Fuzzy methodology for wide range of data in medical science(some special case of tumor growth)

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Abstract:

The development of fuzzy technology is currently a major topic of attention. Fuzzy mathematical modeling has been widely used recently as a practical technique to gain a deeper and more thorough understanding of a specific medical issue, such as cancer. The fuzzy mathematical model provides a tool for assessing the results of various components and developing behavioral projections. It also allows one to use mathematical techniques to investigate the structure both qualitatively and statistically. To reduce the ambiguity of model parameters and fit the Gompertz model, a fuzzy environment has been created to address a more accurate mathematical tumor growth model.With the help of fuzzy differential equations, the fuzzy mathematical model is able to fully represent the pattern of tumor growth mechanisms. Linear programming, nonlinear programming, geometric programming, dynamic programming, and integer programming are a few of the modeling techniques used in fuzzy logic. These methods are used with fuzzy logic to produce an optimal point under ambiguous settings, giving the decision-maker a wider range of options. The use of fuzzy multicriteria decision analysis in medicine has been made possible by the efficiency and effectiveness of this method for assessing options that must satisfy several competing criteria.

***Keywords*:** fuzzy logic, inference system, clustering method, soft computing, decision analysis and benign tumor.

1. INTRODUCTION:

An interdisciplinary field of scientific study with numerous applications in biology, medicine, and biotechnology is mathematical and theoretical biology. The field may be referred to as theoretical biology, mathematical biology, or biomathematics to stress the mathematical or biological aspects, respectively. Biological mathematical modeling, Relational biology/complex systems (CSB), bioinformatics and bio-modeling or bio-computing computational are at least four of the primary sub-fields that fall under this umbrella. Mathematical methods and procedures are used in mathematical biology to describe rate and analyze biological processes. It affects research in evolution, biomedicine and biotechnology both theoretically and practically. In the interdisciplinary discipline of mathematical biology, which is very active and expanding quickly, mathematical principles, tools, and models are used to solve a variety of developmental biology and biomedical sciences challenges,Ahmad et al 2011. An aesthetic portrayal of a structure based on mathematical concepts is known as mathematical modeling. It is used to evaluate the effects of particular components and, as a result, to reach conclusions, Almir et al 2015 The benefits of mathematical modeling for biological and medical research are realized not only in the creation and evaluation of predictions from

experimental data, but also in the simulation of these models,Barro et al 2002. Since mathematical models are fundamentally unfinished, the same mechanism may have diverse, if not competing, shapes. A model should only be chosen among the alternatives as the one that is least likely to be incorrect because it should never be accepted or proven to be the correct one.

Many medical applications have made extensive use of fuzzy logic. As a common symptom in a patient may result in numerous diseases, there are various levels of fuzziness and vagueness associated with the diagnosed condition. This is inherent to medicine, therefore fuzziness enhances clarity in the field of medicine, Awotunde et al 2014. In accordance with Aristotelian logic, a particular proposition or statement can only have two logical values, such as True or False, Black or White, Yes or No, or 1/0, however in real-world circumstances, things frequently turn out to be 0.05, 0.99, 0.90, etc. meaning that the range could be in the degree of the measure. There are many different health conditions which includes a headache or stomachache or some serious conditions. These common symptoms indicate that person is no longer healthy and sick. In mathematics example of this is: If person X have headache, that indicates that person is not healthy; if person Y does not have, it indicates that person is healthy. Everybody is somewhat healthy and somewhat ill,Mahfouf et al 2001. We might state that someone is 99% well and 1% sick if they merely have a headache. The level of headache tolerance varies from person to person and includes terms like bearable headache, typical headache, severe headache, and terrible headache. In the Natural Language Process, these linguistic variables take place. Fuzzy Logic is a means to model and handle it using natural language and also falls under a qualitative approach. Recently, uncertainty has been seen as crucial for scientific investigation, Jagmohan et al 2021. The medical industry has developed applications for fuzzy logic and membership functions that highlight their ability to access nature and assess diseases including cancer, diabetes, asthma, and cardiovascular.

A decline in cell cooperation characterizes cancer, a condition that affects multicellular organisms. During carcinogenesis, tumor cells multiply and change, increasing the tumor's size and invasiveness. In terms of population size, mutation rate, selective advantage and number of vulnerable genes, analytically, the expected waiting time for the progression from benign to malignant tumor had been formulated and investigated by observed data, Mehrbakhsh et al 2017. Even if the data is accurate, errors could still occur in real-world situations. Therefore, in such cases, we must employ an imprecise parameter in order to limit the inaccuracy. A specific query, though, is whether the behavior of the crisp and fuzzy models is similar or not. The actions are very different. And we must ascertain how a model functions in that setting. The current study used differential equations to create a number of models in order to reveal the tumor growth mechanism in a fuzzy environment.

2.0 METHODOLOGY

2.1 Fuzzy Logic:

Jan Lukasiewicz, a Polish philosopher, developed fuzzy logic in 1930 by extending the range of truth values from 0 to 1. Later, the first Fuzzy Set is defined by Max Black (1937). Lotfi Zadeh rediscovered fuzziness in 1965 and used terminology, membership function, and application to name and investigate it. Researchers across the board now choose fuzzy logic due to its flexible structure and reliance on intuitive methods. This reasoning has been utilized extensively to evaluate ambiguous knowledge in systems and processes, including hazy human assessments of issues. A set of mathematical rules called fuzzy logic uses degrees of membership rather than the sharp membership of traditional binary logic to express knowledge. Fuzzy Logic is multi-valued and deals with degrees of membership and degrees of truth, in contrast to two-valued Boolean logic. Partial truth values that fall between yes and no are introduced by fuzzy logic. For instance, if you ask a patient how much pain they experienced following surgery, the answer might be less pain, tolerable pain, more pain, slightly painful, which can be described verbally, and it also varies from patient to patient depending on their immune or metabolic systems. Here, the ambiguity and usage of fuzzy logic to create a model that matches the grammar of genuine speech result in a qualitative computational method. The mathematical idea of the fuzzy set, which is a comprehensive view of the classical set theory that represents fuzziness, serves as the foundation for fuzzy logic, which is an extension of Boolean logic. Fuzzy logic tries to mimic our verbal comprehension, judgment, and common sense, but it lags behind the development of more human-like intelligent systems. The construction of an intelligent computer for the prediction of diseases and their features present everywhere in the globe is being worked on by more researchers (inter and interdisciplinary), and the fuzzy logic method is the way of the future. The use of fuzzy logic in medicine has gained a lot of attention lately.Fuzzy logic uses language nuances in place of a rigid "Yes/No" and replaces it with a more flexible "More or Less" to obtain more accurate results. Several medical diagnostic systems have been created and used in the detection and treatment of diabetes, cancer, HIV, and other conditions based on the fuzzy logic concept. The Fuzzy Logic Controller (FLC), which serves as the control unit for medical equipment, is one of the current research projects of fuzzy logic in the field of medicine. The human immune system was assessed using an algorithm and a fuzzy cognitive map. Data analysis use fuzzy logic to assess facial expression and behavior in people Fuzzy Logic in medical practice. Generally speaking, the intricacy of the many concepts used in modern medical practices leads to improper analysis. Without a clear definition and understanding of the boundaries, traditional approaches tend to be imprecise, unclear, and fraught with extra uncertainties because it is unable to give accurate definitions and symptoms of medical concepts. One of the AIT's fuzzy logic algorithms as well as other combinations of neural networks, machine learning algorithms, genetic algorithms, and classification models must be used to deal with these circumstances. Here are a few examples of illness categories where fuzzy logic is used. One of them is to determine the proper anesthetic dosage for a C-section and dosage of radiotherapy for cancer patients. The location of tumor at central nervous system can be identified regardless of its size or location by this method. The dosage of medication of diabetes than the usual one can be determined and can be quantitatively

modified. Diagnosis of COVID – 19 with significant symptoms can also be done. Fuzzy Logic is used to identify medical papers using Medline. The total number of papers that were published till date with year are mentioned in Table 1 using data from PubMed's main database. Fuzzy Logic has 6323 papers from 2000 to 2021, while Fuzzy Logic in Medicine has 479 publications. Although the Fuzzy Logic technique was developed in the last decade of the 20th century, its voyage in the 21st century demonstrates an exponential rise in the medical area by utilizing digital initiative's advancements.

2.2 Fuzzy Membership Function:

A Relationship A: X→ [0, 1] is the function for a fuzzy set A on the discourse universe X, where each element of X is mapped to a value between 0 and 1. The grade of Membership of the element in X to the Fuzzy Set A is quantified by this value, which is also known as the membership value or degree of membership. Here, A is the fuzzy set obtained from X, which is the universal set. The degree of membership of any value in a given fuzzy set can be graphically represented using the fuzzy membership function. The X-axis of the graph denotes the scope of speech, and the Y-axis the degree of membership in the interval [0.1]. There are 11 built-in Membership function types in the toolbox. Some functions, such as piecewise linear functions, the Gaussian distribution function, the sigmoid curve, quadratic and cubic polynomial curves, are constructed from a number of fundamental functions. By custom, the letters'mf' are added to the end of the names of all membership functions. In order to create the membership functions, straight lines are used. Formula used for fuzzification are of two types type 1 and type 2, is given as.

2.2.1 Triangular Membership Function:

$$\text{triangle}\,(x,a,b,c) = \begin{cases} 0 & x \le b \\ \dfrac{x-a}{b-a} & a \le x \le b \\ \dfrac{c-x}{c-b} & b \le x \le c \end{cases}$$

$$\text{triangle}\,(x,a,b,c) = max\left(\min\left(\frac{x-a}{b-a}, 1, \frac{c-x}{c-b}\right), 0\right)$$

2.2.2 Trapezoidal Membership Function:

$$\text{trapezoid}(x,a,b,c) = max\left(\min\left(\frac{x-a}{b-a}, 1, \frac{d-x}{d-c}\right), 0\right)$$

$$\text{trapezoid}(x,a,b,c,d) = \begin{cases} 0, & x \le a \\ \dfrac{x-a}{b-a}, & a \le x \le b \\ 1, & \text{b} \le \text{x} \le \text{c} \\ \dfrac{d-x}{d-c}, & c \le x \le d \\ 0 & d \le x \end{cases}$$

2.3 Gaussian Membership Function:

$$\text{gaussian}\ (x; c, \theta) = e^{-\frac{1}{2}\left(\frac{x-c}{a}\right)^2}$$

2.4 Bell-Shaped Membership Function:

$$\text{bell}\ (x,a,b,c) = \frac{1}{1+\left|\frac{x-c}{a}\right|^{2b}}$$

2.5 Sigmoidal Membership Function:

$$\varphi(v) = \frac{1}{1+e^{-av}}$$

Above these functions are very important function of fuzzy logic in decision making process. Most of the researcher were used these formulae to find out optimum solution.

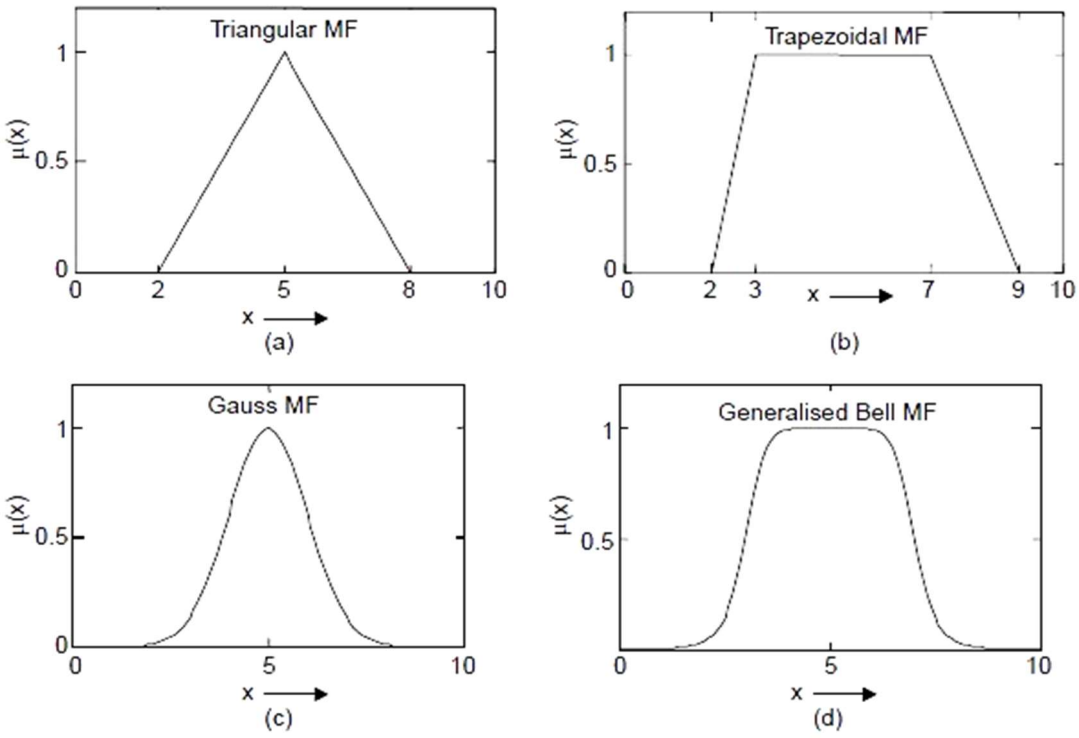

Figure 1.

Membership functions in fuzzy logic can be classified as either (a)triangular," (b)trapezoidal," (c)gaussian," or (d)generalized Bell."

2.6 Cancer Disease:

In the modern world, cancer is a fatal illness. Due to the lack of medical resources and inability to effectively utilize those that are available, more than hundreds of people per year pass away from cancer. Utilizing numerical (quantitative) tools inside the medical system helps decrease patient mortality. For those who have not yet developed an illness like cancer, which has a high mortality rate and expensive treatment, taking precautions as soon as possible is crucial. As a result of DNA damage and out-of-program cells, cancer is caused by aberrant cell development and proliferation. The more quickly cancer is discovered, the more effective the treatment would be. Most malignancies are treatable, and treatment options include chemotherapy, radiation, and/or surgery. The system uses the Fuzzy Logic model, which enables it to produce effective outcomes based on uncertain verbal knowledge much like human logic, which is the rationale for the use of the fuzzy logic model. Lung cancer is a hereditary disease that manifests as the expansion of aberrant cells that first appear in one or both lungs. In 2003, Ravi Jain conducted a comparative analysis of four strategies for generating fuzzy rules that provide Fuzzy If-Then rules for breast cancer. A Fuzzy Logic method for predicting the risk of breast cancer using the patient's age and automatically derived tumor traits was put out by Victor BALANICA in 2011. A Fuzzy decision support system for the identification of cancer risk status in conditions of data diversity and imprecision was created by Ahmed Abou Elfetouh Saleh in 2011 . A fuzzy tool box was used to develop a neuro-fuzzy and fuzzy rule-based inference system for the identification and diagnosis of lung cancer. The Fuzzy Logic toolbox is used to receive the input variables and produce the results.

The preliminary step is brain segmentation, A reliable method utilizing histogram scale-space analysis and morphological procedures is used for this objective. The statistical parameters of the primary tissue classes that will be utilized in the classification process are initially calculated using this method. After removing the brain, the tumor is roughly segmented using the Fuzzy Possiblistic C-Mean approach, which is histogram-based. For the final accurate tumor segmentation, this rough segmentation serves as the beginning surface of a deformable model.

One of the most used sigmoid models for fitting growth data and other data is the Gompertz model. Aadil and co-workers used uncertainty based Gompertz growth model for tumor population and its numerical analysis, which is perhaps second only to the logistic model. Numerous dynamic growth rate functions have been discussed with regard to tumor growth. It has been shown that Gompertz growth can mimic cell proliferation that slows with population density, making it acceptable to detect tumor growth slowing down with tumor size.The growth rate is derived by subtracting the carrying capacity from the negative logarithm of the current population size:

$$\dot{N}(t) = -\gamma N(t)\log\left(\frac{N(t)}{K}\right);\ t>0$$

$$N(0) = n_0\ ,\ \gamma > 0 \text{ and } k>0$$

Here N(t) denotes the tumor cell concentration inthe target organism, $\dot{N}$(t) denotes the derivative of N concerning time t≠ 0,γ indicates the netrate of tumor replication, and K >0 denotes the tumor carrying capacity or the volume at which itstabilizes when the resource supply remains constant. Even thoughsuch parameters arecommonly regarded as trustworthy, it is critical in creating realistic and empirical models to assess the uncertainty associated with their inherent variance or complexity. The genesis of the Gompertz model has been disputed for years, numerous independent investigations have found a strong anda substantial connection between the Gompertz model parameters and in either experimental systems or human data, and some researchers hypothesized that this would indicate a consistentmaximum tumor size across tumor kinds within a species. The dynamics of N(t) over time are defined by the Gompertz model. In this context, a significantquery that frequently arises in research is whenN(t) approaches a particular interest value.Thesolution of equation is given by

$$\delta_t(n_0, \gamma, K) = \mathrm{K}\ e^{-l}\ \left(\frac{K}{N_0}\right) e^{-\gamma t}$$

It has already been established that dealing withparameter inaccuracy is not always suitable due to a lack of comprehensive knowledge or estimation failure. A basic technique of coping with Gompertz equation uncertainties is utilized to obtain these parameter estimations by utilizing the equation to calculate the average approximations and to assess the complexity.Let us now suppose that the fuzzy marks constrain the parameters$n_0, \gamma\ and\ K$. In otherwords, we suppose that such parameters fulfill anassertion such as the fuzzy variable (ψ) generally isa_0. So the membership grade of the fuzzymark is roughly the probability distribution of the fuzzy variable (ψ) as per Zadeh. As the term $\delta_t(n_0, \gamma, K)$ of equation is a fuzzy variable fora specified timet >0, so the termsn_0, γ andK in equation are also fuzzy variables.Withthe help of Zadeh extension,the procedures mentioned in the earlier parts on the parameters $n_0, \gamma\ and\ K$of the possibility distribution function$n_0, \gamma\ and\ K$for a fixedt >0 can be obtained.To create a realistic and practical model, it is necessary to remember that the parameters of equation are approximate owing to the assumedlack of information and the mistakes in the calculation technique inherent in the relevant issuesof the tumor growth. Different approaches, suchas the use of random variables, are considered tocharacterize these parameters. The authors occasionally evaluate the Gompertz equation with changes in the carrying capacity (K).

Uncertainty in the starting state,if we wish to estimate the population of tumor cells after a specific amount of time. Due to the inaccuracy of the count, we were forced to estimate the initial number of tumor cells, which is impossible to determine in precise numbers. Use of the original history as a guiding principle is therefore preferred. Uncertainty in the coefficient: It is challenging to calculate an exact value when the number of tumor cells is growing at an unknown rate. For this reason, the value should be regarded as equivocal. Fuzziness in the coefficient and the beginning condition: If both situations are included in a model, this case can be employed as Carrying capacity is viewed as ambiguous since it evolves over time in response to gradual environmental changes, such as climate change or ecological succession. This paper's Figure illustrates how the fuzzy parameter system is created using the Gompertz growth equation.

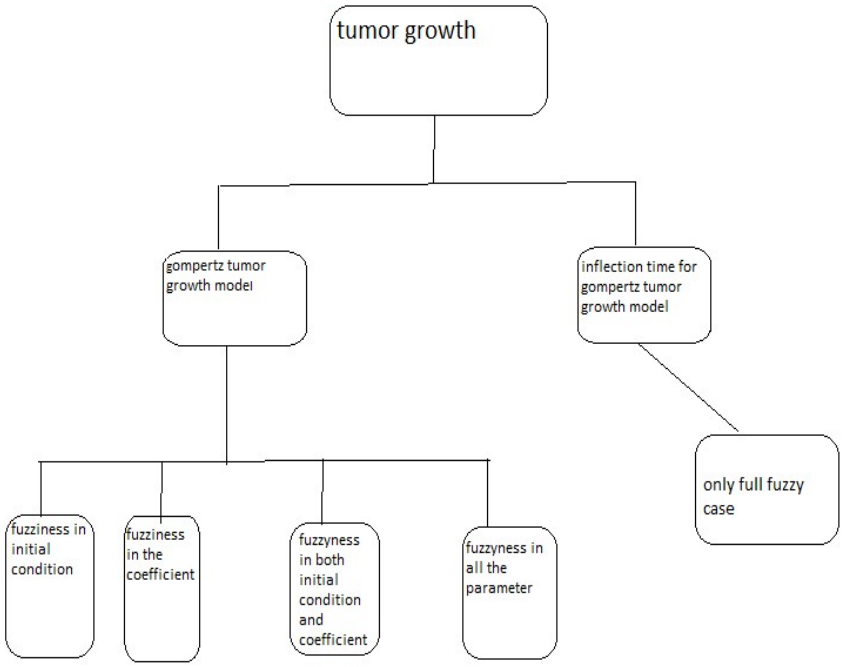

Figure2.

Fuzzy transformation mechanism of the Gompertz tumor growth model

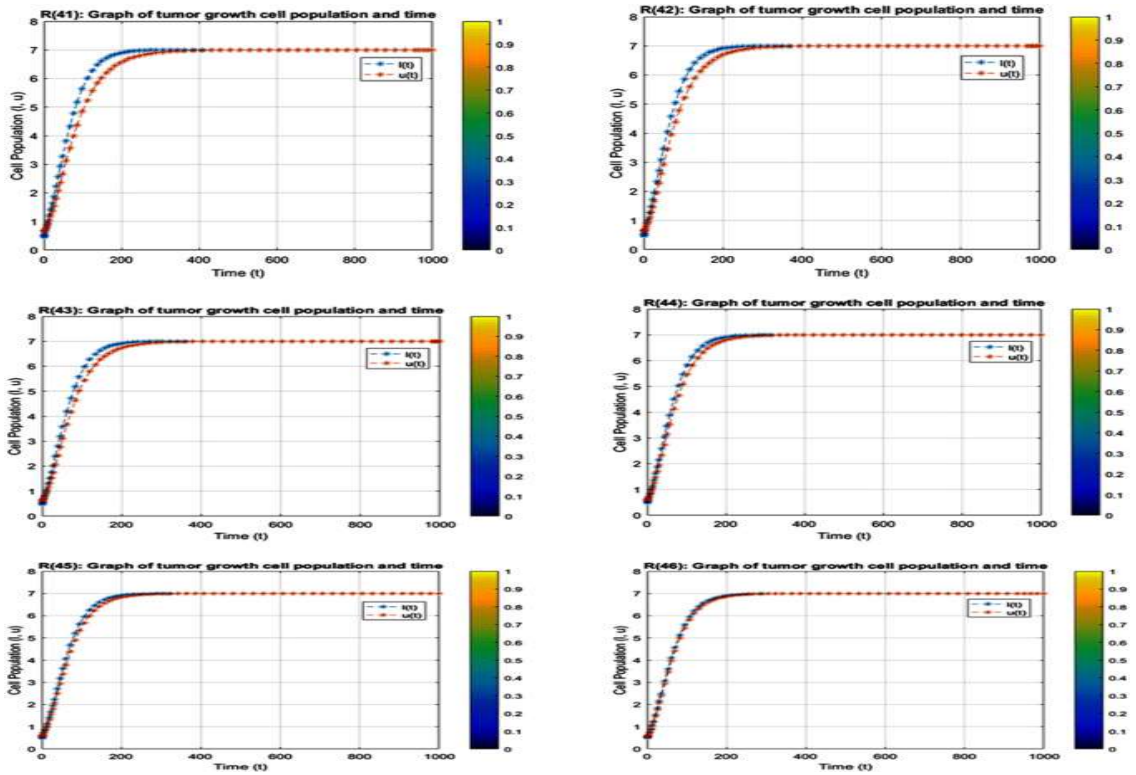

Figure 3.
Graph of tumor growth with time and cell population. Rubeena Khaliq et. al. 2022

3.0 RESULTS AND DISCUSSION:

With the aid of some precision, a fuzzy mathematical model of the tumor development trajectory makes great strides toward depicting the realistic course of tumor growth. The Gompertz equation for tumor development can be resolved using the possibility distribution function in an uncertain setting. The lower and upper -cuts for the probability distribution function for a particular parameter of the Gompertz equation are used to illustrate how the net tumor volume or the tumor cell concentration changes as the carrying capacity is reached at different intervals. As a result, the region of uncertainty for the net tumor volume is shown by the lower and upper -cuts of the probability distribution function. Because of some negative effects of defensive qualities during tumor cell differentiation, the absence of replication time at the early stages of a tumor is thought to be a variation process or a response of the body to the illness. However, in some circumstances, the defensive process would have been suppressed right away, leading to a rapid surge that is directly correlated with the rate of tumor growth. The linear phase of the growth process is unaffected, and maximal rise occurs at K/2, showing that the defensive system is actually functional. However, as a tumor grows larger, it gets more complex to develop, and eventually the pace of growth slows. As a result of these and other factors, the tumor enters a plateau phase. The logistic model, which incorporates an intersection point on an asymmetrical graph, is expanded by the Gompertz model. The Gompertz model, which represents the tumor's inherent phases and so best addresses its growth pattern. The crisp mathematical model of tumor growth differs from the fuzzy mathematical model in that the parameters in the crisp model are fixed, whereas the parameters in the fuzzy model are variable because of a number of factors, including the fact that tumors are continuously evolving and leading to changing dynamics The growth inside the binary value can be mathematically studied in a clear way. However, by altering the starting tumor cell population, tumor net population rate, and carrying capacity of the tumor through the alpha -cut in a fuzzy model, this work illustrates the behavior of tumor development. This feature makes it possible to determine tumor load based on the degree of accuracy, which could be crucial for tumor staging and analysis.

Since Nov 2019 world had been dealing with epidemic or pandemic issues under the term COVID-19 which originated in Wuhan and expanded throughout China between January 2020 and at present several variations came into being. The people not only had to deal with the patients symptoms which include fever, cough and shortness of breath, but also its spread from one person to another, as well as its variants. Covid-19 has quickly established itself as a global pandemic, causing a rapid shift in the number of infected people, rising mortality rates, a significant global economic burden, and the mobilization of medical resources around the world In this Fuzzy Expert System, the better model for analysis and result prediction is based on the nature of the variation as per the geographical and environmental location. Different countries suffered greatly due to the imprecision and vagueness found in the symptoms of the virus. A smart fuzzy inference system was suggested by Maad et al. (2021) for the infrequent identification of COVID-19 based on the symptoms of fever, flu, dry cough, cold, breathing problems, sore throat,

and headache. A model using 13 linguistic Fuzzy Rules based on the Gaussian Membership Function can help the doctor diagnose ailments. Additionally, COVID-19 can be combined with other identifying methods like PCR tests and CT scans. Muhamed and Ajay (2021) proposed a fuzzy rule system that is implemented with MATLAB fuzzy tools for simulation to evaluate the health of the patients and prevent from COVID-19 disease, as well as validating the identification symptoms by applying the fuzzy rules and an effort to face the situations.

4.0 CONCLUSION:

Cancer's progression, remission, and therapy mechanisms are still unknown due to the disease's great complexity. The uncertainty is addressed through fuzzy mathematical modeling, which provides a workable solution to deal with it at every stage. To provide a more accurate depiction of reality, some real-world events must be replicated using fuzzy mathematical modeling. The overall residuals in the tumor growth fuzzy model will be reduced by altering the model parameters, reducing the discrepancy between the numerical forecasting model and the real outcomes of medical investigations. The membership grade of fuzzy sets has been used in this study to interpret the initial state, net population rate, and carrying capacity as a collection of fuzzy variables with a possible distribution function. This method's fact-based foundation makes it possible to find the best medication faster by removing the element of uncertainty surrounding tumor growth. As a result, fuzzy mathematical modeling aids in the resolution of discrepancies in calculation parameters, enabling the distinction between modeling of actual and anticipated tumor growth. In a fuzzy environment, it is also feasible to enhance tumor growth by fusing numerous derived principles using various fuzzy techniques. This study uses numbers to illustrate the tumor development process.

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