ANALYZING CUSTOMER SATISFACTION: AN INNOVATIVE DECISION SUPPORT SYSTEM BASED ON FUZZY INFERENCE RULES

Jugendra Kumar Dongre[1*], Dr. Ajay R. Raundale[2]

Research Scholar, Department of Computer Science & Engineering, Faculty of Engineering & Technology, Dr. A. P. J. Abdul Kalam University, Indore (M. P.) –452010

Research Guide, Department of Computer Science & Engineering, Faculty of Engineering & Technology, Dr. A. P. J. Abdul Kalam University, Indore (M. P.) –452010

*Corresponding Author:- Jugendra Kumar Dongre
*Department of Computer Science & Engineering Email: jdongre1976@gmail.com

Abstract:

Customer relationship management (CRM) is a big deal in business these days. It's all about making sure customers are happy. One way to measure customer satisfaction is by using a special system called a fuzzy rule based decision support system. This system is helpful when things aren't simple and straightforward. It can handle situations where different things are connected and when you need to make judgments based on the specific situation. In this paper, we're looking at how the cost of recharge coupons and the amount of talk time and validity affect customer satisfaction. We want to find the recharge coupon that makes customers happy and makes the company money. We're using a fuzzy logic approach to figure out what makes customers satisfied. In the end, we'll have a model that shows how satisfied customers are based on their recharge coupon and talk time.

Keywords: Customer relationship management, Customer Satisfaction, linguistic judgment, fuzzy sets, Membership functions.

1. Introduction

Businesses have to work really hard to make their products and services better because there is a lot of competition and the market is global. This means that companies have to find ways to improve how they make things and how they treat their customers. Customers are really picky now and they want good service. They have the power to choose which companies they want to buy from. So, companies have to figure out how to make their service better and make their customers happy. When customers are happy, they will keep buying from the company and tell their friends about it. This helps the company grow and get more customers.

Vol. 29

No. 11

计算机集成制造系统

Computer Integrated Manufacturing Systems

ISSN

1006-5911

Companies want to keep customers for a long time because they are super valuable. It helps them beat their competition. Customers feel happy when they get good service. This can depend on things like time, place, and situation. For example, if the service is better than expected or if there's not a big difference between what was expected and what was received, customers will be satisfied. People use different methods to measure customer satisfaction. They often use surveys with questions. One common way to rank answers is with a Likert scale. It goes from 1 for "strongly agree" to 5 for "strongly disagree." But the scale doesn't show how big the difference is between each number. So, you can't use regular math to analyze the results. It's not easy to measure satisfaction and service quality because they are hard to describe and measure. Fuzzy inference system can be used to solve this problem. In this paper fuzzy inference system solving such problem because fuzzy logic deals with ambiguity. MATLAB fuzzy tool can design a FIS which contains rules and rules are used for decision making.

2. Literature Review

Samavat 2023 et al. So, there's this thing called a regulator that helps make a group of planets work better. We have two types of regulators, called Mamdani and Sugeno, and we want to figure out which one is better. We also want to know how well the regulators can learn and use information. So, we gave each regulator a special ability to learn information. It's important to know that these regulators are part of a fuzzy system, which is a type of artificial intelligence. People made these fuzzy systems because they wanted to make certain jobs easier. We tested four different fuzzy systems on a group of planets and used a program called MATLAB Simulink to see how well they worked. [1].

Sonia 2023 et al. This cool new system uses a special computer program called a multi-layer neural network to figure out what kind of diabetes someone has. The program has two main parts: the development phase and the testing phase. First, it looks at people with type 1 diabetes, then people with normal blood sugar, then people with type 2 diabetes, and finally pregnant women with diabetes. The program learns from all the different traits that are important for each type of diabetes. This makes it really good at telling them apart. After doing some tests, the program can tell if someone has diabetes with a high level of accuracy. It can even say how sensitive and specific the diagnosis is, with values of 0.95 and 0.97. [2]

Shwetha 2023 et al. In addition, preprocessed photographs are used to collect data on 14 variables. Identification of retinal lesions can be aided by methods for the early diagnosis and treatment of diabetic retinopathy, a condition that is frequently seen. provide a novel criterion for locating the optical disc, where we first identify the key blood vessels and then use the points of intersection to locate the optical disc. In the future, localization will use colour features. Show that when utilised properly, a variety of morphological approaches can be used to identify a collection of characteristics, including blood vessels, mucus, micro aneurysms, and haemorrhages. [3]

Sadat Asl 2022 et al. The interval type-2 fuzzy expert system predicts the ICU admission for COVID-19 patients. For this prediction job, a system for adaptive neuro-fuzzy inference (ANFIS) was further developed. Additionally, the results of these fuzzy systems are contrasted with those

Vol. 29

No. 11

计算机集成制造系统

Computer Integrated Manufacturing Systems

ISSN

1006-5911

of other well-known classification methods, including Naive Bayes (NB), Case-Based Reasoning (CBR), Decision Tree (DT), and K Nearest Neighbour (KNN). The findings show that the ANFIS and type-2 fuzzy expert system models compete favourably in terms of accuracy and F-measure when compared to other system modelling approaches. [4]

Sangeetha Devi, 2022. et al. put forward a new A Several fuzzy graph operations, including cycle, union, join, and products, are used to find the Sugeno-Type Fuzzy Graph of Groups. A figure that is representative depending on those vertices in all paths with those vertices as their starts and ends is the minimal number of shared edges chosen by those vertices in the formations that comprise all paths with those vertices as their starts and ends to compare with other paths. The Sugeno dominating path-colouring number, which exists in all sets of shared edges, allows for a range of methods because it exists in all sets of shared edges. With the aid of these new discoveries, several newly created chromatic number graphs are studied. [5]

Kotiyal 2022 et al. Given that a substantial section of the population is affected, big data is relevant to this problem. Deep Learning can solve the issues that Big Data faces, notwithstanding these issues. Big data and deep learning are consequently particularly interesting to academics. In this study, we attempted to employ effective preprocessing and Deep Learning approaches to achieve binary classification of diabetic retinopathy. The experiment makes use of an Indian-sourced Kaggle dataset. The peculiarity of the research is that three models—InceptionV3, Xception, and VGG19—and the performance of the Logistic Regression classifier are contrasted on the Spark platform. The models' precision is compared as a comparison metric. The trial's results show that InceptionV3 is 95% accurate, Xception is 92.50% accurate, and VGG19 is 89.94% accurate. InceptionV3 outperforms the other two models as a result. [6]

Lin, Jing 2022 et al. Grade 1 corresponds to 42.50 percent of the 54 DKD cases, Grades 2, 3a, 3b, and Grade 4 to 18.52 percent, 11.1 percent, 9.2 percent, 18.52 percent, and 18.52 percent, respectively, according to the eGFR grading. Despite there being a negative correlation between blood Hb levels and the course of DKD, blood urea and creatinine levels were considerably positively connected. The main renal artery (MRA), segment renal artery (SRA), and interlobular renal artery (IRA) all had considerably lower Vsmax and Vdmin values than in healthy instances, according to ultrasonography. The IR of the aforementioned arteries was noticeably enhanced, and the changes in the aforementioned data were also more pronounced than those in the lower extremities. The correlation between RI and DKD grades was positive, whereas the correlation between MRA, SRA, and IRA grades was adverse. Although RI of the arteries is negatively connected with kidney health, we found that the level of Hb is positively correlated with it. This is caused by the convergence of RI and Hb level. Conclusions. Indicators of the development of DKD include the haemoglobin (Hb) level and the intrarenal artery resistance index (RI), as evaluated by. [7]

Srivastava 2022 et al. This good study is all about sorting out the different types of heart problems that people in Southeast Asia might have. The smart scientists looked really closely at how doctors use medical info to get better at diagnosing these heart issues. They even tested

Vol. 29

No. 11

计算机集成制造系统

Computer Integrated Manufacturing Systems

ISSN

1006-5911

this system to see if it works well by checking if the stuff you put in matches the stuff that comes out. [8]

Abhilash 2022 et al. The two diabetes mellitus disease datasets (DMDDs) used in the integrated dataset on which the system is trained utilising EDL techniques are the Pima Indians Diabetes Dataset (PIDD) and the Hospital Frankfurt Germany Diabetes Dataset (HFGDD). Both the UCI-ML and Kaggle repositories were used to obtain these datasets. The suggested system has been utilised to demonstrate a number of characteristics, including precision, recall, accuracy, F-measure, latency, arbitrator time, jitter, processing time, throughput, energy consumption, bandwidth utilisation, networking utilisation, and more. The IoT-cloud connection is helpful for remotely and instantly diagnosing diabetic patients. The findings highlight the benefits of using FC ideas and the extent to which they can be used to quickly diagnose diabetes patients remotely. The text PACS-key contains a description of the key. written explanation of the PACS-key. [9]

Tian 2022 et al. examined the relationship between CHD and the serum Sestrin2 levels in people with type 2 diabetes. 69 T2DM patients without coronary heart disease participated in the trial. Both clinical characteristics and metabolic markers were discovered. Sestrin2 levels in serum were determined using ELISA. Results: The T2DM-CHD groups had significantly lower serum levels of sestrin2 than the T2DM group (11.17 (9.79, 13.14) ng/mL vs. 9.46 (8.34, 10.91) ng/mL). Serum Sestrin2 levels were shown to be negatively correlated with age ($r = 0.256$, $P = 0.002$), BMI ($r = 0.206$, $P = 0.015$), FBG ($r = 0.261$, $P = 0.002$), and Tyg index ($r = 0.207$, P 0.014) in bivariate correlation analysis. By using binary logistic regression, it was found that there was a significant (P 0.05) correlation between lower blood Sestrin2 levels and a higher risk of T2DM-CHD. In order to predict T2DM-CHD patients, sestrin2 was utilised, and its area under the curve (AUC) achieved 0.724 (95% CI 0.641-0.808, P 0.001). Sestrin2 levels and CHD were strongly correlated in diabetic individuals. Serum sestrin2 may impact the prevalence and progression of diabetic heart disease. [10]

Zhang 2022 et al. a vehicle's suspension can be controlled effectively, more reliably, and with less energy use. Based on bionic nonlinear dynamics, a fuzzy SMC technique for active suspension systems is developed. In contrast to earlier findings, the proposed control strategy effectively makes use of the beneficial nonlinear stiffness or damping of the biomimetic reference model, resulting in performance that is energy-saving. Furthermore, a number of real-world concerns are carefully considered, such as input saturation, dead zones, unknown/uncertain dynamics, and outside interference. According to theoretical analysis and simulation results, the suggested fuzzy SMC approach based on bionic dynamics may successfully reduce energy consumption, improve ride comfort, and efficiently reduce the vibration of the active suspension system.[11]

Afrash 2022 et al. In an effort to develop a system for decision support (DSS) based on the use of machine learning (ML) for DN diagnosis, it was tried to identify the variables that were relevant in predicting DN. Methods: Retrospective analysis was performed on the medical records of 327 people who had diabetes (types 1 and 2). The predicted variables affecting DN following data processing were identified using the genetic algorithm's (GA) feature choice method. Then, in

Vol. 29

No. 11

计算机集成制造系统

Computer Integrated Manufacturing Systems

ISSN

1006-5911

addition to other ML methods, the support vector machine (SVM), decision tree (DT), K-nearest neighbour (KNN), and artificial neural networks (ANN) were used to train prediction models based on the selected features. The performance of the developed models was then evaluated using the accuracy, specificity, and sensitivity criteria over the course of ten independent runs. [12]

Galo, 2022 et al. This article suggests the application of computational tools for decision-making using fuzzy inference systems as a way to potentially improve the triage procedures in Brazil. We contend that the use of natural language to describe the patient's symptoms makes it simpler for medical personnel to understand the problem and that fuzzy set theory is applicable. We used a pilot test after simulating the issue in a fuzzy system. The model takes into account the symptoms that doctors now utilise to evaluate COVID-19 cases. The findings point to the model's possible use in aiding triage for the classification of the seriousness of COVID-19 cases by showing convergence with the sample data. One advantage of the suggested model . We place particular emphasis on the contributions that reduce the amount of time and personnel needed for triage and the exposure of medical personnel and other patients who may be carrying the virus. In this sense, this study offers a chance to acquire social contributions for the enhancement of services in public hospitals..[13]

Chakraborty 2021 et al. Applying a fuzzy inference system & machine learning techniques, a COVID-19 risk prediction model for diabetes patients is suggested. This study sought to determine the COVID-19 risk level in diabetes individuals without seeking medical advice in order to take prompt action and reduce the multifold COVID-19 mortality rate amongst diabetic patients. Eight factors that were identified as having the greatest influence on diabetic patients' symptoms serve as inputs for the suggested model. Fifteen models were built utilising a range of cutting-edge machine learning techniques, with the rule base serving as the framework. The CatBoost classifier delivers the highest kappa, F1, recall, accuracy, and other measures. The CatBoost classifier achieved 76% accuracy after hyper-parameter optimisation, along with improvements in recall, precision, F1 score, and kappa score. Then, with 75.1% accuracy, came logistic regression and XGBoost. [14].

Fuzzy Logic:

Fuzzy logic is a derivative from classical Boolean logic and implements soft .linguistic variables on a continuous range of truth values to be defined between conventional binary. It can often be considered a suspect of conventional set theory. Since fuzzy logic handles approximate information in a systematic way, it is ideal for controlling non-linear systems and for modeling complex systems where an inexact model exists or systems where ambiguity or vagueness is common.

A typical fuzzy system consists of a rule base, membership functions and an inference procedure [15]. Fuzzy logic is a super set of conventional Boolean logic that has been extended to handle the concept of partial truth-truth-values between "completely true" and "completely false".

Fuzzy subsets:

In classical set theory, a subset U of asset S can be defined as a mapping from the elements of S to the elements the subset [0, 1], U: S -> {0, 1}

Vol. 29

No. 11

计算机集成制造系统

Computer Integrated Manufacturing Systems

ISSN

1006-5911

The mapping may be represented as a set of ordered pairs, with exactly one ordered pair present for each element of S. The first element of the ordered pair is an element of the set S, and the second element is an element of the set (0, I). Value zero is used to represent non-membership, and the value one is used to represent complete membership. The truth or falsity of the statement. The 'X is in U' is determined by finding the ordered pair whose first element is X. The statement is true if the second element of the ordered pair is 1, and the statement is false if it is 0.

Merits of fuzzy logic:

The reasons why fuzzy logic is used are as follows [16]:

An alternative design methodology, which is simpler and faster.

It reduces the design development cycle.

It simplifies design complexity.

A better alternative solution to non-linear control.

It improves control performance.

It is simple to implement.

It reduces hardware cost.

Structure of Fuzzy Rules:

Examine fever on the basis of body temperature:

Conventional model –

if temperature > X, take paracetamol

else, stop taking paracetamol

Fuzzy System -

if temperature = hot, take paracetamol of high mg

if temperature = warm, take paracetamol of low mg

if temperature = normal, stop taking paracetamol

In fuzzy rules, the linguistic variable temperature also has the range (the universe of discourse) between 99 and 105, but this range includes fuzzy sets, such as hot, warm and normal. The universe of discourse of the linguistic variable take paracetamol can be between 150 and 500 mg and may include such fuzzy sets as high, low and stop.

A fuzzy rule can be defined as a conditional statement in the form:

IF   x   is A

THEN   y   is B

Where x and y are linguistic variables; and A and B are linguistic values determined by fuzzy sets on the universe of discourses X and Y, respectively.

3. Methodology

Customer Satisfaction Modeling by Fuzzy Association Rules:

Vol. 29

No. 11

计算机集成制造系统

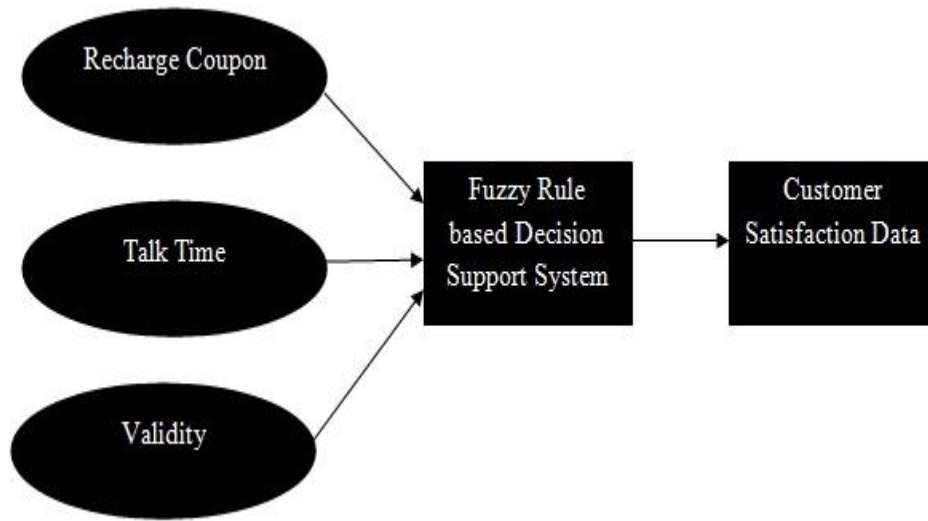Computer Integrated Manufacturing Systems

ISSN

1006-5911

Fig.1. fuzzy decision support system for finding customer satisfaction data.

A fuzzy logic approach is used to construct the satisfaction model given above. Modeling of Fuzzy decision support system is depends on the three variables these are cost of recharge coupon, talk time and validity. The sets can be used to aid in finding customer satisfaction data or decision making for finding batter recharge coupon. Given four types of recharge coupon (C_1, C_2, C_3, and C_4), our task is to choose the best recharge coupon that will give us the highest talk time , more validity in low cost. Customer satisfaction factor depends upon these three linguistic terms.   The first constraint of recharge coupon talk time can be represented with the following fuzzy set.

Talk time=

FuzzySet [{{1, .6 },{2, .7 }, {3, .9 }, {4, .5 }}

Universal space-> {1, 4, 1}

We can see that recharge coupon   3 has the highest membership grade, meaning that recharge coupon   is the highest talk time of the four recharge coupon. Recharge coupon 4 on the other hand is the least talk time, since it has a membership grade of only 0.5.

We can form a fuzzy set for our second constraint in a similar manner. Here is a fuzzy set used to represent the validity of recharge coupon to the four recharge coupons.

Validity=

FuzzySet [{{1, .5 },{2, .7 }, {3, .6 }, {4, .8 }}

Universal space-> {1, 4, 1}

In the fuzzy set above, the membership grades indicate the validity of recharge coupon. A high membership grade indicates that it is a long validity. A small membership grade indicates an undesirable, short validity. From the fuzzy set above, we can see that the validity of recharge coupon 4 is high means it is giving the highest validity period in low cost., while the validity of recharge coupon b 1 is a short validity . Finally, we need to figure in the goal of a cost of the recharge coupon. There is no real difference between a constraint and a goal in this problem, so

Vol. 29

No. 11

计算机集成制造系统

Computer Integrated Manufacturing Systems

ISSN

1006-5911

we figure in the worth of the cost of the recharge coupon the same way we did for the previous constraints. We could use a formula to convert a salary into a membership grade for each recharge coupon, but to stay with the tradition of our previous constraints, we arbitrarily assign a membership grade to each recharge coupon based on cost.

Cost=

FuzzySet [{{1, .2},{2, .5}, {3, .7 }, {4, .3 }}

Universal space-> {1, 4, 1}

From this fuzzy set, we see that recharge coupon 1 has least cost , and recharge coupon 3 has highest cost . Now that all of our criteria is represented as fuzzy sets, we need to decide on a function to make the decision. We will use the standard Intersection to make the fuzzy decision. Applying the Intersection operation can be thought of as adding the constraints and goals to come up with the best overall decision. A Customer really wants a recharge coupon with highest talk time with longer validity in low cost. Any telecommunication company giving this type of offer then the customer   satisfaction level will be high.

The fuzzy intersection of A and B is

A ∩ B ≡ {x, $\mu_{A \cap B}$ (x) | x ∈ U and $\mu_{A \cap B}$ (x) =min (μ_A (x), μ_B (x))}

Fuzzy rules for finding customer satisfaction for a recharge coupon

If the cost of recharge coupon is low and talk time is excellent and validity is long then customer may give the excellent response.

If the cost of recharge coupon is high   and talk time is good and validity is medium then customer may give the average response.

If the cost of recharge coupon is average and talk time is excellent and validity is long then customer may give the better response.

If the cost of recharge coupon is high and talk time is moderate and validity is short then customer may give the poor response.

Customer satisfaction = Intersection [talk time, validity, cost]

Intersection will compute the minimum of all three variables and compute the result which is given in the table no.

Table 1 Customer response

Recharge Coupon	Degree of Talk time	Degree of Validity	Degree of cost	Degree of customer satisfaction
C_1	0.6	0.5	0.2	0.2
C_2	0.7	0.7	0.5	0.5
C_3	0.9	0.6	0.7	0.6
C_4	0.5	0.8	0.3	0.3

Table 1 Customer response

Vol. 29

No. 11

计算机集成制造系统

Computer Integrated Manufacturing Systems

ISSN

1006-5911

According   result after intersecting the degree's of talk time, validity and cost of recharge coupon the customer no.C3 is more satisfied because he is getting highest talk time with more validity in medium cost.Table1 and chart 1 is justifying the above given fuzzy rules.ʹ
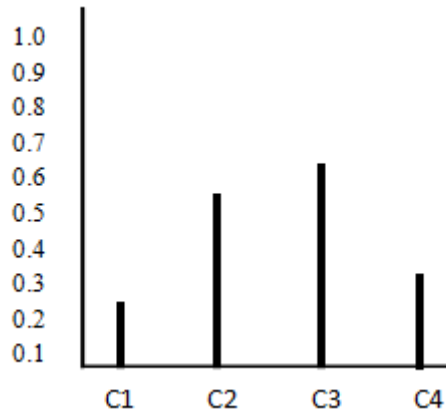

Chart 1. Customer satisfaction with membership degree

4. Conclusion

Fuzzy decision support system can be used for making better decision in the various fields, in this paper we only focused on the types of recharge coupons. Our system basically helps for selecting a better plan so that we can get more benefit and more satisfaction. The example given in this paper is clearly justifying the use of fuzzy association rules for giving batter business decision and understanding of customer behavior and buying habits. The method given in this paper may improve enterprise's benefit.

References

[1] Samavat*et al.*, "Research Article A Comparative Analysis of the Mamdani and Sugeno Fuzzy Inference Systems for MPPT of an Islanded PV System," vol. 2023, 2023.

[2] J. J. Sonia, P. Jayachandran, A. Q. Md, S. Mohan, A. K. Sivaraman, and K. F. Tee, "Machine-Learning-Based Diabetes Mellitus Risk Prediction Using Multi-Layer Neural Network No-Prop Algorithm," *Diagnostics*, vol. 13, no. 4, pp. 1–16, 2023, doi: 10.3390/diagnostics13040723.

[3] G. K. Shwetha, U. K. R. K. R, J. A. Rathod, and B. P. Sathyaprakash, "INTELLIGENT SYSTEMS AND APPLICATIONS IN Diabetic Retinopathy Prediction using Modified Inception V3 Model Structure," vol. 11, no. 1, pp. 261–268, 2023.

[4] A. Sadat Asl, M. M. Ershadi, S. Sotudian, X. Li, and S. Dick, "Fuzzy expert systems for prediction of ICU admission in patients with COVID-19," *Intell. Decis. Technol.*, vol. 16, no. 1, pp. 159–168, 2022, doi: 10.3233/IDT-200220.

[5] Sangeetha Devi, "An Extensive Study on Graph Colourings and Dominator Chromatic Number of Sugeno-Type Fuzzy Graphs," *Math. Probl. Eng.*, vol. 2022, 2022, doi: 10.1155/2022/3135201.

Vol. 29

No. 11

计算机集成制造系统

Computer Integrated Manufacturing Systems

ISSN

1006-5911

[6] Bk. Otiyal and H. Pathak, "Diabetic Retinopathy Binary Image Classification Using Pyspark," *Int. J. Math. Eng. Manag. Sci.*, vol. 7, no. 5, pp. 624–642, 2022, doi: 10.33889/IJMEMS.2022.7.5.041.

[7] J. Lin, G. Liu, Y. Lin, C. Wei, S. Liu, and Y. Xu, "Ultrasonography Combined with Blood Biochemistry on the Early Diagnosis of Diabetic Kidney Disease," *Dis. Markers*, vol. 2022, 2022, doi: 10.1155/2022/4231535.

[8] P. Srivastava, N. Sharma, and C. S. Aparna, "Fuzzy Soft System and Arrhythmia Classification," *Chinese J. Math.*, vol. 2014, pp. 1–12, 2014, doi: 10.1155/2014/164781.

[9] Patiet al., "Diagnose Diabetic Mellitus Illness Based on IoT Smart Architecture," Wirel. Commun. Mob. Comput., vol. 2022, 2022, doi: 10.1155/2022/7268571.

[10] X. Tian*et al.*, "The association between serum Sestrin2 and the risk of coronary heart disease in patients with type 2 diabetes mellitus," *BMC Cardiovasc. Disord.*, vol. 22, no. 1, 2022, doi: 10.1186/s12872-022-02727-1.

[11] M. Zhang and J. Zhang, "Fuzzy SMC Method for Active Suspension Systems with Non-ideal Inputs Based on a Bioinspired Reference Model," *IFAC-PapersOnLine*, vol. 55, no. 27, pp. 404–409, 2022, doi: 10.1016/j.ifacol.2022.10.547.

[12] M. R. Afrash, F. Rahimi, H. Kazemi-Arpanahi, M. Shanbezadeh, M. Amraei, and F. Asadi, "Development of an intelligent clinical decision support system for the early prediction of diabetic nephropathy," *Informatics Med. Unlocked*, vol. 35, no. May, p. 101135, 2022, doi: 10.1016/j.imu.2022.101135.

[13] N. R. Galo, M. P. Roriz Junior, and R. P. Tóffano Pereira, "A fuzzy approach to support decision-making in the triage process for suspected COVID-19 patients in Brazil [Formula presented]," *Appl. Soft Comput.*, vol. 129, p. 109626, 2022, doi: 10.1016/j.asoc.2022.109626.

[14] G. S. Chakraborty, D. Singh, M. Rakhra, S. Batra, and A. Singh, "Covid-19 and Diabetes Risk Prediction for Diabetic Patient using Advance Machine Learning Techniques and Fuzzy Inference System," *Proc. 5th Int. Conf. Contemp. Comput. Informatics, IC3I 2022*, vol. 2022, pp. 1212–1219, 2022, doi: 10.1109/IC3I56241.2022.10073256.

[15] Timothy J.Rose, "FUZZY LOGIC WITH ENGINEERING APPLICATIONS, Mc – Graw Hill.Inc, Newyork, 1997.

[16] http://www.aptronix.com.