Практическое задание №1

Установка необходимых пакетов:

```
!pip install -q tqdm
!pip install --upgrade --no-cache-dir gdown
```

```
Requirement already satisfied: gdown in /usr/local/lib/python3.10/dist-packages (4.6.
Collecting gdown
  Downloading gdown-4.7.1-py3-none-any.whl (15 kB)
Requirement already satisfied: filelock in /usr/local/lib/python3.10/dist-packages (f
Requirement already satisfied: requests[socks] in /usr/local/lib/python3.10/dist-pack
Requirement already satisfied: six in /usr/local/lib/python3.10/dist-packages (from g
Requirement already satisfied: tqdm in /usr/local/lib/python3.10/dist-packages (from
Requirement already satisfied: beautifulsoup4 in /usr/local/lib/python3.10/dist-packa
Requirement already satisfied: soupsieve>1.2 in /usr/local/lib/python3.10/dist-packag
Requirement already satisfied: charset-normalizer<4,>=2 in /usr/local/lib/python3.10/
Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.10/dist-package
Requirement already satisfied: urllib3<3,>=1.21.1 in /usr/local/lib/python3.10/dist-p
Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3.10/dist-p
Requirement already satisfied: PySocks!=1.5.7,>=1.5.6 in /usr/local/lib/python3.10/di
Installing collected packages: gdown
  Attempting uninstall: gdown
    Found existing installation: gdown 4.6.6
    Uninstalling gdown-4.6.6:
      Successfully uninstalled gdown-4.6.6
Successfully installed gdown-4.7.1
```

Монтирование Вашего Google Drive к текущему окружению:

```
from google.colab import drive
drive.mount('/content/drive', force_remount=True)
```

```
Mounted at /content/drive
```

Константы, которые пригодятся в коде далее, и ссылки (gdrive идентификаторы) на предоставляемые наборы данных:

```
EVALUATE_ONLY = True
TEST_ON_LARGE_DATASET = True
TISSUE_CLASSES = ('ADI', 'BACK', 'DEB', 'LYM', 'MUC', 'MUS', 'NORM', 'STR', 'TUM')
DATASETS_LINKS = {
    'train': '1XtQzVQ5XbrfxpLHJuL0XBGJ5U7CS-cLi',
    'train_small': '1qd45xXfDwdZjktLFwQb-et-mAaFeCzOR',
    'train_tiny': '1I-2ZOuXLd4QwhZQQltp817Kn3J0Xgbui',
```

```
    'train_tiny': '1I-2ZOuXLd4QwhZQQltp817Kn3J0Xgbui',
    'test': '1RfPou3pFKpuHDJZ-D9XDFzgvwpUBFlDr',
    'test_small': '1wbRsog0n7uGlHIPGLhyN-PMeT2kdQ2lI',
    'test_tiny': '1viiB0s041CNsAK4itvX8PnYthJ-MDnQc'
}
```

Импорт необходимых зависимостей:

```
from pathlib import Path
import numpy as np
from typing import List
from tqdm.notebook import tqdm
from time import sleep
from PIL import Image
import IPython.display
from sklearn.metrics import balanced_accuracy_score
import gdown
import tensorflow as tf
```

Класс Dataset

Предназначен для работы с наборами данных, обеспечивает чтение изображений и соответствующих меток, а также формирование пакетов (батчей).

```
class Dataset:

    def __init__(self, name):
        self.name = name
        self.is_loaded = False
        url = f"https://drive.google.com/uc?export=download&confirm=pbef&id={DATASETS_LIN
        output = f'{name}.npz'
        gdown.download(url, output, quiet=False)
        print(f'Loading dataset {self.name} from npz.')
        np_obj = np.load(f'{name}.npz')
        self.images = np_obj['data']
        self.labels = np_obj['labels']
        self.n_files = self.images.shape[0]
        self.is_loaded = True
        print(f'Done. Dataset {name} consists of {self.n_files} images.')

    def image(self, i):
        # read i-th image in dataset and return it as numpy array
        if self.is_loaded:
            return self.images[i, :, :, :]

    def images_seq(self, n=None):
        # sequential access to images inside dataset (is needed for testing)
```

```
        for i in range(self.n_files if not n else n):
            yield self.image(i)

    def random_image_with_label(self):
        # get random image with label from dataset
        i = np.random.randint(self.n_files)
        return self.image(i), self.labels[i]

    def random_batch_with_labels(self, n):
        # create random batch of images with labels (is needed for training)
        indices = np.random.choice(self.n_files, n)
        imgs = []
        for i in indices:
            img = self.image(i)
            imgs.append(self.image(i))
        logits = np.array([self.labels[i] for i in indices])
        return np.stack(imgs), logits

    def image_with_label(self, i: int):
        # return i-th image with label from dataset
        return self.image(i), self.labels[i]
```

Пример использвания класса Dataset

Загрузим обучающий набор данных, получим произвольное изображение с меткой. После чего визуализируем изображение, выведем метку. В будущем, этот кусок кода можно закомментировать или убрать.

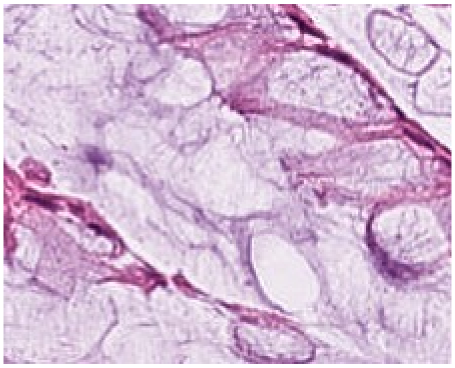
```
d_train_tiny = Dataset('train_tiny')

img, lbl = d_train_tiny.random_image_with_label()
print()
print(f'Got numpy array of shape {img.shape}, and label with code {lbl}.')
print(f'Label code corresponds to {TISSUE_CLASSES[lbl]} class.')

pil_img = Image.fromarray(img)
IPython.display.display(pil_img)
```

```
Downloading...
From: https://drive.google.com/uc?export=download&confirm=pbef&id=1I-2ZOuXLd4QwhZQQlt
To: /content/train_tiny.npz
100%|██████████| 105M/105M [00:00<00:00, 118MB/s]
Loading dataset train_tiny from npz.
Done. Dataset train_tiny consists of 900 images.

Got numpy array of shape (224, 224, 3), and label with code 6.
Label code corresponds to NORM class.
```



Класс Metrics

Реализует метрики точности, используемые для оценивания модели:

1. точность,
2. сбалансированную точность.

```
class Metrics:

    @staticmethod
    def accuracy(gt: List[int], pred: List[int]):
        assert len(gt) == len(pred), 'gt and prediction should be of equal length'
        return sum(int(i[0] == i[1]) for i in zip(gt, pred)) / len(gt)

    @staticmethod
    def accuracy_balanced(gt: List[int], pred: List[int]):
        return balanced_accuracy_score(gt, pred)

    @staticmethod
    def print_all(gt: List[int], pred: List[int], info: str):
        print(f'metrics for {info}:')
        print('\t accuracy {:.4f}:'.format(Metrics.accuracy(gt, pred)))
        print('\t balanced accuracy {:.4f}:'.format(Metrics.accuracy_balanced(gt, pred)))
```

Класс Model

Класс, хранящий в себе всю информацию о модели.

Вам необходимо реализовать методы save, load для сохранения и заргрузки модели. Особенно актуально это будет во время тестирования на дополнительных наборах данных.

> *Пожалуйста, убедитесь, что сохранение и загрузка модели работает корректно. Для этого обучите модель, протестируйте, сохраните ее в файл,*

> *корректно. Для этого обучите модель, протестируйте, сохраните ее в файл, перезапустите среду выполнения, загрузите обученную модель из файла, вновь протестируйте ее на тестовой выборке и убедитесь в том, что получаемые метрики совпадают с полученными для тестовой выбрки ранее.*

Также, Вы можете реализовать дополнительные функции, такие как:

1. валидацию модели на части обучающей выборки;
2. использование кроссвалидации;
3. автоматическое сохранение модели при обучении;
4. загрузку модели с какой-то конкретной итерации обучения (если используется итеративное обучение);
5. вывод различных показателей в процессе обучения (например, значение функции потерь на каждой эпохе);
6. построение графиков, визуализирующих процесс обучения (например, график зависимости функции потерь от номера эпохи обучения);
7. автоматическое тестирование на тестовом наборе/наборах данных после каждой эпохи обучения (при использовании итеративного обучения);
8. автоматический выбор гиперпараметров модели во время обучения;
9. сохранение и визуализацию результатов тестирования;
10. Использование аугментации и других способов синтетического расширения набора данных (дополнительным плюсом будет обоснование необходимости и обоснование выбора конкретных типов аугментации)
11. и т.д.

Полный список опций и дополнений приведен в презентации с описанием задания.

При реализации дополнительных функций допускается добавление параметров в существующие методы и добавление новых методов в класс модели.

```
class Model:

    def __init__(self, input_shape=(224, 224, 3), num_classes=9):
        self.model = self.model1(input_shape, num_classes)


    def model1(self, input_shape, num_classes):
        base = tf.keras.applications.ResNet101V2(weights='imagenet', include_top=False, i
        model = tf.keras.models.Sequential([base, tf.keras.layers.GlobalAveragePooling2D(
        return model
```

```
    def save(self, name: str):
        self.model.save(f'{name}.h5')

        # todo
        # pass
        # example demonstrating saving the model to PROJECT_DIR folder on gdrive with nam
        #arr = np.array([1, 2, 3, 4, 5], dtype=np.float32)
        #np.savez(f'/content/drive/MyDrive/{name}.npz', data=arr)

    def load(self, name: str):
        # todo
        #pass
        # example demonstrating loading the model with name 'name' from gdrive using link
        name_to_id_dict = {
            'best_last': '1vNk3nybza57Vu2vbIdD-ZOC8uGDkNRuO',
            'best_small':'1-39DXzB7Mv1_qXIKrpv1vSN8keNRUKlH',
            'best_tiny': '1jA5LOMT6H7-s4QaUQjsDkLUN1sYNw7AI'
        }
  #      output = f'{name}.npz'
  #      gdown.download(f'https://drive.google.com/uc?id={name_to_id_dict[name]}', output
 #       np_obj = np.load(f'{name}.npz')
 #       print(np_obj['data'])

        link = f"https://drive.google.com/uc?export=download&id={name_to_id_dict.get(name
        gdown.download(link, f'{name}.h5', quiet=False)
        self.model.load_weights(f'{name}.h5')



    def train(self, dataset: Dataset, epochs=10, batch_size=64):
        print(f'training started')
        self.model.compile(optimizer=tf.keras.optimizers.Adam(), loss='sparse_categorical
        self.model.fit(dataset.images, dataset.labels, epochs=epochs, batch_size=batch_si
        print(f'training done')


    def test_on_dataset(self, dataset: Dataset, limit=None):
        # you can upgrade this code if you want to speed up testing using batches
        predictions = []
        n = dataset.n_files if not limit else int(dataset.n_files * limit)
        for i in tqdm(range(n)):
            img, label = dataset.image_with_label(i)
            predictions.append(self.test_on_image(img))

        return predictions

    def test_on_image(self, img: np.ndarray):
        prediction = self.model.predict(np.expand_dims(img, axis=0))[0]
        return np.argmax(prediction)
```

Классификация изображений

Используя введенные выше классы можем перейти уже непосредственно к обучению модели классификации изображений. Пример общего пайплайна решения задачи приведен ниже. Вы можете его расширять и улучшать. В данном примере используются наборы данных 'train_tiny' и 'test_tiny'.

```
d_train_tiny = Dataset('train_tiny')
#d_test = Dataset('test')
```

```
Downloading...
From: https://drive.google.com/uc?export=download&confirm=pbef&id=1I-2ZOuXLd4QwhZQQlt
To: /content/train_tiny.npz
100%|██████████| 105M/105M [00:00<00:00, 135MB/s]
Loading dataset train_tiny from npz.
Done. Dataset train_tiny consists of 900 images.
```

```
model = Model()
```

```
model.train(d_train_tiny)
model.save('/content/drive/My Drive/Colab Notebooks/best_tiny')
```

```
training started
Epoch 1/10
15/15 [==============================] - 88s 929ms/step - loss: 1.0581 - accuracy: 0.
Epoch 2/10
15/15 [==============================] - 13s 853ms/step - loss: 1.0652 - accuracy: 0.
Epoch 3/10
15/15 [==============================] - 13s 871ms/step - loss: 0.6257 - accuracy: 0.
Epoch 4/10
15/15 [==============================] - 13s 888ms/step - loss: 0.5175 - accuracy: 0.
Epoch 5/10
15/15 [==============================] - 14s 918ms/step - loss: 0.6645 - accuracy: 0.
Epoch 6/10
15/15 [==============================] - 14s 912ms/step - loss: 0.4607 - accuracy: 0.
Epoch 7/10
15/15 [==============================] - 13s 888ms/step - loss: 0.4352 - accuracy: 0.
Epoch 8/10
15/15 [==============================] - 13s 878ms/step - loss: 0.4233 - accuracy: 0.
Epoch 9/10
15/15 [==============================] - 13s 877ms/step - loss: 0.2517 - accuracy: 0.
```

```
Epoch 10/10
15/15 [==============================] - 13s 886ms/step - loss: 0.1778 - accuracy: 0.
training done
/usr/local/lib/python3.10/dist-packages/keras/src/engine/training.py:3079: UserWarnir
  saving_api.save_model(
```

```
d_train_small = Dataset('train_small')
```

```
Downloading...
From: https://drive.google.com/uc?export=download&confirm=pbef&id=1qd45xXfDwdZjktLFwQ
To: /content/train_small.npz
100%|██████████| 841M/841M [00:13<00:00, 62.9MB/s]
Loading dataset train_small from npz.
Done. Dataset train_small consists of 7200 images.
```

```
model = Model()
model.load('best_tiny')  # Loading the weights from the previous step
model.train(d_train_small)
model.save('/content/drive/My Drive/Colab Notebooks/best_small')
```

```
Downloading...
From (uriginal): https://drive.google.com/uc?export=download&id=1jA5LOMT6H7-s4QaUQjsD
From (redirected): https://drive.google.com/uc?export=download&id=1jA5LOMT6H7-s4QaUQj
To: /content/best_tiny.h5
100%|██████████| 512M/512M [00:04<00:00, 110MB/s]
training started
Epoch 1/10
113/113 [==============================] - 165s 991ms/step - loss: 0.4464 - accuracy:
Epoch 2/10
113/113 [==============================] - 107s 942ms/step - loss: 0.2408 - accuracy:
Epoch 3/10
113/113 [==============================] - 107s 944ms/step - loss: 0.1598 - accuracy:
Epoch 4/10
113/113 [==============================] - 106s 942ms/step - loss: 0.1340 - accuracy:
Epoch 5/10
113/113 [==============================] - 106s 942ms/step - loss: 0.1144 - accuracy:
Epoch 6/10
113/113 [==============================] - 106s 942ms/step - loss: 0.1306 - accuracy:
Epoch 7/10
113/113 [==============================] - 106s 941ms/step - loss: 0.0714 - accuracy:
Epoch 8/10
113/113 [==============================] - 106s 940ms/step - loss: 0.0553 - accuracy:
Epoch 9/10
113/113 [==============================] - 106s 941ms/step - loss: 0.0458 - accuracy:
Epoch 10/10
113/113 [==============================] - 106s 942ms/step - loss: 0.0397 - accuracy:
training done
```

```
d_train = Dataset('train')
```

```
Downloading...
From: https://drive.google.com/uc?export=download&confirm=pbef&id=1XtQzVQ5XbrfxpLHJuL
To: /content/train.npz
```

```
To: /content/train.npz
100%|██████████| 2.10G/2.10G [00:21<00:00, 97.4MB/s]
Loading dataset train from npz.
Done. Dataset train consists of 18000 images.
```

```
model = Model()
model.load('best_small')  # Loading the weights from the previous step
model.train(d_train)
model.save('/content/drive/My Drive/Colab Notebooks/best_last')
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-applications/re
171317808/171317808 [==============================] - 1s 0us/step
Downloading...
From (uriginal): https://drive.google.com/uc?export=download&id=1-39DXzB7Mv1_qXIKrpv1
From (redirected): https://drive.google.com/uc?export=download&id=1-39DXzB7Mv1_qXIKrp
To: /content/best_small.h5
100%|██████████| 512M/512M [00:04<00:00, 107MB/s]
training started
Epoch 1/10
282/282 [==============================] - 353s 1s/step - loss: 0.1346 - accuracy: 0.
Epoch 2/10
282/282 [==============================] - 285s 1s/step - loss: 0.0983 - accuracy: 0.
Epoch 3/10
282/282 [==============================] - 285s 1s/step - loss: 0.0684 - accuracy: 0.
Epoch 4/10
282/282 [==============================] - 285s 1s/step - loss: 0.0600 - accuracy: 0.
Epoch 5/10
282/282 [==============================] - 285s 1s/step - loss: 0.0573 - accuracy: 0.
Epoch 6/10
282/282 [==============================] - 284s 1s/step - loss: 0.0445 - accuracy: 0.
Epoch 7/10
282/282 [==============================] - 285s 1s/step - loss: 0.0228 - accuracy: 0.
Epoch 8/10
282/282 [==============================] - 285s 1s/step - loss: 0.0420 - accuracy: 0.
Epoch 9/10
282/282 [==============================] - 286s 1s/step - loss: 0.0355 - accuracy: 0.
Epoch 10/10
282/282 [==============================] - 285s 1s/step - loss: 0.0245 - accuracy: 0.
training done
/usr/local/lib/python3.10/dist-packages/keras/src/engine/training.py:3079: UserWarnir
  saving_api.save_model(
```

Пример тестирования модели на части набора данных:

```
model = Model()
model.load('best_last')

# evaluating model on 10% of test dataset
d_test = Dataset('test')
pred_1 = model.test_on_dataset(d_test, limit=0.1)
Metrics.print_all(d_test.labels[:len(pred_1)], pred_1, '10% of test')
```

```
Downloading...
```

```
From (uriginal): https://drive.google.com/uc?export=download&id=1vNk3nybza57Vu2vbIdD-
From (redirected): https://drive.google.com/uc?export=download&id=1vNk3nybza57Vu2vbIc
To: /content/best_last.h5
100%|██████████| 512M/512M [00:04<00:00, 115MB/s]
Downloading...
From: https://drive.google.com/uc?export=download&confirm=pbef&id=1RfPou3pFKpuHDJZ-D9
To: /content/test.npz
100%|██████████| 525M/525M [00:10<00:00, 49.3MB/s]
Loading dataset test from npz.
Done. Dataset test consists of 4500 images.
```

100% 450/450 [00:53<00:00, 11.99it/s]

```
1/1 [==============================] - 4s 4s/step
1/1 [==============================] - 0s 43ms/step
1/1 [==============================] - 0s 37ms/step
1/1 [==============================] - 0s 44ms/step
1/1 [==============================] - 0s 44ms/step
1/1 [==============================] - 0s 46ms/step
1/1 [==============================] - 0s 47ms/step
1/1 [==============================] - 0s 43ms/step
1/1 [==============================] - 0s 42ms/step
1/1 [==============================] - 0s 47ms/step
1/1 [==============================] - 0s 49ms/step
1/1 [==============================] - 0s 42ms/step
1/1 [==============================] - 0s 42ms/step
1/1 [==============================] - 0s 39ms/step
1/1 [==============================] - 0s 43ms/step
1/1 [==============================] - 0s 38ms/step
1/1 [==============================] - 0s 37ms/step
1/1 [==============================] - 0s 44ms/step
1/1 [==============================] - 0s 47ms/step
1/1 [==============================] - 0s 42ms/step
1/1 [==============================] - 0s 38ms/step
1/1 [==============================] - 0s 39ms/step
1/1 [==============================] - 0s 38ms/step
1/1 [==============================] - 0s 40ms/step
1/1 [==============================] - 0s 40ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 28ms/step
1/1 [==============================] - 0s 27ms/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 28ms/step
1/1 [==============================] - 0s 28ms/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 24ms/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 33ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 25ms/step
```

```
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 25ms/step
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1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 27ms/step
1/1 [==============================] - 0s 24ms/step
1/1 [==============================] - 0s 28ms/step
1/1 [==============================] - 0s 24ms/step
1/1 [==============================] - 0s 32ms/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 27ms/step
1/1 [==============================] - 0s 28ms/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 27ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 70ms/step
1/1 [==============================] - 0s 79ms/step
1/1 [==============================] - 0s 48ms/step
1/1 [==============================] - 0s 90ms/step
1/1 [==============================] - 0s 82ms/step
1/1 [==============================] - 0s 47ms/step
1/1 [==============================] - 0s 53ms/step
1/1 [==============================] - 0s 92ms/step
1/1 [==============================] - 0s 127ms/step
1/1 [==============================] - 0s 129ms/step
1/1 [==============================] - 0s 69ms/step
1/1 [==============================] - 0s 103ms/step
1/1 [==============================] - 0s 76ms/step
1/1 [==============================] - 0s 68ms/step
1/1 [==============================] - 0s 51ms/step
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Пример тестирования модели на полном наборе данных:

```
model = Model()
model.load('best_last')

# evaluating model on full test dataset (may take time)
if TEST_ON_LARGE_DATASET:
    pred_2 = model.test_on_dataset(d_test)
    Metrics.print_all(d_test.labels, pred_2, 'test')
```

```
Downloading...
From (uriginal): https://drive.google.com/uc?export=download&id=1vNk3nybza57Vu2vbIdD-
From (redirected): https://drive.google.com/uc?export=download&id=1vNk3nybza57Vu2vbIc
To: /content/best_last.h5
100%|██████████| 512M/512M [00:10<00:00, 48.4MB/s]
```

100% 4500/4500 [08:56<00:00, 9.40it/s]

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Результат работы пайплайна обучения и тестирования выше тоже будет оцениваться. Поэтому не забудьте присылать на проверку ноутбук с выполнеными ячейками кода с демонстрациями метрик обучения, графиками и т.п. В этом пайплайне Вам необходимо продемонстрировать работу всех реализованных дополнений, улучшений и т.п.

Настоятельно рекомендуется после получения пайплайна с полными результатами обучения экспортировать ноутбук в pdf (файл -> печать) и прислать этот pdf вместе с самим ноутбуком.

Тестирование модели на других наборах данных

Ваша модель должна поддерживать тестирование на других наборах данных. Для удобства, Вам предоставляется набор данных test_tiny, который представляет собой малую часть (2% изображений) набора test. Ниже приведен фрагмент кода, который будет осуществлять тестирование для оценивания Вашей модели на дополнительных тестовых наборах данных.

Прежде чем отсылать задание на проверку, убедитесь в работоспособности фрагмента кода ниже.

```
final_model = Model()
final_model.load('best_last')
d_test_tiny = Dataset('test_tiny')
pred = model.test_on_dataset(d_test_tiny)
Metrics.print_all(d_test_tiny.labels, pred, 'test-tiny')
```

```
Downloading...
From (uriginal): https://drive.google.com/uc?export=download&id=1vNk3nybza57Vu2vbIdD-
From (redirected): https://drive.google.com/uc?export=download&id=1vNk3nybza57Vu2vbIc
To: /content/best_last.h5
100%|██████████| 512M/512M [00:11<00:00, 45.7MB/s]
Downloading...
From: https://drive.google.com/uc?export=download&confirm=pbef&id=1viiB0s041CNsAK4itv
To: /content/test_tiny.npz
100%|██████████| 10.6M/10.6M [00:00<00:00, 51.0MB/s]Loading dataset test_tiny from np
```

```
100%|██████████| 10.6M/10.6M [00:00<00:00, 51.9MB/s]Loading dataset test_tiny from np
Done. Dataset test_tiny consists of 90 images.
```

100% 90/90 [00:09<00:00, 12.53it/s]

```
1/1 [==============================] - 0s 35ms/step
1/1 [==============================] - 0s 27ms/step
1/1 [==============================] - 0s 27ms/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 27ms/step
1/1 [==============================] - 0s 24ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 24ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 26ms/step
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1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 24ms/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 29ms/step
1/1 [==============================] - 0s 36ms/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 33ms/step
1/1 [==============================] - 0s 27ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 27ms/step
1/1 [==============================] - 0s 30ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 27ms/step
1/1 [==============================] - 0s 30ms/step
1/1 [==============================] - 0s 39ms/step
1/1 [==============================] - 0s 48ms/step
1/1 [==============================] - 0s 43ms/step
1/1 [==============================] - 0s 47ms/step
1/1 [==============================] - 0s 45ms/step
1/1 [==============================] - 0s 40ms/step
1/1 [==============================] - 0s 43ms/step
1/1 [==============================] - 0s 41ms/step
1/1 [==============================] - 0s 42ms/step
1/1 [==============================] - 0s 48ms/step
1/1 [==============================] - 0s 37ms/step
1/1 [==============================] - 0s 39ms/step
1/1 [==============================] - 0s 45ms/step
1/1 [==============================] - 0s 40ms/step
1/1 [==============================] - 0s 39ms/step
1/1 [==============================] - 0s 42ms/step
1/1 [==============================] - 0s 44ms/step
1/1 [==============================] - 0s 37ms/step
1/1 [==============================] - 0s 37ms/step
1/1 [==============================] - 0s 44ms/step
1/1 [==============================] - 0s 42ms/step
```

```
1/1 [==============================] - 0s 47ms/step
1/1 [==============================] - 0s 41ms/step
1/1 [==============================] - 0s 39ms/step
1/1 [==============================] - 0s 44ms/step
1/1 [==============================] - 0s 38ms/step
1/1 [==============================] - 0s 39ms/step
1/1 [==============================] - 0s 38ms/step
1/1 [==============================] - 0s 43ms/step
1/1 [==============================] - 0s 43ms/step
1/1 [==============================] - 0s 43ms/step
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1/1 [==============================] - 0s 44ms/step
1/1 [==============================] - 0s 42ms/step
1/1 [==============================] - 0s 41ms/step
1/1 [==============================] - 0s 47ms/step
1/1 [==============================] - 0s 40ms/step
1/1 [==============================] - 0s 38ms/step
1/1 [==============================] - 0s 42ms/step
1/1 [==============================] - 0s 41ms/step
1/1 [==============================] - 0s 54ms/step
1/1 [==============================] - 0s 41ms/step
1/1 [==============================] - 0s 47ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 29ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 27ms/step
1/1 [==============================] - 0s 32ms/step
1/1 [==============================] - 0s 27ms/step
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1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 25ms/step
metrics for test-tiny:
    accuracy 0.8333:
```

Отмонтировать Google Drive.

```
drive.flush_and_unmount()
```

Дополнительные "полезности"

Ниже приведены примеры использования различных функций и библиотек, которые

Ниже приведены примеры использования различных функций и библиотек, которые могут быть полезны при выполнении данного практического задания.

Измерение времени работы кода

Измерять время работы какой-либо функции можно легко и непринужденно при помощи функции timeit из соответствующего модуля:

```
import timeit

def factorial(n):
    res = 1
    for i in range(1, n + 1):
        res *= i
    return res


def f():
    return factorial(n=1000)

n_runs = 128
print(f'Function f is caluclated {n_runs} times in {timeit.timeit(f, number=n_runs)}s.')
```

Scikit-learn

Для использования "классических" алгоритмов машинного обучения рекомендуется использовать библиотеку scikit-learn (https://scikit-learn.org/stable/). Пример классификации изображений цифр из набора данных MNIST при помощи классификатора SVM:

```
# Standard scientific Python imports
import matplotlib.pyplot as plt

# Import datasets, classifiers and performance metrics
from sklearn import datasets, svm, metrics
from sklearn.model_selection import train_test_split

# The digits dataset
digits = datasets.load_digits()

# The data that we are interested in is made of 8x8 images of digits, let's
# have a look at the first 4 images, stored in the `images` attribute of the
# dataset.  If we were working from image files, we could load them using
# matplotlib.pyplot.imread.  Note that each image must have the same size. For these
# images, we know which digit they represent: it is given in the 'target' of
```

```
# the dataset.
_, axes = plt.subplots(2, 4)
images_and_labels = list(zip(digits.images, digits.target))
for ax, (image, label) in zip(axes[0, :], images_and_labels[:4]):
    ax.set_axis_off()
    ax.imshow(image, cmap=plt.cm.gray_r, interpolation='nearest')
    ax.set_title('Training: %i' % label)

# To apply a classifier on this data, we need to flatten the image, to
# turn the data in a (samples, feature) matrix:
n_samples = len(digits.images)
data = digits.images.reshape((n_samples, -1))

# Create a classifier: a support vector classifier
classifier = svm.SVC(gamma=0.001)

# Split data into train and test subsets
X_train, X_test, y_train, y_test = train_test_split(
    data, digits.target, test_size=0.5, shuffle=False)

# We learn the digits on the first half of the digits
classifier.fit(X_train, y_train)

# Now predict the value of the digit on the second half:
predicted = classifier.predict(X_test)

images_and_predictions = list(zip(digits.images[n_samples // 2:], predicted))
for ax, (image, prediction) in zip(axes[1, :], images_and_predictions[:4]):
    ax.set_axis_off()
    ax.imshow(image, cmap=plt.cm.gray_r, interpolation='nearest')
    ax.set_title('Prediction: %i' % prediction)

print("Classification report for classifier %s:\n%s\n"
      % (classifier, metrics.classification_report(y_test, predicted)))
disp = metrics.plot_confusion_matrix(classifier, X_test, y_test)
disp.figure_.suptitle("Confusion Matrix")
print("Confusion matrix:\n%s" % disp.confusion_matrix)

plt.show()
```

```
Classification report for classifier SVC(gamma=0.001):
              precision    recall  f1-score   support

           0       1.00      0.99      0.99        88
           1       0.99      0.97      0.98        91
           2       0.99      0.99      0.99        86
           3       0.98      0.87      0.92        91
           4       0.99      0.96      0.97        92
           5       0.95      0.97      0.96        91
           6       0.99      0.99      0.99        91
           7       0.96      0.99      0.97        89
           8       0.94      1.00      0.97        88
```

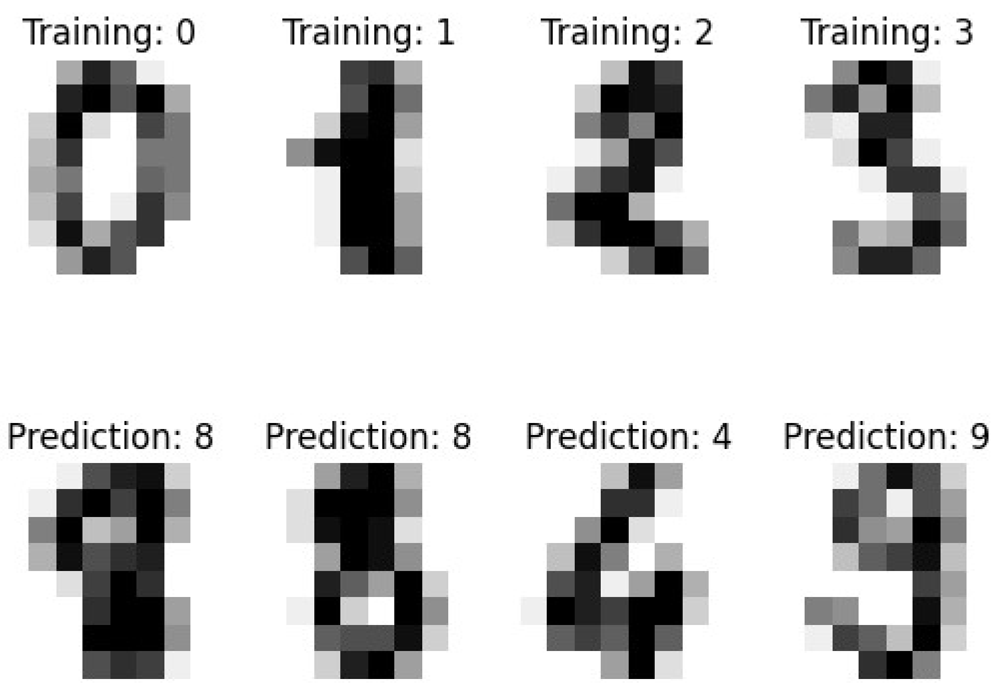
```
           9       0.93      0.98      0.95        92

    accuracy                           0.97       899
   macro avg       0.97      0.97      0.97       899
weighted avg       0.97      0.97      0.97       899


---------------------------------------------------------------------------
AttributeError                            Traceback (most recent call last)
<ipython-input-9-30c1ac115f06> in <cell line: 50>()
     48 print("Classification report for classifier %s:\n%s\n"
     49       % (classifier, metrics.classification_report(y_test, predicted)))
---> 50 disp = metrics.plot_confusion_matrix(classifier, X_test, y_test)
     51 disp.figure_.suptitle("Confusion Matrix")
     52 print("Confusion matrix:\n%s" % disp.confusion_matrix)

AttributeError: module 'sklearn.metrics' has no attribute 'plot_confusion_matrix'
```

ИСКАТЬ НА STACK OVERFLOW



Scikit-image

Реализовывать различные операции для работы с изображениями можно как самостоятельно, работая с массивами numpy, так и используя специализированные библиотеки, например, scikit-image (https://scikit-image.org/). Ниже приведен пример использования Canny edge detector.

```
import numpy as np
import matplotlib.pyplot as plt
```

```
from scipy import ndimage as ndi

from skimage import feature


# Generate noisy image of a square
im = np.zeros((128, 128))
im[32:-32, 32:-32] = 1

im = ndi.rotate(im, 15, mode='constant')
im = ndi.gaussian_filter(im, 4)
im += 0.2 * np.random.random(im.shape)

# Compute the Canny filter for two values of sigma
edges1 = feature.canny(im)
edges2 = feature.canny(im, sigma=3)

# display results
fig, (ax1, ax2, ax3) = plt.subplots(nrows=1, ncols=3, figsize=(8, 3),
                                    sharex=True, sharey=True)

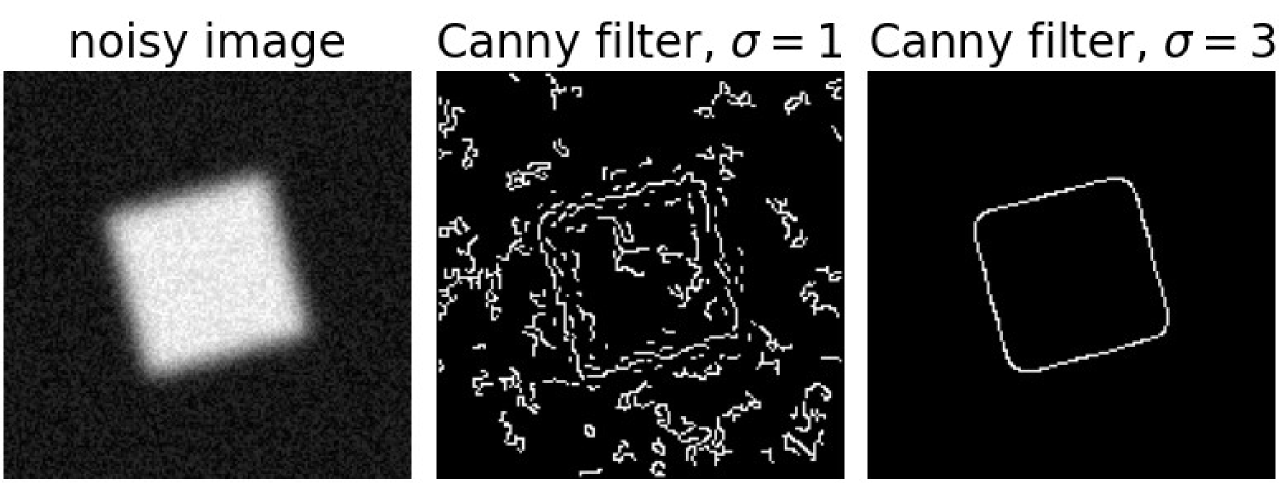
ax1.imshow(im, cmap=plt.cm.gray)
ax1.axis('off')
ax1.set_title('noisy image', fontsize=20)

ax2.imshow(edges1, cmap=plt.cm.gray)
ax2.axis('off')
ax2.set_title(r'Canny filter, $\sigma=1$', fontsize=20)

ax3.imshow(edges2, cmap=plt.cm.gray)
ax3.axis('off')
ax3.set_title(r'Canny filter, $\sigma=3$', fontsize=20)

fig.tight_layout()

plt.show()
```



Tensorflow 2

Для создания и обучения нейросетевых моделей можно использовать фреймворк глубокого обучения Tensorflow 2. Ниже приведен пример простейшей нейроной сети, использующейся для классификации изображений из набора данных MNIST.

```
# Install TensorFlow

import tensorflow as tf

mnist = tf.keras.datasets.mnist

(x_train, y_train), (x_test, y_test) = mnist.load_data()
x_train, x_test = x_train / 255.0, x_test / 255.0

model = tf.keras.models.Sequential([
  tf.keras.layers.Flatten(input_shape=(28, 28)),
  tf.keras.layers.Dense(128, activation='relu'),
  tf.keras.layers.Dropout(0.2),
  tf.keras.layers.Dense(10, activation='softmax')
])

model.compile(optimizer='adam',
              loss='sparse_categorical_crossentropy',
              metrics=['accuracy'])

model.fit(x_train, y_train, epochs=5)

model.evaluate(x_test,  y_test, verbose=2)
```

```
Epoch 1/5
1875/1875 [==============================] - 5s 3ms/step - loss: 0.2915 - accuracy: 0
Epoch 2/5
1875/1875 [==============================] - 5s 3ms/step - loss: 0.1445 - accuracy: 0
Epoch 3/5
1875/1875 [==============================] - 6s 3ms/step - loss: 0.1111 - accuracy: 0
Epoch 4/5
1875/1875 [==============================] - 5s 3ms/step - loss: 0.0908 - accuracy: 0
Epoch 5/5
1875/1875 [==============================] - 6s 3ms/step - loss: 0.0770 - accuracy: 0
313/313 - 1s - loss: 0.0765 - accuracy: 0.9760 - 912ms/epoch - 3ms/step
[0.07647889107465744, 0.9760000109672546]
```

Для эффективной работы с моделями глубокого обучения убедитесь в том, что в текущей среде Google Colab используется аппаратный ускоритель GPU или TPU. Для смены среды выберите "среда выполнения" -> "сменить среду выполнения".

Большое количество туториалов и примеров с кодом на Tensorflow 2 можно найти на официальном сайте https://www.tensorflow.org/tutorials?hl=ru.

Также, Вам может понадобиться написать собственный генератор данных для Tensorflow 2. Скорее всего он будет достаточно простым, и его легко можно будет реализовать, используя официальную документацию TensorFlow 2. Но, на всякий случай (если не удлось сразу разобраться или хочется вникнуть в тему более глубоко), можете посмотреть следующий отличный туториал: https://stanford.edu/~shervine/blog/keras-how-to-generate-data-on-the-fly.

Numba

В некоторых ситуациях, при ручных реализациях графовых алгоритмов, выполнение многократных вложенных циклов for в python можно существенно ускорить, используя JIT-компилятор Numba (https://numba.pydata.org/). Примеры использования Numba в Google Colab можно найти тут:

1. https://colab.research.google.com/github/cbernet/maldives/blob/master/numba/numba_cuda.ipynb
2. https://colab.research.google.com/github/evaneschneider/parallel-programming/blob/master/COMPASS_gpu_intro.ipynb

> Пожалуйста, если Вы решили использовать Numba для решения этого практического задания, еще раз подумайте, нужно ли это Вам, и есть ли возможность реализовать требуемую функциональность иным способом. Используйте Numba только при реальной необходимости.

Работа с zip архивами в Google Drive

Запаковка и распаковка zip архивов может пригодиться при сохранении и загрузки Вашей модели. Ниже приведен фрагмент кода, иллюстрирующий помещение нескольких файлов в zip архив с последующим чтением файлов из него. Все действия с директориями, файлами и архивами должны осущетвляться с примонтированным Google

Drive.

Создадим 2 изображения, поместим их в директорию tmp внутри PROJECT_DIR, запакуем директорию tmp в архив tmp.zip.

```
PROJECT_DIR = "/dev/prak_nn_1/"
arr1 = np.random.rand(100, 100, 3) * 255
arr2 = np.random.rand(100, 100, 3) * 255

img1 = Image.fromarray(arr1.astype('uint8'))
img2 = Image.fromarray(arr2.astype('uint8'))

p = "/content/drive/MyDrive/" + PROJECT_DIR

if not (Path(p) / 'tmp').exists():
    (Path(p) / 'tmp').mkdir()

img1.save(str(Path(p) / 'tmp' / 'img1.png'))
img2.save(str(Path(p) / 'tmp' / 'img2.png'))

%cd $p
!zip -r "tmp.zip" "tmp"
```

Распакуем архив tmp.zip в директорию tmp2 в PROJECT_DIR. Теперь внутри директории tmp2 содержится директория tmp, внутри которой находятся 2 изображения.

```
p = "/content/drive/MyDrive/" + PROJECT_DIR
%cd $p
!unzip -uq "tmp.zip" -d "tmp2"
```