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Development of an Intelligent Queue Manager That Takes Account of the Social and Health Context

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Abstract

Virus prevention has been considered central to the fight against the COVID-19 coronavirus pandemic. To limit the spread of the virus in public places, several measures have been taken, in particular respect for barrier gestures. This work is part of this dynamic and sets up a new wireless version of an electronic and nominative queue manager using artificial intelligence for more equity, inclusion and solidarity. This system, named Gifa is developed in our laboratory. The first prototype, whose connections are largely provided by a wired system with an artisanal acquisition module, is difficult to deploy for general public use, especially in buildings already built. This article deals with an artificial intelligence queue management system, presenting more functionalities, whose access to the service is ensured in very large part by wireless exchanges with a modern acquisition module realized by 3D printing. The flexible and autonomous design of this device makes it particularly easy to deploy on premises open to the public without having to modify the existing installation for commissioning. The manager is equipped with a configuration terminal, and at the counters the call is made by a cashier also equipped with a tablet connected to the wifi network. Its display screen shows certain information relating to the identity of the customer such as his face, his order number, his first name and last name. This reduces the authentication time of the person at the checkout, queue bypasses for more fairness and less stress. This work has resulted in the improvement of queue management systems by giving them more flexibility to make them more adaptable in several types of environments and other contexts.

Keywords

GiFa, Public Health, Wireless, Node Red, Arduino, Cloud and AI, 3D Printing

1. Introduction

The aim of this study in Senegal is to help improve waiting and access conditions in establishments open to the public, taking into account behavioral and social realities in the context of a pandemic.

The objective of the work is to automate a number of tasks carried out by staff for users, from the moment they arrive to the moment they leave an establishment once they have obtained the service they require.

Not all establishments open to the public are equipped with effective technical queue management systems, and in some cases, it is even a member of staff who deals with this manually, sometimes with the complicity of fraudsters. In addition to this injustice, which is a source of stress, there is the frustration of illiterate people who cannot read their ticket numbers, which are themselves a potential vector for the spread of viruses. They are also dependent on their neighbours by not respecting the social distance during a pandemic such as COVID-19. Long waiting times for frail people such as the elderly and disabled can affect their general state of health, posing a public health problem. During a pandemic, it is often the staff who ensure that preventive measures such as masks, temperatures, distances and gauges are respected.

The work presented in this article uses automation to provide humanized management of electronic queues, with qualities of fairness, solidarity, inclusion, public health and ecology.

With the global health crisis of the COVID-19 pandemic, several authors have looked into work to find solutions to reduce the transmission of the virus. In this context, we have implemented an artificial intelligence electronic queue management system [1]. Although integrating several modules related to the respect of barrier gestures, it is a cumbersome device using wire to connect the different entities, which can lead to a need to do new installation work thus favoring a labor additional and may cause some collateral damage in new buildings. It is therefore a laboratory prototype with an artisanal acquisition module integrating the selection of the operating mode normally reserved for the manager. It is in this context that the work on a wireless system is carried out for which the cashiers and the manager of the establishment will be equipped with tablets for wifi connection. The display screen for progress monitoring is also wireless, providing more flexibility for deployment. There will of course be more exposure to electromagnetic waves, the impact on health of which is already the subject of analysis [2] and leads to the consideration of people living in exposed areas [3]. Indeed, entirely legitimate concerns have been raised about the harmfulness and carcinogenic properties associated with electromagnetic fields [4] [5] [6], but scientific studies on the dangerousness to date remain inconclusive and contradictory [7]. Nevertheless, with the absence of causality with current diseases and the presence of waves [8], what is required of the public authorities is to apply the precautionary principle in order to modify current standards and reduce emission levels.

This work focuses on the development of an artificial intelligence queue management solution offering more flexibility with a modern acquisition module made under 3D printing. The solution aims to increase the quality of service with also positive discrimination of the elderly and disabled people who do not tolerate long waiting times that are harmful to their state of health.

2. Material and Methods

The automated and flexible queue management system is composed of different interconnected elements as shown in **Figure 1**.

Compared to the existing device [1], the acquisition module is composed of a camera instead of a smartphone to avoid the interruption of recordings due to frequent restarting of the phone with use all day long. Call push buttons have been replaced by tablets with wireless access to avoid too much clutter and allow cashiers to have customer information before they arrive at the counter, which will reduce the duration of authentications.

The proposed solution is based on the principle of authenticating people by personalizing their place in the queue. It is a system for registering by name in the queue and calling the counter, also by name. This technical device is entirely autonomous thanks to an automation system that uses artificial intelligence services from the world leaders in digital technology.

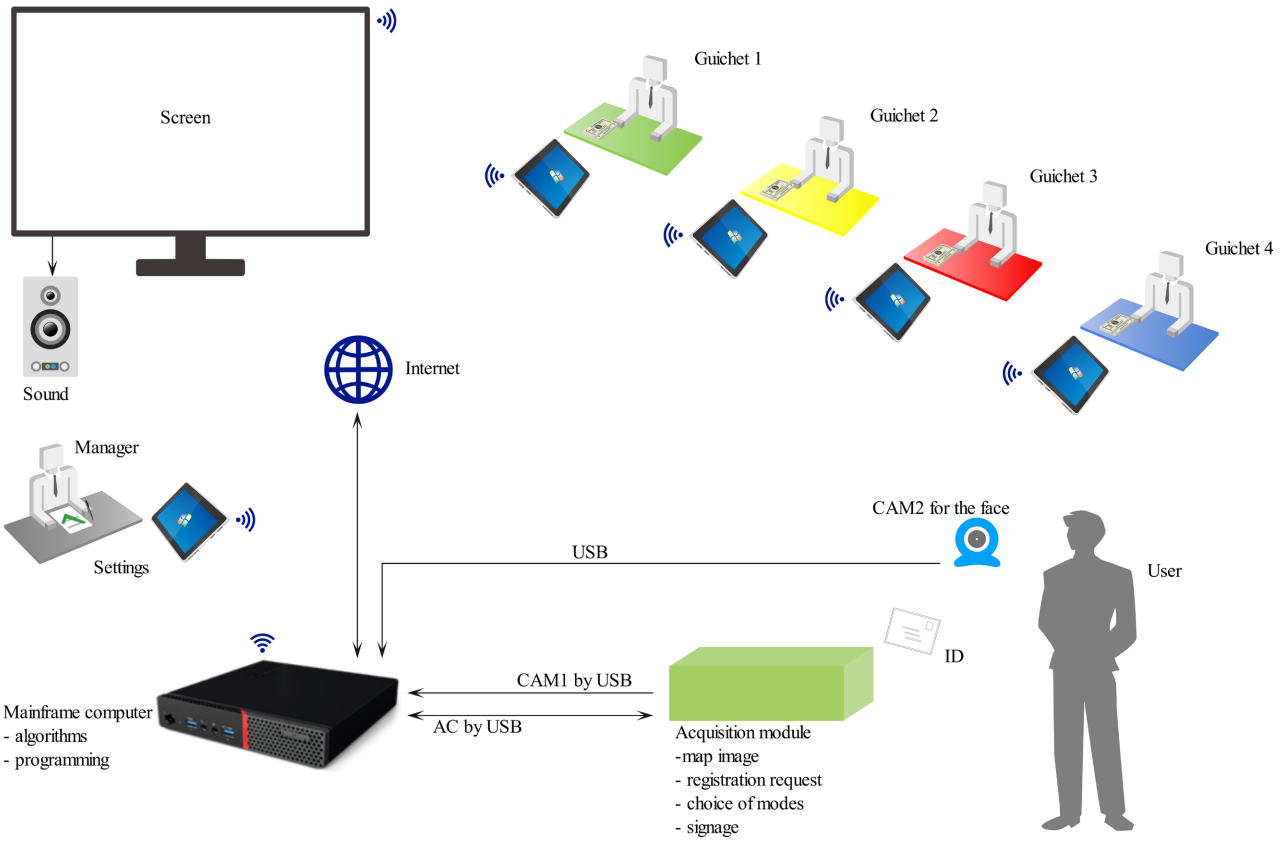

Figure 1. GiFa system overview.

A basic algorithm coded in Python language runs the various stages in the operation of this connected robot. The choice of the cloud for data processing by artificial intelligence enabled the use of a low-computing power consumer computer.

The work carried out produced an electronic manager that identifies the user on the basis of his or her identification document, and then the person is enrolled in the queue after authentication by comparing the face with the one on the identification document. For this new version, the HMI developed for the facility manager allows him or her to choose operating modes from his or her desk.

2.1. Computer

The system is programmed with a mini computer (Figure 2) which is sufficiently powerful, less bulky and has a wifi connection. It integrates the python program and is used as a server with a Node-RED program to allow access to the service of the various wireless terminals. Table 1 presents the main characteristics of this central computer.

Figure 2. GiFa central computer.

Table 1. Lenovo ThinkCentre M700 Mini PC Intel

Processor	• Dual Core Intel Core i3-6100T processor clocked at 3.2 GHz • 3 MB of cache memory
Memory	• 4 GB of 2133 MHz DDR4 SDRAM • Expandable to a maximum of 32 GB • 2 SO-DIMM slots
Storage	• 500 GB Hybrise HDD • 8 GB hard drive cache memory
Graphic Card	• Intel HD Graphics 530
Connectivity	• Wi-Fi 802.11 ac • Bluetooth v4.0 • Ethernet 10/100/1000 Mbit/s
Front Interfaces	• 2 USB 3.0 ports • 1 × 3.5 mm microphone jack input • 1 × 3.5 mm headphone jack output
Rear Interfaces	• 4 USB 3.0 ports • 2 Display Ports • 1 LAN RJ45 port • 1 × 3.5 mm headphone jack
Operating System	• Windows 7/10 Pro 64 Bits

2.2. Cloud

The cloud is used for data processing by artificial intelligence from AWS, and the control of personal data remains a major issue for the protection of privacy [9]. Although there are safety and security risks in the cloud [10] [11], it is nonetheless unavoidable on a global scale with growing confidence, particularly in the French public health system whose treatment and Health data storage is provided by an American cloud [12] [13]. With the system studied, upstream the use of a security firewall is required for the protection of local data and downstream the processing of data in the cloud is provided by AWS which offers a security model with shared responsibility (**Figure 3**) [14].

However, Amazon Web Service ensures the protection of the global infrastructure made up of hardware, software and network infrastructures used to run its services. Indeed, under the General Data Protection Regulation (GDPR), AWS acts as a data processor and controller [15] and thus adopts the suggestions made on the types of security action including pseudonymization, encryption and personal data. With a heavy investment in data protection, with the projected annual privacy budget expected to exceed $2.5 million by 2024 [16], security is the top priority at AWS. However, Amazon S3 (Cloud Online Data Storage) data-at-rest protection, according to the threat profile, is provided through six (6) feature levels [17]. **Figure 4** illustrates the different levels.

2.3. Acquisition System

The basic data processed by the central computer are transmitted or received by an electronic card, a human-machine interface, image sensors and a screen.

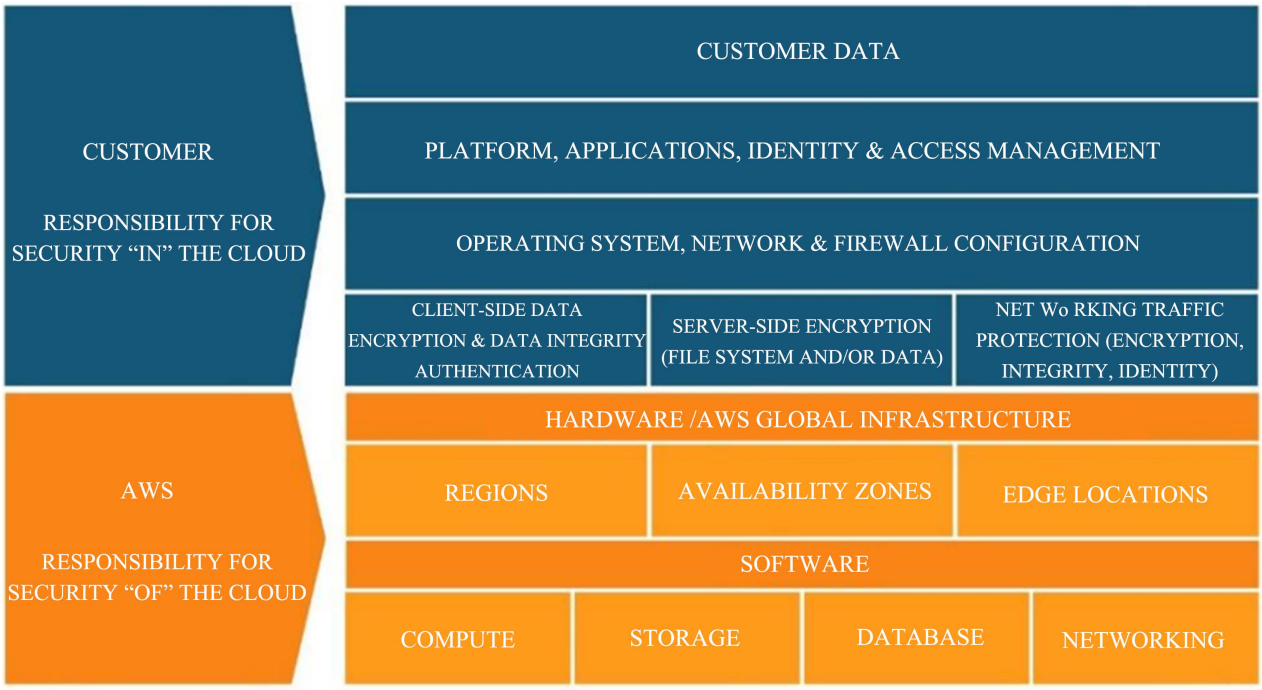

Figure 3. Shared responsibility security model.

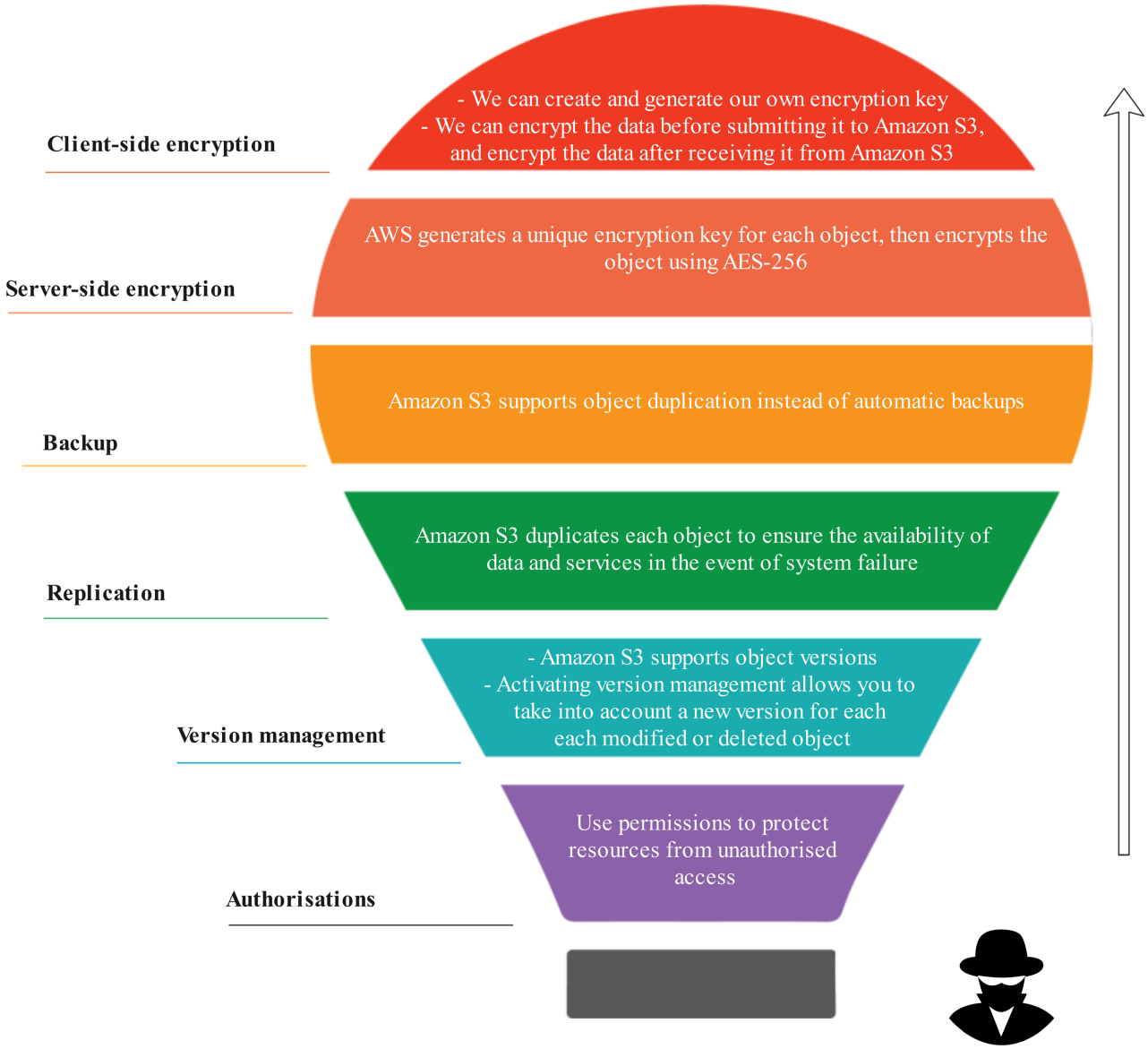

Figure 4. Amazon S3 features for protecting data at rest.

2.3.1. Electronic Card

The Arduino card in **Figure 5**, robust and available, allows bidirectional exchanges with the external environment through the binary input and output ports.

For this second version of the queue manager, the Arduino card is no longer connected to electrical switches for the choice of operating parameters. **Table 2** presents the elements wired to the ports of the Arduino electronic board.

2.3.2. Counter Call Terminals

Each counter is equipped with a tablet (**Figure 6**), the characteristics of which are listed in **Table 3**, on which certain information relating to the identity of the called customer is displayed, such as his face, his order number, his first name and name. For this new version, the call button is no longer an electrical element but a tactile one on the tablet.

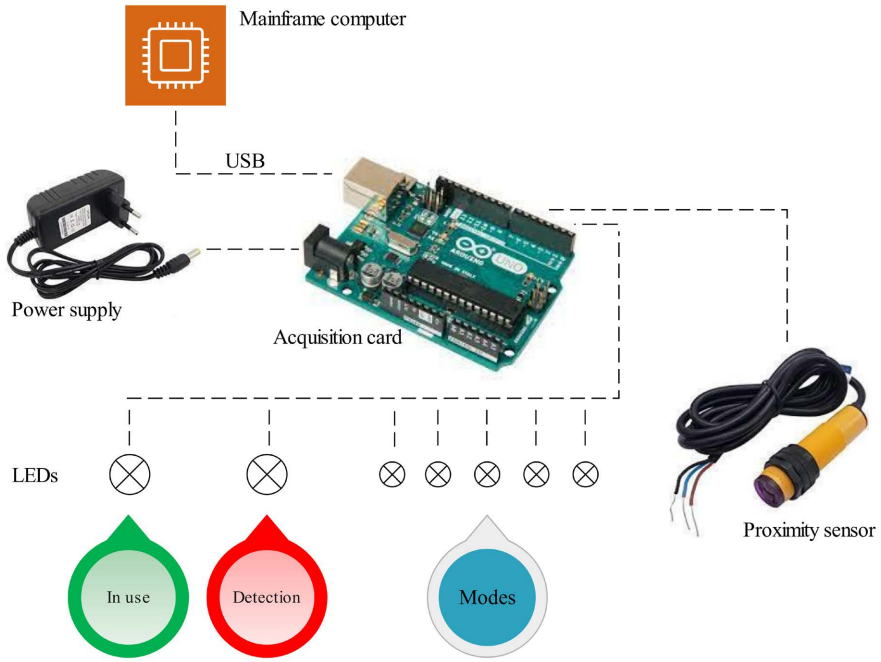

Figure 5. Arduino card connections.

Figure 6. HMI touch screen.

Table 2. Elements connected to Arduino.

Element	Description
Proximity sensor	Manual command to start registration process in GiFa
LEDs of 3 mm	Indication of parameter choices made
Red LED of 5 mm	Indicator of the detection of a registration request in the GiFa
Green LED of 5 mm	Indicator of busy or ready for recording

2.3.3. Configuration Terminal for the Manager

The manager is also equipped with a tablet (**Figure 6**) to choose the functionalities according to the context of the day and the moment (priority for disabled people, priority for the elderly, control of the COVID-19 brand, QR-code control of the health pass).

Table 3. Touchscreen features.

Element	Description
Operating System (OS)	Android
OS Version	Android 10
Screen size	10.1 inch
SIM card support	dual SIM
Data	5G/LTE
Connectivity	WiFi, Bluetooth
Storage	128 Go
RAM	4 Go
Type of processor	1.3 GHZ Quad Core
Camera	dual camera (front/rear)
Type of camera	primary 5 MP, secondary 2 MP
Media Ports	TFCard memory card up to 64 GB
Battery	6000 mAh

2.3.4. Capturing Images

For the digitization of the person's identification document, the webcam camera is used (**Figure 7**), the characteristics of which are summarized in **Table 4**. This device is chosen because of its high image quality and its capacity to work all day long without interruption.

The tripod (**Figure 8**) is the element that supports the webcam for a good viewing angle when taking the image. The latter, represented in **Figure 9**, makes it possible to capture the face of the customer, which will then be processed by the AI.

2.4. Visual and Sound Communication System

To follow the progress of the queue, the user is informed by a visual device (**Figure 10**) connected to the system by wifi whose characteristics are established in **Table 5** and by sound (**Figure 11**) given by AI.

These devices are connected to the PC by wifi and are controlled by a program in Python language.

3. Results and Discussion

Starting from the first version of the queue manager [1], the development of this second version gave results on the electronic, computer and 3D manufacturing aspects.

3.1. Acquisition Module

The acquisition module comprises a box divided into two parts (**Figure 12**), the first of which represents the control part and the second performs the function of scanning the card placed on the opening slot.

Figure 7. Webcam for the card.

Figure 8. Tripod.

Table 4. Scanner webcam features.

Element	Description
Sensor	Aptina MI5100
Lenz size	1/2.5 pouces (4:3)
Pixel size	2.2 um
Image area	5.7 mm × 4.28 mm
Maximum resolution	2592 (H) × 1944 (V)
Compression Format	MJPEG/YUV2 (YUYV)

Figure 9. Webcam.

Figure 10. Display screen.

Figure 11. Speakers.

Table 5. Display screen features.

Element	Description
Connections	2 * HDMI, 2 * USB, WiFi
Display technology	LED UHD-4K
Energy efficiency class	A+
Screen size	65 POUCES (144.8 × 89.8 × 27.5 cm)
Item Weight	17.4 kg
Operating system	ANDROID TV
Surround Sound	2 × 8 W (Dolby Audio)
Options	DOLBY DIGITAL PLUS, Decoder, HDR 10, HLG

The new design of this module takes into account the functionalities transferred to the HMI of the manager of the establishment which is now equipped with a configuration terminal.

Figure 13 presents the acquisition module in its software modeling phase for its manufacture by 3D printing.

For the manufacturing phase, the Somos Evolve material is used because of its resistant and detailed prototypes. It is a liquid polymer used on industrial-grade 3D printers with the stereolithography process. Table 6 gives the main characteristics of the object thus created.

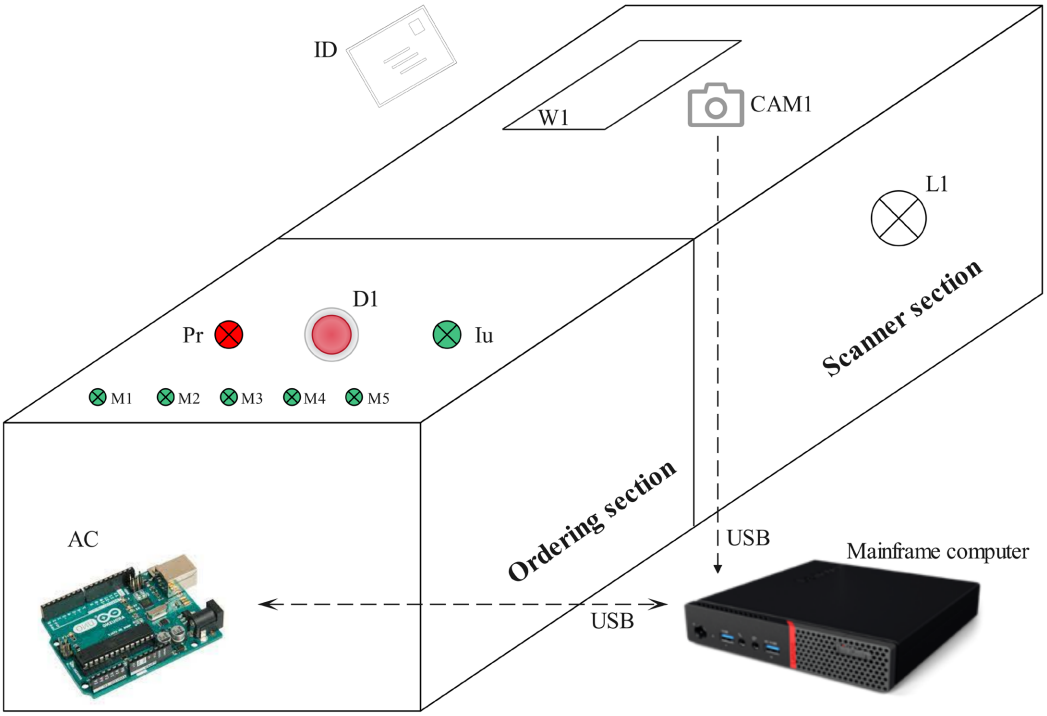

Figure 12. Acquisition module.

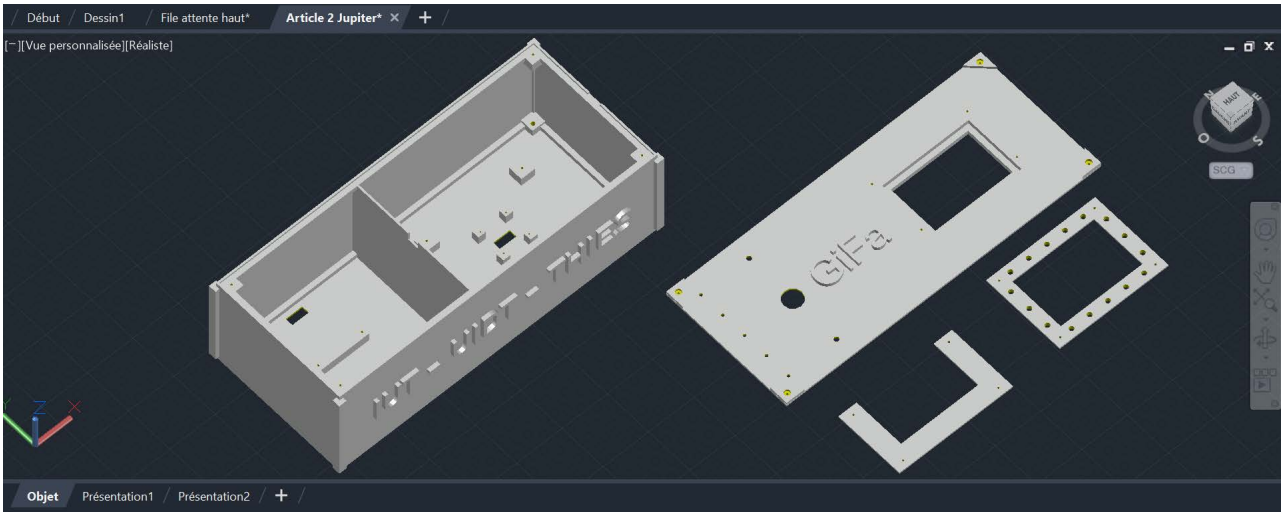

Figure 13. Acquisition module designed in 3D.

Table 6. 3D manufacturing data.

Parameter	Data
Technology	SLA
Material	Somos Evolve
Precision	±0.2%
Minimum wall thickness	0.6 mm
Wall build thickness	3 mm
Finishing	Standard Smooth
Dimensions	358 × 158 × 110 mm

3.2. Python Language Coding

A program developed in python language runs on the main computer and drives the acquisition card, the HMIs, the cameras, the screen and the requests for delocalized artificial intelligence services in the AWS cloud. The collaborative work that led to these results required modular programming shown in Figure 14.

Thus, several specialized libraries are created for acquisition, images, text, graphics, automation, recording.

Figure 15 and Figure 16 show the main modules called by the main function in the PyCharm (Community Edition) environment.

3.3. Development of Control-Command HMIs

The realization of a Node-RED program allowed the exchange of data between the central computer and the HMI tablets by a wifi link on the server-client model. Figures 17-19 present the different tools developed for the new wireless version of the queue manager.

3.4. Metric Experimentation

Figure 20 shows the implementation of the wireless intelligent queue management system.

3.5. Comparison of Registration Time between Queue Management Systems with Three Types of Identification Card

Performance tests of the system are carried out to know the time required for the registration of a customer compared to the solutions already proposed [1]. The experiment is carried out, with a 4G+ connection for both models, on Thursday March 02, 2022 between 1:00 pm. and 2:00 pm. and Thursday April 13, 2023 between 9:00 am. and 2:00 pm., on three types of identification documents:

- Printed card with name, date of birth, photo, status (an establishment could issue it to its customers);
- Senegalese national identification card of the ECOWAS space;
- Senegalese driver's license.

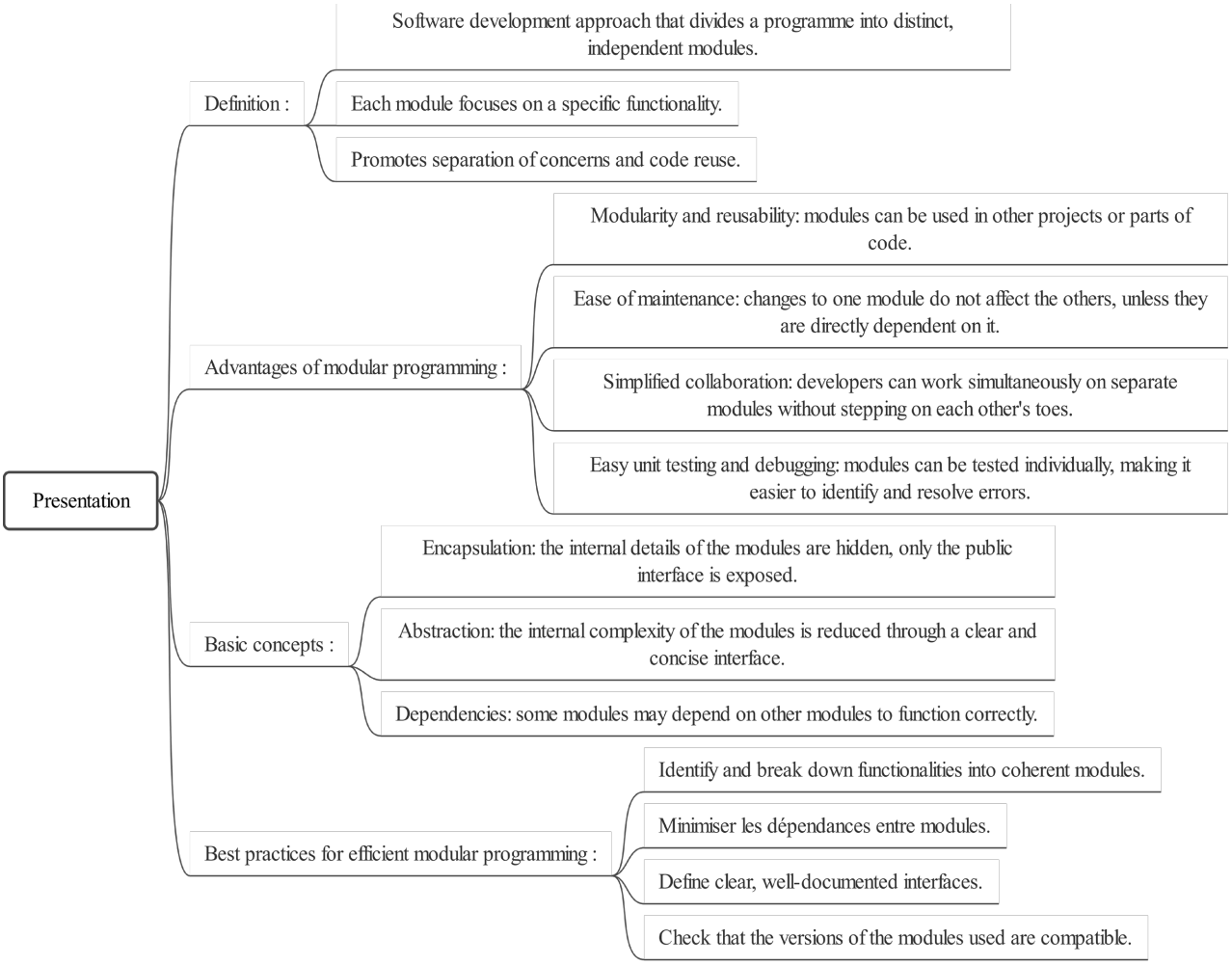

Figure 14. Principle of modular programming.

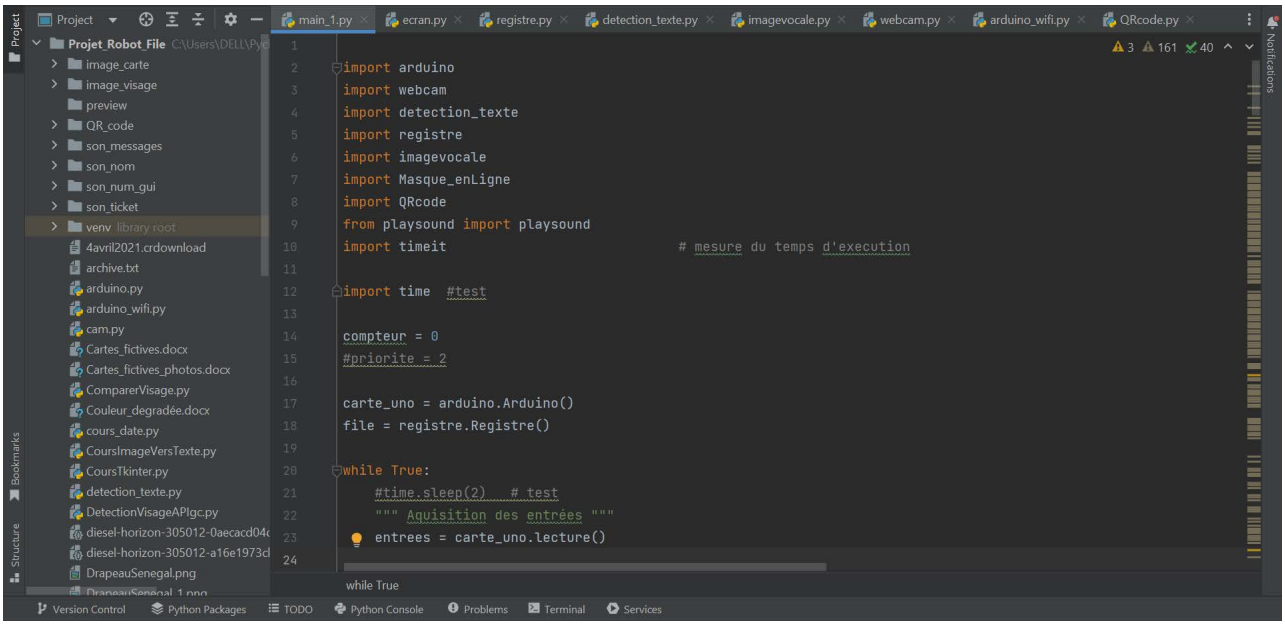

Figure 15. Main function of the GiFa program.

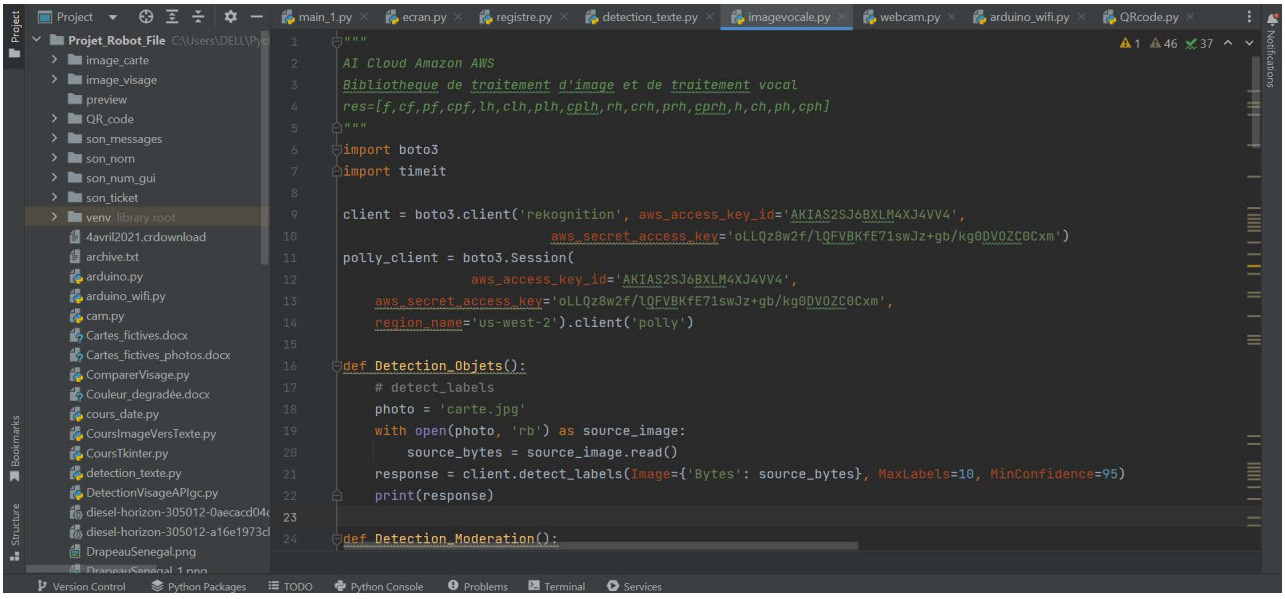

Figure 16. Artificial intelligence module of the GiFa program.

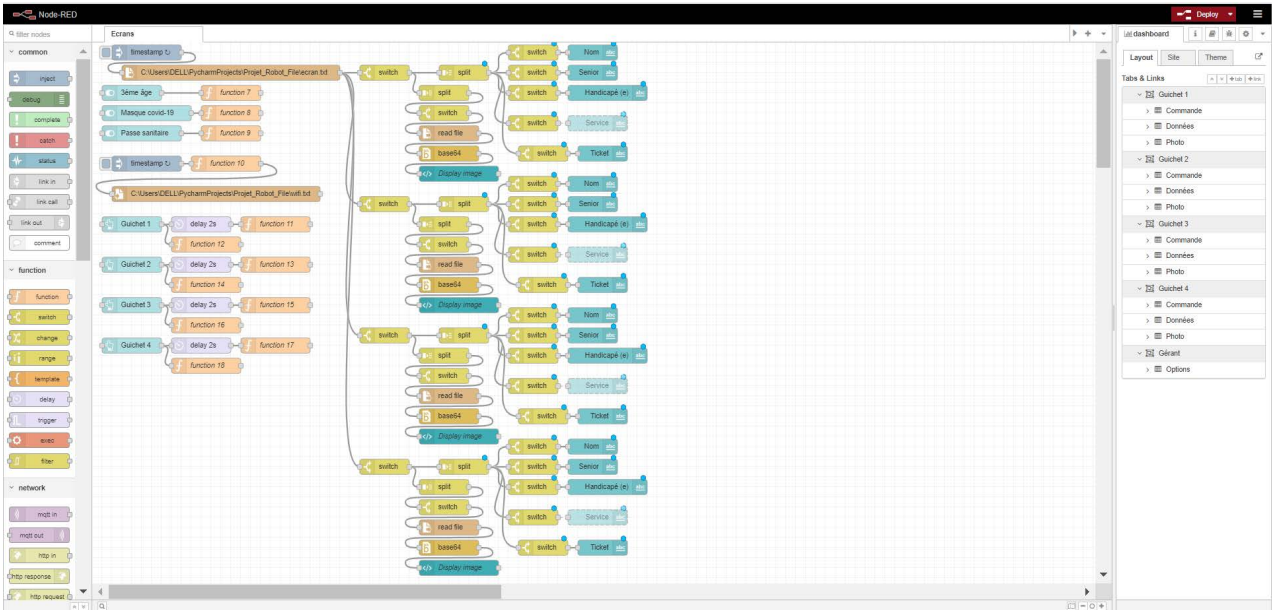

Figure 17. Mainframe Node-RED program.

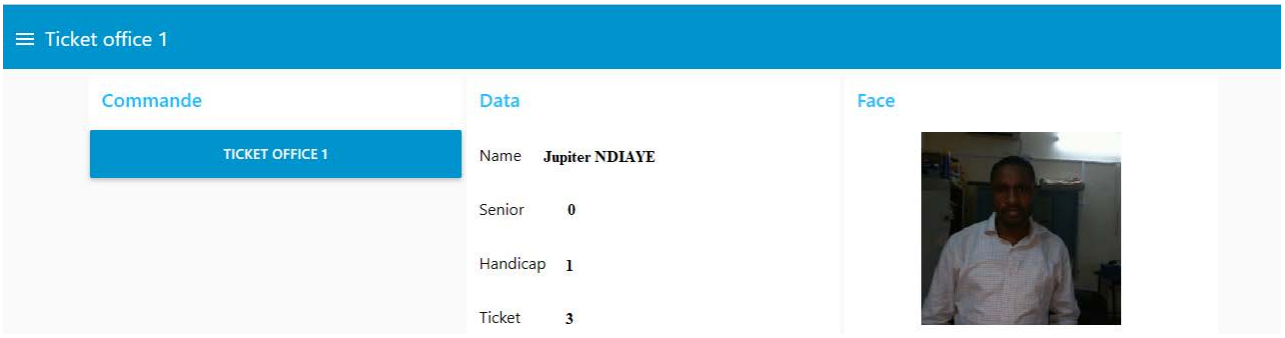

Figure 18. Counter user interface.

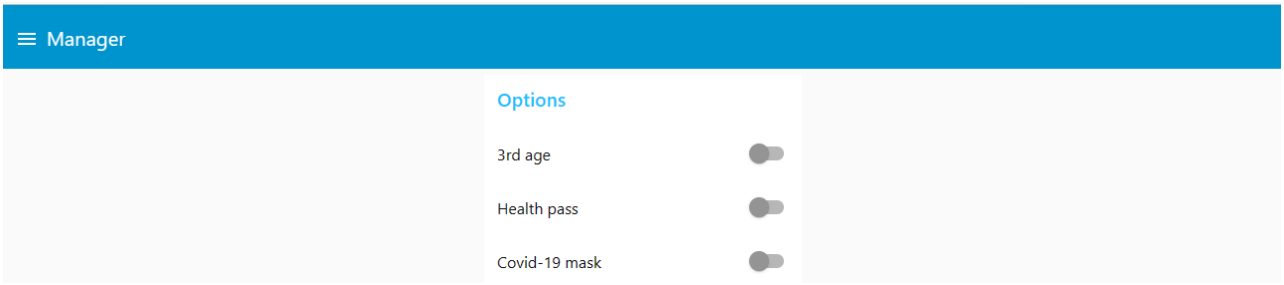

Figure 19. Manager user interface.

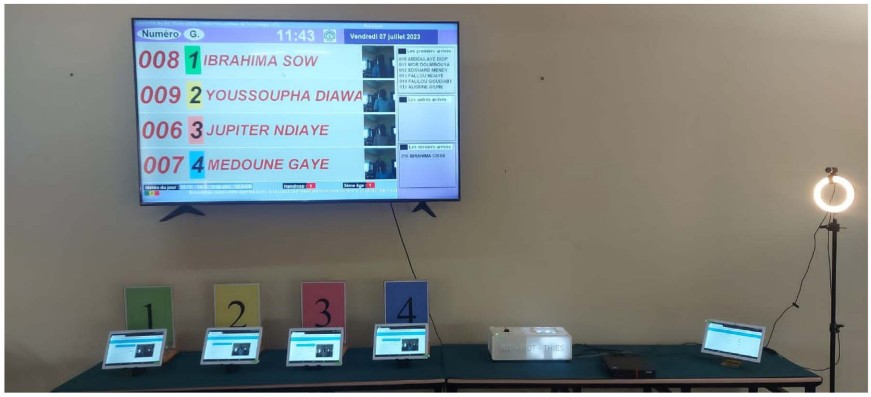

Figure 20. Overview of the queue manager system.

3.5.1. Check-In Time Comparison between Queue Management Systems with a Printed Map

Figure 21 and Figure 22 summarize the registration times with a printed card for the two types of queues.

For Figure 21, the recording time is between 7.68 seconds and 12.94 seconds. Thus, the average time for these twenty consecutive recordings is 9.91 seconds.

For Figure 22, the recording time is between 7.64 seconds and 10.93 seconds. However, the average time of consecutive recordings is 8.9 seconds.

Analysis of the results shows a slight reduction in the system's performance, resulting in a small increase in the time taken to process a user's recording. In fact, based on the average acquisition time, the delay observed is around 11%.

3.5.2. Comparison of Check-In Time between Queue Management Systems with a National Identity Card

Figure 23 and Figure 24 summarize the registration times with a national identity card for the two types of queues.

For Figure 23, the recording time is between 7.77 seconds and 15.26 seconds with an average time of 10.21 seconds.

For Figure 24, the recording time is between 8.03 seconds and 15.94 seconds. It is thus noted that the average time for recordings is 10.05 seconds.

Analysis of the results shows a very slight reduction in the system's performance, resulting in a very small but insignificant increase in the time taken to process a user's recording. In fact, based on the average acquisition time, the delay observed is of the order of 1.5%.

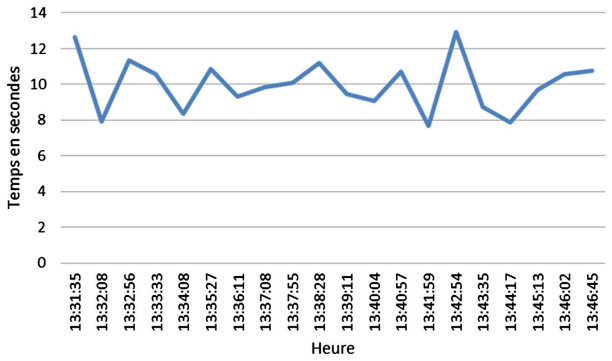

Figure 21. Printed card registration for counters connected by wifi.

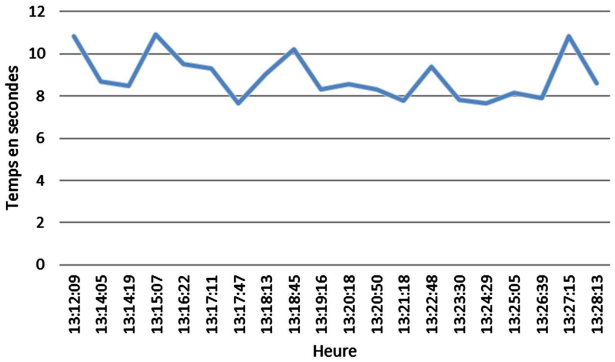

Figure 22. Printed card registration for counters connected by cable.

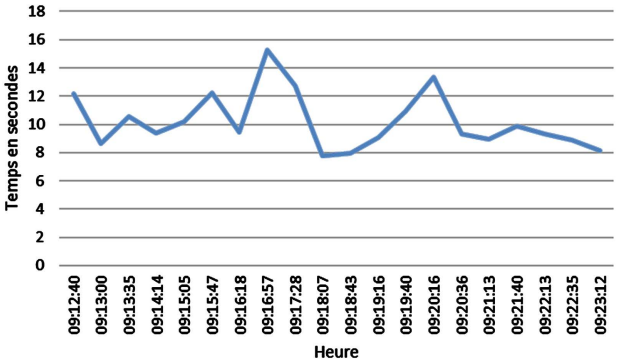

Figure 23. CNI registration for counters connected by wifi.

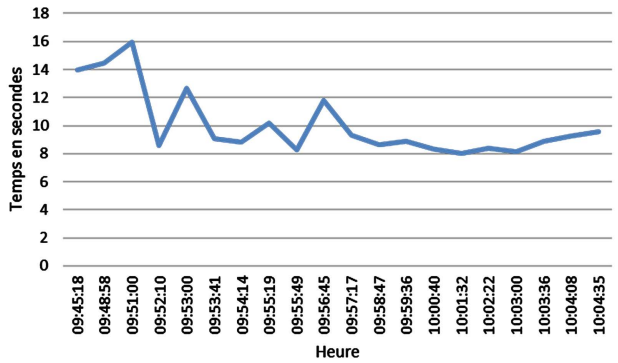

Figure 24. CNI registration for counters connected by cable.

3.5.3. Comparison of Check-In Time between Queue Management Systems with a Driver's License

Figure 25 and Figure 26 summarize the check-in times with a driving license for the two types of queue.

The recording time for Figure 25 is between 8 seconds and 14.93 seconds. Thus, the average time is 9.15 seconds.

Regarding Figure 26, the recording time is between 8 seconds and 11.06 seconds. We note an average time of 8.83 seconds.

Analysis of the results shows a slight reduction in the system's performance, resulting in a small but insignificant increase in the time taken to process a user's recording. In fact, based on the average acquisition time, the delay observed is around 3.6%.

Overall, we note that with the three types of cards, the average user registration time is slightly longer, almost one second, for the queue with counters connected by wifi compared to the first wired version. Thus, there is no significant degradation of system performance with the introduction of wireless links in this second highly technological version. What's more, the best performances are observed with the national identification card, which can therefore be recommended for use with the proposed solution for intelligent queue management.

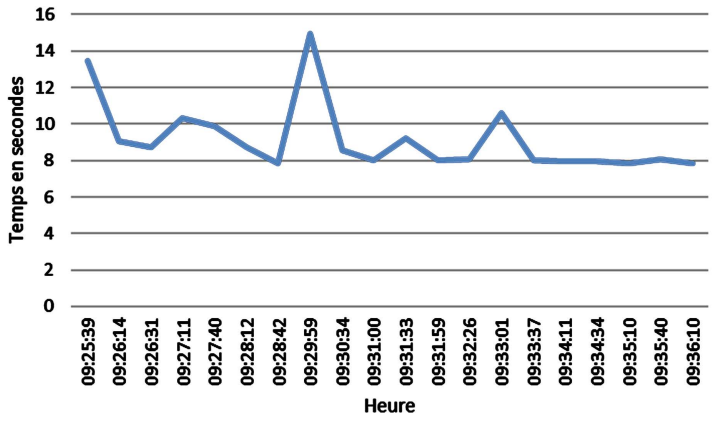

Figure 25. Driving license registration for counters connected by wifi.

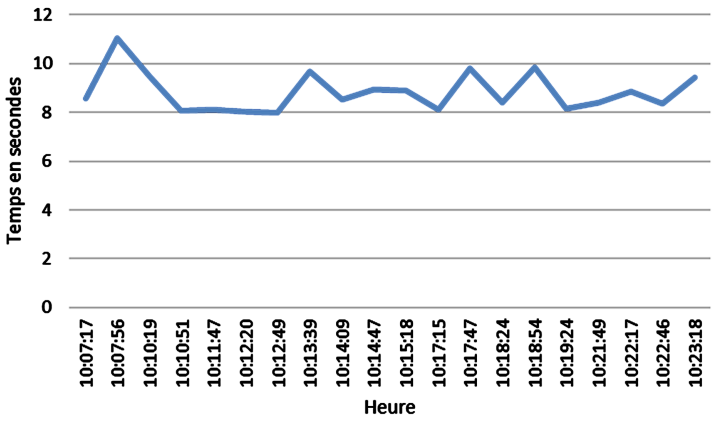

Figure 26. Registration driver's license for counters connected by cable.

4. Conclusions

The reception of users is always an important factor in structures welcoming the public, especially in difficult contexts such as during an epidemic or even a pandemic. This is how, in this work, technological solutions are developed and proposed for the good management of queues by integrating certain current societal and cultural realities including the global health crisis, the various inequalities and environmental issues (less printed thermal paper for user tickets).

This work contributes to an intelligent queue management solution in order to make it more flexible and less cumbersome. With the use of wireless to connect the various entities, the work carried out has facilitated deployment in the premises. This system also optimizes the authentication time at the checkout since as soon as the customer calls, all the necessary information relating to the latter is processed by the AI and also transferred when the time comes to the counter equipped with a tablet. With the latest developments in the GiFa system, the facility manager has a wifi-connected HMI for real-time control and parameterization according to the context and situation.

Conflicts of Interest

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

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