Toward a Digitalized Holistic and Integrated Healthcare Vision Driven by Deep Learning and IoT

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Abstract: Internet of Things, deep learning, and smart Healthcare are terms that have been very popular over the last decade, with hundreds of searches being conducted around the world on one or more aspects related to all three words. Some of them are surveys on the use of Deep Learning in Healthcare, and others are surveys on the use of Deep Learning in sensor networks; some have focused on the emergence of IoT in Industry 4.0 for the Healthcare sector or deployment of deep neural network architecture in sensor networks. The present work is a shortcut to several studies on different aspects, all dealing with three elements mentioned above, giving a critical analysis of missed aspects or which would be bringing more value to these works.

1 INTRODUCTION

Deep Learning, IoT, and smart Healthcare have been increasingly co-existing and cooperating in the last few years.

Indeed, the fast progress in technology that the world of data has experienced, specifically the emergence of management, storage, and processing of voluminous data platforms, contributed to this. This volume, which wasa significant challenge for infrastructure that existed not very long ago, is itself a valuable asset that has given the height of artificial intelligence technology with all its sub-domains, particularly Machine Learning and Deep Learning.

This huge volume of data is also due, among other sources, to the connected objects explosion with arrival of IoT concept, which is one of the areas that have experienced an exponential emergence and development of fastest in history of information technology, with more than 50 billion devices at the end of the previous year 2020 (Ray et al., 2016). This field [(Abawajy & Hassan, 2017)] hasa wide range of use cases, from industry, telecommunications, entertainment, smart cities, smart homes to one of the most sensitive areas for humanity; I refer to the field of health and medicine, continues to generate interest and is driving studies and research, especially in the age of industry 4.0.

Our interest focuses on the intersection of these three technologies, in particular deep learning techniques applied to data collected from connected medical objects, which is an Artificial Intelligence aspectfor the internet of medical things IoMT.

The present work offers a shortcut to studies and research related to one or two elements of the triplet of our paper (DL, IoT, and Healthcare), with the purpose to summarize, analyze and discuss research addressed in this work; moreover, we will bring out points and axis that these researches could have strengthened, that can open new researches perspectives.

This paper is structured as follows, after introduction, section 2 presents methodology followed, Section 3 discusses the core ofthe work, namely the presentation of related work, discussion and criticism with the opening of new horizons and new research axis and, then a conclusion and references used to construct this paper.

2 METHODOLOGY

The survey in this article is conducted as follows: After identifying an extensive collection of articles from 2016 to 2020. An in-depth reading has been done with a view to identifying the essence of concerned article, article type and, key points addressed.

After, a cross-analysis was carried out on all of these summaries, which allowed us to identify the

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shortcomings in the insights discussed above and to conclude the need for a shortened point to these research panoplies presented in our paper; figure 1 summarizes said methodology.

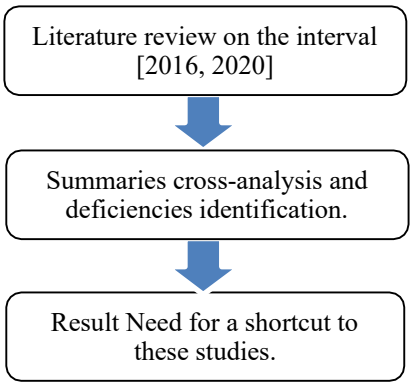

Figure 1: Followed methodology

3 SURVEY: LITERATURE AND CRITICAL ANALYSIS REVIEW

In (Gavrilović & Mishra, 2020) paper's, the software architecture part dedicated to the IoT for Healthcare was addressed. They first proposed a global architecture for all sectors potentially affected by IoT, as shown in Figure 2.

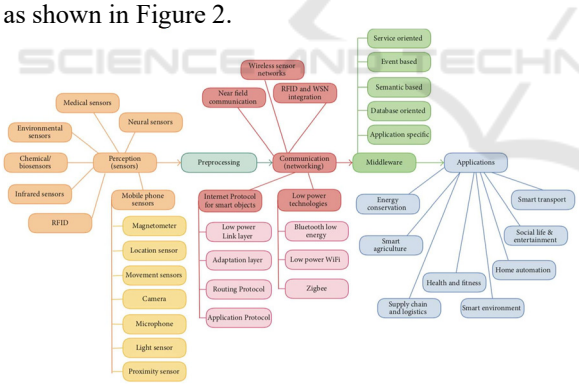

Figure 2: Global IoT architecture for a variety ofindustries (Sethi & Sarangi, 2017)

They then proposed dedicated architectures for three sectors: Smart Cities, Healthcare, and Agriculture.

They also emphasized the importance of using a software architecture dedicated to the Healthcare sector, as shown in Figure 2. To meet IoT system requirements, any IoT architecture must befunctional, scalable, available, and resilient. In the Healthcare field, an IoT architecture allows the interconnection of several functionalities and collects data from several sensors types (portable, inertial, location, and physiological sensors) using a dedicated sensor layer (Kamienski et al., 2017).

(Yao et al., 2018) have attempted to provide answers to 4 key questions to propose and design a Deep Learning framework applied to IoT datafrom sensor networks; these questions are: What neural network structures can efficiently process andmerge data from connected objects? How to take into account the low consumption of resources by the connected objects in the design of neural network architectures, given that these architectures have a very high resources consumption? What are the metrics to be measured to determine the relevance of Deep Learning models for the IoT? And finally, they highlighted the significant need for labelled data in the training process in these cases andthe need to minimize it for performance gains. They also proposed using a neural network compression algorithm called Deep IoT, and for measures of accuracy of obtained results, they proposed the use of the RdeepSense algorithm (Yao et al., 2017), which allows making precise and well-calibrated estimates by changing objective function.

In the same spirit (Fadlullah et al., 2018) have proposed a solution based on deep neural networks, specifically the CNN convolutional neural network on the data retrieved from the IoT devices of individual users to translate the analysis and processing of these data from the Cloud to the edge of the IoT network to overcome the problem of non-tolerance to delay of certain types of data that are sensitive in the Healthcare process.

The proposed solution involves three phases, namely data collection, chosen neural network training , and prediction from new data via the model generated in the second phase.

They evaluated the relevance of the proposed solution through Python programming of a simple neural network using the Keras library, the Theano library and Tensorflow.

This solution could have been extended by testing itsoperation and measuring its relevance at the three possible sites in IoT network architectures, namely Cloud, Edge, and Fog Computing.

On the other hand, the application of Deep Learning and Machine Learning algorithms to Healthcare data, in general, has been the subject of many articles and research works.

Among these researches, we have (Pandey & Janghel, n.d.); according to this work, the most relevant deep neural network architectures for these use cases are Autoencoder, Restricted Boltzman Machine, Deep Belief Network, Recurrent Neural

Network, Convolutional Neural Network, and GenerativeAdversarial Networks.

All these Neural Network architectures apply to the Healthcare field, with both advantages and disadvantages.

The application of these deep neuronal architectures on data obtained from medical IoTs has been the subject of another research.

Indeed, (Dourado et al., 2021) have proposed an online Framework in the context of computational intelligence to be used with IoT devices.

This Framework has the particularity of not requiring any advanced skills or knowledge in AI or image processing: any user can load his images, and perform training of algorithm and then generate the appropriate model.

This Framework is validated using data from three medical databases and is based on the CNN (Convolutional Neural Network), which is one of the most important neural network architectures; CNNs are mainly used to classify images, group them by similarities, and then perform object recognition. Many algorithms using NDCs can identify faces, traffic signs, and animals.

(Granados et al., 2018) have proposed an IoT platform for ECG analysis (electrocardiogram, which is a graphical representation of heart's electrical activity using connected electrodes placed on patient's skin in the area of heart); this intelligent system has consisted of connected ECG sensors, a webgateway from the smartphone and a server in the Cloud integrating a deep neural network as shown in the following figure 3:

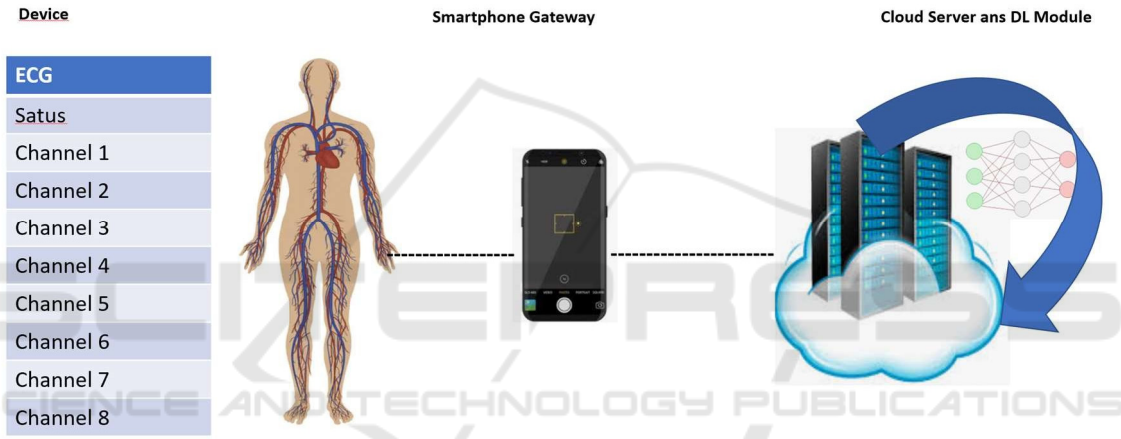

Figure 3: Cloud-based ECG analysis platform based on Deep Neural Network and the IoT (Granados et al., 2018)

(Suneetha et al., 2020) proposed a review of some works that have proposed platforms for analyzing Healthcare data collected from IoT devices to diagnose and predict diseases to anticipate and improve people's health global condition.

The authors of this work reviewed 12 papers.

{ (Kaur et al., 2018); (Lakshmanaprabu et al., 2019); (F. Aliet al., 2018) ; (S. A. Ali et al., 2020) ; (Chen et al., 2017) ;(Din et al., 2019) ;(Satapathy et al., 2015); (Guptaet al., 2017) ; (Liu et al., 2019) ;(Kaur et al., 2018) ; (Samuel et al., 2017) ; (Zhang et al., 2018) }

And then, they listed the types of Deep Neural Architectures used, the number of diseases involved in each work, the constraints faced as well as the metrics andmethods used to measure the relevance of each model generated.

Most of the articles approached by this review deal with heart disease cases; thus, it is concluded that the study is interesting. It would be more interesting if it covered a wide spectrum of diseases; moreover, the datasets used are not all generated by the IoT devices.

As concerns (Zikria et al., 2020), they discussed the application of Deep Learning algorithms on smart IoT; they also highlighted the need to orient the conception and design of next-generation wireless networks towards high autonomy and robustness in order to overcome the limitations of IoT devices, especially in terms of computing power, energy autonomy, and memory. They also highlighted the significant challenge of merging the techniques of Deep Learning and Machine Learning with the functionalities provided by IoT devices to improve IoT applications. The optimization of these applications depends on the software and hard architectures as well as the site of implementation; they can be deployed in the Cloud, Edge, or Fog computing.

(Irshad et al., 2020) have gone beyond the building ofintelligent systems using Deep Learning, IoT for health care data analysis; they have focused on optimizing these systems, especially biological systems. In this perspective, they proposed a smart system based on RNN (Recurrent Neural Network) and LSTM (Long short-term memory) combined with state-of-the-art probabilistic methods to predict performance needs and anticipate situations. This system would have more impact and usability if expanded to cover all intelligent Healthcare systems, specifically those based on AI and IoT.Other research has focused on the security aspect of Deep learning and IoT and the privacy respect in the Healthcare field. In this context (Thakkar & Lohiya, 2020) have focused on using Deep Learning and Machine Learning algorithms to predict potential intrusions in IoT devices in all fields, particularly thedetection of attacks in IoT networks. These intrusions are increasingly numerous, and they are very harmful, in particular, in the healthcare domain because there is a need to preserve patients' privacy while handling data collected from IoMTs;

In this research, there is neither a segmentation of security risks nor a focus on the criticality of this issue at Healthcare level.

4 DISCUSSION

Nowadays, research is focused on challenges posed by data specificities collected from IoMT, as well as on nature of devices that generate these data, in particular, sensors with memory, energy autonomy, and computing power constraints.

Others focused on the technical aspect by presenting the mathematical and algorithmic details of the various deep neuronal architectures. While othershave been focused on the aspect of using these algorithms for a specific purpose, which may be the intrusions detection in IoT networks, the automation of Healthcare processes through the application of DL on medical sensor data, or purely medical purpose including the prediction of various diseases through images analysis, patient's data analysis and patient's vital signal This is done for several purposes, including early intervention by the medical profession, the prescription of more appropriate treatments, prediction of the evolution of a disease and more.

In this paper, we have discussed the gaps, the omitted facets, the aspects that could have been included in each research overview as it is discussed.

The main thing we have concluded is the fact that while there has been an enormous amount of research onthese topics, mainly on Deep Learning, Machine Learning, IoT, Healthcare, security, software architecture, we lack a holistic approach to bring all these elements together in the sameFramework, the same study, the same survey, thus providing a single, shortcut access to this large and vast world structured around three dimensions,notably Deep Learning, IoT and Healthcare, with all the hidden aspects behind each of these three dimensions.

We propose, after this study, to design, develop and deploy a Framework that fulfills this holistic approach.

5 CONCLUSIONS

In this paper, we have tried to summarize all these aspects describing synergies and interactions between Deep Learning, IoT, and the health industry, to create, first, a shortcut to these different aspects from a single point which is this article, second; we have highlighted the lack of holistic studyand research that integrates all these elements intoa single survey.

The purpose of this article is to bring all these elements together in one place with, as a scientific contribution, a layer of analysis and discussion.

This work also allows us to focus, for the next work, on application aspects related to these same topics to propose design, development, and deployment of a global solution, and this, by combining Deep Learning, Machine Learning, and IoT techniques for Healthcare.

Indeed, based on this study, we propose to design, develop and deploy a Framework that meets this global approach. It is planned to design the Framework to be customizable according to a specific configuration (various types of Deep Neural Architectures) and depending on the use case and the location of its deployment (Cloud, Edge or Fog or other depending on the evolution of science) along with a security dimension considering its crucial aspect.

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