

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

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## ABSTRACT

**Aim:** Aim of this research is to analyze and compare ventricular cardiac arrhythmia classification using calcium channel parameters with Artificial Neural Network (ANN) and K- Nearest Neighbour (KNN) classifier. **Materials and Methods:** For the classification of arrhythmias, A.V.Panifilov (AVP) is used. THVCM contains well defined Calcium channel dynamics and its properties. 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 such as K-Nearest Neighbour (KNN) and Artificial Neural Network (ANN) classifiers to find better accuracy. Finally, the results (accuracy) will be validated by using Statistical Package for the Social Science (SPSS) software. **Results:** The results obtained from Normal, Tachycardia and Bradycardia data are imported to the ANN and KNN classifier. In which KNN shows accuracy value (12.3950%), standard deviation (0.96490) and Standard error mean (0.21576). And ANN shows accuracy value (35.3400%), standard deviation (3.22285) and Standard error mean (0.72065). **Conclusion:** From the results, it is concluded that ANN produces better results when compared with KNN classification in terms of accuracy.

## Keywords

Ventricular Cardiac Arrhythmia, Calcium Ion, Calcium Channel, Novel ANN and KNN Classifiers, Action Potential.

## Imprint

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## INTRODUCTION

Cardiac Arrhythmia (CA) is a condition in which normal rhythm of the heart is disturbed. Normal rhythm is called the Sinus Rhythm. CA is an initialization of cardiac excitation, abnormal propagation of the waves, or any combinations (Fenton, Cherry, and Glass 2008). Blood circulation is important in the body which completely depends on the electrical activity of the heart. Any disturbances in these cardiac waves leads to CA. In almost 20 years research about Calcium ions and Calcium channels has been carried out. It plays a very important role in cardiac Action Potential (AP) (Rougier and Abriel 2016). Calcium ions are intracellular signaling ions. They work on regulating the excitation and contraction, in many activities of the enzymes and ion channels. Any change or increase in the  $\text{Ca}^{2+}$  leads to cytotoxicity which is syndrome of sudden death combining Brugada Syndrome and short QT interval in ECG pattern (Grant 2009). On the basis of National health Interview Survey in the year 2017, Record says nearly 2,813,503 resident deaths were registered in a year, which exceeds the survey taken in the year 2016 which is nearly 69,255 deaths. This includes all types of cardiovascular diseases (particularly CA). This increasing rate can be reduced when the diagnosis is done priorly (Virani et al. 2020). To understand and study about these CA, one needs knowledge about the ionic contributions to the cardiac action potential. In this article, the voltage gated calcium channel being a cause of ventricular Cardiac Arrhythmia is reviewed (Tse 2016) from the year 1949, many studies have been developed about mechanisms of the heart rhythm, this has led to many identification of multiple families of ionic currents (Delisle et al. 2004).

In this topic related to Ventricular Cardiac Arrhythmia and calcium channel many studies have been undergone during the last 5 years ( $\cong 17300$  as per google scholar). PubMed have published 30 articles and Sciencedirect have published 12 articles in the current year (2021). Changes in ion channels through ion channels in myocardial cell membrane is a leading cause of CA. There are three main reasons for the occurrence of tachycardia: they are disturbance of normal automaticity, early or late depolarisation and Re-entry mechanism (Borchard and Hafner 2000). Generation of action potential happening throughout the heart results in disturbance in the cell membrane. These ion

channels reduce the energy required to move through the lipophilic cell membrane. It has two fundamental properties such as ion permutation and gating (Grant 2009). Including rhythmicity and contractility, ion channels play a major role. They target cardiac physiology like fibrillation and angina as well as off-target cardiac side effects of development of drugs (Birgit T Priest 2015).  $\text{Na}^+$  and  $\text{Ca}^{2+}$  are the basics of all cardiac functions like excitability, generating rhythm, coordinating and controlling contractions. 20-25% of the death occurs because of the dysfunction in the cardiac ion channels and some because of the direct defects in the gene of the ionic channels. This study is the best study in my opinion because ion channels have become a major reason in the biomedical field as mediators for electrical signals in nerve, muscle, and endocrine cells and are modulated by hormones. Any dysfunction is the massive reason for death and prime drug targets. Because of numerous studies like this  $\text{Na}^+$  and Calcium ion channels are now ready to use as an effective method to prevent cardiac arrhythmias and excitability diseases (Fozzard 2002). Our team has extensive knowledge and research experience that has translate 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 Thirunavukkarasu 2021; Kaja et al. 2020; Antink et al. 2020; Paul et al. 2020; Malaikolundhan et al. 2020)

Since it is difficult to research the human cardiac system in real time to get human experimental data and research prediction (CA). But in animal studies, CA analysis is possible. We cannot prefer animal data because there are many variations in the AP characteristics when compared to humans AP. The alternative way to analyze such CA is through a computational approach. Aim of this research is to analyze and compare ventricular cardiac arrhythmia classification using calcium channel parameters with Artificial Neural Network (ANN) and K- Nearest Neighbour (KNN) classifier.

## 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 calcium parameter conditions. Sample size was calculated as threshold 0.05, G Power 80%, confidence interval 95% and enrolment ratio as 1 ((Birgit T Priest 2015)).

Number of samples considered is 25 for each analysis. In this research 25 samples are considered for analyzing the results. The dataset is obtained for the default normal value of calcium (2), by decreasing the value by 50% (1 mM) and by increasing the value by 100% (4mM). For each three parameters are considered voltage, current and activation gate. The samples are imported to classification learner and trained with two classifiers; they are Novel Artificial Neural Network (ANN) and K-Nearest Neighbour (KNN) (Yamaguchi 2013). The confusion matrix is obtained which gives the simple details about the accuracy of the network.

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

$C_m$  is the Membrane Capacitance ( $\mu\text{F}$ ),  $dv/dt$  is Membrane Potential (mV),  $I_{ion}$  is total ionic current (pA),  $I_{stim}$  is stimulation current as given in Equation (1).

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

This equation (2) is the mathematical equation used to identify the Using SPSS software. Finally we are calculating the group statistics containing the mean, standard deviation and standard error mean.

## Artificial Neural Network

ANN classifier is inspired from the human nervous system. It is a powerful tool to handle complicated data. It is mainly used to identify the hidden data which cannot be seen or calculated manually. It has been widely used in areas like climatic and environmental research areas which require storing large amounts of data (Zhang 2018). In our research it helps in connecting before and after datas and when training this data confusion matrix is obtained in which the accuracy value of different fold cross validation for 25 different samples is obtained and tabulated.

## K-Nearest Neighbor

KNN classifier is mostly used in biomedical signal analysis. By comparing the training sets with given sets that are similar. When this classifier is given to a sample set this will intend the most nearest training set that is stored in the data of the unknown sets. The

K-Nearest neighbor represents the K which is the sample point and “NN” which is the nearest neighbor of the unknown samples (“Human Activity Recognition Using Machine Learning Methods in a Smart Healthcare Environment” 2020). In our research it helps in identifying the abnormal sample data compared with the normal sample data. Which distinguishes the set of samples into Normal, Tachycardia and Bradycardia. This is trained and the confusion matrix is obtained which simplifies the sample data into matrix format.

## Statistical Analysis

To analyze the accuracy and other statistical comparison the product apparatus used in our research is IBM SPSS Statistics 28.0.0.0. The independent sample test (T) was performed to recognise the mean, standard deviation and the standard error mean statistical significance between the groups. On comparing the samples obtained from the two classifiers K-Nearest Neighbor and Artificial Neural network. The SPSS software will give the accurate values for the two different algorithms Novel KNN & ANN which will be utilized with the graph to calculate the significant value with maximum accuracy value 12.3950, standard deviation of about 0.96490 and Standard error mean is 0.21576 in K – Nearest Neighbor. And Artificial Neural Network has accuracy value 35.3400, standard deviation of about 3.22285 and Standard error mean is 0.72065 (Birgit T Priest 2015)).

## RESULTS

Figure 1 (a) and Figure 1 (b) Figure 1 (a) addresses the typical ECG design when all the ions are in ordinary condition the APD distance stays ordinary which shows great cardiovascular wellbeing. Figure 1 (b) addresses the abnormal ECG pattern of about 100% increment in the calcium channel the APD distance extends which decreases the number of beats per minute which prompts Bradycardia of about <70 beats each moment.

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

Figure 3 represents one sample confusion matrix for KNN sample sets which works on the 25 samples which is simplified to a 3\*3 grid which addresses 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 creates better exactness in accuracy from KNN and ANN. From Fig. 1 it is decided ANN produces better results when compared to KNN. The accuracy of KNN is 12.395% whereas ANN is 35.34%.

Table 1 Represents the accuracy obtained for calcium channels by ANN and KNN. 20 sample data were loaded in SPSS for analysis

Table 2 It addresses the group statistics of the accuracy rate of the two groups ANN and KNN classifiers, their mean, standard deviation and standard blunder mean.

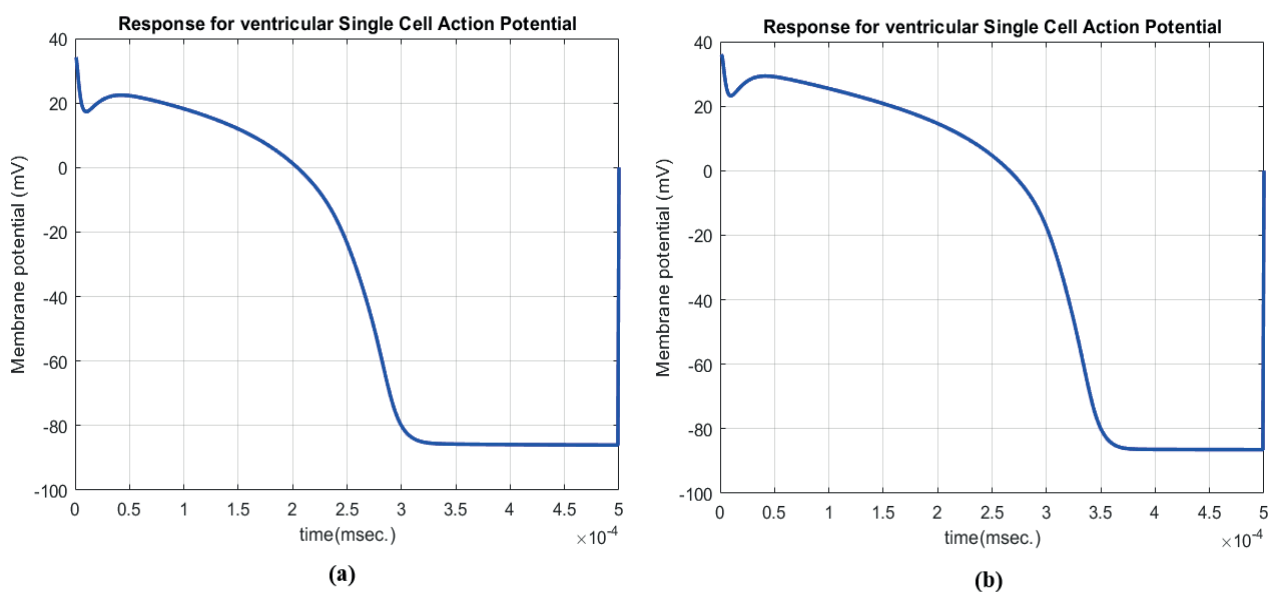


Fig. 1. (a) Represents Normal ECG pattern when the Calcium channel value is normal (2mM). (b) Abnormal ECG pattern when the Calcium channel value is increased by 100% (4mM)

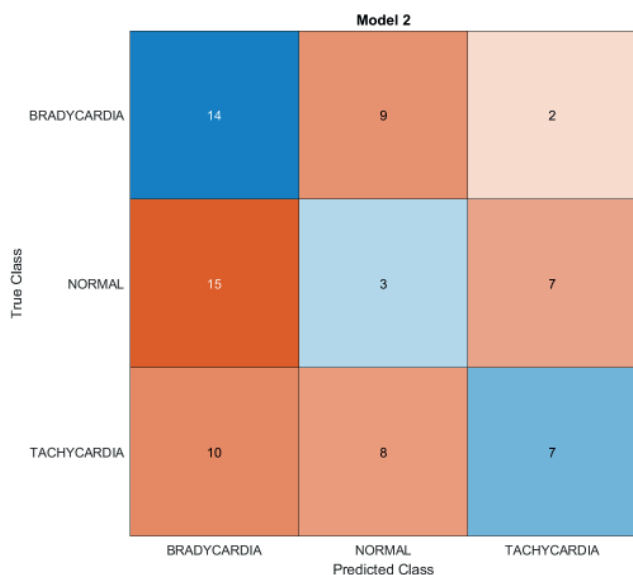


Fig. 2. Confusion Matrix of Artificial Neural Network (ANN)

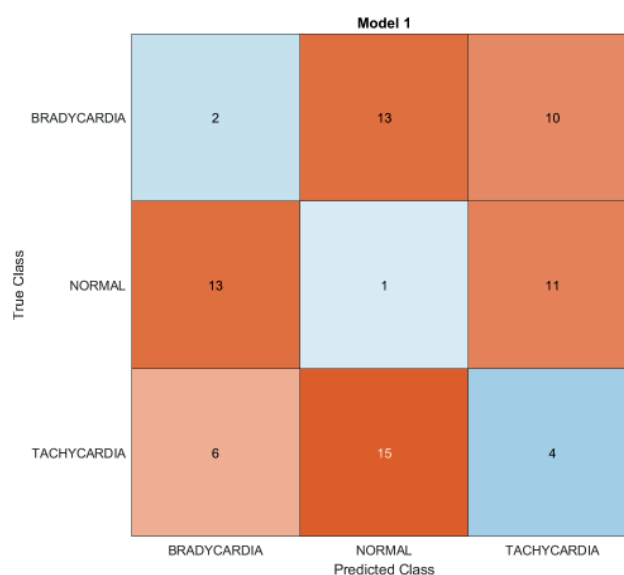


Fig. 3. Confusion Matrix of K-Nearest Neighbor (KNN)

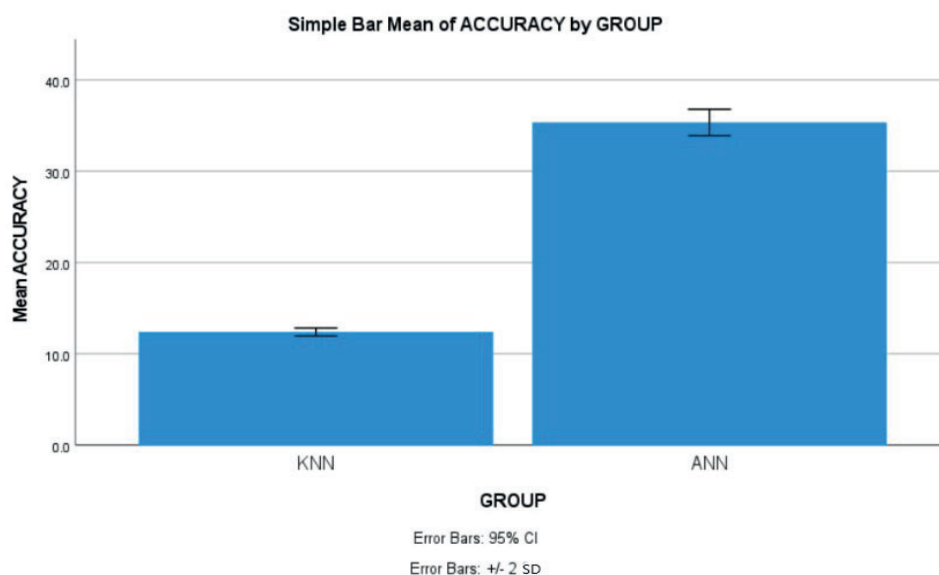


Fig. 4. Mean accuracy rate of accuracy rate of the two groups Artificial Neural Network (ANN) and K-Nearest Neighbor (KNN). X axis: Artificial Neural Network (ANN) and K-Nearest Neighbor (KNN); Y axis: Mean accuracy rate SD+/-2.

Table 1

Accuracy obtained for calcium 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 CALCIUM CHANNEL	ACCURACY OBTAINED THROUGH KNN FOR CALCIUM CHANNEL
1	10.7	38.7
2	13.3	34.7
3	13.3	37.3
4	13.3	33.3
5	13.3	37.3
6	17.7	32
7	10.7	32
8	12	32

S.No	ACCURACY OBTAINED THROUGH ANN FOR CALCIUM CHANNEL	ACCURACY OBTAINED THROUGH KNN FOR CALCIUM CHANNEL
9	12	38.7
10	12	32
11	12	26.7
12	12	34.7
13	13.3	38.7
14	12	37.3
15	12	34.7
16	12	36
17	13.3	38.7
18	12	36
19	12	38.7
20	12	37.3

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.

GROUP STATISTICS

	Group	N	Mean	Std. Deviation	Std. Error Mean
Accuracy	KNN	20	12.3950	0.96490	0.21579
	ANN	20	35.3400	3.22285	0.72065

Table 3 It represents the independent t sample obtained from the SPSS software that compares the differences between KNN and ANN classifiers.

## DISCUSSION

Figure 1 (a) represents the normal AP of the heart rhythm with proper activation and deactivation of the ion channels ( $\text{Ca}^{2+}$  ions is 2) the APD distance is at  $3.2 \times 10^{-4}$  m/sec and Fig. 1 (b) represents the abnormal AP rhythm pattern when the value of the  $\text{Ca}^{2+}$  ions is increased by 100% (4mM) this indicated a rise in APD distance of at  $3.6 \times 10^{-4}$  m/sec. The  $\text{Ca}^{2+}$  ions act as an intermediate to various types of cardiac arrhythmia. There are many complications when  $\text{Ca}^{2+}$  ion is disturbed like gene defects including catecholaminergic polymorphic ventricular tachycardia, congenital long QT syndrome, and hypertrophic cardiomyopathy. There will be an increase or decrease in the APD distance which leads to Tachycardia and Bradycardia respectively.

Figure 2 represents the confusion matrix of the ANN classifier which represents the True Positive (TP), True Negative (TN), False Positive (FP) and False Negative (FN) of the given data set in a simplified 3X3 matrix. This ANN is a non-linear mapping function based on the functions of the human brain. It is

nowadays used in almost all the fields like aerospace, automotive, banking, defense, electronics, entertainment, financial, insurance, manufacturing, medical, oil and gas, speech, securities, telecommunications, transportation, and environment ((Landstrom, Dobrev, and Wehrens 2017; "Artificial Neural Networks" 2008) . Figure 3 represents the confusion matrix obtained after training the KNN classifier. It represents the numbers of normal, tachycardia and bradycardia in a 3x3 matrix. This is a very simple approach which is completely non – parametric. Number of neighbors is usually fixed by using the cross fold validation. The K value will be fixed and based on the k value nearest neighbours will be identified and classified ("Discrimination and Classification" 2010). Figure 4 represents the SPSS software output after analyzing the T independent sample a groups statistics is obtained containing the accuracy of the two groups and comparison between them In our study Statistical Package for Social Science (SPSS) is the software used here to calculate the accuracy of the two classifiers. Using SPSS software we are identifying that the ANN produces better results when compared with KNN (Landstrom, Dobrev, and Wehrens 2017). Where accuracy of KNN is 12.3950%, standard deviation of about 0.96490 and Standard error mean is 0.21576. And ANN has accuracy value 35.3400%, standard deviation of about 3.22285 and Standard error mean is 0.72065. Probability and statistics has been the most important and studied discipline nowadays and in future, SPSS software is very helpful in parameter estimation, hypothesis testing, analysis of variance, regression analysis, mathematical statistics, and most areas of the calculation of probability theory (Yang, Yuan, and Feng 2011). Table 3 represents the independent t sample

Table 3

Independent t sample test for different groups KNN and ANN to check whether their associated population means are significantly different ( $p=0.001$ ).

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	18.483	<.001	-30.502	38	<.001	-22.9450	.7523	-24.4679	-21.4221
	Equal variances not assumed			-30.502	22.379	<.001	-22.9450	.7523	-24.5036	-21.3864



which compares the accuracy of two groups ANN and KNN classifiers associated statistical data are significantly different. This is a parametric test.

Although ANN produces better results than KNN it produces about 35.3400% accuracy which is considerably less compared to other types of classifiers. This is seen as a disadvantage in this research. More number of new classifiers like decision tree and Fuzzy classifiers can be used for better results.

Using SPSS software we are identifying that the ANN produces better results when compared with KNN. Where accuracy of KNN is 12.3950%, standard deviation of about 0.96490 and Standard error mean is 0.21576. And ANN has accuracy value 35.3400%, standard deviation of about 3.22285 and Standard error mean is 0.72065.

Future Works will incorporate exploring more ionic channels and its commitment to the cardiovascular dysfunctions and exactness of numerous different classifiers will be analyzed and learned. Furthermore, a lot more real dataset examples can be gathered and accuracy can be calculated to use it better in real life.

## CONCLUSION

The conclusion exhibits the Novel ANN and KNN, in which the ANN classifier has the highest values. The Accuracy Rate of ANN Algorithm is 35.3400% higher compared with KNN algorithm that has an accuracy rate of 12.3950%. 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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