Report For CS385 Personal Project

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Declare
All the code in this project is written by myself, and you can check it : `https://github.com/lym01803/CS385_Project1`, which is my personal repository. I only use third-party libraries for the following:

- Visualization, e.g. PCA, t-SNE, draw curve and histogram.
- SVM.
- HOG feature.
- For CNN model. The network is built by myself. But I use API for network layers, e.g. Conv, BN.
- Basic matrix operations. For simple models, I only use pytorch to do simple matrix operations on cuda. I do not use any advanced API, such as built-in network layers, optimizers and auto-gradient. In fact, to confirm it, I set the requires_grad attribute of tensors to False.

Note
During the project, I discussed and exchanged opinions with my classmates many times. In the analysis of logistic regression model, my opinion may be similar to that of my classmate Yuxuan Xiong. Please note that if there are some similarities in our analysis, it is the result of our discussion, not plagiarism.

1 Introduction

In this project, I do the following things:

- Processed the data set;
- Implement several basic models: Logistic Regression, LDA, kernel based Logistic Regression, SVM and CNN;
- Try two regular terms: Ridge and Lasso;
- Visualization: HOG feature, CNN feature and distribution of LDA and Logistic Regression;
- Analysis: mainly about the logistic regression.

In fact, the models in this project are all discriminative models, and they are all closely related to logistic regression: LDA and logistic regression have different goals, but they take the same way to solve the discrimination problem: learning a projection direction to separate data; The motivation of the SVM model comes from the discussion of the margin in linear binary discrimination problem; The kernel is an extension of the linear model to the nonlinear model, which is equivalent to a linear model for high-dimensional (probably non-linear) features $\phi(X)$; CNN can be regarded as using a learnable deep network to produce the features of input images instead of using the manual designed HOG features, which is essentially a binary classifier (logistic regression) or a multi-classifier (extension of logistic regression, sigmoid -> softmax) of the CNN based features. Therefore, in the subsequent analysis of the project, the discussion will mainly focus on a basic point, the linear logistic regression model.

2 Data Process

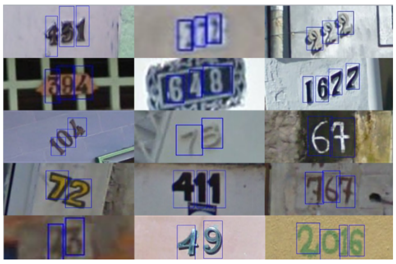
2.1 Crop and Padding

The given data set has two format: 1. original images with character level bounding boxes; 2. The cropped images.

Since the borders of digits are usually not square, the square cropped images mostly contain part of other digits. Although someone says that such noise does not affect the performance of the classifier (most likely because the translation invariance of HOG is not good), I still do not plan to use it.

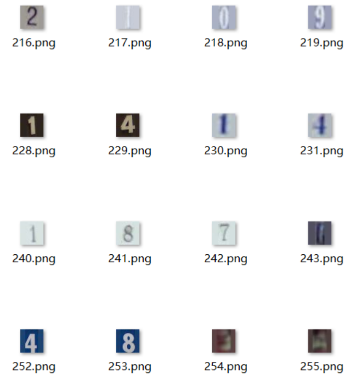
Therefore, I crop the original images by myself according to the given digit boxes, then padding the images into squares symmetrically, and then resize them to a size of 32×32. For the color to padding, I choose the average color of the border pixels of cropped images (averaged for each channel). I am not sure if such an operation meets the specifications of the CV field, but at least the images obtained in this way seems to be of high quality to my eyes and is suitable for training discriminative models, I think.

The comparison between the two official offered data and the data processed by myself is shown in the followed Fig. 1.



Format 1: original images

Format 2: cropped images



Images cropped and paddinged by myself

Figure 1: Comparison between official data and data processed by myself

2.2 HOG Feature

General experience tells us that directly using the three-channel pixels of an image as the input features may not be effective. It is usually believed that the local gradient (both norm and direction) of an image can reflect image features such as object edges and textures. Therefore, the HOG feature of the image is used as the input of models (except CNN) here. A third-party library cv2.HOGDescriptor is used here. The parameters are shown in the following Table 1, and finally 1764-dimensional feature vectors are obtained.

Table 1: The HOG parameters setting

input size	$32 \times 32 \times 3$	window size	32×32
block size	8×8	block stride	4×4
cell size	4×4	bin	9

3 Logistic Regression

3.1 Implement

I follow eq. 1.

$$\begin{aligned} L_i &= y_i \log p_i + (1 - y_i)\log(1 - p_i) \\ &= y_i X_i^\top \beta - \log(1 + \exp(X_i^\top \beta)) \\ \frac{\partial}{\partial \beta} L_i &= y_i X_i - \frac{\exp(X_i^\top \beta)}{1 + \exp(X_i^\top \beta)} \cdot X_i \\ &= (y_i - p_i) \cdot X_i \end{aligned} \tag{1}$$

For efficient calculation, I do not calculate the loss L_i in the program. Instead I directly calculate the gradient $\partial L_i / \partial \beta$ and perform gradient descent.