

Environmental Testing Methodology in Biometrics

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Abstract— Recently, biometrics is used in many security systems and these systems can be located in different environments. As many experts claim and previous works have demonstrated, environmental conditions influence biometric performance. Nevertheless, there is not a specific methodology for testing this influence at the moment. Due to it is essential to carry out this kind of evaluations, a new ISO standard was proposed for regularizing them. Such standard was accepted and it has to be specified now.

In this work, authors have analyzed the first proposal of this project and other standards about environmental testing. According to this new ISO proposal and current ISO standards and considering aspects of these related standards focused in biometric evaluations, a detailed methodology has been defined. This methodology consists of two parts: on the one hand, the definition of the environmental factors to analyse, including how to generate, control and measure them, and on the other hand, the specification about how to perform the biometric evaluation.

Keywords: *Biometric Systems, Environmental Evaluation, Scenario Evaluations, Biometric Performance*

I. INTRODUCTION

Nowadays there are several biometric systems operating in different environments, e.g. airports, ATMs, companies or gyms, and it has been predicted that this kind of systems will be used increasingly in the next years. However, it is well known that the environment can affect biometric systems performance, as well as previous works [1] have proved that most of them do not work properly in all environments.

Therefore, it is necessary to know what could be the influence of a specific environment on a biometric system before this system will be running in such environment. This fact guarantees that the security levels specified for the corresponding application will be met regardless ambient conditions.

Currently, there are defined international standards (ISO standards) for conducting biometric evaluations. ISO/IEC 19795-1 [2] defines three types of evaluations: technology, scenario and operational evaluations. Technology and scenario evaluations are addressed in ISO/IEC 19795-2 [3] and operational evaluations will be addressed in ISO/IEC 19795-6 [4]. Nevertheless, these standards are general for

analysing biometric systems performance but they do not specify exactly how to evaluate the influence of the environment. Specifically, an environmental evaluation is a set of scenario evaluations. In each scenario evaluation the influence of one environmental parameter is analysed.

To complete the previous standards, ISO/IEC 19795-3 [5] Technical Report (TR) describes the variations in methodologies according to the modality under test. This TR explains the environmental factors that could influence in biometric performance; however, it does not specify essential aspects to perform repeatable and reproducible evaluations and obtain intercomparable results as follows:

- Detailed approaches and requirements for generating, controlling and measuring environmental parameters during performance evaluations.
- Ranges of each environmental factor in which the biometric system have to be examined.
- Requirements for test instruments.

Taking into account this situation and the lack of procedures for carrying out these evaluations, a New Work Item (NWI) was proposed in order to develop a new ISO standard for covering them. This NWI was accepted for the ISO organization with the name “Evaluation methodology for environmental influence in biometric systems”.

This NWI is based on previous works [1], [6] and [7], but there are several aspects that shall be thoroughly defined and others that shall be improved. During the first discussion of this project, it was decided to look for other standards related to environmental testing of equipment in order to have a reference for defining it.

In this work, authors have analyzed such standards, and considering them, they have improved the specification of the environmental evaluation proposed at the first version of the NWI. Standard conditions, scenarios to analyze, procedures to generate and control such scenarios, test instruments requirements and how to plan and execute biometric proofs will be described. In addition, authors have defined several details that were not taken into account in such version and have justified their choices.

Next section describes the NWI and explains its structure and the main characteristics of it. In the following section,

related standards will be summarized and relevant information about them will be described. Then, in Section IV, the proposed environmental evaluation will be specified. Finally, section V presents the main conclusions and future works.

II. NEW WORK ITEM

The NWI intends to define an evaluation methodology for testing biometric systems performance when they are working under different environments. In this case, the environment consists of atmosphere parameters (temperature, humidity and pressure) and other physic phenomena that surround the system (illumination and noise). There are other environmental parameters that could be studied, but at present the NWI only considers the above mentioned.

This proposed methodology involves the generation and control of the scenarios corresponding to each parameter to analyse and performs a biometric system evaluation. Particular scenarios will be defined for assessing biometric systems in its operational range (specified by suppliers), and other, for checking it outside this range, including extreme conditions.

To sum up, the standard will address:

- How to plan biometric performance evaluation taking into account the environmental factors.
- Scenarios to analyse and ranges for each environmental parameter.
- Requirements for the test instruments.
- The corresponding specifications for performing biometric trials.

This is a first description of the NWI. However, there is one relevant matter that must be clarified: type of biometric evaluation to execute. The NWI talks about generating and controlling scenarios for environmental factors but it does not really specify these aspects.

As it was mentioned in the introduction, there are 3 types of evaluations. The best thing to do is to specify a scenario evaluation, due to these evaluations analyse end-to-end system performance and it is essential in this case to control environmental conditions for producing repeatable results (it is feasible in scenario evaluations but not in operational evaluations). Nevertheless, it is important to emphasize two issues related to the other evaluations:

- A database could be collected following the same environmental directives for performing technology evaluations lately.
- Operational test will reduce its variability if environmental scenario evaluations have been previously executed and the effects caused on the biometric system performance are known.

Therefore, the scope of this project must be redefined to include the type of biometric evaluations to perform and also it shall be explained that these evaluations are based on the current standard that address them (ISO/IEC 19795-2 [3]).

III. RELATED STANDARDS

Before defining the evaluation methodology, several standards related to environmental testing and other related works have been studied. These are the following:

- MIL-STD-810G, "Test Method Standard for Environmental Engineering Considerations and Laboratory Tests" [8]. It is a military standard of the Department of Defense of The United States. This standard analyzes the influence that environmental stresses have on materiel throughout all phases of its service live. It contains tables with temperature and humidity values for different climatic areas and world maps in which these areas have been identified.
- DEF STAN 00-35 Part 3 Issue 4, "Environmental Handbook for Defence Materiel (Part 3) Environmental Test Methods" [9]. It is also a military standard of The United Kingdom. This standard describes environmental data and tests for analyzing conditions of the life of Defence Materiel. It includes data of standard conditions, requirements for test apparatus and a detailed definition of the trials.
- IEC 60068-1, "Environmental Testing" [10] and IEC 60068-2-X "Tests" with multiple parts (e.g. IEC 60068-2-1 " Tests – Test A: Cold " [11]). This is an international standard that addresses environmental tests and severities to measure how different products work under normal conditions of transportation, storage and operational use. Part 1 defines values for standard conditions and the multiple documents of Part 2 specify different tests.
- CEN EN 12464-1, " Light and lighting - Lighting of work places - Part 1: Indoor work places " [12]. This is a European standard which specify requirements for illumination systems in different indoor working areas. It has tables with the recommended illumination values for many places and for the activities performed in these places.
- Occupational Safe & Safety, "Office Ergonomic Guidelines – General Office Environment" [13]. This document is a guide that suggests a proper office environment. It includes the ranges for many environmental factors.
- ISO/IEC 10373-1, "Identifications Cards - Test methods- Part 1: General characteristics" [14]. This international standard addresses testing methods for characterizing identification cards. These methods do not assess the environment, but other issues. In spite of this fact, such methods have been described for one type of identification systems and can be useful to specify the current methodology.

In general, these documents describe standard conditions, ranges for several environmental factors, tolerances for these factors, requirements for test instruments and methods and

sequences of tests that are very useful to define the NWI methodology.

IV. ENVIRONMENTAL TESTING FOR BIOMETRICS SYSTEMS

The whole evaluation for testing biometric systems working in different environments shall be defined taking into account two parts: environment and biometrics. It entails specifying, on the one hand, how to define, generate and control environmental scenarios, and on the other hand, the biometric system evaluation. Both of them will be explained next.

A. Environmental scenarios

1) Definition of environmental scenarios

a) *Standard scenario*: most of the related standards define standard conditions for the tests (MIL-STD-810G, DEF STAN 00-35 Part 3 Issue 4 and IEC 60068-1) and other recommend values for an office environment (OHS Office Ergonomic Guidelines and CEN EN 12464-1). These conditions are shown in Tables 1 and 2.

TABLE 1. STANDARD CONDITIONS IN RELATED STANDARDS: TEMPERATURE, RELATIVE HUMIDITY AND PRESSURE

	MIL-STD-810G (Controlled ambient)	IEC 60068-1	DEF STAN 00-35 Part 3 Issue 4	OHS Office Ergonomic Guidelines
Temp.	23± 2° C	15° C to 35° C		21° to 24° C (summer) 19° to 22° C (winter)
Relative Humidity	50% ± 5%	25% to 75%		40% to 60%
Pressure	96.45 kPa + 6.6 / -10.0 kPa	86 kPa to 106 kPa		----

TABLE 2. STANDARD CONDITIONS IN RELATED STANDARDS: ILLUMINATION AND NOISE

	OHS Office Ergonomic Guidelines	CEN EN 12464-1
Illumination	Common task 300 to 400 lux Visual tasks 600 lux	Common tasks 500-1000 lux Visual tasks >1000 lux Operating room 5000 lux
Noise	55 to 65 dBA	----

The previous version of the NWI defines this scenario taking in consideration typical indoor conditions. After reviewing the above information, the conditions of the standard scenario shall be redefined as it is shown in Table 3.

Authors suggest that it would be mandatory to control all of them during the evaluation in order to have certain guarantee that other ambient conditions are not affecting the biometric system.

TABLE 3. STANDARD SCENARIO

Temperature	23± 3° C
Relative Humidity	40% to 60%
Illumination	Visible: 300 – 1500 lux NIR: 0 – 1000 lux
Noise	< 60 dBA
Pressure	86 to 103 kPa

b) *Types of scenarios*. To quantify the influence of each environmental parameter, certain scenarios shall be specified. In each scenario only one parameter will be studied. The rest of them shall be kept inside the range specified in the standard scenario. For example, if the evaluated scenario is a illumination scenario and the biometric system under test is a vascular system, only the illumination parameter has a specific value, fixed according to the scenario, and the rest of mandatory parameters to control, such as temperature, relative humidity or noise, must be set to standard conditions.

This requirement allows measuring the effect of each ambient factor in the biometric performance separately. The combination of multiple parameters is more appropriate to evaluate using an operational evaluation.

As well as the related standards in which each test has specified the corresponding value for the parameter to assess, each environmental scenario must also set the environmental factor to examine. These shall be described using common units or units utilized by the most common instruments. Next, the types of scenarios and how to specify them will be explained.

i) *Temperature scenarios*: These scenarios will be specified by means of temperature and relative humidity values. Both parameters have to be set together because they are very dependent. The relative humidity has certain percentage given a specified temperature. This is because if temperature increases, relative humidity decreases because cold air contains less humidity than warm air. In addition, these parameters are usually generated and controlled by the same instrument simultaneously, and therefore, evaluators will set these parameters at the same time.

Temperature shall be described using °C or °F and relative humidity using %.

ii) *Humidity scenarios*: As above mentioned, these scenarios will be also defined specifying temperature and relative humidity values using the same units.

iii) *Illumination scenarios*: Such scenarios have to be determined considering two areas of the spectrum: visible and near infrared light. The illumination standard CEN EN 12464-1 does not do it like this, but there are many biometric

systems that work using near infrared light and it is necessary to consider it.

Illumination shall be described using the lux unit.

- iv) *Noise scenarios*: These scenarios shall be specify by means of the noise level corrected by A scale.

That is why noise shall be set using dBA.

- v) *Pressure scenarios*: Such scenarios must be described by the pressure level.

The unit to define pressure has to be kPa or mmHg.

c) *Scenarios to analyze*. These scenarios shall be specified for analyzing the influence of certain ambient conditions. There are two different approaches: consider the biometric system and its operational range, or the place in which the system will be located. The first option analyze directly the biometric system performance independently where it will be located and the second option check if the specific biometric system is affected by particular environmental factors as in military standards. Both options are acceptable for the purpose of the NWI, but authors think that the first one must be mandatory whereas the second must be optional. In addition, evaluation in the standard conditions scenario always has to be obligatory.

Now, the scenarios corresponding to each option will be specified:

- i) *Operational range*: At least three scenarios must be defined to evaluate this range. One scenario for the minimum value, other for the maximum value and one more scenario for the middle value. This range shall be defined by suppliers at the beginning of the evaluation. If there is not an specified range, the range considered for basic climate regions shall be used. These regions will be explain next.
- ii) *Extreme conditions*: These scenarios have to simulate specific ambient conditions that are achieved in different regions of the world. MIL-STD-810G provides tables and maps to select it. This tables are based on NATO standards and define four kind of climate regions: hot, basic, cold and severe cold.
- iii) *Free conditions*: The NWI should also be open for defining other ranges that suppliers or customers want to analyze. These scenarios will be set before the evaluation and will be reported.

Any scenario will be specified following the directives provided in the previous section (section b).

As well as considering the range of parameters to assess, the set of environmental scenarios have to take into account the type of scenarios to evaluate depending on the biometric modality under test. Table 4 shows the ambient factors that

could affect each biometric modality. This table is based on ISO/IEC TR 19795- 3 [5].

TABLE 4. AMBIENT FACTORS THAT AFFECT EACH BIOMETRIC MODALITY

AMBIENT FACTOR	BIOMETRIC MODALITIES
Temperature	Face, Fingerprint, Vascular, Voice and Hand Geometry
Humidity	Face, Fingerprint, Vascular, Voice and Hand Geometry
Illumination	Face, Vascular, Iris and Fingerprint (optical sensors)
Noise	Voice and audio guides for all modalities
Pressure	Signature

2) *Generation of environmental scenarios*

In order to generate environmental scenarios some specifications for instruments have to be defined. Also, requirements to know if the features of the scenario have been achieved must be addressed. Both definitions are based on similar specification described in the related standards.

a) *Instruments*: Most of the related standards do not specify exactly which equipment must be used during tests. These provide general specification as follows:

- Instruments must be able to achieve the maximum and minimum value of the scenarios to assess.
- The resolution of the instruments must be properly in order to adjust the value of the different scenarios.
- Instruments have to be calibrated previously.

b) *Requirements to assure that the features of scenarios have been achieved*: The particular requirements of one scenario will be achieved if the corresponding parameters do not change or are inside the defined range in a minimum period of half an hour.

During the evaluation, test subjects are going to interact with the biometric system, so the environment could vary sensitively. When this happens, evaluators must wait until the features of the scenario will be achieved again plus an additional time of 2 or 3 minutes for the biometric system to get acclimatized.

In addition, it is recommendable to introduce the biometric system in the scenario before generating the scenario because some factors as temperature could damage the biometric system if they are modified quickly.

3) *Control of environmental scenarios*

In order to produce repeatable and reproducible results, environmental scenarios have to be controlled during all the evaluation. As the generation of environmental scenarios, instruments and requirements to perform this task have to be specified.

a) *Instruments*: in many situations these instruments will be the same instruments used for generating scenarios. Nevertheless, these equipment shall met the following:

- Instruments must be able to measure the maximum and minimum value of the scenarios to assess.
- The resolution of the instruments shall be the appropriate for registering changes.
- Instruments have to be calibrated previously.

b) Requirements for controlling scenarios. The main parameter to control during the evaluation of one scenario will be the specific parameter of such scenario. It will be analysed continuously and it has to be measured near the biometric capture device.

The rest of parameters will be measured before and after the execution of each session of biometric trials. These, are standard parameters that shall surround the biometric system, so it is not necessary to measure them very close to the biometric system (1 or 2 m). In case the evaluator detects anomalies, all these measurements must be repeated.

B. Biometric system evaluation

Biometric system evaluation consists of a scenario evaluation as it was explained above. This kind of evaluation is addressed by ISO/IEC 19795-2 [3]. Also ISO/IEC 19795-5 [15] describes how to plan and execute a scenario evaluation for access control systems.

Taking into account both standards, a general scenario was specified in [16] for performing usability evaluations. Specifically, this scenario is conformance with ISO/IEC 19795-2 and it was tested for some usability factors. Results disclosed that it was appropriate to assess the influence of usability factors in biometric performance.

Considering the previous work, authors have determined a similar scenario adapting it to analyse the influence of environmental factors. Next, the most relevant features of this scenario will be explained. More details about this scenario can be found in [16].

1) General

Firstly, a description of the biometric system under test and the objectives of the evaluation have to be done. For this kind of evaluations, this description must include the definition of environmental scenarios to assess according to the way that has been previously explained.

2) Environment

a) Ambient conditions: These conditions depend on the environmental scenario to evaluate. For each scenario they shall be generated and controlled as it was described in the previous part.

b) Biometric system placement: Sensor must be located in the corresponding environment. This location shall allow that users can interact with the biometric system comfortably. As far as possible, the biometric system has to be placed as suppliers recommend. If there is no guidance for it, sensor will be positioned straight, in front of test subjects, without inclinations. The height depends on the type of sensor:

- Desk device: between 70 to 75cm (standard height table).
- Wall device: sensor has to be placed according the average human height and the biometric characteristic to evaluate.

3) Test crew

The test crew for a scenario evaluation has to be general and representative of a real-world application. It also shall be enough to achieve significant results.

a) Demographics: A balanced set of test subjects minimizes the effects of biologic differences between human beings. ISO/IEC 19795 – 5 [15] specifies a proper group. Authors suggest to use the same directives for this kind of evaluations:

- Age: people from 18 to 70 years old. The number of test subjects shall be equally distributed for each range of age: 18 to 30, 31 to 50, and 51 to 70. It shall be from 25 to 40% of the test crew.
- Gender: 40% to 60% of men and 60% to 40% of women.

b) Size: The number of test subjects that are going to take part in the evaluation must be defined taking into account the rule of three or the rule of thirty following ISO/IEC 19795-2 specification.

After applying one of these rules, evaluators will obtain the following data:

- *Number of test subjects to recruitment.* Authors suggest increasing the number of test subjects around 10% because some subjects could leave the evaluation before it has finished.

- *Number of genuine and impostor transactions to execute per test subject to achieve a significant number of comparisons.* To calculate this number, evaluators must consider that the number of attempts per transaction will be three.

c) Selection: Test subjects could be selected randomly whenever the age and gender requirements will be met and they do not have to be involved during the biometric system implementation or tune.

d) Training and guidance of test subjects:

- Test information:* Test subjects must receive relevant information about the evaluation: objectives, number of visits and legal issues related to their participation in the evaluation.
- Test instructions:* An explanation of evaluation phases (enrolment and verification) and what test subjects must do in each of these phases have to be explained to them.

If there are some instructions that test subjects must follow according to the environmental scenarios, they have also to be explained.

- iii) *Training*: Test subjects shall perform practical trials. Test operators shall supervise these trials and correct mistakes.
- iv) *Guidance*: During the training and the enrolment process test subjects must be guided. During the verification process test operators will check that test subjects interact correctly with the biometric system.
- v) *Feedback*: If the biometric system shows information related to the capture of the biometric sample and the result of matching per each attempt, it shall be made known to test subjects for improving their interactions.

e) *Visits*: The number of visits should be as much as possible. As minimum, test subjects will attend to test facility twice. At the first visit test, subjects shall perform practical trials, then, perform the enrolment process and finally the first session of verification transactions. At the subsequent visits, test subjects will only have to carry out the next sessions of verification transactions. Visits shall be separated as later as possible (one week at least).
In addition, all transactions shall be done with disengagement from the device.

4) *Levels of effort and decision policies*

- Two enrolment transactions. The second transaction should be only executed if the first transaction fails.
- Three verification transactions and three attempts per each transaction.
- The maximum time for enrolment and verification depends on the biometric system under test. A reasonable time is 2.5 times the average time. The evaluators must calculate the average time executing some trials.

5) *Error protocols*

During the evaluation, different errors could happen. It is essential to specify some actions for the most typical errors. These are the following:

a) *General errors*: These errors happen when the biometric sensor does not work correctly. In this case, the test operator has to stop the evaluation and solve the problem. Once the biometric system works well again, the evaluation can continue. Errors and its solution shall be reported.

b) *Environmental anomalies*: If test operators detect changes at the environment, they must measure the environmental parameters and check if these are inside its specified range. If there are any parameters outside the range, they shall stop the evaluation and correct the potential problems. Once the scenario is stable and inside the corresponding range, the evaluation can be resumed. Test operators must report these anomalies.

c) *Enrolment and verification errors*: When test operators detect that the test subject has introduced a wrong identifier or has presented a wrong biometric characteristic,

he has to cancel the attempt, inform the test subject about the error and repeat the attempt.

6) *Data to record and test results*

To quantify biometric performance in each scenario, several metrics and statistics must be calculated and reported. It means that relevant information shall be collected during the evaluation. Regarding biometrics, ISO/IEC 19795 Part 1 [2], Part 2 [3] and Part 5 [15] address which data shall be collected and reported. Regarding environment, the following information shall be reported:

- Environmental scenarios to assess including the specific values of them.
- Test instruments used to generate and control scenarios.
- Metrics and/or graphics of the environmental parameters that shall be controlled during all evaluation.
- Measurements of the standard conditions parameters that have to be measured, only before and after performing biometric trials.
- Environmental anomalies.

7) *Tests procedures*

The procedure for quantifying biometric system performance should allow comparing the performance of the multiples scenarios. Authors recommend measuring the biometric system performance in the standard conditions scenario firstly, and then in the other environmental scenarios.

Moreover, they consider that enrolment is performed in indoors conditions most of the times (e.g. the human resources department, police station, etc) and therefore, the enrolment process has to be carried out in the standard conditions scenario.

8) *Execution sequence*

For performing the biometric evaluation, a set of tasks has to be executed by test operators and test subjects. These tasks have to follow an appropriate sequence. Authors suggest the following one:

a) *Pre-test activities*

- Examine the biometric system under testing and implement the essential application for performing the evaluation. It has to be able to collect the essential information and has to be conformance with the levels of effort and decision policies defined above.
- Plan the evaluation scenarios and the proper test instruments.
- Develop the evaluation schedule and how to recruit test subjects.
- Implement legal forms, data forms and guides for test subjects.
- Instruct test operators about how the biometric system works, how to use the evaluation application,

how to handle test instruments and all necessary details to carry out the evaluation.

- Calibrate test instruments and check how they work if it is necessary.

b) Test activities

i) Procedures before the first visit

- Recruit test subjects.
- Introduce the biometric system in the standard conditions scenario and establish this scenario for enrolment.
- Conduct a system operability analysis for enrolment and verification processes.

ii) First visit

- Explain test instructions to test subjects.
- Train test subject for enrolment
- Measure environmental conditions before the enrolment
- Carry out enrolment. Remind that the second transaction must only be executed when the first transaction fails.
- Measure again the environmental conditions after enrolment.
- Generate the first environmental scenario. Do not forget to introduce the biometric system in the simulated environment before starting to adjust the corresponding values.
- Wait until this scenario is stable. During this time test operators can perform the training for test subjects in verification process.
- Measure environmental parameters.
- Verify test subject in this scenario:
 1. Perform the first session of genuine and impostor transactions in the common scenario. If the environmental conditions are modified due to the interaction of the test subject, between each transaction, it is important to wait for the scenario stabilization and for the biometric system to get acclimatized.
 2. Measure environmental parameters again.
 3. Generate the next scenario.

The last two steps have to be done for the evaluation of all the specific scenarios.

iii) Subsequent visits

- Establish again the standard scenario and check that it works.
- Remind the test subjects the test instructions for the verification process.
- Measure the environmental conditions.
- Perform a session of genuine and impostor transactions in the standard scenario.
- Measure again the environmental parameters.

- Establish the first environmental scenario to test. Remind to introduce previously the biometric system in the scenario.
- Measure the environmental parameters before the verification transactions
- Execute the set of verification transactions as it was indicated at the first visit. Take into account the above mentioned protocols between transactions if the ambient conditions are affected by test subject interactions.
- Measure again the environmental parameters.
- Generate the next scenario and repeat the four last steps for all the environmental scenarios to analyze.

c) Post-test activities

- Analyze all the information collected during the evaluation.
- Calculate performance rates, graphics and metrics.
- Generate reports including all mandatory data to report.

V. CONCLUSIONS AND FUTURE WORKS

In this work, a general and independent methodology has been implemented to assess the influence of the environment in biometric systems performance. Firstly, a review of the first ISO proposal for this methodology has been performed. Then, other standards for executing the environmental testing of different products have been studied. Finally, a detailed environmental methodology has been described improving the first version of the NWI and taking into account the information obtained from the other standards.

Nevertheless, part of this methodology has been specified considering standards aimed to other products, so as a future work, the methodology should be exhaustively checked for biometric systems.

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