

Analysis And Comparison Of Ventricular Cardiac Arrhythmia Classification Using Sodium Channel Parameters With ANN And KNN Classifier

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ABSTRACT

Aim: Aim of this research is to analyze and compare ventricular Cardiac Arrhythmia (CA) classification using Sodium Channel (Na^+) parameters with Artificial Neural Network (ANN) and K-Nearest Neighbour (KNN) classifiers. **Materials and Methods:** Ten Tusscher Human Ventricular Cell Model (THVCM) (data) is used for arrhythmias classification. THVCM has well defined sodium (Na^+) channel dynamics. Sample size was calculated by keeping threshold 0.05, G Power 80%, confidence interval 95% and enrolment ratio as 1. Number of samples considered is 20 for each analysis and will be imported to the classifier, K-Nearest Neighbour (KNN) and Artificial Neural Network (ANN) classifier to find better accuracy. Finally, the results (accuracy) will be validated by using Statistical Package for the Social Science (SPSS) software. **Result:** Ventricular normal, tachycardia and bradycardia data are fed into novel ANN and KNN classifiers. The results obtained from classifiers for 20 samples are fed to SPSS. In that ANN shows accuracy of 35.6% with standard deviation (3.17822) and Standard error mean (0.71067). Similarly KNN produces an accuracy value of 18.05% with standard deviation (1.19593) and Standard error mean (0.26739). **Conclusion:** As per the results, it clearly shows that the novel ANN has better accuracy for classification than KNN.

Keywords

Ventricular Cardiac Arrhythmia, Sodium Ion, Sodium Channel, Novel ANN and KNN Classifiers, Action Potential, Bradycardia, Tachycardia.

Imprint

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INTRODUCTION:

Cardiac Arrhythmia (CA) can be called an unjustified electrical activity pattern which differs from the normal electrical activity. More advanced studies in cardiac patterns have witnessed many more types of CA (Antzelevitch and Burashnikov 2011). Majority of the cardiac failures occur in the ventricles chamber, because of the improper contraction and enlargement of the heart to pump the blood. Arrhythmias like bradycardia are defined as heart beats <60 beats per minute whereas tachycardia is about >100 beats per minute. More specifically, cardiac voltage gated sodium channel is more responsible for proper electrical conduction in the heart. Na^+ causes disturbances during the conduction process which may lead to the Ventricular Cardiac Arrhythmia (VCA). In Spite of studying the characteristics of the Na^+ , not many studies have been made targeting the treatment procedure specifying the Na^+ channel (C. A. Remme and Wilde 2014). Na^+ has been the leading cause of CA. Voltage gated sodium channel is very important in Action Potential (AP) and heart contractions. They are transmembrane proteins activated by membrane potential and lead to transient influx in Na^+ (de Lera Ruiz and Kraus 2015). The major reason is inability of the Na^+ to close completely or at the exact time which actually lead to prolongation of ventricular cardiac arrhythmia and in some special and extreme cases leads to brugada syndrome (dangerous irregular heartbeat at the ventricles) which will lead to death (de Lera Ruiz and Kraus 2015). When inactivation of Na^+ channel does not occur properly a certain amount of current of about 0.5% stays in the myocytes without leaving which is called late I_{Na} . This current stays because Na^+ did not activate properly. I_{Na} current indirectly changes the value of AP duration (APD) which leads to sustainable entry of depolarising Na^+ . The changes disturbs the other channels like K^+ in their process (Mangold et al. 2017). The applications of this study is wide because Cardiac sodium channel protein is an multimeric channel consisting of α and an auxiliary β -subunit genes which are connecting the sodium channels is cloned and sequenced. Any dysfunction in the Na^+ will alter the cur-

rent and inactivation process causing QT syndrome (fast heartbeats) and many other complications (Grant 2005). In this research paper we will study more details about the Mechanism of sodium channel, how sodium channel is involved in the Cardiac health, and the model is obtained by calculating in novel ANN and KNN classifiers the result obtained discusses about the type of Arrhythmia namely Tachycardia and Bradycardia. ventricular cardiac arrhythmia occurring by sodium channel which creates more awareness and identifies the exact cause of the arrhythmia. (Carol Ann Remme and Bezzina 2010). This sodium channel dysfunction can cause life – threatening conditions and arrhythmia disorder when these channels are in dysfunction any prescribed drugs for channel modification can produce greater risk to the patients when not identified correctly (Smits et al. 2008). Our team has extensive knowledge and research experience that has translated into high quality publications (Chellapa et al. 2020; Lavanya, Kannan, and Arivalagan 2021; Raj R, D, and S 2020; Shilpa-Jain et al. 2021; S, R, and P 2021; Ramadoss, Padmanaban, and Subramanian 2022; Wu et al. 2020; Kalidoss, Umapathy, and Rani Thirunavukkarsu 2021; Kaja et al. 2020; Antink et al. 2020; Paul et al. 2020; Malaikolundhan et al. 2020)

This topic about Ventricular CA in Na^+ channel is researched widely in the last 5 years (2016 – 2021) (according to Google Scholar \approx 17800 articles) in which PubMed have published 202 articles and Sciencedirect have published 623 articles in the current year (2021). Voltage gated sodium channel is a major complex structure consisting of various α and β subunits with numerous protein patterns these will be connected directly or indirectly with the genetic functions. Any dysfunction and loss or gain of sodium ions will lead to diseases like Brugada syndrome (dangerous irregular heart beat), long QT syndrome (expansion of QT interval), sick sinus syndrome (inability of pacemaker to make proper heartbeat) (Savio-Galimberti, Argenziano, and Antzelevitch 2018). The sodium current I_{Na} initializes the AP by depolarising the Membrane Potential (MP) (V_m) from -60mV to +40mV. In milliseconds the Na^+ depolarises and allows K^+ current to repolarize. When Na^+ does not inactivate properly a measurable current of about 0.5% persists in the myocyte known as late or persistent I_{Na} (Savio-Galimberti, Argenziano, and Antzelevitch 2018; Mangold et al. 2017). Sodium channel antagonism which is a treatment procedure for CA by preventing the re entry of the electrical impulse that

could lead to myocardial damage. Which is now seen as an off-target in pharmacology that attenuates during the mutation process (Jenkinson et al. 2018). According to me this article seems to be more accurate and specific. Sudden Cardiac death is the leading cause of cardiovascular mortality. Cardiac voltage gated sodium channel is important for proper electrical conduction. Altered Na^+ causes conduction disturbances and CA. Na^+ are highly reactive to metabolic and physiological factors including intracellular calcium levels, extracellular protons and pH (Jenkinson et al. 2018; C. A. Remme and Wilde 2014).

Since it is hard to explore the human heart system continuously to get human trial information and examination (CA). However, in animal studies, CA examination is conceivable. We can't prefer creature information that there are numerous varieties in the AP attributes when contrasted with human AP. The elective method to examine such CA is through computational methodology. Aim of this research is to analyze and compare ventricular Cardiac Arrhythmia (CA) classification using Sodium Channel (Na^+) parameters with Artificial Neural Network (ANN) and K-Nearest Neighbour (KNN) classifiers.

MATERIALS AND METHODS

This research is worked out in the Digital Signal Processing laboratory in the department of Biomedical Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences. The research analysis is carried out in a single group with different sodium parameter conditions. Sample size was calculated by keeping threshold 0.05, G Power 80%, confidence interval 95% and enrolment ratio as 1. Number of samples considered is 25 for each analysis. This paper's dataset was obtained from Matlab. It contains about 25 samples each which are labeled as Normal, Bradycardia and Tachycardia (Tusscher et al. 2004). The parameters used to identify the accuracy are Voltage, Current and Activation Gate of the channels.

The values for the sodium channels are obtained by alternating the values from normal (140mM). Initially the Normal value is obtained later the values for 50% decrease (70) and 100% increase (280mM) is obtained. This is done for the Extracellular Sodium Channel. It is observed that there is a decrease in AP distance (APD) when the value is decreased to 50% which means the number of heart beats per minute increases which leads to Tachycardia. When the value

is increased 100% the number of heart beats decreases per minute which leads to Bradycardia. Based on this the dataset is tabulated in Microsoft Excel sheet and imported to the classification learner. Model type is selected as KNN and ANN

$$C_m(dV/dt) = -(I_{ion} + I_{stim}) \quad (1)$$

C_m is the Membrane Capacitance (MC) (μF), dv/dt is Membrane Potential (MP) (mV), I_{ion} is total ionic current (pA), I_{stim} is stimulation current (pA) as given in Equation (1).

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \quad (2)$$

Equation (2) is used to find the accuracy using the confusion matrix obtained from the classifiers individually. Using SPSS software finally we are calculating the group statistics containing the mean, standard deviation and standard error mean.

Artificial Neural Network

ANN is termed as a biological human brain which contains up to 60 trillions of interconnected sets of neurons to perform network patterns. It is based on the idea of connecting very simple interconnected neurons that act as a single processor. For dealing with complex datas it requires more patterns and processes (Farizawani et al. 2020). Generally in our research, it helps in connecting with the immediately preceding or succeeding datas. A confusion matrix for the classifier is obtained which summarizes the data into simple matrix format. From which the accuracy of the network is calculated.

K-Nearest Neighbor

KNN is a simple and more effective classifier in many cases. It is a non-parametric classification method. Main work of the KNN is to classify the unlabeled data and assemble them to the most similarly labeled data (Zhang 2016). The use of KNN in our research paper is, it collects the data to our labeled parameters like Normal, Bradycardia and Tachycardia. A confusion matrix is obtained to summarize the dataset which is imported based on the KNN classifiers algorithm. From this the Accuracy is calculated as number of all correct prediction divided by all other outcomes

Statistical Analysis

For the statistical approach, the software tool used in our research is IBM SPSS Statistics 28.0.0.0. The in-

dependent sample test (t) was performed to identify the mean, standard deviation and the standard error mean statistical significance between the groups. The comparison of the two groups, one from the sample data from KNN and other from the ANN are labeled as group 1 and group 2. The SPSS software will give the accurate values for the two different algorithms (KNN & ANN) which will be represented with the graph to calculate the significant value with maximum accuracy value 18.05, standard deviation of about 1.19593 and Standard error mean is 0.26739 in KNN. And accuracy value 36.60, Standard deviation of about 3.17822 and Standard error mean is 0.71067 in ANN (Tusscher et al. 2004).

RESULTS

Figure 1 (a) represents the normal ECG pattern when all the ion channels are in normal state the APD remains normal which indicates good cardiac health.

Figure 1 (b) represents the abnormal ECG pattern of about 100% increase in the sodium channel the APD expands which increases the time for beating which leads to Bradycardia of about <70 beats per minute.

Figure 2 represents one sample confusion matrix of ANN Sample sets which shows the data into simplified matrix format. This matrix represents the True Positive, True Negative, False Positive and False Negative.

Figure 3 represents one sample confusion matrix for KNN sample sets which simplifies the 25 samples it to a 3*3 matrix which represents the True Positive, True Negative, False Positive and False Negative.

Figure 4 shows detection of the ventricular Cardiac Arrhythmia whether Normal, Bradycardia and Tachycardia which classifier produces better accuracy in KNN or ANN From Fig. 4 it is concluded the ANN produces better results when compared to KNN. The accuracy of KNN is 18.05% whereas ANN is 35.6%.

Table 1 depicts the accuracy obtained for sodium channels by ANN and KNN. 20 sample data were loaded in SPSS for analysis. Table 2 Represents the group statistics of the accuracy rate of the two novel ANN and KNN classifiers, their mean, standard deviation and standard error mean.

Table 3 Represents the independent t test data obtained from the SPSS software which compares the novel ANN and KNN classifiers and checks if the data is different.

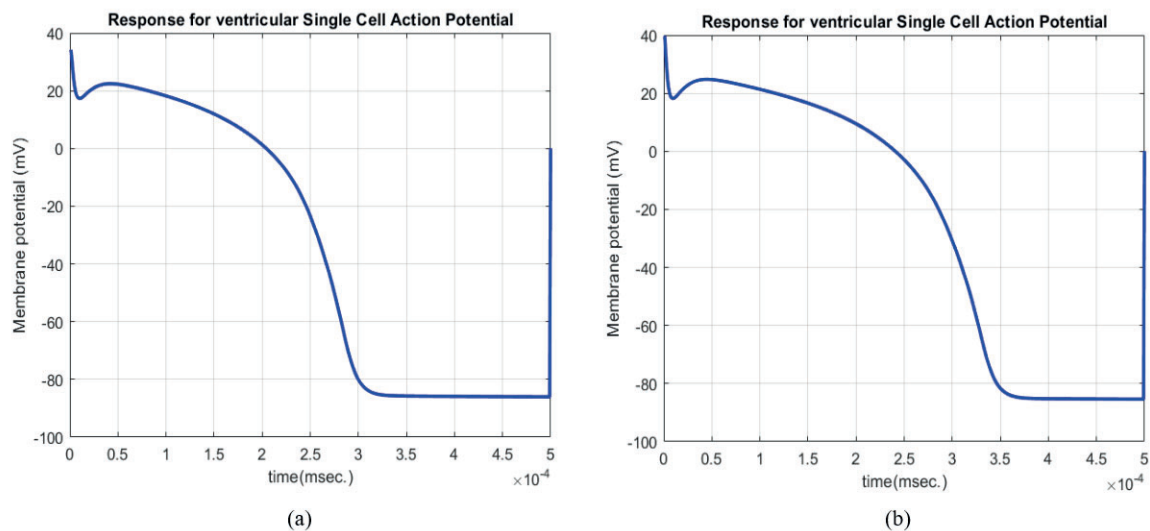


Fig. 1. (a) Normal AP of single ventricular cell at Extracellular Na⁺ concentration of 140mM. (b) AP of single ventricular cell at Extracellular Na⁺ concentration of 280mM. Abnormal cardiac activity which occurs when the sodium ion is increased by 100% (280mM) the AP distance is at 3.8×10^{-4} m/sec.

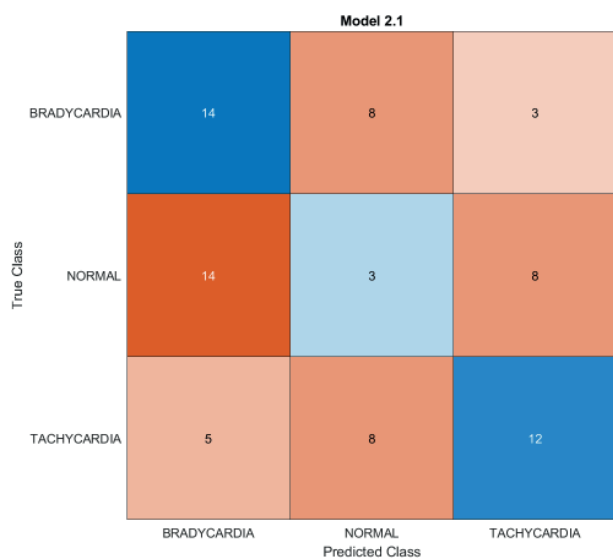


Fig. 2. Confusion Matrix of Artificial Neural Network (ANN)

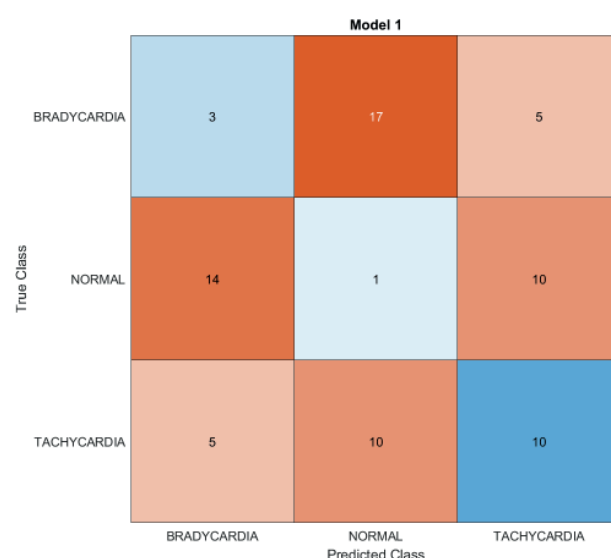


Fig. 3. Confusion Matrix of K-Nearest Neighbor (KNN)

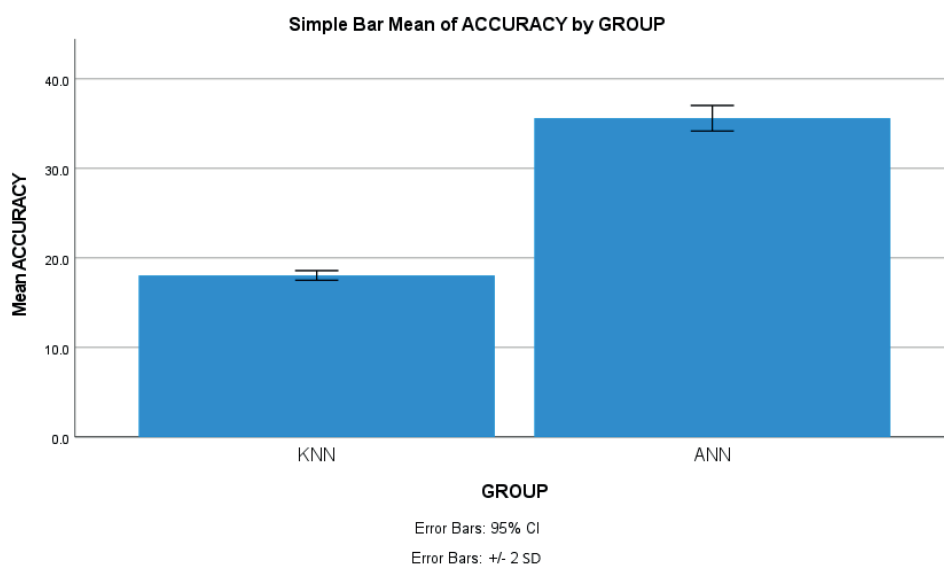


Fig. 4. Output of the mean accuracy rate of accuracy rate of the two groups Artificial Neural Network (ANN) and K-Nearest Neighbor (KNN). X axis: Artificial Neural Network (ANN) and K-Nearest Neighbor (KNN); Y axis: Mean accuracy rate SD+/-2.

Table 1

Accuracy obtained for sodium channel by Artificial Neural Network (ANN) and K-Nearest Neighbor (KNN). 20 sample data were loaded in SPSS for analysis.

S.No	ACCURACY OBTAINED THROUGH ANN FOR SODIUM CHANNEL	ACCURACY OBTAINED THROUGH KNN FOR SODIUM CHANNEL
1	18.7	30.7
2	20	36
3	18.7	34.7
4	21.3	40
5	18.7	32
6	17.3	32
7	17.3	36
8	18.7	33.3
9	17.3	36
10	17.3	37.3
11	17.3	38.7
12	20	40
13	17.3	37.3
14	17.3	36
15	17.3	28
16	17.3	36
17	17.3	36
18	17.3	37.3
19	17.3	40
20	17.3	34.7

Table 2

Group statistics of the accuracy rate of the two groups Artificial Neural Network (ANN) and K-Nearest Neighbor (KNN), their mean, standard deviation and standard error mean. ANN produces better results when compared to KNN. The accuracy of KNN is 18.05% whereas ANN is 35.6%

GROUP STATISTICS

	Group	N	Mean	Std. Deviation	Std. Error Mean
Accuracy	KNN	20	18.0500	1.19583	0.26739
	ANN	20	35.6000	3.17822	0.71067

Table 3

Independent Sample t test which compares the two independent groups (KNN and ANN). The data was statistically significant between the two groups.

Independent Sample Test										
		Levene's Test for Equality of variances		T-test for Equality of Means						
		F	Sig.	t	df	Sig (2.tailed)	Mean diff	Std. diff error	5%confidence interval of the difference	
									Lower	Upper
ACCURACY	Equal variances assumed	8.643	0.006	-23.113	38	<.001	<.001	-17.5500	.7593	-19.0871
	Equal variances not assumed			-23.113	24.274	<.001	<.001	-17.5500	.7593	-19.1162

DISCUSSION

The Fig. 1 (a) shows the action potential of a normal cardiac (140mM) activity where the AP distance is at 3.2×10^{-4} m/sec and Fig. 1 (b) shows the action potential of abnormal cardiac activity which is occurred when the sodium ion is increased by 100% (280mM) the AP distance is at 3.8×10^{-4} m/sec. Na^+ channel has been a substrate in mutations in antiarrhythmic drugs. Which occurs during the action potential and leads to insufficient time to recover and abbreviation of diastole period and many other complications. The changes in the APD when the value of the sodium channel changes abruptly. Which leads to Bradycardia and Tachycardia. Figure 2 is a confusion matrix of ANN classifiers which is represented in a 3x3 matrix format. Experimental results show the number of Normal, Tachycardia and Bradycardia in terms of True Positive (TP), True Negative (TN), False Positive (FP) and False Negative (FN).

It is a classifier which has been used in a variety of fields like business and scientific disciplines during the past few years. This works similarly to the brain and neurons (Grant 2009; "Artificial Neural Networks" 2003). Figure 3 is a confusion matrix of KNN from 20 sample data obtained represented in a 3x3 matrix format. It shows the values of Normal, Tachycardia and Bradycardia representing TP, TN, FP and FN. This is the most simplified and arguably used approach of all supervised learning. This method simply chooses the "k" value and identifies the nearest neighbors to classify the data (Ebbels 2007). Figure 4 represents the SPSS graph with two groups KNN and ANN at X axis and accuracy at Y axis. It consists of Error bars at 95% CI which means it has a confidence limit of 95% and only 5% of it is not included into the error bar. It is a software used for data management and software

analysis. It helped researchers in revolutionizing the updated versions which helped to conduct complicated statistical analysis on big datasets ((Ebbels 2007; Frey 2017). Table 1 represents the accuracy of ANN and KNN classifiers for sodium channels. Table 2 consists of the data obtained from the SPSS software and shows that in our study we are concluding that ANN produces better results when compared with KNN. ANN gives accuracy of 35.6%, standard deviation of about 3.17822 and Standard error mean is 0.71067. KNN gives an accuracy value of 18.05%, standard deviation of about 1.19593 and Standard error mean is 0.26739. Table 3 represents the independent t sample which is a parametric test data obtained from the SPSS software to compare the groups ANN and KNN it helps in identifying the mean of two groups, mean of two intervention and mean of two change scores (Grant 2009).

The disadvantage of our result is, though ANN produces better accuracy of 35.6% it is still less accurate compared to many other classifiers like fuzzy classifier and Naive bayes classifier which produces higher accuracy than ANN and KNN.

Future Works will include researching more sodium ion channels and its contribution to the cardiac pattern and accuracy rate of many other classifiers will be compared and studied about them. And many more real life samples can be collected and studied to apply it in real life.

CONCLUSION

The conclusion exhibits that between ANN and KNN, in which the ANN classifier has the highest values. The Accuracy Rate of ANN classifier accuracy is 35.6% and KNN algorithm has an accuracy rate of 18.05%. The Precision and Recall of ANN Algorithm is efficient when compared with KNN.

DECLARATIONS

Conflict of Interests

No conflict of interest in this manuscript.

Authors Contributions

Author GBM was involved in literature survey in mathematical models, Euler integration matlab code development, Arrhythmia analysis and manuscript writing. Author SN involved in conceptualization, data validation and critical review of manuscript.

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