Atena: A Public Primary Healthcare Environment Supported by an Implementation Science Approach

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Research

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***Abstract*— Public primary healthcare environments are facing grand challenges related to digital transformations. This is reported from many studies, in several countries, and observed from diverse areas. The present war against the Covid-19 pandemic has shown the required utilization of combined information and communications technology approaches. In this paper we present the Atena research work, which is a proposal development that focus on a public primary healthcare system digital transformation. The approach of implementation science is observed through our scientific studies of methods to gather the digital data, and recommendation strategies to facilitate healthcare personal, and using the evidence-based practice from the Atena. Study scenarios provide interesting view of several elements which can help to enhance a wider discussion about technologies and their scientific implementation. We considered wearable devices used by different groups of voluntaries. Vital digital signals from these voluntaries were gathered to afterwards be evaluated by professionals inside the healthcare premises. To provide a better understanding of these people´s behaviors, a recommendation system (RS) is being conceived as a support tool, utilizing their digital vital signals. Another element from the proposal is a simulator-based architecture. This component highlights people´s movement and predictable scenarios of contamination. A common daily monitoring scenario can be enhanced from these simulations' experiences. After our initial results, it is possible to affirm that the Antena proposal provides a valuable approach to face several efforts in digital transformation in public primary healthcare structures. This transformation can be verified in the present pandemic scenario. Experiences from this research indicates that the adoption of some computational technologies requires major changes on the present behavior from governments and citizens.**

***Index Terms*— Public primary healthcare, implementation science, digital transformation, recommendation systems, IoT-Fog-Cloud environments, simulation-based architecture.**

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I. Introduction

Reports from World Health Organization (WHO) [1,2] and studies from the International Monetary Fund (IMF)[3] state an interesting view the actual scenario which we are facing. The first organization reports that the present challenge of Covid-19 is similar in two hundred and thirteen countries. In addition, the major advice to everybody, based upon health specialists, is to obey the social isolation. On the other hand, as IMF observes the challenge to keep people and economies in an appropriate synchronism is special hard. Interesting to mention that the recommendation to stay at home is similar to the influenza pandemic from 1918. This is a clear evidence that the health digital transformation does not occurs around the world as it was expected to be. Therefore, efforts are required to answer how information and communications technologies (ICT) could represent essential elements for health enhancement and protection of individuals and economies.

A document from the IMF, present in [3], shows that to provide foundations bases for a differentiated recovery, their policy advice will require a new approach to evolving realities. Essential to have a better view of the challenges, risks, and tradeoffs related to each country and how these will gradually restart their economies. However, IMF to provide an accurate advice would have to access to a large and diverse health digital dataset, which could provide a differentiated approach to a possible data analytics research.

In the literature, it is possible to find that the business data is wider and bigger than health data. For example, in [4] it is mentioned that to really understand big data, it is helpful to have some historical background. Gartner's big-data definition is [5]: high-volume, high-velocity and/or high-variety information assets that demand cost-effective, innovative forms of information processing that enable enhanced insight, decision making, and process automation. However, these massive volumes of data are being commonly utilized in *business* problems and not in *health* area. Where the data capture suffers from government policies and citizen behavior.

Nowadays one important effort in the health field would be the digital transformation, because it allows an enhanced insight, decision making, and process automation in healthcare. Authors illustrated in [6] that the persistent lack of progress has led researchers to ask deeper questions about what is occurring when teams evaluate the benefits of digital

transformation. Novel works are presenting proposal studies, for healthcare, which represents improvements in gathering data, which could be transformed into information, and then in valuable knowledge. An example is presented in [7], where an energy-efficient and highly accurate toothbrushing monitoring system exploits IMU-based wrist-worn gesture sensing using unmodified toothbrushes. The data collected from this process may be transformed into valuable information, and then transform into knowledge to avoid some cardiovascular heart diseases, which are imputed to come from the lack of brushing [8].

The paradigm of Recommendations Systems (RS) is characterized by set software package that point out a set of resources to users considering their interest. In other words, these systems can provide relevant information available in a large specific repository, according to their tastes, preferences, and requirements [9]. Therefore, it acts as ancillary tool to knowledge systems.

In this paper, we present Atena ongoing research (coined because of the Greek wisdom goddess). The idea is to build a foundation to primary public healthcare (wisdom) software infrastructure. Atena is characterized by some main elements, these are: support to a digital transformation gap, usually found in a public primary healthcare premise, targeting for example the Covid-19 pandemic scenario; a RS algorithm developed to provide knowledge about users´ behaviors, based upon their vital signals; adopting a simulation-based software helping to foresee and highlight people movement and predictable contamination scenarios. The implementation science is observed through our scientific studies of methods to gather the digital data, and recommendation strategies to facilitate processes to the healthcare personal and using the evidence-based practice from the Atena.

The paper is organized as follows. In section II, we present materials and methods related to this research work. Section III shows the experimental environment and results. Section IV presents a discussion about this contribution. Section V presents conclusions.

II. Materials and Methods

This section presents some relevant elements from the Atena proposal. It also shows methods employed for evaluation from its diverse dimensions.

A. Computer and Communications infrastructure

One fact that is a common ground among all researchers in the e-health field is how to differentially tackle the challenge of digital transformation. In the other side of the coin, how those digital features will be use is also a relevant concern. As a result, this section represents our initial effort contribution. We present aspect related to a contemporary infrastructure conceived to prove an improved public primary healthcare monitoring environment.

To reach a level of modern approach our first study focusses on the fog-cloud collaboration environments, in contrast to conventional cloud configurations. Because of that, we provide a view of up-to-date studies available in the literature. Studies such as [10,11,12] are interesting to elucidate the cooperation among fog and cloud environments. The adoption of this new paradigm is an essential movement in a modern architecture to consider huge among of digital data collection and treatment.

The experience presented in [10] shows a large amount and various applications generated by the IoT devices, supported by a fog computing environment as a key element to be an extra part from cloud services. The work presents an argument that this configuration offers cloud similar services, but the location is found at the edge of the network, with the advantage of low latency and real-time answers. It is reported that the large-scale, geographical distribution, and heterogeneity of edge computational nodes make service placement in such infrastructure a challenging issue. User expectations in different dimensions and IoT devices characteristics also complicate the deployment problem.

The aspect of workload offloading which is performed by fog tier is reported in [11]. The research provides an idea where a set of fog nodes can provide an interesting offloading from conventional cloud environments. Authors considered the quality-of-experience (QoE) and fog infrastructure power efficiency.

The work presented in [12] shows an interesting research about the conventional cloud-based tiers and the exponential requirements from IoT applications. This is typically the case of several e-healthcare applications.

The document highlights two important parameters. The throughput and latency. The view of new tiers cooperative collaboration is pointed out. Authors from this work mention the crescent IoT growth and development forecasts and problems related to the IoT potential. The scenario of cloud, fog and edge environments must collaborate, however new challenges will occur about hardware, communications, security, and approaches such as machine learning.

As it is illustrated in Fig.1, a successfully adopted fog-cloud paradigm to connect locally devices through a fog environment and then send the processed data to a cloud infrastructure [13]. In the Atena architecture advantages of this approach are several. It includes capture of personal distributed health digital data, possibility to ad-hoc local storage, use of local artificial intelligence efforts, also a local data sanitization facility, and then submission of all data to the cloud. These facilities enhance the quality of data that will be uploaded to the cloud tier. As a result, this effort provides an accurate view from edge nodes inside the fog tier, which will be transformed in knowledge.

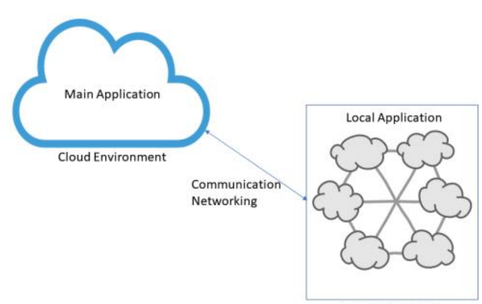

Fig. 1. Atena fog-cloud infrastructure

After chosen to Atena which type of computer

infrastructure and communication paradigm was the most appropriated system, the public primary healthcare Atena architecture conceived is presented in figure 2. Our proposal observes important challenges pointed out in [14.15]. In other words. Atena is oriented to e-health information exchange for public services and a balance between centralized and decentralized activities.

Fogs environments considered in our architecture have three different characteristics types:

- Fog 1: This group was characterized by group six students from one university. They were voluntaries in terms of collaboration with this work, in which they were monitored inside some situations.
- Fog 2: A poor community was the characteristic of the second group. The price and quality of wearable devices are relevant to people from this scenario and with different ages, sex, and health conditions.
- Fog 3: Retirement homes and people with some disabilities compound this group, where mobile facilities and computers exists.

Scientific observations, from previous research from our group [16], is the main reason for these diverse fog's classification. The effort of an evaluation the quality of context is minimized when an appropriate environment is designed with peers' actors. In other words, we are effectuating an important preprocessing action for any assistant front-end inside a hospital.

Challenge which came on the next stage was to design how the data will gather from the fogs, would be received, and treat inside the hospital structure. Therefore, understanding the local procedure from a public hospital we considered a stage called as front-end and another back end. Similar to computer science jargon, the first element receives and preprocesses the received digital data. The second level, coined as back end, is the location for a physician responsible for the central monitoring and assignments.

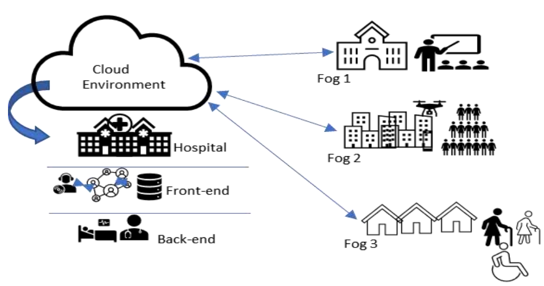

Fig. 2. The Atena healthcare architecture

Facilities conceived, as commented in [17,18], to a public primary healthcare environment must observe:

1. The health provision and cost require a balance attention. Digital data gathering could lead to an enhanced option related to assignments, dropping costs with specialists and facilities. This is an scenario found in Covid-19 pandemic.
2. The unnecessary Covid-19 tests from persons could be reach from, for example, fresh digital data gathered from users. Fog environments could represent an up-to-date figure of the out-side scenarios.
3. This digital transformation innovation could materialize several benefits. Examples are the data storage for future differential data analytics, and also the use of new AI software packages.

III. Experimental Environment and Results

The experimental Atena environment and its related results are shown in this section. Results are illustrated through five scenarios from the architecture. The three fog environments are presented first. The fourth scenario represents a real hospital. The last set of results come from the simulation-based scenario, which could serve as advice support to the previous four environments.

As it was previously mention, the implementation science is characterized in the Atena project through our scientific studies of methods to gather the digital data. In addition, recommendation strategies to facilitate procedures to the healthcare personal, and using the evidence-based practice from our overall experiences.

A. Fog 1

The first fog environment seeks to present recommendations to stakeholders to assist them in decision making. Figure 3 shows a detailed view of fog nodes from the perspective of the recommendation system. This structure was defined considering previous work where a fog-cloud cooperation proved a differentiated approach for processing large volumes of data in an Ambient Assisted Living [20].

In each fog node, the *data monitoring* component is responsible for monitoring the data collected by sensors (wearable or environment). This component organizes the collected data and sends it to the data processing component.

The *data processing* module is responsible for processing, local storage, and sending data to the cloud infrastructure. This approach provides an interesting feature to help both people involved in health data monitoring and physicians (back-end) inside a hospital.

The *Recommendation System* acts in two moments: (i) recommending to end-users, in which fog node users receive recommendations considering the data collected. These users can be students, relatives, and health professionals (working directly with monitored users), (ii) recommending to back-end people, where the system consolidates the patient's history (admitted to the hospital) and presents the patient's health status and recommendations that assist, for example, doctors in decision-making.

This proposed infrastructure allows decentralizing the processing of the *Recommendation System* for the fogs nodes. Consonant with the communications policies between fogs-cloud, with this effort, it is possible to avoid bottlenecks in the

cloud infrastructure. This solution provides enhanced monitoring and a differential processing from fog´s data.

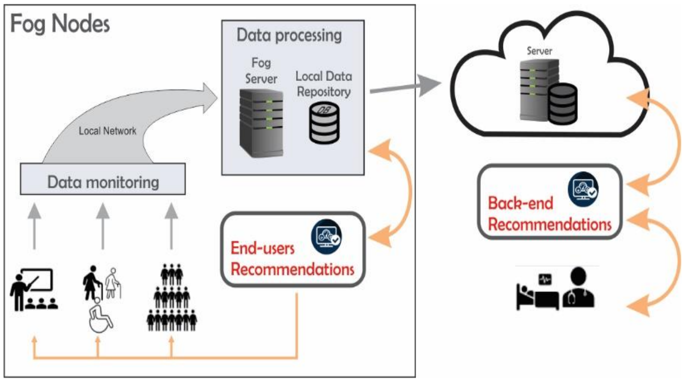

Fig. 3. Primary healthcare architecture under the recommendation system perspective

This first fog environment was characterized by students from a public university, where they were monitored targeting to capture their vital signals. The *Hold-up* [19], a recommendation system, was developed and implemented, and the voluntaries students were submitted to it. The *Hold-up* RS execution phases, as illustrated in Figure 4. It detects heart rate oscillations through wearable sensors and defines the student's emotional profile and context.

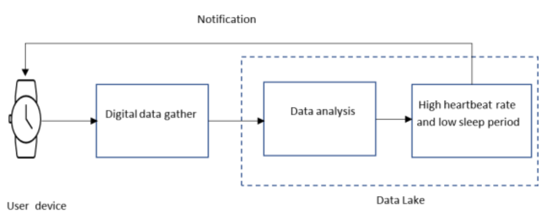

Fig. 4. *Hold-up* RS execution processes view

Aiming to define the student's context, we are using the environment data. Thus, the recommendation system receives data from students that are monitored by their wearable sensors. Through data extraction and classification, individuals' activities within the defined assisted environment are recognized and used to describe the student's context, which will receive the recommendation system's resources.

In this work, the user's location data is extracted through an application via GPS and Wi-Fi. The proposed system's architecture consists of applications executed locally for data management and another application executed remotely to store users' location data. Therefore, we can identify the environment in which the student finds himself when he presents stress characteristics, or other anomalies related to signals such as temperature, blood pressure, blood oxygen, and heartbeat. We can determine whether the student is in a closed or open environment, which allows for richer recommendations by the SR.

The technologies used by the environmental monitoring system are:

- Docker: creation of containers for the services used.
- Docker-compose: installation and configuration of containers.
- Node-RED: creation of automation, access to stored data, and export to dedicated databases.
- FIND3 Internal Positioning: application that scans Wi-Fi and Bluetooth signals and associates them with previously defined environments via Machine Learning.
- MongoDB: dedicated database.
- Mongo Express: the user interface for managing the created databases.

Targeting to collect user data, applications on their phones must have access to a server with the FIND3 application container running. Therefore, for the system to work, it was necessary to grant remote access to students with the server in question – both–for data extraction and for managing and analyzing them locally.

The digital data was collected from six students, as shown in Table I. This table presents 3 cases (different types of examinations) in which the students were submitted. Interesting to see that they have, as expected, different patterns in different cases. The student number #2 was the unique that was calm in all measure's cases. Another interesting aspect was their sleep patterns, where student #3 has the smallest deep sleep record. These digital data were gathered through the smart band, then were sent to a MongoDB database. This is a NoSQL database widely used in data lake solutions. Subsequently, these data were analyzed, and the Hold-up software package, which traced the context students to identify their emotional states and verify requirements to send any recommendation.

Table I: Students digital data from the monitoring approach

	Heartbeat			**Sleep**		
USERS	Case 1 (bpm)	Case 2 (bpm)	Case 3 (bpm)	Light	Deep	Total
#1	83	103	78	1h59min	4h17min	6h16min
#2	64	70	68	3h13min	4h43min	7h56min
#3	115	93	53	6h49min	2h30min	8h19min
#4	61	88	69	5h24min	1h17min	6h41min
#5	68	98	72	1h36min	4h51min	6h27min
#6	70	101	65	4h19min	4h20min	8h39min

Variations in heart rate may indicate stress situations that, when uncontrolled, impact student's performance during university activity. Based on [19], we can say that the results point to the feasibility of the proposal (architecture and infrastructure), and the comments provided by students involved in the experiment gave us positive indications that this approach can be used in the proposed environments.

B. Fog 2

Figure 5 shows outputs from wearable devices related to heartbeat, blood pressure and blood oxygen. These devices were acquired considering characteristics from a poor community, which composed this fog environment. This means the price of these devices and how complex were the

wearables to setup. Figure 5 illustrates outputs from their devices related to heartbeat, blood pressure and blood oxygen.

Fig. 5. Wearable digital vital signals

Targeting to reach a level of a friendly interface, it was development a large search about wearable device. The key parameter to this effort was the best cost benefit, due to the lack of financial resources for public primary healthcare and could fulfill characteristics of simplicity and open digital data. The Kaihai IP68 wearable devices were bought for our experiments, which could provide an easier fashion to gather personal data.

These devices provide facilities to open access of the data by third parties applications, as shown in figure 6. This figure shows in the footnote the variety of applications that can receive the collected data. Important to mention that the first set of wearable devices does not have the temperature as parameter to be collected. More recently, it was possible to acquire other wearables with the four desirables parameters (heartbeat, blood pressure, blood oxygen, and temperature) to the Covid-19 indication.

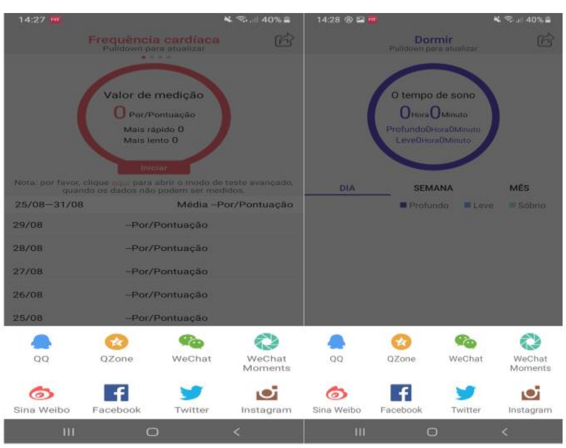

Fig. 6. Software packages to share the data from the wearable.

C. Fog 3

An application, called *e-Health*, was developed due to the fact of the characteristics of the people inside this fog configuration. The reason was to have this application inside the mobile phone, and which could help in the query to execute synchronizations (e.g., heartbeat, blood pressure, blood oxygen, temperature, steps, sleep, and emergence). These parameters can indicate interesting signals for the Covid-19 to health professionals which are remote monitoring these persons. Figure 7 highlights an output from a heartbeat, and the facility to do connection to a device. These facilities are in the stage of tests because some challenges were found during some experiments with some smart wearable and mobile devices.

Fig. 7. Mobile phone *e-Health app* features.

A hardware prototype is being developed looking for a better cost benefit, with the purpose of being accessible to most of the population, portable, with low energy consumption and easy installation.

We chose to use these sensors, because the objective of this research is providing a low-cost device, that can be used on large scale, for example, in the public health network. The total cost of the prototype developed is estimated at $ 35. The diagram from Figure 8 illustrates the components used in building the prototype.

Atmega2560 is microcontroller which support voltages in the threshold from 5V until 20V. This pattern provides an interesting feature to supply utilizing small rechargeable batteries. LiPo battery of 7.4, 2500 mAh was the power for the microcontroller, sensors and communication module utilized in this work. The portability aspects were the key element in this choice. Size characteristics were 9cm X 2cm X 3.5cm. The weight was only 0.214 Kg. In other words, ease of use and long service life. The drawback of this microcontroller is the lack of wireless communication. As a result, the HC-05 module was chosen. The first sensor chosen was the AD8232 ECG module, which allows monitoring the patient's ECG through 3 electrodes, in addition to measuring heart rate. The temperature is measured by the MLX90614 sensor, which has high sensitivity and uses infrared technology with low energy consumption. Blood pressure will be measured by the MPXV5050GP non-invasive sensor. Blood saturation will be obtained by the MAX30100 sensor, which can also be used to read the heart rate and, together with the AD8232 sensor, more accurate results are obtained in the reading of the beats. The physical position of the user of the device will be obtained by the MPU 6050 accelerometer sensor. The GY-NE06MV2

GPS sensor will be used to send the location in real-time in cases of urgency. With Bluetooth (HC-05), wireless (NRF24101+), and 3G (SIM5320E) communication sensors, it will be possible to maintain a more comprehensive connection.

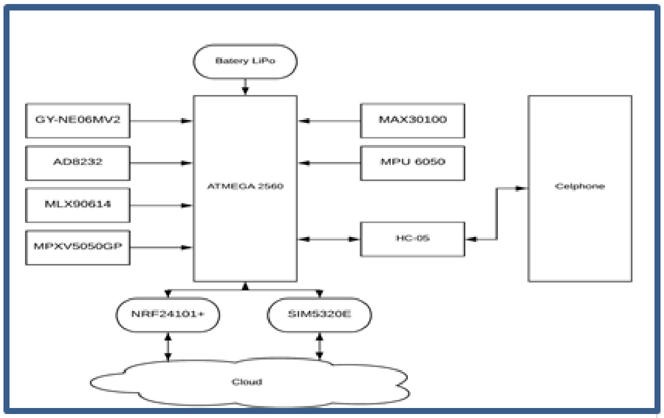

Fig. 8. Prototype of the wearable hardware.

The theoretical values of the energy consumption were calculated by the formula: battery capacity divided by the sum of the power of each component, totaling an average of 20 days of use, with records of the vital signals sent every 5 (five) minutes. All sensors used are homologated by ANATEL (Brazilian National Telecommunication Agency), making the process of obtaining a license simplified when necessary. The prototype was designed according to the Brazilian standards. When the prototype is in use by the patients, we will submit to the NBR IEC 60601-1:2016 standard (ABNT NBR IEC 60601, 2016) to assure major reliability.

D. *Public Healthcare Scenario*

The public healthcare scenario considered was a public hospital. This environment will be the healthcare providers for the Covid-19, as mention in reference [14]. The partners for the research were a public hospital and a specialized clinic in neurology in the city of Juiz de Fora, in Minas Gerais, Brazil, which clearly understood the goal and benefits from e-health digital data.

The public hospital is a regional reference for the care of patients in the mesoregion of the Zona da Mata of the state of Minas Gerais with a current capacity of 50 ICU beds and 129 infirmary beds, with both able to receive patients diagnosed with COVID-19 and other diseases, such as cardiovascular diseases, both part of the study of this research. The experimental development of a front-end and a back-end is being developed in parallel with the hospital software application. Important to mention that this is an ongoing project that has a thigh-couple cooperation between the two parts (the Federal University of Juiz de Fora and the public hospital).

The experimental development of a front-end and a back-end in parallel with the hospital software application is presented in the Figure 9 and Figure 10. In figure 9 it is possible to validate our proposal, where it is possible to visualize a screen shot where it is possible to see the temperature and heartbeat from a patient, which could be a hundred kilometers from the hospital in a Fog. Through this system, it is possible to consult patient data, including data from the electronic medical record (for example, history of consultations and administered drugs), parameters collected from the devices (for example, body temperature and heart rate) and patient historical series. From the analysis of the collected data, this system allows intervention actions by the monitoring center, which range from an online assessment with the patient to the dispatch of a medical team to the patient's residence for emergency care. In the patient's residence, the health agent uses the mobile application developed to register the treatment to the patient.

Fig. 9. Temperature and heartbeat from patient interface

Figure 10 illustrates the monitoring web system for data collected from patients, which functions as a monitoring center composed of a coordinator doctor and a team of nurses and health agents. The figure also shows how the coordinator doctor usually acts in the hospital software package. The collaboration allows for the gathering of the experimental digital data from our fogs.

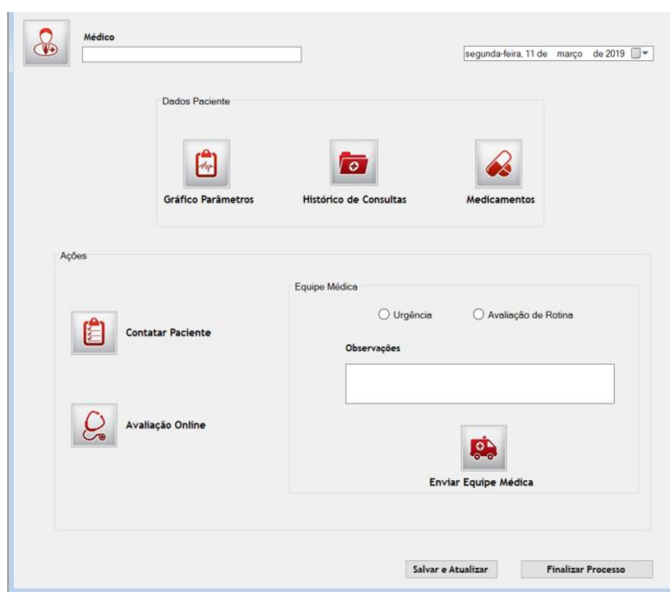

Fig. 10. An interface for the Coordinator Doctor.

It is important to mention is that the current stage involved tests of the hardware prototype and monitoring system with volunteers' users. The next stage corresponds to conducting the study with real patients and health professionals in the neurology clinic and the public hospital, partners for the research. Moreover, we highlight that all those experiments utilized the digital data from the researchers involved in this effort. The hospital side is a replication of your real environment. The feedback from hospital personnel has been incredibly positive. However, the regulatory preconditions (as mentioned in [14]) exist and are barriers to be surmounted.

E. Simulation Environment

The Federal University of Juiz de Fora (UFJF) has the main campus in the city of Juiz de Fora, which is a city in southeastern Brazil, with a population of around five hundred and sixty thousand people. As the main city from the region, it provides a healthcare supports for around a million and a half people. The City Hall is working together with the university researchers are developing cooperation to tackle several problems during the Covid-19 pandemic. The majority of hospitals found in the city are public.

The University area is one million and three hundred square meters, divided by nineteen thousand students, professors, and staff. The university campus map and a simulation of people movement inside the campus, considering several infected people, are represented in figure 13. The Siafu simulator [22] was the simulation tool utilized to provide our visualization scenarios. As it is highlighted in figure 14, executing this simulation was possible to generate an interface example. This picture shows the number of infected, cured, and dead persons. Our figures are based upon input parameters from heathcare specialists.

The proposed architecture aims to support the development, testing and validation of applications using the Internet of Things paradigm in smart cities. It considers mainly the absence of software architectures based on simulations that are available, flexible, and adaptable to different contexts of cities. In this research, we are more interested in the challenges imposed by Covid-19.

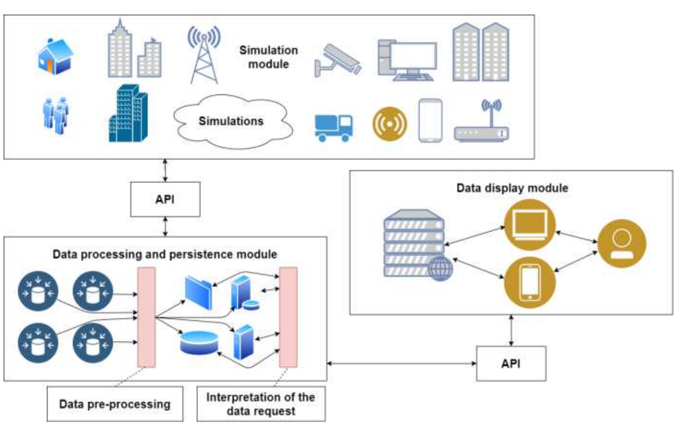

Fig. 11. Simulation-based architecture

Figure 12 offers a view of the implemented solution, using the three modules previously proposed. The first module uses simulations to generate data and build the scenario. The second, using APIs, stores the data in files (.csv) and in the PostgreSQL relational database [21]. Finally, the data visualization module displays the data through dashboards.

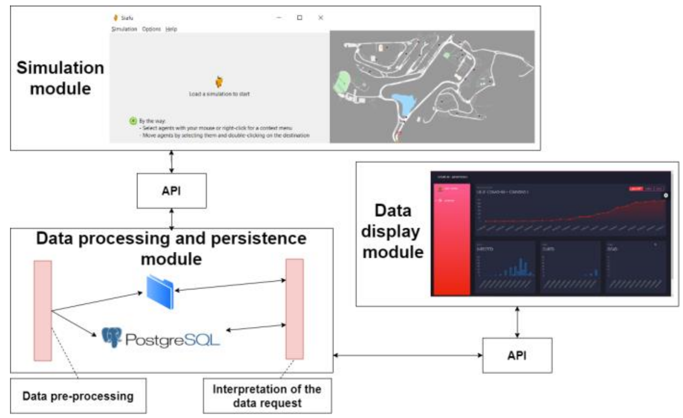

Fig. 12. Simulation-based architecture with applications.

Impacts on transmission given a social distancing strategy are based on the Imperial College Report 12 [23], providing 3 scenarios further to the no action taken. Figure 13. Illustrates Siafu graphical interface when running the built simulation.

In addition to the arrangement of persons on the map, as illustrated in Figure 13, individual information for each person can be seen. It is possible to observe a person who is infected, where he/she is traveling, how many days are left for his/her cure, as well as other information about him/her (indicate in the Figure 13). A video illustrating the simulation of persons moving around the University Campus, as well as the information obtained through the simulation. The data visualization dashboard can be seen at address: https://drive.google.com/file/d/1A1uXwagb3F41RAVU7dkE3gPlc6OPBzuN/view?usp=sharing.

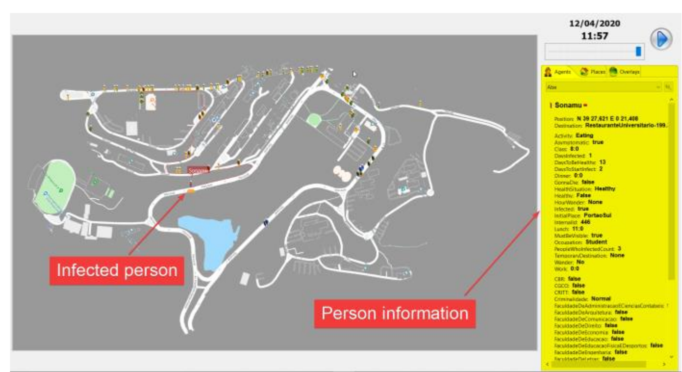

Fig. 13. Siafu execution considering one UFJF scenario.

Figures 13 and 14, and others similar to these, we developed to the City Hall to teach local people the importance of social isolation. Specialists provide the original data idea. In other words, these experiments target to illustrate the scientific importance of staying at home.

Fig. 14. A dashboard screenshot after the university simulation.

IV. Discussion

A public primary healthcare system is well-known by the large number of persons looking for special care. On the other hand, it is usual an insufficient financial support to provide healthcare to everybody. The theoretical balance between the possible health provision and cost easily collapse in a pandemic situation. That was the case which we saw in Brazil, and specially in our state and city. Therefore, this research work effort targeted to tackle part of this issue throughout the approach of gathering digital data. This could represent a best choice of healthcare assignments and avoid unnecessary costs related to professional's people and facilities. This fact was locally observed in the begin of the Covid-19 pandemic.

The Atena research project was born targeting to a digital transformation through the fresh digital data gather from users, which would represent an up-to-date figure of the out-side fog scenarios. Avoiding, for example, unnecessary people movements and frequently cost related to Covid-19 tests. The blood pressure, blood oxygen, temperature and heartbeat parameters can represent an ancillary information to health personal, from unusual patterns from these monitored fogs.

In addition, the *Hold-up* (recommendation system) and simulation environment provided valuables aggregated aspects to the Atena project. The first element shown to be important to provide filters and recommendations to the fog 2 environment, which can be apply to the others fog scenarios. On the other hand, the simulation-base architecture is an especially useful tool, providing interesting and visual results to healthcare experts and ordinary persons.

The implementation science paradigm was observed through our scientific studies of methods to gather the digital data, and strategies to facilitate protocols to the healthcare personal and locally policymakers to have a more broadly view of the Covid-19 pandemic. The evidence-based practice from the Atena opens a large door to discussion of technologies´ improvements, similar to works found in [24,25,26]. In addition, regulatory efforts, examples such as pointed out in [27,28], and different security strategies, as proposed in [29,30], inside the healthcare scenarios policies.

Results from our experiments´ scenarios indicate the success of the proposal and illustrated interesting software tolls facilities and challenges for further developments.

V. Conclusions

In this paper we presented the ongoing Atena proposal. A public primary healthcare environment support by an implementation science approach, which is been utilized for Covid-19 pandemic scenario.

The implementation science of the proposal could be understood through the researcher's scientific studies of methods to gather the digital data, and recommendation strategies to facilitate processes to the healthcare personal. Utilizing evidence-based practice from own experiences.

Experimental scenarios were conceived targeting to learn and tackle challenges from different type of communities, and their characteristics, related to health digital data acquisition.

The evidence-based practices from the Atena´s results open scenarios to discussion of technologies´ improvements and use, regulatory efforts, and security strategies to the healthcare policies, for example in a fight against a pandemic, such as the Covid-19.

Author Contributions: M.A.R.D..- Design of the IoT, Fog-Cloud environments; F.A.C. – Recommendation software conceived features; F.M.M.—Hospital software development; J.M.D- Simulation software engineering design ; A.A.M.M.—hardware prototype and tests; V.S.- Recommendations system software design; M.G.N- Simulation programming and tests; G.I. – Recommendation systems programming and tests; T.G.T- Mobile software development and tests. All authors have read and agreed to the published version of the manuscript.

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Figures

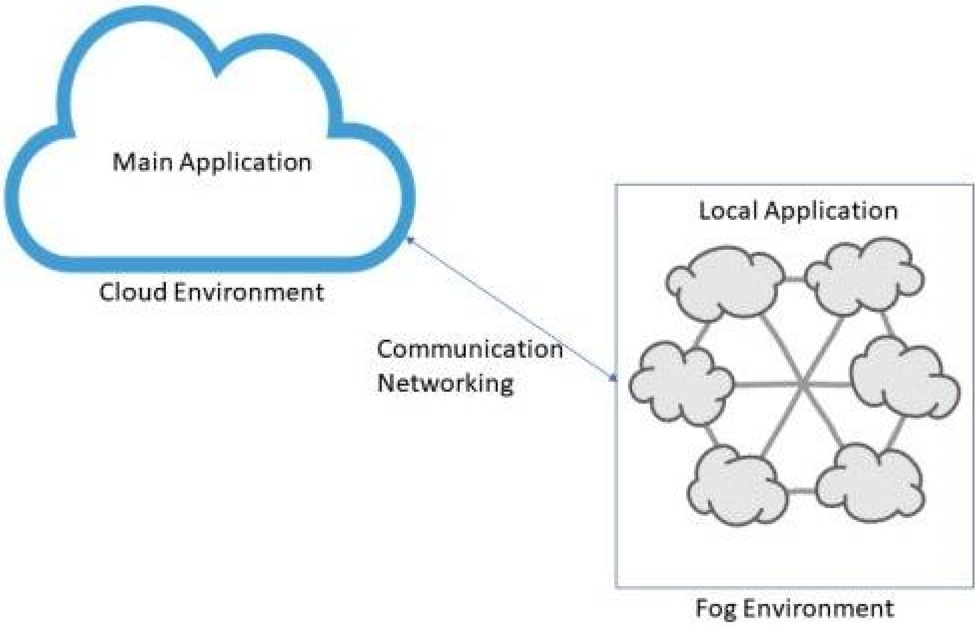

Figure 1

Atena fog-cloud infrastructure

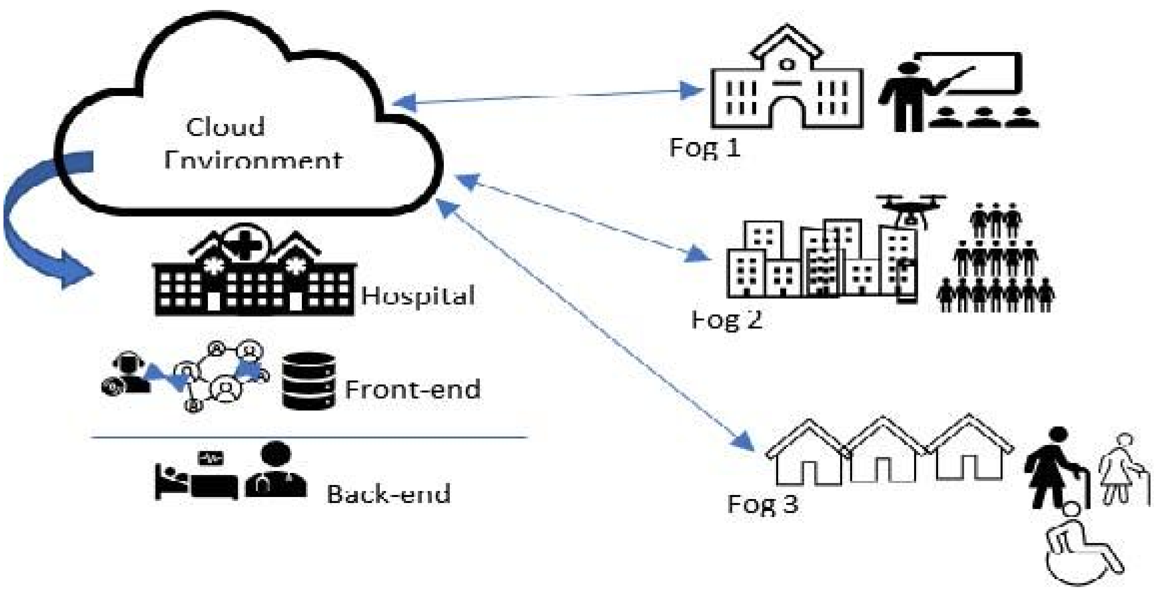

Figure 2

The Atena healthcare architecture

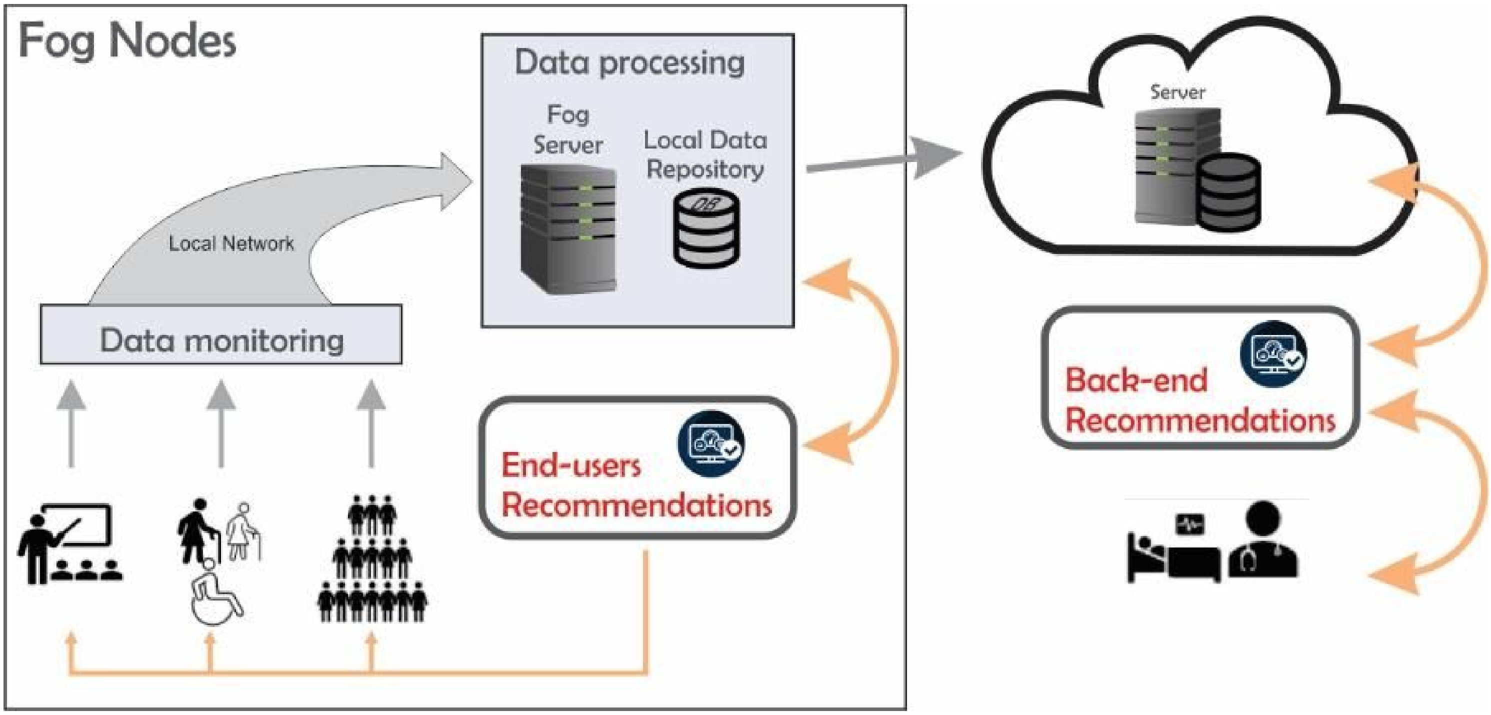

Figure 3

Primary healthcare architecture under the recommendation system perspective

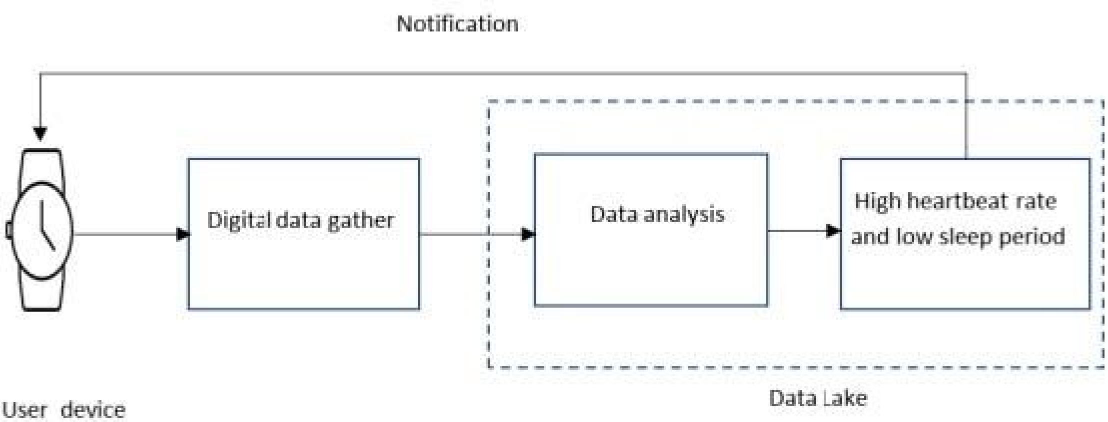

Figure 4

Hold-up RS execution processes view

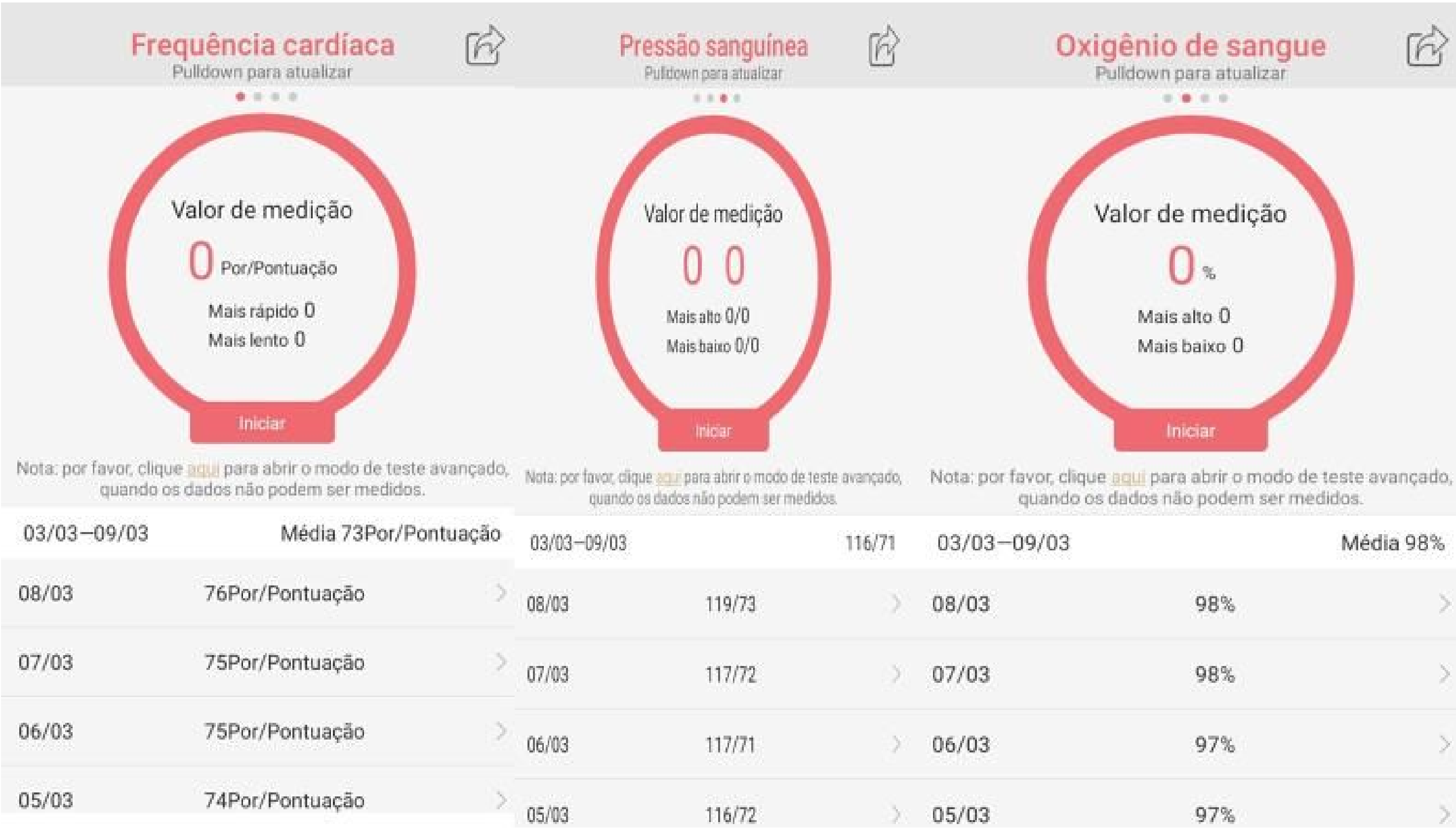

Figure 5

Wearable digital vital signals

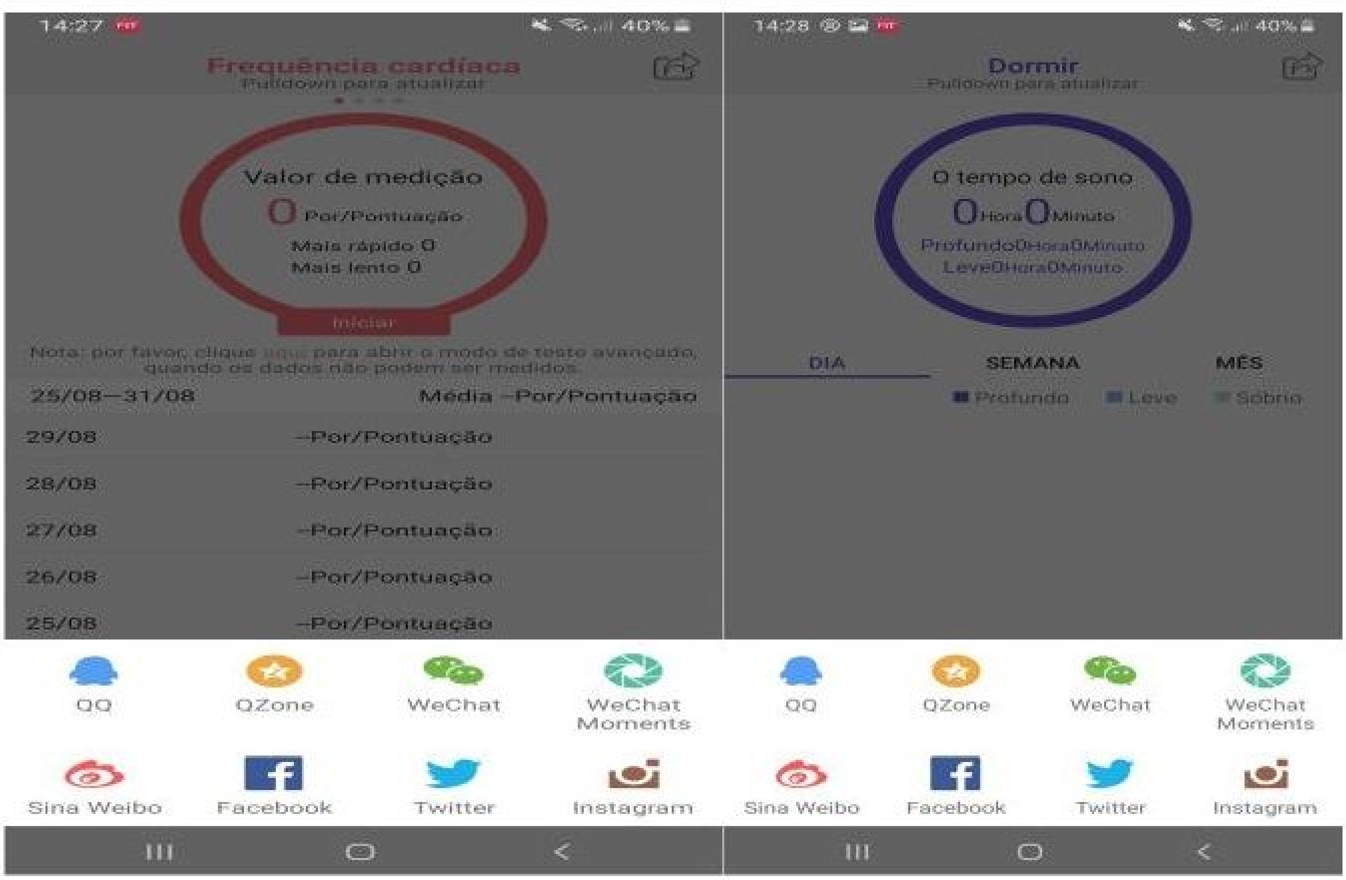

Figure 6

Software packages to share the data from the wearable.

Figure 7

Mobile phone e-Health app features.

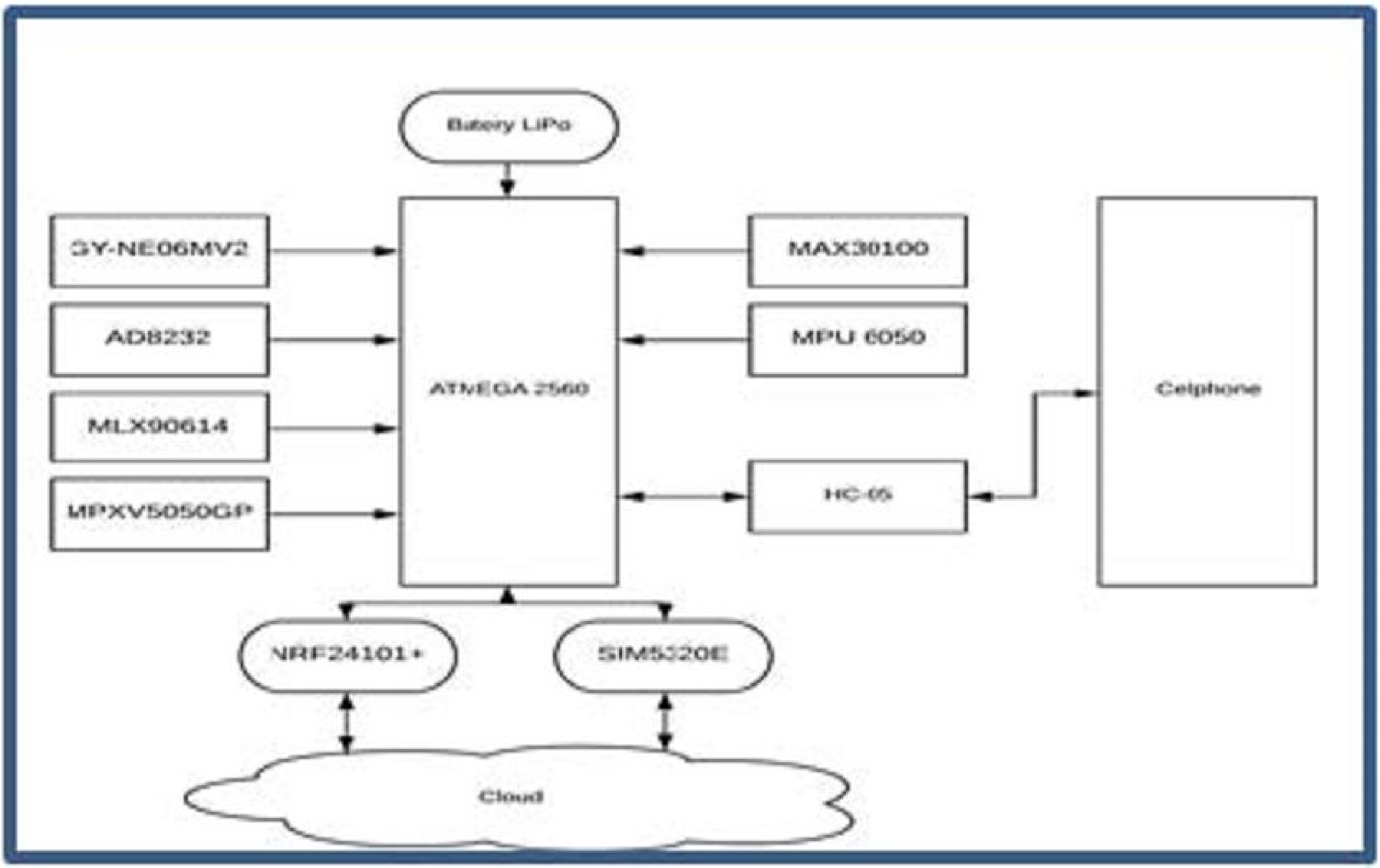

Figure 8

Prototype of the wearable hardware.

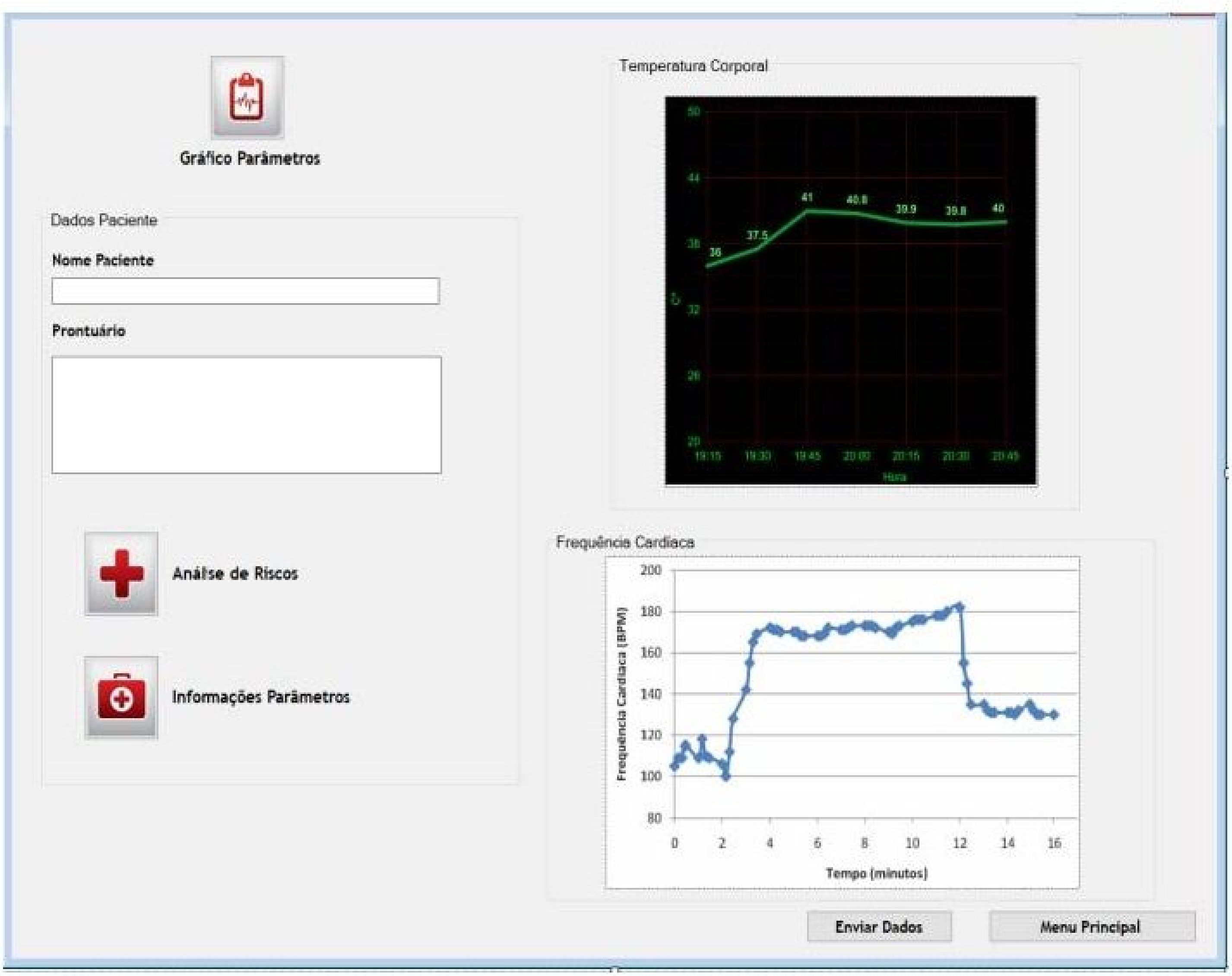

Figure 9

Temperature and heartbeat from patient interface

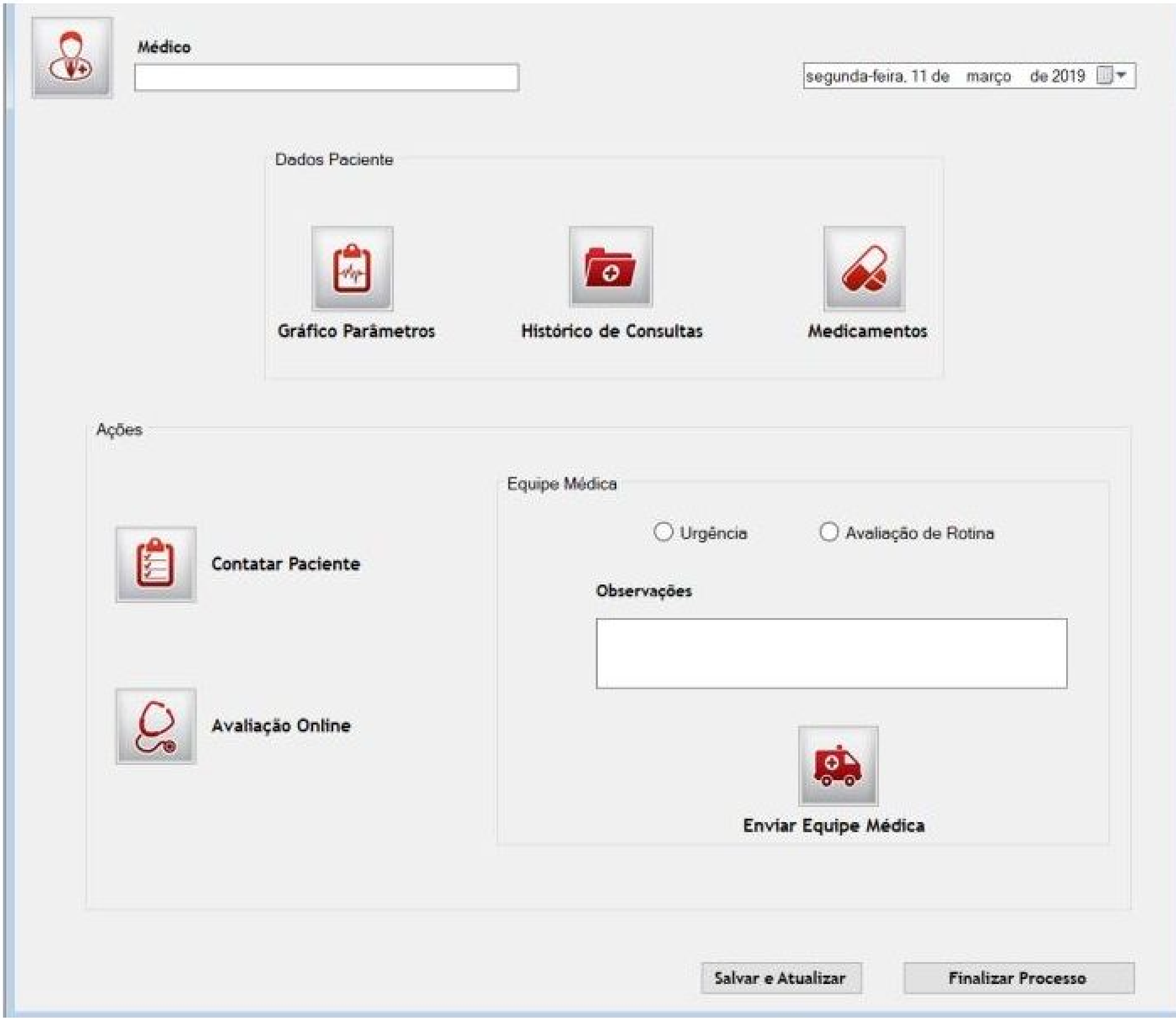

Figure 10

An interface for the Coordinator Doctor.

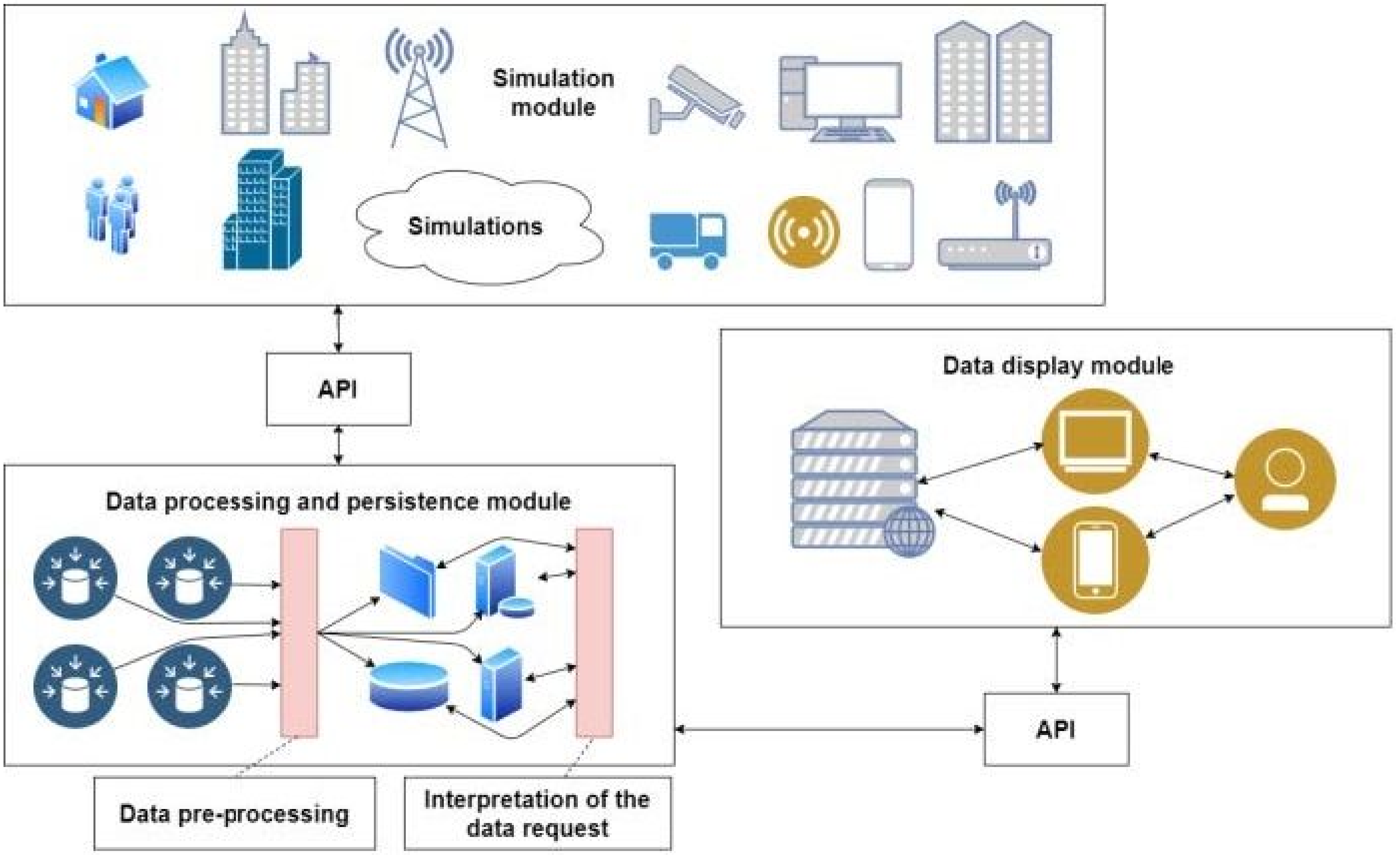

Figure 11

Simulation-based architecture

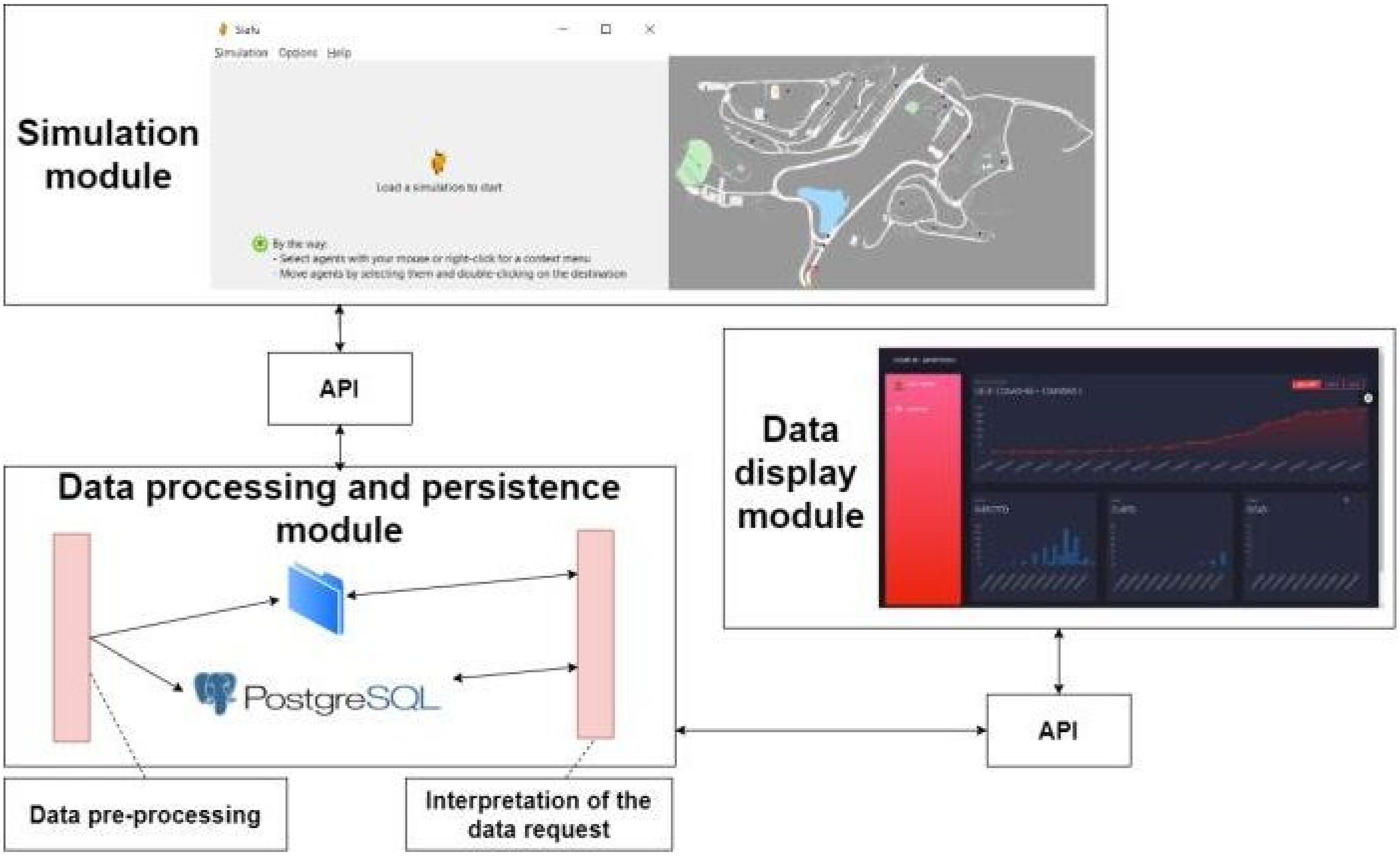

Figure 12

Simulation-based architecture with applications.

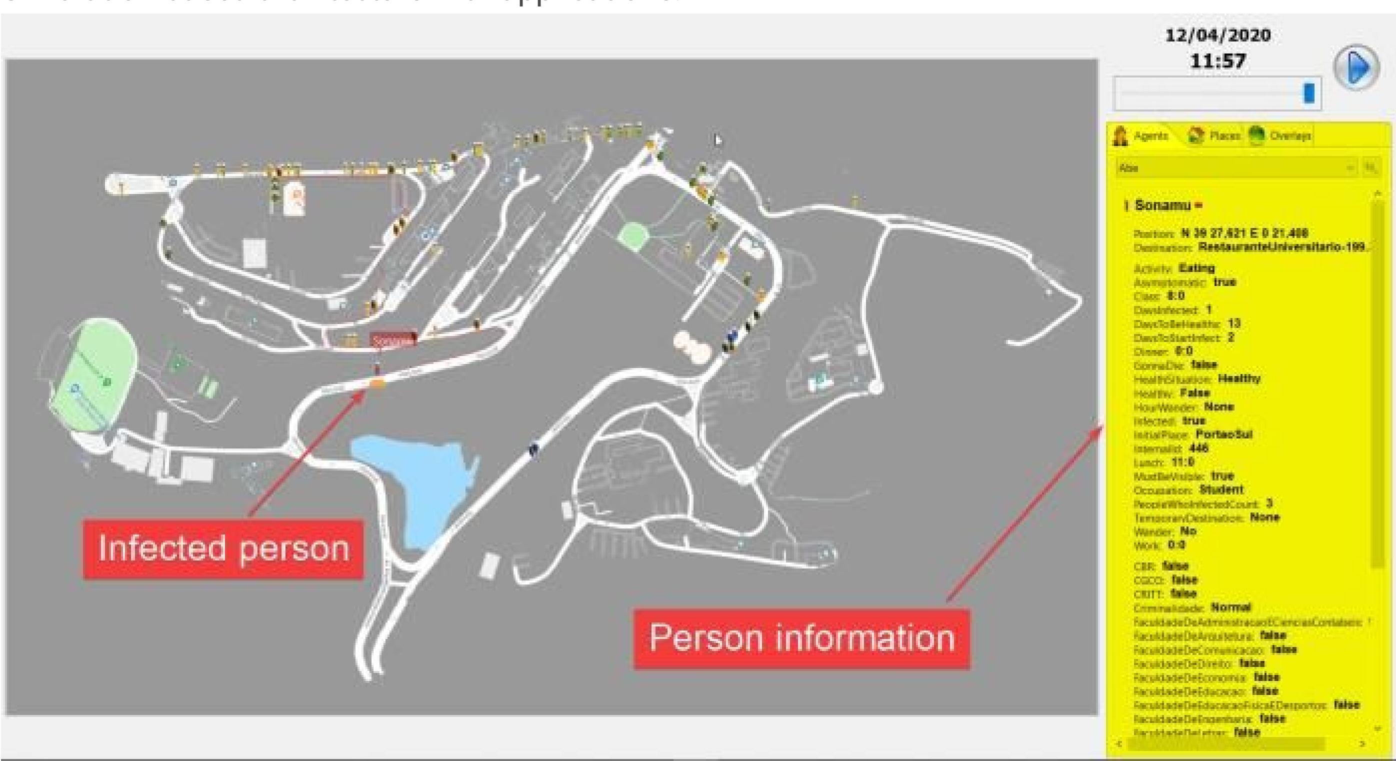

Figure 13

Siafu execution considering one UFJF scenario.

Figure 14

A dashboard screenshot after the university simulation.