Scientific Research Publishing

Open Journal of Applied Sciences, 2022, 12, 2019-2036
https://www.scirp.org/journal/ojapps
ISSN Online: 2165-3925
ISSN Print: 2165-3917

Electronic System Using Artificial Intelligence for Queue Management

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How to cite this paper: Ndiaye, J., Sow, O., Traore, Y., Diop, M.A., Faye, A.S. and Diop, A. (2022) Electronic System Using Artificial Intelligence for Queue Management. *Open Journal of Applied Sciences*, **12**, 2019-2036.
https://doi.org/10.4236/ojapps.2022.1212141

Received: November 6, 2022
Accepted: December 18, 2022
Published: December 21, 2022

Abstract

The Covid-19 pandemic has brought changes in behaviour in public places. Indeed, the health and political authorities, in order to fight against the virus in a preventive manner, require the respect of barrier gestures: social distance, mask, vaccine, gel. Still in terms of public health, long waits in a place for a service have a negative impact on the health of fragile categories such as the disabled, pregnant women and the elderly. The technical devices used for queue management must now take into account the health context, identity, particularity and behaviour of people. This paper presents an electronic system developed with artificial intelligence for queue management in public facilities. This design personalises the user's ticket by automatically integrating the name, facial image, age and possible disability status. At the counters, a system of name calling, sound and screen display, allows users to follow the queue without having a ticket printed on thermal paper with a high carbon footprint. This solution also makes illiterate users autonomous in the queue, allowing them to maintain their dignity and to respect the safety distance between people. The device allows the establishment's manager, depending on the context, to activate positive discrimination of the disabled or the elderly, to control the Covid-19 mark or the health pass by QR Code. This queue manager performs biometric authentication by facial recognition before the user is registered in the queue register, which prevents fraud by people who do not want to respect the order of arrival of users. This work has led to the improvement of the technical management of queues by introducing more equity, inclusion, solidarity, health and ecology.

Keywords

Public Health, Automation, Arduino, Artificial Intelligence, Queue

1. Introduction

By 2050, Africa is expected to have a population of about 2.5 billion [1]. This will be the fastest growth rate in the world. African cities are expected to be home to an additional 950 million people [2].

However, their development is accompanied by an increase in demand for health, banking and administrative services.

The UEMOA area, with a population of only 123.6 million [3], would have 3762 branches for customers in 2020 in banking services [4].

In order to access services in public facilities, users are often impatient and stressed and progress through queues [5]. The latter does not always take into account behavioural and societal realities. Moreover, long queues are a physical burden for the elderly, whose numbers are expected to quadruple by 2050, representing 9% of Africans [6]. People with disabilities, who make up 10% of Africa's population [7], are another vulnerable group that queue management systems do not automatically take into account.

In response to this situation, some researchers have proposed theoretical methods for monitoring queues [8] [9] [10] [11]. Others have developed queue management techniques based on computer networks associated with electronics [12] [13] [14] [15].

Societies are now heavily influenced by technology with increasingly intelligent machines interacting directly with people. In Africa, electronic queuing devices do not sufficiently integrate artificial intelligence to improve the quality of the service provided to users. While artificial intelligence (AI) [16], is poised to transform the world after the digital revolution led by the American GAFAM (Google, Apple, Facebook, Amazon and Microsoft) and the Chinese BATX (Baidu, Alibaba, Tencent, Xiaomi) [17] [18].

This work presents an electronic queue management device capable of authenticating, through artificial intelligence, people who are then automatically registered in the queue with their personal data. The present solution also aims at the suppression of tickets, printed on paper, thanks to a vocal and visual interattraction using artificial intelligence. It also makes the illiterate person autonomous in his or her progress through the queue.

2. Material and Methods

The queuing device, which is an automated and autonomous robot, is composed of several interconnected elements as shown in **Figure 1**.

It consists of a computer that processes the algorithms, a scanner that digitises the person's identification document, a camera that takes the image of the person's face, and an electronic acquisition card that is connected to the control elements and signals. This automatic device also uses a screen and loudspeakers for communication with the persons as shown in the system architecture in **Figure 2**.

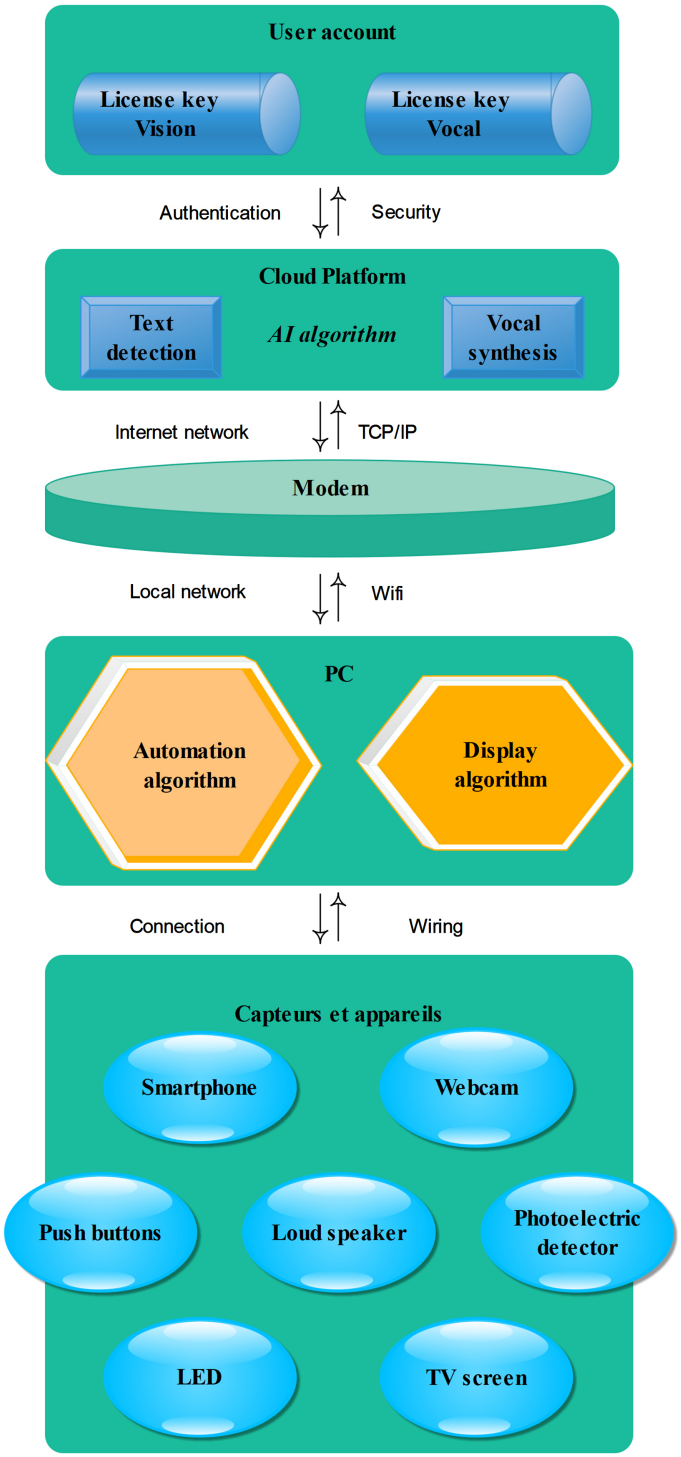

Figure 1. Architecture of the proposed solution.

2.1. Computer

For computational power, the queue management robot's computer system consists mainly of two data processing units that are connected via the Internet as shown in Figure 3. The robot performs control and command tasks with a main algorithm that runs on a personal computer (PC) that is locally wired to the rest

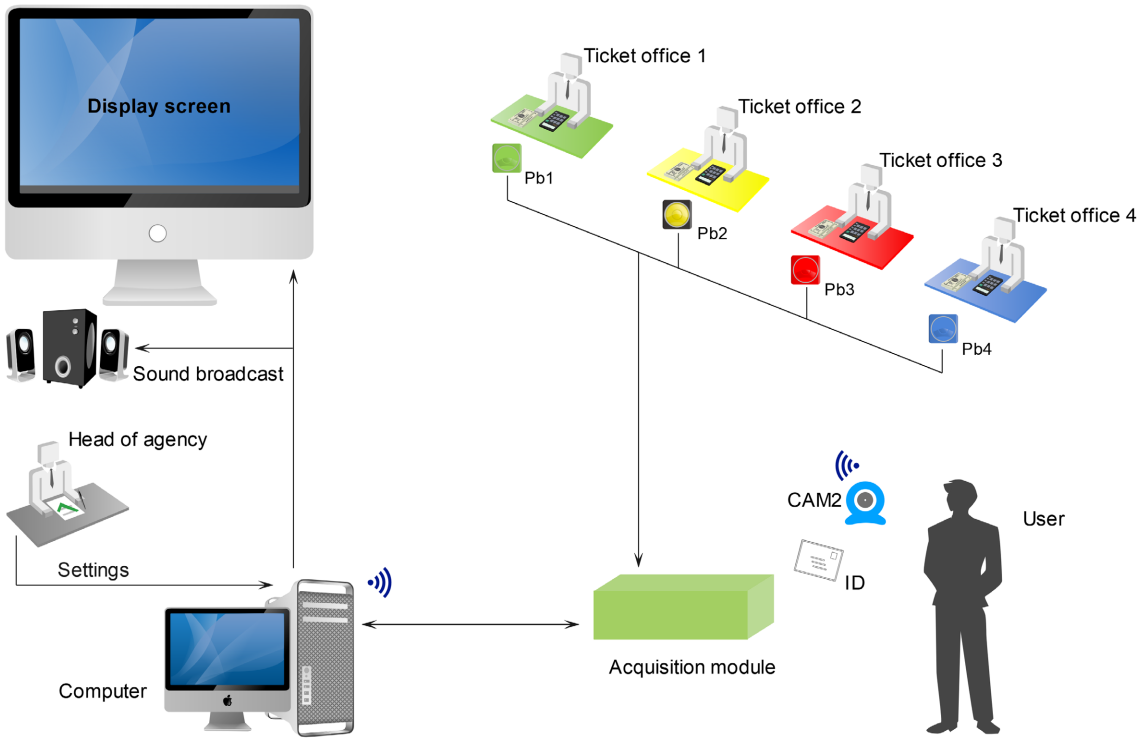

Figure 2. Overview of the electronic intelligent queue management system.

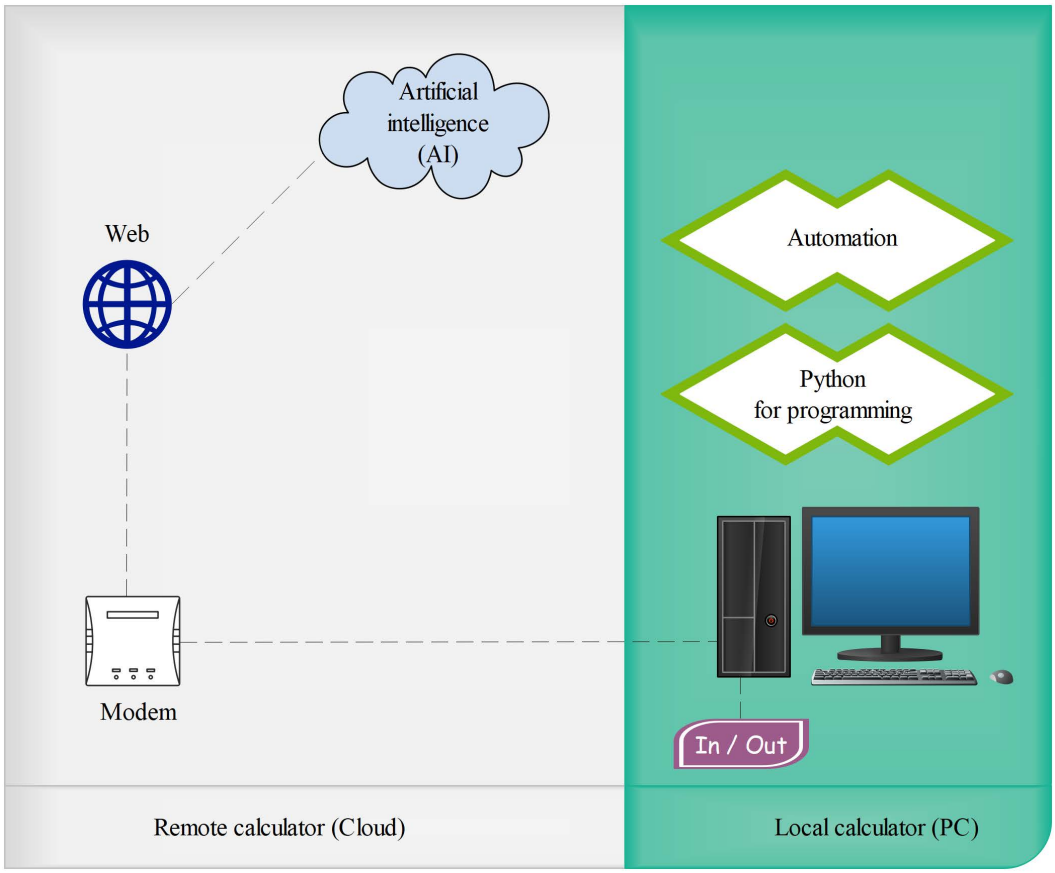

Figure 3. Equivalent computer for data processing.

of the hardware elements of the device. During the operation of the queuing device, this personal computer sends pre-processed data to the Cloud [19] [20] [21] in real time for processing by the off-site artificial intelligence.

The software part is developed with open source tools to facilitate future developments. This is why the Python language is used for programming [22]. On the cloud, artificial intelligence services are accessible remotely by programming in Python on a local computer [22].

2.2. Acquisition System

The electronic acquisition card allows, at the input, to collect the Boolean information necessary for the operation of the system. On the output side, this card allows visual signals to be activated.

Figure 4 illustrates the generation and transmission of input and output binary data.

Table 1 shows the addressing used to connect the inputs and outputs of the electronic board.

2.2.1. Electronic Board

The Arduino UNO microcontroller, an open source hardware, is used through its digital ports and is connected to the computer by a USB cable.

2.2.2. Call Buttons

To call the next customer from one of the four counters, four electric push buttons are connected to the Arduino board. Each counter staff has its own call button.

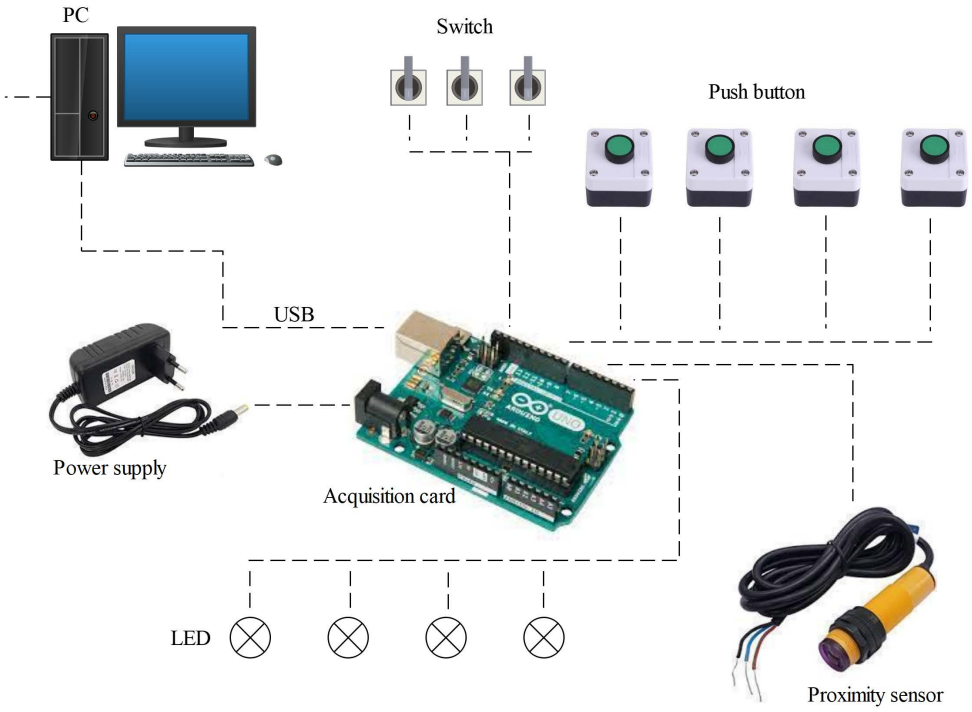

Figure 4. Input and output connections to the Arduino board.

Table 1. Addressing of the electronic board.

Address	Nomenclature	Function
Pin 2	D1	Manual contactless registration request
Pin 10	K1	Manual mode selection control
Pin 11	K2	Manual mode selection control
Pin 12	K3	Manual mode selection control
Pin 7	V1	Signal lamp
Pin 9	V2	Signal lamp
Pine 13	V3	Signal lamp
Pin 3	Pb1	Counter 1 call control
Pin 4	Pb2	Counter 2 call control
Pin 5	Pb3	Counter call control 3
Pin 6	Pb4	Counter call control 4

2.2.3. Mode Switches

Three electrical switches are connected to the computer through the Arduino board. They allow the selection of different operating modes. The facility manager chooses, depending on the context, whether or not to activate the options shown in Table 2.

2.2.4. Start-Up Control

A proximity sensor is also connected so that the user can request registration in the contactless queue. Thus, after placing his identification document on the scanner, the user passes his hand over the sensor at a distance of 10 cm.

2.2.5. Indicator Lights

Useful information is displayed on four LEDs to indicate current modes and system status.

2.2.6. Image Capture

A smartphone camera (Figure 5) is used to scan the person's identification document. The choice of such a device is explained by the very high quality of the images, for better performance of the AI algorithm. The device is directly connected to the PC for the acquisition of the user's personal data.

The person's face is scanned by the webcam in Figure 6 which is connected directly to the PC for biometric authentication by the AI. The Tripod in Figure 7 supports the webcam for a good viewing angle.

2.3. Visual and Audio Communication System

As the user progresses through the queue, the device automatically informs the user by image on screen (Figure 8) and sound (Figure 9) synthesised by AI.

These calls are connected directly to the PC and are controlled by a program in Python.

Figure 5. Smartphone.

Figure 6. Webcam.

Figure 7. Tripod.

Table 2. Operating modes.

Option	Switch	Description
Disabled people	-	Disabled people come first
Older people	K1	If K1 is activated, a senior citizen every time 3 people pass
Control of the Covid-19 mark	K2	If K2 is activated, the mask is mandatory for the integration in the queue
Health pass control	K3	If K3 is activated, the QR Code is mandatory for integration in the queue

Figure 8. Display screen.

Figure 9. Speakers.

This man-machine interface solution makes it possible to avoid printing tickets on paper and to make illiterate people autonomous in their progress through the queue.

Tkinter is the free Python graphics library used to design the screen display system.

3. Results and Discussions

3.1. Acquisition Module

The acquisition module is a box divided into two compartments (Figure 10). The first part, the scanner, has an illuminated opening that receives the identification document that the camera placed inside scans.

The second part, for control and command, is equipped with the Arduino board which centralises the Boolean inputs and outputs.

3.2. Automation of Queue Management Tasks

The automatic and autonomous operation of the intelligent queue manager is dictated by a set of specifications with a number of parameters.

Upon entering the facility, the user places his or her identification document (ID) in the slot provided on the acquisition module. Facing the second camera, he passes his hand over the detector to start the system. The cycle begins with the acquisition of the image of the ID card by the first camera and the acquisition of the image of the person's face by the second camera. Then the machine extracts data such as name, age, disability status, and starts the facial verification. If the ID holder is not authenticated as the owner, then the registration in the queue is rejected with a voice notification of the reason for rejection.

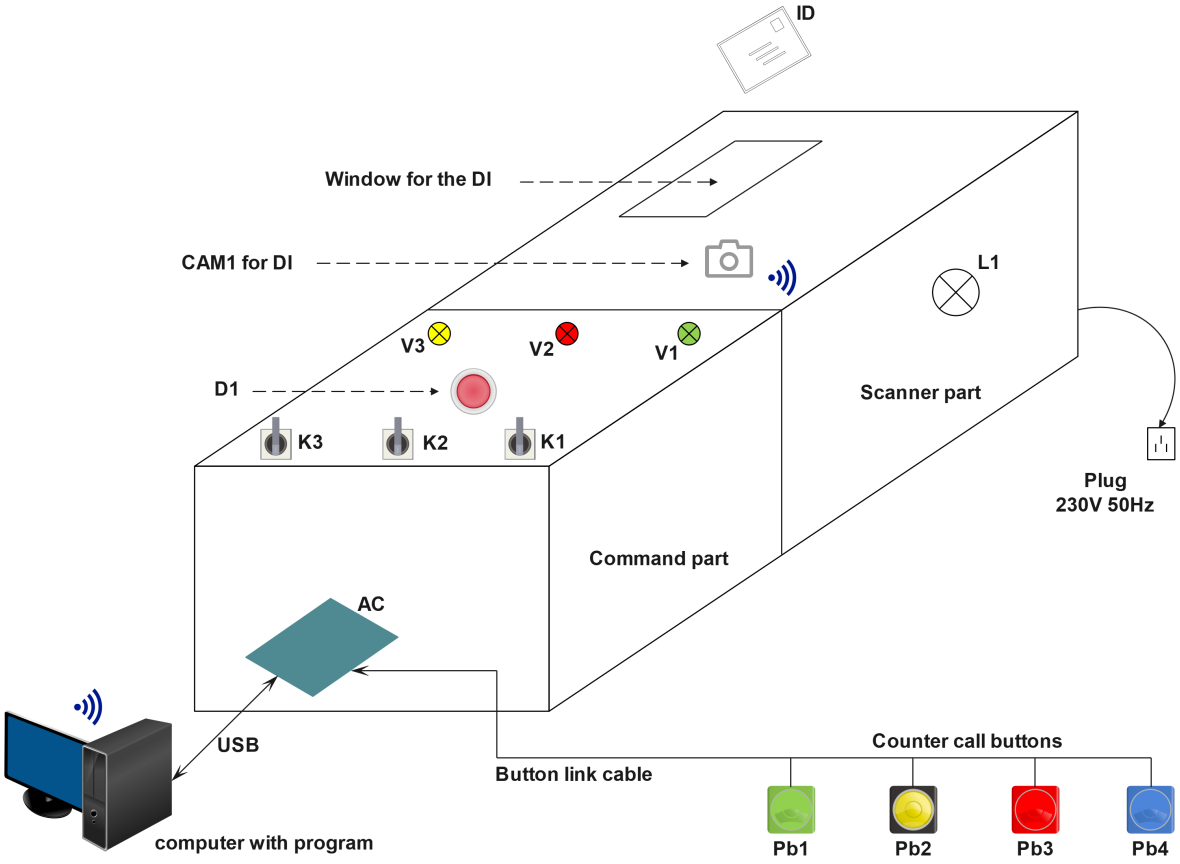

Figure 10. Queue manager acquisition module.

Then, if the mask port option is active, a voice notification informs the user that the mask is being checked. If the mask port is not confirmed then the mask is rejected from the queue with a voice notification of the reason for rejection.

Afterwards, if the sanitary pass option is active, a voice notification informs the user that the QR Code has been checked. If the QR Code is not valid, then the registration in the queue is rejected with a voice notification of the reason for the rejection.

If all the checks are successful, the system registers the user in the queue with the following data: arrival number, name, age, physical status, arrival time, arrival date.

When the call button of a counter is pressed, the data of the next user is assigned to this counter and this user accesses the service. Disabled people with an equal opportunities card, issued by the state authorities, with the mention "disability" have absolute priority and will be called first.

If the option elderly person is active, an elderly person is called after three unfavoured persons have been called.

The choice is to make, for more interoperability, a modular design for the development of the software part with the programming language Python. Figure 11 shows the main algorithm which calls, during its execution, several sub-programs in the form of modules:

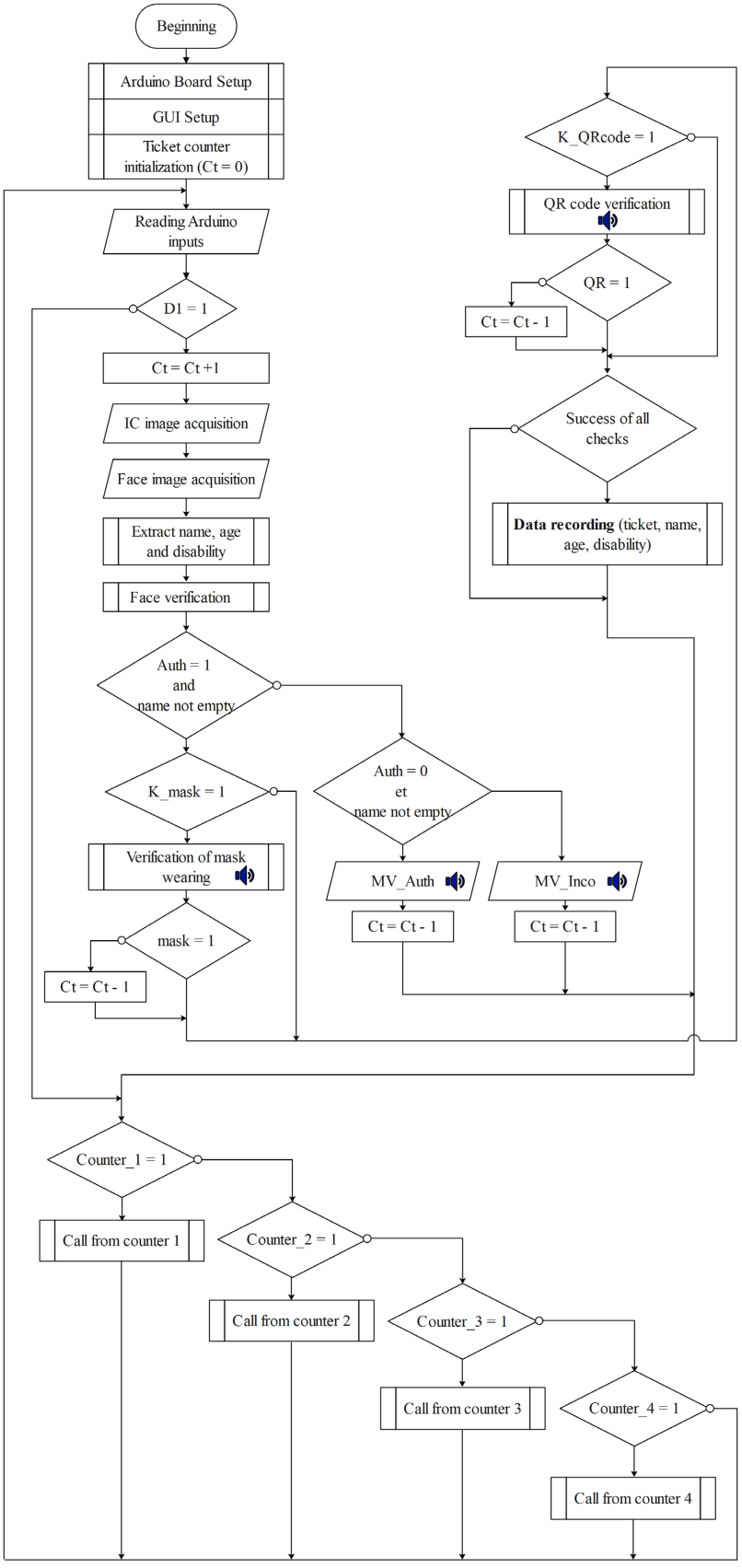

Figure 11. Main algorithm.

- Acquisition module for the arduino board;
- Image capture module for both cameras;
- Cloud-based computer vision AI module;
- Cloud-based text-to-speech AI module;
- User registration and call module;
- GUI module.

Figure 12 shows the subroutine responsible for registering a new person in the queue, while Figure 13 shows the subroutine that processes counter calls.

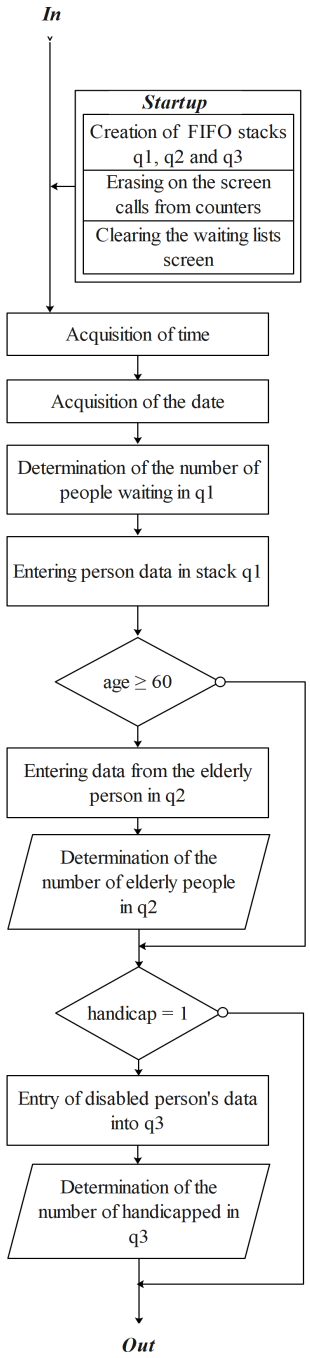

Figure 12. Data logging sub-program.

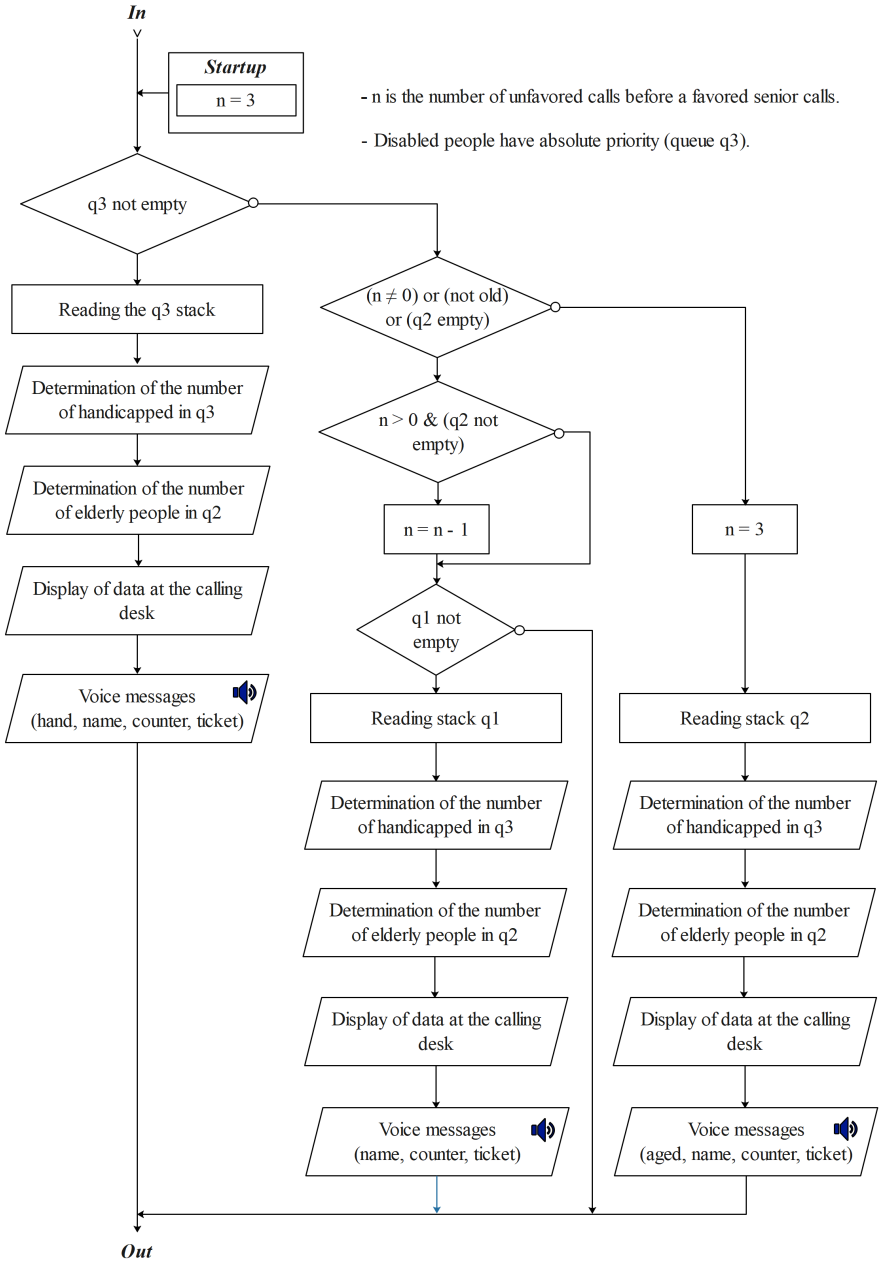

Figure 13. Counter call sub-programme.

3.3. Development of the Graphical Interface

The design and realisation of the graphic interface is one of the important steps in the execution of this project. Thus, several areas are created on the display screen for innovative communication with users during the progression of the queue:

- Static display area for the names of the first 6 finishers;
- Static display area for the names of the last 6 arrivals;
- Dynamic display area for the names of all the other people in the queue;
- Display area for each counter with arrival number, counter number, name, face photo, colour;

- Display area for the number of disabled people in the queue;
- The number of elderly people in the queue is displayed in the display area.

Figure 14 shows the complete composition of the graphical interface developed for the users. Figure 15 shows an illustration of the display screen with historical personalities.

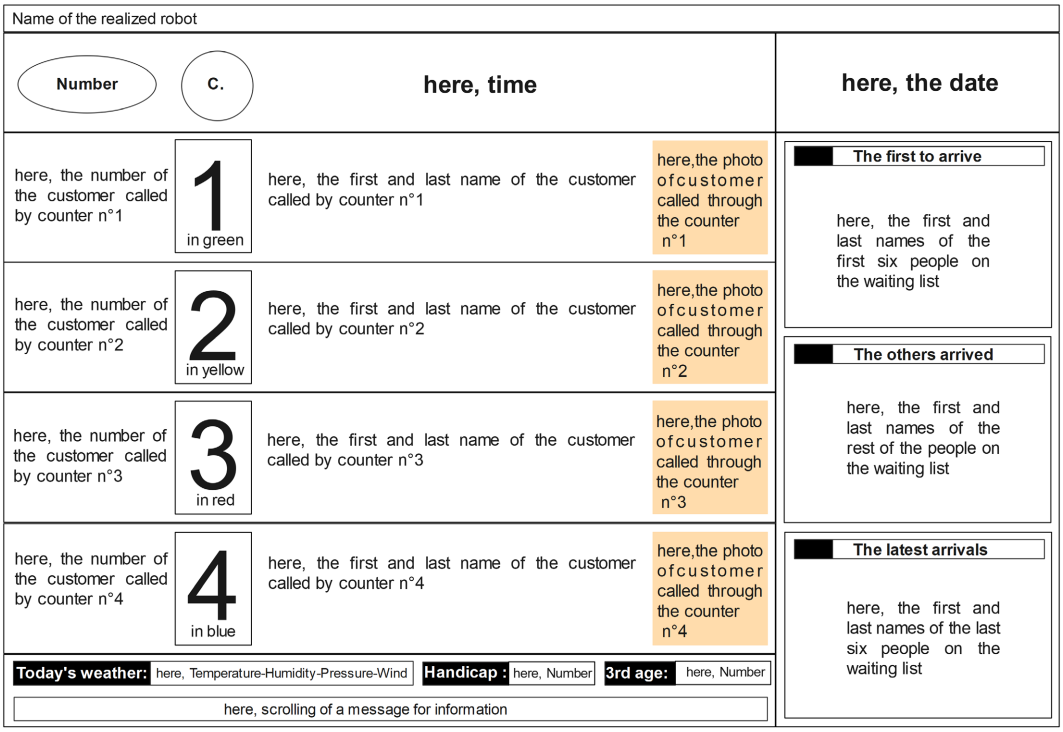

Figure 14. Presentation of the user display screen.

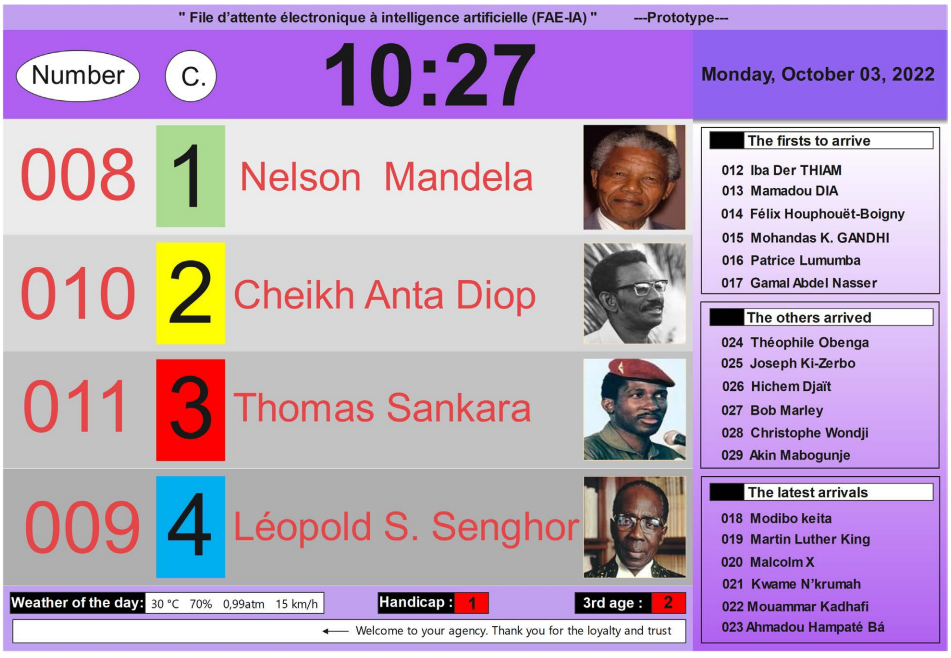

Figure 15. Simulation of the queue manager GUI.

3.4. Metric Experimentation

Figure 16 and Figure 17 show the implementation of the electronic intelligent queue management system.

3.4.1. Comparison of Registration Time with Three Types of Identification Cards

The performance of the system is tested by measuring the time needed to register users. The experiment is carried out, with a 4G+ connection, on Thursday 06 October 2022 between 15:00 and 16:15, on three types of identification document:

- Senegalese national identification card in the UEMOA region;
- Senegalese driving licence;
- Printed card with name, date of birth, photo, status (an establishment could issue it to its customers).

Figure 16. Overview of the queue management system.

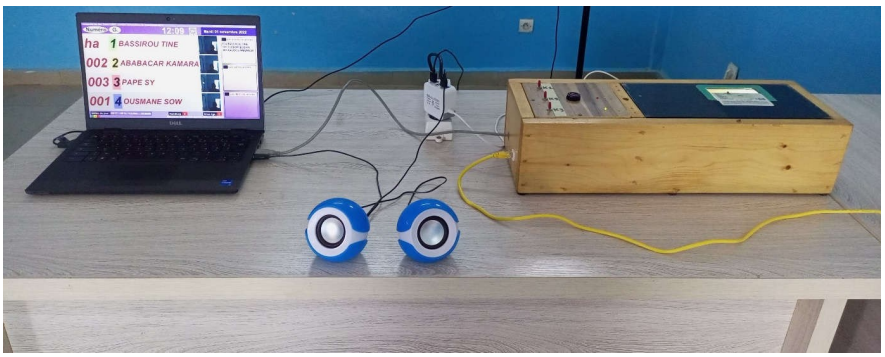

Figure 17. Zooming in on the screen and the queue manager acquisition module.

For the printed card in Figure 18, the recording time is between 5.71 seconds and 8.95 seconds with an average duration of 7 seconds.

With the national ID card, in Figure 19, the registration time ranges from 6.41 seconds to 12.21 seconds with an average duration of 8 seconds.

For the driver's licence in Figure 20, the recording time is between 6.22 seconds and 8.93 seconds with an average duration of 7.5 seconds.

It is noted that the average recording time of users depends on the type of map and varies between 7 and 8 seconds. As the maps have the same dimensions, the differences are therefore due to the composition of each type of map in images and text. Indeed, the amount of data processed by the main program's snowshoes, together with the artificial intelligence of the cloud, is different from one type of map to another.

3.4.2. Comparison of Recording Time between Wifi and 4G+

The solution is also being tested with two different internet networks during the morning of Thursday 13 October 2022 to get the average time of registration of users. In this experiment, only the national card identification is used.

The observation in Figure 21 is that the recording time is more regular with the 4G+ network, which also has lower peaks. Overall, the average recording time with the wifi network, on Figure 22, is greater than that of the 4G+. This result can be explained by the high traffic on the University of Thies internet network during the test period, or by the settings of the university network administrator.

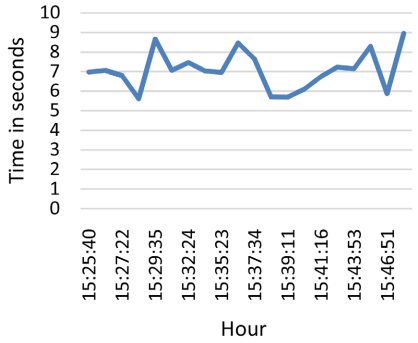

Figure 18. Printed card.

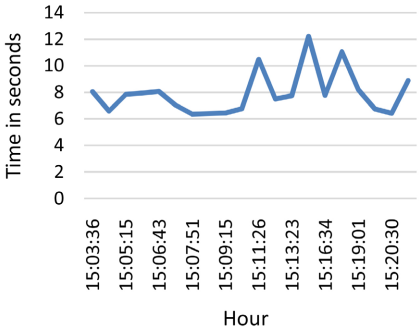

Figure 19. Senegalese national identity card.

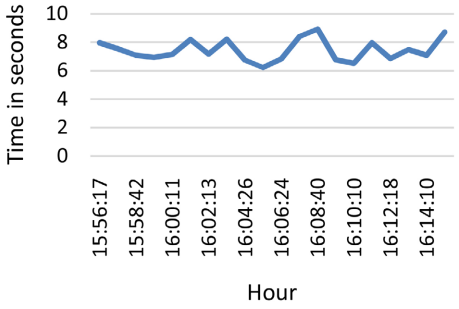

Figure 20. Senegalese driving licence.

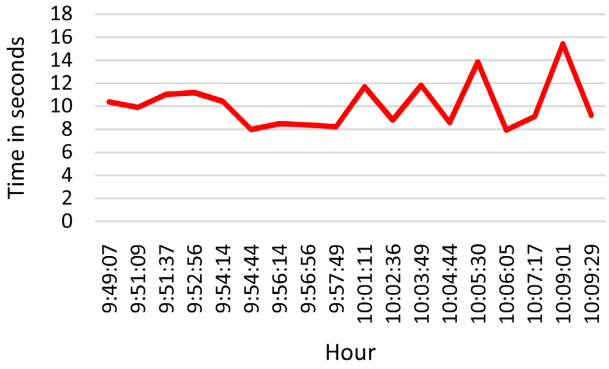

Figure 21. Registration with 4G+.

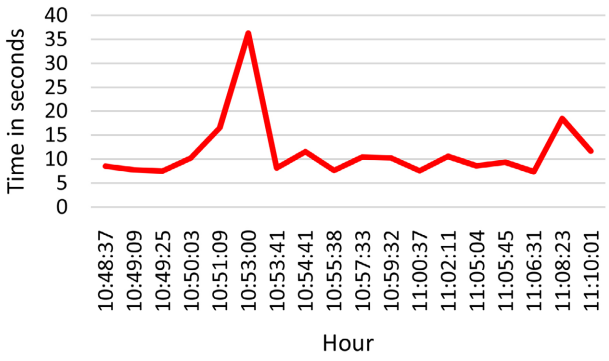

Figure 22. Registration with Wifi.

4. Conclusions

Queues play an important role in the reception and orientation of users in establishments receiving the public: hospitals, banks, administrations, etc. Today, the technological machines that manage queues must integrate other functions linked to the various changes in societies marked by pandemics, climate change and various inequalities. This study is a contribution to more intelligent management of queues. Indeed, it is a design and implementation of a hardware and software device with strong technological integration to robotize the management of queues. From a behavioural point of view, the proposed solution removes the human factor to fight against incivility, from certain impatient people, source of injustice among users. The automatic device developed takes into ac-

count the need for the elderly, which is a social asset. The algorithm that makes the machine work discriminates positively against disabled people for their well-being by limiting the waiting time in the establishments. This work has empowered illiterate people to progress through a queue with an innovative graphical and voice interface. This project was sensitive to environmental issues and the results obtained mean that the user's ticket is not printed, while remaining efficient.

Ultimately, this work has led to the development of an intelligent automatic queue manager with attributes of public health, solidarity, inclusiveness, equity and ecology.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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