EEL6814: Project 2

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Joseph Madden  
*Electrical and Computer Engineering*   
*University of Florida*Gainesville, FL USA  
josephmadden@ufl.edu  
  
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*Abstract*—This report presents the development and evaluation of a Stacked Autoencoder Network (SAE) integrated with a Multi-Layer Perceptron (MLP) classifier for application on the Kuzushiji-MNIST dataset. The project aims to explore feature extraction for image classification by experimenting with various SAE configurations, particularly focusing on the dimensions of the bottleneck layer and network hyperparameters. Additions to this model include adding impulsive noise in the input data and employing a correntropy cost function in place of the traditional Mean Squared Error (MSE). Furthermore, the study introduces a distinctive penalty function in the SAE’s reconstruction cost, designed to create discriminative code targets in the latent space, thereby enhancing classification accuracy. Comparative analysis using confusion matrices and computation time evaluations assesses the performance of the SAE+Classifier model against a baseline MLP classifier. The outcomes underscore the model's enhanced noise resilience and superior classification efficiency, underscoring its potential in refining deep learning strategies for image classification tasks.

Keywords—stacked autoencoder network, image classification

# Introduction

In the realm of machine learning, deep learning techniques have revolutionized the approach to complex tasks, particularly in image classification. Among these techniques, Stacked Autoencoder Networks (SAE) have emerged as a powerful tool for feature extraction, enabling the transformation of high-dimensional data into a more manageable and representative form. This report focuses on the design and evaluation of an SAE integrated with a Multi-Layer Perceptron (MLP) classifier, applied to the Kuzushiji-MNIST dataset.

The Kuzushiji-MNIST dataset, a variant of the traditional MNIST dataset, presents unique challenges due to its intricate patterns and historical significance in Japanese literature. This project aims to explore the potential of SAE in enhancing feature extraction capabilities for this complex dataset. Central to this exploration is the investigation of various configurations of the SAE, particularly the impact of the size of the bottleneck layer and the choice of hyperparameters on the overall classification performance.

Moreover, this study delves into the robustness of the SAE under conditions of impulsive noise. By substituting the traditional Mean Squared Error (MSE) with a correntropy cost function, the project evaluates the network's capacity to handle noise in input data, a crucial aspect for real-world applications. Additionally, the introduction of a novel penalty function in the SAE's reconstruction cost aims to foster discriminative feature learning, potentially enhancing classification accuracy.

The comparative analysis of the SAE+Classifier model against a standalone MLP classifier offers insights into the effectiveness of the proposed methods. This report documents the methodology, findings, and implications of these innovations, contributing to the ongoing research in the field of deep learning and image classification.

# Methodology

This study develops and evaluates a SAE with a MLP classifier for the Kuzushiji-MNIST dataset. The approach involves optimizing the SAE, particularly its bottleneck layer and hyperparameters, and adapting it to handle impulsive noise using a correntropy-based cost function. Additionally, a specialized penalty function is implemented to enhance feature discrimination.

## Creating the Stacked Autoencoder Network

The architecture of the Stacked Autoencoder Network (SAE) was crafted using Python, employing the Keras-Tensorflow libraries. The network is structured with an input layer, five hidden layers, and an output layer. The input layer, the first two hidden layers, and the bottleneck layer are all stored in one *Sequential* model and the remaining layers are stored in another. This split design is to make the later SAE+Classifier model easier to design.

The input layer is configured to handle arrays of 784 pixels, which correspond to 28x28 pixel grayscale images, with each pixel normalized within a 0 to 1 range. The output layer is the same, outputting the decoded image. The hidden layers are arranged in the sequence of 800-200-100-200-800 units. The central layer, hereafter known as the bottleneck layer, initially comprises 100 units and is designated as a hyperparameter for experimental variation. The activation function of the hidden layers is the Rectified Linear Unit (ReLU) function.

## Training the SAE

Identify applicable funding agency here. If none, delete this text box.

The training process for the Stacked Autoencoder Network (SAE) is designed to optimize its performance using a substantial portion of the image data. Specifically, 70% of the image data is allocated for training, while the remaining 30% is set aside for validation purposes. To ensure a balanced representation, both the training and validation sets are stratified based on their class labels. The KMNIST dataset creators already provide the test set.

Key to the training process are the hyperparameters: the width of the bottleneck layer and the batch size for each training epoch. To efficiently tune these hyperparameters, KerasTuner from the Scikit-Learn library is utilized. The width/height of the bottleneck layer will vary in multiples of 5, ranging from 50 to 100 inclusive. For the batch sizes, the range considered is between powers of two from 32 to 256 inclusive. This approach results in a total of 44 distinct trials, allowing for a comprehensive exploration of the hyperparameter space.

Each model iteration is granted a maximum of 20 epochs for convergence, with the incorporation of callbacks to terminate training early. The specific callback criterion is set to halt training if there's no improvement of at least 0.01 in the loss over a span of 3 epochs. The chosen loss function for this training is crossentropy, and the ADAM optimizer from the Keras-Tensorflow library is employed for learning. The labels for the training data will be the same as the samples for the training data.

## Designing the SAE+Classifier

The encoder extracted from the Stacked Autoencoder Network (SAE) was integrated with a Multi-Layer Perceptron (MLP) classifier, forming a comprehensive classification model. This integration was also facilitated using the Keras-Tensorflow libraries.

The input layer of the MLP is aligned with the width of the bottleneck layer from the SAE, ensuring seamless integration and data flow between the encoder and the classifier. The output layer of the MLP classifier consists of 10 perceptrons, each corresponding to one of the classes in the dataset. The number and width of hidden layers is a hyperparameter and discussed in the following sub-section.

For the hidden layers, the Rectified Linear Unit (ReLU) function is chosen as the activation function. The output layer employs the softmax activation function, standard for classification problems. Additionally, the hidden layers of the MLP classifier are constructed using 'Dense' layers from the Keras-Tensorflow library.

# Results

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