Demo: Real-time Breath Monitoring Using Wireless Signals

Fadel Adib Zachary Kabelac Hongzi Mao Dina Katabi Robert C. Miller
Massachusetts Institute of Technology
{fadel,zek,hongzi,dk,rcm}@csail.mit.edu

ABSTRACT

This demo presents Vital-Radio, a wireless sensing technology that monitors breathing remotely, without requiring any body contact. Vital-Radio operates by transmitting a low-power wireless signal and monitoring its reflections off the human body. It uses these reflections to track motion associated with breathing, i.e., the chest movements caused by inhaling and exhaling. The demo will enable any person to sit in front of the device and check that it tracks their inhale and exhale process. The person may hold his/her breath and check that the device detects the breath holding event in real-time.

Categories and Subject Descriptors C.2.2 [**Network Architecture and Design**]: Wireless Communication. H.5.2 [**Information Interfaces and Presentation**]: User Interfaces - Input devices and strategies.

Keywords Wireless; Vital Signs; Breathing; Smart Homes; Seeing Through Walls

1. INTRODUCTION

The past few years have witnessed a surge of interest in ubiquitous health-monitoring [4, 5]. Today, we see smart homes that continuously monitor temperature and air quality and use this information to improve the health and comfort of their inhabitants. As health-monitoring technologies advance further, one would imagine that future smart homes would not only monitor the environment, but also monitor our vital signs, such as breathing. They may use this information to track our activity level, e.g., "did the user exercise today?" or alert us to subtle health issues: "does the user breathe regularly during sleep?" If non-intrusive in-home continuous monitoring of breathing existed, it would enable healthcare professionals to study how these signals correlate with our sleep quality and our overall health, which can have a significant impact on our healthcare system.

Unfortunately, existing technologies for tracking breathing typically require body contact. In particular, they require the user to wear a chest band [6] or nasal probe [3], or to lie on a special mattress [1], and hence are inconvenient for continuous monitoring. Some recent advances can extract breathing from a video by tracking subtle chest motion [7]. While these technologies operate without body contact, they require the users to continuously face a video camera, which would interfere with their daily activities. Ideally, one would like a smart home to monitor its inhabitants' vital signs the same way it monitors air quality, i.e., without requiring the user to wear or carry a device or interrupt her natural activities.

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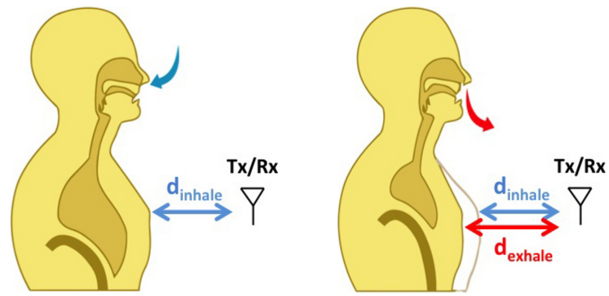

(a) **Inhale Motion** (b) **Exhale Motion**

Figure 1: Chest Motion due to Breathing. (a) shows how when the person inhales, his chest expands and becomes closer to the antenna (the distance between the chest and the antenna is d_{inhale}). (b) shows how when the person exhales, his chest contracts and becomes further away from the antenna, and the distance between the chest and the antenna d_{exhale} is larger than d_{inhale}.

In this demo, we take the first step toward smart homes that monitor people's vital signs without body instrumentation, and actively contribute to their inhabitants' well-being. The demo presents Vital-Radio a technology that tracks breathing remotely without physical contact with the body. It does so by monitoring the minute chest motion due to the inhale and exhale process as shown in Fig. 1. It works in non-controlled settings with no prior training. Further, since Vital-Radio uses wireless signals that can traverse walls and obstacles, it operates correctly even if the user is in an adjacent room or occluded by a piece of furniture.

2. OVERVIEW OF VITAL-RADIO

Vital-Radio transmits a low-power wireless signal and monitors its reflections off the human body. It processes these reflections to identify subtle periodic motions like breathing, and distinguish them from large or non-periodic movements due to a person walking or moving a limb.

To develop Vital-Radio, we built on WiTrack [2], which provides accurate motion tracking using radio reflections off a human body. WiTrack uses a frequency sweeping technique called FMCW to separate reflected signals according to the distance of the reflector from the device. WiTrack then eliminates signals reflected off static objects like furniture and walls by leveraging that such static reflections do not change over time and hence can be canceled by subtracting consecutive versions of the received signal. This leaves the system with signals reflected off moving objects and the locations of such reflectors. WiTrack processes these signals to localize a moving person and track his location over time. The accuracy of WiTrack's localization however is 10cm to 15cm. Hence, the system is too coarse to detect changes in the chest position due to breathing.

Vital-Radio builds on WiTrack and operates in three steps. In the first step, Vital-Radio uses WiTrack to eliminate reflections from

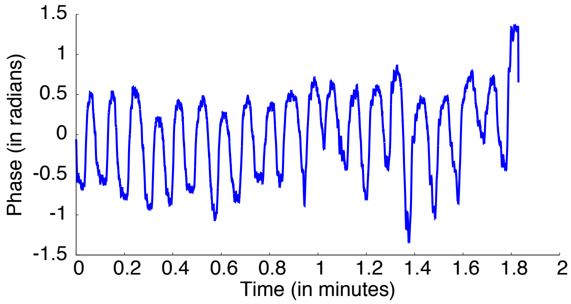

Figure 2: Breathing Motion. The figure shows the breathing motion of a person in terms of the phase.

static objects (e.g., walls and furniture) and sort reflections from moving objects (i.e., people) into bins based on their distances from the device. Thus, at the output of this step, we have the time signal reflected off the human body, $s(t)$, and we will have eliminated interference and noise due to reflections off other objects.

In the second step, Vital-Radio identifies changes in the signal due to body motion as opposed to breathing motion. Specifically, when a person moves his arm or walks around, the motion of his body parts would be much larger than his chest movements, and would mask breathing. Vital-Radio needs to identify limb motion from breathing motion to prevent such movements from causing errors in breath monitoring and being detected as breathing irregularities. To do that, Vital-Radio leverages that the breathing motion is slow in comparison to human body motion. For example, a person walks at about one meter per second; however, when breathing, the chest moves less than a millimeter per second. Hence, in comparison to breathing, a leg or arm movement would cause very rapid variations. Vital-Radio embeds this observation in an algorithm for detecting body motion. Once it detects large motion intervals, it eliminates them and focuses on the time intervals which have no major limb motion.

In the third step, Vital-Radio analyzes the signal to track the breathing motion. In contrast to WiTrack, however, which looks only at the signal's power to detect the presence of a moving reflector, Vital-Radio focuses on the phase of the reflected signal. It uses the phase variations to track subtle sub-centimeter oscillations in a reflector (e.g., chest breathing motion) even when the reflector itself does not change its overall distance from the device. Fig. 2 shows the phase variations due to the breathing of a person sitting 3 meters away from the device. The increase and decrease in the phase correspond to the inhale and exhale process. This person's breathing rate is 11 breaths per minute.

3. DEMO SETUP

Our demo setup is shown in Fig. 3. It includes the WiTrack [2] hardware connected to a transmit-receive antenna pair at the front-end and to a machine via the USRP software radio at the back-end. Processing is performed in real-time in the UHD driver of the USRP and the phase of the FMCW bin that corresponds to the chest location is output on the screen in real-time. The proposed demo at MobiCom will be set up in a $3m \times 2.5m$ space in a corner of a room.[1] The demo will monitor the breathing of a user who sits on a chair within that region. The user can move his chair as desired within the region.

[1]Placing the setup in the corner of the room, i.e., near 2 walls, will allow us to minimize interference due to reflections of other people in the vicinity.

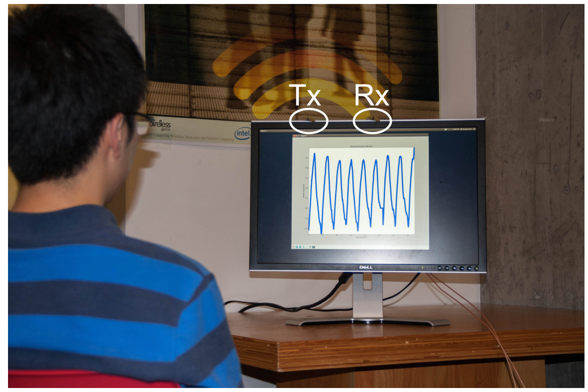

Figure 3: Demo Setup. The figure shows a person sitting on a chair in front of a screen that outputs the exhale and inhale motion due to his breathing as demonstrated by the crests and valleys respectively. The transmit and receive antennas of Vital-Radio are placed on top of the screen.

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