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Stand-Alone Patient Reception and Referral System with Health Data Management

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Abstract

The COVID-19 pandemic has exposed vulnerabilities within our healthcare structures. Healthcare facilities are often faced with staff shortages and work overloads, which can have an impact on the collection of health data and constants essential for early diagnosis. In order to minimize the risk of error and optimize data collection, we have developed a robot incorporating artificial intelligence. This robot has been designed to automate and collect health data and constants in a contactless way, while at the same time verifying the conditions for correct measurements, such as the absence of hats and shoes. Furthermore, this health information needs to be transmitted to services for processing. Thus, this article addresses the aspect of reception and collection of health data and constants through various modules: for taking height, temperature and weight, as well as the module for entering patient identification data. The article also deals with orientation, presenting a module for selecting the patient's destination department. This data is then routed via a wireless network and an application integrated into the doctors' tablets. This application will enable efficient queue management by classifying patients according to their order of arrival. The system's infrastructure is easily deployable, taking advantage of the healthcare facility's local wireless network, and includes encryption mechanisms to reinforce the security of data circulating over the network. In short, this innovative system will offer an autonomous, contactless method for collecting vital constants such as size, mass, and temperature. What's more, it will facilitate the flow of data, including identification information, across a network, simplifying the implementation of this solution within healthcare facilities.

Keywords

Public Health, Health Data, Wireless Network, Security, Artificial

Intelligence, Instrumentation, Mechatronics

1. Introduction

In addition to the shortage of medical staff in healthcare establishments, there is also a lack of basic infrastructure [1] [2] [3] [4] [5]. This results in an excessive workload for existing staff, compromising the accurate collection of health constants and essential medical data at the start of diagnosis. Manual methods of collecting and transmitting these data, including health parameters, cause delays in the execution of care steps and have an impact on the reliability of vitals acquisition. With this in mind, we have developed a robot with artificial intelligence, designed to collect health constants autonomously and without contact [6]. This efficient device focuses exclusively on capturing health parameters, and storing this data locally on a computer.

At the end of this data collection, the facility's services need patient information and the order of arrival for queue management. The time patients spend waiting in these healthcare facilities is a major concern, as it can even be detrimental to the patient if care is delayed. A number of studies have been carried out in this field [7] [8] [9] [10] [11]. We have therefore implemented modules that enable us to take information from patient ID cards and select the destination service for each patient. To reinforce security, we encrypt [12] the data before storing it in a database. Access to this data is facilitated by the use of an existing wireless network [13] within the healthcare facility, guaranteeing trouble-free deployment. Each department offers doctors the option of authenticating themselves via a mobile application on a tablet, giving access to an ordered list of waiting patients, thus simplifying queue management.

In this article, we present an artificial intelligence robot that not only collects personal data such as the patient's first name, surname and age, while directing them to the desired service, but also collects vital health constants. The main objective is to implement and evaluate the effectiveness of this autonomous robot in improving the efficiency of healthcare services by reducing waiting times, the accuracy of vitals and identification data collection, and the management of patient referrals.

2. Materials and Methods

Our autonomous robot for collecting health constants is made up of various interconnected components, as illustrated in **Figure 1**. In addition to the existing modules (computer, acquisition card, sensor, actuator), the new version of the robot integrates a module dedicated to reading patient information (surname, first name, age and gender) from the patient's identity card, enabling identification. Push-buttons are also integrated to select the destination service.

All this information is stored in a computer database. This approach saves time by collecting several pieces of information before the patient goes to the

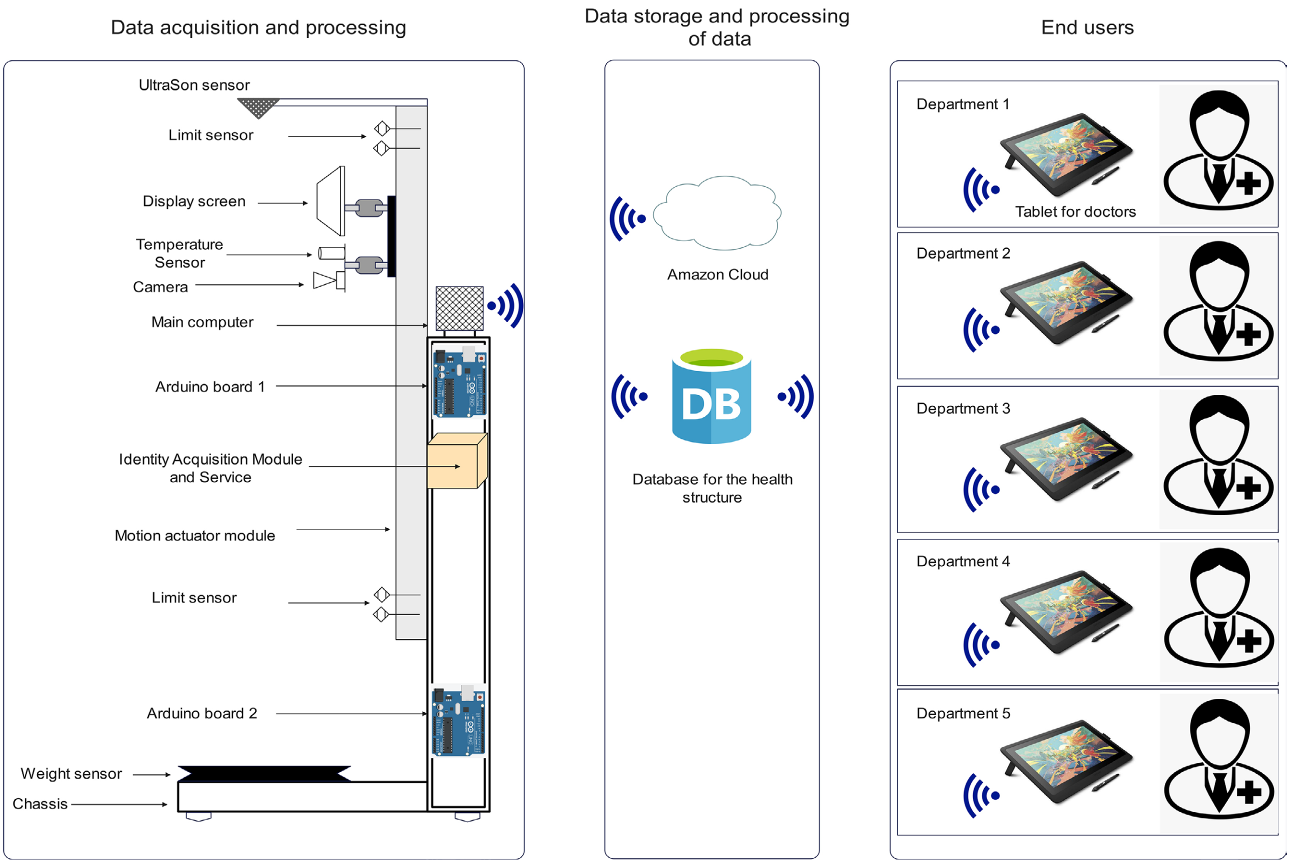

Figure 1. Overview of the autonomous robot with artificial intelligence for reception and orientation.

service in question. Within each medical department, a mobile application offers access to a secure database, providing all the necessary data even before the patient arrives at the department. This facilitates queue management by organizing patients according to their order of arrival in each department.

2.1. The Computer

The computer (**Figure 2**) plays a central role in the system. It facilitates data acquisition via the sensors [14], then sends them to the cloud to be processed by the artificial intelligence. It also ensures precise control of the robot's actuators, increasing their efficiency. The computer has the ability to secure the data after encryption in a local database. The data in this database can later be used by the mobile application of the doctors in each department within the healthcare facility, to manage waiting lists. It also offers the possibility of interacting with patients via visual or vocal interfaces, improving acquisition accuracy or providing guidance.

2.2. Acquisition Boards

The acquisition boards used in this project are Arduino boards [15] housed in an aluminum case with a screw terminal shunt module. The purpose of the housing is to protect the board, while the bypass module is designed to simplify wiring.

Figure 2. Dell minicomputer.

The first board (**Figure 3**) is a simple way of connecting multiple circuits with multiple components, as well as programming them to control actuators and perform specific tasks. This board is used in this project to collect health constants such as height, temperature and weight. This data is then sent to a python program, which executes commands for actuators and indicators.

The second acquisition board (**Figure 4**) collects information from the sensors and buttons, enabling it to detect the presence of patients and offer them the possibility of choosing their destination department within the health structure. **Figure 5** shows the addressing of all the components connected to this board.

2.3. Display Screen

The function of the display (**Figure 6**) is to show the health data collected by the sensors. It also displays body mass index, enabling patients to obtain this information before going to the doctor.

2.4. The Cameras

Two cameras (**Figure 7**) are used in this program.

The first captures an image of the face, enabling Artificial Intelligence to assess whether a hat is being worn, and to photograph the feet to check whether shoes are being worn.

This facial image will also be used to identify patients for the health facility's queue management application.

The second camera is used to capture an image of the ID, in order to use cloud services to identify the patient's information (first name, surname, gender, date of birth) and thus determine the patient's age.

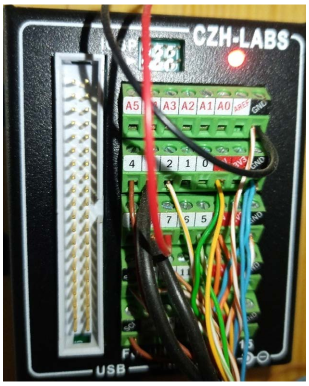

Figure 3. Arduino 1 board in aluminium housing with screw terminal bypass module.

Figure 4. Arduino 2 board in aluminium housing with screw terminal bypass module.

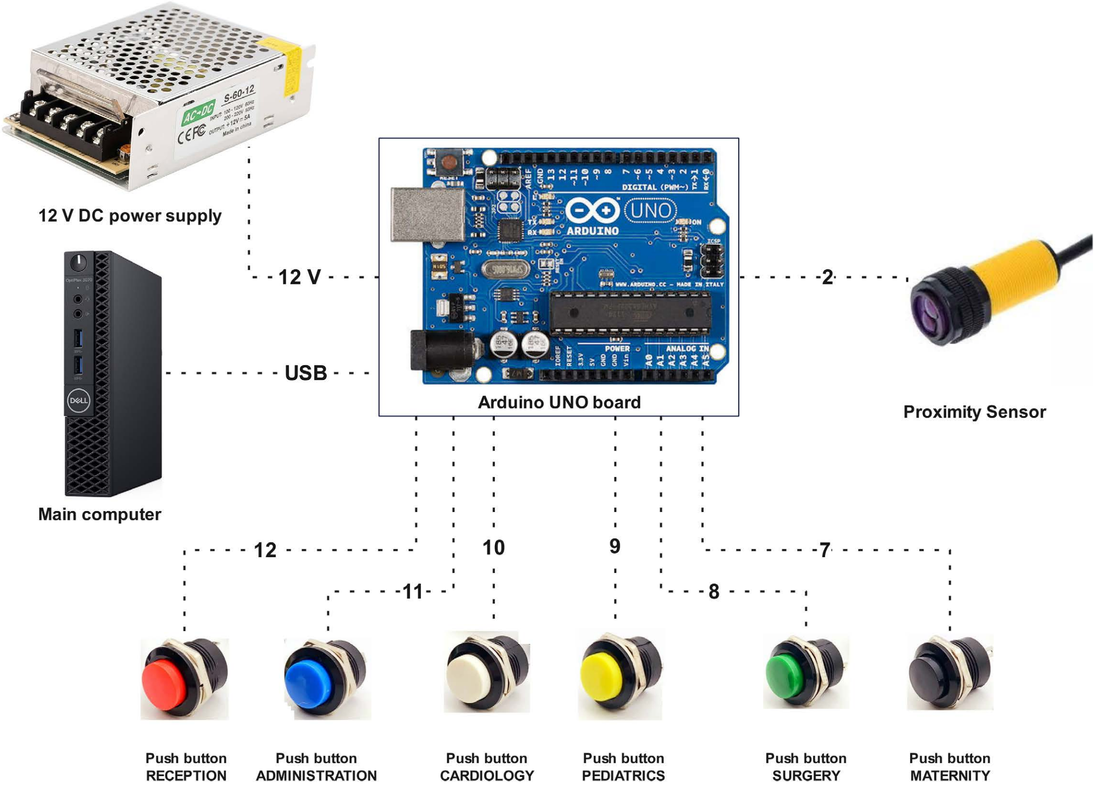

Figure 5. Overview of identity and service acquisition card with electronic card addressing.

Figure 6. Health constants display screen.

Figure 7. USB camera.

2.5. The Identity and Service Acquisition Module

This module (Figure 8) detects the presence of a person with a presence sensor, then takes information from the patient's ID card. Using the camera and artificial intelligence processing, the module extracts information such as first name, surname, gender and age. Once this information has been acquired, the module uses its push-buttons to allow patients to choose from a range of hospital services, before inserting them into a waiting queue.

2.6. Terminal for Doctors

The doctors' tablets (Figure 9) will enable each department in the healthcare structure to access the list of patients in the queue, in order to call them. The management application was developed using the Java programming language via the Android Studio platform. The application is both intuitive and secure, allowing access to these interfaces after entering a username and password.

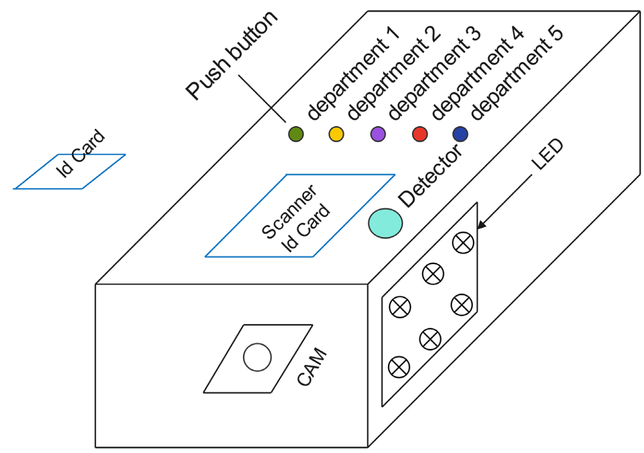

Figure 8. Identity and service acquisition module.

Figure 9. Tablet for doctors with mobile queue application.

2.7. The Cloud

AWS (Amazon Web Services) is cloud computing environment enabling rapid and secure deployment of applications and data with great flexibility. AWS complies with the guidelines of the General Data Protection Regulation (GDPR) [16] to guarantee data security and confidentiality, using pseudonymization and personal data encryption as advanced encryption mechanisms for data in transit and at rest [17].

In this project, the local computer transmits the collected data to the Amazon cloud service for processing. To retrieve information from a patient's ID card or to detect the face, the Amazon Web service with Amazon Rekognition offers several functionalities [18] for data processing, image detection and processing for text recognition (patient information), face detection (patient identification) and label detection (hat, shoe detection).

As far as Amazon's security is concerned, it should be noted that the security of AWS services is a major concern. Amazon implements robust security measures to protect sensitive data stored and processed in its cloud environment [19]. These include seven design principles:

- Establish a solid identity base: Give the minimum of privilege by associating each task that interacts with AWS resources with an appropriate authorization, and concentrate authorizations to move towards the elimination of static credentials.
- Enable traceability: Provide real-time supervision of actions and changes in the environment, integrating the collection of logs and metrics across systems to investigate and take action.
- Apply security at all levels: Apply a highly advanced defense method based on multiple security controls, applied at all levels.
- Automate security best practices: Use security mechanisms based on automated software to improve scalability with greater security, speed and cost-effectiveness.
- Protect data in transit and at rest: Depending on the sensitivity of the data, classify it and use security methods such as encryption, tokenization and access control.
- Keep people away from data: Avoid direct contact with data, using tools and mechanisms to reduce the risk of human error or mishandling of sensitive data.
- Prepare for security events: With incident management policies and processes tailored to the organization's needs. Run simulations to respond to incidents, and use automated tools to increase speed of detection, investigation and recovery.

These security principles are based on six areas of best practice:

- Workload operations security: Apply best practices across all security zones. Stay up-to-date on AWS recommendations and threat information, automate security processes, testing and validation.
- Identity and Access Management: Authorize only appropriate, authenticated users and components to access resources. Use AWS Identity and Access Management (IAM) to manage authorizations and policies, and enforce the management of credentials.
- Detection: Use detection controls to identify potential threats or security incidents with tools such as CloudTrail, CloudWatch, and Amazon GuardDuty.
- Infrastructure protection: To meet best practices and regulatory obligations, use infrastructure protection methods such as defense-in-depth, using VPC on Amazon to create a private and secure environment.
- Data protection: Classify data according to its sensitivity, and use protection techniques such as encryption. AWS makes encryption and key management easy.

- Incident response: Prepare for security incidents by implementing processes to isolate systems, restore operations, and conduct investigations. Use detailed logs and automation tools to facilitate incident response.

These best practices help prevent financial loss, comply with regulations and strengthen the overall security of workloads in the AWS cloud. Amazon offers its customers a shared responsibility model for achieving their security objectives. AWS customers can therefore use services for their specific needs, while benefiting from a secure cloud infrastructure and automated tools for managing security events.

3. Results and Discussion

3.1. The Health Constants Acquisition System

The acquisition system is made up of several elements, including the robot (Figure 10), which comprises several modules: the vitals acquisition module, the patient information acquisition module and the destination department. The system also comprises the queue management module, with tablets that provide a real-time list of patients in order of arrival and according to department.

3.2. Identity and Service Acquisition Module

To set up the information and service acquisition system, a modification was required to the python program already in place. In addition, a Java program has been developed for the mobile application that will display patient data on the health facility's services. The flow chart below (Figure 11) illustrates the instruction sequences of this new module.

Figure 10. Overview of the health constants acquisition system.

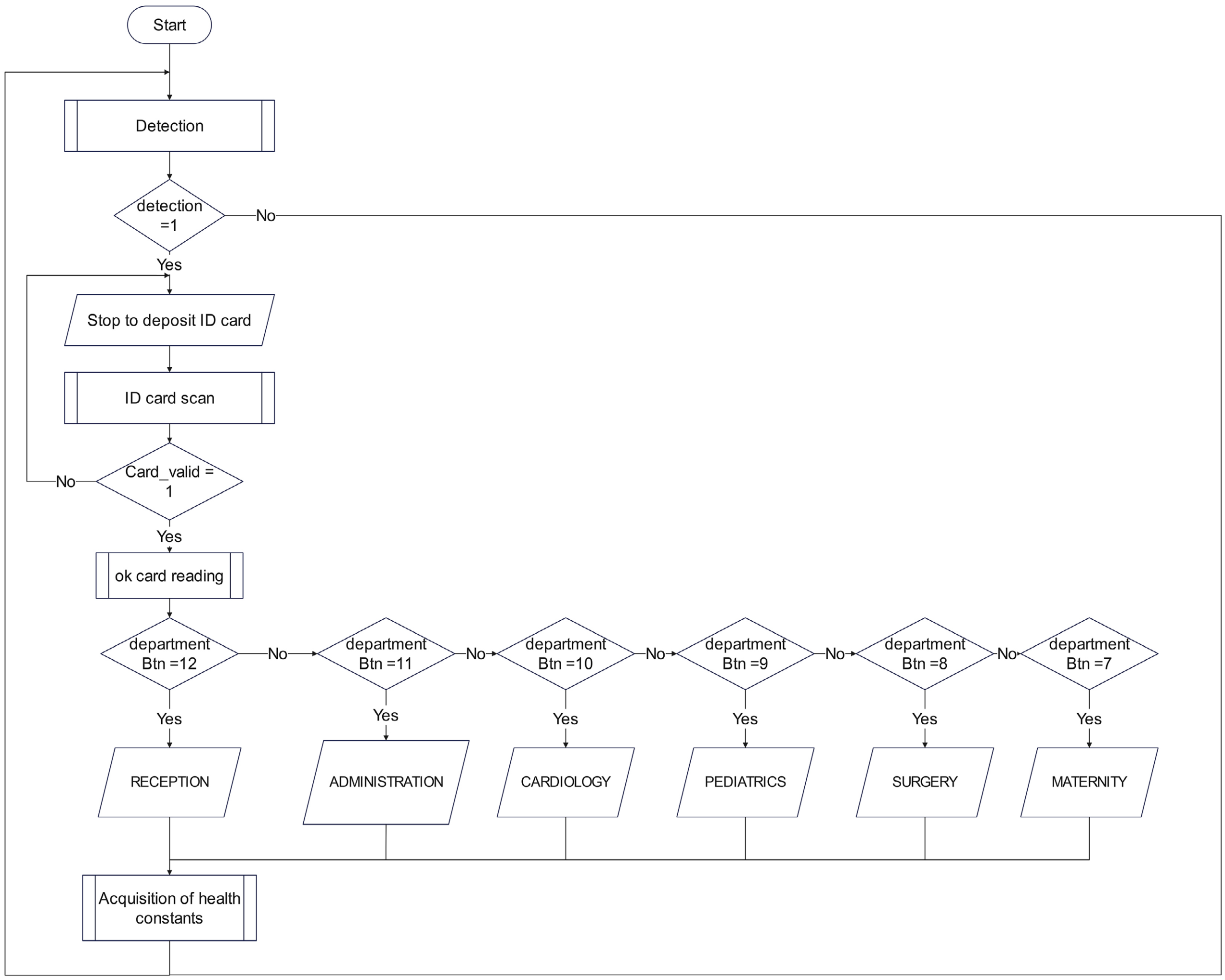

Figure 11. Flowchart of the identity acquisition system and service.

The identity and service acquisition module detects a person's presence before reading their ID. It then takes a photo and sends it to the AI tool, which extracts the information (first name, surname, date of birth). Once this information has been collected, the module waits for the service button to be selected, then redirects the patient to the vitals acquisition module, which will take his or her health constants. While waiting for the module to be built, as illustrated in Figure 12 using 3D printing, push-buttons placed on a test plate are used to test the services. In addition, identity photos taken with a cell phone are used to simulate the scanning of identity documents.

3.3. The Database

Thanks to artificial intelligence, our acquisition module is able to extract data from each patient's ID card and enter it into the database using a Python program. This database is made up of two tables:

User Table 1 is the user table, which stores the logins and passwords of healthcare personnel. This table will be used to check the conformity of the data

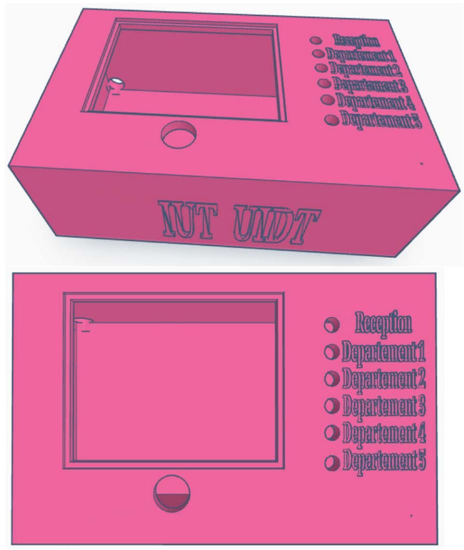

Figure 12. 3D printing of identity data acquisition module and service.

Table 1. Table Utilisateurs de la base de données MySQL.

Users
id
name
first name
mail
pass
department

entered on the mobile application's login interface, in order to authorize access to patient data.

The patient information (Table 2) stores information on each patient, including height, temperature, weight, photo, first name, age, sex and department. This data is used to ensure proper medical follow-up.

3.4. The Mobile Patient Display Application

This Android application, developed in Java with Android Studio, is a patient data management application for a healthcare facility, designed to improve reception and referral management. It is structured into several classes, listed below with their roles in the application:

LoginActivity:

The LoginActivity class (Figure 13) is the application's main activity class, which manages the login page. In this login page, users enter their username or e-mail address and password. It sends this information to the server and manages the server response. If the connection is successful, the activity redirects the user to the second activity (Figure 14).

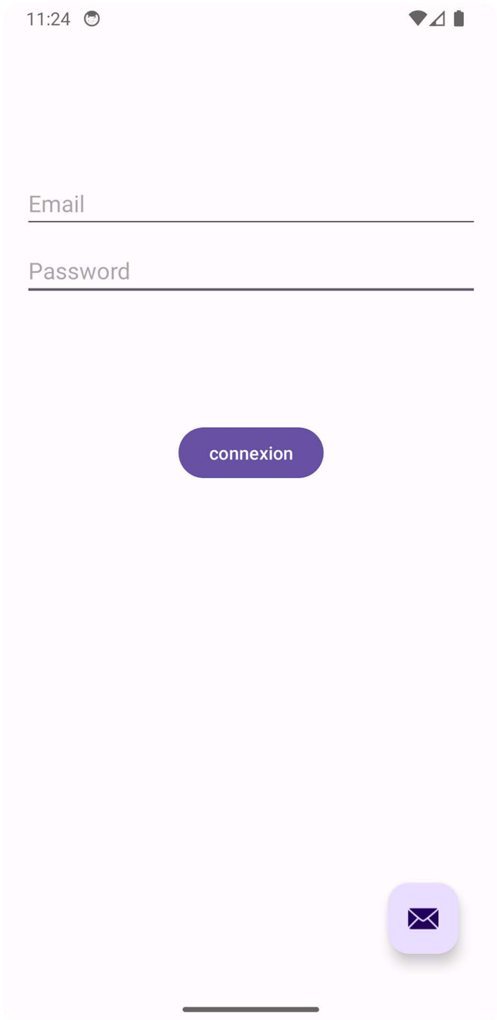

Figure 13. Doctor's login page.

Table 2. Patient information table in MySQL database.

Patient information
id
size
temperature
weight
picture
name
first name
age
sex
department
consultation

ListePatientsActivity:

This is the second activity (Figure 14) of the application, which, after entering the correct login and password, displays the list of patients according to the department of the logged-in user. It also communicates with the main computer via the wireless network to retrieve patient data from a MySQL database. It manages patient searches in the list and periodic data updates.

PatientActivity:

The PatientActivity class (Figure 15) manages the display and modification of patient details within the application. This activity enables you to view and update patient information, such as surname, first name, age, gender, health constants and consultation status.

Patient:

This class is used to store patient information, such as surname, first name, age, sex, temperature, weight, height, etc. It provides a well-defined data structure to represent patient information, making it easy to manage and use within the application. It provides a well-defined data structure to represent patient information, making it easy to manage and use within the application.

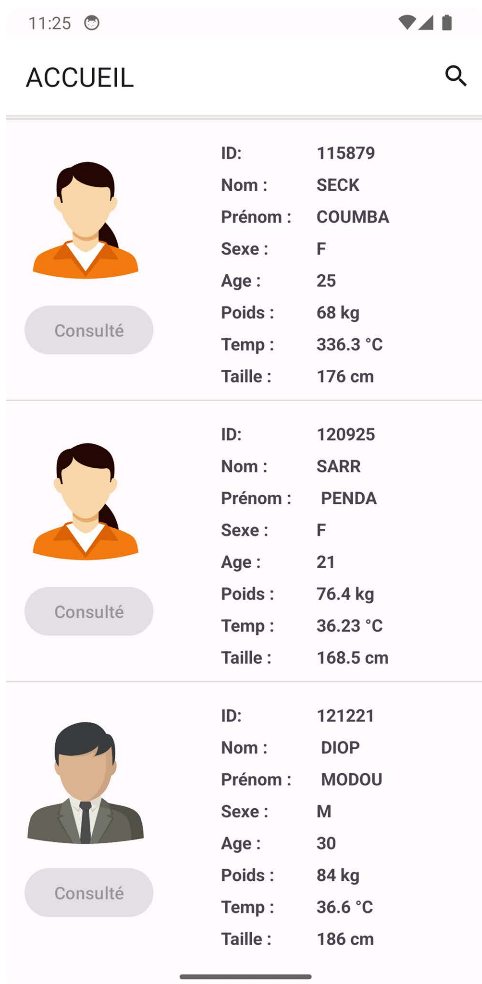

Figure 14. Patient list display page.

Figure 15. Patient display page.

This application therefore enables the doctors in each department to view the list of patients in the queue. The first page (Figure 13) allows the user to log in using an email address and password. The second page (Figure 14) displays the list of patients in the user's department. The doctor can perform a search on the same page, or click on a patient to open the third page (Figure 15) and modify the information if necessary, or validate the consultation.

4. Conclusions

Taking health vitals and receiving patients in health facilities are crucial steps in the process. In order to optimize the efficiency of health facilities, and to address certain weaknesses observed during the COVID-19 pandemic, we implemented a system to collect medical data through a robot for health constants and an identity and service acquisition module. This module detects the presence of patients, automatically collects their information "by reading their identity card with artificial intelligence, and directs them to the appropriate service". This improvement will enable faster, more efficient patient care.

The implementation of an epidemiological monitoring system through a supervisory interface for several robots distributed in different zones is envisaged.

This interface will enable real-time monitoring of the data collected by the acquisition systems in each zone, facilitating early warning of epidemic trends and strategic public health decision-making.

Conflicts of Interest

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

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