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A novel and powerful framework based on neutrosophic sets to aid patients with cancer

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HIGHLIGHTS

- Fog-based scalable and cost-effective computing model to detect and monitor cancer.
- Online and real-time analytic at the fog layer even in case of bad connection with the cloud.
- Support diverse sensor types and communication protocols.
- Improving the quality of life of patients with cancer.

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ABSTRACT

Developments in the internet of things technology (IoT) have greatly influenced the way we live and have been seen in a variety of application areas, including health care. Most of the papers reviewed dealt with some health care services, and there is little scientific literature on the application or implementation of IoT in cancer detection and treatment services. This encouraged us to (re) evaluate the provision of health-care services and their location to harness the benefits associated with the use of IoT. Also, the lateness which caused by transmitting data to the cloud and back to the application is inadmissible for healthcare systems which based on IoT. As well, it is not efficient to transmit so much data to the cloud for processing and storage, because it would saturate network bandwidth and not be scalable. This also encouraged us to use fog computing which take advantages of cloud resources and coordinate the utilization of geographically distributed edge devices. So, this paper proposes the implementation of healthcare system which based on IoT and fog computing technologies for averting the spread of cancer via early detection, evaluation of disease's symptoms, and also analyzing health data that gathered from IoT through various sensor networks and other smart devices to help healthcare professionals to turn a stream of data into actionable insights and evidence-based healthcare decision-making to improve and enhance cancer treatment.

Due to the similarity of the general symptoms of cancer with some other diseases , we also proposed a neutrosophic multi-criteria decision making technique for assisting healthcare professionals to predict disease that patient may be suffers from if he/she does not have cancer. This technique depends on gathered data from proposed healthcare system and able to handle uncertainty of imprecision and ambiguity which resulted from the proportional priority scales of different symptoms of disease.

1. Introduction

Cancer is a key public health problem worldwide and it is the second reason of death in the USA. In 2017, 1688,780 recent cancer cases and 600,920 cancer deaths are projected to happen in the United States. For all sites incorporated, the cancer infection rate is 20% higher in men than in women, whereas the death rate is 40% higher. On the other hand, sex disparities differ by cancer kind [1].

According to numerous doctors and specialists, cancer is a silent-killer since most cancer patients are insensible of the things occurring in their body. The earlier cancer is discovered, the better the opportunity that it can be treated successfully. Around 50% of all cancers begin in parts of the body that a physician can routinely check during an office visit. Even though a doctor may believe he or she has come across a cancer he or she has to have extra examinations to decide if he or she is correct and it is a time consuming and costly process. So, we need a smart healthcare system which able to discover disease remotely and observe patients periodically with minimum cost.

The main defy in any healthcare system is the following:

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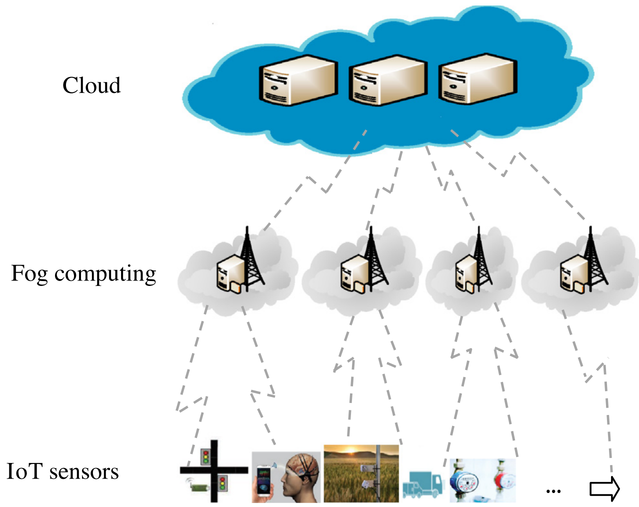

Fig. 1. Fog computing concept.

- Invasion of information attached to the health of the patient in real time, and
- Requirement of large storage capacity and high computing power for storing and processing the data.

New progress in distributed and sensing technologies such as (IoT), and cloud computing makes it potential to build healthcare system which enables remote and continual monitoring of patients. The environments of IoT produce unprecedented amounts of data which can be useful in various ways, especially if construed for insights [2]. But, the volume of data can overcome today's storage systems.

Cloud computing can offer scalable storage and processing services which can scale to IoT demands. But, for health-controlling, contingency-response, and other sensitive applications, the lateness which caused by transmitting data to the cloud and back to the application is inadmissible. As well, it is not efficient to transmit so much data to the cloud for processing and storage, because it would saturate network bandwidth and not be scalable [3]. Also the data owned by stakeholders is rarely shared to each other due to privacy concerns and the formidable cost of data transportation. Modern analysis of a healthcare systems that relate to IoT application with 30 million users displayed data flows up to 25,000 tuples per second.

For addressing these issues, edge computing was presented to utilize computing resources close IoT sensors for domestic storage and preparatory data processing. This would reduce network overcrowding, as well as expedite analysis and the decision making. But, edge devices cannot handle numerous IoT applications competing for their bounded resources, which results in resource contention and increments processing latency.

For overcoming these limitations, fog computing combine edge devices and cloud resources. It avert resource contention at the edge by taking advantages of cloud resources and coordinating the utilize of geographically distributed edge devices. It also appends an additional layer of computing power among the device and the cloud, conserving critical analytics nearer to the device, and consequently minimizing the time it takes from demand to response [4]. The fog computing architecture presented in Fig. 1, and the difference between cloud and fog computing presented in Fig. 2. We can say that Fog = IoT + Cloud. It also expands the cloud to be nearer to the things which produce and act on IoT data.

The applications of fog are as various as the IoT itself. Both can monitor or analyze real-time data from network-linked things and then starting an action. Since the objective of the healthcare IoT is to make it simpler for patients to remain linked to their providers, and for their providers to transfer responsible, value-founded care to their populations. Fog computing is the basic infrastructure to transform the healthcare IoT from novelty to actuality.

In this paper, we suggested IoT-based fog computing model for detecting and monitoring cancer efficiently and in real time through using wireless body area network (WBAN) that consist of a variety of body sensors. These sensors responsible for collecting essential information about patient's body for using it in long observation of diseases. Massive amount of data produced by these sensors and needs processing and storing in real time. A tracking process of the present status of the outbreak and recognizing infected users to treat them early for achieving a high rates of cure will performed by the proposed system.

Firstly, in proposed model each user will register in system via mobile application and insert all personal information. Then, a unique identification number (UID) creates by system automatically for each registered user. For continuous communication among users and health care center, this UID is generated. The data of cancer symptoms from body sensors is gathered by user's mobile phone through the Bluetooth or Wi-Fi technology and transferred by a smart gateway with fog computing to cloud database for storing it. Then, from users database the doctors begin to categorize users into different groups based on their symptoms.

Once the users are categorized into groups (i.e. infected or uninfected), an electronic health record contains doctor's diagnosis of disease and recommended advices sent to users via the shared interface. If he/she is infected person, then doctors should determine the type and stage of cancer disease for determining the method of treatment.

If the user does not suffer from cancer disease, how about the symptoms which are inserted and resemble the symptoms of cancer?. In this case, we need to remove symptoms uncertainty and become able to predict and examine certain differences of diseases based on symptoms that patient reported. To lower the risk for complications, we proposed a neutrosophic multi-criteria decision making (N-MCDM) technique for handling vague, uncertainty, incompleteness of reported symptoms and distancing clearly among cancer or similar diseases in the symptoms. The N-MCDM technique depends on collected data form proposed healthcare system for predicting and determining which disease that user suffers from and have some symptoms similar to cancer symptoms but not cancer.

In summary, the major contributions of this paper are as follows:

1. Fog-based scalable and cost-effective computing model is presented to detect and monitor cancer. The model integrates the WBANs system, cloud and fog computing for capturing and processing the huge data produced by the sensors in real time.
2. Low utilization of bandwidth and least-latency data processing at smart gateways.
3. Support diverse sensor types and communication protocols.
4. On-line and real-time analytic at the fog layer even in case of bad connection with the cloud.
5. Support electronic healthcare records systems and preventive care.
6. Enhance hospital information management system via decreasing operational costs, improving quality outcomes of the treatment through virtual infrastructures and accessibility of real-time information for making informed decisions, improving disease management, reducing errors, and enhancing patient experience.

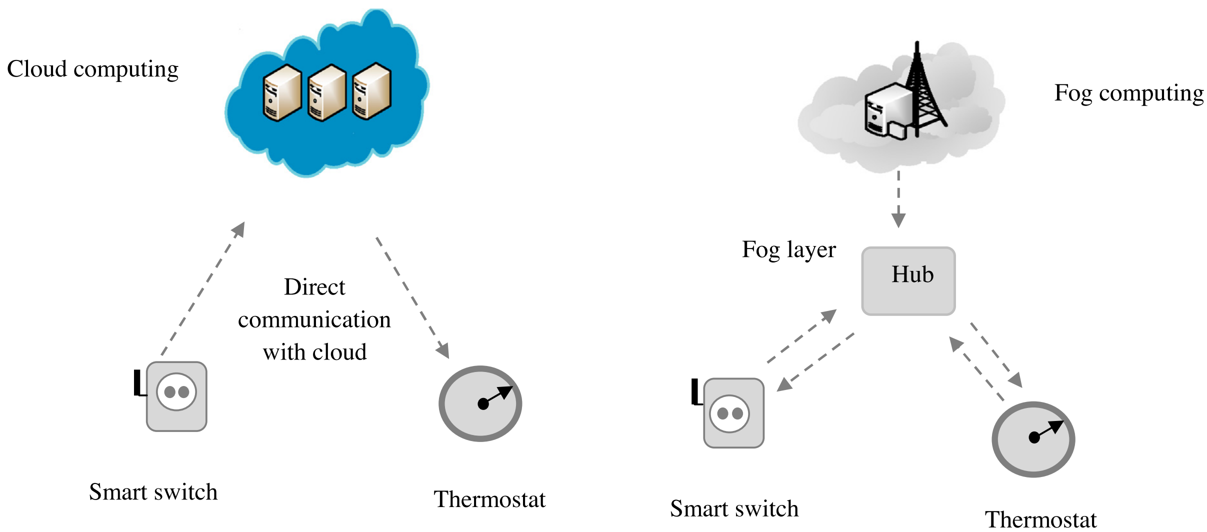

Fig. 2. Cloud computing vs fog computing.

7. Handling vague, uncertainty, incompleteness of reported symptoms, and distancing clearly among cancer or similar diseases in the symptoms via developing a N-MCDM technique.

The remaining parts of this paper is presented as follows: survey about healthcare systems that based on the IoT, cloud and fog computing introduced in Section 2. A model to detect and monitor the cancer is suggested in Section 3. Section 4 presents a N-MCDM technique for handling vague, uncertainty, incompleteness of reported symptoms and distancing clearly among cancer or similar diseases in the symptoms. In Section 5, the case study and experimental results of our suggested technique are presented. Section 6 concludes and determine future trends of this paper.

2. Literature review

Healthcare systems always require modern methods of delivering services, reducing costs and improving the quality of health care services; consequently, dependence of healthcare systems on IoT technology will be raised [5]. These technologies allow patients to keep track of person-care basics with minimum cost. Moreover, systems which based on IoT technology can be used to monitor physiological status in patients, which need persistent attention [6–9]. In recent times, the development of remote healthcare system has been expanded due to different architectures of IoT [10].

The healthcare services will balance between hospital and home in 2020, and in 2030 will be home services [11,12]. Healthcare services that introduced homely based on IoT, are between the favorable approaches for overcoming the obstacles which associated with aging population [13]. Using IoT technologies in healthcare system will enhance aging life extensively, in next year's [14]. This revolution in technology and smart objects will lead to better connection between patients, objects and simplify the remote monitoring process [15]. Using various technologies of IoT in health and home care systems have become a widespread phenomenon [16,17]. Zgheib et al. [18] proposed system to detect bedsores through sensors. Also, IoT technology used in [19], for cardiac monitoring and stroke rehabilitation. Estimating the quality of sleep at different ages and assessing the effect of drugs on sleep patterns presented by [20,21], and also based on IoT technology. Various wearable sensors are used to collect physiological signals of the human body via the software application and then transfer it to healthcare institutions. These signals help healthcare professionals to know emergency cases, and make them able to take appropriate actions [22,23]. The development of IoT technologies provides a personalized approach in healthcare delivery. It also identifies innovative solutions for communicating patients with physicians, and creating the best treatment strategies [24]. The immediate access to patient data increase the quality of provided services, satisfaction degree of patient, and support for timely intervention [25]. Different services such as remote monitoring of old people, remote contact with professionals, and robotic assisted surgery are presented in [26,27]. Mobile-health tools are identified in [28] for obesity, diabetes and breast cancer. Also, diabetic patients enabled to monitor themselves via measuring blood glucose patterns and calculating insulin as supported in [29]. By using mobile phone applications, patients are nowadays able to track their calories, and contact with professionals who can introduce useful advices. A healthcare system for measuring blood pressure, oxygen intake, and body temperature [30] has been developed by Sung et al. [31]. A system based on IoT technology is proposed in [32] for ophthalmology domain.

Avoiding infections, defining a comprehensive plan for educating patients, managing emergency and logistics systems, have been presented in hospital management [33,34]. In hospital management the careful planning and reasonable framework for making decision are critical elements of the global flow of patients from access to health institutions until departure. For overcoming this defy, IoT technologies introduced appropriate solutions for remote monitoring of patient persistently and effectively [35,36]. A system for identifying patients and their related medication based on RFID has been proposed by Esteban-Cartelle et al. [37]. Also, to monitor patients after colorectal surgery, a study was demonstrated by Bragg et al. [38]. Also, for controlling outbreak of Ebola virus, an IoT based cloud computing framework has been presented by Sareenet al. [39].

Although most of the literatures presented the application of IoT in healthcare systems, but there is practically little literature on the application of IoT in cancer detection and care service.

Meena and Indumathi [40] used support vector machine and particle swarm optimization algorithm to detect skin cancer based on IoT.

Also, Onasanya and Elshakankiri presented a general framework to cancer care based on IoT [41]. In their work they did not explain how to detect cancer but they provided a simple and general framework of cancer car service.

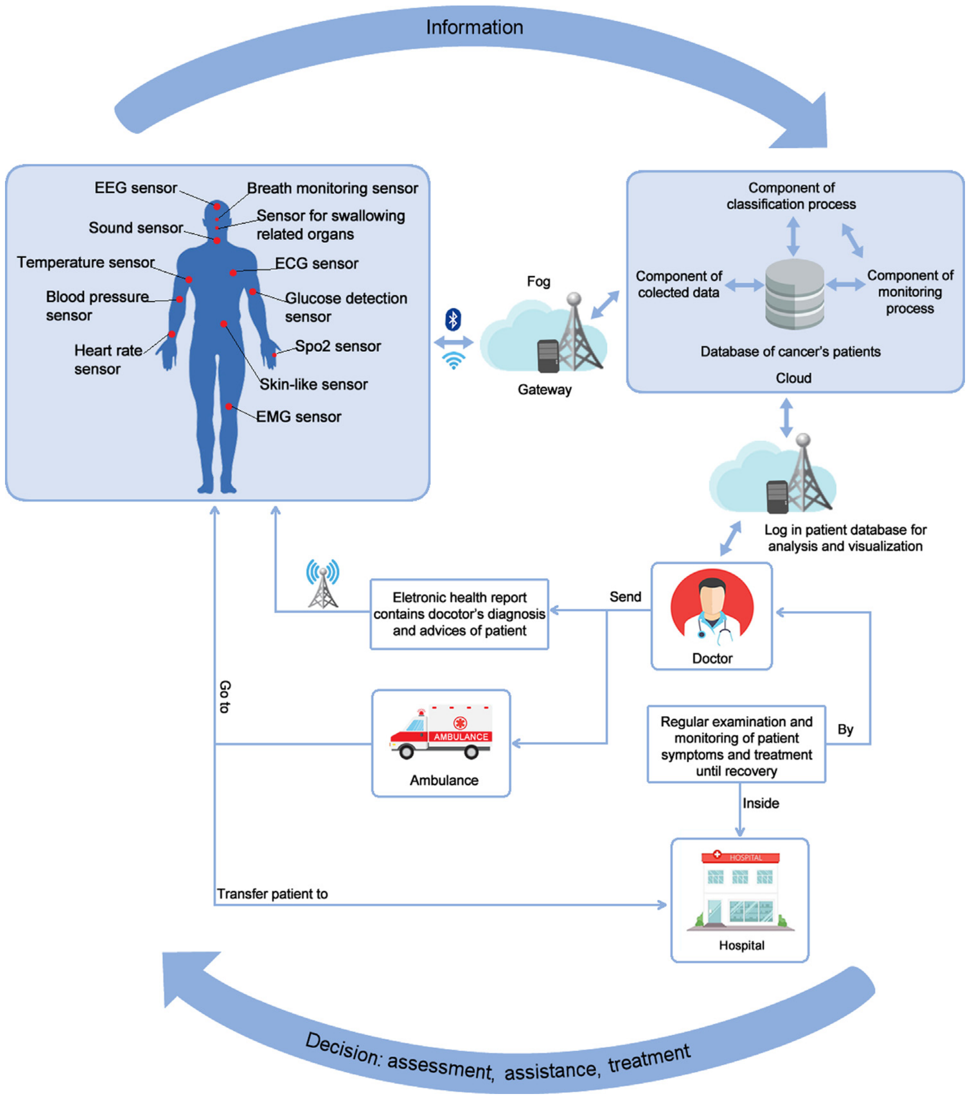

Fig. 3. Architecture of proposed model.

Table 1
Personal symptoms of cancer disease.

General symptoms	Value	Certain symptoms	Value
Unexplained weight loss	(Yes/ No)	Change in bowel habits or bladder function	(Yes/ No)
Fever	(Yes/ No)	Sores that do not heal	(Yes/ No)
Fatigue	(Yes/ No)	White patches inside the mouth or white spots on the tongue	(Yes/ No)
Pain	(Yes/ No)	Unusual bleeding or discharge	(Yes/ No)
Skin changes	(Yes/ No)	Thickening or lump in the breast or other parts of the body	(Yes/ No)
		Indigestion or trouble swallowing	(Yes/ No)
		Recent change in a wart or mole or any new skin change	(Yes/ No)
		Nagging cough or hoarseness	(Yes/ No)

Because the IoT technology produce unprecedented amounts of data which can be useful in various ways, especially if construed for insights. But, the volume of data can overcome today's storage systems. This motivated us to use fog computing in our healthcare system which combine edge devices and cloud resources. Also our model seeks to detect existing of cancer in patient's body, and it is not limited to one type of cancer.

3. Proposed model

The suggested model for detecting and monitoring the cancer disease is presented in this section as in Fig. 3. It also able to detect, and monitor infected users remotely and in real time through using fog computing and WBAN.

Usually, health monitoring systems includes several devices for collecting data from patient body and transmitting it to a visualization or processing device through wires and cables for diagnosis and monitoring. The key drawbacks of such systems are the unsupported remote monitoring and mobility, which cause many disturbances for both patients and doctors. For example, diabetes health and cardiovascular need constant monitoring 24 h a day, 7 days a week. By applying traditional system in such cases, many devices and cables must be carried by patient during long time of monitoring hours, and any motion activity of patient will cause improper collection of data.

Table 2
Personal data of users suffering from cancer disease.

Serial number	Attribute	Description
1	Mob	Mobile number
2	Name	User name
3	Age	User age
4	Gender	Male or female
5	Address	Persistent user address
6	FCN	Mobile number of family member
7	Email	Email address of user

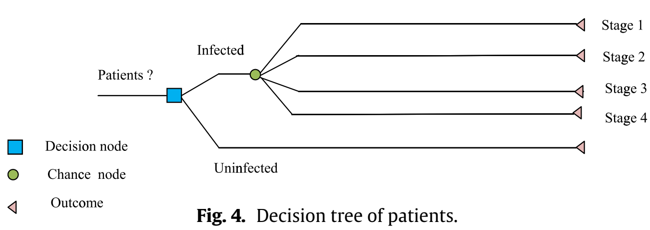

Fig. 4. Decision tree of patients.

Our proposed system based on WBAN for its mobility and wireless transference characteristics, and then be able to address traditional system drawbacks.

The proposed model consist of the following parts:

(1) The first part of proposed healthcare system is ''medical sensor node'': it is a combination of numerous physical devices involving sensors which are wearable or implantable and incorporated to a small wireless module for collecting data that help doctors to detect cancer disease in the early stages. These sensors includes: temperature, blood pressure, heart rate, glucose detection, breath monitoring, skin-like,swallowing,SpO2, ECG, EMG, EEG sensors.

By using medical data which obtained from sensors, the symptoms of cancer which presented in Table 1 can be detected. Since by using temperature sensor the doctors can determine fever symptom. The skin changes and pain symptoms can measure by using skin-like sensor [42], which simulate real skin with high resolution and also able to sense different pains and produce a three dimensional figure of objects. Then, by using this sensor the doctors and specialists will be able to determine pain location in patient body and also any changes in patient skin. By using SpO2 sensor the doctors can measure what ratio of the oxygen-carrying molecules in the blood. A fundamental cause of cancer is typically due to low cellular oxygenation levels. Dr Warburg, in 1931 won Nobel Prize for confirming cancer is caused by a shortage of oxygen respiration in cells [43]. Dean Burk and Mark Woods [44] also noted that the maximum fermentation rates cause highest growth rates of cancer. The slower a cancer grew, the less it used fermentation to produce energy. Also, a Swedish study of about 65,000 people found a link between high sugar levels and cancer. In the light of these results, Dr. Bar Satin, who supervised the study, said that the second type of diabetes, which results from a lack of pancreatic secretion of the insulin hormone, increases the likelihood of liver, pancreatic and colon cancer. So, we also used glucose sensor in proposed system. In order to estimate if patient suffers from swallowing trouble or not, several sensors were utilized such as: sound sensors [45], EGG [46], EMG [47] sensors. Also, the EEG sensor used as the first diagnostic method for tumors. The fatigue symptom can also measure through various sensors such as blood pressure sensor, heart rate sensor, breath monitoring sensor, and ECG sensor.

The remaining symptoms will enter via mobile application interface of users. These symptoms will enter by users in form 'Yes' or 'No'.

After using sensors and mobile application interface for collecting symptoms that patient suffer from it, the personal information of patient must be collected also. Table 2 shows these personal information of the users which stores in database.

The medical data that generated from WBAN transmit then to the mobile application through Bluetooth or Wi-Fi and forward to the cloud server using smart gateway with fog computing in real time for handling the big data efficiently.

(2) The second part is gateway: it plays a significant role in systems which based on WBAN since it link abundance of sensor with a distant cloud server. In case of occurring a bottle-neck at gateway or the gateway not function correctly, the entire system will be affected. Consequently, real-time patient's data cannot be properly accessed at a cloud server. Current health monitoring systems that based on WBAN, use traditional gateway and have the previous drawbacks. But, a smart gateways with fog computing has been used in our system as an alternatives to the gateways of conventional systems. A high level of precedent services in the fog computing platform will be provided by smart gateway.

(3) Lastly, third part is the back-end: it involves a cloud server and back services that varies from system to system depending on provided services and technologies. To store, process and broadcast data, a cloud server is used whereas back-end services are responsible for exemplifying real time data for visualization and analysis.

For analyzing data that gathered in the first part using sensors and stored in cloud through transmitting it using smart gateway with fog computing, the doctors and specialists must access it in this part. After then, the doctors and specialists are able to classify patients either as infected (I) or uninfected (U). If patient is infected person (i.e. have cancer) then, doctors will send an electronic health report to patient. The role of this report is to inform patient with the result of diagnosis and need to be in the hospital for performing more checks to determine the stage of cancer. An ambulance will be sent to patient for bringing him to perform more checks and receive treatment, if he/she is in critical case. After bringing patient to the hospital, a CT or CAT scans, which are special X-ray tests that produce cross-sectional images of the body using X-rays and computer must perform to determine stage and type of cancer. These images must store in cloud database of patients for treatment and monitoring process. The classification of patient and stages of cancer presented in Fig. 4. A brief summary of these stages of cancer is as follows: if cancer is comparatively small and included within the organ which started in, then it is the first stage. But if the tumor is greater than in stage one, and has not initiated to spread into the adjacent tissues, then it is the second stage. Occasionally stage two means that cancer cells have spread into lymph nodes near to the tumor and this depends on the specific type of cancer. If the cancer is large, have started to spread into adjacent tissues and there exist cancer cells in the lymph nodes in the area, then it is the third stage of disease. If the cancer has spread to another body organ then it is the fourth stage. Determining the stage helps the treatment team to know which treatments patient need. Sometimes doctors may advised a local treatment, such as surgery or radiotherapy, if the cancer is just in one place. The local treatment treats only a region of the body. But if the cancer has spread a treatment which circulates throughout the whole body is required. These are called systemic treatments and include: chemotherapy, hormone therapy, or targeted cancer drugs.

The most important part after determining type, stage of cancer and selecting treatment method, is the regular examination. It help system to maintain the whole history of patients. The monitoring process of patient is occurred at various intervals of time which depends upon the patient's condition. The monitoring interval also changes according to specialized doctor opinion. The monitoring of infected patients perform continuously until they are finally recovered from the disease. After then, a notification and alert message are sent to infected patients via their phones. The evaluation of patient category for monitoring him periodically, appears in Algorithm 1. If the patient recovered from the disease, then alert message send to the user by the system. Also the record of patient updates accordingly.

Algorithm 1 Re-check symptoms and class of patients for monitoring process

Input Symptoms and UID of patient
Output Revised class of user based on input symptoms
Read the symptoms data using WBAN and UID of the patient;
If UID of patient is already exists **Then**
  Update the record with recently generated data;
Else
  Create a novel record using UID number of the patient and store the symptoms;
End If
Enter the advanced symptoms;
Construct the decision tree of the patient based on revised category
If revised category = old category **Then**
  Notify next evaluation date to the patient;
  Update patient record in the database;
Else
  Update the evaluation period;
  Update the category of the patient in the database;
  Send an alert message to doctor and fix an appointment;
  Notify next evaluation date to patient;
End If

We can summarize the overall algorithm of the proposed system for detecting and monitoring cancer patients as in Algorithm 2:

Algorithm 2 Detecting and monitoring cancer's patients

Step 1: The patient begin to register for the proposed service by his mobile phone and internet. Then, a UID is created and allocated to each user at the time of registration.
Step 2: After then, the vital symptoms such as fever, fatigue, skin changes, swallowing trouble and pain are collected via WBAN and other symptoms enters through application interface. All symptoms and personal information of patient are sent by Bluetooth or Wi-Fi of the mobile phone to the fog gateway and from fog gateway to the cloud database.
Step 3: The doctors in health-care centers begin to login cloud database of patients for making further analysis.
Step 4: Begin to classify patients into diverse categories of cancer infection using decision tree.
Step 5: If patient is infected person, then an electronic health report send to patient which contains a diagnosis results and advice to visit healthcare center for examination and treatment.
Step 6: If patient status is critical then the healthcare center will send an ambulance.
Step 7: The system continuously monitors and examines the user regularly until the patient is recovered.
Step 8: If patient is uninfected person, then an electronic report also send to him. But the electronic health record in this case contains the diagnosis result, and the disease that patient has chance to suffer from it. For example, if patient symptoms similar with general symptoms of cancer but after examination, the doctors determined that the user is uninfected with cancer disease, then in this case the electronic report includes that the patient has a great chance to suffer diabetes by 20%, 30% skin disease, etc. In order to do this, a neutrosophic MCDM technique will present in the next section.

4. Neutrosophic multi-criteria decision making technique

The objective of this section is to extra examine and forecast certain differences of diseases based on reported symptoms of patient if he/she did not infected with cancer and inserted some symptoms which common with cancer symptoms. This suggested solution integrates conceptual design and MCDM technique with triangular neutrosophic numbers for dealing with the uncertainty of imprecision and ambiguity which created from the proportional priority scales of different factors of diseases. This approach can assist specialists to determine the weights of different diseases based on the symptoms and scores selected by the users thereby offering quality of life assistance services.

Table 3
Linguistic variables for weighting criteria (symptoms).

Linguistic variables	Triangular neutrosophic numbers
Less dangerous	⟨(0.5, 0.5, 1.0); (0.9, 0.1, 0.1)⟩
Equally dangerous	⟨(1.0, 1.0, 1.0); (0.9, 0.1, 0.1)⟩
Moderately dangerous	⟨(1.0, 2.0, 3.0); (0.9, 0.1, 0.1)⟩
Strongly dangerous	⟨(2.0, 3.0, 4.0); (0.9, 0.1, 0.1)⟩
Extremely dangerous	⟨(3.0, 4.0, 5.0); (0.9, 0.1, 0.1)⟩

4.1. Multi-Criteria decision-making (MCDM) techniques

A well-known method to make decision by analyzing, determining complex problems, and evaluating the best feasible solution from different conflicting objectives is the MCDM technique [48,49]. The MCDM techniques are grouped by many authors into two kinds: multi-objective decision making (MODM) and multi-attribute decision making (MADM) techniques. It also applied in diverse fields such as operation research, politics, business, environment and energy through organizing the multifaceted complexities [50,51]. Also, the MCDM techniques provides feasible and efficient solutions to the contradictory criteria which satisfy and produce better decisions. It can also assist decision makers to make rational decisions to yield an improve hassle-free life. The widespread problems in everyday life are MCDM problems which involves numerous, multiple and conflicting criteria. Also, the information of MCDM techniques are vague, uncertain, and to deal with such states, fuzzy set theory was proposed by Zadeh in 1965 [52]. The fuzzy MCDM techniques applied widely for handling the vagueness of human's judgment [53]. In fuzzy MCDM techniques, the significant weights of criteria are evaluated by fuzzy numbers. But, fuzzy MCDM techniques did not represent vague information efficiently because it considered the membership degree only and failed to consider indeterminacy. For overcoming fuzzy theory drawbacks, the intuitionistic fuzzy sets was presented by Atanassove [54]. The MCDM techniques which based on intuitionistic fuzzy theory, succeeded in dealing with incomplete information efficiently but also failed to consider indeterminacy. For introducing comprehensive solution which consider vague, incomplete and inconsistent information for simulating natural decision making process, Smarandache presented neutrosophy in 1995 [55]. We can say that neutrosophic set is a popularization of classic, fuzzy, and intuitionistic fuzzy sets [56–67]. For simplifying the application process of neutrosophic sets, the authors in [68] proposed single-valued neutrosophic set (SVNS). For further information about neutrosophic set see this researches [69]. Since the traditional, fuzzy and intuitionistic MCDM techniques were ineffectual in handling the uncertainty condition of judgments. So, in this study we integrated neutrosophic theory with simple additive weighting (SAW) method for handling vague, incomplete and inconsistent information by considering truth, indeterminacy and falsity membership degrees.

Table 4
Linguistic variables for rating alternatives (disease) with respect each symptom.

Linguistic variables	Triangular neutrosophic numbers
Less occurrence	⟨(0.5, 0.5, 1.0); (0.9, 0.1, 0.1)⟩
Equal occurrence	⟨(1.0, 1.0, 1.0); (0.9, 0.1, 0.1)⟩
Moderate occurrence	⟨(1.0, 2.0, 3.0); (0.9, 0.1, 0.1)⟩
Strong occurrence	⟨(2.0, 3.0, 4.0); (0.9, 0.1, 0.1)⟩
Extreme occurrence	⟨(3.0, 4.0, 5.0); (0.9, 0.1, 0.1)⟩

4.2. Proposed technique

Simple Additive Weighting (SAW) or weighted linear combination or scoring approach is the simplest and most widely used multi attribute decision technique. It based on the weighted average approach [70]. The evaluation degree for each alternative calculates by summing each of scale value of alternative with respect to different criteria multiplying by the relative weights of all criteria. The benefit of this approach is the simplicity and proportional linear conversion of the raw data. The limitation of traditional SAW method is that it fails to deal with vague and uncertain information. This uncertainty and vagueness cannot be measured precisely (i.e. using crisp values). For solving these drawbacks we enlarged the proposed model by using neutrosophic numbers.

The steps of proposed model are as follows:

Step 1. Choose panel of experts who have powerful background about the domain of problem. Since the problem domain in our research paper is the medical domain then, we selected doctors who are specialists and consultants.

Step 2. Determine decision criteria. In our study the criteria are the symptoms which are entered via proposed health care system in the first part of the paper.

Step 3. Determine also all available alternatives. In our study the alternatives are the diseases which have common symptoms with cancer disease according to specialists and consultants opinions .

Step 4. Begin to draw the hierarchical structure of problem for simplifying and visualizing it clearly, via illustrating main objective, criteria and available alternatives.

Step 5. After structuring the hierarchy, the importance of each criterion(symptom) and evaluation of alternatives(diseases) must be calculated. The experts will make their judgments on the criteria and alternatives via using linguistic variables. Because this study deals with symptoms and diseases, then we will change the term "the importance of each criterion" with" the dangerous of each symptom".

Step 6. In this step the suitable neutrosophic linguistic variables for both criteria and alternatives will present by specialists and consultants. A five point scale was used by specialists and consultants in this evaluation process as in Tables 3 and 4.

In Table 3, each triangular neutrosophic number consist of two parts:

Table 7
The weighted symptoms.

c_1	c_2	c_3	c_4	c_5
0.45	0.18	0.18	0.11	0.09

The first part is the value of triangular neutrosophic number which consist of lower (l), median (m), and upper bound (u) of this number, and the second part is the confirmation degree of this value which is the truth T, indeterminacy I and falsity F degree. In our study we fixed the confirmation degree for all neutrosophic values and made it equal (0.9, 0.1, 0.1), and this is because there is no absolute truth in reality and every fact is exposed to prove it is opposite. So we usually want to maximize the truth degree (T), minimize indeterminacy (I) and falsity (F) in everything in our life. Here $T = 0.9$, $I = 0.1$, $F = 0.1$ and this is according to specialists opinions.

Step 7. Construct comparison matrix of symptoms according to each expert and begin to aggregate the neutrosophic evaluation values of experts by using the geometric mean operator as in Eq. (1). For doing this the reader should be aware of the major operations of triangular neutrosophic numbers which illustrated with detail in [69].

$$\tilde{x}_{ij} = (\tilde{x}_{ij}^{1} + \tilde{x}_{ij}^{2} + \cdots + \tilde{x}_{ij}^{k})/k, \tag{1}$$

Where k is the number of experts and $\tilde{x}_{ij}$ is the aggregated value of neutrosophic rating of criteria. The "tilde" indicate triangular neutrosophic numbers.

You should note that in decision matrix of criteria $\tilde{x}_{ji} = \frac{1}{\tilde{x}_{ij}}$.

Step 8. Calculate weight of criteria (symptoms) as follows:

- After constructing comparison matrix of criteria we should make normalization process of this matrix by using Eq. (2) as follows:

$$\tilde{N}_{ij} = \tilde{x}_{ij} / \sum_{i=1}^{m} \tilde{x}_{c_j} \quad i = 1, \ldots, m, j = 1, \ldots, n \tag{2}$$

Where $\tilde{N}_{ij}$ is the normalized value, i, j are the alternatives and criteria respectively.

- Take the average of normalized matrix raw values then,

$$\tilde{w}_i = \frac{\sum_{j=1}^{n} \left\langle \tilde{N}_{ij} \right\rangle}{n} \tag{3}$$

Step 9. Deneutrosophic weight values for obtaining crisp values of weights by using the following equation:

Let $\tilde{A} = \langle (a_1, a_2, a_3)(T, I, F) \rangle$ be a single valued triangular neutrosophic number, then, the score function $S(\tilde{A})$ are as follows:

$$S(\tilde{A}) = \left(\frac{1}{12}\right)[a_1 + 2a_2 + a_3] \times [2 + T - I - F] \tag{4}$$

Table 5
The aggregated comparison matrix of symptoms.

	Fever	Weight loss	Pain	Skin changes	Fatigue
Fever	⟨(1.0, 1.0, 1.0); (0.9, 0.1, 0.1)⟩	⟨(2.0, 3.0, 4.0); (0.9, 0.1, 0.1)⟩	⟨(2.0, 3.0, 4.0); (0.9, 0.1, 0.1)⟩	⟨(3.0, 4.0, 5.0); (0.9, 0.1, 0.1)⟩	⟨(3.0, 4.0, 5.0); (0.9, 0.1, 0.1)⟩
Weight loss	⟨(0.2, 0.3, 0.5); (0.9, 0.1, 0.1)⟩	⟨(1.0, 1.0, 1.0); (0.9, 0.1, 0.1)⟩	⟨(1.0, 1.0, 1.0); (0.9, 0.1, 0.1)⟩	⟨(1.0, 2.0, 3.0); (0.9, 0.1, 0.1)⟩	⟨(1.0, 2.0, 3.0); (0.9, 0.1, 0.1)⟩
Pain	⟨(0.2, 0.3, 0.5); (0.9, 0.1, 0.1)⟩	⟨(1.0, 1.0, 1.0); (0.9, 0.1, 0.1)⟩	⟨(1.0, 1.0, 1.0); (0.9, 0.1, 0.1)⟩	⟨(2.0, 3.0, 4.0); (0.9, 0.1, 0.1)⟩	⟨(2.0, 3.0, 4.0); (0.9, 0.1, 0.1)⟩
Skin changes	⟨(0.2, 0.2, 0.3); (0.9, 0.1, 0.1)⟩	⟨(0.3, 0.5, 1.0); (0.9, 0.1, 0.1)⟩	⟨(0.2, 0.3, 0.5); (0.9, 0.1, 0.1)⟩	⟨(1.0, 1.0, 1.0); (0.9, 0.1, 0.1)⟩	⟨(1.0, 1.0, 1.0); (0.9, 0.1, 0.1)⟩
Fatigue	⟨(0.2, 0.2, 0.3); (0.9, 0.1, 0.1)⟩	⟨(0.3, 0.5, 1.0); (0.9, 0.1, 0.1)⟩	⟨(0.2, 0.3, 0.5); (0.9, 0.1, 0.1)⟩	⟨(1.0, 1.0, 1.0); (0.9, 0.1, 0.1)⟩	⟨(1.0, 1.0, 1.0); (0.9, 0.1, 0.1)⟩

Table 6
The normalized matrix of symptoms.

	Fever	Weight loss	Pain	Skin changes	Fatigue
Fever	⟨(0.4, 0.5, 0.5); (0.9, 0.1, 0.1)⟩	⟨(0.2, 0.5, 0.9); (0.9, 0.1, 0.1)⟩	⟨(0.3, 0.5, 0.9); (0.9, 0.1, 0.1)⟩	⟨(0.2, 0.4, 0.6); (0.9, 0.1, 0.1)⟩	⟨(0.2, 0.4, 0.6); (0.9, 0.1, 0.1)⟩
Weight loss	⟨(0.1, 0.1, 0.3); (0.9, 0.1, 0.1)⟩	⟨(0.1, 0.2, 0.2); (0.9, 0.1, 0.1)⟩	⟨(0.1, 0.2, 0.2); (0.9, 0.1, 0.1)⟩	⟨(0.1, 0.2, 0.4); (0.9, 0.1, 0.1)⟩	⟨(0.1, 0.2, 0.4); (0.9, 0.1, 0.1)⟩
Pain	⟨(0.1, 0.1, 0.3); (0.9, 0.1, 0.1)⟩	⟨(0.1, 0.2, 0.2); (0.9, 0.1, 0.1)⟩	⟨(0.1, 0.2, 0.2); (0.9, 0.1, 0.1)⟩	⟨(0.1, 0.3, 0.5); (0.9, 0.1, 0.1)⟩	⟨(0.1, 0.3, 0.5); (0.9, 0.1, 0.1)⟩
Skin changes	⟨(0.1, 0.1, 0.2); (0.9, 0.1, 0.1)⟩	⟨(0.0, 0.1, 0.2); (0.9, 0.1, 0.1)⟩	⟨(0.2, 0.3, 0.5); (0.9, 0.1, 0.1)⟩	⟨(0.1, 0.1, 0.1); (0.9, 0.1, 0.1)⟩	⟨(0.1, 0.1, 0.1); (0.9, 0.1, 0.1)⟩
Fatigue	⟨(0.1, 0.1, 0.2); (0.9, 0.1, 0.1)⟩	⟨(0.0, 0.1, 0.2); (0.9, 0.1, 0.1)⟩	⟨(0.0, 0.0, 0.1); (0.9, 0.1, 0.1)⟩	⟨(0.1, 0.1, 0.1); (0.9, 0.1, 0.1)⟩	⟨(0.1, 0.1, 0.1); (0.9, 0.1, 0.1)⟩

Table 8
Aggregated data based on neutrosophic scale.

	c_1	c_2	c_3	c_4	c_5
Typhoid	⟨(2.0, 3.0, 4.0); (0.9, 0.1, 0.1)⟩	⟨(0.5, 0.5, 1.0); (0.9, 0.1, 0.1)⟩	⟨(2.0, 3.0, 4.0); (0.9, 0.1, 0.1)⟩	⟨(0.5, 0.5, 1.0); (0.9, 0.1, 0.1)⟩	⟨(2.0, 3.0, 4.0); (0.9, 0.1, 0.1)⟩
AIDS	⟨(3.0, 4.0, 5.0); (0.9, 0.1, 0.1)⟩	⟨(2.0, 3.0, 4.0); (0.9, 0.1, 0.1)⟩	⟨(3.0, 4.0, 5.0); (0.9, 0.1, 0.1)⟩	⟨(3.0, 4.0, 5.0); (0.9, 0.1, 0.1)⟩	⟨(2.0, 3.0, 4.0); (0.9, 0.1, 0.1)⟩
Viral hepatitis	⟨(0.5, 0.5, 1.0); (0.9, 0.1, 0.1)⟩	⟨(0.5, 0.5, 1.0); (0.9, 0.1, 0.1)⟩	⟨(2.0, 3.0, 4.0); (0.9, 0.1, 0.1)⟩	⟨(2.0, 3.0, 4.0); (0.9, 0.1, 0.1)⟩	⟨(2.0, 3.0, 4.0); (0.9, 0.1, 0.1)⟩

Step 10. Begin to rank alternatives (diseases) using NSAW as follows:

- Use five point scale which presented in Table 4 and construct decision matrix of alternatives according to each criterion. Aggregate experts opinions as we illustrated in step 7.
- Use Eq. (4) to obtain crisp matrix of alternatives.
- The normalized decision matrix must be calculated for positive criteria as follows:

$$N_{ij} = \frac{x_{ij}}{x_j^*} \quad i = 1, \ldots, m, j = 1, \ldots, n, \tag{5}$$

and x_j^* is the largest number of x in the column of j.
But the normalized decision matrix for negative criteria calculates as follows:

$$N_{ij} = \frac{x_j^-}{x_{ij}} \quad i = 1, \ldots, m, j = 1, \ldots, n, \tag{6}$$

and x_j^- is the smallest number of x in the column of j. But in our study we deal with positive criteria, since in case of having disease then the result is positive. So, we will use Eq. (5) in our study.
- Begin to estimate each alternative A_i via using the following formula:

$$A_i = \sum x_{ij} * w_j \quad i = 1, \ldots, m, j = 1, \ldots, n, \tag{7}$$

and x_{ij} is the score of the i th alternative according to the j th criterion, w_j is the weighted criteria.

5. Application of proposed technique — a case study

In this part we will complete the first part of proposed healthcare system. Because the general symptoms of cancer may be similar to other existing diseases, we need to detect the disease that user is suffering from, if he/she does not have cancer according to proposed model of healthcare system. So we will apply the proposed (N-MCDM) technique for helping specialists and consultants to predict and detect which diseases that patient has a chance to be infected by it, and then advising him in an electronic healthcare record to go to the right specialist and out of the maze of disease. Here we will use the five linguistic variable scale for comparing the diverse elements of the subjects.

By using the proposed health care system, the healthcare professionals founded that the user does not have cancer. But by analyzing obtained data from proposed healthcare system they founded that he suffers from these symptoms: S = {*Fever, Weight loss, Pain, Skin changes, Fatigue*}. Thereafter, the specialists and consultants send a questionnaire to patient by email, for gathering more information about patient's status. By obtaining questionnaire's answer they expected that the patient have one of these diseases: D = {*Typhoid, AIDS, Viral hepatitis*}. In order to determine the degree of association of each disease with patients' symptoms do the following steps:

Step 1. Select healthcare professionals who are specialists and consultants for helping in decision making.

Predict patient's disease

Step 2. Construct the hierarchical structure of problem for simplifying it as appears in Fig. 5.

Step 3. Use the triangular neutrosophic scale which presented in Table 3 for constructing decision matrix of criteria according to each expert opinion, and after that, aggregate all opinions of experts via using geometric mean as in Eq. (1). The aggregated matrix of experts is as in Table 5, since we have four specialists (experts) which aid in this case study:

Step 4. Calculate weight of symptoms:

The neutrosophic normalized matrix for decision matrix of symptoms as in Table 6.

Then, take the average of each row in the normalized matrix of symptoms by using Eq. (3). then,

$\tilde{w}_1 = \langle(0.3, 0.5, 0.7); (0.9, 0.1, 0.1)\rangle$,
$\tilde{w}_2 = \langle(0.1, 0.2, 0.3); (0.9, 0.1, 0.1)\rangle$,
$\tilde{w}_3 = \langle(0.1, 0.2, 0.3); (0.9, 0.1, 0.1)\rangle$,
$\tilde{w}_4 = \langle(0.1, 0.1, 0.2); (0.9, 0.1, 0.1)\rangle$,
$\tilde{w}_5 = \langle(0.1, 0.1, 0.1); (0.9, 0.1, 0.1)\rangle$,

Step 5. Deneutrosophic weight values for obtaining crisp values of weights by using Eq. (4). The weights of criteria (symptoms) summarized in Table 7.

$w_1 = 0.45$, $w_2 = 0.18$, $w_3 = 0.18$, $w_4 = 0.11$, $w_5 = 0.09$.

Note that c_j stand for criterion j or symptom j and $j=1,\ldots,n$.

Step 6. Use neutrosophic scale which presented in Table 4 and construct decision matrix of diseases according to criteria. After that aggregate experts matrices as we illustrated in proposed technique with detail. The aggregated matrix presented in Table 8.

Step 7. Use Eq. (4) to obtain crisp matrix of alternatives (diseases) as presented in Table 9.

Table 9
Crisp matrix of diseases data.

	c_1	c_2	c_3	c_4	c_5
Typhoid	3	1	3	1	3
AIDS	4	3	4	4	3
Viral hepatitis	1	1	3	3	3

Step 8. Construct normalized decision matrix by using Eq. (5). The normalized decision matrix of diseases presented in Table 10.

Table 10
Normalized matrix of diseases data.

	c_1	c_2	c_3	c_4	c_5
Typhoid	0.75	0.33	0.75	0.25	1
AIDS	1	1	1	1	1
Viral hepatitis	0.25	0.33	0.75	0.75	1

Step 9. Begin to estimate each disease A_i via using Eq. (7). The result presented in Table 11.

Table 11
The evaluation of diseases.

Disease	Evaluation value
Typhoid	0.64
AIDS	1
Viral hepatitis	0.48

As appears in Fig. 6, the specialists and consultants decided that this patient suffers from AIDS disease.

6. Conclusions and future works

For any country and healthcare agencies, the cancer disease is a global challenge. In this paper, we suggested IoT-based fog computing model for detecting and monitoring cancer. The social interactions and symptoms of user's body are captured via using

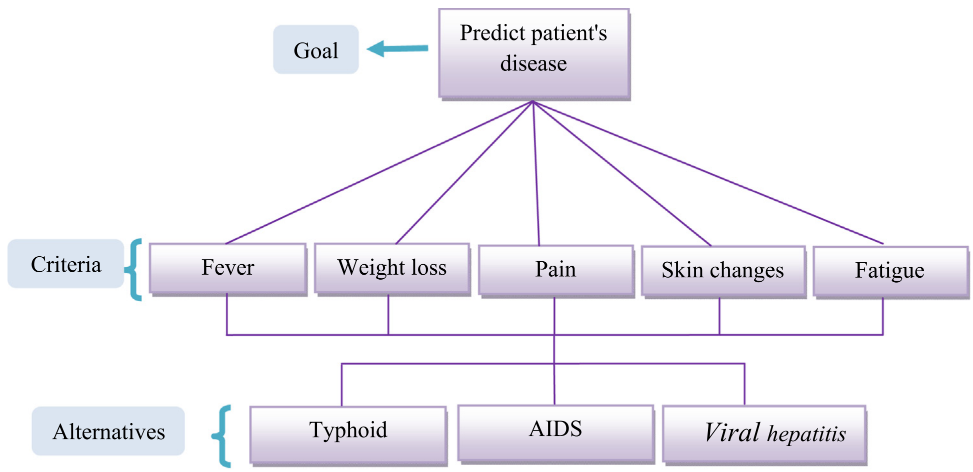

Fig. 5. Hierarchical structure of problem.

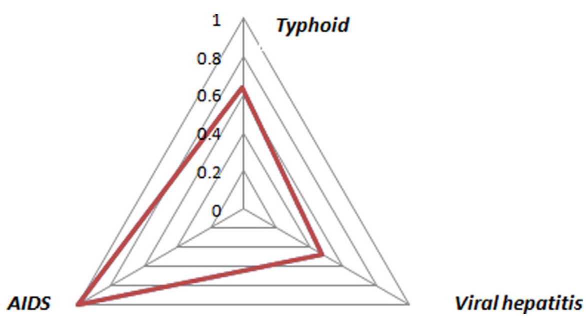

Fig. 6. Evaluation results of diseases.

WBAN and mobile application interface. After collecting personal information and symptoms, we classified users into infected or uninfected persons. If user is infected person, then the type, stage, and treatment method of cancer determines through the proposed system. But if user is uninfected person (does not have cancer) and suffers from symptoms which are similar to cancer's symptoms, we proposed a neutrosophic MCDM technique to extra examine and forecast certain differences of diseases based on reported symptoms of patient. The proposed technique has achieved many advantages for transacting with uncertain and inconsistent information which exist in MCDM problems.

From time to time, the patients are not ready to carry sensors on their bodies, so our future trend is to design a smart heath care system which support this part and achieve users satisfaction.

Limitation of Proposed Study: More posts from more firms will make our study better.

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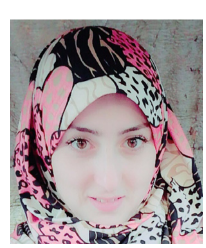

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