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Fabric Defect Highlighting using Machine Learning

P. Kamakshi Thai[*1], *Mohammed Adnan*[*2], *M.Madhusudhan*[*3], *P Maneesh Kumar*[*4]
[1]Assistant Professor Of Department Of CSE (AI & ML) Of ACE Engineering College, India.
[2],[3],[4]Students Of Department Of CSE (AI & ML) Of ACE Engineering College, India.

ABSTRACT

Quality inspection is crucial in textile manufacturing, but traditional manual methods are slow, inconsistent, and prone to human error. To address these challenges, this project proposes an automated fabric defect detection system using computer vision and machine learning. The system identifies defects such as holes, stains and uneven weaves through image analysis. It leverages OpenCV for image processing and Support Vector Machines (SVMs) for defect classification. Deployment through Flask or Streamlit enables easy application access, while real-time camera integration supports immediate defect detection, enhancing the efficiency of textile quality control.

.INTRODUCTION

In textile production, ensuring fabric quality is crucial, as defects can lead to significant economic losses and customer dissatisfaction. Traditionally, quality assessment relies on manual inspection by human inspectors, but this method faces challenges such as labor shortages, high costs, slow processing, and inconsistent results. This project aims to develop an efficient, fast, and automated system for fabric defect detection using machine learning and image processing. By training the system on a dataset of defective and non-defective fabric samples, it can accurately detect and localize anomalies. The project highlights how artificial intelligence (AI) can modernize traditional industries by reducing labor dependency, lowering operational costs, and improving product quality. Technologies like OpenCV, TensorFlow, PyTorch, and Scikit-learn are used for preprocessing.

LITERATURE REVIEW

1. **H. Xu, Z. Zhang, and H. He (2020)**

These researchers proposed a multi-scale convolutional neural network (CNN) model specifically tailored for detecting fabric defects in woven materials. Their model captures defect features at various spatial resolutions, enabling it to better detect small and subtle anomalies that often go unnoticed. The architecture merges multiple layers outputs to form a comprehensive feature representation. While this approach leads to high accuracy and precise localization, it is computationally demanding. This makes the model less suitable for real-time applications or environments where hardware resources are limited.

2**. M. S. Bhuyan, M. K. Hasan, and M. A. H. Akhand (2019)**

This study focuses on traditional texture-based analysis using Gabor wavelet transformations to extract directional patterns in the fabric. These features are then fed into a k-Nearest Neighbours (k-NN) classifier for defect detection. The method showed over 90% accuracy in controlled environments. The Gabor filters effectively capture the orientation and frequency properties of textures, which helps distinguish between regular patterns and defects. However, the approach is less reliable in non-uniform backgrounds or where lighting conditions vary, limiting its robustness in industrial environments.

3. **X. Dong, J. Zhou, and X. Lin (2017)**

This work employs a classical image processing pipeline using techniques like morphological operations and thresholding to identify defects such as holes, stains and misweaves. It is a lightweight and computationally efficient method, making it easy to implement in low-power environments. However, it lacks flexibility—it performs well only under specific lighting and material conditions, and struggles when applied to fabrics with varying textures or colors. This limits its scalability in diverse industrial setups.

4. **D. Uçar, H. Yilmaz, and A. K. Erdem (2021)**

These authors implemented a real-time detection system based on YOLOv4, a state-of-the-art object detection model. Their system identifies multiple types of fabric defects with high speed and accuracy, making it ideal for live inspection in production lines. YOLOv4's efficiency lies in its ability to process images rapidly without sacrificing accuracy. However, it requires a large amount of labeled training data and has difficulty generalizing to unseen fabric types, which can lead to reduced performance in dynamic or less controlled environments.

5. **A. Shrivastava and S. R. Dubey (2022)**

This research introduces an unsupervised defect detection framework using autoencoders. The autoencoder learns to reconstruct normal (defect-free) fabric patches, and any deviation in reconstruction indicates a potential defect. This is highly beneficial in situations where labeled data is scarce, as the model can be trained using only clean fabric images. However, the method may misinterpret complex textures as defects, resulting in false positives. It's a promising approach for low-label settings, but requires careful tuning to balance sensitivity and specificity.

6. **H. H. Khalil, A. Al-Azzawi, and A. Kadhim (2018)**

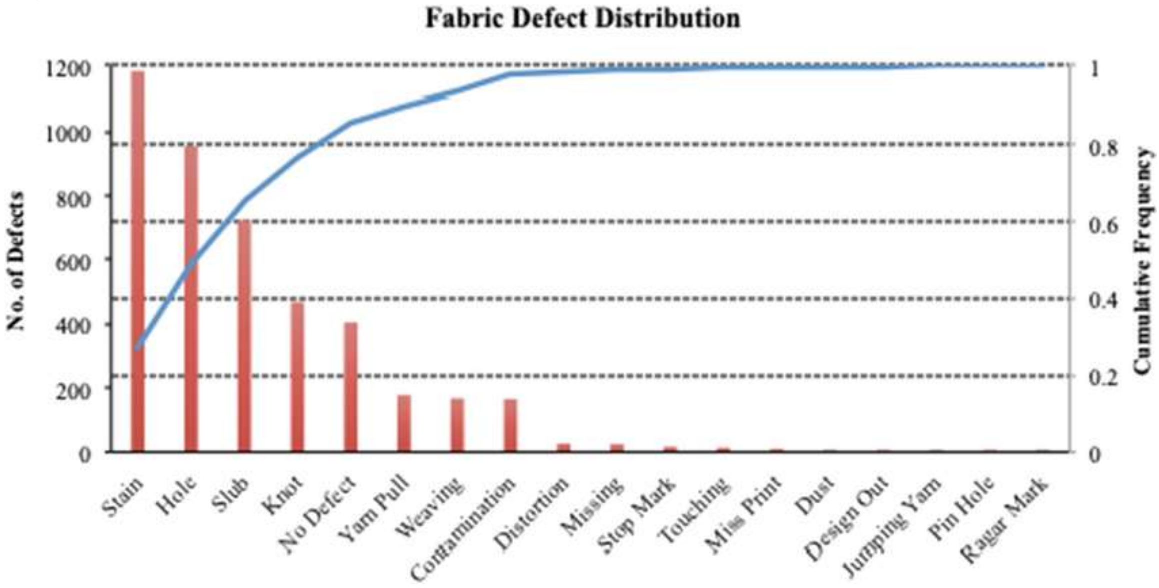
This paper explores a simple yet effective method using OpenCV and morphological analysis. By detecting pixel-level differences across image frames, the system identifies and highlights anomalies. It's best suited for small-scale industries looking for a low-cost solution, as it has minimal computational requirements. However, the approach lacks the depth to detect more complex or subtle defects, and it doesn't incorporate machine learning, which limits its adaptability and intelligence over time.

COMPARISON TABLE

Authors	Year	Methodology	Strengths
H. Xu, Z. Zhang, and H. He	2020	Proposed a multi-scale CNN model for detecting fabric defects in woven materials. The model captures defect features at multiple spatial resolutions by merging outputs from several	High detection accuracy- Good at localizing small and weak defects- Deep feature perception- However, computationally demanding, making it less ideal for real-time applications

		convolutional layers.	
M. S. Bhuyan, M. K. Hasan, M. A. H. Akhand	2019	Utilized Gabor wavelet-based texture feature extraction followed by k-Nearest Neighbors (k-NN) classification for defect detection.	More than 90% accuracy in controlled settings- Suitable for periodic and directional textures- Easier to train and use than deep learning- However, less reliable in varying lighting and non-uniform backgrounds
X. Dong, J. Zhou, X. Lin	2017	Employed traditional image processing methods like morphological operations and thresholding to detect defects like holes, stains, and mis-weaves.	Computationally inexpensive and speed-efficient- Easy to implement on low-cost hardware- No training required- However, not flexible for diverse fabric textures and lighting conditions
D. Uçar, H. Yilmaz, A. K. Erdem	2021	Developed a real-time fabric defect detection system based on YOLOv4, trained on various defect datasets.	Very accurate and quick- Real-time inspection for production lines- Detects multiple defect types in one pass- However, requires large labeled datasets and may struggle to generalize to unseen fabric types
A. Shrivastava and S. R. Dubey	2022	Introduced an unsupervised defect detection method using autoencoders to reconstruct normal fabric patches and identify anomalies.	Useful in low-label scenarios- Can detect defects without needing defect-labeled data- Suitable for varying types of fabrics- However, prone to false positives on complex textures, requiring careful tuning
H. H. Khalil, A. Al-Azzawi, and A. Kadhim	2018	Used OpenCV and morphological analysis to detect pixel-level differences across image frames for defect detection.	Minimal computational requirements- Ideal for small-scale industries and low-cost solutions- Easy to deploy without complex hardware- However, less effective for complex or subtle defects and lacks machine learning adaptability

Fig 1: pareto chart for types of fabric defects



RESEARCH GAPS

Despite recent advancements, several challenges remain in the domain of fabric defect detection:

1. **Limited Generalization Across Different Fabrics** – Many models, such as those proposed by Xu et al. and Uçar et al., work well on specific datasets but struggle to generalize across diverse fabric types. Our project aims to design a system that is more adaptable to different textures and weave patterns.

2. **Dependence on Labeled Data** – Approaches like YOLOv4 and multi-scale CNNs require large annotated datasets for training, which may not always be feasible. Our project seeks to implement semi-supervised techniques to minimize the reliance on labeled samples.

3. **High Computational Cost** – Although CNN-based models show high accuracy, they are resource-intensive and not ideal for low-power environments. Our system focuses on optimizing models for better real-time performance without heavy hardware requirements.

4. **Sensitivity to Lighting and Background Variations** – Methods based on Gabor wavelets and traditional image processing show reduced reliability when lighting changes or background noise is introduced. Our project incorporates robust pre-processing techniques to mitigate such environmental impacts.

5. **Inadequate Defect Visualization and Classification** – Several models detect the presence of a defect but fail to intuitively highlight or classify different defect types. In contrast, our project aims to integrate advanced visualization methods alongside defect classification for clearer interpretation by end-users.

PROPOSED SYSTEM

The system to be proposed makes use of OpenCV, a powerful computer vision library, in the critical process of preprocessing images of fabric. Preprocessing the images involves operations like the conversion of color images to grayscale, different filtering processes, and edge detection to identify significant outlines and boundaries in the images. Following preprocessing, a Convolutional Neural Network, commonly referred to as a CNN, is utilized to systematically derive meaningful features from the images and identify significant regions where anomalies or defects can be observed. Following the identification of these regions, they are marked for better visualization for greater understanding and clarity. Streamlit will also be employed to create an interactive web-based interface so that users can easily upload their images of fabric and observe the detected defects in real time, for a smooth user interface. In future development, there may be scopes of integrating a classifier that can effectively identify the types of defects, i.e., holes or stains, and thus add to the overall functionality and usefulness of the system.

Conclusion

This project illustrates how a combination of machine learning, computer vision, and web technologies can lead to an efficient, real-time fabric defect detection system. The suggested system overcomes these by utilizing a balanced architecture that balances usability with efficiency. It offers a platform for visual defect highlighting and possible classification, enabling production-line quality control. Moreover, using tools such as Streamlit, the system can be deployed across a variety of hardware and environments, making it accessible. In general, the work offers a practical, flexible, and scalable solution for fabric quality inspection and paves the way for future innovation, including the integration of self-learning algorithms, extension to video stream analysis, and integration of IoT sensors for smart textile manufacturing.

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