Robust respiration tracking in high-dynamic range scenes using mobile thermal imaging

YOUNGJUN CHO,[1,*] SIMON J. JULIER,[2] NICOLAI MARQUARDT,[1] AND NADIA BIANCHI-BERTHOUZE[1]

[1]*Interaction Centre, Faculty of Brain Sciences, University College London, London, WC1E 6BT, UK*
[2]*Department of Computer Science, University College London, London, WC1E 6BT, UK*
**youngjun.cho.15@ucl.ac.uk*

Abstract: The importance of monitoring respiration, one of the vital signs, has repeatedly been highlighted in medical treatments, healthcare and fitness sectors. Current ubiquitous measurement systems require to wear respiration belts or nasal probe to track respiration rates. At the same time, digital image sensor based photoplethysmography (PPG) requires support of ambient lighting sources, which does not work properly in dark places and under varied lighting conditions. Recent advancements in thermographic systems, shrinking their size, weight and cost, open new possibilities for creating smart-phone based respiration rate monitoring devices that do no suffer from lighting conditions. However, mobile thermal imaging is challenged in scenes with high thermal dynamic ranges (e.g. different ambient temperature distributions in inside and outside) and, as for PPG with noises amplified by combined motion artefacts and breathing dynamics. In this paper, we propose a novel robust respiration tracking method which compensates for the negative effects of variations of the ambient temperature and the artefacts can accurately extract breathing rates from controlled respiration exercises in highly dynamic thermal scenes. The method introduces three main contributions. The first is a novel *optimal quantization technique* which adaptively constructs a color mapping of absolute temperature matrices. The second is *Thermal Gradient Flow* mainly based on the computation of thermal gradient magnitude maps in order to enhance accuracy of nostril region tracking. We also present a new concept of *thermal voxel* to amplify the quality of respiration signals compared to the traditional averaging method.

We demonstrate the high robustness of our system in terms of nostril-and respiration tracking by evaluating it during both controlled respiration exercises in high thermal dynamic scenes (e.g. strong correlation (r=0.9983)). We also demonstrate how our algorithm outperformed standard algorithms in settings with different amount of human motion and thermal changes. Finally, we open the datasets collected for these studies (i.e., under both controlled and unconstrained real-world settings) to the community to foster work in this area.

1. Introduction

Monitoring respiration-related signs plays a key role in a variety of sectors spanning from direct diagnosis of, and treatment for, lung troubles (e.g. hyperventilation, apnea and interstitial lung disease) and cardiovascular conditions to supporting a person's psychological needs (e.g. stress, anxiety regulation) [1,2]. Despite its importance, it has been largely disregarded in real world healthcare technology applications [3]. One of its possible reasons is the inconvenience of conventional respiration measurement systems (e.g., chest-belt, oronasal probes) demanding direct physical contact as discussed in the literatures [4–6]. These systems are often uncomfortable to wear and prone to motion artefacts, possibly causing wrong sensor readings. In addition, in some medical and chronic conditions where monitoring everyday physiological processes may be pivotal to help functioning, direct contact on the skin may not be acceptable (e.g. Complex Regional Pain Syndrome [7]). Contactless ways to measure respiration-related signatures (e.g. remote-PPG [5,8], Doppler radar [9], thermal