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An Entropy based Classification of Body Fat using Fuzzy Rules Commingled with Genetic Algorithm

J. Grace Hannah, D. Gladis

Abstract*: *A perennial inflated malady under the radar which has become an imperative thrust of colloquies in various parts of the world is "Obesity". It is a health gremlin which curtails a person's quotidian lifestyle and stems from the physical apathetic torpor, phrenic nerves, deleterious food habits and the frailty of genetic constitution. Bariatrics is that discipline of science which deals with the surgical procedures and consultations for obese individuals. Prolific research and anatomizations have been carried out on the sundry tenacious health impediments germinating due to obesity. The assaying of body fat percentage of every individual in a punctilious method is a desideratum. The previous work entailing body fat percentage comprehensively included an individual's Body Mass Index (BMI) with respect to their age and gender. The factual composition of a person's fat constitution and the muscle tissue configuration is not computationally explicated using BMI. Thus, the strictures imposed by the formula vitiates the veracity for an individual having more muscle mass than fat mass. The proposed indagation gives a pellucid, novel formula which is procured through the integrant crude parameters of an individual. This aids in overcoming the fallibilities of the previous formula for body fat. The classification accuracy is augmented by implementing fuzzy rules synthesized into genetic algorithm. The Ethical Committee approval for this study has been obtained from the Institutional Ethics Committee, Madras Medical College, Chennai. The empirical study has been simulated using Matlab and the results have been successfully acquired in the GUI mode.

Keywords* : *Obesity, Body Fat Percentage, Fuzzy Rules, Genetic Algorithm, Matlab

I. INTRODUCTION

Obesity is a nodus which has raised a lot of awareness in various parts of the world. In recent times, surveys have shown that nearly thirty percent of the entire population is obese, and almost three million reportedly suffer from concomitant obesity lurgies including heart diseases, cancer and diabetes. Most of the world's population lives in countries where overweight and obesity kills more people than underweight. The study organized by WHO also showed that 41 million children under the age of 5 were overweight or obese [5], [19], [20]. A neoteric and unabating realm in the health industry is the advancement in bariatric sector [20]. The age at which a person becomes obese metamorphoses the ability of the individual to lose calories. The energy imbalance between the ingested calories and the calories expended is considered as the outset of obesity and uncurbed fat [19], [20].

Obese individuals can have great difficulty losing weight. The uncurbed energy and White Adipose Tissues (WAT) can cause serious detriments like Cushing's syndrome, Hypothyroidism, Neurologic disturbances and various other health impediments [9], [19], [20]. Though dieting and exercise are solutions for weight reduction, studies show that only the size of the fat cells are pruned, instead of annihilating them completely [4], [19], [20]. To anatomize the growth of adipose cells in the human body a meticulous analysis about the White Adipose Tissue (WAT) and Brown Adipose Tissue (BAT) is done [20]. Brown Adipose Tissue (BAT) are an important integrant which proselytizes the excessive fat in the body by incinerating them [6], [7], [19], [20]. They comprise of several lipid droplets, with ginormous quantum of iron. On the other hand, WAT consists of a single lipid droplet, less mitochondria, and are regarded as the unbridled, unseared body fat which usually leads to obesity and other diseases [8], [19], [20]. In children, the excess calories and WAT are converted into new fat cells (hyperplasic obesity) [1], [2], [19], [20], while the nimiety of calories consumed by an adult proliferates the existing fat cells (hypertrophic obesity) [4], [19], [20]. The body fat percentage is a primary factor that connotes if a person is healthy or not. Body fat is divided into two categories such as the subcutaneous fat and the visceral fat [11], [13], [19], [20]. Subcutaneous fat is that which is located beneath the skin [11], [19], [20], while the visceral fat is located inside the peritoneal cavity surrounding the peritoneal organs [12], [19], [20]. The various approaches for treating obesity incorporate studies of hormones like Leptin and Ghrelin [20]. These hormones are secretions of the fat cells in the body. Leptin is concomitant to the reproductive function, and Ghrelin stimulates the pituitary gland to release growth hormones. Hyperlipidemia and proliferation of fat are often analogized as they correlate and aid in procuring better cognizance of obesity disorders [20]. The previous work of study involved the assessment of BMI, but for an athlete or a healthy person with more muscle mass the above formula using BMI can lead to fallacious results.

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* Correspondence Author
J. Grace Hannah*, Research Scholar, Presidency College, University of Madras, Chennai, India, hannahgrace161289@gmail.com
Dr. D. Gladis, Principal, Bharathi Women's College, Chennai, India

This paper aims to effectuate and proliferate the efficiency and precision of the derived novel body fat formula using the Lipid Profile and Bio-Electric Impedance (BIA) method from an individual.

The classification accuracy of the different classes such as the obese and non-obese category in male and female is further enhanced by using fuzzy rules combined with genetic algorithm, and the respective information gain for each class are computed. The paper is organized as follows: section I gives a brief study of the techniques implemented; section II annotates the employment of the methodology and the Section III reinforces the accuracy percentage using the novel formula for body fat percentage. Section IV presents a schematic overview of the results obtained from the fuzzy rules integrated with genetic algorithm, and section V concludes the work done with the future work that can be implemented.

II. TECHNIQUES USED

The study population includes adult patients who were obese, hyperlipidemic and faced other problems due to unbridled disintegration of fat cells. The data samples were obtained from Rajiv Gandhi Government General hospital, Park Town, Chennai. The body fat percentage is computed by formulating the values obtained from the blood tests and the bioelectric impedance (BIA) method for a person [19], [20]. Pregnant women, patients having bleeding disorders, anaemic and suffer from any other serious ailments were excluded from the study [19], [20].

The lipid profile test involved the sample blood drawn from patients who fasted for 9-12 hours. The lipid levels are checked for factors such as Total Cholesterol (TC), High-density Lipoprotein (HDL), Low density Lipoprotein (LDL) and Triglycerides (TG), which are then centrifuged and then combined with the Cfas lipid reagent along with the necessary preci-controls to acquire the values of each of the factors [20]

The Bio - Electric Impedance Analysis (BIA) is a non-invasive method. It employs a technology which is extensively used, and aids in providing impeccable analysis of the body composition for an individual [15], [19], [20]. It operates at a temperature humidity of 5 to 35 degree Celsius with no corrosive gas in the surrounding air. Bioelectric Impedance expounds as the opposition of a conductor to the flow of an alternating current, and consists of two constituents: resistance (R) and reactance (Xc) [17], [18], [19], [20]. The Resistance has a low frequency of 40-50 kHz and is the radical opposition of the conductor [18], [20]. Reactance is the additional opposition or the ephemeral storage of the electric charge by a condenser. The lipid components of the membranes of the Body Cell Mass (BCM) behave as capacitors and reduce the flow of intracellular ions [18], [19]. Despite a general perception that BIA estimates body fat, the technology actually determines the electrical impedance of body tissues and adiposity [16], [19]. The BIA quantifies the resistance of body tissues through the flow of small electrical signals through the ions present in the fluid content of a human body. The device uses a pair of electrodes through which a low level imperceptible electric current flows and divulges the estimates of water content and body fat in the blood, tissues and bones. The fat in the body is analyzed depending on where they are distributed. The electric current which passes through the body is at differential rate depending on the body composition [18], [19], [20]. Hence there is a direct relationship between the concentrations of the ions and electric conductivity, and an indirect relationship exists between the ion concentration and the resistance [18], [19]. The BIA enumerates and itemizes the body facets such as visceral fat percentage, subcutaneous fat percentage and segmental subcutaneous fat percentage, age of the individual cognate to their fat percentage, Body Mass Index (BMI), muscle mass percentage, its corresponding segmental muscle mass percentage and the total body fat percentage [19], [20]. The BIA is currently used in diverse settings including private clinics, hospitals and across a spectrum of ages, body weights and disease states [19], [20].

III. METHODOLOGY

The dataset procured from the blood samples and the BIA method is simulated in MATLAB to peruse the precision, coherence of the novel derived body fat formula. The datasets are catalogued germane to the body fat percentage and cholesterol levels of an individual. A nexus of fuzzy rule calibrations assimilating with genetic algorithms [21] is implemented on the dataset before the denouement stratification. The inceptive phase entails an aleatoric permutation to bifurcate the dataset into testing and training dossiers. Pre-processing of data is a rudimentary aspect to curtail noise and coarct the data without any attenuation. Thus, the segregated datasets are discretized along with the appropriate information gain for each attribute. Finally, the process of fuzzification along with the genetic operators [21] such as selection, crossover and mutation are implemented to obtain the best chromosome from the population. The fuzzy rules which qualify the fitness function is selected and stored in the rule database.

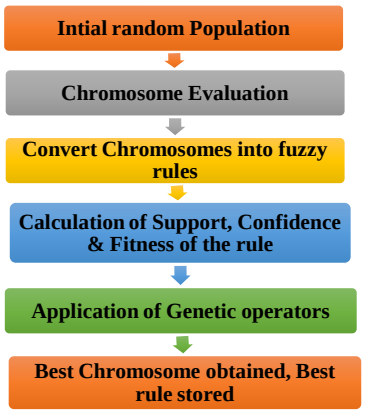

Fig 1: Fuzzy rule extraction integrated with Genetic Algorithm

IV. PERFORMANCE ANALYSIS

The existing body fat formula is given as:

[(1.2*BMI) + (0.23*Age) – (10.8*Gender) – 5.4] [14], [19], [20]

Though the above formula has been widely accepted as the standard measure to analyze body fat percentage, it has been observed that for a person who is muscular and has more muscle mass, the BMI increases considerably, thereby placing him/her in the morbidly obese or overweight category [19], [20]. Therefore, to avoid fallacious calculations, the below formula involving the total Cholesterol (TC) from the lipid profile, subcutaneous and visceral fat from the BIA, age pertaining to the fat accumulation in the body and gender of the person is taken into consideration. The optimal feasible formula thus obtained is as follows:

Body fat % = [(0.5613 *(SF+VF)) + (0.0572 (Age(M) -Age) + (0.0290 * TC)- (10.889 *Gen) + 10.0822] (1)

Where SF & VF signifies the subcutaneous and the visceral fat, age (M) is the age of the person with respect to the body fat and Age is the original age of the person, gender (Gen) takes the value of 0 for female and 1 for male.

A performance analysis has been performed to vindicate and augment the derived formula which has been subsumed using fuzzy rules integrated with genetic algorithm to procure the precision rate for each of the classified target classes. The classification analysis has rendered an accuracy of 97% and 94% for all classes in the training phase and testing phase respectively.

V. RESULT OBTAINED

The dataset incorporated into MATLAB provides better classification accuracy, and has yielded the below results in GUI. Figure 2 elucidates the attributes which are fuzzified according to the fuzzy antecedents, along with the information gain of each attribute. The features are selected based on the highest amount of information gained by each attribute.

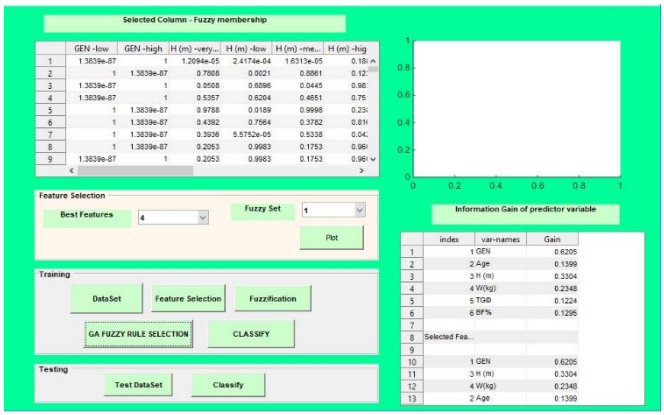

Fig 2 : Fuzzified Dataset with Information gain of attributes

Figure 3 explains the classification of the target classes which are obese – Male, Obese-Female, Non-Obese-Male andNon-Obese-Female along with the confusion matrix for betteranalysis. The plotting of the graph can be implemented for all attributes based on the fuzzy antecedents. But in the below figure, the plotting of the age attribute with its respective fuzzy antecedents is displayed.

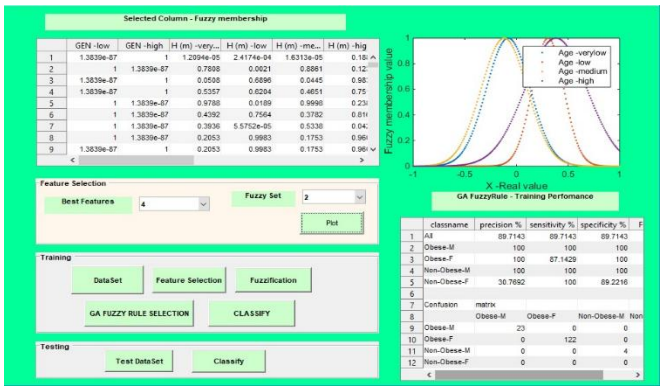

Fig 3: Classification of Training dataset, accuracy measurement and plotting of fuzzy values

Figure 4 elucidates the classification and selection of the testing dataset along with the summary of precision, sensitivity,specificity and F-score percentage for each of the target classes have been analyzed and shown. The below figure also illustrates the plotting of the attribute – Body Fat Percentage according to the classified fuzzy antecedents.

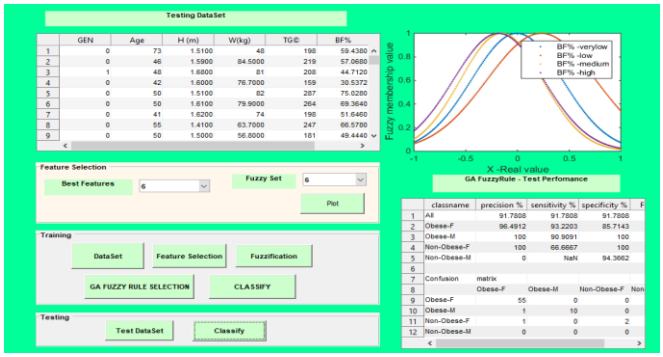

Fig 4: Classification of Testing Dataset and plotting of the Body Fat Percentage Attribute

VI. CONCLUSION

This study has bolstered the computation of the novel body fat formula by explicating the data obtained from BIA and blood samples of an individual. It has also contributed in gaining the fathomless intellect of an individual's intramural and over the skin fat depositions. The novel formula aids to proselytize and overcome the gremlins encountered by the previously indited formula for body fat. Thus, making it an unambiguous and unswerving measure to be used in the future to meliorate the health milestones. The simulation in MATLAB has asseverated the classification precision by entailing the process of fuzzification and obtaining the information gain for each target class. This has vouchsafed the prominence of the attributes in the dataset, and has capacitated the cogent panacea of the problem by generating error rates as low as 3% & 6% for all classes in the training and testing phases of classification.

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AUTHORS PROFILE

J. Grace hannah is a research scholar pursuing her Ph.D in Computer Science from the University of Madras. She has more than eight research papers to her credit, and has participated in various National and International conferences.

Dr. D. Gladis is the Principal of Bharathi Women's College, Chennai. She has headed the Department of Computer Science & Research Institute in Presidency College, Chennai. She has guided more than fifteen research scholars under the M.Phil and Ph.D courses and has been an active researcher. Her area of interests are Neural Networks, Image Processing, Data Mining to name a few.