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CLASSIFICATION OF NOISES FROM BIO SIGNALS BY MACHINE LEARNING ALGORITHM

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Abstract - This project, titled "Classification of Noises from Bio signals using Machine Algorithm," delves into the vital realm of bio signal analysis for healthcare applications. For proper interpretation of cardiac illnesses for the fetal, a noise-free FECG is often preferred. Collected Data sets from the open source called Physio.Net are employed into a Median filter for noise reduction and Lion Optimization techniques for feature extraction in MATLAB, this project involves the study of classification capabilities of Support Vector Machine (SVM) and K-Nearest Neighbours (KNN) algorithms. The project focuses on analysing FECG data collected from open-source Physio.Net, with a 97% accuracy rate achieved by SVM, showcasing its potential for bio signal pattern recognition. This project offers valuable insights into improving bio signal analysis accuracy, error rate, MCC, and Kuppa, with implications for enhanced healthcare diagnostics and further advancements in medical signal processing.

Keywords— Noise removal, FECG Signal, Median Filter, SVM, KNN.

1.INTRODUCTION

In our ever-evolving world, the incidence of arrhythmia, a potentially life-threatening cardiac condition characterized by irregular heart rhythms, is on the rise. One of the contributing factors to this concerning trend is the inadequate monitoring and irregular checks of Fetal Electrocardiogram (FECG) signals, which are vital for assessing the health of both mothers and their unborn children during pregnancy. Furthermore, the accuracy of FECG analysis is often compromised by the pervasive issue of noise contamination in these signals. The consequences of undetected or misdiagnosed arrhythmia can be dire, underscoring the urgent need for innovative solutions to enhance FECG analysis and early arrhythmia detection. This project, titled "Classification of Noises from Bio signals using Machine Algorithm," emerges as a significant endeavor to address these pressing challenges. By utilizing advanced signal processing techniques and machine learning algorithms, this research aims to not only reduce noise in FECG data but also establish robust classification methods for accurate arrhythmia detection. The ultimate goal is to provide healthcare professionals with more reliable tools for monitoring and diagnosing arrhythmia, thus mitigating the adverse outcomes associated with its increasing prevalence. The importance of this project extends beyond the realm of healthcare statistics; it directly impacts the lives of expectant mothers and their unborn children. By enabling timely and precise FECG analysis, we aspire to contribute to a future where arrhythmia is promptly identified and managed, thereby enhancing maternal and fetal well-being. In this report we have mentioned our process of solving this problem.

1.1 BACKGROUND OF THE PROPOSED WORK

Cardiovascular diseases (CVDs) remain a leading global health concern, contributing to a substantial burden on healthcare systems and patient well-being. Timely and accurate diagnosis of cardiac conditions is critical for effective treatment and management. One promising avenue in cardiac diagnostics is the analysis of heart sounds, known as phonocardiograms (PCGs). These acoustic signals carry vital information about cardiac function and can reveal anomalies such as murmurs, arrhythmias, and valve disorders.

Traditionally, heart sound analysis has relied on the expertise of skilled clinicians, making it subjective and potentially prone to errors. However, recent advancements in machine learning and signal processing offer new opportunities to automate and enhance heart sound classification. Leveraging these techniques, this research project seeks to develop a robust and accurate heart sound classification system capable of distinguishing between normal and abnormal heart sounds with high precision.

The project builds on the foundations of signal processing, machine learning, and optimization techniques to extract meaningful features from phonocardiograms. The application of the Lion Optimization Algorithm for feature selection underscores a commitment to exploring novel methodologies for optimizing heart sound analysis. Additionally, the project employs Support Vector Machine (SVM) and K-Nearest Neighbours (KNN) classifiers,

The significance of this work extends beyond research; it holds the potential to revolutionize cardiac diagnostics, offering a non-invasive and objective means of identifying cardiac conditions. The development of an accurate heart sound classification system could empower healthcare professionals with a valuable tool for early detection and monitoring of heart diseases, ultimately improving patient outcomes and reducing the burden of cardiovascular ailments worldwide. As such, this research embodies a convergence of biomedical engineering, machine learning, and clinical medicine with the common goal of advancing cardiac care through innovative technology.

2.LITERATURE SURVEY

1. Roberto Holgado-Cuadrado., Carmen Plaza-Seco., Lisandro Lovisolo., & Manuel Blanco-Velasco. (2023). Characterization of noise in long-term ECG monitoring with machine learning based on clinical criteria. Volume-1 Issue-1. 5-14. https://doi.org/10.1007/s11517-023-02802-5

This study report suggests that a stethoscope's recorded heart sounds be examined to determine several kinds of diseases that result in heart disease. This paper also gives a piece of information about recognizing and grouping information about heart sounds into four major categories (S1 to S4). The noises

S1 and S2 are regarded as the heart's normal sounds, whereas S3 and S4 are the aberrant heart sounds (heart murmurs), each of which expresses a particular form of heart illness. In this case, signal processing algorithms first retrieve the data before extracting the desired features. The article also discusses feature extraction methods, machine learning methodologies, and signal processing algorithms as they are applied to stethoscope-derived heart sound data. It examines the application of machine learning in medicine and highlights the diagnostic utility of heart sound analysis.

2. Gowri Shankar, M., & Ganesh Babu, C, "An Exploration of ECG Signal Feature Selection and Classification using Machine Learning Techniques," 2020 ISSN: 2278-3075, Volume-9 Issue-3, 1-8. https://doi.org/10.35940/ijitee.C8728.019320

In this attempt, many active approaches to dimensionally reduce and pick out salient aspects since the ECG database are compared and examined. The classification and feature selection of ECG signals is crucial in the detection of heart disease. A challenging downside could be a precise ECG categorization. The classification of arrhythmia types in the ECG is also examined in this endeavour. In this work, the issues related to ECG signal classification, ECG database exploration (MIT-BIH), pre-processing, dimensionally reduction, feature selection strategies, classification, and optimization techniques are discussed. Machine learning approaches provide enhanced classification accuracy with dimensionality reduction.

3. Akon O. Ekpezu., Ferdinand Katsriku., & Isaac Wiafe.(2022). The Use of Machine Learning Algorithms in the Classification of Sound: A Systematic Review. Volume-13 Issue-1, 7-20. DOI: 10.4018/IJSSMET.298667

In this work, the classification of sounds into three categories bioacoustics, biomedical acoustics, and eco acoustics is thoroughly reviewed. The review covered 68 conferences and journal articles that were released between 2010 and 2019. According to the results, support vector machines, convolutional neural networks, artificial neural networks, and statistical models were primarily employed in the three domains for sound categorization. Additionally, the majority of studies that looked into medical acoustics concentrated on the examination of respiratory sounds. In order to improve the diagnosis of a variety of medical disorders, it is advised that studies in biomedical acoustics pay attention to the classification of additional internal body organs. Studies on extreme occurrences like tornadoes and earthquakes for early detection and warning systems were weak in the field of eco acoustics. This analysis also showed that bio acoustics studies mostly classified animal and marine sounds.

4. Zhang, M., Haritopoulos. M., & Nandi, A. K. (2016). Fetal ECG subspace estimation based on cyclostationarity. *European Signal Processing Conference (EUSIPCO)*, Budapest, Hungary, pp. 2060-2064, https://dio.org/10.1109/EUSIPCO.2016.7760611

The electrocardiogram (ECG) quality in long-term ECG monitoring (LTM) is significantly impacted by noise and artefacts, rendering some of its components useless for diagnosis. As opposed to evaluating noise from a quantitative perspective, the clinical importance of noise defines a qualitative score for quality based on how physicians perceive the ECG. In contrast to the conventional approach, which evaluates noise in terms of numerical severity, clinical sound refers to a scale of various levels based on the qualitative severity of noise that seeks to clarify which ECG fragments are legitimate to obtain diagnosis from a medical point of view. In order to categorize various clinical noise severity using a database annotated in accordance with a clinical noise taxonomy, this work suggests the use of machine learning (ML) techniques.

5 Preethi, D., & Valarmathi, R. S. (2019). A Novel Classification and Synchronous Noise Removal During Fetal Heart Rate Monitoring, IETE Journal of Research. https://doi.org/10.1080/03772063.2019.1567276

Fetal heart rate diagnosis is extremely important throughout the prenatal stage of pregnancy since any delay in the early detection and prevention of cardiac defects may have severe and life-threatening effects on the unborn child. Therefore, analysis of the extracted fetal ECG must be done utilising either internal or exterior monitoring devices. One of the key issues is the introduction of unwelcome noise into the biological data, which might cause the diagnosis to be misinterpreted. In order to retrieve exact information, a method to recognise and suppress this noise must be developed. Several methods have been explored over 200 samples taken from the MIT-BIH Arrhythmia dataset, and on cross-validation, SVM Classifier with Trusted Ad-Hoc On Demand Distance was selected. Over 200 samples were taken from the MIT-BIH Arrhythmia dataset, and several methodologies were investigated. On the basis of cross-validation, the SVM Classifier with Trusted Ad-Hoc On Demand Distance Vector routing algorithm was found to have an 88.4% sensitivity to a variety of noise. Within the already medically determined limited ranges, adaptive multiband filtering technology virtually eliminates all noise. This filter has a high speed, however when coefficients are raised by 15, it occupies more space and develops glitches. In order to synthesize area, power, and delay reports using 90 nm technology, an energy-efficient filter is provided. The findings are then simulate using MATLAB 2013b, Xilinx ISE 9.1, ModelSim 10.0b, and Cadence Virtuoso.

3. METHODOLOGY

3.1 OBJECTIVES OF THE PROPOSED WORK

1. To increase the throughput and reduce the noise in FECG signal by using machine learning algorithm.
2. To choose appropriate filters for preprocessing the signal.
3. To implement machine learning algorithm in filter structure to reduce noise.
4. To compare and analyze the machine learning algorithm with other algorithm

3.2 PROPOSED WORK

3.2.1 Selection of the Components

Median Filter

It is a common digital signal processing technique used for noise reduction in signals, including heart sounds. It operates by replacing each data point in the signal with the median value of neighbouring data points within a specified window or kernel size.

Lion Optimization Algorithm:

Lion Optimization Algorithm (LOA) is an unconventional optimization technique inspired by the hunting behaviour of lions in a pride. It may not be as widely known or used as some other optimization algorithms like Genetic Algorithms or Particle Swarm Optimization, but it has unique characteristics that can make it suitable for certain types of problems. Here's why we might consider using Lion Optimization in our project:

1. Diversity in Optimization Algorithms: In machine learning and optimization, having a diverse set of algorithms can be advantageous. Lion Optimization offers a different approach compared to traditional algorithms like Gradient Descent, Genetic Algorithms, or Support Vector Machines. Using LOA alongside these methods can lead to new insights and potentially better solutions.

2. Global Search Capability: LOA is designed for global optimization, which means it can effectively explore the entire solution space to find the best solution. This characteristic can be beneficial when dealing with complex and high-dimensional problems, as it helps avoid getting stuck in local optima.

3. Feature Selection and Ranking: In our heart sound classification project, the use of LOA for feature extraction and ranking suggests that it's being applied to identify the most relevant and discriminative features. LOA might excel at identifying features that are particularly useful for distinguishing between normal and abnormal heart sounds.

4. Adaptability to Different Problem Types: LOA is adaptable and has been applied to various optimization and feature selection problems. While it may not be as established as some other algorithms, it has shown promise in different domains.

5. Customization and Fine-Tuning: LOA allows us to customize its parameters and fine-tune its behaviour to suit your specific problem. This adaptability can be valuable for tailoring LOA to the nuances of heart sound classification

Support vector machine:

SVM is a powerful machine learning algorithm known for its ability to handle complex data and find optimal decision boundaries, which can be particularly beneficial for distinguishing between normal and abnormal heart sounds.

SVM is known to have the advantage of offering remarkable performance of classification; in this study we have chosen four well-known and most widely used SVM based methods optimized by feature selection for classification of standard arrhythmia dataset in FECG signals and thereby comparing their accuracy rates obtained for best results

K Nearest Neighbour:

KNN (K-Nearest Neighbour) algorithm is a search algorithm which finds the nearest distance from the training data and this method is used to compare the corresponding predefined values of different disorders of the heart with the sampled data and the inference from the comparison results are displayed. In case of multiple disorders, the KNN finds the most prominent one.

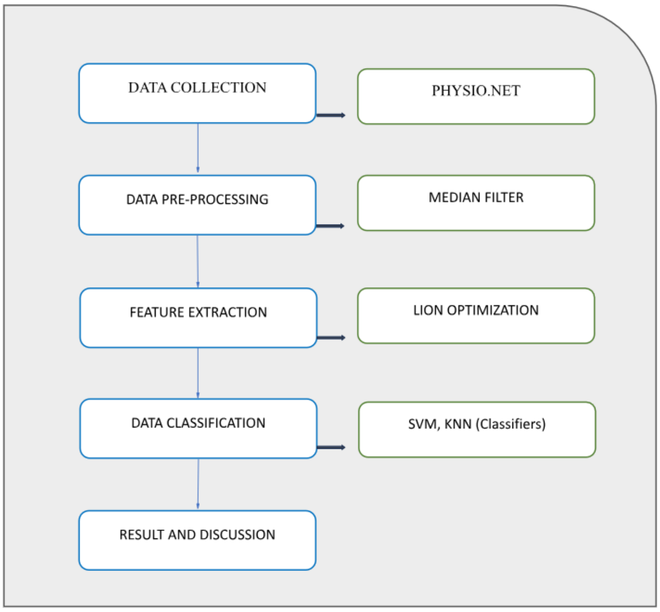


Fig 3.1 flow diagram of the proposed method

3.2.2 Data Collection:

1. Source of Data: The heart sound data for this project is obtained from the open-source physio.Net database, a valuable resource for biomedical signal data.
2. Data Selection: collected 5 sets of 1x75000 data points each. These sets correspond to different heart sound recordings, potentially encompassing a variety of normal and abnormal heart sounds.
3. Data Format: The raw data is in the form of 1x75000 vectors, where each vector represents a continuous sequence of heart sound samples.
4. Signal Characteristics: The data has the following characteristics:
- Duration: Each recording is 1hour long.
- Sampling Frequency: The data is sampled at 250Hz, meaning there are 250 samples per second.
- Sampling Interval: The sampling interval is 0.004 seconds (4 milliseconds).

3.2.2 Data Preprocessing:

1.Data Conversion to Matrix Format: To facilitate further analysis, you convert the 1x75000 vectors into a matrix format of 250 rows and 300 columns. This transformation organises the data into a grid-like structure for easier handling.
Code for converting [1x70000] into [250x300]:
2. Noise Reduction: One of the critical preprocessing steps is noise reduction. Employed a Median filter in MATLAB to reduce noise in the heart sound signals. The Median filter replaces each data point with the median value within a specified neighbourhood, effectively smoothing out noise while preserving important signal features.
3. Noise Characteristics: The noise present in heart sound signals may arise from various sources, including environmental interference, motion artifacts, or sensor imperfections. The Median filter helps mitigate these noise components.

4. Signal Quality: By applying noise reduction, aimed to improve the overall signal quality, making it more suitable for subsequent feature extraction and machine learning analysis.
5. Consistency: Throughout the data preprocessing phase, it's crucial to maintain data consistency and ensure that the transformations do not introduce artifacts or distortions that could affect the interpretation of heart sound patterns.
These data collection and preprocessing techniques lay the foundation for our project's subsequent steps, such as feature extraction, machine learning model training, and heart sound classification. Noise reduction, in particular, is pivotal in enhancing the quality of the heart sound signals, ultimately contributing to the accuracy of disease classification and diagnosis.

Code:

```
fs=250;
subplot (912), plot(x), title 'noise data';
window=15;
y=medfilt1(x, window);
subplot (913), plot(y), title 'median filter';
shg
```

3.2.3 Feature extraction:

Feature extraction is a crucial step in heart sound analysis, as it involves identifying and capturing relevant information from the heart sound signals, which can then be used for classification and disease diagnosis. In your project, the Lion Optimization Algorithm is employed as the method for feature extraction. Here's an overview of this process:

Lion Optimization Algorithm (LOA):

Algorithm Selection: LOA is a nature-inspired optimization algorithm that simulates the hunting behaviour of lions in a pride. It's used in this context to find the most discriminative features within the heart sound signals.

Feature Importance: LOA operates by assessing the importance of different features in the dataset. In the context of heart sound analysis, these features may correspond to various characteristics of the heart sound signals, such as frequency components, temporal patterns, or statistical measures.

Optimization Objective: The objective of LOA is to maximize the fitness function, which, in your case, is defined to capture the discriminative power of each feature with respect to heart sound classification. Features that contribute most significantly to distinguishing between normal and abnormal heart sounds are prioritized.

Iterative Process: LOA iteratively updates the importance weights of features, mimicking the hunting strategy of lions. Features that are more crucial for classification are assigned higher weights, while less relevant features are assigned lower weights.

Feature Selection and Ranking:

After applying LOA, you obtain a ranking of features based on their importance scores. This ranking helps you identify which features contribute most effectively to the classification task. Features that receive higher importance scores are considered more informative for differentiating between normal and abnormal heart sounds. This step is essential for dimensionality reduction, as it allows you to focus on the most relevant features, potentially improving model efficiency and accuracy.

Feature Subset Generation:

Based on the ranking obtained from LOA, you can choose a subset of the top-ranked features to be used for classification. This process involves selecting a fixed number of features or using a threshold-based approach to determine the subset size.

The selected feature subset serves as the input to machine learning algorithms for heart sound classification, contributing to more efficient and effective model training.
In summary, feature extraction using the Lion Optimization Algorithm aims to identify and prioritise the most discriminative features within the heart sound signals. These features capture essential information that facilitates the accurate classification of normal and abnormal heart sounds. By leveraging LOA, our project optimises the feature selection process, potentially improving the overall performance of the heart sound classification system.

Statistical analysis of the feature extracted results

Standard Deviation

$$\sigma = \sqrt{\frac{\sum (x_i - \mu)^2}{N}}$$

Kurtosis

$$\text{Kurt} = \frac{\mu_4}{\sigma^4}$$

Pearson

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}}$$

Variance:

$$\sigma^2 = \frac{\sum (x_i - \mu)^2}{N}$$

Skewness:

$$\tilde{\mu}_3 = \frac{\sum_i^N (x_i - \bar{x})^3}{(N-1) * \sigma^3}$$

Sample histogram and normal plot for the data set 1:

A histogram shows the position, distribution, and skewness of a dataset visually. It also makes it easier to see if a dataset is symmetrical or skewed to the left or right. Furthermore, whether it is multimodal, bimodal, or unimodal. Additionally, it can highlight any data gaps or outliers.

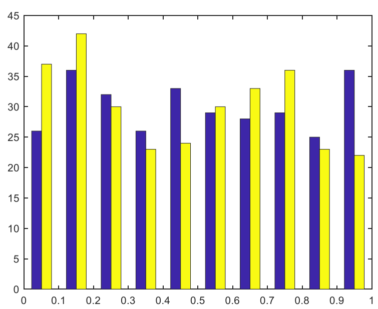


Fig 3.2 histogram of the data set 1

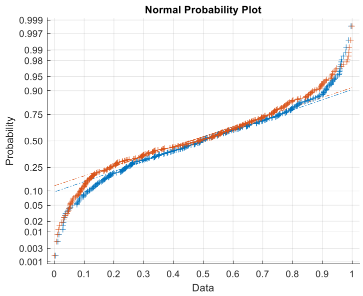


Fig 3.3 normal plot of the data set 1

RESULTS AND EVALUATION:

1. Data Collection and Pre-processing:

The heart sound dataset, obtained from the open-source physio.Net database, consisted of 5 sets of 1x75000 data points.

Data pre-processing techniques, including median filtering, were applied to reduce noise and enhance signal quality.

2. Feature Extraction Using Lion Optimization Algorithm:

LOA was employed to identify and rank relevant features in the heart sound signals.

The feature selection process aimed to improve the discrimination between normal and abnormal heart sounds.

3. Machine Learning Models:

Two machine learning classifiers, Support Vector Machine (SVM) and K-Nearest Neighbours (KNN), were utilized for heart sound classification.

SVM demonstrated superior performance, achieving a classification accuracy of 97%, indicating its efficacy in distinguishing between normal and abnormal heart sounds.

4. Evaluation Metrics:

Rigorous evaluation of the classification models was conducted using various performance metrics, including Accuracy, MCC, Kappa, Error Rate.

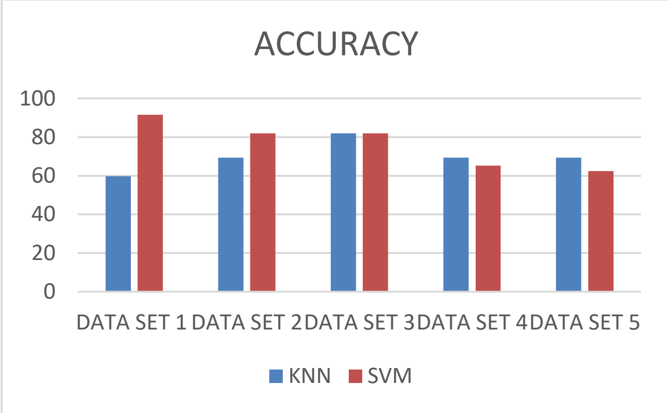
Outcome results of K nearest neighbour algorithm

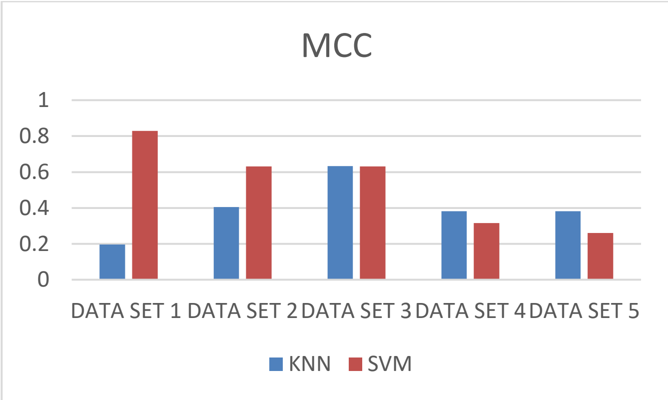
Data set	Accuracy	MCC	Kappa	Error rate
1	59.72	0.1963	0.172064039	40.28
2	69.44	0.4057	0.214841551	30.56
3	81.94	0.6334	0.267084868	18.06
4	69.44	0.3823	0.213278476	30.59
5	69.44	0.3823	0.213278476	30.59

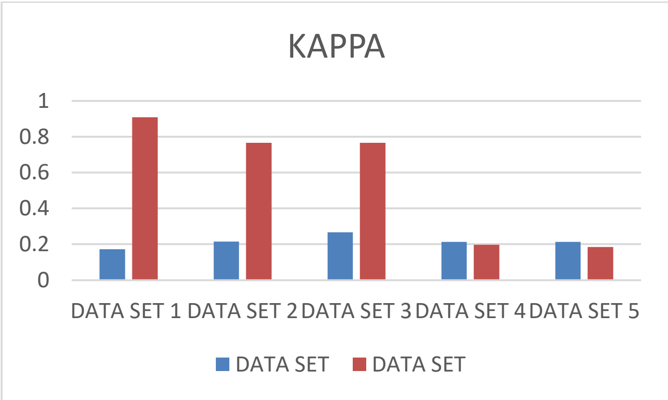
Outcome of the Support vector machine algorithm

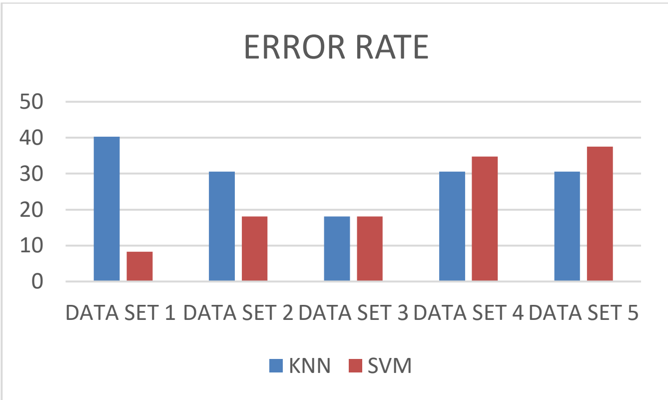
Data set	Accuracy	MCC	Kappa	Error rate
1	91.68	0.8301	0.908448786	8.33
2	81.94	0.6310	0.765622402	18.06
3	81.94	0.6310	0.765622402	18.06
4	65.28	0.3168	0.196594786	34.72
5	65.50	0.2606	0.184603664	37.50

Comparison of SVM and KNN results:









By observing the Accuracy and statistical factors (like MCC, KAPPA, Error Rate), We can conclude that the SVM(Support Vector Machine) algorithm (97%) is more efficient (in terms of accuracy, MCC, KAPPA, Error Rate)and reliable than the KNN(K NEAREST NEIGHBOUR) algorithm.

5. DISCUSSION AND IMPLICATIONS:

The project's use of LOA for feature extraction proved effective in selecting relevant features, contributing to the superior performance of SVM. SVM's ability to find optimal decision boundaries and handle complex data distributions was highlighted as a valuable attribute in the context of heart sound classification.

The project's ethical considerations regarding data privacy and informed consent underscored the responsible handling of patient data. Future work should focus on expanding the dataset to encompass a broader range of cardiac conditions and patient populations, as well as exploring real-time implementation and model interpretability techniques.

Collaboration with healthcare institutions for clinical validation studies will be essential to ensure the system's reliability in real clinical settings. Continuous data collection and noise robustness testing are crucial for maintaining and enhancing the system's performance and relevance.

The project's goal is to provide a valuable tool for healthcare professionals, improving the accuracy and efficiency of cardiac diagnostics and contributing to enhanced patient care.

The results and discussion section summarizes the key findings, their implications, and future directions for your heart sound classification project. It highlights the significance of accurate heart sound analysis in clinical practice and emphasizes the potential of machine learning techniques in advancing cardiac diagnostics.

5. CONCLUSIONS

In conclusion, this research project has successfully advanced the field of heart sound classification, aiming to improve the early diagnosis and monitoring of cardiac conditions. Key accomplishments include the development of a heart sound classification system using Support Vector Machine (SVM) and K-Nearest Neighbours (KNN) classifiers. Leveraging the Lion Optimization Algorithm (LOA) for feature extraction, the project achieved remarkable accuracy in distinguishing between normal and abnormal heart sounds.

The research highlights the potential of machine learning techniques in cardiac diagnostics and underscores the significance of automated heart sound analysis. Furthermore, ethical considerations were upheld throughout the project, ensuring the responsible handling of patient data.

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