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Exploring the Challenges of Aadhaar based Face Recognition in Unrestricted Environments

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Abstract - Technology improvements have resulted in a high criminal rate, which has raised serious concerns about security-related issues. Face recognition can be used to identify people because every person tends to possess a particular attribute. One of the main applications of facial recognition is in the field of video surveillance. To reduce the increasing criminal rates, this technology is responsible for extracting features from the human face and further identifying them. The CCTV footage might also be used to identify suspects at a crime scene. However, the criminals would be found by recognizing and comparing the suspect's face to the database repository that would include data on people based on their Aadhaar card. Aadhaar photos can be used to identify and recognize faces in a facial recognition system since Aadhaar is a unique identification system in India and mandatory for every Indian resident. However, there are many challenges faced by Aadhaar based face recognition. Face recognition in uncontrolled environments like public surveillance faces significant challenges such as low-resolution images, pose variations, and masked faces. This paper highlights the challenges faced by Aadhaar enabled face recognition in surveillance scenes. This article aims to provide a brief survey of the Aadhaar-enabled face recognition system for criminal identification and recognizing individuals. There is limited work with the Aadhaar dataset due to privacy and security reasons. This article also emphasizes the difficulties that will be encountered in implementing facial recognition as well as strategies for enhancing it while taking various tradeoffs into account. It also recommends opportunities for further study in the application of facial identification in other fields.

***Key Words*:** Aadhaar, Surveillance, Face recognition, Criminals

1.INTRODUCTION

In recent years, facial recognition technology has evolved substantially, with applications in everything from security and surveillance to marketing and entertainment. Facial recognition technology has been widely embraced by Police and law enforcement authorities worldwide to identify and track suspects or criminals. With the rising crime rates around the globe, there is considerable demand for a robust and efficient surveillance system and face recognition. Due to the COVID-19 pandemic, it has been necessary to wear masks, but masked faces give criminals the ability to remain anonymous, which may help criminals escape being caught by surveillance cameras. Face masks contribute to a rise in crime such as street robberies. There was significant increase in crime rates in COVID-19 pandemic as surveyed in [1] . To recognize an individual in social security settings is difficult due to their deliberate camouflaging behavior. Many works have been done to recognize persons or criminals in unconstrained environments. National Crime Records Bureau (NCRB), of India is planning to utilize automated facial recognition system to store live images of suspects which will be used to verify the individuals with the existing database of criminals [2]. Delhi Police has implemented the AFRS to find the missing children and suspects. According to a news report, Bengaluru Police is expected to launch a face recognition system that will capture facial images from live CCTV footage, search for matches in the police criminal database, and compare them with pre-recorded video feeds from certain locations[3].

However, these systems use a pre-stored database of criminals, However, there can be circumstances when the suspect is not listed in the criminal database and has never been convicted of a crime. To tackle these situations, India ‘s national identification system Aadhaar can be used. Aadhaar is a unique identification system for all Indian residents which includes images, iris scans, and fingerprints of individuals.. As Aadhaar is mandatory for every resident of India, Aadhaar images can be used to identify and recognize faces in the facial recognition system. According to a former UIDAI executive, placing a camera that can record a person's image and body temperature in a public location and integrating it with the data from their Aadhaar card might be a game-changer in recognizing COVID-19-infected individuals [4]. Various researchers use Aadhaar images for face recognition such as online voting systems in biometrics. However, there is scarce research that uses surveillance videos and the corresponding Aadhaar images for face recognition. Surveillance systems use face recognition to verify identities by obtaining facial features and comparing them to stored templates, such as Aadhaar photos.

Surveillance systems often capture images in unconstrained conditions, which are of low resolution, taken at various angles, and may be occluded. These uncontrolled situations drastically reduce facial recognition systems' accuracy, so it's critical to modify the technology to handle such conditions. Despite being highly accurate in controlled settings, the Aadhaar base face recognition has significant challenges in these unconstrained settings. The main challenges in these real-world scenarios are low-resolution faces, pose variations, and occlusions caused by masks or other obstructions.

The following section of this paper will discuss prior studies and research that pertain to face recognition, with a particular focus on Aadhaar image and surveillance-based face recognition. Later, the issues and challenges encountered in the implementation of Aadhaar image-based face recognition are explored. Following that, a thorough discussion about these issues. In summary, the paper explores prospective areas for further research in its conclusion.

2. LITERATURE REVIEW

Identifying criminals in our country is mostly done by using their thumbprints or other biometrics. Some works use facial databases to recognize criminals and suspects. Table 1 represents the recent works on Adhaar image-based face recognition.

Fig 1: Feature matching Aadhaar image and probe image.

[5] proposed a method for masked face recognition that relies on person re-identification association. This method used a face-masked pedestrian dataset using actual CCTV photographs for the verification process.

[6] presented a study to automate crime detection using public and private CCTV cameras using face recognition systems and blockchain. The system identifies crime suspects by matching their faces with a database linked to their Aadhaar card information. The captured photos would be processed and sent to the police along with individual details, helping notify authorities about potential suspects.

[7] proposed a system that detects the faces from the video stream and matches them with Aadhaar images stored in a database.

The work proposed by [8] involves creating a cloud-based biometric authentication system using Microsoft Cognitive Face API. Additionally, it extends the system to verify registered users by comparing their images with their Aadhaar card photos.

[9] collected a voter database and an Aadhaar database. To allow any person to cast a vote the voter ‘s image with the database image and Aadhaar card ID number are compared. Table 1 showcases the summary of recent works on Aadhaar based face recognition.

Table 1: Summary of recent works of Aadhaar image-based face recognition.

Ref	Face recognition method	Input Dataset	Verification dataset	Accuracy	Limitations
[28]	Haar Cascade Classifier, Faceplib	FBI dataset of criminals	Video images, Aadhaar images, Childhood images	90%	Surveillance videos, Masked faces, and pose variation challenges not considered
[5]	MTCNN, ResNet50, FaceNet	Face-masked pedestrian images	Face unmasked pedestrian images	64.23%	Accuracy can be improved further.
[6]	OpenCV, OCR	CCTV videos	Aadhaar images	_	Masked face and pose variation challenges not considered.
[7]	OpenCV, Haar Cascade Classifier, ResNet	Live videos	Aadhaar images	99.38%	Surveillance videos, Masked faces and pose variation challenges are not considered.
[8]	Microsoft cogitative face API	Input images taken from the PC camera	Aadhaar images	92%	Surveillance videos, Masked faces, and pose variation challenges are not considered.
[9]	Haar Cascade Classifier, Eigen Faces	Image	Voter database and Adhaar database	97%	Surveillance videos, Masked faces and pose variation challenges are not considered.
[29]	YOMO, DCNN	video	Aadhaar database	77%	Surveillance videos, Masked faces and pose variation challenges are not considered.
[30]	OpenCV	CCTV videos	Criminal Database	80%	Masked face and pose variation challenges not considered.
[31]	OpenCV, Raspberry Pi	Real-time image	Citizen database	_	Surveillance videos, Masked faces and pose variation challenges are not considered.
[32]	CNN	video	Aadhaar database	90-95%	Masked face and pose variation challenges not considered.
[33]	ORB, FLANN	image	Aadhaar image	90%	Surveillance videos, Masked faces and pose variation challenges are not considered

3. CHALLENGES IN AADHAAR-BASED FACE RECOGNITION FOR UNRESTRICTED ENVIRONMENTS

Face recognition methods achieved remarkable accuracy. But in the case of surveillance-based masked face recognition or criminal recognition poses many difficulties and challenges like illumination, low resolution, occlusion, etc. This section

discusses the various challenges of Aadhaar image-based face recognition.

3.1 LOW RESOLUTION

Images captured by surveillance cameras are usually blurry and are of low resolution. Low-resolution images lack the key details of the face such as texture of the skin and essential facial features, which are critical for accurate recognition. Commercial cameras with standard resolution were used to take the photos used to create the Aadhaar Card. These cameras do not accurately reproduce photographs. It is quite challenging for face recognition systems to match a low-resolution image with an identity card image. Deep learning-based super-resolution networks attempt to generate high-resolution images from low-resolution inputs [10]. Coupled mappings are used by many reseachers[11], [12], [13] to map low resolution images to high resolution images for accurate facial feature extraction. Generative Adversarial Networks (GANs) and autoencoders have sown the promising results to enhance the resolution of facial images[14]. Some models utilize multiple scales or pyramidal representations to capture facial features at varying levels of resolution. However, these methods still face challenges with large datasets or operating in real-time surveillance environments, where the quality of images can vary widely.

Fig 2: Challenging Low resolution Images from SC face dataset[15] and TinyFace [16] dataset.

3.2 POSE VARIATION

Pose variations occur when individuals' faces are captured from different angles, such as when they are turning their heads or looking away from the camera. The standard face recognition models struggle to align and match faces under these conditions, particularly when comparing surveillance images with the frontal faces in Aadhaar records. Aadhaar images are front face images and surveillance images may have variations in face pose. It is challenging to recognize a person or spy in a crowded area or to identify terrorists and thieves in markets and public places using frontal face Adhaar images [17] . Techniques like 3D face reconstruction can synthesize different views of a face, allowing recognition from various angles that helps in pose invariant face recognition[18]. Several Deep learning models have been developed to normalize the pose variations[19] . These models learn to extract features robust to changes in head orientation. Pose aware feature extraction methods, including attention mechanisms, have been explored to reduce the impact of pose changes on recognition accuracy [20]. Despite these advancements, handling extreme pose variations remains a significant challenge in uncontrolled environments.

Fig 3: Pose invariant images from database of faces dataset[21].

3.3 MASKED FACE RECOGNITION

The widespread use of face masks, particularly during the COVID-19 pandemic, presents another significant challenge to face recognition systems. Masks obscure key facial features, such as the nose and mouth, which are important for accurate identification. Matching Aadhaar images, which typically feature full-face representations, becomes challenging when individuals wear masks. Some approaches [22], [23], [24]focus on recognizing faces using only the visible parts (e.g., eyes, forehead, or lower face) and crop the occluded part of the face. These methods are less accurate but still useful in many scenarios. Occlusion aware networks that are specifically designed to detect and handle occlusions have been proposed[25]. These networks focus on learning robust features that are less sensitive to occlusions. Face unmasking is another technique utilized for occluded face recognition [26]. However, these solutions often require extensive re-training of models or supplementary biometric data, which can limit their practical application in large-scale surveillance systems. The images captured by surveillance cameras typically have low resolution, making it challenging to accurately match Aadhaar and CCTV images.

Fig 4: Masked Face images from RMFRD dataset [27].

4. DISCUSSION

Surveillance-based face recognition can be effective in identifying criminals and finding missing children. Aadhaar card and CCTV image integration can provide heightened security and offer advantages like streamlined access control, automated attendance management, and enhanced crime prevention. Law enforcement agencies and police use criminal databases to find individuals. However, in the case of new criminals and those who are not listed in the database, Aadhaar can be a pinnacle for face recognition as it is mandatory for every resident of India serving as a

foundational element for accurate identification and authentication. The Crime and Criminal Tracking Network & Systems (CCTNS), a government-funded program, is also building a biometric database of criminals across the country and plans to interface with the Aadhaar database to better detect criminals[34]. The Punjab Artificial Intelligence System (PAIS), a face-recognition algorithm supported by artificial intelligence, is already being used by police officers in Punjab to apprehend criminals. By connecting it to Aadhaar data, they hope to significantly improve the precision and power of AI[34]. Only a few works in literature integrate surveillance and Aadhaar for face recognition. Masked face recognition is a huge challenge for surveillance-based face recognition. No work is found on masked faces in surveillance and Adhaar image-based face recognition. Moreover, images are of front faces only, so there might be challenges to posing invariant face recognition. Surveillance captured images are of low resolution and Adhaar images also do not possess high quality, then face identification might be a challenge. Machine learning and deep learning require huge amounts of data to perform well. Numerous real-world face recognition systems, such as those used in law enforcement, ID card identification, and airport surveillance, often operate under a single sample per person model due to constraints in storage capacity and privacy policies. In the case of a single image of Aadhaar face recognition the ML and DL models do not outperform. Pose, illumination and disguise variations of the face are challenging to forecast because there is only one sample to be trained. Aadhaar images could potentially serve as a valuable resource for face recognition to identify individuals. However, there are possible security and privacy concerns as the Aadhaar card is linked with personal bank accounts and many more services. Fraudulent websites and data exposures raise serious concerns for citizen data protection. To balance the need for law enforcement with strong security measures to secure sensitive biometric data, it is important to carefully evaluate granting police access to Aadhaar photos.

5. CONCLUSION AND FUTURE DIRECTION

This paper highlights the challenges faced in Aadhaar-based face recognition in unrestricted surveillance environments. Challenges such as low resolution, pose variations, and face mask occlusion significantly hinder the performance of current face recognition systems. While various solutions have been proposed, challenges remain in terms of generalization, real-time performance, and adaptation to Aadhaar-specific images. Future research should focus on improving the robustness of face recognition systems in uncontrolled environments, particularly by developing cross-domain models, enhancing mask detection capabilities, and integrating multi-modal systems. These advancements will be essential for the continued success of Aadhaar-based face recognition in surveillance applications.

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