Acoustic-based Vital Sign Monitoring

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***Abstract*—Vital sign (e.g., breathing rate) monitoring has become increasingly more important because it offers useful clues of medical conditions such as sleep disorders or anomalies. Traditional systems require a person to wear special devices, such as a pulse oximeter to monitor the breathing beats, which are inconvenient and uncomfortable, especially for the elders and infants. There is a compelling need for technologies that enable contact-free, easy deployment, and long-term vital sign monitoring for healthcare. In this paper, we present a SonarBeat system with smartphones to exploit a phase based active sonar for monitoring breathing rates caused by the rises and falls of the chest when inhaling and exhaling. We design and implement the SonarBeat system, with components including signal generation, data extraction, received signal preprocessing, and breathing rate estimation, with Android smartphones. First, the Sonarbeat system transmits an inaudible sound signal in the frequency range of 18-22 kHz by using the smartphone speaker as a continuous-wave (CW) radar. Then, the signal is reflected by the chest of the person and is then received by the microphone of the same smartphone. The received signal is then processed and the breathing signal will be recovered. Our experimental results validate the superior performance of SonarBeat in different indoor environment settings.**

I. Introduction

Currently, the smartphones can be exploited for vial sign measurement with the built in accelerometer, gyroscope [1] and microphone [2]. Usually, the smartphone needs to be placed near the body, or the person needs to wear special types of sensors that connect to the smartphone. Note that for device-free and contact-free monitoring of vital signs, attached sensors should not be used. In a recent work [3], the authors propose to use the active sonar in the smartphone by leveraging the frequency modulated continuous wave (FMCW) radar technique for breathing monitoring. However, the FMCW based technique requires an accurate estimation of the distance between the smartphone and the chest of the person, before it can monitor the respiration of the person. When the body suddenly moves (e.g., rolling over in bed), the system needs to detect the new smartphone-chest distance, thus leading to an additional time complexity.

Motivated by these interesting studies, we design SonarBeat, a robust breathing monitoring system by using active sonar phase information with smartphones [4], [5]. The SonarBeat system consists of four modules implemented in the smartphone, including signal generation, data extraction, received signal preprocessing, and breathing rate estimation in Fig. 1. First, it transmits an inaudible sound signal in the frequency range of 18-22 kHz by utilizing the smartphone speaker as a continuous-wave(CW) radar. Then, the signal is reflected by the chest of the person and is then received by the microphone of the same smartphone. The received signal is then processed and the breathing signal will be recovered. We implement SonarBeat with two different smartphones and validate its performance with extensive experiments that involve five persons over a period of three months in three different environments, including an office scenario, a bedroom scenario, and a movie theater scenario. The experimental results show that SonarBeat can achieve a low mean estimation error for breathing rate estimation, with a medium error of 0.2 bpm. we also find that SonarBeat is highly robust to different experimental parameters and settings.

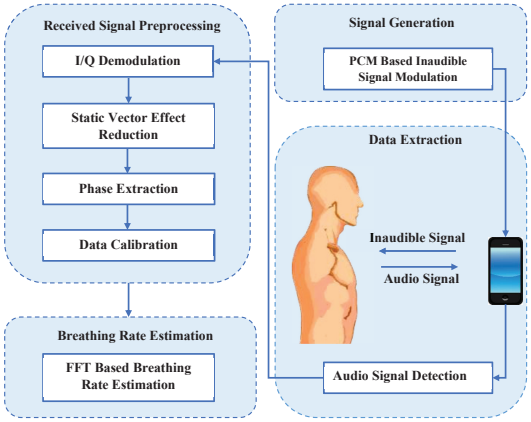

Fig. 1. SonarBeat system architecture.

Acknowledgments

This work was supported in part by the US NSF under Grants ECCS-1923163, ECCS-1923717 and CNS 2105416.

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