Лабораторная работа №4

Реализация приложения по распознаванию номеров домов

Набор изображений из *Google Street View* с изображениями номеров домов, содержащий 10 классов, соответствующих цифрам от 0 до 9.

- 73257 изображений цифр в обучающей выборке;
- 26032 изображения цифр в тестовой выборке;
- 531131 изображения, которые можно использовать как дополнение к обучающей выборке;
- В двух форматах:
  - Оригинальные изображения с выделенными цифрами;
  - Изображения размером 32×32, содержащие одну цифру;
- Данные первого формата можно скачать по ссылкам:
  - http://ufldl.stanford.edu/housenumbers/train.tar.gz (http://ufldl.stanford.edu/housenumbers/train.tar.gz) (обучающая выборка);
  - http://ufldl.stanford.edu/housenumbers/test.tar.gz (http://ufldl.stanford.edu/housenumbers/test.tar.gz) (тестовая выборка);
  - http://ufldl.stanford.edu/housenumbers/extra.tar.gz (http://ufldl.stanford.edu/housenumbers/extra.tar.gz) (дополнительные данные);
- Данные второго формата можно скачать по ссылкам:
  - http://ufldl.stanford.edu/housenumbers/train_32x32.mat (http://ufldl.stanford.edu/housenumbers/train_32x32.mat) (обучающая выборка);
  - http://ufldl.stanford.edu/housenumbers/test_32x32.mat (http://ufldl.stanford.edu/housenumbers/test_32x32.mat) (тестовая выборка);
  - http://ufldl.stanford.edu/housenumbers/extra_32x32.mat (http://ufldl.stanford.edu/housenumbers/extra_32x32.mat) (дополнительные данные);
- Описание данных на английском языке доступно по ссылке:
  - http://ufldl.stanford.edu/housenumbers/ (http://ufldl.stanford.edu/housenumbers/)

Задание 1

Реализуйте глубокую нейронную сеть (полносвязную или сверточную) и обучите ее на синтетических данных (например, наборы *MNIST* (http://yann.lecun.com/exdb/mnist/ (http://yann.lecun.com/exdb/mnist/)) или *notMNIST*).

Ознакомьтесь с имеющимися работами по данной тематике: англоязычная статья (http://static.googleusercontent.com/media/research.google.com/en//pubs/archive/42241.pdf (http://static.googleusercontent.com/media/research.google.com/en//pubs/archive/42241.pdf)), видео на *YouTube* (https://www.youtube.com/watch?v=vGPI_JvLoN0) (https://www.youtube.com/watch?v=vGPI_JvLoN0)).

Используем архитектуру *LeNet-5* и обучим сеть сначала на данных из набора *MNIST*.

In [0]:

```
import warnings

warnings.filterwarnings('ignore')
```

In [0]:

```
! pip install tensorflow-gpu --pre --quiet
```

In [0]:

```
import tensorflow as tf
from tensorflow import keras
```

In [0]:

```
import numpy as np
```

In [0]:

```
from tensorflow.keras.datasets import mnist

(x_train, y_train), (x_test, y_test) = mnist.load_data()
```

In [0]:

```
x_train = tf.keras.utils.normalize(x_train, axis = 1)
x_test = tf.keras.utils.normalize(x_test, axis = 1)
```

In [0]:

```
x_train = x_train[..., np.newaxis]
x_test = x_test[..., np.newaxis]
```

In [8]:

```
from tensorflow.keras.utils import to_categorical

y_train, y_test = to_categorical(y_train), to_categorical(y_test)

y_train.shape
```

Out[8]:

```
(60000, 10)
```

In [0]:

```
IMAGE_DIM_0, IMAGE_DIM_1 = x_train.shape[1], x_train.shape[2]
```

In [0]:

```
CLASSES_N = y_train.shape[1]
```

In [11]:

```
x_train.shape, x_test.shape
```

Out[11]:

```
((60000, 28, 28, 1), (10000, 28, 28, 1))
```

In [0]:

```
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import AveragePooling2D, Conv2D, Dense, Flatten

model = tf.keras.Sequential()

model.add(Conv2D(6, kernel_size = (5, 5), strides = (1, 1),
                 activation = 'tanh', padding = 'same',
                 input_shape = (IMAGE_DIM_0, IMAGE_DIM_1, 1)))
model.add(AveragePooling2D(pool_size = (2, 2), strides = (2, 2),
                           padding = 'valid'))
model.add(Conv2D(16, kernel_size = (5, 5), strides = (1, 1),
                 activation = 'tanh', padding = 'valid'))
model.add(AveragePooling2D(pool_size = (2, 2), strides = (2, 2),
                           padding = 'valid'))
model.add(Flatten())
model.add(Dense(120, activation = 'tanh'))
model.add(Dense(84, activation = 'tanh'))
model.add(Dense(CLASSES_N, activation = 'softmax'))
```

In [0]:

```
# 'sparse_categorical_crossentropy' gave NAN loss

model.compile(optimizer = 'adam',
              loss = 'categorical_crossentropy',
              metrics = ['categorical_accuracy'])
```

In [14]:

```
model.summary()
```

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d (Conv2D)              (None, 28, 28, 6)         156
_________________________________________________________________
average_pooling2d (AveragePo (None, 14, 14, 6)         0
_________________________________________________________________
conv2d_1 (Conv2D)            (None, 10, 10, 16)        2416
_________________________________________________________________
average_pooling2d_1 (Average (None, 5, 5, 16)          0
_________________________________________________________________
flatten (Flatten)            (None, 400)               0
_________________________________________________________________
dense (Dense)                (None, 120)               48120
_________________________________________________________________
dense_1 (Dense)              (None, 84)                10164
_________________________________________________________________
dense_2 (Dense)              (None, 10)                850
=================================================================
Total params: 61,706
Trainable params: 61,706
Non-trainable params: 0
_________________________________________________________________
```

In [0]:

```
EPOCHS_N = 20
```

In [0]:

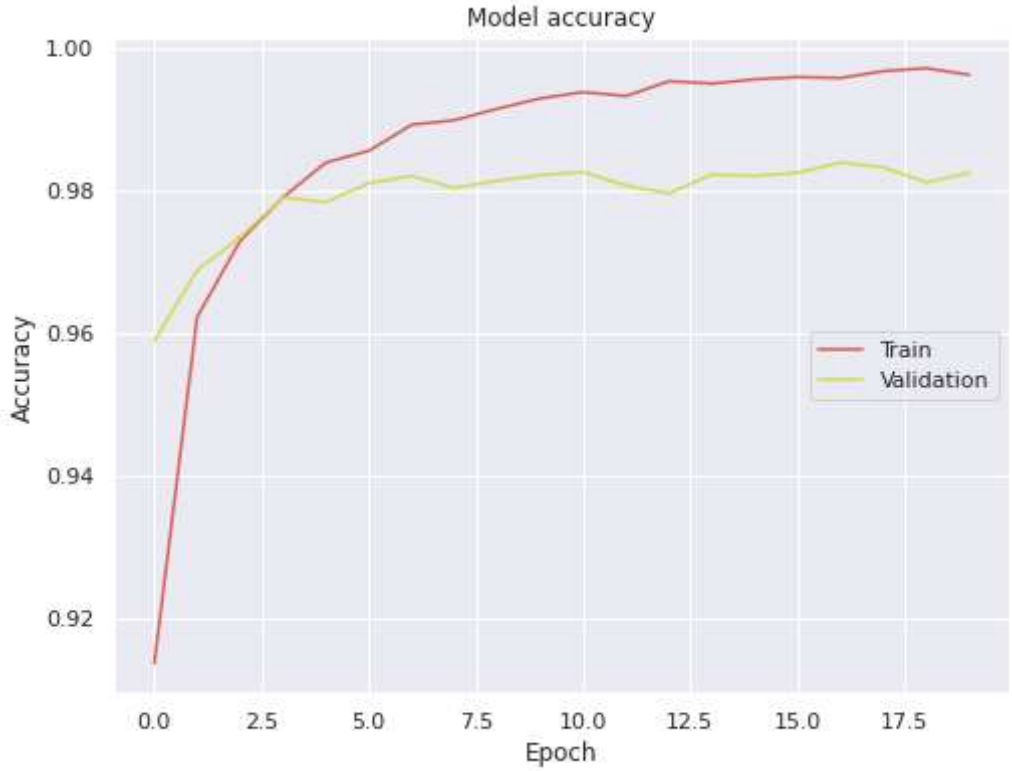
```
history = model.fit(x = x_train, y = y_train, validation_split = 0.15,
                    epochs = EPOCHS_N, verbose = 0)
```

In [0]:

```
%matplotlib inline

import matplotlib.pyplot as plt
import seaborn as sns
from matplotlib import rcParams

rcParams['figure.figsize'] = 8, 6

sns.set()
sns.set_palette(sns.color_palette('hls'))

def plot_accuracy(_history,
                  _train_acc_name = 'accuracy',
                  _val_acc_name = 'val_accuracy'):

    plt.plot(_history.history[_train_acc_name])
    plt.plot(_history.history[_val_acc_name])

    plt.title('Model accuracy')

    plt.ylabel('Accuracy')
    plt.xlabel('Epoch')

    plt.legend(['Train', 'Validation'], loc = 'right')

    plt.show()

def plot_loss(_history):

    plt.plot(_history.history['loss'])
    plt.plot(_history.history['val_loss'])

    plt.title('Model loss')

    plt.ylabel('Loss')
    plt.xlabel('Epoch')

    plt.legend(['Train', 'Validation'], loc = 'right')

    plt.show()
```

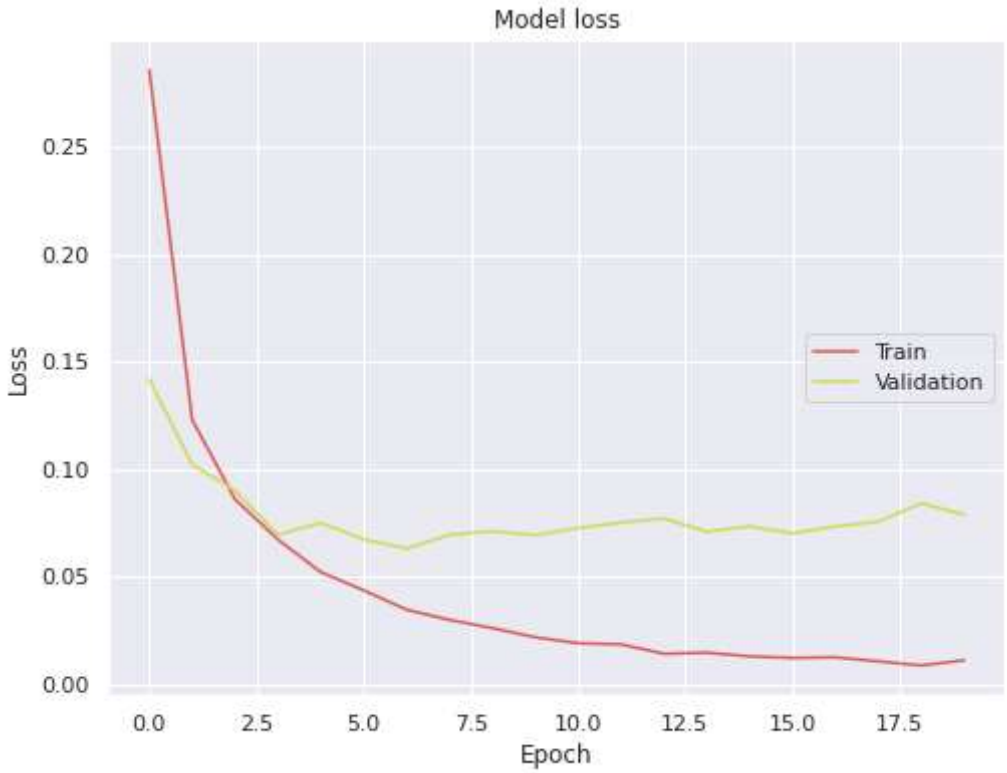
In [18]:

```
plot_accuracy(history, 'categorical_accuracy', 'val_categorical_accuracy')
```



In [19]:

```
plot_loss(history)
```



In [20]:

```
results = model.evaluate(x_test, y_test)

print('Test loss, test accuracy:', results)
```

```
313/313 [==============================] - 1s 2ms/step - loss: 0.0734 - cate
gorical_accuracy: 0.9818
Test loss, test accuracy: [0.07340481877326965, 0.9818000197410583]
```

Удалось достичь отличного результата — точность распознавания на тестовой выборке составила 98%.

Задание 2

После уточнения модели на синтетических данных попробуйте обучить ее на реальных данных (набор *Google Street View*). Что изменилось в модели?

Одна цифра

In [0]:

```
DS_URL_FOLDER = 'http://ufldl.stanford.edu/housenumbers/'

FIRST_DS_EXT = '.tar.gz'
SECOND_DS_EXT = '_32x32.mat'

TRAIN_DS_NAME = 'train'
TEST_DS_NAME = 'test'
EXTRA_DS_NAME = 'extra'
```

In [0]:

```
from urllib.request import urlretrieve
import tarfile
import os

def load_file(_url_folder, _name, _ext, _key, _local_ext = ''):

    file_url_ = _url_folder + _name + _ext

    local_file_name_ = _name + '_' + _key + _local_ext

    urlretrieve(file_url_, local_file_name_)

    return local_file_name_

def tar_gz_to_dir(_url_folder, _name, _ext, _key):

    local_file_name_ = load_file(_url_folder, _name, _ext, _key, _ext)

    dir_name_ = _name + '_' + _key

    with tarfile.open(local_file_name_, 'r:gz') as tar_:
        tar_.extractall(dir_name_)

    os.remove(local_file_name_)

    return dir_name_
```

In [0]:

```
second_ds_train_file = load_file(DS_URL_FOLDER, TRAIN_DS_NAME, SECOND_DS_EXT,
                                 'second')
second_ds_test_file = load_file(DS_URL_FOLDER, TEST_DS_NAME, SECOND_DS_EXT,
                                'second')
second_ds_extra_file = load_file(DS_URL_FOLDER, EXTRA_DS_NAME, SECOND_DS_EXT,
                                 'second')
```

In [0]:

```
from scipy import io

second_ds_train = io.loadmat(second_ds_train_file)
second_ds_test = io.loadmat(second_ds_test_file)
second_ds_extra = io.loadmat(second_ds_extra_file)
```

In [25]:

```
X_second_ds_train = np.moveaxis(second_ds_train['X'], -1, 0)
X_second_ds_test = np.moveaxis(second_ds_test['X'], -1, 0)
X_second_ds_extra = np.moveaxis(second_ds_extra['X'], -1, 0)

y_second_ds_train = second_ds_train['y']
y_second_ds_test = second_ds_test['y']
y_second_ds_extra = second_ds_extra['y']

print(X_second_ds_train.shape, y_second_ds_train.shape)
print(X_second_ds_test.shape, y_second_ds_test.shape)
print(X_second_ds_extra.shape, y_second_ds_extra.shape)
```

```
(73257, 32, 32, 3) (73257, 1)
(26032, 32, 32, 3) (26032, 1)
(531131, 32, 32, 3) (531131, 1)
```

In [0]:

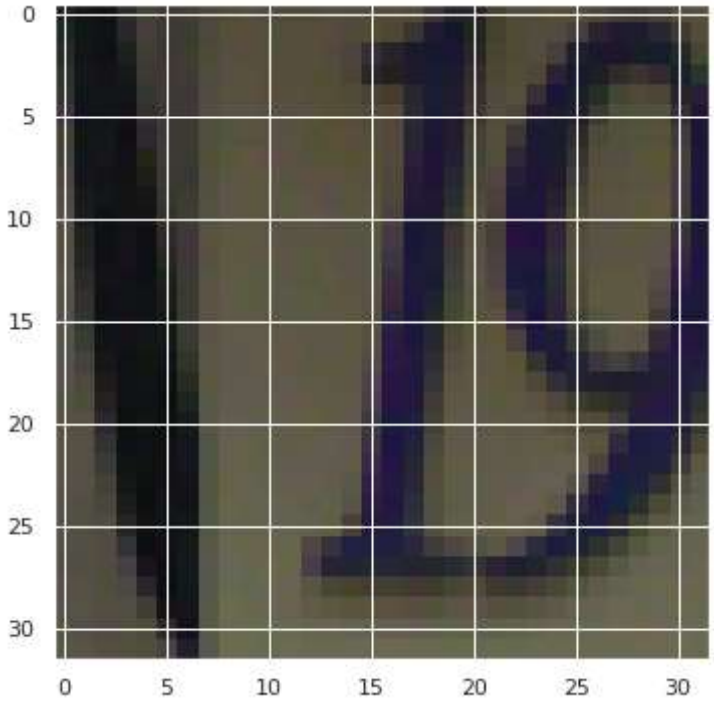
```
%matplotlib inline

import matplotlib.pyplot as plt
```

In [0]:

```
import seaborn as sns

from matplotlib import rcParams

rcParams['figure.figsize'] = 8, 6

sns.set()

sns.set_palette(sns.color_palette('hls'))
```

In [28]:

```
plt.imshow(X_second_ds_train[0])

plt.show()
```



In [0]:

```
IMAGE_DIM_0_2 = X_second_ds_train.shape[-3]
IMAGE_DIM_1_2 = X_second_ds_train.shape[-3], X_second_ds_train.shape[-2], X_second_ds_train
IMAGE_DIM_0_2, IMAGE_DIM_1_2, IMAGE_DIM_2_2 = X_second_ds_train.shape[-3], X_second_ds_trai
```

In [0]:

```
y_second_ds_train_cat = to_categorical(y_second_ds_train)
y_second_ds_test_cat = to_categorical(y_second_ds_test)
```

In [0]:

```
CLASSES_N_2 = y_second_ds_train_cat.shape[1]
```

In [0]:

```
model_2 = tf.keras.Sequential()

model_2.add(Conv2D(6, kernel_size = (5, 5), strides = (1, 1),
                   activation = 'tanh', padding = 'same',
                   input_shape = (IMAGE_DIM_0_2, IMAGE_DIM_1_2, IMAGE_DIM_2_2)))
model_2.add(AveragePooling2D(pool_size = (2, 2), strides = (2, 2),
                             padding = 'valid'))
model_2.add(Conv2D(16, kernel_size = (5, 5), strides = (1, 1),
                   activation = 'tanh', padding = 'valid'))
model_2.add(AveragePooling2D(pool_size = (2, 2), strides = (2, 2),
                             padding = 'valid'))
model_2.add(Flatten())
model_2.add(Dense(120, activation = 'tanh'))
model_2.add(Dense(84, activation = 'tanh'))
model_2.add(Dense(CLASSES_N_2, activation = 'softmax'))
```

In [0]:

```
model_2.compile(optimizer = 'adam',
                loss = 'categorical_crossentropy',
                metrics = ['categorical_accuracy'])
```

In [34]:

```
model_2.summary()
```

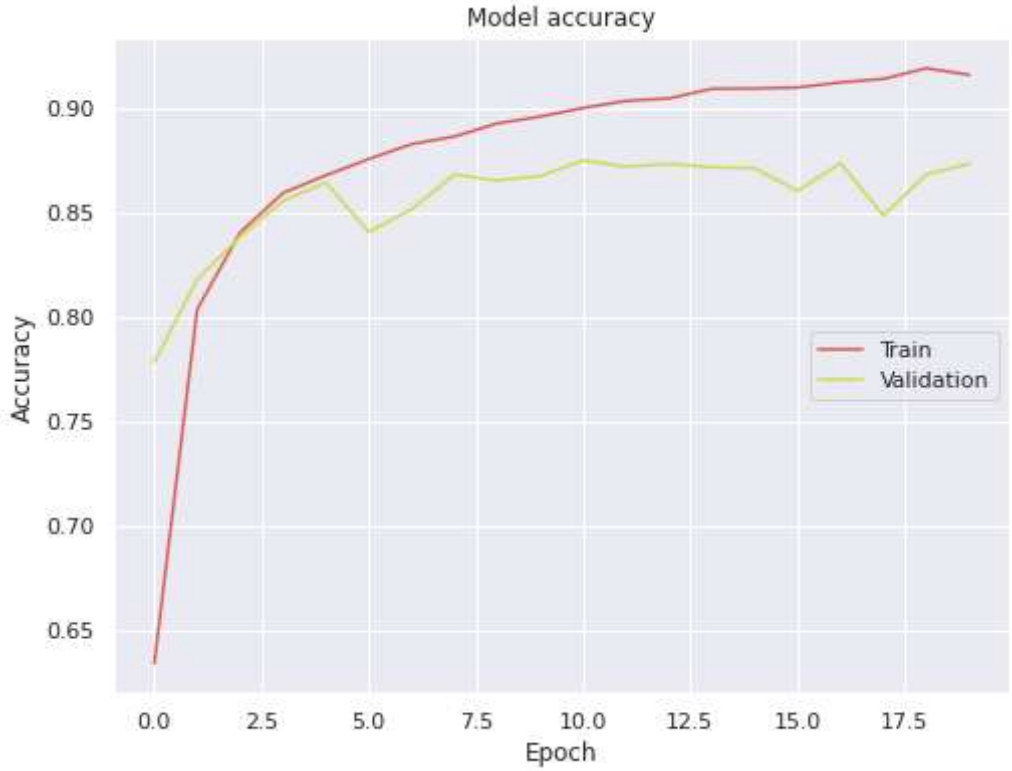
```
Model: "sequential_1"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_2 (Conv2D)            (None, 32, 32, 6)         456
_________________________________________________________________
average_pooling2d_2 (Average (None, 16, 16, 6)         0
_________________________________________________________________
conv2d_3 (Conv2D)            (None, 12, 12, 16)        2416
_________________________________________________________________
average_pooling2d_3 (Average (None, 6, 6, 16)          0
_________________________________________________________________
flatten_1 (Flatten)          (None, 576)               0
_________________________________________________________________
dense_3 (Dense)              (None, 120)               69240
_________________________________________________________________
dense_4 (Dense)              (None, 84)                10164
_________________________________________________________________
dense_5 (Dense)              (None, 11)                935
=================================================================
Total params: 83,211
Trainable params: 83,211
Non-trainable params: 0
_________________________________________________________________
```

In [0]:

```
history_2 = model_2.fit(x = X_second_ds_train, y = y_second_ds_train_cat,
                        validation_split = 0.15, epochs = EPOCHS_N, verbose = 0)
```

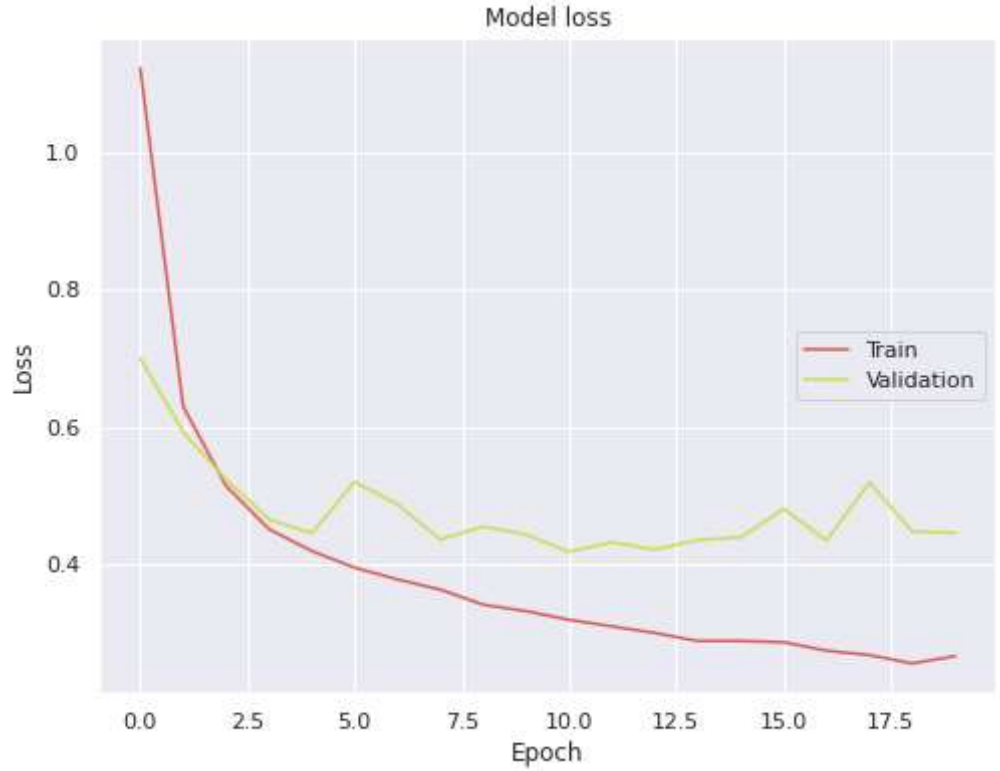
In [36]:

```
plot_accuracy(history_2, 'categorical_accuracy', 'val_categorical_accuracy')
```



In [37]:

```
plot_loss(history_2)
```



In [38]:

```
results = model_2.evaluate(X_second_ds_test, y_second_ds_test_cat)

print('Test loss, test accuracy:', results)
```

```
814/814 [==============================] - 2s 2ms/step - loss: 0.5066 - cate
gorical_accuracy: 0.8534
Test loss, test accuracy: [0.5066487193107605, 0.8534111976623535]
```

Здесь в модели изменилось то, что добавился ещё один класс — *не распознано*.

Эти данные более сложны для распознавания, что повлияло на результат — точность распознавания на тестовой выборке составила 83%.

Несколько цифр

Загрузим первый датасет — реальные изображения с несколькими цифрами и рамками границ.

In [0]:

```
from imageio import imread
import pandas as pd

def image_to_array(_image):
    try:
        array_ = imread(_image)

        return True, array_
    except:
        return False, None

def dir_to_dataframe(_dir_path):

    data_ = []

    files_ = sorted(os.listdir(_dir_path))

    for f in files_:
        file_path_ = os.path.join(_dir_path, f)

        can_read_, im = image_to_array(file_path_)

        if can_read_:
            data_.append(im)

    dataframe_ = pd.DataFrame()

    dataframe_['data'] = np.array(data_)

    return dataframe_
```

In [0]:

```
first_ds_train_dir = tar_gz_to_dir(DS_URL_FOLDER, TRAIN_DS_NAME, FIRST_DS_EXT,
                                   'first')
first_ds_test_dir = tar_gz_to_dir(DS_URL_FOLDER, TEST_DS_NAME, FIRST_DS_EXT,
                                  'first')
```

In [0]:

```
first_ds_train_subdir = os.path.join(first_ds_train_dir, 'train')
first_ds_test_subdir = os.path.join(first_ds_test_dir, 'test')
```

In [0]:

```
first_ds_train_images_df = dir_to_dataframe(first_ds_train_subdir)
first_ds_test_images_df = dir_to_dataframe(first_ds_test_subdir)
```

In [0]:

```
import h5py

first_ds_train_boxes_mat = h5py.File(
    os.path.join(first_ds_train_subdir, 'digitStruct.mat'), 'r')
first_ds_test_boxes_mat = h5py.File(
    os.path.join(first_ds_test_subdir, 'digitStruct.mat'), 'r')
```

In [0]:

```
import numpy as np
import pickle
import h5py

def mat_to_pickle(_mat_path, _key):

    f = h5py.File(_mat_path, 'r')

    metadata = {}

    metadata['height'] = []
    metadata['label'] = []
    metadata['left'] = []
    metadata['top'] = []
    metadata['width'] = []

    def print_attrs(name, obj):
        vals = []
        if obj.shape[0] == 1:
            vals.append(int(obj[0][0]))
        else:
            for k in range(obj.shape[0]):
                vals.append(int(f[obj[k][0]][0][0]))
        metadata[name].append(vals)

    for item in f['/digitStruct/bbox']:
        f[item[0]].visititems(print_attrs)

    with open('{}.pickle'.format((_key)),'wb') as pf:
        pickle.dump(metadata, pf, pickle.HIGHEST_PROTOCOL)
```

In [0]:

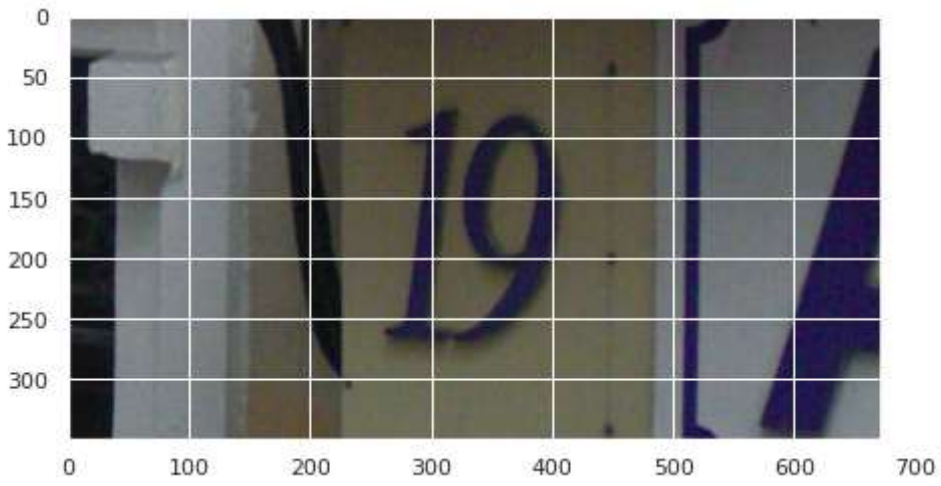
```
mat_to_pickle(
    os.path.join(first_ds_train_subdir, 'digitStruct.mat'), 'train_bbox')
mat_to_pickle(
    os.path.join(first_ds_test_subdir, 'digitStruct.mat'), 'test_bbox')
```

In [0]:

```
train_bbox_data = np.load('train_bbox.pickle', allow_pickle = True)
test_bbox_data = np.load('test_bbox.pickle', allow_pickle = True)
```

In [47]:

```
plt.imshow(first_ds_train_images_df['data'][0])

plt.show()
```



In [48]:

```
train_bbox_data['label'][0]
```

Out[48]:

```
[1, 9]
```

Задание 3

Сделайте множество снимков изображений номеров домов с помощью смартфона на ОС *Android*. Также можно использовать библиотеки *OpenCV*, *Simple CV* или *Pygame* для обработки изображений с общедоступных камер видеонаблюдения (например, https://www.earthcam.com/ (https://www.earthcam.com/)).

В качестве примера использования библиотеки *TensorFlow* на смартфоне можете воспользоваться демонстрационным приложением от *Google* (https://github.com/tensorflow/tensorflow/tree/master/tensorflow/examples/android) (https://github.com/tensorflow/tensorflow/tree/master/tensorflow/examples/android)).

Задание 4

Реализуйте приложение для ОС *Android*, которое может распознавать цифры в номерах домов, используя разработанный ранее классификатор. Какова доля правильных классификаций?