Практическое задание №2

Общая терминология по используемым данным

Предоставляемые данные для разработки моделей и алгоритмов трекинга мяча в теннисе представляют собор набор игр (game), состоящих из нескольких клипов (clip), каждый из которых состоит из набора кадров (frame). Обратите внимание на структуру организации файлов внутри предоставляемого датасета для полного понимания.

Большинство алгоритмов трекинга объектов работают с несколькими последовательными кадрами, и в данном задании также подразумевается использование этого приема. Последовательность нескольких кадров будем именовать стопкой (stack), размер стопки (stack_s) является гиперпараметром разрабатываемого алгоритма.

Заготовка решения

Загрузка датасета

Для работы с данными в ноутбуке kaggle необходимо подключить датасет. File -> Add or upload data, далее в поиске написать tennis-tracking-assignment и выбрать датасет. Если поиск не работает, то можно добавить датасет по url: https://www.kaggle.com/xubiker/tennistrackingassignment. После загрузки данные датасета будут примонтированы в ../input/tennistrackingassignment.

Установка и импорт зависимостей

Установка необходимых пакетов (не забудьте "включить интернет" в настройках ноутбука kaggle):

```
!pip install moviepy --upgrade
!pip install gdown
```

```
Collecting moviepy
  Downloading moviepy-1.0.3.tar.gz (388 kB)
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 388.3/388.3 kB 2.4 MB/s eta
0:00:00a 0:00:01
etadata (setup.py) ...  moviepy)
  Downloading decorator-4.4.2-py2.py3-none-any.whl (9.2 kB)
Requirement already satisfied: tqdm<5.0,>=4.11.2 in
/opt/conda/lib/python3.10/site-packages (from moviepy) (4.66.1)
Requirement already satisfied: requests<3.0,>=2.8.1 in
/opt/conda/lib/python3.10/site-packages (from moviepy) (2.31.0)
Collecting proglog<=1.0.0 (from moviepy)
  Downloading proglog-0.1.10-py3-none-any.whl (6.1 kB)
```

```
Requirement already satisfied: numpy>=1.17.3 in
/opt/conda/lib/python3.10/site-packages (from moviepy) (1.24.3)
Requirement already satisfied: imageio<3.0,>=2.5 in
/opt/conda/lib/python3.10/site-packages (from moviepy) (2.31.1)
Collecting imageio_ffmpeg>=0.2.0 (from moviepy)
  Obtaining dependency information for imageio_ffmpeg>=0.2.0 from
https://files.pythonhosted.org/packages/1a/98/3df1d8dd8f2c121b6c588b1e
0d604f36592d56df9c41fb155ed546c6a5ed/imageio_ffmpeg-0.4.9-py3-none-
manylinux2010_x86_64.whl.metadata
  Downloading imageio_ffmpeg-0.4.9-py3-none-
manylinux2010_x86_64.whl.metadata (1.7 kB)
Requirement already satisfied: pillow>=8.3.2 in
/opt/conda/lib/python3.10/site-packages (from imageio<3.0,>=2.5-
>moviepy) (10.1.0)
Requirement already satisfied: setuptools in
/opt/conda/lib/python3.10/site-packages (from imageio_ffmpeg>=0.2.0-
>moviepy) (68.1.2)
Requirement already satisfied: charset-normalizer<4,>=2 in
/opt/conda/lib/python3.10/site-packages (from requests<3.0,>=2.8.1-
>moviepy) (3.2.0)
Requirement already satisfied: idna<4,>=2.5 in
/opt/conda/lib/python3.10/site-packages (from requests<3.0,>=2.8.1-
>moviepy) (3.4)
Requirement already satisfied: urllib3<3,>=1.21.1 in
/opt/conda/lib/python3.10/site-packages (from requests<3.0,>=2.8.1-
>moviepy) (1.26.15)
Requirement already satisfied: certifi>=2017.4.17 in
/opt/conda/lib/python3.10/site-packages (from requests<3.0,>=2.8.1-
>moviepy) (2023.11.17)
Downloading imageio_ffmpeg-0.4.9-py3-none-manylinux2010_x86_64.whl
(26.9 MB)
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 26.9/26.9 MB 42.4 MB/s eta
0:00:00:00:0100:01
oviepy
  Building wheel for moviepy (setup.py) ... oviepy: filename=moviepy-
1.0.3-py3-none-any.whl size=110721
sha256=1b796cb9f5a72e5224cd400c5f4ca905158f41be8d6bfd0802f6262a36749c3
4
  Stored in directory:
/root/.cache/pip/wheels/96/32/2d/e10123bd88fbfc02fed53cc18c80a171d3c87
479ed845fa7c1
Successfully built moviepy
Installing collected packages: proglog, imageio_ffmpeg, decorator,
moviepy
  Attempting uninstall: decorator
    Found existing installation: decorator 5.1.1
    Uninstalling decorator-5.1.1:
      Successfully uninstalled decorator-5.1.1
ERROR: pip's dependency resolver does not currently take into account
```

```
all the packages that are installed. This behaviour is the source of
the following dependency conflicts.
gcsfs 2023.6.0 requires fsspec==2023.6.0, but you have fsspec
2023.12.2 which is incompatible.
Successfully installed decorator-4.4.2 imageio_ffmpeg-0.4.9 moviepy-
1.0.3 proglog-0.1.10
Collecting gdown
  Downloading gdown-4.7.1-py3-none-any.whl (15 kB)
Requirement already satisfied: filelock in
/opt/conda/lib/python3.10/site-packages (from gdown) (3.12.2)
Requirement already satisfied: requests[socks] in
/opt/conda/lib/python3.10/site-packages (from gdown) (2.31.0)
Requirement already satisfied: six in /opt/conda/lib/python3.10/site-
packages (from gdown) (1.16.0)
Requirement already satisfied: tqdm in /opt/conda/lib/python3.10/site-
packages (from gdown) (4.66.1)
Requirement already satisfied: beautifulsoup4 in
/opt/conda/lib/python3.10/site-packages (from gdown) (4.12.2)
Requirement already satisfied: soupsieve>1.2 in
/opt/conda/lib/python3.10/site-packages (from beautifulsoup4->gdown)
(2.3.2.post1)
Requirement already satisfied: charset-normalizer<4,>=2 in
/opt/conda/lib/python3.10/site-packages (from requests[socks]->gdown)
(3.2.0)
Requirement already satisfied: idna<4,>=2.5 in
/opt/conda/lib/python3.10/site-packages (from requests[socks]->gdown)
(3.4)
Requirement already satisfied: urllib3<3,>=1.21.1 in
/opt/conda/lib/python3.10/site-packages (from requests[socks]->gdown)
(1.26.15)
Requirement already satisfied: certifi>=2017.4.17 in
/opt/conda/lib/python3.10/site-packages (from requests[socks]->gdown)
(2023.11.17)
Requirement already satisfied: PySocks!=1.5.7,>=1.5.6 in
/opt/conda/lib/python3.10/site-packages (from requests[socks]->gdown)
(1.7.1)
Installing collected packages: gdown
Successfully installed gdown-4.7.1
```

После установки пакетов для корректной работы надо обязательно перезагрузить ядро. Run -> Restart and clear cell outputs. Без сего действа будет ошибка при попытке обращения к библиотеке moviepy при сохранении визуализации в виде видео. Может когда-то авторы библиотеки это починят...

Импорт необходимых зависимостей:

```
from pathlib import Path
from typing import List, Tuple, Sequence
```

```
import numpy as np
from numpy import unravel_index
from PIL import Image, ImageDraw, ImageFont
from tqdm import tqdm, notebook

from moviepy.video.io.ImageSequenceClip import ImageSequenceClip

import math
from scipy.ndimage import gaussian_filter

import gc
import time
import random
import csv
```

```
/opt/conda/lib/python3.10/site-packages/scipy/__init__.py:146:
UserWarning: A NumPy version >=1.16.5 and <1.23.0 is required for this
version of SciPy (detected version 1.24.3
  warnings.warn(f"A NumPy version >={np_minversion} and
<{np_maxversion}"
```

Набор функций для загрузки данных из датасета

Функция load_clip_data загружает выбранный клип из выбранной игры и возвращает его в виде numpy массива [n_frames, height, width, 3] типа uint8. Для ускорения загрузки используется кэширование - однажды загруженные клипы хранятся на диске в виде npz архивов, при последующем обращении к таким клипам происходит загрузка npz архива.

Также добавлена возможность чтения клипа в половинном разрешении 640x360, вместо оригинального 1280x720 для упрощения и ускорения разрабатываемых алгоритмов.

Функция load_clip_labels загружает референсные координаты мяча в клипе в виде numpy массива [n_frames, 4], где в каждой строке массива содержатся значения [code, x, y, q]. x, y соответствуют координате центра мяча на кадре, q не используется в данном задании, code описывает статус мяча:

- code = 0 - мяча в кадре нет
- code = 1 - мяч присутствует в кадре и легко идентифицируем
- code = 2 - мяч присутствует в кадре, но сложно идентифицируем
- code = 3 - мяч присутствует в кадре, но заслонен другими объектами.

При загрузке в половинном разрешении координаты x, y делятся на 2.

Функция load_clip загружает выбранный клип и соответствующий массив координат и возвращает их в виде пары.

```
def get_num_clips(path: Path, game: int) -> int:
    return len(list((path / f'game{game}/').iterdir()))
```

```
def get_game_clip_pairs(path: Path, games: List[int]) ->
List[Tuple[int, int]]:
    return [(game, c)  for game in games for c in range(1,
get_num_clips(path, game) + 1)]


def load_clip_data(path: Path, game: int, clip: int, downscale: bool,
quiet=False) -> np.ndarray:
    if not quiet:
        suffix = 'downscaled' if downscale else ''
        print(f'loading clip data (game {game}, clip {clip})
{suffix}')
    cache_path = path / 'cache'
    cache_path.mkdir(exist_ok=True)
    resize_code = '_ds2' if downscale else ''
    cached_data_name = f'{game}_{clip}{resize_code}.npz'
    if (cache_path / cached_data_name).exists():
        clip_data = np.load(cache_path / cached_data_name)
['clip_data']
    else:
        clip_path = path / f'game{game}/clip{clip}'
        n_imgs = len(list(clip_path.iterdir())) - 1
        imgs = [None] * n_imgs
        for i in notebook.tqdm(range(n_imgs)):
            img = Image.open(clip_path / f'{i:04d}.jpg')
            if downscale:
                img = img.resize((img.width // 2, img.height // 2),)
            imgs[i] = np.array(img, dtype=np.uint8)
        clip_data = np.stack(imgs)
        cache_path.mkdir(exist_ok=True, parents=True)
        np.savez_compressed(cache_path / cached_data_name,
clip_data=clip_data)
    return clip_data


def load_clip_labels(path: Path, game: int, clip: int, downscale:
bool, quiet=False):
    if not quiet:
        print(f'loading clip labels (game {game}, clip {clip})')
    clip_path = path / f'game{game}/clip{clip}'
    labels = []
    with open(clip_path / 'labels.csv') as csvfile:
        lines = list(csv.reader(csvfile))
        for line in lines[1:]:
            values = np.array([-1 if i == '' else int(i) for i in
line[1:]])
            if downscale:
                values[1] //= 2
                values[2] //= 2
            labels.append(values)
```

```
    return np.stack(labels)


def load_clip(path: Path, game: int, clip: int, downscale: bool,
quiet=False):
    data = load_clip_data(path, game, clip, downscale, quiet)
    labels = load_clip_labels(path, game, clip, downscale, quiet)
    return data, labels
```

Набор дополнительных функций

Еще несколько функций, немного облегчающих выполнение задания:

- prepare_expariment создает новую директорию в out_path для хранения результатов текущего эксперимента. Нумерация выполняется автоматически, функция возвращает путь к созданной директории эксперимента;
- ball_gauss_template - создает "шаблон" мяча, может быть использована в алгоритмах поиска мяча на изображении по корреляции;
- create_masks - принимает набор кадров и набор координат мяча, и генерирует набор масок, в которых помещает шаблон мяча на заданные координаты. Может быть использована при обучении нейронной сети семантической сегментации;

```
def prepare_experiment(out_path: Path) -> Path:
    out_path.mkdir(parents=True, exist_ok=True)
    dirs = [d for d in out_path.iterdir() if d.is_dir() and
d.name.startswith('exp_')]
    experiment_id = max(int(d.name.split('_')[1]) for d in dirs) + 1
if dirs else 1
    exp_path = out_path / f'exp_{experiment_id}'
    exp_path.mkdir()
    return exp_path


def ball_gauss_template(rad, sigma):
    x, y = np.meshgrid(np.linspace(-rad, rad, 2 * rad + 1),
np.linspace(-rad, rad, 2 * rad + 1))
    dst = np.sqrt(x * x + y * y)
    gauss = np.exp(-(dst ** 2 / (2.0 * sigma ** 2)))
    return gauss


def create_masks(data: np.ndarray, labels: np.ndarray, resize):
    rad = 64 #25
    sigma = 10
    if resize:
        rad //= 2
    ball = ball_gauss_template(rad, sigma)
    n_frames = data.shape[0]
    sh = rad
```

```
    masks = []
    for i in range(n_frames):
        label = labels[i, ...]
        frame = data[i, ...]
        if 0 < label[0] < 3:
            x, y = label[1:3]
            mask = np.zeros((frame.shape[0] + 2 * rad + 2 * sh,
frame.shape[1] + 2 * rad + 2 * sh), np.float32)
            mask[y + sh : y + sh + 2 * rad + 1, x + sh : x + sh + 2 *
rad + 1] = ball
            mask = mask[rad + sh : -rad - sh, rad + sh : -rad - sh]
            masks.append(mask)
        else:
            masks.append(np.zeros((frame.shape[0], frame.shape[1]),
dtype=np.float32))
    return np.stack(masks)
```

Набор функций, предназначенных для визуализации результатов

Функция visualize_prediction принимает набор кадров, набор координат детекции мяча (можно подавать как референсные значения, так и предсказанные) и создает видеоклип, в котором отрисовывается положение мяча, его трек, номер кадра и метрика качества трекинга (если она была передана в функцию). Видеоклип сохраняется в виде mp4 файла. Кроме того данная функция создает текстовый файл, в который записывает координаты детекции мяча и значения метрики качества трекинга.

Функция visualize_prob принимает набор кадров и набор предсказанных карт вероятности и создает клип с наложением предсказанных карт вероятности на исходные карты. Области "подсвечиваются" желтым, клип сохраняется в виде mp4 видеофайла. Данная функция может быть полезна при наличии в алгоритме трекинга сети, осуществляющей семантическую сегментацию.

```
def _add_frame_number(frame: np.ndarray, number: int) -> np.ndarray:
    fnt = ImageFont.load_default() # ImageFont.truetype("arial.ttf",
25)
    img = Image.fromarray(frame)
    draw = ImageDraw.Draw(img)
    draw.text((10, 10), f'frame {number}', font=fnt, fill=(255, 0,
255))
    return np.array(img)


def _vis_clip(data: np.ndarray, lbls: np.ndarray, metrics: List[float]
= None, ball_rad=5, color=(255, 0, 0), track_length=10):
    print('perfoming clip visualization')
    n_frames = data.shape[0]
    frames_res = []
```

```
    fnt = ImageFont.load_default() # ImageFont.truetype("arial.ttf",
25)
    for i in range(n_frames):
        img = Image.fromarray(data[i, ...])
        draw = ImageDraw.Draw(img)
        txt = f'frame {i}'
        if metrics is not None:
            txt += f', SiBaTrAcc: {metrics[i]:.3f}'
        draw.text((10, 10), txt, font=fnt, fill=(255, 0, 255))
        label = lbls[i]
        if label[0] != 0: # the ball is clearly visible
            px, py = label[1], label[2]
            draw.ellipse((px - ball_rad, py - ball_rad, px + ball_rad,
py + ball_rad), outline=color, width=2)
            for q in range(track_length):
                if lbls[i-q-1][0] == 0:
                    break
                if i - q > 0:
                    draw.line((lbls[i - q - 1][1], lbls[i - q - 1][2],
lbls[i - q][1], lbls[i - q][2]), fill=color)
        frames_res.append(np.array(img))
    return frames_res


def _save_clip(frames: Sequence[np.ndarray], path: Path, fps):
    assert path.suffix in ('.mp4', '.gif')
    clip = ImageSequenceClip(frames, fps=fps)
    if path.suffix == '.mp4':
        clip.write_videofile(str(path), fps=fps, logger=None)
    else:
        clip.write_gif(str(path), fps=fps, logger=None)


def _to_yellow_heatmap(frame: np.ndarray, pred_frame: np.ndarray,
alpha=0.4):
    img = Image.fromarray((frame * alpha).astype(np.uint8))
    maskR = (pred_frame * (1 - alpha) * 255).astype(np.uint8)
    maskG = (pred_frame * (1 - alpha) * 255).astype(np.uint8)
    maskB = np.zeros_like(maskG, dtype=np.uint8)
    mask = np.stack([maskR, maskG, maskB], axis=-1)
    return img + mask


def _vis_pred_heatmap(data_full: np.ndarray, pred_prob: np.ndarray,
display_frame_number):
    n_frames = data_full.shape[0]
    v_frames = []
    for i in range(n_frames):
        frame = data_full[i, ...]
        pred = pred_prob[i, ...]
```

```
        hm = _to_yellow_heatmap(frame, pred)
        if display_frame_number:
            hm = _add_frame_number(hm, i)
        v_frames.append(hm)
    return v_frames


def visualize_prediction(data_full: np.ndarray, labels_pr: np.ndarray,
save_path: Path, name: str, metrics=None, fps=15):
    with open(save_path / f'{name}.txt', mode='w') as f:
        if metrics is not None:
            f.write(f'SiBaTrAcc: {metrics[-1]} \n')
        for i in range(labels_pr.shape[0]):
            f.write(f'frame {i}: {labels_pr[i, 0]}, {labels_pr[i, 1]},
{labels_pr[i, 2]} \n')

    v = _vis_clip(data_full, labels_pr, metrics)
    _save_clip(v, save_path / f'{name}.mp4', fps=fps)


def visualize_prob(data: np.ndarray, pred_prob: np.ndarray, save_path:
Path, name: str, frame_number=True, fps=15):
    v_pred = _vis_pred_heatmap(data, pred_prob, frame_number)
    _save_clip(v_pred, save_path / f'{name}_prob.mp4', fps=fps)
```

Класс DataGenerator

Класс, отвечающий за генерацию данных для обучения модели. Принимает на вход путь к директории с играми, индексы игр, используемые для генерации данных, и размер стопки. Хранит в себе автоматически обновляемый пул с клипами игр.

В пуле содержится pool_s клипов. DataGenerator позволяет генерировать батч из стопок (размера stack_s) последовательных кадров. Выбор клипа для извлечения данных взвешенно-случайный: чем больше длина клипа по сравнению с другими клипами в пуле, тем вероятнее, что именно из него будет сгенерирована стопка кадров. Выбор стопки кадров внтури выбранного клипа полностью случаен. Кадры внутри стопки конкатенируются по последнему измерению (каналам).

После генерирования количества кадров равного общему количеству кадров, хранимых в пуле, происходит автоматическое обновление пула: из пула извлекаются pool_update_s случайных клипов, после чего в пул загружается pool_update_s случайных клипов, не присутствующих в пуле. В случае, если размер пула pool_s больше или равен суммарному количеству клипов в играх, переданных в конструктор, все клипы сразу загружаются в пул, и автообновление не производится.

Использование подобного пула позволяет работать с практически произвольным количеством клипов, без необходимости загружать их всех в оперативную память.

Для вашего удобства функция извлечения стопки кадров из пула помимо самой стопки также создает и возвращает набор сгенерированных масок с мячом исходя из референсных координат мяча в клипе.

Функция random_g принимает гиперпараметр размера стопки кадров и предоставляет генератор, возвращающий стопки кадров и соответствующие им маски. Данный генератор может быть использован при реализации решения на tensorflow. Обновление пула происходит автоматически, об этом беспокоиться не нужно.

```
class DataGenerator:

    def __init__(self, path: Path, games: List[int], stack_s,
downscale, pool_s=30, pool_update_s=10, pool_autoupdate=True,
quiet=False) -> None:
        self.path = path
        self.stack_s = stack_s
        self.downscale = downscale
        self.pool_size = pool_s
        self.pool_update_size = pool_update_s
        self.pool_autoupdate = pool_autoupdate
        self.quiet = quiet
        self.data = []
        self.masks = []

        self.frames_in_pool = 0
        self.produced_frames = 0
        self.game_clip_pairs = get_game_clip_pairs(path,
list(set(games)))
        self.game_clip_pairs_loaded = []
        self.game_clip_pairs_not_loaded =
list.copy(self.game_clip_pairs)
        self.pool = {}

        self._first_load()

    def _first_load(self):
        # --- if all clips can be placed into pool at once, there is
no need to refresh pool at all ---
        if len(self.game_clip_pairs) <= self.pool_size:
            for gcp in self.game_clip_pairs:
                self._load(gcp)
            self.game_clip_pairs_loaded =
list.copy(self.game_clip_pairs)
            self.game_clip_pairs_not_loaded.clear()
            self.pool_autoupdate = False
        else:
            self._load_to_pool(self.pool_size)
        self._update_clip_weights()

    def _load(self, game_clip_pair):
```

```
        game, clip = game_clip_pair
        data, labels = load_clip(self.path, game, clip,
self.downscale, quiet=self.quiet)
        masks = create_masks(data, labels, self.downscale)
        weight = data.shape[0] if data.shape[0] >= self.stack_s else 0
        self.pool[game_clip_pair] = (data, labels, masks, weight)
        self.frames_in_pool += data.shape[0] - self.stack_s + 1
        # print(f'items in pool: {len(self.pool)} -
{self.pool.keys()}')

    def _remove(self, game_clip_pair):
        value = self.pool.pop(game_clip_pair)
        self.frames_in_pool -= value[0].shape[0] - self.stack_s + 1
        del value
        # print(f'items in pool: {len(self.pool)} -
{self.pool.keys()}')

    def _update_clip_weights(self):
        weights = [self.pool[pair][-1] for pair in
self.game_clip_pairs_loaded]
        tw = sum(weights)
        self.clip_weights = [w / tw for w in weights]
        # print(f'clip weights: {self.clip_weights}')

    def _remove_from_pool(self, n):
        # --- remove n random clips from pool ---
        if len(self.game_clip_pairs_loaded) >= n:
            remove_pairs = random.sample(self.game_clip_pairs_loaded,
n)
            for pair in remove_pairs:
                self._remove(pair)
                self.game_clip_pairs_loaded.remove(pair)
                self.game_clip_pairs_not_loaded.append(pair)
            gc.collect()

    def _load_to_pool(self, n):
        # --- add n random clips to pool ---
        gc.collect()
        add_pairs = random.sample(self.game_clip_pairs_not_loaded, n)
        for pair in add_pairs:
            self._load(pair)
            self.game_clip_pairs_not_loaded.remove(pair)
            self.game_clip_pairs_loaded.append(pair)

    def update_pool(self):
        self._remove_from_pool(self.pool_update_size)
        self._load_to_pool(self.pool_update_size)
        self._update_clip_weights()

    def get_random_stack(self):
```

```
        pair_idx = np.random.choice(len(self.game_clip_pairs_loaded),
1, p=self.clip_weights)[0]
        game_clip_pair = self.game_clip_pairs_loaded[pair_idx]
        d, _, m, _ = self.pool[game_clip_pair]
        start = np.random.choice(d.shape[0] - self.stack_s, 1)[0]
        frames_stack = d[start : start + self.stack_s, ...]
        frames_stack = np.squeeze(np.split(frames_stack,
indices_or_sections=self.stack_s, axis=0))
        frames_stack = np.concatenate(frames_stack, axis=-1)
        mask = m[start + self.stack_s - 1, ...]
        return frames_stack, mask

    def get_random_batch(self, batch_s):
        imgs, masks = [], []
        while len(imgs) < batch_s:
            frames_stack, mask = self.get_random_stack()
            imgs.append(frames_stack)
            masks.append(mask)
        if self.pool_autoupdate:
            self.produced_frames += batch_s
            # print(f'produced frames: {self.produced_frames} from
{self.frames_in_pool}')
            if self.produced_frames >= self.frames_in_pool:
                self.update_pool()
                self.produced_frames = 0
        return np.stack(imgs), np.stack(masks)

    def random_g(self, batch_s):
        tr = 0.2
        while True:
            imgs_batch, masks_batch = self.get_random_batch(batch_s)
            masks_batch = (masks_batch > tr).astype(int)
            yield imgs_batch,
masks_batch.reshape((masks_batch.shape[0], -1, 1))
```

Пример использования DataGenerator

Рекомендованный размер пула pool_s=10 в случае использования уменьшенных вдвое изображений. При большем размере пула есть большая вероятность нехватки имеющихся 13G оперативной памяти. Используйте параметр quiet=True в конструкторе DataGenerator, если хотите скрыть все сообщения о чтении данных и обновлении пула.

```
stack_s = 3
batch_s = 4
train_gen =
DataGenerator(Path('../input/tennistrackingassignment/train/'), [1, 2,
3, 4], stack_s=stack_s, downscale=True, pool_s=10, pool_update_s=4,
quiet=False)
for i in range(10):
```

```
    imgs, masks = train_gen.get_random_batch(batch_s)
    print(imgs.shape, imgs.dtype, masks.shape, masks.dtype)
```

```
loading clip data (game 3, clip 7) downscaled
loading clip labels (game 3, clip 7)
loading clip data (game 1, clip 7) downscaled
loading clip labels (game 1, clip 7)
loading clip data (game 1, clip 9) downscaled
loading clip labels (game 1, clip 9)
loading clip data (game 1, clip 11) downscaled
loading clip labels (game 1, clip 11)
loading clip data (game 4, clip 6) downscaled
loading clip labels (game 4, clip 6)
loading clip data (game 1, clip 10) downscaled
loading clip labels (game 1, clip 10)
loading clip data (game 2, clip 2) downscaled
loading clip labels (game 2, clip 2)
loading clip data (game 4, clip 12) downscaled
loading clip labels (game 4, clip 12)
loading clip data (game 2, clip 7) downscaled
loading clip labels (game 2, clip 7)
loading clip data (game 1, clip 12) downscaled
loading clip labels (game 1, clip 12)
(4, 360, 640, 9) uint8 (4, 360, 640) float32
(4, 360, 640, 9) uint8 (4, 360, 640) float32
(4, 360, 640, 9) uint8 (4, 360, 640) float32
(4, 360, 640, 9) uint8 (4, 360, 640) float32
(4, 360, 640, 9) uint8 (4, 360, 640) float32
(4, 360, 640, 9) uint8 (4, 360, 640) float32
(4, 360, 640, 9) uint8 (4, 360, 640) float32
(4, 360, 640, 9) uint8 (4, 360, 640) float32
(4, 360, 640, 9) uint8 (4, 360, 640) float32
(4, 360, 640, 9) uint8 (4, 360, 640) float32
```

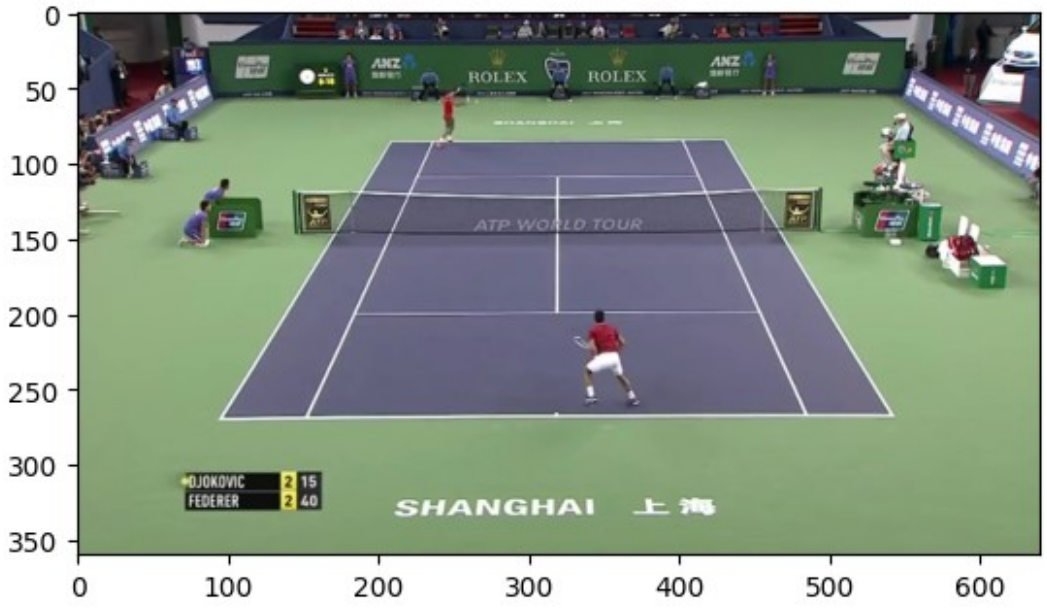
```
import matplotlib.pyplot as plt

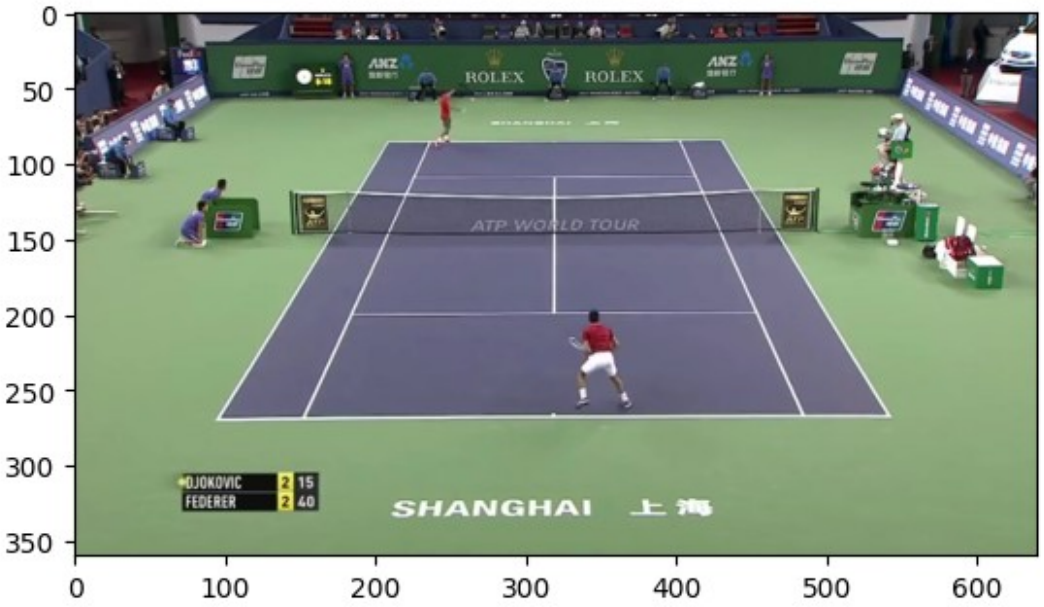
stack_s = 3
train_gen =
DataGenerator(Path('../input/tennistrackingassignment/train/'), [1],
stack_s=stack_s, downscale=True, pool_s=10, pool_update_s=4,
quiet=False)
stack, mask = train_gen.get_random_stack()
print(stack.shape, mask.shape)

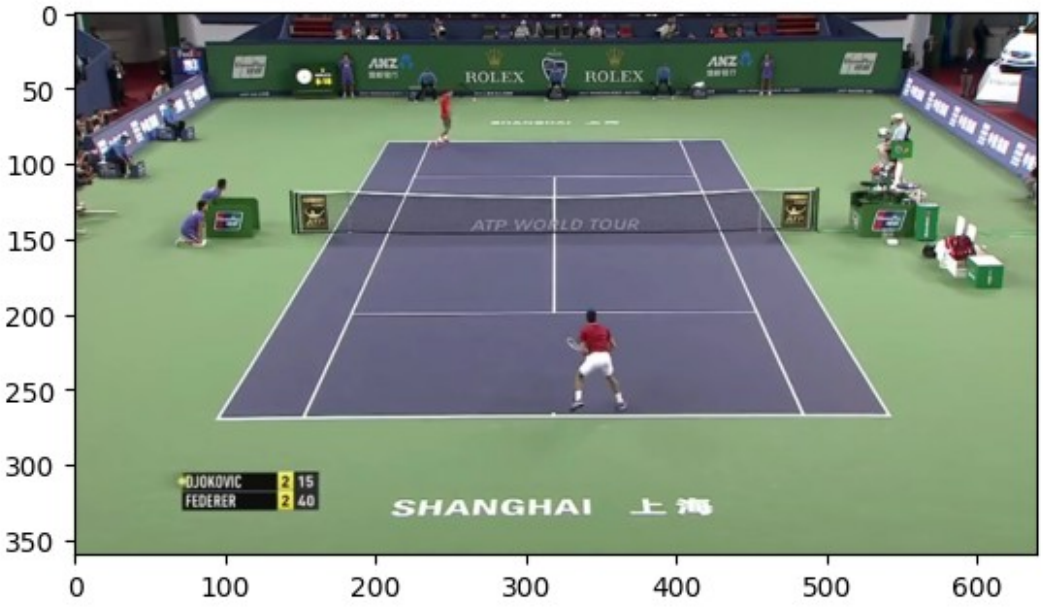
for i in range(stack_s):
    plt.figure()
    plt.imshow(stack[:, :, 3 * i: 3 * i + 3])
```

```
loading clip data (game 1, clip 5) downscaled
loading clip labels (game 1, clip 5)
```

```
loading clip data (game 1, clip 1) downscaled
loading clip labels (game 1, clip 1)
loading clip data (game 1, clip 3) downscaled
loading clip labels (game 1, clip 3)
loading clip data (game 1, clip 7) downscaled
loading clip labels (game 1, clip 7)
loading clip data (game 1, clip 12) downscaled
loading clip labels (game 1, clip 12)
loading clip data (game 1, clip 11) downscaled
loading clip labels (game 1, clip 11)
loading clip data (game 1, clip 4) downscaled
loading clip labels (game 1, clip 4)
loading clip data (game 1, clip 10) downscaled
loading clip labels (game 1, clip 10)
loading clip data (game 1, clip 13) downscaled
loading clip labels (game 1, clip 13)
loading clip data (game 1, clip 2) downscaled
loading clip labels (game 1, clip 2)
(360, 640, 9) (360, 640)
```







Класс Metrics

Класс для вычисления метрики качества трекинга SiBaTrAcc. Функция evaluate_predictions принимает массив из референсных и предсказанных координат мяча для клипа и возвращает массив аккумулированных значений SiBaTrAcc (может быть полезно для визуализации результатов предсказания) и итоговое значение метрики SiBaTrAcc.

```
class Metrics:

    @staticmethod
    def position_error(label_gt: np.ndarray, label_pr: np.ndarray,
```

```
step=8, alpha=1.5, e1=5, e2=5):
        # gt codes:
        # 0 - the ball is not within the image
        # 1 - the ball can easily be identified
        # 2 - the ball is in the frame, but is not easy to identify
        # 3 - the ball is occluded
        if label_gt[0] != 0 and label_pr[0] == 0:
            return e1
        if label_gt[0] == 0 and label_pr[0] != 0:
            return e2
        dist = math.sqrt((label_gt[1] - label_pr[1]) ** 2 +
(label_gt[2] - label_pr[2]) ** 2)
        pe = math.floor(dist / step) ** alpha
        pe = min(pe, 5)
        return pe

    @staticmethod
    def evaluate_predictions(labels_gt, labels_pr) ->
Tuple[List[float], float]:
        pe = [Metrics.position_error(labels_gt[i, ...],
labels_pr[i, ...]) for i in range(len(labels_gt))]
        SIBATRACC = []
        for i, _ in enumerate(pe):
            SIBATRACC.append(1 - sum(pe[: i + 1]) / ((i + 1) * 5))
        SIBATRACC_total = 1 - sum(pe) / (len(labels_gt) * 5)
        return SIBATRACC, SIBATRACC_total
```

Основной класс модели SuperTrackingModel

Реализует всю логику обучения, сохранения, загрузки и тестирования разработанной модели трекинга. Этот класс можно и нужно расширять.

В качестве примера вам предлагается заготовка модели, в которой трекинг осуществляется за счет предсказания маски по входному батчу и последующему предсказанию координат мяча по полученной маски. В данном варианте вызов функции предсказания координат по клипу (predict) повлечет за собой разбиение клипа на батчи, вызов предсказания маски для каждого батча, склеивание результатов в последовательность масок, вызов функции по вычислению координат мяча по маскам и возвращения результата. Описанные действия уже реализованы, вам остается только написать функции predict_on_bath и get_labels_from_prediction. Эта же функция predict используется и в вызове функции test, дополнительно вычисляя метрику качества трекинга и при необходимости визуализируя результат тестирования. Обратите внимание, что в результирующем numpy массиве с координатами помимо значений x и y первым значением в каждой строке должно идти значение code (0, если мяча в кадре нет и > 0, если мяч в кадре есть) для корректного вычисления качества трекинга.

Вам разрешается менять логику работы класса модели, (например, если решение не подразумевает использование масок), но при этом логика и работа функций load и test должна остаться неизменной!

```
!sed -i 's/from scipy.spatial import ConvexHull, QhullError/from
scipy.spatial import ConvexHull/g' /opt/conda/lib/python3.10/site-
packages/skimage/morphology/convex_hull.py
from skimage import img_as_ubyte
from skimage.transform import hough_circle, hough_circle_peaks
from skimage.feature import canny
import cv2
import tensorflow as tf
from tensorflow.keras.layers import Conv2D, MaxPooling2D, Dropout,
Conv2DTranspose, concatenate, Input, Reshape

import cv2
from tensorflow.keras.layers import *
from keras.models import *

import tensorflow as tf
from tensorflow.keras.preprocessing import image
from tensorflow.keras.applications.efficientnet import
preprocess_input
import time
from tensorflow.keras.optimizers import Adam, Adadelta
from tensorflow.keras.losses import SparseCategoricalCrossentropy

import tensorflow_addons as tfa
```

```
/opt/conda/lib/python3.10/site-packages/tensorflow_addons/utils/
tfa_eol_msg.py:23: UserWarning:

TensorFlow Addons (TFA) has ended development and introduction of new
features.
TFA has entered a minimal maintenance and release mode until a planned
end of life in May 2024.
Please modify downstream libraries to take dependencies from other
repositories in our TensorFlow community (e.g. Keras, Keras-CV, and
Keras-NLP).

For more information see:
https://github.com/tensorflow/addons/issues/2807

  warnings.warn(
```

```
import tensorflow as tf
from tensorflow.keras.layers import Conv2D, MaxPooling2D, Dropout,
Conv2DTranspose, concatenate, Input, Reshape

def ImprovedUNet(input_size, num_classes=2):
    # Build the model
    inputs = Input(input_size)

    # Contraction path
```

```
    c2 = Conv2D(32, (3, 3), activation='relu',
kernel_initializer='he_normal', padding='same')(inputs)
    c2 = Dropout(0.1)(c2)
    c2 = Conv2D(32, (3, 3), activation='relu',
kernel_initializer='he_normal', padding='same')(c2)
    p2 = MaxPooling2D((2, 2))(c2)

    c3 = Conv2D(64, (3, 3), activation='relu',
kernel_initializer='he_normal', padding='same')(p2)
    c3 = Dropout(0.2)(c3)
    c3 = Conv2D(64, (3, 3), activation='relu',
kernel_initializer='he_normal', padding='same')(c3)
    p3 = MaxPooling2D((2, 2))(c3)

    c4 = Conv2D(128, (3, 3), activation='relu',
kernel_initializer='he_normal', padding='same')(p3)
    c4 = Dropout(0.2)(c4)
    c4 = Conv2D(128, (3, 3), activation='relu',
kernel_initializer='he_normal', padding='same')(c4)
    p4 = MaxPooling2D(pool_size=(2, 2))(c4)

    c5 = Conv2D(256, (3, 3), activation='relu',
kernel_initializer='he_normal', padding='same')(p4)
    c5 = Dropout(0.3)(c5)
    c5 = Conv2D(256, (3, 3), activation='relu',
kernel_initializer='he_normal', padding='same')(c5)

    # Expansive path
    u6 = Conv2DTranspose(128, (2, 2), strides=(2, 2), padding='same')
(c5)
    u6 = concatenate([u6, c4])
    c6 = Conv2D(128, (3, 3), activation='relu',
kernel_initializer='he_normal', padding='same')(u6)
    c6 = Dropout(0.2)(c6)
    c6 = Conv2D(128, (3, 3), activation='relu',
kernel_initializer='he_normal', padding='same')(c6)

    u7 = Conv2DTranspose(64, (2, 2), strides=(2, 2), padding='same')
(c6)
    u7 = concatenate([u7, c3])
    c7 = Conv2D(64, (3, 3), activation='relu',
kernel_initializer='he_normal', padding='same')(u7)
    c7 = Dropout(0.2)(c7)
    c7 = Conv2D(64, (3, 3), activation='relu',
kernel_initializer='he_normal', padding='same')(c7)

    u8 = Conv2DTranspose(32, (2, 2), strides=(2, 2), padding='same')
(c7)
    u8 = concatenate([u8, c2])
    c8 = Conv2D(32, (3, 3), activation='relu',
```

```
kernel_initializer='he_normal', padding='same')(u8)
    c8 = Dropout(0.1)(c8)
    c8 = Conv2D(32, (3, 3), activation='relu',
kernel_initializer='he_normal', padding='same')(c8)

    outputs = Conv2D(num_classes, (1, 1), activation='softmax')(c8)
    x = Reshape((-1, num_classes))(outputs)

    model = tf.keras.Model(inputs=[inputs], outputs=[x])

    # Use categorical_crossentropy for multiclass segmentation
    model.compile(optimizer='adam', loss='categorical_crossentropy',
metrics=['accuracy'])

    return model

from keras.layers import Concatenate

def TrackNetWtihSkipkonModel(height, width, stack_s):
    input_images = Input(shape=(height, width, stack_s))

    batch_norm_1 = BatchNormalization()(input_images)

    # Encoder
    conv1 = Conv2D(64, (3, 3), kernel_initializer='random_uniform',
padding='same')(batch_norm_1)
    relu1 = Activation('relu')(conv1)
    batch_norm_2 = BatchNormalization()(relu1)

    conv2 = Conv2D(64, (3, 3), kernel_initializer='random_uniform',
padding='same')(batch_norm_2)
    relu2 = Activation('relu')(conv2)
    batch_norm_3 = BatchNormalization()(relu2)

    pool1 = MaxPooling2D((2, 2), strides=(2, 2))(batch_norm_3)

    conv3 = Conv2D(128, (3, 3), kernel_initializer='random_uniform',
padding='same')(pool1)
    relu3 = Activation('relu')(conv3)
    batch_norm_4 = BatchNormalization()(relu3)

    conv4 = Conv2D(128, (3, 3), kernel_initializer='random_uniform',
padding='same')(batch_norm_4)
    relu4 = Activation('relu')(conv4)
    batch_norm_5 = BatchNormalization()(relu4)

    pool2 = MaxPooling2D((2, 2), strides=(2, 2))(batch_norm_5)

    conv5 = Conv2D(256, (3, 3), kernel_initializer='random_uniform',
padding='same')(pool2)
    relu5 = Activation('relu')(conv5)
```

```
    batch_norm_6 = BatchNormalization()(relu5)

    conv6 = Conv2D(256, (3, 3), kernel_initializer='random_uniform',
padding='same')(batch_norm_6)
    relu6 = Activation('relu')(conv6)
    batch_norm_7 = BatchNormalization()(relu6)

    conv7 = Conv2D(256, (3, 3), kernel_initializer='random_uniform',
padding='same')(batch_norm_7)
    relu7 = Activation('relu')(conv7)
    batch_norm_8 = BatchNormalization()(relu7)

    pool3 = MaxPooling2D((2, 2), strides=(2, 2))(batch_norm_8)

    # Decoder with Skip Connections
    conv8 = Conv2D(512, (3, 3), kernel_initializer='random_uniform',
padding='same')(pool3)
    relu8 = Activation('relu')(conv8)
    batch_norm_9 = BatchNormalization()(relu8)

    conv9 = Conv2D(512, (3, 3), kernel_initializer='random_uniform',
padding='same')(batch_norm_9)
    relu9 = Activation('relu')(conv9)
    batch_norm_10 = BatchNormalization()(relu9)

    conv10 = Conv2D(512, (3, 3), kernel_initializer='random_uniform',
padding='same')(batch_norm_10)
    relu10 = Activation('relu')(conv10)
    batch_norm_11 = BatchNormalization()(relu10)

    upsample1 = UpSampling2D((2, 2))(batch_norm_11)

    # Concatenate skip connection
    skip1 = Concatenate(axis=-1)([upsample1, batch_norm_8])

    conv11 = Conv2D(256, (3, 3), kernel_initializer='random_uniform',
padding='same')(skip1)
    relu11 = Activation('relu')(conv11)
    batch_norm_12 = BatchNormalization()(relu11)

    conv12 = Conv2D(256, (3, 3), kernel_initializer='random_uniform',
padding='same')(batch_norm_12)
    relu12 = Activation('relu')(conv12)
    batch_norm_13 = BatchNormalization()(relu12)

    conv13 = Conv2D(256, (3, 3), kernel_initializer='random_uniform',
padding='same')(batch_norm_13)
    relu13 = Activation('relu')(conv13)
    batch_norm_14 = BatchNormalization()(relu13)
```

```
    upsample2 = UpSampling2D((2, 2))(batch_norm_14)

    # Concatenate skip connection
    skip2 = Concatenate(axis=-1)([upsample2, batch_norm_5])

    conv14 = Conv2D(128, (3, 3), kernel_initializer='random_uniform',
padding='same')(skip2)
    relu14 = Activation('relu')(conv14)
    batch_norm_15 = BatchNormalization()(relu14)

    conv15 = Conv2D(128, (3, 3), kernel_initializer='random_uniform',
padding='same')(batch_norm_15)
    relu15 = Activation('relu')(conv15)
    batch_norm_16 = BatchNormalization()(relu15)

    upsample3 = UpSampling2D((2, 2))(batch_norm_16)

    # Concatenate skip connection
    skip3 = Concatenate(axis=-1)([upsample3, batch_norm_2])

    conv16 = Conv2D(64, (3, 3), kernel_initializer='random_uniform',
padding='same')(skip3)
    relu16 = Activation('relu')(conv16)
    batch_norm_17 = BatchNormalization()(relu16)

    conv17 = Conv2D(64, (3, 3), kernel_initializer='random_uniform',
padding='same')(batch_norm_17)
    relu17 = Activation('relu')(conv17)
    batch_norm_18 = BatchNormalization()(relu17)

    conv18 = Conv2D(1, (3, 3), kernel_initializer='random_uniform',
padding='same')(batch_norm_18)
    sigmoid_output = Activation('sigmoid')(conv18)
    reshaped_output = Reshape((-1, 1))(sigmoid_output)

    model = Model(input_images, reshaped_output)
    return model
```

Итоговая модель

```
from keras.layers import Input, Conv2D, MaxPooling2D, UpSampling2D,
BatchNormalization, Activation, Reshape
from keras.models import Model


# architecture https://medium.com/geekculture/track-a-tennis-ball-
with-computer-vision-4f8d2f9c0412
def conv_block(input_layer, filters, kernel_size=(3, 3), strides=(1,
1)):
```

```
    conv = Conv2D(filters, kernel_size,
kernel_initializer='random_uniform', padding='same', strides=strides)
(input_layer)
    relu = Activation('relu')(conv)
    batch_norm = BatchNormalization()(relu)
    return batch_norm

def upsample_block(input_layer, filters, kernel_size=(3, 3)):
    upsampled = UpSampling2D((2, 2))(input_layer)
    conv = Conv2D(filters, kernel_size,
kernel_initializer='random_uniform', padding='same')(upsampled)
    relu = Activation('relu')(conv)
    batch_norm = BatchNormalization()(relu)
    return batch_norm

def VGG16ForTrack(input_size):
    input_images = Input(shape=input_size)
    batch_norm_1 = BatchNormalization()(input_images)

    # Encoder
    conv1 = conv_block(batch_norm_1, 64)
    conv2 = conv_block(conv1, 64)
    pool1 = MaxPooling2D((2, 2), strides=(2, 2))(conv2)

    conv3 = conv_block(pool1, 128)
    conv4 = conv_block(conv3, 128)
    pool2 = MaxPooling2D((2, 2), strides=(2, 2))(conv4)

    conv5 = conv_block(pool2, 256)
    conv6 = conv_block(conv5, 256)
    conv7 = conv_block(conv6, 256)
    pool3 = MaxPooling2D((2, 2), strides=(2, 2))(conv7)

    # Decoder
    conv8 = conv_block(pool3, 512)
    conv9 = conv_block(conv8, 512)
    conv10 = conv_block(conv9, 512)
    upsample1 = UpSampling2D((2, 2))(conv10)

    conv11 = conv_block(upsample1, 256)
    conv12 = conv_block(conv11, 256)
    conv13 = conv_block(conv12, 256)
    upsample2 = UpSampling2D((2, 2))(conv13)

    conv14 = conv_block(upsample2, 128)
    conv15 = conv_block(conv14, 128)
    upsample3 = UpSampling2D((2, 2))(conv15)

    # Output layer
    conv16 = conv_block(upsample3, 64)
```

```
    conv17 = conv_block(conv16, 64)
    conv18 = Conv2D(1, (3, 3), kernel_initializer='random_uniform',
padding='same')(conv17)
    sigmoid_output = Activation('sigmoid')(conv18)
    reshaped_output = Reshape((-1, 1))(sigmoid_output)

    model = Model(input_images, reshaped_output)
    return model

class SuperTrackingModel:

    def __init__(self, batch_s, stack_s, out_path,
downscale,height=720, width=1280):
        self.height = height
        self.width = width
        if downscale:
            self.height //= 2
            self.width //= 2
        self.batch_s = batch_s
        self.stack_s = stack_s
        self.model = VGG16ForTrack((self.height, self.width, 3 *
self.stack_s))
        self.out_path = out_path
        self.downscale = downscale

    def save(self, name: str):
        print("Saving to folder /working")
        self.model.save_weights(f'/kaggle/working/{name}.h5',
save_format='h5')

    def load(self, name: str):
        models = {
            'best_model': '1isDvGUI3C5Br2XEHJGUHuPcNhX_SWKrj',
            'test': '1Lfvi3r9DFtKipFGug1jE5k9-Qkrcc658'
        }
        output = f'/kaggle/working/{name}.h5'
        gdown.download(f"https://drive.google.com/uc?
export=download&confirm=pbef&id={models[name]}", output, quiet=False)

        self.model.load_weights(output)
        print('Loading model done.')

    def predict_on_batch(self, batch: np.ndarray) -> np.ndarray:
        predictions =
self.model.predict(batch).reshape((batch.shape[0], batch.shape[1],
batch.shape[2]))
        return predictions

    def _predict_prob_on_clip(self, clip: np.ndarray) -> np.ndarray:
        print('doing predictions')
```

```
        n_frames = clip.shape[0]
        # --- get stacks ---
        stacks = []
        for i in range(n_frames - self.stack_s + 1):
            stack = clip[i : i + self.stack_s, ...]
            if self.stack_s > 1:
                stack = np.squeeze(np.split(stack, self.stack_s,
axis=0))
            stack = np.concatenate(stack, axis=-1)
            stacks.append(stack)
        # --- round to batch size ---
        add_stacks = 0
        while len(stacks) % self.batch_s != 0:
            stacks.append(stacks[-1])
            add_stacks += 1
        # --- group into batches ---
        batches = []
        for i in range(len(stacks) // self.batch_s):
            batch = np.stack(stacks[i * self.batch_s : (i + 1) *
self.batch_s])
            batches.append(batch)
        stacks.clear()
        # --- perform predictions ---
        predictions = []
        for batch in batches:
            pred = np.squeeze(self.predict_on_batch(batch))
            predictions.append(pred)
        # --- crop back to source length ---
        predictions = np.concatenate(predictions, axis=0)
        if (add_stacks > 0):
            predictions = predictions[:-add_stacks, ...]
        batches.clear()
        # --- add (stack_s - 1) null frames at the begining ---
        start_frames = np.zeros((stack_s - 1, predictions.shape[1],
predictions.shape[2]), dtype=np.float32)
        predictions = np.concatenate((start_frames, predictions),
axis=0)
        print('predictions are made')
        return predictions

    def get_labels_from_prediction(self, pred_prob: np.ndarray,
upscale_coords: bool) -> np.ndarray:
        n_frames = pred_prob.shape[0]
        coords = np.zeros([n_frames, 3])
        for i in range(n_frames):
            prediction_mask = pred_prob[i]
            if prediction_mask.sum() < 1:
                coords[i] = [0, -1, -1]
            else:
```

```
                prediction_mask[prediction_mask < 0.5] = 0
                prediction_mask[prediction_mask >= 0.5] = 1

                code = 0
                x, y = -1, -1

                image = img_as_ubyte(prediction_mask)
                edges = canny(image, sigma=3, low_threshold=10,
high_threshold=50)
                hough_res = hough_circle(edges, np.arange(15, 30, 2))
                acc, cx, cy, rad = hough_circle_peaks(hough_res,
np.arange(15, 30, 2),
                                                      total_num_peaks=1)
                if cx.size > 0:
                    x, y, code = cx[0], cy[0], 1
                if upscale_coords:
                    x, y = 2 * x, 2 * y
                coords[i] = [code, x, y]

        return coords

    def predict(self, clip: np.ndarray, upscale_coords) -> np.ndarray:
        prob_pr = self._predict_prob_on_clip(clip)
        print(prob_pr.shape)
        labels_pr = self.get_labels_from_prediction(prob_pr,
upscale_coords)
        return labels_pr, prob_pr

    def test(self, data_path: Path, games: List[int],
do_visualization=False, test_name='test'):
        game_clip_pairs = get_game_clip_pairs(data_path, games)
        SIBATRACC_vals = []
        for game, clip in game_clip_pairs:
            data = load_clip_data(data_path, game, clip,
downscale=self.downscale)
            if do_visualization:
                data_full = load_clip_data(data_path, game, clip,
downscale=False) if self.downscale else data
            labels_gt = load_clip_labels(data_path, game, clip,
downscale=False)
            labels_pr, prob_pr = self.predict(data, self.downscale)
            SIBATRACC_per_frame, SIBATRACC_total =
Metrics.evaluate_predictions(labels_gt, labels_pr)
            SIBATRACC_vals.append(SIBATRACC_total)
            if do_visualization:
                visualize_prediction(data_full, labels_pr,
self.out_path, f'{test_name}_g{game}_c{clip}', SIBATRACC_per_frame)
                visualize_prob(data, prob_pr, self.out_path,
f'{test_name}_g{game}_c{clip}')
                del data_full
```

```
            del data, labels_gt, labels_pr, prob_pr
            gc.collect()
            print("curr_acc", sum(SIBATRACC_vals) /
len(SIBATRACC_vals))
        SIBATRACC_final = sum(SIBATRACC_vals) / len(SIBATRACC_vals)
        return SIBATRACC_final

    def train(self, train_generator, val_gen, epochs=5):
        self.epochs = epochs
        #ДОП 1, 2

self.model.compile(optimizer=tf.keras.optimizers.Adam(learning_rate=1.
0),loss=tf.keras.losses.BinaryCrossentropy())
        # ДОП 5
        self.model.fit(train_generator, validation_data=val_gen,
epochs=self.epochs, steps_per_epoch = 1000 // self.batch_s,
validation_steps=1000 // 5 // self.batch_s)
        #Доп 3
        self.save('tmp_last_model')
        print('Training done')
```

Загрузка датасета

```
batch_s = 6
stack_s = 3
downscale = True

output_path = prepare_experiment(Path('/kaggle/working'))
train_gen =
DataGenerator(Path('../input/tennistrackingassignment/train/'), [1, 2,
3, 5], stack_s=stack_s, downscale=True, pool_s=10, pool_update_s=4,
quiet=False)
val_gen =
DataGenerator(Path('../input/tennistrackingassignment/train/'), [4,
6], stack_s=stack_s, downscale=True, pool_s=4, pool_update_s=2,
quiet=False)
```

```
loading clip data (game 2, clip 9) downscaled
loading clip labels (game 2, clip 9)
loading clip data (game 1, clip 8) downscaled
loading clip labels (game 1, clip 8)
loading clip data (game 2, clip 4) downscaled
loading clip labels (game 2, clip 4)
loading clip data (game 1, clip 2) downscaled
loading clip labels (game 1, clip 2)
loading clip data (game 5, clip 3) downscaled
loading clip labels (game 5, clip 3)
loading clip data (game 3, clip 1) downscaled
```

```
loading clip labels (game 3, clip 1)
loading clip data (game 3, clip 7) downscaled
loading clip labels (game 3, clip 7)
loading clip data (game 5, clip 2) downscaled
loading clip labels (game 5, clip 2)
loading clip data (game 3, clip 4) downscaled
loading clip labels (game 3, clip 4)
loading clip data (game 5, clip 4) downscaled
loading clip labels (game 5, clip 4)
loading clip data (game 4, clip 14) downscaled
loading clip labels (game 4, clip 14)
loading clip data (game 6, clip 5) downscaled
loading clip labels (game 6, clip 5)
loading clip data (game 4, clip 8) downscaled
loading clip labels (game 4, clip 8)
loading clip data (game 4, clip 6) downscaled
loading clip labels (game 4, clip 6)
```

Тренировка модели

```
model = SuperTrackingModel(batch_s, stack_s, out_path=output_path,
downscale=downscale)
model.train(train_gen.random_g(batch_s), val_gen.random_g(batch_s))

Running stub for training model...
Epoch 1/10
166/166 [==============================] - 228s 1s/step - loss: 0.1818
- val_loss: 0.0271
Epoch 2/10
166/166 [==============================] - 199s 1s/step - loss: 0.0179
- val_loss: 0.0316
Epoch 3/10
166/166 [==============================] - ETA: 0s - loss:
0.0069loading clip data (game 4, clip 6) downscaled
loading clip labels (game 4, clip 6)
loading clip data (game 4, clip 2) downscaled
loading clip labels (game 4, clip 2)
166/166 [==============================] - 200s 1s/step - loss: 0.0069
- val_loss: 0.0172
Epoch 4/10
  7/166 [>.............................] - ETA: 2:58 - loss:
0.0054loading clip data (game 1, clip 2) downscaled
loading clip labels (game 1, clip 2)
  8/166 [>.............................] - ETA: 2:57 - loss:
0.0057loading clip data (game 1, clip 12) downscaled
loading clip labels (game 1, clip 12)
loading clip data (game 1, clip 1) downscaled
  9/166 [>.............................] - ETA: 2:56 - loss:
```

```
0.0054loading clip labels (game 1, clip 1)
loading clip data (game 1, clip 10) downscaled
loading clip labels (game 1, clip 10)
166/166 [==============================] - 199s 1s/step - loss: 0.0044
- val_loss: 0.0129
Epoch 5/10
166/166 [==============================] - ETA: 0s - loss:
0.0037loading clip data (game 6, clip 9) downscaled
loading clip labels (game 6, clip 9)
loading clip data (game 6, clip 6) downscaled
loading clip labels (game 6, clip 6)
166/166 [==============================] - 201s 1s/step - loss: 0.0037
- val_loss: 0.0082
Epoch 6/10
129/166 [======================>.......] - ETA: 41s - loss:
0.0033loading clip data (game 2, clip 4) downscaled
130/166 [======================>.......] - ETA: 40s - loss:
0.0033loading clip labels (game 2, clip 4)
131/166 [======================>.......] - ETA: 39s - loss:
0.0033loading clip data (game 5, clip 1) downscaled
loading clip labels (game 5, clip 1)
132/166 [======================>.......] - ETA: 38s - loss:
0.0033loading clip data (game 1, clip 5) downscaled
loading clip labels (game 1, clip 5)
loading clip data (game 2, clip 6) downscaled
loading clip labels (game 2, clip 6)
166/166 [==============================] - 199s 1s/step - loss: 0.0035
- val_loss: 0.0085
Epoch 8/10
166/166 [==============================] - ETA: 0s - loss:
0.0032loading clip data (game 6, clip 9) downscaled
loading clip labels (game 6, clip 9)
loading clip data (game 6, clip 2) downscaled
loading clip labels (game 6, clip 2)
166/166 [==============================] - 201s 1s/step - loss: 0.0032
- val_loss: 0.0121
Epoch 9/10
100/166 [=================>............] - ETA: 1:14 - loss:
0.0031loading clip data (game 5, clip 8) downscaled
loading clip labels (game 5, clip 8)
loading clip data (game 1, clip 12) downscaled
101/166 [=================>............] - ETA: 1:13 - loss:
0.0031loading clip labels (game 1, clip 12)
loading clip data (game 1, clip 10) downscaled
loading clip labels (game 1, clip 10)
loading clip data (game 1, clip 13) downscaled
102/166 [=================>............] - ETA: 1:11 - loss:
0.0031loading clip labels (game 1, clip 13)
166/166 [==============================] - 199s 1s/step - loss: 0.0031
```

```
- val_loss: 0.0050
Epoch 10/10
166/166 [==============================] - 199s 1s/step - loss: 0.0030
- val_loss: 0.0068
training done.
```

Тестирование модели

```
import gdown
output_path = prepare_experiment(Path('/kaggle/working'))
new_model = SuperTrackingModel(batch_s, stack_s, out_path=output_path,
downscale=downscale)
new_model.load('best_model')

sibatracc_final =
new_model.test(Path('../input/tennistrackingassignment/test/'), [1],
do_visualization=False, test_name='test')
print(f'SiBaTrAcc final value: {sibatracc_final}')
```

```
Downloading...
From: https://drive.google.com/uc?
export=download&confirm=pbef&id=1isDvGUI3C5Br2XEHJGUHuPcNhX_SWKrj
To: /kaggle/working/best_model.h5

  0%|          | 0.00/42.4M [00:00<?, ?B/s]

Loading model done.
loading clip data (game 1, clip 1) downscaled
loading clip labels (game 1, clip 1)
doing predictions
1/1 [==============================] - 0s 352ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 26ms/step
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1/1 [==============================] - 0s 27ms/step
1/1 [==============================] - 0s 27ms/step
1/1 [==============================] - 0s 25ms/step
```

```
1/1 [==============================] - 0s 26ms/step
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1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 25ms/step
predictions are made
(361, 360, 640)
curr_acc 0.8067432536705007
loading clip data (game 1, clip 2) downscaled
loading clip labels (game 1, clip 2)
doing predictions
1/1 [==============================] - 0s 28ms/step
```

```
1/1 [==============================] - 0s 29ms/step
1/1 [==============================] - 0s 27ms/step
1/1 [==============================] - 0s 30ms/step
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1/1 [==============================] - 0s 28ms/step
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1/1 [==============================] - 0s 28ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 29ms/step
1/1 [==============================] - 0s 26ms/step
predictions are made
(199, 360, 640)
curr_acc 0.8457551171621386
loading clip data (game 1, clip 3) downscaled
loading clip labels (game 1, clip 3)
doing predictions
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 26ms/step
predictions are made
(36, 360, 640)
curr_acc 0.8230960040340184
loading clip data (game 1, clip 4) downscaled
loading clip labels (game 1, clip 4)
```

```
doing predictions
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 26ms/step
predictions are made
(45, 360, 640)
curr_acc 0.8139886696921804
loading clip data (game 1, clip 5) downscaled
loading clip labels (game 1, clip 5)
doing predictions
1/1 [==============================] - 0s 27ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 26ms/step
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1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 34ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 27ms/step
1/1 [==============================] - 0s 26ms/step
predictions are made
```

```
(196, 360, 640)
curr_acc 0.8179606445037961
loading clip data (game 1, clip 6) downscaled
loading clip labels (game 1, clip 6)
doing predictions
1/1 [==============================] - 0s 28ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 42ms/step
1/1 [==============================] - 0s 26ms/step
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```

```
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1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 25ms/step
predictions are made
```

```
(551, 360, 640)
curr_acc 0.8262903479077464
loading clip data (game 1, clip 7) downscaled
loading clip labels (game 1, clip 7)
doing predictions
1/1 [==============================] - 0s 28ms/step
1/1 [==============================] - 0s 27ms/step
1/1 [==============================] - 0s 27ms/step
1/1 [==============================] - 0s 27ms/step
1/1 [==============================] - 0s 26ms/step
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1/1 [==============================] - 0s 28ms/step
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1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 26ms/step
predictions are made
(189, 360, 640)
curr_acc 0.8177230303117423
loading clip data (game 1, clip 8) downscaled
loading clip labels (game 1, clip 8)
doing predictions
1/1 [==============================] - 0s 27ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 29ms/step
```

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1/1 [==============================] - 0s 26ms/step
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1/1 [==============================] - 0s 28ms/step
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1/1 [==============================] - 0s 27ms/step
1/1 [==============================] - 0s 27ms/step
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```

```
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 25ms/step
predictions are made
(645, 360, 640)
curr_acc 0.8263548555683663
SiBaTrAcc final value: 0.8263548555683663
```

Во время самостоятельного тестирования попробуйте хотя бы раз сделать тестирование с визуализацией (do_visualization=True), чтобы визуально оценить качество трекинга разработанной моделью.

Загрузка модели через функцию load должна происходить полностью автоматически без каких-либо действий со стороны пользователя! Один из вариантов подобной реализации с использованием google drive и пакета gdown приведен в разделе с дополнениями.

Дополнения

Иногда при записи большого количества файлов в output директорию kaggle может "тупить" и не отображать корректно структуру дерева файлов в output и не показывать кнопки для скачивания выбранного файла. В этом случае удобно будет запаковать директорию с экспериментом и выкачать ее вручную. Пример для выкачивания директории с первым экспериментом приведен ниже:

```
%cd /kaggle/working/
!zip -r "exp_1.zip" "exp_1"
from IPython.display import FileLink
FileLink(r'exp_1.zip')
```

удалить лишние директории или файлы в output тоже легко:

```
!rm -r /kaggle/working/exp_1
```

Для реализации загрузки данных рекомендуется использовать облачное хранилище google drive и пакет gdown для скачивания файлов. Пример подобного использования приведен ниже:

1. загружаем файл в google drive (в данном случае, это npz архив, содержащий один numpy массив по ключу 'w')
2. в интерфейсе google drive открываем доступ на чтение к файлу по ссылке и извлекаем из ссылки id файла
3. формируем url для скачивания файла
4. с помощью gdown скачиваем файл
5. распаковываем npz архив и пользуемся numpy массивом

Обратите внимание, что для корректной работы нужно правильно определить id файла. В частности, в ссылке https://drive.google.com/file/d/1kZ8CC-zfkB_TlwtBjuPcEfsPV0Jz7IPA/

view?usp=sharing id файла заключен между ...d/ b /view?... и равен 1kZ8CC-zfkB_TlwtBjuPcEfsPV0Jz7IPA

```
import gdown

id = '1kZ8CC-zfkB_TlwtBjuPcEfsPV0Jz7IPA'
url = f'https://drive.google.com/uc?id={id}'
output = 'sample-weights.npz'
gdown.download(url, output, quiet=False)

import numpy as np

weights = np.load('/kaggle/working/sample-weights.npz')['w']
print(weights)
```