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Fuzzy logic in Sports: A Review and an Illustrative Case Study in the Field of Cycling

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ABSTRACT: In this fast world where everyone is in a race against time, putting ourselves under deep stress we tend to ignore our health. A healthy mind resides in a healthy body. Cycling is one such exercise that offers cardiovascular benefits, it strengthens muscles, helps in building strong bones and maintain a healthy body weight. Exercise bike is one option where one can exercise at comfort of their home. Fuzzy logic concept is used in the effective realization of approximate, vague, uncertain, dynamic, continuous and at the same time, more realistic conditions, which are closer to the actual physical world and human thinking. This paper aims at using fuzzy logic in modeling an exercise bike controller. The model takes into account the gathered data from sensor-equipped machines and recommended suggestions and criteria regarding a proper execution. The final aim is to integrate the designed procedures into a computer-based coaching framework, returning automated feedback on the performed technique.

KEYWORDS: Fuzzy logic, exercise bike, MATLAB, feedback

I.INTRODUCTION

In general, the fuzzy logic design concept involves the idea of vagueness rather than exact probabilistic reasoning with varying degrees of truth. Basic ideas on many-valued logic systems were already investigated by Łukasiewicz [1] in 1920, who proposed the use of three-valued logic by adding the indeterminate condition in addition to false and true. The first mentioning of the term fuzzy logic, however, dates back to the year 1965, when Zadeh published a couple of scientific research papers in which he introduced the so-called fuzzy sets as an alternative tool for the definition of more realistic classes of objects taken from real life [2, 3]. In particular, the author suggested the use of membership functions in combination to a particular set of rules in order to be also able to represent ambiguous states by mapping them to intermediate values between 0 and 1. In this way, this theorem can be seen as an enhancement of the boolean algebra [4]. The major goal of the present research was to apply the idea of fuzzy logic and vague states for the evaluation and classification of exercises performed on sensor-equipped Exercise bike.

II.DATA USED

The data used in building the model are obtained from training session in real time. The values of input parameters, i.e. Distance(in Km), Heart rate (in BPM) and cadence(in rpm). Were recorded and logged into an excel sheet for analysis. Once the data was collected they were analyzed to form fuzzy rules. Once the model was built it was used to analyze the outputs i.e. Torque(in Nm) and power(in W).

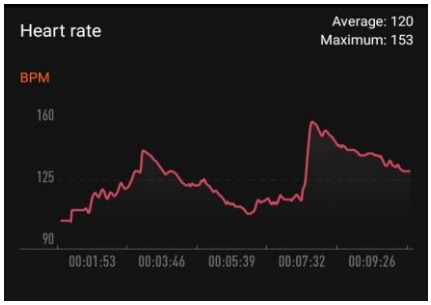

Fig. 1. Example of a data caption.

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III.METHODOLOGY

MATLAB is used to model and test the design concept using the fuzzy logic toolbox.

A. Fuzzy Logic

Fuzzy Logic is a more efficient approach to tackle nonlinear and vague problems, for instance the one faced by meteorological phenomena, where an expert system can be embedded with the mathematical model in the form of Fuzzy Interreference System (FIS). It incorporates rules and membership functions and is important for modelling systems that are hard to represent through mathematical formulas and models. Fuzzy logic is chosen for weather forecasting because of its ability to handle imprecisions well. In recent times, fuzzy logic had drawn attention towards handling non-linear models such this [5]. In this methodology we make use of fuzzy logic and rule-based reasoning to predict rainfall events for given data. L.A. Zadeh was the first person to introduce the fuzzy theory [2] and it worked on three crucial steps: 1. Fuzzification 2. Fuzzy rule determination and fuzzy interference 3.Defuzzification In the paper published by Somia A. Asklany, Khaled Elhelow, I.K. Youssef and M. Abd El- wahab titled "Rainfall events prediction using rule-based fuzzy inference system", [7] the same principles were used to design a fuzzy interference system which implemented the use of 5 input parameters and 118 rules to predict the occurrence of rainfall in 2 locations in Egypt. In the paper it was stated that use of more input parameters would improve the performance and accuracy of the system. In the present study 7 input parameters were used with 100 IF-THEN rules to support the fuzzy interference system (in figure 2 and 4). Two of the most common FIS types are Sugeno and Mamdani type. In this model, Mamdani type was used as Mamdani solely requires expert knowledge and hence is easy to implement. Mamdani consists of the following processes; (1) the input variables are fuzzified, (2) an "OR" or "AND" fuzzy operator is used to relate all the input variables, (3) The weight of each rule is set, (4) The outputs are then aggregated, (5) the output is then defuzzied and a crisp output is obtained. For defuzzification, the centre of mass method was used, which is computed by

$$\frac{\int_a^b x_a \, u_c(x_a)}{\int_a^b u_c(x_a)} \qquad (1)$$

Where X is centre of mass, is membership function in class c at value xa.

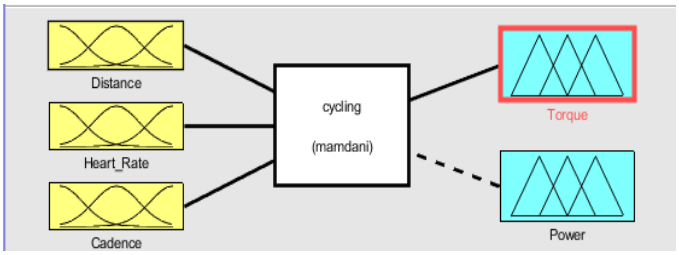

Fig. 2. The Fuzzy Interference System

IV.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]

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Fig. 3. Exercise bike

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 [9].

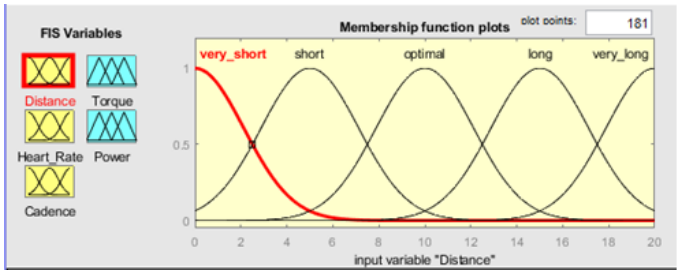

Fig. 4. Linguistic variables and membership function of Distance

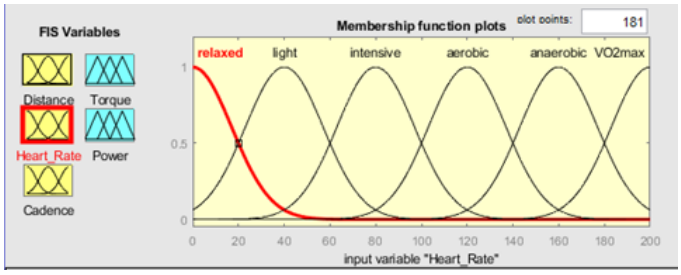

Fig. 5. Linguistic variables and membership function of heart rate

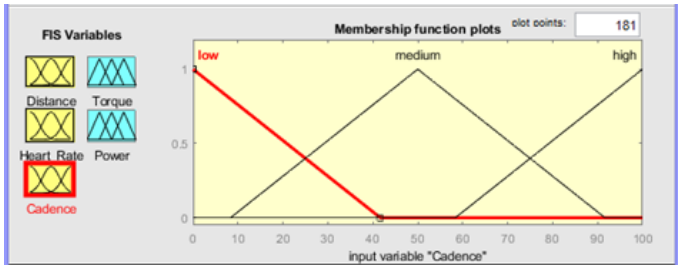

Fig.6. Linguistic variables and membership function of cadence

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Based on the description of the input and output parameters, 70 consequential rules were established for mapping purposes. In the following, some of the most illustrative rules (including the specified weights), which are also taken for the subsequent simulation scenario, are depicted:
Rule 12: .If (Distance is very_short) and (Heart_Rate is light) and (Cadence is low) then (Torque is low) (1)

Rule 14: If (Distance is optimal) and (Heart_Rate is light) and (Cadence is medium) then (Torque is medium) (1)

Rule 17: If (Distance is short) and (Heart_Rate is light) and (Cadence is low) then (Torque is low) (1)

Rule 19: If (Distance is optimal) and (Heart_Rate is light) and (Cadence is low) then (Power is low) (1)

Rule 57: If (Distance is optimal) and (Heart_Rate is relaxed) and (Cadence is low) then (Power is medium) (1)

Rule 59: If (Distance is long) and (Heart_Rate is VO2) and (Cadence is medium) then (Power is low) (1)

Rule 62: If (Distance is long) and (Heart_Rate is VO2 max) and (Cadence is high) then (Power is low) (1)

Rule 64: If (Distance is very_long) and (Heart_Rate is anerobic) and (Cadence is high) then (Power is low) (1)

Fig.8. Example of output rules

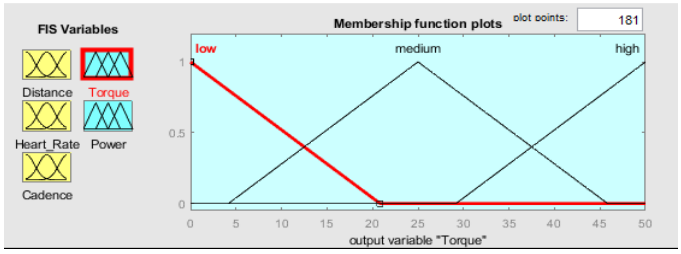

Fig.7. Example of output variable

VI.RESULTS

From the rule-based system of the FIS as shown in figure 7, the input parameter values were provided according to the data collected from sensor equipped exercise bike.

The outputs obtained from the FIS system can be used in modeling a controller for the exercise bike. The power and torque of the motor can be automatically adjusted according to the performance of the person.

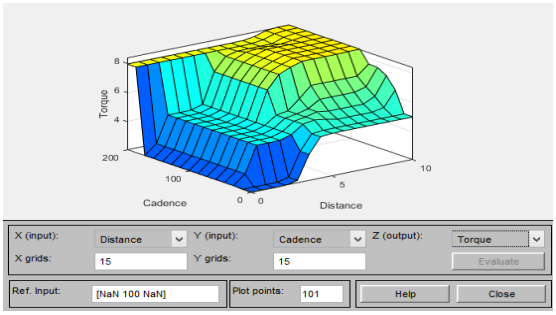

Fig.9. Surface view of output

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VII.CONCLUSION

From this project it can be concluded that the accuracy of a FIS model can be further improved by including more input parameters and more rules to the system. The usage of FIS system has a drawback where:

1.The accuracy of a model is highly dependent on the experience of the person who implements the rules.

2.Fuzzy logic doesn't create a relation amongst the input variables to get the output if not included in the rules. Neural networks don't rely too much into the experience of the person designing as the data has to be simply fed to the model to be trained and the process of nominalization of input data generates a relationship amongst the input parameters. This hence gives it an upper hand over FIS model. In the model implemented in this paper the performance of the model was solely determined from the data, as to design a highly efficient model that can determine the variation of power and torque with excellent precision, more data has to be used and with times series-based feature. For future, implementation of hybrid intelligent system merging the FIS model and neural network model may provide the ability to learn and predict data with a higher degree of accuracy.

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