Exploring Tongue Print as a Biometric Authentication Feature: A Promising Avenue

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Abstract. The tongue, situated within the oral cavity, presents a formidable barrier to imitation due to its unique and inaccessible nature. Its intricate characteristics, spanning shape, texture, and color, provide a rich vein of study for researchers. Investigations have unveiled a notable array of variations in both the ventral and dorsal aspects of individual tongues, underscoring the potential for leveraging these distinctions in authentication protocols. Furthermore, the process of extracting a tongue print is notably uncomplicated when the tongue is protruded from the mouth, adding to its viability as a biometric marker.

This paper embarks on a comprehensive review of prior endeavors in the realm of tongue print authentication methodologies. It scrutinizes various tongue print techniques employed and the establishment of comprehensive tongue image databases. By synthesizing and evaluating the existing body of research, this study endeavors to propel the evolution of tongue-based authentication systems forward. Our aim is to not only consolidate existing knowledge but also to illuminate potential avenues for future research and innovation in this burgeoning field of biometric authentication. Through this endeavor, we seek to contribute to the refinement and widespread adoption of tongue-based authentication technologies.

Keywords: Biometric Authentication · Lingual Features · Tongue Print

1 Introduction

In the world of information, the authentication of person has emerged as one of the most crucial procedures. Passwords, pins, or physical characteristics can all be used to identify and verify a person. Greek words for life and measurement, respectively, are bios and metron [1]. Due to their precision and uniqueness, biometric approaches are undoubtedly more effective for authentication than passwords and pins. Additionally, a password or pin could be lost, stolen, or accessed by someone using any of the above techniques. Biometrics, in contrast, are challenging to duplicate, cannot be easily stolen, falsified, or snatched. Consequently, a crucial authentication requirement is the biometric feature. Identification and verification are the first two steps in the authentication

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process. The degree of attention applied to identification and verification is different. Due to their uniqueness, physical characteristics of the object (human being, animal, etc.) that needs to be validated might be extremely important for the goal of authentication. A quick method of performing biometric authentication is to create a digital record of a person's physical characteristics and compare it to a database of numerous individuals. The software then analyses the input and returns a value by comparing a specific input point with the database.

Human physical traits have been used for authenticating purposes since the seventeenth century. Authentication can be done using physical cues including hand structure, stride, vein pattern, speech pattern, Deoxyribonucleic acid (DNA), signature, finger print, skin tone, iris pattern, and face recognition. Biometric authentication is the process of identification using these characteristics. However, these methods were not actually put to use until the early twentieth century. Beginning in the early twentieth century, police departments from many different nations began using fingerprints as an identification method to track down offenders.

2 Scope of Using Tongue Print as a Unique and Robust Biometric Feature

An attempt is made to investigate the scope of using tongue print as a means of identification. There are numerous internal and external aspects that could affect the characteristics of the various traits, including Hand structure, Vein Pattern, Voice Pattern, DNA, Signature, Finger Prints, skin colour, and Face Detection [2–4].

The fingerprint can be altered by operating it or by continual use in environments with high workloads [5, 6]. Advanced approaches can even be used to create DNA and speech patterns [7]. An iris scanner can recognise someone wearing spectacles. A variety of environmental factors, such as sunlight and chemical interaction with the skin, can affect skin colour.

Face pattern recognition needs a lot of photos, powerful computing power, and time. A person's voice can alter due to illness, such as a throat infection, or due to laryngeal surgery. Over time, the signature might alter. The shape and other physical characteristics of the tongue do not change throughout time. Additionally, because it is contained inside the mouth, it is hard to forge and is naturally shielded from outside environmental influences. On the other hand, the tongue is distinctive in terms of its shape, surface structure, and papillae colour [8]. It has been demonstrated that every person, including identical twins, has unique information on their tongue's dorsal surface [2]. The different shapes of tongue from the frontal and profile view are shown in Figs. 1 and 2 respectively. Some sample tongue's frontal surface with different textures is shown in Fig. 3.

Both static and dynamic data on the tongue can be used for authentication. Being a sensory organ, it contains a wealth of information in its ventral, dorsal, and lateral parts that can be easily gathered by extending it from the body for examination [2]. The Traditional Chinese Medicine (TCM) has demonstrated that the above-mentioned characteristics of the tongue change as a result of diseases [9], and as a result, the various attributes of the tongue's like shape, surface structure, and colour carry enormous information about one's health and can be used in the detection of various diseases. In

Fig. 1. Shapes of tongues from the frontal view [10]

Fig. 2. Shapes of tongues from the profile view [10]

Fig. 3. Tongues with different textures [10]

TCM, the majority of research is focused on chromatic feature extraction [11, 12]. Additionally, personal authentication can be done via tongue recognition [13].

To determine if the tongue may be utilised as a characteristic of humans for biometric authentication, Omer A. Musa et al. conducted an experiment [2] on 50 individuals, including 20 identical twins (40 individuals) and 10 generic individuals of varied ages and gender. Digital cameras were used to take pictures of each person's tongue, and then a specific portion of each picture was chosen for papillae examination. ASCII generator-2, a computer programme that produces high-quality ASCII art-text made up of letters and digits, was used to evaluate the photos. Additionally, it produces graphs that represent the original photos.

Nadeem Jeddy et al. [9] investigated the morphological characteristics of the tongue in 20 participants, including people of various gender (12 males & 8 females). It is demonstrated that the lingual imprints of the dorsal region of the tongue may be successfully captured using the alginate technique. The shape, presence of fissures, and pattern of their distribution were examined by taking digital photos and casting the front and back portions of the tongue using Type-II dental stone. After examining by two observers, it is concluded that every individual had fissures. These fissures could be central, vertical, horizontal, many, or vertical central in type. Female individuals frequently had a vertical fissure, but male participants frequently had several fissures. Unlike males, who have shallow nature fissures, females have deep nature fissures. Majority of tongues in both

males and females were U-shaped, with the exception of a few female participants who had V-shaped tongues with sharp tips as shown in Fig. 4.

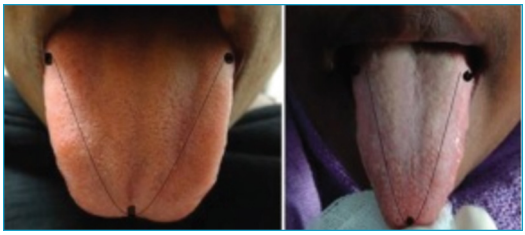

Fig. 4. Reference points for determining the shape of the tongue [9]

Corina Laura Stefanescu et al. [8] examined the lingual structural traits and their vitality as a key element in employing for authentication. Authors studied 270 males and females between the ages of 21 and 40. Casts were created using IV dental stone and alginate impressions of the subjects' dorsal surface and lingual lateral borders. The experimental results showed that there are 0.7% participants have scrotal type tongue and 0.3% have geographic tongue of total participants especially in female category as shown in Figs. 5 and 6. Also, results revealed that 1% participants have a visible fibrous belt in the lingual tip area.

Fig. 5. Geographic tongue aspect in 23 years of female subject [8]

Fig. 6. Scrotal tongue aspect in 25 years of female subject [8]

To improve the effectiveness of the tongue print authentication system used in banking systems, Sowmya Suryadevara et al. [14] employed Visual Cryptography method

that combined with tongue print. The Visual Cryptography System (VCS) decrypts data using only the human visual system; a decryption algorithm is not necessary. Digital camera photos of the tongue are combined with visual cryptography to create a tongue code. For the purpose of authentication, this tongue code will be compared with the database held on verification servers together with the customer identification number (CIN) that the user would input while accessing the automatic teller machine.

Authors in [15] showcased the dorsal surface of the tongue found that it exhibits sexual dimorphism, which can be used as an additional trait for identification. Authors used the tongue's liveliness, colour, shape, moisture content, and mobility as analysis criteria while carrying out the trials. Authors research showed that the scrotal and geographic tongues of women were shorter and wider than those of men. Males possessed a septate tongue, whilst females had a pointed tip. Additionally, studies highlighted how the orientation of the tongue's muscle fibers differs between males and females.

Ryszard S. Choras [16] proposed the colour and texture of the tongue are integrated with other biometric parameters in a tongue-based recognition system. A sensor, a feature extraction module, a biometric database, a matching score module, and decision-making modules made up the system the author proposed. To identify the tongue, a colour feature and the Gabor filter were coupled for feature extraction.

3 Methods of Printing Tongue

There are various method of tongue printing. The alginate moulding process, which produces a finely detailed tongue structure is a reliable method for modelling the structure of the tongue's surface. This type of process is hown in Figs. 7 and 8. The aspect of tongue mould is shown in Fig. 9.

Fig. 7. Female Subject [8]

Alginate stands out as an elastic hydrocolloid impression material, essential for dental procedures. These impressions, once set, become integral to indirect restorations. Widely utilized in dentistry, alginate offers a straightforward, economical, and indispensable solution for dental practices, making it a cornerstone of dental care. For making perfect alginate impressions on the initial attempt need a skilled professional to ensure the consistent, predictable impressions, thereby minimizing the need for repeat impressions or restorations.

Fig. 8. Applying alginate on the surface of the dorsum tongue from the level of the oral commissures up to the lingual tip including edges [8]

Fig. 9. The aspect of the tongue mold [8]

In a technical method, 3-D examination of the tongue structure can be performed to determine its precise shape and texture [14].

The tongue print imaging system technique is used for taking pictures of the tongue operates as shown in Fig. 10.

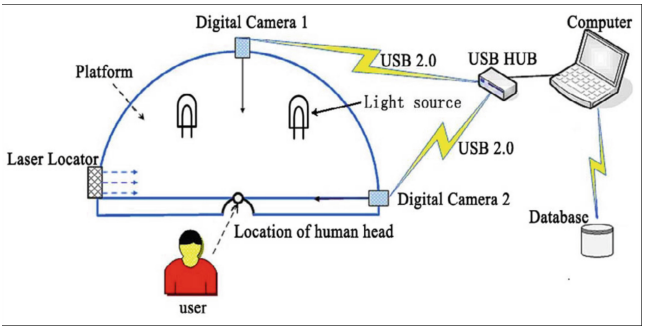

Fig. 10. Tongue-print imaging system setup [17]

The apparatus depicted in Fig. 11 can be used to acquire the tongue image. A digital computer that can automatically correct colour and hue as well as any positional changes

brought on by camera conditions has been developed as a consequence of research advancements [18]. It then validates the information with the database. For the analysis, a video streaming of the tongue can be captured which can be divided into frames or pictures.

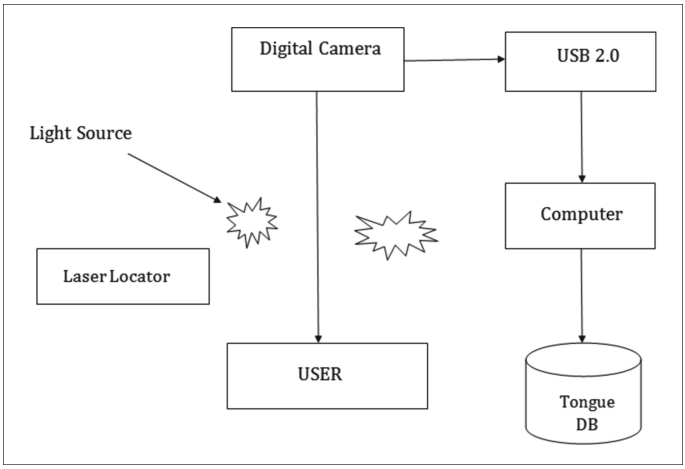

Fig. 11. Tongue Capture Technique (TCT) system setup [18]

The reviewed literature provides valuable insights into the advancements of tongue print recognition technology for biometric authentication. Zhang [10] proposed a method based on enhanced deep features and spatial attention mechanism for tongue biometric recognition, enhancing accuracy and robustness. Sadasivanet al. in [19] introduced a novel approach using Convolutional Neural Networks (CNNs) for tongue print recognition, demonstrating promising results in terms of accuracy and efficiency. Das et al. [20] presented a tongue print recognition system utilizing CNNs for biometric authentication, highlighting its effectiveness in security applications. Sufian and Mahmood [21] explored the emerging use of tongue biometrics as a security solution in IoT environments, emphasizing its potential in enhancing system security. Additionally, Ahmed Shallal Obaid and et al. [22] focused on deep learning-based tongue print recognition, showcasing its applicability and effectiveness in biometric authentication. These papers collectively contribute to the growing body of research on tongue print recognition, showcasing its potential as a reliable biometric authentication method.

Other methods include sublingual vein analysis, an ultrasound method that uses an ultrasonic sensor for sublingual analysis [23], and histological analysis, which can be utilised for tongue analysis.

The characteristics of the biometric feature have been described by [13]. One of the aforementioned biometrics could be deemed perfect if it demonstrates the qualities listed below:

1. Uniqueness: It must be specific to that person.
2. Robust: Consistent over time for a specific person.

3. Availability: Multiple or replicated images ought to be accessible.
4. Accessibility: It is the number of people processed in a given amount of time.
5. Acceptable: The action must be conducted with the user's or participant's approval.

4 Tongue Print Verification

The Fig. 12 shown below illustrates the model developed for the tongue print verification which includes acquired tongue images data set used as training data for the model. These images are pre-processed and is analysed to study the texture and shape of the tongue. Further, when the biometric authentication is to be done, the test image is captured in real-time and same procedure is repeated as that of while training the data set. Both the images are matched and matching score for shape vector and texture code is recorded. Bothe the images are fused to extract maximum information and matching decision is done based on the predefined threshold.

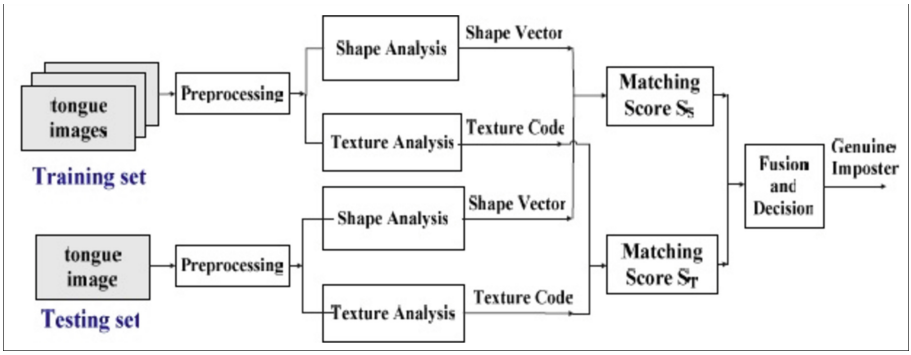

Fig. 12. The block diagram of tongue-print verification procedure [10]

The mathematical model for tongue print verification can be developed as below:

Tongue Image Acquisition: By using the imaging devices such as cameras or specialized tongue scanners, high-resolution images of the tongue are to be captured. While capturing the images, consistent lighting conditions and camera settings for accurate image acquisition is ensured. Thus, the set of training images is produced.

Preprocessing: Preprocessing techniques are applied to trained data set to enhance the quality of the acquired images. This may involve noise reduction, contrast enhancement, and normalization to standardize image characteristics. Let$I(x,y)$ be the acquired tongue print image, where x and y are the spatial coordinates. Pre-processing involves noise reduction and contrast enhancement. This can be represented by Eq. (1).

$$I\text{pre}(x, y) = \text{Preprocess}(I(x, y)) \tag{1}$$

Feature Extraction: Distinctive features from the processed tongue images can serve as unique identifiers. These features may include the shape, texture, color, and spatial distribution of papillae and other anatomical structures on the tongue surface. It can be expressed with help of a function given by Eq. (2).

Let F represent the set of extracted features then,

$$F = \text{ExtractFeatures}(I\text{pre}(x, y)) \tag{2}$$

These extracted features can be represented mathematically, asan example, if texture fea-tures are extracted using a histogram-based approach, we can represent it as a histogram vector given in Eq. (3).

$$\text{Texture\_hist} = [h1, h2, ..., hi] \tag{3}$$

where, hi represents the frequency of occurrence of the ith texture pattern.

Feature Matching: To compare and match tongue print features for authentication pur-poses, let us use a similarity metrics such as Euclidean distance, cosine similarity, or correla-tion coefficients to quantify the similarity between feature representations extracted from different tongue images. To extract features such as texture, shape, and color from the pre-processed tongue print image, Let F represent the set of extracted features, so Eq. (4).

$$\text{F} = \text{ExtractFeatures } (Ipre(x, y)) \tag{4}$$

Compares the extracted features of the query tongue print with those in the database using a similarity measure with Euclidean distance given by Eq. 5:

$$\text{Distance} = \sqrt{\sum_{\text{i=1}}^{\text{n}} \left(\text{F}_{\text{query}}^{\text{i}} - \text{F}_{\text{database}}^{\text{i}}\right)^2} \tag{5}$$

After matching the features, decision of detection can be taken as by setting a threshold T to determine if the test tongue print matches any entry in the database as given by Eq. (6),

$$\begin{aligned} \text{Authentication} = \ & \text{Authenticated} \ \ldots \text{if Distance} \ < T \\ & \text{NotAuthenticated} \ \ldots \text{otherwise} \end{aligned} \tag{6}$$

Image Fusion: To enhance the robustness and security of the tongue print biometric system, trained and tested image which have met the matching score are fused to extract the maximum information which can conclude the biometric authentication. Further, the methods like data encryption, error correction codes, and anti-spoofing measures to mitigate potential security threats can be added to ensure the reliable authentication performance. Decision level fusion uses the information that has been obtained by processing the input images as input to the fusion algorithm, where the information is merged using decision rules [24]. The most often used form of fusion is the pixel level since it is straightforward to use and less likely to result in artifacts in the fused image than a feature or decision level fusion approach. Image fusion offers a variety of benefits, such as decreased uncertainty, improved spatial and temporal coverage, greater dependability, and improved system performance resilience. The main challenge of picture fusion is deciding which approach to use for combining the many source images. Three essential qualities: high computational efficiency, maintenance of high spatial resolution, and reduction of color distortion should be present in a flawless image fusion technique.

5 Results and Discussions

Digital images are taken with the identical lighting and location for all participants which can be used to create a database of tongue prints for examination. A comprehensive dataset of tongue images collected from diverse individuals are used to validate the mathematical model. The performance of the model is evaluated in terms of accuracy, speed, and resilience to variations in tongue appearance and environmental conditions.

The database has been created which includes personal information and tongue photo of participants. It is observed through experimentation that males have longer and wider measurements of tongue than females. Additionally, both in the identical twins and in other participants, the tongues were visually different. The ASSCI generator tool revealed that each participant has a unique tongue anatomy as shown in Fig. 13 [2].

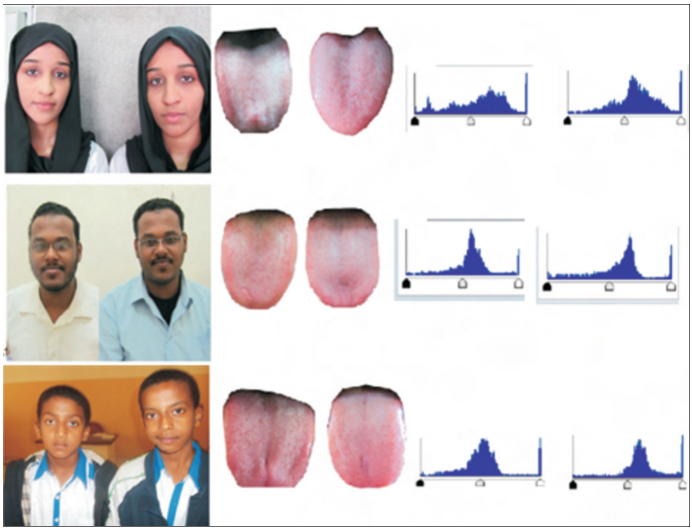

Fig. 13. Identical twin with tongue surfaces and their histograms by ASCII generator tool [2]

So, it is interpreted that the tongue shape and surface vary with each person including the identical twins & tongue can be used as a significant tool for authentication purpose.

6 Conclusion

The human tongue's static and dynamic characteristics can be utilised for authentication because they vary from person to person. According to research, tongue traits are sexually dimorphic. Additionally, the characteristics of the human tongue differ in identical twins and even in individual. Utilizing 3-D imaging and alginate molding techniques, collecting and building databases of tongue prints is now a simple process. Tongue prints are a versatile biometric feature that can be used alone for authentication or in conjunction with other biometric features to increase security in a variety of settings. Though it

should have been, tongue print authenticity has not yet been proven, it has far greater promise because a tongue print carries a wealth of data that can be utilised to authenticate a person.

References

1. Siddhesh, A., Reema, B., Hemli, C.: Biometrics: a Further echelon of security. Biomed. Eng. J. 375–379 (2005)
2. Musa, O.A., et al.: Tongues: could they also be another fingerprint. Int. J. Foren. Med. Toxicol. **1**(8), 171–175 (2014)
3. Patil, R.R., et al.: Qualified scrutiny for real-time object tracking framework. Int. J. Emerg. Technol. **3**(11), 313–319 (2020)
4. Vaidya, O.S., et al.: Embedded vision based cost effective tele-operating smart robot. Int. J. Innov. Technol. Explor. Eng. **7**(8), 1544–1550 (2019)
5. Phade, G., et al.: A novel ICT tool for interactive learning for electronics engineering based on augmented reality. Int. J. Sci. Technol. Res. **8**(8), 1886–1893 (2019)
6. Maltoni, D., et al.: Handbook of Fingerprint Recognition. 1st edn. Springer, New York (2003)
7. Lewis, R.: DNA (Deoxyribonucleic Acid) fingerprints: witness for the prosecution. Discover **9**(6), 44–52 (1988)
8. Corina Laura Stefanescuetal: Preliminary study on the tongue-based forensic identification. Roman. Soc. Legal Med. **22**(4), 263–266 (2014)
9. Jeddy, N., et al.: Tongue prints in biometric authentication: a pilot study. J. Oral Maxillo. Pathol. **21**(1), 176–179 (2017)
10. Zhang, D., Liu, Z., Yan, Jq., Shi, Pf.: Tongue-print: a novel biometrics pattern. In: Lee, SW., Li, S.Z. (eds.) Advances in Biometrics. ICB 2007. Lecture Notes in Computer Science, vol. 4642. Springer, Heidelberg (2007). https://doi.org/10.1007/978-3-540-74549-5_122
11. Li, C.H., Yuen, P.C.: Tongue image matching using the color content. Patt. Recogn. **35**(2), 407–419 (2002)
12. Li, W., et al.: The separation framework of tongue coating and proper in traditional Chinese medicine. In: Proceedings of the 7th International Conference Information, Communications and Signal Processing, Macau, pp. 1–4 (2009)
13. Jain, A.K., et al.: Biometrics: Personal Identification in Networked Society. Kulwer Academic, London (1999)
14. Suryadevara, S., et al.: Visual cryptography improvises the security of tongue as a biometric in banking system. In: International Conference on Computer and Communication Technology. IEEE, Allahabad (2010)
15. Radhika, T., et al.: Tongue prints: a novel biometric and potential forensic tool. J. Foren. Dental Sci. **8**(3), 117–119 (2016)
16. Choras, R.: Bydgoszcz: Biometric identification through tongue texture measurements. Int. J. Comput. **1**, 73–77 (2016)
17. Liu, Z., Yan, J.-Q., Zhang, D., et al.: A tongue-print image database for recognition. In: Proceedings of the Sixth International Conference on Machine Learning and Cybernetics. IEEE, Hong Kong (2007)
18. Naaz, R., et al.: Tongue image extraction technique from face and its application in public use system (Banking). In: International Conference on Communication Systems and Network Technologies. IEEE Computer Society, Rajkot (2012)
19. Sadasivan, S., et al.: Tongue print identification using deep CNN for forensic analysis. J. Intell. Fuzzy Syst. Appl. Eng. Technol. **38**(5), 6415–6422 (2020)

20. Das, A., Bhattacharya, A., Basu, S.: Tongue print recognition using convolutional neural network for biometric authentication. In: Proceedings of the 2023 6th International Conference on Inventive Computation Technologies (2023)
21. Sufian, A.B., Mahmood, A.N.: Tongue biometric system: an emerging security solution in IoT environment. Int. J. Adv. Comput. Sci. Appl. **14**(6), 525–531 (2023)
22. Obaid, A.S., Kamil, M.Y., Hamza, B.H.: People identification via tongue print using fine-tuning deep learning. Int. J. Reconfig. Embed. Syst. **3**(12), 433–441 (2023)
23. Menard L et al.: Measuring tongue shapes and positions with ultrasound imaging: A validation experiment using an articulatory model. Folia Phoniatr Logop, (2012)
24. Bhatambarekar, P., et al.: Advancements in spatial domain image fusion: a comprehensive review and comparative analysis of techniques. In: International Conference on Deep Learning, IoT, Drone Technology, Smart Cities and Application, Nashik (2023)