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FREQUENCY ANALYSIS OF SOUNDS OF ANIMALS

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A harmonic sound is made from a fundamental harmonic or a series of harmonics. A non-periodic sound can be considered as periodic with an infinitely large period and because of that it can be described as an infinite sum of components whose frequencies are infinitely close. To fully describe such sound, it is necessary to specify the level and the frequency of each component. This can be done by using the Fourier transform. Frequency analysis is a technique used to determine the values of dominant frequencies from the measured signal. In this article we demonstrate, how we can use the frequency analysis for the demonstration and the motivation of the study of Physics (especially Acoustics) on every level of school system. Using this analysis the frequency characteristics of sounds of animals can be determined.

Keywords: Frequency analysis, Acoustics, Physical education

1 Introduction

What microscopes were for the emergence of cell biology as a discipline, or the catode-ray oscilloscope for neurophysiology, it was the sound spectrograph that enabled the birth of the science of birdsong [1]. With remarkable rapidity sonograms became the standard method for not only birdsong study. Oscillograms were useful for the study of insect sound, but not very helpful for analyzing sounds with a more complex frequency structure, like birthsongs or human speech. Around 1940 a group of researchers decided to develop methods for making the details of speech more visible and intelligible. Sound spectrograms of speech became a basic tool in linguistics and remained so for years. And moreover of investigation of voice it is also perfect for the study of sounds of animals.

2 Non stationary acoustic signal and analysis with Fast Fourier Transform (FFT)

A continuous train of speech can be considered as non-stationary signal and can be divided into short individual sounds (vowels and consonants for people, etc). The process of dividing up such a continuous signal is called „time windowing". The whole signal can be viewed through a window which transmits the portion of interest. The simplest way of applying such a window is to cut off the signal at each end. This procedure can be considered as a multiplication by a rectangular weighting function. The effect of this procedure on a typical frequency spectrum components is equivalent to the spectrum filtering by a filter characteristic corresponding to the Fourier transform of the rectangular weighting function. A more desirable filtering effect provides smooth non-uniform weighting functions, obviously incorporated into software, used for the spectral analysis of the speech signal. Such a window function can be moved along a speech record to permit successive analysis of the various components of a particular utterance. The result of multiplication of the original signal by the weighting curve is a transient and is normally interpreted in terms of the power of the equivalent stationary signal represented by the windowed segment.

It is possible to move a time window along a non-stationary signal and obtain the frequency spectrum of each windowed section. The individual spectra can then be placed into a 3-dimensional diagram to see the development of the frequency spectrum with time. The effect of applying the rectangular weighting function on the spectrum is to convolve it with the spectrum of the rectangular function. The problems with a rectangular window arise from the sudden transitions at each end. Use of a smoother weighting function nullifies such transitions.

As an algorithm for obtaining Discrete Fourier Transform (DFT) of sampled non-stationary windowed speech signal, the fast Fourier transform (FFT) with a greatly reduced number of arithmetic operations compared with a direct evaluation is often used. Since its first publication in 1965 it has revolutionized the field of signal analysis and now it is still probably the most important single analysis technique available. The Discrete Fourier Transform – forward and inverse – are represented by the expressions

$$G(k) = \frac{1}{N}\sum_{n=0}^{N-1} g(n)\exp\left(-j\frac{2\pi kn}{N}\right) , \tag{1}$$

$$g(n) = \sum_{k=0}^{N-1} G(k)\exp\left(j\frac{2\pi kn}{N}\right) . \tag{2}$$

The advantages of the FFT can be achieved in a variety of ways. In a Radix 2 algorithm N is a power of 2, g is the sampled speech signal (time domain), G are spectrum components of g, (frequency domain), N is the number of discrete samples [2].

3 Graphic Representation of Sounds

For recording, replaying and analyzing the sound of animals we can use a free program Audacity [3].

Three types of graphs are commonly used to visualize sounds [1]. These graphs illustrated in Figures (A), (B) and (C) were all made from one recording of an animal song. The first graph illustrates intensity fluctuations over the time – the *amplitude wave form – oscillogram* (A). The x-axis represents the passing of time while the sound volume is reflected in the height of the spikes above and below this axis. Usually the y-axis indicates the relative amplitude. In no spikes no sound results and the loudest sound reaches the maximum extension possible in the graph.

The second is the *sonogram* (B). The sonogram includes information on the pitch or more precisely the frequency of the sound. The x-axis again represents time and the y-axis pitch, with low-frequency sound near the baseline and high-frequency sound higher up. The frequency of birdsongs usually falls between 500 Hz and 10 000 Hz. In this frequency–time graph, information on amplitude is depicted by the darkness of the gray-scale with black reflecting frequencies of the highest amplitude. This gray-scale often disappears in print, replaced by a black and white version. The gray-scale is replaced by a color-scale in many computer programs.

The third is the *power spectrogram* (C), which displays amplitude versus frequency, summated for an entire song or only a segment of sound. It shows the distribution of power through the sound spectrum for a certain song, note or call, depicting the sound energy present at each frequency.

The same sound can appear very differently if generated with different analysis bandwidths. It is technically important to state the bandwidth employed in an analysis, but generally people use similar wideband settings for birdsong, making sonograms more or less comparable, as in the next illustrations. The sounds of birds are used from [4].

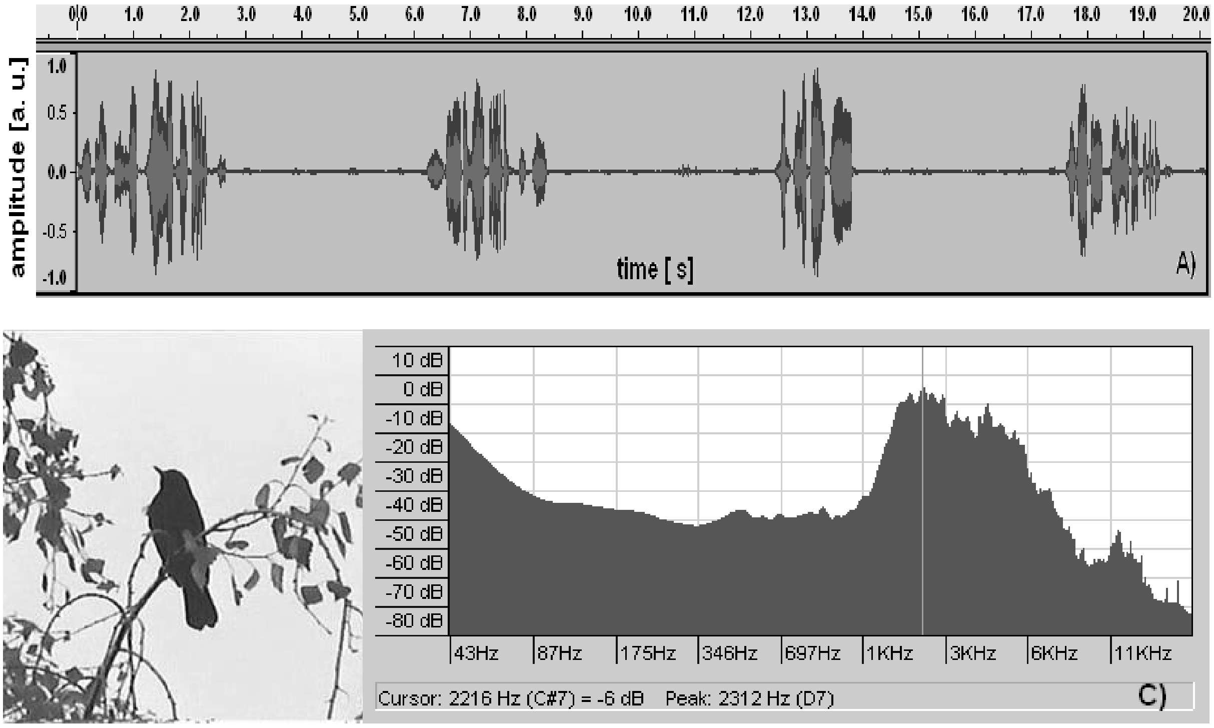

Fig. 1. Blackbird (Turdus merula). Oscillogram (A) in the time 20 second and its power spectrogram (C) from which we determine the dominant frequency f = 2312 Hz.

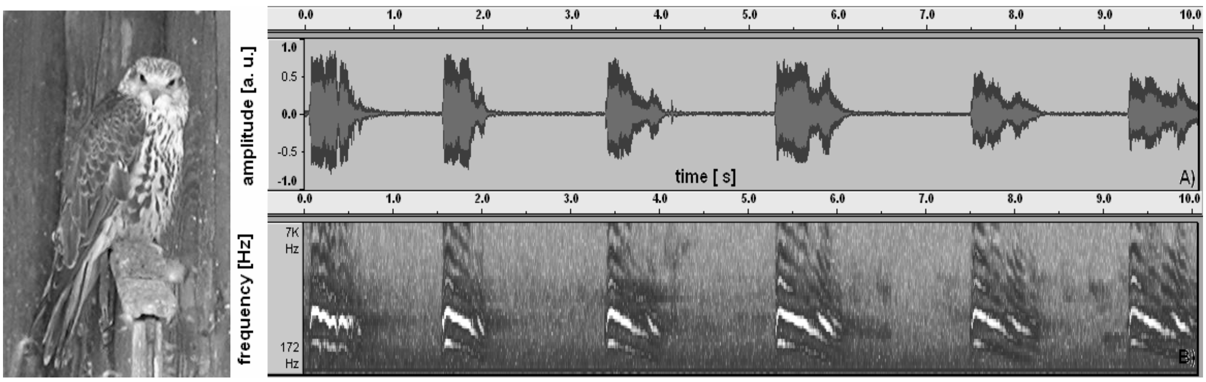

Fig. 2. Common Buzzard (Buteo buteo). Its amplitude wave form – oscillogram (A) and sonogram (B) in frequency range 172 Hz – 7 kHz.

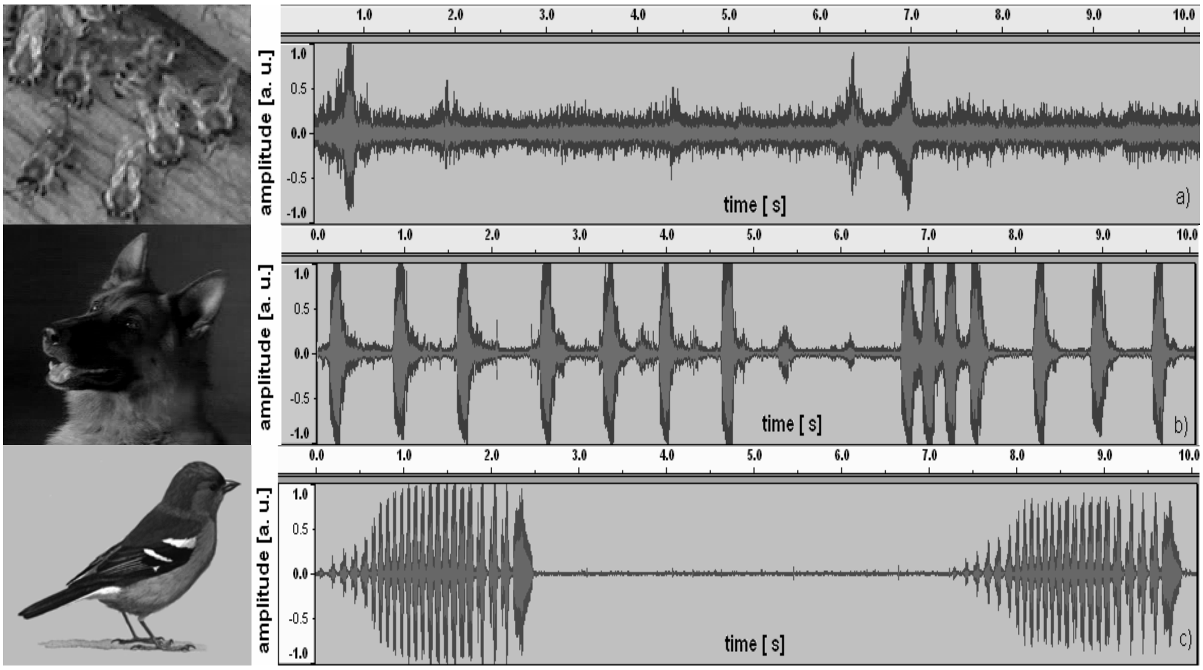

Fig. 3. Comparing individual oscillograms (A) for bee (a), dog (b) and raven with various values of dominant frequency: (f = 226 Hz) (a), (f = 933 Hz) (b) and (f = 3347 Hz) (c).

Using the program Audacity we analyzed and compared the sound of animals and determined some physical characteristics typical for individual animals.

4 Conclusion

The aim of this contribution is to show how students can be motivated in the physics classes. Using frequency analysis we demonstrate, how various sounds can be recorded and replayed. Differences for various animals can be seen on the recorded oscillograms and sonograms (for children attending primary schools), the relation between the frequency and the time period (for students at grammar schools) and the importance of the Fourier transform for finding dominant frequency of individual sounds of animals (for students at universities) can be demonstrated.

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