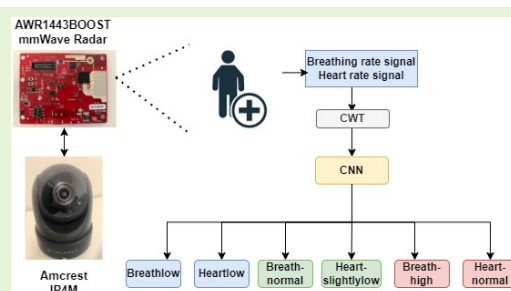


Automatic Contact-Less Monitoring of Breathing Rate and Heart Rate Utilizing the Fusion of mmWave Radar and Camera Steering System

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Abstract—The demand for noncontact breathing and heart rate measurement is increasing. In addition, because of the high demand for medical services and the scarcity of on-site personnel, the measurement process must be automated in unsupervised conditions with high reliability and accuracy. In this article, we propose a novel automated process for measuring breathing rate and heart rate with mmWave radar and classifying these two vital signs with machine learning. A frequency-modulated continuous-wave (FMCW) mmWave radar is integrated with a pan, tilt, and zoom (PTZ) camera to automate camera steering and direct the radar toward the person facing the camera. The obtained signals are then fed into a deep convolutional neural network to classify them into breathing and heart signals that are individually low, normal, and high in combination, yielding six classes. This classification can be used in medical diagnostics by medical personnel. The average classification accuracy obtained is 87% with precision, recall, and an F1 score of 0.93.

Index Terms—Breathing rate classification, breathing rate sensor, continuous wavelet transform, deep convolutional neural network (CNN), heart rate classification, heart rate sensor, machine learning, mmWave sensor.



I. INTRODUCTION

BREATHING and heart rate, blood pressure, and temperature are the four main vital signs that must be accurately measured and classified in order to diagnose a variety of diseases [1]. A respiration rate is the number of breaths taken

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TABLE I
CATEGORIZATION OF BREATHING RATE [2]

S.No.	Type	BPM(Breaths per minute)
1.	Low	Under 12
2.	Normal	12 - 25
3.	High	Over 25

TABLE II
CATEGORIZATION OF HEART RATE [3]

S.No.	Type	BPM(Beats per minute at rest)
1.	Low	< 90
2.	Slightly Low	90 - 109
3.	Normal	110 - 159
4.	High	160 - 179

in 1 min by a person. Table I shows the respiration rates as normal, low, and high. An abnormal breathing rate is an early sign of an underlying disease that necessitates prompt medical attention [1]. A pulse or heart rate, on the other hand, refers to the number of heartbeats per minute and can be classified as low, normal, slightly low, and high, as shown in Table II.

Monitoring these vital signals is critical in medical diagnosis and treatment. As a result, real-time monitoring of breathing and heart rate is essential. There are numerous methods for measuring them in the literature. However, some lack accuracy or necessitate the presence of trained personnel,