Application Philosophy of Fuzzy Regression

T. D. Dongale, S. R. Ghatage, R. R. Mudholkar

Abstract— The uncertainties and its prediction normally tend to be complex phenomena. The randomness and fuzziness are two kinds of uncertainties possible in real time. The randomness deals with the general uncertainties whereas; the fuzzy logic addresses the linguistic uncertainties. The fuzzy logic and its allied field deal with the every part of uncertainties in fuzzy way. For a situation where, complex predictions are to tackle then statistical regression methodology is used from many years. The next step in this scenario for dealing with uncertainties is the 'Fuzzy Regression'. This paper presents the elementary theory of fuzzy regression and the philosophy behind its potential application.

Keywords— Fuzzy Logic, Fuzzy Regression, Uncertainties, Computational Intelligence

I. INTRODUCTION

Fuzzy Sets or fuzzy logic are meant to deal with situations where boundaries are not well determined. In such cases humans prefer to use linguistic labeling, and to do soon generalize mathematical framework the fuzzy sets are a good alternative. They help in expressing an uncertainty about tangible meaning of the labels used, and tolerate the soft constraints and/or flexible requirements. These distinct characteristics provide a gradual and smooth transition from one label to another and avoid abrupt discontinuities at the boundaries over a domain. *'Defining Fuzzy Logic is fuzzy as fuzzy logic itself'*. Pioneer workers and researchers of Fuzzy Logic have manifested their views on Fuzzy Logic by putting forth the manifold definitions [1].

- Fuzzy Logic is a very efficient technology to put knowledge right in to a technical solution.
- Fuzzy Logic is a computer technique invented by Prof. L. Zadeh, which allows expressing and evaluating complex relations in a linguistic way. [2]
- Fuzzy Logic is a branch of logic that uses the degrees of membership in sets rather than a strict true and false membership or crisp values. [3]
- Fuzzy Logic is a technique that imitates the human observation-action-decision process in a system. [4]
- Fuzzy Logic is a branch of machine intelligence that helps computer paint gray, commonsense pictures of an uncertain world. [5]

Prof. L. Zadeh proposed a mathematical way of looking at the intrinsic vagueness of natural language, and extremely qualitative and ambiguous thinking of human. He called this approach as a *"Fuzzy Logic"* [6-8]. The prime objective of Fuzzy Logic is to stand as a golden rapprochement between human's thinking abilities and computer's computing capabilities [9]. Fuzzy Logics an extension of conventional binary logic basically founded on Fuzzy Set Theory.

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During 1970 to 1980, decision supporting fuzzy systems found their ways besides engineering in to management and business. This is marked by linguistic description of human judgments in the Expert Systems for medical diagnosis, access structural damage and strategic planning [10]. These Expert Systems exploited the uncertain knowledge acquired to help user in the domain of interest. Then Fuzzy Logic Control (FLC) appeared that was meant to control the complex technical processes ranging from camera and vacuum cleaner [15] to cement kiln [11], model car [12] and train [13]. Surprisingly it remained neglected by European and American until the end of 1980, but Japanese successfully exploited the power of FLC. Since then it began to establish itself as technology paradigm. The transition from fuzzy set theory to fuzzy logic during first half of the 1990 was very fast [13, 16]. This is mainly because of creation of numerous software and hardware tools that considerably improve the design of fuzzy systems making them more applicable and portable. Since 1994, Fuzzy Set Theory, AI, Neural Network and Genetic Algorithm began to come closer, and now they are together called as *"Computational Intelligence"* [14].

Fuzzy logic exploits various aspect of vagueness of every walk of life, the control system, real time problem, expert system and so on. In the sky of fuzzy logic, the regression methodology and its allied aspect of prediction plays an important role. Regression extracts valuable information from imprecise data, predict and model the *fuzzy* things.

II. FUZZY REGRESSION

Fuzzy linear regression was introduced in 1980 by Tanaka, Uejima and Asai [18, 23]. Fuzzy regression method is beneficial in estimating the relationships between variables where the available data are very limited and imprecise, and variables are interrelated with uncertainty, moreover the relationship between the variables can be best expressed qualitatively using words rather than pure numbers. Existing Prediction Techniques include *Statistical Techniques* and *Artificial Intelligent Techniques* like Artificial Neural Network (ANN), Support Vector Machine (SVM), Fuzzy Logic, k-nearest neighbors (k- NN), Fuzzy Neural Network (FNN) and Fuzzy Regression, which are practices for prediction of uncertainties [18, 19]. However there are limitations and drawbacks of the above listed prediction techniques. Problems normally arise in statistical prediction when there is an inadequate number of observations and when distribution assumptions are not satisfied [20]. As for the artificial intelligent prediction techniques is concerned, the common limitations involve low interpretation ability due to the 'Black box' nature of the model (ANN and SVM), limited model ability to explicitly identify possible causal relationships between variables, over fitting problems (ANN and SVM),

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difficult to build (k- NN), lack in flexibility to incorporate new knowledge (SVM), risk of eroding old but valid information when new knowledge are introduced in the system (SVM) and unsuitable use for high-dimensional data (SVM) [17-19, 21].

Regression analysis is a mathematical technique used to model relationship between explanatory and response variables [23]. Two types of fuzzy regression approaches available are *Tanaka's Linear Programming Approach* and the *Fuzzy Least-Squares Approach*. The use of prediction interval in machine learning is referred to as fuzzy linear regression. Fuzzy regression techniques are applicable to linear functions only [17, 20, 22, 24].

The regression methodology is one of the most widely used statistical techniques to model and represent the relationship among variables to describe or predict uncertain phenomena. In this case, the statistical techniques are well suited for the model determination when deviations between the observed and the estimated values are supposed to be due to measurement errors or random variations. However, in many real time applications, the deviations are due to the imprecise observed data or the indefiniteness of the system structure and parameters. Fuzzy regression helps evaluating the functional relationship between dependent and independent variables in a fuzzy environment. In this context, it has been stated that fuzzy regression analysis offers an efficient tool for analyzing complex systems. Indeed, these systems have different nature (qualitative or quantitative) and the knowledge about them is vague and imprecise. So, the use of fuzzy modeling techniques provides good concepts for dealing with these types of uncertain information. Fuzzy regression is different from conventional regression techniques in the sense that, it is a non-statistical method. Unlike statistical regression modeling that is based on only probability theory, fuzzy regression is not only based on possibility theory but also founded on fuzzy set theory. [25]

There are two categories of Fuzzy Regression analysis:

Category- 1

The first is a Possibilistic regression analysis which is based on possibility concepts. Possibilistic regression analysis uses the fuzzy linear system as a regression model, whereby the total vagueness of the estimated values for the dependent variables is minimized. [17, 20, 23]

The adaptive fuzzy logistic regression model is based on Tanaka's Possibility regression analysis described above in which the response variable Y is written as,

$$Y=A_0X_0 + A_1X_1 + A_2X_2 +\ldots..+ A_j X_j +\ldots+ A_k X_k \quad (1)$$

Where Y is the fuzzy output, $X = [X_1, X_2, \ldots, X_k]$ T is the real-valued input vector of independent variables and each regression coefficient Aj, j=0, . . ., k, was assumed to be a symmetric triangular fuzzy number with center α_j and half-width C_j, $C_j \geq 0$

Tanaka's Possibility Fuzzy Regression Technique is however applicable to linear functions only. Due to the fact that binary response variable defies the linearity functional relationship that must be satisfied, suitable transformation involving logic (logarithm of odds) transformation must be carried out to unfold the hidden linear relationship. [17]

Category- 2

The second category of fuzzy regression analysis adopts the *Fuzzy Least Squares Method* (FLSM) for minimizing errors between the given outputs and the estimated outputs. The advantage of Tanaka's Possibility model is in its simplicity in programming and computation, while FLSM in its minimum degree of fuzziness between the observed and estimated values [23].

The statistical linear regression method has been used in every field of science and engineering. The purpose of regression analysis is to explain the variation of a dependent variable Y in terms of the variation of variables X as,

$$Y = f(x) \quad (2)$$

Where, $f(x)$ is a linear function. The statistical regression model can be applied only if the given data are distributed according to a statistical model, and the relation between x and y is crisp value, Since the fuzzy regression method can be applied to many real-time problems in which the classical statistical regression method cannot be satisfied, However, there are critiques regarding Tanaka's model as summarized as follows: [26]

- The input data and output data may not always be crisp and linear [27, 28].
- The original Tanaka's model was extremely sensitive to the outliers [29].
- There is no proper interpretation about the fuzzy regression interval.
- Issue of forecasting has not yet been addressed [30].
- The fuzzy linear regression may tend to become multicolinear as more independent variables are collected [31].

III. CONCLUSION

The fuzzy regression is an alternative for statistical regression model, where relationship between data set is imprecise or insufficient. The statistical regression model is based on *randomness* of error and fuzzy regression is based on *fuzziness* of error. But *randomness* of error and *fuzziness* of error are two distinct types of uncertainties. A complete regression analysis should include both random and fuzzy types of uncertainty, but fuzziness type of uncertainty exists only when regression data contain fuzziness [32]. From the viewpoint of applicability of fuzzy regression in various domains of information sciences, it is not wonder when the fuzzy regression analysis is immortal part of prediction methodology. In this context the future of fuzzy regression is promising in the field of real time applications [33].

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