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

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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.**

Keywords—Big Data, Covid-19, Digital Transformation, e-Health, IoT, Recommenadion Systems.

I. INTRODUCTION

Based on reports from World Health Organization (WHO) [1,2], the actual challenge of Covid-19 is similar in two hundred and thirteen countries, especially in the computation point of view. The main advice to everyone, based upon health specialists is to stay at home, similar to 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 communication technologies could be key elements for health enhancement and protection of individuals.

On the other hand, beside of the health concerns, and very tight coupled to this problem, the challenge to keep people and economies in an appropriated synchronism is special hard. The IMF states that [3]: to help lay the foundations for a strong recovery, our policy advice will need to adapt to evolving realities. It is important to have a better understanding of the specific challenges, risks, and tradeoffs facing every country ad they gradually restart their economies. How can IMF advise without any health digital data for a proper analytics research?

As it is mention in [4], to really understand big data, it is helpful to have some historical background. It is reported the Gartner's definition, circa 2001 (which is still the go-to definition): Big data is data that contains greater variety arriving in increasing volumes and with ever-higher velocity. In addition, it is stated that big data is larger, more complex data sets, especially from new data sources. These data sets are so voluminous that traditional data processing software just cannot manage them. 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 people behavior.

Digital transformation is one of the main goals of today health field. As it is reported in [5], studies have observations for both the quality of evaluations and the quality of evaluation research. In addition, these researchers observe 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. On the other hand, other research works may provide interesting enhancement in the health area. An example is presented in [6], with a proposal work which represents an energy-efficient and highly accurate toothbrushing monitoring system which exploits IMU-based wrist-worn gesture sensing using unmodified toothbrushes.

Recommendations Systems (RS) are software paradigms that highlight a set of resources to users considering their interest. These systems help users to identify relevant resources available in a large specific repository, according to their tastes, preferences, and requirements [7].

In this paper, we present an ongoing research effort which is differentiated and characterized for: (i) supporting a digital transformation gap found in a public primary health unit targeting Covid-19; (ii) a RS algorithm developed to understand users´ behaviors, based upon their vital signals; (iii) utilizing simulator software to highlight people movement and predictable scenarios of Covid-19 contamination.

The paper is organized as follows. In section II, we present some aspects related to big data, recommendation systems and digital transformation in the e-health field. Section III shows related work and describes the proposed architecture to support a public primary healthcare approach. Section IV shows preliminaries experimental results. Section VI presents conclusions and future work.

II. Big Data, Recommendation Systems and Digital Transformation

In this section, we present concepts related to big data, recommendation systems, and digital transformation for e-health. This is interesting to the Covid-19 pandemic challenges.

A. Big Data

The sensing of an environmental signals, may consider, for example, both the environment and persons, as it shown research presented in [8]. This work provides an example which was developed for an e-health proposal. Results of large amount of useful data from the home and people inside this environment. This research work example was chosen because it is an objective interesting effort which generates a large amount of e-health big data, without exposing person and professionals´ health. In [9], there is a proposal to reduce energy consumption and enhance the battery lifetime and reliability of massive medical data collected by the internet of things (IoT) based on wearable devices. In [10], it is shown an approach, which manages the selection of the cloud service adequate to big data based on its parameters and criteria. Authors applied this approach on a case study context of National Health Service (NHS) of United Kingdom (UK).

B. Recommendation Systems (RS)

Recommendation Systems (RS) are programs that present a set of resources (items, videos, articles, services, among others) to users considering their interests [7]. These systems help users to identify relevant resources available in a large repository, according to their tastes, preferences, and requirements.

Users who consume these resources, available from an environment, are an important part of an RS. Because, through the information of their profiles and contexts, it is possible to recommend resources as adherent as possible to them. As it is stated in [11], the profile of a user is the set of characteristics or standards used to describe him. The authors consider the definition of the user profile for online systems to be especially decisive. Since the profile will enable the capture of their preferences and the recommendation of personalized products and services. Thus, improving their satisfaction when using this environment. When defining the user's profile, the system starts to understand it, therefore improving the experience while using the system environment.

The profile can be extracted in two ways: explicit and implicit. Explicit extraction occurs when the system asks the user to fill in their information, promoting the definition of their initial profile, which can be updated over time. This filling is done through forms, surveys and evaluations of information presented to him. The implicit extraction occurs when the information to define the profile is obtained without an action on the part of the user. In other words, it occurs in a passive way, generally reflecting his behavior in an environment. Systems that use an approach where the profile extraction is performed in a first phase are explicitly common, and at a different time, the extraction is performed implicitly, composing an even more complete profile extraction.

C. Digital Transformation

As it is discussed in [12], health care is facing the challenge of affordability in a growing and aging population. The authors argue that the progress in data-enabled precision medicine is beginning to transform traditional linear models to an environment of multi-sided market variants. In this scenario, healthcare *providers* (examples are hospitals, pharmaceutical companies, doctors), on the one side, and healthcare *payers* (governments, insurance companies, patients) on the other requires to have a balance between the best possible health provision and cost. The researchers also observe that the future healthcare affordability, patient experience, treatment efficacy, healthcare capacity, and system efficiency will all depend on the success of health information exchange platforms and the leveraging of electronic health records.

The work present in [13] provides an interesting view how to govern the digital transformation of health services. The authors mention that similar to other innovations and (new) technologies, such promises could or could not materialize and potential benefits. In addition, it is also highlight that may also be accompanied by unintended and/or negative (side) effects in the short or long term. As a result, observed by the authors, the introduction, implementation, utilization, and funding of digital health technologies should be carefully evaluated and monitored. The document brings an important aspect that governments should play a more active role in the further optimization both process of decision making (both at the central and decentral level) and the related outcomes. Authors also argue that governments need to find a balance between centralized and decentralized activity. Moreover, the broader preparation of the health care system to be able to deal with digitalization. It is mention that the threshold rises from education, through financial and regulatory preconditions, to implementation of monitoring systems to monitor its effects on health system performance remains important.

III. Related Work and Proposed Architecture

The previous section clearly let us to infer that to differentially tackle the challenge of heath digital transformation, the adoption of new technologies must be carefully employed. Therefore, this section represents the first step on this paper contribution. Because, it highlights how we conceive a modern environment design to support a public primary healthcare monitoring.

The approach to be tackle was the ordinary idea of cloud computing facilities and infrastructure. Therefore, we present some recent efforts found in the literature, examples are [14,15,16] which are related to the fog-cloud environment cooperation. This cooperation is a vital element inside an architecture to collect and gather large amount of digital data.

In [14] it is stated that to support the large and various applications generated by the Internet of Things (IoT), fog computing was introduced to complement the cloud facilities. Thus, it offers cloud-like services at the edge of the network with low latency and real-time responses. Authors also mention that large-scale, geographical distribution, and heterogeneity of edge computational nodes make service placement in such infrastructure a challenging issue. Diversity of user expectations and IoT devices characteristics also complicate the deployment problem.

On the other hand, a study on the workload offloading problem to fog computing networks is presented in [15]. This work suggests that a set of fog nodes can offload part (or all) the workload originally targeted to the cloud data centers to further improve the quality-of-experience (QoE) of users. Authors also investigate two performance metrics for fog computing networks: users' QoE and fog nodes' power efficiency.

An interesting research presented in [16] mentioned that the traditional cloud-based infrastructures are not enough for the current demands of Internet of Things (IoT) applications. Authors claim that two major issues are the limitations in terms of latency and network bandwidth. In addition, authors call the attention that in recent years, the concepts of fog computing and edge computing were proposed to alleviate these limitations by moving data processing capabilities closer to the network edge. They also mention that considering IoT growth and development forecasts, for the full potential of IoT can, in many cases, only be unlocked by combining cloud, fog and edge computing. Authors also highlight developments and possibilities as well as consider challenges for implementation in the areas of hardware, machine learning, security, privacy, and communication.

In figure 1, it is illustrated a successfully adopted new paradigm (from one our previous research) to connect locally devices through a fog environment and then to a cloud infrastructure [17]. Advantage of this approach are several, including capture of personal distributed data health, possibility to local storage, possibility of use of local AI applications, data clean locally, facility of gather several data sources and then submit to the cloud. These facilities enhance the quality of data that will be uploaded to the cloud, therefore providing a more accurate information about the edge points in the fog environment.

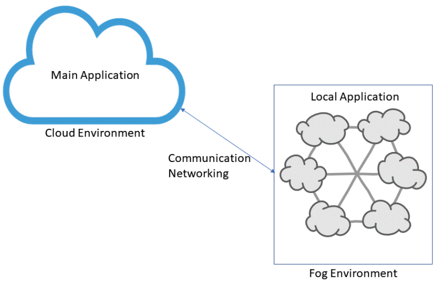

Figure 1: Proposed fog-cloud infrastructure

After chosen which type of communication network paradigm was the most appropriated infrastructure, the public primary health care architecture conceived is presented in figure 2. Relevant to mention that our case study efforts were born from Federal Brazilian Government proposal call targeting public services polices. Therefore, our proposal is oriented to (i) health information exchange for public services and (ii) a balance between centralized and decentralized activity, important challenges highlighted in related works [12,13].

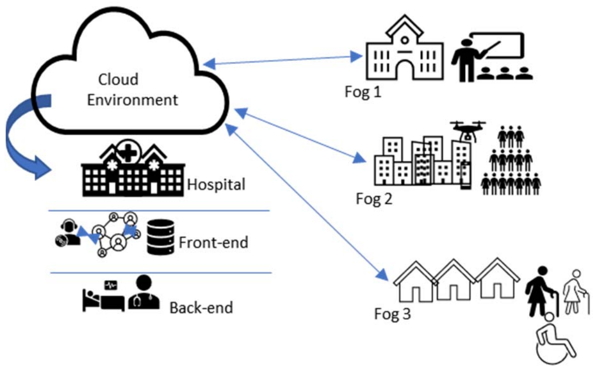

Figure 2: The public primary health care architecture

In our architecture we have three different type of fog environments:

- Fog 1: in this group we considered six students from a university, which spontaneous collaborate with our research to be monitored inside some duties.
- Fog 2: this second group was a group from poor communities (or slums). People with different age, sex, and health conditions.
- Fog 3: in this group we considered elderly people from, for example, retired homes and people with disabilities. In addition, local computer and mobile facilities were considered.

One of the main reasons for these diverse fog's classification is based a scientific observation from previous research works, such as those presented in [18]. The effort of an evaluation of quality of context is minimized when an appropriated environment is designed with the peer actors. In other words, we were effectuating an important preprocessing action for assistant's frond-end inside the hospital.

The next stage was to design how the data 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 frond-end and another back end. Similar to computer science jargon, the first element receives and preprocess the received digital data. The second level, coined as back end, is the location for a doctor responsible for the central monitoring and assignments.

As it is presented [13,14], a conceived public primary healthcare environment may provide the following facilities:

- A balance between the best possible health provision and cost. Because, gathering digital data could enhance the best choice of assignments and avoid unnecessary costs with professional's people and facilities, as the Covid-19 pandemic.
- The fresh digital data gather from users would represent an up-to-date figure of the out-side scenarios, from the fogs. Avoiding, for example, unnecessary Covid-19 tests from persons.
- This innovation with new technologies, could materialize potential benefits in terms of data

storage for future differential data analytics, utilizing new AI software packages.

IV. Experimental Results

In this section, it is presented experimental results from our ongoing project. Therefore, we are going to present four elements of the architecture. Fog environments are the first three ones, followed by the fourth scenario representing the real hospital. This choice was based upon the level of technology familiarity from persons involved experiments.

A. Fog 1 Scenario

In this space students from one university were monitoring targeting to capture their vital signals. A recommendation system, called as *Hold-up* [19], was implemented students submitted to it. The *Hold-up* RS execution steps, as illustrated in figure 3, detects heart rate oscillations through sensors and defines the student's emotional profile and context. Variations in heart rate may indicate stress situations that, when uncontrolled, impact student's performance during university activity. The results point to the feasibility of the proposal and the comments provided positive indications that this approach can be used in educational environments.

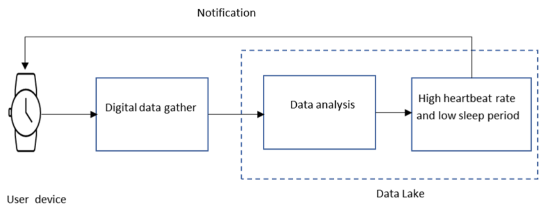

Figure 3: Execution steps from the *Hold-up* RS.

The digital data collected from six students, as shown in Table I. This table presents 3 cases (different type of examinations) 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 were calm in all measure's cases. Other 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

B. Fog 2 Scenario

In the Fog 2 we considered a population from a poor community, where devices with complexity to setup and high cost do not correspond to their reality. Figure 4 show outputs from their devices related to heartbeat, blood pressure and oxygen.

Figure 4: Heartbeat, blood pressure and blood oxygen from Kaihai IP68

Because of the necessary friendly interface, we perform a search for smart bands with the best cost benefic, which could fulfill our requirements of simplicity and open digital data. The devices bought for their experiments were the Kaihai IP68. On the other hand, they could provide an easier way to gather the personal data. They provide facilities to an open access of the data by third parties applications, as shown in figure 5.

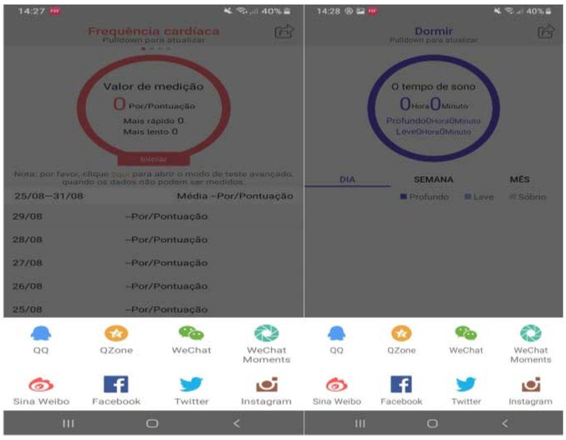

Figure 5: Facility to shared the data from the smart band Kaihai IP68

C. Fog 3 Scenario

Due to the characteristics from the people inside this fog configuration, we decide to develop an application, called as IoT App. The goal was to have the IoT App in the mobile phone, and which could help in the query to execute synchronizations (e.g. heartbeat, blood pressure, blood oxygen, steps, sleep, and emergence). These parameters can indicate interesting signals for the Covid-19 to health professionals which are remote monitoring these persons. Figure 6 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 the tests with some smart band devices.

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. The diagram from figure 7 illustrates the components used in building the prototype. A microcontroller Atmega2560, it works with voltages between 5v and 20v, which facilitates the supply by means of small rechargeable batteries.

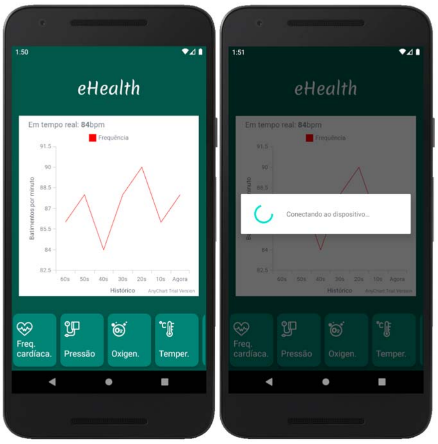

Figure 6: Mobile phone IoT APP facilities and connecting to a device.

The power for the microcontroller, sensors and communication module used in this research was the LiPo battery of 7.4, 2500 mAh. It was chosen for its portability, to have approximately 9cm X 2cm X 3.5cm, in addition to weighing only 0.214 Kg, ease of use and long service life. Although the microcontroller is highly efficient, it does not have wireless communication. For this, we chose to use the HC-05 Module, because it has a reasonable energy efficiency, compatibility with the microcontroller and ease of implementation. 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 prototype is in the stage of final implementation and will be utilize by people form this Fog 1.

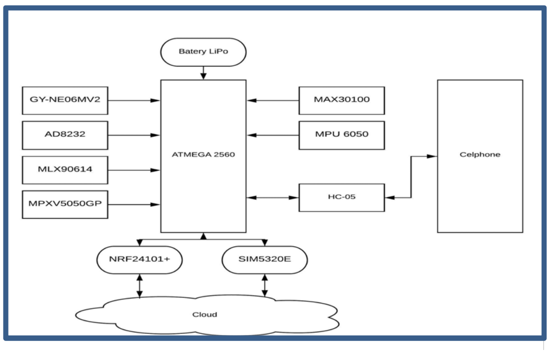

Figure 7: The developing smart band hardware prototype.

D. Hospital Scenario

The hospital scenario was the public hospital, which in the end of the day will be the healthcare providers for the Covid-19, as mention in reference [12]. The partner from the research was a public hospital in the city of Juiz de Fora, in Brazil, which clearly understand the goal and benefits from a e-health digital data. 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 and the public hospital).

In figure 8 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 hundred kilometers from the hospital in a Fog.

Important to mention that all those experiments were realized utilizing the digital data from the researchers involved in this effort. The hospital side is a replication of the real environment that exists in their environment. The return from the personnel from the hospital has been incredibly positive. However, the regulatory preconditions (as mentioned in [12]) exists and are barriers to be transposes.

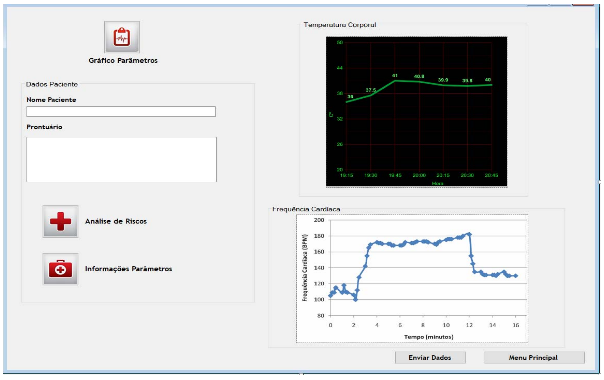

Figure 8: An interface example of patient temperature and heartbeat

E. University Scenario

The UFJF has the main campus in the city of Juiz de Fora, which is a city in southeastern Brazil, with a population around five hundred thousand people. As the main city from a mesoregion, called Zona da Mata of the state of Minas Gerais, it provides a healthcare supports for around a million and half people. Therefore, this period of Covid 19 the City Hall with the university researchers are developing cooperation to tackle several problems. Most hospitals in the city are public.

The UFJF has around nineteen thousand students in an area of one million and three hundred square meters. Therefore, our group were invited to execute simulations for the Covid-19, considering the university as a neighborhood with the students as the local citizens. The figure 9 represents the university campus map and shows a simulation of student's movement inside the campus, considering several infected people. This environment is a screen shot from the Siafu simulator [20]. Executing this simulation was possible to generate an interface example, as it shown in figure 10, with the number of infected, cured, and dead persons. All pictures from this figure are based upon a set of data from specialists of the UFJF-City Hall cooperation, which provide the local input parameters.

Figures 9 and 10, and others similar to these, we developed to the City Hall to teach local people the importance of social isolation. The original data idea was provided by specialists. In other words, these experiments target to illustrate the importance to stay at home.

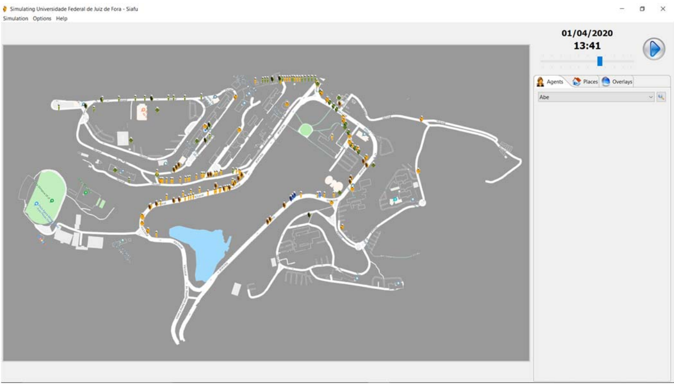

Figure 9: The university campus as a neighborhood and students´ moviment.

Figure 10: An interface example with the number of infected, cured, and dead.

As researchers we are happy helping in this effort. However, a necessary question must arise: why not to have a real digital data from all those students to provide a better public primary healthcare environment and help to avoid difficulties situations found in the Covid-19?

V. Conclusions and Future Work

In this paper, we present an ongoing project which target to help the gap to collect vital signals as digital data to be utilized on a public primary healthcare unit. This is especially true for the Covid-19 pandemic. Different fogs environments were configurated, with different type of persons, in different environments to better understand and help challenges to hospital digital data gather, communication, and policies issues.

Some efforts as future work actions (which are underway) are: (i) the empirical tests of the smart band hardware prototype (ii) a large effort in terms of search for a more appropriate commercial smart bands in terms of cost benefit; (iii) enhancements on the IoT App to connect a set of mobile devices to the selected smart bands; (iv) the execution of the recommendation system *Hold-up* in all fogs from the architecture; (v) realize other experiments in Covid-19 health units, example the university hospital.

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References

[1] WHO, http://www.who.int/emergencies/diseases/novel-coronavirus-2019 accessed in June 2020;

[2] WHO,https://apps.who.int/iris/bitstream/handle/10665/331685/nCoVsitrep01Apr2020-eng.pdf, accessed in June 2020

[3] IMF, http://www.inf.org/en/Topics/imf-and-covid19 accessed in May 2020

[4] Oracle, https://www.oracle.com/big-data/what-is-big-data.html, acesseded in June 2020

[5] Andrew Burton-Jonesa, Saeed Akhlaghpoura , Stephen Ayreb , Payal Bardec , Andrew Staibd , Clair Sullivan: Changing the conversation on evaluating digital transformation in healthcare: Insights from an institutional analysis, Information and Organization, V30 (1), March 2020.

[6] C. Luo *et al.*, "Brush like a Dentist: Accurate Monitoring of Toothbrushing via Wrist-Worn Gesture Sensing," *IEEE INFOCOM 2019 - IEEE Conference on Computer Communications*, Paris, France, 2019, pp. 1234-1242.

[7] Saurabh Kulkarni, Sunil F. Rodd, Context Aware Recommendation Systems: A Review Of The State Of The Art Techniques, Computer Science Review, V 37, August 2020, 100255,

[8] Madalena Pereira da Silva, Alexandre Leopoldo Gonçalves. Mário Antônio Ribeiro Dantas: A conceptual model for quality of experience management to provide context-aware eHealth services. Future Gener. Comput. Syst. 101, 1041-1061 (2019).

[9] T. Zhang et al., "A Joint Deep Learning and Internet of Medical Things Driven Framework for Elderly Patients," in IEEE Access, vol. 8, pp. 75822-75832, 2020, doi: 10.1109/ACCESS.2020.2989143.

[10] Fatima Ezzahra Mdarbi, Nadia Afifi, Imane Hilal, Hickam Belhadaoui, An Approach For Selecting Cloud Service Adequate To Big Data Case Study: E-Health ContextInternational Journal of Computer Science and Information Security (IJCSIS), Vol. 16, No. 8, August 2018

[11] Gatziolis, K.; Boucouvalas, A. C. User Profile Extraction Engine. Proceedings Of The 20th Pan-Hellenic Conference On Informatics - PCI'16, P. 1–6, 2016.

[12] Tardieu H., Daly D., Esteban-Lauzán J., Hall J., Miller G. (2020) Case Study 2: The Digital Transformation of Health Care. In: Deliberately Digital. Future of Business and Finance. Springer, Cham

[13] Ricciardi,W.,Barros,P,Bourek,A.,Brouwer,W.,Kelsey,T.,Lehtonen, L. Expert Panel on Effective Ways of Investing in Health (EXPH), How to govern the digital transformation of health services, *European Journal of Public Health*, Volume 29, Issue Supplement_3, October 2019, pp 7–12.

[14] Salaht, F., Desprez, F., Lebre, A., An Overview of Service Placement Problem in Fog and Edge Computing, ACM Computing Surveys, Vol. 53, No. 3, Article 65. Publication date: June 2020.

[15] Du, Jianbo & Zhao, Liqiang & Feng, Jie & Chu, Xiaoli. (2017). Computation Offloading and Resource Allocation in Mixed Fog/Cloud Computing Systems with Min-Max Fairness Guarantee. IEEE Transactions on Communications. 1-1. 10.1109/TCOMM.2017.2787700.

[16] Yong Xiao and Marwan Krunz, QoE and Power Efficiency Tradeoff for Fog Computing Networks with Fog Node Cooperation, IEEE INFOCOM 2017 - IEEE Conference on Computer Communications, pp. 1-9, 2017.

[17] Mario A.R. Dantas,Paulo Eduardo Bogoni, Paulo José de Freitas Filho: An Application Study Case Tradeoff Between Throughput and Latency on Fog-Cloud Cooperation, International Journal of Networking and Virtual Organisation, Vol. 23, No. 3, pp.247-260, 2020.

[18] Débora Cabral Nazário, Pedro J. Campos, Eduardo C. Inacio, Mario A.R.Dantas,: Quality of Context Evaluating Approach in AAL Environment Using IoT Technology, CBMS 2017, pp 558-563, 2017.

[19] Gabriel Silva, Victor Stroele, Mario Dantas, Fernanda Campos: Hold Up: Modelo de Detecção e Controle de Emoções em Ambientes Acadêmicos, Brazilian Symposium on Computer in Education, 2019.

[20] Siafu Simulator, http://siafusimulator.org , accessed in June 2020.