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Machine Learning Algorithms and Wireless Sensor Network Applied to Medical Diagnosis: A Systematic Review

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Abstract: In this research work systematic approach were used to conduct a survey on recent contributions of the authors that applied Machine learning algorithms or computational intelligence, Artificial intelligence and soft computing techniques such as Artificial Neural Network, Fuzzy logic Genetic algorithm, Artificial Immune System Swarm intelligence among others or any combination of these techniques Neuro-fuzzy, Adaptive Neuro-fuzzy, Neuro-genetic, fuzzy-genetic, and so on that is soft computing to medical diagnosis and also a systematic review on the application of wireless sensor network, wireless sensor is a veritable embedded system with a wireless communication function, and that is capable to: Collect physical quantities such as heat, humidity, temperature, vibration, radiation, sound, light, movement, etc. Convert them into digital values which are sent as sensed data to a remote processing station or base station (WSN) to medical and health care delivery. However the survey believed that combining wireless sensor network with soft computing techniques, artificial intelligence techniques can perform well in providing health care services compare to one technique because any of these techniques has certain limitations but together perhaps they two or three techniques connected together would reduce error to a minimum level.

Keywords: Computational Intelligence, Artificial Intelligence, Soft Computing, Wireless Sensor Network

1. Introduction

Machine Learning algorithms are also known as Computational Intelligence such as Artificial Neural Network (ANN), Fuzzy logic (FL), Genetic algorithm (GA), Swarm Intelligence (SI), Artificial Immune System (AIS), Simulated Annealing (SA), Genetic Programming (GP), Evolutionary Strategy (ES), Evolutionary Programming (EP), Multi Agent System (MAS) Ant Colony Optimization (ACO) and Particle Swarm Optimization (PSO) Probabilistic Reasoning (PB) and the combination of two or three of these techniques resulted in hybrid system technically known as soft computing which includes Neuro-fuzzy, is a combination of Neural network and fuzzy logic, Neuro-Genetic which is a combination of Neural Network and Genetic algorithm, Fuzzy-Genetic which is a combination of Fuzzy logic and Genetic algorithm, are widely used in modeling intelligent systems for medical diagnosis and prognosis.

2. Neuroscience and Neurocomputing

Neurocomputing also known as artificial neural network or connectionist is a mathematical representation of the human neural architecture, reflecting its "learning" and "generalization" abilities. For this reason, ANNs belong to the area of computational intelligence/artificial intelligences. It also belong to a machine learning algorithms. Neural network are widely applied in model highly non-linear systems in which the relationship among the variables is unknown or very complex [1].

Neuroscience also known as the science of brain. Human brain is a source of natural intelligence and a truly remarkable parallel computational system. Brain cells function about 10^6 times slower than electronic circuit gates, but human brains process visual, sense of touching and auditory information much faster than any modern computer

could do in millions of years. The method behind this speed is the number of the neurons which is around 10^{10} with the number of connections. As shown in figure 1.
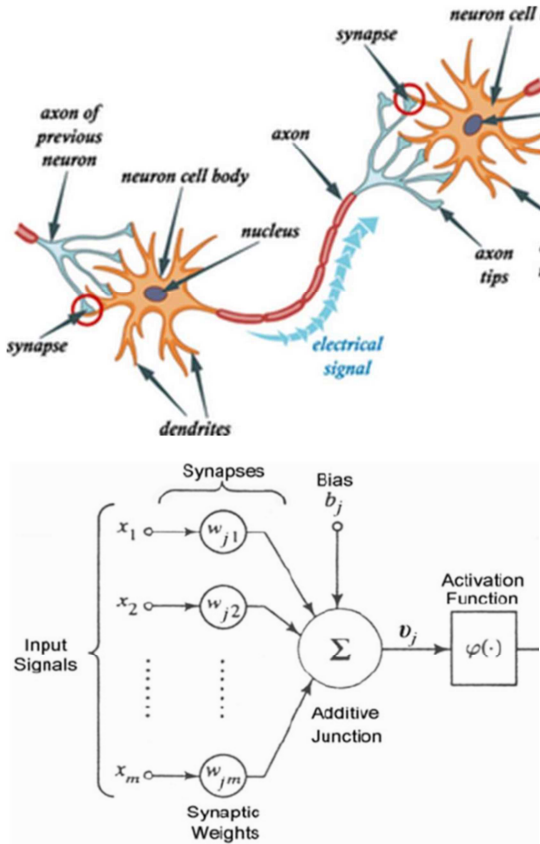

Figure 1. Biological neurons and artificial neural network [36].

Most of the computational intelligence techniques that are applied to medical diagnosis consider symptoms, biochemical analysis in labs and other feature like age, gender, as an inputs parameters to the systems, these would be further define with some linguistic variables like mild, moderate, severe, very severe, old, young, and so on, numeric values are assign to this variables which would form a datasets for training and testing of the system as illustrated in figure 1 below; where Artificial Neural Network are applied to medical diagnosis.
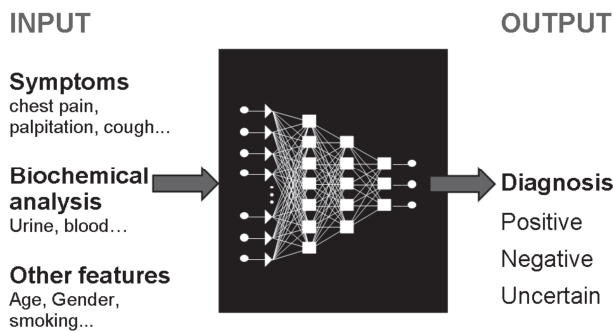

Figure 2. Detail of inputs and output parameters in ANN-based diagnosing system [1].

Artificial Neural Network is machine learning algorithms that require datasets for training and testing. It is made up of inputs layers, hidden layers and the output layers. In inputs layers every input has some weight which are subject to adjustment.

3. Fuzzy Logic

The mathematical foundation of fuzzy logic rest on the shoulder of fuzzy sets. Fuzzy set was first introduced by Lofti Zadeh in which it derived from classical set theory. Fuzzy logic consist of inputs parameters knowledge based and outputs the number of inputs and output are strongly depend on the complexity of the system build. The inputs parameter has some linguistic variables which would be used to build the rules for the system. In fuzzy logic membership functions are also required such as trapezoidal, Gaussian, Singleton, Triangular etc. Fuzzy logic are also applied in medical diagnosis using either of its two methodologies that is Sugeno and Mamdani. The figure 2 below illustrates how Sugeno model used in medical diagnosis;
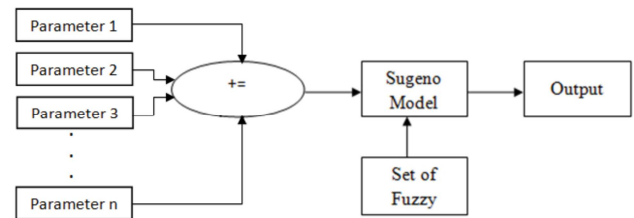

Figure 3. Fuzzy Sugeno model for disease diagnosis [48].

3.1. Membership Functions

In fuzzy logic there many membership functions applied to different research area such as Gaussian, triangular, trapezoidal, singleton among others which are all presented mathematically and graphically.

3.2. Triangular Membership Function

Triangular is a linear membership function illustrated in the figure below; where a, b and c represent the x coordinates of the three vertices of $\mu A (x)$ in the fuzzy set A. The coordinate "a" is defined as the lower boundary in set A whose degree of membership is zero. The coordinate "c" is defined as the upper boundary whose degree of membership is also zero. Finally, coordinate "b" is the third apex of the triangle whose degree of membership is one. [66] As shown in the figure 4 below;
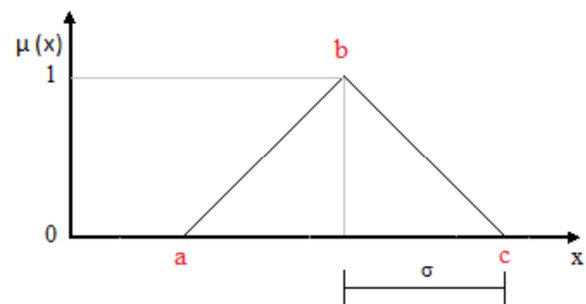

Figure 4. Triangular membership function.

Mathematically can be represented as;

$$f(x;a,b,c) = \max\left\{\min\left(\frac{x-a}{b-a}, \frac{c-x}{c-b}\right), 0\right\} \qquad (1)$$

3.3. Gaussian Membership Function

The Figure 5 below; illustrates a typical Gaussian membership function where x is the input variable, b is the center of the membership function and σ is the constant that represents the width of the membership function [66].
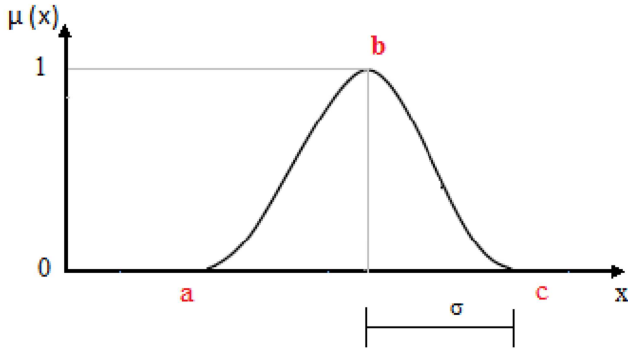

Figure 5. Gaussian membership function.

Mathematically can be represented as

$$f(x;\sigma,c) = e^{\frac{-(x-c)^2}{2\sigma^2}} \qquad (2)$$

3.4. Bell-Shaped Membership Function [67]

A bell-shaped MF has symmetric shape and is given by the expression

$$f(x;a,b,c) = \frac{1}{1 + \left|\dfrac{x-c}{a}\right|^{2b}} \qquad (3)$$

3.5. A Trapezoidal Membership Function [67]

A trapezoidal MF is described by four parameters; *a, b, c,* and *d* and it is given by the expression

$$f(x,a,b,c,d) = \max\left\{\min\left(\frac{x-a}{b-a}, 1, \frac{d-x}{d-c}\right), 0\right\} \qquad (4)$$

4. Soft Computing

In soft computing that is when two computational intelligence techniques are applied to medical diagnosis for example Neuro-fuzzy are applied in diagnosis of tuberculosis as shown in figure 3 below;
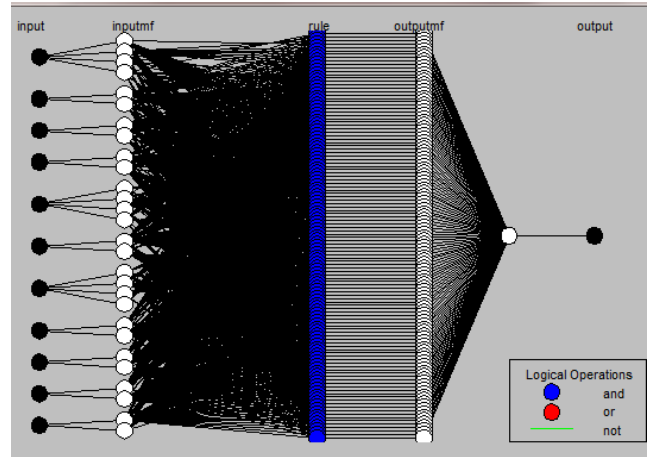

Figure 6. Neuro-fuzzy models for TB diagnosis [27].

5. Machine Learning Algorithms Applied to Medical Diagnosis

In [38] Developed knowledge-based Expert system for diagnosing tropical infectious diseases on web based platform to receive input in the form of physical symptoms and results of complete blood examination in the laboratory. [16] Developed a Fuzzy Inference System model for medical diagnosis in the area of psychology and psychiatry. [17] Presented a kidney diseases Diagnosis system using fuzzy logic the results of the research indicated that, in the diagnosis of eight cases of kidney diseases through the examination of 21 indicators using fuzzy logic. [9] Developed a decision support system which predicts the possibility of heart disease risk of patients for the next ten-years using fuzzy logic and decision tree. [41] Used artificial neural networks with six factors (smoking, age, weight, height, sex and High blood lipid) for high blood pressure. [2] Developed an adaptive Neuro-Fuzzy Inference System for Diagnosis of Ebola Hemorrhagic Fever.

In the work of [3] developed a medical diagnostic system using Visual Prolog Programming language. [54] Fuzzy Abdominal Obesity models were developed on the basis of Body Mass Index, Waist Circumference and Weight to Height ratio measurements. [5] Developed a Fuzzy Expert system with 8 fuzzy rules for the diagnosis of hypertension. Fuzzy logic was applied in the work of [64] to health monitoring system using wireless sensor network for deciding final observation of patient health status based on bio-signal reading. [65] Have determined the relationship between risk factors (insulin, leptin, homocysteine, and urinary albumin excretion) and circadian Blood Pressure variations in essential hypertensive subjects. In [47] Artificial Immune Recognition System (AIRS) with fuzzy labeling was used to form an unsupervised learning AIRS approach and to substantiate tuberculosis diagnosis identification by using clinical tuberculosis diagnostic data sets. [15] Developed an expert system for human disease diagnosis it works on the patient data by combining production rules and a neural network. [19] investigated the risk factors for the

development of diabetes mellitus, the hypertension, and the dyslipidemia simultaneously in a community-based observational cohort study using sex, age, Body Mass Index, smoking, alcohol and exercise parameters. [59] Proposed a Hybrid system for diagnosis chest diseases using Artificial Neural Network (ANN) and Genetic Algorithm (GA). In the research of [61] they have developed a Web based Fuzzy inference tool that evaluates the risk of exacerbating cardiovascular disease.

In [4] Develop an expert system for diagnosis of diseases thyroid cancer by combining the methods of neural network and certainty factor, In the research of [18] they have developed expert systems for diagnosis of asthma disease by the method of Fuzzy Logic. [32] Developed expert system for diagnosis of heart disease by the method of Fuzzy Logic. [60] In his work titled "Fuzzy Expert System for Medical Diagnosis" [14] developed a web-based Fuzzy Expert System for the public to diagnose the hypertension risk. [63] tested a logistic regression model to examine the independent

influence of changes in body mass index, health related behaviors and social risk factors on changes in self-reported diagnosis of hypertension with using body mass index, physical activity, smoking, alcohol, acute condition, memory status, gender, residence, education, marital status, and income parameters.

6. Systematic Literature Review

Machine learning algorithms or Computational intelligence techniques are recently applied for classification, prediction of the presence of microorganism, biomedical medical image extraction, selection, and Medical diagnosis, optimization of medical system, estimation, pattern recognition, testing, data mining, and determination of severity level of disease among others. The contributions of authors that applied computational intelligence and/or Artificial intelligence techniques and soft computing to medical diagnosis are systematically summarize in the table 1 below;

Table 1. Summary of Literature review.

S/N	Authors	Techniques used
1.	Abdel-Badeeh *et al* (2003) [4]	Neural Network and case based adaptive model applied to thyroid cancer diagnosis
2.	Polat *et al.*, (2007) [40]	"Breast cancer and liver disorders classification using Artificial Immune Recognition System (AIRS) with performance evaluation using fuzzy resource allocation Mechanism"
3	Polak & Mendyk, (2008) [41]	Artificial neural networks based Internet Hypertension Prediction tool development and validation
4	Sen-C. & Yuan-H., (2008) [53]	Fuzzy Theory applied depression disorder classification using Fuzzy Clustering means
5	Neshat & Yaghobi, (2009) [32]	Fuzzy Expert System for Diagnosing Hepatitis B Intensity Rate and Comparative analysis using Adaptive Neuro-fuzzy inference system
6	Danijela *et al.*, (2010) [12]	Fuzzy logic applied to the management of Diabetes mellitus
7	Fazel, *et al,* (2010) [18]	Diagnosing Asthma using fuzzy rule based
8	Abdallah *et al.*, (2011) [5]	Fuzzy expert system applied to diagnosing of hypertension
9	Djam & Kimbi, (2011) [13]	Decision Support System for Tuberculosis Diagnosis
10	Djam. & Kimbi, (2011) [14]	Fuzzy Expert System applied to the Management of Hypertension
11	Dipanwita *et al.* (2011) [15]	Expert system for Disease Diagnosis System
12	Imianvan & Obi, (2011) [23]	Fuzzy Cluster Means methodology applied to TB Diagnosis
13	Kavitha & Duraiswamy (2011) [30]	"Adaptive Neuro-Fuzzy Inference System Approach for the Automatic Screening of Diabetic Retinopathy in Fundus Images"
14	Rajeswari & Vaithiyanathan, (2011) [42]	Modeling the Fuzzy system and Artificial Neural network to the diagnose Diabetes
15	Zhao *et al.,* (2011) [63]	"BMI and lifestyle Changes as Correlates to changes in self-reported diagnosis of hypertension among older Chinese adults"
16	Putu & Ketut, (2012) [38]	Fuzzy Knowledge-based System with Uncertainty for Tropical Infectious Disease Diagnosis
17	Patil, (2012) [64]	Texture analysis of TB x-ray images using image processing Techniques,
18	Nesma et al., (2012) [34]	Fuzzy cluster means and Adaptive Neuro-fuzzy inference system applied to diagnose diabetes with the reduction of fuzzy rules
19	Pradhan *et al.*, (2012) [37]	Detecting diabetes using Genetic Programming
20	Chandrika *et al.*, (2012) [10]	Used artificial neural network to diagnosed pulmonary tuberculosis
21	Amato *et al.* (2013) [1]	Artificial Neural Network applied to medical diagnosis
22	Ekong *et al*, (2013) [16]	Fuzzy inference system applied to predicting depression risk level
23	Karahoca & Karahoca, (2013) [29]	Tuberculosis disease diagnosis by using Adaptive Neuro-fuzzy Inference system and rough sets
24	Prakashgoud & Samina, (2013) [39]	Fuzzy Logic based Health Care System using Wireless Body Area Network
25	Smita *et al.*, (2013) [51]	Generic Medical Fuzzy Expert System for Diagnosis of Cardiac Diseases
26	Tadeusz & Krzysztof, (2013) [54]	Fuzzy Logic Approach to the Evaluation of Health Risks Associated with Obesity
27	Anant & Kapil, (2013) [7]	Medical image classification using ANFIS and Neuro-fuzzy
28	Hoang, *et al.,* (2013) [21]	Analysis on Heart beat Interval using Neuro-fuzzy
29	Umoh & Ntekop, (2013) [57]	Presented a framework for diagnosing and monitoring Cholera using Fuzzy logic
30	Awotunde *et al*, (2014) [3]	Fuzzy expert system for medical diagnosis
31	Bapita & Heena, (2014) [8]	Classification of EMG based Diseases using Fuzzy Logic
32	Cinetha & Uma, (2014) [9]	Fuzzy logic applied to Coronary Heart Disease
33	Neeraj, Anjali & Praveen (2014) [35]	Early detection of Diabetes using soft computing
34	Shahaboddin *et al.,* (2014) [47]	Artificial Immune Recognition System applied in diagnosing TB

S/N	Authors	Techniques used
35	Annie *et al*, (2015) [2]	Diagnosis of Ebola using Adaptive Neuro-fuzzy inference system
36	Adlassnig, (2015) [6]	Medical diagnosis using fuzzy sets theory
37	Filipe & Henrique, (2015) [20]	Artificial Neural network applied to diabetes control
338	Mahmoud *et al*, (2015) [31]	Artificial Immune recognition system applied to TB identification
39	Farzad, (2015) [17]	Fuzzy logic applied to kidney disease diagnosis
40	Navneet *et al*, (2015) [33]	Fuzzy Based Decision Support System applied in identification of TB
41	Vally & Sarma, (2015) [59]	Neuro-genetic technique applied in diagnosing chest disease
42	Varinder, (2015) [60]	Medical Diagnosis using fuzzy system
43	Vaishali & Supriya (2015) [58]	Diagnosing diabetes using Fuzzy logic
45	Tejashri & Satish (2015) [58]	Neural Network, fuzzy logic and Gaussian Kernel methodologies applied to the prognosis of diabetes
46	Yuanda *et al.*, (2015) [61]	Risk Assessment of Cardiovascular Disease using web-based fuzzy system
47	Zeinab & Hamid, (2015) [62]	Fuzzy and Neural network used in diagnosing of Hypertension
48	Chanchal & Tejalal, (2015) [11]	Implement fuzzy web based system for diagnosing Epistaxis
49	Ricard *et al.*, (2015) [46]	Malaria Diagnosis using ANFIS
50	Iryna P. *et al.* (2016) [25]	Neuro-fuzzy techniques used medical diagnosis task with online mode
51	Kamble *et al*, (2016) [28]	Image Processing technique used in detecting TB
52	Ramana & Prasad, (2016) [45]	Radial Basis and fuzzy logic used for detection and diagnosis of lung cancer
53	Rupali & Jyoti, (2016) [49]	Soft computing applied in predicting TB
54	Radek *et al.* (2016) [50]	Adaptive Neuro-fuzzy inference system used in extraction of fetal electrocardiogram
55	Tran *et al.*, (2016) [56]	Clustering combined with fuzzy ruled based applied to medical diagnosis from dental X-ray
56	Shashank *et al.*, (2016) [48]	Neuro-fuzzy applied to e-health for monitoring disease diagnosis
57	Ibrahim *et al..* (2017) [24]	Neuro-fuzzy model used to predict the presence of *Mycobacterium* TB
58	Jerome *et al.*, (2017) [26]	Adaptive Neuro-fuzzy used in determine the severity level of osteomyelitis
59	Jerome *et al.*, (2018) [27]	Neuro-fuzzy methodology applied to TB diagnosis and control

7. Wireless Sensor Network

The recent development of high performance microprocessors and novel sensing materials has stimulated great interest in the development of smart sensors physical, chemical, or biological sensors combined with integrated circuits. It is not uncommon to place multiple sensors on a single chip, with the integrated circuitry of the chip controlling all these sensors [68]. An emerging application for wireless sensor networks involves their use in medical care. In a hospital or clinic, outfitting every patient with tiny, wearable wireless vital sensors would allow doctors, nurses and other caregivers to continuously monitor the status of their patients. In an emergency or disaster scenario, the same technology would enable medics to more effectively care for large numbers of casualties. First responders could receive immediate notifications on any changes in patient status, such as respiratory failure or cardiac arrest. Wireless sensors could replace existing wired telemetry systems for many specific clinical applications, such as physical rehabilitation or long-term ambulatory monitoring [69].

7.1. Types of Wireless Sensor Network

[70] itemize four (4) types of Wireless Sensor Network as follow;
i. Terrestrial Wireless Sensor Network
ii. Underground Wireless Sensor Network
iii. Multi-media Wireless Sensor Network
iv. Mobile Wireless Sensor Network.

7.1.1. Terrestrial Wireless Sensor Network

This type of sensor is mainly applicable in the environmental monitoring and surveillance [71].

7.1.2. Underground Wireless Sensor Network

This type of sensor is usually applicable in agricultural practices [71].

7.1.3. Underwater Wireless Sensor Network

This type of network are mostly deployed in hostile environment and it suffered a lot of communication problems due to the nature of the environment [71].

7.1.4. Multimedia Wireless Sensor Network

This type of sensor are applicable to computer graphics which includes images, videos and audios [71].

7.1.5. Mobile Wireless Sensor Network

This type of sensor has the ability to move from one point to another [71].

7.2. Architecture of Wireless Sensor Network

Basically we have two types of architecture used in wireless sensor network this are flat and hierarchical architecture

7.2.1. Flat Architecture

In flat architecture, except for sink node, the other nodes are identical, they have the same capacity in terms of energy and computing, also, they have the same role in sensing task. Node can directly communicate with a sink in single hop manner or communication with sink can be in multi hops manner [71].

7.2.2. Hierarchical Architecture

A hierarchical architecture to deploy a large number of sensors. The network is divided into several groups or clusters which are the organizational unit of the network. Depending of cases, a more expensive cluster node type and more powerful than other nodes or a normal node in the

cluster is designated as group leader called cluster head that is responsible of coordination of the sensors under its responsibility and act as a gateway to another cluster [71].

8. Application of Wireless Sensor Network to Health Care Systems

In the research of [72] Improving Health Care through Mobile Medical Devices and Sensors recommends that Mobile technology offers interesting ways to help with health care access, affordability and service delivery. [73] In their research paper they have identified challenges those developing countries particularly Tanzania will face while adopting e-healthcare. [73] agree that apart from the identified challenges; privacy, security and confidentiality are among the common challenges to both developed and developing countries. [74] They conduct a surveyed on the existing middleware design approaches for wireless sensor networks. [75] In their research paper present a monitoring system that has the capability to monitor physiological parameters from multiple patient bodies. [76] Developed a robust, scalable software platform for medical sensor networks, called Code Blue. [77] Believed that with all new technologies we face with problem of failure or success. Despite the promising features, risks of failure are always present. [78] In their paper, medical sensors were used to collect physiological data from patients and transmit it to Intelligent Personal digital Assistant (IPDA) using ZigBee/IEEE802.15.4 standard and to medical server using 3G communications. [79] Believed that the application of the Wireless Sensor Networks in healthcare systems is divided into three categories: monitoring of patients in clinical settings, home and elderly care center monitoring for chronic and elderly patients, and collection of long-term databases of clinical data. [80] In their research paper; they describe the potential of biomedical smart sensors they also explain the challenges for wireless networking of human embedded smart sensor arrays and the preliminary approach for wireless networking of retina prosthesis. [81] Their research paper evaluate the integration of Cloud computing, wireless sensor technology and Internet of Things in a healthcare environment.

9. Conclusion

Machine learning algorithms or Computational intelligence techniques are recently applied for classification, prediction of the presence of microorganism, biomedical medical image extraction, selection, and Medical diagnosis, optimization of medical system, estimation, pattern recognition, testing, data mining, and determination of severity level of disease among others. The contributions of authors that applied computational intelligence and/or Artificial intelligence techniques and soft computing to medical diagnosis are systematically. However, in this survey a system review were also conducted on application of

wireless sensor network in health care services then we proposed that combining machine learning algorithms and wireless sensor network would improve the performance of health care system.

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