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A Study on Mathematics Modeling using Fuzzy Logic and Artificial Neural Network for Medical Decision Making System

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***Abstract*—The conceptual formulation for diabetes & hepatitis in what seems like a fuzzy & neural network is investigated in this article. Because certain facts in a real-world situation cannot be recognized with precision, the metrics are used as approximate values. The membership functions and set of rules that make up the diabetes framework include fuzzy logic as their beginning premise. Fuzzy logic is just an augmentation of propositional logic which works with uncertainty and ambiguity in systems and offers a powerful mathematical tool to express data in a fashion that mimics naturally occurring human consciousness. ANN is a computational structure with biological inspiration made up of intricately linked adaptable simple processing units that can process information and convey information in a highly comparable manner. Investigators and academics from a diverse range of scientific and engineering disciplines were drawn to the emerging need for responsive intelligent machines because of the integration of Fuzzy Inference algorithms with Artificial Neural Networks. Fuzzy Systems, that can rationalize with imperfect information, are more adept at explaining their choices than artificial neural networks, which struggle to do so. Nevertheless, fuzzy systems are unable to learn the rules they employ to make decisions. Owing to these restrictions, intelligent hybrid systems have been developed to solve the issues using specific methodologies. The much more popular hybrid Neuro-Fuzzy approaches are discussed in this questionnaire survey, along with their benefits and drawbacks.**

***Index Terms*—Medical System, Fuzzy Logic, Neural Networks, Neuro Fuzzy Systems.**

I. Introduction

In the modern era, mathematics is successfully used in a variety of crucial medical fields, which include bio fluids, cardiovascular problems, diagnostic timeframes and test results, analysis of data, medicinal chemistry and revelation, epidemiological studies, genetic predispositions, image analysis, virology, measuring instruments, cell biology, cognitive science, oncology, epidemiology, and more. As examples, membership functions and fuzzy logic involving rules are two of the most well-known. All of this study has helped, and continues to assist more and more, in both improving our understanding of medical occurrences and identifying useful course of action. Several areas of mathematical modelling, such as biomathematics and computational neurobiology, have developed as a result of this attempt. The improvements in medicine and living quality brought on, for example, by early and precise diagnoses, better effective medications, the suppression of outbreaks, and microbiological know-how, has, nevertheless, remained the most significant result.

The need for formal logic to comprehend complex phenomena is the underlying cause of mathematics' pervasiveness in contemporary science. Characterization of measurements, parameterization, categorization, minimization, data analysis, investigation, forecasting, and verification are all aspects of the mathematical approach. The famous theoretical physicist Eugene Wigner used the phrase ”the unreasonable effectiveness of mathematics in the natural sciences” [1] to describe the success of the mathematical method. It is additionally evident that arithmetic draws heavily from the scientific method, as well as progressively from biology, psychology, the economics, sociology, and healthcare. Time-series analysis, chaotic differential equations, demographics, predictive arithmetic, and biologically motivated algorithms for categorization, optimizing, and computing, like neural networks, genetic algorithms, and DNA computation, are some traditional instances. The possibility for mathematics to exert an influence on the biological and other ”soft” sciences will keep growing as data collecting and processing skills improve. The importance of multidisciplinary collaboration

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for the advancement of science in overall and arithmetic in specific is highlighted by all of this.

In actuality, it is challenging for medical systems to uncover the views into what is particularly important for the sufferers because many areas of management of clinical systems are quantifiable and the quantity of information inside the health care industry grows by the hour. The foundation of efficient medical system administration is a data-driven approach to assessing health outcome measures, intelligent systems, and arithmetical, computer simulation, epistemological, and advances in technology [2-4]. When a randomized controlled trial is morally or practically impractical, modelling in medicine can be a useful tool for planning and evaluating interventions [5-6]. A developing field in medicine is the creation of such mathematical equations that can simulate health outcomes. Predictive modelling, simulation, and decision analysis are a few names for mathematical modelling. Model - based techniques are typically used in the health care industry for planning health services, evaluating their efficacy and consequences, analysing the financial impact of providing healthcare, conducting health economic analyses, monitoring disease outbreaks, forecasting the consequences of health services, as well as other uses. When economic, moral, regulatory, monetary, technological, or some other constraints like a rare incident make it impossible to carry out RCTs and comparable studies or extend investigations on real patients [7-8], mathematical modelling can also be useful. By including case studies and real-world examples of mathematical modelling and models for the best decision-making in healthcare, we contribute to the literature with this special issue. We want to answer data analytics-related queries and find solutions to issues with outcome prediction in therapeutic and health policy. Diabetes is among the illnesses that is most commonly dreaded in today's society. Diabetes is a condition marked by elevated blood sugar levels [9]. It is brought on by glucose, which is derived from previously consumed food. Individuals suffering from this illness are now experiencing problems not just in affluent nations, but also in emerging and impoverished nations. Irrespective of a country's developmental level, it affects everyone on the planet [10]. Several causes are frequently connected to the onset of diabetes. One of the most frequently discussed concerns is elevated blood pressure. He [11] made the observation that a patient's elevated blood pressure may play a role in the development of diabetes. In respect of respective biological ages, a diabetic and a healthy individual must also be distinguished from one another. According to [12], those older than 40 years old are among the possibilities for a diabetes diagnosis. Another element that has been linked to diabetes is obesity. Diabetes may be discovered in a person who has an obese or overweight problem. When type-2 diabetes in Caucasian morbidly obese people is examined at the micro level, low serum creatinine is a contributing factor that is unaffected by age, sex, history of diabetes, anthropometric, hypertension, or smoking habits. According to their findings [13-15], people with diabetes, regardless of whether they have also hypertension issues, are more likely to have overall serum cholesterol levels. Other variables, such genetic predisposition or familial background, can potentially cause diabetes [16]. There is a huge list of factors linked to diabetes, but there is no clear consensus on which elements are more crucial than the others. Several potential risk indicators have been put up to this point, but it has been difficult to pinpoint an actual, legitimate potential risk.

II. Literature Review

A. Mathematical Modelling in Medical System

The application of computer modelling to the healthcare sector and epidemiologic studies chronic diseases, such as diabetes as well as hepatitis, has indeed been effective [17-18]. It plays a crucial role in the procedures of characterization, prognostication, and assessment of these diseases. Using various data and analysis techniques, various modelling studies have recently projected the diabetes incidence and its worldwide frequency for various nations, especially SA. In [19], approximations of diabetic in terms of incidence, frequency, and fatality rate were examined using a computational formula built on a collection of nonlinear equations. In furthermore, a logistic regression analysis was used by IDF

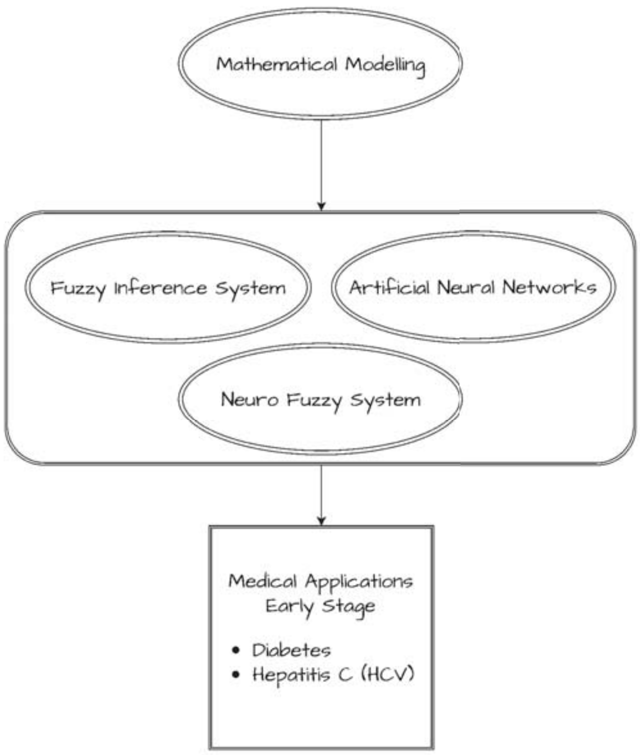

Fig. 1. Mathematical Modelling System

[20] and then another worldwide study [21] to determine the incidence of diabetes all through the world. Also, a subsequent

investigation by the NCD Risk Factor Consortium utilised a Hierarchical Bayesian model to estimate the incidence rates of diabetes in various nations [22]. Each approach has benefits and drawbacks of its own. Nevertheless, in this investigation, we created various computational equations (MLR, ANFIS, ANN, SVR, and BLR) to make into account each model's strengths while compensating for its flaws if employed alone. Accuracy is a major problem that might change depending on the information. These algorithms were merged and calibrated to attain consistent precision in order to obtain precise forecasts of the incidence rates of diabetic and the hazard variables, with the goal of assisting healthcare policy formulation and determining the financial requirements for diabetes management in SA.

B. Fuzzy Logic

Fuzzy rule-based categorization delivers enhanced functionality and much more easily comprehensible outcomes. The effectiveness of neural network models and the explainability of fuzzy rule-based categorization are combined in dynamic neuro-fuzzy classification. When confronted with a high quantity of rules, regulation categorization method performs worse [23] constructed a classification rules utilising fuzzy logic classifiers. In a fuzzy logic inference engine, segmentation of the classifiers has been proposed. A classification technique divides groups into comparable clusters according on resemblance. For patients with Type 1 diabetes mellitus, he [24] demonstrated a method built on FIS to continually monitor physiological signals and give hypoglycaemia diagnosis. One of the system's inputs utilised to identify hypoglycaemics spells was indeed the cardiovascular system and adjusted delay of the ECG data. The FIS characteristics that control the fuzzy

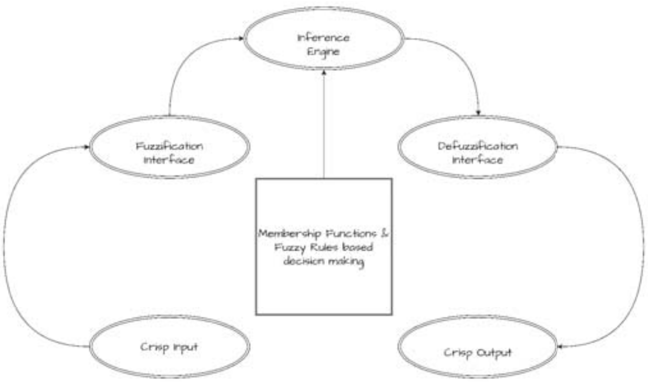

Fig. 2. Fuzzy Logic System

sets and membership function parameters are optimised using an intelligence optimizer. In order to diagnose diabetes, he [25] constructs a performance analysis comparing Mamdani-type versus Sugeno-type fuzzy membership functions of FIS. [26] employed the FIS that's been genetically tuned for image classification. P.B. Khanale and colleagues (2011) proposed a FIS for the diagnosis of thyroid disorders. For the purpose of predicting the clinical stage of hepatocellular carcinoma, a fuzzy system is presented [27]. Next, using fuzzy sets through If-Then, he [28] applies the technique to diagnosis individuals having oral pre-cancers.

C. Artificial Neural Network

One of the quickly expanding topics of study includes artificial neural networks (ANN), also known as neural processing, which draws researchers out of a wide range of engineering specialties, including software engineering, applied sciences, and operations research [29]. An artificial neural network (ANN) is a computational framework inspired by biology that consists of intricately interwoven adaptable basic processing units that can carry out extremely parallel processing enabling data acquisition and information retrieval. The goal of neural

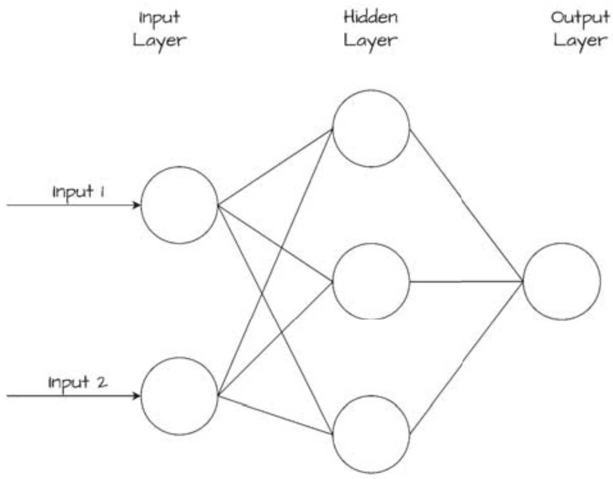

Fig. 3. Artificial Neural Network

networks is to slightly resemble how the biological brain functions in conventional computers. When the connection between inputs and outputs is inherently unpredictable, ANNS operates at its best. It is also well suited to tackling issues in which there are no predefined techniques or guidelines. Simple processing components, modules, or terminals together referred to as "neurons" and help facilitate to nerve neurons make up an ANN. The factors that connect every neuron to the others. The intrinsic component connexion intensities, or loads, acquired through a procedure of adapting to, or acquiring knowledge from, a collection of training sequences, are where the network's computing power is kept. The weights contain the data necessary for the input-output translation of the net. Although being used on machines, ANNs are not designed to carry out certain tasks. Instead, unless they understand the characteristics that are shown to them, they are taught with regards to data sets. Trends may well be offered to all of them for prognosis or categorization after training.

D. Neuro Fuzzy System

In so many spheres of our cultural and technological existence, NFS usage is expanding. In their research study,

[30] categorised NFS applications used in different investigation and concern realms into multiple categories based on the nature of the accumulated on NFS implementations. These classifications included academic modelling systems, healthcare systems, monetary systems, electrical and electronic systems, traffic monitoring, image analysis & extraction of features, manufacturing & system modelling, predicting & prognostications, NFS improvements, and sociology. The organisation of individuals, organizations, and assets to provide healthcare insurance services to satisfy the requirements of target populations is known as a health industry. Due to periodic population expansion, illnesses are currently the leading cause of death in emerging nations like Ethiopia, both within urban and rural sections of the nation. If the illnesses are detected in their early stages, it will be more beneficial. The likelihood of dying from many diseases will reduce with accurate disease diagnosis. To determine whether the disease is present, numerous clinical tests are conducted. Several pertinent studies have been done as a result of the enormous emphasis that neurofuzzy implementations in healthcare treatments have received over the past 10 years. NFS are used to diagnose a number of common diseases, including brain disorders, cardiac conditions, carcinoma, Alzheimer's, thyroid problems, leukaemia, hypotension, and heart disease.

III. Applications used for Mathematical Modelling in Medical System

A. Hepatitis

Viral hepatitis is a condition with an increasing global impact; in 2013, it was the seventh most common cause of death globally [31]. These deaths were largely caused by the hepatitis C virus (HCV) and the hepatitis B virus (HBV). In response, the World Health Organization (WHO) set goals in 2016 for the "elimination of HBV and HCV as a public health concern by 2030 [32]. These goals include a 65% decrease in HCV-related morbidity and an 80% decrease in HCV infections when contrasted to a baseline year of 2015. In order to prioritise populations and determine the amount and coverage of prevention efforts needed to reach these targets both nationally and among at-risk groups, governments are increasingly resorting to epidemic models.

A blood-borne virus called HCV can cause liver cirrhosis, hepatocellular carcinoma, and even death if left untreated. Individuals who inject drugs (PWID) continue to be the largest vulnerable group for HCV infection in the majority of industrialised and many developing nations, and as such, they are a shining examples for preventative strategies [33]. The prevalence of HCV in PWID is substantial; according to estimates by [34], 52% of PWID worldwide have a background of HCV infection. An emphasis on limiting dissemination among PWID is essential as nations work to stop new HCV diagnoses in order to achieve the WHO eradication targets. Although there is presently no HCV vaccine, there are a number of extremely successful harm reduction strategies that can be used to stop HCV recurrence. A person's risk of contracting HCV among PWID is reduced by 50% by opiate replacement treatments (OST), including such methadone and buprenorphine [35]. A person's risk of contracting HCV is reportedly reduced by 74% when OST and build lasting syringe and needle programmes (NSP) are used together [36]. There are essentially two methods for calculating the effect of treatment at the population level. The WHO HCV fatality target can be achieved in a variety of settings with current or moderately continued to increase levels of treatment aimed at individuals with much more advanced liver disease, according to burden of disease models that take progression of the disease but not transmission into account [37]. However, because they do not molecularly account for disease transmission, these increased infection models are unable to provide insight into what is necessary to meet the WHO incidence eradication target. Instead, they are particularly beneficial in determining the level and trying to target of treatment necessary to reduce HCV mortality. They disregard both the probable risk of reinfection and the potential benefits of treatment for prevention as a result. Dynamic dissemination models, which mechanically simulate bacterial contamination and take into account both the danger of reinfection and the decrease in onward shipment brought on by therapy, are a complement to burden of illness models.

Hepatitis C virus (HCV) infection is a global public health issue with an alarming frequency of 2–15% [38]. It wasn't until 1975 that the presence of hepatitis C became recognised. At that time, newly discovered diagnostic tests involving hepatitis A and B showed that many instances were hardly hepatitis A neither hepatitis B. In 1989, the responsible party was found [39]. The HCV is frequently spread by blood and blood-derived products. Other methods of dissemination, including as unprotected sexual intercourse, transmission during pregnancy from a contaminated mother to her child, etc., have been hypothesised, although they are still debatable and likely of minimal significance. Hepatitis C takes 50 days on average to incubate. Acute hepatitis C typically has a 1% fatality rate and is a minor condition. Although more than 50% of symptomatic patients become chronic, certain of them will ultimately proceed to cirrhosis or cellular malignancy, and even both [40]. Fatigue is the most prevalent symptom of an initial illness. Nonetheless, up to 90% of patients are asymptomatic. This makes hepatitis C diagnosis very challenging. Interferon (IFN) a-2b is being used as a therapeutic for hepatitis C, with doses ranging from 3 to 15 million foreign units. IFN therapy, though, only works in 11–30% of patients. An investigation of the effectiveness of IFN-a therapy is provided in [41]. Moreover, IFN has been shown to be more effective when combined with ribavirin, another antiviral medication, than when administered alone [42]. As the likelihood of significant antigenic diversity between strains is a key barrier to vaccine development, there is currently no vaccination for hepatitis C. [43]

B. Diabetes

Yet, the bulk of today's anti-diabetic medications show a variety of negative effects. In addition, weight gain and hypoglycemic incidents are linked to insulin therapy. Hence, the design and development of anti-diabetic drugs is a major concern and a research problem [44]. There is still a lot to be learned about the etiopathology, treatment, screening, and administration of DM, despite the fact that intensive research has contributed significantly to our understanding over the past few decades. Using such procedures, the medical management of the disease could advance significantly in terms of diagnosis, prognosis appraisal of the best course of treatment, as well as clinical administration. In such an attempt, the use of a sizable and quickly growing collection of clinical and scientific data assists to create a solid foundation for safe assessment and follow-up care. Data mining and artificial intelligence learning thus become important processes that significantly influence the clinician's judgement. So, the goal is to establish a connection between data assessment, diagnosis, and sensible drug therapy decisions. A diabetic person has a disorder where the level of blood glucose in their blood is too high [45]. Because of one of these two conditions, our body either does not create enough insulin, does not make any insulin, or just has cells that don't react appropriately to the medication our cells of the pancreas. Ultimately, this extra blood glucose leaves the body through the urination [46]. So, despite the fact that the blood contains an abundance of glucose, the lymphocytes are unable to utilise it for energy and development. Having 62 million diabetic people worldwide, hyperglycemia is on the rise, and India is among the contributing factors [47]. Diabetes prevalence has risen over the last 30 years, reaching 12–18% in urban India and 3-6% in rural India. So according Mohan V. et al. (2007), this rate of expansion is 50–80% higher than China's (10%). The "diabetes capital of the world" is India, which the International Diabetes Federation (IDF) claims is home to the greatest proportion of diabetic individuals [48]. In India, the cost of effectively diabetes management is predicted to be USD 2.2 billion, despite the country only allocating USD 61 per person to medical in 2012[49].

There have been numerous options of the technologies to diagnosable disorder systems. The categorization work, offline simulation techniques and diagnostics, online decision support systems, and process tools can all be accomplished with the help of these programmes. The methods for resolving a theoretical formulation for hepatitis & diabetes in a neuro-fuzzy, ANN, and fuzzy environment, which would be regarded as a key research area in biology. To clarify the fuzzy resolutions of the provided model, the methods of fuzzy system of equations, membership functions, and rules were used. Lastly, in order to create a more effective medical detection approach, neural networks are categorized using fuzzy-based principles.

IV. Conclusion

This questionnaire paper illustrated a computational formula for hyperglycemia and infections that used a scheme of sequential normal differential equations and fuzzy numbers to accommodate imprecise parameters as well. This is advantageously helpful for decision-makers because it allows them to analyse the circumstance more precisely. reviewed the idea of artificial neural networks and fuzzy inference systems as computational models, as well as the motivation for the development of neuro-fuzzy systems. As was mentioned, this fusion can effectively combine the fuzzy rules' high expressive capacity and simple interpretability with the learning and adaptability characteristics of neural networks. Gradient descent methods are typically used in NF models to learn the parameters of membership functions. It is frequently challenging to conceptually compare the many neuro-fuzzy models and assess their performance in comparison because there is no universal framework. To demonstrate that NF is much more reliable than the competition, it is still necessary to apply the neuro-fuzzy systems under discussion to actual problems. As a result of these theories and models, we are also able to create practical solutions that have been demonstrated to improve numeric data understanding while essentially eradicating biases and delusions in judgement and judgement situations. Such models have yet to fully realise their potential for enhancing the comprehension and implementation of statistical information in practical everyday tasks like making medical decisions. Last but not least, this theme issue includes a number of excellent contributions at the interface between arithmetic and healthcare, not as an activity in mathematical modeling but rather as a collaborative research project that fascinates both professions and our society at large.

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