UNIVERSITY OF TECHNOLOGY SYDNEY
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# Heartbeat Detection with complicated Noises Using FMCW Radar

by

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# Certificate of Authorship/Originality

I, Jingwei Liu declare that this thesis, is submitted in fulfilment of the requirements for the award of Master of Computer Science, in the FEIT at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

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# ABSTRACT

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Remote heartbeat detection is particular useful for applications in smart home, digital health, and disaster relief (e.g. earthquakes) because of its ability to conduct accurate monitoring of heartbeats at a long distance. The millimeter wave band is of great sig-nificance for remote heartbeat detection, and the millimeter wave-based frequency modulated continuous radar (FMCW) radar is an excellent device for remote heartbeat detection. In the research of radar-based heartbeat detection, an important problem is the interference of human motion in the signal. Artifacts caused by motion appear across all frequency bands, thereby polluting the true heartbeat waveforms. Therefore, removing random body motion (RBM)'s interference to heartbeat detection has become the most challenging task at present. In this thesis, the heartbeat detection technology based on FMCW radar is studied and contributions to the research of the following two issues is made:

1. In heartbeat detection, greatly reduce the interference of motion artifacts and background noise when using the sparsity difference to extract the heartbeat waveform.
2. The subject's small degree of random movement (upper body movement, lower body static) caused greater interference.

For the first question, we use convolutional sparse coding (CSC) to replace the sparse coding (SC) in the previous work. In order to simulate complex phase noise and motion artifacts, we use gaussian mixture model (GMM) to model the noise. When solving the CSC problem, in order to speed up the entire process, we use (non-convex inexact accelerated proximal gradient )niAPG to achieve rapid decline. Simulations and experiments verify the effectiveness of our method. For the second question,

we added an additional clustering step to the ordinary decomposition algorithm, and proposed new parameters to improve the accuracy of clustering. We extract the initial static data as the initial input, and compare the data of two adjacent time windows to extract the peak heartbeat. For the task of extracting the heartbeat from the target of the upper body motion (large range of random motion), our method proved effective.

# Dedication

To my parents Yin Xu and Shengxi Liu.

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# List of Publications

## Conference Papers

**Jingwei Liu**, and J.Andrew.Zhang, “Gaussian Mixture Model based Convolutional Sparse Coding for Radar Heartbeat Detection,” *Proc. IEEE Int. Conf. on ICSPCS*, Dec. 14-16, 2020.

# Contents

# List of Figures

# Abbreviation

APG - Accelerated Proximal Gradient

BSS - Blind Source Separation

CSC - Convolutional Sparse Coding

ECG - Electrocardiography

EM - Expectation Maximization

EMD - Empirical Mode Decomposition

FMCW - Frequency Modulated Continuous Wave

ICA - Independent Component Analysis

GMM - Gaussian Mixture Model

IF - Intermediate Frequency

LO - Local Oscillator(In some down-convert process, LO signal can betreated as transmitted signal)

MIMO - Multi input multi output

MA - Motion Artifact

PPG - Photoplethysmography

RBM- Random Body Movement

RMSE - Root Means Square error

RSM - Random System Movement

SHSC - Second Harmonic Signal Component

SSA - Singular Spectrum Analysis

# Nomenclature and Notation

Capital letters denote matrices.

Lower-case alphabets denote column vectors.

$(.)^T$ denotes the transpose operation.

$I_n$ is the identity matrix of dimension $n \times n$.

$0_n$ is the zero matrix of dimension $n \times n$.

$\mathbb{R}$, $\mathbb{R}^+$ denote the field of real numbers, and the set of positive reals, respectively.