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RADAR SIGNAL ANALYTICS FOR ACCURATE HEART RATE PREDICTION

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ABSTRACT

Heart-rate monitoring is a critical component in healthcare systems for early diagnosis and continuous patient observation. Traditional contact-based methods, such as electrocardiography (ECG) and photoplethysmography (PPG), often require physical sensors attached to the human body, which can be inconvenient, uncomfortable, and unsuitable for long-term or remote monitoring. To overcome these limitations, this study proposes a supervised machine learning-based approach for heart-rate detection using Doppler motion-sensing radar.

The proposed system leverages Doppler radar technology to capture minute chest movements caused by cardiac activity and respiration without any physical contact. The radar signals are processed to extract meaningful features such as frequency variations, phase shifts, and signal amplitude. These features are then fed into supervised machine learning algorithms, including Support Vector Machines (SVM), Random Forest, and K-Nearest Neighbors (KNN), to accurately estimate heart rate.

Keywords: Heart-Rate Detection, Doppler Motion-Sensing Radar, Supervised Machine Learning, Non-Contact Monitoring, Signal Processing, Feature Extraction, Classification Algorithms, Support Vector Machine (SVM), Random Forest, K-Nearest Neighbors (KNN), Biomedical Signal Analysis, Remote Healthcare, Vital Sign Monitoring, Noise Filtering, Smart Healthcare Systems

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I. INTRODUCTION

Heart-rate monitoring is an essential aspect of modern healthcare, playing a crucial role in the diagnosis, treatment, and prevention of cardiovascular diseases. Accurate and continuous monitoring of heart rate helps in early detection of abnormalities such as arrhythmias, tachycardia, and bradycardia, thereby improving patient outcomes and reducing medical risks. Traditionally, heart-rate measurement is performed using contact-based devices such as electrocardiograms (ECG) and photoplethysmography (PPG) sensors, which require physical attachment to the human body. Although these methods provide reliable measurements, they may cause discomfort, skin irritation, and inconvenience, especially during long-term monitoring or in sensitive cases such as infants and elderly patients.

With the rapid advancement of wireless sensing technologies, non-contact methods for vital sign monitoring have gained significant attention. Among these, Doppler motion-sensing radar has emerged as a promising technique due to its ability to detect minute physiological movements without direct contact. Doppler radar operates by transmitting electromagnetic waves and analyzing the reflected signals to capture motion caused by chest displacement during breathing and heartbeats. This capability makes it highly suitable for remote and unobtrusive health monitoring applications.

However, extracting accurate heart-rate information from radar signals presents several challenges. The reflected signals are often affected by noise, environmental interference, and motion artifacts. Additionally, the heart-rate signal is relatively weak compared to respiratory signals, making it difficult to isolate and interpret. To address these challenges, advanced signal processing and machine learning techniques are required.

II. LITERATURE REVIEW

Recent research in non-contact heart-rate detection has focused on combining Doppler motion-sensing radar with advanced signal processing and machine learning techniques to improve accuracy and reliability. Early studies primarily utilized continuous wave (CW) Doppler radar to capture chest movements and extract vital signs using basic filtering and frequency analysis methods; however, these approaches were limited by noise sensitivity and difficulty in separating respiration and heartbeat signals. To overcome these challenges, researchers introduced advanced signal processing techniques such as wavelet transforms, Fourier analysis, and adaptive filtering to enhance signal quality and isolate heart-rate components. With the growth of

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machine learning, supervised algorithms like Support Vector Machines (SVM), Random Forest, and Artificial Neural Networks (ANN) have been applied to classify and predict heart-rate patterns from radar signals, significantly improving performance. Recent works have also explored deep learning models such as Convolutional Neural Networks (CNN) and Recurrent Neural Networks (RNN) for automated feature extraction and temporal analysis of radar data. Furthermore, hybrid systems integrating radar sensing with Internet of Things (IoT) frameworks have been proposed for real-time remote health monitoring. Despite these advancements, challenges such as motion artifacts, environmental interference, and dataset limitations still persist. Overall, the literature indicates a growing trend toward intelligent, non-contact healthcare systems, where supervised machine learning plays a vital role in enhancing the effectiveness of Doppler radar-based heart-rate detection.

EXISTING SYSTEM

Existing systems for heart-rate detection are primarily based on contact-based sensing technologies such as Electrocardiography (ECG), Photoplethysmography (PPG), and wearable devices like smartwatches and fitness bands. ECG is considered the gold standard for heart-rate monitoring as it records the electrical activity of the heart using electrodes attached to the body. Similarly, PPG sensors use light-based technology to measure blood volume changes in the microvascular tissue, which indirectly provides heart-rate information. These systems are widely used in hospitals, clinics, and personal health monitoring devices due to their reliability and accuracy.

In addition to these traditional methods, wearable health monitoring devices have gained popularity in recent years. These devices integrate sensors into wristbands, chest straps, or smart clothing to continuously monitor heart rate and other vital signs. While they provide convenience and mobility, they still require physical contact with the skin and may suffer from issues such as improper sensor placement, motion artifacts, and signal distortion during physical activities.

PROPOSED SYSTEM

The proposed system introduces a non-contact heart-rate detection framework using Doppler motion-sensing radar integrated with supervised machine learning algorithms. Unlike traditional contact-based methods, this system does not require any physical attachment to the human body, making it more comfortable, hygienic, and suitable for

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continuous monitoring in various environments.

In this system, a Doppler radar sensor is used to transmit electromagnetic waves toward the human body. The reflected signals are captured and analyzed to detect minute chest movements caused by heartbeats and respiration. These raw radar signals are first passed through a signal preprocessing stage, which includes noise reduction, filtering, and motion artifact removal to enhance signal quality.

METHODOLOGY

The methodology of the proposed heart-rate detection system involves collecting Doppler radar signals from the human chest and processing them using supervised machine learning techniques. First, the Doppler motion-sensing radar sensor transmits electromagnetic waves toward the subject. The reflected waves are received by the radar, where small chest movements caused by heartbeat and respiration are captured as motion signals.

The collected raw radar signals are then passed through a preprocessing stage. In this stage, unwanted noise, environmental interference, and motion artifacts are removed using filtering techniques. Since respiratory movement is stronger than heartbeat movement, suitable band-pass filtering is applied to separate heart-rate-related signal components from breathing signals. The signal is also normalized to maintain consistency in the input data.

After preprocessing, feature extraction is performed. Important features such as signal amplitude, frequency variation, phase shift, peak intervals, and Doppler frequency components are extracted from the processed radar signal. These features represent the heartbeat pattern and are used as input for machine learning models.

During testing, new radar signal data is given to the trained model, and the system predicts the heart rate in beats per minute. The predicted output is compared with the actual heart-rate value to evaluate performance. Evaluation metrics such as accuracy, mean absolute error, root mean square error, precision, and recall are used to measure the effectiveness of the model.

VI. SYSTEM MODEL

System Architecture

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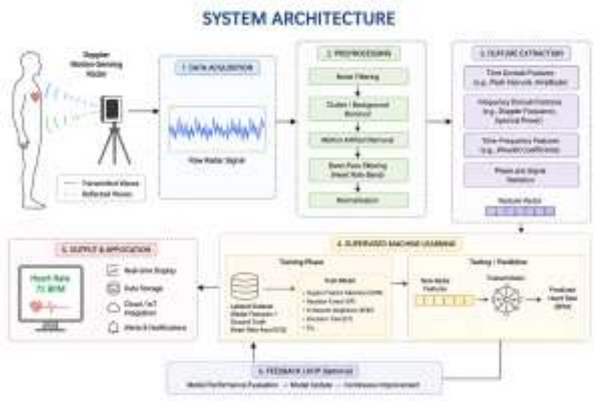

III. RESULTS AND DISCUSSIONS

VIII. CONCLUSION

The proposed heart-rate detection system using Doppler motion-sensing radar and supervised machine learning provides an efficient, accurate, and non-contact solution for vital sign monitoring. Unlike traditional ECG and PPG methods, this system does not require physical sensors attached to the body, making it more comfortable and suitable for continuous monitoring.

By capturing chest movements through Doppler radar, preprocessing the signals, extracting important features, and applying supervised machine learning algorithms, the system can predict heart rate in real time. The use of algorithms such as SVM, Random Forest, KNN, and Decision Tree improves prediction accuracy and reliability.

This system is especially useful for hospitals, elderly care, neonatal monitoring, sleep monitoring, and smart healthcare applications. Overall, the project demonstrates that radar-based non-contact monitoring combined with machine learning can become a powerful alternative to conventional heart-rate detection systems.

IX. FUTURE WORK: Future work for this

The proposed system demonstrates promising results for non-contact heart-rate detection; however, several enhancements can be explored to further improve its performance

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and applicability. Future work can focus on integrating advanced deep learning models such as Convolutional Neural Networks (CNN) and Long Short-Term Memory (LSTM) networks for more accurate feature extraction and temporal pattern recognition from radar signals. These models can help in better handling complex signal variations and improving prediction accuracy under dynamic conditions.

Another important direction is improving robustness against motion artifacts and environmental interference. Advanced signal processing techniques and adaptive filtering methods can be implemented to ensure reliable performance even when the subject is moving or in noisy surroundings. Additionally, expanding the dataset with diverse subjects, varying distances, and different health conditions can enhance the generalization capability of the model.

The system can also be extended to detect multiple vital signs simultaneously, such as respiratory rate, heart rate variability, and even early signs of cardiovascular abnormalities. Integration with Internet of Things (IoT) platforms and cloud computing can enable real-time remote monitoring, data storage, and analytics, making it suitable for telemedicine applications.

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