# problem-1-starter-1-1-1

December 2, 2025

# **№1**

:

[1]:
```
!pip install -q tqdm
!pip install --upgrade --no-cache-dir gdown
```

```
Requirement already satisfied: gdown in /usr/local/lib/python3.12/dist-packages
(5.2.0)
Requirement already satisfied: beautifulsoup4 in /usr/local/lib/python3.12/dist-
packages (from gdown) (4.13.5)
Requirement already satisfied: filelock in /usr/local/lib/python3.12/dist-
packages (from gdown) (3.20.0)
Requirement already satisfied: requests[socks] in
/usr/local/lib/python3.12/dist-packages (from gdown) (2.32.4)
Requirement already satisfied: tqdm in /usr/local/lib/python3.12/dist-packages
(from gdown) (4.67.1)
Requirement already satisfied: soupsieve>1.2 in /usr/local/lib/python3.12/dist-
packages (from beautifulsoup4->gdown) (2.8)
Requirement already satisfied: typing-extensions>=4.0.0 in
/usr/local/lib/python3.12/dist-packages (from beautifulsoup4->gdown) (4.15.0)
Requirement already satisfied: charset_normalizer<4,>=2 in
/usr/local/lib/python3.12/dist-packages (from requests[socks]->gdown) (3.4.4)
Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.12/dist-
packages (from requests[socks]->gdown) (3.11)
Requirement already satisfied: urllib3<3,>=1.21.1 in
/usr/local/lib/python3.12/dist-packages (from requests[socks]->gdown) (2.5.0)
Requirement already satisfied: certifi>=2017.4.17 in
/usr/local/lib/python3.12/dist-packages (from requests[socks]->gdown)
(2025.11.12)
Requirement already satisfied: PySocks!=1.5.7,>=1.5.6 in
/usr/local/lib/python3.12/dist-packages (from requests[socks]->gdown) (1.7.1)
```

Google Drive :

[3]:
```
from google.colab import drive
drive.mount('/content/drive', force_remount=True)
```

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

, , (gdrive ) :

[4]:
```
EVALUATE_ONLY = False
TEST_ON_LARGE_DATASET = True
PROJECT_DIR = '/content/drive/MyDrive/'
TISSUE_CLASSES = ('ADI', 'BACK', 'DEB', 'LYM', 'MUC', 'MUS', 'NORM', 'STR',␣
 ↪'TUM')
DATASETS_LINKS = {
    'train': '16ljuhaPfmjE2Nnsa9H4ndvXN-5Yu4oVj',
    'train_small': '1qd45xXfDwdZjktLFwQb-et-mAaFeCzOR',
    'train_tiny': '1I-2ZOuXLd4QwhZQQltp817Kn3J0Xgbui',
    'test': '1Ij785V4snC5VaDY_Pc5hKidW0johHggk',
    'test_small': '1wbRsogOn7uGlHIPGLhyN-PMeT2kdQ2lI',
    'test_tiny': '1viiBOs041CNsAK4itvX8PnYthJ-MDnQc'
}
```

:

[5]:
```
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, confusion_matrix,␣
 ↪classification_report
import gdown
from typing import List
from tqdm import tqdm
from sklearn.model_selection import train_test_split
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.preprocessing import StandardScaler
import joblib
from sklearn.decomposition import PCA
from sklearn.feature_selection import SelectKBest, f_classif
import gc
import os
import time
from scipy import stats
from sklearn.ensemble import RandomForestClassifier
from sklearn.model_selection import cross_val_score
```

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### 0.0.1 Dataset

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[6]:
```python
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]
```

### 0.0.2 Dataset

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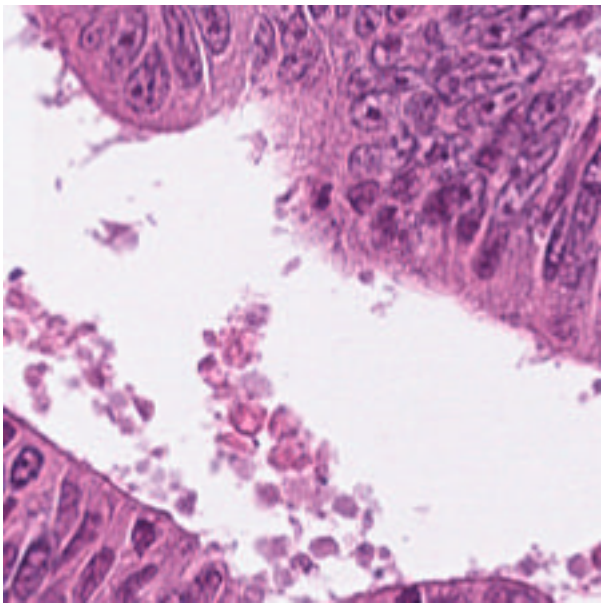
[7]:
```
d_train_tiny = Dataset('train_tiny')

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-2ZOuXLd4Qwh
ZQQltp817Kn3J0Xgbui
To: /content/train_tiny.npz
100%|      | 105M/105M [00:01<00:00, 58.3MB/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 8.
Label code corresponds to TUM class.
```



### 0.0.3 Dataset PyTorch

[ ]:
```
# ============================================================
# (      )        Dataset              PyTorch
# ============================================================

#     :
#                ,                       PyTorch.
#        ,    "      "    Dataset   torch.utils.data.DataLoader.
'''
try:
    import torch
    from torch.utils.data import Dataset as TorchDataset, DataLoader
    import torchvision.transforms as T
    from PIL import Image

    class HistologyTorchDataset(TorchDataset):
        """
               Dataset             PyTorch.

        base_dataset:       Dataset('train'), Dataset('train_small'), etc.
        transform:        /   ,                (PIL.Image -> torch.Tensor).

        """
        def __init__(self, base_dataset, transform=None):
            self.base = base_dataset
            #        transform        :
            # np.uint8 [0, 255] -> float32 [0.0, 1.0]
            self.transform = transform or T.ToTensor()

        def __len__(self):
            #
            return len(self.base.images)

        def __getitem__(self, idx):
            """
                  (image_tensor, label)    PyTorch.
            image_tensor: torch.Tensor     [3, H, W]
            label: int
            """
            img, label = self.base.image_with_label(idx)  # img: np.ndarray (H,␣
 ↪W, 3)
            img = Image.fromarray(img)                    #   PIL.Image
            img = self.transform(img)                     #   torch.Tensor
            return img, label

except ImportError:
```

```
    HistologyTorchDataset = None
    print("PyTorch / torchvision       .      HistologyTorchDataset      .")
    '''
```

```
---------------------------------------------------------------------------
KeyboardInterrupt                         Traceback (most recent call last)
/tmp/ipython-input-1555254540.py in <cell line: 0>()
      8
      9 try:
---> 10     import torch
     11     from torch.utils.data import Dataset as TorchDataset, DataLoader
     12     import torchvision.transforms as T

/usr/local/lib/python3.12/dist-packages/torch/__init__.py in <module>
    425     if USE_GLOBAL_DEPS:
    426         _load_global_deps()
--> 427     from torch._C import *  # noqa: F403
    428
    429

/usr/lib/python3.12/importlib/_bootstrap.py in _lock_unlock_module(name)

KeyboardInterrupt:
```

### 0.0.4 HistologyTorchDataset

[ ]:
```
'''if "HistologyTorchDataset" not in globals() or HistologyTorchDataset is None:
    print("PyTorch                          -          .")
else:
    print("            PyTorch-       Dataset")

    base_train = Dataset('train_tiny')

    #      PyTorch-
    train_ds = HistologyTorchDataset(base_train)

    # DataLoader
    from torch.utils.data import DataLoader
    train_loader = DataLoader(train_ds, batch_size=8, shuffle=True)

    #
    images_batch, labels_batch = next(iter(train_loader))

    print("             :", tuple(images_batch.shape))  # [batch, 3, 224, 224]
    print("          :", tuple(labels_batch.shape))        # [batch]
    print("       :", labels_batch[:10].tolist())
```

```
    print("   images_batch:", type(images_batch))
    print("   labels_batch:", type(labels_batch))
'''
```

PyTorch- Dataset

```
Downloading…
From: https://drive.google.com/uc?export=download&confirm=pbef&id=1I-2ZOuXLd4Qwh
ZQQltp817Kn3J0Xgbui
To: /content/train_tiny.npz
100%|      | 105M/105M [00:00<00:00, 111MB/s]

Loading dataset train_tiny from npz.
Done. Dataset train_tiny consists of 900 images.
             : (8, 3, 224, 224)
           : (8,)
       : [0, 7, 6, 6, 1, 3, 3, 3]
   images_batch: <class 'torch.Tensor'>
   labels_batch: <class 'torch.Tensor'>
```

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### 0.0.5 Metrics

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[8]:
```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)))
```

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### 0.0.6 Model

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save, load .

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[9]:
```
class Model:
    def __init__(self, n_folds=3, use_pca=True):
        self.model = None
        self.scaler = StandardScaler()
        self.pca = None
        self.use_pca = use_pca
        self.classes = TISSUE_CLASSES
        self.n_folds = n_folds
        self.history = []
        self.feature_selector = None
        self.feature_names = []
        self.original_feature_dim = None

    def save(self, name: str):
        if self.model is None:
            print("   -    ,   -          ")
            return

        model_data = {
            'model': self.model,
            'scaler': self.scaler,
            'pca': self.pca,
            'use_pca': self.use_pca,
            'history': self.history,
            'classes': self.classes,
            'feature_names': self.feature_names,
            'original_feature_dim': self.original_feature_dim
        }
```

```
        save_path = os.path.join(PROJECT_DIR, f'{name}.joblib')
        joblib.dump(model_data, save_path)
        print(f"    c       {save_path}")

    def load(self, name: str, cloud_source=None):
        cache_dir = Path.home() / '.histology_models'
        cache_dir.mkdir(exist_ok=True)

        local_path = cache_dir / f'{name}.joblib'

        if cloud_source:
            print(f"               : {cloud_source}")

            try:
                success = self._download_from_cloud(cloud_source, local_path)

                if success:
                    print(f"                          : {local_path}")
                else:
                    print("                    ,              ...")
                    if not local_path.exists():
                        local_path = Path(f'{name}.joblib')

            except Exception as e:
                print(f"                 : {e}")
                print("              ...")

        try:
            if local_path.exists():
                model_data = joblib.load(local_path)
            else:
                possible_paths = [
                    Path(f'{name}.joblib'),
                    Path(PROJECT_DIR) / f'{name}.joblib',
                    Path('weights') / f'{name}.joblib',
                ]

                for path in possible_paths:
                    if path.exists():
                        model_data = joblib.load(path)
                        print(f"             : {path}")
                        break
                else:
                    raise FileNotFoundError(f"    {name}       ")

            self.model = model_data['model']
```

```
            self.scaler = model_data['scaler']
            self.pca = model_data.get('pca')
            self.use_pca = model_data.get('use_pca', True)
            self.history = model_data.get('history', [])
            self.classes = model_data.get('classes', self.classes)
            self.feature_names = model_data.get('feature_names', [])
            self.original_feature_dim = model_data.get('original_feature_dim')
            print(f"    {name}          ")

        except Exception as e:
            print(f"            : {e}")
            print("              ...")
            self.__init__()

    def _download_from_cloud(self, url: str, destination: Path) -> bool:
        if 'drive.google.com' in url or 'drive.google.com/uc?id=' in url:
            return self._download_from_google_drive(url, destination)

        elif url.startswith('http'):
            return self._download_from_url(url, destination)

        else:
            raise ValueError(f"         URL: {url}")

    def _download_from_google_drive(self, url: str, destination: Path) -> bool:
        try:
            import gdown

            if 'id=' in url:
                file_id = url.split('id=')[1].split('&')[0]
            elif '/file/d/' in url:
                file_id = url.split('/file/d/')[1].split('/')[0]
            else:
                raise ValueError("          ID       Google Drive    ")

            download_url = f'https://drive.google.com/uc?id={file_id}'

            print(f"        Google Drive, ID: {file_id}")
            gdown.download(download_url, str(destination), quiet=False)

            return destination.exists()

        except Exception as e:
            print(f"               Google Drive: {e}")
            return False

    def _download_from_url(self, url: str, destination: Path) -> bool:
```

```
        try:
            print(f"         URL: {url}")

            response = requests.get(url, stream=True, timeout=30)
            response.raise_for_status()

            with open(destination, 'wb') as f:
                for chunk in response.iter_content(chunk_size=8192):
                    f.write(chunk)

            return True

        except Exception as e:
            print(f"                URL: {e}")
            return False

    def extract_features(self, img):
        img_normalized = img / 255.0

        features = []

        for ch, color in enumerate(['R', 'G', 'B']):
            channel_data = img_normalized[:, :, ch]
            flat_channel = channel_data.flatten()

            features.extend([
                np.mean(channel_data),
                np.std(channel_data),
                np.percentile(flat_channel, 25),
                np.percentile(flat_channel, 50),
                np.percentile(flat_channel, 75),
                np.max(channel_data),
                np.min(channel_data),
                np.mean(np.abs(channel_data - np.mean(channel_data))),
                np.var(channel_data),
                np.sum(channel_data > 0.5) / channel_data.size,
                np.sum(channel_data < 0.3) / channel_data.size,
            ])

        gray = np.mean(img_normalized, axis=2)
        grad_x = np.abs(np.gradient(gray, axis=0))
        grad_y = np.abs(np.gradient(gray, axis=1))

        features.extend([
            np.mean(grad_x), np.std(grad_x),
            np.mean(grad_y), np.std(grad_y),
            np.mean(np.sqrt(grad_x**2 + grad_y**2)),
```

```
            np.std(np.sqrt(grad_x**2 + grad_y**2)),
        ])

        features.extend([
            np.mean(img_normalized[:, :, 0]),
            np.mean(img_normalized[:, :, 1]),
            np.mean(img_normalized[:, :, 2]),
        ])

        r_g_ratio = np.mean(img_normalized[:, :, 0]) / (np.mean(img_normalized[:
↪, :, 1]) + 1e-10)
        r_b_ratio = np.mean(img_normalized[:, :, 0]) / (np.mean(img_normalized[:
↪, :, 2]) + 1e-10)
        g_b_ratio = np.mean(img_normalized[:, :, 1]) / (np.mean(img_normalized[:
↪, :, 2]) + 1e-10)

        features.extend([r_g_ratio, r_b_ratio, g_b_ratio])

        for ch in range(3):
            hist, _ = np.histogram(img_normalized[:, :, ch].flatten(), bins=5,␣
↪range=(0, 1))
            features.extend(hist / hist.sum())

        points = [(56, 56), (56, 168), (168, 56), (168, 168)]
        for idx, (x, y) in enumerate(points):
            patch = gray[max(0, x-1):min(224, x+2), max(0, y-1):min(224, y+2)]
            if patch.size > 0:
                features.append(np.std(patch))
            else:
                features.append(0)

        hist_gray, _ = np.histogram(gray.flatten(), bins=20, density=True)
        hist_gray = hist_gray[hist_gray > 0]
        entropy = -np.sum(hist_gray * np.log2(hist_gray))
        features.append(entropy)

        return np.array(features, dtype=np.float32)

    def process_dataset_chunked(self, dataset, limit=None, chunk_size=500):
        n = dataset.n_files if not limit else int(dataset.n_files * limit)

        sample_img = dataset.image(0)
        sample_features = self.extract_features(sample_img)
        feature_dim = len(sample_features)
        self.original_feature_dim = feature_dim

        X = np.zeros((n, feature_dim), dtype=np.float32)
```

```
        y = np.zeros(n, dtype=np.int32)

        for start_idx in tqdm(range(0, n, chunk_size), desc="           "):
            end_idx = min(start_idx + chunk_size, n)

            for i in range(start_idx, end_idx):
                img = dataset.image(i)
                X[i] = self.extract_features(img)
                y[i] = dataset.labels[i]

            if start_idx % (chunk_size * 5) == 0:
                gc.collect()

        return X, y

    def visualize_data(self, X_train, y_train, X_val, y_val):
        fig, axes = plt.subplots(2, 2, figsize=(15, 12))
       #LB1
        train_counts = np.bincount(y_train)
        axes[0, 0].bar(range(len(self.classes)), train_counts, color='skyblue',␣
↪alpha=0.7, label='Train')
        val_counts = np.bincount(y_val)
        axes[0, 0].bar(range(len(self.classes)), val_counts,␣
↪color='lightcoral', alpha=0.7, label='Val')
        axes[0, 0].set_title('            ', fontsize=12)
        axes[0, 0].set_xlabel('   ', fontsize=10)
        axes[0, 0].set_ylabel('     ', fontsize=10)
        axes[0, 0].set_xticks(range(len(self.classes)))
        axes[0, 0].set_xticklabels(self.classes, rotation=45, fontsize=9)
        axes[0, 0].legend()
        plt.show()

    def train(self, dataset: Dataset):
        print(f'            {dataset.name}\n\n')

        start_time = time.time()

        X, y = self.process_dataset_chunked(dataset, chunk_size=300)

        print(f"          : {X.shape[0]}")
        print(f"           : {X.shape[1]}")
        print(f"         : {len(np.unique(y))}")
        #LB2
        X_train, X_val, y_train, y_val = train_test_split(
            X, y, test_size=0.2, random_state=42, stratify=y
        )
```

```
        del X, y
        gc.collect()

        print(f"       : {X_train.shape[0]}      ")
        print(f"       : {X_val.shape[0]}      ")

        X_train_scaled = self.scaler.fit_transform(X_train)
        X_val_scaled = self.scaler.transform(X_val)

        param_grid = {
            'n_estimators': [50, 100],
            'max_depth': [10, 15, 20],
            'min_samples_split': [2, 5]
        }

        best_score = 0
        best_params = None
        best_model = None

        for n_est in param_grid['n_estimators']:
            for depth in param_grid['max_depth']:
                for min_split in param_grid['min_samples_split']:
                    model = RandomForestClassifier(
                        n_estimators=n_est,
                        max_depth=depth,
                        min_samples_split=min_split,
                        min_samples_leaf=2,
                        random_state=42,
                        n_jobs=-1,
                        class_weight='balanced'
                    )

                    try:
                        scores = cross_val_score(model, X_train_scaled, y_train,
                                                 cv=min(3, len(np.
↪unique(y_train))),
                                                 scoring='balanced_accuracy',
                                                 n_jobs=-1)
                        mean_score = np.mean(scores)

                        if mean_score > best_score:
                            best_score = mean_score
                            best_params = (n_est, depth, min_split)
                            best_model = model
                    except Exception as e:
                        continue
```

```
        if best_model is None:
            best_model = RandomForestClassifier(
                n_estimators=100,
                max_depth=15,
                min_samples_split=5,
                min_samples_leaf=2,
                random_state=42,
                n_jobs=-1,
                class_weight='balanced'
            )
            best_params = (100, 15, 5)

        print(f"         : n_est={best_params[0]}, depth={best_params[1]},␣
↪min_split={best_params[2]}")
        print(f"    CV score: {best_score:.4f}")

        self.model = best_model
        self.model.fit(X_train_scaled, y_train)

        y_val_pred = self.model.predict(X_val_scaled)
        val_accuracy = Metrics.accuracy(y_val, y_val_pred)
        val_balanced_accuracy = Metrics.accuracy_balanced(y_val, y_val_pred)

        print("             \n\n")
        print(f"Accuracy: {val_accuracy:.4f}")
        print(f"Balanced Accuracy: {val_balanced_accuracy:.4f}")

        self.visualize_data(X_train, y_train, X_val, y_val)
        self.plot_confusion_matrix(y_val, y_val_pred, "Validation Set")

        self.history.append({
            'val_accuracy': val_accuracy,
            'val_balanced_accuracy': val_balanced_accuracy,
            'best_params': best_params,
            'best_cv_score': best_score,
            'training_time': time.time() - start_time,
            'n_features': X_train_scaled.shape[1],
            'n_samples': X_train_scaled.shape[0]
        })

        training_time = time.time() - start_time
        print(f"\n             {training_time:.2f}    )")
    #LB3
    def plot_confusion_matrix(self, y_true, y_pred, title):
        cm = confusion_matrix(y_true, y_pred)

        fig, (ax1, ax2) = plt.subplots(1, 2, figsize=(16, 6))
```

```
        sns.heatmap(cm, annot=True, fmt='d', cmap='Blues', ax=ax1,
                    xticklabels=self.classes,
                    yticklabels=self.classes)
        ax1.set_title(f'Confusion Matrix - {title}', fontsize=14)
        ax1.set_xlabel('Predicted', fontsize=12)
        ax1.set_ylabel('True', fontsize=12)

        cm_norm = cm.astype('float') / cm.sum(axis=1)[:, np.newaxis]
        sns.heatmap(cm_norm, annot=True, fmt='.2f', cmap='Blues', ax=ax2,
                    xticklabels=self.classes,
                    yticklabels=self.classes)
        ax2.set_title(f'Normalized Confusion Matrix - {title}', fontsize=14)
        ax2.set_xlabel('Predicted', fontsize=12)
        ax2.set_ylabel('True', fontsize=12)

        plt.tight_layout()
        plt.savefig(f'confusion_matrix_{title.replace(" ", "_")}.png',
                    dpi=100, bbox_inches='tight')
        plt.show()

        print("\n        :")
        for i, true_class in enumerate(self.classes):
            total = cm[i, :].sum()
            correct = cm[i, i]
            accuracy = correct / total if total > 0 else 0

            errors = []
            for j, pred_class in enumerate(self.classes):
                if i != j and cm[i, j] > 0:
                    error_rate = cm[i, j] / total
                    errors.append((pred_class, cm[i, j], error_rate))

            errors.sort(key=lambda x: x[1], reverse=True)

            if len(errors) > 0:
                print(f"\n{true_class}: {accuracy:.1%}      ")
                for pred_class, count, rate in errors[:3]:
                    print(f"            {pred_class}: {count}    ({rate:.1%})")

    def test_on_dataset(self, dataset: Dataset, limit=None):
        n = dataset.n_files if not limit else int(dataset.n_files * limit)
        predictions = []

        pbar = tqdm(total=n, desc="       ")

        for i in range(n):
```

```
            img = dataset.image(i)
            pred = self.test_on_image(img)
            predictions.append(pred)

            pbar.update(1)

            if i % 100 == 0:
                gc.collect()

        pbar.close()

        return predictions

    def test_on_image(self, img: np.ndarray):
        if self.model is None:
            return np.random.randint(9)

        features = self.extract_features(img)
        features_scaled = self.scaler.transform(features.reshape(1, -1))

        if self.use_pca and self.pca is not None:
            if features_scaled.shape[1] != self.pca.n_components_:
                features_scaled = self.pca.transform(features_scaled)

        prediction = self.model.predict(features_scaled)
        return int(prediction[0])

    def visualize_predictions(self, dataset: Dataset, n_samples=9):
        fig, axes = plt.subplots(3, 3, figsize=(15, 12))
        axes = axes.ravel()

        samples_collected = 0
        attempts = 0
        max_attempts = n_samples * 5

        while samples_collected < n_samples and attempts < max_attempts:
            idx = np.random.randint(dataset.n_files)
            img, true_label = dataset.image_with_label(idx)
            pred_label = self.test_on_image(img)

            if samples_collected < 3 or true_label != pred_label or attempts >␣
↪n_samples * 2:
                ax = axes[samples_collected]
                ax.imshow(img)

                color = 'green' if true_label == pred_label else 'red'
```

```
                ax.set_title(f'True: {self.classes[true_label]}\nPred: {self.
↪classes[pred_label]}',
                             color=color, fontsize=11, pad=10)
                ax.axis('off')

                for spine in ax.spines.values():
                    spine.set_color(color)
                    spine.set_linewidth(3)

                samples_collected += 1

            attempts += 1

        for i in range(samples_collected, n_samples):
            axes[i].axis('off')
            axes[i].set_title('      ', fontsize=11)

        plt.suptitle('                ', fontsize=14, y=1.02)
        plt.tight_layout()
        plt.savefig('predictions_visualization.png', dpi=100,␣
↪bbox_inches='tight')
        plt.show()
```

---

### 0.0.7

. . . . ‘train_small’ ‘test_small’.

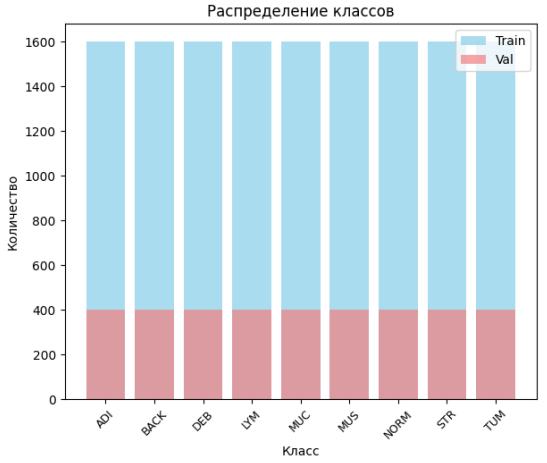
[10]:
```
d_train = Dataset('train')
d_test = Dataset('test')
```

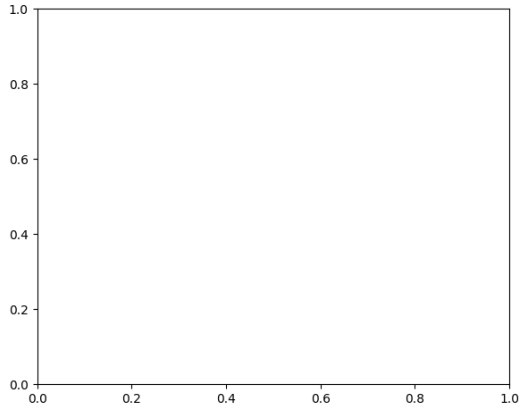
```
Downloading…
From: https://drive.google.com/uc?export=download&confirm=pbef&id=16ljuhaPfmjE2N
nsa9H4ndvXN-5Yu4oVj
To: /content/train.npz
100%|      | 2.10G/2.10G [00:34<00:00, 61.5MB/s]

Loading dataset train from npz.
Done. Dataset train consists of 18000 images.

Downloading…
From: https://drive.google.com/uc?export=download&confirm=pbef&id=1Ij785V4snC5Va
DY_Pc5hKidW0johHggk
To: /content/test.npz
100%|      | 525M/525M [00:04<00:00, 105MB/s]

Loading dataset test from npz.
```

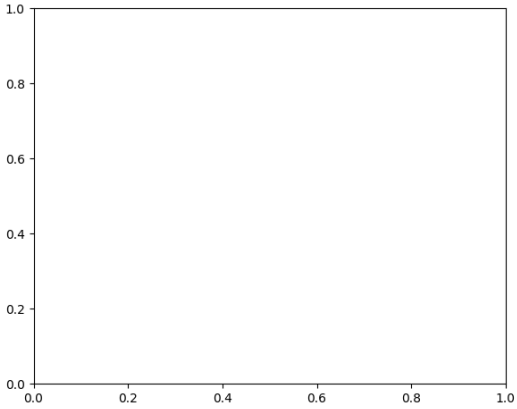
```
Done. Dataset test consists of 4500 images.
```

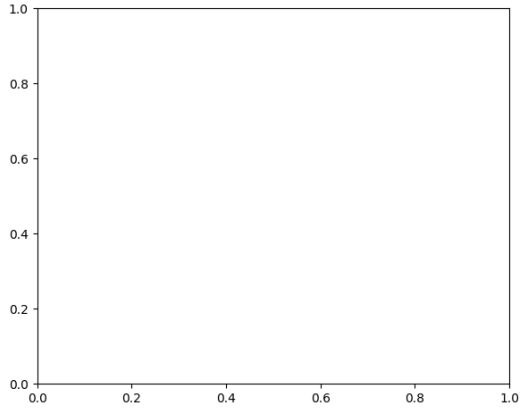
[11]:
```python
model = Model()
if not EVALUATE_ONLY:
    model.train(d_train)
    model.save('best')
else:
    model.load('best', cloud_source='https://drive.google.com/uc?
 ↪id=11nSgrZmK0ZA7f9kjF9e1_m8k-eLuOFtM')
```

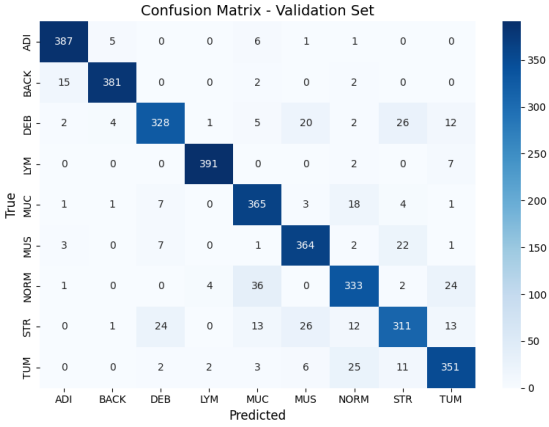
```
            train



           : 100%|      | 60/60 [05:16<00:00,  5.28s/it]

          : 18000
           : 65
         : 9
       : 14400
       : 3600


         : n_est=100, depth=20, min_split=5
    CV score: 0.8804



Accuracy: 0.8919
Balanced Accuracy: 0.8919
```

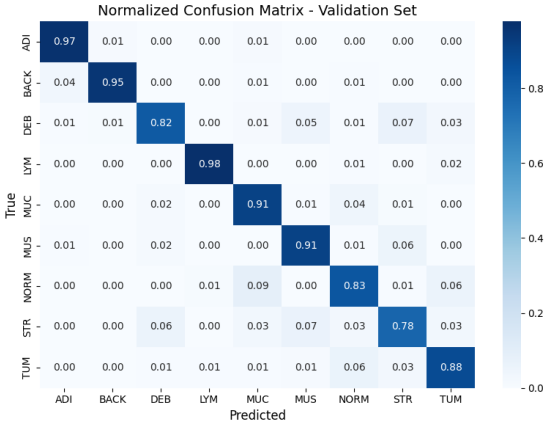









:

ADI: 96.8%

MUC: 6 (1.5%)

```
            BACK: 5    (1.2%)
            MUS: 1    (0.2%)

BACK: 95.2%
            ADI: 15    (3.8%)
            MUC: 2    (0.5%)
            NORM: 2    (0.5%)

DEB: 82.0%
            STR: 26    (6.5%)
            MUS: 20    (5.0%)
            TUM: 12    (3.0%)

LYM: 97.8%
            TUM: 7    (1.8%)
            NORM: 2    (0.5%)

MUC: 91.2%
            NORM: 18    (4.5%)
            DEB: 7    (1.8%)
            STR: 4    (1.0%)

MUS: 91.0%
            STR: 22    (5.5%)
            DEB: 7    (1.8%)
            ADI: 3    (0.8%)

NORM: 83.2%
            MUC: 36    (9.0%)
            TUM: 24    (6.0%)
            LYM: 4    (1.0%)

STR: 77.8%
            MUS: 26    (6.5%)
            DEB: 24    (6.0%)
            MUC: 13    (3.2%)

TUM: 87.8%
            NORM: 25    (6.2%)
            STR: 11    (2.8%)
            MUS: 6    (1.5%)

              506.76    )
    c       /content/drive/MyDrive/best.joblib
```

:

[12]:
```
# evaluating model on 10% of test dataset
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')
```

```
      : 100%|      | 450/450 [00:20<00:00, 22.32it/s]
```

```
metrics for 10% of test:
         accuracy 0.9756:
         balanced accuracy 0.9756:


/usr/local/lib/python3.12/dist-packages/sklearn/metrics/_classification.py:2524:
UserWarning: y_pred contains classes not in y_true
  warnings.warn("y_pred contains classes not in y_true")
```

:

[13]:
```
# 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')
```

```
      : 100%|      | 4500/4500 [03:20<00:00, 22.50it/s]
```

```
metrics for test:
         accuracy 0.8838:
         balanced accuracy 0.8838:
```

.

, .. ,

..

pdf ( -> )

pdf .

**0.0.8**

. , test_tiny,

(2% ) test. ,

.

, .

[14]:
```
final_model = Model()
final_model.load('best', cloud_source='https://drive.google.com/uc?
 ↪id=11nSgrZmKOZA7f9kjF9e1_m8k-eLuOFtM')
d_test_tiny = Dataset('test')
pred = final_model.test_on_dataset(d_test)
Metrics.print_all(d_test_tiny.labels, pred, 'test')
```

```
                :
https://drive.google.com/uc?id=11nSgrZmK0ZA7f9kjF9e1_m8k-eLuOFtM
        Google Drive, ID: 11nSgrZmK0ZA7f9kjF9e1_m8k-eLuOFtM

Downloading…
From: https://drive.google.com/uc?id=11nSgrZmK0ZA7f9kjF9e1_m8k-eLuOFtM
To: /root/.histology_models/best.joblib
100%|      | 29.0M/29.0M [00:00<00:00, 228MB/s]

                            :
/root/.histology_models/best.joblib
    best

Downloading…
From: https://drive.google.com/uc?export=download&confirm=pbef&id=1Ij785V4snC5Va
DY_Pc5hKidW0johHggk
To: /content/test.npz
100%|      | 525M/525M [00:02<00:00, 215MB/s]

Loading dataset test from npz.
Done. Dataset test consists of 4500 images.

      : 100%|      | 4500/4500 [03:20<00:00, 22.47it/s]

metrics for test:
         accuracy 0.8838:
         balanced accuracy 0.8838:
```

Google Drive.

[15]:
```
drive.flush_and_unmount()
```

---

# 1 “ ”

, .

### 1.0.1

- timeit :

[ ]:
```
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.')
```

### 1.0.2 Scikit-learn

“ ” scikit-learn (https://scikit-learn.org/stable/). MNIST SVM:

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

# Import datasets, classifiers and performance metrics
from sklearn import datasets, svm, metrics
from sklearn.metrics import ConfusionMatrixDisplay
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)))

#          +              API
cm = metrics.confusion_matrix(y_test, predicted)
disp = ConfusionMatrixDisplay(confusion_matrix=cm,
                              display_labels=classifier.classes_)

fig, ax = plt.subplots(figsize=(4, 4))
disp.plot(ax=ax)
ax.set_title("Confusion Matrix")
plt.tight_layout()
plt.show()
```

### 1.0.3 Scikit-image

, numpy, , , scikit-image (https://scikit-image.org/). 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()
```

### 1.0.4 Tensorflow 2

Tensorflow 2.

, 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)
```

, Google Colab
GPU TPU. “ ” -> “ ”.

Tensorflow 2
https://www.tensorflow.org/tutorials?hl=ru.

, Tensorflow 2. ,
, TensorFlow 2. , (
), : https://stanford.edu/~shervine/blog/keras-how-to-generate-data-on-the-fly.

### 1.0.5 PyTorch

[ ]:
```
# ============================================================
#        :    -   PyTorch
# ============================================================
#        ,    PyTorch/
try:
    import torch
    import torch.nn as nn
    import torch.nn.functional as F
    from torch.utils.data import DataLoader
except ImportError:
    print("PyTorch          -          .")
    import sys
    raise SystemExit

if "HistologyTorchDataset" not in globals() or HistologyTorchDataset is None:
    print("HistologyTorchDataset        -          .")
    import sys
    raise SystemExit


# ---     : tiny-    ,                ---
base_train = Dataset('train_tiny')
base_test  = Dataset('test_tiny')

train_ds = HistologyTorchDataset(base_train)           # ToTensor
test_ds  = HistologyTorchDataset(base_test)
```

```
train_loader = DataLoader(train_ds, batch_size=16, shuffle=True)
test_loader  = DataLoader(test_ds,  batch_size=32, shuffle=False)

# ---   -   :        CNN +    FC (       ,       ) ---
class TinyCNN(nn.Module):
    def __init__(self, num_classes=len(TISSUE_CLASSES)):
        super().__init__()
        self.conv1 = nn.Conv2d(3, 8, kernel_size=3, padding=1)
        self.conv2 = nn.Conv2d(8, 16, kernel_size=3, padding=1)
        self.pool  = nn.MaxPool2d(2, 2)  # 224->112->56
        self.fc    = nn.Linear(16 * 56 * 56, num_classes)

    def forward(self, x):
        x = self.pool(F.relu(self.conv1(x)))  # [B, 3, 224, 224] -> [B, 8, 112,␣
 ↪112]
        x = self.pool(F.relu(self.conv2(x)))  # [B, 8, 112, 112] -> [B, 16, 56,␣
 ↪56]
        x = x.view(x.size(0), -1)
        x = self.fc(x)
        return x

device = torch.device("cuda" if torch.cuda.is_available() else "cpu")
print("Device:", device)

model = TinyCNN(num_classes=len(TISSUE_CLASSES)).to(device)
criterion = nn.CrossEntropyLoss()
optimizer = torch.optim.Adam(model.parameters(), lr=1e-3)

# ---            "    "          ---
model.train()
xb, yb = next(iter(train_loader))
xb = xb.to(device)
yb = yb.to(device, dtype=torch.long)

optimizer.zero_grad()
logits = model(xb)
loss = criterion(logits, yb)
float_loss = float(loss.detach().cpu())
loss.backward()
optimizer.step()

print(f"Loss          train_tiny: {float_loss:.4f}")

# ---                        (         /   ) ---
model.eval()
with torch.no_grad():
    xt, yt = next(iter(test_loader))
```

```
    xt = xt.to(device)
    logits_t = model(xt).cpu()
    y_pred = logits_t.argmax(dim=1).numpy()
    y_true = yt.numpy()

print("      :", {"y_true": y_true.shape, "y_pred": y_pred.shape})
Metrics.print_all(y_true, y_pred, "_")  # balanced accuracy/accuracy
 ↪

#                                                ,
#      /      ,      /       ,                    .
```

### 1.0.6 PyTorch

- **PyTorch** — https://pytorch.org/tutorials/
- **“Deep Learning with PyTorch: 60-Minute Blitz”** — https://pytorch.org/tutorials/beginner/deep_learning_60min_blitz.html
- **Transfer Learning for Computer Vision** — https://pytorch.org/tutorials/beginner/transfer_learning_t
- **PyTorch Get Started (  )** — https://pytorch.org/get-started/locally/
- **Dive into Deep Learning (D2L, PyTorch)** — https://d2l.ai/chapter_preliminaries/index.html
- **Fast.ai — Practical Deep Learning for Coders** — https://course.fast.ai/
- **Learn PyTorch.io (Zero to Mastery)** — https://www.learnpytorch.io/

### 1.0.7 Numba

, ,
for python , JIT- Numba (https://numba.pydata.org/). Numba Google Colab : 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

, Numba , , ,
. Numba .

### 1.0.8 zip Google Drive

zip . ,
zip . ,
Google Drive.

2 , tmp PROJECT_DIR, tmp 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"
```

tmp.zip tmp2 PROJECT_DIR. tmp2 tmp, 2 .

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