Физтех-Школа Прикладной математики и информатики (ФПМИ) МФТИ

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Путешествие по Спрингфилду.

Сегодня вам предстоить помочь телекомпании FOX в обработке их контента. Как вы знаете сериал Симсоны идет на телеэкранах более 25 лет и за это время скопилось очень много видео материала. Персоонажи менялись вместе с изменяющимися графическими технологиями и Гомер 2018 не очень похож на Гомера 1989. Нашей задачей будет научиться классифицировать персонажей проживающих в Спрингфилде. Думаю, что нет смысла представлять каждого из них в отдельности.

Установка зависимостей

In [1]:

```python
# ignore deprication warnings
import warnings
warnings.filterwarnings(action='ignore', category=DeprecationWarning)

# standard python modules
import os, sys
import time


# standard ml modules
import random
import numpy as np
import pandas as pd
from matplotlib import pyplot as plt, colors
# work in interactive mode
%matplotlib inline


# loading files (in parallel)
from pathlib import Path
from multiprocessing.pool import ThreadPool


# working with images
import PIL
from PIL import Image
from skimage import io

# preprocessing
from sklearn.preprocessing import LabelEncoder


# torch
import torch
import torch.nn as nn
from torch.utils.data import Dataset, DataLoader
import torch.optim as optim
from torch.optim import lr_scheduler
# torchvision
import torchvision
from torchvision import transforms


# interacrive timing
from tqdm import tqdm, tqdm_notebook

# saving models
import pickle
import copy
```

In [2]:

```python
print(PIL.__version__)
```

```
7.0.0
```

In [3]:

```python
print("torch.__version__ :", torch.__version__)
print("torchvision.__version__ :", torchvision.__version__)
```

```
torch.__version__ : 1.7.0+cu101
torchvision.__version__ : 0.8.1+cu101
```

Выбираем GPU для обучения

In [4]:

```
# we will verify that GPU is enabled for this notebook
# following should print: CUDA is available!  Training on GPU ...
#
# if it prints otherwise, then you need to enable GPU:
# from Menu > Runtime > Change Runtime Type > Hardware Accelerator > GPU

train_on_gpu = torch.cuda.is_available()

if not train_on_gpu:
    print('CUDA is not available.  Training on CPU ...')
else:
    print('CUDA is available!  Training on GPU ...')
```

```
CUDA is available!  Training on GPU ...
```

In [63]:

```
!nvidia-smi
torch.cuda.is_available()
```

```
Tue Dec  1 13:02:38 2020
+-----------------------------------------------------------------------------+
| NVIDIA-SMI 455.38       Driver Version: 418.67       CUDA Version: 10.1     |
|-------------------------------+----------------------+----------------------+
| GPU  Name        Persistence-M| Bus-Id        Disp.A | Volatile Uncorr. ECC |
| Fan  Temp  Perf  Pwr:Usage/Cap|         Memory-Usage | GPU-Util  Compute M. |
|                               |                      |               MIG M. |
|===============================+======================+======================|
|   0  Tesla K80           Off  | 00000000:00:04.0 Off |                    0 |
| N/A   71C    P0    84W / 149W |   9120MiB / 11441MiB |      0%      Default |
|                               |                      |                 ERR! |
+-------------------------------+----------------------+----------------------+

+-----------------------------------------------------------------------------+
| Processes:                                                                  |
|  GPU   GI   CI        PID   Type   Process name                  GPU Memory |
|        ID   ID                                                   Usage      |
|=============================================================================|
|  No running processes found                                                 |
+-----------------------------------------------------------------------------+
```

Out[63]:

```
True
```

In [5]:

```
# different modes of dataset
DATA_MODES = ['train', 'val', 'test']
# all images will be scaled to size 224x224 px
RESCALE_SIZE = 224
# we work on a video card
DEVICE = torch.device("cuda" if torch.cuda.is_available() else "cpu")
```

In [6]:

```
DEVICE
```

Out[6]:

```
device(type='cuda')
```

In [7]:

```
# делаем результат воспроизводимым
SEED = 111

random.seed(SEED)
np.random.seed(SEED)
torch.manual_seed(SEED)
torch.cuda.manual_seed(SEED)
torch.backends.cudnn.deterministic = True
```

Подготовка данных

В нашем тесте будет 990 картинок, для которых вам будет необходимо предсказать класс.

https://jhui.github.io/2018/02/09/PyTorch-Data-loading-preprocess_torchvision/ (https://jhui.github.io/2018/02/09/PyTorch-Data-loading-preprocess_torchvision/)

Ниже мы используем враппер над датасетом для удобной работы. Вам стоит понимать, что происходит с LabelEncoder и с torch.Transformation.

ToTensor конвертирует PIL Image с параметрами в диапазоне [0, 255] (как все пиксели) в FloatTensor размера (C x H x W) [0,1] , затем производится масштабирование: $input = \frac{input - \mu}{\text{standard deviation}}$,
константы - средние и дисперсии по каналам на основе ImageNet

Стоит также отметить, что мы переопределяем метод **getitem** для удобства работы с данной структурой данных. Также используется LabelEncoder для преобразования строковых меток классов в id и обратно. В описании датасета указано, что картинки разного размера, так как брались напрямую с видео, поэтому следуем привести их к одному размер (это делает метод _prepare_sample)

Класс для параллельной загрузки данных из папок

In [8]:

```
class SimpsonsDataset(Dataset):
    """
    Датасет с картинками, который
    - параллельно подгружает их из папок
    - производит скалирование
    - превращение в PyTorch тензоры

    Class to work with image dataset, which
    - loads them form the folders in parallel
    - converts to PyTorch tensors
    - scales the tensors to have mean = 0, standard deviation = 1
    """
    def __init__(self, files, mode):
        super().__init__()
        self.files = sorted(files) # list of files to be loaded
        self.mode = mode           # working mode

        if self.mode not in DATA_MODES:
            print(f"{self.mode} is not correct; correct modes: {DATA_MODES}")
            raise NameError

        self.len_ = len(self.files)

        self.label_encoder = LabelEncoder()

        if self.mode != 'test':
            self.labels = [path.parent.name for path in self.files]
            self.label_encoder.fit(self.labels)

            with open('label_encoder.pkl', 'wb') as le_dump_file:
                  pickle.dump(self.label_encoder, le_dump_file)


    def __len__(self):
        return self.len_


    def load_sample(self, file):
        image = Image.open(file)
        image.load()
        return image


    def _prepare_sample(self, image):
        image = image.resize((RESCALE_SIZE, RESCALE_SIZE))
        return np.array(image)


    def __getitem__(self, index):
        # converts to PyTorch tensors and normalises the input

        # augumentation realised here
        data_transforms = {
            'train': transforms.Compose([
                transforms.Resize(size=(RESCALE_SIZE, RESCALE_SIZE)),
                transforms.RandomRotation(degrees=30),
                transforms.RandomHorizontalFlip()
                transforms.RandomHorizontalFlip(),
                transforms.ColorJitter(hue=.1, saturation=.1),
                transforms.ToTensor(),
                transforms.Normalize([0.485, 0.456, 0.406], [0.229, 0.224, 0.225])
            ]),
            'val_test': transforms.Compose([
                transforms.Resize(size=(RESCALE_SIZE, RESCALE_SIZE)),
                transforms.ToTensor(),
                # у этих картинок mean и std задаются такими значениями
                transforms.Normalize([0.485, 0.456, 0.406], [0.229, 0.224, 0.225])
            ]),
        }

        transform = (data_transforms['train'] if self.mode == 'train' else data_transforms['val_test'])

        x = self.load_sample(self.files[index])  # load image
        x = transform(x)                         # apply transform defined above

        if self.mode == 'test':
            return x
        else:
            label = self.labels[index]
            label_id = self.label_encoder.transform([label])
            y = label_id.item()
            return x, y
```

In [9]:

```
def imshow(inp, title=None, plt_ax=plt, default=False):
    """Imshow для тензоров"""
    inp = inp.numpy().transpose((1, 2, 0))
    mean = np.array([0.485, 0.456, 0.406])
    std = np.array([0.229, 0.224, 0.225])
    inp = std * inp + mean
    inp = np.clip(inp, 0, 1)
    plt_ax.imshow(inp)
    if title is not None:
        plt_ax.set_title(title)
    plt_ax.grid(False)
```

Считываем файлы

In [10]:

```
# подключаемся к Google Drive
from google.colab import drive
drive.mount('/content/gdrive/')
```

```
Mounted at /content/gdrive/
```

In [11]:

```
!unzip -q /content/gdrive/\ MyDrive/Simpsons_kaggle/simpsons_dataset.zip -d train
!unzip -q /content/gdrive/\ MyDrive/Simpsons_kaggle/testset.zip -d test
```

In [12]:

```
# Путь до директории на Google Drive
TRAIN_DIR = Path('train/simpsons_dataset')
TEST_DIR = Path('test/testset')

train_val_files = sorted(list(TRAIN_DIR.rglob('*.jpg')))
test_files = sorted(list(TEST_DIR.rglob('*.jpg')))
```

In [13]:

```
print(len(train_val_files), 'train files')
train_val_files[:2]
```

```
20933 train files
```

Out[13]:

```
[PosixPath('train/simpsons_dataset/abraham_grampa_simpson/pic_0000.jpg'),
 PosixPath('train/simpsons_dataset/abraham_grampa_simpson/pic_0001.jpg')]
```

In [14]:

```
print(len(test_files), 'test files')
test_files[:2]
```

```
991 test files
```

Out[14]:

```
[PosixPath('test/testset/img0.jpg'), PosixPath('test/testset/img1.jpg')]
```

In [15]:

```
# path.parent.name returns a folder
# in which the image is, which corresponds to the label in nthis case
train_val_labels = [path.parent.name for path in train_val_files]
```

In [16]:

```
print(len(train_val_labels), 'train_val_labels')
train_val_labels[:2]
```

```
20933 train_val_labels
```

Out[16]:

```
['abraham_grampa_simpson', 'abraham_grampa_simpson']
```

Обучение

Разделение на train-validation

In [17]:

```
from sklearn.model_selection import train_test_split
train_files, val_files = train_test_split(train_val_files, test_size=0.20, stratify=train_val_labels)
```

In [18]:

```
N_CLASSES = len(np.unique(train_val_labels))
```

In [19]:

```
val_dataset = SimpsonsDataset(val_files, mode='val')
```

In [20]:

```
if val_dataset is None:
    val_dataset = SimpsonsDataset(val_files, mode='val')

train_dataset = SimpsonsDataset(train_files, mode='train')
```

Среди изображений есть персонажи, которые всречаются всего несколько раз в тренировочной выборке. Дополним число изображений с этими персонажами до 100 штук, аугументацию не используем.

In [21]:

```
def create_dct_path_labels(train_files, train_labels):
    dct_simpsons = {}
    for label_i in np.unique(train_labels).tolist():
        dct_simpsons[label_i] = []

    for path_i, label_i in zip(train_files, train_labels):
        dct_simpsons[label_i].append(path_i)

    return dct_simpsons

# Создадим словарь в котором ключами будут персонажи Симпсонов, а значениями списки с путями к картинкам.
dct_path_train = create_dct_path_labels(train_files, train_dataset.labels)

# Дополним картинки классов у которых менее 100 картинок, до 100 картинок в классе
for person in dct_path_train:
    if len(dct_path_train[person]) < 100:
        dct_path_train[person] = dct_path_train[person] * (100 // len(dct_path_train[person]))
        dct_path_train[person].extend(dct_path_train[person][:100 - len(dct_path_train[person])])
# Проверим что получилось
for person in dct_path_train:
    print(f"{person}\t{len(dct_path_train[person])}")
new_train_files = []

for person in dct_path_train:
    new_train_files.extend(dct_path_train[person])

val_dataset = SimpsonsDataset(val_files, mode='val')
train_dataset = SimpsonsDataset(new_train_files, mode='train')
```

```
abraham_grampa_simpson  730
agnes_skinner   100
apu_nahasapeemapetilon  498
barney_gumble   100
bart_simpson    1074
carl_carlson    100
charles_montgomery_burns        954
chief_wiggum    789
cletus_spuckler 100
comic_book_guy  375
disco_stu       100
edna_krabappel  366
fat_tony        100
gil     100
groundskeeper_willie    100
homer_simpson   1797
kent_brockman   398
krusty_the_clown        965
lenny_leonard   248
lionel_hutz     100
lisa_simpson    1083
maggie_simpson  102
marge_simpson   1033
martin_prince   100
mayor_quimby    197
milhouse_van_houten     863
miss_hoover     100
moe_szyslak     1161
ned_flanders    1163
nelson_muntz    286
otto_mann       100
patty_bouvier   100
principal_skinner       955
professor_john_frink    100
rainier_wolfcastle      100
ralph_wiggum    100
selma_bouvier   100
sideshow_bob    702
sideshow_mel    100
snake_jailbird  100
troy_mcclure    100
waylon_smithers 145
```

Давайте посмотрим на наших героев внутри датасета.

In [22]:

```
fig, ax = plt.subplots(nrows=3, ncols=3,figsize=(8, 8), \
                        sharey=True, sharex=True)
for fig_x in ax.flatten():
    random_characters = int(np.random.uniform(0,1000))
    im_val, label = val_dataset[random_characters]
    img_label = " ".join(map(lambda x: x.capitalize(),\
                val_dataset.label_encoder.inverse_transform([label])[0].split('_')))
    imshow(im_val.data.cpu(), \
          title=img_label,plt_ax=fig_x)
```

Bart Simpson
Charles Montgomery Burns
Chief Wiggum
Chief Wiggum
Chief Wiggum
Apu Nahasapeemapetilon
Bart Simpson
Charles Montgomery Burns
Abraham Grampa Simpson
0
50
100
150
200
0
100
200

Функции для тренировки сети

In [23]:

```
def fit_epoch(model, train_loader, criterion, optimizer):
    # initialize tracked variables
    running_loss = 0.0
    running_corrects = 0
    processed_data = 0

    for inputs, labels in train_loader:
        inputs = inputs.to(DEVICE)
        labels = labels.to(DEVICE)

        # reset the gradient
        optimizer.zero_grad()

        # predictions (probabilities), loss, backprop
        outputs = model(inputs)
        loss = criterion(outputs, labels)
        loss.backward()

        # weights update
        optimizer.step()

        # predictions (classes)
        preds = torch.argmax(outputs, 1)

        # record tracked items
        running_loss += loss.item() * inputs.size(0)
        running_corrects += torch.sum(preds == labels.data)
        processed_data += inputs.size(0)

    # record train loss and train accuracy
    train_loss = running_loss / processed_data
    train_acc = running_corrects.cpu().numpy() / processed_data
    return train_loss, train_acc
```

In [24]:

```
def eval_epoch(model, val_loader, criterion):
    # set model model into the evaluation mode (e.g. for Dropout)
    model.eval()

    # initialize tracked variables
    running_loss = 0.0
    running_corrects = 0
    processed_size = 0

    for inputs, labels in val_loader:
        inputs = inputs.to(DEVICE)
        labels = labels.to(DEVICE)

        with torch.set_grad_enabled(False):
            outputs = model(inputs)
            loss = criterion(outputs, labels)
            preds = torch.argmax(outputs, 1)

        # record tracked items
        running_loss += loss.item() * inputs.size(0)
        running_corrects += torch.sum(preds == labels.data)
        processed_size += inputs.size(0)

    # record val loss and val accuracy
    val_loss = running_loss / processed_size
    val_acc = running_corrects.double() / processed_size
    return val_loss, val_acc
```

In [25]:

```
def train(train_dataset, val_dataset, model, criterion,
          epochs, batch_size, optimizer, scheduler,
          shuffle=True, sampler=None, patience=5):

    # to record the total training time
    since = time.time()

    # note: 4 workers loading the data
    train_loader = DataLoader(train_dataset, batch_size=batch_size, shuffle=shuffle, sampler=sampler, num_workers=4)
    val_loader = DataLoader(val_dataset, batch_size=batch_size, shuffle=False, num_workers=4)

    # init variables to store best model weights, best accuracy, best epoch number, epochs since best accuracy acheived
    best_model_wts = copy.deepcopy(model.state_dict())
    best_loss = 10
    best_epoch = 0
    epochs_since_best = 0

    # history and log
    history = []
    log_template = "\nEpoch {ep:03d} train_loss: {t_loss:0.4f} \
    val_loss {v_loss:0.4f} train_acc {t_acc:0.4f} val_acc {v_acc:0.4f}"

    with tqdm(desc="epoch", total=epochs) as pbar_outer:

        for epoch in range(1, epochs+1):
            print(f"epoch {epoch}:\n")

            print("Fitting on train data...")
            # all arguments except train loader are from parameters passed to train() arguments
            train_loss, train_acc = fit_epoch(model, train_loader, criterion, optimizer)
            print("train loss:", train_loss)

            print("Evaluating on validation data...")
            val_loss, val_acc = eval_epoch(model, val_loader, criterion)
            print("val loss:", val_loss)

            # record history
            history.append((train_loss, train_acc, val_loss, val_acc))

            # update learning rate for the optimizer
            scheduler.step()

            # display learning status
            pbar_outer.update(1)
            tqdm.write(log_template.format(ep=epoch, t_loss=train_loss,\
                                           v_loss=val_loss, t_acc=train_acc, v_acc=val_acc))

            # deep copy the model if it acheives the best validation performance
            if val_loss < best_loss:
                best_acc = val_loss
                best_epoch = epoch
                best_model_wts = copy.deepcopy(model.state_dict())
                print()
            else:
                epochs_since_best += 1

            # early stopping
            if epochs_since_best > patience:
                print(f'Stopping training. The validation metric has not improved for {patience} epochs.')
                break


    time_elapsed = time.time() - since
    print('Training complete in {:.0f}m {:.0f}s'.format(
    time_elapsed // 60, time_elapsed % 60))
    print('Best val loss: {:4f}'.format(best_loss))
    print('Best epoch: {}'.format(best_epoch))

    # load best model weights
    model.load_state_dict(best_model_wts)

    return history
```

In [26]:

```
def predict(model, test_loader):
    with torch.no_grad():
        logits = []

        for inputs in test_loader:
            inputs = inputs.to(DEVICE)
            model.eval()
            outputs = model(inputs).cpu()
            logits.append(outputs)

    probs = nn.functional.softmax(torch.cat(logits), dim=-1).numpy()
    return probs
```

Тренируем только последний слой сети

In [27]:

```
!pip install efficientnet_pytorch
```

```
Collecting efficientnet_pytorch
  Downloading https://files.pythonhosted.org/packages/4e/83/f9c5f44060f996279e474185ebcbd8dbd91
179593bffb9abe3afa55d085b/efficientnet_pytorch-0.7.0.tar.gz
Requirement already satisfied: torch in /usr/local/lib/python3.6/dist-packages (from efficientn
et_pytorch) (1.7.0+cu101)
Requirement already satisfied: numpy in /usr/local/lib/python3.6/dist-packages (from torch->eff
icientnet_pytorch) (1.18.5)
Requirement already satisfied: typing-extensions in /usr/local/lib/python3.6/dist-packages (fro
m torch->efficientnet_pytorch) (3.7.4.3)
Requirement already satisfied: dataclasses in /usr/local/lib/python3.6/dist-packages (from torc
h->efficientnet_pytorch) (0.8)
Requirement already satisfied: future in /usr/local/lib/python3.6/dist-packages (from torch->ef
ficientnet_pytorch) (0.16.0)
Building wheels for collected packages: efficientnet-pytorch
  Building wheel for efficientnet-pytorch (setup.py) ... done
  Created wheel for efficientnet-pytorch: filename=efficientnet_pytorch-0.7.0-cp36-none-any.whl
size=16031 sha256=7e4fe0e591fc6851d0f0fcd47910284c19a15e803a7f32fc1d3a805230e1d5c2
  Stored in directory: /root/.cache/pip/wheels/e9/c6/e1/7a808b26406239712cfce4b5ceeb67d9513ae32
aa4b31445c6
Successfully built efficientnet-pytorch
Installing collected packages: efficientnet-pytorch
Successfully installed efficientnet-pytorch-0.7.0
```

In [28]:

```
from efficientnet_pytorch import EfficientNet
```

In [29]:

```
model_name = 'efficientnet-b2'
```

In [30]:

```
model = EfficientNet.from_pretrained(model_name)
```

```
Downloading: "https://github.com/lukemelas/EfficientNet-PyTorch/releases/download/1.0/efficient
net-b2-8bb594d6.pth" to /root/.cache/torch/hub/checkpoints/efficientnet-b2-8bb594d6.pth


Loaded pretrained weights for efficientnet-b2
```

In [31]:

```
model
```

Out[31]:

```
EfficientNet(
  (_conv_stem): Conv2dStaticSamePadding(
    3, 32, kernel_size=(3, 3), stride=(2, 2), bias=False
    (static_padding): ZeroPad2d(padding=(1, 1, 1, 1), value=0.0)
  )
  (_bn0): BatchNorm2d(32, eps=0.001, momentum=0.010000000000000009, affine=True, track_running_
stats=True)
  (_blocks): ModuleList(
    (0): MBConvBlock(
      (_depthwise_conv): Conv2dStaticSamePadding(
        32, 32, kernel_size=(3, 3), stride=[1, 1], groups=32, bias=False
        (static_padding): ZeroPad2d(padding=(1, 1, 1, 1), value=0.0)
        (static_padding): ZeroPad2d(padding=(1, 1, 1, 1), value=0.0)

      )
      (_bn1): BatchNorm2d(32, eps=0.001, momentum=0.010000000000000009, affine=True, track_runn
ing_stats=True)
      (_se_reduce): Conv2dStaticSamePadding(
        32, 8, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_se_expand): Conv2dStaticSamePadding(
        8, 32, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_project_conv): Conv2dStaticSamePadding(
        32, 16, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn2): BatchNorm2d(16, eps=0.001, momentum=0.010000000000000009, affine=True, track_runn
ing_stats=True)
      (_swish): MemoryEfficientSwish()
    )
    (1): MBConvBlock(
      (_depthwise_conv): Conv2dStaticSamePadding(
        16, 16, kernel_size=(3, 3), stride=(1, 1), groups=16, bias=False
        (static_padding): ZeroPad2d(padding=(1, 1, 1, 1), value=0.0)
      )
      (_bn1): BatchNorm2d(16, eps=0.001, momentum=0.010000000000000009, affine=True, track_runn
ing_stats=True)
      (_se_reduce): Conv2dStaticSamePadding(
        16, 4, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_se_expand): Conv2dStaticSamePadding(
        4, 16, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_project_conv): Conv2dStaticSamePadding(
        16, 16, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn2): BatchNorm2d(16, eps=0.001, momentum=0.010000000000000009, affine=True, track_runn
ing_stats=True)
      (_swish): MemoryEfficientSwish()
    )
    (2): MBConvBlock(
      (_expand_conv): Conv2dStaticSamePadding(
        16, 96, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn0): BatchNorm2d(96, eps=0.001, momentum=0.010000000000000009, affine=True, track_runn
ing_stats=True)
      (_depthwise_conv): Conv2dStaticSamePadding(
        96, 96, kernel_size=(3, 3), stride=[2, 2], groups=96, bias=False
        (static_padding): ZeroPad2d(padding=(1, 1, 1, 1), value=0.0)
      )
      (_bn1): BatchNorm2d(96, eps=0.001, momentum=0.010000000000000009, affine=True, track_runn
ing_stats=True)
      (_se_reduce): Conv2dStaticSamePadding(
        96, 4, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_se_expand): Conv2dStaticSamePadding(
        4, 96, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_project_conv): Conv2dStaticSamePadding(
        96, 24, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn2): BatchNorm2d(24, eps=0.001, momentum=0.010000000000000009, affine=True, track_runn
ing_stats=True)
      (_swish): MemoryEfficientSwish()
    )
    (3): MBConvBlock(
      (_expand_conv): Conv2dStaticSamePadding(
        24, 144, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn0): BatchNorm2d(144, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_depthwise_conv): Conv2dStaticSamePadding(
        144, 144, kernel_size=(3, 3), stride=(1, 1), groups=144, bias=False
        (static_padding): ZeroPad2d(padding=(1, 1, 1, 1), value=0.0)
      )
      (_bn1): BatchNorm2d(144, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_se_reduce): Conv2dStaticSamePadding(
        144, 6, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_se_expand): Conv2dStaticSamePadding(
        6, 144, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_project_conv): Conv2dStaticSamePadding(
        144, 24, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn2): BatchNorm2d(24, eps=0.001, momentum=0.010000000000000009, affine=True, track_runn
ing_stats=True)
      (_swish): MemoryEfficientSwish()
    )
    (4): MBConvBlock(
      (_expand_conv): Conv2dStaticSamePadding(
        24, 144, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn0): BatchNorm2d(144, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_depthwise_conv): Conv2dStaticSamePadding(
        144, 144, kernel_size=(3, 3), stride=(1, 1), groups=144, bias=False
        (static_padding): ZeroPad2d(padding=(1, 1, 1, 1), value=0.0)
      )
      (_bn1): BatchNorm2d(144, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_se_reduce): Conv2dStaticSamePadding(
        144, 6, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_se_expand): Conv2dStaticSamePadding(
        6, 144, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_project_conv): Conv2dStaticSamePadding(
        144, 24, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn2): BatchNorm2d(24, eps=0.001, momentum=0.010000000000000009, affine=True, track_runn
ing_stats=True)
      (_swish): MemoryEfficientSwish()
    )
    (5): MBConvBlock(
      (_expand_conv): Conv2dStaticSamePadding(
        24, 144, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn0): BatchNorm2d(144, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_depthwise_conv): Conv2dStaticSamePadding(
        144, 144, kernel_size=(5, 5), stride=[2, 2], groups=144, bias=False
        (static_padding): ZeroPad2d(padding=(2, 2, 2, 2), value=0.0)
      )
      (_bn1): BatchNorm2d(144, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_se_reduce): Conv2dStaticSamePadding(
        144, 6, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_se_expand): Conv2dStaticSamePadding(
        6, 144, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_project_conv): Conv2dStaticSamePadding(
        144, 48, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn2): BatchNorm2d(48, eps=0.001, momentum=0.010000000000000009, affine=True, track_runn
ing_stats=True)
      (_swish): MemoryEfficientSwish()
    )
    (6): MBConvBlock(
      (_expand_conv): Conv2dStaticSamePadding(
        48, 288, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn0): BatchNorm2d(288, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_depthwise_conv): Conv2dStaticSamePadding(
        288, 288, kernel_size=(5, 5), stride=(1, 1), groups=288, bias=False
        (static_padding): ZeroPad2d(padding=(2, 2, 2, 2), value=0.0)
      )
      (_bn1): BatchNorm2d(288, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_se_reduce): Conv2dStaticSamePadding(
        288, 12, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_se_expand): Conv2dStaticSamePadding(
        12, 288, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_project_conv): Conv2dStaticSamePadding(
        288, 48, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn2): BatchNorm2d(48, eps=0.001, momentum=0.010000000000000009, affine=True, track_runn
ing_stats=True)
      (_swish): MemoryEfficientSwish()
    )
    (7): MBConvBlock(
      (_expand_conv): Conv2dStaticSamePadding(
        48, 288, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn0): BatchNorm2d(288, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_depthwise_conv): Conv2dStaticSamePadding(
        288, 288, kernel_size=(5, 5), stride=(1, 1), groups=288, bias=False
        (static_padding): ZeroPad2d(padding=(2, 2, 2, 2), value=0.0)
      )
      (_bn1): BatchNorm2d(288, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_se_reduce): Conv2dStaticSamePadding(
        288, 12, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_se_expand): Conv2dStaticSamePadding(
        12, 288, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_project_conv): Conv2dStaticSamePadding(
        288, 48, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn2): BatchNorm2d(48, eps=0.001, momentum=0.010000000000000009, affine=True, track_runn
ing_stats=True)
      (_swish): MemoryEfficientSwish()
    )
    (8): MBConvBlock(
      (_expand_conv): Conv2dStaticSamePadding(
        48, 288, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn0): BatchNorm2d(288, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_depthwise_conv): Conv2dStaticSamePadding(
        288, 288, kernel_size=(3, 3), stride=[2, 2], groups=288, bias=False
        (static_padding): ZeroPad2d(padding=(1, 1, 1, 1), value=0.0)
      )
      (_bn1): BatchNorm2d(288, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_se_reduce): Conv2dStaticSamePadding(
        288, 12, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_se_expand): Conv2dStaticSamePadding(
        12, 288, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_project_conv): Conv2dStaticSamePadding(
        288, 88, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn2): BatchNorm2d(88, eps=0.001, momentum=0.010000000000000009, affine=True, track_runn
ing_stats=True)
      (_swish): MemoryEfficientSwish()
    )
    (9): MBConvBlock(
      (_expand_conv): Conv2dStaticSamePadding(
        88, 528, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn0): BatchNorm2d(528, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_depthwise_conv): Conv2dStaticSamePadding(
        528, 528, kernel_size=(3, 3), stride=(1, 1), groups=528, bias=False
        (static_padding): ZeroPad2d(padding=(1, 1, 1, 1), value=0.0)
      )
      (_bn1): BatchNorm2d(528, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_se_reduce): Conv2dStaticSamePadding(
        528, 22, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_se_expand): Conv2dStaticSamePadding(
        22, 528, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_project_conv): Conv2dStaticSamePadding(
        528, 88, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn2): BatchNorm2d(88, eps=0.001, momentum=0.010000000000000009, affine=True, track_runn
ing_stats=True)
      (_swish): MemoryEfficientSwish()
    )
    (10): MBConvBlock(
      (_expand_conv): Conv2dStaticSamePadding(
        88, 528, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn0): BatchNorm2d(528, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_depthwise_conv): Conv2dStaticSamePadding(
        528, 528, kernel_size=(3, 3), stride=(1, 1), groups=528, bias=False
        (static_padding): ZeroPad2d(padding=(1, 1, 1, 1), value=0.0)
      )
      (_bn1): BatchNorm2d(528, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_se_reduce): Conv2dStaticSamePadding(
        528, 22, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_se_expand): Conv2dStaticSamePadding(
        22, 528, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_project_conv): Conv2dStaticSamePadding(
        528, 88, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn2): BatchNorm2d(88, eps=0.001, momentum=0.010000000000000009, affine=True, track_runn
ing_stats=True)
      (_swish): MemoryEfficientSwish()
    )
    (11): MBConvBlock(
      (_expand_conv): Conv2dStaticSamePadding(
        88, 528, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn0): BatchNorm2d(528, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_depthwise_conv): Conv2dStaticSamePadding(
        528, 528, kernel_size=(3, 3), stride=(1, 1), groups=528, bias=False
        (static_padding): ZeroPad2d(padding=(1, 1, 1, 1), value=0.0)
      )
      (_bn1): BatchNorm2d(528, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_se_reduce): Conv2dStaticSamePadding(
        528, 22, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_se_expand): Conv2dStaticSamePadding(
        22, 528, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_project_conv): Conv2dStaticSamePadding(
        528, 88, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn2): BatchNorm2d(88, eps=0.001, momentum=0.010000000000000009, affine=True, track_runn
ing_stats=True)
      (_swish): MemoryEfficientSwish()
    )
    (12): MBConvBlock(
      (_expand_conv): Conv2dStaticSamePadding(
        88, 528, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn0): BatchNorm2d(528, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_depthwise_conv): Conv2dStaticSamePadding(
        528, 528, kernel_size=(5, 5), stride=[1, 1], groups=528, bias=False
        (static_padding): ZeroPad2d(padding=(2, 2, 2, 2), value=0.0)
      )
      (_bn1): BatchNorm2d(528, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_se_reduce): Conv2dStaticSamePadding(
        528, 22, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_se_expand): Conv2dStaticSamePadding(
        22, 528, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_project_conv): Conv2dStaticSamePadding(
        528, 120, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn2): BatchNorm2d(120, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_swish): MemoryEfficientSwish()
    )
    (13): MBConvBlock(
      (_expand_conv): Conv2dStaticSamePadding(
        120, 720, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn0): BatchNorm2d(720, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_depthwise_conv): Conv2dStaticSamePadding(
        720, 720, kernel_size=(5, 5), stride=(1, 1), groups=720, bias=False
        (static_padding): ZeroPad2d(padding=(2, 2, 2, 2), value=0.0)
      )
      (_bn1): BatchNorm2d(720, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_se_reduce): Conv2dStaticSamePadding(
        720, 30, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_se_expand): Conv2dStaticSamePadding(
        30, 720, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_project_conv): Conv2dStaticSamePadding(
        720, 120, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn2): BatchNorm2d(120, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_swish): MemoryEfficientSwish()
    )
    (14): MBConvBlock(
      (_expand_conv): Conv2dStaticSamePadding(
        120, 720, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn0): BatchNorm2d(720, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_depthwise_conv): Conv2dStaticSamePadding(
        720, 720, kernel_size=(5, 5), stride=(1, 1), groups=720, bias=False
        (static_padding): ZeroPad2d(padding=(2, 2, 2, 2), value=0.0)
      )
      (_bn1): BatchNorm2d(720, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_se_reduce): Conv2dStaticSamePadding(
        720, 30, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_se_expand): Conv2dStaticSamePadding(
        30, 720, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_project_conv): Conv2dStaticSamePadding(
        720, 120, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn2): BatchNorm2d(120, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_swish): MemoryEfficientSwish()
    )
    (15): MBConvBlock(
      (_expand_conv): Conv2dStaticSamePadding(
        120, 720, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn0): BatchNorm2d(720, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_depthwise_conv): Conv2dStaticSamePadding(
        720, 720, kernel_size=(5, 5), stride=(1, 1), groups=720, bias=False
        (static_padding): ZeroPad2d(padding=(2, 2, 2, 2), value=0.0)
      )
      (_bn1): BatchNorm2d(720, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_se_reduce): Conv2dStaticSamePadding(
        720, 30, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_se_expand): Conv2dStaticSamePadding(
        30, 720, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_project_conv): Conv2dStaticSamePadding(
        720, 120, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn2): BatchNorm2d(120, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_swish): MemoryEfficientSwish()
    )
    (16): MBConvBlock(
      (_expand_conv): Conv2dStaticSamePadding(
        120, 720, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn0): BatchNorm2d(720, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_depthwise_conv): Conv2dStaticSamePadding(
        720, 720, kernel_size=(5, 5), stride=[2, 2], groups=720, bias=False
        (static_padding): ZeroPad2d(padding=(2, 2, 2, 2), value=0.0)
      )
      (_bn1): BatchNorm2d(720, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_se_reduce): Conv2dStaticSamePadding(
        720, 30, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_se_expand): Conv2dStaticSamePadding(
        30, 720, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_project_conv): Conv2dStaticSamePadding(
        720, 208, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn2): BatchNorm2d(208, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_swish): MemoryEfficientSwish()
    )
    (17): MBConvBlock(
      (_expand_conv): Conv2dStaticSamePadding(
        208, 1248, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn0): BatchNorm2d(1248, eps=0.001, momentum=0.010000000000000009, affine=True, track_ru
nning_stats=True)
      (_depthwise_conv): Conv2dStaticSamePadding(
        1248, 1248, kernel_size=(5, 5), stride=(1, 1), groups=1248, bias=False
        (static_padding): ZeroPad2d(padding=(2, 2, 2, 2), value=0.0)
      )
      (_bn1): BatchNorm2d(1248, eps=0.001, momentum=0.010000000000000009, affine=True, track_ru
nning_stats=True)
      (_se_reduce): Conv2dStaticSamePadding(
        1248, 52, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_se_expand): Conv2dStaticSamePadding(
        52, 1248, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_project_conv): Conv2dStaticSamePadding(
        1248, 208, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn2): BatchNorm2d(208, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_swish): MemoryEfficientSwish()
    )
    (18): MBConvBlock(
      (_expand_conv): Conv2dStaticSamePadding(
        208, 1248, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn0): BatchNorm2d(1248, eps=0.001, momentum=0.010000000000000009, affine=True, track_ru
nning_stats=True)
      (_depthwise_conv): Conv2dStaticSamePadding(
        1248, 1248, kernel_size=(5, 5), stride=(1, 1), groups=1248, bias=False
        (static_padding): ZeroPad2d(padding=(2, 2, 2, 2), value=0.0)
      )
      (_bn1): BatchNorm2d(1248, eps=0.001, momentum=0.010000000000000009, affine=True, track_ru
nning_stats=True)
      (_se_reduce): Conv2dStaticSamePadding(
        1248, 52, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_se_expand): Conv2dStaticSamePadding(
        52, 1248, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_project_conv): Conv2dStaticSamePadding(
        1248, 208, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn2): BatchNorm2d(208, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_swish): MemoryEfficientSwish()
    )
    (19): MBConvBlock(
      (_expand_conv): Conv2dStaticSamePadding(
        208, 1248, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn0): BatchNorm2d(1248, eps=0.001, momentum=0.010000000000000009, affine=True, track_ru
nning_stats=True)
      (_depthwise_conv): Conv2dStaticSamePadding(
        1248, 1248, kernel_size=(5, 5), stride=(1, 1), groups=1248, bias=False
        (static_padding): ZeroPad2d(padding=(2, 2, 2, 2), value=0.0)
      )
      (_bn1): BatchNorm2d(1248, eps=0.001, momentum=0.010000000000000009, affine=True, track_ru
nning_stats=True)
      (_se_reduce): Conv2dStaticSamePadding(
        1248, 52, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_se_expand): Conv2dStaticSamePadding(
        52, 1248, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_project_conv): Conv2dStaticSamePadding(
        1248, 208, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn2): BatchNorm2d(208, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_swish): MemoryEfficientSwish()
    )
    (20): MBConvBlock(
      (_expand_conv): Conv2dStaticSamePadding(
        208, 1248, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn0): BatchNorm2d(1248, eps=0.001, momentum=0.010000000000000009, affine=True, track_ru
nning_stats=True)
      (_depthwise_conv): Conv2dStaticSamePadding(
        1248, 1248, kernel_size=(5, 5), stride=(1, 1), groups=1248, bias=False
        (static_padding): ZeroPad2d(padding=(2, 2, 2, 2), value=0.0)
      )
      (_bn1): BatchNorm2d(1248, eps=0.001, momentum=0.010000000000000009, affine=True, track_ru
nning_stats=True)
      (_se_reduce): Conv2dStaticSamePadding(
        1248, 52, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_se_expand): Conv2dStaticSamePadding(
        52, 1248, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_project_conv): Conv2dStaticSamePadding(
        1248, 208, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn2): BatchNorm2d(208, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_swish): MemoryEfficientSwish()
    )
    (21): MBConvBlock(
      (_expand_conv): Conv2dStaticSamePadding(
        208, 1248, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn0): BatchNorm2d(1248, eps=0.001, momentum=0.010000000000000009, affine=True, track_ru
nning_stats=True)
      (_depthwise_conv): Conv2dStaticSamePadding(
        1248, 1248, kernel_size=(3, 3), stride=[1, 1], groups=1248, bias=False
        (static_padding): ZeroPad2d(padding=(1, 1, 1, 1), value=0.0)
      )
      (_bn1): BatchNorm2d(1248, eps=0.001, momentum=0.010000000000000009, affine=True, track_ru
nning_stats=True)
      (_se_reduce): Conv2dStaticSamePadding(
        1248, 52, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_se_expand): Conv2dStaticSamePadding(
        52, 1248, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_project_conv): Conv2dStaticSamePadding(
        1248, 352, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn2): BatchNorm2d(352, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_swish): MemoryEfficientSwish()
    )
    (22): MBConvBlock(
      (_expand_conv): Conv2dStaticSamePadding(
        352, 2112, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn0): BatchNorm2d(2112, eps=0.001, momentum=0.010000000000000009, affine=True, track_ru
nning_stats=True)
      (_depthwise_conv): Conv2dStaticSamePadding(
        2112, 2112, kernel_size=(3, 3), stride=(1, 1), groups=2112, bias=False
        (static_padding): ZeroPad2d(padding=(1, 1, 1, 1), value=0.0)
      )
      (_bn1): BatchNorm2d(2112, eps=0.001, momentum=0.010000000000000009, affine=True, track_ru
nning_stats=True)
      (_se_reduce): Conv2dStaticSamePadding(
        2112, 88, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_se_expand): Conv2dStaticSamePadding(
        88, 2112, kernel_size=(1, 1), stride=(1, 1)
        (static_padding): Identity()
      )
      (_project_conv): Conv2dStaticSamePadding(
        2112, 352, kernel_size=(1, 1), stride=(1, 1), bias=False
        (static_padding): Identity()
      )
      (_bn2): BatchNorm2d(352, eps=0.001, momentum=0.010000000000000009, affine=True, track_run
ning_stats=True)
      (_swish): MemoryEfficientSwish()
    )
  )
  (_conv_head): Conv2dStaticSamePadding(
    352, 1408, kernel_size=(1, 1), stride=(1, 1), bias=False
    (static_padding): Identity()
  )
  (_bn1): BatchNorm2d(1408, eps=0.001, momentum=0.010000000000000009, affine=True, track_runnin
g_stats=True)
  (_avg_pooling): AdaptiveAvgPool2d(output_size=1)
  (_dropout): Dropout(p=0.3, inplace=False)
  (_fc): Linear(in_features=1408, out_features=1000, bias=True)
  (_swish): MemoryEfficientSwish()
)
```

In [32]:

```
for param in model.parameters():
    param.requires_grad = False

# Parameters of newly constructed modules have requires_grad=True by default
num_ftrs = model._fc.in_features
model._fc = nn.Linear(num_ftrs, N_CLASSES)

# to GPU
model = model.to(DEVICE)

# loss
criterion = nn.CrossEntropyLoss()

# learning rate optimizer
optimizer = torch.optim.AdamW(model.parameters())

# scheduler for the lr optimizer
scheduler = torch.optim.lr_scheduler.StepLR(optimizer, 3, 0.5)
```

In [33]:

```
model._fc
```

Out[33]:

```
Linear(in_features=1408, out_features=42, bias=True)
```

In [34]:

```
# feature_extr_epochs = 1 # test run
feature_extr_epochs = 5 # performance run
```

In [35]:

```
history_feature_extr = train(train_dataset, val_dataset, model=model, criterion=criterion,
                             epochs=feature_extr_epochs, batch_size=256, optimizer=optimizer, scheduler=sche
duler)
```

```
epoch:   0%|          | 0/5 [00:00<?, ?it/s]

epoch 1:

Fitting on train data...
train loss: 2.7967385551962
Evaluating on validation data...

epoch:  20%|██        | 1/5 [03:38<14:33, 218.30s/it]

val loss: 2.4756865210996652

Epoch 001 train_loss: 2.7967     val_loss 2.4757 train_acc 0.3339 val_acc 0.4402

epoch 2:

Fitting on train data...
train loss: 1.9789676396965687
Evaluating on validation data...

epoch:  40%|████      | 2/5 [07:15<10:53, 217.91s/it]

val loss: 1.7165832539461152

Epoch 002 train_loss: 1.9790     val_loss 1.7166 train_acc 0.5623 val_acc 0.6274

epoch 3:

Fitting on train data...
train loss: 1.5327676245894801
Evaluating on validation data...

epoch:  60%|██████    | 3/5 [10:56<07:17, 218.75s/it]

val loss: 1.4464469699094311

Epoch 003 train_loss: 1.5328     val_loss 1.4464 train_acc 0.6405 val_acc 0.6742

epoch 4:

Fitting on train data...
train loss: 1.3563814569548776
Evaluating on validation data...

epoch:  80%|████████  | 4/5 [14:35<03:39, 219.08s/it]

val loss: 1.3642601476012877

Epoch 004 train_loss: 1.3564     val_loss 1.3643 train_acc 0.6762 val_acc 0.6869

epoch 5:

Fitting on train data...
train loss: 1.2748973303741322
Evaluating on validation data...

epoch: 100%|██████████| 5/5 [18:16<00:00, 219.22s/it]

val loss: 1.297978401468795

Epoch 005 train_loss: 1.2749     val_loss 1.2980 train_acc 0.6907 val_acc 0.6993

Training complete in 18m 16s
Best val loss: 10.000000
Best epoch: 5
```

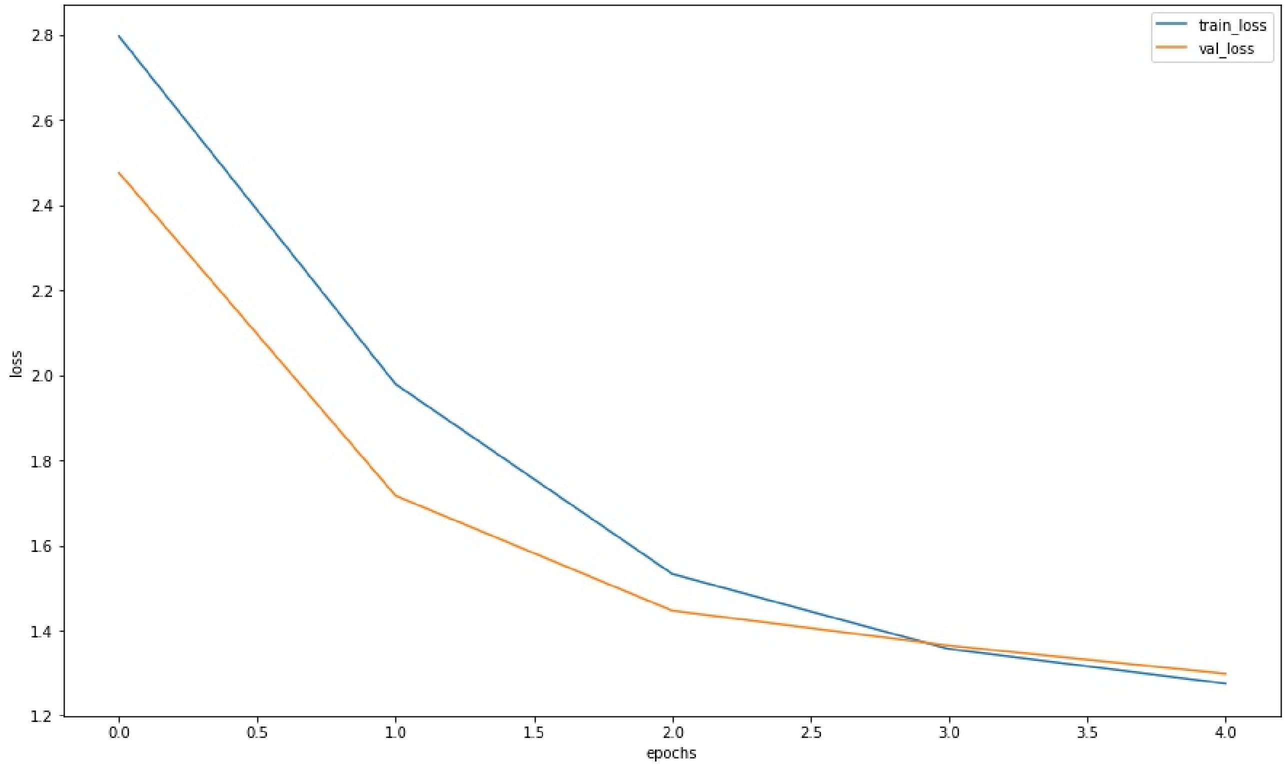
Построим кривые обучения

In [36]:

```
loss, acc, val_loss, val_acc = zip(*history_feature_extr)
```

In [37]:

```
plt.figure(figsize=(15, 9))
plt.plot(loss, label="train_loss")
plt.plot(val_loss, label="val_loss")
plt.legend(loc='best')
plt.xlabel("epochs")
plt.ylabel("loss")
plt.show()
```



Тренируем все слои сети

In [38]:

```
for param in model.parameters():
    param.requires_grad = True
```

In [39]:

```
# finetuning_epochs = 1 # test run
finetuning_epochs = 15 # performance run
```

In [40]:

```
history_fine_tune = train(train_dataset=train_dataset, val_dataset=val_dataset, model=model, criterion=crite
rion,
                          epochs=finetuning_epochs, batch_size=64, optimizer=optimizer, scheduler=scheduler)
```

```
epoch:   0%|          | 0/15 [00:00<?, ?it/s]

epoch 1:

Fitting on train data...
train loss: 0.35643348333933456
Evaluating on validation data...

epoch:   7%|█         | 1/15 [07:22<1:43:12, 442.30s/it]

val loss: 0.17322989011012999

Epoch 001 train_loss: 0.3564     val_loss 0.1732 train_acc 0.9062 val_acc 0.9575

epoch 2:

Fitting on train data...
train loss: 0.08512868887066401
Evaluating on validation data...

epoch:  13%|█▎        | 2/15 [14:44<1:35:48, 442.21s/it]
```

```
val loss: 0.12804103522677823

Epoch 002 train_loss: 0.0851     val_loss 0.1280 train_acc 0.9784 val_acc 0.9678

epoch 3:

Fitting on train data...
train loss: 0.057929131542141875
Evaluating on validation data...

epoch:  20%|██        | 3/15 [22:06<1:28:26, 442.23s/it]

val loss: 0.12429919949409528

Epoch 003 train_loss: 0.0579     val_loss 0.1243 train_acc 0.9861 val_acc 0.9725

epoch 4:

Fitting on train data...
train loss: 0.03782579450755795
Evaluating on validation data...

epoch:  27%|██▋       | 4/15 [29:28<1:21:04, 442.25s/it]

val loss: 0.13293134766013134

Epoch 004 train_loss: 0.0378     val_loss 0.1329 train_acc 0.9892 val_acc 0.9701

epoch 5:

Fitting on train data...
train loss: 0.015102485562001363
Evaluating on validation data...

epoch:  33%|███▎      | 5/15 [36:51<1:13:42, 442.28s/it]

val loss: 0.10854844581749507

Epoch 005 train_loss: 0.0151     val_loss 0.1085 train_acc 0.9959 val_acc 0.9792

epoch 6:

Fitting on train data...
train loss: 0.009279073929172313
Evaluating on validation data...

epoch:  40%|████      | 6/15 [44:13<1:06:19, 442.13s/it]

val loss: 0.10706306140623402

Epoch 006 train_loss: 0.0093     val_loss 0.1071 train_acc 0.9974 val_acc 0.9830

epoch 7:

Fitting on train data...
train loss: 0.0062956163417282485
Evaluating on validation data...

epoch:  47%|████▋     | 7/15 [51:34<58:55, 441.91s/it]

val loss: 0.11663408884125781

Epoch 007 train_loss: 0.0063     val_loss 0.1166 train_acc 0.9980 val_acc 0.9826

epoch 8:

Fitting on train data...
train loss: 0.005218786438859095
Evaluating on validation data...

epoch:  53%|█████▎    | 8/15 [58:58<51:37, 442.50s/it]

val loss: 0.11854823664169577

Epoch 008 train_loss: 0.0052     val_loss 0.1185 train_acc 0.9983 val_acc 0.9835

epoch 9:

Fitting on train data...
train loss: 0.0030786064233403014
Evaluating on validation data...
```

```
epoch:  60%|██████    | 9/15 [1:06:22<44:17, 442.96s/it]

val loss: 0.11796792255210894

Epoch 009 train_loss: 0.0031     val_loss 0.1180 train_acc 0.9994 val_acc 0.9826

epoch 10:

Fitting on train data...
train loss: 0.001990109160894455
Evaluating on validation data...

epoch:  67%|██████▋   | 10/15 [1:13:47<36:57, 443.60s/it]

val loss: 0.1280293590686695

Epoch 010 train_loss: 0.0020     val_loss 0.1280 train_acc 0.9994 val_acc 0.9826

epoch 11:

Fitting on train data...
train loss: 0.0016433709118035909
Evaluating on validation data...

epoch:  73%|███████▎  | 11/15 [1:21:13<29:36, 444.22s/it]

val loss: 0.11990588904974417

Epoch 011 train_loss: 0.0016     val_loss 0.1199 train_acc 0.9995 val_acc 0.9842

epoch 12:

Fitting on train data...
train loss: 0.0013022593160653053
Evaluating on validation data...

epoch:  80%|████████  | 12/15 [1:28:37<22:12, 444.32s/it]

val loss: 0.118093865692435

Epoch 012 train_loss: 0.0013     val_loss 0.1181 train_acc 0.9995 val_acc 0.9840

epoch 13:

Fitting on train data...
train loss: 0.0016854263127656789
Evaluating on validation data...

epoch:  87%|████████▋ | 13/15 [1:36:02<14:49, 444.53s/it]

val loss: 0.1281294782729913

Epoch 013 train_loss: 0.0017     val_loss 0.1281 train_acc 0.9993 val_acc 0.9823

epoch 14:

Fitting on train data...
train loss: 0.0013546139436647435
Evaluating on validation data...

epoch:  93%|█████████▎| 14/15 [1:43:27<07:24, 444.54s/it]

val loss: 0.11727093156193842

Epoch 014 train_loss: 0.0014     val_loss 0.1173 train_acc 0.9996 val_acc 0.9852

epoch 15:

Fitting on train data...
train loss: 0.0013362383001859677
Evaluating on validation data...

epoch: 100%|██████████| 15/15 [1:50:51<00:00, 443.45s/it]

val loss: 0.11529863828859119

Epoch 015 train_loss: 0.0013     val_loss 0.1153 train_acc 0.9996 val_acc 0.9845

Training complete in 110m 52s
Best val loss: 10.000000
Best epoch: 15
```

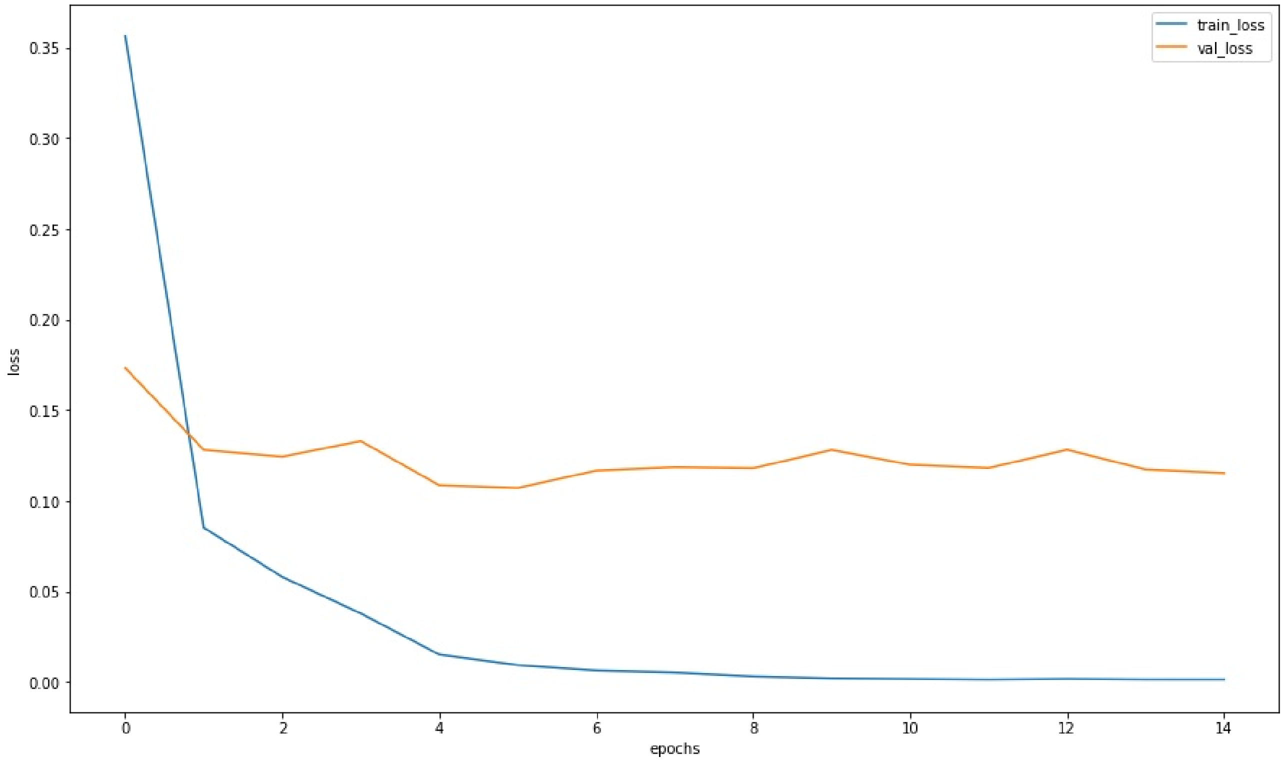
Построим кривые обучения

In [41]:

```
loss, acc, val_loss, val_acc = zip(*history_fine_tune)
```

In [42]:

```
plt.figure(figsize=(15, 9))
plt.plot(loss, label="train_loss")
plt.plot(val_loss, label="val_loss")
plt.legend(loc='best')
plt.xlabel("epochs")
plt.ylabel("loss")


plt.savefig(f"{model_name}_{feature_extr_epochs}FeatureExtrEpochs-{finetuning_epochs}FinetuningEpochs-LearningCurve.png")
plt.show()
```



In [43]:

```
f"{model_name}_{feature_extr_epochs}FeatureExtrEpochs-{finetuning_epochs}FinetuningEpochs-LearningCurve.png"
```

Out[43]:

```
'efficientnet-b2_5FeatureExtrEpochs-15FinetuningEpochs-LearningCurve.png'
```

In [44]:

```
# save the weights of our net
model_weights = copy.deepcopy(model.state_dict())
torch.save(model_weights, f"{model_name}_{feature_extr_epochs}FeatureExtrEpochs-{finetuning_epochs}FinetuningEpochs-weights.pth")
```

In [45]:

```
%ls
```

```
efficientnet-b2_5FeatureExtrEpochs-15FinetuningEpochs-LearningCurve.png
efficientnet-b2_5FeatureExtrEpochs-15FinetuningEpochs-weights.pth
gdrive/
label_encoder.pkl
sample_data/
test/
train/
```

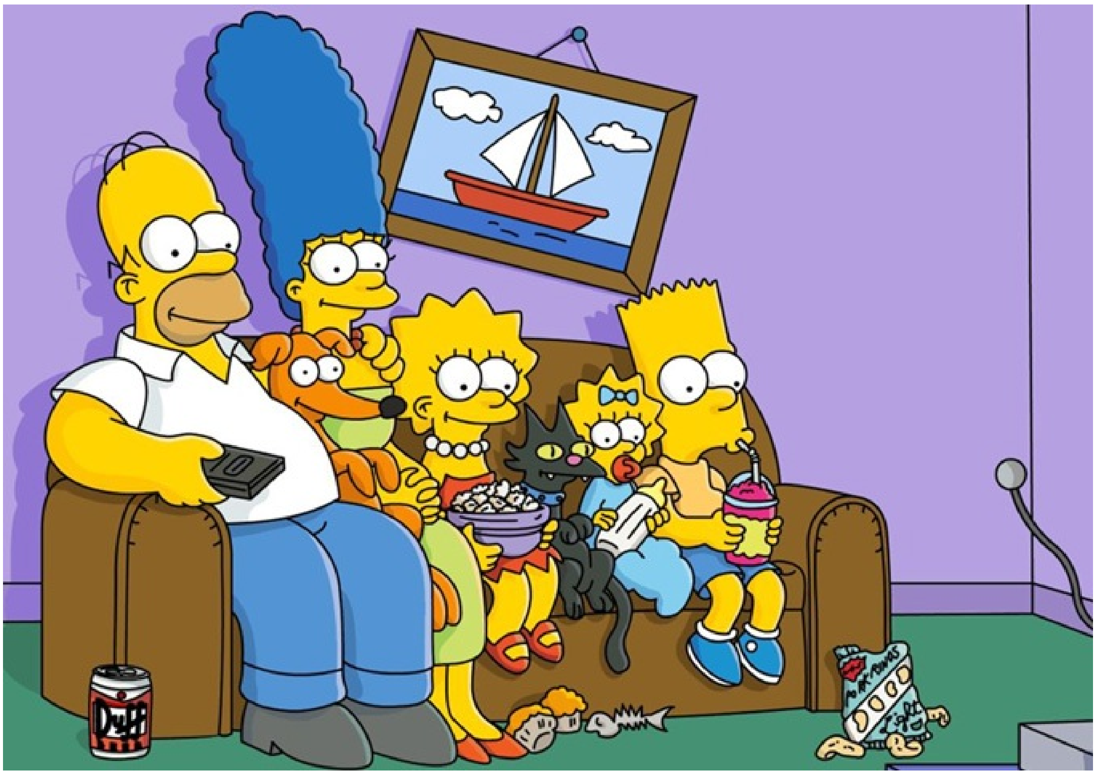
In [46]:

```
# загружаем сохраненное состояние весов нейросети
model.load_state_dict(torch.load(f"{model_name}_{feature_extr_epochs}FeatureExtrEpochs-{finetuning_epochs}Fi
netuningEpochs-weights.pth"))
```

Out[46]:

```
<All keys matched successfully>
```

Ну и что теперь со всем этим делать?



Хорошо бы понять, как сделать сабмит. У нас есть сеть и методы eval у нее, которые позволяют перевести сеть в режим предсказания. Стоит понимать, что у нашей модели на последнем слое стоит softmax, которые позволяет получить вектор вероятностей того, что объект относится к тому или иному классу. Давайте воспользуемся этим.

In [47]:

```
def predict_one_sample(model, inputs, device=DEVICE):
    """Предсказание, для одной картинки"""
    with torch.no_grad():
        inputs = inputs.to(device)
        model.eval()
        logit = model(inputs).cpu()
        probs = torch.nn.functional.softmax(logit, dim=-1).numpy()
    return probs
```

In [48]:

```
random_characters = int(np.random.uniform(0,1000))
ex_img, true_label = val_dataset[random_characters]
probs_im = predict_one_sample(model, ex_img.unsqueeze(0))
```

In [49]:

```
idxs = list(map(int, np.random.uniform(0,1000, 20)))
imgs = [val_dataset[id][0].unsqueeze(0) for id in idxs]

probs_ims = predict(model, imgs)
```

Сравниваем фактические классы с предсказанными ids

In [50]:

```
actual_labels = [val_dataset[id][1] for id in idxs]
actual_labels
```

Out[50]:

```
[4, 4, 6, 2, 2, 7, 2, 6, 6, 0, 2, 6, 7, 2, 6, 2, 4, 6, 0, 0]
```

In [51]:

```
y_pred = np.argmax(probs_ims, -1)
y_pred
```

Out[51]:

```
array([4, 4, 6, 2, 2, 7, 2, 6, 6, 0, 2, 6, 7, 2, 6, 2, 4, 6, 0, 0])
```

Обратите внимание, что метрика, которую необходимо оптимизировать в конкурсе --- f1-score. Вычислим целевую метрику на валидационной выборке.

In [52]:

```
from sklearn.metrics import f1_score

f1_score(actual_labels, y_pred, average='weighted')
```

Out[52]:

```
1.0
```

Сравниваем фактические классы с предсказанными (strings)

In [53]:

```
label_encoder = pickle.load(open("label_encoder.pkl", 'rb'))
```

In [54]:

```
actual_class = [label_encoder.classes_[i] for i in actual_labels]
actual_class
```

Out[54]:

```
['bart_simpson',
 'bart_simpson',
 'charles_montgomery_burns',
 'apu_nahasapeemapetilon',
 'apu_nahasapeemapetilon',
 'chief_wiggum',
 'apu_nahasapeemapetilon',
 'charles_montgomery_burns',
 'charles_montgomery_burns',
 'abraham_grampa_simpson',
 'apu_nahasapeemapetilon',
 'charles_montgomery_burns',
 'chief_wiggum',
 'apu_nahasapeemapetilon',
 'charles_montgomery_burns',
 'apu_nahasapeemapetilon',
 'bart_simpson',
 'charles_montgomery_burns',
 'abraham_grampa_simpson',
 'abraham_grampa_simpson']
```

In [55]:

```
preds_class = [label_encoder.classes_[i] for i in y_pred]
preds_class
```

Out[55]:

```
['bart_simpson',
 'bart_simpson',
 'charles_montgomery_burns',
 'apu_nahasapeemapetilon',
 'apu_nahasapeemapetilon',
 'chief_wiggum',
 'apu_nahasapeemapetilon',
 'charles_montgomery_burns',
 'charles_montgomery_burns',
 'abraham_grampa_simpson',
 'apu_nahasapeemapetilon',
 'charles_montgomery_burns',
 'chief_wiggum',
 'apu_nahasapeemapetilon',
 'charles_montgomery_burns',
 'apu_nahasapeemapetilon',
 'bart_simpson',
 'charles_montgomery_burns',
 'abraham_grampa_simpson',
 'abraham_grampa_simpson']
```

In [56]:

```
from sklearn.metrics import f1_score

f1_score(actual_class, preds_class, average='weighted')
```

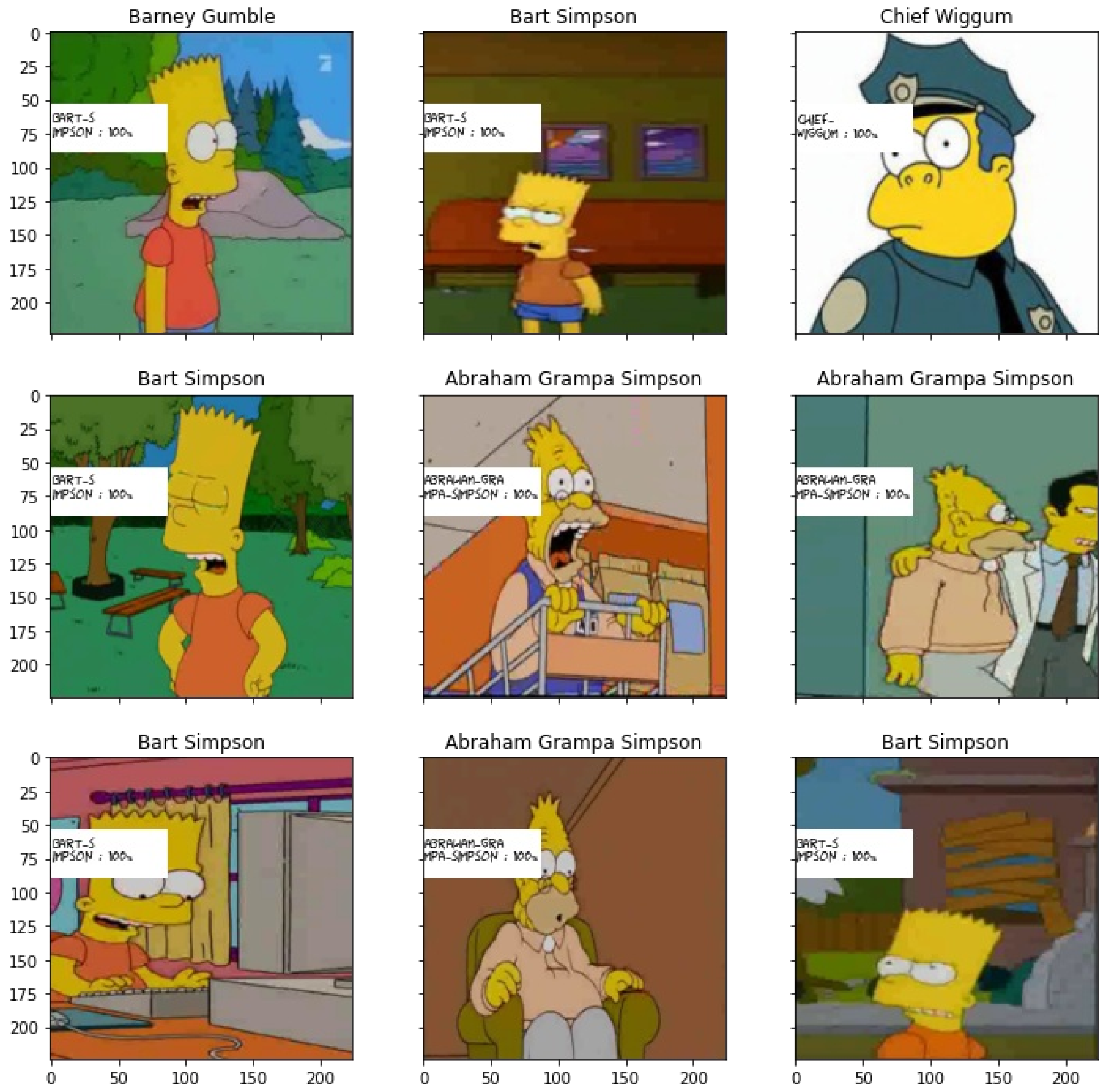
Out[56]:

```
1.0
```

Сделаем классную визуализацию, чтобы посмотреть насколько сеть уверена в своих ответах. Можете исследовать это, чтобы отлаживать правильность вывода.

In [57]:

```
import matplotlib.patches as patches
from matplotlib.font_manager import FontProperties

fig, ax = plt.subplots(nrows=3, ncols=3,figsize=(12, 12), \
                        sharey=True, sharex=True)
for fig_x in ax.flatten():
    random_characters = int(np.random.uniform(0,1000))
    im_val, label = val_dataset[random_characters]
    img_label = " ".join(map(lambda x: x.capitalize(),\
                val_dataset.label_encoder.inverse_transform([label])[0].split('_')))



    imshow(im_val.data.cpu(), \
          title=img_label,plt_ax=fig_x)

    actual_text = "Actual : {}".format(img_label)

    fig_x.add_patch(patches.Rectangle((0, 53),86,35,color='white'))
    font0 = FontProperties()
    font = font0.copy()
    font.set_family("fantasy")
    prob_pred = predict_one_sample(model, im_val.unsqueeze(0))
    predicted_proba = np.max(prob_pred)*100
    y_pred = np.argmax(prob_pred)

    predicted_label = label_encoder.classes_[y_pred]
    predicted_label = predicted_label[:len(predicted_label)//2] + '\n' + predicted_label[len(predicted_label
)//2:]
    predicted_text = "{} : {:.0f}%".format(predicted_label,predicted_proba)

    fig_x.text(1, 59, predicted_text , horizontalalignment='left', fontproperties=font,
                    verticalalignment='top',fontsize=8, color='black',fontweight='bold')
```



Попробуйте найти те классы, которые сеть не смогла расспознать. Изучите данную проблему, это понадобится в дальнейшем.

Submit на Kaggle

In [58]:

```
test_dataset = SimpsonsDataset(test_files, mode="test")
test_loader = DataLoader(test_dataset, shuffle=False, batch_size=64, num_workers=4)
probs = predict(model, test_loader)


preds = label_encoder.inverse_transform(np.argmax(probs, axis=1))
test_filenames = [path.name for path in test_dataset.files]
```

In [59]:

```
import pandas as pd
sample_submit = pd.read_csv("gdrive/MyDrive/Simpsons_kaggle/sample_submission.csv")
sample_submit.head()
```

Out[59]:

	Id	Expected
0	img0.jpg	bart_simpson
1	img1.jpg	bart_simpson
2	img2.jpg	bart_simpson
3	img3.jpg	bart_simpson
4	img4.jpg	bart_simpson

In [60]:

```
my_submit = pd.DataFrame({'Id': test_filenames, 'Expected': preds})
print(my_submit.shape)
my_submit.head()
```

```
(991, 2)
```

Out[60]:

	Id	Expected
0	img0.jpg	nelson_muntz
1	img1.jpg	bart_simpson
2	img10.jpg	ned_flanders
3	img100.jpg	chief_wiggum
4	img101.jpg	apu_nahasapeemapetilon

In [61]:

```
# TODO : сделайте сабмит (это важно, если Вы не справляетесь, но дошли до этой ячейки, то сообщите в чат и Вам помогут)
```

In [62]:

```
path = 'gdrive/MyDrive/Simpsons_kaggle/'
my_submit.to_csv(path + f"{model_name}_{feature_extr_epochs}FeatureExtrEpochs-{finetuning_epochs}FinetuningEpochs-submission.csv")
```

Приключение?

А теперь самое интересное, мы сделали простенькую сверточную сеть и смогли отправить сабмит, но получившийся скор нас явно не устраивает. Надо с этим что-то сделать.

Несколько срочныйх улучшейни для нашей сети, которые наверняка пришли Вам в голову:

- Учим дольше и изменяем гиперпараметры сети
- learning rate, batch size, нормализация картинки и вот это всё
- Кто же так строит нейронные сети? А где пулинги и батч нормы? Надо добавлять
- Ну разве Адам наше все? adamW (https://www.fast.ai/2018/07/02/adam-weight-decay/) для практика, статейка для любителей (https://openreview.net/pdf?id=ryQu7f-RZ) (очень хороший анализ), наши (https://github.com/MichaelKonobeev/adashift/) эксперименты для заинтересованных.
- Ну разве это deep learning? Вот ResNet и Inception, которые можно зафайнтьюнить под наши данные, вот это я понимаю (можно и обучить в колабе, а можно и готовые (https://github.com/Cadene/pretrained-models.pytorch) скачать).
- Данных не очень много, можно их аугументировать и доучититься на новом датасете (который уже будет состоять из, как пример аугументации, перевернутых изображений)
- Стоит подумать об ансамблях

Надеюсь, что у Вас получится!