A System Architecture to Implement Deep Learning Techniques for Patients Monitoring with Heart Disease: Case of Telerehabilitation

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Abstract: The development of information technologies and the introduction of artificial intelligence in the healthcare sector is becoming a great wealth. It allows timely remote diagnosis by specialists and then reduces the cost of unnecessary transfers. Nowadays, older people and the increase of chronic diseases pose new challenges to health systems. We can overcome these challenges by the use of new technologies and artificial intelligence tools. This work aims to present a new approach to use machine learning to predict cardiac problems. As known, heart disease is the deadliest reason for morbidity. However, early detection of cardiac anomalies can prevent heart attack and solve patient life. That is why we think to design and build an e-health platform that will enable telemedicine acts such as remote monitoring and remote assistance. We will first focus on the telerehabilitation of patients suffering from heart disease.

1 INTRODUCTION

Even if life expectancy has increased since 2000 and become five years more than before, the health system in Morocco still faces many challenges:

- Material and especially human resources still largely insufficient
- Significant disparities in access to care (including primary care) between urban and rural areas
- Epidemiological transition situation still significant share of mortality linked to 6 diseases/health priorities
- ~ 270 rural communes are in critical health isolation (distance > one hour from a hospital structure), including 160 priority communes representing ~ 2 Million inhabitants.

All these challenges are due to the lack of infrastructure, technical and human resources. To overcome these problems, we think to benefit from telemedicine which is very promising and very useful. Indeed, telemedicine combines scientific knowledge and the development of IT. Also, it has shown its benefits all over the world, and it can have a significant contribution to the resolution of the above problems. Thanks to telemedicine, people can benefit from permanent medical monitoring from their houses; this, can reduce patient visits to the hospital and save them travel costs and time.

Figure 1 is a graph that describes six health priorities addressable by telemedicine in Morocco. We had this graph from a public health congress. As shown, in morocco, as in the whole world, heart disease is the primary cause of death. This is due to the emergency of heart attacks, and as known, only a few minutes between detection of the heart anomaly and the intervention of doctors/specialists can make a huge difference and can save many lives. Furthermore, real-time diagnosis and preventives alerts help patients feel more secure (Shishvan et al., 2020). Thanks to the Internet of Things (IoT) and the development of Artificial Intelligence technologies, health services have been omnipresent in patient life (Benjemmaa et al., 2020).

The deep learning approach is also used to automate cardiac diagnosis (Bernard et al., 2018) and help in the development of smarter healthcare (Simsek et al., 2020) with better performance than handcrafted features (Habibzadeh and Soyata, 2020).

Our work will treat the use of telemedicine and especially the advances in artificial intelligence (AI) in cardiology. We will discuss at first previous

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works on the prevention and monitoring of heart diseases. In the second section, we will propose a new architecture and talks about methods and tools and we will conclude with a discussion and perspectives.

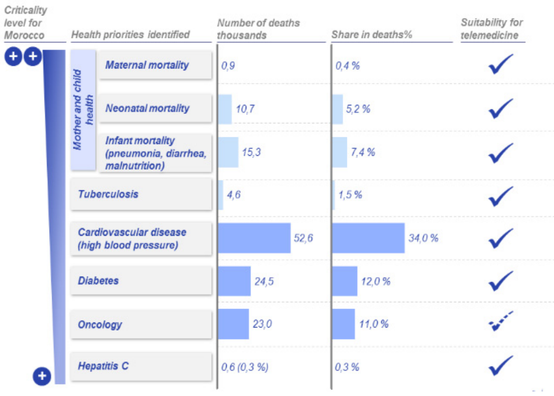

Figure 1: Health priorities addressable by telemedicine (Chaachou, 2019)

2 RELATED WORKS

This section provides existing literature on cardiac prediction, reviews the different tools and technologies used, and gives challenges and limitations of existing approaches.

We can avoid cardiovascular disease if cardiac anomalies/problems had been detected early and in real-time happening. This issue is the leading cause behind the implementation of many studies in this field. Using sensors and wearable devices connected to mobile applications make it possible to pursue patients, analyze ECG diagram, detect heart attacks and eventual cardiac arrest and then transfers results to doctors and emergency unit (Leijdekkers and Gay, 2008).

Cardiologists or practitioners need to check multiple parameters such as blood pressure, oxygen saturation, heart rate, and analyze electrocardiogram, before making any decision (Darwaish et al., 2019).

We can get all these parameters are given from biomedical devices (ECG, Holter, pulse oximeter …), which collecting and transmitting health data remotely using wireless communication. MyHeart (Luprano et al., 2006) is an example of a project which uses wearable sensors to extract data, analyses ECG variability, and then give the classification of body activities.

Some literature reviews highlight the great interest of having the possibility to diagnosis cardiac activities via wireless communication technologies. This method will reduce the mortality rate for patients with heart diseases (Ghosh et al., 2021). Besides, as cardiac patients are threatened to have a heart attack anytime, a new concept of remote applications is developed using wearable sensors, mobile applications, and web applications (Ltifi et al., 2016).

Data are collected and transferred via Bluetooth or Wi-Fi to the smartphone, which transmits it to the web application (Kakria et al., 2015). Data mining and multi-agent systems provide real-time analysis for complex and various data (Jemmaa et al., 2016).

One of the significant challenges of all these applications and studies is to reduce the delay time between the onset of a heart attack and the signal alert sent to the emergency services (Raihan, M., et al, 2021).

Table 1 summarises the major applications of deep learning in health sectors and their associated techniques.

Table 1: A summary of deep learning & telemedicine applications in the health sector.

Theme / Application	Description
Medical imaging: Organ Identification	Development and Validation of a Deep Learning Algorithm for Detection of Diabetic Retinopathy in Retinal Fundus Photographs (Stacked Autoencoder) (Gulshan et al., 2016)
	Stacked Autoencoders for Unsupervised Feature Learning and Multiple Organ Detection in a Pilot Study Using 4D Patient Data (Stacked Autoencoder) (Shin et al., 2012)
Medical imaging: Tumor detection	DeepMitosis: Mitosis Detection via Deep Detection, Verification and Segmentation Networks (CNN)(Li et al., 2018)
Medical imaging: Echocardiography	Fast and accurate view classification of echocardiograms using deep learning (CNN) (Madani et al., 2018)
	Clinically Feasible and Accurate View Classification of Echocardiographic Images Using Deep Learning (CNN)(Kusunose et al., 2020)
Bioinformatic: Protein Structure prediction	Predicting Backbone Cα Angles and Dihedrals from Protein Sequences (Sparse autoencoder)(Lyons et al., 2014)
	Boosted Categorical Restricted Boltzmann Machine for

	Computational Prediction of Splice Junctions (RBM)(Lee et al., 2015)
Bioinformatic: Cancer detection and identification	Prostate cancer diagnosis using deep learning with 3D multiparametric MRI (CNN)(Liu et al., 2017)
	Deep Learning Model Based Breast Cancer Histopathological Image Classification (Wei et al., 2017)
Bioinformatic: Gene expression	Deep learning of the tissue-regulated splicing code (DNN)(Leung et al., 2014)
	A deep learning framework for modeling structural features of RNA-binding protein targets (DNN)(Zhang et al., 2016)
Predictive analytics: Patients health prediction	Deep Patient: An Unsupervised Representation to Predict the Future of Patients from the Electronic Health Records (Denoising autoencoder)(Miotto et al., 2016)
	DeepCare: A Deep Dynamic Memory Model for Predictive Medicine (Denoising autoencoder)(Pham et al., 2016)
Telemedicine: Monitoring the Health Status	Building a Telemedicine System for Monitoring the Health Status and supporting the social adaptation of children with Autism spectrum disorders(Artificial neural network)(Lebedev et al., 2019)
	MediumTerm Effectiveness of a Comprehensive Internet-Based and Patient-Specific Telerehabilitation Program With Text Messaging Support for Cardiac Patients: Randomized Controlled Trial(Artificial neural network)(Frederix et al., 2015)
	Application of Telemedicine for the Control of Patients with Acute and Chronic Heart Diseases (Artificial neural network)(Escobar-Curbelo et al., 2019)

3 PROPOSED APPROACH

In this part, we will discuss our new architecture for remote monitoring heart disease systems. We will explain the components of our system and compare our methods with previous ones.

3.1 System Architecture

Figure 2 presents an overview of our proposed architecture for monitoring heart systems. Through telerehabilitation, heart patients can be more independent and will be under continuous surveillance.

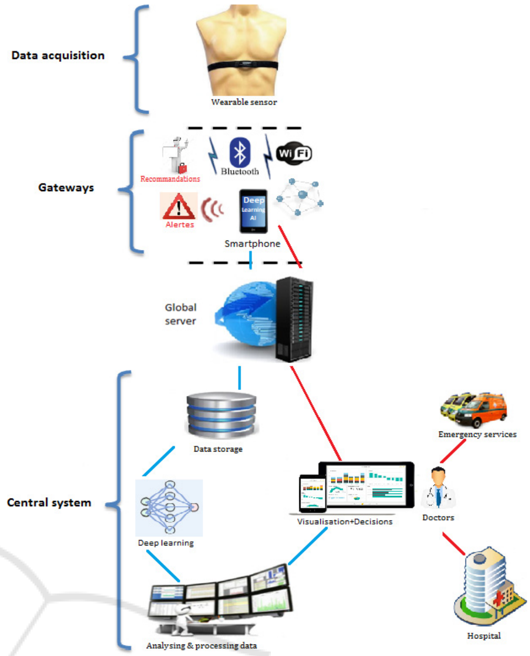

Figure 2: System architecture

- **Data acquisition:** Data acquisition mainly consists of sensors equipped with a wireless data transmission device allowing the recovery of the patient's health indices such as temperature, pulse, blood pressure, ECG ... These sensors can be placed on different parts of the patient's body or integrated into intelligent clothing. The big challenge in this part is to reduce power (Krachunov et al., 2017) consumption and offer a very high level of communication.
- **Gateway:** The gateway part will consist of a smartphone which will allow acquiring the data emitted by the wearable sensors, and then it will use the collected data in two ways:
- The first operation is ensured by a local deep learning application installed on the smartphone. It analyses data and communicates alerts or recommendations to the patient.
- The second operation is to send this data and the patient geolocation coordinates to the central system.
- **Central system:** The last part of our architecture is the central system. It consists of a Big Data infrastructure that will store the data received from the gateway and host deep

learning applications. As the first step, the deep learning applications will allow performing an in-depth and complete analysis of acquired data which allows sending more precise alerts and recommendations in real-time to the patient and at the same time gives accurate information for the services concerned and the practitioner who monitors the patient. In the second step, deep learning applications will perform analysis on the data stored over a long period to display statistical data in a graphical form, allowing visualizing the evolution of the patient's state of health.

3.2 Discussion

Our proposed architecture, as we have seen, is a combination of three primary layers. We choose this structure to ensure a real-time response.

This is the main problem of all previous approaches: they are not feasible in real-time. Besides, this architecture can analyze many heterogeneous data thanks to the big data platforms and AI tools. Alarms and alerts are the significant challenges of our work. We aim that patients feel safe every second; that is why we think about the integration of a mobile deep learning application which no one of previous studies has deployed. Streaming data will give our application a wealth of information that can be used to produce real-time analysis and also to develop machine learning algorithms.

4 CONCLUSIONS

In this study, we have discussed the utility of telemedicine to pursue cardiovascular disease. In fact, because of the high level of heart problems, one minute can make a significant change in the cardiac patient life. Hence, to have permanent diagnostic, we propose in this work a global architecture of a remote monitoring and rehabilitation system.

We have presented several studies which have been realized to minimize the risk of heart attack and cardiac problems. Following our analysis, we deduced that the development of IoT and AI technologies provide a revolution in telemedicine, and based on previous works, we have improved a new telerehabilitation conception of cardiac disease.

Our system is a part of an e-health platform that aims to prevent and reduce heart attack consequences. Thanks to alert notifications, the patient and doctor can be connected and warned of any abnormal changes.

In global architecture, we divide our system into three main parts: Data acquisition, gateway, and the central system. We will equip each patient with sensors and deep learning mobile application which gives him measures and alerts when something goes wrong. Thanks to the communication with the other parts of the system, doctors, and healthcare centers are also alerted.

In our future work, we plan to develop a mobile deep learning application, which will catch sensors values and give first analysis and alert patients and health centers.

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