International Journal for Research in Applied Sciences and Biotechnology

ISSN: 2349-8889
Volume-9, Issue-3 (May 2022)

www.ijrasb.com

https://doi.org/10.31033/ijrasb.9.3.22

Fuzzy Logic Based Diagnostic System for Immunodeficiency and Tumor Threat in Space

Areeba Shamsi[1], S.K. Jain[2] and Sanjeev Kumar[3]
[1]Department of Mathematics, Dr. Bhimrao Ambedkar University, Khandari Campus, Agra 282002, INDIA.
[2]Department of Computer Science, Dr. Bhimrao Ambedkar University, Khandari Campus, Agra 282002, INDIA.
[3]Department of Mathematics, Dr. Bhimrao Ambedkar University, Khandari Campus, Agra 282002, INDIA.

[1]Corresponding Author: shamsi.ada@gmail.com

ABSTRACT

Fuzzy logic is now frequently utilized in medical diagnostic control systems, including diabetes, dysplasia prediction, tumor progression, and so on. Many studies have been published that use fuzzy logic models to predict the structure and content of proteins and amino acids. RBCs, neutrophils, protein, eosinophils and lymphocytes were used as input variables in a fuzzy logic-based system recently developed to identify haemorrhage and brain tumor disorders. The immune system for the preservation of the human body was designed using the projected capabilities of the Fuzzy Cognitive Map (FCM). The neuro-medical area has adopted fuzzy modeling approaches to assess the FL based on facial expressions and human behavior. As a result, an effort has been made to build a diagnosis system for immunodeficiency and tumor growth in space based on this research.

Keywords- Space missions, gravity, radiation, health threat, fuzzy System.

I. INTRODUCTION

Space is a frightening, inhospitable location where you are separated from your family and friends and exposed to radiation that might raise your cancer risk over time. The most deadly part of space travel is space radiation. Astronauts aboard the International Space Station are exposed to 10 times the amount of radiation that happens naturally on Earth. The magnetic field and atmosphere of our planet shield us from harmful cosmic rays. Further, the Earth's air shielding is no longer available at higher altitudes, which may raise cancer risk, and the magnetic field is weaker, resulting in less protection against ionizing particles. In addition, in space, microgravity has a variety of effects on the body. On Earth, gravity and radiation exposure are normal, causing our immune systems to work to their full potential and reducing the chances of tumor induction; however, in space, where there are high levels of radiation exposure, and no gravity both factors influence the human immune system, increasing the chances of tumor induction.

To dwell in space for a longer amount of time, the influence of space conditions on various physiological functions must be researched for research purposes. The immune system is one of the most important consequences observed during space flight. The ability of the host to resist infection and malignancies was harmed when the immune system was disrupted. Further, it is obvious that some alteration of immunological parameters transpires during space flight. Microgravity, stress, and radiation are all potential contributors to such impacts. It's been difficult to determine how much each of these elements contributed to changes in immunological markers caused by space flight. The tumor and immune system are affected by gravity, radiation, and stress levels.

The proposed work leads the diagnostic system to determine the chances of tumor situations and bearing of immunity owing to radiations and gravity repercussions utilizing fuzzy control logic. There are three input factors in this suggested diagnostic system: gravity, radiation, and stress, as well as two output variables: immunity and tumor trigger. The basic composition of the proposed model is to elaborate the algorithm of fuzzy logic for the analytical system, while in the next part results and discussion along with simulation results of this system are given.

As far as the fuzzy logic's work in the direction of medical science is concerned then Baro & Marin, (2002) worked on the concept of Fuzzy Logic in Medicine. Heidelberg, further Torres& Nieto (2006) also did their work in the direction of fuzzy logic in medicine and bioinformatics. Faran et al (2011) worked to design a model of fuzzy logic medical diagnosis control system.

Kumar et al (2013) made a proposition for using mathematical models founded on a fuzzy system with the application. Again, Kumar et al (2014). Mathematical structure fuzzy modelling of medical diagnosis with the help of clustering models. In the same year Cucinotta et al (2014). worked on the space radiation hazards to the central nervous system. Kumar et al (2014) discussed the derivation of interval type-2 fuzzy sets and systems on the continuous domain: theory and application to heart diseases. Dagar et al (2015). The medical diagnostic system uses fuzzy logic toolbox. Mathur et al (2017) worked on the finding of a brain tumour in MRI image through a fuzzy-based approach. Jandial et al (2018) worked in the direction of the space brain and observed the adverse things of space exposure on the central nervous system.

Karar (2020) has published a novel closed-loop fuzzy logic controller constructed on intuitionistic fuzzy sets as well as the invasive weed optimization (IWO) method for managing intravenous anti-cancer medicine administration. The created intuitionistic fuzzy logic controller (IFLC) makes the subsequent contributions: First, the settings of IFLC are adaptive and properly calibrated to obtain desirable medication concentrations at the tumor site, thereby eliminating virtually all cancer cells by the conclusion of therapy. Another, drug delivery restrictions, such as authorized drug dosage levels and growing poisonousness, are naturally included in the project of the augmented IFLC to assure cancer patients' clinical wellbeing. Lastly, the created drug delivery control system is strong enough to manage any physiological variables that may arise during therapy, including patient sensitivity to harmfulness. Extensive simulation results along with the comparative assessment of a mathematical patient model were used to evaluate and authorize the act of the proposed IFLC. In earlier related investigations, it was demonstrated that our optimum adaptive IFLC outperforms other approaches, subsequently in the finest performance index and the smallest number of residual cancer cells of 27.63 and 0.806, respectively.

Furthermore, Chen et al (2021) focused on the HIV (human immunodeficiency virus), which is the dangerous virus and has a negative impact on the immune system of humans. As a result, a big figure of research has been dedicated to the growth of antiretroviral therapy for HIV infection. We offer a novel regulator strategy for a fractional-order HIV contamination model in this paper. To begin, a fractional model of the HIV model is examined, as well as the significance of the fractional-order derivative in system modeling is demonstrated. After that, a type-2 fuzzy logic controller for HIV antiretroviral treatment is presented. Two independent controllers and an aggregator make up the designed control mechanism. The best aggregator adjusts each individual controller's output. Simulations are run for two distinct tactics. Only reverse transcriptase inhibitor (RTI) is utilized in the first approach, demonstrating the lead of the suggested regulator over a standard fuzzy controller. Finally, both RTI and protease inhibitors (PI) are administered together in the second method. An optimum type-2 fuzzy aggregator is also provided in this scenario to change the productivity of the distinct regulators using optimal rules. The simulation results show that the developed control technique for the uncertain system performs well.

Elementary Structure of the Proposed Diagnostic Model: The suggested diagnostic model's fundamental structure contains four linguistic values: 02 for each input variable. The human decision-based Rule-base was then advanced by these language values. Finally, following the defuzzification procedure, two clear output values are presented to reflect the disease's expectation: immunity and tumor.

Design Algorithm: The algorithm sketched for the diagnostic control system consist of three fuzzy input variables. Six fuzzy Membership functions (MF) for gravity are: G_1 (0-2), G_2 (0-4), G_3 (2-6), G_4 (4-8), G_5 (6-10) G_6 (8-10) and for radiation input are shown as: lowest (0-100), low (0-200), below medium (100-300), medium (200-400), high (300-500) and very high (400-500) and for stress are as: no stress (0-100), alarming (0-200), resistance (100-300), adaption (200-400) and exhausted (300-500). Two outputs of this proposed diagnostic system are immunity and tumour. Six MF are for immunity: lowest (0-5), lower (0-20), low (10-50), medium (40-60), higher (50-90) and highest (80-100) whereas six MF for tumor are: impossible (0-20), rare (0-40), moderate (20-60), uncertain (40-80), probable (60-100) and severe (80-100).

***Fuzzifier**:* For two input variables, Fuzzifier produces four linguistic values, two for each input variable. The descriptions of range, MF and occupied region are given in Table 1, 2 & 3, which clearly shows the range of six MFs of gravity and radiation along with the regions occupied which are shown in fig. 1&2. The six MFs G_1 - G_6 are used to present the different varieties of input fuzzy variable **'GRAVITY'** in a plot comprising of five regions as described in fig.1.The six MFs very low, low, below medium, medium, high, and high are used to describe the various varieties of input fuzzy variable **'RADIATION'** in a plot comprising of five regions as shown in fig. 2.The five MFs no stress, alarming stage, resistance, adaption, and burn-out are utilised to describe the several ranges of input fuzzy variable **'STRESS'** in a plot comprising of 05 regions as shown in fig. 3.

Intelligence, self-esteem, and sadness are examples of psychological notions that are not readily visible because they represent behavioural inclinations or complicated patterns of behavior and internal processes that change from person to person. Since stress is a psychological factor, assessment of psychological problems cannot happen on a numeric scale. We have taken three input variables viz gravity, radiation and stress but further, we will be proceeding with only two outputs *i.e.* radiation and gravity in output calculation since stress is a factor that can't be measured on a scale to give exact enumeration. Therefore, including just actionable data in calculating our output, we will proceed with radiation and gravity as our only input variables.

Table 4 elaborates linguistic fuzzifier outputs for gravity & radiation respectively in each occupied region (each variable contains two fuzzifier outputs). The plotting of the 04 linguistic variables for 02 of these input variables in 05 regions are shown in Table 4.

Fuzzy set values are done on purpose by using the given values of input variables and are dispensed in Table 5. In this instance, value of gravity is 0.5 that is lying in the middle of '0' and '2' in Region-1 and radiation exposure is 440 of Region-5 betwixt values '400' and '500'. Table 5 bestows the fuzzification results for both of the input variables viz. gravity and radiation.

International Journal for Research in Applied Sciences and Biotechnology

ISSN: 2349-8889
Volume-9, Issue-3 (May 2022)

www.ijrasb.com

https://doi.org/10.31033/ijrasb.9.3.22

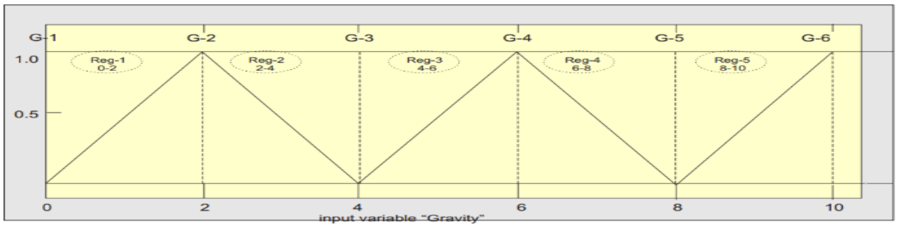

Figure 1: Scheme of membership or association functions for input variable 'GRAVITY' demonstrating the regions occupied by MF of gravity.

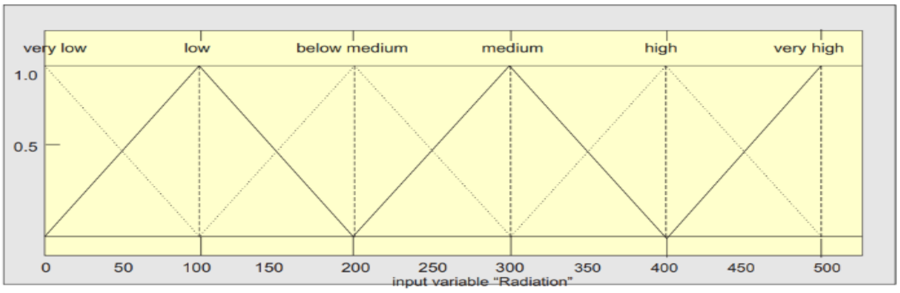

Figure 2: Plot of membership or association functions for input variable 'RADIATION' displaying visibly the regions employed by MF of radiation.

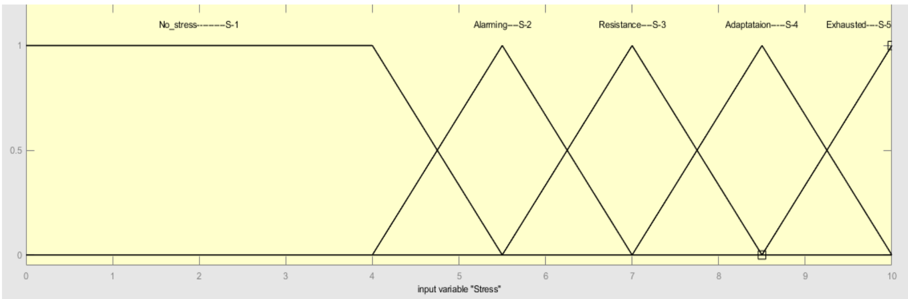

Figure 3: Scheme of membership or association functions for input variable 'STRESS' demonstrating the regions occupied by MF of stress.

Ference Engine: If x indicates the maximum number of membership or association functions and y stands for the total number of input variables, then total number of rules= x^y .In such case we have $6^3 = 6 \times 6 \times 6 = 216$ are the total no. of rules, but for the sake of simplicity we have described eight rules (Table 6 & 7) here from which we have selected only four rules for the further study which are shown in Table 8.

Table 1: Membership function and range of input variable Gravity

Membership Function (MF)	Range	Region Occupied
G_1	0 to 2	1
G_2	0 to 4	1 to 2
G_3	2 to 6	2 to 3
G_4	4 to 8	3 to 4
G_5	6 to 10	4 to 5
G_6	8 to 10	5

In every region, there is a mapping of two linguistic variables for each input variable, therefore four rules are required for the specific values of two variables. The inference engine produces 04 R-values next carrying out *Min-AND* operation betwixt the four inputs as expressed in fig. 9. *Min-AND* operation is denoted by the symbol ^ betwixt the membership values.

$$R_1 = f_1 \wedge f_3 = 0.75 \wedge 0.6 = 0.6 \qquad R_2 = f_1 \wedge f_4 = 0.75 \wedge 0.4 = 0.4$$

$$R_3 = f_2 \wedge f_3 = 0.25 \wedge 0.6 = 0.25 \qquad R_4 = f_2 \wedge f_4 = 0.25 \wedge 0.4 = 0.25$$

Table 2: Membership function and range of input variable Radiation

Membership Function (MF)	Range	Region Occupied
Lowest	0-100	1
Lower	0-200	1-2
Low	100-300	2-3
Medium	200-400	3-4
Higher	300-500	4-5
Highest	400-500	5

Table 3: Membership function and range of input variable Stress

Membership Function (MF)	Range	Region Occupied
No Stress	0-100	1
Alarming	0-200	1-2
Resistance	100-300	2-3
Adaption	200-400	3-4
Exhausted	300-500	4

Rule Selector: By applying two crisp values of gravity and radiation, the rule selector generates singleton values for the output function. Table 5 and 6 confers the corresponding singleton values of two inputs. Table 8 represents the rules applied with the given values and their levels.

Table 4: Linguistic values of fuzzifier outputs in all regions

Input variables	Linguistic fuzzifier outputs	Region 1	Region 2	Region 3	Region 4	Region 5
Gravity	f_1	$f_1[1]$	$f_1[2]$	$f_1[3]$	$f_1[4]$	$f_1[5]$
	f_2	$f_1[2]$	$f_1[3]$	$f_1[4]$	$f_1[5]$	$f_1[6]$
Radiation	f_3	$f_2[1]$	$f_2[2]$	$f_2[3]$	$f_2[4]$	$f_2[5]$
	f_4	$f_2[2]$	$f_2[3]$	$f_2[4]$	$f_2[5]$	$f_2[6]$

Table 5: Results of fuzzification

Input Variables	Values	Region Selection	Fuzzy Set Calculation
Gravity	$x = 0.5$	$0 = x < 2$ Region-I	$f_1 = (2-0.5)/2 = 0.75,\ f_2 = 1 - f_1 = 1 - .75 = 0.25$
Radiation	$x = 440$	$400 = x < 500$ Region-5	$f_3 = (500-440)/100 = 0.6,\ f_4 = 1 - f_3 = 1 - 0.6 = 0.4$

**we've taken approximate values for radiation & gravity.*

Table 6: Sample rule base of TUMOR CHANCES for the fuzzy logic based expert system

if (Input)		then (Output)	
Gravity	**Radiation**	**Stress**	**Tumor Chances**
Yes	Lowest	Lowest	Impossible
Yes	Lowest	Low	Rare
Yes	Lowest	Medium	Rare
No	Lowest	High	Moderate

ISSN: 2349-8889
Volume-9, Issue-3 (May 2022)

https://doi.org/10.31033/ijrasb.9.3.22

No	Low	Highest	Uncertain
No	Medium	Highest	Probable
No	High	Highest	Probable
No	Highest	Highest	Severe

Table 7: Sample rule base of IMMUNITY DECREASE for the fuzzy logic-based system

if (Input)			**then (Output)**
Gravity	**Radiation**	**Stress**	**Immunity Decrease**
Yes	Lowest	Lowest	Highest
Yes	Lowest	Low	Highest
Yes	Lowest	Medium	High
Yes	Lowest	High	Medium
No	Low	Very High	Medium
No	Medium	Very High	Low
No	High	Very High	Low
No	Highest	Highest	Lowest

Defuzzifier: Two defuzzifiers evaluates input values and stretch two crisp yields to investigate the behaviour of the immune system and to find the chances of occurrence of tumour. The membership functions of the two output variables are itemized in Tables 8 & 9. It displays the range of six MFs of output variables Immunity and Tumor along with the regions occupied.

In this plan of action 8 inputs are given to each of the two defuzzifiers. Four values of R_1, R_2, R_3 & R_4 from the outputs of the inference engine and four values S_1, S_2, S_3 & S_4 from the rule selector are displayed in fig. 6. The mathematical statement $\sum S_i * R_i / \sum R_i$ where i=1 to 4 denotes the Centre of Average method. One defuzzifier comprises of one adder for $\sum R_i$, 8 multipliers for the product of $S_i * R_i$, one adder for $\sum I * R_i$ and one divider for $\sum S_i * R_i / \sum R_i$. In the end, a defuzzifier evaluates the valued crisp value output.

Table 8: Output variable immunity decrease with MF

MFs	**Range**	**Immunity**
MF1	0-5	Lowest
MF2	0-20	Lower
MF3	10-50	Low
MF4	40-60	Medium
MF5	50-90	Higher
MF6	80-100	Highest

Table 9: Output variable tumor inductionwith MF

MFs	**Range**	**Immunity**
MF1	0-20	Impossible
MF2	0-40	Rare
MF3	20-60	Moderate
MF4	40-80	Uncertain
MF5	60-100	Probable
MF6	80-100	Severe

ISSN: 2349-8889
Volume-9, Issue-3 (May 2022)

https://doi.org/10.31033/ijrasb.9.3.22

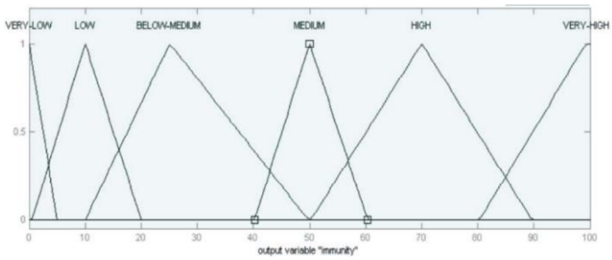

Fig 4: Scheme of membership or association function for output or productivity variable 'IMMUNITY' demonstrating the variety of decline in immunity against input variables.

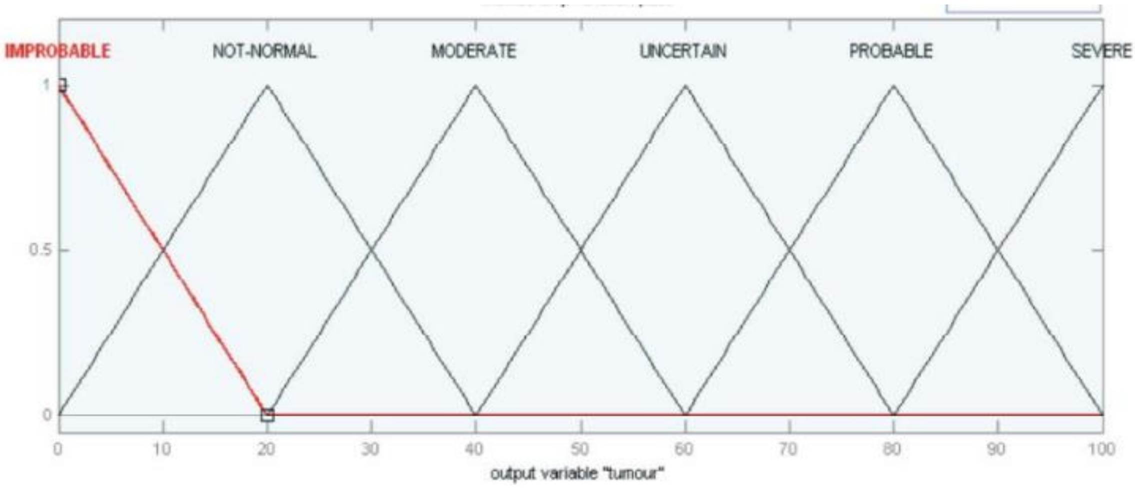

Fig 5: Scheme of membership or association function for output or productivity variable 'TUMOR' demonstrating the range of lessening in tumor against input variables.

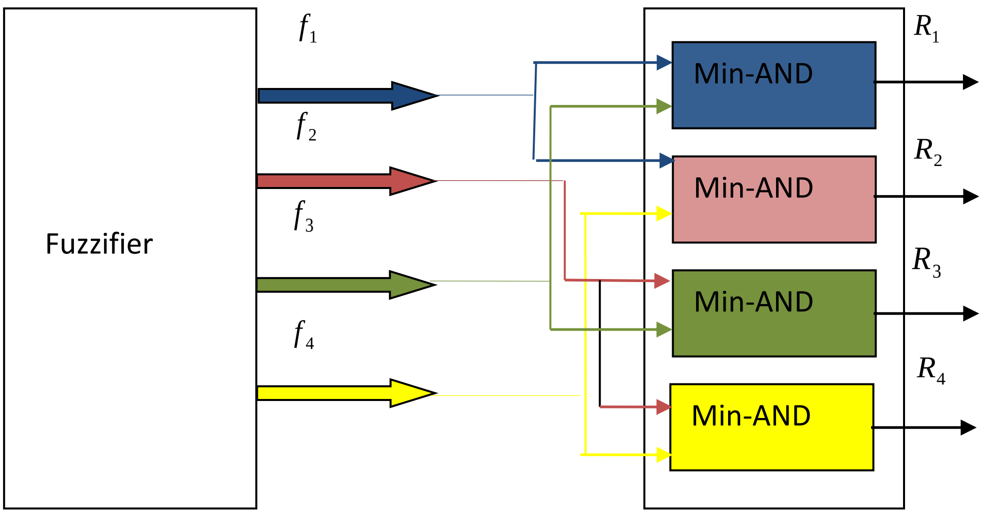

Fig. 6: Block diagram of inference engine showing the Mamdani-min procedure that produces the 04 R values.

Table 10: Designed values for tumor and immunity chances

Designed	values	for	Immunity	Designed	values	for tumor	Induction
i	R_i	S_i	$R_i * S_i$	i	R_i	S_i	$R_i * S_i$
1	0.6	0	0	1	0.6	0.8	0.48
2	0.4	0	0	2	0.4	1	0.4
3	0.25	0.1	0.025	3	0.25	0.8	0.2
4	0.25	0.1	0.025	4	0.25	0.8	0.2

II. RESULTS AND DISCUSSION

The development of a fuzzy-based expert system for the decrease in community and tumour induction due to high radiations and microgravity gravity in space is reported in this chapter. Man has been discovered traveling in space for lengthy periods of time for experiments, and it has been suggested that space stations be established for long-term study reasons. The astronauts' health is jeopardized by the highly constrained climatic conditions in space, which include steadily increasing radiation levels and decreasing gravity values. It has been demonstrated in experiments that lowering gravity progressively disrupts the immune system and increases stress levels, whilst increasing radiation produces severe mutations and tumor growth. When these two major elements are combined, astronauts face a significant health risk. This health risk is hypothetically assessed using an artificial intelligence FL-based diagnostic model. Finally, the total of all R is 1.5, as per the induction engine's output.

The designed values for the two output variables have been displayed by Table 10 i.e. tumour & immunity orientation.

$\sum R_i * S_i = 1.28, \sum R_i * S_i / \sum R_i = 1.28/1.5 = 0.853 = 85.3\%$. There are 85% chances of Tumor & $\sum R_i * S_i = 0.05, \sum R_i * S_i / \sum R_i = 0.05/1.5 = 0.033 = 3.33\%$. chances for Immunity. Table 11 illustrates the immunity and tumor induction probabilities in relation to the computed values of the input components, gravity, and radiation. When gravity is approximately equal to 10m/s2, our bodies exhibit typical immune system activity. The chances of developing a brain tumor are slim at this point.

Table 11: Plan of membership or association functions for simulation

Rule No.	Gravity 0.5	Immunity	Radiation 440	Tumor
1	G_1	Very Low	High	Probable
2	G_2	Low	Very High	Severe
3	G_3	Low	High	Probable
4	G_4	Low	Very High	Probable

III. CONCLUSION

The purpose of this research was to create a fuzzy logic-based diagnostic system that could forecast the risks that come with the restricted ecological parameters in space that astronauts face during long trips to space. The impact of rising radiations and progressively reducing gravity on various physiological activities will be useful to investigate. To improve our ability to analyze the diagnostic system more successfully, we may extend this constructed model to any number of input variables.

ACKNOWLEDGEMENTS

This research work is supported by UP State Govt. Research Project

REFERENCES

[1] Mandel, A. D. and Balish, E. (1977). Effect of spaceflight on cell-mediated immunity. Aviat. Space Environ. Med. 48: 1051-1057.
[2] Yagar, R.R. (1982). Fuzzy prediction based on regression models. Information Science,45-63.
[3] Yager, R.R., Ovchinnikov, S., Tong, R.M. and Ngugen, H.T. (1987). Fuzzy Sets and Applications: Collected Papers of Lotfi A. Zadeh, John Wiley & Sons. New York, ISBN: 0471857106.
[4] Kosko, B. (1993). Fuzzy Thinking: The New Science of Fuzzy Logic. Hyperion, New York.
[5] Zadeh, K. S. (2000). Fuzzy health, illness and disease. Journal of Medicine and Philosophy, 25(5):605-638.
[6] Baro, S. and Marin, R. (2002). Fuzzy Logic in Medicine. Heidelberg: Physica-Verlag.
[7] Torres, A. and Nieto, J. J. (2006). Fuzzy logic in medicine and bioinformatics. Journal of biomedicine and biotechnology, 1-7.
[8] Faran, B., Khan, M. S., Noor, Y. and Imran, M. (2011). Design model of fuzzy logic medical diagnosis control system. International Journal on Computer Science and Engineering (IJCSE), 2093-2108.
[9] Kumar, S., Hndoosh, R. W. and Sarora, M. S. (2013). A proposition for using mathematical models based on a fuzzy system with the application. International Journal of Mathematical Sciences, 33(2), 1356-1373.
[10] Cucinotta, F. A., Alp, M., Sulzman, F. M. and Wang, M. (2014). Space radiation risks to the central nervous system. Life Sciences in Space Research, 2, 54-69.
[11] Kumar, S., Hndoosh, R. W. and Sarora, M. S. (2014). Mathematical structure fuzzy modelling of medical diagnosis by using clustering models. International Journal of Scientific and Engineering Research, 5(8), 545-554.
[12] Kumar, S., Sarora, M. S. and Hndoosh, R. W. (2014). The derivation of interval type-2 fuzzy sets and systems on the continuous domain: theory and

ISSN: 2349-8889
Volume-9, Issue-3 (May 2022)

https://doi.org/10.31033/ijrasb.9.3.22

application to heart diseases. International Journal of Science, 3, 35-54.
[13] Dagar, P., Jatain, A. and Gaur, D. (2015). Medical diagnostic system using the fuzzy logic toolbox. International conference on computing, communication and automation (ICCCA 2015).
[14] Mathur, N., Mathur, S., Mathur, D. and Meena Y. K. (2017). Detection of a brain tumour in MRI image through the fuzzy-based approach. Big Data and Cognitive Computing, 27(3).
[15] Jandial, R., Hoshide, R., Waters, J. D. and Limoli, C. L. (2018). Space Brain- The Negative Effects of space Exposure on the Central Nervous System. Surgical Neurology International.
[16] Patel, S. (2020). The effects of microgravity and space radiation on cardiovascular health: From low-Earth orbit and beyond. IJC Heart & Vasculature.30.
[17] Karar, M.E., Elgarawany, A.H. and El-Brawany, M. (202) Optimal adaptive intuitionistic fuzzy logic control of anti-cancer drug delivery systems, Biomedical Signal Processing and Control 58.
[18] Chen, S.; Rajaee, F.; Yousef pour, A.; Alcaraz, R.; Chu, Y.; G Ãmez-Aguilar, J.F.; Bekiros, Stelios; Aly, Ayman A. and Jahanshahi, Hadi (2021) Antiretroviral therapy of HIV infection using a novel optimal type-2 fuzzy control strategy, Alexandria Engineering Journal, 60, 1

