iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** XII **Month of publication:** December 2025

DOI: https://doi.org/10.22214/ijraset.2025.76190

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue XII Dec 2025- Available at www.ijraset.com

A Study on Convolutional Neural Network and Face Recognition Techniques

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Abstract: Computer vision is a technology that helps computers understand images and videos just like humans do. Today, Convolutional Neural Networks (CNNs) are widely used because they can learn patterns from images very effectively by edges, shapes, and facial features from images. CNNs work through a series of steps that include filtering the image, picking out important information, and finally recognizing what the image represents. One of the most important uses of CNNs is face recognition, where a system identifies a person by studying key features of the face. This research paper explores how CNNs work, how they are used for face recognition, the benefits of using them, and the problems that still need to be solved. The main goal is to present these ideas in a simple and easy-to-understand manner for students, beginners, and researchers who are new to the field of computer vision.

I. INTRODUCTION

Computer vision is a way for gaining higher level understanding from digital images and videos. It takes ideas from many field including robotics, mathematics, statics and computer science. The main aim of computer vision is to interpret and understand the visuals for identifying people, name objects or geometry of things. Hence, it involves many tasks like image segmentation, object detection, edge and pattern detection, feature matching or facial recognition, etc.

Deep Learning have excellent abilities to learn and make decisions, just like human brain does. Deep learning is a branch of machine learning that uses networks inspired by the human brain to learn from large amounts of data. Learning can take place in a supervised, unsupervised or semi supervised environment. Supervised learning learns with labeled data. We have to provide input or the correct output and the model learns the mapping from it. While Unsupervised learning learn from unlabeled data and the model tries to find pattern and structure on its own. Whereas semi supervised learns from a few correctly marked examples along with many examples that have no labels.

II. CNN ARCHITECTURE

Deep learning is well known techniques that include convolutional neural network also known as ConvNet. CNN efficiently analyze and classifies images because of there deep design which contains convolutional layer for feature extraction and dimensionality reduction.

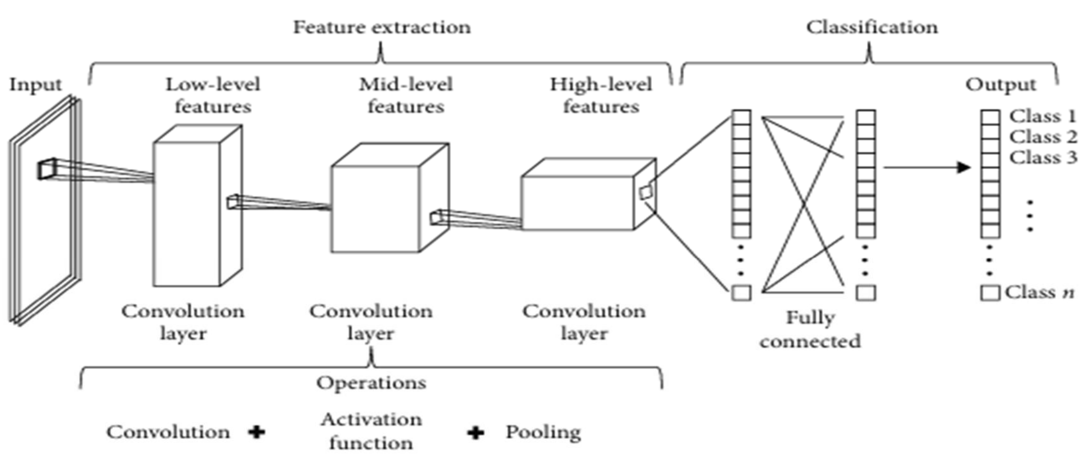

Figure 1: Basic CNN architecture for image classification.

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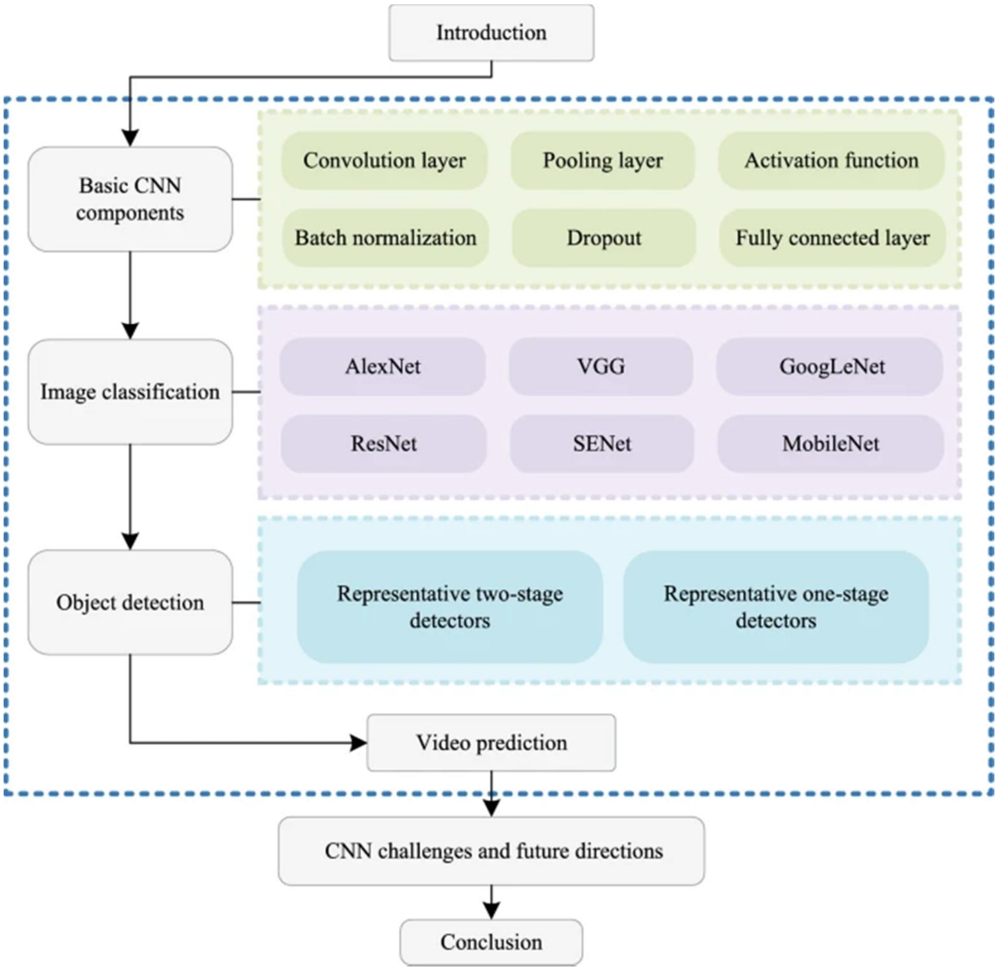
CNN model recognizes a face by passing the input image through different layers and then outputting the results. CNN have wide range of applications in real world domains such as the diagnosis of plant disease to protect agricultural crops, the detection of endangered species in complex natural environment and even help predict the 3D shape of proteins just by analyzing their amino-acid sequences. CNN are also utilized for monitoring water quality through biomonitoring techniques that use macro inverbates as environmental indicators. In the medical field, they support computed tomography analysis for breast cancer detection and assist in identifying facial phenotypes associated with genetic disorders. CNNs have best approach that generate outstanding approach on specific problems and has captured the attention of the computer vision community.



III. CNN BASIC OPERATIONS

CNN operation	Analogy	Purpose
Convolution	Looking through the small window scanning the image.	Detects Pattern like edges, lines and textures.
ReLU Activation	Removing negative or weak signal.	Keeps essential information only.
Pooling	Passes the largest value of the selection.	Reduces image size and keeps important details.
Flattening	Streching the picture into one long line.	Convert 2D images into 1D vector for final prediction.

IV. FACE RECOGNITION

Face Recognition uses distinct facial features for detecting to providing a high level of accuracy and security to identify individuals. Face Recognition act essential in the field of biometric authentication systems over the past decades. Face Recognition system have two main phases such as i) Face Verification and ii) Face identification.

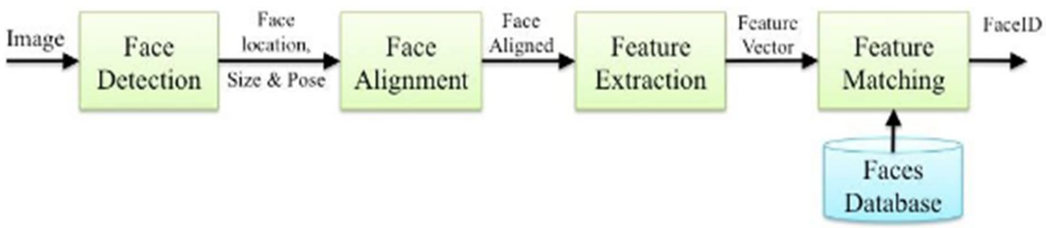


Figure 1. Face Recognition Processes Pipeline

The first phase detects the face matches to the correct identity and the second phase checks or figure out whether the detected face is stored in the database or not. Face verification ensures whether two facial images belong to the same person. It determines by comparing the feature extracted from the facial image and its features like mouth, nose, eyes, shape, texture and other facial parameter to confirm that they are similar enough to be consider the same person. Face recognition can be classified into two dimensional and three dimensional.

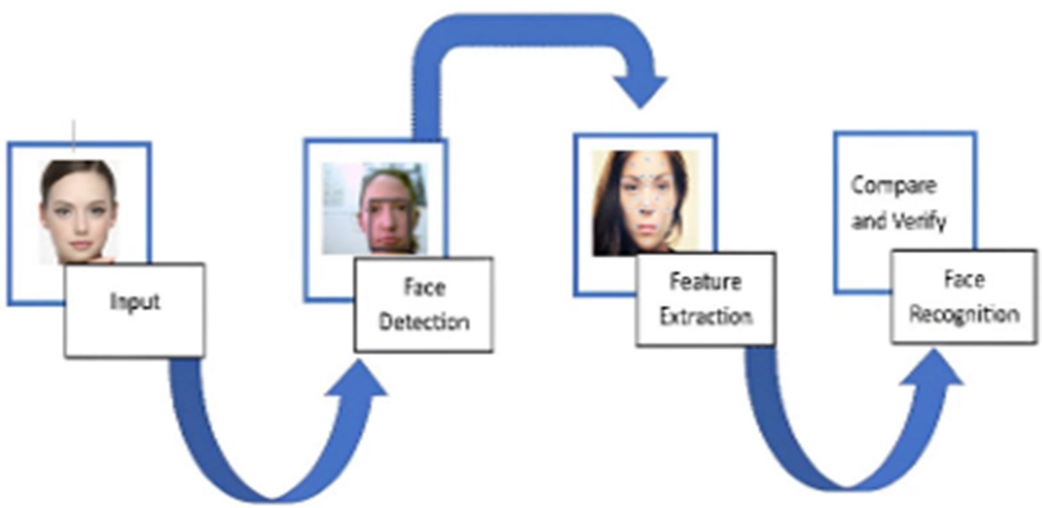


FIGURE 1. The workflow of a standard automated FR system biometric.

A. Face Detection

In any face recognition systems Face detection is the first step. The goal is simply to locate **where the face is** in a picture. Before the system identifies "who" the person is, it must first figure out **whether there is a face** and **where it is located**.

However, this process can become difficult because people may have different expressions, lighting may be too bright or too dark, and the face may be tilted or partially hidden. Some of the popular methods of face detection are like Viola -Jones Method, HOG (Histogram of Oriented Gradient), PCA (Principal Component Analysis), Color-Based Methods, etc.

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B. Feature Extraction

Once the face is detected, the next step is to extract important details that make each face unique. This is known as Feature extraction and there are basically two main ways to do this are global method and local methods. In global method the entire face is considered as a single unit and in local methods only important regions such as eyes, nose, mouth or other key points are analysed. It works better because they are less affected by Different face poses, aging, lightening and small changes in expression.

V. FACE RECOGNITION FEATURES

Application area	Description	Benefits	Challenges	New Technologies
Security &Surveillance	Used in CCTV camera building ,airports to identify people.	Safer places ,help stop crimes ,better-border security.	Privacy concerns.	More accurate face recognition cameras.
Retail and Marketing	Used in shops or malls to understand customer behaviour.	Better offer for customers, less shoplifting, improved shopping experience.	Customers may feel watched; raises privacy questions	Self -checkout stores using face recognition.
Education	Used in schools or colleges for attendance and exam monitoring.	Saves time, prevent exam cheating keeps record easily.	Student may feels monitored; system accuracy issues.	Smart classroom sending real-time attendance to parent and students.
Social Media	Used in apps to tag people in photos and organize pictures automatically.	Easy photo organizing, safer online interactions.	People may not want automatic tagging or tracking	Better privacy settings for face recognition features.
Healthcare	Used in hospitals to identify patients and access their reports.	Correct medical records, fewer mistakes, better treatment tracking.	Sensitive patient data needs strong protection.	AI systems that study a person's face to help with diagram.

VI. CNN LIMITATIONS

Even though CNNs (Convolutional Neural Networks) work extremely well for image classification and have improved a lot. Powerful hardware like GPUs, researchers have recently found several problems or weaknesses in CNNs. When a CNN fails to give good classification results, we say it has limited performance.

Here are the limitations of the CNNs model that we have grouped into following categories:

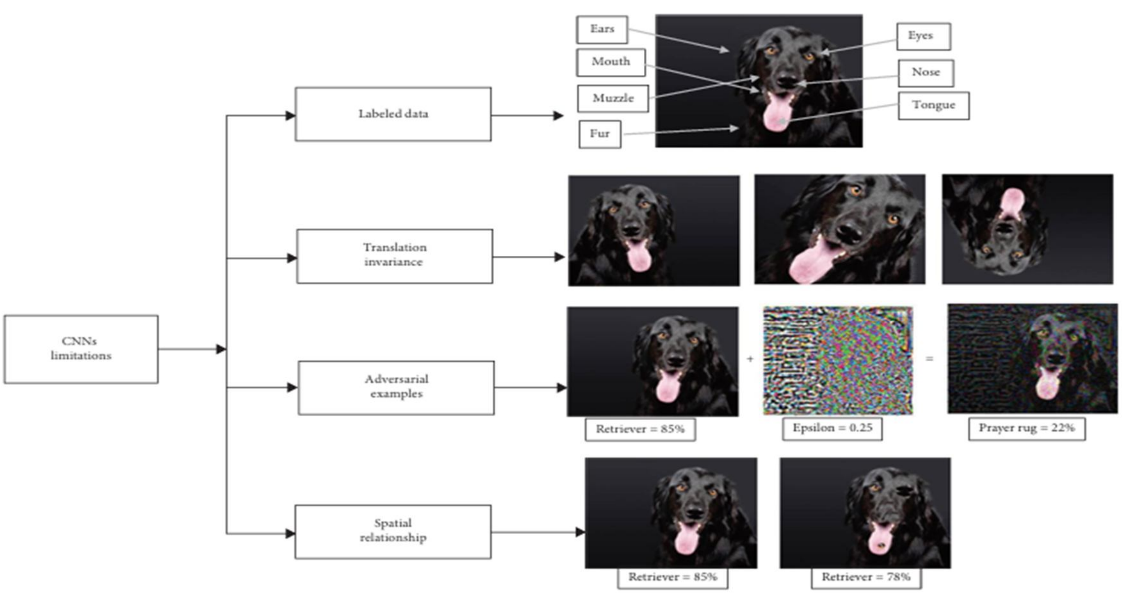

FIGURE 2: CNNs limitations with examples. It illustrates the four categories defined as CNNs limitations.

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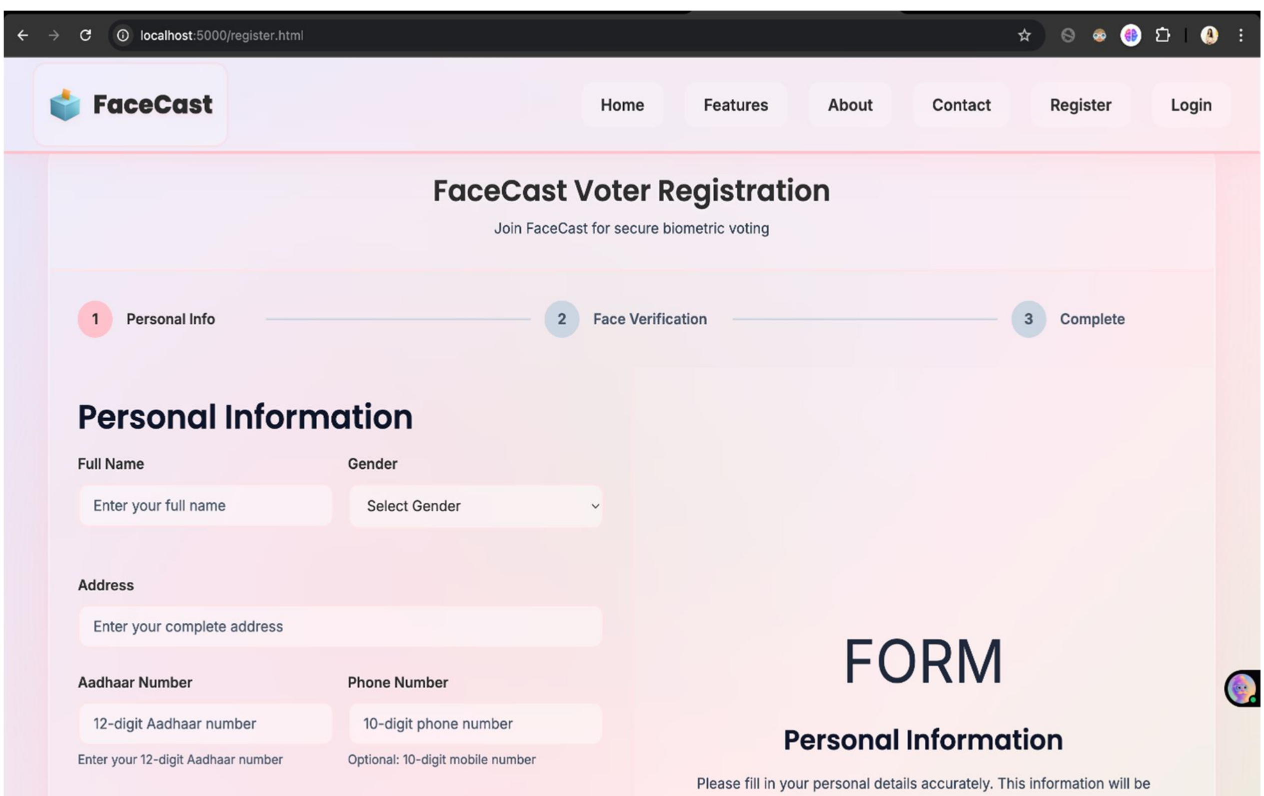
1) Labeled data: CNN models need a very large number of images that are already labeled by humans to learn properly. For example, if we want a CNN to recognize dogs, we may need thousands of dog pictures labeled as "dog". This labeling work takes a lot of time, money, and human effort. In real life, it is difficult to collect and label such huge amount of data, so CNNs struggle when labeled data is limited.
2) Translation invariance: CNN don't understand that an object stays same even if it is rotated ,flipped, moved to another position or slightly cropped in the image .For example ,if a CNN learns to recognize a dog in the middle For example, if a CNN learns to recognize a dog in the center of a picture, it might fail to recognize the same dog when it appears in the corner or turned sideways. Unless we train the CNN with many different versions of the same object, it will not perform well on these variations.
3) Adversarial examples: CNNs can be easily tricked by very small changes in an image so small that humans may not even notice them. These tiny changes, called adversarial attacks. They can cause the model to give a completely wrong prediction. For example, by adding a little noise or changing just one pixel, the CNN might think a picture of a dog is a cat. This shows that CNNs can be sensitive and unreliable when dealing with slightly altered input.
4) Spatial relationship: CNNs have difficulty to understand how different parts of an object are connected or arranged. They focus only on small local features, not on the overall structure. For example, a CNN may not understand that eyes must be above the nose in a face. It might still classify a scrambled image as a face because it sees familiar features but doesn't understand their correct positions. This means CNNs often ignore the bigger picture or the relationship between object parts.

VII. CASE STUDY

We have made project FaceCast where logic meets identity which is basically an online voting system with face recognition and OTP verification. As in traditional voting system people faces problem in casting vote as they have to stand in long line and there is risk of duplicate votes ,security as well so in our approach we address these problems by creating multi layered authenticated online voting system in which user has to mention there details with VoterId and facial image and when they login for casting vote it matches the credentials and send OTP to the registered mail and if the voter is valid then they can cast their vote and there is also an admin dashboard where they can create election ,manage candidate by adding them to the system ,manage positions and can view voting results.



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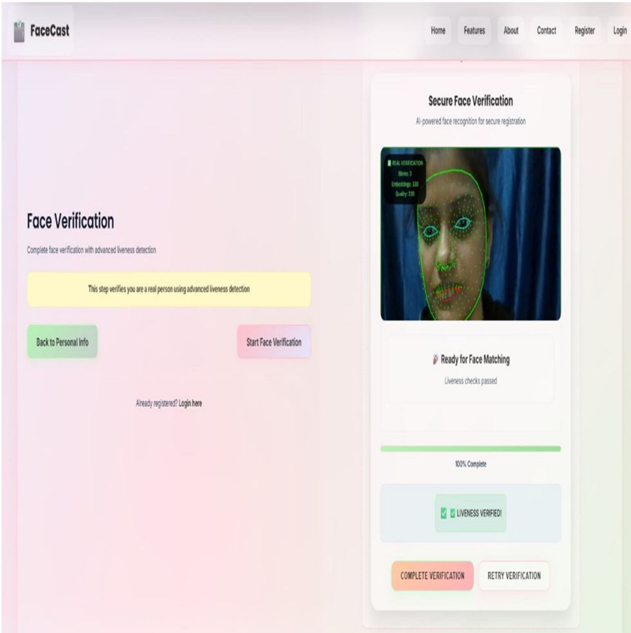

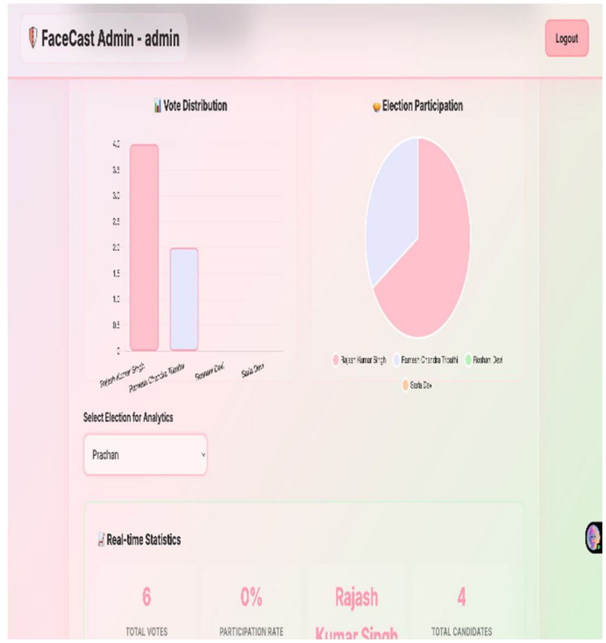

VIII. DISCUSSION

This research paper highlights how Convolutional Neural Networks (CNNs) help computers make sense of images and identify faces. From the findings, it is clear that CNNs are effective because they learn useful patterns from pictures on their own instead of depending on manual feature creation. The whole process, starting from finding a face in an image to identifying who the person is, depends on several steps working together. Each of these steps—face detection, feature extraction, and final recognition—adds to the accuracy and reliability of the system.

The discussion also shows that different face detection methods, such as Viola–Jones, HOG, and PCA, are helpful in spotting faces even when lighting or expressions are not ideal. Once the face is detected, feature extraction methods focus on capturing the essential characteristics of a person's face. These features make it easier to compare new images with stored ones and decide whether they match.

The study also highlights that face recognition technology is widely used today, from unlocking smartphones to increasing security in public areas. Although the results show strong potential, there are still challenges. CNNs require large amounts of labeled images to learn effectively, and their accuracy may drop when the face appears in different angles or lighting. They can also be fooled by very tiny changes in the image, which humans would not even notice.

Overall, this research emphasizes both the strengths and the limitations of CNN-based face recognition. While the technology is powerful and useful in many applications, there is still room for improvement, especially in handling varied conditions and protecting user privacy.

IX. CONCLUSION

In this research paper, we explored how Convolutional Neural Networks (CNNs) and face recognition systems work together to make computers understand human faces. CNNs learn from images by spotting patterns step by step, which makes them very effective for identifying people. The study covers how faces are detected, how features are collected, and how the final identification is made. Each stage contributes to building an accurate and dependable recognition system.

The paper also highlights how widely face recognition is used today, from improving security to simplifying everyday tasks like unlocking devices or marking attendance. These uses clearly show the growing importance of the technology. At the same time, the study points out that CNNs still face several challenges. They need a lot of labeled data to learn well, they struggle with changes in lighting or angle, and they can sometimes be fooled by very small changes in an image.

Overall, this research makes it clear that while face recognition powered by CNNs is highly useful, it is not perfect. There is still a need for systems that are more flexible, more accurate, and more secure. With ongoing improvements and smarter algorithms, these technologies will continue to evolve and offer even better performance in the future.

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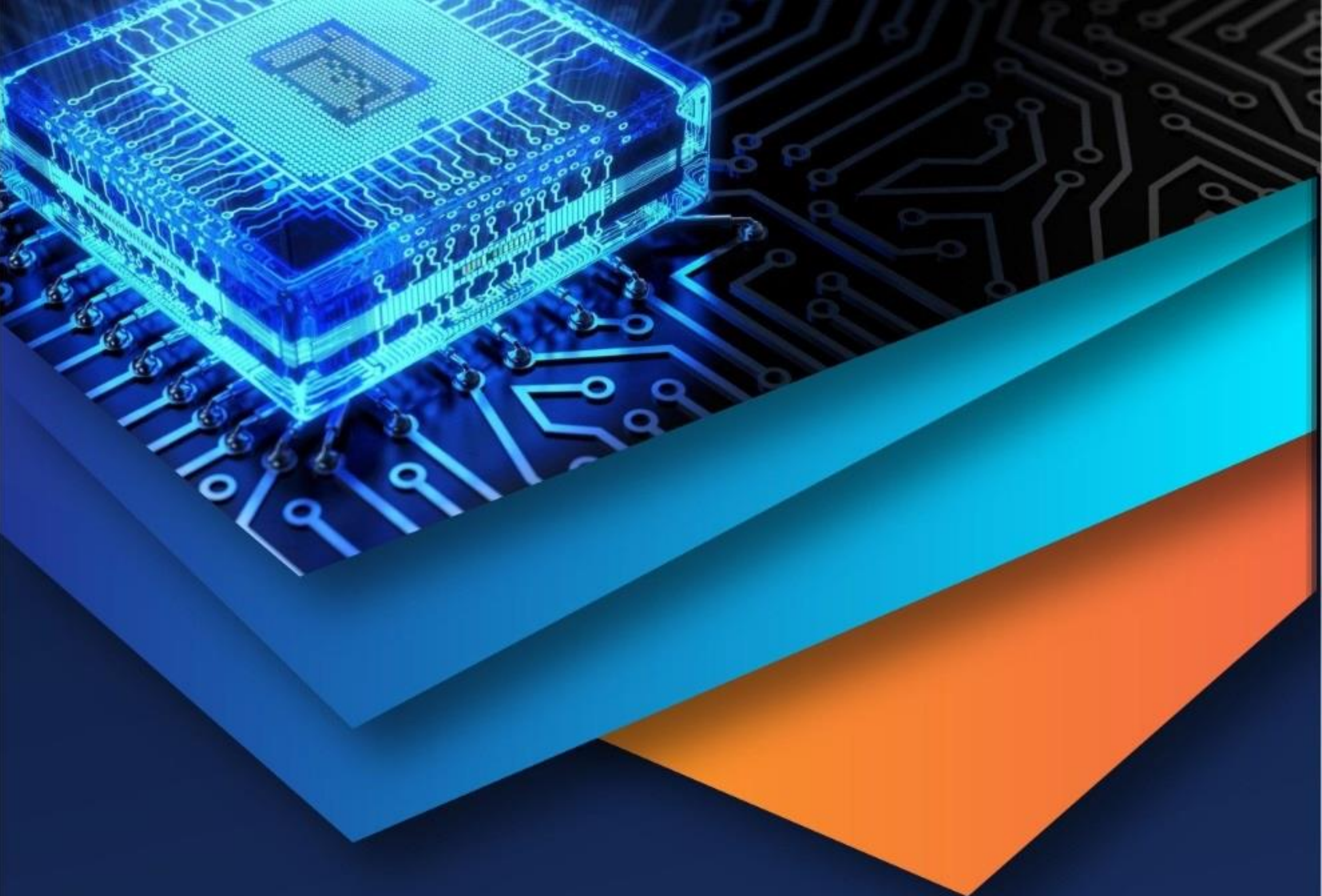

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