Biometrics Systems Challenges in a Post-COVID-19 Pandemic World: A review

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Abstract: One of the most serious health disasters in recent memory is the COVID-19 epidemic. Several restriction rules have been forced to reduce the virus spreading. Masks that are properly fitted can help prevent the virus from spreading from the person wearing the mask to others. Masks alone will not protect against COVID-19; they must be used in conjunction with physical separation and avoidance of direct contact. The fast spread of this disease, as well as the growing usage of prevention methods, underscore the critical need for a shift in biometrics-based authentication schemes. Biometrics systems are affected differently depending on whether are used as one of the preventive techniques based on COVID-19 pandemic rules. This study provides an overview of biometrics systems and approaches in the post-COVID-19 pandemic. The fundamental COVID-19 prevention rules are first reviewed. The relationships between each regulation and the biometrics that may be impacted are then thoroughly investigated. Recommendations for future trends of feasible approaches are provided to assist researchers in advance and enhance the performance of the biometric system for the post-COVID-19 pandemic environment.

Keywords: COVID-19 pandemic, prevention, biometrics, contact-based, contactless.

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1. Introduction

The COVID-19 pandemic has affected the world life dimensions without any clear prediction of the end of its long-term effect. However, the technology could help to overcome the pandemic consequences to the lowest level like biometric systems, which are considered an essential factor of any country's security system [1][2].

Conceptually, biometric systems work by individual data acquisition, feature extraction, and then template comparison. They are secured trusted systems for individual identifications depending on several behavioral and physiological human characteristics such as iris, gait, and keystroke [3]. The covid-19 social distancing scenarios have harmed the majority of biometric systems. Many of these required a long capture time or surface contact, resulting in rapid virus dissemination [4]. Thus, there is an urgent need to investigate the impact of the Covid-19 epidemic on biometric data.

Only one prior non-peer-reviewed study [5] looked into the impact of the COVID-19 pandemic on biometrics systems. It investigated the impacts of wearing masks on biometric systems, which was insufficient to cover the majority of the COVID-19 effects. However, this work could be expanded to encompass additional variations of COVID-19 effects on different biometric data, to accelerate the time for developing accurate biometric systems in the face of the COVID-19 pandemic. The structure of the remaining paper is as follows: Sections 2 and 3 demonstrate the work motivations and contributions and search strategy, respectively. Section 4 discusses COVID-19 transmission and prevention methods. The relations between COVID-19 prevention rules and biometrics systems are reviewed in Section 5. Recommendations for the possible future directions of biometrics systems in the post-COVID-19 world are listed in Section 6. Finally, work conclusions are presented in Section 7. However, when beam-column joints were severely damaged, in many cases observed or reported building failures may happen as shown in Figure 1.

2. Work Motivations and Contributions

In the aftermath of the COVID-19 pandemic, traditional biometrics systems have faced new challenges. Furthermore, insufficient reviews and surveys have been conducted to investigate the impact of this pandemic on the performance of biometrics systems.

As a result, the purpose of this paper is to pave the way for defining emerging challenges and making recommendations for some potential solutions to the challenges encountered in biometrics systems.

The following contributions are made in this article:

1. It discusses and analyzes the impact of COVID-19 prevention strategies on biometrics systems.
2. It examines some of the existing biometrics systems that were created in response to the COVID-19 pandemic's challenges to biometrics systems.
3. It discusses current challenges and future research directions for biometrics systems.

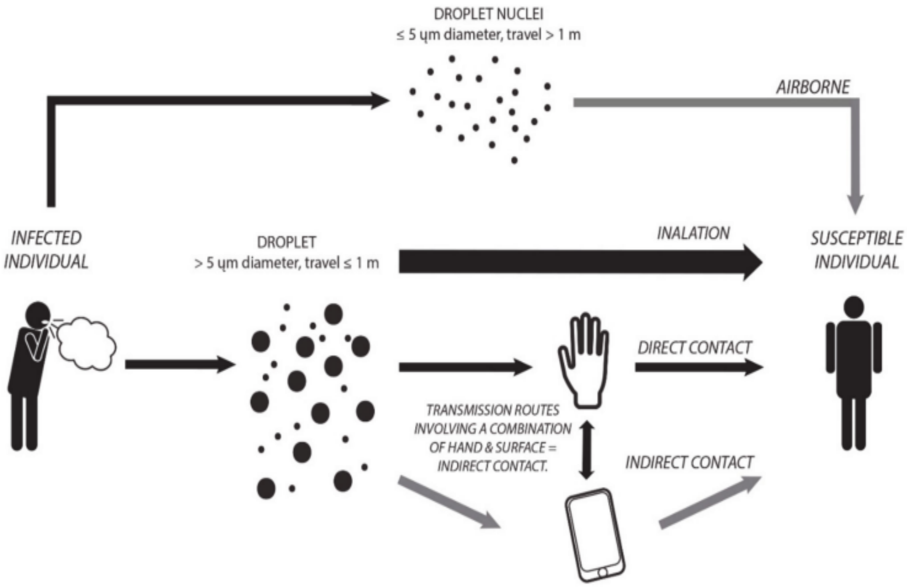


Figure 1: Transmission ways of COVID-19 [6]

3. Searching Strategy

The research questions were explicitly stated before undertaking the literature search. Following that, online electronic databases such as Science Direct, Google Scholar, IEEE Xplore Digital Library, Web of Science, Springer Link, and the Google search engine are used. The following Boolean search string led the literature search:: (“COVID-19 prevention” OR (“COVID-19 face mask” AND (“face recognition” OR “speech recognition”)) OR((“retina recognition” OR “iris recognitions” OR “Fingerprint” OR “Palm veins” OR “ear recognition” OR “breath biometric”) AND (“COVID-19 pandemic” OR “touchless biometrics” OR “physical distancing”)) OR COVID-19 vaccines OR (“DNA biometrics” AND “COVID-19 vaccines”)).

4. COVID-19 Transmission and Prevention Methods

The coronavirus mostly transmits directly from person to person. Even if there are no symptoms, an infected person may generate aerosols while talking. Several mechanisms might cause the virus to propagate.

The coronavirus is mostly transmitted from one person to another. The virus can be propagated through a variety of means listed as the following and clarified in Figure 1 [6]:

1. Aerosols are contagious virus particles that may drift for up to three hours throughout the air. Someone else might inhale these aerosols and become infected with the coronavirus. Generated liquids during symptomatic patients' talking, coughing, and sniffling can spread up to 1–2 m.
2. It can also be spread by direct or indirect contact with infected people, or by depositing virus-containing droplets on surfaces (handshake, greeting, hug).

World Health Organization (WHO) reported the safety rules that needed to be followed to reduce COVID-19 transmission. The basic rules are listed as follows [7] [8]:

- **Rule 1** (Wearing Masks). Wearing a mask is necessary for public places and it should cover the nose, mouth, and chin.
- **Rule 2** (Physical Distancing). Maintaining a 1-meter diameter distance between the individual and those around them, even if they are symptom-free.
- **Rule 3** (Direct and Indirect Contact Avoidance). Surfaces should be cleaned and sanitized regularly, especially those with large, shared surfaces.
- **Rule 4** (Vaccines). Getting Vaccine.

5. COVID-19 Prevention Rules and Biometrics Systems

Biometric systems have been brought into the spotlight as a key technology for early detection, patient screening, and public safety monitoring, to contain the spread of Covid-19. Surveillance, border control, law enforcement, healthcare, and biotechnologies are the key markets that are rapidly introducing biometrics into infectious disease prevention and control protocols [9]. In this review, a relationship between COVID-19 has been studied as well as the prevention rules and biometrics systems, and highlights challenges raised in these systems due to prevention rules.

However, since there are a huge number of physical and behavioral biometrics, the biometrics which are likely to be affected by the prevention rules has been considered as shown in Figure 2.

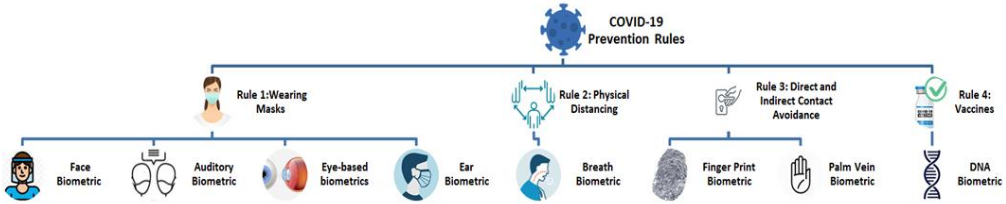


Figure 2: The relation between COVID-19 prevention rules and biometrics [9]

5.1 Rule 1: Wearing Masks

Masking is analogous to safe driving in that it benefits other road users and pedestrians, and if everyone drives cautiously, the likelihood of road traffic accidents is minimized. The Centers for Disease Control and Prevention (CDC) in the United States now recommends wearing masks in public, as many countries, including Canada, South Korea, and the Czech Republic, compel or urge their residents to wear masks in public [10]. This affects many biometrics systems such as speaker recognition and face recognition. Also, the used mask type is influenced differently based on their shape and on the final accuracy of such systems. Algorithms developed before the epidemic operate less accurately with digitally disguised faces [11]. Therefore, it is important to improve the recognition performance of existing biometrics systems that use masked faces. [12].

The following subsections provide a quick overview of the many types of masks used by individuals. The effect of wearing a mask is next investigated in terms of its effects on the existing biometrics in the human face (facial, auditory, ear, and eye-based biometrics) and the resilience of these biometrics to the first COVID-19 prevention rule.

There are various types of face masks available (as shown in Figure 3):

1. The surgical (disposable) masks. Disposable face masks are commonly available. They are also known as surgical masks. A surgical mask is a one-use, loose-fitting device that forms a physical barrier between the wearer's lips and nose and possible pathogens in the immediate surroundings. [13].
2. Homemade (Cloth) Masks. Cloth Masks may be manufactured from a range of materials, and there are many different varieties of cloth masks available. These can be constructed of tightly woven, breathable fabric like cotton or other fabrics. Large respiratory droplets from coughing or sneezing may be captured by fabric masks. Those constructed of various types of fabric have a wide range of capacities to filter virus-sized particles, with a trade-off

between filtration and breathability depending on the number and types of layers employed [14].

3. N95 masks. N95 face masks have been standardized by the National Institute for Occupational Safety and Health (NIOSH) in the United States. The letter "N" indicates "not resistant to oil," while the number "95" signifies its minimum filter capacity of 95 percent for capturing viruses as tiny as 0.3 microns. An N95 respirator is a type of respiratory protection gear that is designed to provide a very close face fit as well as extremely effective filtration of airborne particles [15]. Face Filtering Piece (FFP) masks are popular in Europe and are classified into three types: FFP1, FFP2, and FFP3. According to European regulations, each kind can filter particles as small as 0.3 microns. In Europe, they are analogous to N95 [16].
4. Transparent face shields. Facial shields come in a variety of shapes and sizes, but they all consist of a translucent plastic face covering. They are mostly used in healthcare settings. They are meant to give the best protection by covering the entire face (from the top of the head to the chin and covering the ears horizontally) and shielding the wearer from virus spray particles [17][13].

5.1.1 Face Biometric

The human face contains a wealth of information about a person. The identity of the individual and their emotional state are the two most significant pieces of information in a face. In the current COVID-19 epidemic, various nations are advising citizens to use face masks. The mask rule opens a whole new field for face recognition by partially obscuring typical and often observed faces. [19-22].

Figure 3: Face mask types [18], (a) surgical mask, (b) homemade mask made of cloth, (c) FFP2 mask, (d) and (e) transparent face shields.

The sort of worn mask can influence the facial recognition system. Additional difficulties will occur, depending on the type of mask:

1. Transparent masks enable portions of the masked face to be seen, but their effect is likely to be significant. Light reflection, optical distortion, and/or

blurring can be caused by transparent masks. Presentation conflicts may become more dangerous because of this. Masks with particular patterns, for example, might be used to launch concealing or impersonation attacks. [5].

2. Surgical, homemade, and N95 masks: These masks conceal the bottom half of the face, including the nose, jaw, and mouth. Most facial recognition systems, on the other hand, focus on data collected from all elements of the face, such as the mouth, nose, jaw angle, and so on. When recognizing a face with a mask, losing these areas presents a unique problem [23].

There have been several questions raised regarding the capability of present facial recognition algorithms to accurately detect people wearing masks. This has sparked a race among technology businesses and researchers to find alternate ways for facial recognition. Carragher and Hancock (2020) [20] overlaid images of surgical masks on people's faces to see how they affected facial recognition accuracy. Their findings show that surgical face masks decrease the ability of individuals' basic face recognition systems to complete visual face-matching tasks. They conclude that decisions on identifying covered faces should be made with caution. Wu (2021) [24] utilized an attention method to enhance the recognition rate of masked face pictures, and the Wuhan University databases Real-world Masked Face Recognition Dataset (RMFRD) and Simulated Masked Face Recognition Database (SMFRD) were used to compare the recognition rate. The experimental findings demonstrate that the suggested algorithm performs well in terms of recognition rate. Vu et al. (2021) [25] employed Local Binary Pattern (LBP) characteristics and deep learning to detect the masked face by extracting LBP features from the masked face's eye, forehead, and brow regions. The recognition rate of 87 percent was achieved using the dataset termed COMASK20, which was gathered from 300 participants at the author's university. Deng et al. (2021) [11] developed a masked-face recognition method that is based on a wide-margin cosine loss (MFCosface). Thomas et al. (2021) [26] applied Principal Component Analysis (PCA) and HAAR Cascade Algorithm. Kumari and Seeja (2021) [27] implemented CNN on the obtained ROIs of two distinct forms (polygon and rectangular) by utilizing five reference points (inner and outer canthus points, two endpoints, and the midway of the forehead) to accommodate the whole shape of an individual's periocular area. Li et al. (2021) [28] developed the Convolutional Block Attention Module (CBAM), which is used in the areas around the eyes.

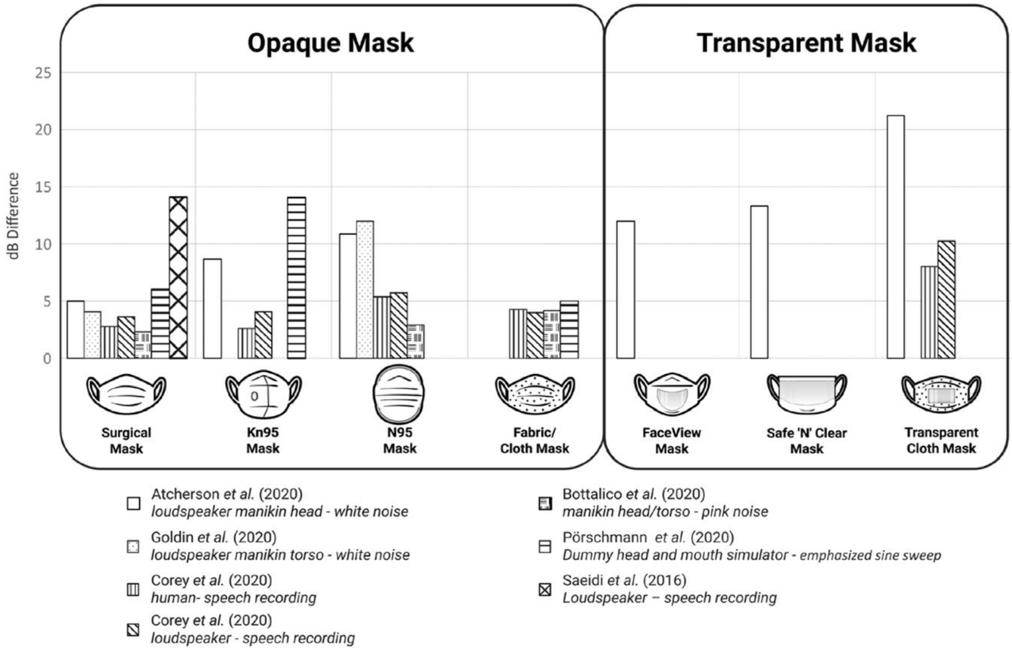
5.1.2 Auditory Biometric

Masks are believed to impact the tone of a person's voice. Several investigations have compared the deterioration of the acoustic signal caused by using a face mask. [29]. There are numerous possible explanations for poor speech comprehension. Probably the most important are [18] [30, 31]:

1. Using a face mask as an acoustical filter.
2. The mask acts as a barrier, preventing the listener from seeing the speaker's lips movements during a conversation.
3. Changes in the articulation of the individual speaking while wearing the mask. The impact of reduced speech intelligibility on communication quality is considerable, particularly in situations with high levels of background noise and sound reverberation.

The acoustic attenuation generated by different face masks has varied consequences. Several types of research have studied the acoustic signal degradation that happens when wearing a face mask and discovered that there is significant variance across mask styles (as shown in Figure 4) [32] [29]:

1. Transparent masks: They perform poorly in terms of acoustics as compared to both cotton and medical masks.
2. The surgical masks: The surgical mask has the least acoustic reduction when compared to the signal produced without a mask [peak reduction 2.3 dB].
3. N95 respirator: It reduced high frequencies by roughly 6 dB.
4. The cloth masks: They differed greatly depending on the composition and weave. The acoustic performance of the 100% cotton masks in jersey and plain weaves was equivalent to that of the surgical mask. Cotton/spandex mixes produce the worst results. Surprisingly, the 2-layer cotton/spandex mask attenuated more than the 3-layer cotton/spandex mask, maybe because it has a higher proportion of spandex and fits more tightly on the face.



Note. These masks have been designed using resources from Freepik.com

Figure 4: Maximum sound pressure level reduction caused by opaque (left) or transparent (right) masks compared to no mask [29].

Researchers are interested in voice recognition while wearing a mask in the post-COVID-19 period. Yi et al. (2021) [33] looked at the impact of wearing transparent face masks and speaking clearly in verbal communication. The findings reveal that whether the speaker wore a transparent or disposable face mask in the presence of noise, listeners performed worse than when the speaker did not wear a mask. Toscano and Toscano (2021) [31] investigated the effect of four masks (a surgical mask, an N95 respirator, and two fabric masks) on spoken phrase recognition under multi-talker babble and varying noise conditions. They discovered that using masks lowered low levels of background noise by around 5.5 percent when compared to a no-mask condition. In the presence of high noise levels, mean accuracy was 2.8-18.2 percent worse than when no mask was used, but the surgical mask had no impact. The results show that different types of masks give equal accuracy in low levels of background noise, but at high levels of noise, differences between masks become more obvious. Brown et al. (2021) [34] investigated the impact of several facial masks and noise levels on speech perception and observed listening to difficulties in older and young adult listeners.

In silence, they observed that mask type did not influence speech perception as compared to speech created without a mask for both old and young people. In all age groups, however, when moderate (5 dB SNR) and high (9 dB SNR) levels of background noise were introduced, intelligibility decreased considerably for all types of face masks.

5.1.3 Eye-based biometrics

Because contact-based technology poses a significant danger to sanitary safety, a new standard of touchless identification systems has been developed. Simultaneously, and much to many people's surprise, facial recognition technology began to confront a dilemma when masks became obligatory in public places. The act of removing their masks to have their faces recognized is extremely risky since it increases the risk of infection throughout the population and is not user-friendly. Although several prominent biometric suppliers have enabled facial recognition technology with hygienic masks, the algorithms are only viewed as a temporary compromise. Taking this change into account, eye-based biometrics is often regarded as the greatest answer by far. This technique can overcome the partial concealing constraints imposed by individuals wearing masks for health reasons during COVID-19 or a veil for cultural reasons in regular life [35].

The human eye is made up of the sclera, pupil, cornea, lens, retina, iris, choroid, optic nerve, and other components. Eye biometrics have a higher amount of unpredictability as compared to other biometrics. The layout of the retinal blood vessels and iris is unique even in identical twins. Furthermore, ocular biometrics remain consistent during a person's life. As a result, systems based on ocular biometrics have an exceptionally low error rate [35, 36].

5.1.3.1 Retina biometric

The retina is the most recognized characteristic for individual verification due to the obvious uniqueness of the blood vessel pattern and its stability throughout one's life [36]. However, in medical research conducted by [37] to investigate the influence of COVID-19 on the individual after a specific period of survival, Cotton Wool Spots (CWSs) formed in the right eye fundus after 58 days after COVID-19 diagnosis, as shown in Figure 5. This might provide a different experience for retina-based biometric techniques.

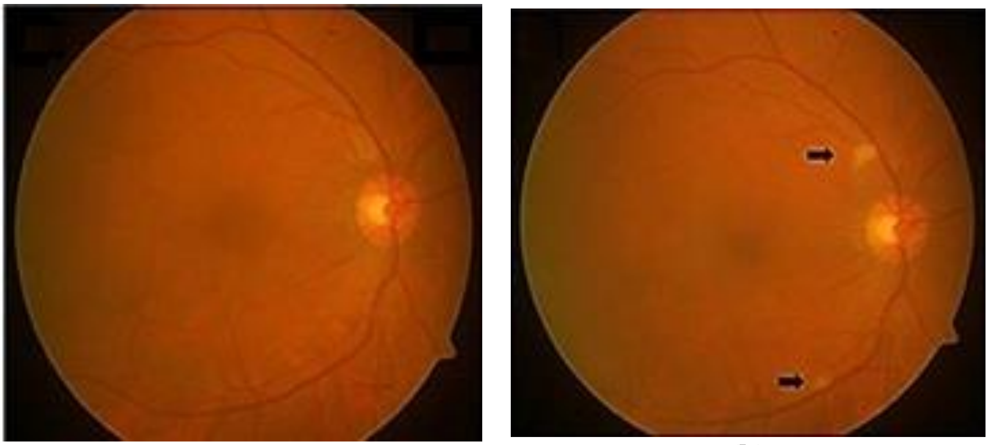
5.1.3.2 Iris biometric

Iris recognition systems outperform other types of biometric systems in terms of accuracy. Because of its precision, it has been used to screen and discover terrorists, criminals, fugitives, and migrants [38, 39]. Iris scanning is feasible in clinical tests; however, it requires a trained operator to reduce the duration and number of attempts to identify a person. Visual distortions, light reflections, and blurring can occur during iris capture when using transparent masks, such as those employed in face biometrics [40].

The COVID-19 epidemic has prompted researchers to consider contactless biometrics systems like a contactless iris scanner. It is a great alternative to touch-based scanners. Touchless iris scanners are available from companies such as IriTech. A contactless system can be readily deployed at a minimal cost and with high accuracy using IriTech's iris recognition technology. Irises may also be scanned from 50 cm [35].

5.1.4 Ear Biometric

The human ear has a rigid form that is different for every person. Furthermore, the human ear acquisition approach is contactless and non-intrusive. Also, it does not require the consent of the individual being recognized [41]. When face recognition using profile faces fails in surveillance applications, the ear might serve as a source of information about the subject in the security cameras. As a result, automated person identification based on ear images is quickly being investigated for possible commercial applications [42].



(a) (b)

Figure 5: Color fundus photographs of a patient in convalescent phase [37], (a) a normal fundus of the right eye (b) Two new CWSs (arrows) appeared in the right eye after 58 days from COVID-19 diagnosis

Automated person identification using ear pictures is a hot topic in the biometrics industry. The ear, like other biometrics like the iris, face, and fingerprints, contains several particular and unique characteristics that allow for human identification. Due to the mask-wearing scenario, most face identification techniques fail in this current international epidemic of COVID-19. The human ear is an ideal source of information for passive person identification since it does not require the cooperation of the individual. As the system is attempting to recognize and anatomy of the ear does not vary much over time. When other system information is inconsistent or even missing, the ear biometric system can supplement the other biometric systems in an automated person recognition system and give identity clues [42].

However, in a realistic scenario like the COVID-19 epidemic, the ear picture is frequently partially or completely obscured by a face mask, earrings, hair, headphones, scarf, and other things, as seen in figure 6. Furthermore, similar occlusions might occur throughout the identification process, resulting in a significant decrease in recognition performance. To minimize misclassifications, an effective ear identification system should be provided with automatic detection of the existence of occlusions [43].

(a) (b) (c) (d)

Figure 6. Ear images occluded by face masks, (a) Cloth mask [44], (b) Transparent mask [45], (c) Disposable mask [46], (d) N95 mask [47]

5.2 Rule 2: Physical Distancing

Since the first occurrence of a novel coronavirus infection was discovered, it has spread around the world, sparking a strong response from all over the world. This has resulted in extraordinary efforts to implement the practice of physical distance (social distancing) in countries throughout the world. It leads to a change in national behavioral patterns and shutdowns of normal day-to-day functioning

[48]. Physical separation entails preserving our distance from one another and restricting our activities outside the house [49].

The breath biometric may be impacted by the physical distancing rule. Many people have never heard of this biometric due to its limited implementation, but it may become one of the biometric identities in the future. It maintains a rigid individual identification. All the microorganisms that live in our bodies contribute to the fact that everyone has a unique breath print. Breath is a unique signature of the human respiratory system that provides excellent results for speaker identification. The benefit of this biometric is that each individual has a distinct metabolism and bodily process that results in a change in the breath pattern [50]. Another advantage of this biometric is that these breakpoints differ not only across persons but also fluctuate during the day within individuals as a result of changing chemical interactions within the body. Even from a 10–20 cm distance, the breathing noises are virtually inaudible. Because of its passive nature, fewer occurrences, short duration, and easy processing, it results in a text-independent, lightweight, and transparent system, which is called Breath ID [51, 52]. Medical practitioners require non-contact equipment to limit the danger of viral transmission. People with COVID-19, on the other hand, generally have a temperature and trouble breathing. This may influence the person's breath print [53].

5.3 Rule 3: Direct and Indirect Contact Avoidance

As a result of the COVID-19 epidemic, automatic contactless person identification based on the human hand has become an extremely important and desirable biometric characteristic. Since then, individuals are obliged to wear masks and are urged to avoid contact with objects. Contact-based hand biometrics are well-known to suffer from difficulties such as deformation owing to unequal pressure distribution or poor sensor placement, as well as hygiene concerns. To address such issues, contactless imaging is projected to gather hand biometrics information without deformation, resulting in greater person recognition accuracy while also addressing sanitary and pandemic concerns [54].

Scanners are used in biometric systems to authenticate human identity by measuring patterns of behavioral or physiological features. Some biometric systems are contactless but do not involve actual touch to perform features' readings; others, such as fingerprint verification systems, require the user to make physical contact with the scanner for a predetermined period for the user's biometric pattern to be read properly and measured. This may raise the risk of microbial pathogen contamination or cross-infection of food and drink by future users. Physical contact also enhances the chance of dangerous microbial infections inoculating the respiratory system and causing infectious illnesses. Touch-based biometrics, in general, covers hand-based qualities such as palm vein, fingerprint, and palm vein [55].

5.3.1 Fingerprint Biometric

The major goal of fingerprint recognition is to offer reliable authentication of users to limit access to devices such as computers along with essential facilities like offices and hospitals. Despite their numerous advantages, fingerprint scanners are possible sources of transmission of infection due to contamination from several touches by different users in a variety of dubious sanitary settings; as a result, these scanners offer potential transmission hazards [56]. Almost all businesses have discontinued the use of contact-based biometric systems, which may be a major source of coronavirus propagation [57].

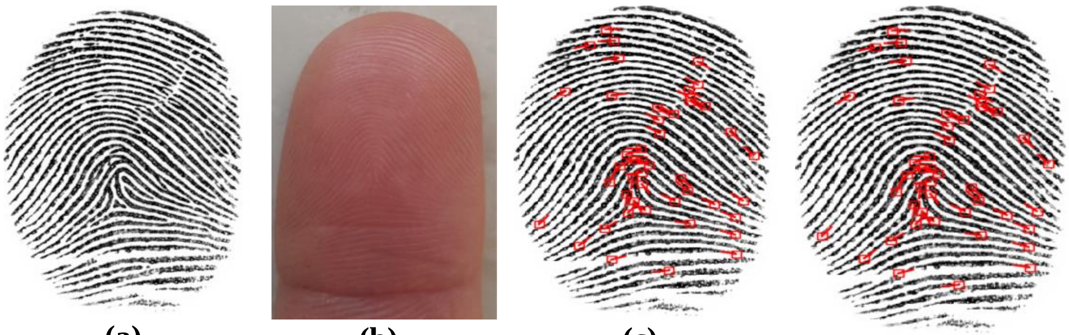
Almost all organizations have stopped the use of contact-based biometric systems, which can be a major reason to spread coronavirus. As a result, fingerprint recognition systems installed in small organizations in places where security is a high priority will no longer be regarded as a safer alternative for authentication [57].

It is worth noting that contactless fingerprint scanners have previously been created but have encountered certain fundamental issues, such as [58]:

1. Background that is uncontrolled.
2. Changing the lighting.
3. Finger location, as well as the accurate detection and focusing of a given finger.
4. Impurities on the surface of the finger.
5. Due to low contrast, the fingerprint impression is noisy.
6. Environmental factors or a comparison of different sensor kinds may reduce performance.
7. Ineffective methods for reconciling discrepancies in the prominent characteristics of pictures obtained by touch-based fingerprint devices and those captured by contactless fingerprint devices. Figure 7 shows fingerprint imprints recorded with a touch-based fingerprint sensor and the matching finger picture captured with a touchless device.
8. Inadequate preprocessing of the obtained finger picture.Two methods for acquiring contactless fingerprints have been reported: two-dimensional (2-D) and three-dimensional (3-D) imaging techniques. The 2-D approach uses a single camera to collect pictures, but the 3-D method involves several cameras, which necessitates image superimposition and the employment of sophisticated algorithms. However, the existing contactless fingerprint 2-D scanners are constrained by their fingerprint acquisition methods. They are

also influenced by differences in background lighting and reflections, resulting in low-resolution fingerprint pictures.

The 3-D method focuses on obtaining additional data about the fingerprint by adding dimensions in the x, y, and z axes. Multiple-view setup, structured lighting, and photometric stereo approaches are examples of 3-D image capture techniques. Unfortunately, the added features bring flaws such as perspective distortions and inconsistent resolution, lowering the correlation factors. The issue is visible when converting touch-equivalent fingerprints from 3-D to 2-D pictures. Similarly, light absorption by the skin's epidermis during finger scans lowers the resolution of pictures obtained by the contactless technique [59].



(a) (b) (c) (d)

Figure 7: Fingerprint image for the same person with touch-based and touchless sensor [58], (a) touch-based image, (b) touchless fingerprint image, (c) features generated using a touch-based image; (d) features generated using a touchless image.

The touch-based fingerprint picture may be utilized directly for feature extraction, but the touchless fingerprint image requires further preprocessing. Various studies are presently being conducted to close this gap utilizing a variety of approaches. Lin and Kumar (2019) [60] utilized deep learning to include the most reliable minutiae features, as well as the corresponding ridge flow maps, to provide robustness in the learning minutiae feature correspondences. Birajadar et al. (2019) [61] used a unique monogenic-wavelet-based method for touchless fingerprint enhancement utilizing phase congruency characteristics. Dwivedi et al.

(2021) [62] employed hierarchical agglomerative clustering, which makes use of cluster formation in pre-processed fingerprint sets. The intra-cluster distances are then compared to perform cluster-based verification with authentic and non-genuine samples.

5.3.2 Palm Vein Biometric

In recent years, there has been a lot of focus on the palm vein. This technology is accurate, durable, and contactless, making it an appealing alternative for clinical applications. To match the identity, it employs palm vascular patterns of individuals as an identifying measure. According to observations, the vein structure under the palm surface has a more intricate pattern than the back of the hand, fingers, or other easily accessible vein networks in the body. As a result, the palm vein can give additional characteristics for authentication [63].

Contactless vein biometric technologies, like fingerprints, are becoming increasingly significant because of their benefits, particularly during the current COVID-19 epidemic, since they may be used to prevent the transmission of such viruses [64]. PalmSecure is an example of a touchless palm vein sensor that extends beyond the surface and authenticates users based on blood vein pattern identification. PalmSecure captures vein patterns that are unique to each user by producing near-infrared rays (as illustrated in Figure 8 a) that are absorbed by deoxygenated hemoglobin contained in blood flowing through the user's palm veins. This results in the recording of a picture of the palm as an image feature (as shown in Figure 8 b), which is subsequently validated against the user's pre-registered pattern to give (or refuse) access to a physical place or computer network [65].

5.4 Rule 4: Vaccines

1. Since the beginning of the year 2020, the globe has been racing to create vaccinations to combat the COVID-19 epidemic. Over 250 initiatives have been launched for this aim, but only 14 have been approved for usage. COVID-19 vaccinations are classified as either virus-based or protein-based. The former includes knocked-out virus vaccines, such as Sinopharm vaccine, which employ inactive or weak viruses. The latter includes nucleic acid vaccines, which are made up of snippets of the virus's genetic code and are injected into human cells, such as the Pfizer–BioNTech vaccine (PBV)[66, 67].

2. Among the numerous biometric identification systems available, deoxyribonucleic acid (DNA) provides the most dependable personal identity. DNA polymorphism data, such as Short Tandem Repeats (STRs) and Single Nucleotide Polymorphisms (SNPs), may give the most reliable identity information. This data may be accurately specified to the most minute level, is fundamentally digital, and does not change during or after a human's life. As a result, DNA-identifying data is used in forensic sciences. On the negative side, the most significant disadvantage of utilizing DNA is the time necessary for nucleic acid extraction and the assessment of STR or SNP data. There are also numerous additional factors to consider, such as the high expense of analysis, challenges posed by monozygotic twins, and ethical considerations [68].

(a) **(b)**

Figure 8: PalmSecure palm vein sensor [65], (a) PalmSecure and its usage, (b) palm vein image taken by PalmSecure sensor

3. DNA-based vaccinations, on the other hand, operate as chemical intermediates between the DNA in our chromosomes and the cellular machinery that generates the proteins we require to function: DNA supplies the instructions this equipment requires to construct these proteins. The present worries stem from the fact that the technology that underpins it has been under development for the previous two decades and may have a long-term impact on our biology. Even though DNA vaccines are a novel technology, there is no reason to believe that they will have any long-term impact on our biology – other than teaching our immune systems to avoid COVID-19 illness [69, 70].

6. Recommendations

1. Implementing contactless biometrics technologies. Although many biometric systems need physical contact with the scanner to get the user's biometric picture, technology companies are researching totally contactless biometric scanners at various levels. Contactless biometrics systems are gaining popularity for a variety of reasons, including the reduction of the propagation and spread of touch-dependent infectious illnesses. Furthermore, research in this field is progressing, and some examples may be commercially accessible shortly.
2. Creating 3-D biometrics systems. A picture of a hand can fake a 2D system; however, 3-D overcomes this by recovering and analyzing 3-D textures and characteristics. A contactless collection of 3-D biometrics is also possible, which is essential for maintaining cleanliness and simplicity of use.
3. Increased use of Machine Learning and Artificial Intelligence. Increased adoption of cloud-based services for contactless biometric systems, such as Artificial Intelligence and Machine Learning, is projected to increase demand for contactless biometric systems, improving system compatibility for diverse applications.
4. Systems for Multi-Factor Biometrics. Individual identification using uni-biometrics is restricted owing to the problems involved with each biometric, but multi-biometric systems can successfully surpass uni-biometrics by overcoming the gap that exists in individual biometrics.
5. Creating mask-based biometrics systems. Recognizing mask type helps effectively scale difficulties that may occur if mask type is not taken into account. In auditory biometrics, for example, the mask might have varying degrees of influence on the voice signal. As a result, if a speaker identification system is created concerning the mask type, the recognition rate may be increased.
6. Collecting more biometric data. Additional data may be required to address problems that occur with COVID-19 biometrics. Training biometrics systems on such data can enhance their flexibility to respond to changes caused by the corona epidemic.
7. Concentrating on medical research that investigates the influence of COVID-19 on human biometric components. New problems that may impact the accuracy of biometrics systems may arise.

7. Conclusions

Biometric systems are gaining popularity as a next-generation technology that not only enhances security but also accessibility and health care. However, the COVID-19 pandemic had a significant impact on the world. Biometrics systems are among the numerous items impacted by this virus. As a result of COVID-19 avoidance regulations, several difficulties have arisen in biometrics-based systems. These problems prompted the urgent need for additional advancements in current biometrics technologies. Further research on biometric techniques can be done to make them more suited for the post-COVID-19 epidemic environment.

Table (1) summarizes the problems presented to various biometrics systems because of COVID-19 pandemic restrictions and preventive regulations. Each biometric method listed in the table is affected by at least one of the COVID-19 pandemics. The challenges are mentioned too in the table. Some challenges could be materials like a face mask that is hiding face biometrics or changes in the human voice. Also, regarding the social distancing rule many biometrics devices couldn't be used due to its contact-based requirement. In addition to the rules, some biometrics changed after the infection of COVID-19 like the retina.

Table 1: Challenges added to the biometrics systems due to COVID-19 pandemic constraints.

Biometric	Virus Prevention Rules				After Survival	Added Challenges
	Rule1	Rule2	Rule3	Rule4		
Face Biometric	/					- Surgical, homemade, and N95 masks occlude the lower features of a face. - Transparent masks can cause light reflections, visual distortions, and/or blurring.
Auditory Biometric	/					- A face mask acts as an acoustic filter. - The mask acts as a barrier, blocking visual access of the listener to the speaker's mouth movements during communication. - Changes in the articulation of the speaking person wearing the mask.
Retina Biometric	/				/	- CWSs appeared in the eye fundus after COVID-19 diagnosis and survival.
Iris Biometric	/					- The growing demands for contactless authentication options.

Ear Biometric	/					- Ear image is often partially or fully occluded by face mask.
Breath Biometric		/				- People with COVID-19 usually experience fever and have difficulty breathing which makes breath biometric difficult.
Finger Print Biometric			/			- Necessity for moving to touchless fingerprint scanners. However, there are some underlying challenges like: 1) uncontrolled background, varying illumination, noisy fingerprint impression due to low contrast, 2) Varying camera setup especially on smartphones, 3)Ineffective approaches to reconciling differences between the salient features of the images captured by touch-based fingerprint devices and those captured via contactless fingerprint devices. 4) Lack of the appropriate preprocessing of the acquired finger image.
Palm Vein Biometric			/			- The growing demands for contactless authentication options.
DNA biometric				/		- Till now, there are no proven alterations in the human DNA due to protein-based COVID-19 vaccines.

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تحديات الانظمة البايومترية في جائحة كورونا :مراجعة

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المستخلص: يعد وباء COVID-19 أحد أخطر الكوارث الصحية في الذاكرة الحديثة. تم فرض العديد من قواعد التقييد للحد من انتشار الفيروس. يمكن أن تساعد الأقنعة في منع انتشار الفيروس من الشخص الذي يرتدي القناع إلى الآخرين. الأقنعة وحدها لن تحمي من COVID-19 ؛ يجب استخدامها بالاضافة الى التباعد الاجتماعي وتجنب الاتصال المباشر. يؤكد الانتشار السريع لهذا المرض ، فضلاً عن الاستخدام المتزايد لأساليب الوقاية ، على الحاجة الماسة إلى حدوث تحول في الانظمة البايومترية. تتأثر الانظمة البايومترية بشكل متباين اعتمادًا على ما إذا كانت تُستخدم كأحد الأساليب التي تم تقييدها في جائحة COVID-19. تقدم هذه الدراسة لمحة عامة عن الانظمة البايومترية والنهج المتبع في جائحة COVID-19. تتم مراجعة قواعد الوقاية من COVID-19 الأساسية أولاً. يتم بعد ذلك مراجعة العلاقة بين كل المحددات و القيود في جاحة COVID-19. يتم تقديم توصيات للاتجاهات المستقبلية للطرق الممكنة لمساعدة الباحثين مقدمًا وتعزيز أداء الانظمة البايومترية لبيئة جائحة ما بعد COVID-19.

الكلمات المفتاحية: جائحة COVID-19 ، الوقاية ، الانظمة البايومترية ، تباعد اجتماعي.

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