ms/step - loss: 0.3385
Epoch 162/500
8/8 [==============================] - 0s 2ms/step - loss: 0.3377
Epoch 163/500
8/8 [==============================] - 0s 3ms/step - loss: 0.3360
Epoch 164/500
8/8 [==============================] - 0s 3ms/step - loss: 0.3342
Epoch 165/500
8/8 [==============================] - 0s 3ms/step - loss: 0.3329
Epoch 166/500
8/8 [==============================] - 0s 2ms/step - loss: 0.3316
Epoch 167/500
8/8 [==============================] - 0s 3ms/step - loss: 0.3305
Epoch 168/500
8/8 [==============================] - 0s 3ms/step - loss: 0.3292
Epoch 169/500
```

```
8/8 [==============================] - 0s 2ms/step - loss: 0.3275
Epoch 170/500
8/8 [==============================] - 0s 2ms/step - loss: 0.3263
Epoch 171/500
8/8 [==============================] - 0s 3ms/step - loss: 0.3253
Epoch 172/500
8/8 [==============================] - 0s 3ms/step - loss: 0.3247
Epoch 173/500
8/8 [==============================] - 0s 2ms/step - loss: 0.3228
Epoch 174/500
8/8 [==============================] - 0s 2ms/step - loss: 0.3214
Epoch 175/500
8/8 [==============================] - 0s 2ms/step - loss: 0.3209
Epoch 176/500
8/8 [==============================] - 0s 2ms/step - loss: 0.3193
Epoch 177/500
8/8 [==============================] - 0s 3ms/step - loss: 0.3182
Epoch 178/500
8/8 [==============================] - 0s 2ms/step - loss: 0.3175
Epoch 179/500
8/8 [==============================] - 0s 2ms/step - loss: 0.3158
Epoch 180/500
8/8 [==============================] - 0s 2ms/step - loss: 0.3152
Epoch 181/500
8/8 [==============================] - 0s 3ms/step - loss: 0.3140
Epoch 182/500
8/8 [==============================] - 0s 2ms/step - loss: 0.3131
Epoch 183/500
8/8 [==============================] - 0s 2ms/step - loss: 0.3118
Epoch 184/500
8/8 [==============================] - 0s 2ms/step - loss: 0.3110
Epoch 185/500
8/8 [==============================] - 0s 2ms/step - loss: 0.3098
Epoch 186/500
8/8 [==============================] - 0s 2ms/step - loss: 0.3089
Epoch 187/500
8/8 [==============================] - 0s 2ms/step - loss: 0.3079
Epoch 188/500
8/8 [==============================] - 0s 3ms/step - loss: 0.3073
Epoch 189/500
8/8 [==============================] - 0s 3ms/step - loss: 0.3060
Epoch 190/500
8/8 [==============================] - 0s 3ms/step - loss: 0.3052
Epoch 191/500
8/8 [==============================] - 0s 3ms/step - loss: 0.3042
Epoch 192/500
8/8 [==============================] - 0s 3ms/step - loss: 0.3035
Epoch 193/500
8/8 [==============================] - 0s 2ms/step - loss: 0.3027
```

```
Epoch 194/500
8/8 [==============================] - 0s 2ms/step - loss: 0.3019
Epoch 195/500
8/8 [==============================] - 0s 2ms/step - loss: 0.3008
Epoch 196/500
8/8 [==============================] - 0s 3ms/step - loss: 0.3002
Epoch 197/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2993
Epoch 198/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2983
Epoch 199/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2978
Epoch 200/500
8/8 [==============================] - 0s 3ms/step - loss: 0.2970
Epoch 201/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2963
Epoch 202/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2953
Epoch 203/500
8/8 [==============================] - 0s 3ms/step - loss: 0.2947
Epoch 204/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2939
Epoch 205/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2932
Epoch 206/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2924
Epoch 207/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2918
Epoch 208/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2913
Epoch 209/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2904
Epoch 210/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2897
Epoch 211/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2891
Epoch 212/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2889
Epoch 213/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2879
Epoch 214/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2872
Epoch 215/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2867
Epoch 216/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2861
Epoch 217/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2854
Epoch 218/500
```

```
8/8 [==============================] - 0s 2ms/step - loss: 0.2850
Epoch 219/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2843
Epoch 220/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2837
Epoch 221/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2831
Epoch 222/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2830
Epoch 223/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2820
Epoch 224/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2817
Epoch 225/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2811
Epoch 226/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2805
Epoch 227/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2800
Epoch 228/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2796
Epoch 229/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2792
Epoch 230/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2787
Epoch 231/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2780
Epoch 232/500
8/8 [==============================] - 0s 3ms/step - loss: 0.2778
Epoch 233/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2772
Epoch 234/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2767
Epoch 235/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2762
Epoch 236/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2758
Epoch 237/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2754
Epoch 238/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2752
Epoch 239/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2745
Epoch 240/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2741
Epoch 241/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2738
Epoch 242/500
8/8 [==============================] - 0s 3ms/step - loss: 0.2733
```

```
Epoch 243/500
8/8 [==============================] - 0s 3ms/step - loss: 0.2729
Epoch 244/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2726
Epoch 245/500
8/8 [==============================] - 0s 3ms/step - loss: 0.2721
Epoch 246/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2717
Epoch 247/500
8/8 [==============================] - 0s 3ms/step - loss: 0.2714
Epoch 248/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2710
Epoch 249/500
8/8 [==============================] - 0s 3ms/step - loss: 0.2706
Epoch 250/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2703
Epoch 251/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2699
Epoch 252/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2695
Epoch 253/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2693
Epoch 254/500
8/8 [==============================] - 0s 3ms/step - loss: 0.2688
Epoch 255/500
8/8 [==============================] - 0s 3ms/step - loss: 0.2685
Epoch 256/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2682
Epoch 257/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2678
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8/8 [==============================] - 0s 2ms/step - loss: 0.2678
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8/8 [==============================] - 0s 3ms/step - loss: 0.2671
Epoch 260/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2668
Epoch 261/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2665
Epoch 262/500
8/8 [==============================] - 0s 3ms/step - loss: 0.2664
Epoch 263/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2659
Epoch 264/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2657
Epoch 265/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2653
Epoch 266/500
8/8 [==============================] - 0s 4ms/step - loss: 0.2653
Epoch 267/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2647
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Epoch 268/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2644
Epoch 269/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2641
Epoch 270/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2640
Epoch 271/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2636
Epoch 272/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2633
Epoch 273/500
8/8 [==============================] - 0s 3ms/step - loss: 0.2630
Epoch 274/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2628
Epoch 275/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2625
Epoch 276/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2623
Epoch 277/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2623
Epoch 278/500
8/8 [==============================] - 0s 3ms/step - loss: 0.2617
Epoch 279/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2616
Epoch 280/500
8/8 [==============================] - 0s 3ms/step - loss: 0.2612
Epoch 281/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2609
Epoch 282/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2608
Epoch 283/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2604
Epoch 284/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2602
Epoch 285/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2602
Epoch 286/500
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Epoch 291/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2586
Epoch 292/500
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8/8 [==============================] - 0s 3ms/step - loss: 0.2583
Epoch 293/500
8/8 [==============================] - 0s 3ms/step - loss: 0.2581
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Epoch 299/500
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Epoch 301/500
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Epoch 304/500
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8/8 [==============================] - 0s 3ms/step - loss: 0.2556
Epoch 306/500
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Epoch 309/500
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Epoch 311/500
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Epoch 312/500
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Epoch 315/500
8/8 [==============================] - 0s 4ms/step - loss: 0.2538
Epoch 316/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2536
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Epoch 317/500
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Epoch 319/500
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Epoch 326/500
8/8 [==============================] - 0s 3ms/step - loss: 0.2520
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8/8 [==============================] - 0s 2ms/step - loss: 0.2516
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8/8 [==============================] - 0s 3ms/step - loss: 0.2514
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Epoch 335/500
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Epoch 336/500
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Epoch 337/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2502
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Epoch 340/500
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Epoch 341/500
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8/8 [==============================] - 0s 2ms/step - loss: 0.2495
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Epoch 364/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2463
Epoch 365/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2460
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Epoch 366/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2459
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Epoch 389/500
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Epoch 390/500
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8/8 [==============================] - 0s 3ms/step - loss: 0.2430
Epoch 391/500
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Epoch 414/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2403
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Epoch 415/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2402
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Epoch 439/500
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8/8 [==============================] - 0s 3ms/step - loss: 0.2377
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Epoch 463/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2356
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Epoch 464/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2354
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Epoch 488/500
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8/8 [==============================] - 0s 2ms/step - loss: 0.2333
Epoch 489/500
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Epoch 497/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2327
Epoch 498/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2325
Epoch 499/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2323
Epoch 500/500
8/8 [==============================] - 0s 2ms/step - loss: 0.2322

plot_loss(train_info2)
```
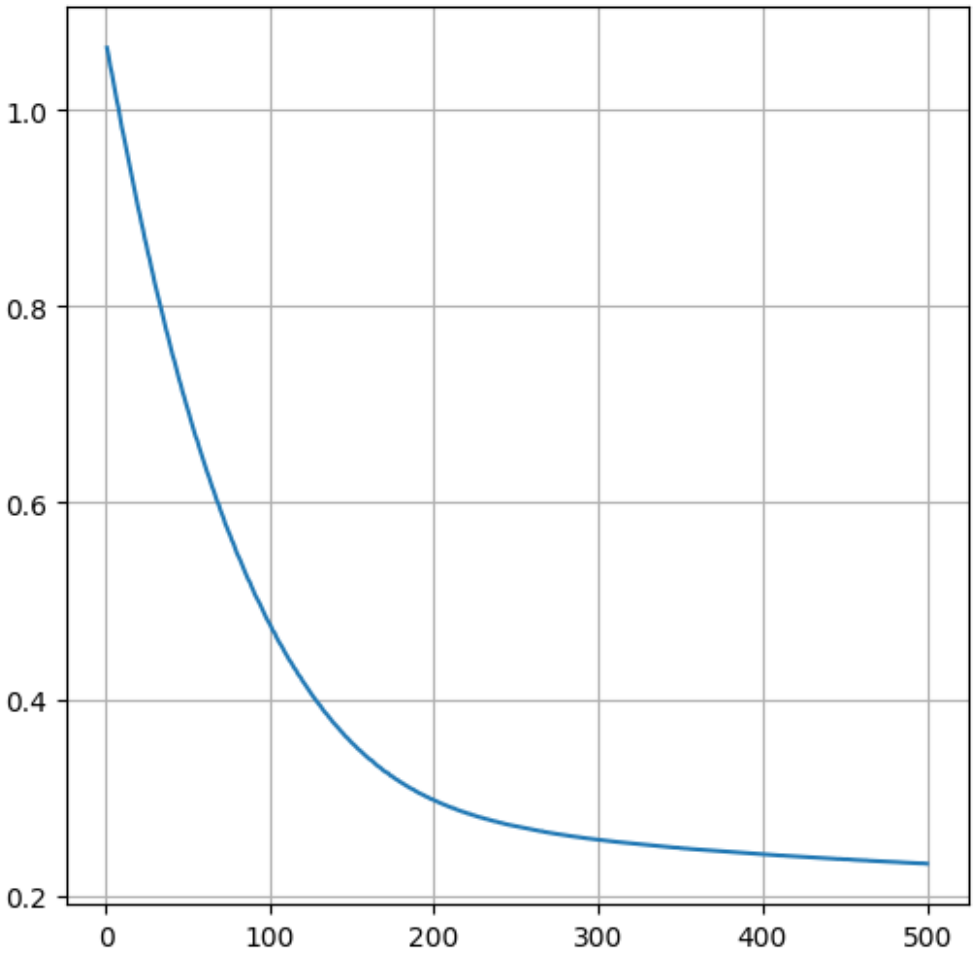



Сейчас мы классифицируем уже на 4 класса, поэтому разделяющих прямых будет две.

Перцептрон в текущем задании эквивалентен формуле:

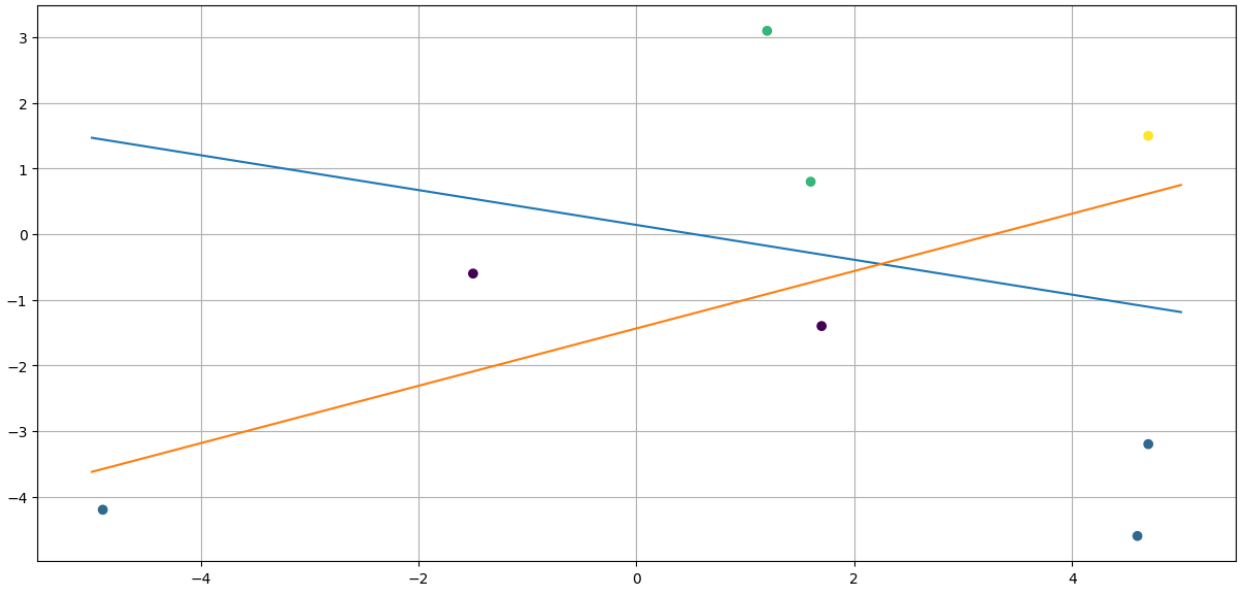
$$perceptron(x,y)=(x\ y)\begin{pmatrix}a_{00} & a_{01}\\ a_{10} & a_{11}\end{pmatrix}+\begin{pmatrix}b_0\\ b_1\end{pmatrix}=\begin{pmatrix}a_{00}x+a_{10}y+b_0\\ a_{01}x+a_{11}y+b_1\end{pmatrix}$$

Построив две разделяющие прямые, мы разобьем координатную плоскость на 4 сектора-класса.

Модифицируем функцию:

```
def plot_result_4classes(data, labels, model, show_result=True):
    plt.figure(figsize=(15,7))

    plt.scatter(data[:, 0], data[:, 1], c=[int(str(i*10 + j), 2) for
i, j in labels])

    A, b = model.layers[0].get_weights()

    x_disc = np.linspace(-5, 5, 5)
```

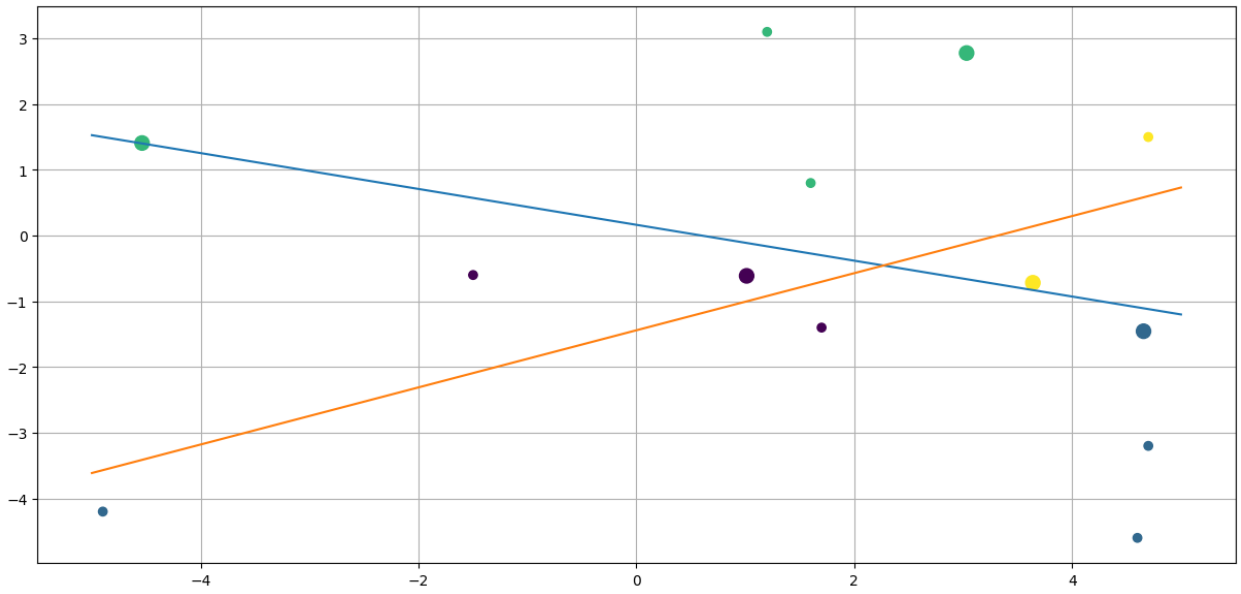
```
    plt.plot(x_disc, (-A[0][0] * x_disc - b[0]) / A[1][0])
    plt.plot(x_disc, (-A[0][1] * x_disc - b[1]) / A[1][1])

    plt.grid()
    if show_result:
        plt.show()

plot_result_4classes(data2, labels2, model2)
```



2 точки вылезли из своих четвертей. Это связано с датасетом.

Тестируем перцептрон.

```
def check_model_4classes(data, labels, model, n=5, threshold=0.5):
    plot_result_4classes(data, labels, model, show_result=False) #
train data and line

    test_data = np.random.uniform(-5, 5, (n, 2))
    test_labels = model.predict(test_data) > threshold

    plt.scatter(test_data[:, 0], test_data[:, 1],
                c=[int(str(i*10 + j), 2) for i, j in test_labels],
s=100)
    plt.show()

check_model_4classes(data2, labels2, model2)

1/1 [==============================] - 0s 185ms/step
```



Видим, что перцептрон неплохо справляется с классификацией тестовых точек

Вывод

В данной работе я решил задачу классификации на 2 и 4 класса с помощью однослойной нейросети. Обученный перцептрон довольно неплохо справляется со своей задачей - в этом мы убедились, проверив его на тестовой выборке. Стоит отметить, что мы не можем гарантировать стопроцентное качество обученных моделей, так как для обучения использовалось очень мало данных.