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Article

Validating the Correct Wearing of Protection Mask by Taking a Selfie: Design of a Mobile Application "CheckYourMask" to Limit the Spread of COVID-19

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Abstract: In a context of a virus that is transmissive by sputtering, wearing masks appear necessary to protect the wearer and to limit the propagation of the disease. Currently, we are facing the 2019–2020 coronavirus pandemic. Coronavirus disease 2019 (COVID-19) is an infectious disease with first symptoms similar to the flu. The symptom of COVID-19 was reported first in China and very quickly spreads to the rest of the world. The COVID-19 contagiousness is known to be high by comparison with the flu. In this paper, we propose a design of a mobile application for permitting everyone having a smartphone and being able to take a picture to verify that his/her protection mask is correctly positioned on his/her face. Such application can be particularly useful for people using face protection mask for the first time and notably for children and old people. The designed method exploits Haar-like feature descriptors to detect key features of the face and a decision-making algorithm is applied. Experimental results show the potential of this method in the validation of the correct mask wearing. To the best of our knowledge, our work is the only one that currently proposes a mobile application design "CheckYourMask" for validating the correct wearing of protection mask.

Keywords: Face protection masks; public health support; health education; COVID-19; coronavirus; e-health; m-health; mobile health; public health system; epidemic prevention and control

1 Introduction and Motivation

In the context of transmitted virus between humans by sputtering (spraying), wearing the mask on the face appears necessary to protect people and to limit the propagation of the disease. Currently, we are facing the 2019–2020 coronavirus pandemic. Coronavirus disease 2019 (COVID-19) is an infectious disease with first symptoms similar to the flu. The symptom of COVID-19 was reported first in China and very quickly spreads to the rest of the world. The COVID-19 contagiousness is known to be high by comparison with the flu. In this paper, we propose a design of a mobile application allowing people able to take a picture with a smartphone to verify that his/her protection mask is correctly positioned on his/her face. Such application can be particularly useful for people using face protection mask for the first time and notably for children and old people.

The contagiousness of COVID-19 is discussed in [1]. Authors show Figures that permits to become aware about the interest of face mask wearing in the COVID-19 context. In particular, the Figure on Page 8 of their article illustrates the distance of virus dispersion according to postilions, sneezing or coughing and the Figure on Page 7 illustrates the risks of contamination according to different face-to-face scenarios with mask wearing and/or not wearing. For this latter, 4 levels of risks are represented and described.

Although many people are already convinced of the interest for wearing face protection mask such as suggested by the World Health Organization [2] and scientific studies [3–5], one can observe that many individuals do not correctly wear their masks (see various mask wearing configurations in Fig. 1). These observations have led nurses and other citizens to initiate prevention campaigns related to the public health education in wearing the mask. Precisely, these campaigns consist of sensitizing people about the correct and incorrect manner to wear face protection masks by disseminating prevention posters and drawings [6–9]. In our case, we propose to support these public health campaigns by designing an image-based analysis method and an associated digital tool that are dedicated to the verification of the correct mask wearing by exploiting a smartphone and its frontal camera. We emphasize that the current number of smartphone users in the world today is 3.5 billion, and this means 45.04% of the world's population

Figure 1: Various configurations related to the mask wearing. (a) no mask; (b) unprotected nose; (c) unprotected chin (d) unprotected; (e) unprotected chin and mouth; (f) protected nose, mouth and chin

owns a smartphone (information [10] referring to the portal for statistics "Statista"). Hence, mobile-based COVID-19-related applications are then highly accessible.

In the literature, some research works study the mobile phone data such as positioning data to carry out contact tracing in relation to COVID-19 [11–13]. People can receive information about those that have been infected and near them. They can also alert the connected people if they are themselves infected. This can permit connected people to get COVID-19 maps and to avoid areas with high risks of contamination.

Besides, the detection of mask through camera acquisition systems has also been investigated. In this context, applications are developed for detecting the presence of mask or not [14–16] for the counting of individual wearing mask towards carrying out crowd statistics and even for facial identification of people wearing mask [17]. Most of research systems in favor of the fight against COVID-19 are focused on people monitoring.

To the best of our knowledge, our work is the only one that currently proposes a mobile application design "CheckYourMask" for validating the correct wearing of protection mask. In particular, major advantages of the presented work are as follows: (i) a first m-health application is designed for reinforcing the sensitizing campaigns launched with posters towards informing general public about the correct way of mask wearing (tool for limiting the inter-human contamination), (ii) an original mask-related approach is designed toward being accessible to all individuals having a smartphone (high accessibility), (iii) the designed approach directly works from real-time selfie analysis (fast and easy checking), (iv) the designed mask-related checking application takes place upstream of crowd monitoring applications (e.g., validating the correct wearing of masks for travelers at airport gates) to limit the spread of COVID-19 (i.e., a complementary attribute by an individual monitoring). In Section 2, we present our algorithm. Section 3 exposes experimental results and Section 4 summarizes the contributions and presents future works.

2 Proposed Face-Feature Based Method to Validate the Wearing of the Mask

The designed preliminary method combines Haar-like feature descriptors to detect the face as well as key features of the face from the camera-based acquisition of a mobile phone; namely e.g., detection of eyes, mouth, nose [18]. Nowadays, Haar-related analysis techniques are very investigated to perform face feature analysis. In [19], the authors exploit Haar-based feature analysis in a hybrid processing scheme and a comparative study shows their efficiencies. In this paper, the design of our method conjointly employs Haar-based face feature detection techniques. Fig. 2, shows a decision flowchart which describes major logic stages of the proposed approach.

It is assumed that a video selfie is taken when the camera is frontally facing the face for facilitating the face detection. Then a decision-making algorithm is applied from the detected face features (see basis Algorithm 1). In this version of the algorithm, if a face is detected, then it is assumed that the mask wearing is valid if the eyes are detected and if at the same time the detection of the nose, the mouth and the chin fail. Otherwise, it is concluded that the mask wearing is not valid. It is assumed that the method analyzes faces wearing conventional masks; namely with a unique and opaque color. The presented preliminary mask wearing validation system aims to manage all mask wearing configurations of Fig. 1.

The basis principle of the algorithm notably exploits the real-time detection of multiple faces at different resolutions in video streams [20–22] and Haar feature-based cascade classifiers that rely on [23–25].

In particular, the goal of Haar-like features is to code the variations of pixels content in the image. To this end, a small detection window, composed for instance of two adjacent rectangular zones (black and white), is positioned on the image; then the variation on this part of the image is calculated by subtracting the sum of pixel intensities resulting from the areas covered by black and white zones, respectively. The value obtained from this calculation corresponds to an encoded Haar-like feature that can detect a texture change or the

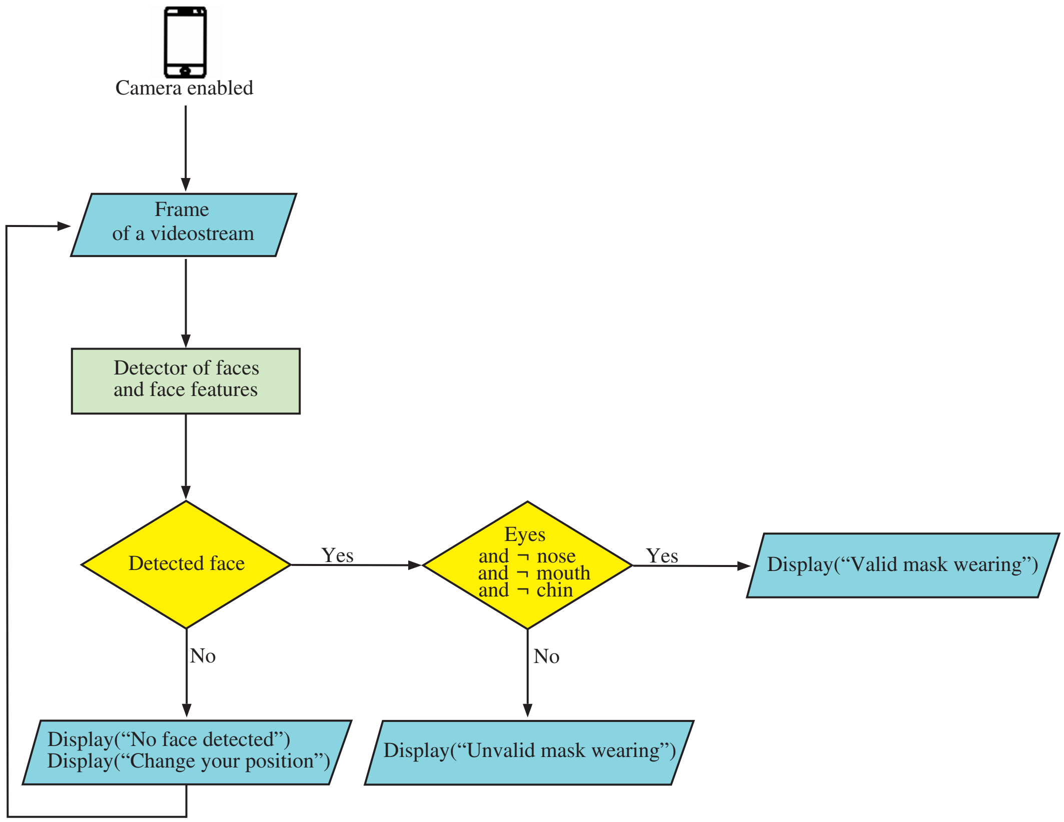


Figure 2: Decision flowchart of the proposed approach

location of a boundary in the image. The window is moved in such a way as to scan the whole surface of the image and its size increases to ensure robustness against scale variations. Moreover, several patterns are exploited on the detection window (not only adjacent rectangles) in order to code different types of relevant information existing in the image. To optimize the computation time of these features the usage of integral images is highly recommended [24].

3 Experimental Study

Experiments have been conducted by exploiting resources in design engineering and in image analysis accessible in Android and OpenCV environments. We observe that the use of Haar-like feature descriptors for detecting face and face features is sensitive. Indeed, various false detections can occur according to the condition of illumination during the acquisition, and to objects or textures that are visible out of the face. For this reason, the Algorithm 1 has been modified by limiting the detection of face features to the nose for preliminary experiments (see Algorithm 2).

The nominal outputs of the designed “CheckYourMask” application are displayed in Fig. 3. In Fig. 3a, the application asks to the user to change his position since no face has been detected. Fig. 3b shows that the face is detected. Since the nose is also detected, then it displays that the mask wearing is not valid. Fig. 3c displays a user view for a similar scenario (nose rectangle is hidden). Fig. 3d displays the obtained outputs when the face is detected and the nose is not detected; namely, mask wearing is valid. The tested mask is a single-use face mask (brand “BYD Electronics”).

Fig. 4 shows a test of configurations such as shown in Fig. 1. Scenario of Fig. 1a is correctly obtained (see Fig. 4a). The scenarios from Figs. 1b and 1c cannot be operated by using the considered white tissue

Algorithm 1: Face protection mask wearing validation

Require: detector of faces and face features.

Ensure: camera enabled for the deployed application, frontally facing the camera.

```
procedure LIVE VIDEO SELFIE ANALYSIS (videostream)
    // basis principle
    for (each frame ∈ videostream) do
        if (detected face) then
            if (eyes and ¬ nose and ¬ mouth and ¬ chin) then
                display("Valid mask wearing")
            else
                display("Unvalid mask wearing")
            end if
        else
            display("No face detected")
            display("To change your position")
        end if
    end for
end procedure
```

mask since it is very rigid and since its ties are short. The scenario of Fig. 1f relatively works (see Fig. 4c) except when the scene illumination is low. For this latter case, it may occur that the nose detector fails by surrounding another image region although the nose is hidden by a mask (see Fig. 4b).

Fig. 5 shows a test of configurations such as shown in Fig. 1 by using a single-use blue face protection mask. For several scenarios, the face is not detected (Figs. 5a, 5c, 5f, and 5h). This can occur when a too large surface of the face is hidden by the mask. Besides, since this mask is relatively flexible, it fits the shape of the nose. Hence, it can cause nose detection (i.e., erroneous interpretation) even when the mask is worn such as shown in Fig. 5d. The detection of the nose, and in particular of the face works when the mask is positioned on the neck and at the boundary of the face (see Fig. 5e).

Fig. 6 shows tests of the designed "CheckYourMask" application carried out by some users having masks of different natures; e.g., disposable and reusable, with dark and light colors (see Figs. 6b, 6d–6f and 6h, respectively). Nominal detections are displayed with low and high image resolutions (e.g., see Figs. 6f and 6h, respectively).

Precisely, the general performance of the designed approach is given in Tab. 1 with respect to the Algorithm 2. This latter combines the use of a Face detector and a Nose detector. Their detection accuracies are respectively reported in Tab. 1 from reference papers [20,25], namely rates of True Detection (TD) and False Detection (FD). The response time of the prototyped application T is approximately equal to 136 ms per frame (320 × 240) by carrying out experiments over 5000 frames by using a widespread smartphone model (Samsung Galaxy S8 SM-G950F). The associated response time

Algorithm 2: Face protection mask wearing validation

Require: detector of faces and face features.

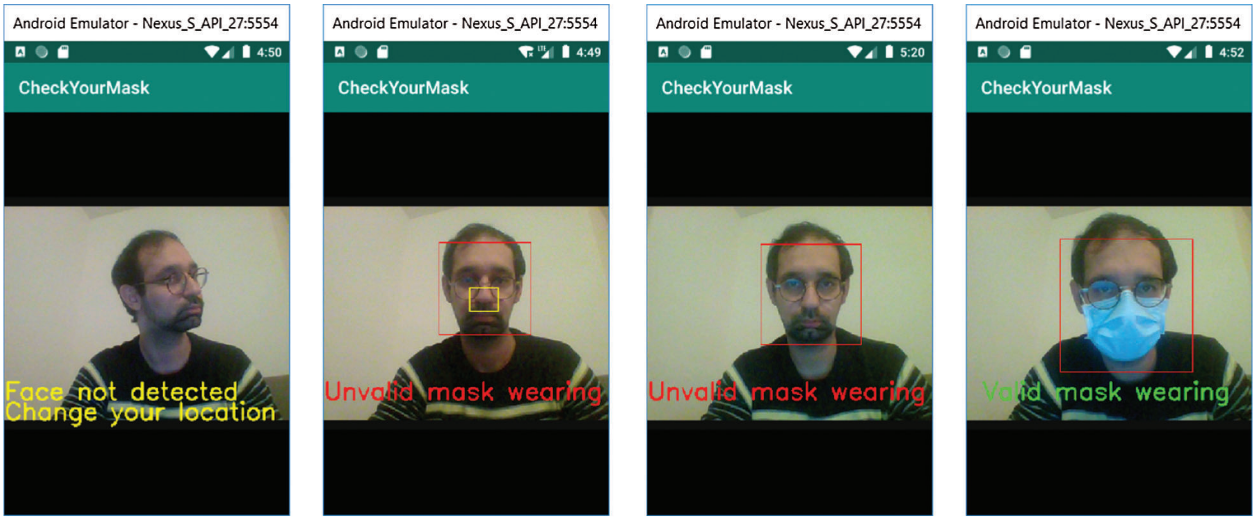
Ensure: camera enabled for the deployed application, frontally facing the camera.

```
Procedure LIVE VIDEO SELFIE ANALYSIS (videostream)
    // basis principle
    for (each frame ∈ videostream) do
        if (detected face) then
            if (¬ detected nose) then
                display("Valid mask wearing")
            else
                display("Unvalid mask wearing")
            end if
        else
            display("No face detected")
            display("To change your position")
        end if
    end for
end procedure
```

Table 1: General performance of the designed approach with respect to the Algorithm 2

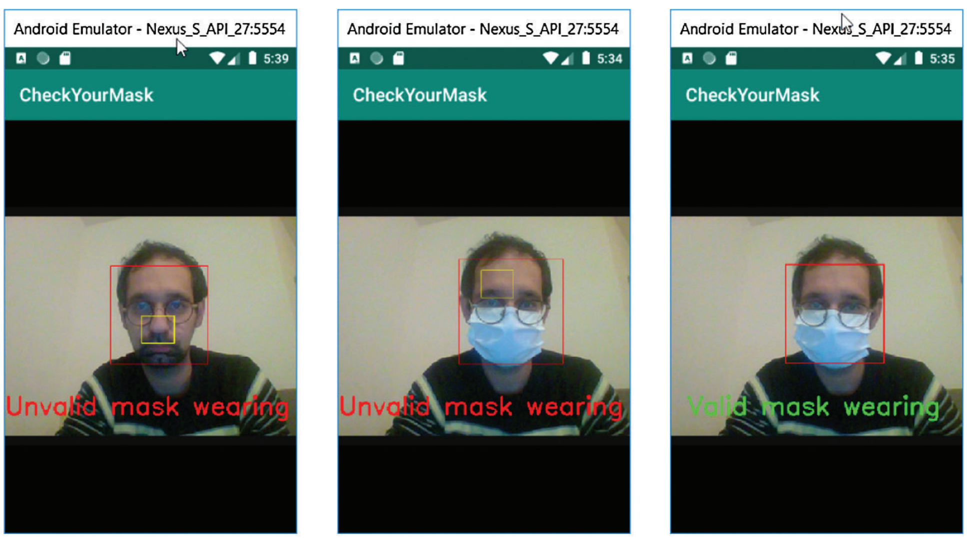
	Our approach				
Combined features	Face [20]		Nose [25]		Graphical displays
	TD	FD	TD	FD	(boxes and message)
Detection accuracy	99.92%	8.07%	100%	29.00%	–
Frame resolution	320 × 240				
CPU & Memory	2.3 GHz Octa-Core, 4 GB RAM				
Response time T (avg. over 5000 frames)	$T \approx 136$ ms ($SD \approx 36$ ms)				$\varepsilon \approx 0.2$ ms($\varepsilon \subset T$)

has a variability rate of approximately 26.5% in regard to the measured Standard Deviation (SD). Hence, a real-time response is obtained by using a smartphone that has a CPU clocked at 2.3 GHz Octa-Core, 4 GB of RAM and the version 9 (named Pie) of the Android operating system.



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

Figure 3: Different outputs of the "CheckYourMask" application. A single-use blue face protection mask is used. (a) Undetected face. (b) Unvalid mask wearing. (c) User view (unvalid). (d) Valid mask wearing



(a) (b) (c)

Figure 4: Test of configurations with respect to Fig. 1. The user wears glasses. The image background is homogeneous. A reusable white face protection mask made in tissue is used. (a) Unvalid wearing. (b) Erroneous case. (c) Valid wearing

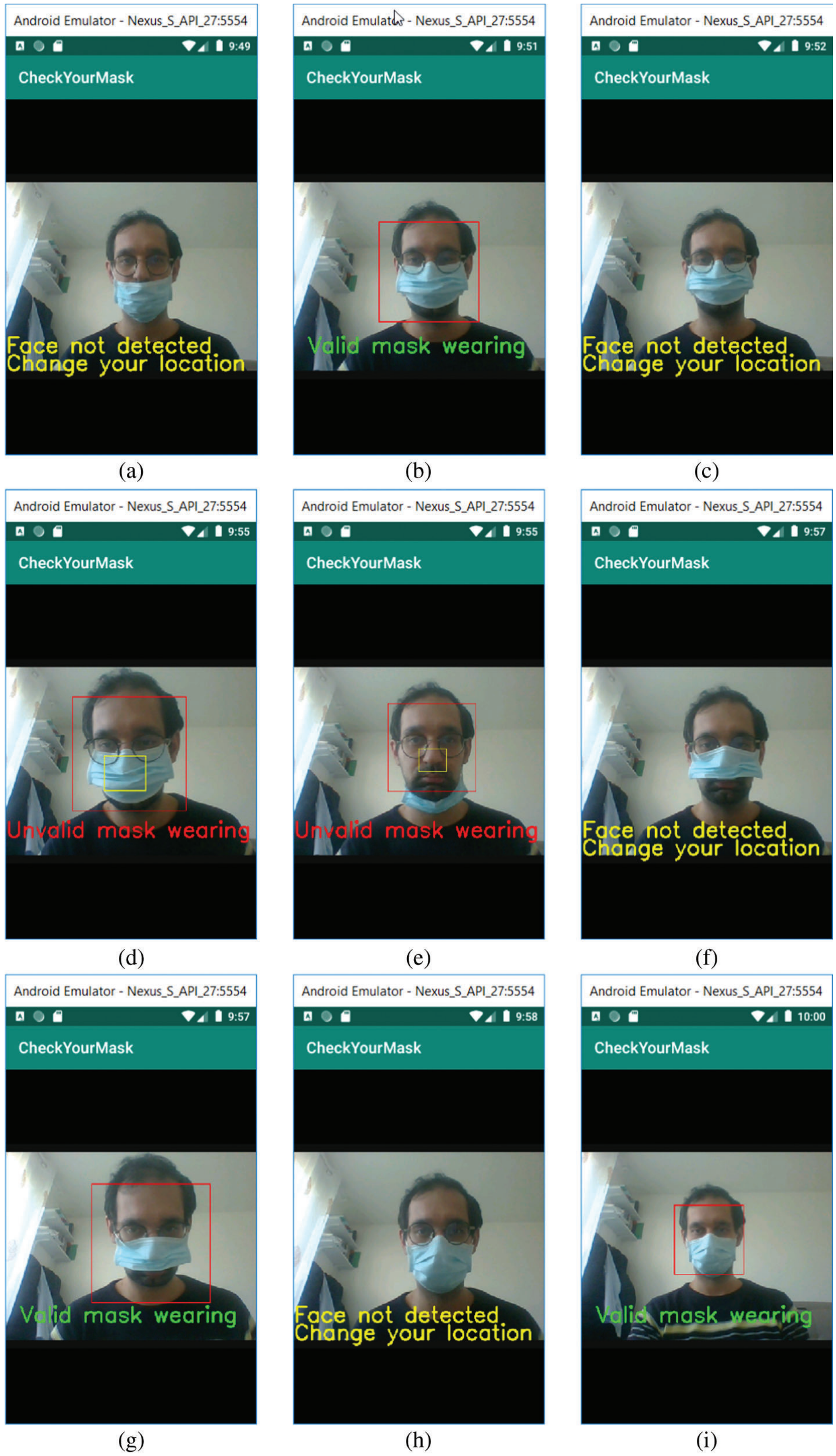


Figure 5: Test of configurations with respect to Fig. 1. The user majoritarily wears glasses. The image background is heterogeneous. A single-use blue face protection mask is used. (a) Unprotected nose. (b) Unprotected chin. (c) Unprotected chin. (d) Unprotected chin. (e) Unprotected. (f) Unprotected chin and mouth. (g) Unprotected chin and mouth. (h) Protected nose, mouth, chin. (i) Protected nose, mouth, chin

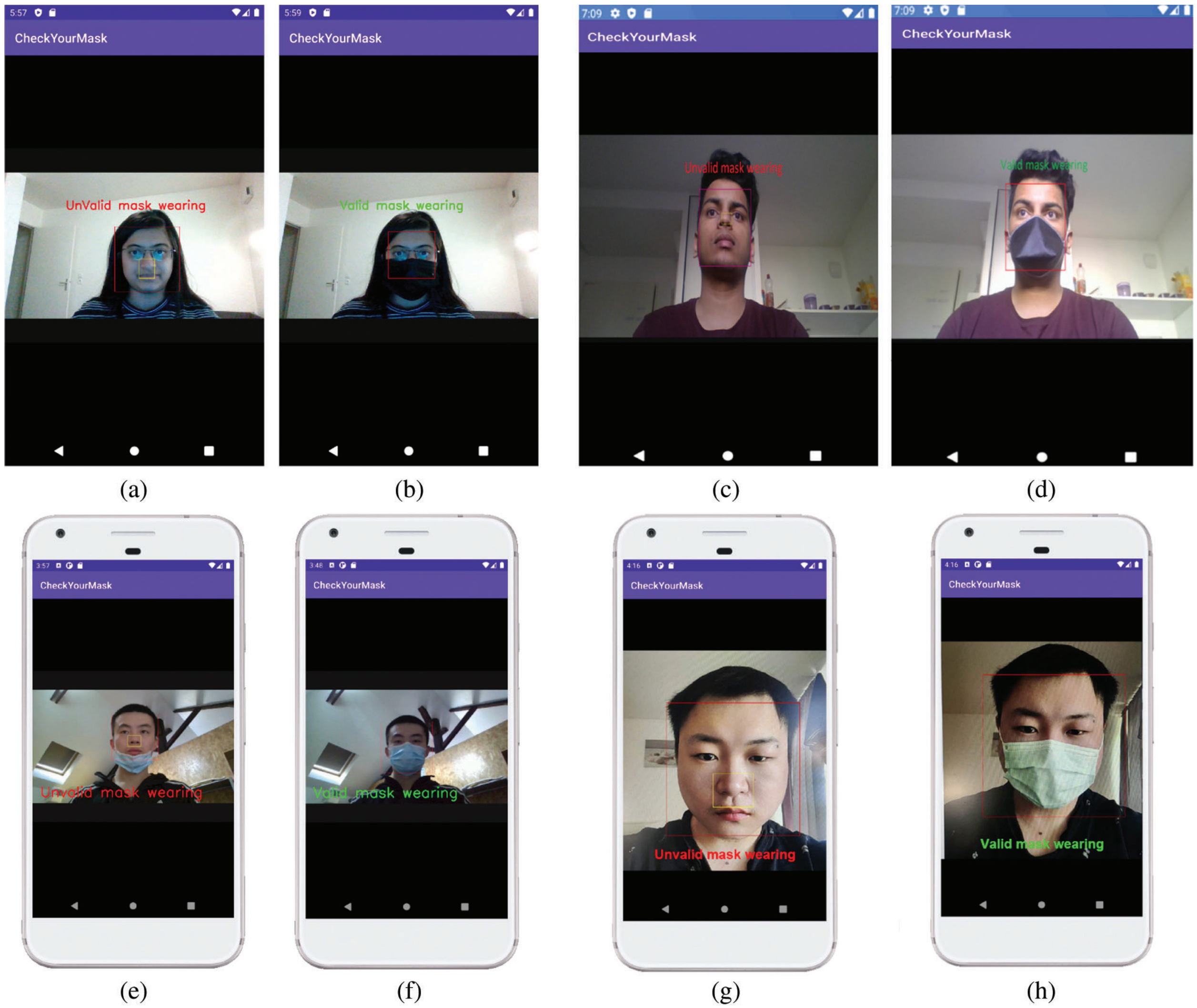


Figure 6: Tests of some users with different types of mask. (a) Unvalid wearing. (b) Valid wearing. (c) Unvalid wearing. (d) Valid wearing. (e) Unvalid wearing. (f) Valid wearing. (g) Unvalid wearing. (h) Valid wearing

4 Conclusion and Future Works

A method is designed for checking the correct wearing of face protection mask from a video selfie. Different analysis scenarios have been experimented using diverse types of conventional mask and varied acquisition conditions. The performance of the designed method relies on the efficiency of the exploited face and face-feature detectors. In the present study, wearing glasses had no negative effect. The use of rigid masks seems preferable because they reduce possibilities of wrong positioning on the face. For this latter, the designed prototype can particularly be efficient. Hence, a promising application "CheckYourMask" has been proposed. A proof of concept as well as a development base are provided towards reducing the spread of COVID-19 by allowing people to validate the wearing of their masks via their smartphones (m-health). Moreover, this self-checking of the correct mask wearing could be exploited by monitoring-related applications as a conformity attribute. Future works may investigate the development of highly robust detectors by training a deep learning model with respect to specific face features or more globally to correctly/incorrectly worn mask classes.

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