Face Anti Spoofing: Handcrafted and Learned Features for Face Liveness Detection

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Abstract

The development of presentation attack detection (PAD) methods has become a high level concern in biometric security. As in other pattern recognition tasks, the use of deep learning is increasingly common. However, it is still doubtful if handcrafted features should be discarded. This work focused on the comparison of using handcrafted features and deep learning techniques at the feature extraction level in a face PAD method. Handcrafted features were based on Local Binary Patterns, while a Convolutional Neural Network based on VGG-16 was used for deep feature extraction. A Support Vector Machine was used for binary classification after dimensionality reduction using Principal Component Analysis. The methods were tested using the NUAA database, and the results show that handcrafted feature extraction still offers better results, with 3.1% APCER and 25.2% BPCER.

1 Introduction

Biometric systems are currently used in several different application scenarios. Border control, military facilities, and the mobile access to personal accounts or banking operations are some of the applications that require high reliability and robustness levels. Face biometric recognition is currently one of the most common traits for several applications due to its advantages over other biometric traits.

As face biometric recognition is increasingly used for access control and authentication, guarding sensitive information and valuable goods, the motivation to attack such systems is growing. Face recognition systems can be attacked using printed photographs, masks, or video displays [1, 4, 8, 9]. Presentation attack detection (PAD) methods have been proposed to tackle this problem in face recognition systems. These feature extraction methods are classified in previous studies into two categories of non-training-based and training-based.

Among non-training-based methodologies, Tan et al. [9] used a sparse low-rank bilinear discriminative model on image features extracted by a difference of Gaussian (DoG) and/or logarithmic total variation (LTV) methods to discriminate the bona fide and presentation attack images. Using the NUAA database [9], they showed that the bona fide and presentation attack images can be discriminated using their proposed method. With the NUAA database, Määttä et al. [4] used three feature extraction methods (Gabor filter, local phase quantization, and local binary patterns LBP) to extract the image features and classify the bona fide and presentation attack images using support vector machines (SVMs). The classification error was significantly reduced compared to those obtained by Tan et al. [9]. Benloucif et al. [1] also used the LBP method for addressing the PAD problem for a face recognition system. They used the Fisher score to reduce the dimensionality of the extracted features.

Parveen et al. [8] proposed a method that uses a dynamic local ternary pattern (DLTP) for detecting presentation attack face images. They used the DLTP method to extract image features and the SVM method for classification. However, the detection accuracy when using the NUAA database was slightly worse than those obtained by Määttä et al. [4] and Benloucif et al. [1]. These results show that the handcrafted features are suitable for presentation attack detection. However, as verified in these studies, the detection accuracy varies significantly among different databases, indicating some of the handicaps of handcrafted features.

Recently, deep learning frameworks have frequently overcome conventional methods in tasks like image classification, object detection, or face-based age estimation. Considering this, training-based feature extraction methods have been studied by Menotti et al. [3]. The results indicate the sufficiency of the deep learning method for detecting presentation attack images in biometric recognition systems. However, the method was unable to outperform the handcrafted feature extraction method in all cases.

In a study by Nanni et al. [5], the deep learning framework was applied for general image classification problem as an image feature extractor. In detail, they used several CNN models which were trained for several different problems to extract image features of the current problem. Based on the extracted image features, they used several SVM models to classify the input images into desired classes.

In another study [6], the authors additionally used several kinds of handcrafted feature extraction methods such as LBP or local ternary patterns (LTP) alongside deep networks. The results show that the handcrafted and deep image features can extract different information from input images. Based on this result, they showed that the combination of handcrafted and deep features is sufficient to lead to an enhancement of classification accuracy.

Nguyen et al. [7] proposed a new PAD method based on hybrid features that combines information from both handcrafted and deep learning features. This is the first approach to PAD for face recognition systems using a combination of deep and handcrafted image features. By combining the deep and handcrafted image features, they enhanced the detection accuracy compared to conventional state-of-the-art detection methods and reduce the variation in detection accuracy caused by the variation in face images.

This work seeks to compare handcrafted and deep feature extraction, and their impact in presentation attack detection performance. It aims to lay the foundations for future work in the application of deep learning for biometric presentation attack prevention.

2 Proposed Methodology

Pipelines of the studied methods are depicted in Fig. 1. A face image is received and processed to produce a binary decision of bona fide or presentation attack. The first step of the method is to extract the image features using handcrafted algorithm local binary pattern (LBP) or convolutional neural network (CNN) or hybrid (LBP + CNN).

The second step is to apply principal component analysis (PCA) for dimensionality reduction. The models are tested with and without PCA to test which present better performance. At last, SVM is used to classify images as bona fide or as presentation attacks. Below, the feature extraction and classification processes are described in detail.

**Feature extraction:** The LBP feature extraction method has been used to extract image features for many computer vision tasks, including face recognition, with advantages in illumination and rotation invariance [2]. The LBP method computes a p-bit binary descriptor for each pixel in a given image using its surrounding pixels. For this study, the LBP used number of points \( p = 8 \) and radius \( r = 1 \). For the CNN, the VGG-16 architecture was used, with VGG-Face pretrained weights. As the dense layers were discarded, the outputs of the last pooling layer of the net-
Using features extracted using the VGG-Face network, with PCA for reduction, we obtain the smallest APCER with Polynomial SVM kernel, 20.38%. However, both errors are much higher than those attained using LBP features. The hybrid solution (LBP + CNN) improved the results of the experiments using only CNN extracted features. However, the sole use of LBP features offered better results than the hybrid version. Considering this, the VGG-Face architecture and weights are likely not adequate for the task of detecting presentation attacks. Moreover, the use of SVM limits the potential of deep learning methodologies. Hence, the use of an end-to-end CNN should be further explored.

5 Conclusions and future work

This work consisted on the study of different methods to detect presentation attack images for a face recognition system. The results indicate that LBP-based handcrafted features are more suitable to detect presentation attacks than VGG-Face features. Additionally, PCA enhanced the performance of the method. Nevertheless, further efforts should be devoted to the study of end-to-end deep networks for PAD, to improve performance and overcome the limitations of current handcrafted solutions.

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Table 1: Summary of the main results of the implemented methodologies.

<table>
<thead>
<tr>
<th>Feature Extraction</th>
<th>SVM Kernel</th>
<th>APCER</th>
<th>BPCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>LBP</td>
<td>Sigmoid</td>
<td>11.005%</td>
<td>20.205%</td>
</tr>
<tr>
<td>CNN</td>
<td>RBF</td>
<td>37.121%</td>
<td>34.022%</td>
</tr>
<tr>
<td>LBP w/PCA</td>
<td>Linear</td>
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<td>25.221%</td>
</tr>
<tr>
<td>CNN w/PCA</td>
<td>Poly</td>
<td>20.375%</td>
<td>32.390%</td>
</tr>
<tr>
<td>(LBP+CNN) w/PCA</td>
<td>Poly</td>
<td>19.393%</td>
<td>32.408%</td>
</tr>
</tbody>
</table>

References