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ORIGINAL ARTICLE

A new hybrid model of convolutional neural networks and hidden Markov chains for image classification

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Abstract
Convolutional neural networks (CNNs) have lately proven to be extremely effective in image recognition. Besides CNN, hidden Markov chains (HMCs) are probabilistic models widely used in image processing. This paper presents a new hybrid model composed of both CNNs and HMCs. The CNN model is used for feature extraction and dimensionality reduction and the HMC model for classification. In the new model, named CNN-HMC, convolutional and pooling layers of the CNN model are applied to extract features maps. Also a Peano scan is applied to obtain several HMCs. Expectation–Maximization (EM) algorithm is used to estimate HMC's parameters and to make the Bayesian Maximum Posterior Mode (MPM) classification method used unsupervised. The objective is to enhance the performances of the CNN models for the image classification task. To evaluate the performance of our proposal, it is compared to six models in two series of experiments. In the first series, we consider two CNN-HMC and compare them to two CNNs, 4Conv and Mini AlexNet, respectively. The results show that CNN-HMC model outperforms the classical CNN model, and significantly improves the accuracy of the Mini AlexNet. In the second series, it is compared to four models CNN-SVMs, CNN-LSTMs, CNN-RFs, and CNN-gcForests, which only differ from CNN-HMC by the second classification step. Based on five datasets and four metrics recall, precision, F1-score, and accuracy, results of these comparisons show again the interest of the proposed CNN-HMC. In particular, with a CNN model of 71% of accuracy, the CNN-HMC gives an accuracy ranging between 81.63% and 92.5%.

Keywords Convolutional neural networks (CNNs) · Hidden Markov chains (HMCs) · Deep learning · Image classification

1 Introduction

A Deep Neural Network is composed of a set of neurons grouped in layers connected to each other. There are three types of layers based on their functions: input layer, hidden layers, and output layer. The input layer is connected to the first hidden layer, and the last hidden layer is connected to the output layer. Each neuron applies the following equation when receiving an input x to produce an output y: $y = f(xW + b)$, where W is called the weights matrix and b is called the bias. The objective is to tune some of the parameters to minimize the error between the produced output and the expected value.

In neural networks there is a category called "deep learning model" in which the network is combined by more than three layers, i.e., it contains more than one hidden layer. Convolutional Neural Network (CNN) is a deep learning model used for image classification. In this

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