Medical Data Analysis Based on Nao Robot: An Automated Approach Towards Robotic Real-Time Interaction with Human Body

Mhd Saeed Sharif
School of Architecture, Computing and Engineering,
UEL, E16 2RD, London, UK.
s.sharif@uel.ac.uk

Mohammed Hayyan Alsibai
Faculty of Engineering Technology University Malaysia
Pahang (UMP) Gambang, Kuantan, Malaysia
hayyan@ump.edu.my

Abstract— **There is a significant increase of strokes, heart diseases and premature death, people need more than ever to be aware of their vital signs such as blood pressure, heart beats, cholesterol level etc. Monitoring and analysing this medical data can help increase the awareness of the risk factor of heart disease. However, there is a huge pressure on medical staff and general practitioners (GPs), therefore this research proposes a medical data analysis based on NAO robots to meet these needs and it will serve as an automated approach towards a robotics real-time interaction with the human body. The proposed research offers a new way to allow users to understand the meaning of their vital signs using a human robot interaction. The developed system has been tested on publicly available data and simulated data. It can predict the future risk of heart disease based on some data attributes. Based on the risk prediction, it can feedback the result and the required lifestyle changes to avoid any related risk.**

***Index Terms*—Medical Data Analysis, Artificial Intelligence, Robotic, Neural Network, Internet of Things, Lifestyle.**

I. Introduction

One of most common cause of premature death is high blood pressure, it also contributes to disability due to heart diseases, strokes and heart attacks. It represents a risk factor for dementia and one of the contributors to kidney diseases. Ethnicity such as African, Caribbean and Asian backgrounds and people over the age of fifty-five years old, are considered as high risk groups [1]. On another note, there is an increase of the number of British adults diagnosed with high blood pressure, cholesterol, diabetes and the risks such disease can caused if left untreated. Health professionals, researchers, charities and the Government are making all the efforts to raise the awareness of the risk linked to high/low blood pressure and how important it is to monitor it [2]. In 2015, the national health service had estimated that almost half of British adults have been diagnosed with hypertension, also known as high blood pressure. Our lifestyle is a contributing factor of the steady increase in the number of high blood pressure cases, diabetes and cholesterol cases every year.

Finding a new approach for analyzing medical data without increasing the pressure on the national health service (NHS) medical staff and NHS medical facilities is really vital to increase the people awareness of such heart disease risk on hand. On the other hand it does not exhaust the existing medical facilities extensively. This approach can be based on robotics for real time interaction with human body, it can provide a new way to detect, prevent and spread awareness of the risks of developing heart diseases based on some vital signs measurements such as blood pressure, heart rate and pulse oxygen, and other information related to other risk factors such age, gender, diabetes history, cholesterol level, etc. The developed approach uses this data to analyze the user's risk status into two categories; the first one at risk of developing heart disease and the second one there is no risk of developing heart disease. Based on the level of the risk, the developed system can provide an appropriate feedback on needed lifestyle changes to control a specific vital value such as blood pressure.

The main aim of this research is to initiate an efficient human robot interaction approach that can provide an automated system to raise the awareness of heart disease, reduce the pressure on the NHS medical facilities, reduce unnecessary visits to the GPs and reduce the waiting time for patients. This approach will deploy artificial intelligence (AI) based technique, such as artificial neural networks, adaptive neuro-fuzzy inference system, fuzzy logic, expert systems, logic programming, robotics, genetic algorithms, natural language processing, speech recognition, intelligent agents [3,4]. The complete system will be deploying medical sensors, Nao robot, the cloud technology to store all the data and facilitate the interaction between the robot and the sensing environment wirelessly and securely. This effective interaction will enable the robot to move freely allowing the users to fully engage when interacting with the humanoid. This research will demonstrate that robots can be used to assess and convey real-time medical information and efficiently engage with the user, as there is a significant increase in the attention towards human robot interaction and the fact that people are emotionally engaged when interacting with computers and robots.

This paper is organised as follows; Section II presents the related background for the vital role of reading medical data, the human robot interaction, artificial intelligence, internet of things and cloud computing. The third section presents the data and methodology, while the results and discussion are shown in Section IV and finally the conclusions are in Section V.

II. Related Background

A. The Vital role of Reading Medical Data

1) Blood pressure readings

The seventh report of the joint national committee on prevention, detection, evaluation and treatment of high blood pressure provides a clear insight of how to interpret high blood pressure readings using a combination of factors which includes patient tolerance, scientific evidence and clinical judgement. High blood pressure readings take in consideration a certain number of factors such as medical background, age, gender. These factors enable researchers to deliver accurate results and diagnostics based on the data collected. For example potential lifestyle modification, suggested medications for treatment in presence of certain medical conditions and when the collected reading needs to be review and analyzed [5]. The know your numbers blood pressure campaign demonstrates how important it is to keep track of your blood pressure readings as well as what NHS is doing to try to make people more aware of its importance. For example, ethnicity such as African, Caribbean and Asian backgrounds and people over the age of fifty-five years old, are considered as high risks groups. The study offers a lot of useful information about high blood pressure which can be used in the design and implementation of this research [6].

2) Cholesterol levels

Cholesterol refers to the membrane of all the cells of the body, formed by blood fat (blood lipid). It carries a type of blood fat (blood lipid) that forms the membrane of each cell of the body. Lipoproteins are a type of protein that carry cholesterol in the blood and are used as measure for a cholesterol blood. High cholesterol levels put people at risk of heart disease and strokes. Many factors can affect people's cholesterol levels such as diet, stress, smoking habits, alcohol. However, lifestyle changes and statins medication can help reduce and control high levels of cholesterol. Having a high cholesterol levels over the years are considered as a great risk of developing health problems [7]. On the other hand people diagnosed with low cholesterol levels may also have the same level of risk. There are 2 types of cholesterol levels:

- High Density Lipoprotein (HDL) which helps to eliminate the surplus of LDL in the blood. HDL is referred as the good cholesterol.
- Low Density Lipoprotein (LDL) which builds up in the blood vessels, it is a considered a bad cholesterol. However, LDL is also needed in the human body so maintaining a sufficient level is important.

3) Diabetes risk factors

In UK, over 90 of the people are diagnosed with type II diabetes. Diabetes usually appear in people over 40 years of age for Caucasian and as early as 25 years of age for people with African Caribbean or Asian and can develop with or without symptoms, therefore early detection is important and can be done via regular checks. People that have a family history of diabetes, high blood pressure readings and people that are overweight are at greater risk to develop such disease. People diagnosed with High blood glucose levels are also at risk of developing Type 2 diabetes, therefore close monitoring and life changes modifications can decrease their levels [8].

B. Human Robot Interaction

1) Human Robot Interaction Using Nao Robot

Nao robot has different interesting features such as its human appearance, its small size and the ability to interact with humans [9]. The Nao robot has successfully demonstrated its ability to teach children with disabilities to interact with humans [10]. The robot has successfully demonstrated that it can be used to provide therapy as its human like appearance helps to engage in a natural manner. However, the robot has limited movement so a good approximation of the natural human behaviours the robot can execute is essential as it is a key factor to human robot interaction [11]. Another research study [12] demonstrates how a Nao robot can interact with children with autism using a mobile application. The developed tool was designed to empower a non -technical person to interact with autistic children for therapeutic and learning purposes using an android app to control the Nao robot during intervention. The study provides a therapist response on how to stimulate a child attention based on the therapist knowledge on autism [13]. Even though the robot does not possess any facial features, emotions can still be portrayed using this method [14].

The robot has been used to assist in the management of diabetes in children based on the internet of things, where a prototype that uses capillary networks of medical sensors and a humanoid robot was used to provide a multidimensional care for the treatment of diabetes which was a network architecture made of capillary networks of physical objects and a web based disease management hub [15]. The implementation of this prototype is based on a distributed architecture which provide a platform made of two main components: The web- centric disease management hub for disease management and patients monitoring and the capillary networks of physical objects surrounding the patients. The long-range connectivity between these two components is done using a wireless connection to connect to the internet. Therefore, each set of medical sensors as well as the robot are linked to the network infrastructure [16]. As the internet of things becomes the future architecture of most new development applications where physical and virtual objects are interconnected to create new services and applications using a broad range of means [17-19], virtual objects become a smart representation of the physical object as they are enriched by user information and cognitive management functions and have many common attributes [20, 21]. The objects can be categorized depending on their type such as process-aware, policy aware and activity aware which were identified as interaction, representation and awareness [22,23].

Robots connected to the cloud have a wide impact on areas such as industrial and healthcare [24]. This provides the robots with an easy access to storage, powerful computational and communication resources based on modern data center which process and share information with other robots and human and allow robot to execute tasks delegated by humans without its presence on site [25].

C. Artificial Neural Network

Artificial neural networks have been used successfully in many research works in different fields. The research work presented in [26] shows different classifications methods used to predict heart disease risk level in patients based on blood pressure, gender, age based on artificial neural networks, Naïve Bayes, KNN, decision tree. Artificial neural networks are mathematical/computational model designed for the emulation of biological neural systems like the model proposed in [27]. This model is composed of three layers; the input layer, hidden and output layers. The inputs go through the input layer and processed through the hidden layer until a result is obtained through the output layer. The actual output is then compare to the expected output. An artificial neural network based on back propagation is useful for the classification problems and it is a suitable and effective technique [28].

D. Internet of Things

The use of Internet of Things (IoT) is becoming more prevalent as people want their everyday devices to interact with each other as well as interacting with them [29]. However, IoT requirements for a successful communication framework for an e-health platform are needed to enable the different components to cooperate with each other to deliver the service, to bound latency and reliability for effective intervention and authentication, integrity and privacy as sensitive data are exchanged through the network [30]. One of the main focus of researchers and engineers worldwide is on healthcare improvements and the achievement of a global health care system capable to provide information to both medical professional and patients whatever their location [18]. This process is referred as an e-health which includes and applies IoT concept to define a global system capable to save human lives based on the advancement in communication, information and technologies as well as the increasing number of smart devices and sensors available on the market. E-health solutions that are powered by IoT contains a broad range of useful information which can be used to make a well-informed decision. The ability to connect people, devices, context and processes create a myriad of opportunities to improve the outcome of IoT powered E-health platform. The most common use of IoT powered E-health platform are proactive monitoring, chronic care disease management, preventive monitoring and follow-up care [30,31].

E. Cloud computing

The challenges of dealing with large amount of data and sharing the data among healthcare professional and patients have been overcome using a specific architecture presented in [32]. In another research work a data gathering technique was presented to offer a system that automates the collection of information about patients. The process uses wireless sensor networks connected to medical equipment used to transfer collected to a healthcare provider center based in the cloud [33]. The integration of cloud computing and other wireless sensor networks can be used as an opportunity to scalability in terms of data storage, processing infrastructure improvement and body sensor data analysis through monitoring and management infrastructure. The system was implemented using the Google App Engine app (GAE) which is a cloud computing provider of Cloud hosting and Web application development [34]. Many technologies available nowadays can be designed to offer a new e-health platform which deliver high quality healthcare services by making healthcare more accessible to anyone regardless location and improve the patients monitoring efficiently.

III. DATA AND METHODOLOGY

The datasets used for this research is based on a new dataset collected from UCI repository [35]. The dataset contains 75 attributes and a heart disease prediction attribute with two classes 0 and 1 where the value 1 represents the presence of heart disease. The data has been preprocessed into a suitable format for further processing. The dataset contains 11 attributes and a prediction status which represents two classes no risk and at risk of developing heart diseases. These attributes include are as follow: age, sex, number of cigarettes per day, number of years as a smoker, hypertension, fasting blood sugar, history of diabetes, family history of coronary artery disease, serum cholesterol, resting heart rate, resting blood pressure (systolic pressure). The dataset has 447 sample/patients. The 11 attributes of the dataset are described in Table I.

This dataset forms the inputs attributes of an artificial intelligence approach based on artificial neural network. This approach was train effectively using this dataset. The samples of the dataset has been divided into a training set, 70%, a testing set,15%, and a validation set, 15%. The achived results are discussed in the following section. After training and testing the developed approach, it has been moved with its oututs to a cloud based area. This area contains a database containing all the required information about the patients, it also store the recived interactive answeres from the Nao robot.

A simple diagram about the developed prediction system is demonstarted in Fig 1. This system has been tested using the above mentioned publicaly availble dataset and a simulated dataset where we passed some simulated new numbers and data to the robot and it sent these details to the cloud system then it provides a pridction about the simulated entered data values. The predication values have been also stored in the related fields of the cloud based database.

TABLE I. DATA DESCRIPTION

Attribute Number	*Abbreviation*	*Description and Values*
1	age	age in years
2	sex	Gender: 1 = male; 0 = female
3	cigs	Number of cigarettes per day
4	cyears	How many years have you been smoking
5	ht	Hypertension: 1= true; 0 = false
6	fbs	Fasting blood sugar >120 mg/dl 1 = true; 0 = false
7	d	Diabetes: 1 = yes; 0 = no
8	fhcad	family history of coronary artery disease 1 = yes; 0 = no
9	chol	serum cholesterol in mg/dl
10	rhr	resting heart rate
11	sbp	resting blood pressure (systolic pressure)

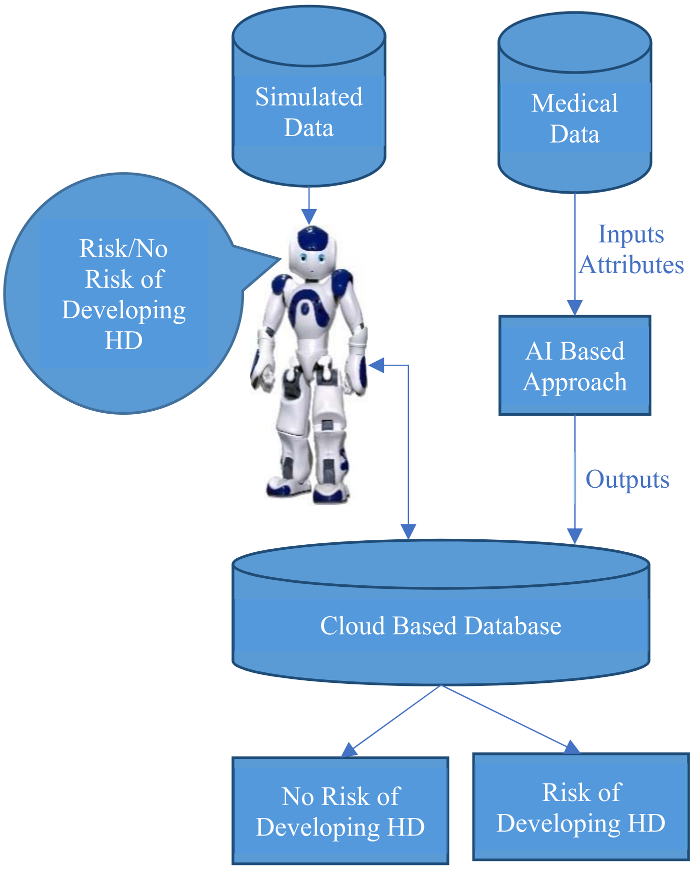

Fig. 1. The Developed Automated Prediction System.

IV. RESULTS AND DISCUSSION

The developed system has been tested using a dataset consists of 447 patients as well as using simulated data. The first component of the system is the AI approach which is based on the artificial neural network. The samples of the dataset have been divided into a training set; 70%, a testing set; 15%, and a validation set; 15%. The training set has been effectively trained using a Levenberg-Marquardt backpropagation training algorithm. This approach is using a combination of techniques including gradient descent approach, and Gauss-Newton technique which allows the artificial neural network to be trained effectively [36]. The trained neural network has been tested thoroughly. A very good accuracy has been achieved, where the confusion matrix shows that there are just two samples out of 255 have been misclassified as at no risk of developing heart disease class. Whereas there are just three out of 192 samples have been misclassified as at risk of developing heart disease class. The total fraction of samples misclassified is 0.0112. The details of the confusion matrix are as follows, where the matrix *S* represents the following rates; the matrix *S* values for both classes are shown in Table II.

S(i,1) = false negative rate = false negatives / all output negatives
S(i,2) = false positive rate = false positives / all output positives
S(i,3) = true positive rate = true positives / all output positives
S(i,4) = true negative rate = true negatives / all output negatives

TABLE II. S MATRIX: FALSE/TRUE, NEGATIVE/POSITIVE RATE FOR CLASS 1 AND CLASS 2.

Class (i)	*S(i,1)*	*S(i,2)*	*S(i,3)*	*S(i,4)*
1	0.0117	0.0104	0.9895	0.9882
2	0.0104	0.0117	0.9882	0.9895

The Nao robot has a dedicated multi-platform desktop called choregraph suite which allows users to use the interface to easily create animations, simulations and use a custom python script to control and enrich the robot’s behaviour. The robot dialogue and motion was created and control through a specific script. The robot was connected wirelessly to the cloud enabling him to send and receive the stored data. The script was designed to make the robot interact with the surrounding environment and ask some specific questions to anyone using the system. The Nao robot questions are summarized as follows:

- What is your name?
- What is your gender?
- Do you smoke?
- How many years as a smoker?
- Have you been diagnosed with Hypertension?
- Is your blood glucose level above 120mg/dl?
- Are you diabetic?
- Do you have a family history of coronary artery disease?
- What is your blood pressure “systolic pressure”?

The robot, as well as the system, have been tested on a simulated data. The answers for all of the robot questions are stored in the database, where the related attributes are sent to AI based model which predict if there is any risk of developing heart disease associated with these attributes. Based on the prediction outputs a specific feedback is sent by the robot, it also provides a direction to seek medical advice if needed.

This system is designed to increase awareness of knowing the vital signs and analyze the data in real time for efficient human-robot interaction. It is designed to increase awareness of the risk factors and to engage with the users, allowing them to simulate a conversation with the robot as their GP. This system could become a useful tool in a surgery as it can be used to manage long queue and patient running late by offering the patient the possibility to have a quick check up whilst waiting for the doctor. The same way, such system can be used in a workplace, for example, a staff room where the staff can have their vital signs checked during their break.

V. Conclusions and Future Work

The proposed research offers a new way to allow users to understand the meaning of their vital signs using a human robot interaction. The developed system has been tested on a publicly available dataset and a simulated dataset. It can predict the future risk of heart disease based on some data attributes. Based on the risk prediction, it can feedback the result and the required lifestyle changes to avoid any related risk. The importance of such system comes from the fact that there is a significant increase of strokes, heart diseases and premature death, people need more than ever to be aware of their vital signs such as blood pressure, heart beats, cholesterol level etc. Moreover, monitoring and analysing this medical data can help increase the awareness of the risk factor of heart disease on one hand. On the other hand, there is a huge pressure on medical staff and GPs, therefore proposing a medical data analysis system based on NAO robots is really vital at this stage as it will serve as an automated approach for a robotics real-time interaction with the human body.

This research has demonstrated that the robots can be used to assess and convey real-time medical information and efficiently engage with the user to provide a useful feedback. This research has used the state-of-the-art technologies, cloud computing and internet of things principles. It has initiated an efficient human robot interaction approach that can provide an automated system to raise the awareness of heart disease, reduce the pressure on the NHS medical facilities, reduce unnecessary visits to the GPs and reduce the waiting time for patients who most in need for such medical visit.

The future work of this research involves the collection of real data from different human participants, test the developed system on this real data. This data will be collected through different bio-sensors (such as blood pressure sensor, a cholesterol sensor, pulse oximeter sensor, etc.) compatible with the developed system and support Wi-Fi/Bluetooth. The participants will be asked a set of questions by the robot. After the data collection, we will perform a full survey to consult the people/participants and the medical professionals about the developed system. This survey will allow us to consider any feedback from the users/medical consultants to improve further the developed system if needed.

References

[1] NHS choices. High blood pressure (hypertension). http://www.nhs.uk/conditions/blood-pressure-(high)/ pages/introduction.aspx, 2017.

[2] Diabetes UK. Diabetes and cholesterol. http://www.diabetes.co.uk/Diabetes-and-cholesterol.html, 2017.

[3] G. Dreyfus, Neural Networks Methodology and Applications, Springer, Berlin, Germany, 2005.

[4] M. A. Arbib, The Handbook of Brain Theory and Neural Networks, Massachusetts Institute of Technology, Cambridge, Mass, USA, 2003.

[5] Health, N. H. L. A. B. I. O. The seventh report of the joint national committe on prevention, Detection, Evaluation, and treatment of high blood pressure- complete report, UK: NIH publication, 2004.

[6] Public health england. Case study - Stockport: "Know your numbers" blood pressure campaign, England: Public Health England, 2014.

[7] Diabetes.co.uk. Diabetes and Cholesterol. http://www.diabetes.co.uk /Diabetes-and-cholesterol.html, 2017.

[8] Diabete UK. DIABETES RISK FACTORS. https://www.diabetes.org.uk/Preventing-Type-2-diabetes/What-does-it-mean-if-Im-at-risk/,2016.

[9] Shamsuddin S. et al. Humanoid robot NAO: Review of control and motion exploration. IEEE International Conference on Control System, Computing and Engineering, Penang, pp. 511-516, 2011.

[10] Miskam, M. A. et al. Study on Socil Interaction between Children with Autism and Humanoid Robot NAO. Journal of Applied Mechanics and Materials, Volume 393, 2013.

[11] Shamsuddin, S. et al. Initial response of autistic children in human-robot interaction therapy with humanoid robot NAO. In: Signal processing and its applications. s.l. IEEE 8th International Colloquimon, pp. 188-193, 2012.

[12] M. A. Miskam, S. Shamsuddin, H. Yussof and A. R. Omar, "Therapists response towards using Android app to control NAO robot during intervention program for children with autism. IEEE International Symposium on Robotics and Intelligent Sensors (IRIS), Langkawi, pp. 154-158, 2015.

[13] Miskam, M. A. et al. Humanoid robot NAO as a teaching tool for children with autism using the Andriod app. In: I. S. o. MHS, ed. Humanoid robot NAO as a teaching tool for children with autism using the Andriod app in MicroNanoMechatronics and Human Science (MHS). s.l. IEEE, pp. 145-149, 2014.

[14] Beck, A., Canamero, L. & Bard, K. A. Towards and Affect space for robots to display emotional body language. Italy, 19th IEEE International Symposium on Robot and Human Interactive Communication, 2012.

[15] M. A. Al-Taee, W. Al-Nuaimy, Z. J. Muhsin and A. Al-Ataby. Robot Assistant in Management of Diabetes in Children Based on the Internet of Things. IEEE Internet of Things Journal, vol. 4, no. 2, pp. 437-445, April 2017.

[16] Aldeberan robotics. NAO humanoid platform. http://www.aldebaran-robotics.com, 2017.

[17] Greengard S. The Internet of Things. MIT Press, 2015.

[18] Miorandi, D., Sicarib, S., De Pellegrinia , F. & Chalmtac, I. Internet of Things : Vision, applications and research challenges. Ad Hoc Networks 10, pp. 1497-1516, 2012.

[19] Evans, D. The internet of things: How the next evolution of the internet is changing everything. Cisco Internet Business Solutions Group , pp. 1-11, 2011.

[20] Stavroulaki, V., Kritikou, Y. & Demestichas, P. Acquiring and learning user information in the context of cognitive device management. pp. 1-5, 2009.

[21] Kortuem, G., Kawsar, F., Sundramoorthy, V. & Fitton, D. Smart objects as building blocks for the internet of things. IEEE Internet of Things, 14(1), pp. 44-51, 2010.

[22] Uckelmann, D., Harrison, M. & Michahelles, F. Architecting the internet of things. Berlin- Heidelberg, Springer-Verlag, 2011.

[23] Jara, J. A., Zamora, M. A. & Skarmeta, A. F. An internet of things- based personal device for diabetes therapy management in ambient assisted living (AAL). Personal and Ubiquitous Computing, 15(4), pp. 431-440, 2011.

[24] Kehoe, B., Patil, S., Abbeel, P. & Goldberg, K. A survey of research on cloud robotics and automation. Transaction on Automation Science and Engeenering IEEE, 12(2), pp. 398-409, 2015.

[25] Kerr, J. & Nickels, K. Robot operating systems: Bridging the gap between human and robot in system theory (SSST). 44th South easthern Symposium on IEEE, pp. 99-104, 2012.

[26] Thomas J. and Princy R. T. Human heart disease prediction system using data mining techniques. International Conference on Circuit, Power and Computing Technologies (ICCPCT), Nagercoil, pp. 1-5, 2016.

[27] Chaitrali, M., Dangare, S. & Apte, S. S. A data mining approach for prediction of heart disease using risk factors. International Journal of Computer Engineering & technology (IJCET), 3(3), pp. 30-40, 2012.

[28] Amin S. U., Agarwal K. and Beg R. Genetic neural network based data mining in prediction of heart disease using risk factors. IEEE Conference on Information & Communication Technologies, JeJu Island, pp. 1227-1231, 2013.

[29] Bui, N. & Zorzi, M. Health Care Applications: A solution Based on The Internet of Things. s.l. Proceedings of the 4th International symposium on Applied Sciences in Biomedical and Communication Technologies, 2011.

[30] IERC. Internet of Things, European Research Cluster on the Internet things. http://www.internet-of-things-research.eu/about_iot.htm, 2017.

[31] Venkatramanan, P. & Rathina, I. Healthcare leveraging Internet of Things to revolutionize Healthcare and Wellness. Tata Consultancy Service limited ed. s.l. IT Services Business Solutions Consulting, 2014.

[32] Louinis , A., Hadjidj, A., Bouabdallah, A. & Challal, Y. Secure scalable cloud based architecture for e-health wireless sensor networks. Computer communications and networks (ICCCN), pp. 1-7, 2012.

[33] Rolim, C. O. et al. A cloud computing solution for patient's data collection in health care institutions in eHealth. International Conference on Telemedecin and social Medecine, pp. 95-99, 2010.

[34] Fortino, G., Pathan, M. & Di Fatta, G. BodyCloud: Integration of Cloud Computing and body sensor networks. Conference on Cloud Computing Technology and Science (CloudCom), pp. 851-856, 2012.

[35] UCI. Machine Learning Repository. http://archive.ics.uci.edu/ml/datasets/Heart+Disease, 2017.

[36] Kermani B. G., Schiffman S. S., and Nagle H. T. Performance of the Levenberg-Marquardt neural network training method in electronic nose applications," Sensors and Actuators B, vol. 110, no. 1, pp. 13–22, 2005.