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Modeling and Implementation of an Automatic Access Control System for Secure Premises using Facial Recognition

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HIGHLIGHTS

- System modelling using SysML diagrams: Requirements, use cases, block definition and internal block.
- Implementation of the facial recognition system: Enrolment and identification.
- Implementation of the embedded system under Arduino for access control to secure premises by facial recognition.
- Evaluation of the performance of the access control system by the confusion matrix.

ABSTRACT

Security is a major concern within companies to prevent access to information by unauthorized persons. In this work, we are interested in access control through facial recognition. To realize this access control system based on facial recognition, we used an embedded system under Arduino which gives us the possibility to assemble the performances of programming and electronics, more precisely, we programmed electronic systems for the automatic opening of doors without the action of a human being. From a sample of 100 individuals composed of 40 women and 60 men, 75 of whom were registered and 25 non-registered, our access control system obtained the results of 70 true positives, 5 false negatives, 8 false positives and 17 true negatives that constitute our confusion matrix. However, from the set of tests performed we can conclude that multi-modality fusion can be leveraged to increase the performance of the verification system as the verification performance of multimodal systems (feature fusion or score fusion) can be applied to give even better results.

Keywords: *Embedded system, biometrics, access control, automation, facial recognition, pattern recognition.*

GENERAL INTRODUCTION

Background

The recognition of individuals is a topical subject which is the subject of several research projects in the computer field. In this context, biometrics is one of the main fields of research. These systems are used both for physical access control (eye, face, etc.) and for logical access control (password, smart card, etc.) **(**Norman, 2011).

In our work, we are interested in access control by facial recognition.

To achieve this access control using facial recognition, we will use an embedded system under Arduino which gives us the possibility to assemble the performances of programming and electronics, more precisely, we will program electronic systems for the automatic opening of doors without the action of a human being.

Issue

Nowadays, it is certainly difficult for anyone present in the Congolese university environment to ignore the real problems that arise about the control of student access in a multi-entrance institution, especially when checking the payment slips for academic fees. These problems are due either to certain unethical practices that we deplore, such as the exchange of payment slips, or to certain students passing themselves off as assistants, former students, administrative staff, etc.

These problems are frequently realized during the access control process when verifying payment of academic fees.

On the other hand, there is also the loss or forgetfulness of the academic fee slip.

Thus, in order to motivate the continuation of this work, questions of the kind listed below will not be ruled out:

- ✓ What are the most effective methods we can apply to properly identify people in a multi-entry institution?
- ✓ How can the problem of access control to the premises in a multi-entry institution be properly addressed?
- ✓ How can a human being be spared the process of verifying payment of academic fees before the student accesses the premises?
- ✓ Will the system to be developed really be able to solve the access control problem in a meaningful way?

These questions constitute the set of issues that we will try to examine in the following lines.

Assumptions

To solve these problems, the optimal solution we propose in this work is to design a biometric recognition system and an embedded system for automatic access control to premises based on facial recognition, which would put an end to the problems found in the current manual access control system.

Indeed, we are going to create a facial recognition system that will interact with an embedded system for the automation of door opening and closing. This new system is divided into two subsystems:

- ❖ Enrolment: the subsystem will be able to register students with their full identities including face captures.

- Verification (the subsystem will be able to verify) :
  - ✓ Before accessing the university premises, the student will be expected to present him/herself in front of the camera or webcam so that the sub-system can check with facial recognition whether he/she is in order or not;
  - ✓ Once the face provided is correct with the current payment settlement then the system opens the door, otherwise the door remains closed.

OBJECTIVES

General objective

The general objective of this work is to design a new system that will allow for better management of access control by eliminating possible recurrent problems due to falsification of slips, impersonation of assistants or former students, lost or forgotten slips for academic fees, etc (Wirotius, M. (2005).).

Specific objectives

Our approach will achieve the following objectives:

- To design an embedded system under Arduino for the automatic opening and closing of doors;
- Designing a biometric pattern recognition system for access control.

Interest of the subject

The interest of such an approach is to bring a valuable help to the scientific community, by providing them with a reliable tool for access control to a multi-entry institution.

SYSTEM MODELLING AND IMPLEMENTATION

Introduction

Access control is a technique which consists of subjecting the entrances to an establishment to prior authorization for access.

Access authorization affects three different ways of proving one's identity to a computer system (Benaliouche & Touahria, 2014):

1. Access authorization by a password or code. The password is entered via an electronic keyboard. This keypad is located inside a closed room and eliminates any possibility of unwanted opening.
2. Access authorization by an object, such as a smart card or badge. In general, the information is stored in a memory inserted on a plastic support. Example: health card or bank card.
3. Access authorization through a specific physical characteristic (biometrics). Example: (eye, face, fingerprint, etc.).

We want to automate the system of checking academic fees within the University of Kinshasa with its students before they access the university premises.

With this in mind, we will build an Arduino-based embedded system that will interact with a facial recognition system.

Project Modelling, Design and Deployment

The evolution of programming techniques has always been driven by the need to design and maintain increasingly complex applications. Modelling a system before it is built allows a better understanding of how it works.

Modelling

All large projects (and ideally even the smallest ones) should be modelled before they are implemented. This ensures that the entire architecture is available from the start and that it is consistent.

System modelling with SysML diagrams

To solve our problem, here is how our modelling looks like, represented by the requirements diagram, the use case diagram, the block definition diagram and the internal block diagram:

Requirements diagram

Requirement diagram (SysML notation: req) describes the requirements of the functional specifications. A requirement expresses a capability or constraint to be satisfied by a system. It can express a function that the system must perform or a condition of technical, physical, safety, reliability, ergonomic, aesthetic performance, etc. Requirements are used to establish a contract between the client and the developers of the future system **(**Bopatriciat Boluma Mangata et al., 2022).

Here is the model of the requirements diagram for our system:

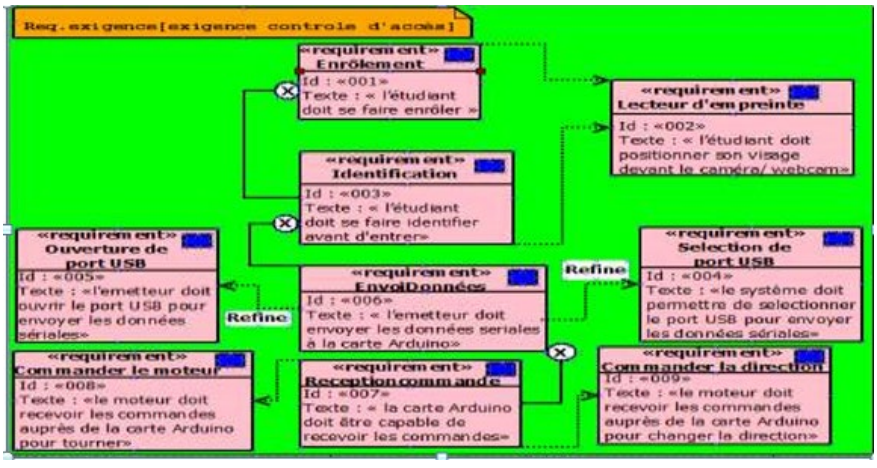

Figure 1: The requirements diagram

Figure 1 shows the requirements diagram specifying the requirements of the functional specifications. These requirements express capabilities to be satisfied by the system. They express functions to be performed by the system (Enroll students, capture face, check face information before entering, select USB port to send data, open doors, send data to Arduino board, receive data from Arduino board, control motor, and finally control steering.

Use case diagram

Use case diagram (SysML notation: uc) shows the functional interactions of the actors and the study system.

It precisely delimits the system, describes what the system will do without specifying how (not what the user will do). It expresses the services (use cases) offered by the system to the users (actors).

Here is the model of the use case diagram for our system:

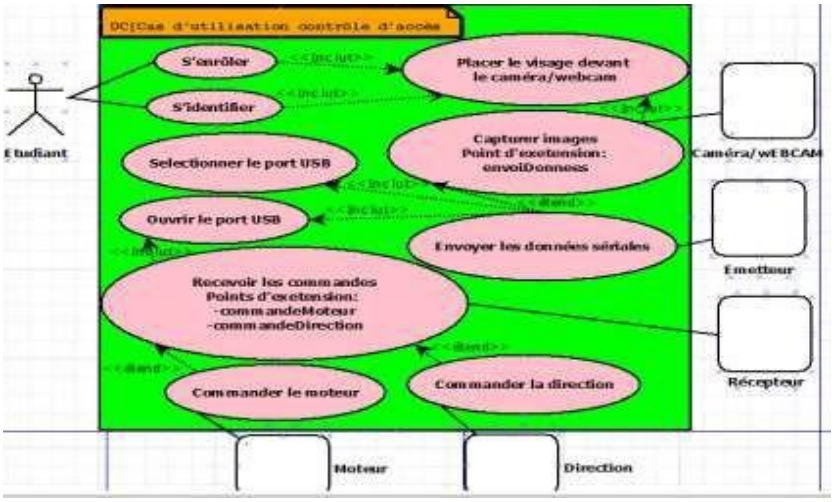

Figure 2: The use case diagram

Figure 2 shows the use case diagram specifying the functional interactions of the actors and the system. It precisely delineates the system, describing what exactly the system will do. The student is the primary actor who stands in front of the camera before enrolling and being audited. The secondary non-human actors in the system include: the camera/webcam, which must capture images in order to send the extension point to the system; the transmitter must check that the USB port is selected and open to send data; the receiver must check that the USB port is open in order to receive commands; the motor must receive commands for its operation; and finally, the steering system which must receive commands to change directions.

Block definition diagram

Block definition diagram (SysML notation: bdd) shows the system from the component point of view. It answers the question "which contains what? The SysML block is the basic building block for modelling the structure of a system. This block can represent a complete system, a subsystem or an elementary component.

Here is the model of the block definition diagram for our system:

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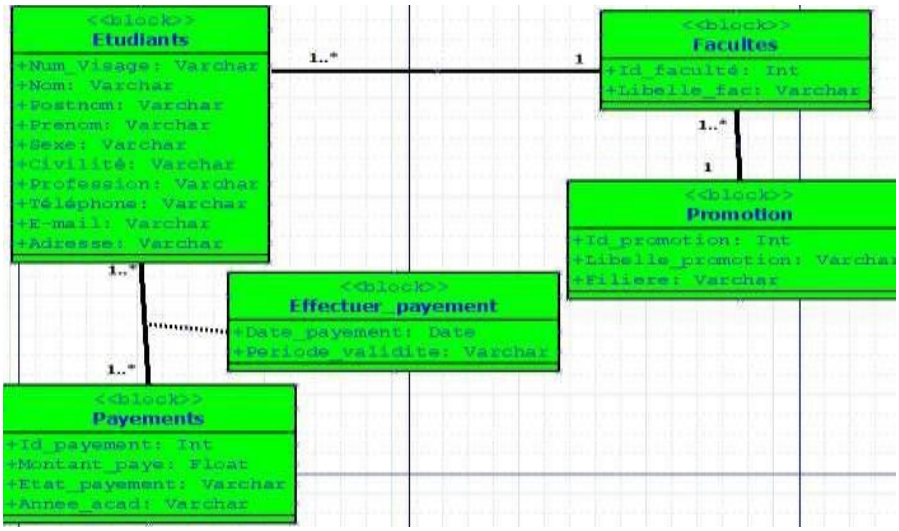

Figure 3: The block definition diagram

Figure 3 shows the block definition diagram specifying the system from a component point of view. The blocks are the basic building blocks for modelling the structure of the system.

The internal block diagram

Internal Block Diagram (ibd) describes the internal view of a block. It is based on the "bdd". It represents the connection between the elements of a block.

The internal block diagram is used to represent the interconnections between blocks. It shows the ports created in the block diagram. It clearly shows the information, energy and material flows, flow ports. The control interfaces, standard ports, are also shown.

Here is the model of the internal block diagram of our system:

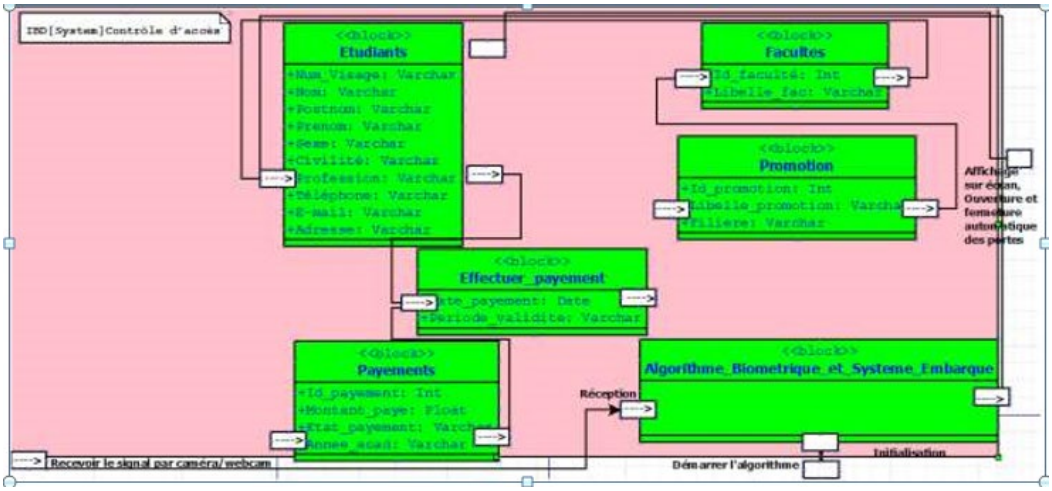

Figure 4: The internal block diagram

Figure 4 shows the internal block diagram specifying the interconnections between the blocks. It shows the ports created in the block diagram. It clearly shows the information, energy and material flows, flow ports. It also shows the control interfaces, standard port (Bowers, 2013).

On the software side, we will have three programs which are:

- ✓ A biometric enrolment program, which will be able to register students with full identities and face captures.
- ✓ A biometric verification program, which will be able to verify information about the person at the door.
- ✓ An Arduino program, which is a program for analyzing and producing electrical signals, so as to perform automatic door opening and closing tasks, access control once the face provided, signal from the biometric verification program is correct then the system automatically opens the door, otherwise the door will remain closed.

The figures below show the biometric enrolment program, the biometric verification program and the Arduino program respectively.

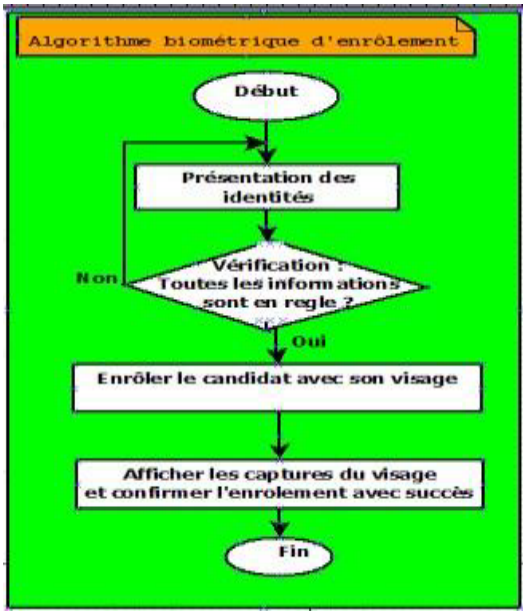

Figure 6: The biometric enrolment program

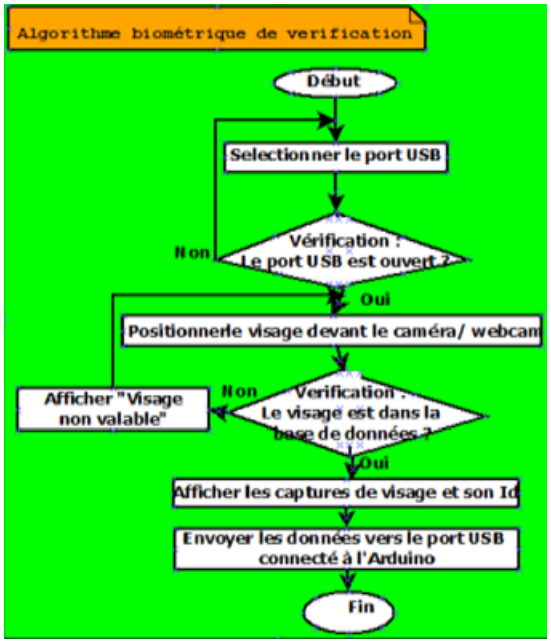

Figure 7: The biometric verification program

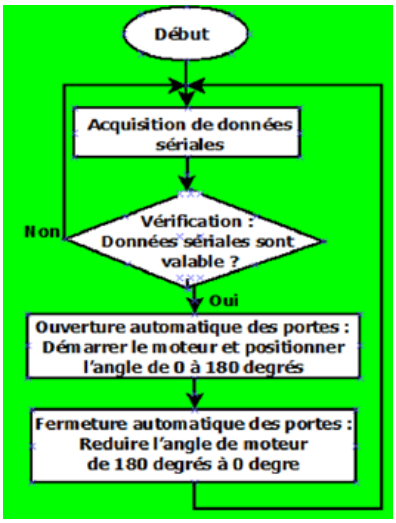

Figure 8: The Arduino program for opening and closing doors

Hardware architecture of the system

The hardware architecture of the project is as follows **(**Bopatriciat Boluma Mangata et al., 2021) :

- ✓ A camera/webcam, communicating with a computer;
- ✓ A computer, containing a biometric application in #C that allows instructions to be given to the Arduino board via the serial port (Mathivet, 2017).

- ✓ The Arduino board, which is programmed to analyse and produce electrical signals, in order to perform automatic door opening and closing tasks (access control).
- ✓ TOWER PROTM Micro Servo 9g SG90, a stepper motor that will allow us to make the opening and closing movements of the doors.

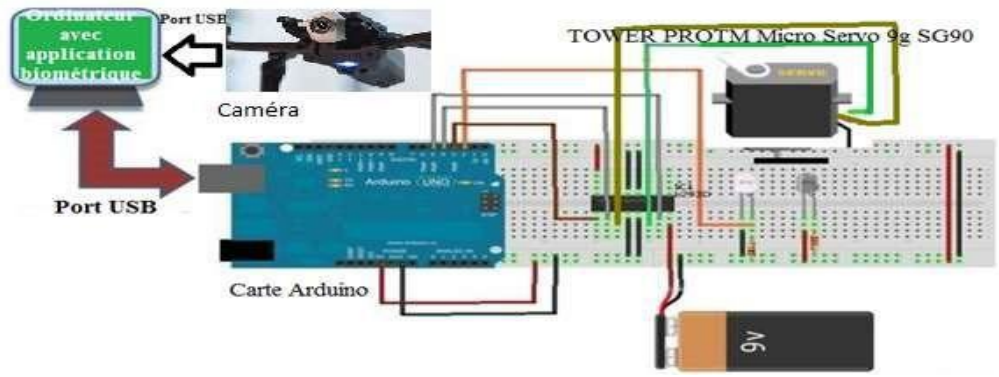

Figure 9: The project's hardware architecture

RESULT

Here is the representation of some graphical interfaces of our application:

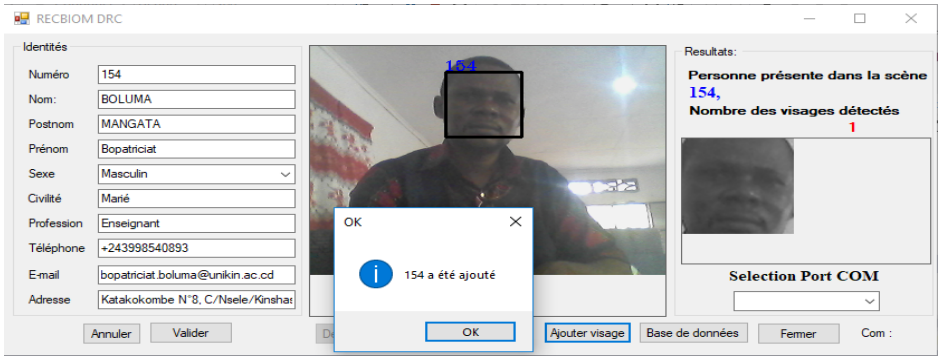

Figure 10 : The enrollment window

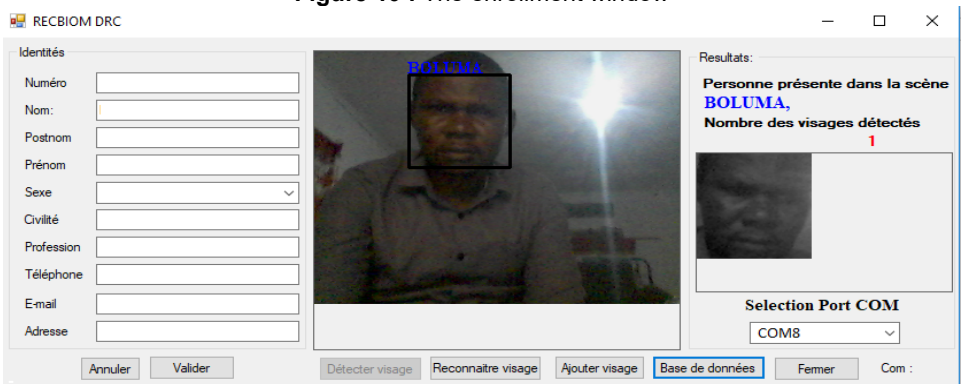

Figure 11: The verification window with a valid face

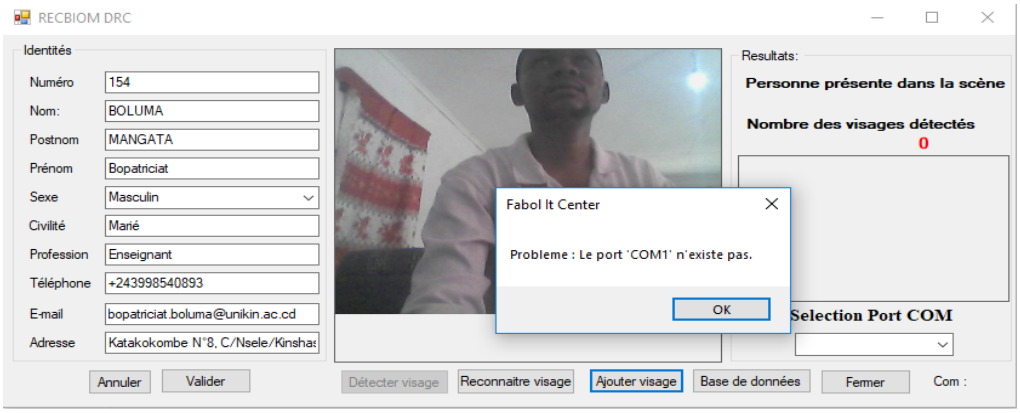

Figure 12: Verification window with serial port not selected

Figure 13: The door opening and closing test window

System performance

This work item evaluates the performance of our facial recognition-based access control system for securing premises (Douaa & Radhwane, 2019).

On a sample of 100 individuals composed of 40 women and 60 men, of which 75 were registered and 25 non-registered, our access control system obtained the following results: 70 true positives, 5 false negatives, 8 false positives and 17 true negatives, which constitute our confusion matrix **(**Guizani, Zavala, & Funamizu, 2016).

Table 1: Confusion matrix

	True Positive	False Negative	True Negative	False Positive	Sum
Women	28	2	7	3	40
Men	42	3	10	5	60
Sum	70	5	17	8	100

Based on this result, which allowed us to evaluate the performance of our system, we can graphically represent it with the help of a bar chart as follows (Markoulidakis, Rallis, Georgoulas, Kopsiaftis, Doulamis & Doulamis, 2021):

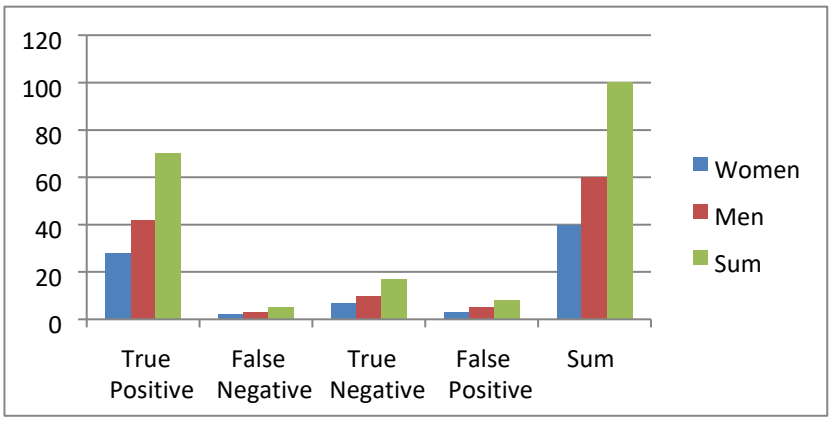

Figure 14: The performance of our system using bar charts

CONCLUSION

The present work consists in modelling and implementing a system of access control to secure premises using facial recognition, in order to put an end to the problems of abusive access control to premises in a multi-entrance institution.

We have applied our approach in a multi-entry university institution, namely the University of Kinshasa, UNIKIN.
In this context, we have developed a facial recognition system that interacts with an embedded system for the automation of door opening and closing. This new system is divided into two subsystems:

- Enrolment: the subsystem can register students with their full identities including face captures.
- Verification, the subsystem can verify:
  - ✓ Before entering the university premises, the student is supposed to present himself in front of the camera or webcam so that the subsystem can check with facial recognition whether he is in order or not;
  - ✓ Once the face provided is correct with the current payment settlement then the system opens the door, otherwise the door remains closed.

The interest of such an approach is to provide a valuable help to the scientific community, by providing them with a reliable tool for access control to premises in a multi-entry institution.

However, from the set of tests performed we can conclude that multi-modality fusion can be leveraged to increase the performance of the verification system as the verification performance of multimodal systems, feature fusion or score fusion can be applied to give even better results.

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CONFLICT OF INTEREST DISCLOSURE

All authors declare that they have no conflicts of interest to disclose.

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