COMPUTER SIMULATION OF THE TRANSMISSION CHANNEL INFLUENCE ON THE VIDEO SIGNAL

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Abstract

This article contains the time-spatial and spectral description of video signals. There are described methods for computer simulations of real transmission channels and for determination of their influence upon the video signal and the quality corresponding picture.

Keywords

video signal, transmission channel, time-spatial domain, spectral domain

1. Introduction

The computer signal processing has significant importance into the television (TV) technique. Even so it is possible to assume the some applications of the analog video signals in the future (for example in TV camera channels, in cameras for security services, etc.). Therefore it is necessary to improve the methods for investigation and evaluation of the influence of various distortions and perturbations, which are characteristic for real transmission channel. These methods must make quantitative expression and minimization of this distortions possible with respect of the requested picture quality. There is described the method in the article and it is proposed special software, which makes requested analysis possible. Described basic version of this program is only determined for the video signals corresponding to the static and monochromatic pictures, but it is also applicable for the dynamic changeable video signals. This program also makes investigation of the distortions possible, which are caused by the overloading of the sampling theorem in the scanner.

2. Characterization and Mathematical Description of the Video Signal

The **picture flow** $O(x,y,t)$ corresponding to a scanned picture is described by the three-dimensional **continuous** function, while **picture information** $I(x,y,t)$ arises from picture flow by the time-spatial scanning in the scanner with scanning function $R(x,y,t)$ (corresponding to the classical camera tube) or by means of the dot scanning function $D(x,y,t)$ (corresponding to the modern monolitic sensors CCD). It is necessary the sampling of the picture as well in the horizontal direction for digital representation of a video signal. Picture information is getting as:

$$I(x,y,t) = O(x,y,t) \cdot R(x,y,t) \qquad (1)$$

$$I(x,y,t) = O(x,y,t) \cdot D(x,y,t) \qquad (2)$$

Transformation is realised by means of three-dimensional (in case of a static picture two-dimensional) Fourier transformation [1] to the spectral domain. Scanning of a static picture by means of the scanning function causes the line character of the corresponding two-dimensional spectrum in the spectral domain. It can be used the two-dimensional integration of the picture information over the variables x and y in accordance with equation (3) for transfer to the one-dimensional expression of the video signal $s(t)$. Limits of integration correspond to the sizes of scanned picture in horizontal (-A to +A) and vertical directions (-B to +B).

$$s(t) = \int_{-B}^{+B}\int_{-A}^{+A} O(x,y,t) \cdot D(x,y,t) \cdot \mathrm{d}x\mathrm{d}y = I(x,y,t) * \delta(t) \qquad (3)$$

3. Transformation of the Video Signal

Analytical expression of a video signal is very difficult, because an arbitrary picture has a stochastic character. It is possible to use computer technique to this purpose. Picture data, corresponding to the one picture or sequence of pictures, are formed by means of digitalisation (sampling fulfilling the Shannon-Kotelnik theorem in all directions of the sampling (x,y,t) and following quantizing end encoding). It is possible to express a dynamic changeable scene by means of the static picture sequences.

We will assume only the static monochromatic picture, which is progressive scanned without consider backward courses in the following explanation. This scanned video signal will be quantized to the 256 levels (8th bit representation of an each picture element). It can be used two-dimensional Discrete Fourier Transformation DFT (FFT) for transfer of the scanned video signal from time-spatial to spectral domain. The DFT is defined in matrix notation as forward transformation:

$$\left[c_{l,k}\right]=[A][f(n,m)][A]_{\mathrm{R}}, \tag{4}$$

backward transformation

$$[f(n,m)]=\left[A^{*}\right]\left[c_{l,k}\right]\left[A^{*}\right]_{\mathrm{R}}. \tag{5}$$

Where $\left[c_{l,k}\right]$ is matrix of spectrum coefficients,

$[A]$, $[A]_{\mathrm{R}}$ are matrix of transformation kernel $\mathbf{W}_1$ a $\mathbf{W}_2$ of Fourier transformation (according [1]),

$[f(n,m)]$ is matrix of luminance distribution in time-spatial domain.

It is possible to obtain two-dimensional spectrum as a function of spatial frequencies f_x, f_y by forward DFT (FFT). This one can be transferred to the one-dimension expression as function of the frequency (see Fig. 1).

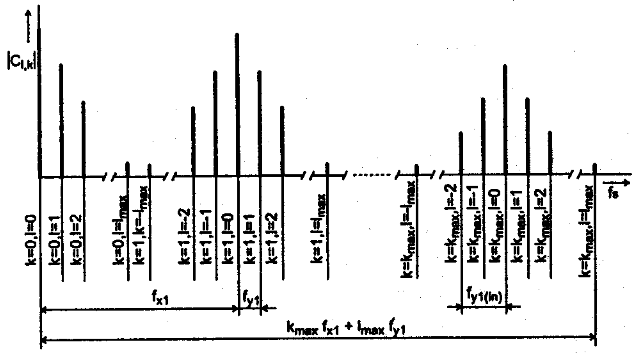

Fig. 1 Example of one-dimensional representation of module spectrum coefficients of the discrete spectrum, which corresponded to the static picture

$$f_s=\left(k+\frac{l}{N}\right)\cdot f_{x1} \tag{6}$$

$$f_s=(k\cdot N+l)\cdot f_{y1} \tag{7}$$

f_s - frequency,

k - index of spectral coefficient in horizontal direction in range (-M/2 to +M/2) according picture resolution,

l - index of spectral coefficient in vertical direction in range (-N/2 to +N/2) according picture resolution,

N - number of lines in vertical direction,

f_{x1} - at least spatial frequency in horizontal direction (line),

f_{y1} - at least spatial frequency in vertical direction (frame frequency).

4. Influence of Real Transmission Channel on the Video Signal

Real transmission channel causes especially linear distortions and some perturbations (noise, hum, harmonic or pulse signals, echo signals etc.) in the transmitted video signal. Situation is more difficult in non-linear transmission channels, where the perturbation signals can cause generating an intermodulation signals. Real transmission channels can be modeled as analog or discrete filters (lowpass, highpass, bandpass filter). Influence of the linear distortion can be investigated by means of module $A_k(f)$ and phase $\varphi_k(f)$ of the transmission function of simulated transmission channel. Exerting of the influence of modelling transmission function to the output video signal is performed by **multiply** one-dimensional discrete spectrum of the video signal and transmission function of the channel (namely both characteristics - module and phase characteristic) in spectral domain. The type of modelling transmission function is depended on the level of the video signal in case non-linear transmission channel. Additional perturbations, which are caused by real transmission channel, are possible to simulate by spectral **superposition** of the mono-spectral and the multi-spectral signals with various amplitude to the one-dimensional spectrum of the video signal. The spectrum of the output signal is transferred to the two-dimensional expression and it is transferred back to the time-spatial domain by means of backward DFT (FFT). That way is possible subjective to evaluate the degradation of the output picture or to quantify them according selected criterions. Process of the analysis, which is realized by proposed program, is on the Fig. 2.

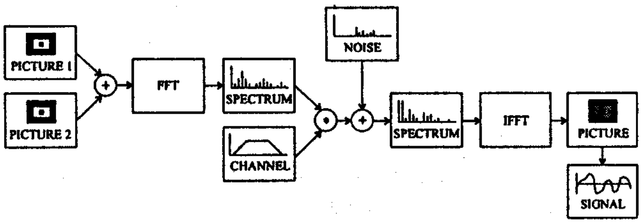

Fig. 2 Ideological simulation process of the influence of real transmission channel, perturbations and double reception to the output video signal

5. Proposed Software

It was developed program for computer simulation of the influence of real transmission channels properties and the outside perturbations on the basis of the methodics described in the previous paragraphs. The program is determined for the PC computers with operating system Windows 95 and it is structured as an interactive didactic aid. This one makes possible to demonstrate relationships of description of the video signals corresponding to the arbitrary static and monochromatic picture in the time-spatial and the spectral domain. Further, it makes possible to investigate the influence of different type of distortions, perturbations and to compare output degenerate pictures with input pictures. The input picture data can be possible to enter by an analytical expression (it is only for simple determined pictures) or by table of the pixels or by scanning arbitrary scene (bitmap). The dimension of the input data scanning raster is optional and it influences especially time counting.

6. Demonstration of the Proposed Program Outputs

On Fig. 3 to 6 are screen shots some outputs of the proposed simulation program. The picture on Fig. 3 is used as the input picture and a lowpass filter and a highpass filter 1st order are used as linear transmission channels. It is obvious the influence of the transmission channel to the input video signal in time, spectral and especially in time-spatial domain from this graphics outputs. The input picture is rastered to 128×128 pixels. The frame period is 40 ms and is used progressive scanning.

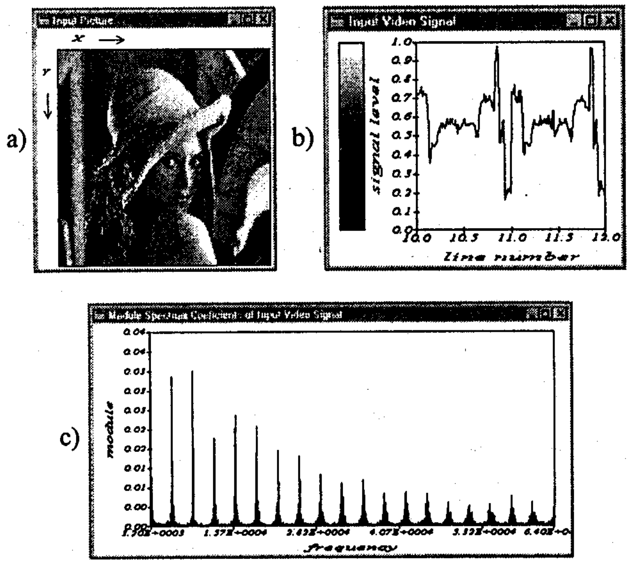

Fig. 3 a) Input picture,
b) Video signal of input picture,
c) Module spectrum coefficients of input picture video signal

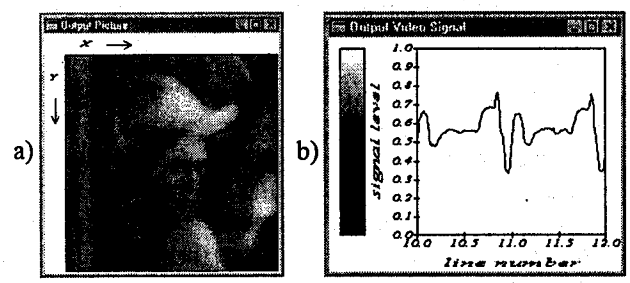

Fig. 4 a) Output picture on the output lowpass filter with treshold frequency 10 kHz,
b) Video signal of output picture on the output lowpass filter with treshold frequency 10 kHz

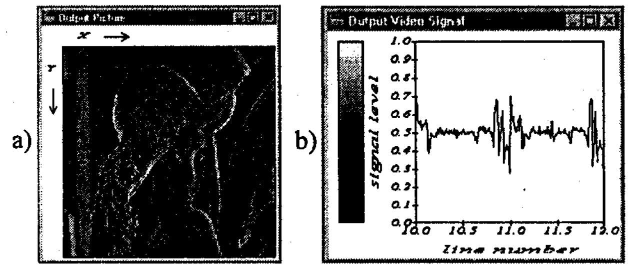

Fig. 5 a) Output picture on the output highpass filter with treshold frequency 50 kHz,
b) Video signal of output picture on the output highpass filter with treshold frequency 50 kHz

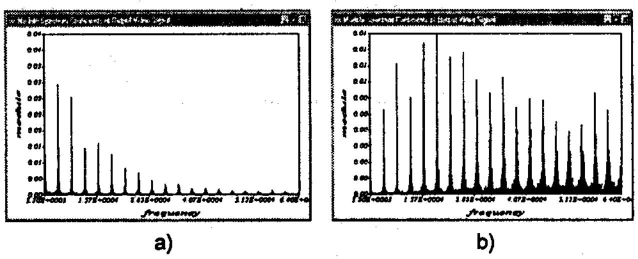

Fig. 6 a) Module spectrum coefficients of video signal on the output lowpass filter with treshold frequency 10 kHz,
b) Module spectrum coefficients of video signal on the output highpass filter with treshold frequency 50 kHz

7. Conclusion

The basic version of proposed program is suitable for investigation and evaluation of linear and non-linear distortions and various perturbations, which occurs in the real transmission channel, and their influences on the video signal corresponding to the static monochromatic picture. This method can also be extended on the video signal corresponding to a dynamic changeable scene. It can be applied separately on the component signals (luminance and chrominance), therefore it is possible to apply its on the colour TV pictures too. On the basic of the numerical evaluation of the admissible picture degradations (for example admissible reduction of the resolution etc.) it is possible defined by means of the regressive operations the tolerance of the channel transmission function. This program can also be applied in the teaching, because it makes possible the demonstration of the time-spatial and the spectral description of the video signals in the basic band and the representation of the transmission channel influences to the resulting picture.

References

[1] PTÁČEK,M.: Digitální zpracování a přenos obrazové informace, NADAS, Praha 1983.

[2] ŘÍČNÝ, V.-PIŠTĚK, M.: Influence of Transmission Channel to Video Signal and its Spectrum, In: *Proceedings of the 8th International Czech-Slovak Scientific Conference „Radioelektronika 98"* VUT Brno 1998, Vol.2, pp.396-399.

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