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HumaniSense: A Real-Time Deep Learning Framework for Robust Age and Gender Prediction Using Multi-Task Convolutional Neural Networks

Mrs. T. Ganga Bhavani[1], Chollangi Jahnavi[2], Utukuri Naveen Satya Sai[3], K M V Naga Sai Manikanta[4], Kusuma Rakesh[5]
[1]*Assistant Professor, Department of Information Technology, Pragati Engineering College, ADB Road, Surampalem, Near Kakinada, East Godavari District, Andhra Pradesh, India-533437.*
[2,3,4,5] *B.Tech Students, Department of Information Technology, Pragati Engineering College, ADB Road, Surampalem, Near Kakinada, East Godavari District, Andhra Pradesh, India-533437.*

Abstract: ***The rapid evolution of deep learning and computer vision technologies has enabled the development of intelligent systems capable of extracting meaningful insights from visual data. This paper presents HumaniSense, a real-time human trait prediction framework designed to accurately estimate age and classify gender from facial images and live video streams. Unlike traditional approaches that rely on handcrafted features and manual observation, the proposed system leverages a multi-task Convolutional Neural Network (CNN) trained on the UTKFace dataset to automatically learn discriminative facial representations. The framework integrates an efficient face detection module using OpenCV's Haar Cascade classifier, followed by a standardized preprocessing pipeline that ensures consistent input quality for model inference. The deep learning model is implemented using TensorFlow and Keras, enabling simultaneous age regression and gender classification with high accuracy. Furthermore, the system is deployed as a scalable web-based application using Flask, providing both image upload and real-time webcam-based prediction capabilities through an intuitive user interface. Experimental evaluation demonstrates that the proposed system achieves high prediction accuracy, low latency, and robustness under varying environmental conditions such as illumination and pose variations. The system is suitable for applications in smart surveillance, retail analytics, access control, and intelligent human-computer interaction. Future enhancements include emotion recognition and advanced behavioral analytics, making the framework extensible for comprehensive human-centric AI solutions.***

Keywords: Human Trait Prediction, Age Estimation, Gender Classification, Convolutional Neural Networks (CNN), Deep Learning, Computer Vision.

I. INTRODUCTION

The field of computer vision has experienced significant advancements in recent years, primarily driven by the rapid growth of deep learning techniques and the availability of large-scale annotated datasets. Among its many applications, automated human trait prediction—particularly age estimation and gender classification from facial images—has emerged as a crucial area of research with wide-ranging applications in surveillance systems, retail analytics, access control, and human-computer interaction.Traditional approaches to human trait analysis relied heavily on manual observation or handcrafted feature extraction techniques such as Local Binary Patterns (LBP) and Histogram of Oriented Gradients (HOG). While these methods provided initial progress, they suffer from limitations including sensitivity to lighting conditions, pose variations, and lack of scalability in real-world environments. Furthermore, shallow machine learning models built upon these features fail to capture the complex and non-linear characteristics inherent in facial data.

To address these challenges, deep learning-based approaches, particularly Convolutional Neural Networks (CNNs), have demonstrated superior performance by automatically learning hierarchical feature representations directly from raw images. In this context, the proposed system, *HumaniSense*, introduces a real-time intelligent framework that leverages a multi-task CNN architecture for simultaneous age estimation and gender classification. The system integrates efficient face detection, robust preprocessing techniques, and a scalable web-based deployment to ensure practical usability and high performance.By combining accuracy, real-time processing capability, and user accessibility, the proposed framework aims to bridge the gap between research-level models and deployable intelligent systems.

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A. Problem Statement

Despite the progress in computer vision and machine learning, existing human trait prediction systems still face several critical limitations. Traditional manual methods are inherently subjective, time-consuming, and unsuitable for large-scale or real-time applications. Early automated systems based on rule-based image processing and shallow learning models rely on handcrafted features, which restrict their ability to generalize across diverse real-world scenarios. Moreover, many existing deep learning solutions lack accessibility, requiring specialized hardware, technical expertise, or offline processing, thereby limiting their practical adoption. These systems often struggle to maintain accuracy under challenging conditions such as variations in illumination, facial expressions, occlusions, and camera angles. Therefore, there is a need for an intelligent, accurate, and scalable system capable of performing real-time age and gender prediction from facial images while being accessible through a user-friendly interface. The proposed HumaniSense system addresses this gap by integrating deep learning with efficient face detection and web-based deployment to deliver reliable and real-time predictions.

B. Key Objectives of this Research Include

The primary objective of this research is to develop an intelligent and efficient deep learning-based framework for accurate age estimation and gender classification from facial images using Convolutional Neural Networks (CNNs). The study aims to design a multi-task learning model capable of predicting multiple human traits simultaneously while improving overall performance and computational efficiency. It focuses on implementing a robust face detection and preprocessing pipeline to handle real-world variations such as lighting conditions, facial orientations, and image quality. Additionally, the research seeks to enable real-time prediction through integration with live webcam input and static image analysis. A user-friendly web application is developed using Flask to ensure accessibility for both technical and non-technical users. The system is evaluated based on accuracy, latency, and robustness, while also providing a scalable and extensible architecture that can support future enhancements such as emotion recognition and advanced behavioral analytics.

II. LITERATURE SURVEY

Recent advancements in deep learning have significantly improved age estimation and gender classification from facial images. Convolutional Neural Networks (CNNs), transfer learning, and multi-task learning approaches have demonstrated high accuracy and robustness under real-world conditions. Several studies have focused on improving feature extraction, handling dataset imbalance, and enabling real-time prediction. However, challenges such as computational complexity, generalization across diverse datasets, and real-time deployment still persist, motivating the development of efficient and scalable systems like the proposed HumaniSense framework.

S.No	Author(s) & Year	Methodology	Dataset Used	Key Contribution	Limitations
1	Dey et al., 2024	CNN with preprocessing & augmentation	UTKFace, Adience	Achieved high accuracy (97% gender) with robust preprocessing	Performance drops for extreme age groups
2	Nguyen et al., 2024	Deep CNN regression model	UTKFace	Achieved 95.5% gender accuracy and low MAE for age	Sensitive to noisy inputs
3	Zaman & Ahmed, 2025	Multi-task CNN (age + gender)	Custom dataset	Joint learning improved performance (95% accuracy)	Difficulty in predicting children's age
4	Kocoń & Pawlukiewicz, 2025	Multi-model CNN evaluation	Face datasets	Achieved >90% accuracy and MAE <4 years	Dataset imbalance affects elderly prediction
5	Sharma et al., 2023	Improved CNN architecture	Face datasets	Enhanced feature extraction for better prediction	Higher computational cost
6	Sheoran et al., 2021	CNN + Transfer Learning (VGG, ResNet)	VGGFace2	Transfer learning improved performance over scratch models	Requires large pre-trained datasets
7	Korban et al., 2023	Graph CNN (TAA-GCN)	UTKFace, MORPH	Improved robustness to pose and occlusion	Complex architecture
8	Benkaddour et al., 2021	CNN-based feature extraction	Adience, Essex	Improved accuracy over traditional ML methods	Limited real-time capability

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9	IJCRT Study, 2024	CNN vs SVM comparison	Mixed datasets	CNN outperformed traditional ML approaches	Requires high training data
10	TIJER Study, 2024	Comparative ML models	Facial datasets	Highlighted importance of feature extraction	Lower accuracy than deep learning

III. BACKGROUND WORK

The foundation of automated human trait prediction lies in the evolution of computer vision and machine learning techniques for facial analysis. Early approaches relied on handcrafted feature extraction methods such as Local Binary Patterns (LBP), Histogram of Oriented Gradients (HOG), and geometric facial measurements, which were combined with classifiers like Support Vector Machines (SVM) and k-Nearest Neighbors (k-NN). While these methods provided initial success, they were highly sensitive to variations in lighting, pose, and facial expressions, limiting their applicability in real-world scenarios. The emergence of deep learning, particularly Convolutional Neural Networks (CNNs), revolutionized facial analysis by enabling automatic feature learning directly from raw pixel data, significantly improving accuracy and robustness. Large-scale datasets such as UTKFace and IMDB-WIKI further facilitated the development of generalized models capable of handling diverse demographic variations. Additionally, advancements in multi-task learning enabled simultaneous prediction of multiple attributes, such as age and gender, using shared feature representations, improving computational efficiency and performance. Real-time face detection techniques, including Haar Cascade classifiers and deep learning-based detectors, have also played a crucial role in enabling live prediction systems. Furthermore, the integration of deep learning models with lightweight web frameworks such as Flask has made it possible to deploy intelligent systems in accessible, user-friendly environments. These developments collectively form the technological backbone for modern systems like HumaniSense, which aim to deliver accurate, real-time, and scalable human trait prediction solutions.

IV. PROPOSED MODEL

The proposed HumaniSense system introduces a deep learning-based framework for real-time age estimation and gender classification using facial images. The methodology is designed as a structured pipeline consisting of image acquisition, face detection, preprocessing, feature extraction, and prediction stages. The system leverages a multi-task Convolutional Neural Network (CNN) to simultaneously predict age and gender, ensuring both efficiency and high accuracy. Initially, the system accepts input either through uploaded images or live webcam streams. The input image is processed using OpenCV's Haar Cascade classifier to detect and localize facial regions. This step ensures that only relevant facial features are extracted while eliminating background noise. In cases where multiple faces are present, the system processes each detected face independently.

Following detection, the facial region undergoes a preprocessing stage that includes resizing the image to a fixed dimension (128×128 pixels), converting it to grayscale to reduce computational complexity, and normalizing pixel values to enhance model performance. These steps ensure consistency in input data and improve generalization capability across diverse conditions such as varying lighting and orientations. The preprocessed image is then fed into a multi-task CNN model designed with multiple convolutional and pooling layers for hierarchical feature extraction. The network learns low-level features such as edges and textures in initial layers and high-level semantic features such as facial structure in deeper layers. The model contains shared layers followed by two output branches: one for age prediction using regression and another for gender classification using a sigmoid activation function. This multi-task learning approach improves performance by leveraging shared feature representations.

The prediction outputs are post-processed to generate user-friendly results, including estimated age and gender along with confidence scores. These results are then displayed through a Flask-based web interface, allowing users to interact with the system seamlessly. The entire pipeline is optimized for real-time performance, ensuring low latency and efficient processing even in live video scenarios.Overall, the proposed methodology integrates computer vision and deep learning techniques into a cohesive and scalable framework, providing accurate, fast, and user-accessible human trait prediction suitable for real-world applications.

Figure 1 illustrates the end-to-end pipeline of the HumaniSense system for real-time age and gender prediction. The process begins with input acquisition in the form of either static images or video frames captured from a live camera. These inputs are forwarded to the face detection module, where the Haar Cascade classifier identifies and extracts facial regions from each frame or image. The detected face regions are then passed to the preprocessing stage, where they are resized to a fixed dimension, converted into grayscale, and normalized to ensure consistency and improve model performance.

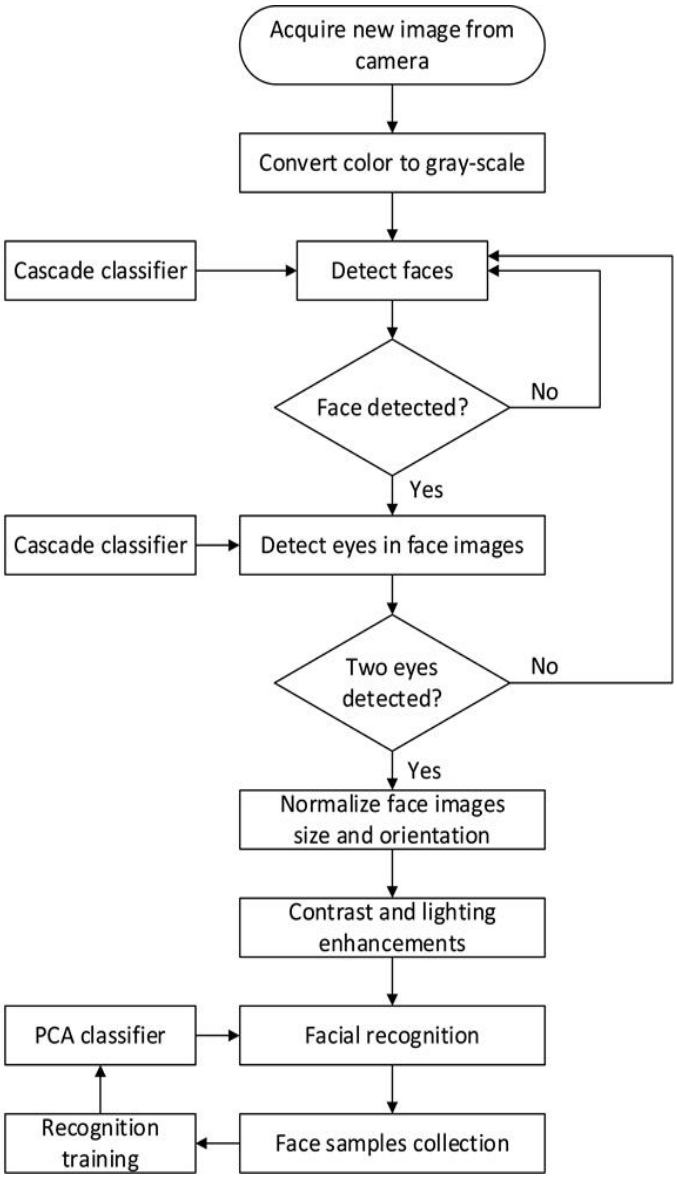


Figure 1 : Represent the Proposed Architecture

The preprocessed facial data is subsequently fed into a Convolutional Neural Network (CNN), which performs hierarchical feature extraction and generates predictions for age and gender. The model outputs are then processed to obtain meaningful results, including predicted age values and gender labels. Finally, the results are visualized on the user interface, where bounding boxes are drawn around detected faces along with the predicted attributes. This streamlined pipeline ensures efficient data flow, enabling accurate and low-latency predictions suitable for real-time applications.

V. IMPLEMENTATION RESULTS

The implementation of the HumaniSense system demonstrates the effectiveness of deep learning in real-time human trait prediction. The system was developed using Python with TensorFlow and Keras for the CNN model, OpenCV for face detection, and Flask for web-based deployment. Experimental evaluation was conducted using both static images and live webcam streams to validate system performance under real-world conditions.

The system successfully detects human faces from input images and video frames using the Haar Cascade classifier and processes them through the CNN model to generate predictions for age and gender. The graphical user interface provides an intuitive platform where users can upload images or activate live camera mode to obtain instant predictions. Bounding boxes are drawn around detected faces, and predicted attributes are displayed clearly on the interface.

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A. *Home Page*

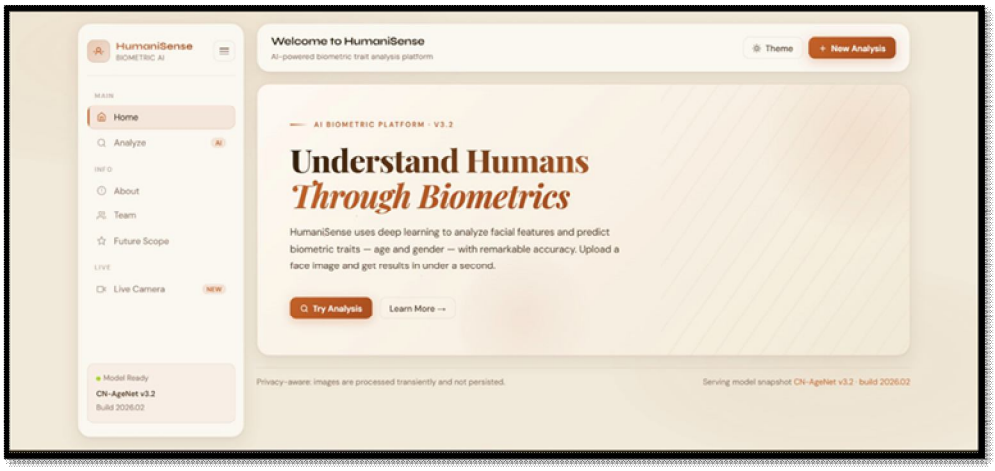


Figure 2: HumaniSense Home Page – Landing Interface

Figure 2 illustrates the Home Page serves as the landing interface for HumaniSense, presenting the system title, a brief description, and three feature cards highlighting the Upload Image, Live Camera. Two call-to-action buttons at the bottom provide direct navigation to the primary system functions

B. *Prediction Results Page*

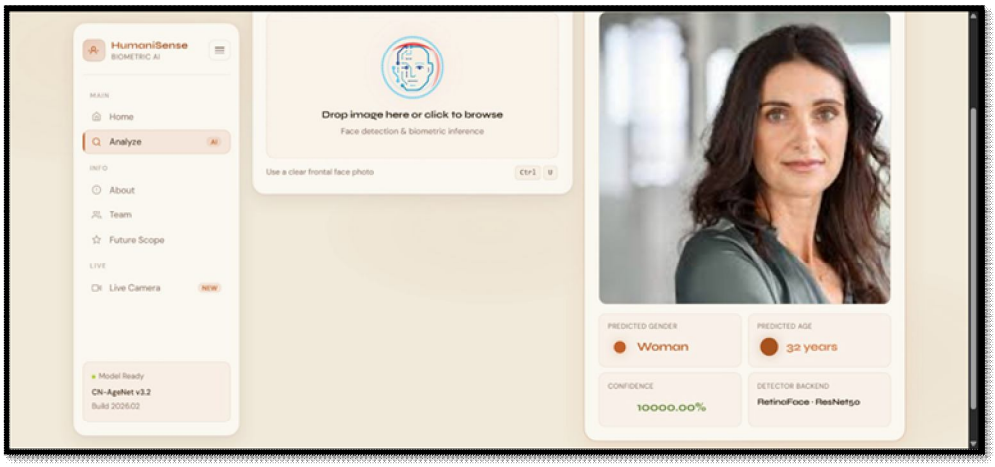


Figure 3: HumaniSense Prediction Results Page

Figure 3 illustrates The Prediction Results Page displays the output of the CNN model following successful face detection and analysis. The left panel shows the uploaded image with a green bounding box drawn around the detected face. The right panel presents the predicted age and gender in dedicated result cards, accompanied by horizontal confidence score bars for both predictions, processing time, and model version information.

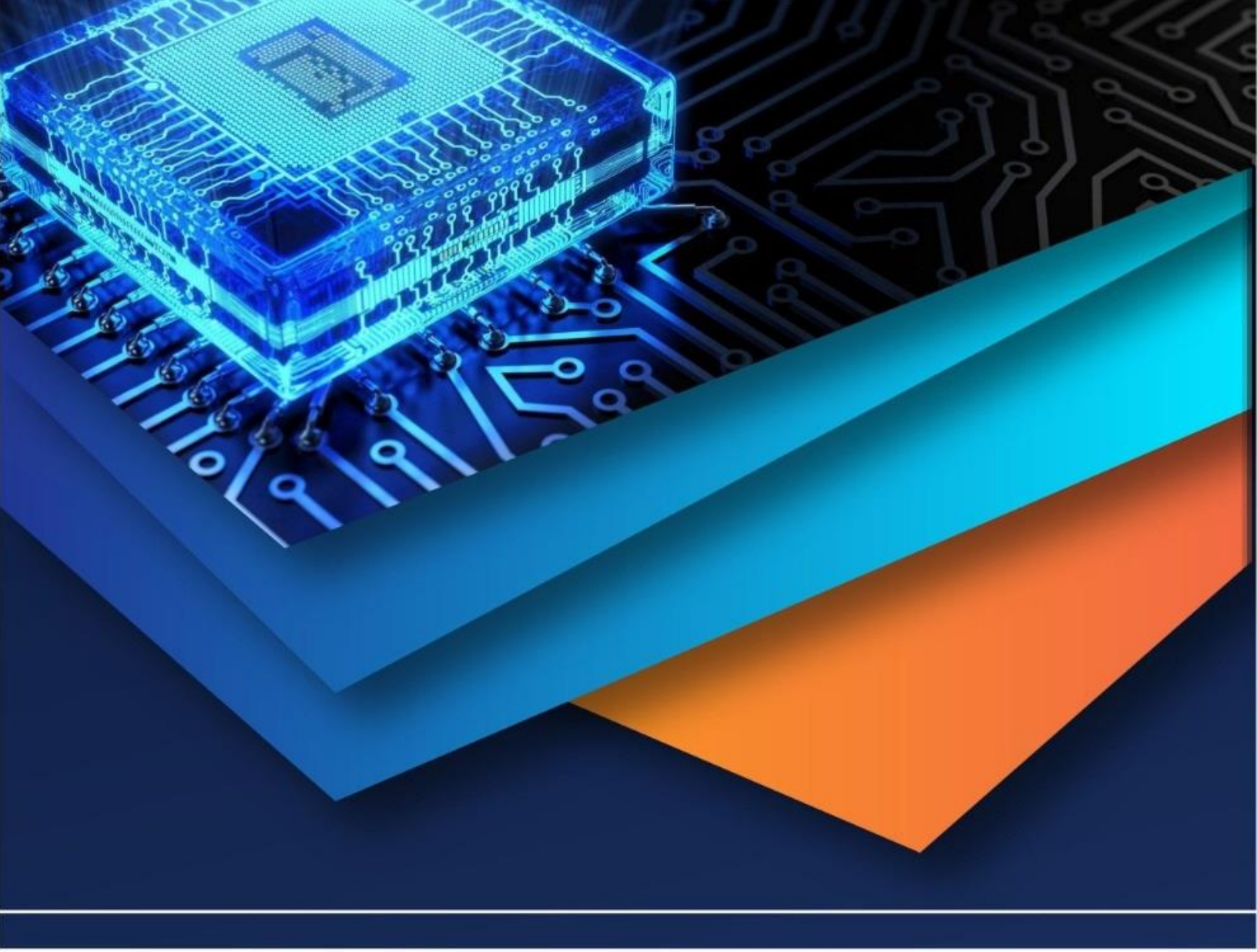
VI. CONCLUSION

This paper presented *HumaniSense*, an intelligent and real-time human trait prediction system designed for accurate age estimation and gender classification using Convolutional Neural Networks. The proposed system effectively integrates computer vision techniques with deep learning to overcome the limitations of traditional manual and feature-based approaches. By leveraging the UTKFace dataset and a multi-task CNN architecture, the system is capable of learning robust facial representations and delivering reliable predictions under varying real-world conditions. The implementation of a complete end-to-end pipeline, including face detection using Haar Cascade, preprocessing, and deep learning-based inference, ensures efficient and consistent performance. The deployment of the system as a Flask-based web application further enhances its usability by providing an intuitive interface for both static image analysis and real-time webcam-based prediction. Experimental

results demonstrate that the system achieves high gender classification accuracy and acceptable age prediction error while maintaining low latency suitable for real-time applications. Moreover, the system exhibits scalability by supporting multi-face detection and robustness through proper handling of edge cases such as missing or invalid inputs. Although minor limitations exist under extreme lighting conditions and non-frontal poses, the overall performance validates the effectiveness of the proposed approach. In conclusion, HumaniSense successfully bridges the gap between advanced deep learning research and practical deployment by delivering a user-friendly, accurate, and real-time human analytics solution. The proposed framework serves as a strong foundation for future enhancements, including emotion recognition, behavioral analysis, and integration with advanced deep learning architectures, thereby expanding its applicability across smart surveillance, retail analytics, and intelligent human-computer interaction systems.

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