

Digital Holography and Artificial Intelligence for Textile Identification Using Fringe-Based CNN Analysis

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Abstract: We present a convolutional neural network (CNN) framework trained on reconstructed holographic fringe patterns for classifying cotton, polyester, and linen. Experiments achieve up to 78% accuracy at high resolution. The proposed approach demonstrates the potential of digital holography for automated fabric identification.

1. Introduction

Digital holography (DH) allows quantitative imaging beyond intensity-based microscopy through the acquisition of interference fringes that carry information about the structure and optical properties of microscopic materials. Recent investigations have demonstrated that it is possible to significantly improve various tasks associated with automatic material analysis, such as microplastic and fiber recognition, through the integration of DH and deep learning (DL) approaches [1, 2]. Parallely, artificial intelligence is being used for various tasks associated with textile inspection, as complex texture patterns and materials make it difficult to identify materials using classical vision-based approaches [3]. In this paper, we aim to investigate whether it is possible to use reconstructed holographic fringe patterns for direct classification through a lightweight CNN.

2. Method

2.1. Digital Holographic Imaging Setup

The setup consists of a coherent red laser source with 632.8 nm wavelength mounted on an optical rail, beam-guiding and height-adjustment posts, a high-resolution CMOS camera positioned above the sample plane, and auxiliary alignment tools for stable sample positioning.

2.2. Datasets

The dataset consists of reconstructed holograms of three textile materials: cotton, linen, and polyester, captured using the laboratory digital holographic imaging system. All holograms were resized into three spatial resolutions (536×400 pixels, 200×200 pixels, and 100×100 pixels) to evaluate the influence of fringe detail on feature learning.

2.3. Fringe-Aware CNN Architecture

A lightweight convolutional neural network designed for holographic fringe analysis was employed for textile classification, as shown in Fig. 1. The architecture of the model consists of four blocks of convolutional layers with Conv2D, batch normalization, concatenated ReLU (CReLU), and max pooling layers.

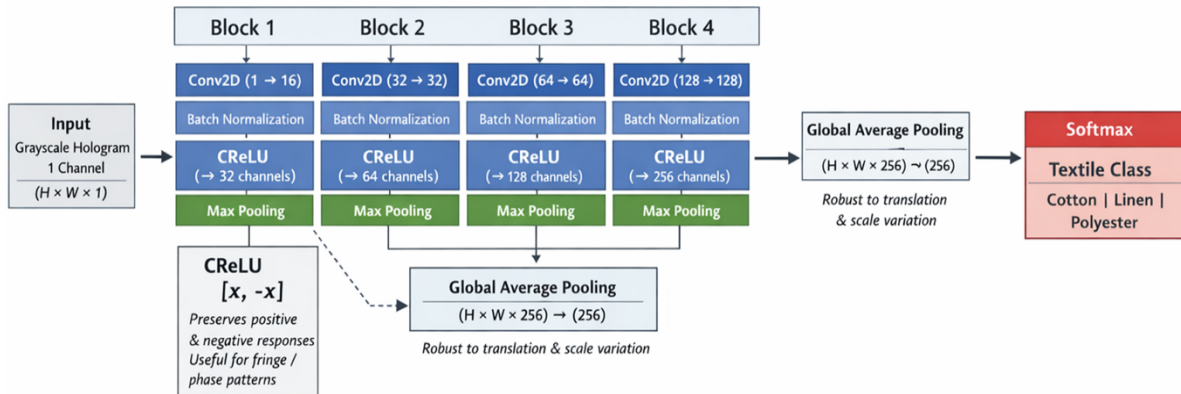


Fig. 1 Fringe-aware CNN architecture for holographic textile classification.

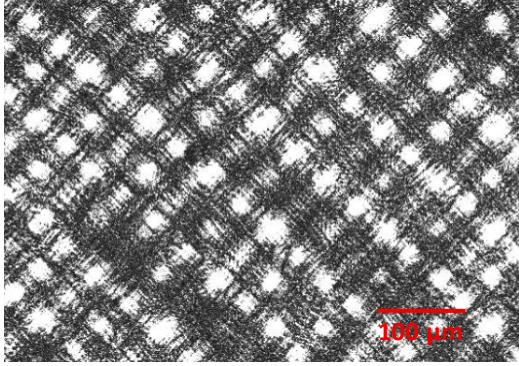


Fig. 2 Cotton hologram (536×400 pixels).

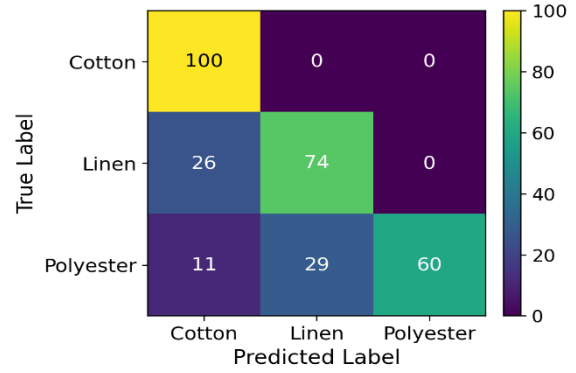


Fig. 3 Confusion matrix for the resolution 536×400 pixels test group.

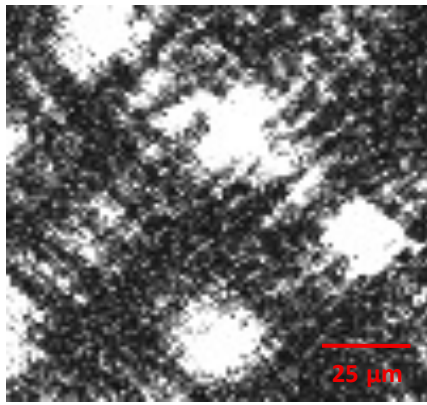


Fig. 4 Cotton hologram (100×100 pixels).

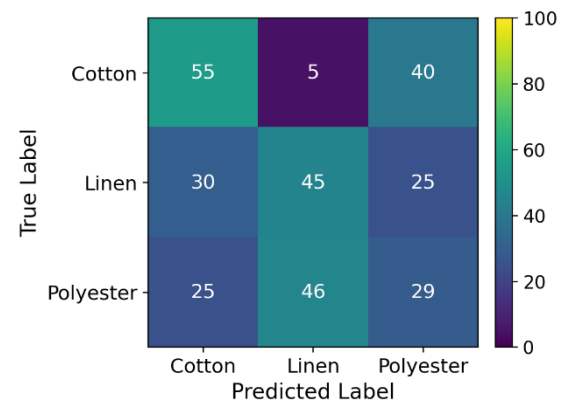


Fig. 5 Confusion matrix for the resolution 100×100 pixels test group.

3. Experiments and Results

The performance of the fringe-aware CNN was evaluated using reconstructed holographic images of textiles and varying spatial resolutions of 536×400 , 200×200 , and 100×100 pixels. The best resolution datasets yielded better performance, with an overall accuracy of 78% recorded. Classification performance reduced significantly as image resolution decreased. Down-sampling an image decreases fringe density and spatial frequency, hence complicating feature extraction. At 100×100 pixels, significant ambiguity exists among classes. The results show that cotton can be classified consistently, and hence it has a distinctive holographic signature. Linen and polyester have similar fringe signatures, resulting in high misclassification rates.

4. Conclusion

This work indicates clearer separability for natural fibers (cotton and linen) than synthetic polyester, which motivates future phase-enhanced holographic learning.

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References

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