MATH 6380O Mini-Project 1: Feature Extraction and Transfer Learning

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1. Introduction

Nowadays, deep learning plays an important role in people's daily events and all works of life. In this project, we explore the **MNIST dataset**, which contains 60,000 training images and 10,000 test images.

We use the **Scattering Net**, **VGG16** and **VGG19** as pretrained CNNs to extract features, which are visualized by t-SNE and PCA. We also try to verify the Neural Collapse phenomena using some statistics of the features. Moreover, we do the classification by traditional supervised learning methods and compare their accuracy. Among all the experiments, the Scattering Net combined with SVM method has the best performance.

2. Framework

Features Extraction

The dimension of each feature vectors extracted from Scattering Net, VGG19 and VGG16 is 833, 512 and 512, respectively.

Visualization

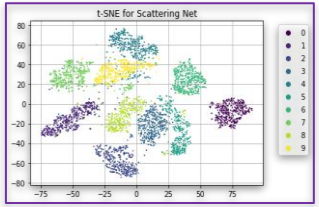
We choose first 5000 features and visualize them using linear and nonlinear dimensionality reduction methods such as PCA and t-SNE. Here we just present the visualization by t-SNE since PCA doesn't perform well.

Classification

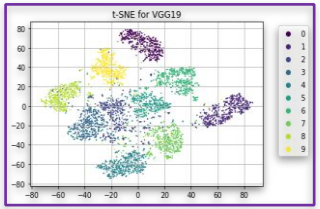
We employ and compare four traditional supervised methods: SVM, Logistic Regression, Random Forest and Decision Tree. To make it clear, we draw a table to compare the accuracy of these four methods based on the features extracted.

3. Visualization

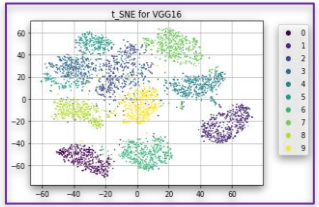
The following figures show the visualizations of the t-SNE results for these three CNNs.



t-SNE results for Scattering Net



t-SNE results for VGG19



t-SNE results for VGG16

4. Classification results on MNIST Dataset

Comparisons between SVM, Logistic Regression, Random Forest and Decision Tree

	Scattering Net	VGG19	VGG16
SVM	0.9907	0.9712	0.9722
Logistic Regression	0.9824	0.9699	0.9676
Random Forest	0.9696	0.9386	0.9249
Decision Tree	0.9165	0.8724	0.8606

5. Analysis & Conclusion

Neural Collapse

Based on the Scattering Net, VGG16 and VGG19, we verify NC1 (Variability collapse) and NC2 (Convergence to Simplex ETF) in ref[1]. The second claim in NC2 shows good result when the classes are different. However, some values are not so close to the expected ones. This phenomenon is probably because the Neural Collapse paper uses features trained beyond zero-error (TPT), whereas our networks are not well-trained (training error still larger than 0), thus leading to unsatisfied results. What's more, these values are all fixed numbers since we don't train the networks, hence showing no trend.

Classification

From the above table, we can see that SVM gives the highest accuracy among all the traditional supervised learning methods, which we use to train starting from the features extracted. And it seems that, Scattering Net gives better features than VGG16 and VGG19 in each method.

6. References

1.Vardan Papyan, X.Y. Han, David L. Donoho, "Prevalence of Neural Collapse during the terminal phase of deep learning training", arXiv: 2008.08186.

2.John Bruna, Stephane Mallat, "Invariant Scattering Convolution Networks", IEEE Transactions on Pattern Analysis and Machine Intelligence, 2012.

3.M. Andreux., T. Angles, G. Exarchakis et al (2019). "Kymatio: Scattering Transforms in Python", arXiv:1812.11214.

7. Contribution

Features extraction
- Yue Wu

Visualization of features and Neural Collapse
- Chutian Huang

Classifications using traditional supervised learning methods based on featured extracted
- Zheyue Fang

Poster
- Lu Yang