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Fuzzy Logic Based Diagnostic System for Microgravity and Radiation Against Immunity Decrease and Tumor Induction in Space

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Abstract: The space environment is inevitable to be beneficial for the human welfare. But the long-term effects of living in space are still unknown and indulge to mitigate the risks during a lengthy space habitation. Microgravity and radiations are the most critical health risk factors affecting the performance of astronauts during their long duration space exploration missions. Microgravity gradually damages the immune system which slows down the body’s ability to protect itself and increased radiation level causes severe mutations resulting in tumors. The Mamdani model, implemented in the Fuzzy Logic Toolbox in MATLAB, was used for data analysis. As inputs to the system “gravity and radiations” risk factors were taken and the outputs were “Immunity and Tumor”. Obtained results show that fuzzy logic can be a functional tool in dealing with this kind of medical/scientific hypothetical issues. A typical Mamdani type fuzzy control system embodies a fuzzifier, inference engine, rule base and a defuzzifier and employs fuzzy sets in the consequent part of the rules. The simulator is a MATLAB toolbox designed to visualize the movement of the “Create” in a predefined algorithm. The whole research revealed that simulation results are in complete accord with the measured values.

Key words: Space missions · Gravity · Health risk · MATLAB.

INTRODUCTION

Fuzzy logic (FL) is a multi-valued logic that has the ability to mimic the human intelligence capabilities. Fuzzy systems has been extensively used in industrial control system, medicine, transportation and household appliances such as self-focusing cameras, washing machines and anti-lock breaking systems and it allows the treatment of indefinite, unpredictable, inaccurate and distracted concepts and knowledge in an exact arithmetical form [1]. When the complexity of a system rises, the capability of making correct decisions about ones behavior reduces and the degree of the result is highly compatible with the fuzzy restriction according to the compatibility principle of Zedeh i.e. "The closer one looks at a 'real' world problem, the fuzzier becomes its solution" [2]. FL has been widely used in medical diagnostic control systems such as diabetes, dysplasia prediction and tumor [3-4]. Lot of work based on FL models has been reported predicting structure and composition of proteins and amino acids [5-6]. Recently, a fuzzy logic based system had been designed to diagnose the hemorrhage and brain tumor diseases in which RBCs, proteins, neutrophils, lymphocytes and eosinophils were taken as as an input variables [7]. Fuzzy logic principles and neural network techniques were applied to adjust intravenous insulin administration rates during the infusion of glucose [8]. Sadegh-Zadeh proposed that health and disease are two fuzzy states of health [9]. Ohayon developed a fuzzy logic based expert system to assess the sleep disorders by using fuzzy sets to meet the diagnostic criteria in terms of frequency, intensity, quantity and graduated yes–no variables [10]. A fuzzy logic based cerebrospinal fluid expert system was designed to identify the possibility of the disease which consists of cytology, glucose concentration and protein level data. Fuzzy modeling techniques were adapted in the neuro medical field which evaluates the fuzzy logic on the

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basis of facial expression and human behavior [11]. The prediction capability of Fuzzy Cognitive Map (FCM) was used to design immune system for the protection of human body [12]. The medical applications of FL range from diagnostic control systems to imaging technology such as magnetic resonance imaging, dynamic single-photon emission tomography (SPECT) imaging, echocardiograms, electrocardiograms and coronary and renal arteriograms [13-15]. A. Sproule *et al*. [16] reviewed the applications of fuzzy logic in the emerging field of pharmacology.

The Effect of space conditions on various physiological functions needs to be investigated to stay for a longer period of time in space for research purpose. One of the most significant effect observes during the space flight is on the immune system [17]. Deregulation in the immunity affected the ability of the host to resist infection and tumors. The reports made on the effects of space flight on the immune system have been interesting but not commemorative [18]. Some constraints originated in the space during the research which is small sample size, the relatively small number of flights available for immunological studies and by experimental conditions [19-20]. On the other hand, it is obvious that some alterations of immunological parameters transpire during space flight. Several factors could contribute to those effects, including microgravity, stress and radiation [21-22]. It has been difficult to conclude the absolute contribution of each of those factors to alterations in immunological parameters induced by space flight. Most important of which is how the immune responses change, the possible effects of space flight on substantial resistance to infection have not been developed/ identified.

Gravity and radiations have an impact on the tumor and immune system. The general criteria of the proposed work are shown in the Fig. 1. On earth, gravity and radiation exposure is normal which make our immune system to work at maximum and as a result tumor induction chances are less. But in space where there is no gravity and high intensity of radiation exposures both factors affect the human immune system hence there is maximum chances of tumor. This proposed work addresses the diagnostic system using fuzzy control logic to find the chances of occurrence of tumor and behavior of immunity due to radiations and gravity effects. This proposed fuzzy logic based diagnostic system consists of two input variables: gravity and radiation and two output variables: immunity and tumor induction.

The basic structure of the proposed model is discussed in Section 2 while Section 3 gives the design algorithm of fuzzy logic for diagnostic system. Section 4 and 5 describes results and discussion along woth the simulation results of this system. Conclusion and future work are given in Section 6.

Basic Structure of the Proposed Diagnostic Model: The basic structure of the proposed model is shown in Fig. 2. Fuzzifier fires four linguistic values: two for each input variable. Further these linguistic values are then processed through human decision based Rule-Base. Finally, after the process of Defuzzification, two output crisp values are given to show the probability of the disease i.e. immunity and tumor.

Design Algorithm: The algorithm designed for diagnostic control system comprises of two 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 given as: lowest 0-100, low 0-200, below medium 100-300, medium 200-400, high 300-500 and very high 400-500. Two outputs of this proposed diagnostic system are: Immunity and Tumor. Six membership functions are for Immunity: lowest 0-5, lower 0-20, low 10-50, medium 40-60, higher 50-90 and highest 80-100 whereas the six membership functions 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 generates four linguistic values, two for each input variable. The descriptions of range, membership functions and the occupied region for two input variables are described in Table 1.

Table 1 clearly shows the range of six membership functions of gravity and radiation along with the regions occupied as shown in Figure 3 and 4.

The six membership functions G_1-G6 are used to present the various ranges of input fuzzy variable "GRAVITY" in a plot consisting of five regions as shown in Fig. 3.

The six membership functions, "very low", "low", "below medium", "medium", "high" and "very high" are used to show the different ranges of input fuzzy variable "RADIATION" in a plot also consisting of five regions as shown in Fig. 4.

Table 2 shows Linguistic Fuzzifier Outputs for gravity and radiation respectively in each occupied regioneach variable contains two fuzzifier outputs

The mapping of the four linguistic variables for two input variables in five regions are given in Table 2 and block diagram of the fuzzifier is shown in Fig. 5.

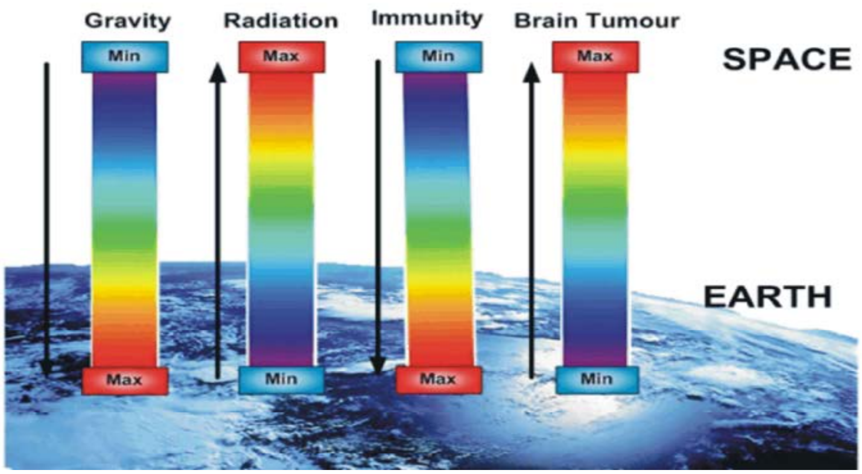

Fig. 1: General Criteria of the Proposed Work clearly showing the gradual change in gravity and radiation in space and decrease in immunity and increase in chances of occurring of tumor

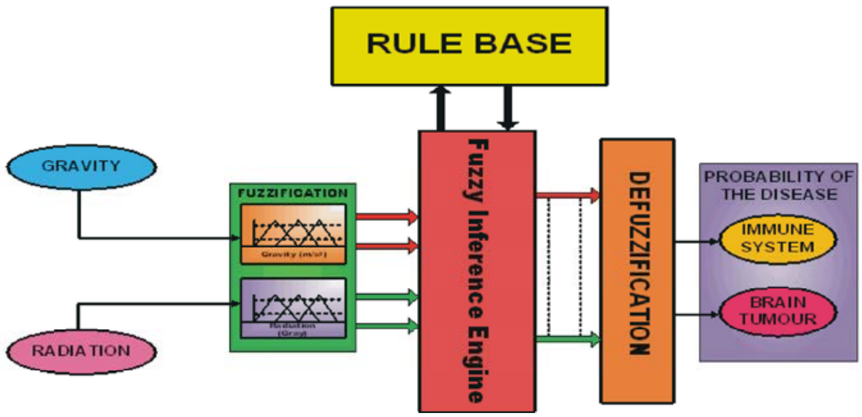

Fig. 2: Block Diagram of Fuzzy Logic Based model showing the input and output values

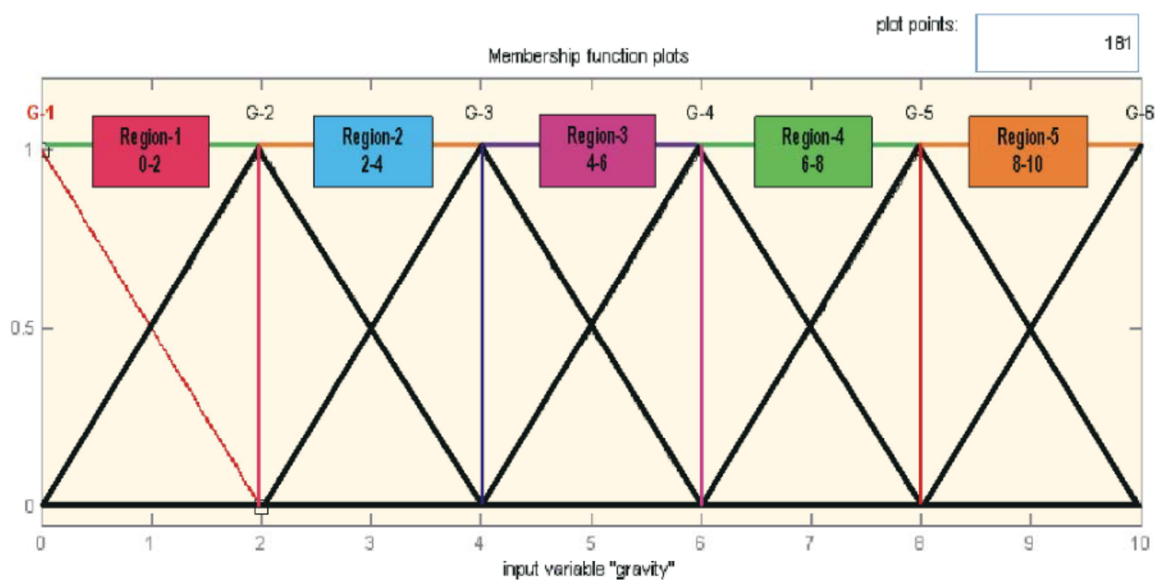

Fig. 3: Plot of membership functions for input variable, “GRAVITY” showing clearly the regions occupied by MF of gravity

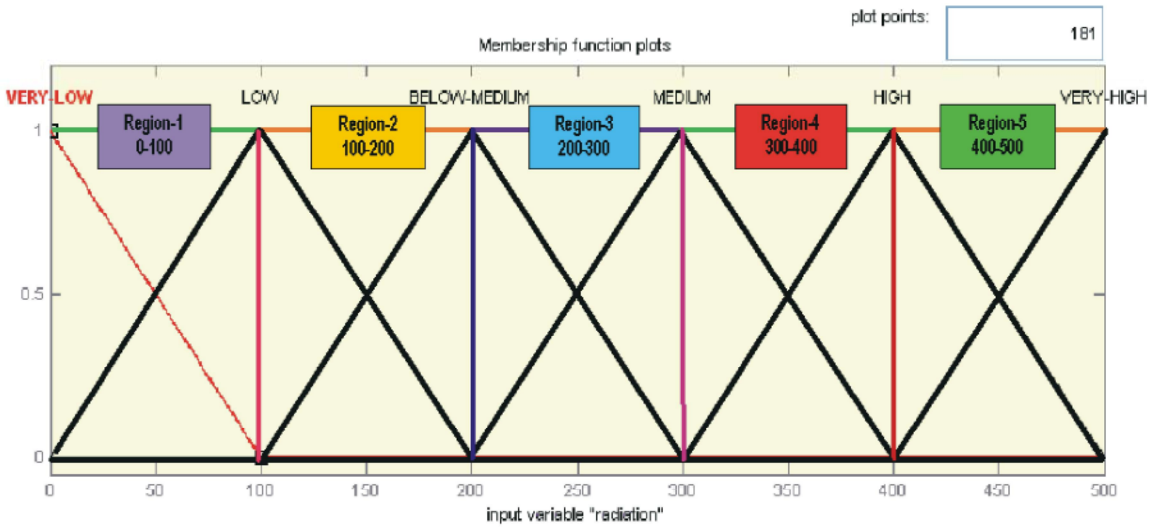

Fig. 4: Plot of membership functions for input variable showing clearly the regions occupied by MF of Radiation

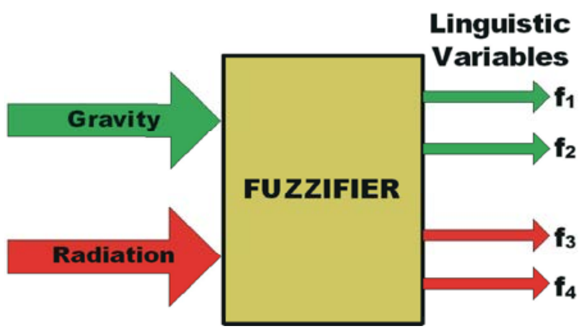

Fig. 5: Fuzzifier block diagram showing the four linguistic values for two input variables i.e gravity and radiation

Table 1: Membership functions and range of input variable gravity and radiation

MF for Gravity			MF for Radiation		
Membership Function (MF)	Range	Region Occupied	Membership Function (MF)	Ranges	Region Occupied
G_1	0-2	1	Lowest	0-100	1
G_2	0-4	1-2	Lower	0-200	1-2
G_3	2-6	2-3	Low	100-300	2-3
G_4	4-8	3-4	Medium	200-400	3-4
G_5	6-10	4-5	Higher	300-500	4-5
G_6	8-10	5	Highest	400-500	5

Table 2: Linguistic values of fuzzifier outputs in all regions

Input Variables	Linguistic Fuzzifiers 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 3: Results of fuzzification

Input Variables	Values	Region Selection	Fuzzy Set Calculation
Gravity	x=0.5	0=x<2 Region-1	f_1=(2-0.5)/2=0.75 f_2=1-f_1=1-0.75=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