

- 1 "C:\Program Files\Python312\python.exe" "E:\My storage\Maga\M0\Lab\_2\_M0.py"
- 2 2025-11-24 10:58:57.024679: I tensorflow/core/util/port.cc:153] oneDNN custom operations are on. You may see slightly different numerical results due to floating-point round-off errors from different computation orders. To turn them off, set the environment variable `TF\_ENABLE\_ONEDNN\_OPTS=0`.
- 3 2025-11-24 10:58:58.636026: I tensorflow/core/util/port.cc:153] oneDNN custom operations are on. You may see slightly different numerical results due to floating-point round-off errors from different computation orders. To turn them off, set the environment variable `TF\_ENABLE\_ONEDNN\_OPTS=0`.
- 4 Загрузка изображений и объединение данных из папки: notMNIST\_large...
- 5 Загрузка изображений для класса 'A'...
- 6 Класс A: 100% |██████████| 52912/52912 [00:11<00:00, 4725.10it/s]
- 7 Загрузка изображений для класса 'B'...
- 8 Класс B: 100% |██████████| 52912/52912 [00:11<00:00, 4509.32it/s]
- 9 Загрузка изображений для класса 'C'...
- 10 Класс C: 100% |██████████| 52912/52912 [00:11<00:00, 4417.34it/s]
- 11 Загрузка изображений для класса 'D'...
- 12 Класс D: 100% |██████████| 52912/52912 [00:12<00:00, 4122.80it/s]
- 13 Загрузка изображений для класса 'E'...
- 14 Класс E: 100% |██████████| 52912/52912 [00:12<00:00, 4108.68it/s]
- 15 Загрузка изображений для класса 'F'...
- 16 Класс F: 100% |██████████| 52912/52912 [00:13<00:00, 4043.44it/s]
- 17 Загрузка изображений для класса 'G'...
- 18 Класс G: 100% |██████████| 52912/52912 [00:13<00:00, 3831.23it/s]
- 19 Загрузка изображений для класса 'H'...
- 20 Класс H: 100% |██████████| 52912/52912 [00:13<00:00, 3808.71it/s]
- 21 Загрузка изображений для класса 'I'...

```
22 Класс I: 100% | 52912/52912 [00:13<00:00,
3997.20it/s]
23 Загрузка изображений для класса 'J'...
24 Класс J: 100% | 52911/52911 [00:08<00:00,
6445.94it/s]
25 Общее количество загруженных изображений: 529114
26 Отображение 10 случайных изображений:
27 Распределение классов:
28 Класс 'A' (0): 52909 изображений (10.00%)
29 Класс 'B' (1): 52911 изображений (10.00%)
30 Класс 'C' (2): 52912 изображений (10.00%)
31 Класс 'D' (3): 52911 изображений (10.00%)
32 Класс 'E' (4): 52912 изображений (10.00%)
33 Класс 'F' (5): 52912 изображений (10.00%)
34 Класс 'G' (6): 52912 изображений (10.00%)
35 Класс 'H' (7): 52912 изображений (10.00%)
36 Класс 'I' (8): 52912 изображений (10.00%)
37 Класс 'J' (9): 52911 изображений (10.00%)
38
39 Минимальное количество: 52909
40 Максимальное количество: 52912
41 Вывод: Классы сбалансиированы (разница менее 10%).
42 Размер обучающей выборки (X_train, y_train): 200000
43 Размер валидационной выборки (X_valid, y_valid):
10000
44 Размер контрольной выборки (X_test, y_test): 19000
45 Вычисление хешей для выборок...
46 Количество дубликатов между Train и Valid: 870
47 Количество дубликатов между Train и Test: 1842
48 Общее количество дубликатов, которые нужно удалить из
Train: 2669
49 Удаление дубликатов из обучающей выборки...
50 Размер Train до очистки: 200000
51 Размер Train после очистки: 194246
52
53 --- Базовая FCNN для сравнения с логистической
регрессией ---
54 C:\Users\user\AppData\Roaming\Python\Python312\site-
packages\keras\src\layers\core\dense.py:95:
UserWarning: Do not pass an `input_shape`/`input_dim
` argument to a layer. When using Sequential models,
```

```
54 prefer using an `Input(shape)` object as the first
layer in the model instead.
55 super().__init__(activity_regularizer=
activity_regularizer, **kwargs)
56 2025-11-24 11:01:14.649006: I tensorflow/core/
platform/cpu_feature_guard.cc:210] This TensorFlow
binary is optimized to use available CPU instructions
in performance-critical operations.
57 To enable the following instructions: SSE3 SSE4.1
SSE4.2 AVX AVX2 FMA, in other operations, rebuild
TensorFlow with the appropriate compiler flags.
58 Базовая модель построена (512 -> 256 -> 10).
59
60 Начинается обучение базовой модели на 5 эпохах...
61 Epoch 1/5
62 1563/1563 ━━━━━━━━━━ 4s 2ms/step - accuracy
: 0.8157 - loss: 0.6509 - val_accuracy: 0.8364 -
val_loss: 0.5598
63 Epoch 2/5
64 1563/1563 ━━━━━━━━━━ 3s 2ms/step - accuracy
: 0.8517 - loss: 0.5133 - val_accuracy: 0.8512 -
val_loss: 0.5092
65 Epoch 3/5
66 1563/1563 ━━━━━━━━━━ 3s 2ms/step - accuracy
: 0.8625 - loss: 0.4717 - val_accuracy: 0.8583 -
val_loss: 0.4790
67 Epoch 4/5
68 1563/1563 ━━━━━━━━━━ 3s 2ms/step - accuracy
: 0.8707 - loss: 0.4424 - val_accuracy: 0.8634 -
val_loss: 0.4585
69 Epoch 5/5
70 1563/1563 ━━━━━━━━━━ 3s 2ms/step - accuracy
: 0.8771 - loss: 0.4193 - val_accuracy: 0.8674 -
val_loss: 0.4414
71
72 Расширение базовой модели с добавлением регуляризации
, Dropout и динамической LR ---
73 Продвинутая модель построена (1280 -> 768 -> 384 ->
256 -> 128 -> 10) с L2, Dropout и динамической LR.
74
75 Начинается обучение продвинутой модели с количеством
```

```
75  эпок = 50...
76 Epoch 1/50
77 782/782 ━━━━━━━━ 13s 15ms/step -
    accuracy: 0.8334 - loss: 0.5926 - val_accuracy: 0.
    8623 - val_loss: 0.5063 - learning_rate: 0.0020
78 Epoch 2/50
79 782/782 ━━━━━━━━ 12s 15ms/step -
    accuracy: 0.8644 - loss: 0.5135 - val_accuracy: 0.
    8780 - val_loss: 0.4768 - learning_rate: 0.0020
80 Epoch 3/50
81 782/782 ━━━━━━━━ 12s 15ms/step -
    accuracy: 0.8744 - loss: 0.4962 - val_accuracy: 0.
    8794 - val_loss: 0.4737 - learning_rate: 0.0020
82 Epoch 4/50
83 782/782 ━━━━━━━━ 11s 14ms/step -
    accuracy: 0.8801 - loss: 0.4942 - val_accuracy: 0.
    8867 - val_loss: 0.4712 - learning_rate: 0.0020
84 Epoch 5/50
85 782/782 ━━━━━━━━ 11s 14ms/step -
    accuracy: 0.8837 - loss: 0.4940 - val_accuracy: 0.
    8874 - val_loss: 0.4725 - learning_rate: 0.0020
86 Epoch 6/50
87 782/782 ━━━━━━━━ 11s 15ms/step -
    accuracy: 0.8864 - loss: 0.4921 - val_accuracy: 0.
    8889 - val_loss: 0.4755 - learning_rate: 0.0020
88 Epoch 7/50
89 782/782 ━━━━━━━━ 12s 15ms/step -
    accuracy: 0.8879 - loss: 0.4953 - val_accuracy: 0.
    8926 - val_loss: 0.4769 - learning_rate: 0.0020
90 Epoch 8/50
91 782/782 ━━━━━━━━ 11s 15ms/step -
    accuracy: 0.8892 - loss: 0.4961 - val_accuracy: 0.
    8912 - val_loss: 0.4812 - learning_rate: 0.0020
92 Epoch 9/50
93 782/782 ━━━━━━━━ 11s 15ms/step -
    accuracy: 0.8912 - loss: 0.4930 - val_accuracy: 0.
    8916 - val_loss: 0.4894 - learning_rate: 0.0020
94 Epoch 10/50
95 782/782 ━━━━━━━━ 12s 15ms/step -
    accuracy: 0.8913 - loss: 0.4977 - val_accuracy: 0.
    8919 - val_loss: 0.4863 - learning_rate: 0.0020
```

```
96 Epoch 11/50
97 782/782 ━━━━━━━━━━ 11s 15ms/step -
    accuracy: 0.8929 - loss: 0.4933 - val_accuracy: 0.
    8959 - val_loss: 0.4851 - learning_rate: 0.0020
98 Epoch 12/50
99 782/782 ━━━━━━━━━━ 12s 15ms/step -
    accuracy: 0.8939 - loss: 0.4892 - val_accuracy: 0.
    8950 - val_loss: 0.4756 - learning_rate: 0.0020
100 Epoch 13/50
101 782/782 ━━━━━━━━━━ 11s 15ms/step -
    accuracy: 0.8944 - loss: 0.4911 - val_accuracy: 0.
    8931 - val_loss: 0.4824 - learning_rate: 0.0020
102 Epoch 14/50
103 782/782 ━━━━━━━━━━ 11s 15ms/step -
    accuracy: 0.8945 - loss: 0.4894 - val_accuracy: 0.
    8968 - val_loss: 0.4751 - learning_rate: 0.0020
104 Epoch 15/50
105 782/782 ━━━━━━━━━━ 11s 15ms/step -
    accuracy: 0.8954 - loss: 0.4874 - val_accuracy: 0.
    8966 - val_loss: 0.4808 - learning_rate: 0.0020
106 Epoch 16/50
107 782/782 ━━━━━━━━━━ 11s 15ms/step -
    accuracy: 0.8966 - loss: 0.4860 - val_accuracy: 0.
    8974 - val_loss: 0.4756 - learning_rate: 0.0020
108 Epoch 17/50
109 782/782 ━━━━━━━━━━ 11s 15ms/step -
    accuracy: 0.8966 - loss: 0.4834 - val_accuracy: 0.
    9009 - val_loss: 0.4727 - learning_rate: 0.0020
110 Epoch 18/50
111 782/782 ━━━━━━━━━━ 11s 15ms/step -
    accuracy: 0.8977 - loss: 0.4827 - val_accuracy: 0.
    9008 - val_loss: 0.4684 - learning_rate: 0.0020
112 Epoch 19/50
113 782/782 ━━━━━━━━━━ 12s 15ms/step -
    accuracy: 0.8977 - loss: 0.4803 - val_accuracy: 0.
    8975 - val_loss: 0.4717 - learning_rate: 0.0020
114 Epoch 20/50
115 782/782 ━━━━━━━━━━ 12s 15ms/step -
    accuracy: 0.8982 - loss: 0.4765 - val_accuracy: 0.
    9014 - val_loss: 0.4666 - learning_rate: 0.0020
116 Epoch 21/50
```

```
117 782/782 ━━━━━━━━ 11s 15ms/step -  
accuracy: 0.8978 - loss: 0.4787 - val_accuracy: 0.  
9019 - val_loss: 0.4595 - learning_rate: 0.0020  
118 Epoch 22/50  
119 782/782 ━━━━━━━━ 12s 15ms/step -  
accuracy: 0.8987 - loss: 0.4720 - val_accuracy: 0.  
8993 - val_loss: 0.4716 - learning_rate: 0.0020  
120 Epoch 23/50  
121 782/782 ━━━━━━━━ 11s 15ms/step -  
accuracy: 0.8986 - loss: 0.4728 - val_accuracy: 0.  
8950 - val_loss: 0.4686 - learning_rate: 0.0020  
122 Epoch 24/50  
123 782/782 ━━━━━━━━ 12s 15ms/step -  
accuracy: 0.8995 - loss: 0.4699 - val_accuracy: 0.  
9012 - val_loss: 0.4647 - learning_rate: 0.0020  
124 Epoch 25/50  
125 781/782 ━━━━━━━━ 0s 14ms/step - accuracy  
: 0.9009 - loss: 0.4664  
126 Epoch 25: ReduceLROnPlateau reducing learning rate  
to 0.0010000000474974513.  
127 782/782 ━━━━━━━━ 12s 15ms/step -  
accuracy: 0.8992 - loss: 0.4719 - val_accuracy: 0.  
9017 - val_loss: 0.4641 - learning_rate: 0.0020  
128 Epoch 26/50  
129 782/782 ━━━━━━━━ 11s 15ms/step -  
accuracy: 0.9096 - loss: 0.4268 - val_accuracy: 0.  
9080 - val_loss: 0.4223 - learning_rate: 0.0010  
130 Epoch 27/50  
131 782/782 ━━━━━━━━ 11s 15ms/step -  
accuracy: 0.9125 - loss: 0.4066 - val_accuracy: 0.  
9080 - val_loss: 0.4131 - learning_rate: 0.0010  
132 Epoch 28/50  
133 782/782 ━━━━━━━━ 12s 15ms/step -  
accuracy: 0.9139 - loss: 0.3944 - val_accuracy: 0.  
9102 - val_loss: 0.4053 - learning_rate: 0.0010  
134 Epoch 29/50  
135 782/782 ━━━━━━━━ 11s 15ms/step -  
accuracy: 0.9145 - loss: 0.3879 - val_accuracy: 0.  
9078 - val_loss: 0.3999 - learning_rate: 0.0010  
136 Epoch 30/50  
137 782/782 ━━━━━━━━ 11s 14ms/step -
```

```
137 accuracy: 0.9152 - loss: 0.3805 - val_accuracy: 0.  
9105 - val_loss: 0.3944 - learning_rate: 0.0010  
138 Epoch 31/50  
139 782/782 ━━━━━━━━ 11s 15ms/step -  
accuracy: 0.9165 - loss: 0.3751 - val_accuracy: 0.  
9097 - val_loss: 0.3922 - learning_rate: 0.0010  
140 Epoch 32/50  
141 782/782 ━━━━━━━━ 11s 15ms/step -  
accuracy: 0.9166 - loss: 0.3725 - val_accuracy: 0.  
9109 - val_loss: 0.3882 - learning_rate: 0.0010  
142 Epoch 33/50  
143 782/782 ━━━━━━━━ 11s 15ms/step -  
accuracy: 0.9173 - loss: 0.3676 - val_accuracy: 0.  
9107 - val_loss: 0.3887 - learning_rate: 0.0010  
144 Epoch 34/50  
145 782/782 ━━━━━━━━ 11s 15ms/step -  
accuracy: 0.9179 - loss: 0.3633 - val_accuracy: 0.  
9082 - val_loss: 0.3946 - learning_rate: 0.0010  
146 Epoch 35/50  
147 782/782 ━━━━━━━━ 11s 14ms/step -  
accuracy: 0.9187 - loss: 0.3607 - val_accuracy: 0.  
9118 - val_loss: 0.3859 - learning_rate: 0.0010  
148 Epoch 36/50  
149 782/782 ━━━━━━━━ 11s 15ms/step -  
accuracy: 0.9193 - loss: 0.3582 - val_accuracy: 0.  
9073 - val_loss: 0.3920 - learning_rate: 0.0010  
150 Epoch 37/50  
151 782/782 ━━━━━━━━ 11s 15ms/step -  
accuracy: 0.9200 - loss: 0.3557 - val_accuracy: 0.  
9120 - val_loss: 0.3835 - learning_rate: 0.0010  
152 Epoch 38/50  
153 782/782 ━━━━━━━━ 12s 15ms/step -  
accuracy: 0.9209 - loss: 0.3533 - val_accuracy: 0.  
9111 - val_loss: 0.3838 - learning_rate: 0.0010  
154 Epoch 39/50  
155 782/782 ━━━━━━━━ 12s 15ms/step -  
accuracy: 0.9207 - loss: 0.3517 - val_accuracy: 0.  
9121 - val_loss: 0.3783 - learning_rate: 0.0010  
156 Epoch 40/50  
157 782/782 ━━━━━━━━ 12s 15ms/step -  
accuracy: 0.9214 - loss: 0.3498 - val_accuracy: 0.
```

```
157 9121 - val_loss: 0.3814 - learning_rate: 0.0010
158 Epoch 41/50
159 779/782 ━━━━━━━━ 0s 14ms/step - accuracy
    : 0.9236 - loss: 0.3451
160 Epoch 41: ReduceLROnPlateau reducing learning rate
    to 0.0005000000237487257.
161 782/782 ━━━━━━━━ 11s 14ms/step -
    accuracy: 0.9222 - loss: 0.3490 - val_accuracy: 0.
    9112 - val_loss: 0.3815 - learning_rate: 0.0010
162 Epoch 42/50
163 782/782 ━━━━━━━━ 11s 14ms/step -
    accuracy: 0.9298 - loss: 0.3213 - val_accuracy: 0.
    9162 - val_loss: 0.3683 - learning_rate: 5.0000e-04
164 Epoch 43/50
165 782/782 ━━━━━━━━ 11s 14ms/step -
    accuracy: 0.9319 - loss: 0.3109 - val_accuracy: 0.
    9160 - val_loss: 0.3674 - learning_rate: 5.0000e-04
166 Epoch 44/50
167 782/782 ━━━━━━━━ 11s 14ms/step -
    accuracy: 0.9332 - loss: 0.3045 - val_accuracy: 0.
    9157 - val_loss: 0.3638 - learning_rate: 5.0000e-04
168 Epoch 45/50
169 782/782 ━━━━━━━━ 11s 14ms/step -
    accuracy: 0.9343 - loss: 0.3002 - val_accuracy: 0.
    9167 - val_loss: 0.3644 - learning_rate: 5.0000e-04
170 Epoch 46/50
171 782/782 ━━━━━━━━ 11s 14ms/step -
    accuracy: 0.9343 - loss: 0.2977 - val_accuracy: 0.
    9148 - val_loss: 0.3576 - learning_rate: 5.0000e-04
172 Epoch 47/50
173 782/782 ━━━━━━━━ 11s 14ms/step -
    accuracy: 0.9351 - loss: 0.2920 - val_accuracy: 0.
    9159 - val_loss: 0.3591 - learning_rate: 5.0000e-04
174 Epoch 48/50
175 782/782 ━━━━━━━━ 11s 14ms/step -
    accuracy: 0.9357 - loss: 0.2886 - val_accuracy: 0.
    9166 - val_loss: 0.3569 - learning_rate: 5.0000e-04
176 Epoch 49/50
177 781/782 ━━━━━━ 0s 14ms/step - accuracy
    : 0.9378 - loss: 0.2814
178 Epoch 49: ReduceLROnPlateau reducing learning rate
```

```
178 to 0.0002500000118743628.  
179 782/782 ————— 11s 14ms/step -  
accuracy: 0.9366 - loss: 0.2853 - val_accuracy: 0.  
9158 - val_loss: 0.3546 - learning_rate: 5.0000e-04  
180 Epoch 50/50  
181 782/782 ————— 11s 14ms/step -  
accuracy: 0.9413 - loss: 0.2690 - val_accuracy: 0.  
9168 - val_loss: 0.3509 - learning_rate: 2.5000e-04  
182 Точность логистической регрессии: ~85.0%  
183 Достигнутая точность базовой FCNN: 86.74%  
184 Финальная точность FCNN с L2, Dropout и динамической  
LR: 91.8000%  
185  
186 Process finished with exit code 0  
187
```