# Automated Border Control Systems: Biometric Challenges and Research Trends


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**Abstract.** Automated Border Control (ABC) systems automatically verify the travelers' identity using their biometric information, without the need of a manual check, by comparing the data stored in the electronic document (e.g., the e-Passport) with a live sample captured during the crossing of the border. In this paper, the hardware and software components of the biometric systems used in ABC systems are described, along with the latest challenges and research trends.


## 1 Introduction

The number of travelers in the world is constantly increasing [12] and International Border Crossing Points (BCP) are required to increase the passenger throughput, without sacrificing security or comfort. In this context, Automated Border Control (ABC) and surveillance systems can be deployed for an automatic, secure, fast, and user-friendly crossing procedure [51, 5, 50, 60].

ABC systems, or e-Gates, typically include three steps: i) the document (e.g., the e-Passport) is checked for authenticity; ii) the identity of the traveler is verified based on his biometric traits; iii) the validity of the traveler authorization (e.g., the visa) is checked. Face and fingerprint recognition techniques are used in most of the e-Gates, with some systems using also the iris. If the biometric recognition is not successful, a manual check of the traveler identity is performed [23].

Three types of automated border crossing procedures are possible: i) one-step process; ii) integrated two-step process; iii) segregated two-step process [50]. In a one-step process, the document, the identity, and the authorization are verified at the same time, inside the e-Gate. In an integrated two-step process, the validity of the document is checked before letting the traveler go inside the e-Gate for the identity verification and for checking his travel authorization. In a segregated two-step process, the validity of the document and the travel authorization can be checked also at a different time and place of the border crossing.

In order to perform the required steps, four subsystems are used: i) the Document Authentication System (DAS), which checks the validity of the document; ii) the Biometric Verification System (BVS), which captures live biometric samples and compares them with the ones contained in the document; iii) the Central

Systems Interface (CSI), which handles communication with external systems; iv) the Border Guard Maintenance System (BGMS), which is used by the officers to monitor the ABC system.

In order to check if the traveler is authorized for passage across the border, the ABC system checks with three external systems: i) the Visa Management Systems (VMS), which contains the visa information [46]; ii) the Registered Traveler Program (RTP), which contains the personal and biometric data of frequent travelers who voluntarily enrolled in the program; iii) the Entry-Exit Management Systems (EEMS), which contains the information about which borders the travelers cross, in order to detect overstayers, illegal immigration, and collect statistical information. In particular, the EU is proposing to officially adopt the RTP and EES in the ABC systems [44, 45, 3, 2].

## 2 Biometric verification in ABC systems

This section describes the biometric verification procedures using the face, the fingerprint, and the iris, which are the biometric traits used in ABC systems, as recommended by the ICAO [61]:

- *Face recognition* is the primary biometric trait adopted in e-Gates [61], since it is socially accepted, non-intrusive, and does not require special training. The biometric face verification consists of six steps: i) the system chooses the camera position based on the traveler's height; ii) information is displayed to instruct the traveler about how to position its head; iii) illumination is automatically adjusted based on environmental lights; iv) the face image is captured; v) a quality assessment module is used to determine if the image complies with the ISO recommendations [64, 61]; vi) the matching between the live image and the sample in the document is performed.
- *Fingerprint recognition* is an optional biometric technology in e-Passports and e-Gates [61], features high recognition performances and good social acceptance, and is widely adopted. The biometric fingerprint verification consists of four steps: i) information is displayed to instruct the traveler about how to position the finger on the sensor; ii) the fingerprint image is captured; iii) a quality assessment module is used to determine if the image meets the required ISO recommendations [63]; iv) the matching between the live image and the sample contained in the document/database is performed. Minutiae-based matching algorithms are the most widespread [67, 55, 58, 72]. Moreover, second generation European e-Passports store both face and fingerprint traits, which can be combined to increase the recognition accuracy [74, 22, 4].
- *Iris recognition* is optional in e-Gates [61] and, while featuring very high recognition performances, is intrusive and has limited social acceptance, and for these reasons is not widely adopted. The biometric iris verification consists of four steps: i) information is displayed to instruct the traveler about where to place his head near the camera; ii) a near-infrared light pulse is

used to illuminate the eye, as well as control the gaze direction and the dilation of the pupil; iii) the iris image is captured; iv) the live image and the sample contained in the document/database are matched.

## 3 Challenges

The most important challenges in the design of ABC systems regard the development of better anti-spoofing techniques, compatibility between systems, scalability of biometric systems, and methods for allowing the use of the e-Gates also to people with reduced mobility and visual impairments. Moreover, other challenges regard the capture of higher quality face and fingerprint images, and the design of less-intrusive iris biometric recognition technologies:

- *Better anti-spoofing techniques*, in particular liveness-based methods, are important to avoid cheating attempts that use, for example, printed face images [69], fake fingers made with silicone [68], or synthetic irises [14]. Recent projects studied enhanced anti-spoofing techniques for biometric systems [1], however the data about impostors trying to gain authorized access in e-Gates are not publicly available.
- *Compatibility between systems* should be realized by adopting a common biometric data format [64, 63, 65], in order to facilitate the adoption of ABC systems. The type of data exchanged (sample or template) must be chosen according to bandwidth and privacy requirements [79, 40, 20, 16, 8, 11, 7, 17, 21]. Moreover, a common standard for cryptographic interoperability could help the widespread adoption of security and privacy protection techniques [40].
- *Scalable biometric systems* must be designed, so that ABC systems are able to work efficiently on a large scale [57, 56].
- *The design for people with reduced mobility and visual impairments* could help people in a wheelchair, with muscular dystrophy, or with walking aids in accessing the e-Gate and interacting with the biometric sensors. Similarly, it could help visually impaired people when they can not see the information displayed to instruct them about the correct procedures.
- *Higher quality face images* greatly increase the recognition performances, but require the users to stand looking directly in front of the camera, which must be placed at the correct height. Moreover, the illumination must be uniform and able to compensate for environmental variations [78].
- *Higher quality fingerprint images* also increase the performance of fingerprint recognition technologies, and can be obtained by enhancing both the usability of the system and the algorithms for the quality estimation [28, 38, 24], without increasing the acquisition time.
- *Less-intrusive iris recognition techniques* could help in extending the field of use iris-based systems, since they are currently the most accurate, but have high costs and intrusiveness. At the moment, iris recognition systems are not considered in e-Passports [71] and require additional systems for their use.

## 4 Research trends

The most promising research trends in the design of innovative ABC systems regard the use of multibiometrics and less-constrained recognition:

- *Multibiometrics* can increase biometric recognition accuracy, usability, and robustness to spoofing attacks, by combining multiple biometric sources [74, 80]. Several studies demonstrate the increase of accuracy fusing face and fingerprint biometrics [77], also in the case of ABC systems [22, 62]. Moreover, the non-universality or low discriminative power of some biometric traits (e.g., soft biometrics) can be compensated by fusing multiple traits [66, 54, 15, 6, 53, 52], which can then be used in automated border control and surveillance [73]. However, multibiometric systems are bigger, more complex, and handle more sensitive data, thus requiring more robust data protection schemes [18, 19].
- *Less-constrained recognition* could increase the usability and social acceptance of biometric systems [70]. In fact, since they allow a touchless recognition, it would be possible to perform the biometric verification at higher distances, with natural light conditions, and while the traveler is moving, by using the fingerprint [34, 35, 41, 33, 30, 29, 26, 39, 25, 32], the palm [59], or the iris [70, 42, 27, 76, 75, 37]. A study showed that touchless fingerprint technologies would be preferred over touch-based systems [35], thus allowing for an increased confidence and adoption of biometric recognition [43]. Moreover, less-constrained biometric recognition techniques using innovative traits are being researched [13, 36, 31], and the advances in three-dimensional reconstruction techniques [9, 10, 47–49] could allow the use of three-dimensional modeling methods for accurate, less-constrained biometric systems [35, 34, 59, 81].

## 5 Conclusions

The paper presented the biometric technologies adopted in ABC systems for the traveler's recognition, with a particular focus on the systems based on the face, the fingerprint, and the iris.

Moreover, the challenges of biometric systems in the context of ABC systems were discussed, with specific attention to their usability and to anti-spoofing techniques. The current issues of face, fingerprint, and iris recognition systems were also presented.

Lastly, the paper introduced the most promising research trends for a more accurate, usable, and socially accepted biometric recognition for travelers in ABC systems, with a specific focus on multibiometrics and less-constrained systems.

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