Journal of Sound and Vibration 374 (2016) 312–328

Contents lists available at ScienceDirect

Journal of Sound and Vibration

journal homepage: www.elsevier.com/locate/jsvi

Pitch features of environmental sounds

Ming Yang, Jian Kang *

School of Architecture, University of Sheffield, Western Bank, Sheffield S10 2TN, United Kingdom

ARTICLE INFO

Article history:
Received 21 October 2015
Received in revised form
16 March 2016
Accepted 28 March 2016
Handling Editor: R.E. Musafir
Available online 14 April 2016

Keywords:
Environmental sound
Pitch estimation
Psychoacoustics
Soundscape

ABSTRACT

A number of soundscape studies have suggested the need for suitable parameters for soundscape measurement, in addition to the conventional acoustic parameters. This paper explores the applicability of pitch features that are often used in music analysis and their algorithms to environmental sounds. Based on the existing alternative pitch algorithms for simulating the perception of the auditory system and simplified algorithms for practical applications in the areas of music and speech, the applicable algorithms have been determined, considering common types of sound in everyday soundscapes. Considering a number of pitch parameters, including pitch value, pitch strength, and percentage of audible pitches over time, different pitch characteristics of various environmental sounds have been shown. Among the four sound categories, i.e. water, wind, birdsongs, and urban sounds, generally speaking, both water and wind sounds have low pitch values and pitch strengths; birdsongs have high pitch values and pitch strengths; and urban sounds have low pitch values and a relatively wide range of pitch strengths.

1. Introduction

Over the past fifteen years, the perception and evaluation of soundscape (referring to the total sound environment [1]) have been researched through numerous studies. It has been revealed that conventional acoustic parameters for noise measurement [2,3], e.g. weighted sound pressure levels (SPLs), alone are not adequate for the measurement of soundscape [4]; more parameters are needed, which are more likely to be correlated with people's subjective evaluation of soundscape [5–7], such as comfort [4], pleasantness [8], annoyance [9], etc. For example, background noise level, standard deviation of short L_{Aeq} [4,8], temporal structure [10,11] and some psychoacoustic parameters [12,13] have been used. In addition to these parameters, there is a recognized need to explore the possibility of additional parameters for soundscape measurement.

Since soundscape and music are closely related, in that music could be regarded as an imitation of environmental soundscapes or an ideal soundscape of the mind [1], musical features, particularly the psychoacoustic parameters that have previously been applied mainly in music perception, may also be applicable in soundscape research. In the fields of music psychology and psychoacoustics, the sensations of hearing are generally studied from four aspects, i.e. loudness, pitch, rhythm, and timbre. While loudness, timbre (including sharpness, tonality, roughness and fluctuation strength), and rhythm have been used to analyze the characteristics of soundscapes and environmental sounds [14–17], further study is required of the pitch aspect. Pitch corresponds to the sound's physical property of frequency, whereas loudness, rhythm, and timbre respectively correspond to amplitude, time, and both frequency and time properties. Pitch may be defined as “that attribute of auditory sensation in terms of which sounds may be ordered on a musical scale” [18,19]. (The pitch value to a sound is

* Corresponding author. Tel.: +44 114 222 0325.
E-mail address: j.kang@sheffield.ac.uk (J. Kang).

http://dx.doi.org/10.1016/j.jsv.2016.03.040
0022-460X/

generally assigned by the frequency of a pure tone having the same subjective pitch as that sound [18].) While pitch or pitch value specifies the pitch sensation along a scale from low to high, other pitch parameters define additional pitch sensations independent of pitch value, e.g., pitch strength specifies the sensation along a scale from faint to distinct [20].

In the field of psychology of music, relations between musical features and humans' emotion and evaluation have been studied for decades. For example, high pitch, wide pitch range and large pitch variation may be associated with emotions like high activation, excitement, surprise [21], happiness [22,23], pleasantness, anger, and fear [24]; low pitch and narrow pitch range may be associated with low activation, calmness, boredom, sadness [22], unpleasantness, and pleasantness, and small pitch variation with anger and fear [25]. (The apparent contradiction, e.g., both high and low pitch are associated with pleasantness, may depend on the context, that is, the combination and interaction with other features [25].) It is expected that these pitch parameters might be useful in soundscape measurement, especially for the emotional evaluation of soundscapes [26]. However, unlike music and speech, environmental sounds may be mainly composed of noise rather than discernable complex and/or pure tones, thus, there is a need to study the applicability of the pitch features to environmental sounds.

This paper, therefore, aims first to explore the pitch algorithms and parameters applicable to soundscape analysis, and then to study the pitch characteristics of various different environmental sounds. In the rest of this paper, first, the method for sound sample collection is described. Then, a number of existing algorithms are implemented with simplification/modification for environmental sounds. From these implemented models, the one with the best simulation performance for environmental sounds is selected, using a small size of sound samples. A number of pitch parameters, which correspond to subjective pitch sensations, and their statistical indices, which describe the variations of these parameters over time, are derived/developed based on the model selected. Finally, the characteristics of, and differences among various environmental sounds are studied in these pitch features, using a relatively large sample size.

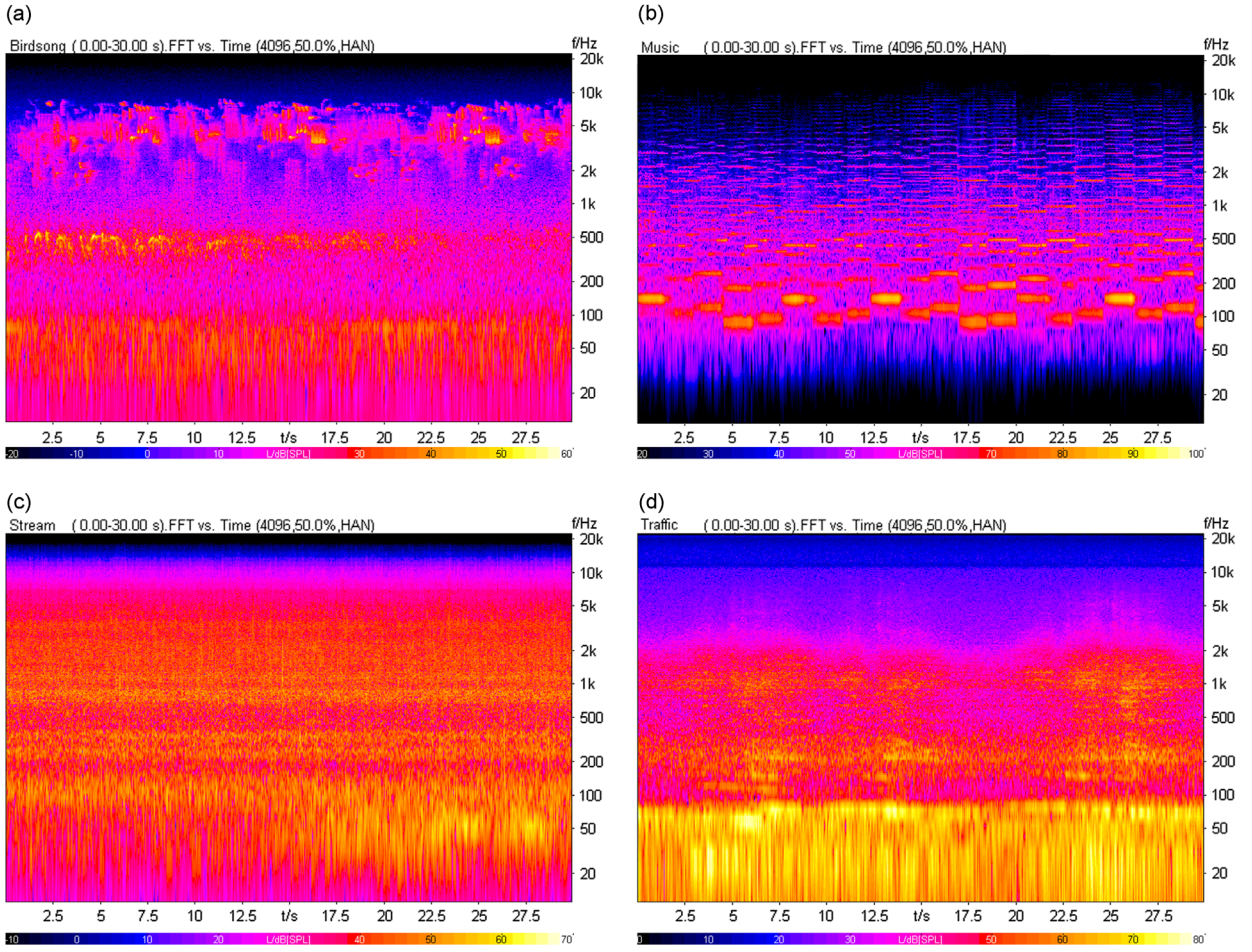

Fig. 1. Spectrograms: (a) birdsong, (b) music, (c) stream, and (d) traffic.