

Transfer Learning-Driven Visual Garment Classification with Enhanced Feature Adaptation on Stitching Net

Md. Sohail¹, Mohammed Afreen², Mattewada Shiva², Lavudya Vinitha², Nakkala Nikhil Yadav²

¹Assistant Professor, ²UG Student, ^{1,2}Department of Computer Science and Engineering (Data Science)

^{1,2}Vaagdevi College of Engineering (UGC-Autonomous), Bollikunta, Warangal, 506005, Telangana.

ABSTRACT

In the modern era of fashion automation and textile manufacturing, the classification of garment types and stitching styles has become increasingly critical for tasks like quality assurance, inventory management, and automated product sorting. With the rising demand for intelligent systems in the apparel industry, there is a growing need for robust image-based garment analysis. Traditional approaches that depend heavily on human inspection or basic image scanning methods are no longer sufficient due to their inability to process high volumes of data with consistent accuracy. Manual classification systems suffer from several limitations including low scalability, inconsistent results, and inability to detect fine-grained stitching patterns. These methods lack automated learning, fail in complex visual conditions, and are inefficient for real-time operations. Traditional systems do not involve machine learning or feature extraction from convolutional networks; instead, they rely solely on visual cues and expert judgment, which introduces a high margin of error. This has created a critical gap that demands a more reliable, accurate, and scalable solution for garment classification. This project proposes an intelligent classification system using transfer learning through EfficientNetB0 for feature extraction, coupled with machine learning models like Deep Neural Networks (DNN), Perceptron, and a Proposed Multi layer perceptron (MLP) for dual-level classification such as identifying both garment category and stitching subclass. The entire workflow is integrated into a user-friendly Python-based Tkinter GUI that allows users to upload datasets, process images, train models, and predict garment types in real-time. By combining deep learning with traditional GUI design, the proposed system significantly improves classification accuracy, minimizes manual effort, and provides a scalable solution suited for smart garment industries.

Keywords: Textile manufacturing, EfficientNetB0, Transfer learning, Visual inspection, Convolutional networks.

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1. INTRODUCTION

Garment selling companies as well as fashion industries have created an interesting research area in the field of image processing and pattern recognition. A company always wants to achieve a competitive advantage against its rivals for sustaining itself in the industry. Thus if a company somehow knows the current design trends and choices of people regarding their clothing, the company can adopt proper

strategies and produce the clothes based on people choices. Besides this, online shopping is becoming very popular now a days. If a retailer knows which type of design for a particular garment is being bought by the consumers, they can increase their stock for that design. Thus, an automatic identification of design class is necessary. Such an automatic identification of garments trend can help different types of people. Recently, garment related research has become popular. Most of

the works focus on the segmentation of garments from real life images. There are also a few works that identify the type of the garments such as which ones are shirts or jackets. Considering all of these are the essential initial works, now it is necessary to develop a system that can also identify the design class of the garments. According to a 2024 market report, computer vision-based applications in manufacturing are expected to grow at a CAGR of 26.3%, emphasizing the urgency and relevance of deploying such models in industrial textile classification tasks. Data mining and machine learning have been at the forefront of research, helping to solve analytical problems and overcoming business problems. The power of data mining in analyzing big data has been proven in various studies. The apparel industry is relatively new to the field of data mining and machine learning; however, it has a gamut of application areas in retail, production, and other business operations. Businesses, such as Myntra, Zalando, and StitchFix are trying to tap into the potential of data to gain deeper insight into their consumer bases [1]. They even provide smart recommendations based on customers past purchases. Some retailers gather data using machine learning models and then use it to make important business decisions [2].

For instance, with the information extracted from data, they can learn what products sell best and which ones need refining. Mined data can be of immense use to marketing teams in designing appealing and targeted promotions to attract more customers. With the advent of the internet and massive technological developments, there has also been a rise in e-commerce in the apparel industry. The number of retail channels has increased, with customers buying products through different retail channels, such as mobile commerce, social media commerce, and retail shops [3]. Due to increasing web interactions, there are

more ways for customers to leave their digital footprints and for businesses to collect data. These data, available from a multitude of sources and channels, necessitate the adoption of the latest technologies, such as artificial intelligence, big data analytics, and machine learning. As the contemporary customer relies on online retail channels to make purchases, the need also arises for powerful and intelligent systems that can recommend, personalize, or help the customer in making purchasing decisions. Such models (decision support systems) can help customers in finding the right garments, according to their requirements [4]. The first step towards achieving this is to make the models recognize the different garment categories and corresponding garment attributes. It is important to recommend the right garment to the customer as it directly impacts the customer's shopping experience as well as the perception of the retailer itself [5]. Moreover, classifying products based on attributes can be beneficial for demand forecasting, as well as efficient assortment planning and comparison by retailers and producers. In this context, this study proposes to utilize the big data available in the apparel industry to support the development of a classification framework by applying data mining and machine learning techniques.

2. LITERATURE SURVEY

Jain S, et al. [6] proposed the article which is devoted to the application of data mining on the industry's product data, i.e., data related to a garment, such as fabric, trim, print, shape, and form. The purpose of this article is to use data mining and symmetry-based learning techniques on product data to create a classification model that consists of two subsystems: (1) for predicting the garment category and (2) for predicting the garment sub-category. Classification techniques, such as Decision Trees, Naïve Bayes, Random

Forest, and Bayesian Forest were applied to the 'Deep Fashion' open-source database. Medina, A.; et al. [7] proposed a CNN model classification for the implementation of these classifiers on cameras. First, the Fashion MNIST was analyzed and compared with the VGG16, Inceptionv4, TinyYOLOv3, and ResNet18 classification algorithms to determine the best clo classifier. Then, for real-time analysis, a new dataset with 12,000 images was created and analyzed with the YOLOv3 and TinyYOLO. Finally, an Azure Kinect DT was employed to analyze the clo value in real-time. Moreover, real-time analysis can be employed with any other webcam. The model recognizes at least three garments of a clothing ensemble, proving that it identifies more than a single clothing garment. Besides, the model has at least 90% accuracy in the test dataset, ensuring that it can be generalized and is not overfitting. Chen, X.; et al. [8] developed a paper that puts forward a style classification method combining fine-grained and coarse-grained techniques. Furthermore, a new deep neural network is proposed, which can improve the robustness of recognition and avoid the interference of image background through the pan learning and the background learning of image features. In order to study the relationship between the fine-grained attributes of clothing and the whole style, firstly, the clothing types are learned to realize the pre-training of model parameters. Secondly, through the transfer learning of the first stage of the pre-training model parameters, the model parameters are fine-tuned to make them more suitable for identifying the coarse-grained style types.

Donati, L.; et al. [9] developed the work, made by using and testing the aforementioned approaches in collaboration with Adidas, describes a real-world study aimed at automatically recognizing and classifying logos, stripes, colors, and other features of clothing, solely from final rendering images of

their products. Specifically, both deep learning and image processing techniques, such as template matching, were used. The result is a novel system for image recognition and feature extraction that has a high classification accuracy and which is reliable and robust enough to be used by a company like Adidas. This paper shows the main problems and proposed solutions in the development of this system, and the experimental results on the Adidas AG™ dataset. Rocha, D.; et al. [10] aimed at categorizing and detecting the presence of stains on garments, using artificial intelligence algorithms. In our approach, transfer learning was used for category classification, where a benchmark was performed between convolutional neural networks (CNNs), with the best model achieving an F1 score of 91%. Stain detection was performed through the fine tuning of a deep learning object detector, i.e., the mask R (region-based)-CNN. This approach is also analyzed and discussed, as it allows us to achieve better results than those available in the literature. Mukhamediev, R.I. et al. [11] described new results achieved with the Fashion-MNIST dataset using classical machine learning models and a relatively simple convolutional network. They present the state-of-the-art results obtained using the CNN-3-128 convolutional network and data augmentation. The developed CNN-3-128 model containing three convolutional layers achieved an accuracy of 99.65% in the Fashion-MNIST test image set. In addition, this paper presents the results of computational experiments demonstrating the dependence between the number of adjustable parameters of the convolutional network and the maximum acceptable classification quality, which allows us to optimize the computational cost of model training.

Paulauskaite-Taraseviciene, A.; et al. [12] presented the state-of-the-art results obtained using the CNN-3-128 convolutional network

and data augmentation. The developed CNN-3-128 model containing three convolutional layers achieved an accuracy of 99.65% in the Fashion-MNIST test image set. In addition, this paper presents the results of computational experiments demonstrating the dependence between the number of adjustable parameters of the convolutional network and the maximum acceptable classification quality, which allows us to optimize the computational cost of model training. Nisa, H.; et al. [13] proposed the garment measurement solution based on image processing technologies, which is divided into two phases, garment segmentation and key points extraction. UNet as a backbone network has been used for mask retrieval. Separate algorithms have been developed to identify both general and specific garment key points from which the dimensions of the garment can be calculated by determining the distances between them. Using this approach, we have resulted in an average 1.27 cm measurement error for the prediction of the basic measurements of blazers, 0.747 cm for dresses and 1.012 cm for skirts. Zulfiqar, A.; et al. [14] explored the systematic review with the applications of AI in evaluating clothing quality and condition within the framework of a circular economy, with a focus on supporting second-hand clothing resale, charitable donations by NGOs, and sustainable recycling practices. A total of 135 research resources were identified through searching academic databases including Google Scholar, Springer, ScienceDirect, IEEE, Taylor and Francis, and Sage journals. These publications were subsequently refined down to 49 based on selected inclusion criteria. The selection of these sources from diverse databases was undertaken to mitigate any potential bias in the selection process. Wilson, S.; et al. [15] described the efforts concerning prediction models related to the textile and polymer industry, especially garment seam strength, emphasizing critical

parameters such as stitch density, fabric GSM, thread type, thread count, stitch classes, and seam types. These parameters play a pivotal role in determining the durability and overall quality of denim jeans based on cellulosic polymer. A significant focus is dedicated to the mathematical computational models employed for predicting seam strength in five-pocket denim jeans.

3. PROPOSED METHODOLOGY

The identification and classification of garments based on their fabric type and stitching pattern are vital in modern textile industries for quality control, sorting, and automated production. Traditionally, this task was carried out manually, which made the process slow, inconsistent, and prone to human error. With the growth in garment varieties and the need for automation, there is a rising demand for intelligent systems that can efficiently and accurately classify garments in real-time. To address this challenge, the current project implements a deep learning-based system that uses transfer learning via EfficientNetB0 for feature extraction.

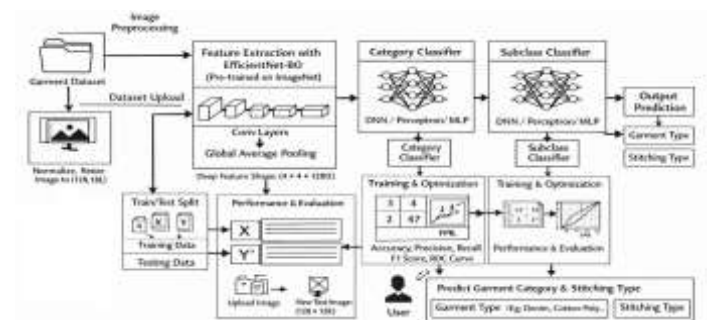


Figure 1. Proposed system architecture.

EfficientNetB0 is a lightweight and high-performing convolutional neural network pretrained on the ImageNet dataset. Instead of relying on handcrafted features, this model automatically learns intricate and abstract patterns from input garment images, which are then passed into machine learning models for classification. These classifiers predict two

labels: the fabric category and the stitching subclass, forming a multi-output classification task. The project incorporates a Tkinter-based graphical user interface (GUI) that allows users to interactively upload datasets, process images, train models, and predict garment types from unseen images. By combining transfer learning with classical classifiers like DNN, Perceptron, and a custom-designed MLP, the system improves accuracy, scalability, and performance over manual and traditional approaches. This makes it suitable for deployment in real-time textile quality control systems.

4. RESULT DESCRIPTION

The garment type classification system using the StitchingNet dataset offers a comprehensive view of the process and results. Figure 2 showcases the GUI after uploading a dataset, which successfully loaded four top-level categories Chiffon-Poly, Oxford-Core, Polyester-Poly, and Satin-Core—each containing three consistent subclass labels: Broken stitch, Normal, and Pinched fabric. This structured dataset layout, organized hierarchically with categories and subcategories, ensures a solid foundation for subsequent processing and classification tasks. The successful upload indicates that the system can handle a multi-level directory structure, a critical feature for managing complex datasets like StitchingNet, which includes diverse fabric and stitching variations. This step also validates the initial data integrity, setting the stage for feature extraction and model training.



Figure 2. Uploading dataset interface after admin login.

Figure 3 depicts the GUI after preprocessing with EfficientNetB0, indicating that the step was completed seamlessly. This phase involved resizing all images to a uniform resolution, normalizing pixel values and extracting deep features using the pre-trained EfficientNetB0 model, which was frozen to leverage its ImageNet-trained weights. The absence of errors suggests that the system efficiently handled the image processing pipeline, including loading, resizing, and feature extraction, and saved the preprocessed data (X, Y1, Y2) as compressed NumPy arrays. This caching mechanism enhances computational efficiency by avoiding redundant preprocessing in subsequent runs, a practical optimization for iterative model development and testing.



Figure 3. Dataset Preprocessing with EfficientNetB0.

Figure 4 illustrates the GUI after dataset splitting, resulting in a total samples, with allocated to the training set and to the testing set, maintaining an 80-20 split. The feature shape aligns with EfficientNetB0's output after global average pooling, reflecting the dimensionality of the extracted features. The labels for y1 (category) and y2 (subcategory) training datasets are confirmed with shapes respectively, indicating a balanced split across the two target variables. This partitioning ensures that the models are trained on a

representative subset of the data while reserving a sufficient portion for unbiased evaluation, adhering to best practices in machine learning for preventing overfitting.

Figure 5 (a) shows MLP multi-output model for category (Y1) classification exhibits perfect discrimination capability in the ROC curve, where all fabric classes such as Chiffon-Poly, Oxford-Core, Polyester-Poly, and Satin-Core achieved an AUC of 1.00, indicating the classifier can completely separate the garment categories without overlap. This ideal behavior is fully supported by the confusion matrix, which shows every sample correctly predicted: Chiffon-Poly (66), Oxford-Core (67), Polyester-Poly (69), and Satin-Core (57) all fall exactly on the diagonal with zero misclassifications, demonstrating that the MLP model learns highly distinctive feature representations and provides flawless category recognition performance.

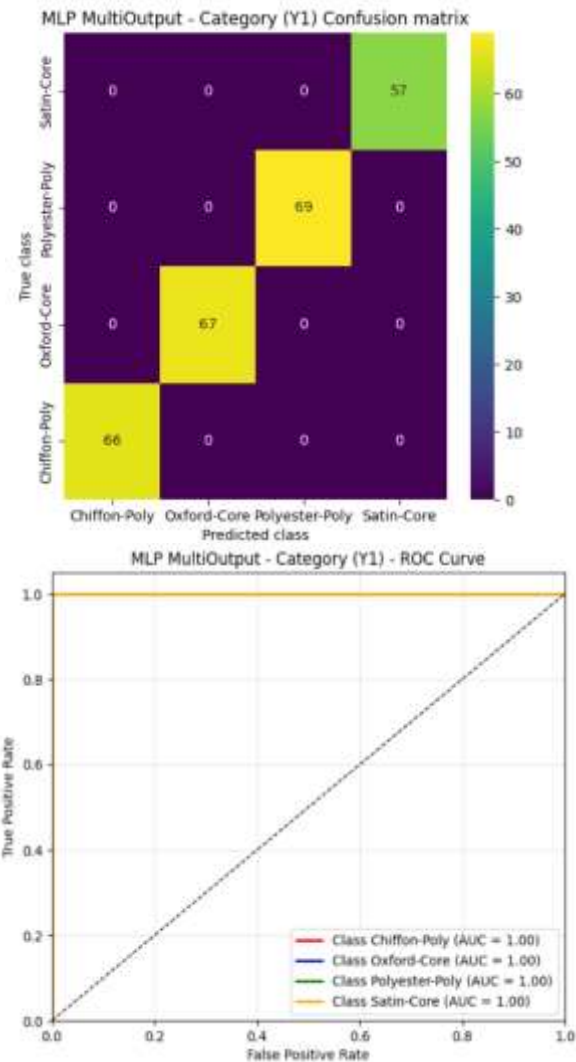


Figure 4. Dataset splitting into training and testing sets.

Figure 5 (a): Confusion matrix and ROC using proposed MLP for subclass Y1.

Figure 6 (b) shows matrix for MLP multi-output model for subclass (Y2) classification shows perfect separability in the ROC curves, where all stitching categories such as Broken stitch, Normal, and Pinched fabric achieve an AUC of 1.00, indicating complete discrimination without overlap between classes. This ideal performance is confirmed by the confusion matrix, in which every sample is correctly classified: Broken stitch (93), Normal (88), and Pinched fabric (78) all lie exactly on the diagonal with zero misclassification, demonstrating that the MLP model learns highly distinctive stitching features and delivers flawless subclass

prediction accuracy. Figure 7 shows predictions produced by the proposed MLP model on unseen test images demonstrate accurate joint recognition of both garment category and stitching type, correctly identifying Polyester-Poly with Pinched fabric stitching, Chiffon-Poly with Pinched fabric stitching, Oxford-Core with Normal stitching, and Satin-Core with Normal stitching.

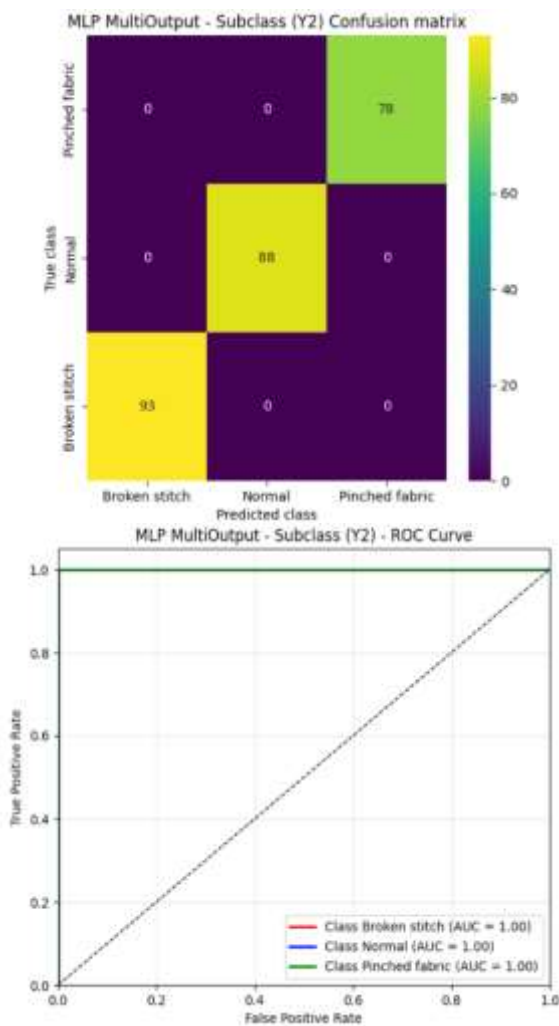


Figure 6 (b). Confusion matrix and ROC using proposed MLP for subclass Y2.

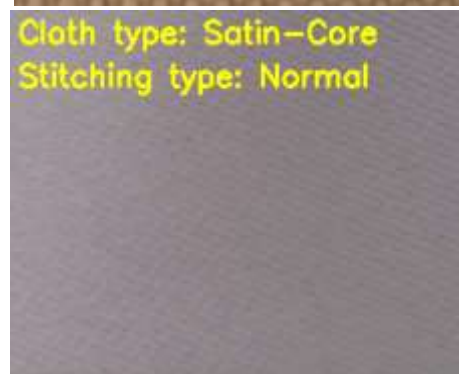


Figure 7. Prediction obtained on test images using proposed MLP.

These results indicate that the model successfully captures distinctive texture patterns for fabric classification while simultaneously learning fine stitching characteristics, showing consistent real-time inference capability and confirming the reliability of the multi-output approach for practical garment inspection scenarios.

5. CONCLUSION

In the research, an intelligent garment inspection system was successfully developed using a transfer learning-based multi-output classification approach capable of simultaneously identifying both fabric category and stitching type from garment images. EfficientNetB0 was employed as a deep feature extractor to capture rich texture and structural patterns from the StitchingNet dataset, and these learned representations were subsequently classified using three models: a DNN, a Perceptron, and the proposed MLP classifier. Experimental evaluation demonstrated that while the DNN and Perceptron achieved high accuracy, the proposed MLP consistently delivered superior performance, reaching 100% accuracy, precision, recall, and F-score for both the main class (fabric type) and subclass (stitching type). ROC curves and confusion matrices confirmed that the extracted deep features were highly separable, and real-time testing on unseen images further validated the reliability of predictions in practical scenarios. The system also incorporated a user-friendly GUI with authentication, dataset handling, feature caching, training, evaluation, and live prediction modules, making it a complete end-to-end application rather than only a model prototype. Overall, the study proves that combining transfer learning with a multi-output MLP classifier can effectively learn fine-grained textile textures and stitching characteristics, reducing manual inspection effort and enabling automated quality

assessment in garment manufacturing environments, with strong potential for deployment in industrial smart inspection systems

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