Chapter 43
Integrated Approach for Automatic Crackle Detection Based on Fractal Dimension and Box Filtering

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ABSTRACT

Crackles are adventitious respiratory sounds (RS) that provide valuable information on different respiratory conditions. Nevertheless, crackles automatic detection in RS is challenging, mainly when collected in clinical settings. This study aimed to develop an algorithm for automatic crackle detection/characterisation and to evaluate its performance and accuracy against a multi-annotator gold standard. The algorithm is based on 4 main procedures: i) recognition of a potential crackle; ii) verification of its validity; iii) characterisation of crackles parameters; and iv) optimisation of the algorithm parameters. Twenty-four RS files acquired in clinical settings were selected from 10 patients with pneumonia and cystic fibrosis. The algorithm performance was assessed by comparing its results with a multi-annotator gold standard agreement. High level of overall performance (F-score=92%) was achieved. The results highlight the potential of the algorithm for automatic crackle detection and characterisation of RS acquired in clinical settings.

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INTRODUCTION

Acute and chronic respiratory diseases are a major health, societal and economic burden worldwide (World Health Organization, 2008). Therefore, during the last decade, several research efforts have been dedicated to improve the diagnosis, management and monitoring of patients with respiratory diseases (Dinis, Campos, Rodrigues, & Marques, 2012).

Although several measures are available to diagnose and monitor respiratory diseases, conventional auscultation remains the most widely used. The stethoscope has been used for 200 years to perform clinical examinations as it is simple, non-invasive, economic, practical and useful in all populations and settings (Bohadana, Izbicki, & Kraman, 2014). However, it is known that conventional auscultation is subjective, i.e., the interpretation of respiratory sounds depends on the stethoscope properties (Welsby & Earis, 2001), hearing ability and clinical experience of users (Sovijärvi, Vanderschoot, & Earis, 2000) and their capacity to memorise sound patterns (e.g., number and characteristics of adventitious respiratory sounds) (Marques, Bruton, & Barney, 2006).

To overcome the subjectivity associated with conventional auscultation, research efforts have been devoted to improve computerised respiratory sound analysis (CORSA). CORSA consists of recording respiratory sounds with an electronic device and objectively analysing/classifying them based on advanced digital signal processing techniques (Sovijärvi, Vanderschoot, & Earis, 2000). The digitalization of respiratory sounds recordings has the advantages of: i) being compatible with digital signal processing techniques for sound analysis and classification; ii) allowing the precise definition of recording characteristics (e.g., recording level and bandwidth), which can be adjusted to the type of signals that are going to be studied (Cheetham, Charbonneau, Giordano, Helistö, & Vanderschoot, 2000); and iii) overcoming the barriers associated with clinicians having to memorise sound patterns. Through CORSA, respiratory sounds were found to be a more sensitive indicator, detecting and characterising the severity of respiratory diseases before any other measure (Gavriely, Nissan, Cugell, & Rubin, 1994). Furthermore, CORSA can also boost the development of mathematical models of the underlying physical mechanisms of respiratory sound production, to characterise the interaction of mechanical forces, airflow and sound transmission within the respiratory tract (Earis & Cheetham, 2000). This may provide important information to understand and relate different processes of diseases (Earis & Cheetham, 2000).

Computerised respiratory sounds are thus a simple, objective and non-invasive measure to assess the function of the respiratory system (Bohadana et al., 2014). Therefore, special attention has been given to their automatic detection and characterisation, as changes in their properties can early inform the presence of several respiratory conditions (Sovijärvi, A., Malmberg, L., et al., 2000), e.g., pneumonia (Piirila, 1992), bronchiectasis and cystic fibrosis (Marques, Bruton, & Barney, 2009).

Briefly, respiratory sounds can be classified into normal and adventitious respiratory sounds. Adventitious respiratory sounds are continuous (i.e., wheezes and rhonchus) or discontinuous (i.e., fine crackles and coarse crackles) sounds superimposed on normal respiratory sounds (Bohadana et al., 2014). The specific characteristics of wheezes, such as its duration (longer than 100 ms) and exhibition of distinct peaks in the frequency domain (> 100 Hz) have facilitated the development of methods for its automatic detection and characterisation (Taplidou & Hadjileontiadis, 2007). Crackles, however, are discontinuous, transient and explosive sounds of no more than 20 ms (Sovijärvi, A., Malmberg, L., et al., 2000). These characteristics introduced additional complexity in their automatic detection, and thus further research is needed to overcome this problem.

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