INTEGRATING CNN AND IMAGE PROCESSING METHODS FOR PRECISE DETECTION AND QUANTIFICATION OF PULP FIBRIL

ABSTRACT

The precision measurement of fibrillation in pulp fibers is essential for improving paper strength, surface bonding, and overall production quality in the pulp and paper industry. Manual microscopic inspection of fibrils is labor-intensive, error-prone, and unsuitable for industrial scalability. This paper presents an automated approach that integrates Convolutional Neural Networks (CNNs) with adaptive image processing techniques to detect and quantify pulp fibrils effectively. The system employs patch-based CNN classification combined with adaptive thresholding, morphological refinement, and postprocessing to achieve robust segmentation under conditions of image noise, low contrast, and structural variability. Experimental validation achieved an average absolute deviation of 0.449% between automated and manual measurements, demonstrating industrial applicability. The proposed hybrid framework enhances efficiency, reduces human bias, and offers a scalable model applicable to other microscopic imaging domains such as materials science and biomedical diagnostics.

Keywords: CNN, Image Processing, Fibril Detection, Pulp Analysis, Deep Learning, Fibrillation Index.

EXISTING SYSTEM

Existing fibril detection systems primarily depend on manual microscopy and basic image processing techniques such as thresholding, edge detection, and morphological operations. These methods require human expertise for region identification and parameter tuning, leading to inconsistencies in fibrillation index computation. Commercial analyzers like Valmet Fiber Analyzer and Kajaani Fiber Analyzer focus on macro-level measurements—fiber width, coarseness, and fines—but do not detect individual fibrils.

Furthermore, conventional image processing approaches often misclassify background textures or illumination artifacts as fibrils, resulting in false positives. Static thresholding techniques fail when images exhibit non-uniform lighting or varying contrast. The absence of adaptive learning restricts these systems from generalizing across diverse pulp samples. In addition, manual methods are unsuitable for real-time industrial environments, as they cannot process large image datasets efficiently.

Some research attempts have integrated machine learning models to enhance detection accuracy; however, they typically operate at the fiber level rather than fibril scale. These systems require intensive training datasets and remain sensitive to noise and resolution variations. Thus, existing solutions either lack automation, struggle with accuracy, or fail to scale efficiently in production scenarios.

Disadvantages of the Existing System:

1. Limited Precision: Traditional methods fail to capture fine fibril details due to resolution and segmentation limitations.
2. Manual Dependency: High reliance on operator input reduces reproducibility and increases processing time.
3. Noise Sensitivity: Image artifacts and background variability cause frequent misclassification and false detection.

PROPOSED SYSTEM

The proposed system, Integrating CNN and Image Processing Methods for Precise Detection and Quantification of Pulp Fibril, introduces a multi-stage hybrid framework combining deep learning and adaptive image analysis to achieve accurate and automated fibril detection.

The process begins with fiber segmentation using adaptive histogram equalization and Bradley's local thresholding algorithm, effectively isolating fibers from the background under uneven illumination. Morphological filtering then refines the segmentation, removing fines and filling structural gaps.

Next, CNN-based patch classification using a fine-tuned ResNet-50 model distinguishes fibril-containing regions from irrelevant areas such as fibers or noise. This patch-based approach enhances detection precision by localizing relevant microstructures.

Following classification, adaptive thresholding and morphological postprocessing are applied to extract fibril features, while a YOLOv4 model eliminates false positives through gap and texture pattern analysis. Finally, the fibrillation index is calculated as the ratio of fibril pixels to fiber pixels, providing an accurate quantitative metric.

Empirical validation demonstrates that the proposed method achieves an average under-detection rate of 18.7%, an over-detection rate of 14.3%, and an average deviation error of 0.449%, outperforming manual and conventional techniques. The system ensures high robustness under variable refining conditions, image noise, and illumination levels.

Advantages of the Proposed System:

1. High Precision and Automation: Integrates CNN classification with adaptive processing for consistent and accurate fibril detection.
2. Noise-Resilient and Scalable: Effectively handles diverse image qualities and illumination variations suitable for industrial deployment.
3. Reduced Human Intervention: Fully automated workflow minimizes manual errors and enhances reproducibility in fibrillation measurement.

SYSTEM REQUIREMENTS

- **H/W System Configuration:-**
- Processor - Pentium –IV
- RAM - 4 GB (min)
- Hard Disk - 20 GB
- Key Board - Standard Windows Keyboard
- Mouse - Two or Three Button Mouse
- Monitor - SVGA

SOFTWARE REQUIREMENTS:

- **Operating system** : Windows 7 Ultimate.
- **Coding Language** : Python.
- **Front-End** : Python.
- **Back-End** : Django-ORM
- **Designing** : Html, css, javascript.
- **Data Base** : MySQL (WAMP Server).