БЕЛОРУССКИЙ ГОСУДАРСТВЕННЫЙ УНИВЕРСИТЕТ

Факультет прикладной математики и информатики

ОТЧЕТ

по лабораторной работе № 5

«Keras»

по дисциплине «Программирование нейронных сетей»

Выполнила:

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Студента 3 курса 4 группы

2024

Первый запуск:

```
 Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/mnist.npz
 11490434/11490434 [==============================] - 0s 0us/step
 Model: "sequential"

  Layer (type)                Output Shape              Param #
 =================================================================
  dense (Dense)               (None, 800)               628000

  dense_1 (Dense)             (None, 10)                8010

 =================================================================
 Total params: 636010 (2.43 MB)
 Trainable params: 636010 (2.43 MB)
 Non-trainable params: 0 (0.00 Byte)
 _____
 None
 Epoch 1/10
 960/960 - 19s - loss: 0.7626 - accuracy: 0.8193 - val_loss: 0.4069 - val_accuracy: 0.8966 - 19s/epoch - 19ms/step
 Epoch 2/10
 960/960 - 11s - loss: 0.3867 - accuracy: 0.8963 - val_loss: 0.3252 - val_accuracy: 0.9122 - 11s/epoch - 11ms/step
 Epoch 3/10
 960/960 - 7s - loss: 0.3277 - accuracy: 0.9099 - val_loss: 0.2895 - val_accuracy: 0.9205 - 7s/epoch - 8ms/step
 Epoch 4/10
 960/960 - 6s - loss: 0.2954 - accuracy: 0.9186 - val_loss: 0.2691 - val_accuracy: 0.9255 - 6s/epoch - 7ms/step
 Epoch 5/10
 960/960 - 8s - loss: 0.2725 - accuracy: 0.9247 - val_loss: 0.2511 - val_accuracy: 0.9302 - 8s/epoch - 8ms/step
 Epoch 6/10
 960/960 - 9s - loss: 0.2543 - accuracy: 0.9300 - val_loss: 0.2377 - val_accuracy: 0.9338 - 9s/epoch - 9ms/step
 Epoch 7/10
 960/960 - 6s - loss: 0.2391 - accuracy: 0.9341 - val_loss: 0.2255 - val_accuracy: 0.9384 - 6s/epoch - 6ms/step
 Epoch 8/10
 960/960 - 8s - loss: 0.2260 - accuracy: 0.9383 - val_loss: 0.2154 - val_accuracy: 0.9413 - 8s/epoch - 8ms/step
 Epoch 9/10
 960/960 - 6s - loss: 0.2143 - accuracy: 0.9417 - val_loss: 0.2062 - val_accuracy: 0.9433 - 6s/epoch - 7ms/step
 Epoch 10/10
 960/960 - 7s - loss: 0.2039 - accuracy: 0.9439 - val_loss: 0.1981 - val_accuracy: 0.9457 - 7s/epoch - 8ms/step
 Точность работы на тестовых данных: 94.50%
 Сохранили Model
```

Для улучшения результатов качества обучения сети:

1) **Количество эпох обучения**

   Зафиксировали остальные гиперпараметры и оцениваем точность работы сети на обучающих и тестовых данных для каждого значения количества эпох

   Epochs=10:

Model: "sequential"

Layer (type)	Output Shape	Param #
dense (Dense)	(None, 800)	628000
dense_1 (Dense)	(None, 10)	8010

Total params: 636010 (2.43 MB)
Trainable params: 636010 (2.43 MB)
Non-trainable params: 0 (0.00 Byte)

None
Epoch 1/10
960/960 - 19s - loss: 0.7626 - accuracy: 0.8193 - val_loss: 0.4069 - val_accuracy: 0.8966 - 19s/epoch - 19ms/step
Epoch 2/10
960/960 - 11s - loss: 0.3867 - accuracy: 0.8963 - val_loss: 0.3252 - val_accuracy: 0.9122 - 11s/epoch - 11ms/step
Epoch 3/10
960/960 - 7s - loss: 0.3277 - accuracy: 0.9099 - val_loss: 0.2895 - val_accuracy: 0.9205 - 7s/epoch - 8ms/step
Epoch 4/10
960/960 - 6s - loss: 0.2954 - accuracy: 0.9186 - val_loss: 0.2691 - val_accuracy: 0.9255 - 6s/epoch - 7ms/step
Epoch 5/10
960/960 - 8s - loss: 0.2725 - accuracy: 0.9247 - val_loss: 0.2511 - val_accuracy: 0.9302 - 8s/epoch - 8ms/step
Epoch 6/10
960/960 - 9s - loss: 0.2543 - accuracy: 0.9300 - val_loss: 0.2377 - val_accuracy: 0.9338 - 9s/epoch - 9ms/step
Epoch 7/10
960/960 - 6s - loss: 0.2391 - accuracy: 0.9341 - val_loss: 0.2255 - val_accuracy: 0.9384 - 6s/epoch - 6ms/step
Epoch 8/10
960/960 - 8s - loss: 0.2260 - accuracy: 0.9383 - val_loss: 0.2154 - val_accuracy: 0.9413 - 8s/epoch - 8ms/step
Epoch 9/10
960/960 - 6s - loss: 0.2143 - accuracy: 0.9417 - val_loss: 0.2062 - val_accuracy: 0.9433 - 6s/epoch - 7ms/step
Epoch 10/10
960/960 - 7s - loss: 0.2039 - accuracy: 0.9439 - val_loss: 0.1981 - val_accuracy: 0.9457 - 7s/epoch - 8ms/step
Точность работы на тестовых данных: 94.50%
Сохранили Model

Epochs=15:

Epoch 1/15
960/960 - 8s - loss: 0.7434 - accuracy: 0.8240 - val_loss: 0.4044 - val_accuracy: 0.8947 - 8s/epoch - 9ms/step
Epoch 2/15
960/960 - 9s - loss: 0.3807 - accuracy: 0.8978 - val_loss: 0.3224 - val_accuracy: 0.9137 - 9s/epoch - 9ms/step
Epoch 3/15
960/960 - 7s - loss: 0.3234 - accuracy: 0.9111 - val_loss: 0.2889 - val_accuracy: 0.9231 - 7s/epoch - 7ms/step
Epoch 4/15
960/960 - 7s - loss: 0.2920 - accuracy: 0.9189 - val_loss: 0.2661 - val_accuracy: 0.9270 - 7s/epoch - 8ms/step
Epoch 5/15
960/960 - 7s - loss: 0.2696 - accuracy: 0.9250 - val_loss: 0.2496 - val_accuracy: 0.9312 - 7s/epoch - 7ms/step
Epoch 6/15
960/960 - 7s - loss: 0.2518 - accuracy: 0.9296 - val_loss: 0.2373 - val_accuracy: 0.9337 - 7s/epoch - 8ms/step
Epoch 7/15
960/960 - 9s - loss: 0.2372 - accuracy: 0.9340 - val_loss: 0.2249 - val_accuracy: 0.9383 - 9s/epoch - 9ms/step
Epoch 8/15
960/960 - 6s - loss: 0.2241 - accuracy: 0.9376 - val_loss: 0.2134 - val_accuracy: 0.9411 - 6s/epoch - 7ms/step
Epoch 9/15
960/960 - 8s - loss: 0.2128 - accuracy: 0.9414 - val_loss: 0.2048 - val_accuracy: 0.9441 - 8s/epoch - 8ms/step
Epoch 10/15
960/960 - 6s - loss: 0.2025 - accuracy: 0.9439 - val_loss: 0.1968 - val_accuracy: 0.9473 - 6s/epoch - 7ms/step
Epoch 11/15
960/960 - 7s - loss: 0.1931 - accuracy: 0.9467 - val_loss: 0.1906 - val_accuracy: 0.9477 - 7s/epoch - 8ms/step
Epoch 12/15
960/960 - 7s - loss: 0.1849 - accuracy: 0.9485 - val_loss: 0.1831 - val_accuracy: 0.9499 - 7s/epoch - 7ms/step
Epoch 13/15
960/960 - 7s - loss: 0.1771 - accuracy: 0.9509 - val_loss: 0.1768 - val_accuracy: 0.9516 - 7s/epoch - 8ms/step
Epoch 14/15
960/960 - 8s - loss: 0.1698 - accuracy: 0.9527 - val_loss: 0.1720 - val_accuracy: 0.9533 - 8s/epoch - 8ms/step
Epoch 15/15
960/960 - 7s - loss: 0.1634 - accuracy: 0.9548 - val_loss: 0.1660 - val_accuracy: 0.9544 - 7s/epoch - 7ms/step
Точность работы на тестовых данных: 95.44%

Epochs=20:

```
None
Epoch 1/20
960/960 - 9s - loss: 0.7562 - accuracy: 0.8167 - val_loss: 0.4027 - val_accuracy: 0.8967 - 9s/epoch - 9ms/step
Epoch 2/20
960/960 - 7s - loss: 0.3813 - accuracy: 0.8976 - val_loss: 0.3223 - val_accuracy: 0.9118 - 7s/epoch - 7ms/step
Epoch 3/20
960/960 - 7s - loss: 0.3228 - accuracy: 0.9108 - val_loss: 0.2867 - val_accuracy: 0.9225 - 7s/epoch - 7ms/step
Epoch 4/20
960/960 - 7s - loss: 0.2907 - accuracy: 0.9195 - val_loss: 0.2649 - val_accuracy: 0.9281 - 7s/epoch - 7ms/step
Epoch 5/20
960/960 - 8s - loss: 0.2685 - accuracy: 0.9256 - val_loss: 0.2479 - val_accuracy: 0.9336 - 8s/epoch - 8ms/step
Epoch 6/20
960/960 - 9s - loss: 0.2509 - accuracy: 0.9299 - val_loss: 0.2350 - val_accuracy: 0.9366 - 9s/epoch - 9ms/step
Epoch 7/20
960/960 - 7s - loss: 0.2360 - accuracy: 0.9348 - val_loss: 0.2223 - val_accuracy: 0.9393 - 7s/epoch - 7ms/step
Epoch 8/20
960/960 - 7s - loss: 0.2233 - accuracy: 0.9380 - val_loss: 0.2126 - val_accuracy: 0.9420 - 7s/epoch - 8ms/step
Epoch 9/20
960/960 - 7s - loss: 0.2119 - accuracy: 0.9409 - val_loss: 0.2040 - val_accuracy: 0.9456 - 7s/epoch - 7ms/step
Epoch 10/20
960/960 - 7s - loss: 0.2016 - accuracy: 0.9443 - val_loss: 0.1957 - val_accuracy: 0.9477 - 7s/epoch - 8ms/step
Epoch 11/20
960/960 - 7s - loss: 0.1922 - accuracy: 0.9466 - val_loss: 0.1892 - val_accuracy: 0.9487 - 7s/epoch - 7ms/step
```

```
Epoch 12/20
960/960 - 8s - loss: 0.1838 - accuracy: 0.9491 - val_loss: 0.1824 - val_accuracy: 0.9513 - 8s/epoch - 8ms/step
Epoch 13/20
960/960 - 8s - loss: 0.1760 - accuracy: 0.9513 - val_loss: 0.1760 - val_accuracy: 0.9537 - 8s/epoch - 9ms/step
Epoch 14/20
960/960 - 7s - loss: 0.1689 - accuracy: 0.9535 - val_loss: 0.1698 - val_accuracy: 0.9549 - 7s/epoch - 7ms/step
Epoch 15/20
960/960 - 8s - loss: 0.1624 - accuracy: 0.9548 - val_loss: 0.1659 - val_accuracy: 0.9557 - 8s/epoch - 8ms/step
Epoch 16/20
960/960 - 7s - loss: 0.1561 - accuracy: 0.9568 - val_loss: 0.1606 - val_accuracy: 0.9568 - 7s/epoch - 7ms/step
Epoch 17/20
960/960 - 8s - loss: 0.1504 - accuracy: 0.9586 - val_loss: 0.1565 - val_accuracy: 0.9587 - 8s/epoch - 9ms/step
Epoch 18/20
960/960 - 9s - loss: 0.1449 - accuracy: 0.9606 - val_loss: 0.1519 - val_accuracy: 0.9597 - 9s/epoch - 9ms/step
Epoch 19/20
960/960 - 7s - loss: 0.1400 - accuracy: 0.9618 - val_loss: 0.1487 - val_accuracy: 0.9607 - 7s/epoch - 7ms/step
Epoch 20/20
960/960 - 7s - loss: 0.1354 - accuracy: 0.9632 - val_loss: 0.1446 - val_accuracy: 0.9611 - 7s/epoch - 7ms/step
Точность работы на тестовых данных: 96.04%
```

Epochs=30:

```
None
Epoch 1/30
960/960 - 8s - loss: 0.7729 - accuracy: 0.8158 - val_loss: 0.4110 - val_accuracy: 0.8967 - 8s/epoch - 8ms/step
Epoch 2/30
960/960 - 7s - loss: 0.3876 - accuracy: 0.8960 - val_loss: 0.3269 - val_accuracy: 0.9118 - 7s/epoch - 7ms/step
Epoch 3/30
960/960 - 8s - loss: 0.3280 - accuracy: 0.9092 - val_loss: 0.2912 - val_accuracy: 0.9195 - 8s/epoch - 8ms/step
Epoch 4/30
960/960 - 6s - loss: 0.2958 - accuracy: 0.9174 - val_loss: 0.2688 - val_accuracy: 0.9242 - 6s/epoch - 7ms/step
Epoch 5/30
960/960 - 8s - loss: 0.2729 - accuracy: 0.9233 - val_loss: 0.2509 - val_accuracy: 0.9312 - 8s/epoch - 8ms/step
Epoch 6/30
960/960 - 7s - loss: 0.2551 - accuracy: 0.9286 - val_loss: 0.2374 - val_accuracy: 0.9348 - 7s/epoch - 7ms/step
Epoch 7/30
960/960 - 7s - loss: 0.2399 - accuracy: 0.9329 - val_loss: 0.2255 - val_accuracy: 0.9377 - 7s/epoch - 8ms/step
Epoch 8/30
960/960 - 9s - loss: 0.2268 - accuracy: 0.9367 - val_loss: 0.2157 - val_accuracy: 0.9404 - 9s/epoch - 9ms/step
Epoch 9/30
960/960 - 7s - loss: 0.2154 - accuracy: 0.9402 - val_loss: 0.2064 - val_accuracy: 0.9437 - 7s/epoch - 7ms/step
Epoch 10/30
960/960 - 9s - loss: 0.2050 - accuracy: 0.9427 - val_loss: 0.1984 - val_accuracy: 0.9458 - 9s/epoch - 9ms/step
Epoch 11/30
960/960 - 9s - loss: 0.1958 - accuracy: 0.9455 - val_loss: 0.1910 - val_accuracy: 0.9482 - 9s/epoch - 10ms/step
```

```
Epoch 12/30
960/960 - 7s - loss: 0.1870 - accuracy: 0.9473 - val_loss: 0.1838 - val_accuracy: 0.9503 - 7s/epoch - 7ms/step
Epoch 13/30
960/960 - 8s - loss: 0.1791 - accuracy: 0.9496 - val_loss: 0.1784 - val_accuracy: 0.9520 - 8s/epoch - 8ms/step
Epoch 14/30
960/960 - 7s - loss: 0.1719 - accuracy: 0.9521 - val_loss: 0.1718 - val_accuracy: 0.9524 - 7s/epoch - 7ms/step
Epoch 15/30
960/960 - 8s - loss: 0.1650 - accuracy: 0.9537 - val_loss: 0.1675 - val_accuracy: 0.9544 - 8s/epoch - 8ms/step
Epoch 16/30
960/960 - 8s - loss: 0.1589 - accuracy: 0.9555 - val_loss: 0.1621 - val_accuracy: 0.9563 - 8s/epoch - 8ms/step
Epoch 17/30
960/960 - 7s - loss: 0.1529 - accuracy: 0.9574 - val_loss: 0.1578 - val_accuracy: 0.9568 - 7s/epoch - 7ms/step
Epoch 18/30
960/960 - 8s - loss: 0.1475 - accuracy: 0.9593 - val_loss: 0.1535 - val_accuracy: 0.9588 - 8s/epoch - 8ms/step
Epoch 19/30
960/960 - 6s - loss: 0.1424 - accuracy: 0.9609 - val_loss: 0.1506 - val_accuracy: 0.9596 - 6s/epoch - 7ms/step
Epoch 20/30
960/960 - 8s - loss: 0.1376 - accuracy: 0.9626 - val_loss: 0.1468 - val_accuracy: 0.9594 - 8s/epoch - 8ms/step
Epoch 21/30
960/960 - 7s - loss: 0.1331 - accuracy: 0.9640 - val_loss: 0.1433 - val_accuracy: 0.9611 - 7s/epoch - 7ms/step
Epoch 22/30
960/960 - 7s - loss: 0.1290 - accuracy: 0.9647 - val_loss: 0.1393 - val_accuracy: 0.9624 - 7s/epoch - 8ms/step
```

```
Epoch 22/30
960/960 - 7s - loss: 0.1290 - accuracy: 0.9647 - val_loss: 0.1393 - val_accuracy: 0.9624 - 7s/epoch - 8ms/step
Epoch 23/30
960/960 - 9s - loss: 0.1250 - accuracy: 0.9665 - val_loss: 0.1376 - val_accuracy: 0.9615 - 9s/epoch - 9ms/step
Epoch 24/30
960/960 - 7s - loss: 0.1211 - accuracy: 0.9672 - val_loss: 0.1348 - val_accuracy: 0.9644 - 7s/epoch - 7ms/step
Epoch 25/30
960/960 - 7s - loss: 0.1175 - accuracy: 0.9685 - val_loss: 0.1318 - val_accuracy: 0.9647 - 7s/epoch - 8ms/step
Epoch 26/30
960/960 - 6s - loss: 0.1142 - accuracy: 0.9699 - val_loss: 0.1294 - val_accuracy: 0.9653 - 6s/epoch - 7ms/step
Epoch 27/30
960/960 - 7s - loss: 0.1109 - accuracy: 0.9702 - val_loss: 0.1266 - val_accuracy: 0.9664 - 7s/epoch - 8ms/step
Epoch 28/30
960/960 - 7s - loss: 0.1079 - accuracy: 0.9712 - val_loss: 0.1250 - val_accuracy: 0.9663 - 7s/epoch - 7ms/step
Epoch 29/30
960/960 - 7s - loss: 0.1049 - accuracy: 0.9720 - val_loss: 0.1230 - val_accuracy: 0.9668 - 7s/epoch - 8ms/step
Epoch 30/30
960/960 - 7s - loss: 0.1021 - accuracy: 0.9731 - val_loss: 0.1216 - val_accuracy: 0.9678 - 7s/epoch - 7ms/step
Точность работы на тестовых данных: 96.67%
```

Точность стала расти. Дальнейшие изменения могут привести к переобучению сети.

2) **Размер мини-выборки**
Больший размер мини-выборки может увеличить стабильность градиентного спуска и улучшить обобщающую способность сети
batch_size=32:

```
None
Epoch 1/10
1500/1500 - 12s - loss: 0.6302 - accuracy: 0.8466 - val_loss: 0.3465 - val_accuracy: 0.9076 - 12s/epoch - 8ms/step
Epoch 2/10
1500/1500 - 10s - loss: 0.3319 - accuracy: 0.9093 - val_loss: 0.2869 - val_accuracy: 0.9198 - 10s/epoch - 7ms/step
Epoch 3/10
1500/1500 - 8s - loss: 0.2828 - accuracy: 0.9220 - val_loss: 0.2522 - val_accuracy: 0.9293 - 8s/epoch - 6ms/step
Epoch 4/10
1500/1500 - 10s - loss: 0.2531 - accuracy: 0.9296 - val_loss: 0.2323 - val_accuracy: 0.9345 - 10s/epoch - 6ms/step
Epoch 5/10
1500/1500 - 9s - loss: 0.2304 - accuracy: 0.9358 - val_loss: 0.2136 - val_accuracy: 0.9420 - 9s/epoch - 6ms/step
Epoch 6/10
1500/1500 - 10s - loss: 0.2119 - accuracy: 0.9413 - val_loss: 0.2010 - val_accuracy: 0.9450 - 10s/epoch - 7ms/step
Epoch 7/10
1500/1500 - 9s - loss: 0.1966 - accuracy: 0.9452 - val_loss: 0.1879 - val_accuracy: 0.9509 - 9s/epoch - 6ms/step
Epoch 8/10
1500/1500 - 9s - loss: 0.1832 - accuracy: 0.9491 - val_loss: 0.1795 - val_accuracy: 0.9529 - 9s/epoch - 6ms/step
Epoch 9/10
1500/1500 - 9s - loss: 0.1714 - accuracy: 0.9523 - val_loss: 0.1706 - val_accuracy: 0.9549 - 9s/epoch - 6ms/step
Epoch 10/10
1500/1500 - 10s - loss: 0.1613 - accuracy: 0.9551 - val_loss: 0.1624 - val_accuracy: 0.9557 - 10s/epoch - 7ms/step
Точность работы на тестовых данных: 95.53%
```

batch_size=64:

```
None
Epoch 1/10
750/750 - 7s - loss: 0.8460 - accuracy: 0.8008 - val_loss: 0.4481 - val_accuracy: 0.8902 - 7s/epoch - 9ms/step
Epoch 2/10
750/750 - 7s - loss: 0.4181 - accuracy: 0.8908 - val_loss: 0.3489 - val_accuracy: 0.9068 - 7s/epoch - 9ms/step
Epoch 3/10
750/750 - 5s - loss: 0.3496 - accuracy: 0.9052 - val_loss: 0.3096 - val_accuracy: 0.9163 - 5s/epoch - 7ms/step
Epoch 4/10
750/750 - 7s - loss: 0.3146 - accuracy: 0.9132 - val_loss: 0.2850 - val_accuracy: 0.9210 - 7s/epoch - 9ms/step
Epoch 5/10
750/750 - 6s - loss: 0.2910 - accuracy: 0.9197 - val_loss: 0.2678 - val_accuracy: 0.9249 - 6s/epoch - 8ms/step
Epoch 6/10
750/750 - 7s - loss: 0.2727 - accuracy: 0.9249 - val_loss: 0.2546 - val_accuracy: 0.9302 - 7s/epoch - 9ms/step
Epoch 7/10
750/750 - 6s - loss: 0.2577 - accuracy: 0.9281 - val_loss: 0.2424 - val_accuracy: 0.9329 - 6s/epoch - 8ms/step
Epoch 8/10
750/750 - 7s - loss: 0.2448 - accuracy: 0.9318 - val_loss: 0.2322 - val_accuracy: 0.9356 - 7s/epoch - 9ms/step
Epoch 9/10
750/750 - 6s - loss: 0.2337 - accuracy: 0.9347 - val_loss: 0.2227 - val_accuracy: 0.9394 - 6s/epoch - 7ms/step
Epoch 10/10
750/750 - 7s - loss: 0.2235 - accuracy: 0.9377 - val_loss: 0.2144 - val_accuracy: 0.9406 - 7s/epoch - 9ms/step
Точность работы на тестовых данных: 94.01%
```

batch_size=128:

```
None
Epoch 1/10
375/375 - 5s - loss: 1.1134 - accuracy: 0.7447 - val_loss: 0.6126 - val_accuracy: 0.8683 - 5s/epoch - 12ms/step
Epoch 2/10
375/375 - 6s - loss: 0.5474 - accuracy: 0.8678 - val_loss: 0.4425 - val_accuracy: 0.8903 - 6s/epoch - 15ms/step
Epoch 3/10
375/375 - 4s - loss: 0.4403 - accuracy: 0.8863 - val_loss: 0.3807 - val_accuracy: 0.9024 - 4s/epoch - 11ms/step
Epoch 4/10
375/375 - 4s - loss: 0.3908 - accuracy: 0.8956 - val_loss: 0.3468 - val_accuracy: 0.9090 - 4s/epoch - 11ms/step
Epoch 5/10
375/375 - 5s - loss: 0.3602 - accuracy: 0.9023 - val_loss: 0.3249 - val_accuracy: 0.9120 - 5s/epoch - 14ms/step
Epoch 6/10
375/375 - 4s - loss: 0.3388 - accuracy: 0.9074 - val_loss: 0.3086 - val_accuracy: 0.9165 - 4s/epoch - 11ms/step
Epoch 7/10
375/375 - 4s - loss: 0.3223 - accuracy: 0.9115 - val_loss: 0.2958 - val_accuracy: 0.9198 - 4s/epoch - 11ms/step
Epoch 8/10
375/375 - 5s - loss: 0.3090 - accuracy: 0.9146 - val_loss: 0.2858 - val_accuracy: 0.9221 - 5s/epoch - 14ms/step
Epoch 9/10
375/375 - 4s - loss: 0.2976 - accuracy: 0.9176 - val_loss: 0.2773 - val_accuracy: 0.9241 - 4s/epoch - 11ms/step
Epoch 10/10
375/375 - 4s - loss: 0.2877 - accuracy: 0.9206 - val_loss: 0.2694 - val_accuracy: 0.9260 - 4s/epoch - 11ms/step
Точность работы на тестовых данных: 92.55%
Сохранили Model
```

Большие мини-пакеты могут содержать больше разнообразия в данных и захватывать большее количество различных шаблонов. В результате градиенты, вычисленные на основе этих мини-пакетов, могут содержать больше шума и быть менее точными. Это может затруднить сходимость модели и привести к ухудшению точности предсказаний

3) **Количество нейронов во входном слое**
   Dense(**512**, input_dim=784, activation="relu", kernel_initializer="normal"):

```
None
Epoch 1/10
1500/1500 - 8s - loss: 0.7016 - accuracy: 0.8320 - val_loss: 0.3695 - val_accuracy: 0.9029 - 8s/epoch - 5ms/step
Epoch 2/10
1500/1500 - 7s - loss: 0.3558 - accuracy: 0.9021 - val_loss: 0.3023 - val_accuracy: 0.9159 - 7s/epoch - 5ms/step
Epoch 3/10
1500/1500 - 8s - loss: 0.3032 - accuracy: 0.9145 - val_loss: 0.2697 - val_accuracy: 0.9254 - 8s/epoch - 5ms/step
Epoch 4/10
1500/1500 - 7s - loss: 0.2719 - accuracy: 0.9246 - val_loss: 0.2464 - val_accuracy: 0.9319 - 7s/epoch - 4ms/step
Epoch 5/10
1500/1500 - 8s - loss: 0.2483 - accuracy: 0.9300 - val_loss: 0.2298 - val_accuracy: 0.9358 - 8s/epoch - 5ms/step
Epoch 6/10
1500/1500 - 8s - loss: 0.2293 - accuracy: 0.9360 - val_loss: 0.2149 - val_accuracy: 0.9409 - 8s/epoch - 5ms/step
Epoch 7/10
1500/1500 - 7s - loss: 0.2131 - accuracy: 0.9407 - val_loss: 0.2026 - val_accuracy: 0.9441 - 7s/epoch - 5ms/step
Epoch 8/10
1500/1500 - 8s - loss: 0.1992 - accuracy: 0.9442 - val_loss: 0.1922 - val_accuracy: 0.9482 - 8s/epoch - 5ms/step
Epoch 9/10
1500/1500 - 7s - loss: 0.1869 - accuracy: 0.9480 - val_loss: 0.1858 - val_accuracy: 0.9498 - 7s/epoch - 4ms/step
Epoch 10/10
1500/1500 - 8s - loss: 0.1762 - accuracy: 0.9506 - val_loss: 0.1739 - val_accuracy: 0.9531 - 8s/epoch - 5ms/step
Точность работы на тестовых данных: 95.07%
Сохранили Model
```

Dense(**1024**, input_dim=784, activation="relu", kernel_initializer="normal"):

```
None
Epoch 1/10
1500/1500 - 13s - loss: 0.6028 - accuracy: 0.8476 - val_loss: 0.3393 - val_accuracy: 0.9097 - 13s/epoch - 8ms/step
Epoch 2/10
1500/1500 - 11s - loss: 0.3227 - accuracy: 0.9117 - val_loss: 0.2781 - val_accuracy: 0.9237 - 11s/epoch - 8ms/step
Epoch 3/10
1500/1500 - 12s - loss: 0.2736 - accuracy: 0.9240 - val_loss: 0.2485 - val_accuracy: 0.9308 - 12s/epoch - 8ms/step
Epoch 4/10
1500/1500 - 12s - loss: 0.2437 - accuracy: 0.9322 - val_loss: 0.2267 - val_accuracy: 0.9368 - 12s/epoch - 8ms/step
Epoch 5/10
1500/1500 - 12s - loss: 0.2212 - accuracy: 0.9387 - val_loss: 0.2094 - val_accuracy: 0.9419 - 12s/epoch - 8ms/step
Epoch 6/10
1500/1500 - 10s - loss: 0.2033 - accuracy: 0.9432 - val_loss: 0.1954 - val_accuracy: 0.9474 - 10s/epoch - 7ms/step
Epoch 7/10
1500/1500 - 11s - loss: 0.1879 - accuracy: 0.9485 - val_loss: 0.1845 - val_accuracy: 0.9501 - 11s/epoch - 8ms/step
Epoch 8/10
1500/1500 - 11s - loss: 0.1748 - accuracy: 0.9517 - val_loss: 0.1752 - val_accuracy: 0.9517 - 11s/epoch - 8ms/step
Epoch 9/10
1500/1500 - 11s - loss: 0.1635 - accuracy: 0.9546 - val_loss: 0.1660 - val_accuracy: 0.9556 - 11s/epoch - 7ms/step
Epoch 10/10
1500/1500 - 11s - loss: 0.1538 - accuracy: 0.9576 - val_loss: 0.1589 - val_accuracy: 0.9562 - 11s/epoch - 8ms/step
Точность работы на тестовых данных: 95.48%
Сохранили Model
```

Dense(**2048**, input_dim=784, activation="relu", kernel_initializer="normal"):

```
None
Epoch 1/10
1500/1500 - 21s - loss: 0.4887 - accuracy: 0.8710 - val_loss: 0.2954 - val_accuracy: 0.9183 - 21s/epoch - 14ms/step
Epoch 2/10
1500/1500 - 19s - loss: 0.2815 - accuracy: 0.9228 - val_loss: 0.2450 - val_accuracy: 0.9315 - 19s/epoch - 13ms/step
Epoch 3/10
1500/1500 - 19s - loss: 0.2381 - accuracy: 0.9339 - val_loss: 0.2151 - val_accuracy: 0.9411 - 19s/epoch - 13ms/step
Epoch 4/10
1500/1500 - 19s - loss: 0.2103 - accuracy: 0.9421 - val_loss: 0.1965 - val_accuracy: 0.9466 - 19s/epoch - 13ms/step
Epoch 5/10
1500/1500 - 19s - loss: 0.1899 - accuracy: 0.9481 - val_loss: 0.1816 - val_accuracy: 0.9514 - 19s/epoch - 13ms/step
Epoch 6/10
1500/1500 - 19s - loss: 0.1736 - accuracy: 0.9526 - val_loss: 0.1699 - val_accuracy: 0.9548 - 19s/epoch - 13ms/step
Epoch 7/10
1500/1500 - 19s - loss: 0.1599 - accuracy: 0.9561 - val_loss: 0.1606 - val_accuracy: 0.9573 - 19s/epoch - 13ms/step
Epoch 8/10
1500/1500 - 18s - loss: 0.1481 - accuracy: 0.9596 - val_loss: 0.1536 - val_accuracy: 0.9592 - 18s/epoch - 12ms/step
Epoch 9/10
1500/1500 - 19s - loss: 0.1379 - accuracy: 0.9624 - val_loss: 0.1457 - val_accuracy: 0.9608 - 19s/epoch - 13ms/step
Epoch 10/10
1500/1500 - 19s - loss: 0.1294 - accuracy: 0.9656 - val_loss: 0.1399 - val_accuracy: 0.9627 - 19s/epoch - 12ms/step
Точность работы на тестовых данных: 96.22%
Сохранили Model
```

4) Количество скрытых слоев

Добавляем второй слой

```
model.add(Dense(500, activation="relu", kernel_initializer="normal"))
```

```
None
Epoch 1/10
1500/1500 - 18s - loss: 0.5777 - accuracy: 0.8540 - val_loss: 0.2989 - val_accuracy: 0.9186 - 18s/epoch - 12ms/step
Epoch 2/10
1500/1500 - 17s - loss: 0.2813 - accuracy: 0.9197 - val_loss: 0.2408 - val_accuracy: 0.9330 - 17s/epoch - 11ms/step
Epoch 3/10
1500/1500 - 17s - loss: 0.2288 - accuracy: 0.9352 - val_loss: 0.2014 - val_accuracy: 0.9447 - 17s/epoch - 11ms/step
Epoch 4/10
1500/1500 - 17s - loss: 0.1951 - accuracy: 0.9444 - val_loss: 0.1783 - val_accuracy: 0.9499 - 17s/epoch - 11ms/step
Epoch 5/10
1500/1500 - 17s - loss: 0.1695 - accuracy: 0.9521 - val_loss: 0.1633 - val_accuracy: 0.9541 - 17s/epoch - 11ms/step
Epoch 6/10
1500/1500 - 17s - loss: 0.1496 - accuracy: 0.9575 - val_loss: 0.1480 - val_accuracy: 0.9580 - 17s/epoch - 11ms/step
Epoch 7/10
1500/1500 - 17s - loss: 0.1332 - accuracy: 0.9630 - val_loss: 0.1412 - val_accuracy: 0.9601 - 17s/epoch - 11ms/step
Epoch 8/10
1500/1500 - 17s - loss: 0.1201 - accuracy: 0.9666 - val_loss: 0.1329 - val_accuracy: 0.9617 - 17s/epoch - 11ms/step
Epoch 9/10
1500/1500 - 17s - loss: 0.1087 - accuracy: 0.9701 - val_loss: 0.1223 - val_accuracy: 0.9658 - 17s/epoch - 11ms/step
Epoch 10/10
1500/1500 - 17s - loss: 0.0989 - accuracy: 0.9725 - val_loss: 0.1156 - val_accuracy: 0.9671 - 17s/epoch - 11ms/step
Точность работы на тестовых данных: 96.66%
```

Добавляем третий слой

```
model.add(Dense(300, activation="relu", kernel_initializer="normal"))
```

```
None
Epoch 1/10
1500/1500 - 20s - loss: 0.6271 - accuracy: 0.8384 - val_loss: 0.2935 - val_accuracy: 0.9130 - 20s/epoch - 13ms/step
Epoch 2/10
1500/1500 - 19s - loss: 0.2644 - accuracy: 0.9239 - val_loss: 0.2154 - val_accuracy: 0.9385 - 19s/epoch - 12ms/step
Epoch 3/10
1500/1500 - 19s - loss: 0.2048 - accuracy: 0.9412 - val_loss: 0.1816 - val_accuracy: 0.9478 - 19s/epoch - 13ms/step
Epoch 4/10
1500/1500 - 19s - loss: 0.1659 - accuracy: 0.9523 - val_loss: 0.1607 - val_accuracy: 0.9544 - 19s/epoch - 12ms/step
Epoch 5/10
1500/1500 - 19s - loss: 0.1395 - accuracy: 0.9599 - val_loss: 0.1391 - val_accuracy: 0.9604 - 19s/epoch - 13ms/step
Epoch 6/10
Epoch 7/10
1500/1500 - 19s - loss: 0.1033 - accuracy: 0.9710 - val_loss: 0.1181 - val_accuracy: 0.9659 - 19s/epoch - 13ms/step
Epoch 8/10
1500/1500 - 21s - loss: 0.0909 - accuracy: 0.9743 - val_loss: 0.1097 - val_accuracy: 0.9692 - 21s/epoch - 14ms/step
Epoch 9/10
1500/1500 - 19s - loss: 0.0794 - accuracy: 0.9776 - val_loss: 0.1065 - val_accuracy: 0.9684 - 19s/epoch - 12ms/step
Epoch 10/10
1500/1500 - 19s - loss: 0.0702 - accuracy: 0.9805 - val_loss: 0.1035 - val_accuracy: 0.9696 - 19s/epoch - 13ms/step
Точность работы на тестовых данных: 96.91%
Сохранили Model
```

Лучший результат:

```
None
Epoch 1/10
1500/1500 - 20s - loss: 0.6271 - accuracy: 0.8384 - val_loss: 0.2935 - val_accuracy: 0.9130 - 20s/epoch - 13ms/step
Epoch 2/10
1500/1500 - 19s - loss: 0.2644 - accuracy: 0.9239 - val_loss: 0.2154 - val_accuracy: 0.9385 - 19s/epoch - 12ms/step
Epoch 3/10
1500/1500 - 19s - loss: 0.2048 - accuracy: 0.9412 - val_loss: 0.1816 - val_accuracy: 0.9478 - 19s/epoch - 13ms/step
Epoch 4/10
1500/1500 - 19s - loss: 0.1659 - accuracy: 0.9523 - val_loss: 0.1607 - val_accuracy: 0.9544 - 19s/epoch - 12ms/step
Epoch 5/10
1500/1500 - 19s - loss: 0.1395 - accuracy: 0.9599 - val_loss: 0.1391 - val_accuracy: 0.9604 - 19s/epoch - 13ms/step
Epoch 6/10
Epoch 7/10
1500/1500 - 19s - loss: 0.1033 - accuracy: 0.9710 - val_loss: 0.1181 - val_accuracy: 0.9659 - 19s/epoch - 13ms/step
Epoch 8/10
1500/1500 - 21s - loss: 0.0909 - accuracy: 0.9743 - val_loss: 0.1097 - val_accuracy: 0.9692 - 21s/epoch - 14ms/step
Epoch 9/10
1500/1500 - 19s - loss: 0.0794 - accuracy: 0.9776 - val_loss: 0.1065 - val_accuracy: 0.9684 - 19s/epoch - 12ms/step
Epoch 10/10
1500/1500 - 19s - loss: 0.0702 - accuracy: 0.9805 - val_loss: 0.1035 - val_accuracy: 0.9696 - 19s/epoch - 13ms/step
Точность работы на тестовых данных: 96.91%
Сохранили Model
```