Paper on Consumer Systems

Improving Face Recognition for Identity Verification by Managing Facial Directions and Eye Contact of Event Attendees

Akitoshi Okumura[1,a]   Susumu Handa[2]   Takamichi Hoshino[2]
Naoki Tokunaga[2]   Masami Kanda[2]

Abstract: This paper proposes an identity-verification system for attendees of large-scale events using continuous face recognition improved by managing facial directions and eye contact (eyes are open or closed) of the attendees. Identity-verification systems have been required to prevent illegal resale such as ticket scalping. The problem in verifying ticket holders is how to simultaneously verify identities efficiently and prevent individuals from impersonating others at a large-scale event at which tens of thousands of people participate. We previously developed two ticket ID systems for identifying the purchaser and holder of a ticket. These systems use two face-recognition systems, i.e., one-stop face-recognition system with a single camera and non-stop face-recognition system with two cameras. The average face-recognition accuracy was respectively 90 and 91%, and the average time for identity verification from check-in to entry admission was respectively 7 and 2.8 seconds per person. One-stop systems have lower equipment cost than non-stop systems because they require fewer cameras for face recognition. Since both systems were proven effective for preventing illegal resale by verifying attendees of large concerts, they have been used at more than 110 concerts. The problem with both systems is regarding face-recognition accuracy. This can be mitigated by securing clear facial photos because face recognition fails when unclear facial photos are obtained, i.e., when event attendees have their eyes closed, are not looking directly forward, or have their faces covered with hair or items such as face-masks and mufflers. In this paper, we propose a system for securing facial photos of attendees directly facing a camera by leading them to scan their check-in codes on a code-reader placed close to the camera just before executing face recognition. The system also takes two photos of attendees with the single camera after an interval of about 0.5 seconds to obtain facial photos with their eyes open. The system achieved 93% face-recognition accuracy with an average time of 2.7 seconds per person for identity verification when they were used for verifying 8,461 attendees of a concert of a popular music singer. The system made it possible to complete identity verification with higher accuracy than previous systems and with shorter average time than the non-stop system using a single camera, i.e., with low equipment cost. Survey results obtained from the attendees showed that 96.4% felt it provided more equity in ticket purchasing than methods without face recognition, 87.1% felt it provided added convenience in verification, and 95.4% felt it would effectively prevent illegal resale.

Keywords: artificial intelligence, authentication, biometrics, face recognition, illegal ticket resale

1. Introduction

Identity verification is required in an increasing number of situations. Let us take an example of a case in which many people are admitted to an event. It used to be that in such cases, having a document, such as a ticket or an attendance certificate, checked was sufficient to gain entry; the need for personal authentication was not seriously considered due to the limited amount of time for admitting all participants. Many events with high ticket prices had designated seating, so it was not necessary to assume that some tickets may have been counterfeit. However, the advent of Internet auctions in recent years has made it easier to buy and sell tickets at the individual level. This has resulted in an increase

in illegal ticket scalping, i.e., tickets being purchased for resale purposes [1]. Equity in ticket purchasing is required not only by ticket purchasers but also by event organizers and performers [2]. Consequently, event organizers have had to deal with complaints about malicious acts by undesignated individuals who take advantage of fans by buying and selling tickets on the Internet. In many cases, therefore, any ticket buying and selling outside the normal sales channels is prohibited. Ticket-sales terms now often stipulate that tickets are invalid when people apply for them using a pseudonym or false name and/or false address or when they have been resold on an Internet auction or through a scalper. Illegally resold tickets have in fact been invalidated at amusement parks and concert halls [3]. Verification has therefore become a more important social issue than ever before. Legally verifying a person's identity requires verifying two points: that "the person actually exists (reality)" and "the person is who he/she claims to be (identity)" [4]. The foundation of reality is the family registry

in Japan. There are limited situations in which "reality" needs to be strictly confirmed, but there are many situations in which "identity" needs to be verified. This personal-authentication confirmation is called "identity" and is often used in the same sense as verification.

Many methods are proposed for personal authentication [5]. Current personal authentication can be done with three methods: (1) knowledge certification using information only the person in question knows, such as a password or personal identification number, (2) possession of certification, i.e., such as an ID card or driver's license, and (3) biometric authentication by confirming a person's fingerprints face, etc. Although knowledge and certification are widely used, such as at bank terminals and in e-commerce, identity can be transferrable with both methods if the individuals purchasing tickets and those entering the event match. Therefore, neither can be an effective means to prevent individuals from impersonating others. Many anticipate that biometric authentication can be a means of solving these problems [6], [7], [8]. One advantage of biometric authentication is that there is no risk of biological information being lost or forgotten. Also, biometric authentication can be considered a means to prevent individuals from impersonating others because it uses person-specific biological information. Biometric authentication verifies identity by matching pre-registered biometric information and collation information obtained through a sensor. For example, both vein authentication used in financial institutions [9] and fingerprint authentication used in national and local governments [10] require dedicated biometric-information sensors. Biometric authentication is thus not acceptable for verifying the identity of the purchaser and holder of a ticket because it is not practical for ordinary people to have their biological information registered in advance at home and checked at event sites on the day of the event with such sensors. On the other hand, a sensor for face recognition is a normal camera that ordinary people can easy handle. Face recognition has been enhanced with the progress of deep learning techniques and the availability of large-scale training datasets [11]. Face recognition has been put into limited practical use for verifying identity such as entrance and exit control for rooms, immigration control, and reception control [12], [13].

The problem in verifying ticket holders is how to simultaneously verify identities efficiently and prevent individuals from impersonating others at a large-scale event at which tens of thousands of people participate. To solve this problem, we previously developed two ticket ID systems that identify the purchaser and holder of a ticket by using face-recognition software, which require ID equipment such as a tablet terminal with a camera or a PC with two cameras, a check-in card reader, and ticket-issue printer [14], [15]. Since the two systems were proven effective for preventing illegal resale by verifying attendees at large concerts of popular music singers and groups, they have been used at more than 110 concerts [16]. However, it is necessary to improve face-recognition accuracy by securing clear facial photos because face recognition fails when unclear facial photos are obtained, i.e., when event attendees have their eyes closed, not looking directly forward, or have their faces covered with hair or items such as facemasks and mufflers. Examples in which recognition was

Fig. 1 Examples of recognition failure.

not successful are shown in **Fig. 1**. The recognition failed because the individuals had their eyes closed (Fig. 1 left), were not looking directly forward (Fig. 1 middle), or had their faces covered with hair (Fig. 1 right).

We propose an identity-verification system for attendees of large-scale events using continuous face recognition improved by managing facial directions and eye contact (eyes are open or closed) of the attendees. The remainder of the paper is as follows. In Section 2, we survey related work on electronic ticketing systems, walk-through systems, and face-recognition software. In Section 3, we describe problems with our two previous Ticket ID systems that verify the identity of ticket holders at large-scale events using face recognition. In Section 4, we describe our proposed system with continuous face recognition improved by managing facial directions and eye contact of the attendees. In Section 5, we report the demonstration results of the proposed system, which was used for verifying 8,461 concert attendees as well as survey results obtained from 109 attendees who had seen the system in use when entering the event. In Section 6, we discuss our proposed system regarding its feasibility of solving the problems with the previous systems and consider the outlook for future issues. We conclude the paper in Section 7.

2. Related Work

2.1 Electronic Ticketing Systems

Electronic ticketing systems have made it unnecessary to issue physical admission tickets and the admission procedure more efficient at large-scale events. These systems provide an electronic ticket, which is a barcode or QR code displayed on a smartphone or tablet terminal instead of a paper ticket. One such system offers an electronic tear-able ticket that is invalidated when it is used for admission in the same way as a normal paper ticket is invalidated when it is physically torn. However, an ordinary electronic ticket is not effective in preventing impersonation because it is transferable. Therefore, an electronic system has been investigated that electrically verifies identities of attendees to control admission. A transfer-prohibited electronic ticket system with anonymity makes it possible to prohibit ticket-transfer with an interactive signature and undeniable signature [17]. Although this system presented promising experimental results, it has not been put into practical use because it uses an IC card securing a secret key for the ticket purchaser on the presupposition that the IC card is never transferred to people other than the purchaser. The system cannot practically prevent impersonation because the presupposition cannot be always verified.
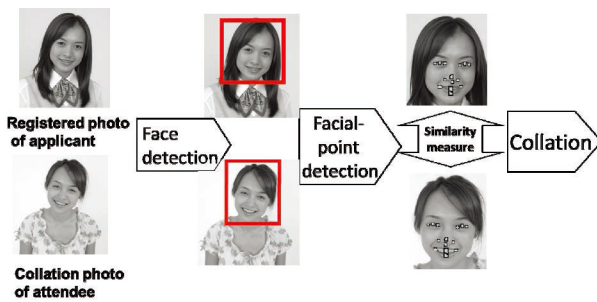
Fig. 2   Outline of face-recognition process.

2.2   Walk-through System

Walk-through systems have been widely used for efficient admission at station and airport gates. A large number of passengers can quickly go through the automatic gates by placing their IC cards or QR codes on reading sensors. Since the systems are based on IC cards and QR codes, which are transferable to people other than the purchaser, they cannot practically prevent impersonation. To prevent illegal rides, regulations on passenger operations of railway companies prohibit passengers from boarding with illegal ticket such as borrowing commuter passes of other passengers [18]. Several automatic gates at railway station are designed to emit a sound and/or a light when passengers go through the gate with children-fare tickets. However, they do not completely work for preventing illegal rides.

As a walk-through system using biometrics authentication, finger-vein authentication resulted in high throughput equal to that of automatic ticket gates [19]. The system makes it possible to quickly recognize finger-vein patterns when passengers pass their hands over the dedicated biometric sensor. However, the sensor is a bottleneck for putting such systems into practical use. For identity verification of large-scale events, it is necessary for ordinary people to have their biological information registered in advance at home and checked at event sites on the day of the event with the sensor. Cost and portability are bottlenecks for walk-through systems using biometrics.

2.3   Face-recognition Software

Many face-recognition software programs have been developed [20]. The face-recognition software that our ticket ID systems use is the high-speed and high-precision commercial product NeoFace [21]. NeoFace exhibited the highest performance evaluation in the Face Recognition Vendor Test 2014 conducted by the U.S. National Institute of Standards and Technology (NIST) [22]. The face-recognition process is outlined in **Fig. 2**.

In this process, registration photos are compared with collation photos to determine whether they show the same person [23]. Our ticket ID systems compare registered photos of applicants with collation photos of individuals entering the event venue. First, face detection is executed by detecting and processing the facial areas for each photo. Next the facial-feature points of the detected areas — the eyes, nose, mouth edges, and so forth — are processed to carry out facial-point detection. Finally, the obtained facial-point positions are used to normalize the size and positions of the facial areas and measure their similarity between a registered and collation photo during the collation process. When

the similarity measure exceeds a certain threshold, face recognition is regarded as successful. The threshold is set in accordance with that of NIST personal identity searches [14]. When Neo-Face is implemented in a commercially available tablet terminal, the recognition result is displayed with regard to the facial photo information of 100,000 people within about 0.5 seconds [14].

3.   Ticket ID System Using Face Recognition

3.1   Requirements in Verifying Identity of Ticket Holders at Large-scale Events

Thorough verification for preventing individuals from impersonating others is in a trade-off relationship with efficient verification. The problem in verifying ticket holders is how to simultaneously verify identities efficiently and prevent individuals from impersonating others at a large-scale event in which tens of thousands of people participate. The solution should be suitable within practical operation costs for various sized events held in various environments including open air. As a practical solution combining efficiency, scalability, and portability for a large-scale event, our one-stop face-recognition system (a tablet-based face-recognition system) [14] and non-stop face-recognition system [15] use NeoFace. Since both systems were proven practically effective for preventing illegal resale by verifying attendees at large concerts of popular music singers and groups, they have been used at more than 110 concerts [16]. Therefore, the systems are highly regarded by the Japanese Society of Artificial Intelligence (JSAI) [24] and the Information Processing Society of Japan (IPSJ) [25], [26].

3.2   Parameters and Threshold for Our Ticket ID Systems

Face recognition is controlled using intrinsic, extrinsic, and operational parameters [14]. Our ticket ID systems are controlled using intrinsic, extrinsic, and operational parameters. The intrinsic parameters are due purely to the physical nature of the face, and are independent of the observer. They include age, expression, and facial paraphernalia such as facial hair, glasses, and cosmetics. Extrinsic parameters are related to the appearance of the face. They include lighting, pose, background, and imaging such as resolution and focus. Operational parameters are related to the interaction between attendants and attendees. They include how many times the face recognition process should be repeated per attendee until his/her identity is verified, whether an attendee should stop for the face recognition process, and whether an attendee should face the camera.

The intrinsic and extrinsic parameters were set up in accordance with the standards of NIST personal identity searches for passport/visa photo images [27]. The standards are suitable for our ticket ID systems, and acceptable for individuals applying for tickets to register. Several specific standards on images are as follows:

1) Photos taken within 3 months
2) Face centered and no hair covering front of face
3) Eyes open on the same horizontal line
4) Single color background
5) No shadows on background and no shadows on face
6) No sunglasses and no glare on glasses

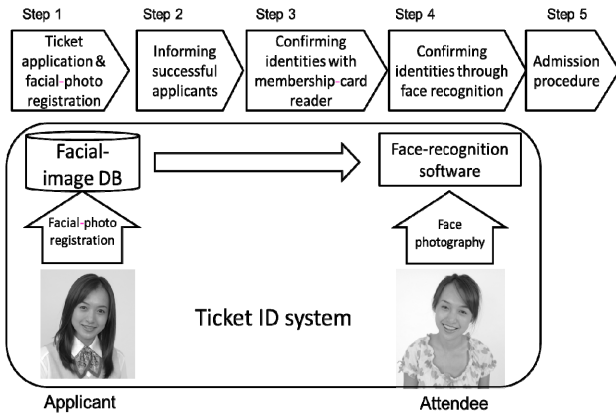**Fig. 3** Ticket-verification procedure with our one-stop face-recognition system.

Fig. 4 One-stop face-recognition system.

Fig. 5 Non-stop face-recognition system.

7) Remove hats and caps

8) No other face, partial face, toys nor other objects in image

9) No camera-capture artifacts and no stretched images

These standards are illustrated on websites for individuals applying for tickets. The operational parameters allowed the face-recognition process to be executed twice per attendee until his/her identity was verified. They made an attendee stop for face recognition and face the camera. As mentioned in Section 2.3, the similarity between a registered image and collation image is determined at the collation process. This is carried out on the assumption that the images were taken in accordance with the parameters. When the similarity measure exceeds a certain threshold, face recognition is regarded as successful. The initial threshold was set up in accordance with that of NIST personal identity searches, which achieved the lowest false reject rate (FRR) 0.3% in processing the passport/visa photo image database at a false accept rate (FAR) of 0.1% [23].

3.3 One-stop Face-recognition System

Our one-stop face-recognition system supports identity verification of attendees. A venue attendant checks in by placing his/her membership card on the card reader and initiates face recognition by the taking of his/her photos. **Figure 3** shows the ticket-verification procedure from the first step of ticket application to the last step of admission supported with our one-stop face recognition system.

Step 1: Tickets to popular events are often sold on a lottery basis at fan clubs or other organizations where membership is registered. Individuals applying for tickets register their membership information as well as their facial photos. At that time, they are advised of the privacy policy in effect regarding the handling of the photo and other personal information and the verification of their identity on the day of the event. In the same way for an ordinary ID photo, the registered facial photo is a clearly visible frontal photo taken against a plain background. The face must not be obstructed by a hat, sunglasses, facemask, muffler, etc., or by excessively long hair or a flashed peace sign.

Step 2: Event organizers notify ticket winners, i.e., successful applicants that have been selected.

Step 3: On the day of the event, venue attendants use a card reader or other means to verify that individuals entering the venue are successful applicants, as shown in **Fig. 4**.
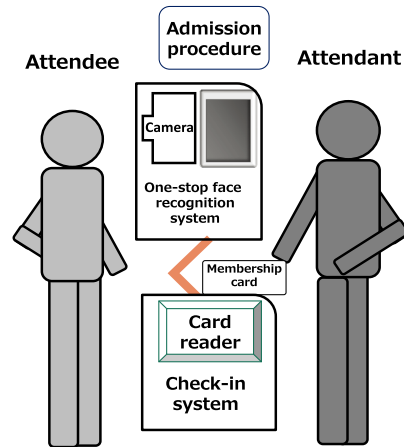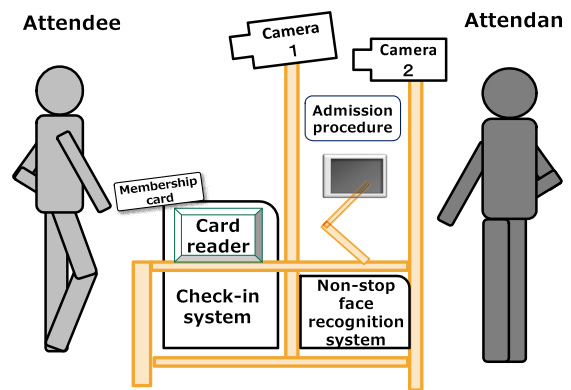
Step 4: At the event, the attendant uses face-recognition software to confirm that the photo taken at the time of application and the collation photo show the same person. The attendant explains the verification through face recognition to the attendees and instructs them where to stand in front of the terminal. Then, they execute the face-recognition process using the terminal to confirm the attendees are those who applied for the tickets.

Step 5: The admission procedure is carried out in accordance with the face-authentication results.

3.4 Non-stop Face-recognition System

Our non-stop face-recognition system takes attendees' photos for face recognition while they are walking. The photos of walking attendees could not be used for face recognition because the attendees are not always directly facing cameras nor have their eyes open when the system takes their photos. To solve this problem, we developed our non-stop face-recognition system, as shown in **Fig. 5**, based on our one-stop face-recognition system with the following improvements:

1) Spacing between a card reader and verification place

A card reader is set up about 1.5 m ahead of a venue attendant. Attendees walk toward the attendant after the attendants check in by placing their membership cards on the card reader. The attendees do not have to stop for their identity verification.

2) Face recognition using two different photos

The system takes two photos of a walking attendee after an in-

terval of about 0.5 seconds with two external cameras set up in noticeable places for attendees. The system collates a registered facial photo of the attendee with the two photos taken from different angles at different times. The system determines that identity verification is successful when either photo is identical to the registered photo.

3.5 Problems with Previous Systems

The average time for identity verification from check-in to entry admission was respectively 7 and 2.8 seconds per person. The average accuracy of face recognition was respectively 90% and 91%. Since the one-stop face-recognition system requires a single camera and the non-stop face-recognition system requires two cameras, the former has lower equipment cost than the latter. While the systems were used at more than 110 concerts, it is necessary to improve face-recognition accuracy by securing clear facial photos because face recognition fails when unclear facial photos are obtained, i.e., when event attendees have their eyes closed, are not looking directly forward, or have their faces covered with hair or items such as facemasks and mufflers. When face recognition fails, venue attendants have to verify attendees carefully by direct visual inspection. This increases the mental and physical burden on attendants, which makes attendees have an unreliable impression of the systems. When face-recognition accuracy is 91%, two attendees are successively verified without face recognition failure with the possibility of 82.8%. This means that 17.2% of the attendees possibly experience face-recognition failure themselves or observe it in front of them. Improving face-recognition accuracy is critical for decreasing attendants' stress and increasing attendees' trust in the systems. Face-recognition accuracy should improve with a single camera. Camera's costs cannot be operationally ignored because large-scale events need more than 120 cameras [14]. They are key-devices for face-recognition accuracy. It is difficult to ensure clear facial photos with inexpensive cameras.

4. Face Recognition for Managing Facial Directions and Eye Contact of Event Attendees

4.1 Managing Facial Directions and Eye Contact

We propose an identity-verification system for attendees of large-scale events using continuous face recognition improved by managing facial directions and eye contact of the attendees. The proposed system is based on our non-stop face recognition system and enables attendees to check in themselves [15]. While the non-stop system is equipped with a card reader set up about 1.5 m ahead of a venue attendant and with two cameras for recognizing faces of walking attendees [15], the proposed system does this with a QR code reader and single camera set up at the same position for recognizing faces of attendees standing still in front of a venue attendant, as shown in **Fig. 6**.

Managing facial directions and eye contact are two major issues regarding facial recognition. The proposed system addresses them with the following methods:
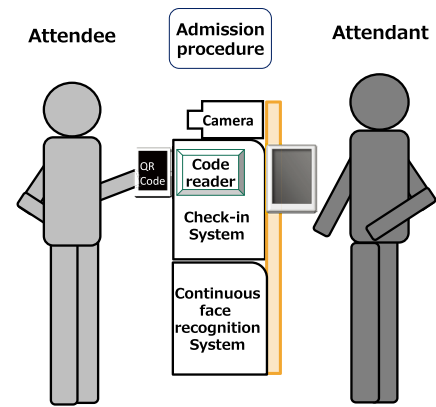

Fig. 6 Continuous face-recognition system.

1) Managing facial direction

The proposed system secures facial photos of attendees directly facing a camera by leading them to scan their QR codes just before executing face recognition. When they start scanning their QR codes on a QR-code reader, continuous face recognition is automatically activated. From our experience with our non-stop face-recognition system, we found that they look at the code-reader, i.e., turn their faces to the reader during check-in. A face-recognition camera of the proposed system is placed at the same position as the code-reader, as shown in Fig. 6, which makes it possible to take an attendee's photo when directly facing the camera when the photo is taken just after check-in.

2) Managing eye contact

The proposed system uses a continuous face-recognition system for accepting two photos of attendees with a single camera successively taken after an interval of 0.5 seconds to obtain facial photos with their eyes open. When we analyzed two photos successively taken after an interval of 0.5 seconds with two external cameras for our non-stop face recognition system, we found that there were no two successive photos including attendee's faces with their eyes closed. This means that either the first or second photo includes the attendee's face with his/her eyes open. Few people spontaneously keep their eyes closed longer than 0.5 seconds because human blink duration is on average between 0.1 and 0.4 seconds [28]. Few people spontaneously blink twice in 0.5 seconds because human blink rate is between 7 and 17 per minute [29]. It is possible to manage eye contact of the attendees when we take the first photo at the same time of attendee's scanning a QR code and then take the second photo after an interval of 0.5 seconds with a single camera.

4.2 Configuration of Proposed System

Figure 6 shows a configuration of the proposed system including the event-attendee control platform and continuous face-recognition system. The configuration is almost the same as that of our non-stop face-recognition system [15] except for the following:

1) A single camera and QR code reader

While our non-stop face-recognition system uses two cameras and a card reader, the continuous face-recognition system of our proposed system uses a single camera with a QR-code reader, as shown in **Fig. 7**. The camera and QR-code reader are com-
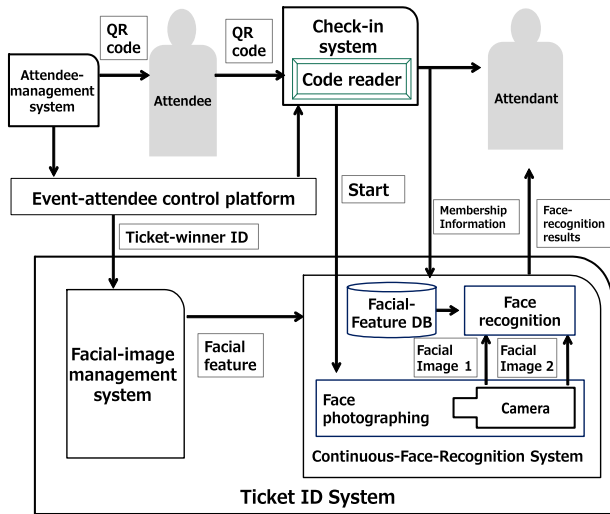
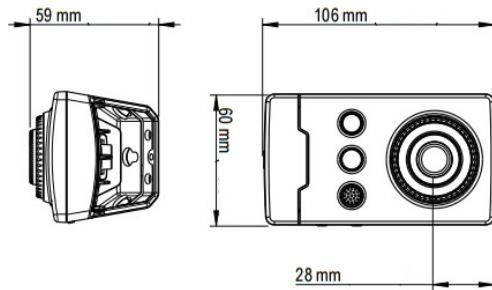**Fig. 7** Configuration of proposed system.
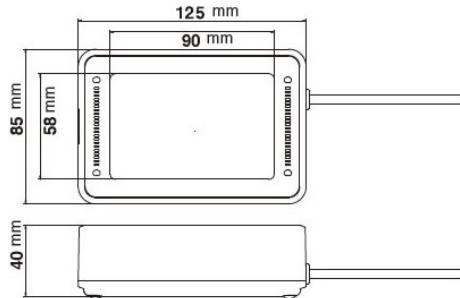

Fig. 8 Camera used for proposed system.

Fig. 9 QR code reader used for proposed system.

pact enough to easily set up and carry. Drawings of the camera and QR-code reader are respectively shown in **Figs. 8** and **9**. The camera has a horizontal field of view of 110° and a vertical field of view of 61°. The resolution of the camera is $1,920 \times 1,080$ Full HD 1,080 p, i.e., 1,920 pixels displayed across the screen horizontally and 1,080 pixels down the screen vertically with progressive scan [30]. The views and resolution are able to provide wide-viewing and high-resolution photos for face recognition when they are taken within a few meters. There is no difference of the image quality affecting face-recognition accuracy between the proposed and previous systems.

2) Ticket with QR code

When attendees check in at a location that has the proposed system installed, they scan their tickets with QR code; attendees used to place their membership cards on a card reader with our non-stop system, as shown in Fig. 5. The attendee-management system provides the attendees the tickets, as shown in Fig. 7, in
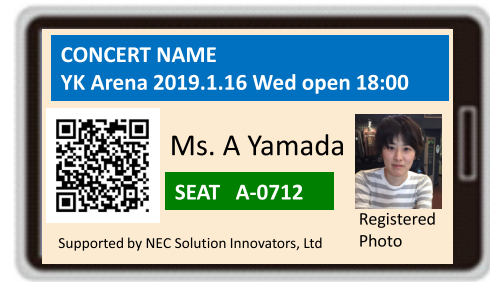

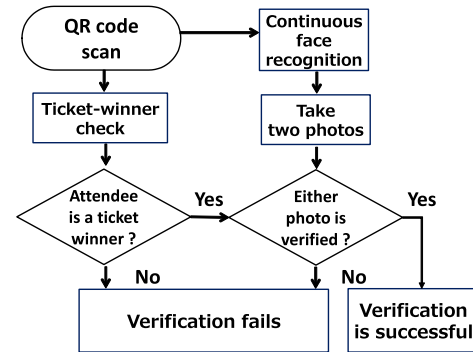**Fig. 10** Example of ticket with QR code.

Fig. 11 Flowchart of verification.

advance of the event day. Attendees can obtain a ticket with a QR code, shown in **Fig. 10**, with their smartphones. The ticket has the concert name, date and time, venue, QR code containing attendee's membership information, his/her name, seat number, registered photos, and so on.

4.3 Identity-verification Procedure

An attendee's identity is verified with the procedure shown in **Fig. 11**. When attendees scan their QR codes, a check-in system performs ticket-winner check as well as showing the attendants the member information of the attendees, which is retrieved from the ticket-winner database with search keys of membership numbers obtained through a QR code reader. Scanning a QR code automatically activates continuous face recognition by taking two photos of the attendee after an interval of 0.5 seconds. When either photo is verified with the registered photo of the attendee, face recognition is successful. When attendees are ticket winners and face recognition is successful, the verification is successful. Otherwise, verification fails.

4.4 Operational Steps

The proposed system has the following operational steps from the first step of ticket application before the event day to the last step of admission on the event day:

Step 1: Ticket application is the same as that of our one-stop face-recognition system described in Section 3.3.

Step 2: Event organizers notify ticket winners, i.e., successful applicants that have been selected. They can obtain attendee's tickets including their QR codes and registered facial photos.

Step 3: At the check-in site on the event day, attendees scan their QR codes with the code reader according to attendant's instruction.

Step 4: Attendants can confirm that attendees are success-

ful applicants who applied for the tickets, as mentioned in Section 4.3.

Step 5: If identity is verified, the attendee is admitted entry. Otherwise, identity is verified by an attendant with direct visual inspection of the facial photo on the ticket.

5. Demonstration of Proposed System

5.1 Demonstration and Results

The proposed system was demonstrated according to the operational steps described in Section 4.4 including the identity-verification procedure described in Section 4.3. Twenty-seven sets of the proposed system were used for a popular concert on November 7, 2018 at Yokohama Arena (Yokohama, Kanagawa Prefecture). They were installed just behind the baggage-inspection site. Face recognition was carried out for 8,461 attendees. The identity-verification time was 2.7 seconds on average in cases in which face recognition was not successful. The face-recognition accuracy was 93%. No cases of attendees impersonating others were reported for the concert. The FRR was 7% and FAR was 0%. There were two reasons for recognition failure: The first was that faces of incorrect attendees were detected when photos contained other attendees behind a correct attendee. The second was that the attendees had their faces covered with hair or items such as facemasks and mufflers. Failure was not observed due to the fact that attendees had their eyes closed or were not directly facing a camera.

5.2 Attendees Survey

An identity-verification system for attendees of large-scale events should be evaluated from the view-point of convenience in verification to show how practical such a system is. Surveys were conducted for attendees who were admitted with the proposed system. They were asked to respond to four questions about the system's equity in ticket purchasing and three questions about its convenience in verification. The 109 survey respondents are broken down by age and gender in **Fig. 12**. The survey results are shown as percentages in **Tables 1**, **2**, **3**, **4**, **5**, **6**, **7**.

(1) Equity in ticket purchasing

Regarding the question, "Should there be more equity in ticket purchasing?" (Table 1), 98.1% of the respondents said either "Definitely yes" or "Yes, I think so."

Regarding the question, "Does the system provide more equity in ticket purchasing than methods without face recognition?" (Table 2), 96.4% of the respondents said either "Yes, much more", "Yes, somewhat more", or "It may; I'm not sure."

Regarding the question, "Why does the system provide more equity in ticket purchasing than methods without face recognition?" (Table 3), the offered responses were, "It makes illegal resale harder", "It makes it easier to get tickets", "It cuts down on scalping", and "It reduces problems for ticket holders."

Regarding the question, "Does the system effectively prevent illegal resale?" (Table 4), 95.4% of the respondents said either "Definitely yes" or "Yes, I think so."

(2) Convenience in verification

Regarding the question, "Is the system more convenient than having the attendant verify ID cards and the like visually?" (Ta-
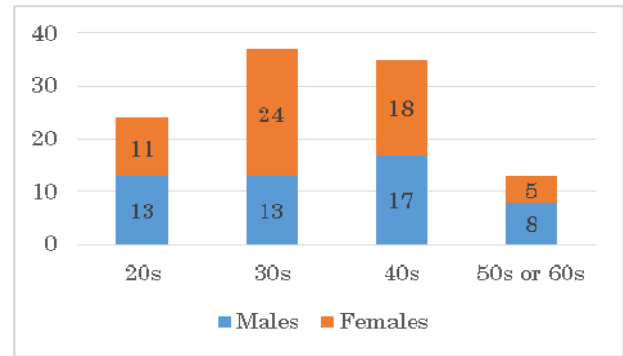

Fig. 12   Survey respondents by age and gender.

Table 1   Should there be more equity in ticket purchasing?

Responses	%
Definitely yes	75.3
Yes, I think so	22.9
No, I don't think so	0.9
Definitely no	0.9

Table 2   Does the system provide more equity in ticket purchasing than methods without face recognition?

Responses	%
Yes, much more	45.0
Yes, somewhat more	37.6
It may; I'm not sure	13.8
No	3.7

Table 3   Why does the system provide more equity in ticket purchasing than methods without face recognition?

Responses	%
It makes illegal resale harder	86.7
It makes it easier to get tickets	69.5
It cuts down on scalping	46.7
It reduces problems for ticket holders	12.4

Table 4   Does the system effectively prevent illegal resale?

Responses	%
Definitely yes	65.1
Yes, I think so	30.3
No, I don't think so	3.7
Definitely no	0.9

Table 5   Is the system more convenient than having the attendant verify ID cards and the like visually?.

Responses	%
Definitely yes	48.6
Yes, I think so	38.5
No, I don't think so	11.9
Definitely no	0.9

ble 5), 87.1% of the respondents said either "Definitely yes" or "Yes, I think so."

Regarding the question, "Why do you think the system is more convenient?" (Table 6), the offered responses included, "It streamlines the admission procedure", "It makes showing an ID

Table 6 Why do you think the system is more convenient?.

Responses	%
It streamlines the admission procedure	74.0
It shortens the waiting time	42.0
It makes showing an ID card unnecessary	41.0
It makes showing the attendant personal data unnecessary	34.0

Table 7 Why do you think the system is not more convenient?.

Responses	%
It makes the admission procedure longer	64.0
The attendant is not used to using it	36.0
I'm concerned it might not recognize me correctly	43.0
I'm concerned about how it will handle my personal data	29.0

Table 8 Results of our previous and proposed systems.

	One-stop face-recognition system	Non-stop face-recognition system	Proposed system
Identity-verification time	7 seconds	2.8 seconds	2.7 seconds
Face-recognition accuracy	90%	91%	93%
Number of cameras	1	2	1
Check-in doer	Attendant	Attendee	
Reasons for recognition failure	Attendees had their eyes closed.		
	Attendees were not directly facing a camera.		
		Incorrect attendee's faces were detected.	
	Attendees had their faces covered with their hair or items such as facemasks and mufflers.		

card unnecessary", and "It shortens the waiting time."

Regarding the question, "Why do you think the system is not more convenient?" (Table 7), the offered responses included, "It makes the admission procedure longer", "The attendant is not used to using it", "I'm concerned it might not recognize me correctly", and "I'm concerned about how it will handle my personal data."

6. Discussion

Table 8 compares the results of our previous systems and the proposed system.

6.1 Identity-verification Time and Face-recognition Accuracy

The proposed system spent 2.7 seconds per person for identity verification on average; 2.5 seconds per person in case of successful recognition and 5.5 seconds per person in case of direct visual inspection. The results are the same as those from the non-stop face recognition system [15]. The average time for identity verification with the non-stop system was 2.8 seconds per person including direct visual inspection. The average time was 0.1 seconds shorter than that of the non-stop system because the face-recognition accuracy of the proposed system was 2% higher than that of the non-stop system. This resulted in decreasing the number of direct visual inspection which increased identity verification time, and relieved the mental and physical burden on attendants

6.2 Number of Cameras

The proposed system achieved shorter identification time with higher face-recognition accuracy using a single camera i.e., with lower cost than the non-stop system. This makes it easy for an event organizer to increase the number of check-in sites for events. Increasing sites will make the process more convenient for attendees. Survey results obtained from attendees showed the opinion that increasing the number of lanes might help shorten the lines of attendees [14]. Even though the system's identity-verification time is shorter, it is essential for an event organizer to

prepare the required number of check-in sites.

6.3 Check-in Doer

Both the non-stop and proposed systems could shorten identity-verification time by enabling attendees to check in compared with the one-stop system. Both systems do not require handing over a membership card or ticket between attendants and attendees, which resulted in shorter identity-verification time than that of the one-stop system, which requires hand-over.

6.4 Reasons of Recognition Failure

Face detection exhibited a problem in that faces of incorrect attendees were detected when photos contained other people behind the attendee. This can be solved by choosing the face with the largest face area among all the detected faces. Face recognition failed when attendees had their faces covered with their hair or items such as facemasks and mufflers. There were no cases in which attendees had their eyes closed or were not directly facing a camera in the two successive photos, i.e., in the first photo and second photo taken after 0.5 seconds. Managing facial direction and eye contact of attendees worked as expected. It is difficult to solve the problem of when the faces of attendees are covered with hair or items such as facemasks and mufflers because there was no differences between the first and second photos on the attendee's covered faces. The attendee's cooperation is necessary for solving this problem.

6.5 Survey of Attendees

Survey results obtained from 109 individuals who had seen the system in use when entering the event showed that 96.4% of them

felt the system provided more equity in ticket purchasing than methods without face recognition. Various reasons were given for this, among them "it's a good system because it will help to control the illegal resale and scalping of tickets (female, 20s) and "I think it will actually make me feel more at ease about the competition involved in purchasing tickets (male, 40s)." Survey results showed that 95.4% of the respondents felt it would effectively prevent illegal resale.

The results obtained from the same 109 individuals showed that 87.1% felt the system provided added convenience in verification. Various reasons were given for this, among them "It makes the admission procedure smoother (male, 40s)" and "It surprised me because the admission was much smoother than expected (female, 20s)." The opinion that "It should be used for all concerts (male, 30s)" was also expressed. This indicates the system is also able to reduce the psychological burden on event attendees. On the other hand, there were attendees who did not feel the system provided added convenience. Reasons given for this included "It makes the registration time longer (male, 30s)", "People wearing face masks, makeup and the like might not be recognized and be denied entry (male, 30s)", and "Misusing my photo concerns me (female, 40s)". The opinion that "Providing battery chargers might help attendees when their smartphones run out of battery (male, 30s)." was also expressed.

7. Future Issues

7.1 Face Detection of Incorrect Attendees

Faces of incorrect attendees were detected when they stood behind a correct attendee. This can be solved by choosing the face with the largest face area among all the detected faces. When it is not solved by the improvement, we are preparing a partitioning screen behind a correct attendee to prevent incorrect attendees from being photographed.

7.2 Attendee's Covered Faces

Covered faces is the largest problem remaining for improving face-recognition accuracy. This problem could be solved with attendee's cooperation. We have been developing an identity-verification system using face recognition from selfies taken by attendees with their smartphone cameras [31]. Through the preliminary tests ensuring the feasibility, self-photographing is regarded as helpful for securing clear facial photos because attendees can control the intrinsic parameters such as their expressions, facial hair, and facial directions. This system may be helpful in simplifying the equipment traditionally required, such as PCs for face recognition, code readers, and cameras, at event sites [31]. Such equipment requires much time to set up and are expensive. Therefore, it is also important to simplify the equipment for identity verification. We are planning a hybrid use of this system and the proposed system for solving the problem of covered faces and simplifying equipment from the view-points of attendees and attendants.

7.3 Prevention of Impersonation

The proposed system has been widely reported in the mass media. The system is highly regarded from reviews on the Inter-

net [32]. After the concert reported above, it was used to carry out face recognition for more than 100,000 attendees at concert halls of Fukuoka, Tottori, Nagoya, Osaka, Saitama and Chiba in 2018. Though no cases of attendees impersonating others were reported for any of these events, i.e., the FAR was 0%; the FAR should be more carefully examined from the view-point of preventing impersonation. It is necessary to evaluate the robustness against impersonation with pseudo attack tests. The tests should include disguise and lookalike tests. A disguise test makes people's facial appearances as similar as possible by using facial paraphernalia such as facial hair, glasses, and makeup. Disguised face recognition is still a challenging task that needs to be investigated due to the numerous variations that can be introduced using different disguises [33], [34]. A lookalike test is conducted for those, such as twins or similar looking siblings, with similar facial features. A disguise test will reveal considerable disguise methods and help in creating operational manuals for venue attendants to detect the methods. A lookalike test will disclose the technical limitations of current face-recognition techniques and help in establishing next-generation technology.

8. Conclusion

We proposed an identity-verification system for attendees of large-scale events using continuous face recognition improved by managing facial directions and eye contact of the attendees. The proposed system could secure facial photos of attendees directly facing a camera by leading them to scan their QR codes on a QR-code reader placed close to the camera just before executing face recognition. The system took two photos of attendees with a single camera after an interval of 0.5 seconds to obtain facial photos with their eyes open. The system achieved 93% face-recognition accuracy with an average time of 2.7 seconds per person for identity verification when they were used for verifying 8,461 attendees at a concert of a popular music singer. The system made it possible to complete identity verification with higher accuracy than previous systems and with shorter average time than our non-stop system using a single camera, i.e., with low equipment cost. Survey results obtained from the attendees showed that 96.4% felt it provided more equity in ticket purchasing than methods without face recognition, 87.1% felt it provided added convenience in verification, and 95.4% felt it would effectively prevent illegal resale. To further streamline the verification procedure, we plan to improve our system.

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Akitoshi Okumura received his B.E. and M.E. degrees in precision engineering from Kyoto University, Kyoto, Japan in 1984 and 1986. He joined NEC Corp. in 1986 for researching natural language processing, speech translation, and AI robots at Central Research Laboratories. He joined DARPA machine translation project as a visiting scientist at the University of Southern California, Los Angeles, USA in 1993. He received his Ph.D. in computer science from Tokyo Institute of Technology, Tokyo, Japan in 1999. He is currently Vice Chairman of Information-technology Promotion Agency, Japan. He is IPSJ Fellow and the recipient of 2007 METI Minister Award from Fuji Sankei Business i, the 2010, 2015, and 2016 Field Innovation Awards from JSAI, 2008 Kiyasu Special Industrial Achievement Award, 2017 Industrial Achievement Award, 2017 Yamashita SIG Research Award, and DICOMO2019 Best Paper Award from IPSJ.

Susumu Handa received his B.S. degree in physics from Chuo University, Tokyo, Japan in 1984 and his Ph.D. in computer science from Kyushu Institute of Technology, Fukuoka, Japan in 2001. He is currently a senior expert in the Advanced Technology Solutions Division at NEC Solution Innovators, Ltd. His current interests include the business promotion and development of computer systems related to advanced technologies, especially face recognition and visualization in a high performance computing area. He is the recipient of the 2015 Gold Award for Field Innovation from JSAI and DICOMO2019 Best Paper Award from IPSJ.

Takamichi Hoshino received his B.E. degree from Tokai University, Kanagawa, Japan in 1983. In 1983, He joined NEC Informatec Systems, Ltd. (currently NEC Solution Innovators, Ltd.). His current interests include the business promotion and development of physical security systems related to advanced technologies. He is the recipient of the 2015 Gold Award for Field Innovation from JSAI and DICOMO2019 Best Paper Award from IPSJ.

Naoki Tokunaga a received his B.E. and M.E. degrees from Kwansei Gakuin University, Hyogo, Japan in 2006 and 2008. He has been engaged in developing software systems at NEC Informatec Systems, Ltd. (currently NEC Solution Innovators, Ltd.) since 2008. His current interests include developing software for face recognition and bioinformatics. He is the recipient of DICOMO2019 Best Paper Award from IPSJ.

Masami Kanda received his B.E. degree in computer science from Toyo University, Tokyo, Japan in 1985. In 1985, He joined NEC Scientific Information System Development Ltd. He has been involved in the development of embedded systems such as telephone network switchboard and mobile phone. He is currently a general manager in the Advanced Technology Solutions Division at NEC Solution Innovators, Ltd. His current interests include the business promotion and development of computer systems related to advanced technologies. He is the recipient of DICOMO2019 Best Paper Award from IPSJ.