Emergency Horn Detection Using Embedded Systems

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Abstract— **currently, the automobile concerns trying to fight for customers in many fields, from the safety of vehicles manufactured after retrofitting and comfort. Usually this is achieved by using the installation of air conditioning, comfortable seats, and high level of noise insulation and modern audio-systems, which will undoubtedly greatly affect the driver's interaction with the environment. One of the current topic in this field is detection of emergency horn by car. We present in this paper technology based on noise signal processing. There were developed new algorithm for emergency horn detection. The proposed algorithm was embedded into myRIO platform using its FPGA and tested in real conditions.**

I. INTRODUCTION

Ambulance cars tend to have significant signal colors, sometimes with reflective stripes or warning lights and sirens. Warning lights work great together with sound, especially in the evening or night hours. In bright daylight, the lights may remain vague. They can be invisible because of the low contrast with the surroundings, or may be blocked by another vehicle. The main method of warning oncoming vehicles of the integrated rescue system is a sound that does not require the ambulance remained in the driver's field of vision.

It is very difficult for many drivers to detect the presence of vehicles of emergency in particular when all windows are closed and the car is running radio. This makes it difficult for the driver to react in time and free up space, and thus not restrict a passing ambulance. This opens up an area important for maintaining safety on the road and rescue vehicles detection in normal operation.

According to research from 1999 dealing with soundproof insulation in modern cars and ambulance sirens downturn. An ambulance was equipped with a siren, which produced the intensity of the noise level of 115 dB. The first test was carried out on a car at a speed of 60 km/h when the car radio and ventilation systems were turned off. The siren was heard at a distance of 100 meters from a moving car. Turning on the air conditioning and radio on the minimum audibility sirens rapidly reduced to 50 meters from the car. Once the radio volume increased to the level of 90dB siren it was worth about 82 dB nearly inaudible. The sound of sirens ambulance could be heard up to a distance of 2 meters from the vehicle [1]

Automatic detection of ambulance sirens is possible using many different principles. Detection can be done for example by patented procedure [2] using a special radio signal, which transmits an ambulance car and receives. This principle is developed further in the field of automotive safety and traffic is directed through a general plane of peer to peer communication between cars. Such as C2C (CAR 2 CAR Comunication Consortium) [3] is engaged in several projects that solving communication between vehicles and the subsequent transmission of information on the traffic situation. They are responsible for solving IT standards for the structure of the automobile transport and so on. The underlying vision in this area are intelligent cities, and early warning systems. The project EAR-IT [4] focus on link building, transportation and wireless communications. The information obtained from traffic are processed and used to control traffic lights and traffic information to participants.

Other methods for detecting emergency vehicles are based on the measurement of sound, or optical signal. Examples includes Integrated Circuit Solution for Detection of Acoustic Signals in Emergency Road Traffic [5] which refers to the sound detection solutions using basic mathematical operations such as convolution and FFT. With the subsequent application to the silicon due to the size, power, current consumption, and SNR ASIC showed good qualities, but the development group warned that further testing under real conditions. Polish group of scientists from the Technical University of Lodz used to detect signals of basic signal processing methods. Method was used for the FFT and after its application, basic parameters were calculated spectrum (the maximum frequency, minimum, average). The algorithm has been applied to an embedded platform. The results of this method, published in the article were not sufficient, because the authors did not count the Doppler effect, and also was applied signal filtering. [6] Based Acoustic Safety Emergency Vehicle Detection for Intelligent Transport Systems [7], which uses the microphone array spread crosswise. Use mathematical methods such as correlation method, the time delay of sound, least squares method and adaptive filter. With the subsequent comparison of methods for detecting and using the place where the audio.

II. MATERIAL AND METHODS

There will be described the typical sound signal of emergency vehicles and further analysis of that in time and frequency domain.

A. Emergency vehicle horn

The sound of horn of emergency could vary in any EU country. It is not defined by law or decree of a general standard for tone curve sirens on vehicles with preferential right away in the Czech Republic. Regulations defines only minimal noise level and the fact that there must be a continuously variable tone. Horns are thus based on a white noise that has the ability to penetrate the

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environment and not cause reflection of sound. This prevents the formation of echoes, which would affect the determination of the direction of the sound source.

In the Czech Republic there are many manufacturers who can own specific course horn tone curve. Most generators sirens contains basic tones.

- Wail
- YELP
- Hi-Lo
- Special horn for highlighting warnings

These generators can automatically combine setting modes: e.g. Hi-Low mode, where in the horn starts in Hi-Low mode automatically after 10 seconds, switches to the mode yelp and vice versa. For the purpose of this work was chosen sound WEIL, which is the most widespread. Basic analysis and finding the characteristics of the horns was necessary to have a signal that is ideally clean and clutter free environment. Such interference could lead to a search processing and the characteristics of the signal for detection. The horn is formed on the generator, which generated audio signal travels to the connected speaker recommended by the manufacturer. [8]

B. *Signal Analysis*

The signal analysis was done using quality recording signal Wail 8000 Hz with a length of 66 seconds. It is a periodic signal with period T = 5 s. The signal is successively unstable.

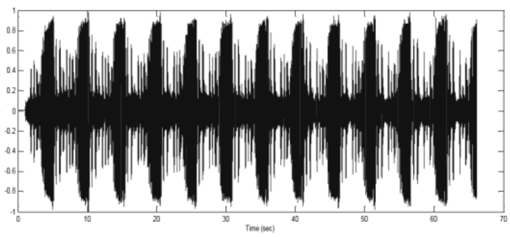

Figure 1. WAIL signal in time domain

From the viewpoint of stationarity was necessary signal segment in order to distinguish between rapid changes in the signal. The frame length should be small enough to be regarded as a signal in a given section in a stationary, but on the other hand acceptably large in order to sufficiently accurately estimate the required parameters. Parameters are frame length, frame shift overlap. [9] The window width w (n) was selected L = 128 samples and corresponds to s (t) = 16 ms without overlap.

When segmenting puts our signal requirement of distinctiveness good time, but according to the Heisenberg Uncertainty Principle lose [10] a good frequency resolution over. The signal is set on high frequencies, hence the higher frequency of 62.5 Hz step is not an obstacle. One of the other requirements for the width of the segment was the speed and simplicity of processing samples [11] on an embedded platform. Segmentation we use Hamming window function [12]. Frequently used rectangular box that has a very narrow width of the transition, but it occurs in its transition to spectral leakage (spectral leakage) to a greater extent than for other windows, and is not suitable for our needs. To view the spectral components in individual segments, we used fast Fourier transform.

In Figure 2, is possible to see detailed spectrogram of WAIL signal.

It was also necessary to choose the window w (n) with a maximum and minimum value of the occupied frequencies that characterize the frequency limits within which the siren moves. Maximum selected threshold frequency is Fmax = 1563 Hz and a minimum limit fmin = 750Hz.

Order in Δf1 = 370 Hz and it can be said that the speed of Δt1 = 2.7 with frequency variations of the signal in this area is very linear. Another characteristic of the signal

Δf2 = 500 Hz, where the abrupt change in the signal is very strong and it is also for the entire waveform unusual and responsible step change from time Δt2 = 0.010 s. The main part of the downlink signal where the siren tone decreases and takes Δt3 = 2 5 s, is slightly shorter than the rising tone of the sirens. The intensity of sound sirens all the time period dramatically changed.

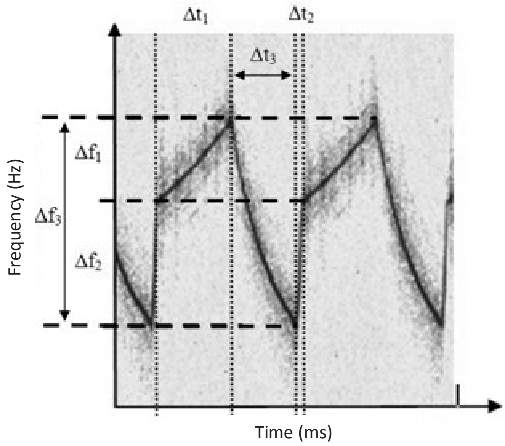

Figure 2. Detailed WAIL spectrogram

The spectral analysis and signal characteristics suspect that the individual segments can be expected dominant amplitude that is characteristic siren sound. According to this idea, we calculate spectral signal applied gravity. Spectral centroid is calculated as a weighted average of the frequencies that were determined using FFT and amplitudes as the weights. The characteristic spike sirens will therefore have the greatest weight in the calculation and the focus should not be cast unwanted frequencies with less weight. Therefore, it was before the calculation of the spectrum of gravity applied to IIR pass filter 500 - 2000Hz, 54th-order Butterworth approximation.

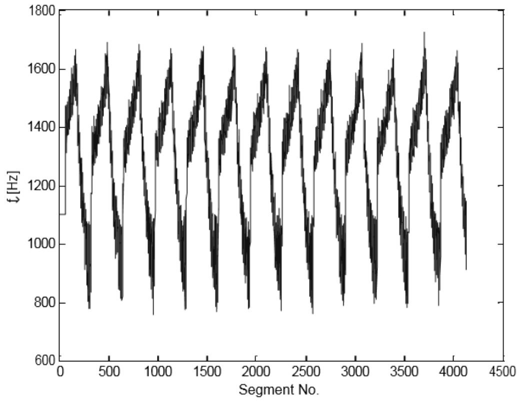

Figure 3. Spectral centroid of WAIL noise (after filtration)

According to the nature of the signal and its linear rise or descent rate, it was appropriate to analyze the growth rate or a decrease in spectral centroid see Figure 3. Using this difference in frequency steps can remove the signals that are rapidly changing character and create the boundaries for detecting siren.

Rate of change of the center of gravity is in the range -150 to 150 Hz. Significant peaks indicate the large change in the frequency spectrum of gravity. These changes correspond to signal the beginning of a new period, where there is a large change in frequency jumps.

For calculating the difference between two spectral centroid it is also possible to detect the relative acceleration of gravity. This acceleration can help us eliminate rapidly changing signals and reduce false detection of sirens.

Another method for the accurate detection were performed to determine the correlation of the movement of the highest peak in the spectrum along the frequency axis. Another parameter is the Middle observed short-term energy segment sirens. The calculation of this parameter, we found what ranges are energy spread of individual segments. Short-range energy can be used to separate segments of silence and siren. From the foregoing calculations, the center of gravity of the spectrum, correlation, gravity acceleration spectra etc. were created boundaries that are significant for detecting siren. Table no. 1 we can see each boundary calculated parameters signal siren. To meet the conditions of detecting each segment must meet the limits, which defines the characteristics of the signal horn.

TABLE I.
WAIL SIGNAL PARAMETERS FOR ALGORITHM DEFINITION

Parameter	Lower Threshold	Upper Threshold
corrTauMaxFreq (Hz)	0	812,5
corrTauMinFreq (Hz)	-812,5	62,5
t_f (Hz)	800	1600
delta_t_f (Hz)	-200	200
accelerationDelta_t_f (Hz)	-200	200
Energy	>= 0.15	

C. Algorithm

The proposed algorithm for horn detection in MATLAB starts with signal recording. The recorded signal is normalized and exchanges. For fast processing and evaluating the signal is segmented using Hamming window function. The window width w (n) is L = 128 samples, a signal is divided into 16 ms segments. All segments is applied band-pass filter. Along with the energy filtering are calculated for each segment. To convert segments of time in the frequency domain using Fast Fourier Transform. For each spectra being calculated spectral center of gravity to determine at which frequencies is concentrated greatest amount of energy. To distinguish signals with rapid changes of frequency change is calculated and the average acceleration of gravity of the spectrum. It can say that in terms of relative growth rate (lowering) the center of gravity frequency spectrum. From the initial analysis of the signal sirens were selected range contains the highest (lowest) rate contained in the siren. These spectra are used in the last block, which calculates correlation. More precisely, all spectra are correlated with the highest and lowest frequencies contained in the siren. In the last part of the diagram is a condition that evaluates all of the calculated parameters recorded signals with the boundaries established by analyzing the recording ambulance horns.

III. EMBEDDED SYSTEM IMPLEMENTATION

To implementation of the above described methods for processing an audio signal and detecting the horn has been selected platform NI MyRIO. It is built hardware appliance based on technology RIO (reconfigurable I / O). NI MyRIO incorporates the latest technology in the form of a system on a chip (SoC) chip Zynq® from Xilinx. This chip combines a dual-core ARM Cortex-A9 and FPGA. NI MyRIO system also includes 10 analog inputs, six analogue outputs, audio input and output channels, 40 digital input output lines.

For the possibility of further testing and development of the algorithm was created by a software application on a personal computer that works with data and values calculated by NI MyRIO. Its task is also to show the results of the detection of ambulance horns.

It allows the use of an additional decision-making level detection algorithm sirens. Use the Threshold condition to enable / disable decision condition. Wanted Peaks window to enter the maximum amount of samples to exceed the preset threshold level. Use the sliders to set the Width and Threshold number of samples and the water level detection. A simple block diagram of the detection procedure is explained.

Input parameter for the service function "peak detection" is a segment of the audio spectrum. According to the set parameters Width and Threshold finds a matching number of values that meet these parameters, but subsequent condition asks whether the number of matching values does not exceed the required threshold values. If the conditions are met, the result is evaluated as True.

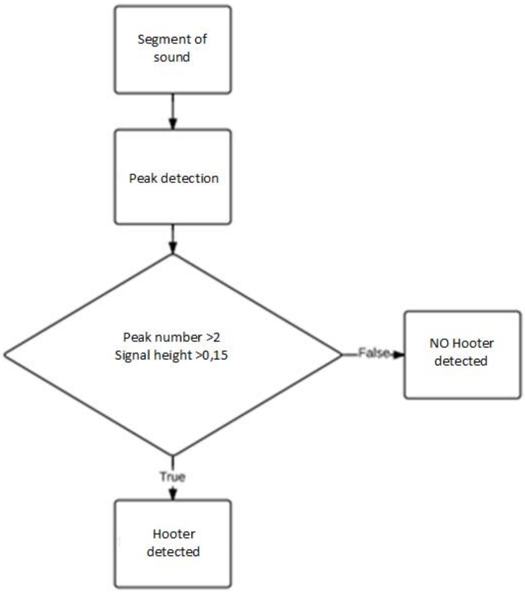

Figure 4. Spike detection algorithm

Figure 5 shows detection during the processing of sound recording sirens. There are three segments – the first one is signal preprocessing, which was implemented in FPGA module of myRIO platform. The second segment includes the next part of signal processing and also partly a decision making is done at Real Time module of myRIO. The last segment includes the last part of signal processing and more adjustable decision making. This segment is implemented into host PC. It allows many different configurations and possible testing of algorithm for decision making. It is necessary to say, that is easy to implement this third part into Real Time module of myRIO too. Threshold levels are set to 0.15 and the desired number of spikes detected is set to 2.

IV. RESULTS

The algorithm was tested on 11 real sound recording. It contained 4 record siren. Values to individual records say how many percent of the total recording time, it was detected as a siren. In Box percentage success is the success of the average value of the detection signal. Detection of signal in normal operation has a value of about 90% successful detection. Of course, decreasing the level of the average number of detection in the given time interval increases the chance of false detection. This trend can be seen in the values in the table.

The table 2 describes the results of an experiment on different levels *Threshold Of Probability* settings.

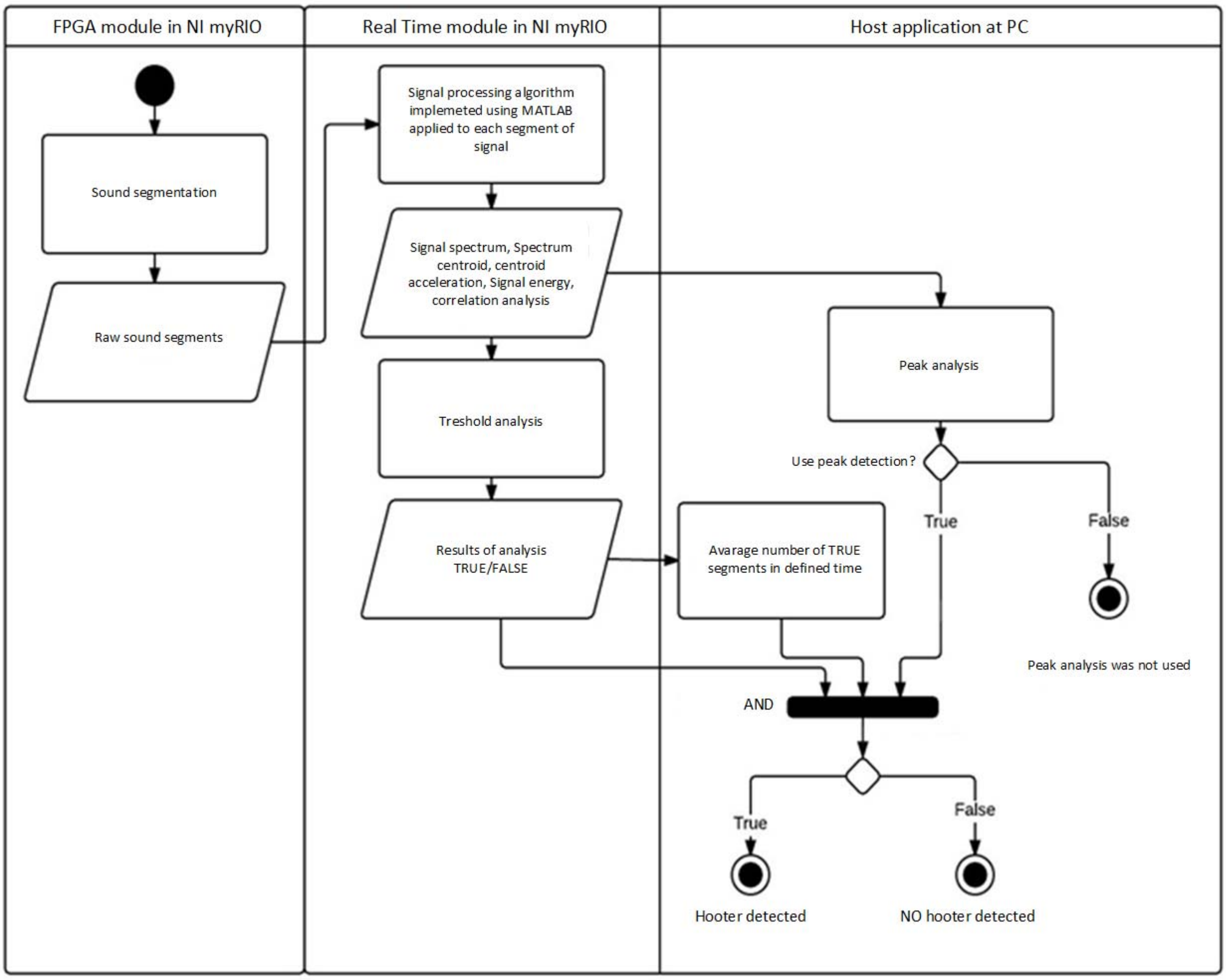

Figure 5. WAIL noise detection algorithm using myRIO

TABLE II.
WAIL SIGNAL PARAMETERS FOR ALGORITHM DEFINITION

Signal description	Threshold Of Probability (%) settings and its detection success (%)						Total detect. success (%)
	100	90	80	70	50	30	
Clear WAIL noise	100	100	100	100	100	100	**100**
EC staying at road with horn	90	95	100	100	100	100	**97,5**
Real traffic at crossing with EC horn	90	95	95	98	98	99	**95,8**
Real traffic at road with EC passing with horn	85	90	95	98	100	100	**94,7**
Traffic noise without EC horn	0	0	0	0	0	0	**0**
Car engine	0	0	0	0	0	0	**0**
BUS passing the road	0	0	0	0	0	0	**0**
Classical Music	0	0	0	0	0	0	**0**
Noise of Bird	0	0	0	0	0	0	**0**
Noise of Helicopter	0	0	0	0	0	0	**0**
Standard car horn	0	10	13	17	20	25	**14,2**
Sound “a”	0	0	50	100	100	100	**58,3**
Colours of Ostrava festival noise	0	0	0	10	20	50	**13,3**

EC = Emergency Car

V. CONCLUSION

There is currently no application solutions for the detection of ambulances. Only some works have pointed to different ways of processing.

The important part is the issue of dismantling the measurement of sound distortion in the environment, and the possibility of subsequent use of mathematical apparatus for detecting and processing the signal itself.

In terms of hardware it is necessary to point out the limitations in the automotive environment. It is the influence of the external environment on the measurement and the subsequent signal processing. What must be the protection of the microphone during bad weather, to avoid endangering the reduction in sound quality? How will it influence the measuring chain outside noises (wind, water, other cars, buildings, combination)? What is the minimum number of microphones to detect the position and its emplacement? It will affect the measurement of sound reflections from various obstacles.

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