DIGITAL CINEMA DIAGNOSTIC SYSTEM BASED ON SPECTRAL ANALYSIS AND ARTIFICIAL INTELLIGENCE METHODS

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Summary
In this paper digital cinema diagnostic complex is described. Its working algorithms are based on wavelet preprocessing, statistic analysis and neural network classification. Considered methods were practically incarnated using modern systems of computer modeling.

Keywords: diagnostics, digital cinema, wavelets, artificial intelligence.

Modern system of digital screening and film production demands modern approach not only from the point of view of equipment developing and designing, but also from diagnostic one. Being a complicated, self-optimizing system, digital cinema complex should be observed as a segment of informational networks, in case of diagnostic view, and imply an estimation of big amount of various parameters.

Such systems consist of number of simple parts, connected to each other. This condition makes difficulties for usage of ordinary automated systems of diagnostic and quality control. The most complicated are description of allowable working rate for hardware parts.

Diagnostic signals are complex-structured and generally transient:

$$s(n)=S(n)+\sigma_1 e_1(n)+\sigma_2 e_2(n) \qquad (1)$$

where *s(n)* – measured signal, *S(n)* – normal functioning signal, $e_1(n)$ - noise, $e_2(n)$ - distortions due to systems defects, σ_1 and σ_2 - distortion levels, *n* – discrete or continuous variable.

Wavelet analysis possesses an ability of time-frequency localization of signals distortion. That is why it is most preferable basis for diagnostic problems solution. For our purposes, the most informative components of signal are the noise ones - $e_1(n)$ and $e_2(n)$, since they carry an original imprint of system, which makes diagnostics possible (figure 1).

The solution of diagnostic task for noise characteristics is rather complicated, because of number of problems supposed to be solved. One of the most important problem is noise separation. It should be divided to local components and background. For each of these two components special analysis and thresholding methods are used. Statistic and spectral analyses of noise components should be performed, including threshold function type, wavelet basis and decomposition level selection.

Wavelet analysis is based on representation

$$s(n)=\sum_k A_k \psi_k(n) \qquad (2)$$

where $\psi_k(n)$ - basis functions, A_k - decomposition coefficients.

Due to its time-frequency localization, wavelets allow to analyze the non-regular signal structure. Time localization implies that wavelet's energy is concentrated in some finite time interval. Frequency localization means compactness of wavelet's Fourier-form, in other words it means its energy localized inside of finite frequency interval. Wavelets could be constructed from mother wavelet function $\psi_k(n)$ by translation $\psi_k(n) \rightarrow \psi_k(n-b)$ and dilatation $\psi_k(n) \rightarrow \psi_k(\frac{n-b}{a})$, where parameter *b* called transition and *a* – scale. Wavelet transform in its discrete version uses *a* and *b* with steps divisible by 2:

$a=2^m, b=k2^m$, $k,m \in Z$.

Thus, wavelet function could be represented like

$$\psi_{m,k}(n)=a_0^{\frac{m}{2}}\psi(a_0^{m}n-k) \qquad (3)$$

where a_0>1 (here we take a_0= 2).

Spectral transform coefficients $A(m,k)$ are defined as convolution of signal $s(n)$ and wavelet $\psi_{m,k}$. Farther, in the course of getting diagnostic information from object, there comes a necessity of incoming data clustering to classes depending on object's characteristics.

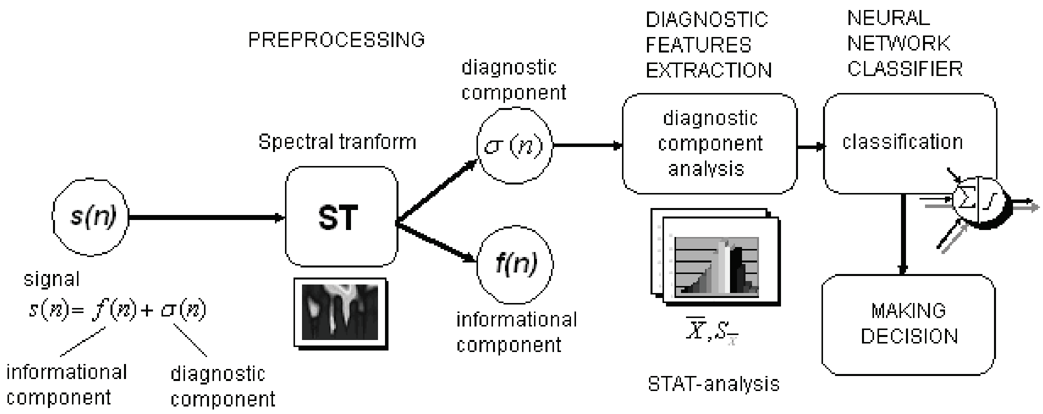

Fig. 1. Diagnostic algorithm

Clustering is performed using neural network algorithms. The present state of neuron is calculated like

$$g(A) = G_i^T A \quad (4)$$

where $G^T = (G_1, G_2, ..., G_n)$ - weight array, *T*-transposition.

Array A is formed from coefficients $A(m,k)$ for fixed frequency ranges $\omega_1, \omega_2, ..., \omega_n$. For components $e_1(n)$ and $e_2(n)$ to be extracted according to [1], the present state of neuron is calculated like

$$g(A) = G_i^T f(A) \quad (5)$$

where $G^T = (G_1, G_2, ..., G_n)$ - weight array, $f(A)$ - array function.

Let us observe an example of $f(A)$ calculation. Informational signal's spectrum could be presented by array $A_m^T = (A_{m1}, A_{m2}, ..., A_{mn})$. Now, we have to transform array's components [2, 3]:

$$f_{mi}(A_{mi}) = \frac{A_{mi}}{2}[\ \mathrm{sgn}(A_{mi} - \Delta_{ki}) + 1\ ] \quad (6)$$

i=1,2,...,n;

$$\mathrm{sgn}\, x = \begin{cases} 1, x > 0; \\ -1, x \le 0, \end{cases}$$

where Δ_{ki} - threshold value for *i* frequency;,

$\Delta_{ki} = k\Delta_i$, $k = 1,2,...$

Diagnosed parameters ***r*** define the values of spectral coefficients (4). Among them, received during statistic or fuzzy analysis of coefficients (4), let us select such frequency ranges $\omega_1, \omega_2, ..., \omega_n$ which coefficients A_{mi} are monotonous functions of ***r***. Threshold value Δ_i should be considered as function of *i*, that is $\Delta_i = \varphi(\Delta, i)$, where Δ - modified parameter.

Frequency-dependent threshold Δ leading is necessarily for excluding of resonance influence to informational signal's analysis while mechanics diagnostic. In case of sound and video processing it allows to exclude non-informational components.

Function $g(A)$ depends on threshold value Δ and diagnosed parameter ***r***:

$$g(A) = \sum_i G_i \left\{ \frac{A_{mi}}{2} \mathrm{sgn}\left(A_{mi}(r) - \varphi(\Delta, i) \right) + 1 \right\}. \quad (3)$$

For classification of diagnostic data Probabilistic Neural Network (PNN) is used. It has a structure based on radial base network architecture. PNN structure [1] for MATLAB modeling is shown on figure 2.

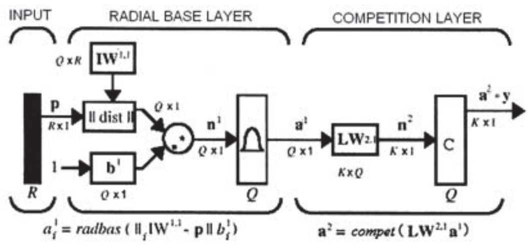

Fig. 2. PNN structure [1].

Let us observe the PNN working algorithm [1]. Let the learning multitude is defined and consists of *Q* pairs of input arrays. Each array consists of *K* elements, which are related to some class. Thus, we get matrix *T* with dimension *K x Q*, its rows correspond to classes and columns do to input arrays. First layer weight matrix $IW^{1,1}$ is formed from input arrays, taken from learning multitude (matrix *P'*). If new array multitude is entered, the ‖dist‖ block calculates proximity of new array to existed ones. Then, proximities are multiplied by deviations and got to activation function input (*radbas*). The nearest learning multitude array to input one will be presented in output array a^1 by number close to 1.

Matrix $LW^{2,1}$ (second layer weight matrix) corresponds to matrix T (current learning multitude tie-up matrix). By multiplication T and a^1, correspond elements of array a^1 will be defined. Thus, function *compet* (competition activation function of second layer) forms 1 if largest value of array n^2 and 0 otherwise. So, reviewed network solves problem of input arrays classification by K classes.

Considered model could be incarnated as *LabView* virtual instrument (VI for short). For this purpose *Advanced Signal Processing Toolkit* is used. It has wide collection of different means of wavelet transform. For example, let us observe the part of diagnostic complex, responsible for noise estimation. On fig. 3 and 4 front panel and block diagram of program are shown.

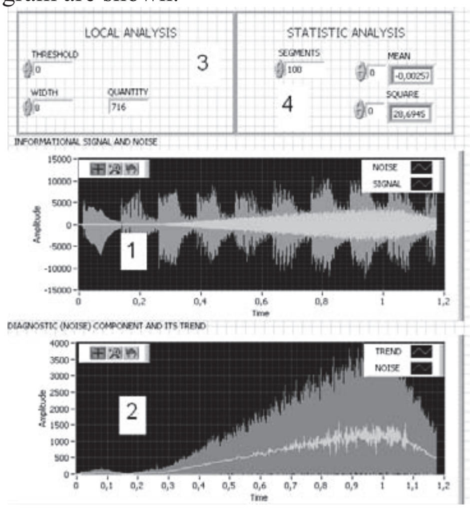

Fig. 3. Front panel of virtual instrument

Assignment of front panel elements:

1. Oscillogram of informational signal and noise component, extracted during wavelet preprocessing
2. Oscillogram of noise (diagnostic) component and noise trend detected
3. Local analysis results (quantity of peaks of certain width in signal)
4. Statistic analysis results (quantity of segments, mean, square values)

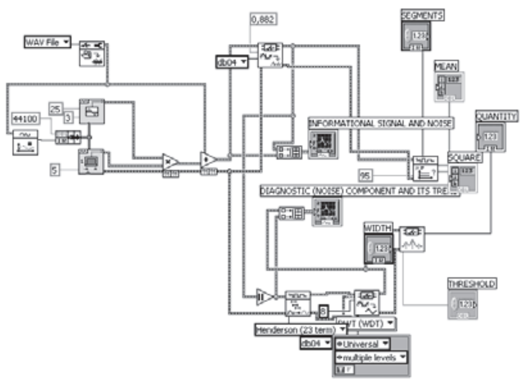

Fig. 4. Block diagram of virtual instrument

Program is based on following VIs - *WA Read From File.vi, WA Detrend.vi, WA Denoise.vi, TSA Stationarity Test.vi.*

In present version, data should be contained in wav file, although *LabView* supports other formats like AIFF, TXT, BMP, JPEG. It should be clear that analysis of 1D signals (vibration, sound) would be performed separately from 2D signal one (pictures) because of wavelet analysis algorithm differences, but in some cases it is useful to estimate distortion correlation between vibrations, sound and picture in the same moments of time. So, on the technologic point, to perform a diagnostic procedure, one just have to start *LabView* and choose some options. If to work with recorded data only, considered version of diagnostic instrument is enough, without supplementary hardware needed to gather information.

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