Enriching Functional outcomes in Ischemic Stroke Patients using Fuzzy ANN and Random Forest

Ms Chanchal Gaikwad
Computer Engineering
Bhivarabai Sawant Institute of Technology and Research,
Pune, India

Prof P B Jawlkar
Computer Engineering
Bhivarabai Sawant Institute of Technology and Research,
Pune, India

***Abstract*— The sudden attack of Ischemic strokes always astonishes the patient, doctor and dear ones to the patient. The proper treatment of the ischemic stroke patient hidden in the fact of the severity of the stroke that the patient is suffering for the moment. Most of the time due to unaware of the severity of the stroke the Doctors follow non required procedures to cure the same using trial and error method, which eventually results in permanent damage of the organs or even as fetal. So it is very important to estimate the functional outcomes of the ischemic stroke patient based on some vital parameters of the patient's health. Some finger counting methodologies are existed to deal with this, because the complexity of the stroke is associated with the numerous attributes that reveal many secrets about the outcome possibilities. As a tiny step towards this proposed model incorporates some finest blends of the machine learning techniques which are enriched in the unique way to get the best functional outcomes for the ischemic Stroke patients. The proposed model uses the K - nearest neighbor algorithm which is powered with the linear regression model to yield the best proportional clusters. Further Fuzzy ANN and Random forest algorithms create a proper learning mechanism model to classify the functional outcomes for the ischemic dataset.**

Keywords*—*Fuzzy ANN, Random Forest, Linear Regression, K-Nearest neighbor, Ischemic Stroke.

I. INTRODUCTION

The Human Heart is one of the most essential organs in the body. It is responsible for a variety of functions such as supplying oxygen and other useful minerals and chemicals inside the body for its proper functioning. It also helps clean up the toxins from the body. Overall it is one of the most important aspects of the human body that is attributed to keeping it alive. The heart and the capillary system form one of the most intensive networks in the body, reaching the corners of the body.

Due to the fact that it is one of the most essential organs in the body for survival. Any harm to this could easily mean the impairment of the system that keeps the person alive. Therefore, a stroke is highly dangerous ailments which can be highly fatal. During a stroke, the supply of blood to the brain is decreased or stopped abruptly. This leads to a scarcity of oxygen and other vital nutrients in the brain as the blood flow is reduced. This is a very alarming emergency and it needs to be treated immediately.

Strokes nowadays can be effectively treated due to advancements in the medical field. But the timing is still very crucial and the patient has very little time to contain the damages done by the stroke on the patient's brain. There are a few signs and symptoms that indicate that the patient is going to have a stoke, such as the patient has difficulty understanding or speaking, loss of vision in one or both the eyes, headache and trouble walking due to numbness in the limbs. If any of the symptoms manifest in the patient they should be immediately given medical assistance.

There can be various different causes for a stroke; primarily this is due to a certain blocked artery, which is known as Ischemia which means a blockage. Most of the strokes that happen are ischemic in nature, which means that the majority of the strokes need to identified and treated immediately. Otherwise, it could lead to various complications such as paralysis and loss of motor functions, and ultimately death.

There are two types of strokes that can occur, the first one is a thrombotic stroke, which is basically caused due to a blood clot that is formed in the blood vessels that supply blood to the brain. This can be caused due to various debris in the blood, mainly cholesterol build-up or the hardening of the arteries due to illnesses or smoking etc. the second type is the Embolic stroke which is slightly different as in this the clot is not formed in the brain but originates in some other part of the body and is transported to the capillaries in the brain which are very narrow and block the blood flow.

This is a form of a classifier that is used for performing classification operations. It is a very basic and simple algorithm that is used for this process. K-Nearest Neighbours is considered as one of the Lazy algorithms. A lazy algorithm is one of the algorithms that does not require to be trained as much with a lot of data; the classifier can accurately perform the classification tasks with the help of very less training.

The classification done in K-Nearest Neighbours is done with respect to the attributes and the features of the data in the dataset. Therefore, this leads to all the data items with similar features to be segregated together in the form of clusters. K-Nearest Neighbours is one of the most powerful and simple algorithms that can be used for the purpose of classification. The algorithm can also be utilized for various purposes and mainly it has been in popular use in the area of prediction.

KNN is one of the most versatile algorithms that are used for the purpose of prediction in various fields, such as estimating the credit rating of the customer with the help of their past financial account details. K-Nearest Neighbours has also been used for the purpose of performing facial recognition and optical character recognition. This is due to the fact that this technique is extremely easy to use and implement.

Random forest is a technique for performing calculation and other predictions, which is done with the help of

databases. This technique is used to identify and segregate the important information of the image. It is one of the most popular algorithms that is used for extracting accurate predictions. Due to their robust nature, they require minimal training to be able to be useful. Therefore, it is one of the most essential concepts that is used for prediction purposes.

Random forests are basically nothing but a large collection of various different decision trees. These trees are collected and interconnected to one another to form a huge network of trees which gave it the name Random Forest. It has been utilized extensively in the field of biomedical and healthcare, where it has been used to accurately approximate the survival chances and various other aspects. It is also heavily used for prediction of the shares and the stock market to identify the trends etc.

Artificial neural networks are computational networks that are designed by the inspiration from the working of the human brain. Both the Artificial Neural Networks and the human brain have the neuron as the smallest computational unit, where a large number of neurons are interconnected to each other. These neurons have a certain excitation level and when the stimulus exceeds this threshold level the neuron excites and sends a signal to the neighboring neurons.

Artificial Neural Networks are very powerful and capable of very high computations. Fuzzy ANN refers to the Fuzzy concept being added to the artificial neural network. This is done to increase the accuracy of the system as well as make the system capable of taking a large range of input. This is highly useful for performing very precise calculations and predictions.

This research paper dedicates section 2 for analysis of past work as literature survey, section 3 deeply elaborates the proposed technique and whereas section 4 evaluates the performance of the system and finally section 5 concludes the paper with traces of future enhancement.

II. LITERATURE REVIEW

Y. Udovychenko [1] states that the concept of magneto cardiography is one of the most innovative tests, as it can identify the changes in the magnetic fields generated by the heart. It is one of the most preferred procedures due to the fact that it is non-invasive in nature and quite safe to administer. This technique is quite instrumental in detecting the magnetic fields generated by the heart due to the changing electrical activity. The authors in this paper utilized the K-Nearest Neighbor classifier for the extracting the density distribution maps. The one main drawback of this procedure is the average accuracy it achieves.

W. Omar presents an innovative concept for the classification and identification of ischemic strokes. As the ischemic strokes have been one of the most fatal of all the strokes that have been encountered. The researchers utilized ANN for this purpose and classified the ischemic stroke patient with respect to the severity of the stroke [2]. The patients were segregated into 3 different groups, Early Group, Intermediate group, and the advanced group. The classification prowess of this technique has been tested against the conventional techniques and it has performed exceptionally with increased accuracy.

A. Vrtkova elaborates on the rising numbers of fatal strokes every year. Out of the fatal strokes, the ischemic strokes are the most fatal and claimed the largest number of lives. To provide a solution to this epidemic, the researchers propose a technique that can predict the condition of a patient with the help of past medical data. The authors implement random forest for the classification of the variables according to their importance. Then a Rankin Scale has utilized the values segregated by the random forest. The proposed algorithm has achieved high levels of accuracy. The only drawback in this paper is that there were very few parameters that were used to do the calculations for the prediction. [3]

T. Kodama introduces the concept of reperfusion therapy for the rehabilitation of patients suffering from acute ischemic stroke. Most of the damage done by the ischemia can be attributed to the slow process of identification that increases the damage done on the patient. Therefore, the researchers aim to reduce this time taken for the identification by introducing a fast and reliable detection method that can reduce the time taken to start the reperfusion therapy on a patient suffering from ischemia [4]. The HRV and MSPC based algorithm have been attributed for its accurate and timely diagnosis of the ischemia. The only drawback in this technique is the unavailability of the data for training purposes.

R. Tao proposes a methodology for helping the doctors and other medical professionals handling the ischemic patients. This is done by utilizing the MGC recordings especially the T-wave segments [5]. The segments are utilized to extract the various features which are subsequently classified into various subsections, namely, Time Domain, Frequency Domain, and information theory features. These Features are then further analyzed with particular attention paid to the stenosis locations for classification into their IHD groups. The XGBoost classifier is used which boosts the classification process by reducing the time and increasing the computational complexity of the system.

C. Zizzo explains that most of the techniques for the identification of the ischemic stroke in a patient are very slow. And the most essential concept for the treatment of the ischemic patients is time, the timely treatment they receive the better are their chances of survival [6]. Therefore, the authors present an innovative technique that combines the ECG and the Automated ST analysis to ascertain the extent of the damage done to the patient, by drawing a real-time 3D diagram of the heart. The presented technique has been extensively tested on various datasets and has been performing exceptionally.

F. Tianxiang [7] have successfully analyzed and implemented a technique for identifying the correlation between the incidence of stroke and the climatic conditions of the area the patient has been residing in at the time of experiencing the stroke. The authors have tested their technique on a large number of datasets, as this was done for a competition, the authors developed various mathematical models for the analysis. The authors concluded that the climate definitely has an effect on the prevalence of the ischemic stroke. This is a highly beneficial prospect as the medical professionals will be ready when there is a climate change that favors ischemic stroke.

S. Gupta states that there has been an increase in the number of ischemic strokes in the population, and as it is one of the most severe types of strokes, it can be fatal. The Magnetic Resonance Imaging is utilized heavily to ascertain the damage done to the brain in the case of ischemic stroke as

well as to declare brain death [8]. The authors present a technique for automatic classification of images depicting ischemic stroke in an MRI scan. This is achieved with the help of image processing. The technique has been tested and has produced promising results and high accuracy.

W. Omar presents an innovative technique for the identification and classification of ischemic strokes. The researchers comment on the rising problem of ischemic strokes and its prevention, as it has become an epidemic in this era [9]. To accurately identify the ischemic strokes, the authors have implemented a technique based on Artificial Neural Networks, on the EEG and its Relative Power Ratio for the assessment of the severity of the ischemic stroke. The framework has been tested extensively and produced accurate results. This technique has one drawback as the Artificial Neural Networks increase the computational complexity of the system.

G. Sahoo [10] elaborates on the concept of utilizing the Electrocardiogram for the purpose of classification and analysis of the patient's heart after an ischemic stroke. Most of the time, there are some abnormalities in the heart that can lead to an ischemic stroke. The authors have implemented a framework capable of identifying the various deformities in the heart with the help of the ECG and predicting an incident of Ischemic stroke in a patient. The authors have tested their technique on a dataset of European patients that resulted in highly accurate results.

I.Grigore states that ischemic strokes can also happen to children. Which was evident in the case of a girl that showed various signs of ischemia such as seizures and the total and sudden loss of motor control [11]. This was due to the fact that this girl was suffering from an iron deficiency that had resulted in anemia, combined with the Leiden deficit led to the stroke. It was also seen that the girl had suffered the ischemic stroke in the right central artery. The girl was then given a dose of anticoagulants that was highly effective and relieved the symptoms of the girl.

H. Tong expresses that the ischemic stroke patients must be looked after as they are very susceptible to a lot of damage in the early hours of the stroke. Therefore, the authors implement a technique for the rehabilitation of the ischemic stroke patients by paying attention to their psychological needs [12]. As most of the patients go through depression and anxiety after a stroke, the researchers have presented a technique that utilizes regression analysis for the purpose of understanding the psychological state of the patients and providing the medical assistance according to them. The presented method has been proven to be highly effective for this purpose.

H. Kuang [13] explains the importance of a CT scan following an ischemic stroke. As a lot of CT scans are performed, the area of damage needs to be localized to provide optimum care to the patient. Most of these images are segregated manually and this process is highly time-consuming, even though there are automated techniques to segregate the images, they are specialized and can only segment either ischemic infarction or hemorrhages. Therefore, the authors implement a technique that combines both of these practices and achieves the segmentation of both the Ischemic infarction and hemorrhage images from the CT scan. The proposed methodology has a very high computational cost.

G. Fuente-Cortes implements an innovative technique for automatic drug administering systems that are implanted into the patient's body. The authors have introduced a classifier that can identify when the heart is going into ischemia, this is done by identifying the ischemic heartbeats in the patient. The technique has been extensively tested against conventional techniques[14]. The various parameters for the detection have been approved by doctors and medical professionals. The researchers have utilized various ECG recordings to train the system to accurately identify the heartbeats in the event of an ischemic stroke.

A.Yahiaoui states the importance and prevalence of Computed Tomography. As it is one of the most essential tests that can diagnose the extent and the occurrence of an ischemic stroke. But this is useful when the stroke has already occurred and to identify the area of the damage. But the early signs of ischemia are not evident in a CT scan, as they are very subtle and unrecognizable. Therefore, the ameliorate this effect, the authors have implemented a technique that increases the contrast of the CT scan images to provide clarity and help identify the subtle signs of ischemia in the patient's brain. The proposed technique has a high time complexity which takes a lot of time to produce usable results. [15]

III PROPOSED METHODOLOGY

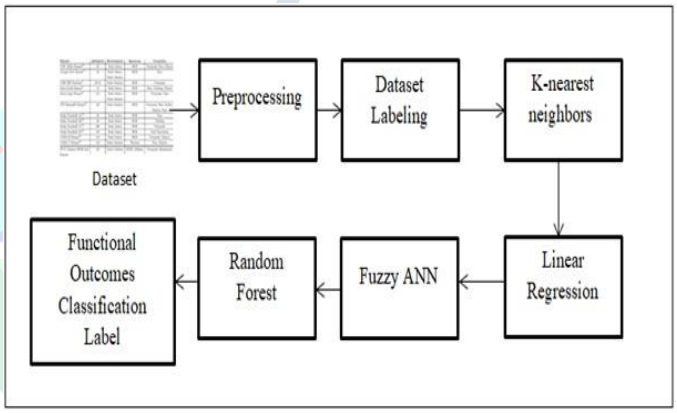

Figure 1: Overview of the Proposed System

The proposed methodology for Estimating functional outcomes in Ischemic stroke patients is depicted in the figure 1.The modules involved in the making of the proposed model are broadly elaborated in the below mentioned steps.

Step 1: Dataset collection, Preprocessing and Labelling- This is the primitive step of the proposed system where the Z-Alizadeh Sani Dataset for Ischemic Stroke is being downloaded from the UCI URL https://archive.ics.uci.edu/ml/datasets/Z-Alizadeh+Sani.

The Obtained dataset contains about 303 instances with 56 attributes. The Proposed model considers some of the attributes if these 56 for the estimation of the functional outcomes, which are tabulated in the table 1.

Age	**Chest pain**
Sex	**St Depression**
BMI	**Fasting blood Sugar (FBS)**
Obesity	**triglycerides (TG)**
Smoker	**Low-density lipoprotein cholesterol (LDL)**
Hypertension	**High density lipoprotein Cholestrol (HDL)**
Thyroid	**White blood cells (WBC)**
Blood Pressure	

Table 1: Attribute List

At the beginning of the model user is provided an interactive User interface to enter all the attribute as mentioned in the table 1. Once the attributes are entered they are made as static and stored for temporarily. Then obtained dataset is stored in the worksheet format, Which is read in the form the double dimension list using the external API JXL.

Once this dataset is collected in a list, then the four attributes are selected for the process of clustering, which plays a vital role in estimating the functional outcomes of the Ischemic Stroke patients. The Selected four attributes are BMI, BP, FBS and WBC. These attributes are collected by labeling the position of the respective columns. So collected attributes for each of the rows are bonded in a new row to store a as preprocessed data.

Step 2: K- Nearest neighbor Clustering - The preprocessed list is considered here to cluster them based on the nearest neighbor estimation. This process involves 5 major steps as described below.

[i] Distance Evaluation - Here in this step a Euclidean distance is evaluated as mentioned in the equation1 for every row with respect to all other rows for the four attributes. The mean of this distance is assigned as the Row distance R_D at the end of each row. Then the average of the all the Row distances yields Average distance of the preprocessed list, that is called as A_D.

$$RD = \frac{\sum_{i=0}^{n}\sum\sqrt{(ATi-ATj)^2}}{n-1} \quad \text{_____(1)}$$

where
R_D - Euclidean Distance
AT- Attributes
n= Number of Rows in the Preprocessed List

[ii] Sorting - The whole preprocessed data where each of the rows are appended with their respective Row distances is sorted based on the RD using the bubble sort technique. This process brings down all the nearest rows together to form best clusters with more semantic distances.

[iii] Data Point Estimation - Some random data points are being estimated based on the given number of clusters. These data points are the pure integers which are in between the range of 1 to 100. Then these integers are normalized based on the size of the preprocessed list. These data points are processed by storing in an integer array to extract the

[iv] Centroid Evaluation- Here the rows are selected for the decided data points. The row distances R_D of each selected row is extracted to store in a list to form the centroid list for the cluster formation process.

[v]Cluster Formation- For each of the centroid a cluster boundary is formed as shown in the equation 2. Then for each of the cluster boundary a deserved row is added whose row distance is in the range of the stated boundary.

$$f(CB) = \int_{i=0}^{n}(Ci - AD) \rightarrow (Ci + AD) \quad \text{_____(2)}$$

Where,
CB - Cluster Boundary
Ci- Centroid
A_D- Average List Distance
n- Number of Centroids

The rows that does not belong to any of the clusters are added to the newly formed cluster called an outlier. This outlier cluster is finally added into a general cluster of nearest neighbors.

Step 3: Linear Regression - *Once* the clusters are formed, then these clusters are set to estimate their regression values. To estimate these regression values each and every single cluster is considered to estimate the mean and standard deviation of the R_D of the cluster row as mentioned in the equation 3 and 4. Then a range of the regression value is estimated based on the mean and standard deviation as described in equation 5. This range denotes the best possible values of the clusters that eventually can yield good outcomes for the Ischemic stroke input data from the user.

To extract the linear regression clusters, each cluster is subjected to filter through the value measuring in the range mentioned in equation 5.

$$\mu = \frac{(\sum_{i=0}^{n} RDi)}{n} \quad \text{_____(3)}$$

$$\delta = \sqrt{\frac{1}{N}\sum_{i=1}^{n}(RDi - \mu)^2} \quad \text{_____(4)}$$

$$f(R_R) = (\mu - \delta) \rightarrow (\mu + \delta) \quad \text{_____(5)}$$

Where,
μ - Mean
δ- Standard Deviation
R_D - Row Distance
n= Number of Rows

Step 4: Fuzzy ANN- This is the core part of the model where the probabilistic outcome for the Ischemic Stroke patients are brought into light. This step considers the regression clusters and the preprocessed list for this operation. In the beginning a smallest and largest sum is estimated for the preprocessed list row attributes to label them as MIN and MAX.

Once the MIN and Max values are estimated, then an absolute distance is calculated between the MIN and MAX and this distance is divided by the 5, Which gives the range distance of the fuzzy crisp values. By using this range distance 5 Fuzzy crisp values are formed as VERY LOW, LOW, MEDIUM, HIGH and VERY HIGH.

This Fuzzy crisp values and Linear regression clusters are fed to form the neurons based on the given algorithm 1

Algorithm 1 : NEURON LIST

// Input : F_C={VL,L,M,H,VH} Fuzzy Crisp values
// L_C : Linear Clusters
// Output : Neurons N_R
Function : neuronList (F_C , L_C)
Step 0: Start
Step 1: N_R = Ø
Step 2: ***for*** i=0 TO Size of L_C
Step 3: S_G=$L_{C[i]}$
Step 4: ***for*** j=0 TO Size of S_G
Step 5: Row= S_{Gj}
Step 6: sum=0
Step 7: ***for*** k=1 TO Size of Row-1
Step 8: sum=sum+$Row_{[k]}$
Step 9: **End *for***
Step 10: ***IF*** sum ∈ $\mathbf{F_C}$

Step 11: **ADD** Row TO ($F_{C\ NR}$)
Step 12: **ADD** ($F_{C\ NR}$) TO N_R
Step 13: **End *for***
Step 14: **End *for***
Step 15: return P_S
Step 16: Stop

The formed neurons are then subjected to estimate the ranks based on the given input of BMI, BP, FBS and WBC. Here in this process each of the rows of a neuron are assigned a rank based on the defined protocol for the four attributes of minimum and maximum ranges. Then a double dimension list is created where row serial number and the ranks are optimized to get the rank list of the neurons. This rank list, then sorted in descending order to select the top 25 ranked neurons.

Step 5: Random forest – The ranked neurons are subject to the random forest tree classification to get the best outcome neurons. Here in the Random forest a tree is created based on the rank of the neurons. Here in this process a neuron is set as the right child, if the value is bigger and as the left child if the value is smaller than the root value.

Once the tree is formed, then this tree is traversed in the pre-order form to estimate the number of the nodes in each of the levels of the tree. Then the node serial numbers for the tree level that contain the maximum number of nodes or neurons are considered as the classified labels.

The original rows for the classified label numbers are extracted and they are estimated for all the input attributes as mentioned in table 1. Then based on this matched attributes an outcome percentage for the Ischemic patient is displayed for the given input.

IV RESULT AND DISCUSSIONS

The proposed model for the outcome of Ischemic stroke patients is being developed in windows based laptop. Which is powered by the Intel Pentium core i5 processor along with 6GB of primary memory. To deploy the model the Java Programming language is being used with Netbeans 8.0 as the standard development IDE.

The proposed model is tested for the Area under the curve (AUC). To measure the AUC proposed model estimates the True positive rates, and False Positive Rates. For the experimental process proposed methodology conducts the 10 trials each trail consists of 10 instance runs. Based on the Obtained result proposed system evaluates the TP and FP as shown in the below mentioned table 2.

Trail No	No of Instances	TP	TN	FP	FN	TPR
1	10	7	0	0	3	0.7
2	10	8	1	1	2	0.8
3	10	9	0	0	1	0.9
4	10	9	1	0	0	1
5	10	10	0	0	0	1
6	10	7	2	1	0	1
7	10	10	0	0	0	1
8	10	7	0	3	0	1
9	10	10	0	0	0	1
10	10	10	0	0	0	1

Table 2: True positive rate estimation Table

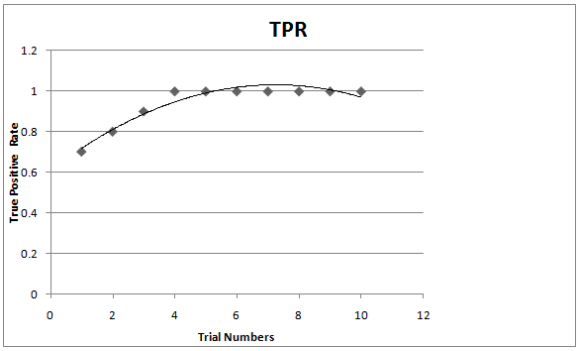

Figure 2: ROC Curve for Fuzzy ANN Methodology

In the conducted experiment True positive are the properly detected positive Outcomes, whereas the True negatives are the properly detected negative outcomes. On the other hand False positive are improperly detected positive outcomes, Whereas the false negatives are the improperly detected negative outcomes.

When a plot is drawn for the ROC (Receiver Operating Characteristic Curve) for True Positive rates that is calculated using the Equation 6.

$$TPR = \frac{TP}{(TP+FN)} \quad \text{(6)}$$

The Obtained curve as seen in Figure 2 provides AUC of about 0.94 which is better than that of [16]. In [16] classification of Ischemic patients outcome purely depends on the Random forest classification model, whereas the proposed model works on some blended techniques using K nearest neighbor and Fuzzy ANN model. Random forest classification model increases the reach of AUC than [16], which is around 0.93.

V CONCLUSION AND FUTURESCOPE

The outcomes of the Ischemic patients are analyzed in the proposed model using the Dataset available in the UCI repository. The proposed model successfully cluster the data based on some important attributes like BMI, BP, FBS and WBC that mostly affect the outcome of the Ischemic Stroke patients using the k Nearest Neighbor technique. Linear regression plays a vital role in the estimation of the quality data of the clusters. Fuzzy ANN eventually form the entitled neurons, which are used by the Random forest classification model to unleash the best outcome of survival of the Ischemic Stroke patients.

The authenticity of the proposed model is evaluated using the models like AUC, which yield a good value of around 0.94.

In the future this model can be enhanced to work on other diseases like liver Diseases, heart attack and many more using deep learning models.

REFERENCES

[1] Y. Udovychenko, A. Popov, I. Chaikovsky, "Ischemic Heart Disease Recognition by k-NN Classification of Current Density Distribution Maps", IEEE 35th International Conference on Electronics and Nanotechnology, 2015.

[2] W. Omar, N. Fuad, M. Taib, R. Jailani, R. Isa, Z. Mohamad, Z. Sharif, "Brainwave Classification for Acute Ischemic Stroke Group Level Using k-NN Technique", Fifth International Conference on Intelligent Systems, Modelling and Simulation, 2014.

[3] A. Vrtkov´a, "Predicting Clinical Status of Patients After an Acute Ischemic Stroke Using Random Forests", The International Conference on Information and Digital Technologies, 2017.

[4] T. Kodama, K. Kamata, K. Fujiwara, M. Kano, T. Yamakawa, I. Yuki, and Y. Murayama, "Ischemic Stroke Detection by Analysing Heart Rate Variability in Rat Middle Cerebral Artery Occlusion Model", IEEE Transactions on Neural Systems and Rehabilitation Engineering, Vol. 26, No. 6, June 2018.

[5] R. Tao, S. Zhang, X. Huang, M. Tao, J. Ma, S. Ma, C. Zhang, T. Zhang, F. Tang, J. Lu, C. Shen and X. Xie, "Magneto cardiography based Ischemic Heart Disease Detection and Localization using Machine Learning Methods", IEEE Transactions on Biomedical Engineering, 2018.

[6] C. Zizzo, A. Hassani, and D. Turner, "Automatic Detection and Imaging of Ischemic Changes During Electrocardiogram Monitoring", IEEE Transactions on Biomedical Engineering, Vol. 55, No. 3, March 2008.

[7] F. Tianxiang, Z. Qiujie, C. Zhiju, and D. Yunli, "Model of Environmental Reason Analysis and Prevention of Stroke on Linear Regression", 11th International Conference on Computational Intelligence and Security, 2015.

[8] S. Gupta, A. Mishra and Menaka, "Ischemic Stroke Detection using Image Processing and ANN", IEEE International Conference on Advanced Communication Control and Computing Technologies, 2014.

[9] W. R. W. Omar, Z. Mohamad, M. N. Taib, and R. Jailani, "ANN Classification of Ischemic Stroke Severity using EEG Sub Band Relative Power Ration", IEEE Conference on Systems, Process and Control (ICSPC 2014), 12 - 14 December 2014, Kuala Lumpur, Malaysia, 2014.

[10] G. Sahoo, S. Ari and S. Patra, "ECG signal analysis for detection of Cardiovascular abnormalities and Ischemic episodes", IEEE Conference on Information and Communication Technologies, 2013.

[11] I. Grigore, G. Diaconu1, A. Mania and I. Ciomaga, "Ischemic Stroke by Multi-factorial Cause in Children", The 6th IEEE International Conference on E-Health and Bioengineering - EHB 2017.

[12] H. Tong, W. Wang and X. Lu, "Alternating Projection Algorithm of Linear Regression Method with Convex Constraint in Cerebral Stroke Patients' Psychological Analysis", International Seminar on Future Bio-Medical Information Engineering, 2008.

[13] H. Kuang, B. Menon and W. Qiu, "Segmenting Hemorrhagic and Ischemic Infarct Simultaneously from Follow-UpNon-Contrast CT Images in Patientswith Acute Ischemic Stroke", IEEE Access, 2019.

[14] Gisela De La Fuente-Cortes, A. Diaz-Mendez, Victor R. Gonzalez-Diaz, "A Fully Integrated Fuzzy Logic Algorithm for Ischemic Heartbeat Classification", 25th IEEE International Conference on Electronics, Circuits, and Systems (ICECS), 2018.

[15] A. Yahiaoui and A. Bessaid, "Segmentation of Ischemic Stroke Area from CT Brain Images", International Symposium on Signal, Image, Video, and Communications (ISIVC), 2016.

[16] Miguel Monteiro, Ana Catarina Fonseca, Ana Teresa Freitas, Teresa Pinho e Melo, Alexandre P. Francisco,Jos´e M. Ferro, and Arlindo L. Oliveira "Using Machine Learning to Improve the Prediction of Functional Outcome in Ischemic Stroke Patients ", DOI 10.1109/TCBB.2811471, IEEE, 2018.