Technical Correspondence

The Mobile Pass Project: A User Interaction Evaluation

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***Abstract*—The Mobile Pass project focused its efforts on developing a technologically advanced mobile equipment for land border crossing points. During the project execution, a mobile device supporting biometric recognition (face and fingerprint) and passport checking was designed and developed. To test this new equipment under an operational environment, a usability evaluation was carried out in the Sculeni border control (border of Romania with Moldavia), being the operators Romanian Policemen and the data subjects' real volunteer travelers. The equipment was used for 2 days under different conditions in real scenarios, and the usability evaluation carried out follows the ISO 9241-11:1998 standard. A total of 93 participants completed the new border checking and fulfilled a satisfaction survey at the end of the experiment. This paper describes the evaluation and reports some preliminary results on the user-Automatic Border Control system interaction and the final conclusions obtained at the end of the project, resulting in a valuable guide for designing user interaction in security areas.**

***Index Terms*—Border control, evaluation, face recognition, fingerprint recognition, human computer interaction (HCI).**

I. Introduction

Border control is currently one of the most worrisome topics within the European Union (EU) and many other parts in the world [1]–[4]. In the case of EU, illegal entrance in a country may guarantee the free movement through the whole EU area and triggers the necessity to increase the control in the Schengen borders. More than a million migrants and refugees crossed into Europe in 2015, mostly due to conflict in countries, such as Syria, Afghanistan, or Iraq. The vast majority of the asylum applications in EU and European Free Trade Association (EFTA) states arrived by sea but some migrants crossed over land, principally via Turkey and Albania. This concern highlights the necessity of analyzing and solving all the possible issues related to border crossing. The increasing flow of people on borders involves a reduction of time for border services to check travel documents and identity [5], increasing the risk of fraud. More generally, reasons of fraud are linked not only to the advantages to cross borders but also to perform crimes under another identity, get undue social allocations, etc. All the process triggers high costs, including production costs and social costs, and further resources.

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A. Biometric Recognition in Border Control

In the context of official identity documents, the biometric identification is still limited to face recognition and fingerprints. In fact, most Automatic Border Control (ABC) systems support only the face as the single identification modality. In contrast to unrestricted applications (e.g., face recognition in surveillance applications), biometrics has been proven successful in scenarios where the user is expected to be cooperative, such as the NIST best practices in mobile ID [6] or the promising results obtained by the DoD (US Department of Defense) [7]. ABC systems is a typical example for the latter, due to the fact that it enables more efficient travelling (best practices defined by FRONTEX [8]). But even in this case, the latest results published from a test performed at Schiphol Airport [9] show the very little level of performance in face recognition, because most of the photographs taken were extremely of low quality and in nonfrontal pose, while at the same time, the images scanned from the passport page and the ones read from the passport chip did not allow the correct authentication of the traveler. This fact shows the necessity of improving the biometric recognition reliability and usability as the main causes of poor systems working. The Mobile Pass project is focused on those challenges.

B. Mobile Pass Project

Mobile Pass is a Seventh Framework Programme (FP7) research project, which started in 2014. Over 2 years, the Mobile Pass Consortium [10] focused its efforts on developing a technologically advanced mobile equipment for the land border crossing points. The major objective of the Mobile Pass is to enhance mobility and speed of European travelers and citizens during the border control while protecting EU against security threats. Mobile Pass developed technological advanced mobile equipment for border control authorities, including devices for full-page e-Passport scanning, and the Mobile Pass Device (MPD), integrating contactless fingerprint scanning, communication reliability, security and speed, and cooperative and fast face capturing and verification.

Once the whole system has been designed and developed, is the Mobile Pass reliable and easy to use? What improvements does it introduce with respect to the previous solutions? Will the travelers be eager to use the MPD? To answer these questions, the last step is to evaluate the usability of the system in an operational environment with real operators and data subjects. In this paper, we show the usability evaluation carried out in Sculeni (border control between Romania and Moldavia) during the last part of the Mobile Pass project (November 2016). This work means a significant step forward in the analysis of the human computer interaction in borders, where users may interact with mobile biometric systems. Moreover, due to the strict security in borders, this kind of evaluations is difficult to carry out, so that, this is a significant novelty. Outcomes of this work will feed future border authentication solutions, improving user experience, and boosting systems' performance.

Next sections include the current state-of-the-art border controls in terms of technology and user interaction (Section II), the evaluation setup and usability metrics used during the Sculeni evaluation (Section III), the results obtained (Section IV), and conclusions (Section V).

II. State of the Art

There are different mobile solutions available on the market to perform border control checking, and they differ at the integration level, mobile or handheld. Most of these devices have similar functionality: Swipe reader for the passport machine readable zone, smart card, and radiofrequency identification readers, fingerprint scanner, webcams for photo acquisition, and different types of communication. The data strip devices are different because they try to get a full-page passport scan but they have mechanics and rollers, which make this processing very difficult and time-consuming. There are full-page optical readers on the market, and although the size of these devices is bigger, they are still mobile but not handheld.

As soon as the system needs to have either a full-page passport reader, or a ten-slap fingerprint scanner, the solutions that many manufacturers provide are usually based on a suitcase with all devices placed inside and with the connections already made so that the operation is nearly ready as the suitcase is opened. Because it is a suitcase, then the central processing and the control of all the systems are performed in a laptop. This increases again not only the cost of the solution but also the weight and decreases the possibility of accessing easily to some travelers (for example, inside a bus).

A. Other User-Interaction Projects in Borders in the EU

The EU has launched several initiatives and funding for projects improving borders crossing, in terms of harmonization, throughput, security, reliability, or usability (CORDIS, European Commission/FP7/ICTSecurity/Projects) [11]. In this context, most of the evaluations of the user interaction in borders were carried out using ABC systems that are fixed and do not consider the use of a mobile device. Examples are FastPass (2013–2017) [12] and ABC4EU (2014–2018) [13]. From the academic point of view, universities are also researching on the use of biometrics in border controls [14]. Authors further research in the area include projects such as EKSISTENZ, dealing with ID theft through the EU [15].

The Mobile Pass project introduces the mobility to the border control, which is really necessary in borders where operators need to move within an area and the control may not be fixed. Moreover, a usability evaluation within an operational scenario was carried out during the project and is broken down in the following sections.

III. Evaluation Setup

The evaluation configuration was designed taking the following factors into account:

1) The scenario is the physical border between Romania and Moldavia, where more than 1000 people cross everyday by car or bus. Therefore, the identity of several people must be checked in a secure and trusted manner.
2) The data recording (i.e., evaluation data) should be carried out safely and without interference with the Romanian Border Police (RBP hereinafter), because this is a high-security scenario.
3) The evaluation data must not be linked with the passengers. Therefore, the passport information is not used and the only personal information gathered (e.g., gender, age, etc.) is collected through the surveys where the traveler's name is not requested.

A. General Evaluation Setup

The evaluation configuration is described through the characteristics listed on the ISO/IEC 19795 (Biometric performance testing and reporting standard series), including user, scenarios, operators, devices, and evaluation workflow.

1) Users: There were no directives to select the evaluation participants and the only requirement was being older than 18 years. Moreover, all the participants signed a consent sheet where they were informed about the characteristics of the evaluation. The participation was voluntary.

A total of 93 participants completed the process of authentication via passport and face recognition. A subset of users also tried the fingerprint capture with the right index only, but this part was not recorded, and the time spent and errors were not compiled (fingerprint recognition is still under testing, and the collected samples were used for quality analysis). In any case, the RBP could observe the captured fingerprint in the MPD screen on the spot, as a way to check quality and detect spoofed fingerprints. Genders are balanced (51% women and 49% men) and regarding the ranges, half of the travelers are between ages 18 and 35 years, 30% are between 36 and 55 years, 15% are older than 55 years, and 5% are younger than 18 years. 82% of the passengers use the e-Passport to cross the border, 13% use passport, and 5% national ID cards. 47% of them crossed the border less than once a month, 24% once a month, 18% once a week, and 11% almost daily.

2) Operators: There were two kinds of operators: those who used the MPD and collected the passengers' biometric and passport data (RBP), and the operators who controlled the communications, noted errors, and other particularities, namely, Mobile Pass Team (MPT hereinafter). Once the evaluation was finished, the RBP fulfilled a survey regarding their impressions about the use of the MPD. Regarding the operators' effect on users' behavior, it is the same effect as in common security scenarios, due to the operators were policemen trained to carry out border control checks.

3) Schedule: The evaluation was divided into 3 days:

1) The first day there was an introduction to the system where the MPT explained to the RBP in detail the system's running and how to handle and manipulate the MPD. Then, the MPT installed the system within the RBP dependencies (indoors). Afterward, the first passengers came, and the evaluation started.
2) In the second day, the evaluation continued during the morning keeping the same scenario (indoors). During the afternoon, the RBP used the MPD also outdoors: inside buses, inside and outside cars.
3) The last day, the MPT and the RBP meet and discuss the evaluation results, mostly about current drawbacks and future improvements.

4) Devices: The devices used during the evaluation are the MPD, the passport reader and the control station. There were also MPT members taking notes, and video recording the operation.

MPD: The MPD first communicates with the passport reader to get the passengers data and the pictures stored in the passport chip. Then, it allows operators to perform face recognition and fingerprint recognition. Operators have feedback of the face recognition (comparisons results in percentages) once they take the pictures, and of the fingerprint quality (green checks if the quality is over a threshold or red crosses if the quality is below a threshold). During the evaluation, the MPD was used for passport reading, face recognition, and fingerprint capture.

Passport reader: The passport reader is a document reader provided by Regula. It is a full-page passport reader with no moving parts inside, which allows automatic reading and authenticity verification of passports, IDs, visas, drivers' licenses, and other identification

documents. During the evaluation, this device gets the information from the passport chip and sends it to a computer (via Wi-Fi). The computer processes the users' data and sends it back to the MPD (via Wi-Fi again), allowing operators to double check identity and passport security features.

Control station: The control station controls the communication flow between the MPD and the passport reader, monitors the whole process, and allows operators to check the systems' running. It contains a computer running the MPD and the Regulas' software and a Wi-Fi router.

5) Scenarios: The MPD was tested within two scenarios: indoors and outdoors. The elements in the indoor operation were located in the same place during all the sessions. During the outdoor phases, operators and travelers were located inside and outside different means of transport (cars and buses). Then, the environment conditions' fluctuation was higher outdoors, where lightning and temperature are more variable. The lightning and temperature indoors varied in accordance with the daytime (e.g., during the morning, the lightning was natural, but during the evening, it was artificial).

Variations in the environment conditions influence on the biometric algorithms and on users/operators (e.g., low temperatures may derive in users and/or operators shivering). There were four kinds of scenarios where the operation was carried out: indoor, outdoor with the traveler outside the car, outdoor with the traveler inside the car, and inside a bus.

6) Evaluation Workflow: The evaluation workflow has the following stages. The first step for all travelers is to complete the current border check. Then, those travelers who voluntarily decide to participate in the evaluation proceed to step A, where an operator explains the whole process. Once the consent is signed, the traveler starts the step B where the passport checking and the face recognition are carried out by an operator. Then, the traveler proceeds to step C, where the other operator captures her fingerprints (both index). Step C was not completed by all the travelers to not make the travelers stay too much time in the border control. Finally, the traveler is requested to complete a survey in step D and finishes the evaluation. The MPT is present during the whole process to overcome any possible inconvenience.

B. Usability Metrics

A more extensive usability evaluation (e.g., following the ISO 9241-210:2010, *Ergonomics of human-system interaction, Part 210, Human-centered design for interactive systems*) could not be carried out due to security restrictions. Then, the measured features were extracted from the ISO 9241-11:1998, where usability is defined as "*The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use.*" Thus, effectiveness, efficiency, and satisfaction are the three usability factors analyzed, and their definitions are the following:

1) *Efficiency:* The completion of tasks on time. The efficiency is calculated in this evaluation as the time spent since the user gives the passport to the RBP until the passport checking and face recognition are completed, as a simulation of a real case of traveler identification in the border. This time was taken for every user during the 2 days of operation, no matter the scenario, to obtain realistic interaction times (in the Romanian-Moldavian border, RBP must perform the checking in different conditions). Time spent with fingerprint recognition is not accounted because it represents the case of a manual control in the ABC machine-based technology.
2) *Effectiveness:* Defined as the task completion by users. Effectiveness is calculated as the wrong interactions during the evaluation involving only the travelers' interaction. Therefore, the only possible wrong interactions may occur during the face presentations (presentation is the action to present the biometric characteristic).
3) *Satisfaction:* The user experience in the evaluation. The satisfaction results were measured through surveys completed by travelers once they have completed the process. The questions completed are related to factors, such as security, borders, or biometrics. Surveys are also publicly available in English, Romanian, and Russian at the following webpage: http://MobilePass-project.eu. RBP who participated as operators completed also another survey, where they were asked about security, comfort and speed of the MPD and the improvement over the current border control in Romania.

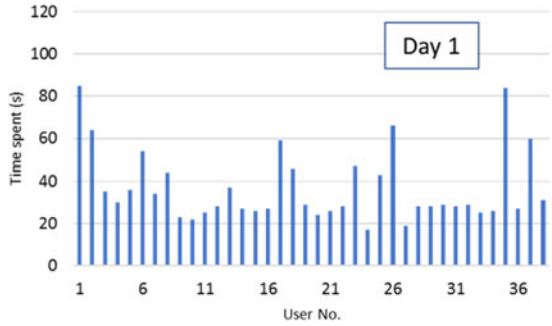

Fig. 1. Time spent in seconds/user in the interaction during day 1.

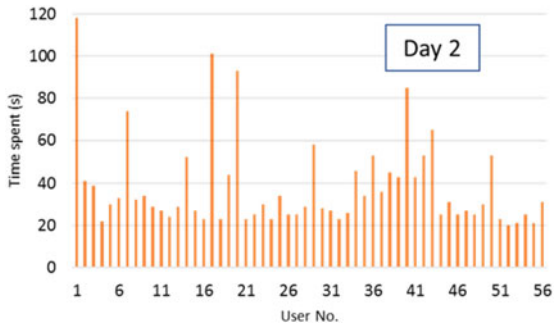

Fig. 2. Time spent in seconds/user in the interaction during day 2.

IV. Results

Outcomes of the evaluation are the usability metrics described in Section III-B and all the information gathered during the experiment process (i.e., videos, notes, and interviews). This section contains the efficiency, effectiveness, and the satisfaction results.

A. Efficiency

Results are in Figs. 1 and 2 in terms of time spent per user. In Table I, average, standard deviation, maximum and minimum time per day, and total are shown. The large variability in terms of time among interactions is due to factors, such as the communication time between the passport reader and the MPD, and the time taken to perform the face recognition (in cases that are delayed because of environmental factors, overall lightning changes). The time spent is longer in average during day 2 because the experiment was carried out partially within

TABLE I
AVERAGE TIME (AVG), STANDARD DEVIATION (STD), MAXIMUM (MAX) AND MINIMUM (MIN) TIME OF THE TRAVELERS' INTERACTION (IN SECONDS)

	Day 1	Day 2	TOTAL
AVG	36, 74	38, 05	37, 52
STD	16, 93	21, 05	19, 40
MAX	85	118	118
MIN	17	20	17

TABLE II
RBP ANSWERS TO SURVEYS. AVERAGE MARKS AND VARIANCE OF THE 7 RBP, RANGED FROM 0 (NOT AT ALL) TO 5 (YES, OF COURSE)

Question	Mark
Is MPD an improvement?	4.43 ± 0.30
Was the procedure uncomfortable?	0.43 ± 0.12
Was the document checking comfortable?	4.43 ± 0.22
Was the fingerprint recognition comfortable?	3.57 ± 0.50
Was the face recognition comfortable?	4.43 ± 0.45
Were travelers comfortable with the system?	4.86 ± 0.35
Would you use the MPD daily?	4.00 ± 0.62

outdoor scenarios where environmental conditions have bigger negative effects.

B. Effectiveness

There were 94 users in the evaluation, performing two interactions each, then there were 184 interactions in total. Because the user interaction during the evaluation was really simple (and mostly guided by the RBP), the number of errors is really low. There were only 11 (6%) wrong interactions during the face recognition, motivated by the lightning changes, and the results were long capture times or impossibility to get the face image.

C. Satisfaction

Satisfaction results are processed surveys, completed by travelers and the RBP at the end of the experiment. An assistant was present during the surveys completion to respond to any possible doubt (the RBP in case of the travelers and a member of the MPT in case of RBP).

1) Traveler's Surveys: Regarding their experience using the system, 97% of the users think the process is quick and easy to understand, and 100% think the system is comfortable and friendly. 78% of the travelers found the face verification positive and 16% very positive. Only 2% considered it negative. A total of 98% would trust the MPD to keep their data safe and only 2% would not. Only 22% would not trust a smartphone-based app for border crossing. Only 2% of the participants dislike the document and the biometric verification.

2) RBP Surveys: Questions of this survey include system and procedure comfort, biometric recognition modalities, and other relevant aspects in ABC systems. Table II contains the answers of the 7 RBP who replied to the survey. Regarding the importance of the daytime, five RBP claimed that lightning is a key factor and two of them noticed the differences in the capture time (faster capture times in the morning).

V. CONCLUSIONS AND FUTURE WORK

This section summarizes the conclusions obtained once all the gathered data have been processed. Future works are at the end of this section.

A. Conclusions Obtained Right After the Evaluation

Fingerprint

1) Fingerprint capture may be time consuming due to potential travelers and/or police hand shivering outdoors. The environmental conditions have high influence on the system.
2) There is not a physical guide to present the fingerprint to the system. Consider the use of other sensors or retractable finger-guides to not waste time calibrating the fingertip distance.
3) Travelers and RBP claimed that asking first for the left hand fingertips is not intuitive. Then, right hand fingertips should be required first.
4) Women fingerprints are more challenging for the system and take more time to capture. One possible reason of this could be the women shorter fingertip size.

Fingerprint outcomes reveal similar concerns than a common mobile contactless fingerprint sensor [16]. To overcome these issues, more guidance may be provided to both operators and travelers.

Face

1) Comparisons results in percentages shown on the screen are useful for RBP, because verifications close to the thresholds could involve further traveler checking (e.g., fingerprint checking or deeper visual inspection).
2) Face recognition is faster and more reliable indoors. The bus and car scenarios introduce further challenges, such as face rotation, unexpected shades, or face hotspots.
3) Better guidance for RBP about face distances is needed (e.g., challenging in buses). Probably, a better knowledge by the RBP about the algorithms' running could help (e.g., against bad lightning conditions).

MPD handling

1) The MPD should not be placed on the arm, because RBP needs free hands for further checking. The MPD should not be placed hanging round the neck, because it is annoying after a certain time. The car belt style is the best choice to carry on the MPD (similar to the passport checking device during the evaluation).
2) RBP prefer the use of only one device better than two (easier to control and carry on).
3) Further screens for vehicles data checking would be useful, because RBP checks also vehicles' plates and this is currently carried out using other equipment. An all-in-one device could save time and resources.
4) An MPD rotary or movable screen (video camera style) could be helpful into buses where the travelers are sitting down.
5) Results from the recognition and the passport check are visible for users, resulting in a security issue. This problem is to be solved, for example, using a filter on the screen.

Others

1) RBP point out that MPD screen should be always in portrait or be rotary (portrait-landscape).
2) RBP suggests face recognition as first control and then fingerprint recognition if necessary. This would save time.
3) RBP suggests the possibility to regulate led power during face and fingerprint recognition, to improve the lightning in the different scenarios.
4) The applicability of the system varies from one scenario to another, being the performance higher indoors. Improvements

should be made to achieve better effectiveness and sample quality in outdoor scenarios, where environmental factors fluctuate severely.

B. Final Conclusions and Future Work

Efficiency results show that time spent during the second day was longer than in the first day in average, standard deviation, maximum, and minimum. This is motivated by the location of scenarios. Face recognition in buses and other outdoor locations was shown to be challenging and time-consuming, involving the majority of the wrong interactions. A solution to overcome this concern could be the improvement of the face detection algorithms applied.

The MPT plan to use a new Regula reader model, which could save between 4 and 7 s for reading the chip. Other improvement suggested by RBP is the "one-button concept," consisting of a hard button on the device allowing speed transition among screens (currently, the MPD requires high and variable operator interaction but the process is quite similar in all cases). Moreover, releasing the second hand will save between 1 and 3 s. Another improvement scheduled is to transfer the passport chip image (and the UV, IR, and Ultraviolet image) only when needed (or transferring only preview images). The MPT estimates that the potential speed increasing could derive in interaction times close to 10 s.

Effectiveness scores are minimum as expected, because the user interaction was designed to be easy and straightforward (only stand and stare at the MPD camera). RBP proceed fast and accurate, resulting in no mistakes on the operator side.

Survey results return high travelers' *satisfaction* . Next are the main conclusions extracted from the surveys:

Travelers

1) Find the MPD easy, fast, and comfortable, as well as biometric recognition. In short, travelers think that the MPD is an improvement of the current system. Only 2% of them do not trust in the MPD security, and 22% would not trust in a smartphone-based solution.
2) Travelers suggested reducing the procedure time and improving the information provided at the beginning.

RBG interviews

1) RBP cited the lightning as an influential negative factor, specially the variation between mornings and afternoons.
2) RBP pointed out that travelers feel confidence after the first explanation.
3) RBP remarks that only a little percentage of the travelers felt reticent about fingerprint recognition.
4) Most of the RBP would use the MPD daily.

At this point, it is important to remark that the current border control in Romania does not include face or fingerprint recognition (which undoubtedly delays the whole process). Nevertheless, the fastest border control reached during the experiment with the MPD was 17 s. Current MPT work goes in the line to decrease the time spent during the border crossing. RBP suggests that once travelers get familiar with the new system, border controls will be faster.

Several changes in the MPD were suggested during this experiment, motivating future improvements, such as face recognition resistance to bad lightning, extend the border control to vehicles or reducing the devices used to only one. Now, all these suggestions must be reviewed by the MPT and check the feasibility to apply them in future deployments.

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