MATH 6380O Project 1: Feature Extraction and Transfer Learning

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An important problem

In this project, we attempt to use different feature extraction models and traditional machine learning methods to test which one is more efficient for image classification by using MNIST dataset.

MNIST Database: It is a dataset of handwritten digits with 60,000 training samples and 10,000 test samples. Each image is represented by 28*28 pixels and each containing a value 0-255 with its grayscale value.

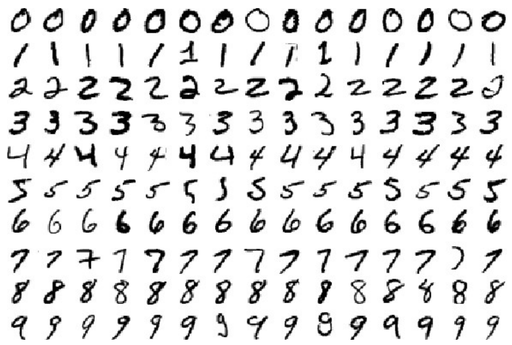


Fig. 1: Sample of MNIST database.

Methodology

Models

- **Scattering Net:** It is a complex-valued convolutional neural network whose filters are fixed to be wavelets and the non-linearity is a complex modulus. Followed by feature extraction, we use PCA and t-SNE to get the visualization of the extracted features and use Logistic Regression, SVM, Random Forest, Decision Tree, Adaboost, and Gradient Boosting for classification.
- **Pre-trained Deep Neural Networks:** We also use three of the famous CNN architectures to do feature extraction. Then we repeat the supervised and unsupervised methods for classification.

	Salient Feature	Structure	Parameters
AlexNet	Deeper	5 convolutional layers and 3 fully connected layers	62M
VGG19	Fixed-size kernels	19 layers and conv kernels are of size 3*3	138M
ResNet18	Shortcut connections	18 layers and solve the vanishing gradient problem	11M

Fig. 2: Three pre-trained networks.

Model Evaluation

- **3-Fold Cross Validation:** CV process is repeated 3 times with each of the 3 subsamples used exactly once as validation data. Then the 3 results are averaged to produce a single estimation.

Scattering Net with Known Variants

Feature Extraction

Give an image with size 28×28, we implement the 2D scatting transform. We use J=2 for scale transform and R=2 as two rotation angles of wavelets to get 17 images with size 7×7. Then we use these 17 images as a feature vector of the original image. The right hand side figure shows 6 examples among the 17 images.

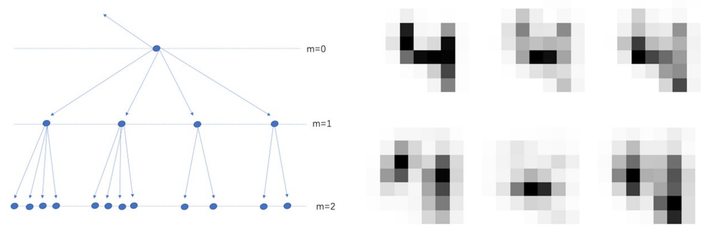


Fig. 3: The Extraction process of Scattering net.

Feature Visualization

We use PCA and t-SNE for dimension reduction and find out the first two principal component. It shows that t-SNE can classify the labels into 10 parts clearly while PCA cannot, which indicates that the features may not be linear correlated.

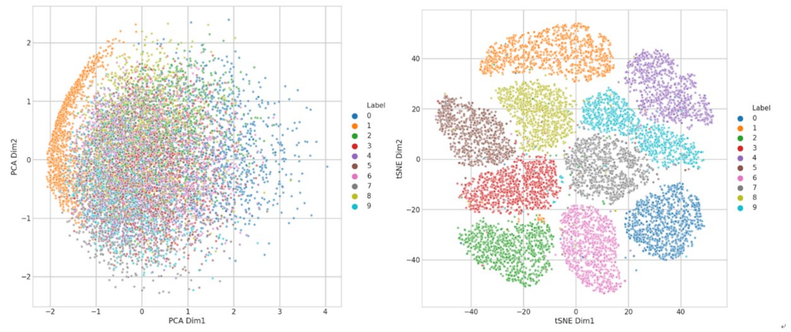
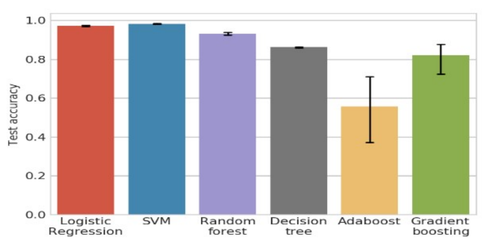


Fig. 4: PCA(left) and t-SNE(right) result for Scattering Net.

Image Classifications

We use traditional unsupervised learning methods to do image classifications based on the features extracted. To evaluate each model, we compute the test accuracy on the test set. The results states that 4 out of the five methods get accuracy bigger than 80% while Logistic Regression and SVM have the best performance. Adaboost is not suitable for the classification of this dataset.



Pre-trained Deep Neural Networks

We only use the first 1000 data to do feature extraction by pre-trained deep neural networks. Take AlexNet as example, the visualized feature show similar results with Scattering Net, which further confirm that PCA cannot classify the images well.

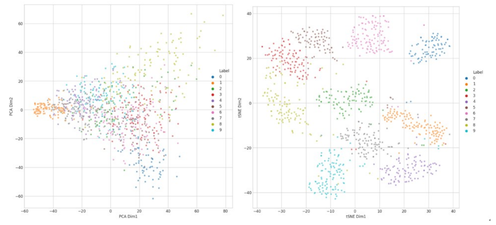


Fig. 6: PCA(left) and t-SNE(right) result for AlexNet.

Cross Validation

In this part, we compare the performance of Scattering Net and pre-trained models. Since cross validation results are random, we just repeat each classification methods for 5 times and choose the average.

Feature Extraction	Classification	Accuracy
Scattering Net	SVM	98.3%
	Logistic Regression	97.2%
Alex Net		96.8%
VGG19		97.5%
ResNet18		97.9%

Fig. 7: comparison of CV results for scattering net and pre-trained models.

All classification methods we list in the table show a good performance with accuracy higher than 90%. Scattering Net, AlexNet, VGG19 and ResNet18 are all effective feature extraction methods for this dataset. Meanwhile, the unsupervised learning methods for these extraction models also prove that the extracted features do not have strong linear correlations since t-SNE perform much better than PCA.

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Reference

J. Bruna and S. Mallat, "Invariant scattering convolution networks," IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 35, No. 8, pp. 1872-1886, 2013.
M. Shaha and M. Pawar, "Transfer Learning for Image Classification," 2018 Second International Conference on Electronics, Communication and Aerospace Technology (ICECA), Coimbatore, 2018, pp. 656-660.