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 (4.7.1)
Requirement already satisfied: filelock in /usr/local/lib/python3.10/dist-packages (from gdown) (3.13.1)
Requirement already satisfied: requests[socks] in /usr/local/lib/python3.10/dist-packages (from gdown) (2.31.0)
Requirement already satisfied: six in /usr/local/lib/python3.10/dist-packages (from gdown) (1.16.0)
Requirement already satisfied: tqdm in /usr/local/lib/python3.10/dist-packages (from gdown) (4.66.1)
Requirement already satisfied: beautifulsoup4 in /usr/local/lib/python3.10/dist-packages (from gdown) (4.11.2)
Requirement already satisfied: soupsieve>1.2 in /usr/local/lib/python3.10/dist-packages (from beautifulsoup4->gdown) (2.5)
Requirement already satisfied: charset-normalizer<4,>=2 in /usr/local/lib/python3.10/dist-packages (from requests[socks]->gdown) (3.3.2)
Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.10/dist-packages (from requests[socks]->gdown) (3.4)
Requirement already satisfied: urllib3<3,>=1.21.1 in /usr/local/lib/python3.10/dist-packages (from requests[socks]->gdown) (2.0.7)
Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3.10/dist-packages (from requests[socks]->gdown) (2023.7.22)
Requirement already satisfied: PySocks!=1.5.7,>=1.5.6 in /usr/local/lib/python3.10/dist-packages (from requests[socks]->gdown) (1.7.1)
```

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',
    'test': '1RfPou3pFKpuHDJZ-D9XDFzgvwpUBFlDr',
    'test_small': '1wbRsog0n7uGlHIPGLhyN-PMeT2kdQ2lI',
    'test_tiny': '1viiB0s041CNsAK4itvX8PnYthJ-MDnQc'
}'''

DATASETS_LINKS = {
    'train': '1xYKk9SxQWouOWGG0-whb07MSBfTcWbqq',
    'train_small': '11ENg_uoR2dHIm4bI0dNl-IkFdMetD-iw',
    'train_tiny': '1ZbXt4TuJyOUbpvSj587PDxaOaTXoI1se',
    'test': '1snA9mev5NDmkvj_aoTSpOOxwRGGlseml',
    'test_small': '1XzTOrE0pZL7njuBx9wEMQC8JInSC2iUe',
    'test_tiny': '1Q6bDJsIxs13gmKfeSepKRz9i44kWOXyC'
}

```

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
```

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_LINKS[name]}"
        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 испульвания 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.

```
```

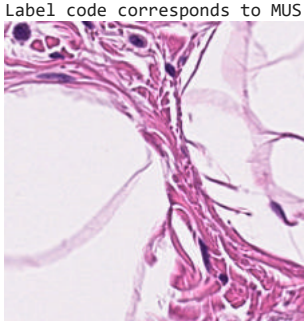
```
d_train_tiny = Dataset('train_tiny')

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=1ZbXt4TuJyOUbpvSj587PDxaOaTXoI1se
To: /content/train_tiny.npz
100%|██████████| 105M/105M [00:01<00:00, 57.3MB/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 5.
Label code corresponds to MUS class.
```



Класс Metrics

Реализует метрики точности, используемые для оценивания модели:

1. точность,
2. сбалансированную точность.

```python
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, 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.

```python
import matplotlib.pyplot as plotter_lib
import numpy as np
import PIL as image_lib
import tensorflow as tflow
from tensorflow.keras.layers import Flatten, Dense
from tensorflow.keras.models import Sequential
from tensorflow.keras.optimizers import Adam
import sklearn
from sklearn.model_selection import KFold

class Model:

    def __init__(self, input_shape=(224, 224, 3), num_classes=9):
        self.resnet_model = self.made_model(input_shape, num_classes)

    def made_model(self, input_shape, num_classes):
        resnet_model = Sequential()
        pretrained_model = tflow.keras.applications.ResNet50(include_top=False,
                    input_shape=input_shape,
                    pooling='avg',
                    classes=num_classes,
                    weights='imagenet')
        for each_layer in pretrained_model.layers:
            each_layer.trainable=False
        resnet_model.add(pretrained_model)
        resnet_model.add(Flatten())
        resnet_model.add(Dense(512, activation='relu'))
        resnet_model.add(Dense(num_classes, activation='softmax'))
        return resnet_model

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

    def load(self, name: str):
        DATASETS_LINKS = {
            'best': '1-jDYVa2CxinJ82482IGt_kvQZRDH1Wgl',
            'best_train_tiny': '1-eyszhdAczAsCC6NoSqRxCOqY1ucCaWW',
            'best_train_small': '1-jDYVa2CxinJ82482IGt_kvQZRDH1Wgl'
        }
        link = f"https://drive.google.com/uc?export=download&id={DATASETS_LINKS.get(name, '')}
        gdown.download(link, f'{name}.h5', quiet=False)
        self.resnet_model.load_weights(f'{name}.h5')

    def train(self, dataset: Dataset):
        X = dataset.images
        y = dataset.labels
        kf = KFold(n_splits = int(0.7 * dataset.n_files))
        for train_index, test_index in kf.split(X):
            X_train, X_test = X[train_index], X[test_index]
            y_train, y_test = y[train_index], y[test_index]
            break

        print(f'training started')
        epochs = 5
        self.resnet_model.compile(optimizer=Adam(lr=0.001),
                                  loss='sparse_categorical_crossentropy',
```

```
                            metrics=['accuracy'])
        history = self.resnet_model.fit(X_train, y_train,
                                validation_data=(X_test, y_test),
                                epochs=epochs)
        '''history = self.resnet_model.fit(X, y,
                                validation_split=0.4,
                                epochs=epochs)'''
        print(f'training done')
        self.resnet_model = self.save(f'/content/drive/My Drive/best_{dataset.name}')
        plotter_lib.figure(figsize=(5, 5))
        epochs_range = range(epochs)
        plotter_lib.plot( epochs_range, history.history['accuracy'],
                         label="Training Accuracy")
        plotter_lib.plot(epochs_range, history.history['val_accuracy'],
                         label="Validation Accuracy")
        plotter_lib.axis(ymin=0.4,ymax=1)
        plotter_lib.grid()
        plotter_lib.title('Model Accuracy')
        plotter_lib.ylabel('Accuracy')
        plotter_lib.xlabel('Epochs')
        plotter_lib.legend(['train', 'validation'])

    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.resnet_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_small' и 'test_small'.

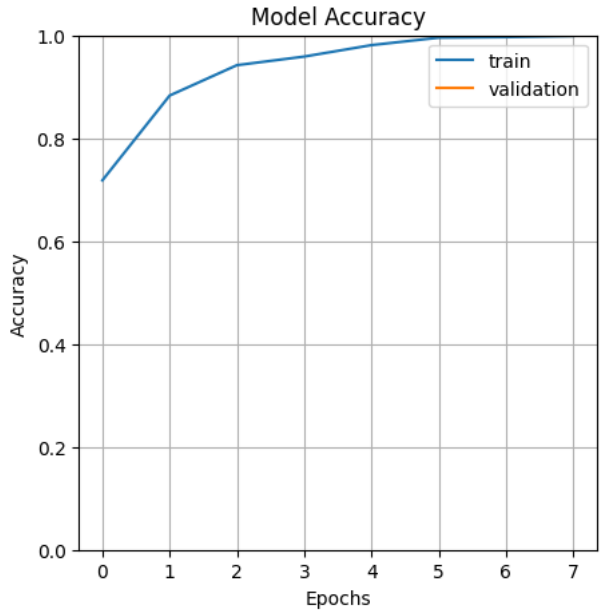
```
d_train_tiny = Dataset('train_tiny')
d_test_tiny = Dataset('test_tiny')
```

```
Downloading...
From: https://drive.google.com/uc?export=download&confirm=pbef&id=1ZbXt4TuJyOUbpvSj587PDxaOaTXoI1se
To: /content/train_tiny.npz
100%|██████████| 105M/105M [00:01<00:00, 57.4MB/s]
Loading dataset train_tiny from npz.
Done. Dataset train_tiny consists of 900 images.
Downloading...
From: https://drive.google.com/uc?export=download&confirm=pbef&id=1Q6bDJsIxs13gmKfeSepKRz9i44kWOXyC
To: /content/test_tiny.npz
```

```
100%|██████████| 10.6M/10.6M [00:00<00:00, 50.7MB/s]Loading dataset test_tiny from npz.
Done. Dataset test_tiny consists of 90 images.
```

```
model = Model()
model.train(d_train_tiny)
```

```
WARNING:absl:`lr` is deprecated in Keras optimizer, please use `learning_rate` or use the legacy optimizer, e.g.,tf.keras.optimizers.legacy.Adam.
training started
Epoch 1/8
29/29 [==============================] - 110s 4s/step - loss: 0.8406 - accuracy: 0.7183 - val_loss: 0.0022 - val_accuracy: 1.0000
Epoch 2/8
29/29 [==============================] - 106s 4s/step - loss: 0.3447 - accuracy: 0.8831 - val_loss: 0.0012 - val_accuracy: 1.0000
Epoch 3/8
29/29 [==============================] - 106s 4s/step - loss: 0.1577 - accuracy: 0.9421 - val_loss: 6.3237e-05 - val_accuracy: 1.0000
Epoch 4/8
29/29 [==============================] - 107s 4s/step - loss: 0.1203 - accuracy: 0.9588 - val_loss: 3.3296e-04 - val_accuracy: 1.0000
Epoch 5/8
29/29 [==============================] - 106s 4s/step - loss: 0.0724 - accuracy: 0.9811 - val_loss: 1.8716e-05 - val_accuracy: 1.0000
Epoch 6/8
29/29 [==============================] - 105s 4s/step - loss: 0.0393 - accuracy: 0.9955 - val_loss: 9.5963e-06 - val_accuracy: 1.0000
Epoch 7/8
29/29 [==============================] - 107s 4s/step - loss: 0.0293 - accuracy: 0.9967 - val_loss: 1.4245e-05 - val_accuracy: 1.0000
Epoch 8/8
29/29 [==============================] - 105s 4s/step - loss: 0.0180 - accuracy: 0.9989 - val_loss: 1.1921e-05 - val_accuracy: 1.0000
training done
/usr/local/lib/python3.10/dist-packages/keras/src/engine/training.py:3079: UserWarning: You are saving your model as an HDF5 file via `model.save()`. This file format is considered legacy. We recc
  saving_api.save_model(
```



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

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

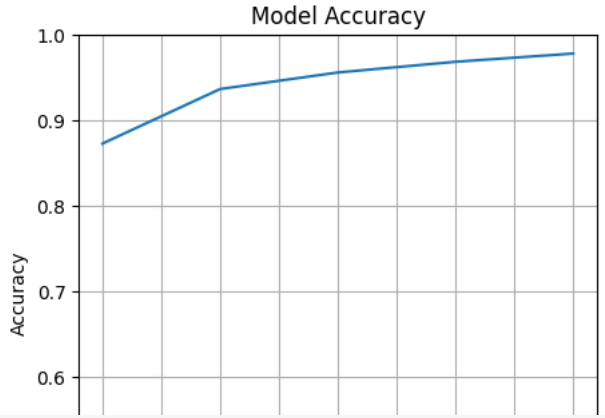
```
Downloading...
From: https://drive.google.com/uc?export=download&id=1-eyszhdAczAsCC6NoSqRxCOqY1ucCaWW
To: /content/best_train_tiny.h5
100%|██████████| 107M/107M [00:02<00:00, 53.4MB/s]
100%                                          9/9 [00:02<00:00, 5.74it/s]
1/1 [==============================] - 1s 805ms/step
1/1 [==============================] - 0s 120ms/step
1/1 [==============================] - 0s 126ms/step
1/1 [==============================] - 0s 121ms/step
1/1 [==============================] - 0s 130ms/step
1/1 [==============================] - 0s 127ms/step
1/1 [==============================] - 0s 123ms/step
1/1 [==============================] - 0s 120ms/step
1/1 [==============================] - 0s 129ms/step
metrics for 10% of test:
         accuracy 0.8889:
         balanced accuracy 0.8889:
/usr/local/lib/python3.10/dist-packages/sklearn/metrics/_classification.py:2184: UserWarning: y_pred contains classes not in y_t
  warnings.warn("y_pred contains classes not in y_true")
```

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

```
Downloading...
From: https://drive.google.com/uc?export=download&confirm=pbef&id=11ENg_uoR2dHIm4bI0dNl-IkFdMetD-iw
To: /content/train_small.npz
100%|██████████| 841M/841M [00:08<00:00, 93.5MB/s]
Loading dataset train_small from npz.
Done. Dataset train_small consists of 7200 images.
Downloading...
From: https://drive.google.com/uc?export=download&confirm=pbef&id=1XzTOrE0pZL7njuBx9wEMQC8JInSC2iUe
To: /content/test_small.npz
100%|██████████| 211M/211M [00:02<00:00, 90.4MB/s]
Loading dataset test_small from npz.
Done. Dataset test_small consists of 1800 images.
```

```
model = Model()
model.train(d_train_small)
```

```
WARNING:absl:`lr` is deprecated in Keras optimizer, please use `learning_rate` or use the legacy optimizer, e.g.,tf.keras.optimizers.legacy.Adam.
training started
Epoch 1/5
225/225 [==============================] - 879s 4s/step - loss: 0.3918 - accuracy: 0.8726 - val_loss: 4.9002e-04 - val_accuracy: 1.0000
Epoch 2/5
225/225 [==============================] - 876s 4s/step - loss: 0.1818 - accuracy: 0.9362 - val_loss: 1.9371e-05 - val_accuracy: 1.0000
Epoch 3/5
225/225 [==============================] - 861s 4s/step - loss: 0.1363 - accuracy: 0.9555 - val_loss: 1.3292e-05 - val_accuracy: 1.0000
Epoch 4/5
225/225 [==============================] - 860s 4s/step - loss: 0.0917 - accuracy: 0.9680 - val_loss: 2.5630e-06 - val_accuracy: 1.0000
Epoch 5/5
225/225 [==============================] - 859s 4s/step - loss: 0.0683 - accuracy: 0.9776 - val_loss: 2.9802e-07 - val_accuracy: 1.0000
training done
/usr/local/lib/python3.10/dist-packages/keras/src/engine/training.py:3079: UserWarning: You are saving your model as an HDF5 file via `model.save()`. This file format is considered legacy. We reco
  saving_api.save_model(
```




```python
# @title
model = Model()
model.load('best_train_small')

# evaluating model on 10% of test dataset
pred_2 = model.test_on_dataset(d_test_small, limit = 0.1)
Metrics.print_all(d_test_small.labels[:len(pred_2)], pred_2, '10% of test')
```

```
Downloading...
From: https://drive.google.com/uc?export=download&id=1-jDYVa2CxinJ82482IGt_kvQZRDH1Wgl
To: /content/best_train_small.h5
100%|██████████| 107M/107M [00:01<00:00, 75.3MB/s]
```

100% 180/180 [00:35<00:00, 5.81it/s]

```
1/1 [==============================] - 1s 1s/step
1/1 [==============================] - 0s 168ms/step
1/1 [==============================] - 0s 166ms/step
1/1 [==============================] - 0s 171ms/step
1/1 [==============================] - 0s 177ms/step
1/1 [==============================] - 0s 168ms/step
1/1 [==============================] - 0s 179ms/step
1/1 [==============================] - 0s 176ms/step
1/1 [==============================] - 0s 169ms/step
1/1 [==============================] - 0s 168ms/step
1/1 [==============================] - 0s 182ms/step
1/1 [==============================] - 0s 175ms/step
1/1 [==============================] - 0s 164ms/step
1/1 [==============================] - 0s 167ms/step
1/1 [==============================] - 0s 167ms/step
1/1 [==============================] - 0s 129ms/step
1/1 [==============================] - 0s 127ms/step
1/1 [==============================] - 0s 132ms/step
1/1 [==============================] - 0s 131ms/step
1/1 [==============================] - 0s 126ms/step
1/1 [==============================] - 0s 131ms/step
1/1 [==============================] - 0s 131ms/step
1/1 [==============================] - 0s 123ms/step
1/1 [==============================] - 0s 126ms/step
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```
d_train = Dataset('train')
d_test = Dataset('test')
```

```
Downloading...
From: https://drive.google.com/uc?export=download&confirm=pbef&id=1xYKk9SxQWouOWGG0-whb07MSBfTcWbqq
To: /content/train.npz
100%|██████████| 2.10G/2.10G [00:41<00:00, 50.9MB/s]
Loading dataset train from npz.
Done. Dataset train consists of 18000 images.
Downloading...
From: https://drive.google.com/uc?export=download&confirm=pbef&id=1snA9mev5NDmkvj_aoTSpOOxwRGGlseml
To: /content/test.npz
100%|██████████| 525M/525M [00:14<00:00, 37.4MB/s]
Loading dataset test from npz.
Done. Dataset test consists of 4500 images.
```

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

if TEST_ON_LARGE_DATASET:
    pred_2 = model.test_on_dataset(d_test_tiny)
    Metrics.print_all(d_test_tiny.labels, pred_2, 'test')
```

```
Downloading...
From: https://drive.google.com/uc?export=download&id=1-eyszhdAczAsCC6NoSqRxCOqY1ucCaWW
To: /content/best_train_tiny.h5
100%|██████████| 107M/107M [00:01<00:00, 101MB/s]
100%                                                  90/90 [00:17<00:00, 5.90it/s]
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```
model = Model()
model.load('best_train_tiny')

if TEST_ON_LARGE_DATASET:
    pred_2 = model.test_on_dataset(d_test_small)
    Metrics.print_all(d_test_small.labels, pred_2, 'test')
```

```
Downloading...
From: https://drive.google.com/uc?export=download&id=1-eyszhdAczAsCC6NoSqRxCOqY1ucCaWW
To: /content/best_train_tiny.h5
100%|██████████| 107M/107M [00:00<00:00, 128MB/s]
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100% 1800/1800 [06:15<00:00, 5.65it/s]

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metrics for test:
        accuracy 0.9072:
        balanced accuracy 0.9072:
```

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

if TEST_ON_LARGE_DATASET:
    pred_2 = model.test_on_dataset(d_test)
    Metrics.print_all(d_test.labels, pred_2, 'test')
```

```
Downloading...
From: https://drive.google.com/uc?export=download&id=1-eyszhdAczAsCC6NoSqRxCOqY1ucCaWW
To: /content/best_train_tiny.h5
100%|██████████| 107M/107M [00:01<00:00, 73.1MB/s]
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100% 4500/4500 [15:13<00:00, 5.21it/s]

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metrics for test:
        accuracy 0.9020:
        balanced accuracy 0.9020:
```

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

if TEST_ON_LARGE_DATASET:
    pred_1 = model.test_on_dataset(d_test_tiny)
    Metrics.print_all(d_test_tiny.labels, pred_1, 'test')
```

```
Downloading...
From: https://drive.google.com/uc?export=download&id=1-jDYVa2CxinJ82482IGt_kvQZRDH1Wgl
To: /content/best_train_small.h5
100%|██████████| 107M/107M [00:01<00:00, 57.1MB/s]
100%                                                  90/90 [00:17<00:00, 5.67it/s]
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```
model = Model()
model.load('best_train_small')

if TEST_ON_LARGE_DATASET:
    pred_1 = model.test_on_dataset(d_test_small)
    Metrics.print_all(d_test_small.labels, pred_1, 'test')
```

```
Downloading...
From: https://drive.google.com/uc?export=download&id=1-jDYVa2CxinJ82482IGt_kvQZRDH1Wgl
To: /content/best_train_small.h5
100%|██████████| 107M/107M [00:00<00:00, 111MB/s]
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100% 1800/1800 [05:44<00:00, 4.24it/s]

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metrics for test:
        accuracy 0.9433:
        balanced accuracy 0.9433:
```

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

if TEST_ON_LARGE_DATASET:
    pred_1 = model.test_on_dataset(d_test)
    Metrics.print_all(d_test.labels, pred_1, 'test')
```

```
Downloading...
From: https://drive.google.com/uc?export=download&id=1-jDYVa2CxinJ82482IGt_kvQZRDH1Wgl
To: /content/best_train_small.h5
100%|██████████| 107M/107M [00:00<00:00, 110MB/s]
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100% 4500/4500 [14:56<00:00, 5.06it/s]

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metrics for test:
         accuracy 0.9458:
         balanced accuracy 0.9458:
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```
model = Model()
model.load('best_train_small')

# evaluating model on 10% of test dataset
pred_2 = model.test_on_dataset(d_test, limit = 0.1)
Metrics.print_all(d_test.labels[:len(pred_2)], pred_2, '10% of test')
```

```
Downloading...
From: https://drive.google.com/uc?export=download&id=1-jDYVa2CxinJ82482IGt_kvQZRDH1Wgl
To: /content/best_train_small.h5
100%|██████████| 107M/107M [00:01<00:00, 88.8MB/s]
100%                                                  450/450 [01:26<00:00, 3.77it/s]
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metrics for 10% of test:
         accuracy 0.9911:
         balanced accuracy 0.9911:
/usr/local/lib/python3.10/dist-packages/sklearn/metrics/_classification.py:2184: UserWarning: y_pred contains classes not in y_true
  warnings.warn("y_pred contains classes not in y_true")
```

Результат работы пайплайна обучения и тестирования выше тоже будет оцениваться. Поэтому не забудьте присылать на проверку ноутбук с выполненными 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')
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: https://drive.google.com/uc?export=download&id=1-jDYVa2CxinJ82482IGt_kvQZRDH1Wgl
To: /content/best.h5
100%|██████████| 107M/107M [00:01<00:00, 89.0MB/s]
Downloading...
From: https://drive.google.com/uc?export=download&confirm=pbef&id=1Q6bDJsIxs13gmKfeSepKRz9i44kWOXyC
To: /content/test_tiny.npz
100%|██████████| 10.6M/10.6M [00:00<00:00, 50.5MB/s]Loading dataset test_tiny from npz.
Done. Dataset test_tiny consists of 90 images.
```

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100%                                                  90/90 [00:17<00:00, 5.80it/s]
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1/1 [==============================] - 0s 134ms/step
1/1 [==============================] - 0s 129ms/step
1/1 [==============================] - 0s 132ms/step
1/1 [==============================] - 0s 135ms/step
1/1 [==============================] - 0s 140ms/step
1/1 [==============================] - 0s 131ms/step
1/1 [==============================] - 0s 129ms/step
1/1 [==============================] - 0s 150ms/step
1/1 [==============================] - 0s 132ms/step
1/1 [==============================] - 0s 138ms/step
1/1 [==============================] - 0s 137ms/step
1/1 [==============================] - 0s 131ms/step
1/1 [==============================] - 0s 131ms/step
1/1 [==============================] - 0s 137ms/step
1/1 [==============================] - 0s 166ms/step
1/1 [==============================] - 0s 175ms/step
1/1 [==============================] - 0s 171ms/step
1/1 [==============================] - 0s 184ms/step
1/1 [==============================] - 0s 175ms/step
1/1 [==============================] - 0s 192ms/step
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1/1 [==============================] - 0s 182ms/step
1/1 [==============================] - 0s 178ms/step
1/1 [==============================] - 0s 173ms/step
1/1 [==============================] - 0s 177ms/step
1/1 [==============================] - 0s 174ms/step
1/1 [==============================] - 0s 172ms/step
1/1 [==============================] - 0s 176ms/step
1/1 [==============================] - 0s 176ms/step
1/1 [==============================] - 0s 168ms/step
1/1 [==============================] - 0s 186ms/step
1/1 [==============================] - 0s 177ms/step
```

Отмонтировать Google Drive.

```
1/1 [==============================] - 0s 133ms/step
```

```
1 drive.flush_and_unmount()
```

```
1/1 [==============================] - 0s 127ms/step
```

Дополнительные "полезности"

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

1/1 [==============================] - 0s 129ms/step

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.')
```

1/1 [==============================] - 0s 129ms/step

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:

1/1 [==============================] - 0s 137ms/step

```
# 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()
```

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)
```