UNIVERSIDADE FEDERAL DE JUIZ DE FORA
INSTITUTO DE CIÊNCIAS EXATAS
Bacharelado em Ciência da Computação

IoT Devices in a Cooperative Fog-Cloud Configuration to Support Predictions in a Healthcare Environment

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MONOGRAFIA SUBMETIDA AO CORPO DOCENTE DO INSTITUTO DE CIÊNCIAS EXATAS DA UNIVERSIDADE FEDERAL DE JUIZ DE FORA, COMO PARTE INTEGRANTE DOS REQUISITOS NECESSÁRIOS PARA A OBTENÇÃO DO GRAU DE BACHAREL EM CIÊNCIA DA COMPUTAÇÃO.

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Dedico este trabalho aos meus pais, pelo amor, apoio e sustento.

Resumo

Com a inesperada pandemia provocada pelo vírus Sars-CoV-2, responsável pela doença Covid-19, a população mundial enfrenta um grande desafio e diversas pesquisas estão em andamento para entender mais sobre o vírus, sua forma de disseminação nos ambientes, métodos de prevenção, dentre outras. Mesmo em um curto período, cientistas e pesquisadores obtiveram conclusões e recomendações fortemente testadas e comprovadas para auxiliar no controle da contaminação, sendo algumas delas o uso de máscaras e o distanciamento social. O presente estudo apresenta um esforço de simulação com base em mudanças de hábitos e comportamentos relacionados aos métodos de prevenção e no uso de dispositivos IoT vestíveis para o monitoramento de pessoas que residem em ambientes onde o isolamento social é complexo. Sendo assim, quatro cenários com diferentes formas de prevenção e isolamento são exibidos neste trabalho, onde os dados de saúde dos agentes simulados são coletados para monitoramento e realização de predições. Experimentos executados mostram que os ambientes nos quais os agentes possuem mais hábitos preventivos e onde houve isolamento de agentes infectados obtiveram menores taxas de contaminação.

Palavras-chave: Internet das coisas, Ambientes domiciliares assistidos, Simulação, Covid-19.

Abstract

With the unexpected pandemic caused by the Sars-CoV-2 virus, responsible for the Covid-19 disease, the world population faces a great challenge and several researches are underway to understand more about the virus, its way of spreading in environments, prevention methods, among others. Even in a short period, scientists and researchers obtained strongly tested recommendations to assist in the control of contamination, and some of those are the use of masks and social distancing. This study presents a simulation effort based on changes in habits and behaviors related to prevention methods and the use of wearable IoT devices for monitoring people who live in environments where social isolation is complex. Thus, four scenarios with different ways of prevention and isolation are shown in this work, where the health data of the simulated agents are collected for monitoring and making predictions. Experiments carried out show that the environments in which the agents have more preventive habits and where there was isolation of infected agents got lower contamination rates.

Keywords: Internet of things, Ambient Assisted Living, Simulation, Covid-19.

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"Nós só podemos ver um pouco do futuro, mas o suficiente para perceber que há muito a fazer.".

Alan Turing

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DCC	Department of Computer Science
UFJF	Federal University of Juiz de Fora
IoT	Internet of Things
AAL	Ambient Assisted Living
FaaS	Function as a Service
IS	Implementation Science
NFC	Near Field Communication

1 Introduction

1.1 Problem Description

There are records of pandemics and their effects since the beginning of human history. With the black plague in 1343 and the Spanish flu in 1918, the world population has adapted to new realities and habits to overcome the effects and consequences of unexpected new diseases.

With the outbreak of the Covid-19, which is caused by Sars-CoV-2 virus, experts and the World Health Organization recommended increasing social isolation as the main preventive measure (WHO, 2020).

Nevertheless, there are environments in which isolation and social distance are more complex, which leads in other preventive measures as attenuators in contagion. In some of these environments, such as schools and universities, there is the possibility of interrupting activities. However, in some others such as nursing homes and clinics, social isolation is made more difficult and other complementary measures must be taken. As the transmission of Covid-19 can occur during the incubation period, intensive monitoring is important in people who reside or frequent such environments (LAUER et al., 2020). Since contact with other people is not recommended, one way to perform the monitoring is remotely, using IoT devices.

With the spread of IoT equipment in recent years, several wearable devices with sensors that allow monitoring human health are easily found on the market. Among the main sensors, some of them can capture important information that can assist in the detection of possible contamination. Some of those are smart bands and smartwatches, that are able to capture heart rate, blood pressure, oxygenation level, temperature, among others vital signals.

Due to the huge amount of collected data, filtering and cleaning processes are important to remove useless information and shrink all the collected information. Thus, a fog-cloud cooperative system is proposed to distribute part or all of the task that would be focused in just one application. As consequence, an unique server can stop doing all the work alone, increasing the efficiency of the process (SALAH; DESPREZ; LEBRE, 2020).

In addition to this, the concept Function as a Service is proposed to manage server and to smooth allocating resources and managing servers tasks. In this way, the application can be divided into several functions which are only executed when requested. This type of approach makes the system more scalable and has a better cost-benefit in terms of active processing time (FOX et al., 2017).

Through the large amount of data obtained by wearable devices and the use of Implementation Science concepts, it is possible for computer systems to use learning techniques to make predictions related to a person's health, and thereby assist in preventing the contamination of an entire environment.

1.2 Objectives

1.2.1 Research Question

One of the biggest difficulties faced in this study was how to adapt a computational proposal that adopts IoT paradigms that allow to understand how the spread of the virus occurs in specific environments.

Due to the fact that the health data obtained by IoT devices are from the users themselves and that they tend not to make the data public, there is a great difficulty in the search for databases that meet all the desired characteristics. Therefore, to concatenate Sars-CoV-2 scenario, IoT and environments where social distance is difficult, simulated environments was used.

Using a simulator allows conceiving our IoT paradigm proposal to be adopted and easily demonstrated in indoor Covid-19 contamination, and to reach this objectives, the Siafu simulator was used (NEC, 2007). Siafu is a simulator that allows to control characteristics of locations, behaviors of agents and the entire context. In addition to having technical features that allow total control of the simulation, the simulator also has a graphical interface and allows the creation and transfer of the generated data.

The approximation of the exposed concepts is represented through the simulation which, with divergent preventive measures, allows the collection of agent's health data and an analysis of the effects of each action that was taken. As a consequence, the attitudes and behaviors of agents can be related to the contamination rates of the environment. Finally, the research question is: How to conceive a computational proposal adopting the IoT paradigm to easily demonstrate the indoor Covid-19 contamination?

1.2.2 Main Objective

Research and develop an IoT computational proposal which could help to understand the indoor Covid-19 propagation.

1.2.3 General Objectives

Some general objectives are :

- Realize a survey about up-to-date formulations related to Covid-19 contamination;
- Search for IoT efforts which could be utilize to monitor people;
- Conceive a computational environment which could be better represent indoor contamination;
- Execute computational simulations upon formulations found in the literature and adopting the IoT paradigm.

1.3 Organization

The next chapters are briefly described here. Chapter 2 presents all knowledge and concepts needed for better understanding of this work. This chapter explains Internet of Things, Ambient Assisted Living, Fog-cloud cooperation and Implementation science. Chapter 3 presents related works, their contributions and the relation with the present work. Chapter 4 describes our efforts in setting up the simulation environment, the proposal configurations and all scenarios to process our indoor Covid-19 simulations tested.

Chapter 5 presents the results obtained and discussions. Finally, Chapter 6 describes an analysis of the contributions of this work and future research directions.

2 Theoretical Foundation

2.1 Internet of Things

Internet of Things (IoT) has as its concept the connection and data transferring between physical objects using chips, sensors and software. Any item that has sensors and systems in order to operate in a smart way by exchanging information with other similar items are known as IoT devices. More and more used by population, wearable IoT devices can have several functionalities, from home automation to health control. Smart bands and smartwatches have its use increased in daily life of the population, assisting users, healthcare professionals and telemedicine in general. Most of these smart devices commonly have sensors capable of obtaining data such as heart rate, blood pressure, oxygenation level, temperature, among others.

Even though these devices do not have the same efficiency and accuracy as medical equipment, the collected data can assist in the control of the patient's health and in the discovery of diseases or accidents. Furthermore, several of these devices are small, have low weight and batteries that last for a long time, which makes their use unnoticed by the user.

2.2 Ambient Assisted Living

Ambient Assisted Living (AAL) is based on the use of IoT devices and ways to ensure that elderly people or anyone who needs assistance can have quality of life and independence in their homes. Some of the IoT devices can be represented by wearables, but they are not the only ones in this concept. Other kinds of smart devices are also able to collect information as shown in Figure 2.1, and they can be smart lamps, surveillance cameras, NFC tags, presence and temperature sensors, alarms, smart refrigerators, among others.

Through a learning engine, this type of light surveillance that uses the collected data can provide to stakeholders warnings about breaking on user habits or standards, which can be related to the health and safety of those being monitored. Accompanied by monitoring with wearables, AAL approaches people with perspectives of usability and accessibility. Thus, large amounts of data can be collected to be interpreted (NAZáRIO et al., 2017).

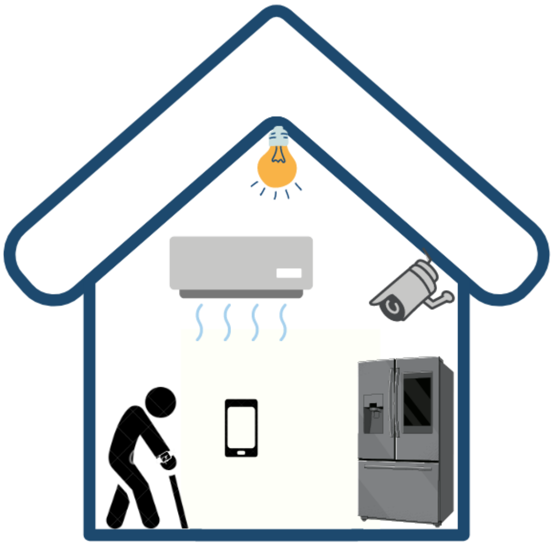

Figure 2.1: Example of smart devices that can collect data

2.3 Function as a Service

Function as a Service (FaaS) is an event-driven computational model that runs in stateless containers. Serverless computing presents interesting features for developers and companies. In these kind of application, the server is fully responsible for allocating resources and managing servers (FOX et al., 2017).

Being developed in this concept, it allows applications to be consisted of many functions. Due to this fact, the server configuration can be reduced and it can quickly increase an application's ability to speed and scale itself in the cloud. Another important point of this concept is the cost-benefit. As functions will only be executed if needed, and in cloud services where the user must pay for minutes of processing, the application will only run if a requisition is send for it.

2.4 Fog-Cloud Cooperation

Cloud computing consists in the possibility of storing and accessing files in addition to providing services through servers spread around the world. Due to the large amount of information collected by IoT devices in the present study, directing all filtering, cleaning and learning processing to cloud services can cause a bottleneck in the effectiveness of the process besides a high financial cost. A fog-cloud environment is based on cooperation between the edges, which are the ends of a determined region, and the cloud (SALAH; DESPREZ; LEBRE, 2020).

In summary, a fog-cloud cooperation is the possibility to distribute part or all of the tasks that would be for a cloud server to several devices in a region. As an example of application of this cooperative system is shown in Figure 2.2, the edges of a fog could be smartphones, computers and local servers of a residence, condominium or even neighborhoods that perform actions on the collected data before sending them forward, thus removing accumulation of processing from the cloud.

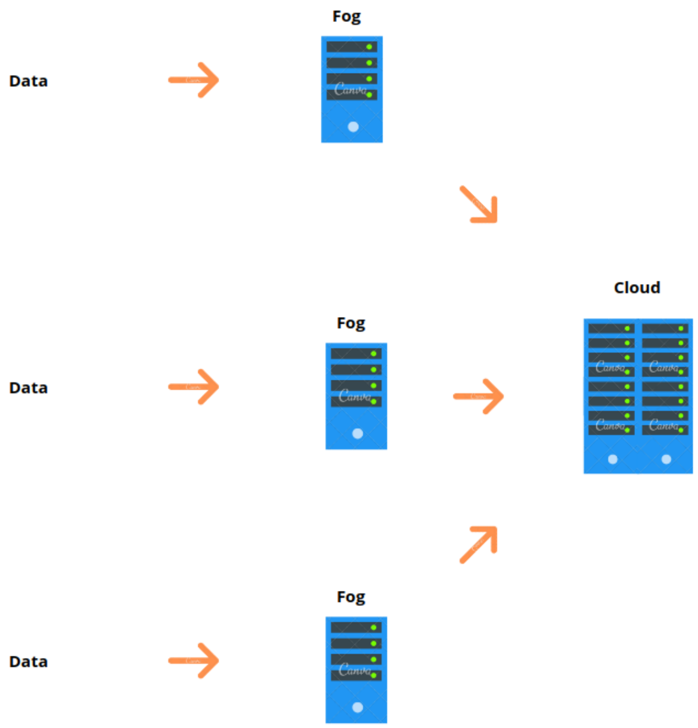

Figure 2.2: Example of a Cooperative Fog-Cloud Configuration

2.5 Implementation Science

"Implementation research is the scientific study of methods to promote the systematic uptake of research findings and other evidence-based practices into routine practice, and, hence, to improve the quality and effectiveness of health services and care." (ECCLES; MITTMAN, 2006)

Even though it is not always used in health concepts, as in (DECAMPS et al., 2020), the initial idea and the main concept of Implementation Science (IS) is focused on the healthcare area. Thereby, the concept of Implementation Science is based on Implementation Research to reach clinical, community and policy contexts using studies to improve the quality and effectiveness of health services, increasing population's quality of life. From other point of view, Implementation Science seeks to understand how citizens, health professionals, healthcare organizations and politics behaviours to find evidence-based strategies to maximize healthcare investments and interventions.

Another important aspect of IS is that it seeks to close the gap between what we know and what we do, always confronting problems and offering solutions for health interventions and evidence based practices.

3 Related Works

The project proposed by (UMILIO; INáCIO; DANTAS, 2019) has as its main objective the protection of data and the privacy of patients who are monitored in AAL. Due to the large amount of important collected data, allowing access to any user of a system is a problem in the privacy and private life of those who are being monitored. For this, an approach of access levels is proposed for each user of the system. Thus, it is possible to allow for health professionals to have access to particular information, such as name and address, while nurses and researchers could only access vital data.

According to his work, it is possible that researchers could have access to important information without violating the patient's privacy. Therefore, a proposal was presented with three modules: Monitored environments, where data collection takes place; Distributed database system, which receives and stores data on different servers; Consultation systems, a web environment for consulting the data. With user access levels to the database, it was possible to maintain the agents' privacy in all tests performed.

Through monitoring activities and use of sensors, (SILVA; STROELE; DANTAS, 2018) proposed the HARA-RS model, a recommendation system approach. Initially, with sensors in the assisted environment and the use of wearable IoT devices, data from accelerometer and user's location are collected. After this, the information is stored, making possible to create a model of each user's routine. In case of detecting irregularities, it is practicable to suggest the user to seek care, to inform about irregularities in sleep, to warn about of sedentary habits, among others.

The HARA-RS architecture is based on 5 layers: Data collection layer, where data is obtained; Transmission layer, responsible for sending the data ahead; Activity detection layer, which interprets the collected information to classify rooms in the environment and recognize activities; Profile and context definition layer, which together with previously informed data, defines the user's profile; Finally, a recommendation layer, which uses a recommendation system to indicate and suggest actions for patients. A preliminary evaluation was carried out to test the model and the data generated by the experiment, reaching the desired objective, according to the authors.

The case study of (SINGH et al., 2020) look at different IoT efforts in the struggle against the pandemic caused by Sars-CoV-2 virus. According to the author, the impossibility of taking care of all infected people can be mitigated through the use of several IoT applications. From the collection of data in smart cities to the use of mobile applications by the population were analysed. The author emphasizes the importance of securing the information collected, as well as the attention on future works related to storage systems that can manage this large amount of data.

Among the examined hypotheses, several approaches seek the integration between different areas that use IoT, such as locating medical equipment in real time to ease service time for people who are in need. There are other ways that also use another lines of research, such as the use of Artificial Intelligence to monitor and track the spread of the disease in cities and the use of medicine to provide remote medical care through monitoring IoT devices. Due to this great amount of possibilities, the author concludes that the use of Internet of Things can helps controlling the spread of Covid-19's disease.

(NASCIMENTO et al., 2020) presents a architecture proposal based on simulation for the development of solutions with IoT applications. The work seeks to allow the development of simulations in different contexts of smart cities and the creation of data through the Internet of Things paradigm. The simulations can have several purposes, from the control of public safety to the health of infected patients, and can use specific scenarios, allowing total control of the environments. Therefore, simulations on the dissipation of the Sars-CoV-2 virus can be performed in many different ways.

Simulations were performed in several environments, including the campus of the Federal University of Juiz de Fora (UFJF). Following the simulation process, it was possible to predict how employees, students and other simulation agents can impact in the spread of the virus, allowing the creation of models to understand how new contamination arises. In addition, the collected data was stored for future work, allowing new studies to be developed.

3.1 Considerations

Through an in-depth analysis of the related works, this study seeks to present the main issues discussed about use of context, IoT and simulation. With the simulation of an environment where social isolation is complex and residents use wearables to collect health information, all information collected must be treated with caution, as personal data says a lot about the user. Thus, with the large amount of data, contexts can be explored, making predictions more effective with specific characteristics for each user. Finally, there is the possibility of increasing the amount of simulated environments, thus expanding knowledge in regions with more people.

4 Materials and Methods

To make a long story short, due to the unexpected outbreak of Covid-19, the limited knowledge of the virus and the sharing of fake news, a large part of the world population had no contact with preventive measures guidelines. With so much divergent information present in the media, a need to associate the more respected and advanced studies on contagion arose. Thus, simulated tests were considered with results found so far.

In addition to the proposed simulation model that is presented in this chapter, the development of the characteristics of the simulated agents, the environment where they reside, the transmission process and the data collection and transmission are described.

4.1 Simulation Environments

In the search for a possible solution, a simulation model for the present work was specified. The scope includes from the collection of data from simulated agents to the computational environment responsible for making the health predictions. In addition to that, technologies like fog-cloud cooperation and the use of FaaS were also expressed in the main idea. The proposed simulation model is shown in Figure 4.1.

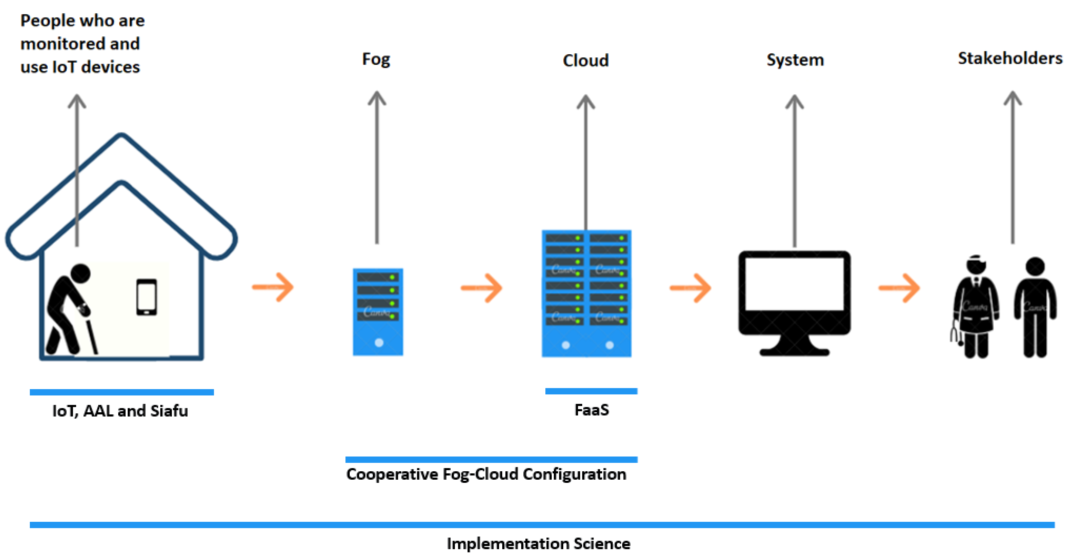

Figure 4.1: Simulation model

In the proposed solution, Siafu Simulator is responsible for simulating the environment where social isolation is complex and the agents, that are the people who need monitoring and use wearable IoT devices in an Ambient Assisted Living. Fogs are devices that correspond to a specific region of agents and their Edges are the mobile smartphones from each agent, that perform computational processes on the agents received information. The cloud uses the Function as a Service concept and is responsible for receiving previously processed information from different Fogs and performing machine learning routines.

In addition, the system represents a web application that has access to the databases located in the cloud and provides predictions, graphs, reports and information that can be used and accessed. The stakeholders in this proposal are the users of the web application who are interested in the generated information, and they can be relatives, doctors, nurses or others health professionals responsible for monitored agents. Finally, the concept of Implementation Science, that assist and support in confronting problems and offering solutions for health interventions and the use of evidence based practices.

Even though they are not present in the image of the proposed model, some important concepts are essential for the consistency of the whole process. Thus, it is important to emphasize the use of security layers to transport the collected information, as they are part of the users' privacy. Moreover, due to the large amount of information, storage systems are also an important part of the model.

For a preliminary appraisal, only the simulation through Siafu, the creation of the data collected by the wearables IoT devices and the mobile application, which works as the Edge of a Fog, were implemented. The environment, the rooms and the characteristics of each agent, just as sleep time, bathroom intervals, and so on, were developed from the beginning. Social distance is complex in this simulated environment, which in this model is a nursing home with 18 agents. No employee or other external agent influences the simulation's progress. The simulated environment consists of six bedrooms, two bathrooms, a living room and a dining room. The described environment is shown in Figure 4.2.

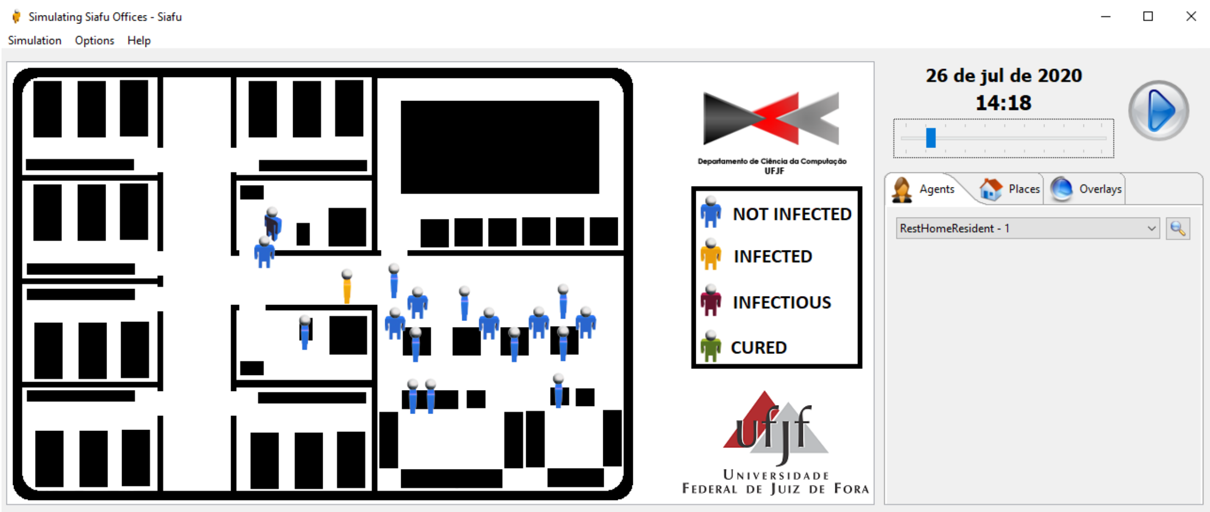

Figure 4.2: Simulation environment

The situation of the contamination in each agent of the simulation is represented by colors. In blue, agents that have not been contaminated. In yellow, those who have the disease but have not yet begun to spread the virus. In red, the agents that can infect others. Finally, the green agents have passed through the disease's timeline and are now cured.

For the beginning of the contamination simulation, it is considered that a single agent has been contaminated and from that moment the simulation is started. This event is considered to be the beginning of the first day. This situation impacts that the result of the contamination has no influence on the number of employees or external agents of the simulation, which is something very variable. In consequence, the contamination depends exclusively on the residents of the house.

The nodes of a fog can be small devices or even local servers. Representing the fog in the proposed simulation model, the mobile application was developed to collect information from wearables, perform cleaning / filtering routines and send these data to the clouds. The application is shown in Figure 4.3, where the main screen and an attempt to connect to an IoT device are displayed.

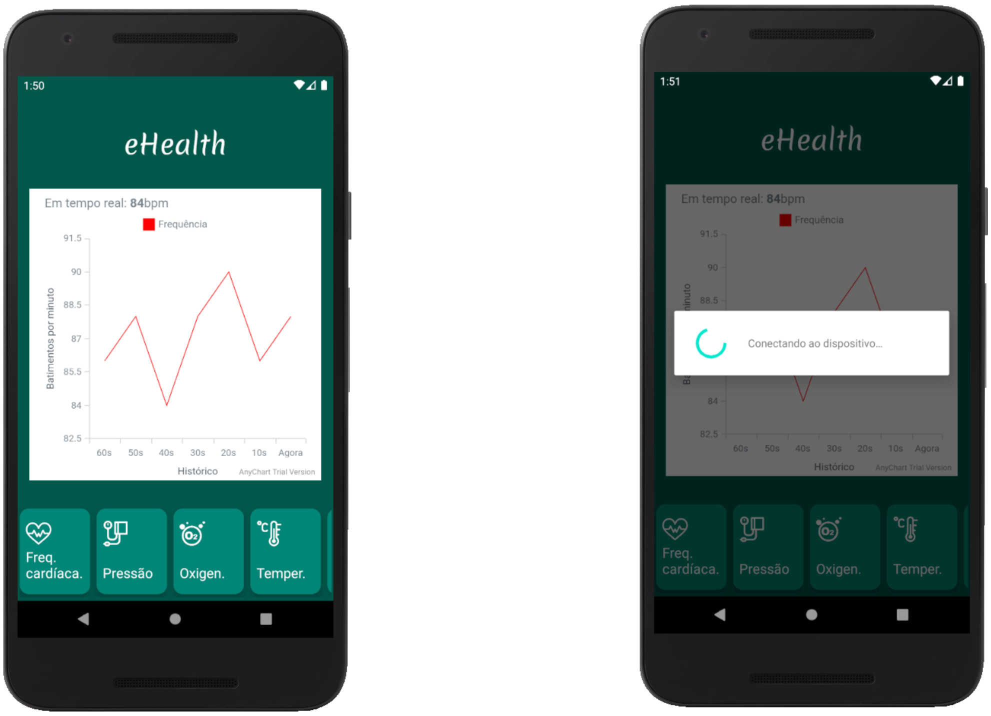

Figure 4.3: Mobile application

4.2 Proposal

To express fidelity in the simulated model, several personalized features were added to the agents. Each one has exact schedules to wake up and sleep, intervals to go to the bathroom and behavior with preventive measures before and after the revelation of the first case in the environment. With the exponential advance of cases, it is common for the population to start changing their habits only when someone near to them is diagnosed and, therefore, the simulation allows parameterizing all these characteristics. In addition, some health data is collected through the use of wearable IoT devices. Among them, it is important to mention heart rate, blood pressure, body temperature and blood oxygenation level.

4.3 Test Scenarios

As a result of the recent Covid-19 pandemic, many researchers and scientists around the world have started studies for learning more about the new disease. Due to different ways in which combat is carried out in each region and country, some figures as percentage of asymptomatic individuals are relatively divergent. For the simulation, it was necessary to compile more reputable and recent studies.

Following the studies of (LIU et al., 2020), (LAUER et al., 2020) and (FERGUSON et al., 2020), the rate of asymptomatic patients for the simulation was adjusted to 30%. So, for every ten infected people, three will be transmitters and the data captured by wearable will not change, preventing the individual from being identified.

According to (CHU et al., 2020), in its systematic review and meta-analysis, the use of N95 masks, classified as PFF2 in Brazil, or even other masks can reduce in a significantly way the chance of contagion. Provided that they are used correctly, studies indicate that as PFF2 masks can reduce the chance of contagion by up to 95 %, while cotton masks can reach 67 %. Another preventive measure analyzed was social isolation, which for a distance of 1 m, reduces the chances of contagion by 82 %. In addition to that, for each additional meter, the risk falls by half. Similarly, another form of protection is the use of eye protection, which also has a significant reduction, reaching values of 78 % of risk mitigation.

The proposed simulation model allows comparison between different situations. From tests on the effectiveness of prevention methods to how the agents' behavior influences the contamination of an environment. Therefore, four environments were prepared to allow the comparison on the habits and practices of the agents as described in Table 4.1, Table 4.2 and Table 4.3.

Table 1 and Table 2 are responsible for categorizing habits and preventive measures in all environments, grouping them in two. On the other hand, Table 3 presents a different approach than the previous ones, separating the previously created groups.

Table 4.1: Habits and preventive measures of agents considering the first case revelation in simulated environments 1 and 3

Habits and preventive measures	Simulated environments 1 and 3	
Period of time about the 1st case revelation	Before	After
Use of PFF2/N95 masks	0%	100%
Use of other kind of masks	50%	0%
Use of eye protection	0%	90%
Average increase in interpersonal distance	0 m	1.5 m

In simulated environments 1 and 3, agents changed their habits subtly after the start of the pandemic, with only 50 % wearing masks before the first case in the environment. The use of PFF2 masks, the use of eye protection and the habit of increasing the distance were ignored by them.

Table 4.2: Habits and preventive measures of agents considering the first case revelation in simulated environments 2 and 4

Habits and preventive measures	Simulated environments 2 and 4	
Period of time about the 1st case revelation	Before	After
Use of PFF2/N95 masks	90%	100%
Use of other kind of masks	10%	0%
Use of eye protection	50%	90%
Average increase in interpersonal distance	1.0 m	1.5 m

In contrast, all agents in simulated environments 2 and 4 used PFF2 or other masks after the beginning of the disease, respectively 90 % and 10 %. In addition to masks, it is important to note the use of eye protection by 50 % of the population and the average increase in distance by one meter.

Table 4.3: Habit of isolating infected agents in simulated environments

Habits	Simulated environments 1 and 2	Simulated environments 3 and 4
Isolation of infected	Yes	No

Furthermore, to increase the precision of the simulation, in environments 1 and 2 when a contaminated agent reaches a clinical picture with symptoms, it is removed from the simulation. In contrast, agents from environments 3 and 4 are not isolated when they experience the first symptoms. Thus, there is no contamination by an agent in which the disease was detected in the first two environments, preventing other agents from continuing their daily routines with an infected agent in which everyone knows its situation.

In all simulated models, the agents' habits and protective measures were similar after the discover of the contamination in the environment. Thus, the diversity and variety between the simulations are found on preventive measures and on the isolation of agents with symptoms. The purpose for these fundamentals is to understand and demonstrate the consequences of the spread of a virus that transmission starts during the incubation period (LAUER et al., 2020).

4.4 Considerations

In this chapter, the proposed simulation was discussed. It is important to note that the environment where the simulation takes place, the varied characteristics for each agent, the global events, the transmission events and the entire process performed after the collection were developed specifically to meet the desired and proposed requirements. In addition, it is important to highlight the assistance of health professionals during the parameterization of the simulated environment.

5 Experimental Environment and Results

During the test period, 50 runs for each of the simulation environments were done and no unexpected problems occurred. All of them were performed on NEC's SX-Aurora TSUBASA (NEC, 2020) computer, witch use vector processors. In all experiments, the agents behaved according to the defined parameters and the values obtained from the sensors, as heart rate, blood pressure, body temperature and blood oxygenation level, were captured successfully.

Some points of interest in the study are described in Table 5.1, Table 5.2, Table 5.3 and Table 5.4. Among them, the average values of contaminated agents before and after the disclosure of the beginning of contamination in the environment. Others points are in figure 5.1, as the amount of simultaneously infected agents. It is substantial to highlight that the exposed average values and the effects of the spread of the disease on the environment are the consequences of preventive habits and isolation.

Table 5.1: Contaminated agents in simulation environment 1

Situation	Contaminated agents in environment 1
Before first case revelation	65.22 %
After first case revelation	2.67 %
Total	67.89 %

Table 5.2: Contaminated agents in simulation environment 2

Situation	Contaminated agents in environment 2
Before first case revelation	11.44 %
After first case revelation	0.67 %
Total	12.11 %

Table 5.3: Contaminated agents in simulation environment 3

Situation	Contaminated agents in environment 3
Before first case revelation	61.56 %
After first case revelation	15.44 %
Total	77.00 %

Table 5.4: Contaminated agents in simulation environment 4

Situation	Contaminated agents in environment 4
Before first case revelation	11.00 %
After first case revelation	14.89 %
Total	25.89 %

According to the results of the executions, it was detected that around 67.89 % of the agents in the simulated environment 1 were contaminated by the end of the simulation. Of the total infected, 65.22 % were contaminated before the first case was found. Otherwise, only 12.11 % of the agents in the simulated environment 2 were contaminated and only 0.67 % oh these were contaminated after the identification of the first case in the environment.

On the other hand, when there was no isolation of agents with symptoms, as in simulations 3 and 4, the amounts of contamination were relatively higher when compared to the first two environments. Thus, 77.00 % of the agents were contaminated in the simulated environment 3 and 25.89 % in the environment 4.

In Figure 5.1, as a result of the contamination that occurred, it is possible to analyze a higher concentration of contamination during the first week in the simulated environments 1 and 3. In addition, with a smaller number of contaminated agents, a smoother distribution occurred along the period in environments 2 and 4.

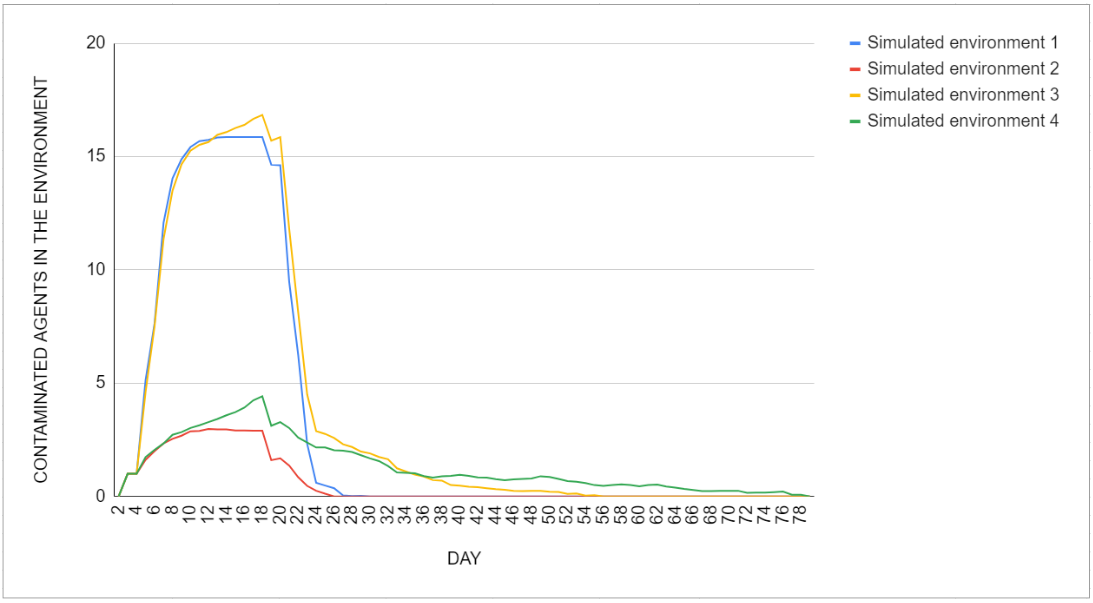

Figure 5.1: Contaminated agents in simulation environments

5.1 Discussion

Different analysis can be performed with the obtained results. When observing environments 1 and 2, it shows that even with different prevention habits, the end of contamination was around the thirtieth day, which is a significantly better result when compared to environments 3 and 4, that the end were after the fiftieth day. Another way of observing the results is when a comparison between environments 1 and 3 is made with environments 2 and 4. The average amount of contaminated agents at the same time in simulations 1 and 3 reaches values up to five times higher than in the simulated environments 2 and 4. This result highlights the need to isolate contaminated agents immediately after identification.

Finally, a closer look to the results reveals that if a merge is done with the best characteristics of both cases, preventive measures and isolation, the best of both worlds is a environment that was already tested. Through the conferences carried out, the simulated environment 2 with previous use of masks and eye protectors, increased distance and isolation of the infected ones presented the best results when compared to the others. With fewer infected agents, it is possible to realize the importance of preventive measures in controlling the spread of Sars-CoV-2 in environments where social isolation is difficult.

6 Conclusion Remarks and Future Works

6.1 Contributions

With the assistance of exposed concepts as Internet of Things, Ambient Assisted Living, Fog-cloud cooperation, Function as a Service, Implementation Science and others, it is possible to perceive some extensions of how this work can be explored. In addition to the advantages of using simulations, with advanced studies on the effectiveness of prevention measures, it was possible to obtain satisfactory results and, even more importantly, to show how important it is to follow the recommendations from World Health Organization and experts.

According to the preliminary evaluation of the model and the simulated environments, it was possible not only to identify the importance of isolation and preventive habits after the discovery of the first case, but mainly the relevance of these same attitudes before the knowledge of the existence of any contaminated agent to facilitate containment of cases.

6.2 Research Directions

For future work, it is intended to implement cleaning and filtering data features in mobile application. Another important tool is the web system for stakeholders, that should be easy to use and provide all necessary information for health professionals. At the same time, due to the huge amount of data, a cooperative fog-cloud system, which implements FaaS, is recommended for the best performance and cost management.

Other studies based on this started until the end of the writing of the first stage of this work. These surveys were divided between the research group from which this one originated and others that are external to the research group. Some of them are based on the digital transformation of the collected data, others are about the amount and quality of the transmitted data. Finally, it is important to highlight that the opportunity of using the concept of Implementation Science in future works increases the possibilities and the confidentiality of these.

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Appendices

A - Published Papers

Covid-19: A Digital Transformation Approach to a Public Primary Healthcare Environment

Authors: M. G. do Nascimento, G. Iorio, T. G.Thomé, A. A. M. Medeiros, F. M. Mendonça, F. A. Campos, J. M. David, V. Ströele, M. A. R. Dantas

Abstract: Digital transformation in e-health is a well-known challenge problem reported from several studies and from several dimensions. In addition, it has been verified a gap in the utilization of new technologies as differential tool in the war against the Covid-19 pandemic. In this paper, we present an ongoing research effort which is characterized for supporting a digital transformation gap found in a public primary healthcare system. Therefore, it can be seen as an interesting case study approach to tackle some challenges found in Covid-19. Utilizing smart bands by groups of different type of voluntaries, where vital signals were collected in a digital data fashion and then evaluated in public health unit. A recommendation system (RS) algorithm was also developed to understand users´ behaviors, based upon their vital signals. In addition, we utilized a simulator software to highlight people movement and predictable scenarios of Covid-19 contamination. This last effort provides a visualization on how the proposal could also help in a real ordinary monitoring scenario. Initial results from this research work indicates a differentiated approach to tackle challenges in digital transformation in a public health scenario, especially in a pandemic. In addition, our experiments illustrate that the adoption of some computational technologies require mainly changes on the present behavior, from governments and people, to be successful approaches to individual protection inside public environments.

ISCC ICTS4eHealth - 2020

Dispositivos IoT em uma Configuração Cooperativa Fog-Cloud para suporte a Predições em um Ambiente Healthcare

Authors: T. G. Thomé, V. Stroele, M. A. R. Dantas

Abstract: The world population faces an unexpected challenge with the Sars-CoV-2 pandemic and several researches are in progress to find ways to reduce contagion. This study presents a simulation effort based on changing habits and the use of wearable IoT devices to monitor and identify cases of contagion in an environment where social isolation is difficult. Thus, four scenarios with divergent prevention methods and the collected data are presented in this article, in which the environment with the most preventive measures and where the infected agents were isolated obtained the lowest contamination rate.

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