**Boğaziçi University**
**Department of Computer Engineering**
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Phase 1

# CMPE 544 Project-Phase 1

- The coding questions should be implemented in Python. You are allowed to use libraries unless otherwise stated in the questions. You are not allowed to train deep models. You may extract features from pre-trained architecture **only if a question asks you to**. Otherwise, please do not use deep learning techniques to boost performance.
- You **CANNOT** form a group of more than two students. If you are a group, then make sure to state the contributions of each member truthfully.
- Please provide a **link to your code** in your PDF report. PDF reports will be collected as Turnitin assignments on Moodle.
- You are **NOT** allowed to use ChatGPT to implement and prepare the project report. Turnitin also returns a similarity score for possible AI-generated material. If a violation of the academic integrity policy is detected, you will fail the class, and disciplinary actions will be taken.

## 1 Dataset

In this project, you will be using The Street View House Numbers (SVHN) dataset [1]. The SVHN dataset comprises ten classes and over 600,000 labeled digit images of size $32 \times 32$. You may consider it as MNIST in the wild. A selection from the dataset is shown below.

Figure 1: Images from SVHN dataset

You may download and import the dataset using a data loader from any library. When you load the dataset, you should see train and test splits of 73,257 and 26,032 images, respectively. Please use the provided train/test splits. You may spare a random subset from the training set for validation purposes.

[1] `http://ufldl.stanford.edu/housenumbers/`

## 2 Feature Extraction

SVHN dataset comprises RGB images, meaning each sample is a $32 \times 32 \times 3$ dimensional tensor. We need a fixed-length vector representation of the SVHN images to train models learned in the class. The vector representation/features should be distinctive enough to facilitate a classification task.

1. (10 pts) Investigate traditional feature extraction techniques. Choose at least five techniques and extract five different sets of features for the SVHN dataset. Among the five techniques, there could be ones you design. Are there any challenging cases in the SVHN dataset? Please discuss and provide example images if necessary.
2. (10 pts) Compare the distinctiveness of the features you extracted. You will not yet learn about dimensionality reduction or clustering in the first phase. Therefore, come up with an evaluation approach where you quantify the distinctiveness of the features from five different techniques. Based on your metric, please discuss which features you would prefer to use for further tasks.
3. (10 pts) For the features of your choice, investigate if there are any classes with low intra-class and high inter-class similarities. Detect the problematic categories that might lead to misclassification errors, if there are any.

## 3 Classification

In this section, you need to train classifiers using the features you extracted in the previous section.

1. (10 pts) Please try to use the non-parametric k-Nearest Neighbors (k-NN) classifier. Please comment on the challenges you encounter while training the k-NN classifier. You may use libraries, but you should be able to answer questions about the techniques that the function you use implements in the background. Please focus on how k-NN is implemented for large-scale datasets such as SVHN.
2. (20 pts) Please use linear discriminant functions for classification. Please compare the performances for different linear discriminant functions and classification with non-linear transformations. Please plot and comment on the convergence of each method you try. Please discuss your strategy to determine the hyperparameters.
3. (10 pts) Do you observe underfitting? Please suggest ways to overcome it and apply your suggestions. If necessary, you may go back to exploring better feature extraction techniques at this point. Please report the changes you made in the feature extraction part. If you observe overfitting, please use regularization to overcome it. Please repeat (2) with the regularized models.

## 4 Metric Learning

In this section, you will use Scale Invariant Feature Transform (SIFT) features.

1. (20 pts) Please implement a distance metric learning framework from scratch. Your goal is to learn a linear projection to map SIFT features into a new space where the Euclidean distance between the samples in the same category will be minimized, and the distance between samples from different categories will be maximized. Please provide your metric learning algorithm in your report. You must design the loss function and any extra terms needed to regularize the training. Make sure the learned distance function will be a valid distance metric.
2. (10 pth) Train your metric learning framework with the training split of SVHN. Apply the learned projection onto SIFT features of the training and test splits. Then, train the best classifier from Section 3 with the new features and report the performance. Could you improve the performance?