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Application of discrete digital transformations with nodes on a centered lattice in post-processing of anti-nicotine animation

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Abstract

Annotation. *The work is devoted to the research and study of the approach application based on discrete digital transformations to reduce interference and visual noise. The numerical results of the experiment are shown in relation to a part of the digitized materials of the Krasnoyarsk film Archive.*

Keywords: *digital discrete transformations, Gaussian filter, anti-nicotine animation, noise reduction, digital filters, transformations with nodes on a centered lattice, the quality comparison of the original and processed video by peak signal-to-noise ratio (PSNR).*

INTRODUCTION

Currently, the total number of film copies of both chronicle-documentary, as well as feature and animated films in the Krai State Independent Organization of Culture (KGAUK) “Yenisei Kino” is approaching 10000 [1]. When holding various festive, commemorative, and event activities at the regional level, digitization of chronicle and documentary film materials is required [2].

At the request of the Krasnoyarsk branch of SBNT, short animated films dedicated to anti-nicotine theme were selected:

“I don't smoke”, 1987, on a 16 mm film;
“Smoking and Children”, 1988, on a 35 mm film;
“Smoking is dangerous for everyone», on a 35 mm film.

The 35 mm film of the cartoon “Smoking is dangerous for everyone” was **particularly susceptible** to **the aging and fading** process (significant redness was visually observed), the film had undergone a sufficient number of screenings and therefore corresponded to the **3rd** quality category in terms of depreciation.

The 16 mm film of the cartoon “I don't smoke” also didn’t escape reddening, but the degree of the film fading was much lower.

On the other hand, the 35 mm film of the cartoon “Smoking and Children” was preserved quite well and **corresponded** to the **1st quality category** in terms of depreciation.

At the preliminary stage, the film was moistened in the filmostat with a special solution based on glycerin, distilled water, and acetone [3]. The mechanical defects and dust were removed manually by a film checker. Additional cleaning took place during the film scanning process.

When the quality of the film copy does not meet the requirements [4], it is reasonable to apply transformations and digital plug-ins, leading to a significant entropy minimization in the picture [5].

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Figure 1 Scanning a 35mm motion picture film

One of the post-processing tools is the application of a modified Gaussian filter [6].

The filter, which application is visually manifested in image blurring; the filter kernel is calculated using the Gaussian distribution function:

$$G(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{x^2}{2\sigma^2}}, \qquad (1)$$

(one-dimensional case)

$$G(x,y) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{x^2+y^2}{2\sigma^2}}, \qquad (2)$$

(two-dimensional case)

where x is the X-axis distance from the origin, y is the Y-axis distance from the origin, σ is the standard deviation of the Gaussian distribution. A filter with such a kernel implements the idea of calculating a weighted average of each pixel**,** where the influence of each pixel on the result depends on its distance to the pixel in question. Theoretically, at each image point, the Gaussian function takes a non-zero value and each pixel should affect the result of calculations for each pixel of the image**.** However, as the values of the Gaussian function at a distance of more than более 3σ from the origin are extremely small, they can be neglected.

It is worth noting two interesting properties of the Gaussian filter [7]:

- applying multiple Gaussian filters one after another has the same effect as applying a single filter with a kernel size equal to the root of the squares sum of the smaller filters kernel sizes;
- the filter application in the two-dimensional case can be decomposed into 2 stages (vertical and horizontal), which reduces the computational complexity of the algorithm.

The Gaussian filter is well-established in computer visualization perception tasks and is often used for noise smoothing as well as in image downsampling (decimation) tasks [8].

To make digital transformations sequential, discrete, and with nodes on a centered lattice [9], a main algorithm was developed (Figure 2).

In this study, the FFT library (a software implementation of the standard FFT algorithm - fast Fouriertrans form, which works only with real numbers [10]), the Gaussian filter, the Butterworth filter, and a number of other digital transformations were used. [11].

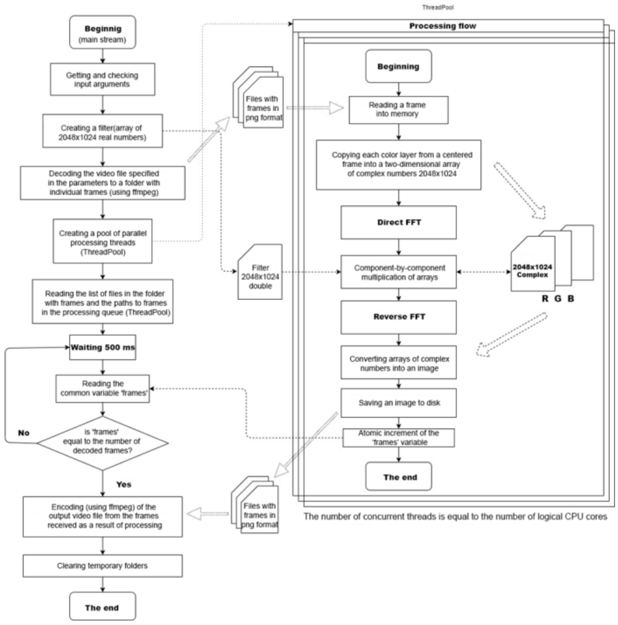

Figure 2 Block diagram of the main algorithm

Numerical results of the Gaussian filter experiment

The rendering in this paper used a step size of 3, 5, 7, 10, 12, 15, 18, 20 and 25 points. However, to demonstrate the results, some of the calculations and iterations were reduced.

Let us introduce the following notation:

FG hf is a Gaussian high-frequency filter.

FG lf is a Gaussian low-frequency filter.

Table 1 Processing results of digitized films with an exposure radius of 3 pixels

Video	**Time** (m., s.)	**Process**	**Exposure radius**	**Processing time** (m., s., split sec.)
I don't smoke (16 mm, color film copy)	4:59	FG hf	3	1:01:00.12
		FG lf	3	1:00:36.24
Smoking and children (35 mm, color film copy)	3:06	FG hf	3	34:21.21
		FG lf	3	34:32.35
Smoking is dangerous for everyone (35 mm, color film copy)	4:55	FG hf	3	58:51.567
		FG lf	3	59:02.35

Tables 1-4 present the processing results of digitized animated films with an exposure radius ranging from 3 to 25 pixels, respectively.

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Table 2 Processing results of digitized films with an exposure radius of 5 pixels

Video	Time (m., s.)	Process	Exposure radius	Processing time (m., s., split sec.)
I don't smoke (16 mm, color film copy)	4:59	FG hf	5	59:28.13
		FG lf	5	59:13.14
Smoking and children (35 mm, color film copy)	3:06	FG hf	5	33:11.14
		FG lf	5	33:15.31
Smoking is dangerous for everyone (35 mm, color film copy)	4:55	FG hf	5	56:41.23
		FG lf	5	55:32.45

Processing and recalculations were carried out on Intel(R) Cor(TM i3-10100 CPU @ 3,60 GHz with 8 GB RAM. The system is 64-bit. Transformation step selection was set manually. Checking of rendering results was performed dynamically.

Table 3 Processing results of digitized films with an exposure radius of 10 pixels

Video	Time (m., s.)	Process	Exposure radius	Processing time (m., s., split sec.)
I don't smoke (16 mm, color film copy)	4:59	FG hf	10	58:21.72
		FG lf	10	59:51.51
Smoking and children (35 mm, color film copy)	3:06	FG hf	10	32:02.13
		FG lf	10	31:54.54
Smoking is dangerous for everyone (35 mm, color film copy)	4:55	FG hf	10	54:11.38
		FG lf	10	55:53.45

Table 4 Processing results of digitized films with an exposure radius of 25 pixels

Video	Time (m., s.)	Process	Exposure radius	Processing time (m., s., split sec.)
I don't smoke (16 mm, color film copy)	4:59	FG hf	25	55:42.33
		FG lf	25	56:23.51
Smoking and children (35 mm, color film copy)	3:06	FG hf	25	30:24.11
		FG lf	25	30:47.45
Smoking is dangerous for everyone (35 mm, color film copy)	4:55	FG hf	25	52:53.46
		FG lf	25	51:10.31

Table 5 shows the processing results of digitized animated films with a total number of frames, and the time for frame-by-frame scanning and convolution.

Table 5 Processing results of digitized films with a total number of frames and the time for frame-by-frame disassembly and assembly

Film Title	Number of frames	Decoding time (m., s., split sec.)	Assembly time (m., s., split sec.)
I don't smoke (16 mm, color film copy)	7190	05:03.32	05:02.41
Smoking and children (35 mm, color film copy)	4526	03:08.58	03:08.45
Smoking is dangerous for everyone (35 mm, color film copy)	7095	04:59.58	04:55.50

It required from 20 minutes to 2 hours for each recalculation. In total, 72 recalculations were made without taking into account erroneous and duplicate miscalculations, which also occurred during processing [12].

Quality comparison of the original and processed video in MSU Video Quality Measurement Tool by PSNR

When evaluating the quality of the processed elements while calculating PSNR (peak signal-to-noise ratio), instead of searching for the maximum ratio between the calculated

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signal and entropy values, the peak surge-to-entropy ratio is calculated [13].

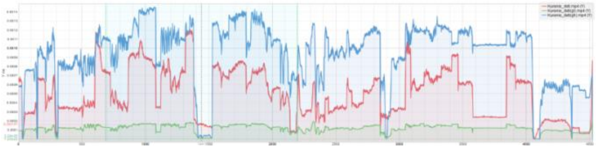

Figure 3 PSNR graph "I don't smoke" (16 mm) with a 5 pixel exposure radius

Figure 4 PSNR graph "Smoking and children" (35 mm) with a 5 pixel exposure radius

Figure 5 PSNR graph "Smoking is dangerous for everyone" (35 mm) with a 5 pixel exposure radius

Figures 2, 3, and 4 show PSNR graphs for color animation scanned from a 35 mm and 16 mm film.

As can be seen from the presented graphs, the smoothest transformation takes place in the cartoon "Smoking and children" (Figure 4). The most dynamically active PSNR graph is observed in the film "Smoking is dangerous for everyone" (Figure 5) which is due to the significant fading of the film itself, as the quality of the archive recording was much worse and the redness of the film was more than noticeable. Therefore, during the work it was required to additionally adjust the colors in the image. It should be also noted, that the PSNR graph looks **quite smooth when comparing** the original and digitally transformed processed film materials of the animated film "I Don't Smoke", which is reflected in Figure 3.

CONCLUSION

The study examined the use of the approach based on the application of discrete digital transformations with nodes on a centered lattice in post-processing of scanned images from a 16 mm and 35 mm film. The numerical experimental results were obtained in the practical application of the algorithm of a discrete two-dimensional fast Fourier transform, the Gaussian filter, the Butterworth filter, and a number of other digital transformations [14]. The developed algorithm is implemented in C++ using the FFT library and provides a software support for the method of digital transformations and processing of short video images provided by KGAUK "Enisei Kino".

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