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Exercise Bike Model using Fuzzy Logic

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Abstract: ***'Healthy mind lives in healthy body', this famous saying indicates that if one is healthy then that person's mind is in peace. In the competitive world, everyone wants to be successful. In this fast world each one is racing against time and trying to complete the daily to do list. To complete the daily task list most of the people are constantly under stressed, ignore their health and don't do any exercise. Exercise are of different types such as running, walking, yoga etc. and different equipments are available for it such as treadmill, exercise bike, slimming belt, home gym, air walker, ab roller etc.***
Cycling is the exercise which offers cardiovascular benefits, which you get from any other cardio exercise. It is one of the exercises which strengthen muscles, helps to build strong bones, helps maintain a healthy weight and improves cardiovascular fitness. Exercise on stationary cycle is a best option for exercise as it can be done indoor, and in all seasons. When one is doing exercise on exercise bike the speed, distance, pulse, time and gears are important factor. Balance of speed and distance with gear is important otherwise overdone of it may cause physical injury to muscles or joints.
This research paper suggests exercise bike model using fuzzy logic and suggests a new view called as Exercise Bike Effect (EBE). EBE can suggest how much cycling activity can be performed without causing any injury. The simulation of suggested model is performed by MATLAB.
Keywords: Exercise Bike Effect, Fuzzy Logic, Inference system, Mathematical model

I. INTRODUCTION

Exercise makes you happier, chiller and more active person. Different types of exercises have various benefits such as cycling helps to get rid of stress, running helps to fight with depression; power workouts improve concentration, regular training helps to fight insomnia, aerobics improves cognitive abilities, in short any physical activity can improve your mood. Though so many benefits of exercises are having the expectations and reality is different hence proper balance of exercise is important to retain the interest of candidate. Many nations throughout the world have experienced huge increase in obesity rates over the past 30 year. The World Health Organization estimates that more than 300 million adults are obese and this increases the risk of diabetes, hypertension, cardiovascular disease, gout, gallstones, fatty liver, and some cancers. The findings reinforce the need for US cities to encourage more walking and cycling for daily travel. [1-6].
Cycling exercise is has many benefits out of that few are listed below [7].

A. Cycling for Muscles

Riding bike is effective for toning and building up of muscles, especially for lower half of the body i.e. calves, thighs and rear end. Cycling is also effective for low –impact mode exercise for those who are suffering from joint conditions or injuries of legs or hips. As per the study which include long distance runners and cyclists, it has been found that the runners suffered 133-144 per cent more muscle damage, 256 percent more, inflammation and delayed-onset muscle soreness (DOMS) 87 percent higher[2].

B. Cycling for Stress Reduction

Cycling reduces the stress. Studies say that playing game or sports decreases the stress. Most of the time playing sports may not be possible for everyone in such cases riding a bicycle / bike is equally effective for stress reduction and depression.

C. Cycling For Arthritis Control

Cycling is one of an effective exercise to prevent and cure arthritis. Both outdoor and indoor static cycling helps to prevent arthritis as the muscles flexing in thighs and lower legs, used during cycling controls arthritis.

D. Cycling for energy Level

Cycling improves body stamina and endurance capacity of a person. Cycling results in high energy level which improves all kind of activities. Devotion at work is also improved with higher energy level.

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E. Cycling For Oxygen And Circulation

Cycling strengthens the respiratory muscles, which helps in improving the ventilation of the lungs and this process in turn has positive effect on oxygen circulation in body. With moderate cycling a huge positive health effect can be accomplished.

F. Cycling In Pain

Cycling is also considered as best exercise for pain management. It is also referred as relaxing exercise. Physiological and psychological issues like tension, pain, stress can be eased up to certain extent with the help of cycling. Hence cycling is recommended as pain lowering strategy for children and adults.

G. Cycling For Diabetes Control

Diabetes increase risk of certain dieses like heart attack, stroke, kidney function, skin dieses etc. Cycling exercise in diabetes helps to control the glucose present in the blood cells. Glucose from blood cells is drained and converted into useful energy.

H. Cycling For Obesity And Weight Control

Cycling raises metabolic rate, build muscles and burns body fat, which means it can control or reduce weight. Cycling with a healthy eating plan provides very good results in weight loss. Cycling is one of the comfortable forms of exercise and can be done by children, adults and senior members too. In cycling exercise time and intensity change can be built up slowly and varied to suit you.

II. EXERCISE BIKE

Exercise bike is a stationary cycle, this device does not have wheels but there are settings on the equipment to indicate resistance levels for the pedals. The resistance mechanism may include magnets, fans or friction devices. Cycling is not treated as a fun way to burn calories and heart pumping but also referred as low-impact mode exercise for injuries. Before starting exercise on stationary bike it is important to set up your exercise bike to improve your safety and get the most out of your cycling workout [8].
The Fig.1 is a sample exercise bike and following things need to be taken care before starting with the exercise

A. Seat height

Adjust seat height so that it is level with your hip bone.

B. Handlebar placement

Adjust the handlebar such that when you hold it your back is straight and arms are slightly bent. Those who are suffering from lower back problems for them handlebar must be slightly upward to prevent back from bending.

C. Foot placement on pedals

Keep the foot in the pedal strap and it should be such that it cannot twist inside pedal.

D. Proper pedal strokes

Place the foot such that when you pedal, the knee should be bent and above toe.

E. Gear (Resistance Knob) Adjustment

The gears provide resistance to the cycling. It reduces the rpm if gear is increased. Beginners can start with moderate resistance and then lower or increase the gears there comfort level. Stay in the two point range of what instructor suggests.



Fig.1: Exercise bike

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III.EXERCISE BIKE EFFECT (EBE)

Daily exercise must be balanced. Heavy exercise may cause severe injuries. This paper introduces Exercise Bike Effect (EBE). If the EBE is more it indicates more intense workout. The exercise effect can be identified as follows. The range is specified

Factor	Range
Very Low (VL)	0 to 20
Low (L)	15 to 35
Medium (M)	30 to 50
High (H)	45 to 65
Very High (VH)	60 to 80
Extreme (E)	75 to 100

EBE shows the degree of exercise effect. If the speed is increased and the distance is more in the constant time indicates the EBE is increased. If the person doing exercise is injured then sudden increase in EBE causes damage or increases severity of injury.

IV.FUZZY LOGIC

Fuzzy logic is a multi-valued logic. The truth values are between 0 to 1. Fuzzy computing I based on "degree of truth" rather than "true or false". The idea of fuzzy logic was first advanced by Dr. Lotfi Zadeh of the University of California at Berkeley in the 1960s. Fuzzy logic is a convenient way to map an input space to an output space. Mapping input to output is the starting point for everything. Fuzzy Logic is applicable to fields like knowledge engineering, artificial intelligence and process control. Fuzzy logic applications are facial pattern recognition, air conditioners, washing machines, vacuum cleaners, antiskid braking systems, transmission systems etc. This theory adds more choices than simply yes/no or black/white [9, 10].

V. FUZZY MODEL FOR EXERCISE BIKE

A fuzzy inference system (FIS) is a system that uses fuzzy set theory to map inputs to outputs. FIS is mainly of two types Mamdani FIS and Sugeno FIS. Mamdani FIS theory was proposed in 1975 by Ebrahim Mamdani to control a steam engine and boiler combination by mixing a set of linguistic control rules in the form if then rule which are acquired from the experience of human operators [11].

A. The following are the key points of Mamdani FIS

1) *Fuzzify input variables:* Determine membership values. The purpose of fuzzification is to map the inputs from a set of sensors to values between 0 to 1 using a set of input membership functions.
2) *Evaluate rules:* Rules evaluation is based on membership values of (composite) antecedents.
3) *Aggregate rule outputs:* Aggregation indicates combine all membership values for the output from all rules. E.g. if rule A and B is given then by fuzzy and rule "$A \cap B = \min(\mu A(x), \mu B(x))$
4) *Defuzzify the output:* To obtain a single crisp value from fuzzy set in FIS is the process of deffuzification. Different deffuzification techniques are available like COG (center of gravity), LOM (last of maximum), MeOM (mean of maxima), MOM (middle of maximum), Center of sums, COA(Center of Area), Weighted average etc. The most common and useful method is Center of gravity (approx. by summation).

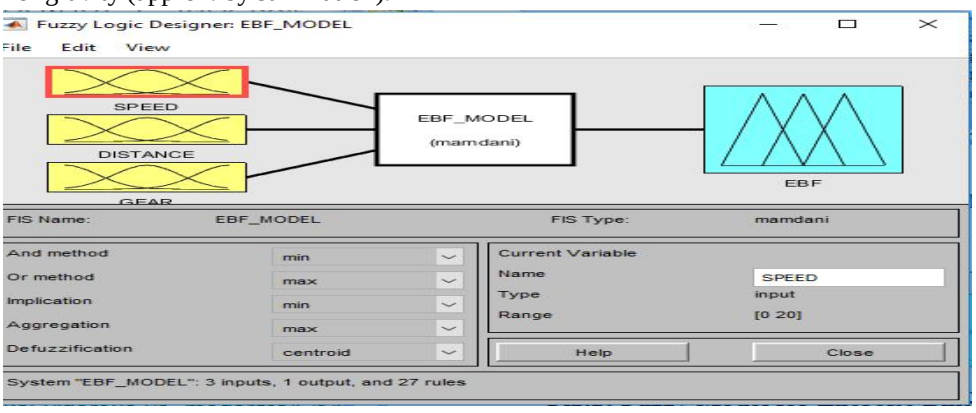


Fig.2: Fuzzy Model for Exercise Bike

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The Fig 2 indicates a fuzzy model for exercise bike system. The inputs supplied to the system are speed, distance and gear and the output generated from the fuzzy system is Exercise Bike Facor (EBF). The factor specifies the Exercise Bike Effect (EBF).
The exercise bike generates results which indicates effects of it, and represents how to use of exercise bike. E.g. if a person is exercising regularly and increased the speed of cycling, this causes increase in the EBF. The sudden increase in EBF may be harmful for a person with injuries; hence the system will help as a mentor for the person.

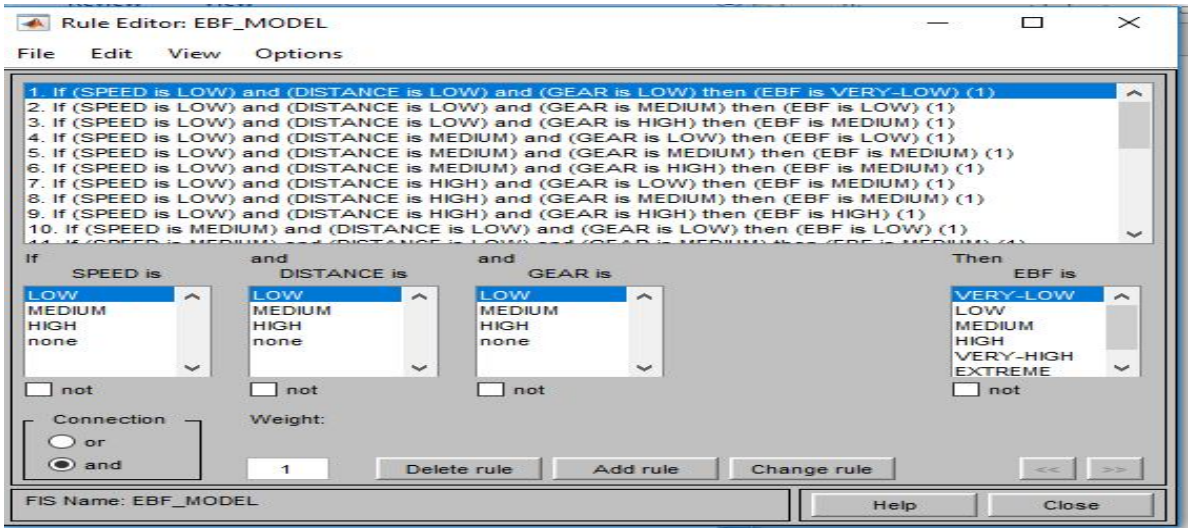


Fig.3: Fuzzy Rule Set for Mamdani FIS

B. The Fig 3 indicates the Fuzzy rule set of Mamdani FIS. Some sample rules are listed below

1) *RULE 1*: if speed is low and distance is low and gear is low then ebf is very low.
2) *Rule7:* if speed is low and distance is high and gear is low then ebf is medium.
3) *Rule 10:* if speed is medium and distance is low and gear is low then ebf is low.
4) *Rule 13:* if speed is medium and distance is medium and gear is low then ebf is medium.
5) *Rule 18:* if speed is medium and distance is high and gear is high then ebf is high.
6) *Rule 26:* if speed is high and distance is high and gear is high then ebf is extreme.
7) *Rule 27:* if speed is high and distance is high and gear is medium then ebf is very high.



Fig.4: Surface View of Exercise Bike

The Fig.4 and 5 indicates the surface view of Exercise bike inputs and output. Fig 4 indicates distance, speed and EBF surface view and fig 5 indicates speed, distance and EBF surface view.

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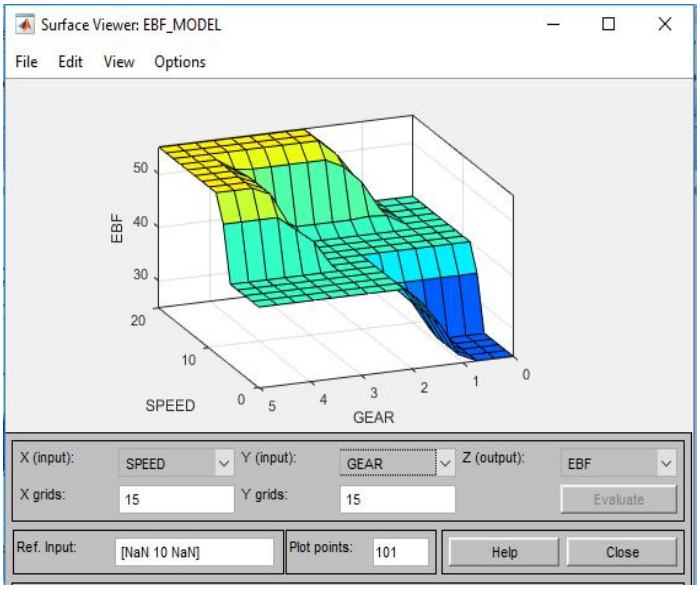


Fig.5: Surface View of Exercise Bike

The rule viewer for exercise bike is displayed below in fig.6. The input supplied is speed=Medium distance=medium and gear=2.5 then output EBF=medium. This indicates that exercise effect is medium.

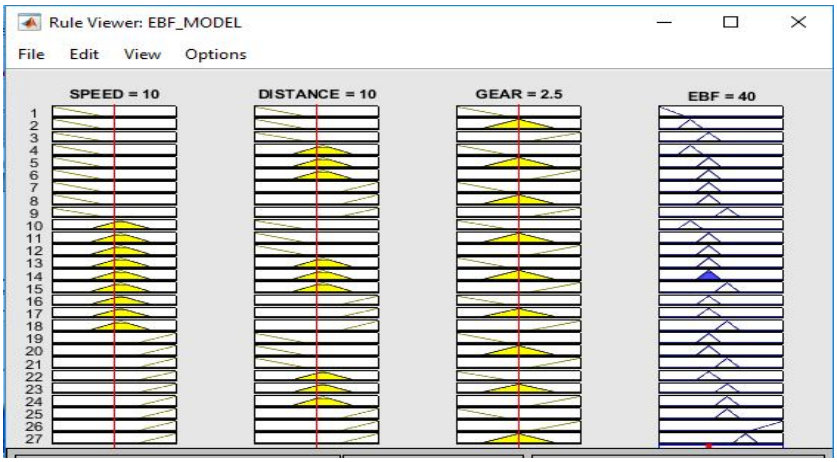


Fig. 6: Rule viewer of exercise bike FIS

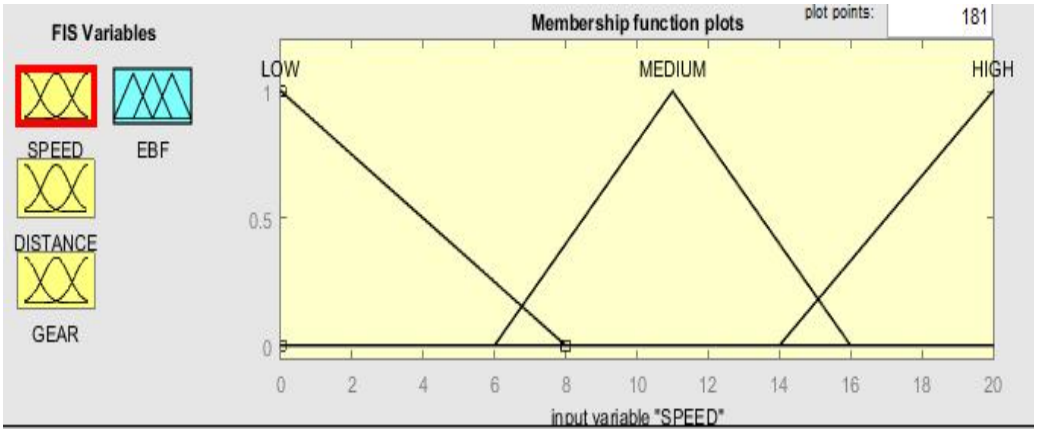


Fig. 7: Linguistic variables and membership function of 'Speed'

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TABLE I
LINGUISTIC REPRESENTATION OF FUZZY INPUT VARIABLE SPEED

Membership function	Type	Range
Low	Trimf	[0 0 8]
Medium	Trimf	[6 11 16]
High	Trimf	[14 20 20]

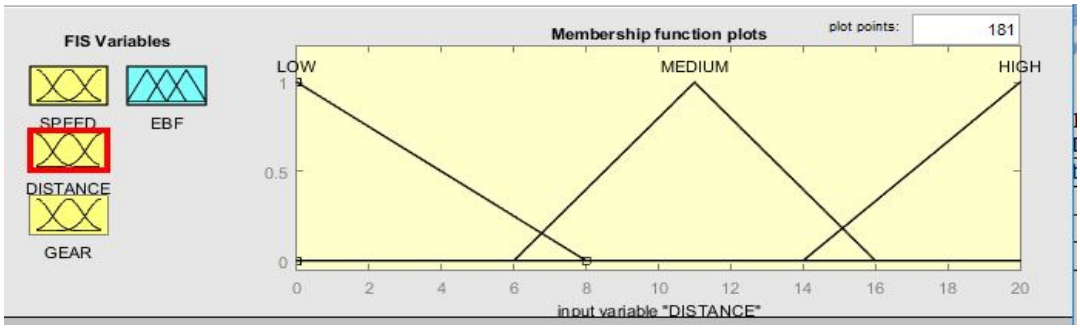


Fig.8: Linguistic variables and membership function of 'Distance'

TABLE II
LINGUISTIC REPRESENTATION OF FUZZY INPUT VARIABLE DISTANCE

Membership function	Type	Range
Low	Trimf	[0 0 8]
Medium	Trimf	[6 11 16]
High	Trimf	[14 20 20]

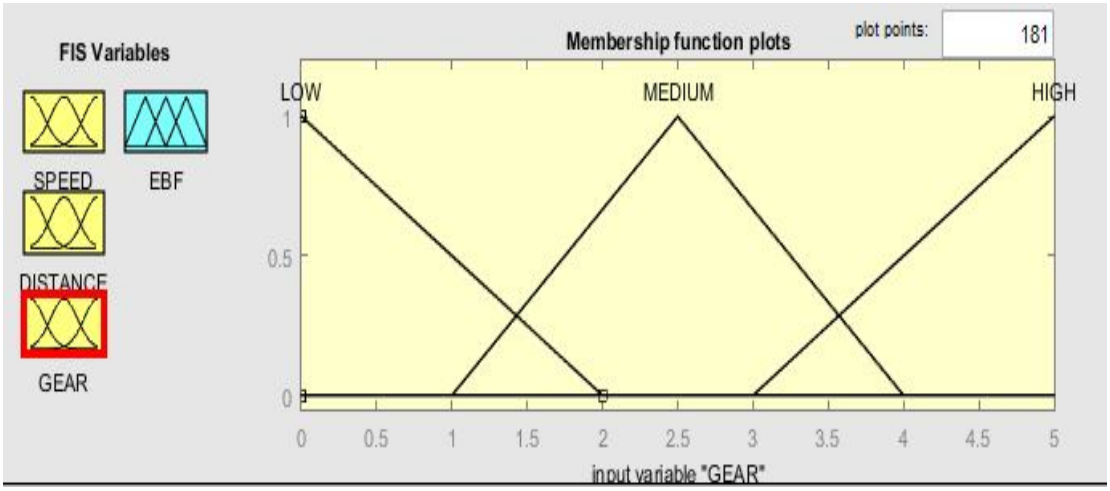


Fig.9: Linguistic variables and membership function of 'Gear'

TABLE III
Linguistic Representation Of Fuzzy Input Variable Gear

Membership function	Type	Range
Low	Trimf	[0 0 2]
Medium	Trimf	[1 2.5 4]
High	Trimf	[3 5 5]

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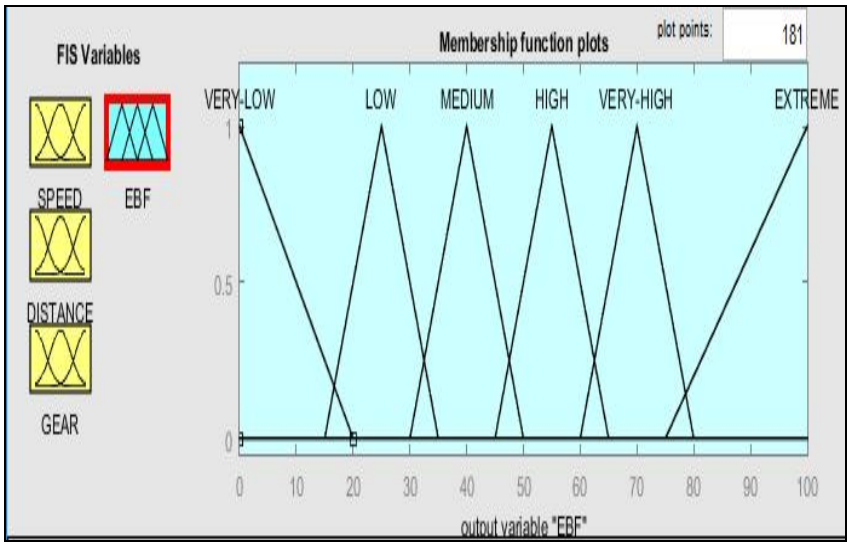


Fig. 10: Linguistic variables and membership function of 'EBF'

Table Iv
Linguistic Representation Of Fuzzy Output Variable Exercise Bike Effect (Ebf)

Membership function	Type	Range
Very Low	Trimf	[0 0 20]
Low	Trimf	[15 25 35]
Medium	Trimf	[30 40 50]
High	Trimf	[45 55 65]
Very High	Trimf	[60 70 80]
Extreme	Trimf	[75 100 100]

The fig. 7, 8, 9, 10 represents input and output membership function. The input linguistic variables used are LOW, MEDIUM and HIGH. Table I, II, III, IV represents fuzzy range of three input and one output variable respectively.

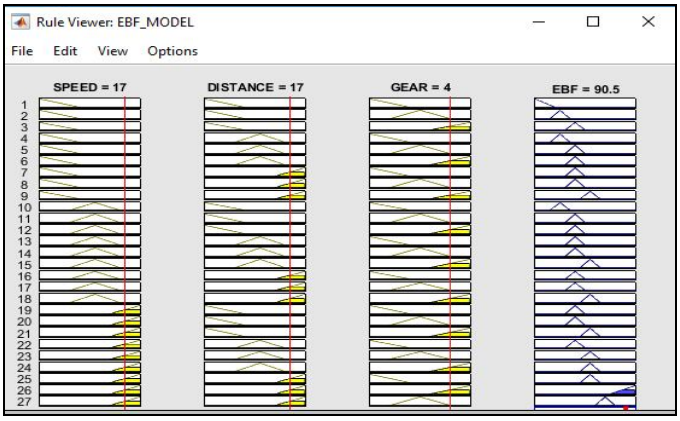


Fig. 11: [17; 17; 4] = 90.5 (Extreme) Exercise Bike Effect

Centroid defuzzification method used in this paper to obtain crisp value. The formula for centroid method is

$$x^* = \frac{\int \mu c(x).x \, dx}{\int \mu c(x) . dx} \qquad (1)$$

Fig. 11 shows the Fuzzy interference rules of the model as shown in MATLAB. This combines the Speed, Distance and Gear the exercise bike to create the Exercise Bike Effect (EBF). For the input vales speed=high, distance=high and gear=high then EBF=Extreme. After defuzzification EBF =90.5 which is the interpretation of extreme effect of exercise; hence it is suggested that

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the one should not over exercise as the effect of exercise is extreme. The formula used for defuzzification is represented in equation (1).

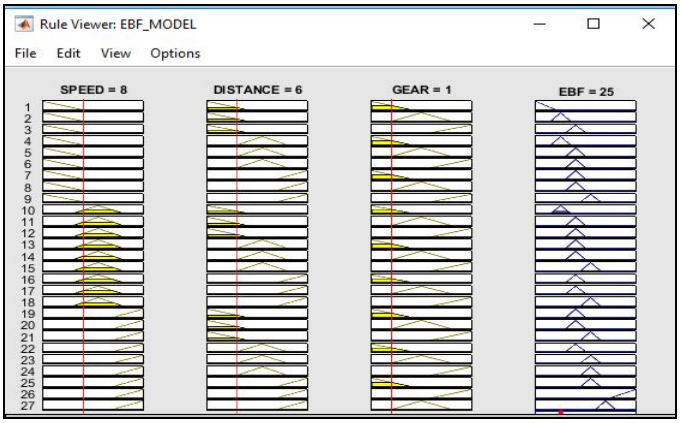


Fig. 12: [8; 6 ;1]=25 (Low) Exercise Bike Effect

Above Fig. 12 indicates the low effect of exercise if the input is 8,6,1 respectively i.e. speed is low distance is low and gear is low. Defuzzified value for all low inputs leads to EBF as low and crisp value obtained is 25.

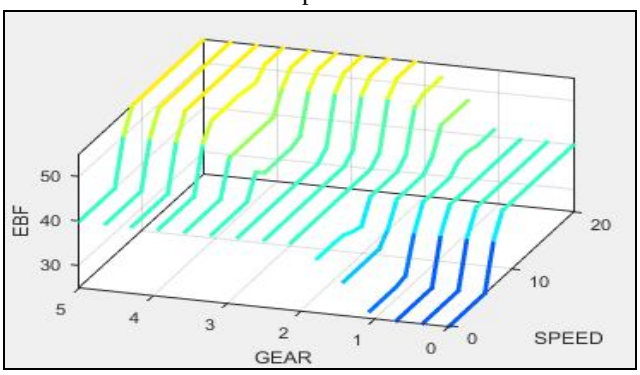


Fig.13: X Mesh Plot where X=Speed Y=Gear Z=EBF

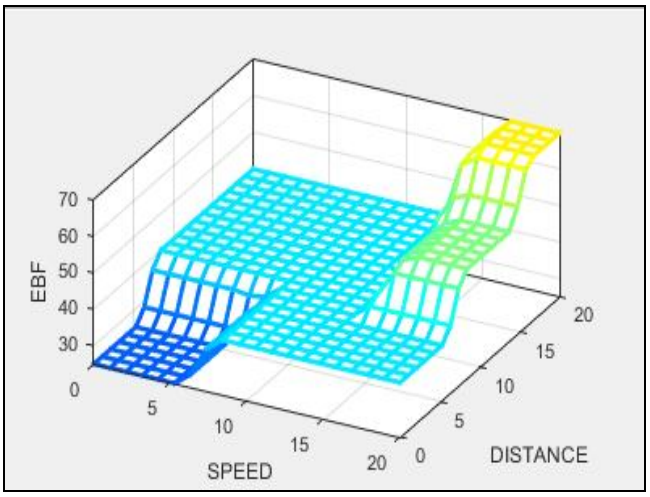


Fig.14: Mesh Plot where X=Speed Y=Distance Z=EBF

Fig. 13 and 14 represents the XMesh and Mesh plot of input and output parameters for Exercise Model. As the speed increases distance increases the EBF is also increasing. Gear supports the EBF calculation. 3D representation of rules is depicted in the above figures 13 and 14.

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VI. ANALYSIS OF DATA

The following table indicates few results of EBE model

Table v
Exercise bike effect calculation for different set of inputs

Case	Speed	Distance	Gear	EBF
1	3	4	1	7.52
2	8	7	1	34.2
3	11.5	11.5	2.5	40
4	8	5	1	25
5	15	18	3	53.7
6	17	16	4	89.7
7	16	18	3	70
8	17	14.5	1	43.3
9	16	11	2	55
10	15.5	14.5	4	65.4

The table V indicates result of different range of inputs and the outcomes for it. The fuzzification process represents the crisp values into linguistic variables such as Low, Medium and High and then fuzzy rules are applied on the data set. The membership function input speed, distance and gear has 3 fuzzy ranges and output has 6 fuzzy ranges. The fuzzy algorithm for Exercise Bike is executed and the result is identified in linguistic term. The defuzzification process provides crisp outcome which is represented as EBE.

VII. CONCLUSION & FUTURE WORK

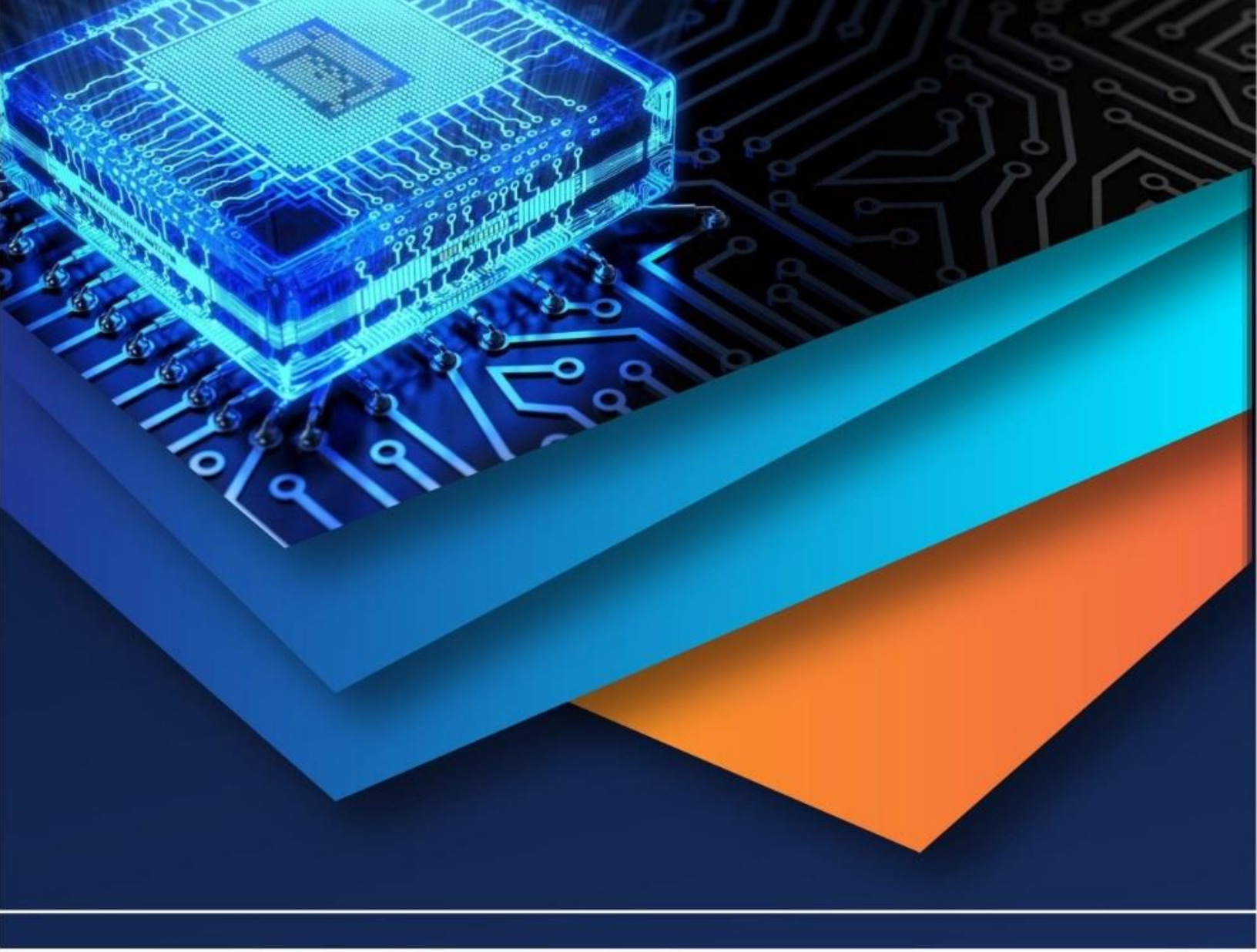
The paper discusses an idea of effect of exercise bike. Usually while exercising the in the gym, the instructors guides about the speed and gear use and manually monitor whether the person exercising is comfortable with cycling activity or not. This model is an aid for exercising person to identify whether the activities performed are injurious to health or not by checking the EBF. One can monitor the cycling activity and can decide whether to reduce the cycling activity or continue with the same using EBF. The Mamdani fuzzy algorithm is used to create the mathematical exercise bike. MATLAB software is used to simulate the model. Exercise Bike Factor model 27rules are created and these rules depicted using 3D visualization technique.

The future enhancement in EBE can be done by evaluation of body type, dieses and age group. Different people have different tolerance level and considering people may be suffering from different dieses then in such cases same exercise for different body type can give different results. Like asthma patient or obese person may find it difficult to achieve moderate range of EBE smoothly.

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