Touch-Free Vital Signs Monitoring for Burn Victims Using Radar System

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Abstract—

Touch-free vital sign monitoring is particularly useful for burn victims and critically ill patients, for whom conventional sensor attachment can cause pain, irritation, or infection. This paper presents a contactless system for real-time monitoring of respiration rate, heartbeat activity, and body temperature using non-invasive sensing techniques integrated with an embedded processing unit. The acquired signals are processed using signal conditioning and filtering techniques to reduce noise and improve measurement reliability. The proposed system is designed to be low-cost, portable, and suitable for real-time operation in burn care units, intensive care, emergency, and remote healthcare environments. By minimizing physical contact, the system provides a practical alternative to conventional monitoring methods while improving patient comfort and supporting timely medical attention.

Keywords— Touch-free vital sign monitoring, burn victims, contactless system, respiration rate, heartbeat activity, body temperature, non-invasive sensing, signal processing.

I. INTRODUCTION

Healthcare monitoring is an essential part of patient care, particularly for critically ill patients and those requiring continuous observation. Conventional monitoring systems generally use sensors, electrodes, and probes that require direct physical contact with the patient's body. Although these methods are widely used, prolonged sensor attachment can cause discomfort, skin irritation, and an increased risk of infection. These limitations are more significant for burn victims and patients with sensitive or damaged skin, where repeated attachment and removal of adhesive sensors can cause pain, wound trauma, delayed healing, and secondary infections. Therefore, there is a growing need for safe, hygienic, and comfortable monitoring techniques that can measure vital signs without direct physical contact.

Recent advancements in non-contact sensing, infrared sensing, wireless technologies, and embedded systems have enabled the development of touch-free healthcare monitoring solutions. The proposed system integrates non-invasive sensing, signal processing, real-time monitoring, and an alert mechanism to measure important physiological parameters. Heartbeat and respiration activity are detected using non-contact sensing techniques, while infrared sensing is used for body temperature measurement. The acquired signals are processed using suitable signal conditioning and filtering techniques to reduce unwanted noise and obtain reliable physiological information. The measured parameters are continuously displayed for real-time observation, and abnormal conditions activate alerts for timely medical attention. The system is designed to be low-cost, portable, and practical, making it suitable for burn care units, intensive care units, emergency healthcare, and remote patient monitoring applications. By minimizing physical contact, the proposed approach aims to improve patient comfort while supporting continuous and efficient healthcare monitoring.

The main objective of the proposed system is to provide continuous and reliable vital sign monitoring while reducing the physical interaction between the patient and monitoring equipment. The system focuses on detecting physiological changes remotely and presenting the measured parameters in an easily accessible form for healthcare personnel. This approach is particularly beneficial in situations where frequent physical interaction with the patient is difficult or undesirable. The integration of non-contact sensing with embedded processing and real-time monitoring provides a flexible solution that can support safer and more comfortable patient care.

II. LITERATURE REVIEW

In [1], Nur Ahmadi et al. (2026) presented a comparative study of signal processing and machine learning algorithms for contactless respiratory rate estimation using FMCW radar. The study investigated different approaches for extracting respiration rate from radar signals, with particular emphasis on comparing conventional FFT-based processing with machine learning techniques. The results showed that FFT combined with multichannel averaging achieved the best performance among the methods considered. This finding indicates that a relatively simple signal processing approach can provide effective respiratory rate estimation without necessarily depending on computationally complex machine learning models. The study also highlights the importance of proper signal processing and averaging techniques in improving the reliability of contactless physiological measurements. However, the work mainly concentrated on respiration rate estimation and did not address the simultaneous measurement of other important vital parameters such as heart rate and body temperature. This creates scope for developing a more comprehensive contactless monitoring system capable of measuring multiple vital signs in real time.

In [2], Laura Miro et al. (2025) evaluated radar-based cardiorespiratory monitoring under different physiological conditions using a 122.5 GHz FMCW radar. The study focused on estimating heart rate and respiration rate and examined the performance of the radar system under both normal and abnormal physiological conditions. The results demonstrated high accuracy in the estimation of the selected cardiorespiratory parameters, showing that high-frequency FMCW radar can be used for reliable contactless physiological monitoring. The study is significant because it considers variations in physiological conditions rather than limiting the evaluation to a single normal condition. However, the proposed monitoring approach was mainly focused on heart rate and respiration rate and did not include body temperature measurement as part of the same monitoring system. In addition, further evaluation involving a wider range of patient conditions would be necessary before such systems can be considered for broader healthcare applications.

In [3], Ashi Singhal et al. (2025) proposed a contactless heartbeat monitoring system using 77 GHz FMCW radar with a specific focus on reducing the effect of motion artifacts. The study combined ICEEMDAN with a multilayer perceptron (MLP) to separate useful heartbeat information from unwanted variations caused by motion. The proposed approach achieved an accuracy of approximately 82.78%, demonstrating that motion-artifact compensation plays an important role in improving heartbeat detection from radar signals. The work also shows how signal decomposition and machine learning can be combined to improve the quality of contactless physiological measurements. However, the use of ICEEMDAN and MLP introduces additional processing complexity and computational requirements. Motion artifacts also remain a major challenge for practical real-time monitoring, particularly when patients are not completely stationary. Therefore, there is a need to explore signal processing approaches that provide a suitable balance between accuracy, computational complexity, and real-time operation.

In [4], Jamal Al-Nabulsi and Jude Haddad (2024) developed a low-cost non-contact patient vital signs monitoring device using FMCW radar and infrared thermography. The system was designed to measure three important physiological parameters: heart rate, respiration rate, and body temperature. The use of FMCW radar enabled contactless detection of physiological movements, while infrared thermography provided a means of obtaining temperature information without direct physical contact. The study demonstrated that combining different non-contact sensing technologies can provide an affordable approach for monitoring multiple vital signs using a single integrated system. This approach is particularly relevant to patients for whom conventional sensor attachment may be uncomfortable or unsuitable. However, further improvements in signal reliability and validation under different patient conditions are required to establish the system's suitability for wider practical healthcare deployment.

In [5], Md. Sayzar Rahman Akash et al. (2024) proposed a contactless human vital sign monitoring system based on mmWave FMCW radar. The system combined FMCW radar for detecting physiological activity with infrared temperature sensing for non-contact body temperature measurement. An ESP32 was incorporated for real-time signal processing and data handling, demonstrating the possibility of implementing contactless vital sign monitoring on an embedded platform. The integration of sensing and embedded processing provides a useful foundation for developing portable and real-time healthcare monitoring systems. The study also demonstrates that multiple physiological parameters can be obtained using a combination of non-contact sensing technologies. However, the reliability of the acquired signals and the effectiveness of real-time processing remain important considerations, particularly when the system is used under practical healthcare conditions involving noise and patient movement.

In [6], Sonu S. Y. et al. (2024) presented a review of different contactless methods used for monitoring vital physiological parameters. The study examined a range of technologies, including mmWave radar, infrared thermography, computer vision, and artificial intelligence-based approaches. By comparing these techniques, the authors highlighted the different advantages and possibilities offered by contactless sensing for healthcare applications. The review also emphasized the potential of integrating AI with sensing technologies to improve the extraction and interpretation of physiological information. Such approaches can help reduce the limitations associated with conventional contact-based monitoring and support continuous patient observation. However, the study primarily provides a review and comparison of existing technologies rather than implementing a complete real-time multi-parameter monitoring system. Hence, there remains a need for practical systems that combine suitable sensing techniques, signal processing, embedded implementation, and real-time patient monitoring.

In [7], Jamal Al-Nabulsi and Jude Haddad (2024) developed a low-cost non-contact patient monitoring system capable of measuring heart rate, respiration rate, and body temperature. The system incorporated FMCW radar, infrared thermography, and other non-contact sensing techniques to obtain multiple physiological parameters without requiring direct attachment to the patient. The study demonstrated the feasibility of using relatively affordable sensing technologies for continuous vital sign monitoring and showed the potential of combining different sensing methods within a single healthcare platform. Such an approach can be particularly useful in situations where direct sensor attachment is difficult or uncomfortable. However, additional testing under different patient conditions and real-world healthcare environments is required to evaluate the long-term reliability and consistency of the measurements. This highlights the importance of developing a portable system with reliable signal acquisition and real-time processing.

In [8], Marco Giordano et al. (2022) presented a survey and comparative analysis of radar technologies used for embedded vital sign monitoring. The study examined different radar frequencies, including 60 GHz, 77 GHz, and 60.5 GHz systems, and investigated signal processing techniques such as Fast Fourier Transform (FFT) and Short-Time Fourier Transform (STFT). The authors showed that both the choice of radar technology and the signal processing algorithm can have a significant effect on the accuracy of physiological parameter estimation. The comparison provides useful information for selecting appropriate radar hardware and processing methods when designing embedded contactless monitoring systems. The study also demonstrates that the choice of processing technique must be considered along with the characteristics of the radar signal. However, as the work mainly focuses on surveying and comparing radar technologies, it does not present a complete multi-parameter patient monitoring platform. This leaves scope for implementing a compact system that combines radar sensing with efficient signal processing and real-time display.

In [9], Panagiota Kontou et al. (2020) developed a low-cost contactless vital sign monitoring system using a 2.4 GHz continuous-wave (CW) radar. The system used an I/Q quadrature receiver to obtain the radar signal and incorporated DC offset cancellation to reduce signal distortion. Heartbeat and respiration signals were then extracted from the received radar information. The study demonstrated that contactless vital sign monitoring can be achieved using relatively simple and low-cost radar hardware, making the approach suitable for applications where cost and implementation complexity are important considerations. The use of DC offset cancellation also shows the importance of signal conditioning in obtaining reliable physiological information from radar measurements. However, radar signals can still be affected by distortion, noise, and environmental interference, which can reduce the consistency of heartbeat and respiration detection. Therefore, additional filtering and signal processing techniques are required to improve reliability in practical monitoring conditions.

In [10], Wen-Cheng Lai (2020) developed a 24 GHz Doppler radar receiver frontend for heart rate detection using a deep neural network (DNN). The proposed system used the DNN to reduce the influence of noise and motion-related interference during heart rate measurement. This approach improved heart rate detection when the subject was moving, addressing one of the major challenges associated with contactless radar monitoring. The study demonstrates the potential of machine learning techniques to distinguish useful physiological information from unwanted signal variations and motion effects. However, the use of a deep neural network increases computational requirements and may make the overall system more complex to implement on low-cost or resource-constrained embedded platforms. For practical healthcare applications, a suitable balance between processing complexity, real-time performance, and measurement reliability is therefore required.

In [11], Marco Mercuri et al. (2018) proposed a direct phase-tracking Doppler radar system using Wavelet Independent Component Analysis (Wavelet ICA) for non-contact respiratory and heart rate monitoring. The approach used Doppler radar along with advanced signal processing techniques to improve the extraction of physiological signals from the received radar data. Wavelet ICA was applied to reduce noise and enhance the quality of the signals associated with heartbeat and respiration. The study demonstrated that appropriate signal separation and filtering techniques can significantly improve the reliability of physiological parameter extraction from contactless radar measurements. However, the use of advanced signal processing methods increases the complexity of the system and may require greater computational resources. This can become a limitation when designing compact, low-cost embedded monitoring systems intended for continuous real-time operation.

In [12], Marco Mercuri et al. (2017) proposed a frequency-tracking continuous-wave Doppler radar system to overcome null-point and signal-distortion problems encountered in contactless vital sign monitoring. The system employed a phase-locked loop (PLL) architecture together with a single-channel mixer to improve the detection of physiological signals. The proposed frequency-tracking approach helped address signal-related limitations and improved the accuracy of heartbeat and vital sign detection. The study demonstrates the importance of radar architecture and signal acquisition methods in obtaining stable physiological measurements. However, the additional hardware architecture and frequency-tracking mechanism can increase the complexity of implementation. Compared with such systems, a practical healthcare monitoring solution may benefit from simpler sensing hardware combined with effective digital signal processing.

In [13], André Gagnon (2016) presented field trial results of a millimeter-wave Doppler radar system for non-contact life-sign monitoring. The system used a 24.125 GHz Doppler radar along with real-time signal processing to detect human vital signs for safety and healthcare applications. Pattern recognition techniques were applied to the acquired radar information to identify physiological activity and extract useful life-sign information. The field trial demonstrated the feasibility of using Doppler radar for monitoring human physiological signals without requiring direct physical contact. This work provides an important foundation for the development of later radar-based contactless monitoring systems. However, improvements in signal processing, noise reduction, motion-artifact handling, and multi-parameter monitoring are required to meet the requirements of modern healthcare applications. The progression of later studies shows how radar technology has evolved toward higher frequencies, improved signal processing, and integration with embedded platforms.

III. METHODOLOGY

This literature review was carried out to examine recent developments in touch-free vital sign monitoring and to identify the technologies and signal processing techniques that can be used for monitoring patients without direct physical contact. The review was particularly focused on applications involving burn victims and critically ill patients, for whom conventional contact-based sensors may cause discomfort, skin irritation, wound trauma, or an increased risk of infection. Therefore, the review considered research works that investigated non-contact approaches for measuring physiological parameters such as heart rate (HR), respiration rate (RR), and body temperature.

The literature was selected based on its relevance to contactless physiological monitoring, radar-based sensing, non-invasive temperature measurement, and signal processing for vital sign extraction. A total of 13 research works published between 2016 and 2026 were considered in the review. The selected studies include recent developments in FMCW radar, continuous-wave (CW) Doppler radar, millimeter-wave radar, infrared thermography, and embedded monitoring systems. Earlier studies were also included to understand the development of Doppler radar-based vital sign monitoring and to observe how sensing and signal processing techniques have evolved over time. The reviewed papers were arranged from the most recent publication to the oldest study to provide a clear view of the progression of the technology.

Each selected study was examined based on four major aspects: the sensing technology used, the physiological parameters monitored, the signal processing or computational technique employed, and the major findings and limitations reported. Radar-based approaches were studied in particular because Doppler and FMCW radar can detect very small chest movements produced by respiration and heartbeat without requiring physical attachment to the patient. The review also considered infrared-based techniques because they provide a means of measuring body temperature without direct contact. Studies involving different radar frequencies, including 2.4 GHz, 24 GHz, 60 GHz, 60.5 GHz, 77 GHz, and 122.5 GHz, were considered to understand the effect of sensing technology on contactless vital sign measurement.

The signal processing techniques reported in the selected studies were also compared. Conventional methods such as Fast Fourier Transform (FFT) and Short-Time Fourier Transform (STFT) were considered along with more advanced approaches such as Wavelet Independent Component Analysis (Wavelet ICA), independent component-based methods, deep neural networks, and other machine learning techniques. Particular attention was given to methods used for noise reduction, motion-artifact removal, signal conditioning, and extraction of meaningful physiological information from radar signals. This comparison was useful in identifying the trade-off between processing complexity and the reliability of vital sign estimation. For example, the reviewed literature indicates that FFT-based processing can provide effective respiratory rate estimation in some applications, while machine learning and advanced signal decomposition techniques can help address noise and motion-related interference.

The selected studies were then compared according to their ability to support real-time and multi-parameter monitoring. Studies focusing only on heart rate or respiration rate were considered alongside systems capable of monitoring multiple parameters, including body temperature. Particular attention was given to low-cost and embedded implementations because portability and real-time operation are important requirements for practical healthcare applications. The review also considered the use of embedded platforms such as the ESP32 for signal processing and data handling, as reported in the literature.

Finally, the limitations identified across the reviewed studies were analyzed to determine the existing research gap. Common challenges observed in the literature include noise, motion artifacts, signal distortion, limited datasets, and insufficient clinical testing. In addition, several studies concentrate on a single physiological parameter, while fewer approaches provide reliable simultaneous monitoring of multiple vital signs. These observations indicate the need for contactless monitoring systems that can provide reliable physiological measurements while maintaining low cost, portability, real-time operation, and minimal physical interaction with the patient.

Based on this methodology, the literature review provides a structured comparison of existing contactless vital sign monitoring approaches and identifies the key technologies, signal processing methods, advantages, and limitations relevant to the development of touch-free monitoring systems for burn victims and other patients requiring minimal-contact healthcare monitoring.

The findings from the reviewed studies were used to guide the selection of sensing and processing techniques for the proposed system. Based on the identified advantages and limitations, emphasis was placed on non-contact sensing, effective noise reduction, real-time signal processing, and simultaneous monitoring of multiple physiological parameters. The methodology therefore focuses on combining suitable sensing technologies with an embedded processing platform to achieve a practical, low-cost, and portable monitoring solution. This approach ensures that the design decisions are supported by the observations from existing research while addressing the identified gaps in contactless vital sign monitoring.

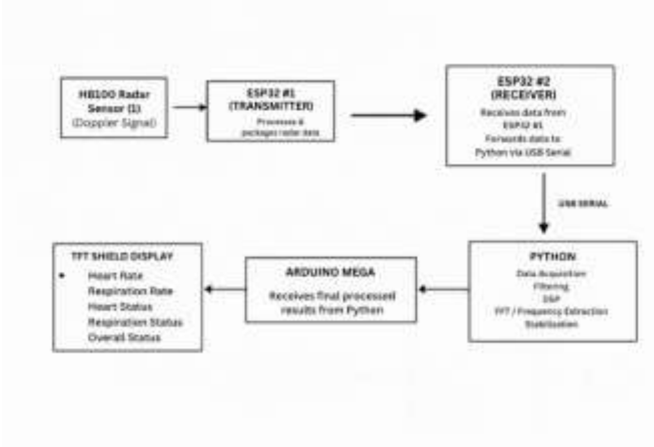

Fig. 1. Proposed system block diagram.

The proposed touch-free vital sign monitoring system consists of a radar sensing unit, wireless communication modules, a signal processing platform, and a real-time display unit. The HB100 Doppler radar sensor is used to detect the minute chest movements associated with the patient's heartbeat and respiration. The Doppler signal generated by the radar is acquired by ESP32 #1 (transmitter), which converts the acquired signal into suitable data packets and transmits them wirelessly to ESP32 #2 (receiver). The receiving ESP32 collects the transmitted radar data and forwards it to a computer through a USB serial connection for further processing. The received data is processed using Python, where data acquisition, signal filtering, Fast Fourier Transform (FFT), frequency analysis, and feature extraction are performed to reduce noise and extract the physiological information corresponding to heart rate and respiration rate. The processed results are then transferred to the Arduino Mega, which serves as the control interface for presenting the final measurements. The TFT shield display provides real-time visualization of the measured heart rate, respiration rate, individual status indicators, and overall patient status. Thus, the complete system provides a continuous flow of sensed data from the patient to the processing unit and finally to the display, enabling contactless and real-time monitoring of vital physiological parameters.

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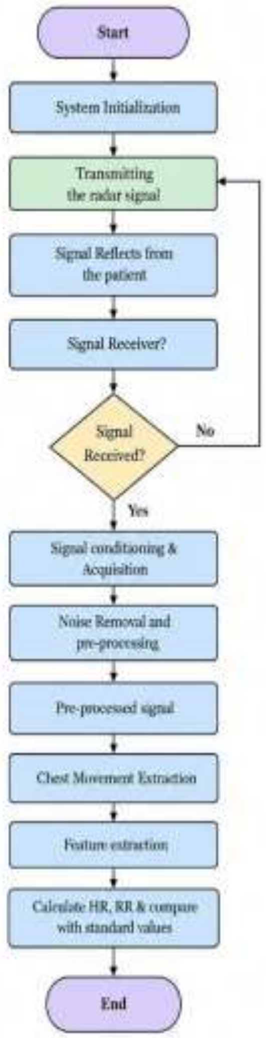

Fig. 2. Operational flow of the proposed system.

The flowchart illustrates the sequential operation of the proposed **touch-free vital sign monitoring system**. The process begins with **system initialization**, after which the radar transmits a signal toward the patient. The reflected signal containing information about the patient's chest movements is then received by the sensing unit. The acquired signal undergoes **signal conditioning and noise removal** to reduce unwanted interference and improve signal quality. The conditioned signal is further preprocessed to extract the relevant chest-movement characteristics associated with heartbeat and respiration. These features are analyzed to calculate the **heart rate (HR) and respiration rate (RR)**. The calculated values are then compared with predefined normal ranges to determine the patient's status. If an abnormal condition is detected, an alert is activated, while the measured vital-sign values are simultaneously presented on the display. This continuous flow enables real-time, contactless monitoring of the patient while minimizing physical interaction.

IV. CONCLUSION

The literature reviewed in this study demonstrates that touch-free vital sign monitoring has significant potential as an alternative to conventional contact-based patient monitoring, particularly for burn victims and critically ill patients. Traditional sensors require direct attachment to the patient's body and may cause discomfort, skin irritation, wound trauma, and an increased risk of infection. These limitations make non-contact monitoring especially valuable in situations where the patient's skin is damaged or highly sensitive. The reviewed research shows that radar-based sensing, particularly Doppler and FMCW radar, can detect the small chest movements associated with respiration and heartbeat without requiring physical contact. Infrared sensing and thermography further provide practical approaches for obtaining body temperature remotely.

The comparison of the selected studies shows that different sensing and signal processing techniques offer different advantages. FMCW and Doppler radar systems have been widely investigated for heart rate and respiration rate estimation, while infrared-based techniques are useful for temperature measurement. Conventional signal processing methods such as Fast Fourier Transform (FFT) and Short-Time Fourier Transform (STFT) provide relatively simple approaches for extracting physiological information, whereas techniques such as Wavelet ICA, signal decomposition methods, deep neural networks, and machine learning can improve signal extraction in the presence of noise and motion artifacts. However, the review also indicates that increasing processing complexity does not always provide a practical advantage, particularly for low-cost and resource-constrained embedded systems. Some studies have demonstrated that simpler techniques, when combined with suitable signal conditioning and averaging, can provide effective physiological parameter estimation.

A major observation from the reviewed literature is that noise, motion artifacts, signal distortion, limited datasets, and insufficient clinical testing remain important challenges in contactless vital sign monitoring. Patient movement can significantly affect radar signals and make it difficult to separate heartbeat and respiration components from unwanted variations. Environmental interference and signal distortion can further reduce measurement reliability. In addition, several existing studies concentrate on individual parameters such as heart rate or respiration rate, while fewer systems provide simultaneous monitoring of heart rate, respiration rate, and body temperature in a compact and practical platform. These limitations highlight the need for improved signal processing, robust sensing techniques, and better validation under realistic healthcare conditions.

Fig. 3. Comparison of conventional and touch-free vital sign monitoring.

The figure compares conventional contact-based monitoring with the proposed touch-free approach. In conventional monitoring, sensors and electrodes are directly attached to the patient’s body, which can cause discomfort, skin irritation, wound trauma, and a higher risk of infection, particularly for burn patients. In contrast, the proposed system uses non-contact sensing to remotely monitor important physiological parameters without requiring physical attachment to the patient. The figure illustrates the monitoring of heart rate, respiration rate, and body temperature, with the measured values displayed in real time. This approach reduces unnecessary physical contact while providing a more comfortable and hygienic method for continuous patient monitoring, making it particularly suitable for patients with sensitive or damaged skin.

Overall, the findings of this review support the development of low-cost, portable, and real-time touch-free vital sign monitoring systems that combine suitable non-contact sensors with efficient embedded signal processing. A system integrating radar-based heart and respiration monitoring with infrared temperature measurement could provide a more complete view of a patient's physiological condition while avoiding unnecessary physical contact. Such an approach can be particularly beneficial in burn care units, intensive care units, emergency healthcare, and remote monitoring environments. The reviewed literature therefore provides a strong foundation for further development of reliable multi-parameter contactless monitoring systems, with future research focusing on reducing motion-related errors, improving signal quality, increasing dataset size, and conducting more extensive clinical validation before widespread healthcare deployment.

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