CHAPTER 5
DETECTION OF BREATHING USING INFRARED THERMAL IMAGING

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5.1 INTRODUCTION

Breathing is a key indicator of general health and a vital physiological phenomenon in humans and contributes to clinical monitoring. A physician could potentially diagnose a variety of conditions, including cardiovascular disease and apnoea through breathing patterns. In general, one breathing cycle refers to the removal of carbon dioxide from our bodies (expiration) and the intake of oxygen (inspiration). A complete breathing cycle is defined as the total duration of time from the beginning of inspiration to the end of the post-expiration phase. Normal breathing typically has a 1:2 ratio of inspiration time (TI) to expiration time (TE), according to Butlet's book 'Laboratory Exercises for Competency in Respiration Care'. This emphasises the significance of the need to measure breathing rate precisely as well as the distinct stages of inspiration and expiration (TI and TE). However, the available methods for evaluating these breathing dynamics remain limited.

Analysing breathing activities can be done in a variety of ways. Currently, there are numerous manual modalities or procedures that

have been developed to monitor human respiratory function, particularly breathing rate. These methods include thermistors for measuring breathing airflow, respiration belts, and capacitive sensors for measuring breathing rates (Basra et al., 2017; Deepika et al., 2016). However, such methods often require direct bodily contact, which may induce discomfort, especially in children and elderly people. Additionally, respiratory rate was the main emphasis in most research on breathing function (Shakhih et al., 2018; Shakhih et al., 2019).

As contactless monitoring advances, non-obtrusive modalities like infrared thermal imaging (IRTI) are emerging for analysing breathing patterns. IRTI uses thermal cameras to capture temperature variations on the body's surface. By analysing these thermal images, breathing patterns can be analysed based on the cyclical fluctuations in heat release from the body, particularly around the face, during inhalation and exhalation. This passive approach holds promise for measuring breathing activities, as it avoids direct bodily contact and utilises infrared rays for temperature detection, eliminating any discomfort or side effects.

On top of that, the procedure of assessing the breathing pattern of a patient may become complex due to the present treatment requiring constant nursing supervision and care. This complexity is further compounded by the fact that the manual calculation approach is time-consuming, as several studies have demonstrated. Manual analysis of breathing patterns can take up to five hours per cycle, significantly impacting efficiency. Therefore, in this research, an automated image segmentation method using thermography is proposed. This method analyses breathing patterns using a region of interest (ROI) tracker, with the potential to significantly reduce computational time. This time-saving approach could be invaluable for medical professionals, allowing them to focus on patient care and potentially improve the diagnosis of breathing disorders while maintaining patient safety and comfort.

The structure of this chapter is as follows. Section 5.2 provides an overview of breathing and thermal image processing. Section 5.3 focuses on the detection of breathing patterns, while Section 5.4 presents the

thermal imaging analysis of the breathing cycle. Finally, Section 5.5 summarises the key findings and conclusions of the study.

5.2 BREATHING AND THERMAL IMAGE PROCESSING

The normal breathing rate of a resting adult typically ranges from 12 to 20 breaths per minute and is referred to as eupnea. Rates falling below or exceeding this range may indicate a health issue. The three primary stages of the breathing cycle are inspiration, expiration, and post-expiration. These phases can be disrupted by various disorders, including tachypnea (rapid breathing), apnoea (breath holding), Kussmaul breathing (deep, sighing breaths), and Cheyne–Stokes respiration (waxing and waning breaths). A visual representation of the breathing pattern is shown in Figure 5.1.

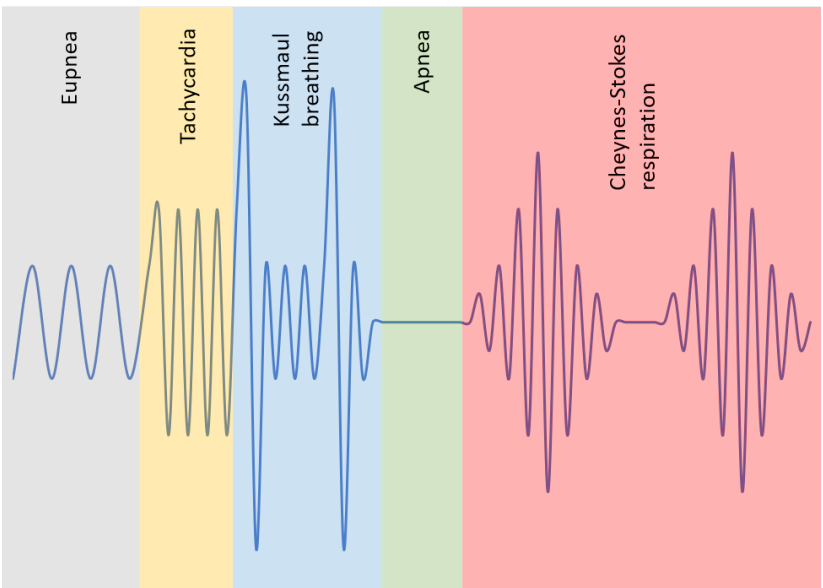

Figure 5.1 Simulated sequence demonstrating normal and abnormal breathing patterns (eupnea, tachypnea, apnea, kussmaul breathing, and cheyne-stokes respiration) (Source: Barbosa Pereira et al., 2017)