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Research Paper

Detection of breathing and heartrate using a simple vital radio system

Sabitha Gauni, C.T.Manimegalai, K.Kalimuthu, M.Anjanasree

Department of Electronics & Communication Engineering, SRM University, Kattankulathur

Abstract

Proposed is a detection technique utilised for the physiological monitoring of heart rate and breathing rate. This new methodology is better than the other conventional systems that utilise either continuous waves or impulse radio systems for detecting remote vital signs that either suffers from non-stationary clutters or anomalies in accuracy. Vital Radio which operates on wireless technology can sense and monitor the breathing rate and the heart beat rate of the concerned person. This device is designed in such a manner that it can be installed in the walls so that it can capture and maintain a health record of a person dwelling in smart homes. It has the prime advantage of revealing high level of accuracy in the detection of the required vital signs.

1. Introduction

In general, the heart beat count of a person, 25 years of age is 140-170 beats per minutes and 60 years of age 115-140 beats per minute .As of now there is hardly any handy device to examine the irregularities in the heart rate and to measure its count. To overcome this problem a smart wireless health monitoring system which is small, easy to use and keeps a surveillance of the internal body variations. Health-monitoring technologies tend to be wearable, or absolutely require some kind of contact with the body, but the vital radio theory suggests that homes may well be capable of passively and substantially monitoring the patient without the need to attach sensors to the observed body system.

Vital radio uses the concept where wireless signals are disturbed by the movements in the surrounding region-as well as the movements that can be as miniscule and seemingly insignificant as the chest rising and falling during inhale and exhale, or skin vibrations caused by heartbeat. It first completely isolates a person's reflection and then focuses to measure the vital signs like heart rate and the breathing rate. For this, the time taken by the device to transmit and reflect a low power wireless signal is measured and observed. Similarly, it is customised in order to result in a more personalised result in public spaces. For example when a person uses vital radio enabled kiosk in an unknown place like airport he should be given due assistance according to his stress conditions.

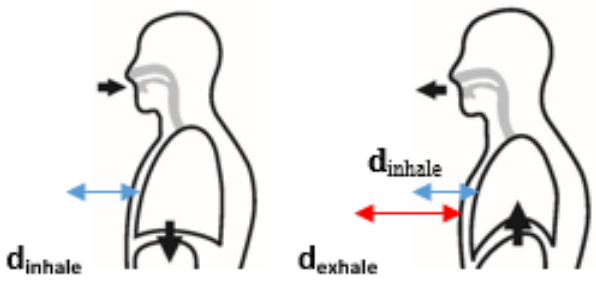


Fig 1: Chest movements

The basic function of human body is represented by the measurements like vital signs. These important signs are monitored by medical and health care providing professionals are: Pulse rate, Respiration rate (rate of breathing) vital signs are very useful in diagnosing or monitoring medical problems. Vital signs can be generally measured in a medical setting, at home, at the site of a medical emergency, or elsewhere.

The pulse rate is the number of times the heart beats per minute, when blood flows through the arteries it gently expands and contracts. When we measure the pulse it gives the heart rate in addition to heart rhythm and pulse strength. The pulse rate for normal adults varies from 60-100 beats per minute whereas athletes, sportsmen (extreme cardio and vascular conditioning) have heart rates nearly 40 beats per minute. Generally females

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above the age of 12 have faster heart rate than that of males. The pulse rate may fluctuate during exercise, intense emotions illness and injury. The respiration rate is the number of breaths taken per minute. When a person is at rest it is measured by counting the number of breaths for a duration of 1 minute. Respiration rates increases with fever and illness. Normal respiration rate for an adult varies from 12-16 breathes per minute.

2. Background

The devices such as health tracker have the ability to monitor the persons vital signs like heartbeat rate, blood pressure and respiration rate basically with the use of the pressure sensors effectively [1]. The integrated heartbeat rate and breathe rate observing system in addition with the electronically operated patient records, involve main challenges in escalating the robustness of the aspired "e-health" application to a stage which clinically purposeful. This method is not very convenient as it is time consuming and costly but this can be overcome by the involvement of novelty methods which can assist in the detection of the signals without allowing them to integrate like the automated methods [2],The latter researches proved to give importance to methods which aims to exhibit how identification of radio frequency, multi-tasking agent and internet of things technologies can enhance peoples access to quality and affordable healthcare services, with the plummeted medical errors, to improve patient health safety and to sincerely led to the betterment of the healthcare processes. Most proposed frameworks for remote human vital sign monitoring leverage a three tier architecture: a Wireless (human) Body Area Networking system (WBAN) consisting of highly useful wearable sensors as the data acquiring unit, communication integrated networking and the appropriate service layer [3], [4]–[5]. However,physiological body parameters such as blood pressure and body temperature require contact devices which tend to be a liability for the users. However, people in military use the concept that breathing blocks wireless signals while radars are being built so that it can sense the presence of a person under rubbles during natural calamities and through walls during war like situations [2, 6, 7, 15]. Especially, because wireless signals traverse through obstacles such that it helps to detect presence of humans in intense situations. Since these devices utilise only military recommended spectrum bands they are difficult to be incorporated with the consumer based equipment [17, 15].Furthermore, this research focussed at detecting the people based on their vital signs rather than estimating, analysing and measuring their vital signs.

Recently, the increasing interest of researchers towards the invention of non- contact devices for monitoring heath conditions proves to be of great help to the human society. The research can be diversified as vision based techniques and wireless techniques. The vision based techniques primarily depends on digital image processing methods for the evaluation of vital signs through video and image feeds which indicates the change or abnormality in vital signs produced by heart and lungs. But this method has a prime limitation that the user need to face the camera and if he/she turns away from the camera and show their back it can led to the misconception of the vital signs which cause adverse implications.

There are various ideas put forth which utilises wireless technology like Doppler radar, Wi- fi Ultra- wideband radar, Zig-bee and Bluetooth module but these methods have an unique challenge that it can be conveniently intervened by any kind of motion in the environment affecting the important minute movements of heart and lungs.

3. Theory of operation

Vital radio uses the fact that wireless signals travels with the speed of light. It measures the time for the low power signals to travel and get reflected back. The distance varies during inhalation, exhalation and heart beats. But the presence of various in between objects like furniture and walls have their contribution of reflections which cause ambiguity in the estimation of vital signs. Therefore the reflections are categorised by following three steps:

Isolate reflections from the users and evict the unwanted reflections from walls and furniture.

Appropriate segregation of signal variations caused by breathing and heart beat by distinguishing them from other limb caused motion.

Deep analysis of the signal variations in order to extract heart and lung caused vital signs.

Step 1: Identify The Reflections Caused From Different Users And Appropriately Eliminate The Unwanted

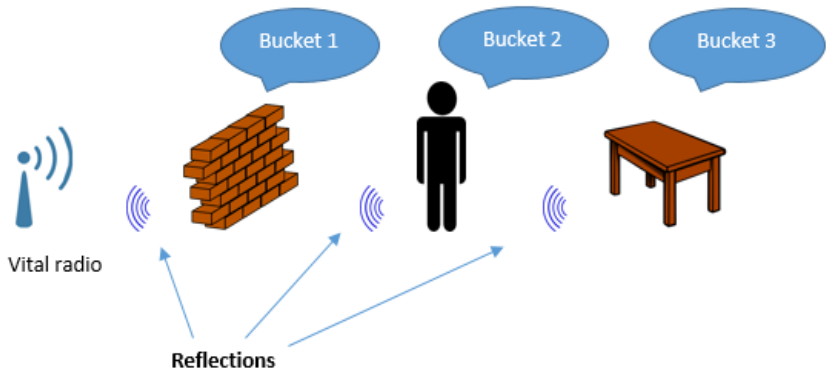


Fig 2: Separating reflectors into different buckets

By using the concept FMCW (Frequency Modulated Carrier Waves) and exploiting one of its key feature that it permits the partition of reflections caused from varied objects into buckets on the basis of their casting duration, has been imparted here. Earlier FMCW was used to identify the power variations as the signals travelled a distance however, Vital radio makes use of the fact that FMCW can help in isolation of signals reflected back from different users located at different distances.

The primary effect of FMCW helps to isolate the signal variations of objects placed at 8 cm distance and categorise the variations into different buckets which helps to focus one user at a time. Secondly it helps to isolate some of the other body limb motions from that of heart beat and the lung movements. By making use of FMCW as a filter. Having done with the later procedure the vital radio makes sure that eradicates the reflections from static objects and keenly helps in isolation of heart and lung created vital signs.

Step 2: Identification Of Reflections Including Breathing & Heart Rate

Vital-Radio magnifies the reflecting signals that are separated and segregated in their buckets and a wave obtained due to wireless reflection has its due phase according to the distance of the transmitted signal $\varphi(t) = 2\pi\, d(t)/\lambda$ where λ subjects to wavelength of the transmitted signal, and d(t) refers the to and fro distance between the reflector and the device. It shows all corresponding variations with reference to inhaling, exhaling and other minute movements. Similarly heartbeat of a person leads to minute movements of his different body parts. Ballistocardiography is a physiological circumstance that make vital radio eligible to extract heart beat rate from the reflecting signals. BCG refers to extremely minuscule movements that takes place in the internal organs of a body in coordination with the heartbeat as a result of ventricular motion. These movements transports the smaller fluctuations in prior to the breathing rate during wireless reflection activity. The capturing of the heart beat is made possible by the periodic timely variation in wireless transfer due to periodic jitters. The orientation of the user makes the periodic heart rate and breathing rate autonomous in nature. Though the user faces back the periodicity is maintained in spite of the signals attaining peaks. Vital-Radio revolves around the fact that motion due to vital signs is rhythmic but that of body and limb motion is not periodic. The periodicity of the signal is measured for each window. If the periodicity of the signal exceeds the threshold value, it concludes that the dominant vital sign rate is recognised else it evicts the window from the process. Determination of the sharpness of the FFT waveform helps to bring an ideology about the periodicity of the signal. Therefore it is significant to note the peak frequency of FFT, value of the peak which is supposed to be above the average power determined value with accordance to the subsequent frequencies. Finally the major part of his present action falls into an allocated FMCW bucket along with that in user's chest. In humans, hand movements causes stretching of muscles, minor shoulder jittering close to ones chest. These non rhythmic movements are weakened at the FFT output whereas the rhythmic vital sign movements were discharged in the FFT operation. This culminates in the persistence of the intervals even during the quasi static scenario.

Step 3: Selecting The Necessary Breathing And Heart Rate

Breathing rate: Breathing is a systematic and normal periodic motion in a human body and their frequency rate is extracted by using the concept of Fourier Transform (FFT).The breathing rate i.e. the dominant frequency is showcased as the peak of the FFT output.The output is clearly obtained as the result of the 30 second functioning of the FFT window leading to the output. This helps to find the initial estimate respiration rate of the person. Particularly, the FFT frequency resolution is 1/window size. For a window size of 30 seconds, the resolution of our breath rate estimate is ≈0.033Hz, i.e., 2 breaths/minute. Though larger windows have the ability to produce better resolution it still has the inability to track and detect the variations in the breathing rate. With highly precise and accurate measurement, utilisation of a renowned property in signal processing postulates that linear regression on phase cane be used for the precise calculation of the particular frequency for the complex time domain signal. .This is followed by the filtering of the FFT output resulting in the retention of only the peak and the adjacent peaks excluding the noise. The complex time domain signals are acquired by performing inverse FFT. Heart Rate Extraction: Just like breathing rate heart beat also produces a periodic and a signal which has undergone modulation .Despite this the magnitude of the breathing signal is way greater than that of heart beat. There is leakage, integration and mixing up of signals with other frequencies which tends to mask and suppress the weaker signals at adjacent frequency. The correction and pacification of these signals is done by the alteration of the frequency domain signal around [40-200] beats per minute is carried out.

4. Implementation

The implementation consists of the following components:

Hardware: The device that needs a sub milli watt power transmission system along with the fact that it produces and carries a signal from 5.46GHz to 7.25GHz for every 2.5 milliseconds. The signal parameters selected such that the regulation of FCC electronic system are in compliance with the transfer system. The FMCW radio and computer are connected over Ethernet. The acquired signal is passed through the Ethernet for the real time computer processing.

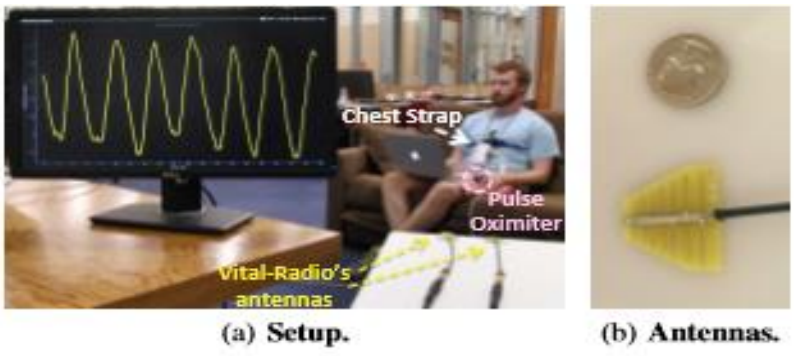


Fig. 3: (a)shows a user sitting about 2.5metres away from antennas of the vital radio; the user is also equipped with chest strap and a pulse oximeter (b)It shows the antenna of vital radio placed near a quarter..

Software: Implementation in C++.The screen has the signal plot resulting from heart and breathing rate as a function of real time. The code operates on shifted overlapping FFT windows and generates newly sorted out estimates every 30ms. The output also indicates whether the person is at rest or involved in a significant motion.

5. Limitations

There are few limitations in using vital radio. They are as follows:

- It requires minimum separation distance between the users .In specific it needs a theoretical distance of 8 cm. However since human beings are not point reflectors it demands 1-2m distance between them.
- The monitoring and detection range of the wireless system determines the SNR (Signal to Noise Ratio).This postulates that the distance has to be maximum at 8m for the vital radio detection for the SNR to be less.
- Quasi Static users are only benefitted by the vital radio in the detection of vital signs. It is not much useful in full body movement as it triggers the small variations to have an effect over the vital signs which are been carefully measured and recorded for further observations.

- Interference of non- human motion is one of the drawbacks for the system. Though non human things like fans have an adverse effect on the detection of human breathing rate it is greatly affected by the presence of pets at home or in the detecting locality leading to the wrong assumption that it is some other individual in the neighbouring arena.

6. Conclusion

The measurements of the subject's heart rate as well as the breathing rate employing the vital radio system were done. Unlike other conventional detection techniques, vital radio technology proves to be sufficiently sensitive in measuring the vital signs with higher resolution by segregating the acquired signals for further analysis. The most paramount feature of the proposed system is its robustness against the periodic movement in the environment. The focus of future work is to compare the proposed vital radio based system with ultra-wideband wave dependent detecting systems. It is also significant to evaluate the accuracy as the distance between the vital radio and the subject changes.

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