In [ ]:

```
Лабораторная работа №1. Логистическая регрессия в качестве нейронной сети
```

In [1]:

```
import cv2
import os
from matplotlib import pyplot as plt
import random
import pdb
import numpy as np
from six.moves import cPickle as pickle
import hashlib
from sklearn.linear_model import LogisticRegression
!python3 -m pip install imageio
import imageio
```

```
Requirement already satisfied: imageio in /home/ermolkin/study/mo/pre
v/lib/python3.7/site-packages (2.8.0)
Requirement already satisfied: pillow in /home/ermolkin/study/mo/prev/
lib/python3.7/site-packages (from imageio) (7.1.1)
Requirement already satisfied: numpy in /home/ermolkin/study/mo/prev/l
ib/python3.7/site-packages (from imageio) (1.18.2)
```

Helpful sources: http://mlwak.blogspot.com/2016/06/udacity-assignment-1-not-mnist.html (http://mlwak.blogspot.com/2016/06/udacity-assignment-1-not-mnist.html) https://github.com/hankcs/udacity-deep-learning/blob/master/1_notmnist.py (https://github.com/hankcs/udacity-deep-learning/blob/master/1_notmnist.py) https://github.com/rndbrtrnd/udacity-deep-learning/blob/master/1_notmnist.ipynb (https://github.com/rndbrtrnd/udacity-deep-learning/blob/master/1_notmnist.ipynb)

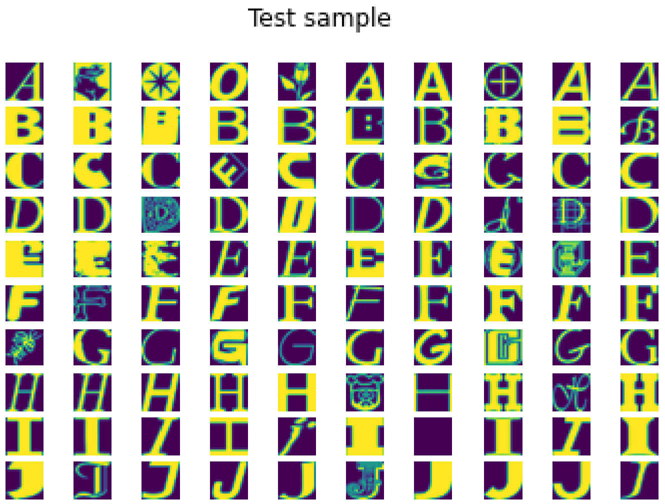
## 1: load data and show some images

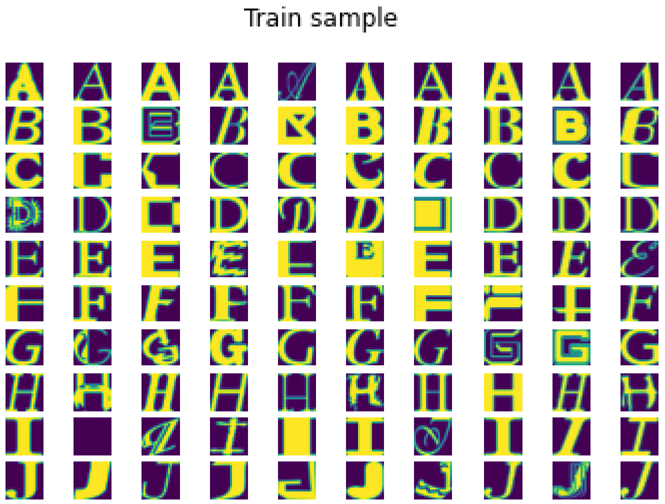
In [2]:

```
def plot_samples(folders, sample_size, name):
    figure = plt.figure()
    figure.suptitle(name)
    for folder in folders:
        image_names = os.listdir(folder)
        image_names_samples = random.sample(image_names, sample_size)
        for image_name in image_names_samples:
            subplot = figure.add_subplot(
                sample_size,
                len(folders),
                list(folders).index(folder) * sample_size + image_names_samples.ind
            )
            image = imageio.imread(os.path.join(folder, image_name))
            subplot.imshow(image)
            subplot.set_axis_off()
    plt.show()
```

In [3]:

```
train_sample_folder = '../data/notMNIST_large'
test_sample_folder = '../data/notMNIST_small'
train_sample_folders = np.sort([os.path.join(train_sample_folder, folder) for folde
test_sample_folders = np.sort([os.path.join(test_sample_folder, folder) for folder

plot_samples(train_sample_folders, 10, 'Test sample')
plot_samples(test_sample_folders, 10, 'Train sample')
```





In [4]:

```
image_size = 28 # Pixel width and height.
pixel_depth = 255.0 # Number of levels per pixel.
```

We'll convert the entire dataset into a 3D array (image index, x, y) of floating point values, normalized to have approximately zero mean and standard deviation ~0.5 to make training easier down the road.

In [5]:

```
def load_letter(folder, min_num_images):
    """Load the data for a single letter label."""
    """image_files is an array of all the filenames"""
    image_files = os.listdir(folder)
    """dataset is an array of length being the total number of images, and each ima
    dataset = np.ndarray(shape=(len(image_files), image_size, image_size), dtype=np
    print(folder)
    num_images = 0
    for image in image_files:
        image_file = os.path.join(folder, image)
        try:
            """this is the normalization step - the formula is [value-(255/2)]/255"
            image_file = imageio.imread(image_file)
            image_data = (image_file.astype(float) - pixel_depth / 2) / pixel_depth
            if image_data.shape != (image_size, image_size):
                raise Exception('Unexpected image shape: %s' % str(image_data.shape
            """after the normalization, stick the normalized image into the dataset
            dataset[num_images, :, :] = image_data
            num_images = num_images + 1
        except Exception as e:
            print('Could not read:', image_file, ':', e, '- it\'s ok, skipping.')
```

In [6]:

```
# Pickle is used for serializing and de-serializing Python object structures,
# also called marshalling or flattening.
def pickle_dataset(data_folders, min_num_images_per_class):
    dataset_names = []
    for folder in data_folders:
        set_filename = folder + '.pickle'
        dataset_names.append(set_filename)
        if os.path.exists(set_filename):
            # You may override by setting force=True.
            print('%s already present - Skipping pickling.' % set_filename)
        else:
            print('Pickling %s.' % set_filename)
            dataset = load_letter(folder, min_num_images_per_class)
            try:
                with open(set_filename, 'wb') as f:
                    pickle.dump(dataset, f, pickle.HIGHEST_PROTOCOL)
            except Exception as e:
                print('Unable to save data to', set_filename, ':', e)

    return dataset_names
```

In [7]:

```
train_datasets = pickle_dataset(train_sample_folders, 45000)
test_datasets = pickle_dataset(test_sample_folders, 1800)
```

```
../data/notMNIST_large/A.pickle already present - Skipping pickling.
../data/notMNIST_large/B.pickle already present - Skipping pickling.
../data/notMNIST_large/C.pickle already present - Skipping pickling.
../data/notMNIST_large/D.pickle already present - Skipping pickling.
../data/notMNIST_large/E.pickle already present - Skipping pickling.
../data/notMNIST_large/F.pickle already present - Skipping pickling.
../data/notMNIST_large/G.pickle already present - Skipping pickling.
../data/notMNIST_large/H.pickle already present - Skipping pickling.
../data/notMNIST_large/I.pickle already present - Skipping pickling.
../data/notMNIST_large/J.pickle already present - Skipping pickling.
../data/notMNIST_small/A.pickle already present - Skipping pickling.
../data/notMNIST_small/B.pickle already present - Skipping pickling.
../data/notMNIST_small/C.pickle already present - Skipping pickling.
../data/notMNIST_small/D.pickle already present - Skipping pickling.
../data/notMNIST_small/E.pickle already present - Skipping pickling.
../data/notMNIST_small/F.pickle already present - Skipping pickling.
../data/notMNIST_small/G.pickle already present - Skipping pickling.
../data/notMNIST_small/H.pickle already present - Skipping pickling.
../data/notMNIST_small/I.pickle already present - Skipping pickling.
../data/notMNIST_small/J.pickle already present - Skipping pickling.
```

2: check if samples are balanced

In [8]:

```
# returns array of images count in each folder
def num_of_images(datasets):
    num = []

    for pickle_file in datasets:
        with open(pickle_file, 'rb') as f:
            data = pickle.load(f)
            print('Total images in', pickle_file, ':', len(data))
            num.append(len(data))

    return num
```

In [9]:

```
def balance_check(sizes):
    mean_val = mean(sizes)
    print('mean of # images :', mean_val)
    for i in sizes:
        if abs(i - mean_val) > 0.1 * mean_val:
            print("Too much or less images")
        else:
            print("Well balanced", i)
```

In [10]:

```
def mean(numbers):
    return float(sum(numbers)) / max(len(numbers), 1)
```

In [11]:

```
# generates array of indexes of letters
def generate_fake_label(sizes):
    labels = np.ndarray(sum(sizes), dtype=np.int32)
    start = 0
    end = 0
    for label, size in enumerate(sizes):
        start = end
        end += size
        for j in range(start, end):
            labels[j] = label
    return labels
```

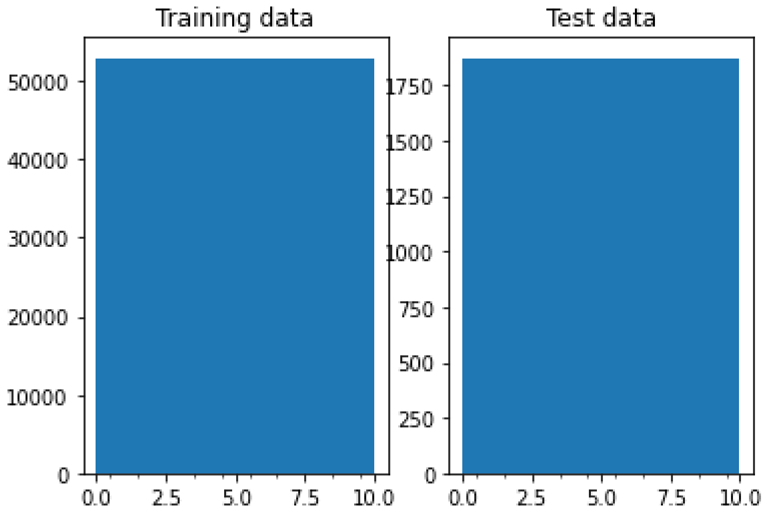
In [12]:

```
def plot_balance(train_labels, test_labels):
    fig, ax = plt.subplots(1, 2)
    bins = np.arange(train_labels.min(), train_labels.max() + 2)
    ax[0].hist(train_labels, bins=bins)
    ax[0].set_xticks((bins[:-1] + bins[1:]) / 2, [chr(k) for k in range(ord("A"), o
    ax[0].set_title("Training data")

    bins = np.arange(test_labels.min(), test_labels.max() + 2)
    ax[1].hist(test_labels, bins=bins)
    ax[1].set_xticks((bins[:-1] + bins[1:]) / 2, [chr(k) for k in range(ord("A"), o
    ax[1].set_title("Test data")
    plt.show()
```

In [13]:

```
test_labels = generate_fake_label(num_of_images(test_datasets))
train_labels = generate_fake_label(num_of_images(train_datasets))

# Checking balance
balance_check(num_of_images(test_datasets))
balance_check(num_of_images(train_datasets))

plot_balance(train_labels=train_labels, test_labels=test_labels)
```

```
Total images in ../data/notMNIST_small/A.pickle : 1872
Total images in ../data/notMNIST_small/B.pickle : 1873
Total images in ../data/notMNIST_small/C.pickle : 1873
Total images in ../data/notMNIST_small/D.pickle : 1873
Total images in ../data/notMNIST_small/E.pickle : 1873
Total images in ../data/notMNIST_small/F.pickle : 1872
Total images in ../data/notMNIST_small/G.pickle : 1872
Total images in ../data/notMNIST_small/H.pickle : 1872
Total images in ../data/notMNIST_small/I.pickle : 1872
Total images in ../data/notMNIST_small/J.pickle : 1872
Total images in ../data/notMNIST_large/A.pickle : 52909
Total images in ../data/notMNIST_large/B.pickle : 52911
Total images in ../data/notMNIST_large/C.pickle : 52912
Total images in ../data/notMNIST_large/D.pickle : 52911
Total images in ../data/notMNIST_large/E.pickle : 52912
Total images in ../data/notMNIST_large/F.pickle : 52912
Total images in ../data/notMNIST_large/G.pickle : 52912
Total images in ../data/notMNIST_large/H.pickle : 52912
Total images in ../data/notMNIST_large/I.pickle : 52912
Total images in ../data/notMNIST_large/J.pickle : 52911
Total images in ../data/notMNIST_small/A.pickle : 1872
Total images in ../data/notMNIST_small/B.pickle : 1873
Total images in ../data/notMNIST_small/C.pickle : 1873
Total images in ../data/notMNIST_small/D.pickle : 1873
Total images in ../data/notMNIST_small/E.pickle : 1873
Total images in ../data/notMNIST_small/F.pickle : 1872
Total images in ../data/notMNIST_small/G.pickle : 1872
Total images in ../data/notMNIST_small/H.pickle : 1872
Total images in ../data/notMNIST_small/I.pickle : 1872
Total images in ../data/notMNIST_small/J.pickle : 1872
mean of # images : 1872.4
Well balanced 1872
Well balanced 1873
Well balanced 1873
Well balanced 1873
Well balanced 1873
Well balanced 1872
Well balanced 1872
Well balanced 1872
Well balanced 1872
Well balanced 1872
Total images in ../data/notMNIST_large/A.pickle : 52909
Total images in ../data/notMNIST_large/B.pickle : 52911
Total images in ../data/notMNIST_large/C.pickle : 52912
Total images in ../data/notMNIST_large/D.pickle : 52911
Total images in ../data/notMNIST_large/E.pickle : 52912
Total images in ../data/notMNIST_large/F.pickle : 52912
Total images in ../data/notMNIST_large/G.pickle : 52912
Total images in ../data/notMNIST_large/H.pickle : 52912
Total images in ../data/notMNIST_large/I.pickle : 52912
Total images in ../data/notMNIST_large/J.pickle : 52911
mean of # images : 52911.4
Well balanced 52909
Well balanced 52911
Well balanced 52912
Well balanced 52911
Well balanced 52912
Well balanced 52912
Well balanced 52912
Well balanced 52912
Well balanced 52912
Well balanced 52911
```



In [14]:

```
# 3: divide into train (200k images), valid (10k images), test (19k images) subsamp
```

In [15]:

```
# creates 2 blank arrays for each class - 1 3D array for the data, and 1 array for
def make_arrays(nb_rows, img_size):
    if nb_rows:
        dataset = np.ndarray((nb_rows, img_size, img_size), dtype=np.float32)
        labels = np.ndarray(nb_rows, dtype=np.int32)
    else:
        dataset, labels = None, None
    return dataset, labels
```

In [16]:

```
# merge samples from each class into 1 dataset
def merge_datasets(pickle_files, train_size, valid_size=0):
    num_classes = len(pickle_files)
    valid_dataset, valid_labels = make_arrays(valid_size, image_size)
    train_dataset, train_labels = make_arrays(train_size, image_size)
    vsize_per_class = valid_size // num_classes
    tsize_per_class = train_size // num_classes

    start_v, start_t = 0, 0
    end_v, end_t = vsize_per_class, tsize_per_class
    end_l = vsize_per_class + tsize_per_class
    for label, pickle_file in enumerate(pickle_files):
        try:
            with open(pickle_file, 'rb') as f:
                letter_set = pickle.load(f)
                # let's shuffle the letters to have random validation and training
                np.random.shuffle(letter_set)
                if valid_dataset is not None:
                    valid_letter = letter_set[:vsize_per_class, :, :]
                    valid_dataset[start_v:end_v, :, :] = valid_letter
                    valid_labels[start_v:end_v] = label
                    start_v += vsize_per_class
                    end_v += vsize_per_class

                train_letter = letter_set[vsize_per_class:end_l, :, :]
                train_dataset[start_t:end_t, :, :] = train_letter
                train_labels[start_t:end_t] = label
                start_t += tsize_per_class
                end_t += tsize_per_class
        except Exception as e:
            print('Unable to process data from', pickle_file, ':', e)
            raise

    return valid_dataset, valid_labels, train_dataset, train_labels
```

In [17]:

```
train_size = 200000
valid_size = 19000
test_size = 10000

valid_dataset, valid_labels, train_dataset, train_labels = merge_datasets(train_dat
_, _, test_dataset, test_labels = merge_datasets(test_datasets, test_size)

print('Training:', train_dataset.shape, train_labels.shape)
print('Validation:', valid_dataset.shape, valid_labels.shape)
print('Testing:', test_dataset.shape, test_labels.shape)
```

```
Training: (200000, 28, 28) (200000,)
Validation: (19000, 28, 28) (19000,)
Testing: (10000, 28, 28) (10000,)
```

In [18]:

```
# 4: check if data from train sample doesn't cross other samples
```

In [19]:

```
pickle_file = '../data/notMNIST.pickle'

try:
    f = open(pickle_file, 'wb')
    save = {
        'train_dataset': train_dataset,
        'train_labels': train_labels,
        'valid_dataset': valid_dataset,
        'valid_labels': valid_labels,
        'test_dataset': test_dataset,
        'test_labels': test_labels,
    }
    pickle.dump(save, f, pickle.HIGHEST_PROTOCOL)
    f.close()
except Exception as e:
    print('Unable to save data to', pickle_file, ':', e)
    raise
```

In [20]:

```
statinfo = os.stat(pickle_file)
print('Compressed pickle size:', statinfo.st_size)
```

```
Compressed pickle size: 719060515
```

In [21]:

```
def extract_overlap_hash_where(dataset_1, dataset_2):
    dataset_hash_1 = np.array([hashlib.sha256(img).hexdigest() for img in dataset_1
    dataset_hash_2 = np.array([hashlib.sha256(img).hexdigest() for img in dataset_2
    overlap = {}
    for i, hash1 in enumerate(dataset_hash_1):
        duplicates = np.where(dataset_hash_2 == hash1)
        if len(duplicates[0]):
            overlap[i] = duplicates[0]
    return overlap
```

In [22]:

```
overlap_test_train = extract_overlap_hash_where(test_dataset, train_dataset)
print('Number of overlaps:', len(overlap_test_train.keys()))
```

```
Number of overlaps: 1278
```

In [23]:

```
def sanitize(dataset_1, dataset_2, labels_1):
    dataset_hash_1 = np.array([hashlib.sha256(img).hexdigest() for img in dataset_1
    dataset_hash_2 = np.array([hashlib.sha256(img).hexdigest() for img in dataset_2
    overlap = []  # list of indexes
    for i, hash1 in enumerate(dataset_hash_1):
        duplicates = np.where(dataset_hash_2 == hash1)
        if len(duplicates[0]):
            overlap.append(i)
    return np.delete(dataset_1, overlap, 0), np.delete(labels_1, overlap, None)
```

In [24]:

```
test_dataset_sanit, test_labels_sanit = sanitize(test_dataset, train_dataset, test_
print('Overlapping images removed from test_dataset: ', len(test_dataset) - len(tes
valid_dataset_sanit, valid_labels_sanit = sanitize(valid_dataset, train_dataset, va
print('Overlapping images removed from valid_dataset: ', len(valid_dataset) - len(v
print('Training:', train_dataset.shape, train_labels.shape)
print('Validation:', valid_labels_sanit.shape, valid_labels_sanit.shape)
print('Testing:', test_dataset_sanit.shape, test_labels_sanit.shape)
```

```
Overlapping images removed from test_dataset:  1278
Overlapping images removed from valid_dataset:  2089
Training: (200000, 28, 28) (200000,)
Validation: (16911,) (16911,)
Testing: (8722, 28, 28) (8722,)
```

In [25]:

```
def randomize(dataset, labels):
    #     permutes the order of the dataset and corresponding labels
    permutation = np.random.permutation(labels.shape[0])
    shuffled_dataset = dataset[permutation,:,:]
    shuffled_labels = labels[permutation]
    return shuffled_dataset, shuffled_labels

train_dataset, train_labels = randomize(train_dataset, train_labels)
test_dataset, test_labels = randomize(test_dataset, test_labels)
valid_dataset, valid_labels = randomize(valid_dataset, valid_labels)
```

In [26]:

```
pickle_file_sanit = '../data/notMNIST_sanit.pickle'

try:
    f = open(pickle_file_sanit, 'wb')
    save = {
        'train_dataset': train_dataset,
        'train_labels': train_labels,
        'valid_dataset': valid_dataset_sanit,
        'valid_labels': valid_labels_sanit,
        'test_dataset': test_dataset_sanit,
        'test_labels': test_labels_sanit,
    }
    pickle.dump(save, f, pickle.HIGHEST_PROTOCOL)
    f.close()
except Exception as e:
    print('Unable to save data to', pickle_file, ':', e)
    raise

statinfo = os.stat(pickle_file_sanit)
print('Compressed pickle size:', statinfo.st_size)
```

```
Compressed pickle size: 708488135
```

In [27]:

```
#5: Create logistic regression classifier
# Постройте график зависимости точности классификатора от размера обучающей выборки
```

In [28]:

```
def disp_sample_dataset(dataset, labels, title=None):
    fig = plt.figure()
    if title: fig.suptitle(title, fontsize=16, fontweight='bold')
    items = random.sample(range(len(labels)), 8)
    for i, item in enumerate(items):
        plt.subplot(2, 4, i + 1)
        plt.axis('off')
        plt.title(chr(ord('A') + labels[item]))
        plt.imshow(dataset[item])
    plt.show()
```

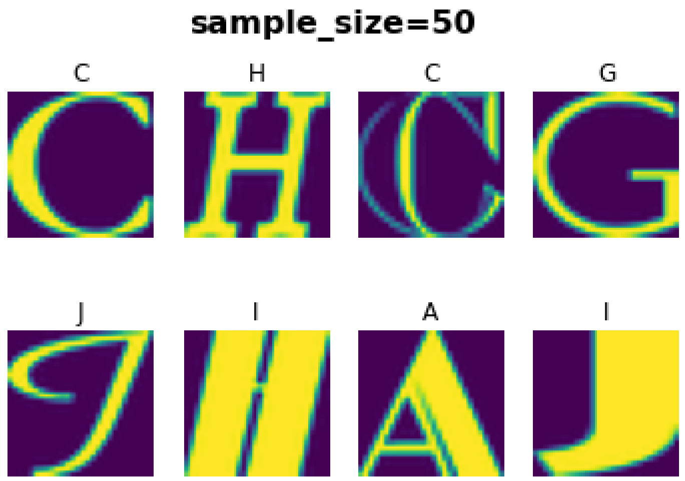
In [29]:

```
def train_and_predict(sample_size):
    regr = LogisticRegression()

    # convert 3d array to 2d
    X_train = train_dataset[:sample_size].reshape(sample_size, 28 * 28)
    y_train = train_labels[:sample_size]
    regr.fit(X_train, y_train)

    X_test = test_dataset.reshape(test_dataset.shape[0], 28 * 28)
    y_test = test_labels

    pred_labels = regr.predict(X_test)

    print('Accuracy:', regr.score(X_test, y_test), 'when sample_size=', sample_size
    disp_sample_dataset(test_dataset, pred_labels, 'sample_size=' + str(sample_size
```

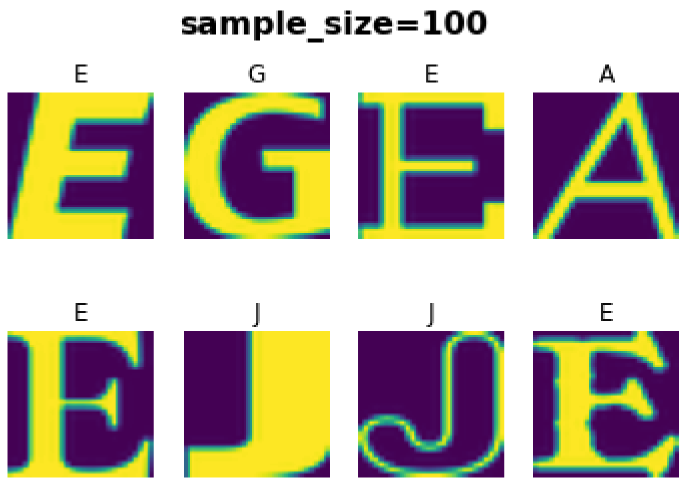
In [30]:

```
for sample_size in [50, 100, 1000, 5000, len(train_dataset)]:
    train_and_predict(sample_size)
```

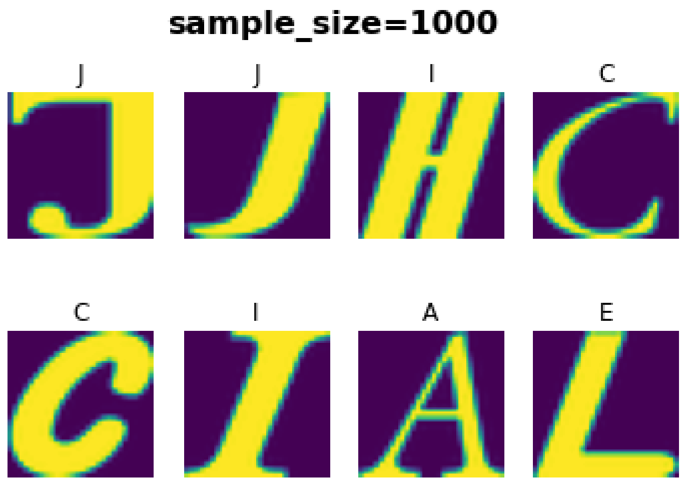
```
Accuracy: 0.5943 when sample_size= 50
```



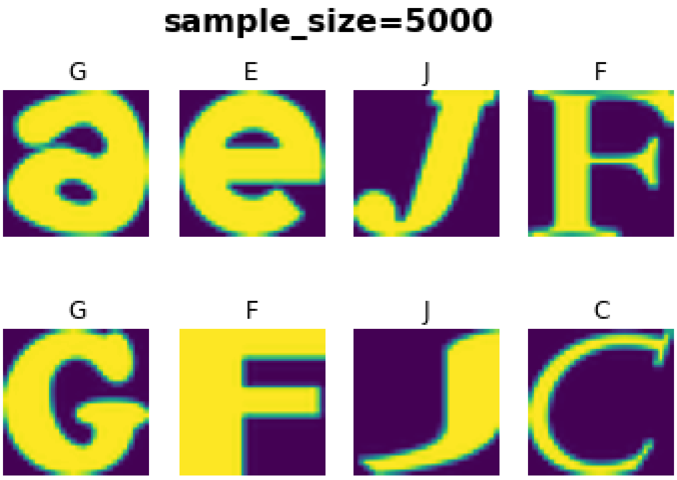
```
Accuracy: 0.7008 when sample_size= 100
```



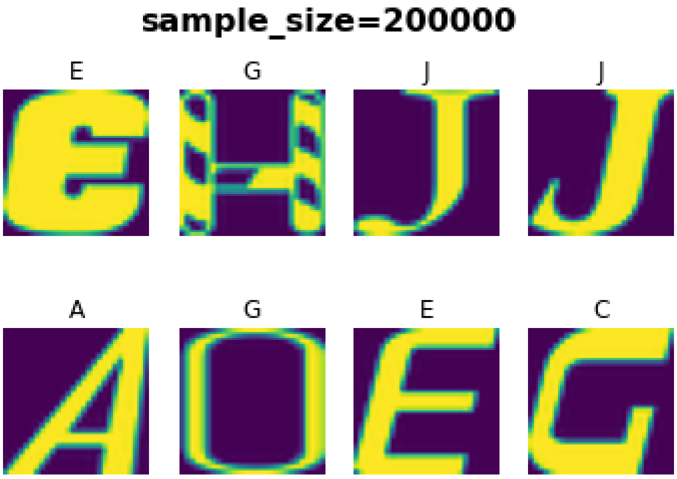
```
Accuracy: 0.8401 when sample_size= 1000
```



```
Accuracy: 0.8457 when sample_size= 5000
```



```
Accuracy: 0.9012 when sample_size= 200000
```


sample_size=200000
E
G
J
J
A
G
E
C