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A Belief Rule Based Expert System to Assess Hyperthyroidism

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Abstract: *Hyperthyroidism is a condition in which the thyroid gland is overactive and makes excessive amounts of thyroid hormone, which could lead to loss of live. The primary diagnosis of hyperthyroidism is carried out by using different signs and symptoms of patient. However, the disease cannot be measured with 100% certainty since the existence of different types of uncertainties with signs and symptoms of a patient. Most common hyperthyroidism sign and symptoms are mood swings, anxiety, trouble sleeping, muscle weakness, weight loss, irregular heartbeat, heat intolerance etc. This paper describes the accuracy of Belief Rule Based Expert Systems (BRBES) over the traditional hyperthyroidism assessment system by using signs and symptoms. Belief rule based expert system can adapt with the uncertainty in hyperthyroidism disease. Such a rule base is capable of capturing vagueness, incompleteness, and randomness in sign and symptoms. The knowledge base framework of this method is based on the expert knowledge. It is noticed that the results obtained from BRBES are more accurate and reliable than expert opinion and fuzzy rule based expert system regarding the disease assessment.*
Keywords: *Hyperthyroidism, Uncertainty, Expert System, Belief Rule Base, Signs and Symptoms.*

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1. Introduction

Hyperthyroidism, which is known as overactive thyroid, is when the thyroid gland makes more thyroid hormones than body needs. The thyroid is a large ductless gland in the neck which secretes hormones regulating growth and development through the rate of metabolism. Thyroid hormones control the way the body uses energy, so they affect nearly every organ in body, even the way heart beats. When these hormones are overproduced, many of the body's functions speed up. The most common cause of hyperthyroidism is Graves' disease, which is an autoimmune condition. Graves' disease causes bulging eyes, sensitivity to light, and blurry vision. The largest gland is thyroid gland among the endocrine glands of the human body and is placed in the middle of the lower neck, below the larynx and above the clavicles. Thyroid gland produces two active thyroid hormones, levothyroxine (T4) and triiodothyronine (T3). These hormones help in regulating the body's metabolism (Zhang & Berardi, 1998). The chief function of the thyroid is the formation and secretion of an active principle "thyroxin". The purpose of thyroxin is to regulate the processes of chemical change within the living cells of the body. An excess of thyroxin accelerates the oxidation of materials within the tissues, thereby increasing the metabolic rate, and producing a condition which we know as hyperthyroidism, Hyperthyroidism may cause proximal muscle weakness and difficulty climbing stairs or combing hair (Temurtas, F. 2009). Thyrotoxic periodic paralysis is a complication of hyperthyroidism that is characterized by muscle palsy and hypokalemia. Although hyperthyroidism is more common in females, thyrotoxic periodic paralysis primarily affects males of Asian descent. Severe hyperthyroidism increases osteoclastic bone resorption and the risk of fractures. Bone density improves with treatment of hyperthyroidism. Thyroid storm is a rare life-threatening endocrine emergency that should be suspected in any patient with hyperthyroidism who demonstrates evidence of systemic decomposition.

Computerizing assessment system on hyperthyroidism is going to use in research works and efforts are also taken to assessment the hyperthyroidism using different data mining techniques in an efficient way. The decision tree is used to classify the thyroid data-set into three classes of thyroid disorders (Margret.J at el. 2012). Many researchers also proposed different types of expert system to diagnosis thyroid disease that means hypothyroidism and hyperthyroidism. Khanale (2011) has found that Fuzzy Inference System 88% accurate to achieve diagnosis of hypothyroidism. Such system is helpful for patients and doctors to identify disease at early stage. Researchers have been using artificial immune recognition system (AIRS) with fuzzy weighted pre-processing for thyroid disease diagnosis (Polat, 2007). Traditional way of determining suspicion of hyperthyroidism is usually carried out by looking the signs and symptoms of the disease. The physician does not consider the uncertainty which exists in the sign and symptoms of this disease. The method of traditional system could be reduced the accuracy of the detection of hyperthyroidism. It is necessary to employ an appropriate knowledge representation schema to handle the uncertain knowledge that exists with the signs and symptoms of hyperthyroidism. To represent this type of knowledge belief Rule Base (BRB) is widely used (Yang at el. 2006).

As well as, BRB can be used to demonstrate the explicit non-linear relationship between the input-output data which is necessary to ensure the transparent diagnosis of hyperthyroidism. Evidential reasoning in combination with the BRB can be used as the inference mechanism of the expert system which is capable to handle all types of uncertainties in an integrated framework (Yang at el. 2001).

The remaining of the paper is organized as follows. Section two presents an overview of ACS signs and symptoms and their uncertainties. Section three describes the BRBES methodology which is used to build the system. Section four describes the design and implementation of the expert system. Section five presents the results and discussion, while Sect. six concludes the paper.

2. Hyperthyroidism

Experts may make a diagnosis of Hyperthyroidism by performing a physical exam, ordering blood tests, or using a thyroid scan for imaging. Symptoms of hypothyroidism may vary with age and sex. It also can vary from person to person and may include: mood swing, anxiety, muscle weakness, heat intolerance, trouble sleeping, irregular heartbeat, weight loss, and mood swings. Hypothyroidism is evaluated and diagnosed by a physician. Symptoms, signs, and several factors are taken into consideration when hypothyroidism is diagnosed- all of which help identify the cause and severity of the disease. Hyperthyroidism diagnosis is reached after a thorough review of the patient's symptoms, medical and family history, risk factors, physical examination, and most effectively, a blood test.

2.1 Uncertainties of Hyperthyroidism signs and symptoms

The suspicion process consists of observation of signs and symptoms of a patient. However, this suspicion process contains errors in the signs and symptoms. The reason for this is that various types of uncertainties are observed during the measurement of signs and symptoms of a patient. Symptoms are expressed by a patient by using linguistic term and hence, it may contain uncertainty due to incompleteness, ambiguity, vagueness, incompleteness, ambiguity, and ignorance. Therefore, it is necessary to develop a computerized system for suspicion of hyperthyroidism by employing a methodology which can handle the mentioned uncertainties. Most common hyperthyroidism sign and symptoms are mood swings, anxiety, trouble sleeping, muscle weakness, weight loss, skin dryness, irregular heartbeat and heat intolerance. Hyperthyroidism sign and symptoms are used as input data in the antecedent part of various rules. Qualitative and quantitative data are most common types of input data. For example, a patient's muscle weakness may be severe, moderate or normal. Qualitative data present the degree of illness. Most people think that overworking, and excessive physical activities are liable for muscle weakness and ignore the symptom. Therefore, ignorance and imprecision and vagueness are the types of uncertainties, associated with muscle weakness. Mood swings, and anxiety are often expressed by the patients by using linguistic terms which are subjective in nature; hence the expression is ambiguous, vague and imprecise. Therefore, it cannot be measured with 100% accuracy. Most the times patients consider trouble sleeping and weight loss as a common event. Ignorance and vagueness are the types of uncertainties these are found in trouble sleeping and weight loss. Daily routine activities can interfere with the accuracy of heart rate measurement. Moreover, in some cases show a false heart rate in a clinical setting due to nervousness. So heart rate has imprecision uncertainty. Most people think that heat intolerance is associated with warm weather and excessive physical activities so they ignore the symptom.

2.2 Hyperthyroidism suspicion

The process of suspecting of hyperthyroidism in human body is known as hyperthyroidism suspicion from signs and symptoms. From the patient symptom and signs the physician suspects the probability of hyperthyroidism. Symptom is given by patient but sign is discovered by physician. In our system we can determine the suspicion of hyperthyroidism from signs and symptoms in a patient. We propose a computerized diagnosis system of suspecting hyperthyroidism by using belief rule based expert system. It can handle the uncertainty of sign and symptoms.

3. Belief rule-based expert systems methodology to assess Hyperthyroidism suspicion

An expert system consists of a knowledge base and inference engine. These systems have considered Rule-Base to develop knowledge of an expert system, while they considered forward or backward chaining as the Inference Engine. Rule-base expert system is a widely used method to help medical diagnosis. However, the system is not enough equipped to handle uncertainties that exists in sign and symptoms of hyperthyroidism. A rule base is designed on the basis of the belief structure, called belief rule base. Such a rule base expert system to suspicion hyperthyroidism is capable of handling uncertainty. Inference in such a rule base is implemented using the evidential reasoning approach which has the capability of handling different types and degrees of uncertainty in signs and symptoms of hyperthyroidism (Yang 2001; Yang and Sen 1994).

Belief rule based expert systems are an extension of traditional rule based systems and are capable of handling different types of information with uncertainties.

3.1 Representation of domain knowledge

A belief rule is the extension of traditional IF-THEN rule, where a belief structure is used in the consequent part. Antecedent part of the belief rule consists of one or more antecedent attributes with associated referential value and consequent part consists of one consequent attribute. Knowledge representation parameters such as rule weight and antecedent attribute weight are used. A belief rule base (BRB) consists of one or more than one belief rules. The reason for adopting IF-THEN rule is that it is considered as an appropriate mechanism to represent human knowledge. In addition, non-linear causal relationship between the antecedent and consequent attributes can be established in a belief-rule-base. Eq. (1) represents an example of belief rule.

$$R_k : \begin{cases} \text{IF} \\ (A_1 \text{ is } A_1^k) \wedge (A_2 \text{ is } A_2^k) \wedge \dots \wedge (A_{T_k} \text{ is } A_{T_k}^k) \\ \text{THEN} \\ \begin{cases} \{(C_1, \bar{\beta}_{k1}), (C_2, \bar{\beta}_{k2}), \dots, (C_N, \bar{\beta}_{kN})\}, \left(\left(\sum_{n=1}^{N} \bar{\beta}_{kn} \leq 1\right)\right), \\ \text{with rule weight } 0 \leq \theta_k \leq 1, \\ \text{and attribute weight} \delta_1^k, \delta_2^k, \dots, \delta_T^k \geq 0 \\ \text{satisfying} \sum_{i=1}^{T_k} \delta_i^k = 1 \end{cases} \end{cases} \quad (1)$$

Where, $A_1, A_2, \dots, A_{T_k}^k, T_k \epsilon \{1,2,\dots,T\}$, are the antecedent attributes used in the *k*-th rule. $A_i^k \boldsymbol{\epsilon} \{A_{i1}, A_{i2}, \dots, A_{ij_i}\}$ is the referential value of antecedent attribute. $C_1, C_2, \dots, C_N$ are the referential values of the consequent attribute while $\bar{\beta}_{ki}$ is the belief degree to which C_i is believed to be true. If $\sum_{i=1}^{N} \bar{\beta}_{ki} = 1$, the belief rule is said to be complete, otherwise it is incomplete.

Rk: IF Mood swings is "L" AND Anxiety is "H" AND Trouble sleeping is "H"
AND Muscle weakness is "H" AND Weight loss is "H" AND Skin dryness
is "H" AND Irregular heartbeat is "H" AND Heat intolerance is "H"
THEN Hyperthyroidism is H (0.80), M (0.20), L (0.00) (2)

where (High, 0.80), (Medium, 0.20), (Low, 0.00) are the referential values along with belief degrees associated with the consequent attribute, which is "Hyperthyroidism" as elaborated in Eq. (1). The degree of belief as distributed with "High" is 80%, with "Medium" is 20% and with "Low" is 0%. Since the sum of the belief degrees is 1 (0.80 + 0.20 + 0.00), the belief rule is said to be complete.

Table I: Input Transformation into referential values

Sl. No.	Input antecedent	Input	Expert belief (E_i)	Referential value		
				High	Medium	Low
1	Weight loss	High	0.5	0.00	1.00	0.00
2	Skin dryness	Low	0	0.00	0.00	1.00
3	Irregular heartbeat	Low	0.2	0.00	0.40	0.60
4	Muscle weakness	High	0.9	0.79	0.20	0.00
5	Weight loss	Medium	0.1	0.00	0.19	0.80
6	Mood swings	Low	0.2	0.00	0.40	0.60
7	Anxiety	High	1.0	1.00	0.00	0.00
8	Trouble sleeping	High	0.8	0.60	0.40	0.00
9	Hot intolerance	Low	0	0.00	0.00	1.00
10	Skin dryness	Medium	0.3	0.00	0.60	0.40
11	Irregular heartbeat	Low	0	0.00	0.00	1.00
12	Muscle weakness	High	0.8	0.60	0.40	0.00
13	Mood swings	Low	0.1	0.00	0.19	0.80
14	Anxiety	Low	0	0.00	0.00	1.00
15	Trouble sleeping	High	0.1	0.60	0.00	0.40

3.2 Inference procedure of belief rule base

Input transformation consists of the distribution of the input value of an antecedent attribute over its different referential values by applying Eq. (3). The distributed value with each referential values of the antecedent attribute is called matching degree or the degree of belief. It is interesting to note that when the value of this matching degree is calculated for each of the referential values of the antecedent attribute, this value is assigned to only those rules where this referential value exits with the antecedent attribute. Consequently, the matching degree, related to a referential value corresponding to the antecedent attribute of a rule is assigned. In this way, input data for the eight antecedent attributes can be collected for a patient and their corresponding matching degree is assigned in a rule. Once the rule is assigned with the corresponding matching degree then it is said to be active and the rule is called packet antecedent. The inference steps of Belief Rule Based Expert System are given below.

Input transformation is known as the distribution of input data into the referential values of the antecedent attribute I_i as shown in Eq. (3).

$H(I_i, \epsilon_i) = \{(A_{ij}, \beta_{ij}), j=1,\ldots, ji\}, i=1,\ldots,T_k$ (3)

P is the evaluation of the degree of belief which is set to the input value. A_{ij} (i-th value) is the j-th referential value of the input Ii. β_{ij} is the degree of belief or the matching degree of the input data to the referential value A_{ij} of an antecedent attribute. The input data on the antecedent attributes are collected from the patients or from the domain expert in linguistic terms such as "High," "Medium" and "Low." The degree of belief ϵ_i is assigned from linguistic terms by considering the view of domain expert's heuristics. Then ϵ_i is transformed into the degree of belief associated with the various referential values A_{ij} [High (H), Medium (M), and Low (L)]. The utility value h_{ij} can be assigned to A_{ij}. For example, "High" referential value can be assigned utility value as $h_{i3} = 1.0$, "Medium" as $h_{i2} = 0.5$ and "Low" as $h_{i1} = 0$. The input transformation procedure is carried out by using Eq. (4) and (5).

IF $h_{i3} \geq \epsilon_i \geq h_{i2}$ THEN $\beta_{i2}=h_{i3}-\epsilon_i/h_{i3}-h_{i2}$,

$\beta_{i3}= (1-\beta_{i2}),\ \beta_{i1}=1-\sum_{j=0}^{2} \beta_{ij}$ (4)

IF $h_{i2} > \epsilon_i \geq h_{i1}$ THEN $\beta_{i1}=h_{i2}-\epsilon_i/h_{i2}-h_{i1}$,

$\beta_{i2}= (1-\beta_{i1}),\ \beta_{i3}=1-\sum_{j=0}^{2} \beta_{ij}$ (5)

The use of above-mentioned equations can be explained by an example. For example, when the input of "weight loss" attribute of hyperthyroidism suspicion is found "High," then the expert belief (ϵ_i) for this input is acquired as 1.0. This (ϵ_i) is to be converted into the belief degree of "weight loss" referential values by applying Eq. (4). The cause for consideration of Eq. (4) instead of Eq. (5) is that the value of expert belief (ϵ_i) in this case is in the range of $1 \geq \epsilon_i \geq 0.5$. If the expert belief ($\epsilon_i$) value is in the range of $0.5 \geq \epsilon_i \geq 0.0$, then Eq. (5) should be applied. Hence, for the referential value medium (h_{i2}) the belief degree can be obtained by applying Eq. (4) as $\beta_{i2} = (1.0 - 1.0)/ (1.0 - 0.5) = 0.0$, while for high ($h_{i3}$) it is $\beta_{i3} = (1.0 - 0.0) = 1.0$ and for low (h_{i3}) it is $\beta_{i1}= 0.0$. The input values transformation of the hyperthyroidism suspicion is shown in Table 1.

3.2.1 Calculation of activation weights

Rule activation weight calculation consists of calculating the combined matching degree (α_k) as well as the weight of a rule in the BRB. Combined matching degree can be calculated by using Eq. 6.

$$\alpha_k = \prod_{i=1}^{T_k} (\alpha_i^k)^{\bar{\delta}_i^k},\ \bar{\delta}_i^k = \frac{\delta_i^k}{\max_{i=1,\ldots,T_k}\{\delta_i^k\}} \quad (6)$$

So that $0 \leq \bar{\delta}_i^k \leq 1$

where, δ_i^k(i=1,....,T_k)is the relative weight of the ***i***-th antecedent attribute in the ***k***-th belief rule.The rule activation weight is calculated by using Eq. 7.

$$\mathcal{W}_k = \{\theta_k \alpha_k\}\{\textstyle\sum_{i=1}^{L} \theta_i \alpha_i\} \quad (7)$$

Where, θ_k is the relative weight of the ***k***-th rule; L is the total number of belief rule in the belief rule-base. When $\mathcal{W}_k$ of a rule is zero then it has no impact in the BRB while it is "1" then its important is high.

3.2.2 Belief degree update

Update belief degrees (Yang at el. 2006) to possible consequents in the BRB based on the input information using following formula:

$$\beta_{ki} = \bar{\beta}_{ki} \frac{\sum_{t=1}^{T_k}\left(\tau(k,t) \sum_{j=1}^{J_i} \alpha_{tj}\right)}{\sum_{t=1}^{T_k} \tau(k,t)} \quad (8)$$

Where, $\tau(k, t) = \begin{cases} 1, if is used in defining R_k (t = 1, \ldots, T_k,) \\ or \\ 0, otherwise \end{cases}$

Here, $\overline{\beta_{ik}}$ is the original belief degree while $\overline{\beta_{ik}}$ is the updated belief degree. The original belief degree updated if any ignorance noticed.

3.2.3 Inference using evidential reasoning

In order to obtain the aggregated value of the referential values of the consequent attribute, based on the input data of the antecedent attributes, either recursive or analytical evidential reasoning (ER) algorithms as shown in (9) can be applied (Yang 2001; Yang and Sen 1994). To reduce the computational complexity analytical ER algorithm is found effective.

$$\beta_j = \frac{\mu \times \left[\prod_{k=1}^{L}\left(\omega_k \beta_{kj} + 1 - \omega_k \sum_{j=1}^{N} \beta_{kj}\right) - \prod_{k=1}^{L}\left(1 - \omega_k \sum_{j=1}^{N} \beta_{kj}\right)\right]}{1 - \mu \times \left[\prod_{k=1}^{L}(1 - \omega_k)\right]},$$

j=1, 2,…, N (9)

with $\mu = \left[\sum_{j=1}^{N} \prod_{k=1}^{L}\left(\omega_k \beta_{kj} + 1 - \omega_k \sum_{j=1}^{N} \beta_{kj}\right) - (N-1) \times \prod_{k=1}^{L}\left(1 - \omega_k \sum_{j=1}^{N} \beta_{kj}\right)\right]^{-1}$

The combined result or output generated by ER is represented by $\{(C_1,\beta_1),(C_2,\beta_2),(C_3,\beta_3),\ldots,(C_N,\beta_N)\}$, where β_j is the final belief degree attached to the ***j***-th referential value C_j of the consequent attribute C, which is obtained after all activated rules in the BRB are combined by using ER. This output can be converted into a crisp/numerical value [as shown in (10)] by assigning a utility score to each referential value of the consequent attributes.

$H(A^*) = \sum_{j=1}^{N} u(C_j)\beta_j$ (10)

Where, H (A^*) is the expected score expressed as a numerical value and $u(C_j)$ is the utility score of **j**-th referential value.

4. BRBES to evaluate Hyperthyroidism suspicion

In order to construct the knowledge base for this BRB system prototype, a BRB framework has been developed.

4.1 System architecture

System architecture can be defined how its components are organized. It is also important to know the pattern of system organization, which is known as architectural style. BRBES presented in this paper follows three-layer architecture, consisting of web-based interface, application and database management layers as shown in Figure1.

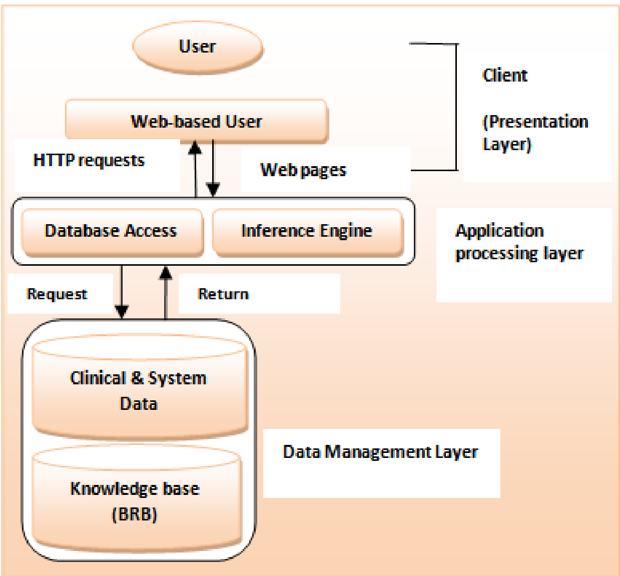

Figure1: System architecture of the Hyperthyroidism suspicion system.

This interface has been developed by integrating various web technologies such as Javascript, Jquery, HTML and CSS. The application layer, which facilities inference and database access, has been developed by using PHP because of its simplicity, shorter development cycle and it can be used through online. The data-base management layer, which consists of clinical data and knowledge-base, developed by using MySQL, which is a relational database management system. MySQL is user friendly and ensures security as well as faster data access.

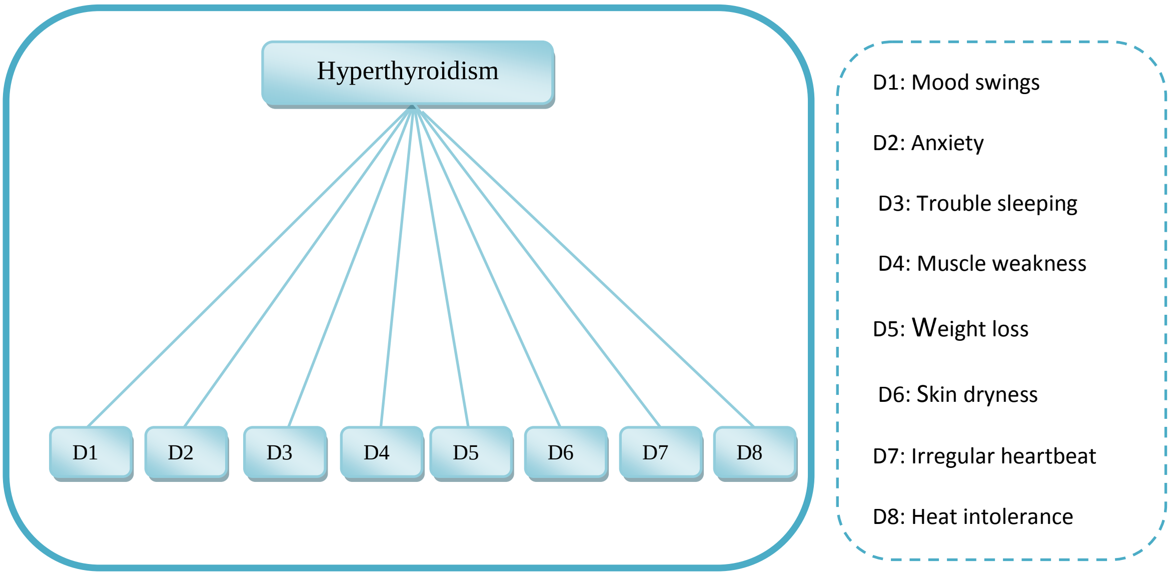

Figure2: The BRB framework for Hyperthyroidism assessment

4.2 System components

In this section the Hyperthyroidism knowledge base, BRBESs inference method and its interface are discussed.

Table II: Initial belief rule base for Hyperthyroidism BRB

Rule ID	Rule Weight	IF								THEN		
		D1	D2	D3	D4	D5	D6	D7	D8	Hyperthyroidism (D9)		
										High	Medium	Low
R1	1	H	H	H	H	H	H	H	H	1.0	0.0	0.0
R2	1	H	H	M	M	M	M	L	L	0.6	0.4	0.0
R3	1	H	H	L	L	H	H	H	H	0.8	0.0	0.2
R4	1	H	M	H	M	H	M	H	H	0.6	0.4	0.0
R5	1	H	M	M	M	M	M	M	H	0.2	0.8	0.0
R6	1	H	M	L	H	L	H	H	H	0.8	0.2	0.0
R7	1	H	L	H	H	H	H	L	L	0.8	0.0	0.2
R8	1	H	L	M	H	M	L	H	L	0.5	0.3	0.2
R9	1	H	L	L	H	H	H	H	H	0.8	0.0	0.2
R10	1	M	H	H	H	M	H	M	M	0.6	0.4	0.0
R11	1	M	H	M	H	H	H	H	H	0.4	0.6	0.0
R12	1	M	H	L	M	H	M	H	M	0.5	0.3	0.2
R13	1	M	M	H	H	H	H	H	H	0.4	0.6	0.0
R14	1	M	M	M	M	M	M	M	M	0.0	1.0	0.0
R15	1	M	M	L	M	M	M	L	L	0.0	0.8	0.2
R16	1	M	L	H	H	M	L	H	M	0.5	0.3	0.2
R17	1	M	L	M	M	M	M	L	L	0.0	0.6	0.4
R18	1	M	L	L	M	M	M	L	L	0.0	0.6	0.4
R19	1	L	H	H	H	H	H	H	H	0.8	0.0	0.2
R20	1	L	H	M	L	H	M	L	H	0.5	0.3	0.2

4.2.1 Knowledge base of BRBES

A belief rule base schema has been formulated to build the knowledge base for the BRBES as shown in Figure 2. A BRB can be constructed in four ways- extracting belief rules from expert knowledge, extracting belief rules by examine historical data, using the previous rule bases if available, and random rules without any pre-knowledge. The initial BRB has been constructed in this article by the domain expert knowledge. The necessary factors to determine the Hyperthyroidism suspicion is shown in Figure 2. These factors are related to signs and symptoms (D1–D8) of hyperthyroidism. The "Hyperthyroidism suspicions BRB" has eight antecedent attributes with three referential values each; hence it comprises 6561 rules. It is assumed that all rules and all antecedent attributes have equal weight. The initial belief degrees allocated to the referential values of the consequent attribute of a belief rule has been carried out by taking opinions of specialists. The referential values for each consequent attribute consist of High (H), Medium (M) and Low (L).

R1: IF Mood swings is "H" AND Anxiety is "H" AND Trouble sleeping is "H" Muscle weakness is "H" AND Weight loss is "H" AND Skin dryness is "H" AND Irregular heartbeat is "H" AND Heat intolerance is "H" THEN Hyperthyroidism is H (0.80), M (0.20), L (0.00).

The belief degrees are embedded in each referential value of the consequent attribute as shown in the above belief rule. This belief degree is embedded by taking account of the signs and symptoms data of the patient. For example, if the survey of the sign and symptoms such as mood swings, anxiety, trouble sleeping, muscle weakness, weight loss, skin dryness, irregular heartbeat, heat intolerance of a patient appears as "High," then the degree of belief associated with the "High" referential value of the consequent attribute "Hyperthyroidism" should be calculated as 1 as shown in rule R1 of Table II.

4.2.2 Inference engine using ER approach

Evidential reasoning (ER) algorithm (Yang 2001; Yang and Sen 1994) is used in the inference engine of this BRBES as discussed in Section 3.2. Inference engine first reads signs and symptoms data either from patients or from the domain expert; secondly, these data are converted into matching degree by using Eq. (6); thirdly, the activation weight of each rule is calculated by using Eq. (7); fourthly, Belief degrees are updated if needed by employing Eq. (8); At the last step, rules are aggregated by using Eq. (9).

4.2.3 System interface

The user interface is the visual part of a computer application or system through which a user interacts with a computer or software. The user interface is one of the most important parts of any program, because it determines how easily the user can make the program to do, what he wants. Our system has been developed using PHP with WAMP server, CSS and MySQL server. It has been designed by hierarchical approach. The graphical user interface of this system is shown in Figure 3. The figure allows the capturing of the data related to the signs and symptoms of Hyperthyroidism as well as the displaying of the BRBESs results.

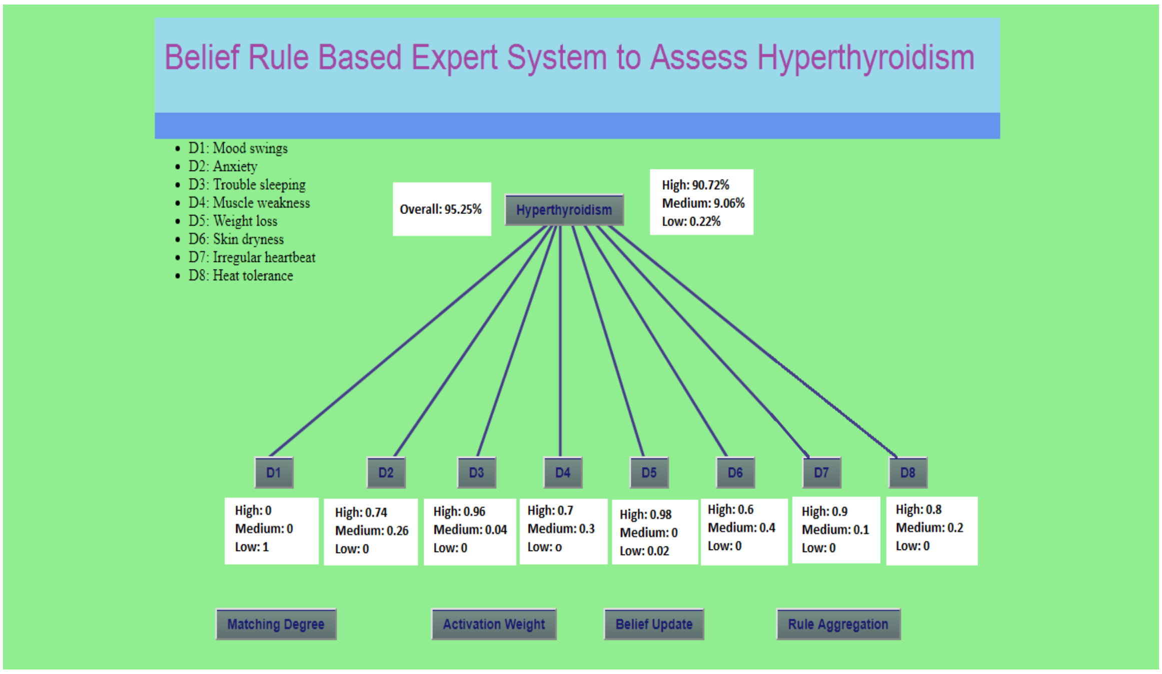

Figure3: Interface of the BRB expert system

For example, Figure 3 shows the outputs for the input data (D1 = "Low," D2 = "High," D3 = "High," D4 = "High," D5 = "High," and D6 = "High," D7 = "High," D8 = "High,"). From the figures it can be noticed that the degree of belief obtained for the referential values of the consequent attribute "Hyperthyroidism BRB" is H (90.72%), M (9.06%), L (0.22%) for the leaf node values (D1–D8) obtained from the patient. The overall assessment of Hyperthyroidism suspicion is transformed into a numerical value by using Eq. (10), which is 95.25% as shown in Figure 3.

5. Results and discussion

The dataset consist of 100 data which were gathered from the hyperthyroidism patient in two major hospitals in Chittagong, Bangladesh. The real laboratory test results of those patients were considered as the benchmark data. If patient has hyperthyroidism in laboratory test, then the benchmark is considered as"1", otherwise it is "0" for that patient. A Fuzzy Rule Based Expert System (FRBES) to measure the suspicion level of hyperthyroidism is developed. Table III presents the data of 20 patients out of 100. It illustrates the collected data on the eight attributes of a patient. Table III also illustrates the BRBES result (Column 10), expert opinion (Column 11) and the fuzzy result (Column 12) on the level of hyperthyroidism suspicion for the same data. The benchmark data is recorded in column 13.

Table III. Hyperthyroidism Assessment by BRBES, Experts and Fuzzy Logic

	Signs and Symptoms								**Result**			
Id.	**D1**	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**	**BRBES Output(%)**	**Expert Opinion (%)**	**Fuzzy Result (%)**	**Benchmark**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**	**(13)**
1.	60	69	87	60	4	75	100	90	84.05	65	73.03	1
2.	85	32	13	20	104	78	1.2	23	65.32	52	55.32	1
3.	55	15	95	60	1.8	20	100	25	62.35	45	58.71	1
4.	88	27	30	12	3.5	25	100	10	65.25	45	32.67	0
5.	82	87	60	80	1.5	15	99.5	18	45.18	41	38.81	0
6.	77	82	46	76	4	68	99	87	84.77	82	75.32	1
7.	45	67	58	67	2.5	16	100	94	74.67	70	70.77	1
8.	20	13	32	23	1.2	78	100	85	64.13	46	49.23	0
9.	80	90	95	85	9.8	87	98	98	95.25	70	76.34	1
10.	92	60	67	15	1.2	67	100	15	58.05	50	45.61	1
11.	83	2	90	100	74	90	80	75	85.18	77	82.12	1
12.	18	98	86	23	9.7	17	98	90	72.45	67	65.53	1
13.	80	2	90	74	75	90	101.5	83	85.18	77	82.12	1
14.	70	1	82	91	46	40	104	75	69.86	45	56.32	1
15.	80	3	85	70	70	66	103	68	80.26	81	78.71	1
16.	95	9.8	90	80	98	87	98	85	95.25	70	76.34	1
17.	15	1	45	22	95	30	103	15	85.45	52	54.72	1
18.	95	1.8	15	55	25	20	102.5	60	42.93	55	58.71	0
19.	30	3.5	27	18	10	25	101.5	12	19.47	45	32.67	0
20.	60	1.5	87	12	18	15	99.5	80	33.28	41	38.81	0

In diagnostic research there are various ways for evaluating accuracy of a diagnosis test such as overall diagnostic accuracy, diagnostic odds ratios, and ROC curve. ROC curve has its benefit in demonstrating diagnostic performances as it can be used to summarize the accuracy of an investigation with a single number by calculating the area under the curve (AUC). The Receiver Operating Characteristic (ROC) (Metz, 1978) curves are usually used to analyze the accuracy and reliability of the diagnostic tests having ordinal or continuous results. Therefore, the method was considered to measure the reliability of BRBES in comparison with expert opinion and Fuzzy Rule Based Expert System (FRBES). The accuracy of a system to assess the level of suspicion of the hyperthyroidism can be measured by calculating the Area Under Curve (AUC) (Metz, 1978; Hanley, 1988). Figure 4 illustrates the ROC curves plotted for BRBES data, Expert Opinion and FRBES data. The ROC curve plotted by the blue line in this figure is associated with the results generated by the BRBES with AUC of 0.859 (95% confidence intervals 0.687 -1.000). The green line in ROC curve is obtained against the physician's opinion, and its AUC is 0.820 (95% confidence intervals 0.621-1.000). The ROC curve with violet line in Fig. 4 is obtained against the FRBES data, and its AUC is 0.771 (95% confidence intervals 0.566 - 0.996).

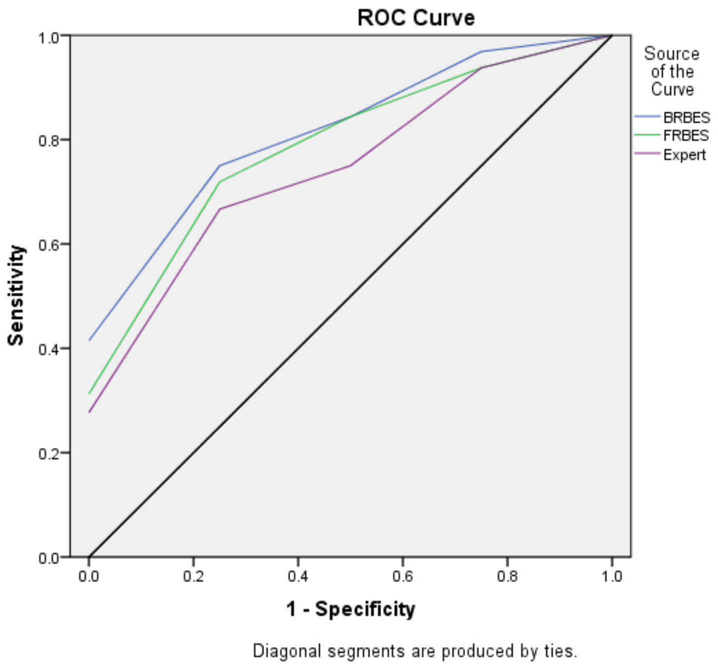

Figure4: ROC Curves Comparing the Result of BRBES and Expert Data

Table IV: Reliability comparison among BRBES, Expert Data and Fuzzy Logic

Area Under the Curve

Test Result Variable(s)	Area	Std. Error	Asymptotic Sig.	Asymptotic 95% Confidence Interval	
				Lower Bound	Upper Bound
BRBES Result	.859	.088	.030	.687	1.000
FRBES	.820	.102	.053	.621	1.000
Expert Data	.781	.110	.089	.566	.996

Table IV summarizes the above results associated with BRBES, Expert Opinion and FRBES. From Figure 4 as well as from Table IV it can be observed that AUC of Expert Opinion is less than from the BRBES. The reason for this is that during the interviewing and conversation with the physicians it has been observed that they are not aware of the uncertainty issues related to the signs and symptoms of the hyperthyroidsom. The reliability of Fuzzy Rule Based Expert System (FRBES) is also lower than BRBES. The SPSS 16.20 has been used to draw the ROC curve and to calculate the AUC of this curve. The reliability of FRBES assessment level of Hyperthyroidism suspicion is also lower than that of BRBES.

6. Conclusions

A Belief Rule Based Expert System (BRBES) has been presented here to produce a reliable and accurate detection of hyperthyroidism by considering all types of uncertainties. The knowledge base of this system is constructed by taking experts' suggestions. The experiments, carried out, by taking the data of 100 patients demonstrate that the BRBES's generated results are more reliable than that of human expert as well as fuzzy rule based expert system. Therefore, the BRBES can provide a decision support platform to the physicians and it can provide primary health care to the people with reduced time and low diagnosis cost. The physician can pay all their attention to the actual hyperthyroidism patients. By using BRBES, a trust can be established between them and the patients.

The great achievement of this research is to overcome the uncertainty problem from suspicion of hyperthyroidism which is not able to overcome by traditional Rule-base system. By using rule-base system with evidential reasoning build system is able to remove uncertainty problem. Online base PHP platform is also a great achievement of this system. By using this anyone from anywhere in the world can detect hyperthyroidism. The system will be developed using Genetic Algorithm (GA) and Artificial Neural Network (ANN) so that a comparison can be done among GA, ANN and BRBES. In next version the expert system assessment performance can be significantly improved after training the BRB through accumulated clinical cases. For accurately detection of hyperthyroidism this system will be beneficiary.

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