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UTILIZATION OF ACOUSTICAL CAMERA FOR OBJECTIFICATION AND EVALUATION OF INDUSTRIAL NOISE

VYUŽITIE AKUSTICKEJ KAMERY PRI OBJEKTIVIZÁCII A HODNOTENÍ PRIEMYSELNÉHO HLUKU

Abstract

The „acoustic camera" is a measurement tool which joined the field of acoustics a few years ago. This technology analyses the actual sound scene, which consists of a superposition of different sound sources, into a visual sound map. The basic principle relies on accurate calculation of the specific runtime delays of acoustic sound emissions radiating from several sources to the individual microphones of an array. An acoustic map of the local sound pressure distribution at a given distance will be calculated using the acoustic data of all simultaneously recorded microphone channels. The sound pressure level is displayed by color coding, similar to popular thermal imaging. Automatic overlay of optical image and acoustic map gives rapid answers about locations of dominating sound sources.

Key words: *acoustic camera, sound map, NoiseImage*

Abstrakt

Akustická kamera je nástrojom, ktorý len nedávno integroval jednotlivé oblasti akustiky. Technológia akustickej kamery umožňuje analýzu reálnych akustických udalostí, ktorá pozostáva zo superpozície rôznych zdrojov zvuku, a ich priemet do vizuálnej hlukovej mapy. Základný princíp spočíva na presnom výpočte oneskorení akustických zvukových signálov vyžarovaných z rôznych zdrojov k jednotlivým mikrofónom antény. Hluková mapa rozloženia parciálneho akustického tlaku v danej vzdialenosti je vypočítaná použitím akustických dát zo všetkých súčasne zaznamenaných mikrofónových kanálov. Hladina akustického tlaku je znázorňovaná farebným rozložením, ktoré je podobné tepelnému zobrazeniu. Automatické prekrývanie optického zobrazovania a hlukového mapovania umožňuje rýchlu a presnú lokalizáciu dominantného zdroja hluku.

Kľúčové slová: akustická kamera, hluková mapa, NoiseImage

1 INTRODUCTION

The configuration containing the acoustic camera is a revolutionary solution of three-dimensional localization of sound emission with their quantitative evaluation and frequency analyses in dynamic mode. The amount of obtained and analyzed information is incomparable with all up to now used methods that leaned on measurements of sound emission in immission point that number is considerably limited. The acoustic camera offers possibilities of ideal frequency analyses of sound sources in distance from few tenth meters up to few hundreds meters. The delivered software equipment is able to localize effectively the sound sources and perform qualitative and quantitative analyses and so form a base for soundproofing arrangements.

The whole measurement and subsequent analyses are characterized by:

- high accuracy,
- high speed,
- dynamic operational mode, high effectiveness,
- transparent result processing (coloured acoustic maps, movies, records).

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2 WORKING PRINCIPLES OF THE ACOUSTIC CAMERA

Actual commercial beamforming systems, among them the acoustic camera, use a rectangular virtual image plane in order to calculate the run times between microphone array and measurement object (figure 1). This way the surface of the device under test is approximated, and the z-axis of the array is usually oriented perpendicularly to the image plane. The assumption is made that the device and hence the image plane do not move during the measuring time. Subdividing the image plane into rows and columns results in a finite amount of rectangular display details (pixels) whose centers of area are used to calculate the delays.

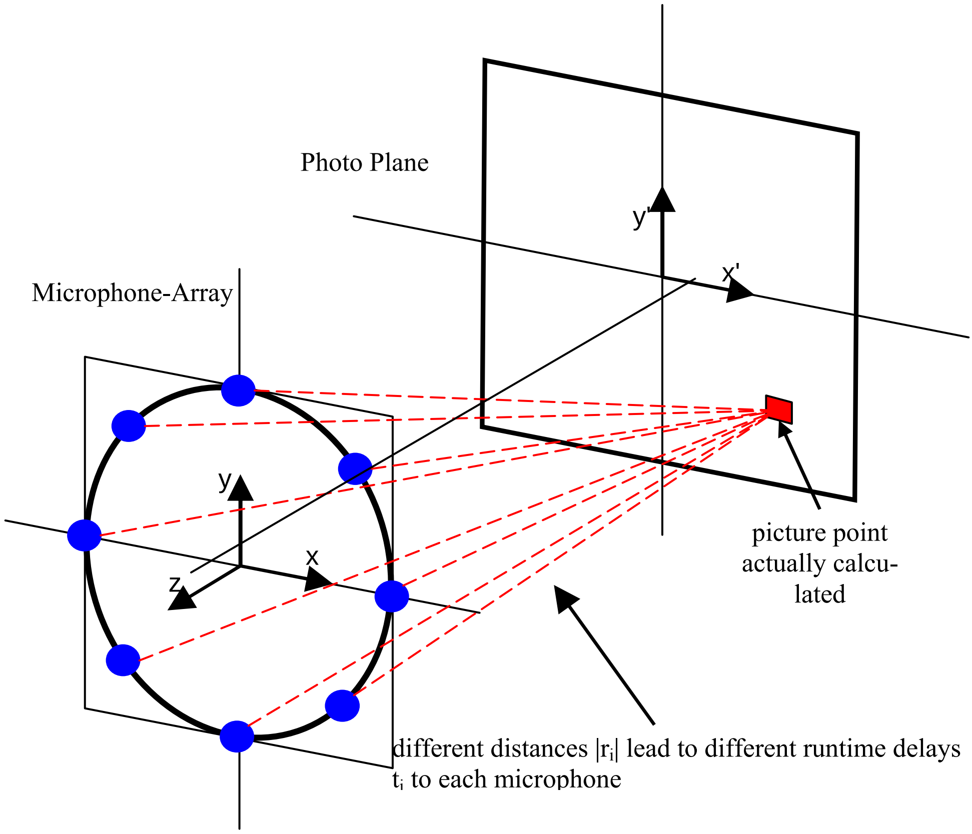


Fig. 1: Runtimes between array and a virtual still image plane

In the most simple case, reconstruction of the time function f of a point x = (x’, y’, z’)^T on the image plane is performed by delay-and-sum beamforming (2) according to equation (1). Here, t denotes time, M is the number of microphones in the array, the w_i are (optional) shading weights, the f_i are the recorded time functions of the individual microphones, and the Δ_i are the appropriate relative time delays, calculated from the absolute run times τ_i as $\Delta_i = \tau_i - \min(\tau_i)$. The absolute run times are trivially determined by $\tau_i = |r_i|/v$, where v is the speed of sound in air and $|r_i|$ is the geometrical distance from mirophone number i to the point of interest x.

$$f(x,t) = \frac{1}{M}\sum_{i=1}^{M} w_i f_i(x,(t-\Delta_i)) \qquad (1)$$

The effective sound pressure at point x is now determined using equation (2); every individual pixel is then coloured corresponding to its effective value and a given colour table. In (2), n is the total number of discrete time samples taken into account for the estimation of the effective value, f is the reconstructed time function (1) of the sound pressure at location x, and t_k is the time value at a discrete sample index k.

$$p_{eff}(x) = \sqrt{\frac{1}{n}\sum_{k=0}^{n-1} f^2(x, t_{kl})} \tag{2}$$

State of the art is the simultaneous taking of an optical photo by means of an integrated digital camera and the subsequent automatic overlay with the acoustic colour map. A typical example of an acoustic image is shown in figure 2.

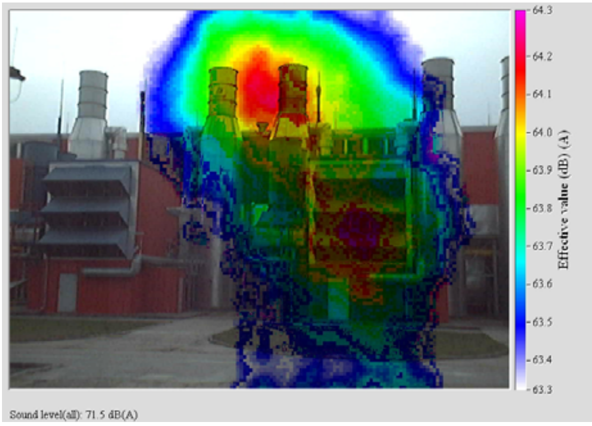


Fig. 2: Acoustic image

The acoustic camera is modular and flexible equipment for visualization and localization of sound sources. Trough visualization, accurate results and fast results decreases the development time of following technical arrangements of noise loading reduction. In the figure 3 is shown the configuration of the acoustic camera.

With Beamforming the main information to find the location of the sound is the run time delay between signals to each microphone. The spatial resolution is in direct relation to the Sampling frequency in the time domain and the microphone spacing.

To resolve two sources the system needs to be able to detect differences in the characteristic patterns in form of run time delays independent of post signal processing. This is independent from the resolution which is determined by the signal frequency.

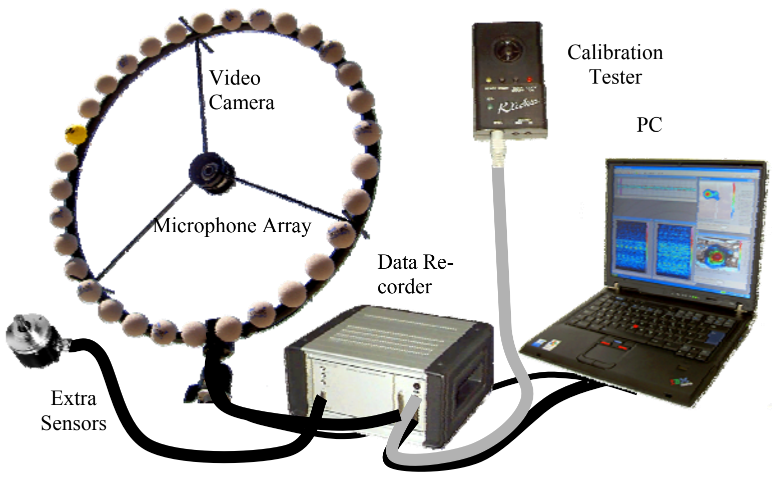


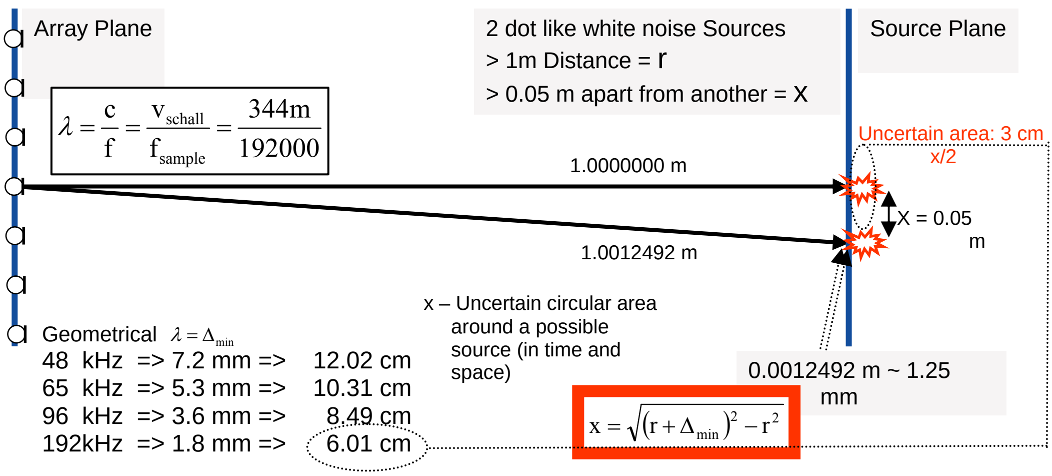
Fig. 3: Modular Measurement Tool

3 SOFTWARE EQUIPMENT OF THE SYSTEM - "NOISEIMAGE"

For working with the software „NoiseImage" a complex but easy to operate intuitive concept of interactions between space, time and frequency has been developed. In order to avoid model assumptions about emitter characteristics, only the equivalent sound pressure level is mapped, i.e. in the acoustic image the value is colour coded that would be generated by a point source in a nonreflexive room at the same distance (Fig. 4).

The recorded time functions can be evaluated according to A-, B- or C-weighting. A universal filter bank allows spectral generalisations. In the spectrogram view, noticable emissions can be marked temporally and spectrally simply by a mouse move and can instantaneously be shown as acoustic photo or movie to identify the related sound source. In photos and movies, the reconstructed time function of every location can be saved as wav-file, it can also be displayed as spectrogram or spectrum. All images can be exported as Bitmaps or JPEGs, movies can be saved as AVI. Spectra can be shown in third octave bands. Listening to the time functions of photos and movies is possible by moving the mouse over the picture. This allows to individually recall recordings even many years old.

When a film is saved as AVI, the stereo sound from the recorded time functions or alternatively the reconstructed time function of a chosen location in the image can be integrated into the exported movie. The according location is then marked by a microphone icon. For the analysis of stationary emissions, the so called „spectral frames" (a type of spectrally sensitive photo) are an additional tool for interactions between image and spectrum. A mouse click into the picture will immediately show the corresponding spectrum of that location, and vice versa selecting a spectral band from the spectrum will show the related acoustic image covering only those selected spectral components.



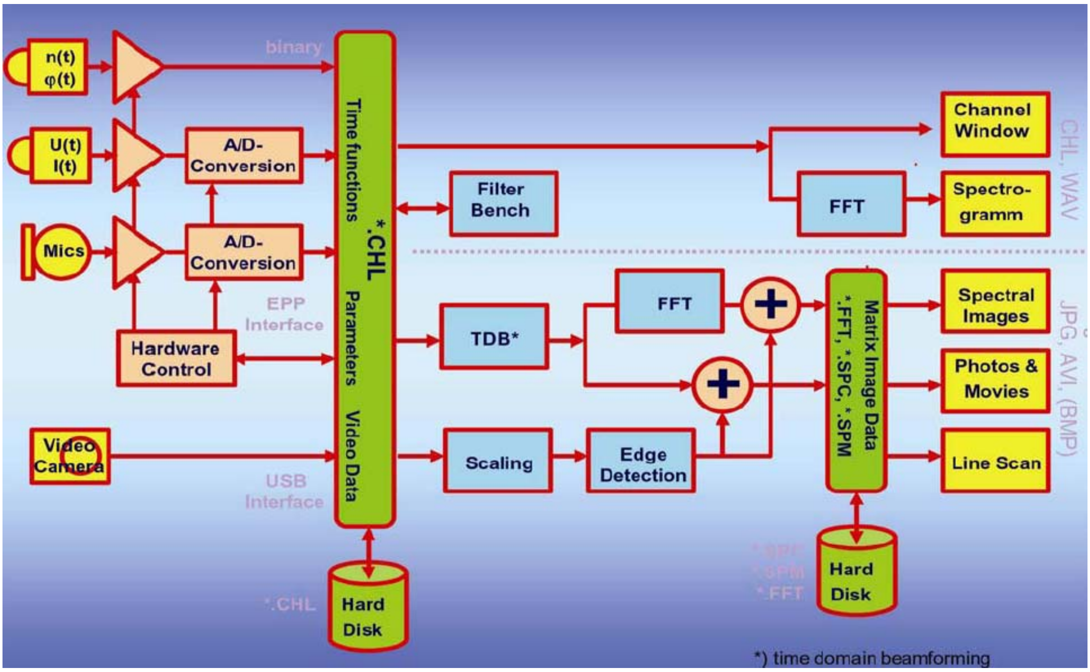


Fig. 4: Data structure of the Acoustic Camera – overview.

Saving a high channel recording generates a file (channel: *.chl) with all the relevant information (time functions, preamplifier parameters, date, distance, video image(s), camera parameters, array coordinates, calibration data etc.). So the channel file does not only contain raw time function data but all necessary parameters belonging to a measurement. Motivation for this decision is a maximum independence of the data analysis from the measurement process: A data file can be evaluated correctly even one year later and even by another person not involved in the measuring process itself.

4 APPLICATION IN THE INDUSTRY

There are exemplified applications of acoustic camera at sound measurements of major industrial sources, in this case turbo-compressors. In the fig. 5 is shown the view of the analyzed turbo-compressor and in the fig. 6 is shown the measurement site with installed acoustic camera. In the fig. 7 is shown the noise emission intensity of the turbo-compressor by its depressurization. The critical frequencies recorded at the measurement site are evident from spectrogram, see fig. 8. Structure of the entire frequency spectrum is obvious from the fig. 9, where are clearly shown the critical frequencies.

Fig. 5: View of the turbo-compressor

Fig. 6: The acoustic camera installed at measurement site

Fig. 7: Visualization of the noise emission intensity by depressurization

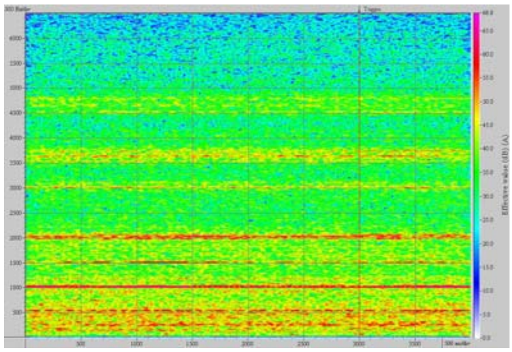


Fig. 8: Spectrogram of the emitted noise

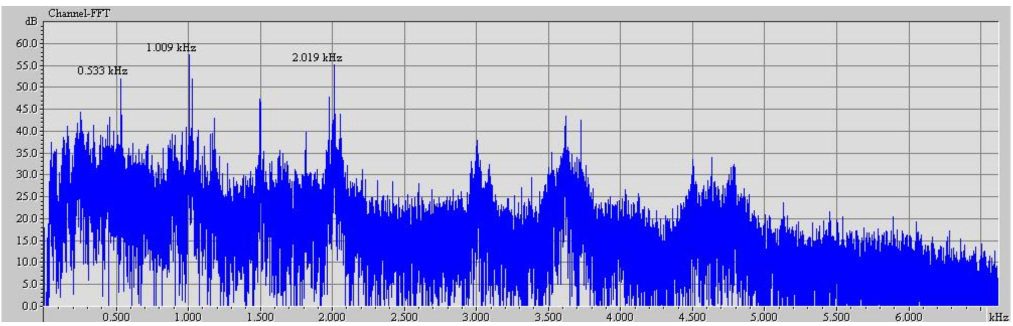


Fig. 9: Frequency spectrum of the recorded noise

CONCLUSION

The acoustic camera extends the present analyses procedure. Also involves general methods of the analyses like A-level evaluation, tertiary and narrow- band analyses, filters and other options. It makes possible to provide detailed analyses. The spectrogram makes possible for example recording of the sounds in time and in transmission bandwidth. From the acoustic photo one can localize the sources of these sounds, recall the emitted noise in certain points, show critical frequencies and do all this after provided measurement. The acoustic camera is a multisensorial virtual studio for sound sources analyses in detail.

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