

University: Sharif University of Technology

Department: Electrical Engineering

Course Name: Advanced Neuroscience

Homework 9 Report

Visual Model

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1 Simulate Sparse Basis Functions of the Natural Images

We start by loading the `IMAGES_RAW.mat` and `IMAGES.mat` files. The `IMAGES_RAW.mat` file contains raw natural images, while the `IMAGES.mat` file contains pre-processed images. To gain an understanding of the dataset, we visualize a subset of the images using the provided code. [Figure 1](#) displays the raw images, while [Figure 2](#) shows the pre-processed images.

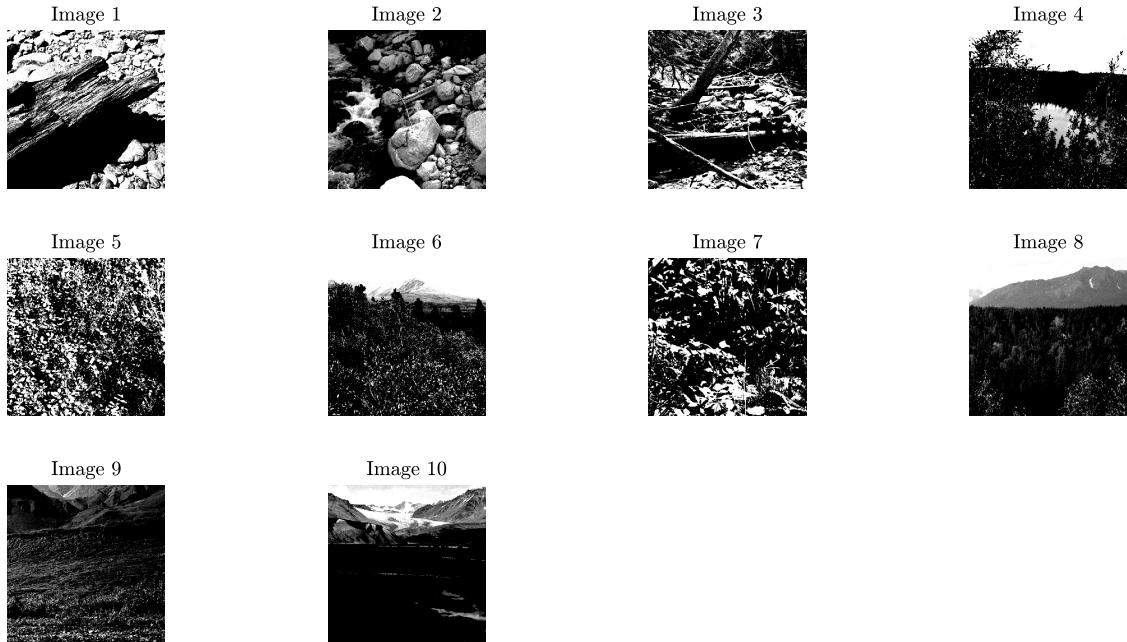


Figure 1: Original Natural Images

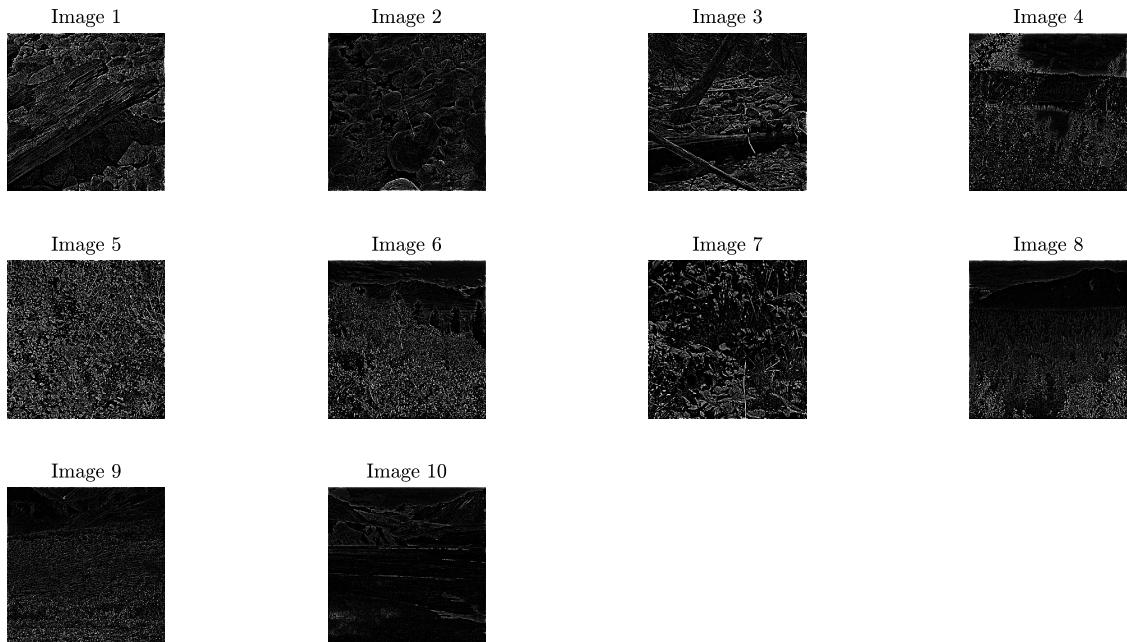
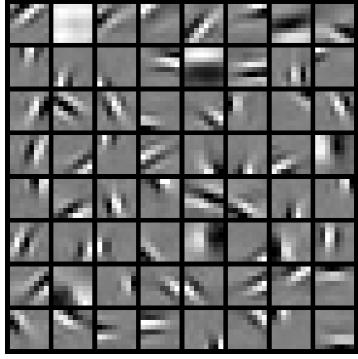
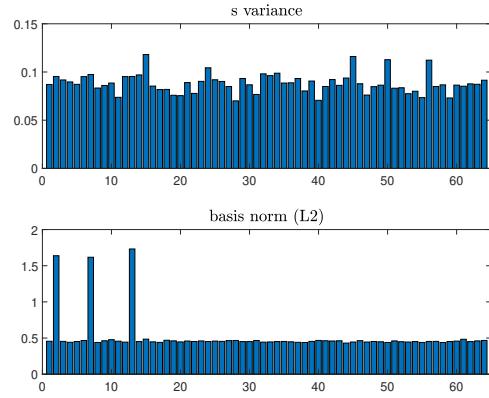


Figure 2: Whitened Natural Images

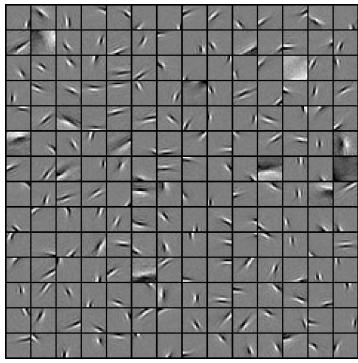


(a) Basis Functions

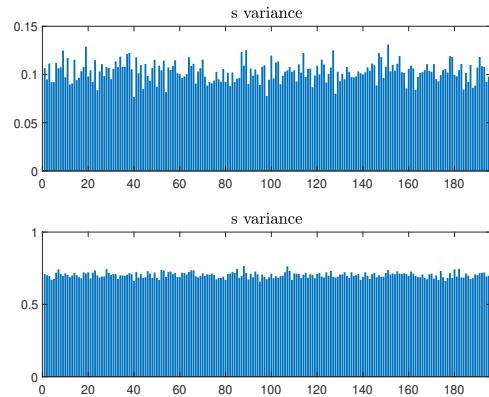


(b) Variance and Norm

Figure 3: Basis functions and their norm and variance; 64 basis functions of size 8×8



(a) Basis Functions



(b) Variance and Norm

Figure 4: Basis functions and their norm and variance; 196 basis functions of size 16×16

Results of sparse coding algorithm (Presented by Olshausen et al. 1996) is shown in [Figure 3](#) and [Figure 4](#). As can be seen, by increasing the number and size of basis functions, we obtain more sparse functions.

- With a larger number of basis functions, the model has a higher capacity to capture fine details and intricate structures present in the natural images. However, an excessively large number of basis functions may lead to overfitting and poor generalization to unseen data. On the other hand, a smaller number of basis functions might result in underfitting and a loss of important information.
- The size of basis functions determines their spatial scale and receptive field properties. Larger basis functions covers more regions of the input images, capturing global structures and larger-scale patterns. On the other hand, smaller basis functions focus on local details and features.

2 Study the Effect of Different Datasets

2.1 Yale Dataset

The Yale dataset contains a collection of face images captured under various lighting conditions, facial expressions, and poses. Here we limit the images to normal conditions and choose a subset of 10 images.

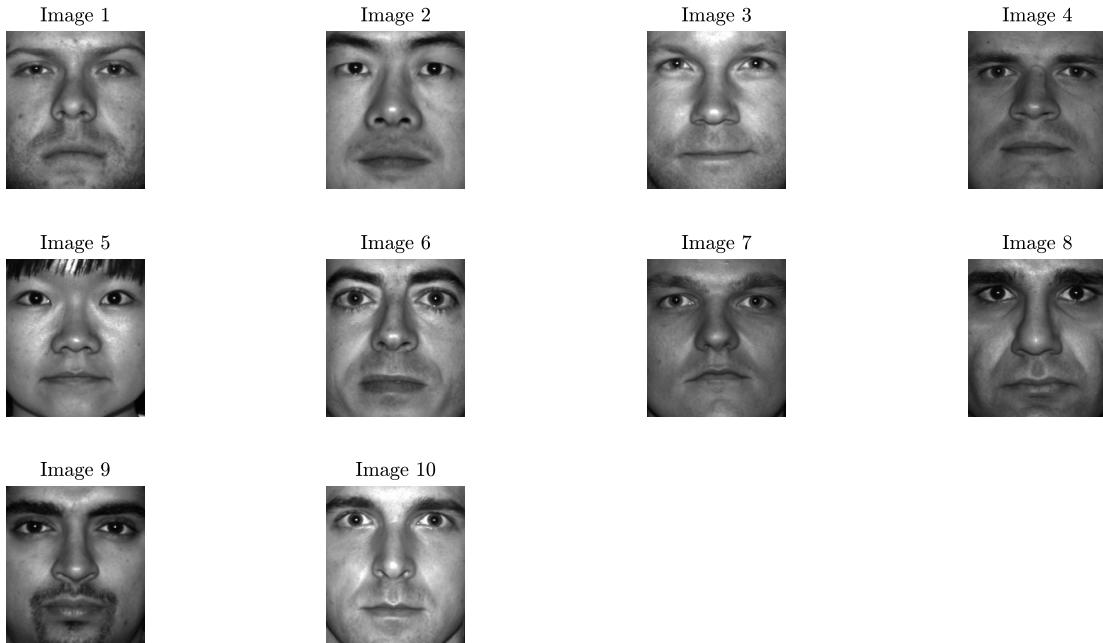


Figure 5: Original Images; Yale Dataset

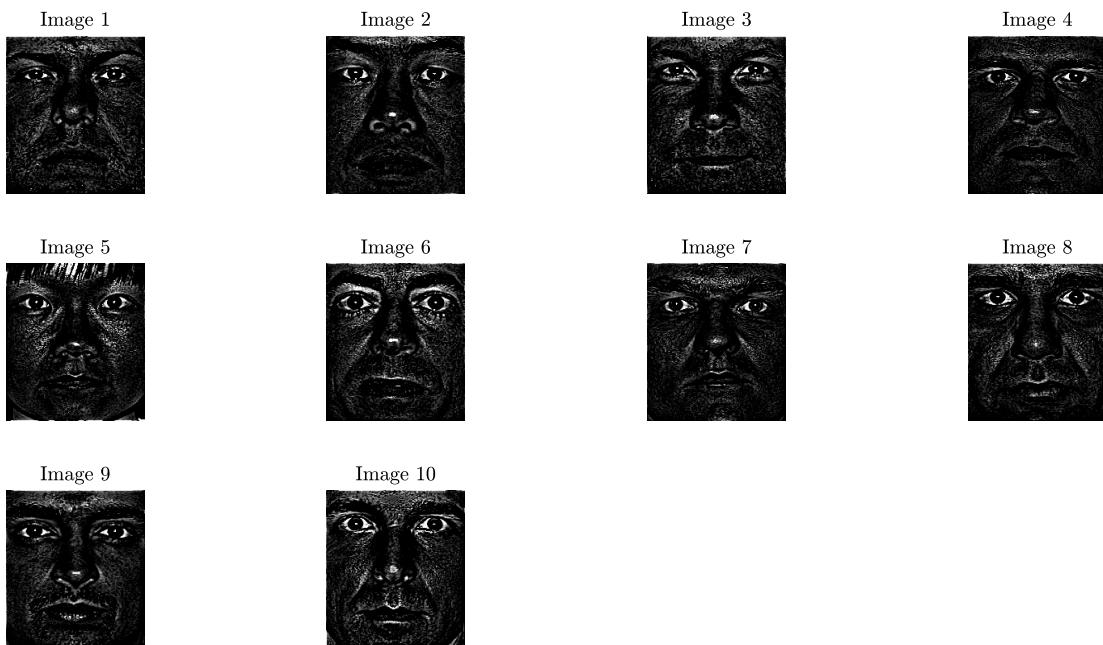
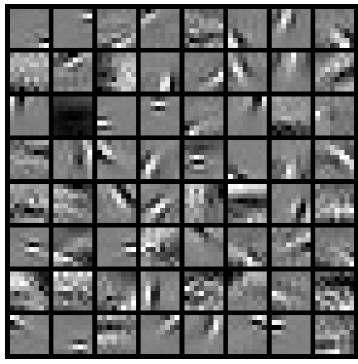
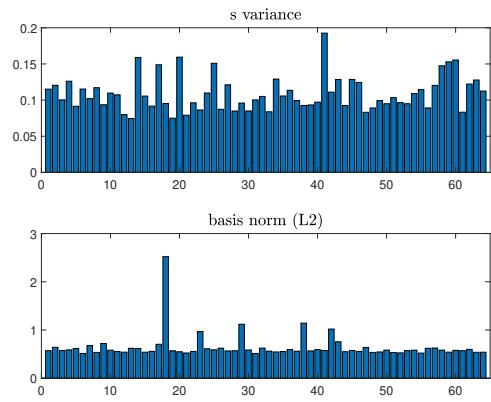


Figure 6: Whitened Images; Yale Dataset

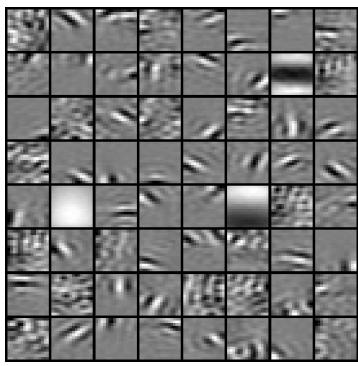


(a) Basis Functions

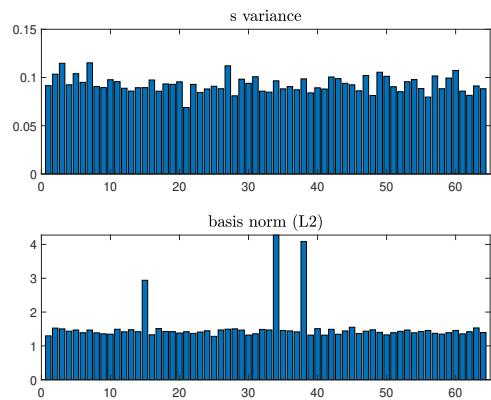


(b) Variance and Norm

Figure 7: Basis functions and their norm and variance; 64 basis functions of size 8×8



(a) Basis Functions



(b) Variance and Norm

Figure 8: Basis functions and their norm and variance; 64 basis functions of size 16×16

As you can see, basis functions look like previous ones in Natural Images and have a gabor shape. By increasing the size of basis functions, more clear representation is obtained.

2.2 MNIST Dataset

The MNIST dataset contains handwritten digits (0-9), each represented as a 28x28 gray-scale image. A subset of 10 images is chosen for sparse coding algorithm.

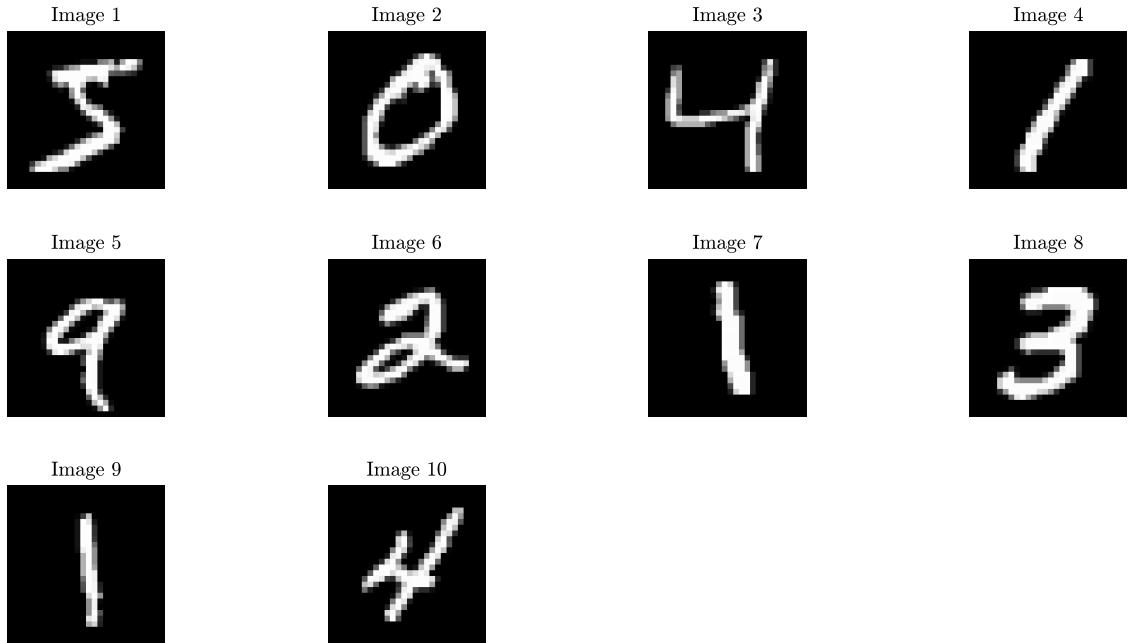


Figure 9: Original Images; MNIST Dataset

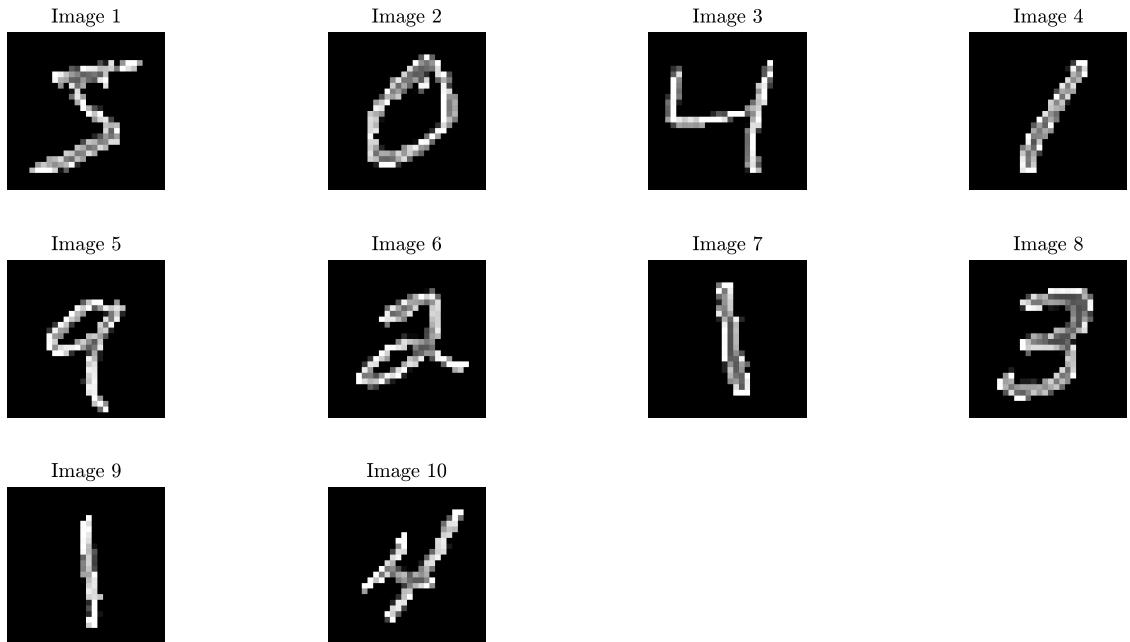
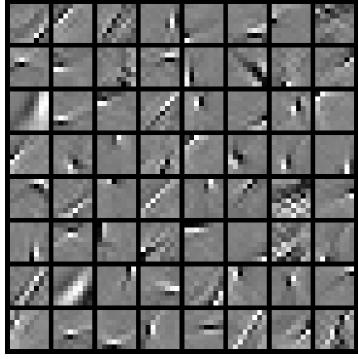
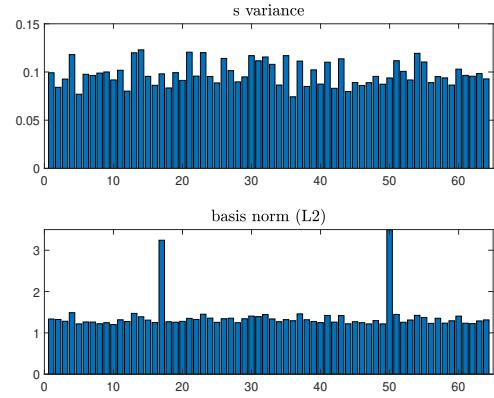


Figure 10: Whitened Images; MNIST Dataset

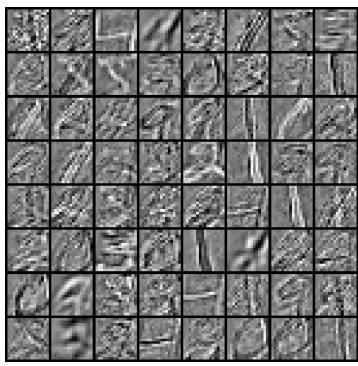


(a) Basis Functions

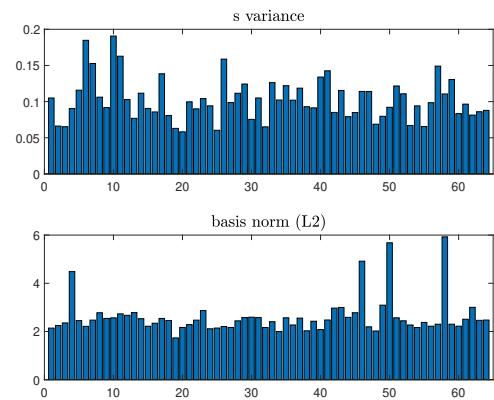


(b) Variance and Norm

Figure 11: Basis functions and their norm and variance; 64 basis functions of size 8×8



(a) Basis Functions



(b) Variance and Norm

Figure 12: Basis functions and their norm and variance; 64 basis functions of size 16×16

In the [Figure 11](#), we can see basis functions both similar and different from previous ones. They seem to be thinner in MNIST dataset where numbers are consist of curved lines only. Since our input images were 28×28 , if we increase the basis function's size to 16×16 , more than half of the image is covered. Hence, basis functions are no longer general and will over-fit to the input images ([Figure 12](#)).

2.3 Caltech 101 (Ant Category)

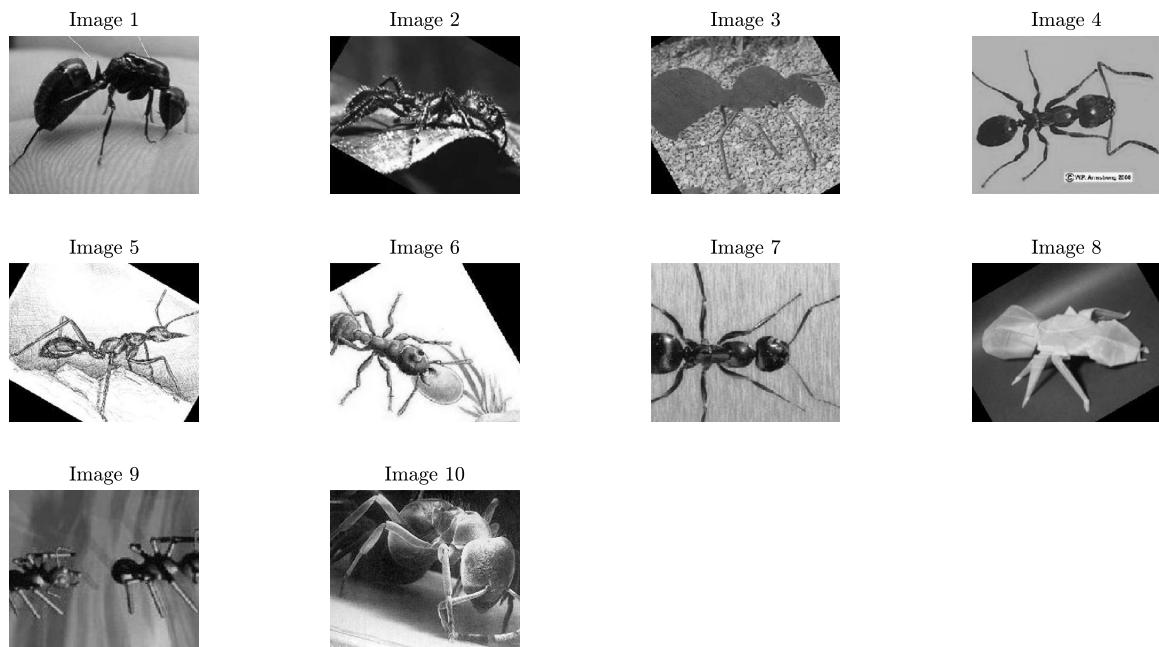


Figure 13: Original Images; Caltech101 Dataset

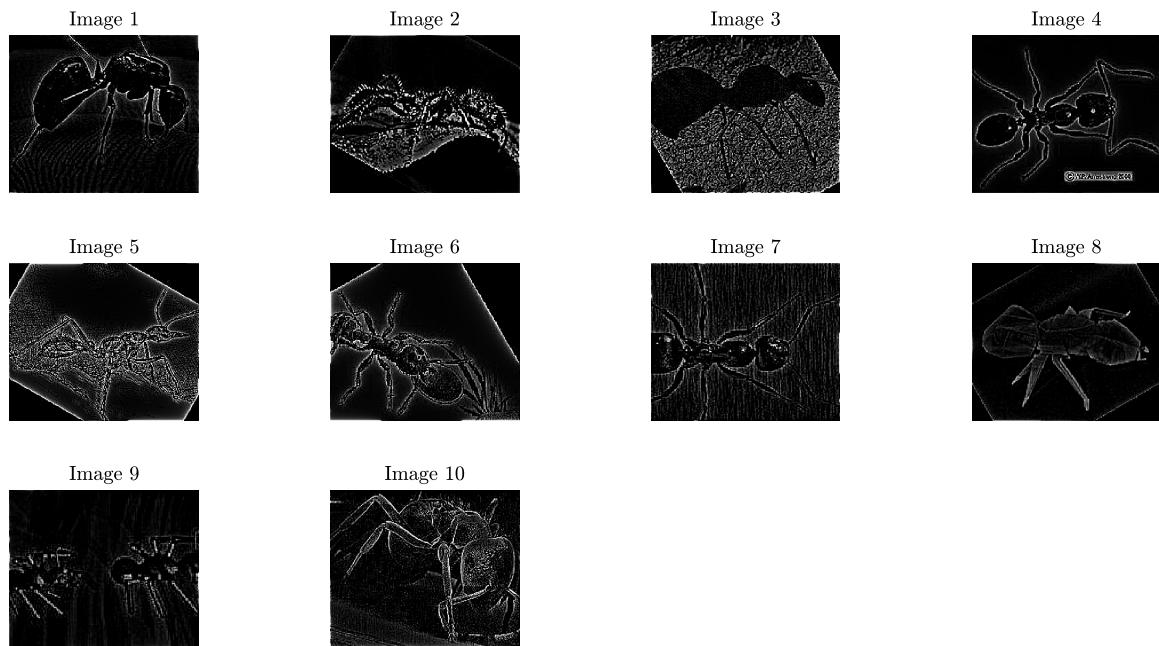
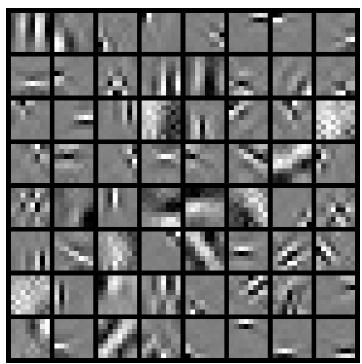
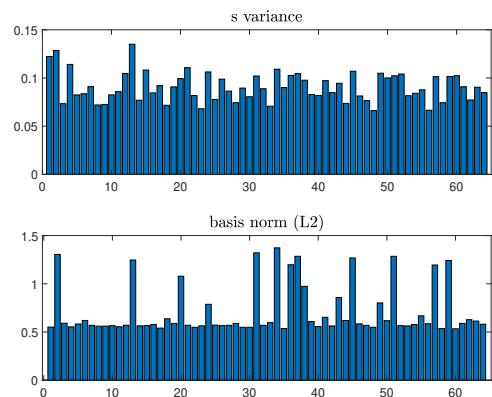


Figure 14: Whitened Images; Caltech101 Dataset



(a) Basis Functions



(b) Variance and Norm

Figure 15: Basis functions and their norm and variance; 64 basis functions of size 8×8

Basis functions look the same as predicted since *Ant Category* are natural images.

3 Study the Dynamics of the Sparse Coefficients

Just like the previous parts, we extract 10 images (10 frames from beginning of the video - [Figure 16](#) and [Figure 17](#)) and run the sparse coding algorithm. The algorithm then finds and converges to basis functions shown in [Figure 18](#) and [Figure 19](#).

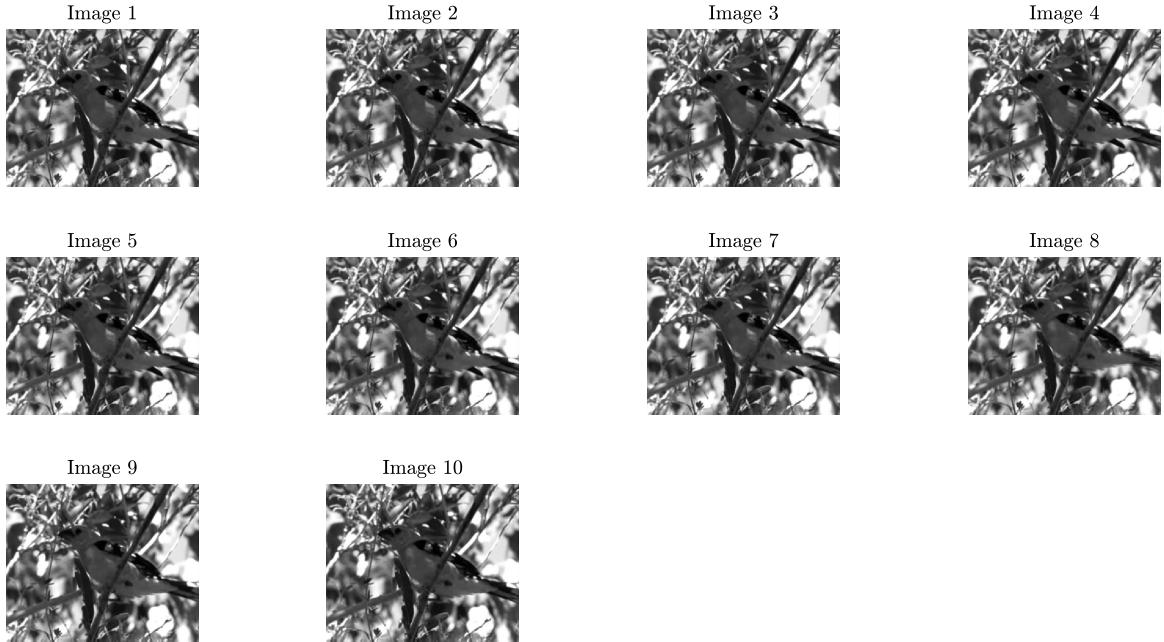


Figure 16: Original Images; Frames of Video

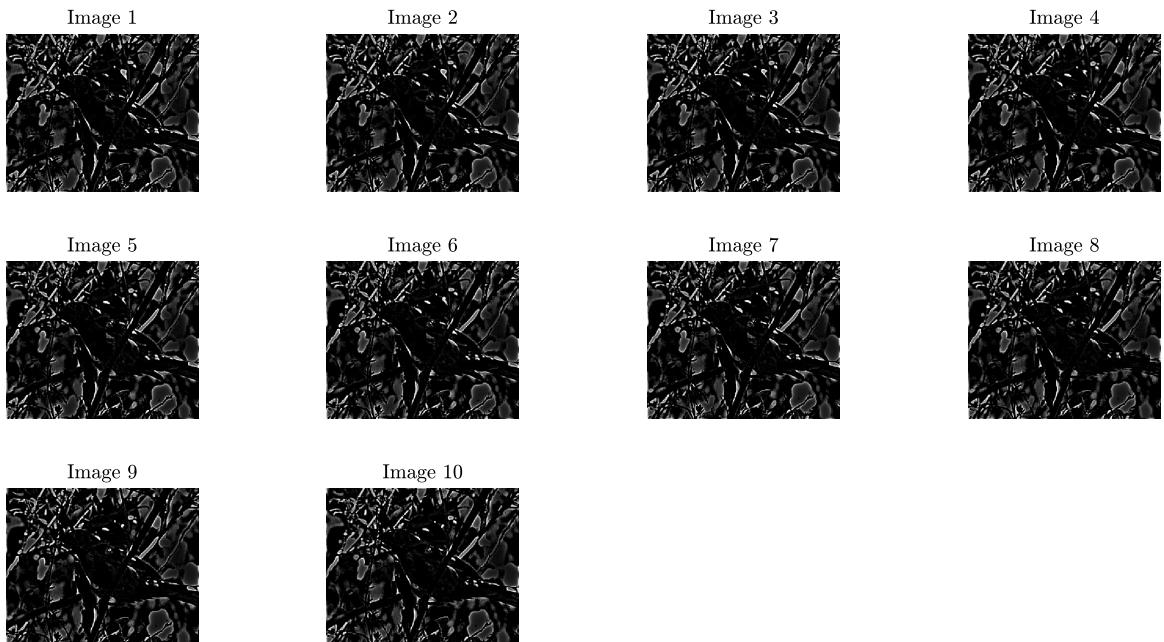
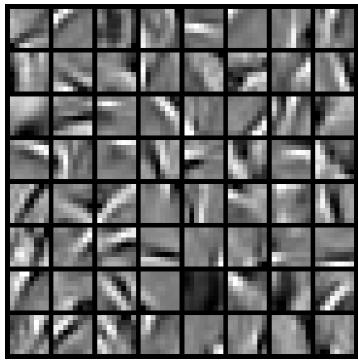
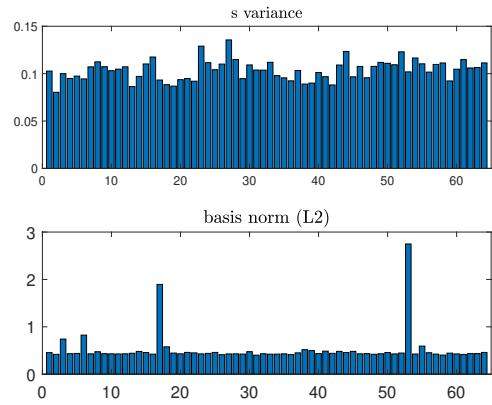


Figure 17: Whitened Images; Frames of Video

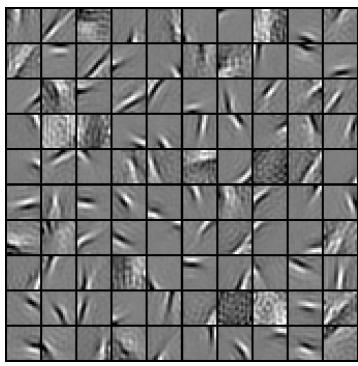


(a) Basis Functions

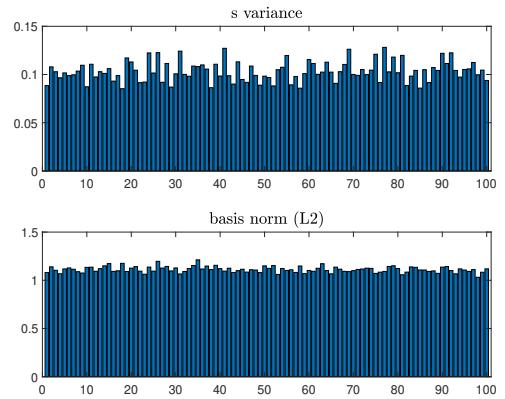


(b) Variance and Norm

Figure 18: Basis functions and their norm and variance; 64 basis functions of size 8×8



(a) Basis Functions



(b) Variance and Norm

Figure 19: Basis functions and their norm and variance; 100 basis functions of size 16×16

With the above basis functions and the function `cgf_fitS()`, we estimate the rest of the frames coefficients. Since we have 64 (or 100) basis functions and 100 random batches and 109 left frames, we get the maximum value of coefficients across batches to be able to plot. In other words, for each frame we will get a coefficient for each basis function. The file `coef-8.avi` and `coef-16.avi` are attached which visualize these coefficients over time. Coefficients seem to be sparse.

Histogram of coefficients are plotted in [Figure 20](#). This figure also indicates that the coding is indeed sparse.

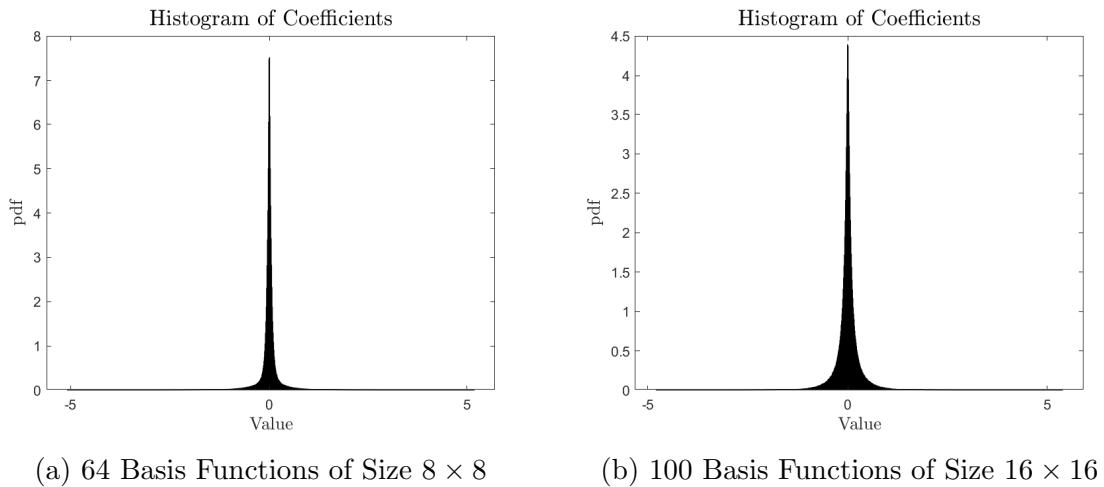


Figure 20: Histogram of Sparse Coefficients

References

Olshausen, Bruno A. and David J. Field (June 1996). “Emergence of simple-cell receptive field properties by learning a sparse code for natural images”. In: *Nature* 381.6583, pp. 607–609.
DOI: [10.1038/381607a0](https://doi.org/10.1038/381607a0).