

## Homework #6

Issued: 04/15/2024

Due: 05/01/2024

### Problem 1: Origin of Green Learning (GL)

#### (a) Feedforward-designed Convolutional Neural Networks (FF-CNNs)

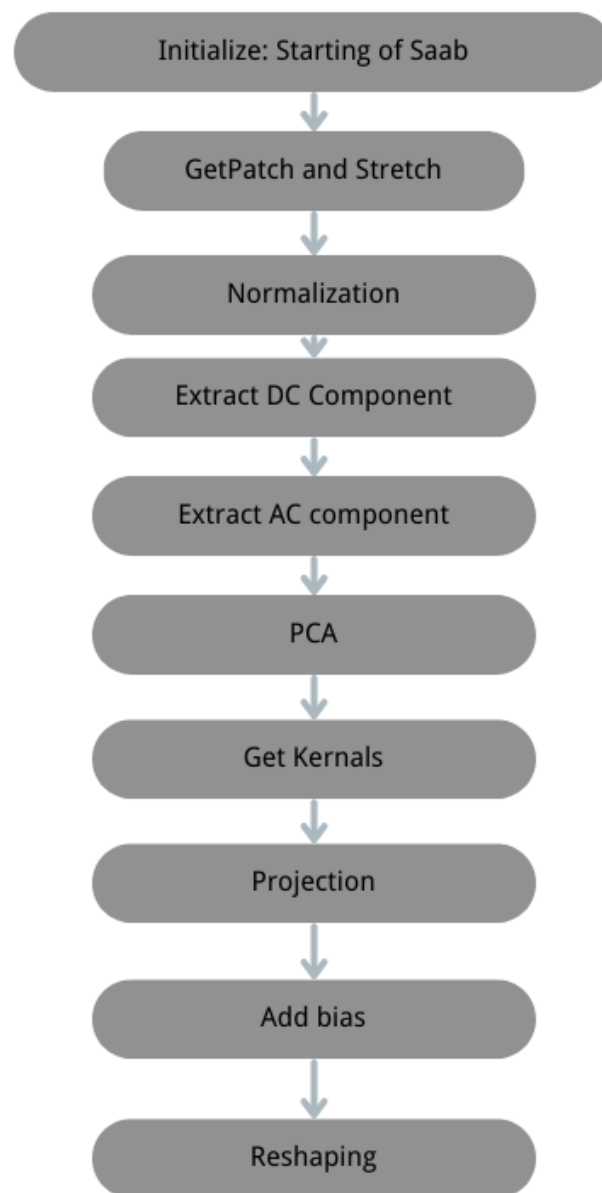


Figure 1: Saab Process

(1) As shown in fig1, the saab process is a transformed way of PCA. In the start of the Saab Process, the data is applied by getPatch and stretch. Then the process tries to calculate DC, then minus all other anchors by DC to get the AC. After getting the component of  $x$  on ac directions, PCA is applied to reduce dimension. Then, get the kernels, and using the largest norm to projection. Then bias are added to the data. Following is the reshaping process, then goes to output.

(2) Similarities and Differences between FF-CNN and BP-CNN:

- Similarities: Both types of CNN have a similar architecture, and both of them are classification models. Both model uses neurons, convergence layers, pooling layers, fully connected layers and output layers.
- Differences: BP-CNN trains its parameters in each layer by a large number of iterations, working along with multiple neurons in calculation. However, FF-CNN is a one-pass system, which means it could just use statistics from last layer, using unsupervised learning in feature extraction to get the parameters. By the way, FF-CNN add a bias term to output feature map, which could improve the efficiency of PCA's simplifying process. In the classification step in FF-CNN, it adapts various subclassifications within a main class, offering more precise classification .
- Advantages: Thanks to FF-CNN's unique features in subclassification, it has much higher accuracy than ordinary BP-CNNs. Also, because it avoids many iterations by adapting one-pass parametering, it is much faster and takes fewer memory when working.

## (b) Understanding PixelHop and PixelHop++

(1) SSL methodology is a computationally efficient method in machine learning. Instead of old models using only supervised BP process, it takes unsupervised learning method including K-means. This could improve its efficiency of computation, and makes it less rely on the size of the training dataset.

(2) The first Module of SSL is extracting features from the input data. The module uses methods including PCA to reduce dimensions of the data without applying any labels. The second module involves aggregating the features to capture more complex structures in the data. It extracts statistical values to enhance the feature maps's features. The third module is used for final classification.

(3) Neighbourhood construction gathers the information on pixels in a window, reshaping the data to get additional information. Pixelhop applying saab transform in subspace approximation, while Pixelhop++ applies channel-wise Saab in this step.

Saab processes the whole feature map, extracting patches from all over the map, and apply PCA to compute the anchor vectors.

Comparing to saab, cwSaab applies the Saab transform channel-wise, which means transform is applied separately to each channel of the input data or feature maps. It provides a

Details of Models	PixelHop	PixelHop++
MINST Final Accuracy	96.7	96.2
Training time	65min	41min
F MINST Final Accurac	84.2	86.8
Training time	63min	43min

more granular approach by processing each channel independently, which can lead to more tailored and potentially more effective feature extraction. It adds a THE 1 and THE2 to decide whether to keep the channel as leaf nodes or discarding them.

## Problem 2: PixelHop & PixelHop++ for Image Classification

### (a) Building PixelHop++ Model

Model Size: (60000, 1, 1, 129) k1: 24; k2: 109; k3: 129

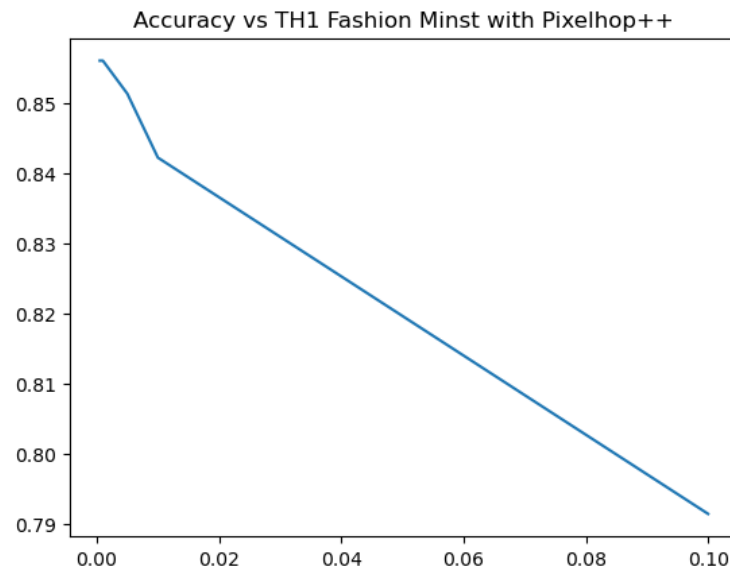


Figure 2: Saab Process

### (b) Comparison between PixelHop and PixelHop++

The table of details of training of PixelHop and PixelHop++ on MINST and Fashion MINST is listed in the table below in 1.

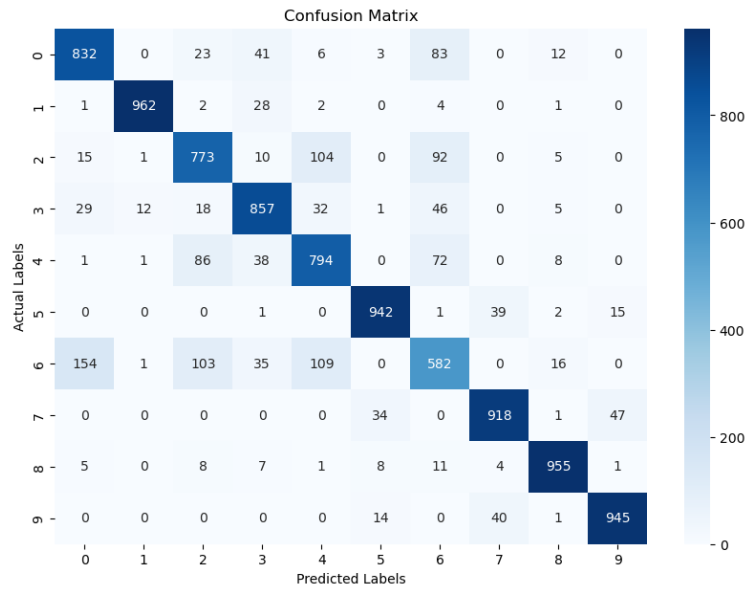
**(c) Error analysis**

Figure 3: Saab Process

We can easily find that 6 is often mistaken for 0, 2, and 4. This maybe because 6 includes circles that might be mistaken.