A Hybrid Deep Learning Framework for Fabric Stain Analysis: YOLOv8 based Detection with ResNet-18 Classification

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Abstract - In the textile industry, identifying the fabric flaws and stains is an essential part of quality control. To achieve this intelligent manufacturing in the textile sector, technology for computer vision inspection is essential for fabric stains. The main aim of my project is in order to recognize and classify the various kinds of stains on fabric automatically. To do this, we are utilizing YOLOv8 and ResNet-18.YOLOv8 is a state-of-art for object recognition framework with a real-time performance algorithms. PyTorch framework is also used to classify stains, the YOLOv8 algorithms have been improved and adapted to more effectively identify and classify stains in fabric images.CNN, Along with reliable performance in a variety of fabric textures and lighting conditions, PyTorch is also used to classify fabric and stains. One of the popular CNN architectures used is ResNet-18 which helps deeper networks to overcome the issues of decreasing gradients by utilizing residual connections. Finding the percentage of stain in a fabric is the goal of this project. Image capture and edge extraction should be prioritized, as the textile method for image processing has been studied. According to the tests, this method has a comparatively high detection rate for textile satins.

Key Words: OpenCV, PyTorch, CNN, YOLOv8, ResNet-18.

1. INTRODUCTION

Most modern things are becoming automatic and advanced with the machines we know they can perform a task quick and fast to achieve consistent work which can assist the laundry industry in identifying stains found at focused positions and the textile industry where they can be quality control machine inspections. Using stain detection is useful because it maintains a fabric's quality and sustainability on a fabric because it allows us to detect stains in this case it enables identifying oils which reduces the use of chemicals on the entire garments. This ensures the hygiene level of the fabric and cleanliness of the fabrics used YOLOv8 to operate with datasets of food and coffee stains on fabrics. We thought if we just solve these that will be a major key to creating an efficient and reliable algorithm for real-time stain detection.

Stain classification using Stella is not exclusive to just stain classification. YOLOv8 may be used in a variety of ways such without any prior knowledge, it may be used to detect objects, text detection (see what output you can find), and deep learning so that stain classification may occur in real time. YOLOv8 is a pretrained model for detecting objects in real time, while stain classification is using Convolutional neural networks (CNNs).Python is a popular language, and most of you might have heard or maybe used Flask as a framework. Since we store the uploaded image inside one Flask, an end-user can only upload an image, and then it will go to Flask and finally on to detect.py. Once the stain detection procedure is done by YOLO, all these processed results will be sent to HTML via calling another Python file on the Flask side and accordingly displayed in the user browser.

The system is especially useful in the textile field for quality control in automatic lines but it is also applicable to other fields. These models have been used in robotic so that self-cleaning robots can identify areas that need to be cleaned but are unclean or discolored. The system helps direct automatic stain-removing actions in industrial settings. The technology utilized here is intended for use in healthcare, but it can also be extended into the hospitality industry by identifying stains on hospital beds or patient clothing, as well as by monitoring cleanliness and other aspects. Home automation system can even identify stains on fabrics through smart devices. Users can do quick image-based scoring through the integration of a Flask web application, which caters to industries like cleanliness, fabric quality & hygiene standards.

YOLOv8 (You Only Look Once version 8) also has an anchor-free architecture, which offers it more flexibility in detecting a variety of objects than previous versions. By only generating bounding boxes, YOLOv8 locates and detects the stains in the image for your projects. Once the desired zone has been established, it is then passed to a ResNet-18 model for further classification. This is a powerful two-step pipeline, where we identify and classify the type of stain. This coordinated approach typifies the best qualities of both models in reliable strain analysis system.

CNNs (Convolutional Neural Networks) it is type of deep neural networks designed to analyze grid-like data inputs, such as images. CNN use built-in layers to create hierarchical representations of spatial features. The first layers, the Convolutional filters to recognize elementary features such as edges and textures. Following the Convolutional filtering, a pooling layer reduces the dimensionality to a sigle, more meaningful representation of data. The largest benefit to the entire model to learn increasingly complex features before the fully connected layers provides a prediction. The stain type classification work presented in this study is simply preceded by the Convolutional neural network concepts stated above as a part of ResNet-18 classifier.

Microsoft Research created the eighteen-layer deep Convolutional neural network known as ResNet-18. Its key feature is the use of "skip connections" or "residual connections", which enable the model to bypass layers. The vanishing gradient issue is resolved and the challenge of training a much deeper network is lessened by ResNet-18's use of skip connections.ResNet-18 functions as a stain classifier in this study using YOLO model-localized images of the stains. Stain can be classified as coffee, ink, etc., and can get a class name, and a level of confidence, by training with specialized data.

2. LITERATURE SURVEY

Ramdas Bagawde, Rahul Gawade, Vrushali More, Sakshi Pawale, Vaishnavi Jadhav. et al.[1]proposed Fashion Material Recognition And Its Damage Detection Using Deep Learning, developed hybrid AI approach combines R-CNN (Region-Based Convolutional Neural Network) and YOLO (You Only Look Once), two high capacity deep learning models. One of the greatest techniques for real-time object detection is YOLO, which rapidly spots possible stains or defects in apparel. The regions are then classified using R-CNN which is known for it's excellent accuracy, making the hybrid systems fast and accurate.

Vaishnavi M Chavan (2024), et al.[2]proposed Fabric Stain Detection using YOLO Algorithm. It uses YOLO (You Only Look Once) algorithm to create automatic fabric stain detection systems which enhance textile quality control process speed and precision. The proposed approach utilizes YOLO for a fast object detection process in real-time and R-CNN as a more accurate but slower-based solution. Our combined approach provides the best speed while retaining a reasonable but better accuracy than only YOLO. This approach reduces the significant costs and error rates in manual inspections. To improve the current weaknesses, such as false positives and patterned fabrics, improvements could utilize new deep learning techniques to allow for better output and adaptability and feature extraction than we have currently.

Farzana Islam, Sumaya, Md Fahad Monir, Ashraful Islam (2024), et al (3), Fabric Spot Defect: An annotated dataset for identifying spot defect in various fabric types. The goal of this project is to create a system of artificial intelligence capable of identifying fabric flaws like holes, oil stains, missing threads, and more by using image processing technology. First a the quality of the fabric is determined from images taken of the defects, then the images will be pre-processed for features extraction and then apply neural networks of different architectures. Although the study aims to increase inspection time and reduce human error for quality checks, the results can still be affected by the variance of training dataset and image quality.

Hugo M. Ferreira, David R. Carneiro, Miguel A. Guimaraes, Filipe V. Oliveira (2024), et al.[4], The system was improved by updating code for Python package alignment, centralizing configurations, and streamlining result storage. Additionally, flawless test images were incorporated into adjusted metric calculations, data augmentation was introduced via Tensor Flow, and Tensor Board with training time recording was added for comprehensive monitoring.

Dennise Mathew and N.C, Brintha (2024), et al. [5], proposed Deep-GD: Deep Learning-Based Automatic Garment Defect Detection and Type Classification. The Deep-GD model used for combining bilateral filtering, SE-Net for feature extraction, and RDF with Bayesian tuning, achieved 97.3% accuracy for classifying 12 types of garment defects, outperforming conventional technique.

Daniel Rocha, Leandro Pinto, José Machado, Filomena Soares, and Vitor Carvalho (2023),et al.[6], This methodology consists of three steps gathering stain and hole datasets. The method employed defect classification to categorize various types of faults and utilized data augmentation to improve the model's generalization to new, unseen garment images. Achieving a maximum precision of 0.76 and a recall of 0.747, the system effectively identified and classified clothing defects by leveraging a deep learning strategy using YOLOv5 models that have been optimized.

Hai Yu, Qiuhua Wan, and Changhai Zhao (2023), et al.[7], proposed Anti-Stain Algorithms Based on Dual Detector Data Interchange in Image-Type Displacement Measurement Technology. This research proposes two algorithms appropriate for utilizing dual image sensors to enhance image-type displacement measurement (IDM) technology performance for stain detection and anti-stain processing. The system is shown to correct many stain-induced errors via the recognition and correction process, indicating that even in cases where the sensor lacks visual capabilities, stain detection can still yield reliable results. The experimental results validate the proposed approach is highly reliable and robust. The configuration of the overall system has increased complexity, due to the dual implementation of sensors and real-time switching logic. More improvements need to be made so that it enters a price zone close enough to attainable, which can allow use for small industrial environments..

Tomas Almeida , Filipe Moutinho, And J. P. Matos-Carvalho (2021),et al.[8],proposed Finding fabric flaws this paper proposed a CNN-based automatic fabric defect detection system using Deep Learning and false negative reduction to detect flaws fast and accurately. When the false negative reduction method was applied, the accuracy of the system was 75% when operator intervention was added, the accuracy increased to 95%. Fifty distinct kinds of defects were used to train the system. Additionally, this through examination using four different datasets, each with its own unique features, is rare in the literature and demonstrates the model's generalizability

Rui Jin and Qiang Niu (2021), et al.[9],proposed Automatic Fabric Defect Detection Based on an Improved YOLOv5, This study discusses fabric flaws. A deep learning-based approach is used, and the teacher-student architecture can accurately identify various fabric flaws. The teacher model's performance and insights are transferred to a lighter student model via a knowledge distillation process, allowing it to conduct real-time detection with little accuracy loss. The suggested model is tested using public datasets as Tianchi AI and TILDA, as well as self-collected textile datasets. The model integrates focal loss and center loss constraints, the advance automatic textile inspection system by combining model efficiency real-time processing capability and with high defect detection accuracy.

Kamil Ksiazek ,Michał Romaszewski , Przemysław Głomb ,Bartosz Grabowski and Michał Cholewa (2020), et al.[10], proposed Blood Stain Classification with Hyper spectral Imaging and Deep Neural Networks, In this paper they are classifying blood and blood-like substances by using hyper spectra l images by using deep learning, and we are using two series of experiments, the HTC, which is a common scenario in hyper spectral classification, We experimented with a variety of models, including 1D/2D/3D CNNs, RNNs, MLPs, and traditional SVMs. To see how well they did, we utilized t-SNE to visualize the findings and look at confusion matrices.

Lithin Chandran, Prashant N Bhat, Bhuvaneshwar Kanade (2019), et al. [11], proposed Identification of Stain on White Fabric and Data Set Generation, we are going to train the dataset to overcome the difficulty in identification of stain in a real time satin identification according to rhat they make use of SSDlite, MoblieNet V2 COCO outperformed Faster RCNN Inception V2 Pets for real-time stain detection on low-end device. The training data was insufficient, leading to inaccurate stain detection. Inaccurate stain detection stemmed from limited training data, focusing only on two stain types on white fabric and ignoring varied lighting. After optimization, The Raspberry pi's it is slow processing speed means need to enhance its performance further.

Murali Krishnan, Dr. M. G. Sumithra (2014), et al. [12], An innovative approach for Automatic Stain Detection on Fabrics Using Image Processing. They use the K-means clustering technique, which is an unsupervised machine learning system that groups comparable pixels based on color intensity. It helps in finding the area of the stain, having the ability to quantify stain intensity through histogram analysis. The invisible stains can be detected using the histogram and a solvent dosage in cleaning machines which may be controlled by a ROI only for specific subsections of the image thereby improving speed and accuracy. This is a cutting edge tool through the use of Fabric Simulation CAD, this feature allows users to execute virtual stain identification and do simulation for forecasting responses of material in different cleaning ways. This technology offers efficient cleaning processes and helps reduce the risk of fabric damage result for best clothing care along with longer product life.

3. MATHAMATICAL MODULE:

I. Input Image Acquisition:

$$I \epsilon\ \mathbb{R}^{H\times W\times C} \text{-----------------} (1)$$

Equation (1) represents,

- H, W=dimensions of input image
- C=color channels
- I = image congaing possible stains

II. Stain Detection using YOLOv8:

$$(B, \text{c}, \text{p}) — \mathcal{M}_{YOLO}(I) \text{ -----------------} (2)$$

- $\mathcal{M}_{YOLO}$ = trained YOLOv8 model
- $B - (x_1, y_1, x_2, y_2)$ = bounding box coordinates of detected stain
- C = predicted class ID of stain
- P = detection confidence score ($0 \le p \le 1$)

III. Stain area calculation

$$\mathbf{A}_{\mathbf{stain}} = (x_2 — x_1) \times (y_2 - y_1) \text{--}(3)$$

- Equation (3) represents,
- A_{stain} = pixel area of stain detected stain
- $(x_1, y_1), (x_2, y_2)$ = bounding box coordinates

IV. Total Image Area:

$$A_{total} = W\times H \text{ ------------------------} (4)$$

- Equation (4) represents:
- A_{total} = total area image in pixels

V. Stain Area Coverage (%)

$$P_{coverage} = \frac{A_{stain}}{A_{total}} \times 100$$

- Equation (5) represents
- $P_{coverage}$ = percentage of image area covered by stain

VI. Accuracy and Loss from Confidence

Accuracy=p×100
Loss=(1-p)×100--------------- (6)

- Equation (6) represents:
- P= detection confidence score
- Accuracy (%) and Loss (%) are derived from the model output

VII. Stain Type Classification using Machine Learning

$\hat{y} = \mu(X)$-------------------- (7)

Equation (7) represents:

- X= cropped stain region from YOLO output
- $\mu(.)$ = classification function
- $\hat{y}$ ∈{Coffee, Ink, Oil, paint}= predicted stain type

VIII. Final Output

O= {$\hat{y}$, Accuracy, Loss, $P_{coverage}$}

4. METHODOLOGY

The proposed techniques offer a computer vision framework for classifying and identifying different types of stains in uploaded photos using deep learning models. To identify the type of stain present in the image and its coverage. The next step is to create bounding boxes around probable locations of the stain locations with a YOLOv8 model. If Stains are detected, those regions are clipped regions are then classified with complex ResNet-18 classifier. This classifier was trained on stain types, such as paint, oil, grease, coffee and ink. The classifier was evaluate the bounding box coordinates, to calculate the percent are of stained area in relationship to the total area of the image, predict the type of stain and provides a confidence score. The annotated image is now saved for display to show the identified stains with their bounding box for OpenCV to recognize it. The framework in Python including PyTorch with ResNet-18 for classification, Ultralytics YOLOv8 for stain detection, and Flask for the user interfaces. Automatic quality control and industrial inspection may all benefit from the proposed real time stain detection, classification and quality assessment.

The fabric stain detection and classification work flow visually representation which includes these steps upload image followed by YOLO detection is used to identify and locate stain area within the uploaded image and then cropped the stain area then passed to ResNet-18 classification model to classify the type of stain from pretrained classes and the final output with the calculation of area of stain.

Fig.1: Block Diagram of Proposed System.

5. RESULT AND DISCUSION

This web application using Flask and YOLOv8 and ResNet-18 model to access and classify stains in images uploaded by users. When an image is passed to the YOLOv8 detection module, stored privately in a folder, and bounding boxes were drawn on the stains locations as detected by the model in order to localize the stains. If the stains are detected, the ResNet-18 classifier takes cropped and processed localizations and makes a prediction on the stain type. The bounding box information also allows for area coverage of stain to be determined. The output is displayed in web-app interface showing the annotated image with highlighted stains, predicted stain type and confidence score, and the area coverage.

Whenever YOLOv8 determines that there are no stains, it prints a default message equal to "no stain was found." This delivers robustness and counteraction to false classifications. As demonstrated, the unified system can detect and classify stains in real-time within a user-friendly browser interface.

The interactive component allows the user to upload an image and received repeatable and immediate classifications on the identification and severity of the stain. This illustrates an example of how the system can be used within typical usage in situations such as quality control, cleaning validation and industrial inspection.

(a) Coffee satin (b) Grease

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(c) Ink stain **(d) Paint stain**

Fig.2: Insert image for stain detection (a), (b), (c) and (d) shows a real time stain image like coffee, oil, ink and paint stain on fabric.

(e) Upload Image

A. Confusion Matrix Evaluation:

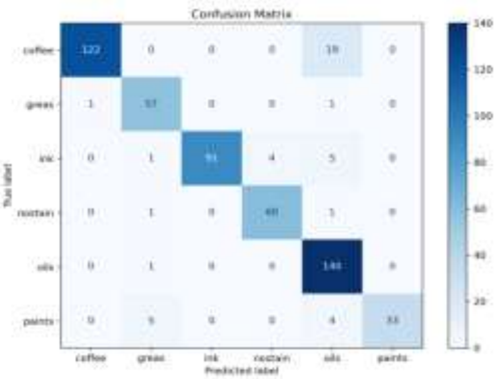


Fig.3: Confusion Matrix

The confusion matrix tells us how well the ResNet-18 model classified different types of stain along with fabric regions. It shows the model performance very well for certain categories. For example, oil stains were accurately categorized 140 times with only one misclassification, whereas coffee stains were correctly predicted 122 times. Additionally, 60 of the total "no stain" areas were correctly classified by the model. Nonetheless, there were a number of noteworthy misclassifications, including five paint spots being confused for grease and 19 coffee stains being incorrectly identified as oil. The similar textures, overlapping colour tones, or transparency of various stain types are most likely the causes of these mistakes.

The model demonstrates excellent results at discriminating visually similar stains shows that the majority of the misclassification occurred between oil or ink and paint, which is reasonable to expect because stains will likely have similar lighting or fabric textures. The results suggest that performance can be improved by enlarging the datasets with more samples using the lighting conditions and types of fabric materials present. Regardless, the analysis contributes to the overall strength of the system and indicates the best road for future improvement.

B. ResNet-18 based on CNN:

Once the stain successfully detected and identified at the particular locations within the image, The next step is to classification was performed using Convolutional Neural Network (CNN) by using ResNet-18 architecture. The ResNet-18 model likely received the identified stain zones as input for its Convolutional neural network (CNN). As it processed these visual cues through its eighteen layers, the network was able to extract features at various levels of abstraction. Ultimately, it classified each localized stain by assigning it to a specific category based on the features it had learned. Once the presence and location of the stain type were established, the entire process enabled automatic identification with remarkable accuracy.

Metric	**Value**
Accuracy	94.6%
Precision	94.3%
Recall	93.7%
F1 Score	94.0%

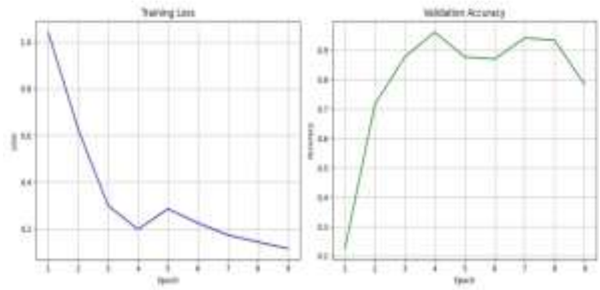


Fig.3: Training loss and validation accuracy of the dataset

ResNet-18 training and validation metrics shows a constant learning process. The model confidence in stain classification was further demonstrated by the validation accuracy, which reached its maximum at 94.6%.

C. Detection Performance of YOLOv8:

The YOLOv8 model has been trained to identify and locate five types of stains: Grease, Paint, Oil, Coffee, and Ink. It will use bounding boxes for annotation. Stain detection can be carried out using standard object detection metrics. Precision, Recall and mAP@0.5 (Mean Average Precision at IoU ≥ 0.5).

Stain Type	Precision	Recall	mAP@0.5
Grease	91.8%	88.9%	90.2%
Paint	90.5%	87.3%	89.0%
Oil	89.7%	86.4%	88.1%
Coffee	93.6%	90.7%	91.5%
Ink	91.0%	88.5%	90.1%

mAP@0.5 = 90.2+89.0+88.1+91.5+90.1 %5

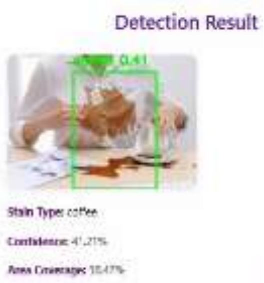
= 449 % 5

Average mAP@0.5 = 89.78%

Perspectives:

- **Coffee** stains were identified with highest accuracy due to its distinct color and edge properties.
- **Oil** and **grease** looks similar and having some same features and having similar appearance and transparent in nature.
- **Paint** due to its different shapes and varied color, paint occasionally had miss-detections.

D. Final Result of stain detection using YOLOv8



(a) Coffee stain

(b) Grease stain

(c) Ink stain

(d) Paint stain

Fig 5: Stain detection and classification output with Stain type, Confidence and Area coverage.

This is the final result we can see that stain successfully classified, which can be done with ResNet-18 and YOLOv8 in an image with 41.21% confidence and estimated that the stain area coverage is 38.47% of the image area. This shows how the model can detect and classify specific stain types, which could be beneficial for broad applications such as damage assessment, quality control, and laundry assistance and for maintane the hygiene.

6. CONCLUSIONS

We have developed an automated system for stain detection using YOLOv8 and ResNet-18. Our algorithm effectively identifies stains and allows for their classification. We have tested our algorithm on numerous images and observed that it accurately identify the stain and classified the stain based on their shape and colour features. We are using the images which contain a stain like coffee, oil, ink, grease and paint stain on fabrics and successfully detected and classified the stain with accuracy of 94.6%. Coffee stain was most accurately detected but having small confusion between oil and grease due to having some similar features.

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