

***PRINT QUALITY ASSESSMENT AND DEFECT DETECTION  
USING COMPUTER VISION***

Abstract Submitted by

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# ***PRINT QUALITY ASSESSMENT AND DEFECT DETECTION USING COMPUTER VISION***

## **1. Introduction**

Printing technologies have rapidly advanced with the digital revolution, leading to improvements in quality, speed, and efficiency. High-quality printed output is critical in industries such as packaging, publishing, textiles, and commercial printing. Print quality represents the combined visual and functional excellence of printed materials, shaped by technical precision and aesthetic appeal. It ensures customer satisfaction, readability, brand identity, and compliance with safety standards. Defects such as scumming, misregistration, show-through, strikethrough, color variation, and doubling compromise appearance, legibility, and functionality. In sectors like pharmaceuticals and food packaging, such flaws may threaten safety, compliance, and traceability. Print quality depends on substrate properties (smoothness, porosity, surface energy), ink attributes (viscosity, tack, drying time), process parameters (speed, temperature, pressure), and environmental conditions (humidity, temperature). Variations in these parameters often result in defects. Despite technological progress, most quality control is manual, subjective, and error-prone, making it unsuitable for large-scale, high-speed production. Automated systems are increasingly necessary for consistent, reliable, and cost-effective evaluation. Computer Vision (CV) offers a transformative solution by objectively analysing visual data to detect defects, ensuring repeatability, reducing waste, and lowering costs.

## **2. Aim of the Thesis**

The research aims to enhance print quality assessment and defect detection using Computer Vision, reducing reliance on manual inspection. Key objectives include:

- Automating defect detection and subsequently assessing the quality to improve speed, accuracy, and reliability of print production.
- Developing cost-effective, time-efficient methods suitable for industry adoption.

The overall goal is to modernize quality control practices, minimize costs, and demonstrate the transformative role of computer vision in print production.

### **3. Scope of the Thesis**

Ensuring high print quality requires precise control over ink properties, substrate characteristics, press settings, and environmental conditions, as variations in these factors often lead to diverse printing defects that demand targeted control strategies. Traditionally, defect detection has relied heavily on human expertise, which introduces delays, increases material waste, and escalates costs. To overcome these limitations, this study applies image processing and machine learning techniques to automate defect detection and quality assessment in real time. The proposed framework focuses on detecting common defects such as scumming, show-through, strikethrough, doubling, and misregistration, while also evaluating print quality parameters including contrast and density. Methods such as Histogram Equalization, Discrete Cosine Transform (DCT), Thresholding, Bit-plane Selection, and Structural Similarity (SSIM) are employed for image feature extraction and analysis, while supervised machine learning models—such as CNN, DNN, RNN, Logistic Regression, Random Forest, and SVR—are used for classification and prediction tasks. Offset printing, owing to its widespread industrial adoption, serves as the primary focus of this research. By integrating computer vision and machine learning, the study demonstrates how automation can reduce human error, enhance efficiency, and ensure consistent print quality in large-scale production.

### **4. Identification and Evaluation of Scumming Printing Defect**

Offset lithography operates on the principle of ink–water balance, where image areas attract ink and repel water, while non-image areas attract water and repel ink. Scumming arises when non-image regions undesirably accept ink, leading to stains that compromise readability and aesthetics. Common causes include poor ink–water balance, fluctuations in dampening solution pH, excessive ink emulsification, plate defects, roller contamination, improper ink viscosity, and elevated press temperature. To address this, the proposed method employs computer vision methods to automatically detect scumming in printed samples. The process begins by converting RGB images to HSV color space and selecting the Saturation channel for analysis. Bit-plane slicing is applied to decompose the channel into eight planes, and an automated histogram-based approach identifies the most informative plane. The Discrete Cosine Transform (DCT) and its inverse (IDCT) are applied to reduce noise while preserving essential details. The Prewitt operator is then used for edge detection, followed by adaptive thresholding to differentiate print from non-print areas. Intensity ranges are further introduced for high-key, mid-key, and low-key images to improve the accuracy of scum segregation. Finally, scumming is quantified by calculating the ratio of scum pixels to the total print pixels. This automated method ensures objectivity, efficiency, and cost-effectiveness, offering a reliable alternative to manual inspection.

## **5. Identification of Show-through and Strikethrough Printing Defects**

Show-through refers to the visibility of printed content from the reverse side of the sheet, primarily caused by low paper opacity, while strikethrough occurs when excessive ink penetration makes the print visible on the opposite side. Both defects are influenced by substrate thickness, porosity, opacity, the presence of fillers such as  $\text{TiO}_2$  and  $\text{CaCO}_3$ , ink viscosity, and press settings. To detect these defects, printed samples are digitized under D65 illumination using a mobile camera. The captured RGB images are converted to grayscale, followed by histogram equalization to enhance contrast. Global thresholding is then applied for segmentation, and image subtraction is used to isolate show-through pixels. Morphological operations such as erosion and dilation are employed to refine the detection results. The study highlights that lower substrate thickness increases show-through even when porosity is relatively low, whereas strikethrough is more challenging to isolate due to higher ink intensity and overlap with background regions. Overall, the proposed method offers a cost-effective mobile-based solution, although defects such as scumming may interfere with detection.

## **6. Identification and evaluation of Doubling Defect Detection using Image Quality Metrics**

Doubling is a printing defect that appears as a faint, displaced duplicate of the image, typically caused by roller misalignment, press vibration, blanket wear, or paper deformation, and is characterized by blur, shadowing, and excessive dot gain. To detect this defect, samples are captured and converted to grayscale, followed by pixel detection using 8-connectivity and adaptive thresholding for segmentation. Prewitt edge detection is then applied to isolate the doubled regions, and the similarity of the detected areas is evaluated using Structural Similarity Index (SSIM), Feature Similarity Index (FSIM), and Mean Squared Error (MSE). The results revealed that SSIM is the most effective in identifying doubling, as it considers luminance, contrast, and structural information, while FSIM is able to capture features but overlooked contrast, and MSE provided only numerical error measurement without perceptual interpretation. For text samples, SSIM achieved similarity accuracy above 95%, whereas image-based doubling showed relatively lower accuracy due to complex variations.

## **7. Identification and evaluation of Misregistration Printing Defect**

Misregistration occurs when CMYK layers are misaligned, resulting in blurred or distorted images. Traditionally, it is detected manually using a linen glass to inspect registration marks. The main causes include paper stretch or shrinkage, plate misalignment, blanket expansion, and moisture variation. In the proposed method, RGB images are converted to CMYK using ICC profiles to preserve color accuracy. The CMYK channels are then separated, and their center points are identified. Displacement is measured using Euclidean and Manhattan distances, where a value of zero indicates proper registration, while any nonzero displacement quantifies the

degree of misregistration with precision, often capturing errors that are beyond human visual perception.

## 8. Prediction of Print Contrast and Density using Machine Learning

Print contrast and density are few quality parameters where print contrast represents the difference in tonal density across highlights, midtones, and shadows, while optical density (OD) measures the light absorption or reflection of the ink film. Since traditional densitometers are costly, this study proposes a mobile-based machine learning solution for predicting these parameters. In the method, Inception V3 is employed as a color classifier to identify CMYK patches, and regression models including Logistic Regression, Random Forest, and Support Vector Regression (SVR) are used to predict density and contrast. The evaluation relies on metrics such as  $R^2$ , RMSE, and MAE. Results show that Inception V3 achieves 98% accuracy for Cyan, Yellow, and Black, with slightly lower performance for Magenta due to 9% misclassification. Among the regression models, Random Forest consistently outperforms Logistic Regression and SVR in predicting both density and contrast across all colors, while SVR shows moderate performance and Logistic Regression performs the weakest.

## 9. Conclusion

This research demonstrates that computer vision significantly improves print quality assessment and defect detection by automating traditional inspection methods. Its key contributions include the detection of defects such as scumming, show-through, strikethrough, doubling, and misregistration, as well as the prediction of quality parameters like contrast and density using machine learning. The mobile-based implementation provides flexibility and cost-effectiveness, ensuring faster, more reliable, and repeatable quality assessments that reduce human error, improve productivity, and lower costs. By delivering practical and resource-efficient solutions, the study makes advanced print quality control accessible to a broader industry base, while mobile tools enhance scalability and ease of deployment. Ultimately, the research highlights the transformative potential of computer vision in modern printing, paving the way for efficient, sustainable, and consistent print quality management.

Future research focuses on advancing machine learning through adaptive models that handle diverse datasets, enabling real-time monitoring with inline detection for high-speed presses, and expanding detection capabilities to include microstructural issues, adhesion failures, and substrate defects. Moreover, other quality parameters need to be included in future work for a robust quality assessment. Integration with IoT systems supports remote monitoring and centralized quality control, while process optimization leverages computer vision data to refine inks, substrates, and press conditions. Additionally, the development of user-friendly interfaces ensures that simplified tools are accessible even to non-experts.

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