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ASSESSING IMPACT OF CLIMATE CHANGE THROUGH DESIGN OF A FUZZY EXPERT SYSTEM

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ABSTRACT

The growth of technology has taken place in leaps and bounds over the years. The rate of increase is more pronounced in the recent years. The level of developments is found to be profound in many areas of science and technology. However, not much importance has been given to maintenance of eco-friendly environment. A wide variety of species are getting extinct and amount of carbon dioxide emissions have shot up over a period of time. This work hence focuses on identifying relationships between changes on environmental parameters and its consequences. Special care has been taken to ensure that production levels do not take a steep fall by taking into consideration the inherent uncertainties involved.

Keywords: climate change, fuzzy logic, gross domestic product, species extinction rate.

INTRODUCTION

Undoubtedly, climate change has been a hot topic for the past few years. Human expansion of the greenhouse effect leads to global warming, which has been accepted as the main cause for climate change by most climate scientists. When the heat radiating from Earth towards space gets trapped by Earth's atmosphere, warming up takes place. This is known as greenhouse effect. Certain gases in the atmosphere blocks heat from escaping. Inert gases that remain semi-permanently in the atmosphere and do not respond physically or chemically to changes in temperature are described as "forcing" climate change. Gases, such as water vapor, which respond physically or chemically to changes in temperature, are seen as "feedbacks". This work takes into consideration factors leading to a rise in Carbon dioxide levels apart from focusing on aspects leading to extinction of a wide variety of species.

LITERATURE SURVEY

It could be inferred that, development was limited till the middle of the twentieth century. With the passage of time, the demand for larger amount of comfort from people across the world led to more and more innovation. With rapid rise in amount and usage of technology, several complex jobs which took years for getting them done could be done in a negligibly small amount of time. However, on the flip side, the environment has been badly affected. In recent years, measures have been taken to control damage to the environment.

In the year 1996, L. Occhipinti and G. Nunnari used a set of artificial intelligence techniques in modeling and controlling climate variables within a green house. They proposed a framework for multi-input multi-output fuzzy logic controllers. Later in the year 1997, R. Caponetto, L. Fortuna, G. Nunnari and L. Occhipinti improved the existing method by considering non-linear physical characteristics in modeling.

In the year 2000, Pan Lanfang, Wang Wanliang and Wu Qidi designed an adoptive fuzzy logic system for a greenhouse climate model. This model is able to handle both numerical date and linguistic information. In the year 2003, Zhany Bau, CW Haishay and Yanfer performed a research on the change of saline – alkaline land by comparing remote sensing images. They in turn monitored the amount of land degradation in a particular province of China named Jilin. In the year 2006, Fang Xu, Jianalizo Zhen, and Hogwan Zian proposed an optimizing fuzzy logic controller for greenhouse temperature using real coded genetic algorithm. They could reach an ideal level of fitness of root mean square error indicating high levels of performance and robustness.

A new problem assumed monotonous significance in the early part of twenty first century. This problem dealt with an abnormal increase in sea levels over several parts of the globe. This in turn led to a blatant change in the life styles of people residing close to sea. With this view point in consideration, Signalled Nerhein performed intense studies on identifying factors leading to rise in sea levels. Special emphasis was given on regions surrounding Sweden and Finland. Further research on controlling sea level rise has been carried out by Oz Sahin and Sherif Mohamed. They designed a model that could dynamically access the vulnerability of water front properties to sea level rise. Besides, adaptation options have also been evaluated. During the same period, Javier Marcello, Alonso Hernández-Guerra and Francisco Eugenio analyzed the variation in sea surface temperature for a period of 20 years from 1987 to 2006 by computing a parameter termed "upwelling index" in North West Africa.

In 2010, Dr. Soheila Khoshnevis Yazdi and Dr. Bahram Shakouri conducted a detailed survey and indentified impact of environment on the tourism industry. Dr. Soheila Khoshnevis Yazdi and Anahita Fashandi further improved on their earlier research by identifying the impact of climate change on aquatic Eco systems.

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They were able to assess the impact of global warming towards aquatic sea life. Tony Prato proposed a framework for evaluating the vulnerability of an ecosystem to losing ecological integrity due to climate change and compensatory management actions for reducing impact the same in a future period.

In the year 2011, Carlos and Benjamin used fuzzy models to predict the range of temperature increase for the future concentration of green house gases mainly due to the emissions of CO_2 up to the year 2100. Ralf Denzer, Sascha Schlobinski and Lars Gidhagen built a decision support system on solving problems related to potential climate change issues for end users like expert planners, city planners and developers/application providers. In the year 2013, Liu Yupeng, Yu Deyong, Xun Bin, Hao Ruifang and Sun Yun examined net primary productivity for 11 years from 2001 to 2011 and identified that 77% of ecosystem productivity depend on climate change.

It has been observed that the extent of impact on climate has been extensive. A large number of factors play a significant role in creating a distinct impact on the environment. With this perspective in mind, it has been decided to propose an efficient fuzzy expert system taking some of the key parameters into consideration.

UNCERTAINITY

Any model developed needs to function precisely based on the real world conditions. However, for accurate results, inputs and outputs must be precise. Achieving this level of precision is not feasible in most cases owing to uncertainty. Uncertainty occurs in all kinds of applications irrespective of the methodology used.

Causes of uncertainty

Most uncertainties occur due to missing or incorrect information. Besides, the calibration level of the measuring instrument also leads to uncertainty. To add to the above, the laziness of the operator and lack of availability could also lead to uncertainty.

In the designed system, the rate at which species get extinct cannot be precisely determined owing to geographical factors. Apart from incorrect measurements, uncertainties can also arise due to various rules, their incompatibilities and during conflict reduction. The designed system is able to ensure that the above mentioned uncertainties are as minimum as possible. Uncertainties are also associated with creation of rules and assignment of values.

Data fusion is another cause of uncertainty. In this case, data is obtained from combining different types of information. Other kinds of uncertainties deal with choosing appropriate membership functions. This characteristic has been elaborated in section on Choice of Membership Functions.

FUZZY LOGIC CONTROL

Sustained efforts have been taken by various organizations in reducing the amount of CO_2 emissions and at the same time increase the gross domestic product level. However, results have shown that these factors do not depend upon a single parameter alone. A number of factors like elevation, relative humidity, temperature, ocean currents, distance from equator and direction of prevailing wind have varying degrees of impact on the environment. As designing the model taking all these factors into consideration is very complex, it has been decided to prune out certain parameters based on their level of influence.

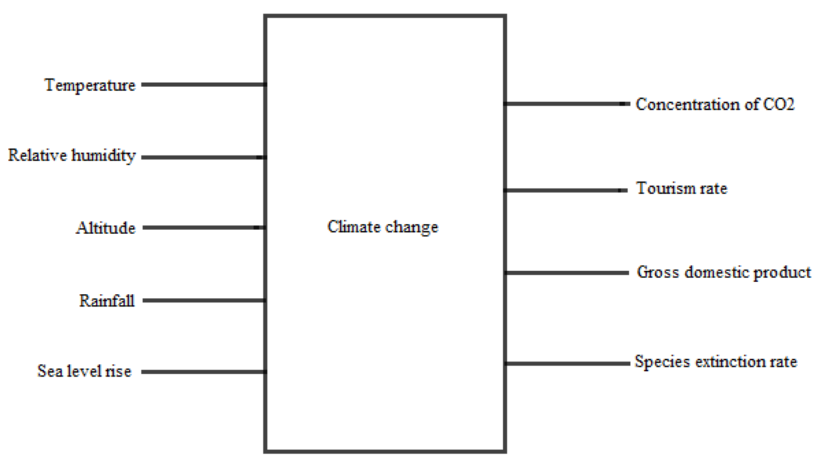

Figure-1.

A Mamdani based fuzzy inference system has been designed. The system taken in consideration uses five inputs namely elevation, rainfall, relative humidity, sea level rise and temperature and generates four outputs namely concentration of CO_2, species extinction rate, GDP and tourism rate.

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A schematic of the system is shown in Figure-1.

CHOICE OF MEMBERSHIP FUNCTIONS

Once, the set of inputs and outputs have been identified, the next step is to apply a suitable Membership Function (MF) for each of the parameters. The only restriction of the membership function is that, it has to satisfy values in the range of zero to one. A set of eleven in-built membership functions are present in The Fuzzy Logic Tool Box. The flexibility provided is that the same fuzzy set could be described by an innumerable number of membership functions. However, this flexibility could also result in complex decision making. On deciding the choice, the membership function can be normalized if necessary. This is to ensure that for some particular value of input, the membership value will be one. Although, a number of membership functions are available, the designed system has used only four membership functions.

Triangular membership function

A triangular membership function is characterized by its simplicity and requires three parameters for specification. A triangular MF is specified by three parameters {a, b, c} as follows:

$$\text{triangle}(x; a, b, c) = \begin{cases} 0, & x \leq a. \\ \frac{x-a}{b-a}, & a \leq x \leq b. \\ \frac{c-x}{c-b}, & b \leq x \leq c. \\ 0, & c \leq x. \end{cases}$$

For one of the inputs namely Relative humidity, a triangular membership function is found to be more appropriate. This has been highlighted in Figure-2.

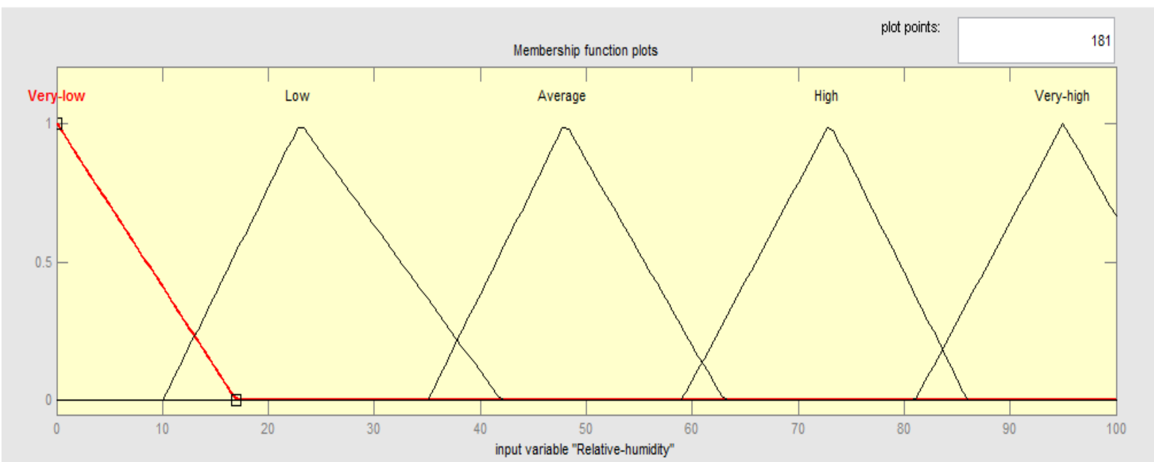

Figure-2. MF for relative humidity.

Trapezoidal membership function

A trapezoidal membership function is specified by four parameters as follows:

$$\text{trapezoid}(x; a, b, c, d) = \begin{cases} 0, & x \leq a. \\ \frac{x-a}{b-a}, & a \leq x \leq b. \\ 1, & b \leq x \leq c. \\ \frac{d-x}{d-c}, & c \leq x \leq d. \\ 0, & d \leq x. \end{cases}$$

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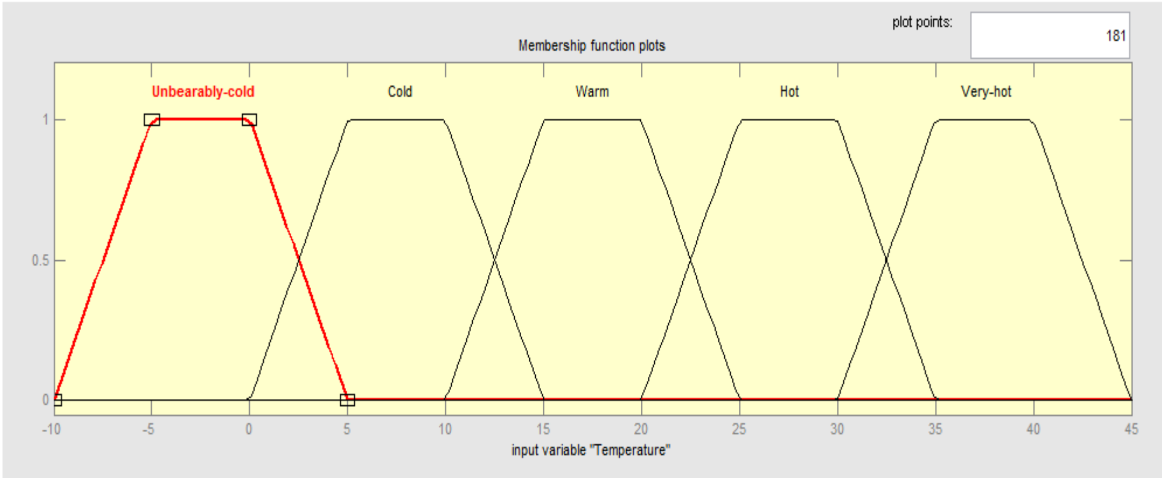

Figure-3. MF for temperature.

The advantage of using triangular and trapezoidal membership function is that they are very simple and only a small amount of data is needed to define them. The parameter temperature is found to exhibit trapezoidal characteristics as shown in Figure-3.

Gaussian membership function

A Gaussian membership function is given by two parameters:

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

Owing to the factor of smoothness, Gaussian MF is found to be suitable while defining the output parameters like Species extinction rate. This has been presented in Figure-4.

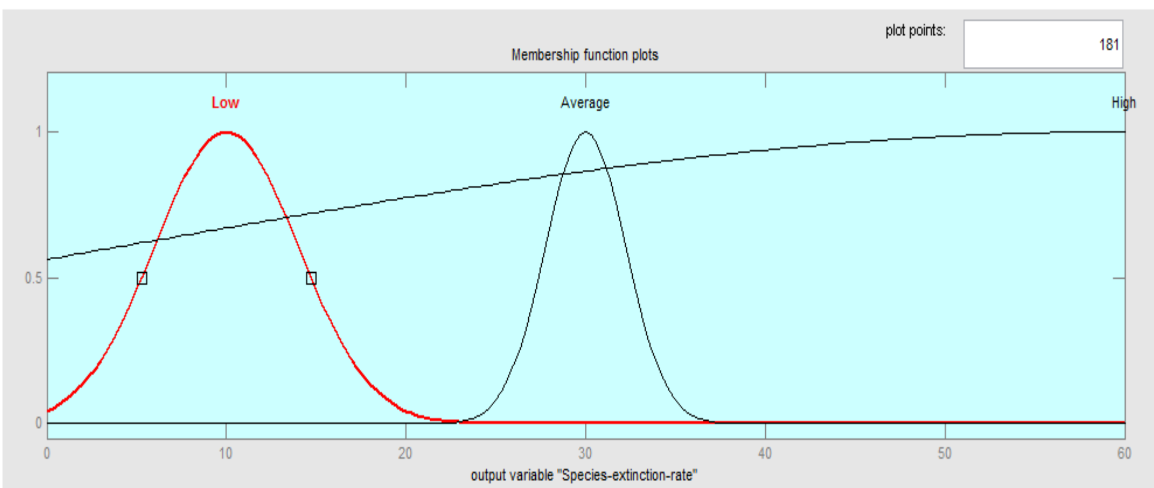

Figure-4. MF for Species extinction rate.

Generalized bell membership function

The generalized bell membership function is specified by three parameters and has the function name gbellmf. The bell membership function has one more parameter than the Gaussian membership function, so it can approach a non-fuzzy set if the free parameter is tuned.

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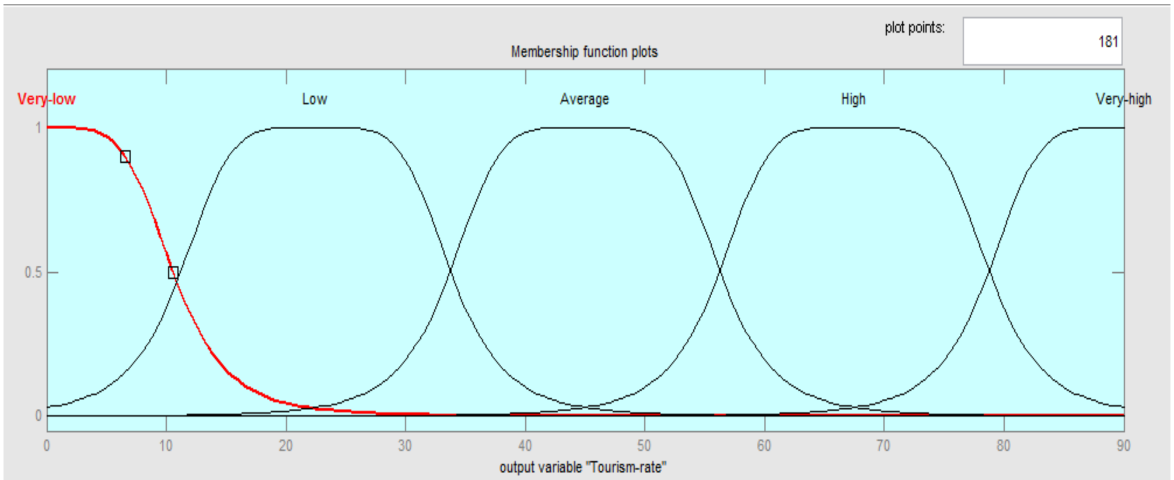

Figure-5. MF for Tourism rate.

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

Both Gaussian membership function and generalized bell membership function have the advantage of being smooth, concise and nonzero at all points. In our designed system, tourism rate is defined by gbell membership function as shown in Figure-5.

DIAGNOSIS OF FUZZY EXPERT SYSTEM

The designed system incorporates a feature of learning. Here, initially the fuzzy IF-THEN rules have to be interpreted. This process involves three steps, namely, fuzzification of inputs, application of fuzzy operator and application of the implication method. All outputs are then aggregated before defuzzification.

The problem with proper inference framing deals with analyzing conflicting rules. The designed system is able to handle incomplete and inconsistent rules. A series of rules have been framed that accurately portray the characteristics of the designed system. With a wide variety of rules leading to generation of a large number of conclusions, situations arise when conclusions contradict each other. A sample situation has been highlighted. Two sets of sample rules are as follows:

a) If (Temperature is Hot) or (Rainfall is Moderate-rain) then (Tourism-rate is Average).
b) If (Temperature is Hot) and (Relative humidity is High), then (Tourism-rate is High).

When temperature is high, rainfall is moderate and relative humidity is high, a conflict arises where the tourism rate could be either average or high. The designed system is able to handle such conflicts thereby generating suitable inferences.

Besides incorrect measurements, uncertainties can also arise due to various rules, their incompatibilities and during conflict resolution. The designed system is able to ensure that the above mentioned uncertainties are as minimum as possible. Uncertainties are also associated with creation of rules and assignment of values.

FRAMING FUZZY INFERENCES

A method of mapping input space with output space is needed. This is carried out by a fuzzy inference system. The general structure of the fuzzy system has been shown in Figure 6.

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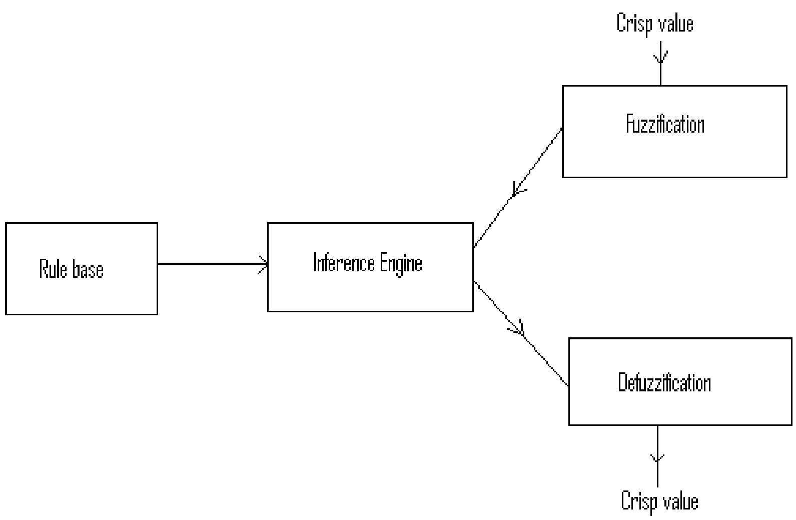

Figure-6. Structure of fuzzy system.

The inference process is performed in a series of four steps:

Fuzzification of input variables

The crisp inputs are chosen. The degrees to which these inputs belong to each of the appropriate fuzzy sets are identified.

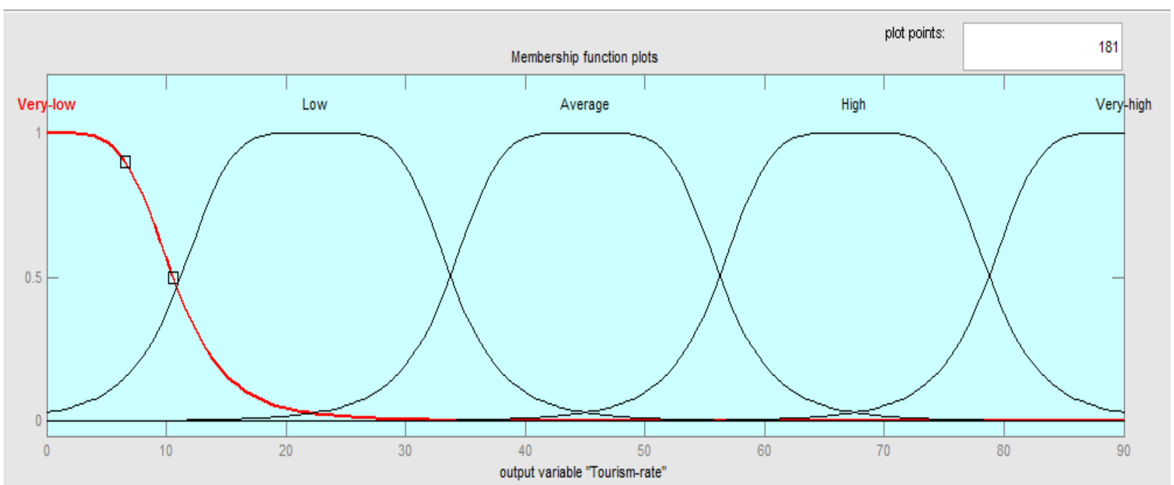

Figure-7. Tourism rate.

Rule evaluation

A sample fuzzification process has been shown:
f(Temperature=27) => f(Temperature=hot with Membership value=1.0),
f(Rainfall=10) => f(rainfall=moderate with Membership value=1.0).

After carrying out fuzzification, the fuzzified inputs are then applied to the antecedents of the fuzzy rules. When multiple antecedents are present in a single fuzzy rule, AND or OR operators chosen to obtain the result.

Sample rules using two antecedents have been illustrated as equations 1 and 2.

a) If (temperature is hot) AND (rainfall is moderate), then (tourism rate is average).
b) If (temperature is hot) OR (relative humidity is high), then (tourism rate is high).

In equation-1, conjunctions of the operations are performed.

Membership value of temperature ∩ membership value of rainfall = minimum (membership value of temperature, membership value of rainfall)

In equation-2, disjunctions of the operations are performed.

Membership value of temperature U membership value of relative humidity = maximum (membership value of temperature, membership value of relative humidity)

The result of the antecedent evaluation has been applied to the membership function of the consequent. In order to correlate the consequent rate with the level of truth in the antecedent, clipping method is performed. The advantage of clipping is its inherent simplicity and higher speed. Besides, it generates an aggregated output. This aggregated output is easier to defuzzify. However, the only drawback is that a small amount of information can be lost during clipping. Apart from clipping, scaling can be performed to retain the original shape of the designed fuzzy set.

16. If (Temperature is Unbearably-cold) then (GDP is Very_low) (1)
17. If (Temperature is Cold) then (GDP is Medium) (1)
18. If (Temperature is Hot) then (GDP is Medium) (1)
19. If (Temperature is Warm) and (Rainfall is Moderate-rain) then (GDP is Very-high) (1)
20. If (Rainfall is Light-rain) then (GDP is Low) (1)
21. If (Rainfall is Violent-rain) then (GDP is Very_low) (1)
22. If (Altitude is High-lands) then (Concentration-of-CO2 is Low) (1)
23. If (Rainfall is Heavy-rain) then (Concentration-of-CO2 is Very-low) (1)
24. If (Rainfall is Violent-rain) then (Tourism-rate is Very-low) (1)
25. If (Rainfall is Moderate-rain) then (Tourism-rate is High) (1)
26. If (Rainfall is Violent-rain) then (GDP is Low) (1)
27. If (Rainfall is Light-rain) then (GDP is High) (1)
28. If (Sea-level-rise is Very-high) then (Species-extinction-rate is High) (1)
29. If (Rainfall is Heavy-rain) then (Species-extinction-rate is Average) (1)
30. If (Rainfall is Violent-rain) and (Sea-level-rise is Very-high) then (Tourism-rate is Very-low)(Species-extinction-rate is Average) (1)
31. If (Rainfall is Violent-rain) and (Sea-level-rise is Very-high) then (GDP is Very_low) (1)
32. If (Rainfall is Violent-rain) and (Sea-level-rise is Very-high) then (Species-extinction-rate is High) (1)

Figure-8. Sample set of rules.

Aggregation of outputs

The output of all the rules are in turn unified and fuzzy set is generated for each output variable.

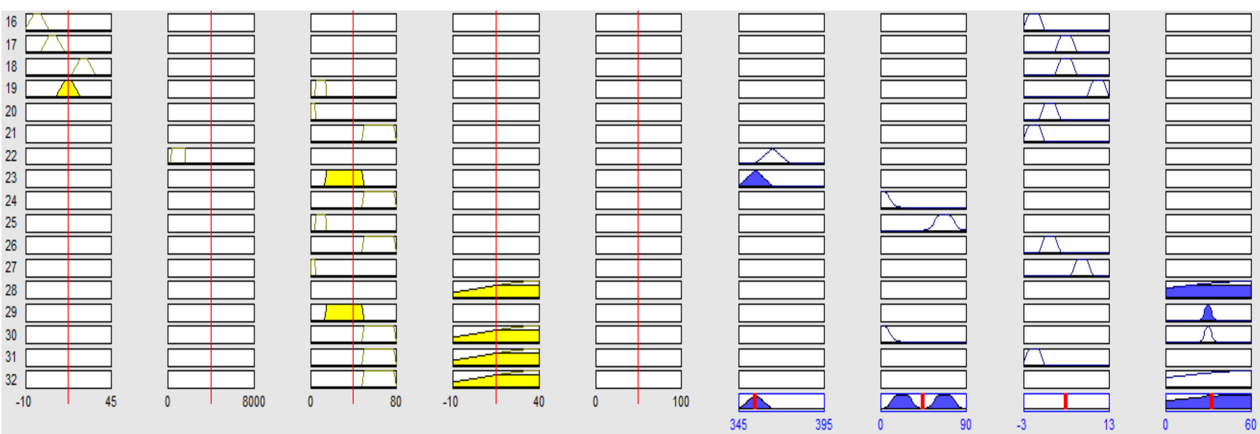

Figure-9. Aggregated output.

For the sample set of rules shown in Figure-8, outputs are aggregated. The simulation results clearly highlight the set of rules which are triggered based on the inputs provided. The level of activation based on membership values can also be observed as shown in Figure-9.

Defuzzification

The final result of the process must be a crisp number. For generating the same, defuzzification is carried out. The centroid method of defuzzification has been used in this work. In this method, a point representing the centre of gravity of every fuzzy set can be computed on a specified interval. With increase in the sample set of points, a good estimate has been obtained.

CONCLUSIONS AND RECOMMENDATIONS

A fuzzy expert system has been designed that takes into consideration parameters like Elevation, Relative Humidity, Sea Level Rise, Temperature and Rainfall and find their effects in the environment. In order to simplify proceedings, four different areas namely Tourism rates, Species Extinction Rate, GDP and Carbon

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Dioxide Concentration have been given a definite emphasis.

The designed model is able to identify the sensitive parameters. It has been observed that, a small increase in rainfall has caused a drastic change in GDP and species extinction rate. An instance is shown where an increase in rainfall by 1.14 cms has caused a corresponding increase in GDP by 5.16 billion. Besides, the same amount of change in rainfall has caused a corresponding decrease in species extinction rate by six million.

The success of the designed fuzzy expert system has been clearly highlighted in identifying the sensitive parameters having a significant influence on various areas.

This work could be extended further by focusing on a larger set of areas apart from considering other possible inputs. Expansion of this work to the effect to other green house gases is left to be explored further. Despite these minor hitches, the system is found to be very efficient.

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