Analysis of Sound Signals Using Wavelet Transform

Dimitrije M. Bujaković, Milenko S. Andrić, Mladen D. Antonić

Abstract — **In this paper is presented a spectrum analysis of real sound signals. This analysis is made by determining spectrogram and scalogram of these signals. Analyzed sequences were got by sampling sound signals made by artillery weapons of different caliber. Results made by spectrogram, have not enought capacity in classification artillery weapons. Using wavelet transform showed that scalar coefficients at eigth level of decomposition of signal can be used as a features that can distinguish artillery weapons of different caliber.**

Key words — **Spectrogram, Continous wavelet transform, Scalogram**

I. INTRODUCTION

One of a crucial phase in developing systems for automatic classification sound signals is proper feature choice of these signals that ensure seperability between classes, [1]. After that it accedes to feature extraction and forming a feature vector.

Artillery projectil, which is flying by supersound speed, create a two wave class. First one is shock wave, that is consequence of projectile flow throught the air, and the second one, muzzle blast, that originate as a result of moving out projectile from the muzzle. Muzzle blast provides opportunity for automatic classification of artillery weapons. These two waves have a different length.

In paper is presented results of sound signals analises using spectrograms and continuous wavelet transform. Analyzed sequences are captured by sampling of sound signals that are made as a result of different caliber artillery weapon action.

II. SPECTROGRAM OF SOUND SIGNAL

Time Depend, or Short Time Fourrier Transform is defined as, [2], [3]:

$$X(n,f) = \sum_{m=-\infty}^{\infty} w[m]x[n+m]e^{-j\lambda m} \,, \qquad (1)$$

where $w[m]$ is a window. In this case a function of one discrete variable $x[n]$ convert in two dimensional function of discrete variable n (time) and continuous variable f (frequency). It should be noticed that Short Time Fourier Transform is periodical at frequencies with period 2π.

Expression (1) can be conssidered as a Fourrier transform of sequence $x[n+m]$ observing through window $w[m]$. As n is changing, signal “goes through” window, which have consequence that for every value of n is taken a different signal segment.

Tipical graphic disply of Short Time Fourrier Transform is spectrogram. On spectrogram apcise is time, ordinate is frequency, and intensity of frequency component at specific frequency and specific time is proportional to blackout of specific spectrogram point.

If signal characterics changes faster, it is necessarly to use of shorter window. Using of shorter window increases time resolution, while frequency resolution decreases. Because that, window choice represent a compromise between disared characteristics by time and frequency.

III. SCALOGRAM OF SOUND SIGNAL

Continous wavelet transform is defined as, [4], [5]:

$$X(b,a) = |a|^{-1/2} \int_{-\infty}^{\infty} x(t)\psi^{*}\left(\frac{t-b}{a}\right)dt \,, \qquad (2)$$

where $x(t)$ is signal of finite energy, and $\psi(t)$ wavelet which is used as transformation center. Value a is scalar (frequency) parameter, while is translation (time) parameter of this transform.

Expression (2) is convolution of signal $x(t)$ and scaled, inverted and conjugate transformation center.

$$X(b,a) = \int_{-\infty}^{\infty} x(t)\psi_a^{\#}(b-t)dt \,, \qquad (3)$$

while:

$$\psi_a^{\#}(t) = |a|^{-1/2}\psi_a^{*}\left(\frac{-t}{a}\right). \qquad (4)$$

As a result of wavelet transform it have been gotten a coeficients of wavelet transform. Signal scalogram has been gotten as display of amplitude square of these coeficients by translation and scalar parameters.

Wavelet transform for large values of scalar parameter a a give information about lower end of signal spectrum. On the other side, information that are on the high of frequency spectrum are be given for small values of scalar parameters.

IV. RESULTS

Sound signals are made as a outcome of different caliber artillery weapon action. After that in a sampling process with freaquency of f_s =*8 kHz*, it had been got

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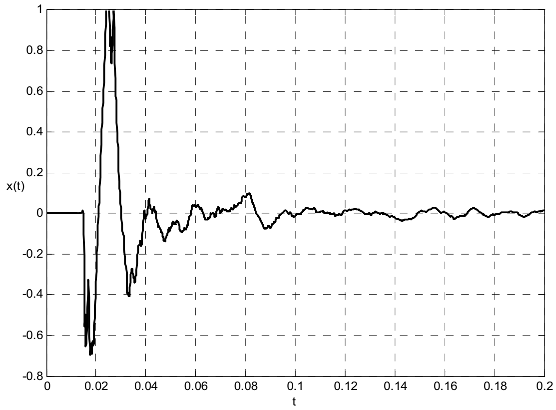
sequences and saved as files. In that manner, we get a database of rougth data for further analysis. For easier analysis, sequence made by 100mm caliber weapon is defined as sequence 1, 152mm caliber as sequence 2 and 125 mm as sequence 3.

Every sequnce has 1600 samples and everyone of them is normalized, how it can been decrease of sound signal amplitude influence on determining spectrograms and scalograms.

In Fig. 1 it has been showed normalized sequences that had been analized.



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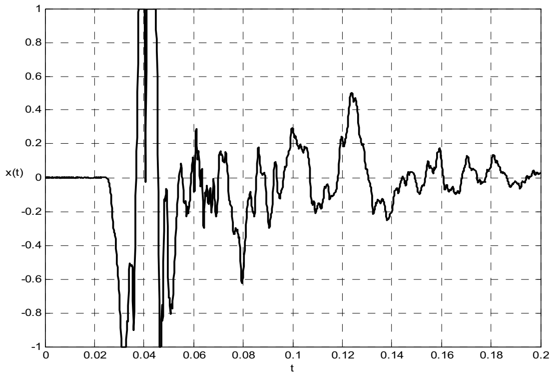

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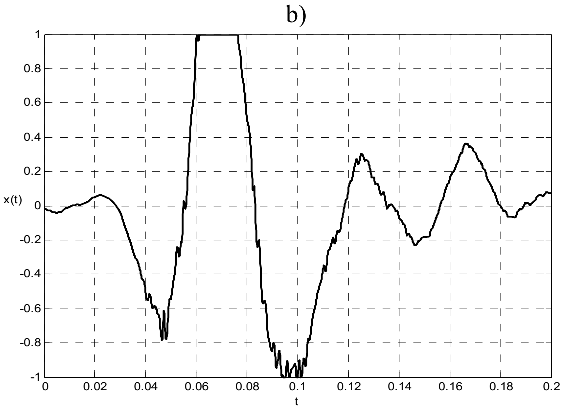
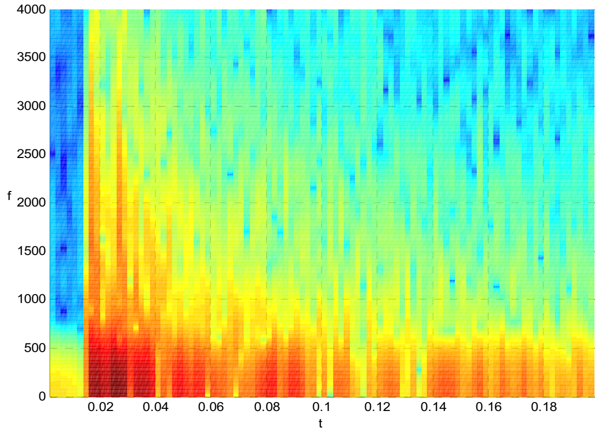


c)

Fig. 1. Normalized sequence a) sequence 1, b) sequence 2, c) sequence 3

In first analysis it had been made a comparation of normalized sound sequence spectrograms. In Fig. 2 it had been showed spectrograms of these sequences. For computing spectrograms, it is used Fourier transform in 1024 samples and Kaiser window with lenght 32 samples and overlap between two windows 50%.



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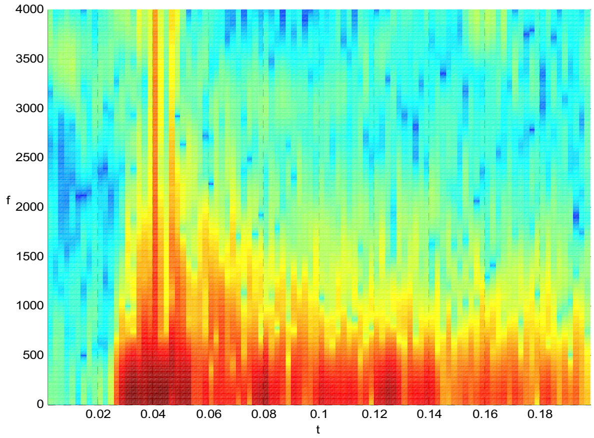

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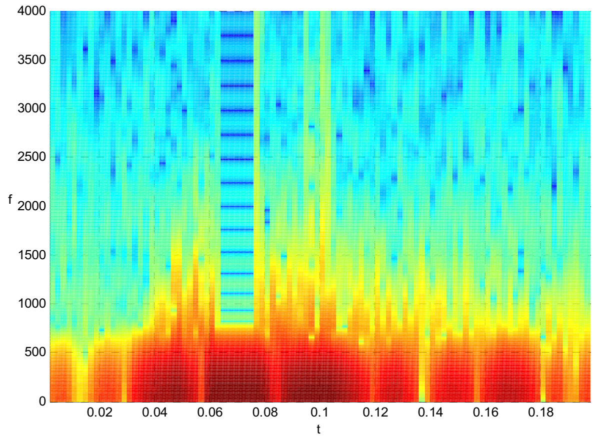

c)

Fig. 2. Spectrograms a) sequence 1, b) sequence 2, c) sequence 3

Comparation spectrograms in Fig. 2, it could be noticed that there is no clear energy area that belongs shock – wave than energy area that belongs muzzle – blast. According to this characteristic, sound signal spectrogram have not a information that could be used in classification of artillery weapons.

In second analysis it is made wavelet transform scalograms of analized sequences. In Fig. 3, these scalograms are plotted.

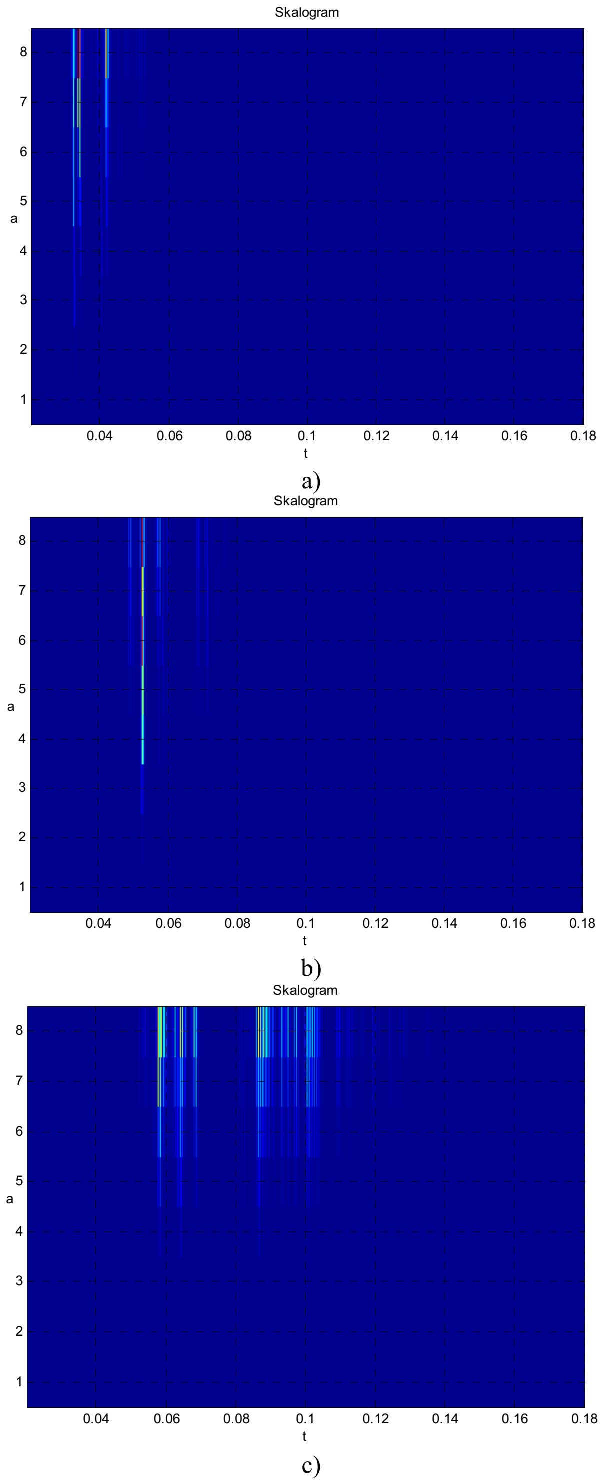

Fig. 3. Wavelet transform scalograms a) sequence 1, b) sequence 2, c) sequence 3

As mother wavelet in this analysis, it was used Daubechi wavelet 4 (DB-4), while signal decomposition is made at eight level.

Analysis of these scalograms, it could be noticed that there is a two areas that contains information about sound signal originate. This have a real phisical explanation where first it could be heard a shock – wave, and then a muzzle blast.

For easier analysis of scalograms, it is showed muzzle – blast wave coefficient moduls at eight level of decomposition in Fig. 4.

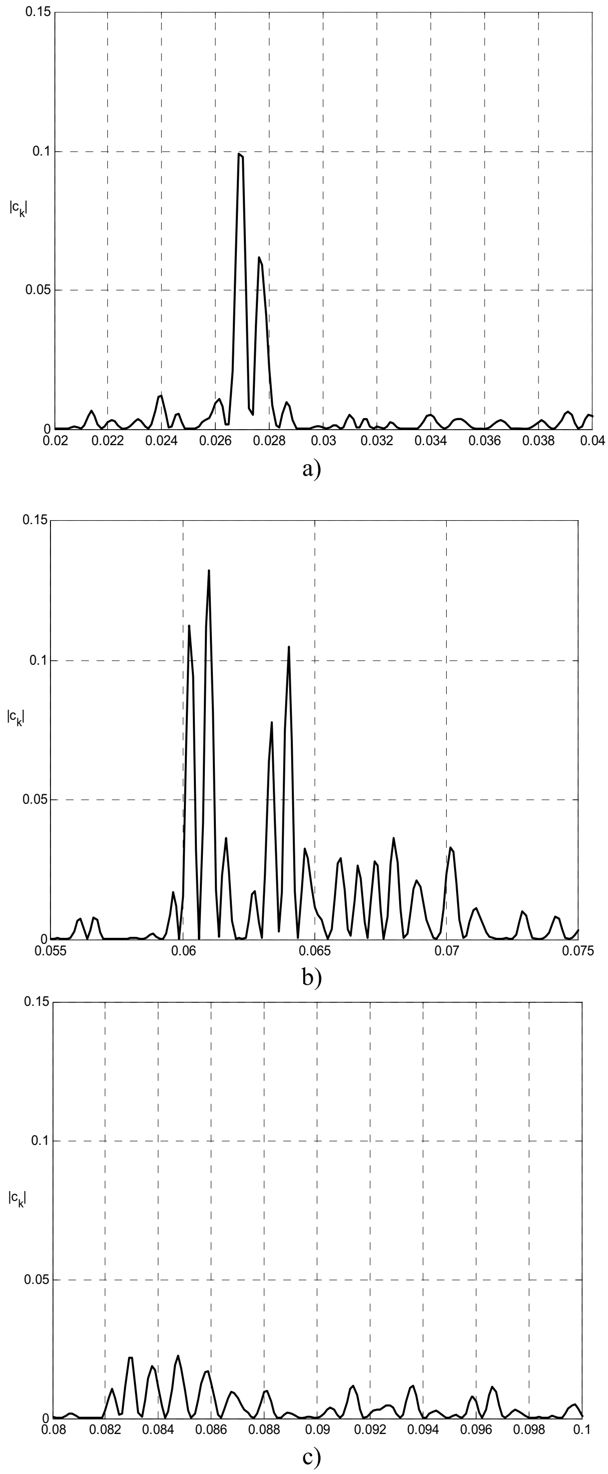

Fig. 4. Wavelet transform module coefficients at eight level of decomposition muzzle – blast wave a) sequence 1, b) sequence 2, c) sequence 3

Comparation of these coefficients of muzzle – blast wave it could be noticed some differencies that depend on artillery weapon caliber.

Probability density shape during time of wavelet transform coefficients moduls at eight level is significant for real sound signal classification. For sequence 1, these moduls have two significant levels, and for sequence 2 have more significant levels. For sequence 3 there is no significant levels. Making histograms of these coefficients during time it could be possible to classificate these signals.

V. CONCLUSION

In this paper is presented comparation of spectrograms and scalograms. It could be noticed that using of wavelet transform could be detected shock - wave than muzzle blast wave. If we using of scalograms, we can not detect these two waves.

Conducted analysis showed that there is some differences between wavelet transform coefficients moduls at eight level of signal decomposition. These differences can be not directly implementated in sequence classification.

Further this can be used in statistical classification of sound sequences that originates from artillery weapon of different caliber.

LITERATURE

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