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Predictive Analytics of Comparison Fuzzy Modelling Towards Symptoms of Colorectal Cancer in Malaysia

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ABSTRACT

Colorectal cancer (CRC) is a cancer that begins in the colon and rectum of the human body and is the third leading cause of death among cancer patients. Colorectal cancer develops when cells in the body begin to proliferate uncontrollably with such symptoms. However, the high-risk symptoms of CRC in Malaysia are still ambiguous and unclear. The problem of using linear regression arises with the use of uncertain and imprecise data. Since the fuzzy set theory's concept can deal with data not to a precise point value (uncertainty data), this study uses comparison fuzzy modelling as predictive analytics to predict the high-risk symptoms that contribute to the development of colorectal cancer in Malaysia. Secondary data of 180 colorectal cancer patients who received treatment in a general hospital with seventeen independent variables with different combinations of variable types were considered. Other than that, the parameter, error, and explanation for the model were included using two measurement statistical errors. Fuzzy linear regression with symmetric parameters found ovarian symptom is the high-risk symptom to develop colorectal cancer. The weightage value is 25.73, with the results of the least value of the mean square error (MSE) value being 98.212 and the root mean square error (RMSE) value being 9.910.

1. Introduction

The Colorectal cancer (CRC) is cancer in the colon and/or rectum. The colon and rectum are the main parts of the human body to digest food and past waste. According to World Health Organization (WHO), colorectal cancer was the third leading cause of death among cancer patients. The risk of this particular cancer is rising in many countries, especially in the Asian Region of Malaysia [1]. Nowadays, the causes of CRC are ambiguous and unclear. However, it involves many factors that contribute in the development of cancer such as increasing age, lack of nutrition's, family history, body weight and so on. People with colorectal cancer may develop a number of non-specific symptoms. Symptoms of

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colorectal cancer typically include rectal bleeding and anaemia which are sometimes associated with weight loss and changes in bowel habits [2].

In Malaysia, the awareness of the importance of CRC screening is very low, especially among the general population as well as the policymakers resulting in inadequate resource allocation for faecal occult blood tests and colonoscopy. The advances in the treatment of colorectal cancer and the effectiveness of the screening program, especially in developed countries resulted in increasing number of colorectal cancer survivors. Not only the disease could be cured but patients can also survive longer with the disease. Therefore, the paradigm of outcome in colorectal cancer treatment in the past decade has slowly shifted towards improving the patients‟ quality of lives, survival and disease-free survival. This shows that health is related to the quality of life and it is one of the fundamental aspects in colorectal cancer management while survival and disease-free survival remains [3]. There are some analyses were applied to manage the mortality rate of colorectal cancer patients by using machine learning approaches such as regression analysis, fuzzy analysis, and so on [4-6].

Regression analysis is widely used for prediction and forecasting, where its use substantially overlaps the field of machine learning. Regression analysis is also used to understand which one among the independent variables are related to the dependent variable and to explore the forms of these relationships. Hence, regression analysis can be used to infer causal relationships between the independent and dependent variables [7]. However, this can lead to illusions or false relationships, therefore caution about the data that applied is advisable.

Many techniques for carrying out regression analysis have been developed. Familiar methods such as linear regression, fuzzy linear regression and ordinary least squares regression are parametric, in that the regression function is defined in terms of a finite number of unknown parameters that are estimated from the data. Nonparametric regression refers to techniques that allow the regression function to lie in a specified set of functions which may be infinite-dimensional.

The performance of regression analysis results depends on the form of the data generating process and how it relates to the regression approach being used. Since the data generating process is generally good or no missing values, the process or results regression analysis on making assumptions will be acceptable. These assumptions are sometimes testable if a sufficient quantity of data is available. Regression models for prediction are often useful even when the assumptions are moderately violated, although they may not perform optimally.

However, this may happen in many applications, especially with small effects or questions of causality based on observational data [8,9]. However, regression models are very sensitive to outliers. An outlier is a data point that differs significantly from other observations. The variability in the measurement may indicate experimental error and an outlier can cause serious problem in regression analysis. A researcher found another linear model that is not focus on outliers such as support vector machine model (SVM). Support vector machine is widely applied to classifying something into a group of objects. In machine 3 learning, support-vector machine (SVM) is supervised learning models with associated learning algorithms that analyse data for classification and regression analysis. There is a lot of using a support vector machine versus artificial neural network to find the minimum errors and the sigmoid function in both [10]. Vladimir N. Vapnik and Alexey Ya. Chervonenkis were the persons who develop the original SVM algorithm in 1963 and extend the algorithm to non-linear classifier by applying the kernel trick to maximum-margin hyperplanes. [11,12].

Lotfi A. Zadeh studied in University of California at Berkeley introduced the paper on fuzzy sets in 1964. Among the contents described in the paper are the idea of grade membership was born, sharp criticism from academic community and waste of government funds. Moreover, on 1965 until 1975

Lotfi A. Zadeh continued to broaden the foundation of fuzzy set theory. The concept fuzzy set theory provides a fuzzy multistage decision making, fuzzy similarity relations, fuzzy restrictions and 4 linguistic hedges. Fuzzy logic can be interpreted in a wider sense as theory of fuzzy sets. As such two objectives, fuzzy logic alleviates difficulties in developing and analysing complex systems encountered by conventional mathematical tools and observing that human reasoning can utilize concepts and knowledge that do not have well-defined and sharp boundaries. Such for examples are tall of human, the lighter of lamp and else [13-15].

Fuzzy logic is a form of many-valued logic which can be any real number or point number between 0 and 1. In contrast with traditional logic theory, binary sets have two valued logic which is the truth value that ranges in degree between 0 and 1 (true and false). The truth value of fuzzy logic may be at range between completely true and completely false. Furthermore, if linguistic variables are used, specific function degree are also managed [16,17].

Fuzzy logic has been applied to many fields such as aerospace, automotive, business, chemistry industry, financial and medical. It allows getting the approximate values and numbers as well as incomplete and ambiguous data in all fields of fuzzy data. Fuzzy logic is able to solve incomplete data using controlling and decision-making part.

Other than that, Hideo Tanaka was the first person that developed fuzzy linear regression both the research as well as statistic. In his study, he concerned with the application of fuzzy linear function to a regression analysis in a vague phenomenon. Usually in regression model, deviations between the observed values and the estimated values are supposed to be due to observation errors. It assumed that these deviations of system parameter depend on vagueness of the system structure. The data considered input and output relations whose vagueness the systems structure [18-20].

There is significant advantage of fuzzy model in analysis which is can be used without any assumptions. If the error of data is not normally distributed, then the data still can be used. It is difference with another regression analysis in statistic. Fuzzy logic provides a fundamental mathematical framework for dealing with vagueness.

Fuzzy regression analysis gives a fuzzy functional relationship between the dependent and independent variables in a vagueness environment. Linear regression is recommended as initial analysis before fuzzy regression analysis to make the 5 more significant decisions in fuzzy data. The input of the fuzzy data may be crisp or fuzzy. There are two types of fuzzy regression models such as Tanaka's linear programming approach and the fuzzy least-squares approach. Several methods have been presented to estimate fuzzy regression models. The first model is fuzzy regression was proposed by Tanaka *et al.,* for linear case by focusing on extension principle [21,22].

Fuzzy regression used in complex systems such as in industry, economy, finance, marketing, and ecology function in the real world and it is more imprecision. Such systems require decisions based on human thinking and judgmental and involve human–machine interactions. In such environments, human often not be able to obtain exact numerical data about the system. The nature of information about the complex systems with vagueness is frequently fuzzy. In general, fuzzy regression seems to be intuitively more adequate for real life problems. Therefore, fuzzy regression analysis is more effective for modelling of complex systems. The pioneering work in this field reported that the authors used Zadeh's extension principle, A-level procedure, interval arithmetic, and linear programming techniques to develop a fuzzy linear regression analysis. Minimization of these distances in the fuzzy number space with respect to the unknown parameters of regression models leads to solving systems of equations [23].

2. Methodology

2.1 Materials

This study focused on tumour size of colorectal cancer at general hospital of Kuala Lumpur as sample for the data and used as secondary data. For the data, the data consists 180 rows of data including the dependent variable which is tumour size and seventeen independent variables which are classification of diseases and related health problems (icd10) (*A1*), diabetes mellitus (*A2*), Crohn's disease (*A3*), ulcerative colitis (*A4*), polyp (*A5*), endometrial (*A6*), gastric (*A7*), small bowel (*A8*), hepatobiliary (*A9*), urinary tract (*A10*), ovarian (*A11*), intestinal obstruction (*A12*), colorectal (*A13*), diarrhoea (*A14*), anaemia (*A15*), blood stool (*A16*) and abdominal pain (*A17*). This study was analysing using Statistical Package for Social Science (SPSS), Microsoft Excel and MATLAB. The flowchart of the study as in Figure 1.

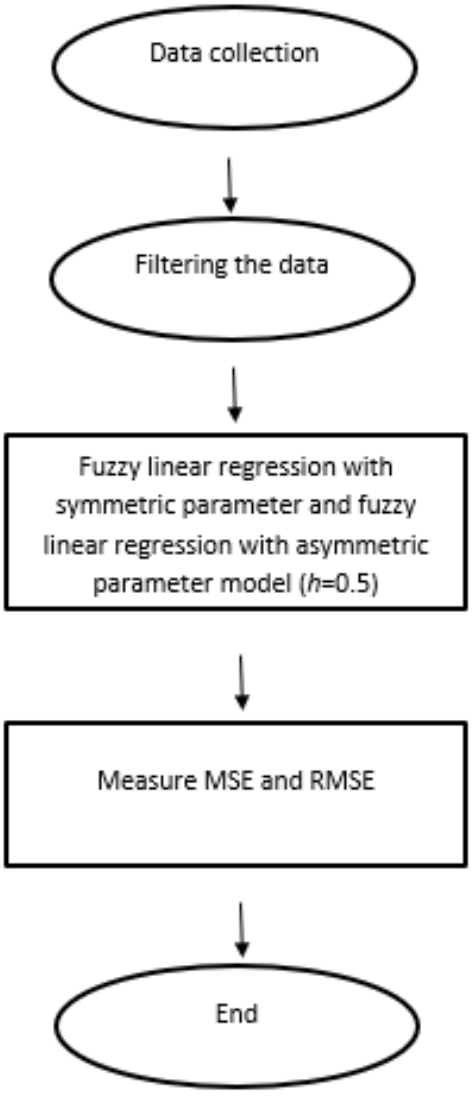

Fig. 1. Flowchart of the study

2.2 Methods

2.2.1 Fuzzy linear regression

Statistical analysis is versatile and can be used in any field, especially linear regression. Fuzzy

linear regression is a fuzzy regression analysis in which some model elements are represented by a fuzzy number. Fuzzy linear regression model (FLRM) is an approach that was researched by Hideo Tanaka. In the research, the main objective of estimating values is obtained as fuzzy quantities that represent the fuzziness of the system structure. At the same time, the conventional confidential interval is related to the observation errors. No assumptions are mandatory for the fuzzy model [8,9].

The data input and output data whose vagueness is derived from the existence of fuzzy parameters. In the model, the deviations among data are explained as the vagueness of the system structure ex-pressed by fuzzy parameters [10].

Fuzzy output is denoted as ($\alpha_0, \alpha_1 \ldots \alpha_g$), where α_i is the centre and $(\varsigma_0, \varsigma_1 \ldots \varsigma_g)$ is a width of the fuzzy triangular diagram. The linear function of fuzzy linear regression is as follows;

$$Y = A_0(\alpha_0, \varsigma_0) + A_1(\alpha_1, \varsigma_1)\, x_1 + \ldots + A_g(\alpha_g, \varsigma_g)\, x_g \quad (1)$$

Where $X=[x_1 \ldots x_g]$ is a vector of independent variables and $A=[A_0,A_1 \ldots A_g]$ is a vector of fuzzy coefficients presented in the form of a triangular fuzzy number. In fuzzy linear regression model, the fitting model can be refined by the data given and solving the linear programming problem. Other than that, the fuzzy parameter can be fined by following a linear programming problem [11]:

$$\alpha^t xi + (1-H)\sum_j c_j \,|x_{ij}| \geq y_i + (1-H)e_i$$

$$-\alpha^t xi + (1-H)\sum_j c_j \,|x_{ij}| \geq -y_i + (1-H)e_i \quad (2)$$

2.2.2 Fuzzy linear regression with symmetric parameter

Fuzzy linear regression with symmetric parameters (FLRWSP) is one of the most commonly used methods by professional researchers in the presence of ambiguous phenomena. Fuzzy linear regression with symmetric parameters represents some conditions that are vague and ambiguous. In the study, the researcher applied fuzzy linear regression to determine the quality of food, especially fried donuts. From a scientific and engineering point of view, model theory is useful for the conceptual framework and results that can be directly applied in system models using the fuzzy approach and recent developments in fuzzy logic [12]. If $\tilde{A}_i$ $(i = 0, 1, \ldots, n)$ is a symmetrical fuzzy number and x_i is a crisp real number, and will be a triangular fuzzy number and defined as, $Y=(f^c(x), f^3(x))$ when $f^c(x)$ is the mode, f^s is symmetric value and $f^3(x)$ is spread of triangular fuzzy number.

The model of FLRWSP can be written as follow:

$$f^c(x) = a_0 + a_1 x_1 + \ldots + a_n x_n \quad (3)$$

Where:

$f^c(x)$ is equation of fuzzy parameter

a_0, a_1, a_n are fuzzy parameter

x_1, x_n are variable of fuzzy parameter

And membership function Y can be defined as follow:

$$Y = 1 - \frac{-(f^c(x) - y)}{f^3(x)} f^s(x) \le y \le f^c(x)$$
$$Y = 1 - \frac{(y - f^c(x))}{f^3(x)} f^c(x) < y < f^c(x) + f^s(x) \quad (4)$$

The target function is defined in the symmetric condition of triangular fuzzy number as follows:

$$(1-h)s_0^L + (1-h)\sum_{i=1}^{n}(s_i^L \mid x_{ji} \mid) - a_0 - \sum_{i=1}^{n}(a_i x_{ji}) \ge -y_j$$
$$(1-h)s_0 + (1-h)\sum_{i=1}^{n}(k_i s_i^L \mid x_{ji} \mid) + a_0 + \sum_{i=1}^{n}(a_i x_{ji}) \ge -y_j \quad (5)$$

Where:
s_0^L, s_i^L are spread left of triangular fuzzy number
s_0, s_i are spread of triangular fuzzy number
α_0, α_i are mode of triangular fuzzy number
h is degree of triangular fuzzy number

2.2.3 Fuzzy linear regression with asymmetric parameter

Fuzzy linear regression asymmetric parameter is there is no properly shape of triangular fuzzy. If If A_i (i= 0, 1, …, n) assumed as asymmetrical fuzzy number and xi is crisp real number Then, the output of $\hat{Y}i = A0 + A1xi1 + + A_jx_{ij}$ will be triangular fuzzy number (Zolfaghari [26]). Fuzzy parameter can be determined by according to formulation and solution of fuzzy and linear programming of fuzzy linear regression asymmetric parameter shows in Eq. (6). The membership function of asymmetrically triangular fuzzy number shown in Figure 2.

$$(1-h)s_0^L + (1+h)\sum(s_i^L \mid x_{ji} \mid) - a_0 - \sum(a_i x_{ij}) \ge -y_j$$
$$(1-h)s_0 + (1+h)\sum(s_i \mid x_{ji} \mid) + a_0 + \sum(a_i x_{ij}) \ge -y_j \quad (3)$$

Where:
s_0^L, s_i^L are spread left of TFN
s_0, s_i are spread of TFN
α_0, α_i are mode of TFN
h is degree of TFN

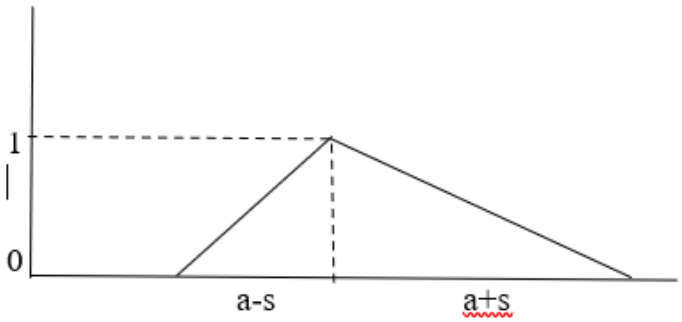

Fig. 2. Membership function of asymmetrically triangular fuzzy number (TFN)

3. Results

3.1 Fuzzy Linear Regression with Symmetric Parameter

Zahra Sadat Zolfaghari [26] approached the work of fuzzy linear regression with symmetric parameter model. This model was used in a study that used data on the stages of colorectal cancer. One dependent variable, tumour size (mm), was used with seventeen predictor factors. Tables 1 and Table 2 present the findings of the analysis.

Table1
Fuzzy parameter (h=0.5)

Fuzzy Parameter	Centre, α_i	Width, c_i
ICD 10 Site (A1)	-6.918	1.39E-14
Diabetes Mellitus(A2)	1.664	-1.14E-14
Crohn's Disease (A3)	10.069	-2.06E-15
Ulcerative colitis (A4)	3.015	-7.33E-15
Polyp (A5)	-3.153	-7.80E-15
Endometrial (A6)	-1.737	1.52E-14
Gastric (A7)	-13.033	-7.97E-15
Small bowel (A8)	-6.66	2.33E-14
Hepatobiliary (A9)	-2.093	1.09E-15
Urinary tract (A10)	5.193	-1.43E-14
Ovarian (A11)	25.73	-1.58E-14
Intestinal Obstruction (A12)	-8.699	2.64E-14
Colorectal (A13)	2.454	5.50E-15
Diarrhoea (A14)	1.499	1.43E-14
Blood stool (A15)	-15.886	2.83E-15
Anaemia (A16)	-4.316	-9.29E-15
Abdominal (A17)	-7.988	1.61E-14

The outcomes of the fuzzy parameter, when h=0.5, where α_i is the fuzzy parameter's centre and c_i is the parameter's fuzziness (width). Seventeen predictor variables were included in the Matlab coding that produced the values for the fuzzy parameter in Table 1. With the highest fuzzy parameter value of 25.730, the ovarian can explain the fuzzy mean value of tumour size (mm).

As a result of fuzzy linear regression's ability to estimate tumour size for colorectal cancer, the doctor can use this information to determine the size of the malignancy in polyps and the predicted tumour size for colorectal cancer.

Table 2 summarises the results of the evaluation of fuzzy linear regression with symmetric mean square error and root mean square error. This model's mean square error was 98.212, and the root mean square error was 9.910.

Table 2
Measurement error of model

Methods Value	Methods Value
Mean square error	98.212
Root mean square error	9.910

The following describes the calculated fuzzy linear regression with symmetric parameter model for patients with colorectal cancer:

$\hat{Y}$ = 44.165 – (6.919, 1.391e-14) icd10 + (1.665, -1.137e-14) diabetes mellitus + (10.070, -2.055e15) Crohn's disease +(3.016, -7.331e-15) ulcerative colitis –(3.153, -7.799e-15) polyp – (1.737, 1.522e-14) endometrial – (13.033, -7.973e-15) gastric –(6.660, 2.332e-14) small bowel – (2.093, 1.095e-15) hepatobiliary +(5.193, -1.425e-14) urinary tract +(25.730, -1.579e-14) ovarian –(8.699, 2.638e-14) intestinal obstruction +(2.454, 5.503e-15) colorectal + (1.499, 1.427e-14) diarrhoea – (15.886, 2.834e-15) blood stool –(4.317, -9.286e-15) anaemia –(7.988, 1.605e-14) abdominal

4. Conclusions

This study used secondary data consisting of 180 patients as respondents, with seventeen variables which are diabetes mellitus, diarrhoea, anaemia, blood stool, abdominal pain and etc., while tumour size of colorectal cancer is the dependent variable. The error of the model was done using cross-validation statistical technique which are MSE and RMSE. This model also was proposed by Zolfaghari [26] as a symmetric and asymmetric triangular fuzzy towards fuzzy structure. The model was applied in this study to analyse the data on colorectal cancer among patients. Seventeen of predictor variables were used against tumour size (mm). The degree of fitting h = 0.5 is also applied in this model based on the reliability and consistency of triangular fuzzy number membership function. The results of analysis are showed Table 3.

The most recent model, fuzzy linear regression with symmetric and asymmetric parameter model, was used in this study. In order to determine the optimal model for predicting the high-risk symptom based on symptoms of colorectal cancer, mean square error and root mean square error are examined.

In general hospitals in Kuala Lumpur, it has been discovered that the fuzzy linear regression with symmetric parameter is the best model for predicting the tumour size of colorectal cancer patients. It is because a fuzzy linear regression with a symmetric parameter has the fewest mean square error and root mean square error values when compared to other models stated as Table 3.

Table 3
MSE and RMSE of models

Models	MSE (RMSE)
Fuzzy Linear Regression with Symmetric Parameter	98.212 (9.91)
Fuzzy Linear Regression with Symmetric Parameter	3107.88 (55.748)

Moreover, many statistical methods in quantitative analysis can be conducted especially the fuzzy linear regression with symmetric parameter is more popular and effective in predicting model

compared to other fuzzy methods. Fuzzy theory and its application are widely applied to various fields, especially in medicine. This study contributes to the application of fuzzy set theory. The fuzzy linear regression with symmetric parameter is proposed in this study and proves to be the best model with the highest accuracy or the model with prediction in the uncertainty data.

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References

[1] Veettil, Sajesh K., Tse Yee Wong, Yee Shen Loo, Mary C. Playdon, Nai Ming Lai, Edward L. Giovannucci, and Nathorn Chaiyakunapruk. "Role of diet in colorectal cancer incidence: umbrella review of meta-analyses of prospective observational studies." *JAMA network open* 4, no. 2 (2021): e2037341-e2037341. https://doi.org/10.1001/jamanetworkopen.2020.37341

[2] McCulloch, Sofia M., Imran Aziz, Annikka V. Polster, Andreas-Bernd Pischel, Henrik Stålsmeden, Morteza Shafazand, Mattias Block *et al.,* "The diagnostic value of a change in bowel habit for colorectal cancer within different age groups." *United European Gastroenterology Journal* 8, no. 2 (2020): 211-219. https://doi.org/10.1177/2050640619888040

[3] Chakrabarti, Sakti, Carrie Y. Peterson, Deepika Sriram, and Amit Mahipal. "Early stage colon cancer: Current treatment standards, evolving paradigms, and future directions." *World journal of gastrointestinal oncology* 12, no. 8 (2020): 808. https://doi.org/10.4251/wjgo.v12.i8.808

[4] Shafi, Muhammad Ammar, Mohd Saifullah Rusiman, Shuhaida Ismail, and Muhamad Ghazali Kamardan. "A hybrid of multiple linear regression clustering model with support vector machine for colorectal cancer tumor size prediction." *International Journal of Advanced Computer Science and Applications* 10, no. 4 (2019). https://doi.org/10.14569/IJACSA.2019.0100439

[5] Shafi, Muhammad Ammar, Mohd Saifullah Rusiman, and S. Abdullah. "Application of fuzzy linear regression with symmetric parameter for predicting tumor size of colorectal cancer." *Mathematics and Statistic (1)* (2021): 36-40. https://doi.org/10.13189/ms.2021.090106

[6] Zakaria, Aliya Syaffa, Muhammad Ammar Shafi, Mohd Arif Mohd Zim, and Siti Noor Asyikin Mohd Razali. "The Use of Fuzzy Linear Regression Modeling to Predict High-risk Symptoms of Lung Cancer in Malaysia." *International Journal of Advanced Computer Science and Applications* 14, no. 5 (2023). https://doi.org/10.14569/IJACSA.2023.0140562

[7] Kutner, Michael H., Christopher J. Nachtsheim, John Neter, and William Li. *Applied linear statistical models*. McGraw-hill, 2005.

[8] Hammerton, Gemma, and Marcus R. Munafò. "Causal inference with observational data: the need for triangulation of evidence." *Psychological medicine* 51, no. 4 (2021): 563-578. https://doi.org/10.1017/S0033291720005127

[9] Hamzah, Diyana Izyan Amir, Mohd Saifullah Rusiman, Norziha Che Him, Muhammad Ammar Shafi, Ozlem Gurunlu Alma, and Suhartono Suhartono. "A time series analysis for sales of chicken based food product." In *AIP Conference Proceedings*, vol. 2355, no. 1. AIP Publishing, 2021. https://doi.org/10.1063/5.0053699

[10] Jack, L. B., and A. K. Nandi. "Fault detection using support vector machines and artificial neural networks, augmented by genetic algorithms." *Mechanical systems and signal processing* 16, no. 2-3 (2002): 373-390. https://doi.org/10.1006/mssp.2001.1454

[11] Basak, D., S. Pal, and D. C. Patranabis. "Support Vector Regression Neural Information Processing–Letters and Reviews." (2007): 203-224.

[12] Pai, Ping-Feng, and Chih-Sheng Lin. "A hybrid ARIMA and support vector machines model in stock price forecasting." *Omega* 33, no. 6 (2005): 497-505. https://doi.org/10.1016/j.omega.2004.07.024

[13] Zadeh, Lotfi A. "Fuzzy sets." *Information and control* 8, no. 3 (1965): 338-353. https://doi.org/10.1016/S0019-9958(65)90241-X

[14] Shafi, Muhammad Ammar, and Mohd Saifullah Rusiman. "The use of fuzzy linear regression models for tumor size in colorectal cancer in hospital of Malaysia." *Applied Mathematical Sciences* 9, no. 56 (2015): 2749-2759. https://doi.org/10.12988/ams.2015.5175

[15] Klir, George, and Bo Yuan. *Fuzzy sets and fuzzy logic*. Vol. 4. New Jersey: Prentice hall, 1995. https://doi.org/10.1109/45.468220

[16] Shafi, Muhammad Ammar Bin, Mohd Saifullah Bin Rusiman, and Nur Syaliza Hanim Che Yusof. "Determinants status of patient after receiving treatment at Intensive Care Unit: A case study in Johor Bahru." In *2014 International Conference on Computer, Communications, and Control Technology (I4CT)*, pp. 80-82. IEEE, 2014.
[17] Imeni, Mohsen. "Fuzzy logic in accounting and auditing." *Journal of fuzzy extension and applications* 1, no. 1 (2020): 66-72.
[18] Nowaková, Jana, and Miroslav Pokorný. "Fuzzy linear regression analysis." *IFAC Proceedings Volumes* 46, no. 28 (2013): 245-249. https://doi.org/10.3182/20130925-3-CZ-3023.00079
[19] Shafi, Muhammad Ammar, Mohd Saifullah Rusiman, Shuhaida Ismail, and Muhamad Ghazali Kamardan. "A hybrid of multiple linear regression clustering model with support vector machine for colorectal cancer tumor size prediction." *International Journal of Advanced Computer Science and Applications* 10, no. 4 (2019). https://doi.org/10.14569/IJACSA.2019.0100439
[20] Asai, H. T. S. U. K., S. Tanaka, and K. Uegima. "Linear regression analysis with fuzzy model." *IEEE Trans. Systems Man Cybern* 12 (1982): 903-907. https://doi.org/10.1109/TSMC.1982.4308925
[21] Ebrahimnejad, Ali, and Naser Amani. "Fuzzy data envelopment analysis in the presence of undesirable outputs with ideal points." *Complex & intelligent systems* 7, no. 1 (2021): 379-400. https://doi.org/10.1007/s40747-020-00211-x
[22] Tanaka, Hideo. "Fuzzy data analysis by possibilistic linear models." *Fuzzy sets and systems* 24, no. 3 (1987): 363-375. https://doi.org/10.1016/0165-0114(87)90033-9
[23] Veettil, Sajesh K., Tse Yee Wong, Yee Shen Loo, Mary C. Playdon, Nai Ming Lai, Edward L. Giovannucci, and Nathorn Chaiyakunapruk. "Role of diet in colorectal cancer incidence: umbrella review of meta-analyses of prospective observational studies." *JAMA network open* 4, no. 2 (2021): e2037341-e2037341. https://doi.org/10.1001/jamanetworkopen.2020.37341
[24] Chakrabarti, Sakti, Carrie Y. Peterson, Deepika Sriram, and Amit Mahipal. "Early stage colon cancer: Current treatment standards, evolving paradigms, and future directions." *World journal of gastrointestinal oncology* 12, no. 8 (2020): 808. https://doi.org/10.4251/wjgo.v12.i8.808
[25] McCulloch, Sofia M., Imran Aziz, Annikka V. Polster, Andreas-Bernd Pischel, Henrik Stålsmeden, Morteza Shafazand, Mattias Block *et al.,* "The diagnostic value of a change in bowel habit for colorectal cancer within different age groups." *United European Gastroenterology Journal* 8, no. 2 (2020): 211-219. https://doi.org/10.1177/2050640619888040
[26] Zolfaghari, Zahra Sadat, Mohebbat Mohebbi, and Marzieh Najariyan. "Application of fuzzy linear regression method for sensory evaluation of fried donut." *Applied Soft Computing* 22 (2014): 417-423. https://doi.org/10.1016/j.asoc.2014.03.010