

Tackling Challenge of Masked and Unmasked Face for Facial Recognition Through Dimensionality Reduction and Deep Learning

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Abstract. Facial recognition systems face considerable performance degradation in the presence of occlusions, particularly face masks, which are increasingly common in public setting. This research examines the impact of such occlusions by employing dimensionality reduction techniques: principal component analysis (PCA) and auto-encoders, combined with convolutional neural networks for classification. Through experiments on custom-built dataset comprising masked, unmasked, and mixed facial images, we observe that PCA consistently outperforms auto-encoders across all evaluation metrics, including accuracy, precision, recall and F1-score. However, PCA is more sensitive to occlusion variability, while auto-encoders exhibit more stable, though generally lower performance. Notably, performance declines significantly when models are evaluated on mixed datasets, emphasizing the complexity of real-world scenarios. Data augmentation yields only marginal improvement, underscoring the limitation of current approaches in handling diverse occlusions. The study also explores the potential of advanced mathematical tools such as higher-order tensor decomposition and fractional differentiation to enhance feature representation and model robustness. Overall, this research directions involving diverse training sets, sophisticated feature extraction and hybrid architectures to enhance model generalization in dynamic environments. Hence, contributing to the development of more reliable biometric systems.

AMS subject classifications: 68T10

Key words: Faces recognition, face occlusion, masked face, PCA, auto-encoder, CNN, machine learning.

1 Introduction

Facial recognition systems are pivotal in various applications, including security, public safety and authentication. However, these systems often face performance challenges

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due to environmental and situational factors such as lighting conditions, variations in face pose, changes in facial appearance and physical obstructions. The global COVID-19 pandemic introduced an additional obstacle: the widespread use of face masks as a protective measure. This highlighted a significant vulnerability in facial recognition systems, which struggled to accurately identify individuals with masked faces. Such challenges have far-reaching implications for critical applications, including access control, security checks at transportation hubs and identity verification systems.

Although the mandatory use of face masks has subsided post-pandemic, many individuals continue to wear them out of habit or for health-related reasons, such as protection from allergies or air pollution. Additionally, face masks have been exploited by some individuals, including criminals, to avoid easy identification, leveraging the occlusion created by masks to evade detection. This has created a dual challenge: ensuring privacy and health safety while addressing potential misuse that may comprise public safety and security measures. As masks obscure a significant portion of the face, including essential features like the mouth, nose and chin. Traditional facial recognition systems, which rely heavily on these regions, encounter substantial difficulties. This occlusion scenario not only reduces accuracy but also raises concerns about the potential for increased criminal activity, as individuals can easily conceal their identities from both human observers and automated recognition systems [15].

The challenges posed by face masks have prompted researchers to explore innovative strategies for improving facial recognition accuracy under occluded conditions. A detailed review of scenarios and environments requiring the use of face masks is presented in [12], which underscores the widespread and ongoing relevance of this issue. Addressing these challenges necessitates robust solutions that can adapt to partial face visibility while maintaining high recognition accuracy. Some of the accuracy of this method can be found in [28]. Previous studies addressing face occlusions have highlighted potential strategies and techniques to mitigate these challenges [17, 22]. Face detection and edge detection can play a significant role on face recognition under occlusion, some of these has been addressed in [2, 3, 10, 11, 14].

In response to these challenges, this study leverages principal component analysis and auto-encoder for dimensionality reduction, Combined with convolutional neural networks (CNNs) as classifier to enhance facial recognition performance. This combined approach aims to improve the robustness of facial recognition systems by focusing on the visible regions of the face and compensating for occlusion induced data loss. The proposed method aims to not only improve recognition accuracy in masked scenarios but also contribute to broader efforts in making facial recognition systems more resilient to a wide range of occlusion challenges.

The structure of this paper is as follows. Section 2 provides an overview of the importance of dimensionality reduction in high-dimensional data analysis. Section 3 examines its practical applications, highlighting its relevance in real-world scenarios. Section 4 introduces a range of dimensionality reduction techniques, with in-depth discussions on principal component analysis in Section 4.1 and auto-encoders in Section 4.2. Section 5