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A Comprehensive Review of Machine Learning and Deep Learning Techniques for Face Mask Detection

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Abstract: ***The COVID-19 pandemic accelerated the development of intelligent monitoring systems capable of ensuring compliance with public health guidelines. Among these technologies, face mask detection systems have emerged as an important application of computer vision, machine learning (ML), and deep learning (DL). Automated mask detection enables real-time monitoring in hospitals, airports, educational institutions, shopping malls, and other public environments. Various techniques including Support Vector Machines (SVM), K-Nearest Neighbors (KNN), Decision Trees, Random Forests, Gradient Boosting, Convolutional Neural Networks (CNN), MobileNetV2, ResNet-50, YOLO, and transfer learning models have been proposed for this purpose.***

Keywords: Support Vector Machines (SVM), K-Nearest Neighbors (KNN), Decision Trees, Random Forests, Gradient Boosting, Convolutional Neural Networks (CNN), MobileNetV2, ResNet-50, YOLO.

I. INTRODUCTION

Face mask detection has become a significant research area in computer vision due to its role in public health monitoring and safety management [1], [2]. The widespread adoption of face masks during infectious disease outbreaks created a demand for automated systems capable of identifying whether individuals are properly wearing masks [3].

Traditional manual monitoring approaches are labor-intensive, time-consuming, and prone to human error. Consequently, researchers have investigated artificial intelligence-based solutions that utilize image processing, machine learning, and deep learning techniques to perform mask detection automatically [4], [5].

Recent advancements in machine learning and deep learning have enabled the development of highly accurate face mask detection systems capable of operating in real-time environments [6], [7].

II. FACE MASK DETECTION FRAMEWORK

A. Data Acquisition

Image datasets containing masked and unmasked faces are collected from public repositories, surveillance systems, and custom image collections. Dataset diversity is crucial for ensuring model generalization and reducing classification bias [9].

B. Data Preprocessing

Image preprocessing techniques such as normalization, resizing, augmentation, and noise reduction improve model performance and minimize overfitting [10].

C. Feature Extraction

Feature extraction identifies important facial characteristics useful for classification. Traditional approaches use handcrafted features such as HOG and Haar features, whereas deep learning methods automatically learn features from images [11].

D. Classification

The extracted features are processed by machine learning or deep learning classifiers to determine mask presence [4], [5].

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III. MACHINE LEARNING APPROACHES

A. K-Nearest Neighbors (KNN)

KNN classifies test samples according to the nearest neighbors in the feature space and has demonstrated effective performance in image classification tasks [12].

B. Support Vector Machine (SVM)

SVM identifies an optimal hyperplane separating masked and unmasked facial images and has been widely used in computer vision applications [13].

C. Decision Tree

Decision Tree algorithms construct hierarchical classification rules and offer interpretability advantages over many complex models [14].

D. Random Forest

Random Forest combines multiple decision trees using ensemble learning techniques and significantly improves robustness and predictive performance [15].

E. Gradient Boosting

Gradient Boosting sequentially improves weak learners by minimizing classification errors and has achieved excellent performance in numerous machine learning applications [16].

IV. DEEP LEARNING APPROACHES

A. Convolutional Neural Networks (CNN)

CNNs automatically learn hierarchical image features through convolutional operations and are considered the foundation of modern computer vision systems [6].

B. MobileNetV2

MobileNetV2 employs depth-wise separable convolutions to reduce computational complexity while maintaining high classification accuracy [7].

C. ResNet-50

ResNet-50 introduces residual learning to overcome degradation problems associated with deep neural networks [17].

D. YOLO

YOLO performs object detection and classification simultaneously, making it suitable for real-time face mask detection systems [18].

E. Transfer Learning

Transfer learning enables the adaptation of pre-trained models to mask detection tasks using comparatively smaller datasets [19].

V. COMPARATIVE ANALYSIS

Deep learning models generally outperform traditional machine learning techniques due to their ability to learn complex image representations automatically [6], [17]. However, machine learning algorithms such as SVM, Random Forest, and Gradient Boosting remain attractive because of their lower computational requirements and faster training times [13], [15], [16].

Several studies have reported accuracy levels exceeding 95% for machine learning classifiers and above 98% for deep learning architectures under controlled conditions [5], [7], [18].

VI. CHALLENGES AND FUTURE DIRECTIONS

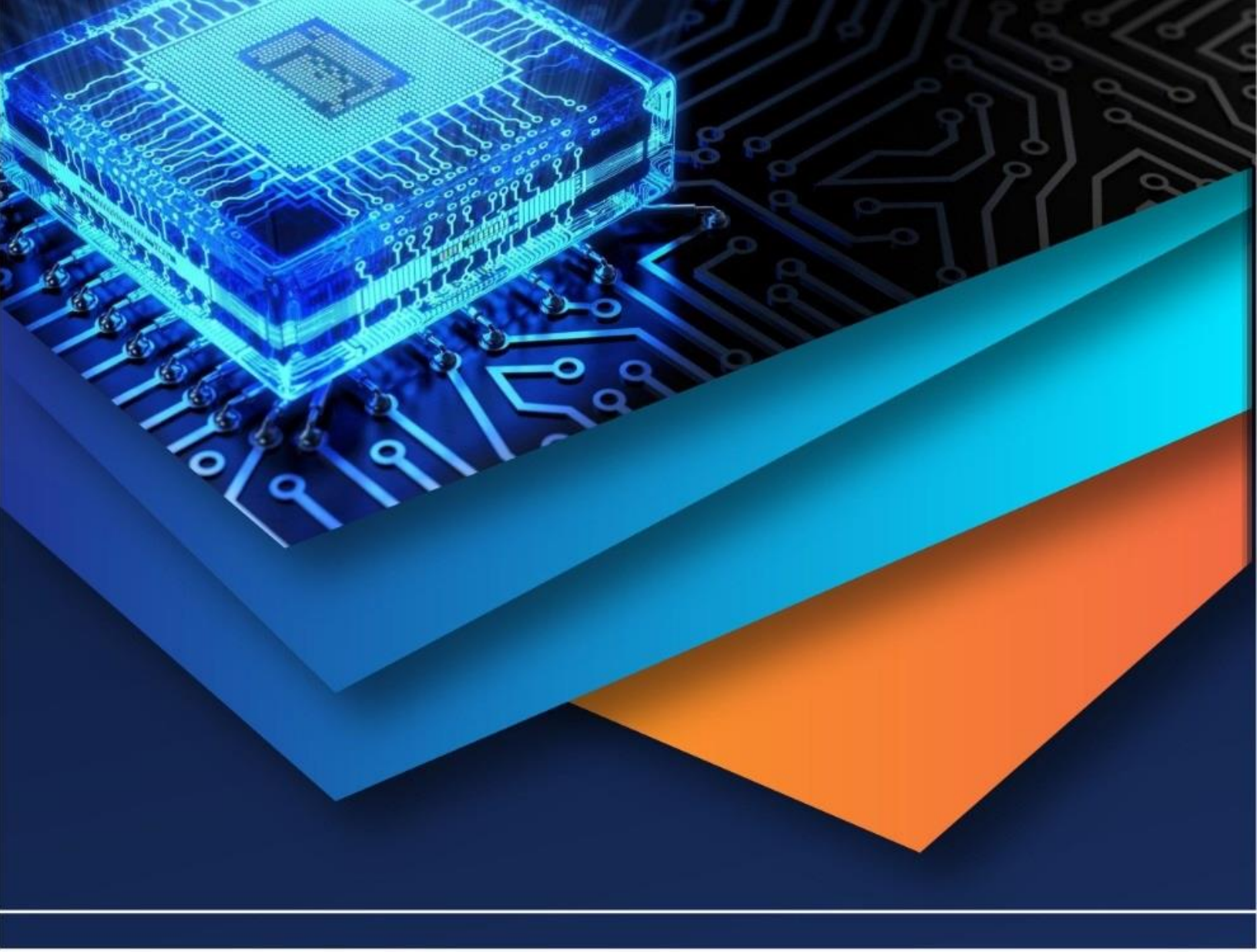
Current challenges include illumination variation, facial occlusion, pose diversity, dataset imbalance, and real-time deployment constraints [20]. Emerging technologies such as Vision Transformers (ViTs), Explainable Artificial Intelligence (XAI), Edge AI, and Federated Learning are expected to improve future face mask detection systems [21], [22].

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