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ENHANCING BUSINESS PROCESS MANAGEMENT THROUGH A MULTI-SENSOR APPROACH: CASE OF A HEALTHCARE PROCESS

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ABSTRACT

Since the global health disaster of COVID-19, the health professionals have been looking for new technologies to monitor and mitigate the number of patients affected by this pandemic. Through this research work, we seek to optimize the healthcare process of the infectious disease department of a hospital through the proposal of an approach that integrates IoT devices into the care process model. More generally, we propose the integration of a set of sensors in business processes and analyze their effect to improve their performance. Given the emergence of the covid-19 pandemic and the importance of the data processed by the Internet of Things (IoT), dealing with the associated security becomes fundamental. The latter will ensure the effectiveness of IoT as a solution which helps healthcare staff in controlling patients infected by the virus. To reach our objective we developed a Framework intended for the doctor which aims to group together the different measurements from the different IoT devices that can be used during COVID-19 health care. We tested the approach by collecting two different measures which are oxygen saturation and heart rate. These measurements were obtained thanks to an oximeter. Our approach is valid for a multi-sensor solution with several measured data. Given the lack of technical means to carry out a test with other devices, we relied on existing values measured in the Farhat Hached hospital in Sousse. We analysed them, by applying the decision tree technique which is one of the data mining techniques, in order to facilitate the diagnosis and improve the COVID-19 care process.

KEYWORDS

E-health, Internet of Things, Business Process Management, Covid-19, Multi-Sensor Approach, Decision Tree

1. INTRODUCTION

Business Process Management (BPM) is a mature discipline, involving the identification, discovery, analysis, design, implementation, execution, monitoring and evolution of business processes (Janiesch et al., 2020).

The trend of the Internet of Things (IoT) has also become very common, helping to automate data collection. It is a revolutionary technology, which constitutes a networked object world, in which everything is interrelated and has a virtual form of expression (Pascual et al., 2011). Through the combination of the Internet, radio frequency identification, real-time positioning, embedded sensors and other emerging technologies, objects in daily life are transformed into intelligent objects that can perceive, interpret and respond to the environment (Vermesan fries, 2013).

The internet of things and BPM are considered to be two independent topics in research and practice. On the other hand, the Internet of Things provides an improvement of the current state of traditional BPM processes (Janiesch et al., 2020). The combination of Internet of Things technology and BPM method has brought great benefits in various fields, especially in the field of medical care. More precisely, nowadays, coronavirus causes many symptoms for infected people (Ciotti et al., 2020). These symptoms can be detected through a set of medical sensors.

These symptoms can be detected through a set of medical sensors, which poses IoT security concerns. Hence, the need for security is required for the IOT system. Therefore, in our project, we are building a secure Internet of Things system, specially dedicated to the healthcare field, which deals with highly sensitive patient data.

This work combines Internet of Things technology and BPM technology to effectively control the patients with covid-19.Section 2 describes some of the work in the literature that combines BPM and the Internet of Things. Section 3 describes the recommended approach. Prototypes and experiments are presented in section 4 and 5. Then we give an analysis of the data collected from the existing executions of COVID-19 health care processes and we present the corresponding result in section 7. In section 8 we describe other experiments conducted with real measurements obtained at the hospital of Farhat Hached in Sousse by adopting an analysis through the decision tree. Then we present the secure Internet of Things system, which handles sensitive patient data. Finally, the conclusion of the article is presented in section 10.

2. RELATED WORKS

In literature, we find a certain number of works on the integration of BPM and the Internet of Things in various fields, especially in the field of health, among which we cite the works below.

The paper of (Fernandez et al., 2017) proposes a new model based on BPM strategy, internet of things and remote sensing to solve the problems of low efficiency of chronic disease clinical process and lack of integration of medical staff, patients and the process itself.

Research of (Antonius Dachyar, 2020) aims to develop a remote patient heart monitoring system (RPM) to improve the hospital's heart service. Through business process reengineering (BPR) and management information system (MIS), the Internet of Things (IoT) is used to reduce emergency response time and outpatient treatment time.

This paper of (Al-jamal et al., 2017) proposes an improved process model of monitoring system for heart disease patients, which simplifies the patient tracking process, realizes remote monitoring, reduces costs and shortens treatment time. The system uses the Internet of Things technology to help doctors monitor patients with heart disease remotely and in real time.

This work (Domingos et al., 2020) focuses on reliability, and suggests using the random workflow reduction (SWR) method to calculate the reliability of BPMN healthcare processes compatible with the Internet of Things. This method treats hypertension patients by integrating the BAN (body area network sensor) sensor connected to the patient's body.

These related work deal with diseases other than COVID-19. Moreover, they do not use data mining techniques for data analysis.

In this context, our contribution in this work is to adopt a combination of BPM and the Internet of Things, using various medical Internet of Things sensors in the process of treating COVID-19 disease, and using data mining for the analysis of the generated patients' data.

3. PROPOSED APPROACH

The basic idea of our approach is to present a way to manage the presence of several IoT sensors in the BPMN model of the process in the health field. More exactly, the process of monitoring people affected by COVID-19 is considered, while taking into account the specification of the two domains (IoT and BPM) and providing the data from the IoT in a compatible way with the process. For that we have developed a general model of a multi-sensor approach for business process management. This model, shown in Figure 1, is represented as a BPMN model, which gives it clarity and makes it easy to evolve. It has 5 main steps which are step1: choose and model the process, step2: Associate Sensors, step3: Implement the solution, step4: Execute the process and step5: Analyze the recorded data.

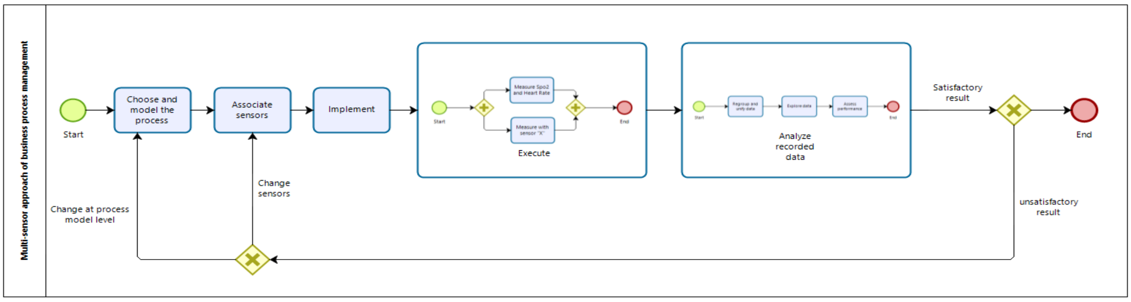

Figure 1. General model of a multi-sensor approach for business process management

We applied this model as a way to describe our approach to modeling and executing health care processes. We aim to provide in a first step a process model that includes the integration of IoT elements which are the main source of data (step 1). The purpose is to provide a coordinated course of care which ensures the safety of patients who need medical supervision.

In the design phase, the IoT elements in the BPMN model can be positioned as an actor. They can be called "IoT devices", whose main task is to provide specific information in the model to be integrated (step 2). Once the model has been presented, the next step is the implementation (step 3). We need to use technical tools to help us implement the "To-be Process" model. In the configuration and execution step of the BPM approach (step 4), the focus is on selecting tools that allows the exchange of data with the IoT sensors. Next, we need to run the BPMN model. Next, we need to run the BPMN model. Once the process is executed, the analysis phase can take place (step 5). During this phase, we make sure that the connected objects are working correctly, it is possible to check whether there are anomalies in the data exchange (example: slowness or erroneous data), then ensure a uniform structure for the data recorded by the connected objects and explore them. Finally, performance is evaluated. This phase ultimately leads to improvements to make, if the results are not satisfactory. Among these improvements, the association of new sensors or changes at the level of the process model will make it possible to achieve a better performance.

In this work, we consider medical IoT devices such as sensors and actors placed on wireless resources with limited human intervention. Each of them has measurements generated in a specific application interface for each sensor. This data can be used in an E-Heath ecosystem to track a patient's physical condition and digitally monitor vital signs of the body.

Our approach is a multi-sensor approach, especially recommended for doctors. In this approach, the aim is, for example, to measure the oxygen level and the heart rate of a patient affected by the COVID-19 pandemic. These two values can be obtained using a connected oximeter.

In our work we have collected two different measurements which are the oxygen saturation and the heart rate thanks to an IoT device which is the oximeter. Our approach is valid for a multi-sensor solution with several measured data.

4. PROTOTYPE FOR MONITORING PATIENT AFFECTED BY THE COVID-19 PANDEMIC

It is difficult to treat patients contaminated by COVID-19 pandemic, especially because such patients need to be isolated and one meter from them should be kept. Given the delicacy of this disease, it is imperative to provide an improved service and adapt the classic COVID-19 healthcare process. More precisely, we conducted a case study in the infectious diseases Department of Farhat Hached University Hospital in Sousse, Tunisia. The main actors involved in this process are administrative agents, doctors and nurses. Administrative agents are responsible for registering patients and giving them appointments. Doctors and nurses carry out medical tasks such as PCR tests, measurement of SpO2, heart rate and body temperature. They are also in charge of monitoring hospitalized patients affected by COVID-19.

In order to realize our proposed solution, we developed a prototype, which is mainly composed of the Covid-19 disease monitoring framework using the "Symfony" framework in which, patients can be added as well as all the information necessary for the doctor to make the diagnosis. This Framework is developed in order to store the oximeter data generated by the “SPO2 assistant” application delivered with the oximeter, in the database, and also to keep the history of the measurements of each patient and group them all in the same space. Each doctor has his own profile in this Framework, in which he will save the list of patients who have symptoms of covid-19 and consult this doctor. When the measurement is finished, the doctor saves the data in a CSV file then imports this file into the Framework. These measurements become instantly available in the COVID-19 disease monitoring framework. Each new measurement will be added in the table displayed on the screen, sorted by decreasing date and also displayed in the form of a statistical curve. After acquiring the data, the Framework will save the data to the MySQL DBMS system.

Upon connection, the first interface is displayed (figure 2). If it's a former patient, the doctor will look for it. He can search either by: last name/first name or by age or by gender or by chronic disease or by more than one variable at the same time. Additionally, the list of all registered patients is displayed.

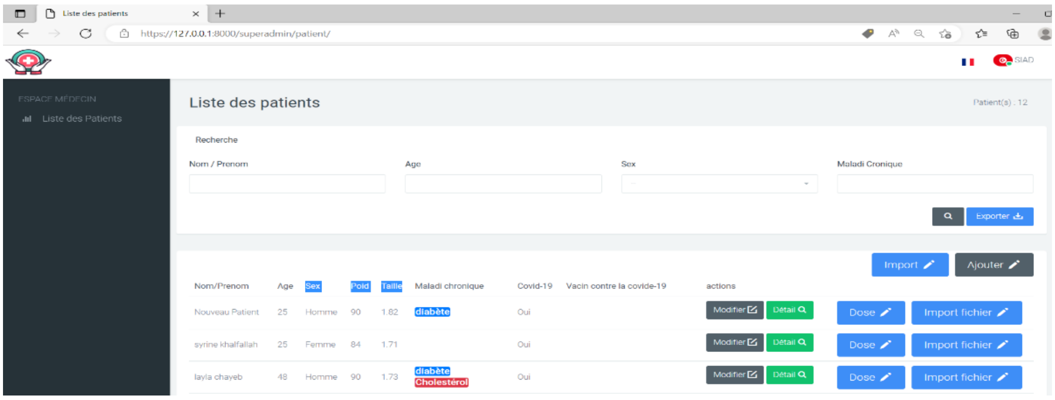

Figure 2. Patient search and list interface

For each patient the doctor can add his last name, first name, gender, weight, height as well as the names of the chronic diseases by which the patient is infected and the name of the COVID-19 vaccine taken by the patient as well as the number of doses taken. Also the doctor can import the different measurements from the different IoT devices that can be used during an assignment by COVID-19. The imported measurements can be viewed by clicking on the "Detail" button in the form of a table and they can also be generated in the form of a statistical curve as shown in figure 3.

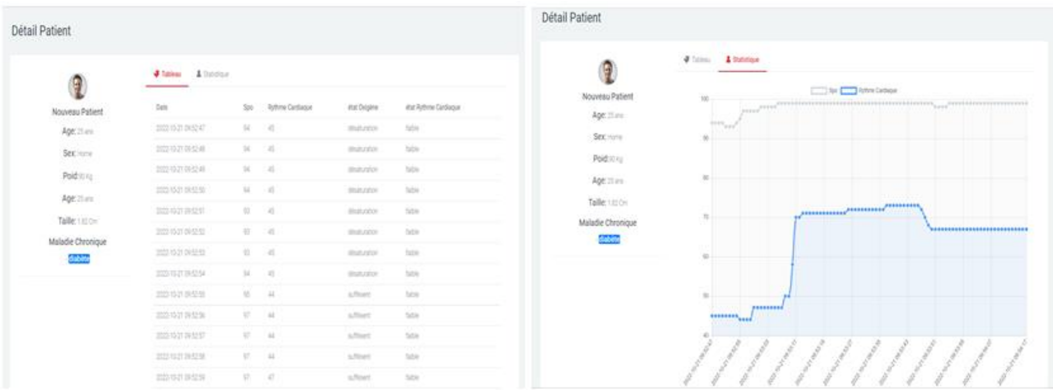

Figure 3. Presentation of SpO2 and heart rate measurements over time in two different forms

5. EXPERIMENTATION OF THE PROPOSED APPROACH

We tested our proposed approach by respecting the various phases of the BPM cycle. We have chosen to apply the model of (Weske, 2019). We have chosen as a concrete case the COVID-19 department of the Farhat Hached University Hospital. Since the treatment of patients contaminated by the COVID-19 pandemic is delicate, especially since this disease requires isolation and requires keeping a distance of one meter from a sick person, we have chosen that the improvement will concern the minimization of the contact between the doctor and the affected patient using one or more connected sensors at a distance of at least one meter and also we have given an analysis study which helps in the diagnosis of the patient's condition, according to the values of the SpO2 and the heartbeat. Then it is possible to predict whether the patient is affected by COVID-19 or not without doing a PCR. Changes and improvements must occur to better facilitate the classic process of treating COVID patients presented by the BPMN model in Figure 4 which we have called the "As-Is model".

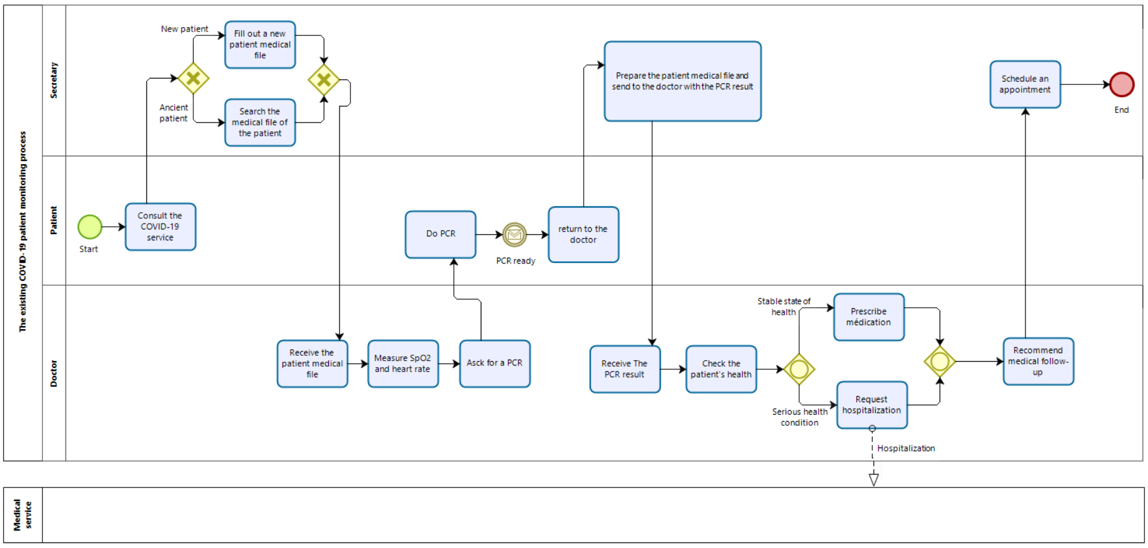

Figure 4. As-Is model: the existing COVID-19 patient monitoring process

This model is triggered when the patient visits the infectious disease department of the hospital and prescribes it for an appointment. The secretary fills out the patient's medical file and then sends it to the doctor, who in turn begins the consultation and monitors the patient's state of health. He/she will first measure the SpO2 level and the heart rate, and then he asks for doing a PCR. If the patient status is very critical, he can decide to hospitalize him/ here before obtaining the result of the PCR. The patient will in turn make an appointment for the PCR, wait for the result for a certain period of time, then he/she returns to the consulting room with the result of the PCR, gives it to the secretary who in turn sends it back to the doctor.

Following this result, the doctor can monitor the patient's condition and specifies medication if the patient's condition is not serious. If the case is critical, he/she asks for hospitalization. In these two cases, the doctor may recommend one or more appointments depending on the improvement in the patient's state of health.

Our contribution will help doctors make decisions based on SpO2 value and heart rate without using PCR.

According to the analysis results of the existing COVID-19 monitoring process, we decided to automate the tasks of filling out medical files and measuring the oxygen level and heart rate using a connected object which is an oximeter, which is placed on the fingertip and measures the oxygen saturation as well as the heart rate. Then we developed an application using the “symfony” framework, we chose to name it “COVID-19 disease monitoring framework”. The improved “To-Be process” is presented in figure 5; it allows managing automatic actions.

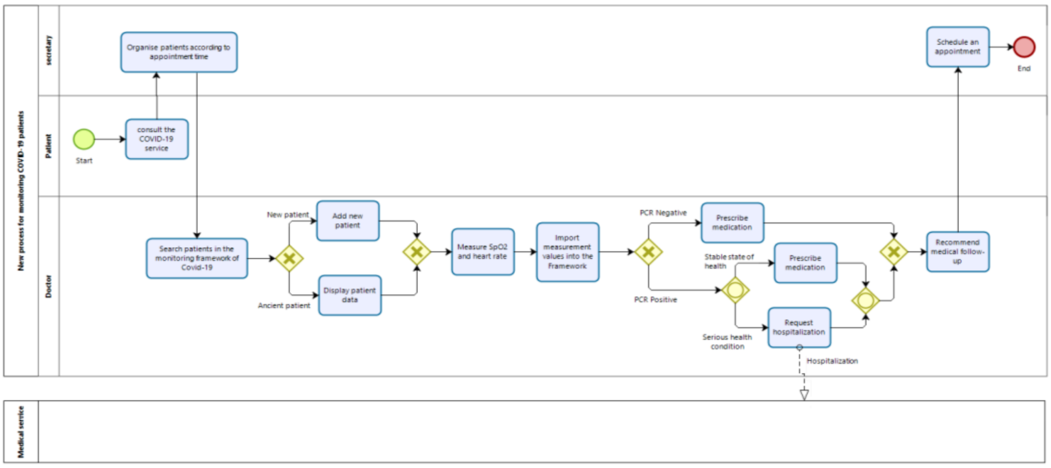

Figure 5. To-Be model: improved COVID-19 patient monitoring process

6. ANALYZE DATA RECORDS FROM "AS-IS MODEL"

In order to analyze the behaviour of the process and make improvements, we use the stored data generated through execution of the existing process (As-Is model) during a period of time.

So our objective is to analyze the actual progress and execution of the process of monitoring COVID-19 patients in its initial form, at the hospital of Farhat Hached in Sousse. We obtained a real Data Set about patients who consulted the COVID department at Farhat Hached Hospital in Sousse and went through the steps of the existing COVID care process. IT includes 64 instances of people who have a negative PCR result and 438 instances, having a positive PCR result. This data set is created between the years 2020 and 2021 and include all the information of the patients who consulted the COVID service of the Farhat Hached hospital in Sousse, namely the measurements of oxygen saturation (SpO2) and cardiac frequency (Pulse).

We cleaned the Data set obtained, by eliminating all the lines which contain missing values (missing data). To obtain a more logical analysis, we balanced the number of people with a negative PCR result with those with a positive PCR. Finally we obtained a structured data set of 152 instances, among which we have 74 negative cases and 78 positive cases, on which we performed our learning.

In order to discover the useful knowledge required by decision-makers, we applied the data mining algorithm to the data set obtained from Sousse Farhat Hached Hospital. We chose decision tree technology as one of the most popular classification technologies. One of the biggest benefits is that it is easy to use and understand even by non-experts.

We were able to extract knowledge from our Data set by the software “Sipina” using the “A Limited search induction tree algorithm” method which led to the construction of the decision tree shown in Figure 6.

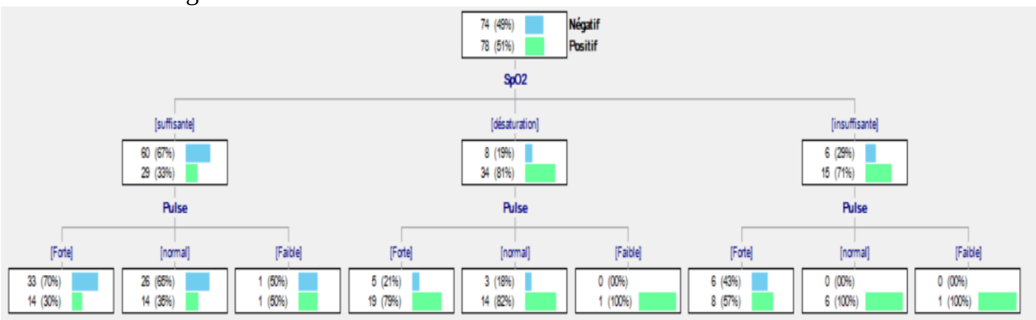

Figure 6. Decision Tree for PCR result of patients with COVID-19 symptoms

We describe the results obtained following the application of the decision tree technique for each value of oxygen and heart rate by the decision rules presented in table 1.

Table 1. Decision rules

SpO2	Pulse	PCR
Enough	Strong	Covid negative (70% cases)
Enough	Normal	Covid negative (65%)
Enough	weak	Patients may be Covid positive/negative (50% of each case)
Desaturation	Strong	Covid positive (79% of cases)
Desaturation	Normal	Covid positive (82%)
Desaturation	weak	Covid positive (100% cases)
Insufficient	Strong	Covid positive (57%)
Insufficient	Normal	Covid positive (100% cases)
Insufficient	weak	Covid positive (100% cases)

The extracted rules corresponding to the decision tree have been validated by a medical expert.

7. EXPERIMENTAL RESULT

According to the results obtained through learning from the real Data Set of the Farhat Hached hospital in Sousse, we were able to propose improvements on the basis of which we defined an improved version of the process. The improvements we propose concern both the patient and the doctor.

In order to facilitate the diagnosis without loss of time, we first propose to minimize the use PCR tests for patients when possible. Given the delicacy of this disease, it will be helpful to eliminate the effort of PCR testing, and mitigate the risk of spreading this pandemic.

Moreover, we offer a decision support system that allows the doctor to make the right choice regarding the patient's state of health without wasting time waiting for the PCR result.

Following the results of the analysis established on the data acquired by the execution of the process in its initial form at the COVID-19 department of the Farhat Hached hospital in Sousse, we have developed a process model based on the analysis of the data of the decision tree shown in Figure 7.

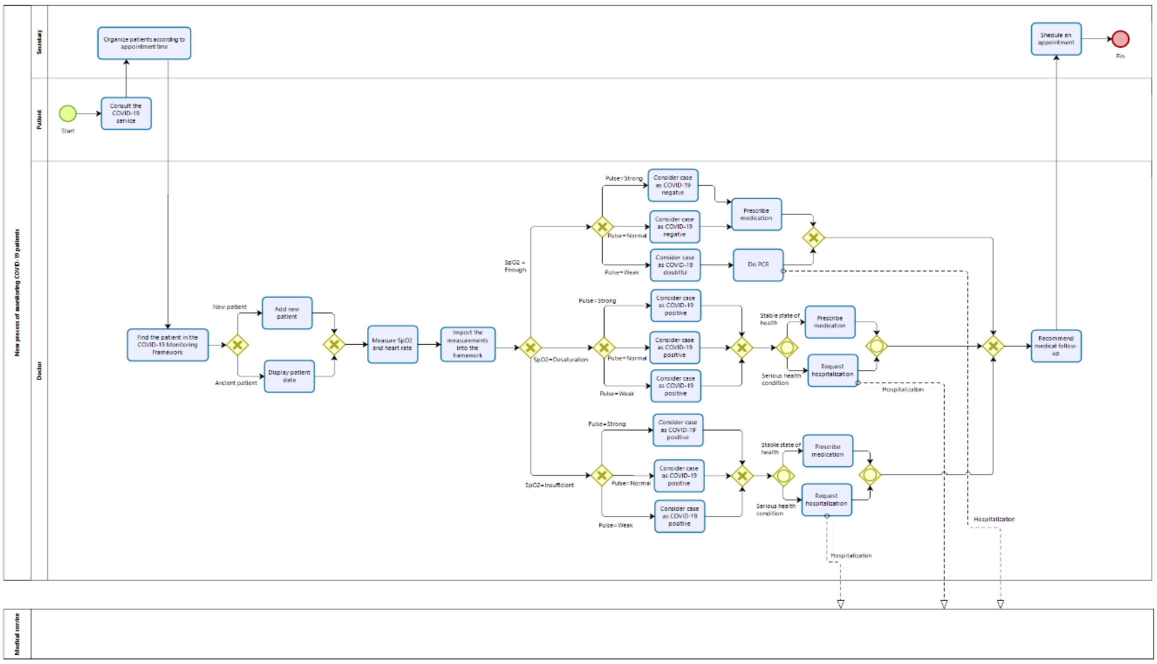

Figure 7. Enhanced COVID-19 patient monitoring process model

In this model, we decided to replace the fragment including the task of PCR detection, wait for the results and return to the consulting room so that the doctor can make his diagnosis according to the result of the PCR and determine the patient's health. All these tasks will be replaced in a way that allows decreasing the waiting time and offering a quick diagnosis to the affected patient without wasting time.

Indeed, the doctor's decisions based on the PCR result have been replaced in the new model by a set of XOR-type gateways, based on the evaluation of the values of oxygen saturation (SpO2) and heart rate (Pulse), in accordance with the obtained decision tree. This made it possible to automate decision-making relating to the patient's state of health without the need, in most cases, to perform a PCR test.

8. OTHER EXPERIMENTS

We have adopted in the tests of our proposed approach, an IoT device which is the connected oximeter, which gives us two measurements which are the SpO2 value and the heart rate. We took advantage of these two measures to show how the approach is valid with more than one value and with a variation of IoT sensors. Given the lack of technical means to carry out a test with other devices, we relied on existing values measured in the Farhat Hached hospital in Sousse, to carry out analyzes through the decision tree technique in order to suggest improvements in the “To-Be process” model. All these values are symptoms of COVID-19 and may influence the PCR result, for example: temperature, cough, anosmia (loss of sense of smell), asthenia (feeling tired) and diarrhea. Our choice of these values is based on the opinion of a medical expert.

8.1 Experiment Based on 3 Values

We repeated the evaluation of the "To Be" model improvement by adding another value, namely temperature, which involves predicting PCR results. We followed the same analytical method as the first experiment and applied the decision tree obtained using software "Sipina".

We analyzed two real datasets of patients visiting the Department of Infectious Diseases at Farhat Hached Hospital in Suse. We extract oxygen saturation, heart rate, temperature and PCR results from each data set, and then collect them into a structured data set for learning test.

We were able to extract knowledge from our Data set by Sipina using the “A Limited search induction tree algorithm (Catlett, 1991)” method which resulted in the construction of the decision tree shown in Figure 8.

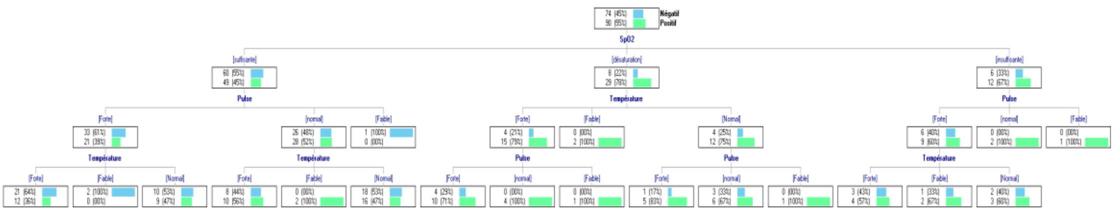

Figure 8. Decision tree for PCR result of patients with symptoms of COVID-19 based on 3 value

We described the results obtained by applying decision tree techniques by the rules of Table 2.

Table 2. Decision rules extracted from experiments based on three values

N°	SpO2	Pulse	Temperature	PCR
1	Enough	Strong	Strong	COVID Negative (21% cases)
2	Enough	Strong	Weak	COVID Negative (100% cases)
3	Enough	Strong	Normal	COVID Negative (53% cases)
4	Enough	Normal	Strong	COVID Negative (56% cases)
5	Enough	Normal	Weak	COVID Positive (100% cases)
6	Enough	Normal	Normal	COVID Negative (53% cases)
7	Enough	Weak	-	COVID Negative (100% cases)
8	Desaturation	Strong	Strong	COVID Positive (71% cases)
9	Desaturation	Normal	Strong	COVID Positive (100% cases)
10	Desaturation	Weak	Strong	COVID Positive (100% cases)
11	Desaturation	-	Weak	COVID Positive (100% cases)
12	Desaturation	Forte	Normal	COVID Positive (83% cases)

13	Desaturation	Normal	Normal	COVID Positive (67% cases)
14	Desaturation	Weak	Normal	COVID Positive (100% cases)
15	Insufficient	Strong	Strong	COVID Positive (57% cases)
16	Insufficient	Strong	Weak	COVID Positive (67% cases)
17	Insufficient	Strong	Normal	COVID Positive (60% cases)
18	Insufficient	Normal	-	COVID Positive (100% cases)
19	Insufficient	Weak	-	COVID Positive (100% cases)

The extraction rules corresponding to the decision tree have been verified by expert doctors. Rule 5 applies to asymptomatic COVID-19 patients. Based on the results obtained by learning its three values, we propose a second improved version of the process based on the decision tree data analysis shown in Figure 8.

In this model, we eliminate the same tasks as the first improved model based on two values, which are the task of carrying out the PCR test, waiting for the result and returning to the consulting room so that the doctor can make his diagnosis according to the PCR result and decide the patient's health status. We have grouped these tasks into a single day in order to decrease the waiting time and offer a quick diagnosis to the affected patient without wasting time. This was possible thanks to the results of the analysis carried out from the two values. Indeed, the doctor's decisions based on the PCR result have been replaced in the new model by a set of XOR-type Gateways based on the evaluation of the values of oxygen saturation (SpO2), heart rate (Pulse) and temperature, accordance with the decision tree obtained for each value of SpO2, PULSE and temperature. This thus allowed automation of decision-making relating to the patient's state of health without the need, in most cases, to perform PCR test.

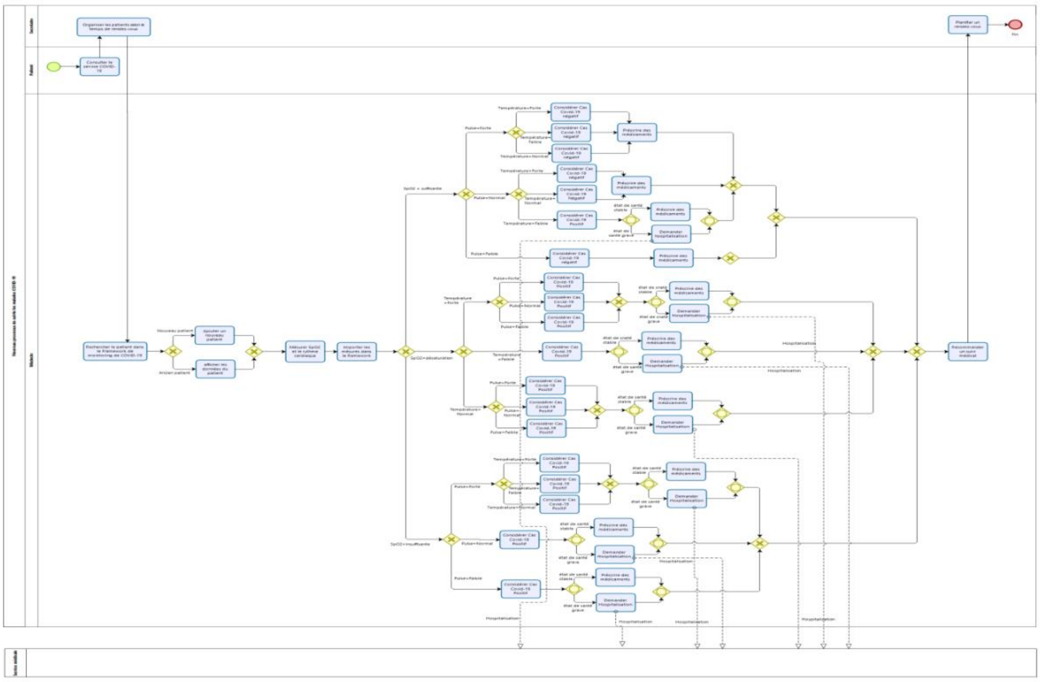

Figure 9. Improved COVID-19 patient monitoring process model based on three values (SpO2, pulse and temperature)

8.1 Multi-Value Experimentation

Due to our multi-sensor approach and the lack of sensors to test our method, we chose to conduct experiments at Farhat Hached Hospital in Sousse based on existing actual values. Other than SpO2, Pulse and Temperature, we have added 4 other values that we have considered useful for the diagnosis of COVID-19, through the advice of a medical expert. These values are: asthenia (fatigue), anosmia, cough and diarrhea which are also symptoms of COVID-19. The new data set to which our analysis has been assigned is a data set of 402 instances. The new decision tree obtained from our Data set of 7 values by Sipina using the “A Limited search induction tree algorithm” method is presented in figure 10.

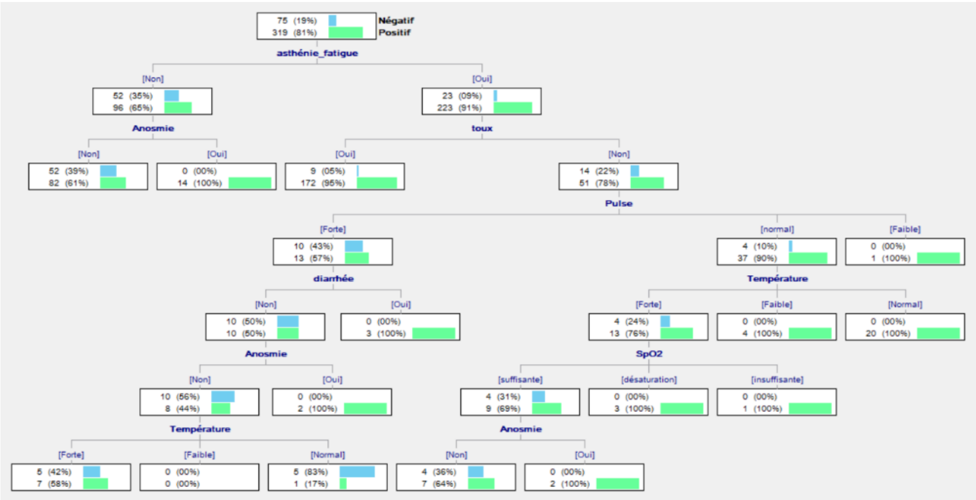

Figure 10. Decision tree for 7 measures based on PCR results of COVID-19 symptomatic patients

After applying decision tree technology to each value of oxygen, heart rate, temperature, fatigue, anorexia, cough, and diarrhea, we extracted 14 withdrawal rules. We describe in table 3, 5 rules among the set of extracted rules.

Table 3. Decision rules extracted from experiments based on seven values

Asthenia	Anosmia	Cough	Pulse	Temperature	SpO2	Diarrhea	PCR
Yes	No	No	Strong	Normal	-	No	COVID Negative (83% cases)
Yes	No	No	Normal	Strong	Enough	-	COVID Positive (64% cases)
Yes	Yes	No	Normal	Strong	Enough	-	COVID Positive (100% cases)
Yes	-	No	Normal	Strong	Desaturation	-	COVID Positive (100% cases)
Yes	-	No	Normal	Strong	Insufficient	-	COVID Positive (100% cases)

Although the result obtained is validated by a medical expert, we applied the transformation of the model only on the basis of the two previous results (based on two and three measurements). Indeed, based on several measurements, the model becomes too complex and difficult to understand.

8.3 Study on the Influence of Chronic Diseases on PCR Value

We carried out the experiment again in order to bring improvements to our “To-Be” model, which concerns the prediction of the PCR result, based on several values, since our approach is multi-sensor. We follow the same way of the analysis as the second experiment based on seven values, adding the blood glucose measurements in order to study the influence of the blood glucose value on the PCR value in each variation.

We found blood glucose values in mmol (mmol/l) in two datasets obtained from Sousse Farhat Hached Hospital. The normal fasting blood glucose level should be lower than 100mg/dl or 3.89mmol/l. If the fasting blood glucose value is greater than 120mg/dl or 6.12mmol/l, it is called high blood glucose level or hyperglycemia. We derived these levels from medical fasting blood glucose analysis.

Between the two data sets, we find just 19 instances that have a blood glucose value measurement, for the others this measurement is not indicated. So we carry out our analysis on the data set composed of 19 instances of patients who consulted the infectious diseases department at the Farhat Hached hospital in Sousse and who had their blood sugar measured. We were able to extract knowledge from our Data set by the software "Sipina" using the method "A Limited search induction tree algorithm" which resulted in the construction of the decision tree presented in the figure 11.

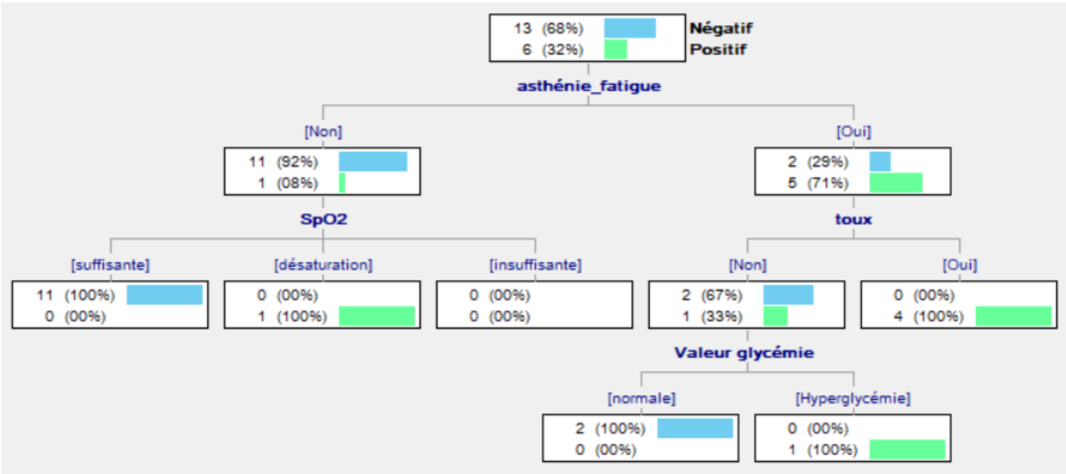

Figure 11. Decision tree based on 8 indicators, including blood glucose values

We tried to do a complementary analysis with 8 measurements as well as a blood sugar measurement value in order to study the influence of this chronic disease on the PCR value of COVID-19 but the result was not conclusive. According to the opinion of a medical expert, the analysis result is insufficient to make a decision, for this we cannot identify decision rules or a modification of the “To-Be” model. According to the opinion of a medical expert, the result can become actionable if we have more data, which requires a larger data set as well as other details of the diabetes disease to study its influence on COVID- 19. For this, we propose in future work to make a complete study on the influence of the values of measurements of chronic diseases (which can be either diabetes or blood pressure or asthma) on the value of PCR as well as on the symptoms and severity of COVID-19 on the patient affected by one or more chronic disease(s) and vice versa.

9. SECURITY IN IOT SYSTEM

The security of connected objects (IoT) is a major area of concern for developers, as these devices are often exposed to security risks due to their connection to the Internet. In addition, IoT security is influenced by several challenges, namely the limited resources of IoT devices in terms of computational power, battery life, etc., as well as the limited standardization of security protocols for IoT and the largely open internet, which is the source of a number of attacks and vulnerabilities. Several research studies have shown that IoT systems suffer from several security issues, including authentication, authorization, information leakage, privacy, verification, eavesdropping, etc. In our work, it is very important to focus on providing strong security to avoid malicious attacks and preserve privacy in IoT systems, especially in the healthcare field, where devices are used in an IoT system and manage critical patient and doctor data.

Although PHP Symfony is a popular framework for web development, it is not commonly used for IoT application development. Nevertheless, security is a crucial aspect for any software development, including that related to connected objects.(Adamu et al.,2020)(Laaziri et al.,2019)

In terms of literature, there are several articles that discuss developing secure IoT applications using PHP Symfony. For example, some articles focus on general security practices that developers should follow to protect IoT applications (Adamu et al.,2020)(Damghani et al.,2019)(Laaziri et al.,2019), citing for example especially:

Using secure communication protocols such as HTTPS, SSL, or TLS to protect data traveling between connected objects and servers, using cryptographic techniques such as encryption and authentication to ensure the integrity and confidentiality of data stored on IoT devices and application database as well. Implementing access and permission management to ensure that only authorized users have access to data on connected objects.

Securing an IoT system developed with PHP Symfony requires implementing measures to protect the various components used, including the devices, the communication channels and the application itself. Here we provide an Encryption for sensitive data transmitted. Using strong encryption algorithms like AES (Advanced Encryption Standard) for secure data transfer and with Applying encryption using libraries like OpenSSL.

In addition, there are specific resources that discuss the security of IoT applications developed with PHP Symfony and explain how to use Symfony's integrated security features to develop secure IoT applications. These features include protection, form validation, permission verification and the placement of a security firewall to block SQL injection attacks.

Although not commonly used for IoT application development, PHP Symfony can be used to develop secure applications by following good security practices and using the framework's integrated security features. It is important that developers consider security risks and follow recommended security practices to protect IoT applications from potential threats. The strength of the IoT is that objects communicate, analyze, process and manage data without any human intervention. However, security issues are severely limiting the evolution and the quick deployment of this high technology. Identity fraud, information stealing and data modification represent a real danger for these kinds of systems. Many researches study in depth the creation of a security system allowing the authentication services of the connected objects, the integrity of the data exchanged between them and the confidentiality of the information.

- **Openssl library**

There are different cryptographic libraries that provide encryption and decryption of sensitive data in php symfony, for example: Defuse Crypto, Halite, CryptLib openssl etc.

For our PHP project with Symfony framework, we chose to use OpenSSL taking into account several advantages namely; OpenSSL is one of the most popular and widely used, it is a polyvalent library that supports a wide range of encryption, hashing and cryptography algorithms. In addition, OpenSSL is widely used in the security industry and has been proven by many applications and systems for many years. It has a large developer community and rich documentation, making it easy to use and fix problems. OpenSSL is included in most PHP installations by default, which means you don't need to install any additional dependencies. It is also supported by Symfony, which makes it easy to integrate into existing Symfony projects.

- **The confidentiality of patient records**

Nevertheless, iot manages a lot of personal data. The loss or misuse of this information can cause many problems for users. However, if a hacker has the ability to retrieve all this important data at any given time, he may be able to deduce some sensitive information that can harm the users. That's why it is necessary to keep the records confidential.

In order to secure critical data stored in the database, we use the openssl library which allows us to encrypt the data using an encryption algorithm before storing it in the database and decrypt it in order to display it in clear text to users while keeping it encrypted in the database.

After configuring communication via HTTPS and the openSSl library, we move on to ensuring the confidentiality of patient records, we need to encrypt the data entered in the form to store it encrypted in the database and decrypt it when retrieved. To do this, we develop an encryption and decryption service; this service class will handle the encryption and decryption operations using the OpenSSl library.

```
class EncryptionService
{
    private $encryptionKey;

    public function __construct(ParameterBagInterface $parameterBag)
    {
        $this->encryptionKey = $parameterBag->get('encryption_key');
    }

    public function encrypt($data)
    {
        $iv = random_bytes(openssl_cipher_iv_length('aes-256-cbc'));
        $encryptedData = openssl_encrypt($data, 'aes-256-cbc', $this->encryptionKey, 0, $iv);

        return base64_encode($iv . $encryptedData);
    }

    public function decrypt($encryptedData)
    {
        $encryptedData = base64_decode($encryptedData);
        $iv = substr($encryptedData, 0, openssl_cipher_iv_length('aes-256-cbc'));
        $data = substr($encryptedData, openssl_cipher_iv_length('aes-256-cbc'));

        return openssl_decrypt($data, 'aes-256-cbc', $this->encryptionKey, 0, $iv);
    }
}
```

Figure 12. Screenshot of the developed service for encryption and decryption using Openssl

After that we have to Use the EncryptionService in the application by Injecting it into the classes where you want to encrypt or decrypt patient data. Therefore, we create a controller class "PatientController "to handle the encryption and decryption operations. Finally, by submitting patient data through a form. The data should be encrypted when stored as shown in figure 13 and decrypted when retrieved.

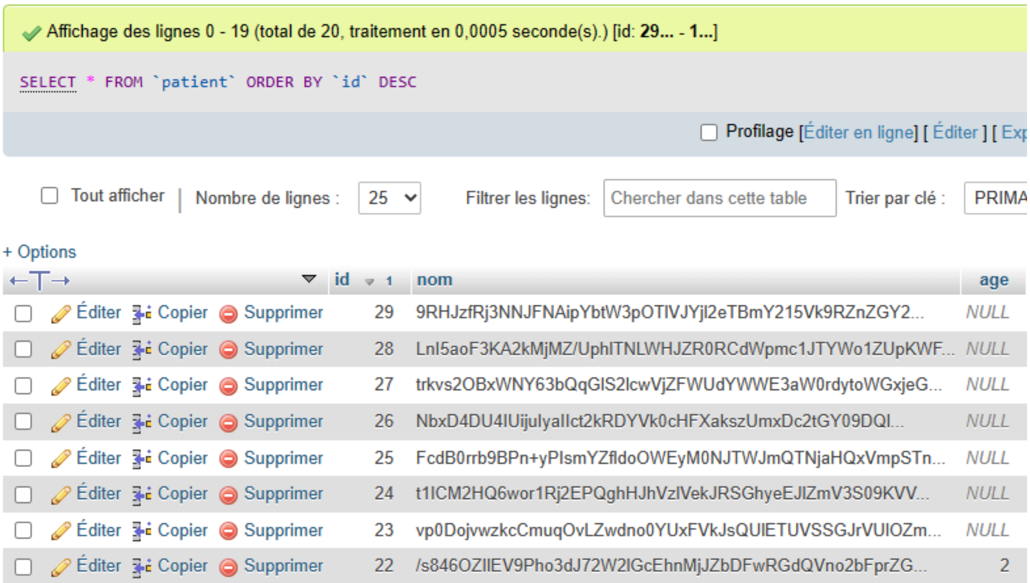

Figure 13. Screenshot of the critical records encrypted in the database

In summary, we can say that IoT is the most interesting and newest technology nowadays. The Internet of Things is used to define the network that is composed of a number of electronic devices interconnected with smart technology. Smart hospital, Smart cities, smart cars, smart home are going to be the next big projects that will make a difference in the way we live, we work and interact. As we know, the IoT suffer from a number of risks and vulnerabilities.

Iot deals with sensitive data that is why security must be ensured, by overcoming these risks, we can take advantage of the services of IoT systems.

10. CONCLUSION

We have proposed a general model that integrates IoT sensors into the BPM model, and we described the approach according to the business process management life cycle proposed by Weske. Then we applied this model in the field of health particularly in the diagnosis of COVID-19 disease.

We also modeled our approach with BPMN. Then we carried out our approach by developing a prototype consisting essentially of a COVID-19 disease monitoring framework intended for doctors. Finally, we took advantage of learning methods to automate decision-making in the proposed process. We have conducted several experiments using real measurements obtained at the Farhat Hached hospital in Sousse. Adopting an analysis through a Data Mining technique allowed to show that our approach is valid with different sensors and several measurements.

Our result is especially valid for people who do not have a chronic disease and have presented symptoms of COVID-19 and not by other diseases which can influence the severity of COVID-19 and their state of health. Our analysis can be complemented by adding other variables from measurements of other chronic disease sensors and studying their effects on COVID-19 symptoms and severity.

This work remains a modest contribution to improving business processes and treating patients infected with COVID-19. It presents multiple perspectives to better optimize, complement and perfect our proposed approach. As future work proposals, we suggest to establish interaction with various connected objects. We can also integrate chronic disease measurement sensors to study the impact of these on COVID-19 and vice versa. Our prototype can also be improved by including a dashboard through which visualizations of data mining and process mining results will be displayed and help in decision making.

On the other hand, given the continuing evolution and presence of connected objects in our lives today and in the future, it would be interesting to continue discussing IoT security concerns. More precisely, it would help developers and researchers find appropriate solutions to avoid problems caused by specific threats.

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