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Determining the Case of Overweight using Intuitionistic Fuzzy Approach

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ABSTRACT

Sometimes BMI at almost the marginally end values of the standard prescribed intervals may wrongly categories a person either into normal or overweight category. This may be sometimes due to either wrong measurement of BMI value or wrong diagnosis of medical practitioner. This may lead to the wrong treatment of the patient. This is a frequent event everywhere in the world. To overcome such type of problems, it is observed that a soft computing approach can only provide a better satisfaction. Since it is a medical diagnosis problem, and since for almost all the medical problems the concerned physicians do always have some amount of hesitation (at best it could be nil), we have no other soft computing theory as our option but the intuitionistic fuzzy set theory of Atanassov only, for approaching towards a satisfactory solution.

I. Introduction

This work is on dealing with overweight cases of human beings. The normal range of Body Mass Index (BMI) for healthy person is 18.5 to 24.99 according to the international prescribed classification as in Table-1. But if BMI is slightly greater than 24.99 (say, equal to 25), then the person is categorized into overweight [1, 10, 19-21]. For this case a mere difference of 0.01 changes the category from 'normal' to 'overweight'. This little amount of change in BMI may be sometimes due to errors in the measurement of weight or height too, which is a case of normal human error (although small error) in villages or remote population areas. Doctor may also do sometimes wrong judgment in categorizing the patient in such cases. A patient with BMI value 24.99 and good physique (due to high body muscles) may be wrongly categorized into 'overweight' and consequently a huge treatment may start for him with a lot of medication for long duration. So a slightly different BMI values give different meaning to the health status. The consequence of this would be that a patient, wrongly declared overweight, may start reducing the intake of fat, protein and other nutrients which was not in fact at all required; and by this way he may lose his good health. Therefore sometimes the doctor's confusion or wrong measurement in weight and height may lead to wrong diagnosis. To overcome such type of problems, a soft computing approach needs to be adopted so that a better results and satisfaction be achieved. Determining the case of overweight is yet a problem to the medical scientists as there is no absolutely correct measuring formula except the existing definition-formula of BMI. In almost all the cases of medical diagnosis problem, the concerned physicians do always have some amount of hesitation in mind while giving decision by their best possible judgments. It has been justified in [7,8] that in many ill defined problems fuzzy set theory [18] may not be an appropriate tool for soft computing in quest of good results. Consequently, in our work here we have the unique option which is the intuitionistic fuzzy set theory of Atanassov [3-6] to solve this problem of health science. Before going for the actual work, we present some basic preliminaries first of all, in the next section.

II. Preliminaries

In this section we present a basic preliminaries of the IFS theory of Atanassov [3-6] and then a brief introduction of Body Mass Index (BMI), Circumference of Waist and Circumference of Neck.

A. Intuitionistic fuzzy set (IFS)

The Intuitionistic fuzzy set (IFS) theory of Atanassov [3-6] is well known as a powerful soft computing tool to the world scientists of soft-computing. Its merit for application in various ill-defined problems have been reported by various authors, but very precisely and mathematically established recently by Biswas in [7,8].

If X be a universe of discourse, an intuitionistic fuzzy set A in X is a set of ordered triplets $A = \{ \langle x, \mu_A(x), \upsilon_A(x) \rangle : x \in X \}$ where $\mu_A, \upsilon_A : X \rightarrow [0, 1]$ are functions such that $0 \leq \mu_A(x) + \upsilon_A(x) \leq 1 \quad \forall x \in X$. For each $x \in X$ the values $\mu_A(x)$ and $\upsilon_A(x)$ represent the degree of membership and degree of non-membership of the element x to belong to A, respectively; and the amount $\pi_A(x) = 1 - \mu_A(x) - \upsilon_A(x)$ is called the hesitation part. Of course, a fuzzy set is a particular case of the intuitionistic fuzzy set if $\pi_A(x) = 0 \ \forall x \in X$. For details of the classical notion of intuitionistic fuzzy set (IFS) theory one could see the books authored by Atanassov [3-6], and also the analysis done by Biswas in [7,8].

B. Hamming Distance between two Intuitionistic Fuzzy Sets

Distance measure is a term used between two objects in metric spaces in mathematical analysis. The Hamming distance between two fuzzy sets are studied. We consider a finite universe of discourse $X = \{x_1, x_2, x_3, \ldots, x_n\}$. If A and B are two fuzzy sets of X with membership function $\mu_A(x)$ and $\mu_B(x)$ respectively, then Hamming distance (d_H) and Normalized Hamming distance (d_{nH}) between the two fuzzy sets A and B are defined as follow:

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Hamming distance between fuzzy sets :

$$d_H(A,B) = \sum_{i=1}^{i=n} |\Delta_\mu(i)| \quad .....(1)$$

where Δ is difference operator described in following equations (a),(b) and (c).

Normalized Hamming distance between fuzzy sets :

$$d_{NH}(A,B) = \frac{1}{n}\sum_{i=1}^{i=n} |\Delta_\mu(i)| \quad .....(2)$$

There are several measures of distance proposed by various authors (for example, see ([12], [14-17]). In our work here for the health science problem on the issue of obesity, we consider the intuitionistic fuzzy Hamming distance mainly because of the reason that this measure considers the information about membership, non-membership and hesitation element-wise.

Suppose that A and B are two intuitionistic fuzzy sets of the universe X with membership functions $\mu_A(x)$ and $\mu_B(x)$ respectively, non-membership functions $\nu_A(x)$ and $\nu_B(x)$ respectively and hesitation function $\pi_A(x)$ and $\pi_B(x)$ respectively. In order to simplify the distance definitions the following notations are used using the distance operator Δ:

$\Delta\mu(i) = \mu_A(x_i) - \mu_B(x_i)$, ...(a)

$\Delta\nu(i) = \nu_A(x_i) - \nu_B(x_i)$, ...(b)

$\Delta\pi(i) = \pi_A(x_i) - \pi_B(x_i)$. ......(c)

Most widely used distance equations are mentioned below:

Hamming distance for intuitionistic fuzzy sets :

$$d_{1H}(A,B) = \frac{1}{2}\sum_{i=1}^{i=n} [\,|\Delta_\mu(i)| + |\Delta_\nu(i)|\,] \quad .....(3)$$

Normalized Hamming distance for intuitionistic fuzzy sets:

$$d_{1NH}(A,B) = \frac{1}{2n}\sum_{i=1}^{i=n} [\,|\Delta_\mu(i)| + |\Delta_\nu(i)|\,] \quad .....(4)$$

Later Szmidt and Kacprzyk justified in [14-17] that the above distance-equations be modified by adding the hesitance index as below:

Modified Hamming Distance between two intuitionistic fuzzy sets :

$$d_{2H}(A,B) = \frac{1}{2}\sum_{i=1}^{i=n} [\,|\Delta_\mu(i)| + |\Delta_\nu(i)| + |\Delta_\pi(i)|\,] \quad ....(5)$$

Modified Normalized Hamming Distance between two intuitionistic fuzzy sets :

$$d_{2NH}(A,B) = \frac{1}{2n}\sum_{i=1}^{i=n} \left[\,|\Delta_\mu(i)| + |\Delta_\nu(i)| + |\Delta_\pi(i)|\,\right] \quad .....(6)$$

C. Body Mass Index (BMI)

Body Mass Index, popularly called in short by the abbreviation BMI, is a indirect measure of fat and mussels. For a person, it is defined by weight (in Kg unit) divided by square of the height (in meter unit). The formula of BMI is given below [9]:

$$BMI = \frac{Weight}{(Height)^2}$$

Thus unit of BMI is Kg/m^2. The BMI value of a person gives a good idea about the health status of him. Indirectly it tells about the fat contents of the body, which is considered as a undesirable part of the body composition. On the basis of BMI score, World Health Organization (WHO) classifies a person into different categories [20] of health as mentioned in Table-1:

Table 1. International Classification of adult underweight, overweight and obesity according to BMI.

Calssification	BMI(kg/m^2)	
	Prinicipal cut-off points	Additional cut-off points
Underweight	<18.50	<18.50
Severe thinness	<16.00	<16.00
Moderate thiness	16.00-16.99	16.00-16.99
Mild thinness	17.00-18.49	17.00-18.49
Normal range	18.50-24.99	18.50-22.99
		23.00-24.99
Overweight	≥25.00	≥25.00
Pre-obese	25.00-29.99	25.00-27.49
		27.50-29.99
Obese	≥30.00	≥30.00
Obese class I	30.00-34.99	30.00-32.49
		32.50-34.99
Obese class II	35.00-39.99	35.00-37.49
		37.50-39.99
Obese class III	≥40.00	≥40.00

Source Adapted from WHO 1995, WHO, 2000 and WHO 2004

D. Circumference of Waist

Matter of overweight and obesity of a person is associated with different kind of diseases or health problems for him. As BMI of a person is an indicator to the health issues so is the 'waist circumference'too. A high value of waist circumference is related to diseases like hypertension, dyslipidmia, type-2 diabetes etc. So waist circumference is an important health index. Therefore, along with BMI value, waist circumference should also be monitored time to time. It indicates about the fat stored around abdomen even when no change in BMI is observed. Consequently, it is fact that both these indicators of a person reveal a lot of information to a doctor. Here Table-2 describes the standard waist circumference classifications [13, 21].

Table 2. Waist Circumference (cm)

S.No.	Category	Measurement (in cm)
1	Normal Range	< 94
2	High Risk	94 - 101.9
3	Obese	≥ 102

E. Circumference of Neck

It is found that there is a correlation [2] between obesity and neck circumference of a human. According to the research work, fatty neck increases the risk factor for high triglycerides and high blood pressure. Scientists at the Department of Family Medicine, Faculty for Health Sciences, Ben-Gurion of the Negev, Israel, suggested the safe neck size not more than 37centimeters [2,11]. Thus circumference of neck is also a good health index used by the doctors while making decisions regarding his patient.

III. An Application of Intuitionistic Fuzzy theory in Decision Making Process on the Health Status (Normal weight or Overweight) of a Person

Intuitionistic fuzzy theory of Atanassov [3-6] is a powerful soft computing tool in decision making [7, 8], especially in the area of medical sciences. In many cases, it becomes difficult for a medical professional to reach to the TRUE (better to say near-true) decision because of the limitation of knowledge and intellectual capability of human beings.

Let P = {P1, P2, P3} be a set of three patients suffering from some diseases related to overweight. Consider a doctor Dr.D under whom these three patients have to undergo treatment.

The patients P1, P2 and P3 are to be categorized into the following category: either Normal weight or Overweight.

Let the three patients P1, P2 and P3 be having following features as a symptom for being categorized as overweight or not :

1. C1 (Waist Circumference)
2. C2 (Neck Circumference)
3. BMI (Body mass Index)

Let the set of diagnoses be C = {Normal Weight, Over Weight}.

The considered set of symptoms is F = {C1, C2, BMI} and set of patients is P = {P1, P2, P3}.

In case of fuzzy theory [18], if adopted by the doctor Dr.D, the Doctor may predict that P1 may be suffering from typhoid and chance for it is 80% (0.8). Similarly chances for P2 and P3 suffering from typhoid are 70% (.7) and 60% (.6) respectively .Thus, first fuzzy set may be represented as F1 = {(P1,0.8), (P2,0.7), (P3,0.6)}. Similarly other fuzzy set, for other disease, may be defined as F2 = {(P1,0.6), (P2,0.7), (P3,0.8)}, and so on.

But considering the rigorous mathematical analysis done in [7,8], and since the Doctor Dr.D. is an expert in intuitionistic fuzzy theory too, he will make a better prediction. He may predict that P1 may be suffering from typhoid and chance for it is 80% (0.8). And chance of "not suffering from typhoid" is 10% (0.1); and rest 10% can not be predicted(a hesitation value). Similarly for P2, and P3 chances, non-chances and hesitations are (0.6, 0.3, 0.1) and (0.7, 0.1, 0.2) respectively. Thus, first intuitionistic fuzzy set may be represented as IF1 = {(P1, 0.8, 0.1, 0.1), (P2, 0.6, 0.3, 0.1), (P3, 0.7, 01, 0.2)} and so on.

On the basis of above two examples, suppose Q is an IF relation between P and F.

Table 3. Q: Relation between P and F.

Q	C1	C2	BMI
P1	(0.6, 0.3, 0.1)	(0.7, 0.1, 0.2)	(0.8, 0.1, 0.1)
P2	(0.6, 0.2, 0.2)	(0.5, 0.3, 0.2)	(0.6, 0.3, 0.1)
P3	(0.8, 0.1, 0.1)	(0.7, 0.1, 0.2)	(0.7, 0.2, 0.1)

Here, meaning of **(**0.6, 0.3, 0.1) is that "the chance of correct measurement of C1 is 60%" **,** "the chance of incorrect measurement is 30%", and the rest amount 10%. is the hesitation part (i.e cannot be said if the measurement was correct or not).

Similarly,suppose R is a IF relation between C and F.

Table 4. R: Relation between C and F.

R	C1	C2	BMI
Normal	(0.5, 03, 0.2)	(0.6, 0.3, 0.1)	(0.6, 0.2, 0.2)
Over Weight	(0.7, 0.1, 0.2)	(0.7, 0.2, 0.1)	(0.8, 0.1, 01)

If doctor finds the observed values of C1, C2, BMI near its upper limit (94 cm, 37 cm and 24.99 respectively) then he may get confused to categorize the patient either into normal weight category or overweight category.

In this context, (0.5, 0.3, 0.2) means that "50% chance is that on the basis of the observed value of C1 the doctor categorizes the patient into normal range". Whereas 30% chance is for overweight and 20% is the hesitation part where doctor is unable to decide the category.

Now using Modified Normalized Hamming distance aforementioned, in equation-6, we calculate the distance between each patients in Table-3 and each of the cases (Normal or Over Weight) in the Table-4 with respect to each of the symptoms. And thus we get the Table-5 showing the relation T between P and C .

Table 5. T Relation between P and C.

T	Normal	Over Weight
P1	0.16	0.10
P2	0.10	0.16
P3	0.20	0.10

The shortest distance of Table-5 tells the health status of the patient. Thus, P1 and P3 are declared in the category of Overweight whereas P2 is declared in the normal category of health/weight.

IV. Conclusion

This paper considers the problem of determining the case of overweight of a person. The work presents a soft approach using intuitionistic fuzzy theory to minimize the errors in measurement and diagnosis. This soft-computing tool is used due to the ill-defined BMI values (BMI value with 24.99 for normal category and BMI value with 25.00 for overweight category). This helps in deciding by how much index a person could be placed in overweight category or in other nearly overlapping categories. This way we get a better diagnostic result.

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