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Review Paper

Feature Extraction Methods Based On Deep Learning

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Abstract: Feature extraction summarizes raw data, like images, into controllable illustrations while protective central details. It's vital for managing large datasets, improving algorithm performance, and reducing resource requirements. In image classification, it transitions from low-level features to higher-level ones, aiding effective learning. By extracting edges, textures, or shapes, complexity decreases while retaining crucial information. Extracted features serve as meaningful representations, enhancing processing efficiency and analysis accuracy. Feature extraction streamlines image representation, fosters effective learning, and boosts classification algorithm performance. In this paper we learn about the how to use deep learning methods in Machine Learning. Importance in Handling Large Datasets. Role of Image Classification for Feature Extraction. How to reduce the complexity while maintaining vital information.

Key words: Feature extraction, Convolutional Neural Network (CNN), Scale Invariant Feature Transform (SIFT), Histograms of Gradients (HOG), Local Binary Patterns (LBP).

1 Introduction

In this paper we learn about the how to Deep learning methods in Machine Learning. Importance in Handling Large Datasets. Role of Image Classification for Feature Extraction. How to reduce complexity while maintaining information. Feature Extraction is process of reducing dimensions from an initial set of raw data into more manageable groups. It is useful when we have a large data set and need to reduce the number of resources without losing any important or relevant information. This helps to improve the performance and efficiency of algorithms and simplify the analysis process. Feature Extraction plays a key role in moving from low level features that are unsuitable for learning practically speaking. We get poor testing results, higher level features that are useful for learning. Feature Extraction is an object-based approach to classify images.
Manual feature extraction for human detection is hindered by time- consuming trial-and-error processes and subjective handcrafting, often resulting in suboptimal outcomes. It may also fail to capture all pertinent information, limiting detection performance. In contrast, deep learning automates feature extraction, yielding more comprehensive and accurate representations without manual intervention. While deep learning can be computationally demanding and reliant on powerful resources, it offers a more efficient and effective solution for human detection compared to manual methods.

The Difference between Machine Learning and Deep learning methods in Feature Extraction is as shown in below figure.

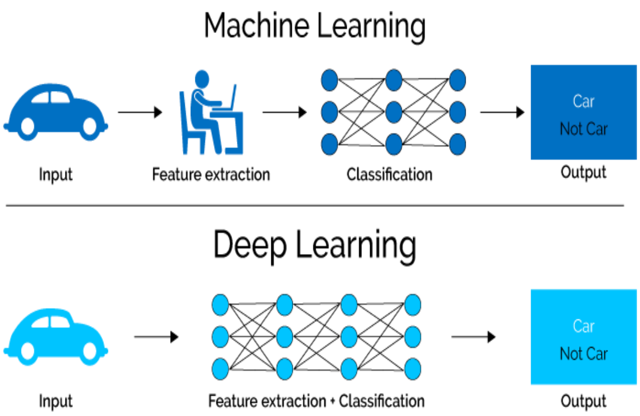

Figure 1: Comparison of Feature Extraction in Machine Learning vs. Deep Learning

Deep Learning [DL] models are divided into supervised learning, unsupervised learning, and reinforcement learning. Supervised learning is the task of learning a function from labelled training data. [1] In supervised learning, all data in the dataset is a pair consisting of an input object and the desired output value. A supervised learning model analyses the training data and produces a function that can be used for prediction. The most commonly used DL models included in this review are Convolutional Neural Networks (CNN) [2] and Recurrent Neural Networks (RNN) [3]. In DL, a Deep Neural Network is used that has number of hidden layers and makes a neural network "deep". These multiple layers are used for feature extraction and each layer uses the output value of the previous layer as an input value.

The Strengths of Deep Learning over other learning techniques are:

- No need for Feature Engineering
- No Need for Libelling of data
- Best Results with Unstructured data
- Efficient at delivering high-quality results

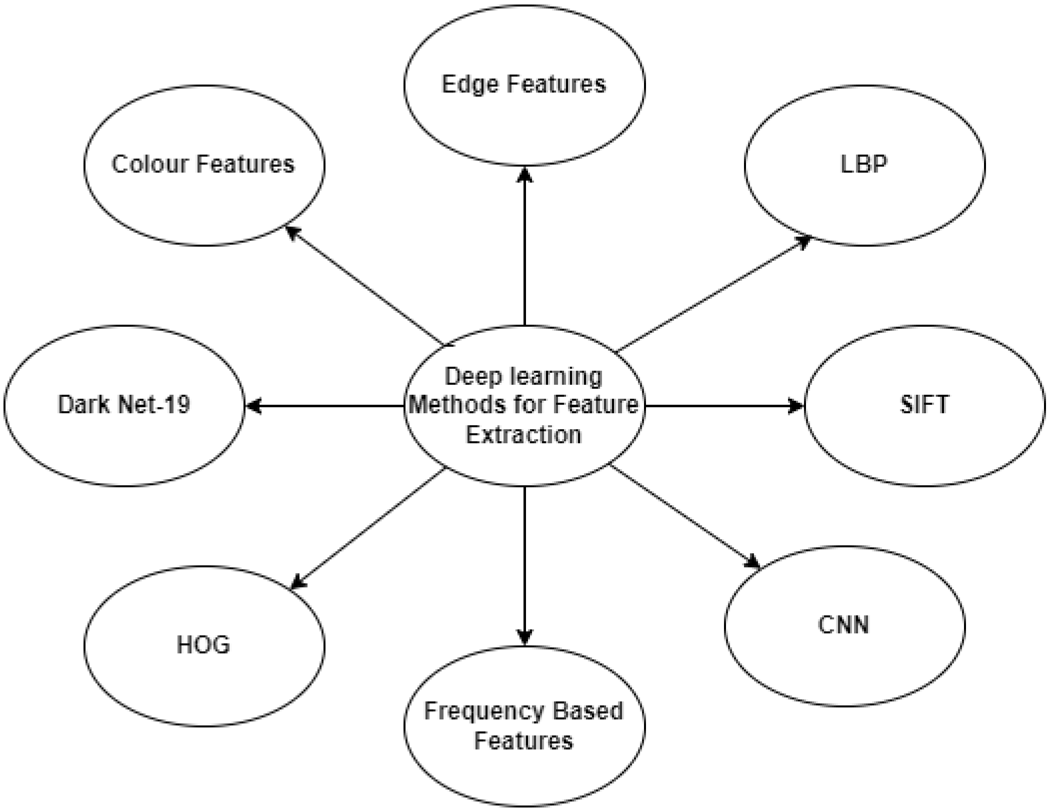

Figure 2: Feature Extraction Techniques based on Deep Learning

Specific Contributions

1. Comparison of Machine Learning and Deep Learning Methods
2. Overview of Deep Learning Models
3. The Strengths of Deep Learning in feature extraction
4. Visual Representation of feature extraction techniques and theirDetailed description

The established deep learning models used for image Feature Extraction are explained as follows:

A. CNN

The CNNs are specifically designed for processing color images and perform more Complex tasks such as image classification, Object detection, or Segmentation. Feature extraction is the way CNNs recognize key patterns of an image in order to classify it. An example of how to perform feature extractions using Tensor Flow and the Keras functional API. But first, in order to formalize these CNN concepts

B. HOG

The HOGs feature extraction divides an image into small cells, Calculates the histogram of the direction gradient for each cell, and combines them from a descriptor for the target. [4]

C. SIFT

The SIFT extract features that is based on detecting key points and extracting local feature descriptors.SIFT is a powerful technique for image matching that can identify and match features in images that are invariant to scaling, rotation, and affine distortion. It is widely used in computer vision applications, including image matching, object recognition, and 3D reconstruction. [5]

D. DARKNET-19

The DarkNet refers to a particular light weight and fast neural network architecture primarily used for object detection, recognition, and classification tasks. It gained significant attention due to its implementation in models like YOLO (You Only Look Once) series, known for their speed and accuracy in real time object detection. [6]

E. EDGE FEATURES

It can be useful for certain image processing tasks that involve detecting and analyzing edges or boundaries in an image like object detection, motion detection, and image segmentation. Edge features can be used to identify variations in pixel intensity and to detect sharp transitions between regions in the image

F. LOCAL BINARY PATTRENS (LBP)

LBPs is a widely used feature extraction method for analyzing texture information in images. LBP captures the local structure of an image by comparing the gray values of a pixel to its surrounding neighbors and encoding the result into a binary pattern.

G. FREQUENCY BASED FEATURES

Frequency based features such as Fourier descriptors, are a type of feature extraction method that captures the frequency content of an image. These features are often used in computer vision applications such as object recognition, texture analysis, data compression and image retrieval.

2. Literature Survey

Cayir et al (2018).[10] Feature Extraction Based on Deep Learning for Some Traditional Machine Learning Methods: This paper explores how deep learning methods, such as autoencoders, CNNs, or RNNs, can recover feature extraction in traditional machine learning systems. The research likely aims to validate the efficiency of participating deep learning-based feature extraction into traditional machine learning pipelines, potentially leading to better presentation and simplification across classification or regression tasks.

Wicht, Baptiste (2018) [11].Deep learning feature extraction transforms image processing by programming the extraction of significant features from images, a task usually performed physically. Using convolutional neural networks (CNNs), deep learning models learn to identify patterns in images, from basic features like edges to complex structures like objects. Overall, deep learning feature extraction for image processing offers a powerful and flexible approach to automatically extracting meaningful information from images, enabling a wide range of applications in fields such as computer vision, medical imaging, remote sensing, and more.

Suresh Dara et al 2018. [12] "Feature Extraction by Using Deep Learning: A Survey" is a complete study paper that explores the application of deep learning techniques for feature extraction across different domains. The paper discusses how convolutional neural networks (CNNs), recurrent neural networks (RNNs), autoencoders, and other deep learning models are used to automatically learn applicable features from raw data. These learned features are then applied to various tasks such as classification, regression, clustering, and dimensionality reduction. The survey covers different architectures and approaches used for feature extraction, highlighting their advantages and limitations. Overall, the paper provides valuable insights into the state-of-the-art techniques in deep learning-based feature extraction and their implications for diverse applications.

Wei Zhou et al. 2020. [13] The "Histogram of Oriented Gradients (HOG) Feature Extraction from Raw Bayer Pattern Images" is a technique used in computer vision and image processing to extract features from raw Bayer pattern images, which are captured directly by digital cameras without undergoing color re- construction. HOG, a popular method for object detection and image classification, computes histograms of gradient orientations in restricted portions of an image. This approach may offer advantages in scenarios where protective raw sensor data is important, such as in low-level image processing or situations with limited computational resources. Overall, this method presents a procedural approach to extracting features from raw Bayer pattern images using the HOG technique, potentially paving the way for more efficient and effective image processing.

Hong Liang et al. 2017. [14] “Text feature extraction based on deep learning: a review" provides a general examination of deep learning techniques for extracting features from textual data. It estimates the performance of these techniques using relevant metrics and compares their accuracy, efficiency, and scalability across different tasks. Additionally, the review discusses real-world applications in natural language processing, such as sentiment analysis, text classification, and machine translation. It also addresses evolving trends, challenges, and future study directions in the field. Overall, this review offers valuable insights for researchers, experts, and industry professionals involved in text analysis and NLP.

Neha Janu et al .2017. [15] The study evaluates various feature extraction methods for facial expression recognition, aiming to improve accuracy. Techniques such as HOG, LBP, Eigenfaces, Fisherfaces, and CNNs are analyzed. Performance is assessed using metrics like accuracy, precision, and recall, with comparative analysis revealing strengths and weaknesses. Perceptions from this analysis can guide the development of facial expression recognition systems for practical applications. Overall, the study offers valuable guidance for researchers and practitioners in selecting effective feature extraction methods.

Nellutla Sasikala et al 2020. [16] “Feature Extraction of Real-Time Image Using SIFT Algorithm" focuses on using the Scale-Invariant Feature Transform (SIFT) algorithm to extract strong features from images in real-time. These features, invariant to scale, rotation, and radiance changes, are crucial for tasks like object detection, image matching, and recognition. The SIFT algorithm finds keypoints and extracts descriptors from images, enabling efficient and fast feature extraction. Overall, this approach enables quick and exact feature extraction for various computer vision applications.

Somaieh Amraee et al 2022. [17] “Analytical study of two feature extraction methods in comparison with deep learning methods for classification of small metal objects” This study equivalences traditional feature extraction methods, such as PCA or wavelet transforms, with deep learning methods for categorizing small metal objects. Overall, the research purposes to provide visions into the efficacy of different methods for this specific classification task, which can support in the development of more effective and precise systems for noticing small metal objects.

3. Future Scope and Challenges

Deep learning techniques are used in Feature Extraction with neural network to predict prices of a stock- market, price variation of an airline. In such applications, where prices are dynamic and keep changing everyday based on availability of trade shares/ available seats. Several areas for Deep learning are still uncovered, but in the existing one, several challenges have been mitigated which are being addressed here:

Deep Learning requires a large amount of data for feature extraction. Feature extraction based on deep learning for traditional machine learning methods involves using deep learning models to automatically extract meaningful features from raw data, which can then be fed into traditional machine learning algorithms for further processing and analysis.

Traditionally, feature extraction was performed manually by domain experts, which could be time-consuming and might not capture all relevant information in the data. However, with the advent of deep learning techniques such as convolutional neural networks (CNNs), recurrent neural networks (RNNs), and auto encoders, it has become possible to automatically learn rich and hierarchical representations directly from raw data.

A deep learning model is trained on a large dataset to learn features that are relevant for the task at hand, such as image classification, natural language processing, or time series analysis. Once the deep learning model is trained, the learned features can be extracted from intermediate layers of the network and used as input to traditional machine learning algorithms such as support vector machines (SVM), random forests, or logistic regression.

The hybrid approach combines the strengths of both deep learning and traditional machine learning methods, leveraging the ability of deep learning models to learn complex representations from raw data, while still benefiting from the interpretability and simplicity of traditional machine learning algorithms. Additionally, it can often lead to improved performance compared to using either approach in isolation, especially when dealing with high-dimensional or unstructured data.

New features created in Feature Extraction are not human readable. If you want to retain the initial features in the dataset then use “feature selection” methods. Another challenge is Scalability. Some of the feature extraction algorithms wouldn’t be feasible to run if the datasets are huge. Especially the complex non- linear feature extraction methods would be infeasible. The scaling of linear feature extraction methods mostly dependent on matrix approximations and linear algebra algorithms. While the computational bottleneck for linear feature extraction methods, most of the time, is the number of features. In kernelized non-linear methods, the bottleneck is the number of instances. [18]

Future work could focus on enhancing network performance through novel data augmentation methods. Additionally, exploring hybrid architectures by combining successful CNN models with Transformers may yield improved classification outcomes. These avenues offer promising directions for advancing small dataset classification in computer vision. [19]

The application of DL to agriculture and biodiversity and highlighted some challenges in this area. The novelty of the application of DL models and the challenges identified in agriculture demonstrates the need for further research. CNN is the most widely used DL model in agriculture. In the future, we expect to develop or improve models that help farmers make crop management decisions. These models can be integrated into decision support tools, and these tools can guide users through precise steps and suggest optimal decision paths. It is expected that the development of these models will also enable biodiversity monitoring. Consequently, the adoption of new sustainable practices supported by DL models and biodiversity monitoring will help manage the farm with minimal human intervention and greater effectiveness. [20]

Deep learning models can be computationally expensive and require access to powerful computational resources. Despite these challenges, deep learning approaches offer a more efficient and effective solution for human detection compared to manual feature extraction methods.

The proposed hardware “VLSI Architecture in for Fine Grained Pipelined Feature Extraction using HOG” improves HOG-based feature extraction, boasting yields over GPU systems in power, speed, and cost. However, its boundaries include narrow application focus, scalability issues, undefined resource utilization, and lack of assessment with alternative hardware solutions. Further estimation is necessary to device its real-world efficacy fully. [21]

The “Performance Analysis of Frequency Domain based Feature Extraction techniques for Facial Expression recognition” climaxes the status of facial expression recognition and mentions different feature extraction techniques but lacks depth in discussing significant challenges. These encounters include limited toughness in different conditions, complexity impacting practicality, data dependence leading to biases, and the need for better generalization across diverse populations. Addressing these issues would provide a more thorough understanding of the complications within the field of facial expression recognition. [22]

The "Feature extraction of real- time image using SIFT algorithm "acknowledges the significance of feature extraction in image processing and highlights algorithm performance improvements. However, it lacks depth in discussing potential drawbacks, including the limited scope of mentioned techniques, dependency on specific algorithms like SIFT, and the absence of comprehensive evaluation metrics beyond speed. Addressing these aspects would offer a more comprehensive understanding of image processing and feature extraction challenges.

The "Edge feature extraction based on digital image processing techniques" description explores various edge detection techniques but lacks depth in addressing potential drawbacks. It overlooks limitations such as the lack of detailed evaluation criteria, applicability to real-world scenarios, and considerations regarding computational complexity. Addressing these drawbacks would enhance understanding of the challenges in edge detection for computer vision and image processing.

4.Limitations of Deep Learning in Feature Extraction

- **Data Quality**: Deep learning algorithms can produce incorrect results if the data is incomplete, poor quality, or incorrect
- **Training**: Training deep learning models can be expensive, and they require large, complex data models and extensive hardware for complex mathematical calculations. Training can also take a long time.
- **Overfitting**: Deep learning models can become too specialized in the training data, which can lead to poor performance on new data. This is especially common with large neural networks and can be caused by insufficient data or model complexity.
- **Multitasking**: Once trained, deep learning models are inflexible and can only solve specific problems. Solving similar problems requires retraining the system.
- **Cross-disciplinary problems**: Deep learning algorithms may not be able to provide conclusions for cross-disciplinary problems.
- **Sequential Data**: Deep learning may be less effective for sequential data.

5. Conclusion

Feature Extraction, essential for data analysis, involves techniques like LBP, HOG, SIFT, CNN for Dimensionality Reduction. By reducing complexity, it enhances efficiency, making it a crucial tool in extracting meaningful patterns from data for better insights and decision- making. Feature extraction in deep learning refers to the process of robotically learning meaningful patterns or features from raw data. In convolutional neural networks (CNNs), for example, feature extraction comprises passing input data done through convolutional layers to extract features at different levels of abstraction. These features capture hierarchical pictures of the input data, which are then used for tasks like classification, detection, or segmentation. Feature extraction is a vital step in deep learning as it helps in learning useful depicts from the data, which in turn permits the model to simplify well to unseen examples. Deep learning methods do not require a separate step for feature extraction, they require more powerful platforms than traditional methods. The strength of conventional feature extraction methods, such as the HOG and LBP, is that the extracted feature vector can be used in different classifiers to select a more accurate classifier. A comparison with other deep learning methods will provide a better understanding of the efficiency of the different feature extraction methods.

Deep learning models can be computationally expensive and require access to powerful computational resources. We can use these Deep learning methods in different sectors like Medical, Engineering, Business, E-Commerce etc. Further, more improvements can give us the more beneficial results.

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