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GENERALIZED DESCRIPTION OF CONTRAST OF IMAGE ELEMENTS

Розглянуто проблему оцінювання якості зображень під час передавання та оброблення відеоданих у інформаційних та телекомунікаційних системах. Вирішується завдання вимірювання без еталону контрасту елементів зображення (об'єктів та фону) для складних багатоелементних зображень. Запропоновано новий метод вимірювання контрасту елементів складних зображень на основі аналітичних оцінок контрасту відповідних елементів на вхідному (первинному) та інвертованому (негативному) зображеннях. Запропоновано узагальнений опис контрасту елементів зображення для різних визначень ядер контрасту, а також нові визначення зваженого та відносного контрастів елементів зображення. Досліджено відомі та запропоновані визначення зваженого і відносного контрастів для оцінювання ефективності вимірювання (кількісної оцінки) контрасту елементів зображення.

Ключові слова: оцінка якості зображення, контраст зображення, контраст елементів зображення, зважений контраст, відносний контраст, ядро контрасту.

The problem of image quality assessment in the transmission and processing of video data in information and telecommunication systems is considered. The task of no-reference measurement of contrast of two image elements (objects and background) for complex (multi-element) images is solved. A new method of contrast measurement of elements of complex images on the basis of analytical assessments of contrast of appropriate elements on initial (primary) and on inverse (negative) images is proposed. A generalized description of image elements contrast for different definition of contrast kernels is suggested. The new definitions of a weighted and relative contrast of image elements are proposed. The research of known and proposed definitions of a weighted and relative contrast to evaluate the efficiency of measuring (of quantitative assessment) of contrast of image elements was carried out.

Key words: image quality assessment, image contrast, contrast of image elements, weighted contrast, relative contrast, contrast kernel.

Introduction

Currently, the various techniques for image quality assessment are widely used in imaging, image processing and analysis for various applications. Therefore, the development of new effective no-reference techniques of quantitative assessment (of measurement) of images quality is currently extremely relevant [1, 2]. The objective image quality is characterized by several basic parameters [3, 4]. Contrast is the main characteristic that determines the objective quality of the image [3, 5]. Contrast of complex images is determined on the basis of assessments of contrast values for all individual pairs of image elements (objects and background) [5–7]. The contrast of two image elements (two objects or an object and a background) is a dimensionless function that characterizes the difference in the values of their brightness. The choice of definition of the contrast of image elements is a very important problem and largely determines the efficiency (accuracy) of the contrast measurement of complex multi-element images [7]. Definitions of the contrast of image elements (often called the kernels of contrast) shall meet the basic requirements to the contrast definitions, should ensure reasonably accurate quantitative assessment (measurement) of contrast of image elements for the real multi-element images with complex structure and should also allow evaluate (predict) the perceived values of image contrast at carrying out of subjective (qualitative) expert assessments [8]. At present, various definitions of the contrast of the image elements are known. However, the known definitions of the contrast of the image elements have a number of significant disadvantages, which significantly limit their practical use. The object of study is the process of measurement of contrast for image quality assessment. The subject of the study is methods of measuring the contrast of elements (objects and background) of complex image. The purpose of the work is to increase the accuracy of measurement the contrast of two image elements. The problem of contrast measuring of image elements (objects and background) on complex images is considered in this paper. The paper deals with the basic requirements to the contrast definition (Section 1). Known definitions of a weighted and relative contrast of two image elements are considered (Section 2). A new method of measurement of contrast for two image elements on the basis of analytical assessments of contrast of appropriate image elements on initial and on inverse images is proposed (Section 3). A generalized description of contrast of two image elements for different definition of contrast kernels is suggested (Section 4). The new definitions of a weighted and relative contrast of image elements are proposed (Section 5). The research of known and proposed definitions of a weighted and relative contrast to evaluate the efficiency of measuring of contrast of image elements was carried out (Sections 6 and 7).

1. The basic requirements to the contrast definition

It is traditionally supposed that the contrast definition has to meet the following basic requirements [7, 8]. Contrast of two image elements (object and background) is a dimensionless function and characterizes the difference of values L_1 and L_2 of their brightness [6]. Contrast of image elements must be an asymmetric function [7]. The sign of contrast indicates which of the values predominates, L_1 or L_2. The maximum value of contrast module must correspond to maximum difference of the values L_1 or L_2 and must be equal to zero for equal values of L_1 and L_2 [8]. It is usually assumed that the change of the absolute values of contrast is limited by the range [0, 1].

Thus, the contrast definition must satisfy the following conditions [6-8]:

1) condition of asymmetry and of equality to entrance of the arguments L_1 and L_2 (axiom of symmetry) [7]:

$$|C(L_1,L_2)| = |C(L_2,L_1)|; \tag{1}$$

$$C(L_1,L_2) = -C(L_2,L_1) . \tag{2}$$

The sign of contrast indicates which of the values predominates, L_1 or L_2.

2) of uniqueness and certainty of the conditions under which the equality to zero is achieved (axioms of identity and of equality) [7, 8]:

$$C(L_1,L_2) = 0 \text{ only when } L_1 = L_2; \tag{3}$$

The value of contrast must be equal to zero for (only when) equal values of L_1 and L_2 [6].

3) of achieving extreme values of the contrast only when one of the values of brightness takes the maximum value L_{max}, and the other takes the minimum permissible value L_{min} [7, 8]:

$$C_{\max} = \max_{L_1,L_2\in[L_{\min},L_{\max}]} |C(L_1,L_2)| \text{ only when}$$

$$(L_1 = L_{\max})\wedge(L_2 = L_{\min}) \text{ or } (L_1 = L_{\min})\wedge(L_2 = L_{\max}). \tag{4}$$

The maximum value of contrast module must correspond to maximum difference of the values L_1 or L_2. It is usually assumed that the change of absolute values of contrast is limited by the range [0,1]:

$$|C(L_1,L_2)| \in [0,1]. \tag{5}$$

Without loss of generality, it is most often assumed that [7]:

$$C(L_{\max},L_{\min})=1 \;\; and \;\; C(L_{\min},L_{\max})=-1. \tag{6}$$

4) of invariance to linear transformations of the brightness scale [10]:

$$C(L_1,L_2)= sign(k)\cdot C(L_1',L_2'); \tag{7}$$

$$L' = k \cdot L + b\,; \tag{8}$$

$$L_1, L_2, L_1', L_2' \in [\,0,1\,],\;\; k \neq 0\,, \tag{9}$$

where L' – brightness of the converted image; k – coefficient of linear stretching; b – size of the linear shift of the brightness scale.

From (7) for k = -1 and b = 1 we obtain the requirement of invariance under inversion:

$$C(\overline{L}_1, \overline{L}_2) = -\,C(L_1, L_2)\,; \tag{10}$$

$$\overline{L} = 1 - L\,; \tag{11}$$

$$L_{\min} = 1 - \overline{L}_{\max}\,,\; L_{\max} = 1 - \overline{L}_{\min}\,,\; \overline{L}_{\min} = 1 - L_{\max}\,,\; \overline{L}_{max} = 1 - L_{min}\,. \tag{12}$$

Expressions (2) – (10) define the basic requirements for contrast definition of image elements.

2. Definitions of a weighted and relative contrast

The definitions for the local contrast of pairs of image elements used in various applications are known [5–7], [11–13]. A definition of the weighted contrast for two elements of a complex image for adaptation level L_0 was proposed in [6]:

$$C_{wei_1}(L_1, L_2) = \left(L_1 \cdot L_2 - L_0^2\right) / \left(L_1 \cdot L_2 + L_0^2\right), \tag{13}$$

where L_0 – adaptation level, generally $L_0 = \overline{L} = mean\,(L)$.

Currently the following definition of weighted contrast has the most widespread use [11–12]:

$$C_{wei_2}(L_1, L_2) = (L_1 - L_2) / (L_1 + L_2)\,. \tag{14}$$

In [8] the definitions of a relative contrast were considered:

$$C_{rel_1}(L_1, L_2) = (L_1 - L_2)\,/\,\max\,(L_1,\,L_2)\,. \tag{15}$$

In [13] the relative contrast is defined as:

$$C_{rel_2}(L_1, L_2) = (L_1 - L_2)\,/\,(\,1 - \min\,(L_1,\,L_2)\,)\,. \tag{16}$$

In [9] the generalized description of a weighted and relative contrast has been proposed:

$$C_{rel_3}(L_1, L_2) = (L_1 - L_2)\,/\,(\max(L_1,\,L_2) + \alpha \cdot \min\,(L_1,\,L_2))\,. \tag{17}$$

The main disadvantages of contrast definitions (14)–(17) are the uncertainty and the multiplicity of the conditions under which the extreme values of weighted contrast (4) are achieved [7].

To address these shortcomings we propose new method of contrast measurement of image elements on the basis of assessments of contrast for appropriate elements on the primary and inverted image.

3. The generalized description of contrast of image elements

For contrast definition of elements of complex images using the chosen (the specified) definition $C(L_1,L_2)$ of contrast kernel we propose the generalized contrast description on the basis of analytical definitions of contrast for the initial (primary) and for inverted (negative) images:

$$\tilde{C}(L_1, L_2) = \alpha \cdot C(L_1, L_2) + \beta \cdot \overline{C}(L_1, L_2)\,, \tag{18}$$

where $\tilde{C}(L_1, L_2)$ – generalized description for additive average contrast of two image elements; α, β – parameters (weighted coefficients);

$$\hat{C}(L_1, L_2) = C(L_1, L_2)^{\omega} \cdot \overline{C}(L_1, L_2)^{\tau}\,, \tag{19}$$

where $\hat{C}(L_1, L_2)$ – generalized description for multiplicative average contrast, ω, τ – parameters;

$$\overline{C}(L_1, L_2) = -C(\overline{L}_1, \overline{L}_2) = C(\overline{L}_2, \overline{L}_1),\;\; \overline{L}_1 = 1 - L_1\,,\;\; \overline{L}_2 = 1 - L_2\,, \tag{20}$$

where $\overline{C}(L_1, L_2)$ – analytical definition of contrast of two image elements for inverse (negative) image.

For the pre-normalized primary image L^* and the pre-normalized inverted image $\overline{L}^*$ in analogy to (18–20) we obtain:

$$\tilde{C}^*(L_1, L_2) = \alpha \cdot C^*(L_1, L_2) + \beta \cdot \overline{C}^*(L_1, L_2)\,, \tag{21}$$

where $\tilde{C}^*(L_1,L_2)$ – generalized description for additive average contrast for pre-normalized primary image;

$$\hat{C}^*(L_1,L_2)=C^*(L_1,L_2)^{\omega}\cdot\overline{C}^*(L_1,L_2)^{\tau}, \quad (22)$$

where $\hat{C}^*(L_1,L_2)$ – generalized description for multiplicative contrast for pre-normalized primary image;

$$C^*(L_1,L_2)=C\left(L_1^*,L_2^*\right),\ \ L_1^*=(L_1-L_{\min})/(L_{\max}-L_{\min}),\ L_2^*=(L_2-L_{\min})/(L_{\max}-L_{\min}), \quad (23)$$

where $C^*(L_1,L_2)$ – analytical definition of contrast for pre-normalized primary image;

$$\overline{C}^*(L_1,L_2)=-C\left(\overline{L}_1^*,\overline{L}_2^*\right)=C\left(\overline{L}_2^*,\overline{L}_1^*\right); \quad (24)$$

$$\overline{L}_1^*=1-L_1^*=(L_{\max}-L_1)/(L_{\max}-L_{\min}),\ \overline{L}_2^*=1-L_2^*=(L_{\max}-L_2)/(L_{\max}-L_{\min}), \quad (25)$$

where $\overline{C}^*(L_1,L_2)$ – analytical definition of contrast for pre-normalized inverted image.

The expressions (18)–(20) and (21)–(25) define a generalized description of contrast of two image elements with the use chosen (specified) definition of contrast kernel.

4. Generalized description for weighted contrast

Currently the weighted contrast is most often defined as (14). On the basis of expressions (18)–(25) we propose the new description of weighted contrast of two image elements with the use kernel (14):

$$C_{wei}(L_1,L_2)=(L_1-L_2)/(L_1+L_2)=C_{wei_1}(L_1,L_2); \quad (26)$$

$$\overline{C}_{wei}(L_1,L_2)=(L_1-L_2)/(2-L_1-L_2); \quad (27)$$

$$\tilde{C}_{wei}(L_1,L_2)=(L_1-L_2)\cdot(2\cdot\alpha+(\beta-\alpha)\cdot(L_1+L_2))\cdot(L_1+L_2)^{-1}\cdot(2-L_1-L_2)^{-1}; \quad (28)$$

$$\hat{C}_{wei}(L_1,L_2)=sign(L_1-L_2)\cdot|L_1-L_2|^{\omega+\tau}\cdot(L_1+L_2)^{-\omega}\cdot(2-L_1-L_2)^{-\tau}. \quad (29)$$

In case of need of the additional pre-normalization of primary image:

$$C_{wei}^*(L_1,L_2)=(L_1-L_2)/(L_1+L_2-2\cdot L_{\min}); \quad (30)$$

$$\overline{C}_{wei}^*(L_1,L_2)=(L_1-L_2)/(2\cdot L_{\max}-L_1-L_2); \quad (31)$$

$$\tilde{C}_{wei}^*(L_1,L_2)=\frac{(L_1-L_2)\cdot(2\cdot(\alpha\cdot L_{\max}-\beta\cdot L_{\min})+(\beta-\alpha)\cdot(L_1+L_2))}{(L_1+L_2-2\cdot L_{\min})\cdot(2\cdot L_{\max}-L_1-L_2)}; \quad (32)$$

$$\hat{C}_{wei}(L_1,L_2)=sign(L_1-L_2)\cdot|L_1-L_2|^{\omega+\tau}\cdot(L_1+L_2-2\cdot L_{\min})^{-\omega}\cdot(2\cdot L_{\max}-L_1-L_2)^{-\tau}. \quad (33)$$

The additive description (28), (32) of the weighted contrast for $\alpha=\beta=1/2$ is defined as:

$$\tilde{C}_{wei}(L_1,L_2)=(L_1-L_2)\cdot(L_1+L_2)^{-1}\cdot(2-L_1-L_2)^{-1}; \quad (34)$$

$$\tilde{C}_{wei}^*(L_1,L_2)=(L_1-L_2)\cdot(L_{\max}-L_{\min})\cdot(L_1+L_2-2\cdot L_{\min})^{-1}\cdot(2\cdot L_{\max}-L_1-L_2)^{-1}. \quad (35)$$

The multiplicative description (29), (33) of the weighted contrast for $\omega=\tau=1/2$ is defined as:

$$\hat{C}_{wei}(L_1,L_2)=(L_1-L_2)\cdot(L_1+L_2)^{-1/2}\cdot(2-L_1-L_2)^{-1/2}; \quad (36)$$

$$\hat{C}_{wei}^*(L_1,L_2)=(L_1-L_2)\cdot(L_1+L_2-2\cdot L_{\min})^{-1/2}\cdot(2\cdot L_{\max}-L_1-L_2)^{-1/2}. \quad (37)$$

The expressions (34)–(37) define the new proposed descriptions of the weighted contrast of image elements on the basis of the use the definitions of contrast kernels (26), (27), (30), (31).

5. Generalized description for relative contrast

Currently the relative contrast is most often defined as (15) and (16). On the basis of the expressions (18)–(25) we propose the new description of relative contrast with the use of kernel (15):

$$C_{rel}(L_1,L_2)=(L_1-L_2)/\max(L_1,L_2); \quad (38)$$

$$\overline{C}_{rel}(L_1,L_2)=(L_1-L_2)/(1-\min(L_1,L_2)). \tag{39}$$

It should be noted that the definitions of (38), (39) and (15), (16) are equivalent.

$$\tilde{C}_{rel}(L_1,L_2)=\frac{(L_1-L_2)\cdot(\alpha+\beta\cdot\max(L_1,\,L_2)-\alpha\cdot\min(L_1,\,L_2))}{\max(L_1,\,L_2)\cdot(1-\min(L_1,\,L_2))}; \tag{40}$$

$$\hat{C}_{rel}(L_1,L_2)=sign(L_1-L_2)\cdot|L_1-L_2|^{\omega+\tau}\cdot\max(L_1,\,L_2)^{-\omega}\cdot(1-\min(L_1,\,L_2))^{-\tau}. \tag{41}$$

In case of need of the additional pre-normalization of primary image for relative contrast we obtain:

$$C^*_{rel}(L_1,L_2)=(L_1-L_2)/(\max(L_1,L_2)-L_{\min}); \tag{42}$$

$$\overline{C}^*_{rel}(L_1,L_2)=(L_1-L_2)/(L_{\max}-\min(L_1,L_2)); \tag{43}$$

$$\tilde{C}^*_{rel}(L_1,L_2)=\frac{(L_1-L_2)\cdot(\alpha\cdot[L_{\max}-\min(L_1,\,L_2)]+\beta\cdot[\max(L_1,\,L_2)-L_{\min}])}{[\max(L_1,\,L_2)-L_{\min}]\cdot[L_{\max}-\min(L_1,\,L_2)]}; \tag{44}$$

$$\hat{C}^*_{rel}(L_1,L_2)=sign(L_1-L_2)\cdot|L_1-L_2|^{\omega+\tau}\cdot(\max(L_1,\,L_2)-L_{\min})^{-\omega}\cdot(L_{\max}-\min(L_1,\,L_2))^{-\tau}. \tag{45}$$

The additive description (40), (44) of the relative contrast for $\alpha=\beta=1/2$ is defined as:

$$\tilde{C}_{rel}(L_1,L_2)=\frac{1}{2}\cdot\frac{(L_1-L_2)\cdot(1+\max(L_1,\,L_2)-\min(L_1,\,L_2))}{\max(L_1,\,L_2)\cdot(1-\min(L_1,\,L_2))}; \tag{46}$$

$$\tilde{C}^*_{rel}(L_1,L_2)=\frac{1}{2}\cdot\frac{(L_1-L_2)\cdot([L_{\max}-L_{\min}]+[\max(L_1,\,L_2)-\min(L_1,\,L_2)])}{[\max(L_1,\,L_2)-L_{\min}]\cdot[L_{\max}-\min(L_1,\,L_2)]}. \tag{47}$$

The multiplicative description (41), (45) of the relative contrast for $\omega=\tau=1/2$ is defined as:

$$\hat{C}_{rel}(L_1,L_2)=(L_1-L_2)\cdot\max(L_1,\,L_2)^{-1/2}\cdot(1-\min(L_1,\,L_2))^{-1/2}; \tag{48}$$

$$\hat{C}^*_{rel}(L_1,L_2)=(L_1-L_2)\cdot(\max(L_1,\,L_2)-L_{\min})^{-1/2}\cdot(L_{\max}-\min(L_1,\,L_2))^{-1/2}. \tag{49}$$

The expressions (46)–(49) define the proposed descriptions of the relative contrast of image elements on the basis of the use the definitions of contrast kernels (15), (16), (42), (43).

Comparative analysis of the known and the proposed definitions of weighted and relative contrast were carried out in Sections 6 and 7.

6. Experimental research

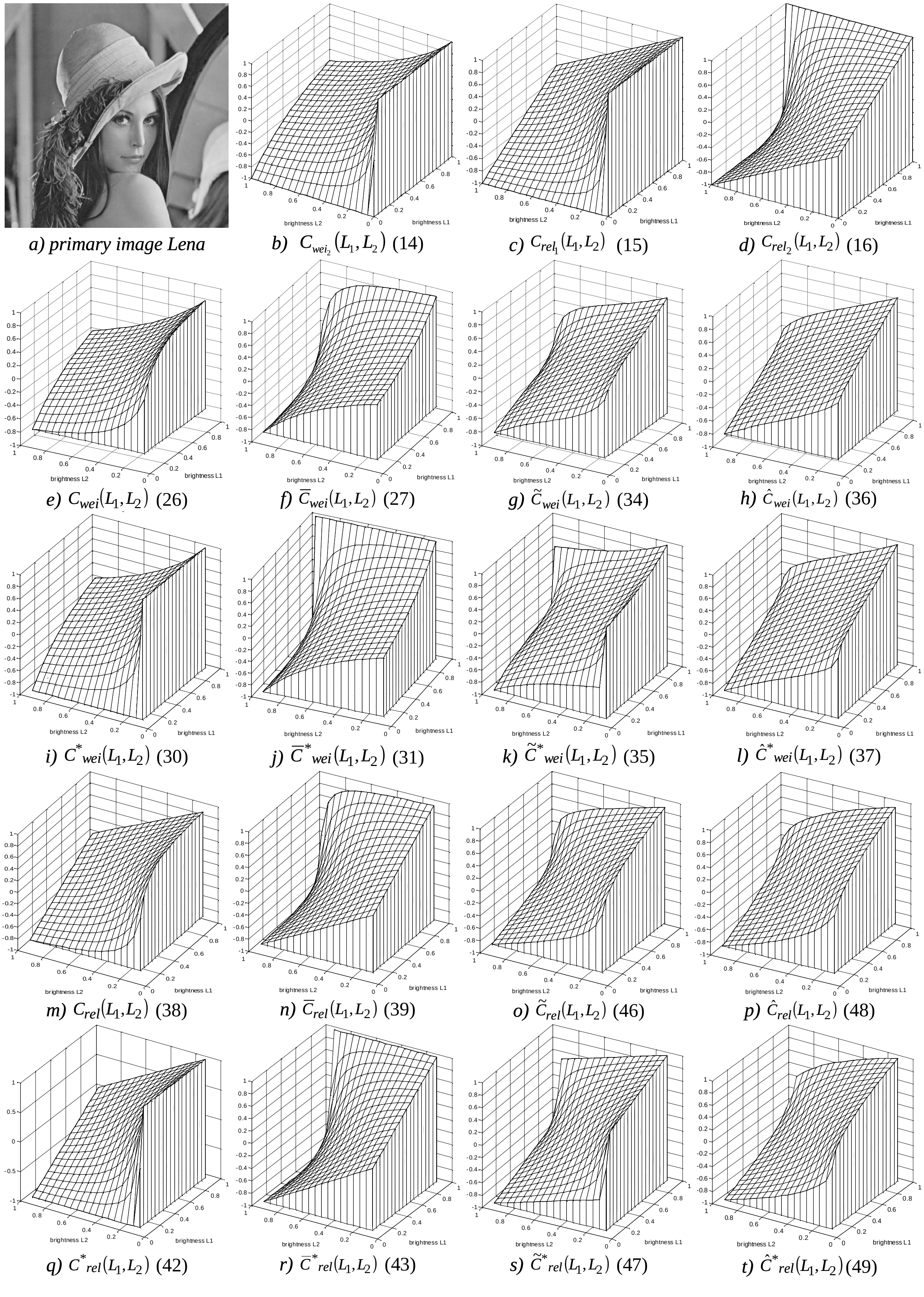
Experimental researches were carried out through the comparative analysis of known and proposed definitions of a weighted and relative contrast for compliance with the basic requirements (1)–(7), (10) to the contrast. 3D graphs of surfaces of the known and proposed definitions of a weighted and relative contrast for primary test image Lena [14] are shown in Fig. 1.

Appearance of the primary image Lena is shown in Fig. 1, *a*. The graphs of the known definitions (14)–(16) of a weighted and relative contrast for pre-normalized images with a brightness range [0,1] (L_{min} =0, L_{max} =1) are shown in Fig. 1, *b*, *c*, *d*.

The graphs of the proposed definitions (26), (27), (38), (39) and generalized descriptions (34), (36), (46), (48) of the weighted and relative contrast for primary image Lena (L_{min}=0,098, L_{max}=0,961) are shown in Fig. 1, *e*, *f*, *m*, *n* and *g*, *h*, *o*, *p*).

The graphs of the proposed definitions (30), (31), (42), (43) and generalized descriptions (35), (37), (47), (49) of the weighted and relative contrast for additional pre-normalization image Lena (L_{min}=0, L_{max}=1) are shown in Fig. 1, *i*, *j*, *q*, *r* and *k*, *l*, *s*, *t*).

The researches of known and proposed definitions and generalized descriptions of a weighted and relative contrast were carried out for compliance with the basic requirements (1)–(7), (10) for contrast definition. Analysis of results of the experimental researches is carried out in section 7.



a) primary image Lena
b) $C_{wei_2}(L_1, L_2)$ (14)
c) $C_{rel_1}(L_1, L_2)$ (15)
d) $C_{rel_2}(L_1, L_2)$ (16)
e) $C_{wei}(L_1, L_2)$ (26)
f) $\overline{C}_{wei}(L_1, L_2)$ (27)
g) $\tilde{C}_{wei}(L_1, L_2)$ (34)
h) $\hat{C}_{wei}(L_1, L_2)$ (36)
i) $C^*{}_{wei}(L_1, L_2)$ (30)
j) $\overline{C}^*{}_{wei}(L_1, L_2)$ (31)
k) $\tilde{C}^*{}_{wei}(L_1, L_2)$ (35)
l) $\hat{C}^*{}_{wei}(L_1, L_2)$ (37)
m) $C_{rel}(L_1, L_2)$ (38)
n) $\overline{C}_{rel}(L_1, L_2)$ (39)
o) $\tilde{C}_{rel}(L_1, L_2)$ (46)
p) $\hat{C}_{rel}(L_1, L_2)$ (48)
q) $C^*{}_{rel}(L_1, L_2)$ (42)
r) $\overline{C}^*{}_{rel}(L_1, L_2)$ (43)
s) $\tilde{C}^*{}_{rel}(L_1, L_2)$ (47)
t) $\hat{C}^*{}_{rel}(L_1, L_2)$ (49)

Fig. 1. 3D graphs of surfaces of the known and proposed definitions of a weighted and relative contrast for primary image Lena

7. Analysis of results of the experimental research

Analysis of the results of the experimental research shows that known definitions of weighted contrast (14) (Fig. 1, *b*) and of relative contrast (15) – (16) (Fig. 1, *c, d*) and their generalized description (17) satisfy the requirements (1)–(3) for contrast definitions (the axioms of symmetry, of identity and of equality).The values changes of contrast (13)–(16) and of their description (17) are limited by the range [-1, 1]:

$$C_{wei_1}(L_1, L_2) \in \left[\left(L_{\min}^2 - L_0^2\right)/\left(L_{\min}^2 + L_0^2\right), \left(L_{\max}^2 - L_0^2\right)/\left(L_{\max}^2 + L_0^2\right)\right]; \quad (50)$$

$$C_{wei_2}(L_1, L_2) \in \left[(L_{\min} - L_{\max})/(L_{\min} + L_{\max}), (L_{\max} - L_{\min})/(L_{\max} + L_{\min})\right]; \quad (51)$$

$$C_{rel_1}(L_1, L_2) \in \left[(L_{\min} - L_{\max})/L_{\max}, (L_{\max} - L_{\min})/L_{\max}\right]; \quad (52)$$

$$C_{rel_2}(L_1, L_2) \in \left[(L_{\min} - L_{\max})/(1 - L_{\min}), (L_{\max} - L_{\min})/(1 - L_{\min})\right]; \quad (53)$$

$$C_{rel_3}(L_1, L_2) \in \left[(L_{\min} - L_{\max})/(L_{\max} + \alpha \cdot L_{\min}), (L_{\max} - L_{\min})/(L_{\max} + \alpha \cdot L_{\min})\right]. \quad (54)$$

However, the extreme values 1 and -1 of contrast (6) can only be achieved for the normalized image (if $L_{\min} = 0 \wedge L_{\max} = 1$) and the requirement (6) in the general case (if $L_{\min} \neq 0 \vee L_{\max} \neq 1$) is not satisfied. The values contrast for known definitions (15) – (17) are changed substantially under linear transformations of the image brightness and not satisfy the requirements (7), (10).

But the main disadvantages of known definitions (13) – (17) of contrast are the uncertainty and the multiplicity of the conditions under which the extreme values of contrast (4) are achieved (Fig. 1, *b*, *c*, *d*):

$$C_{wei_1}(L_1, L_2) = -1, \; if \; L_1 = 0 \; \forall \; L_2 \in (0,1] \vee L_2 = 0 \; \forall \; L_1 \in (0,1]; \quad (55)$$

$$C_{wei_2}(L_1, L_2) = 1, \; if \; L_2 = 0 \; \forall \; L_1 \in (0,1] \; and \; C_{wei_2}(L_1, L_2) = -1, \; if \; L_1 = 0 \; \forall \; L_2 \in (0,1]; \quad (56)$$

$$C_{rel_1}(L_1, L_2) = 1, \; if \; L_2 = 0 \; \forall \; L_1 \in (0,1] \; and \; C_{rel_1}(L_1, L_2) = -1, \; if \; L_1 = 0 \; \forall \; L_2 \in (0,1]; \quad (57)$$

$$C_{rel_2}(L_1, L_2) = 1, \; if \; L_1 = 1 \; \forall \; L_2 \in [1,0) \; and \; C_{rel_2}(L_1, L_2) = -1, \; if \; L_2 = 1 \; \forall \; L_1 \in [0,1); \quad (58)$$

$$C_{rel_3}(L_1, L_2) = 1, \; if \; L_2 = 0 \; \forall \; L_1 \in (0,1] \; and \; C_{rel_3}(L_1, L_2) = -1, \; if \; L_1 = 0 \; \forall \; L_2 \in (0,1]. \quad (59)$$

To address these shortcomings were suggested new contrast definition (34) – (37) (Fig. 1, *g*, *h*, *k*, *l*) and (46)–(49) (Fig. 1, *o*) *p*, *s*, *t*) of weighted and relative contrast on the basis of proposed generalized description (18) – (25) using proposed contrast kernels (26), (27), (30), (31), (38), (39), (42), (43) (Fig. 1, *e*, *f*, *i*, *j*, *m*, *n*, *q*, *r*).

The proposed definition (26), (27), (30), (31), (38), (39), (42), (43) for contrast kernels of weighted and relative contrast for reference and inverse image satisfy the requirements (1)–(3), (5), (7), (10) and not satisfy the requirements (4) and (6) (for (26), (27), (38), (39)).

The proposed definitions of weighted contrast (34), (36) (Fig. 1, g, *h*) and of relative contrast (46), (48) (Fig. 1, *o*, *p*) allow address these shortcomings and satisfy the basic requirements (1)–(5), (7), (10) to the contrast definitions and not satisfy the requirement (6). The proposed definitions of weighted contrast (35), (37) (Fig. 1, *k*, *l*) and of relative contrast (47), (49) (Fig. 1, *s*, *t*) on the pre-normalized images satisfy all to the basic requirements (1)–(7), (10) to the contrast definition.

The proposed definitions of weighted contrast (34)–(37) and of relative contrast (46)–(49) can be recommended for no-reference assessment of image quality in processing and transmission of video data in telecommunication systems.

Conclusions

The problem of contrast measuring of image elements on complex images was considered.

The new method of contrast measurement on the basis of analytical assessments of contrast of appropriate elements on initial and on inverse images was proposed. The generalized description of contrast of image elements for different definition of contrast kernels was suggested. The new definitions of weighted and relative contrast of image elements were proposed. The proposed descriptions of weighted and relative contrast of image elements on the pre-normalized images satisfy all to the known basic requirements to the contrast definition.

The proposed new definitions of weighted and relative contrast of image elements satisfy the basic requirements to the contrast definition and ensure reasonably accurate quantitative assessment (measurement) of contrast of image elements for the real complex images and also allow evaluate (predict) the perceived values of image contrast at carrying out of subjective (qualitative) expert assessments.

The proposed definitions of contrast can be recommended for image quality assessment in processing and transmission of video data in telecommunication systems of various destinations.

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