

Formation of Linear Characteristic of Normalized Raster Transformation for Rhombic Elements

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Abstract

An analytical method of formation of a linear characteristic of normalized raster transformation for rhombic elements with a normalized relative area that changes linearly within [0,1] that is a carrier of information has been developed, the parameters of the adjustment unit that forms the linearity of the transformation have been determined. The structural scheme of the model that gives the chance to calculate and visualize the characteristics of raster transformation has been constructed.

The results of simulation modelling of gradation characteristics, deviations from the linear one have been presented, the parameters of the adjustment unit that provides the formation of the linear characteristic of the normalized raster transformation for rhombic elements have been determined. The advantage of the method is that it allows one to provide the linearization of the raster for a given lineature without changing the parameters of the adjustment unit relatively simply by scaling method.

Keywords

Rasterization, normalization, method, model, linearization, adjustment, rhomb, characteristics, properties

1. Introduction

Rasterization is practically the most important basis for reproducing images in printing industry. Rasterization is used to reproduce images of different shades of tone on the imprint, i.e. the decomposition of the image into small elements, the transformation into a raster plate, manufacturing a raster plate consisting of space and printing elements necessary for printing itself. The information carrier is the area of raster elements that corresponds to the tone of the original. Modern applications for image processing include a rasterization unit, rasterization algorithms, procedures and sequence of area output in the form of bitmaps, which are reduced to the formation of raster dots of a given shape, lineature and the area corresponding to the tone of the original [1, 2, 6]. In modern applications for image processing such as AdobePhotoshop, CorelDRAW and others, one can select the shape of a raster element in the window and set the required lineature [10, 11]. It is known that almost every scanned image requires various adjustments, including tone adjustment [10, 11], so most image processing applications provide many different functions to optimize brightness and contrast [5, 7, 11]. As the raster transformation is nonlinear, and its natural characteristic depends on the lineature, then each time one changes the lineature or shape of the element, one must first linearize the natural characteristic, which is inconvenient for image processing and rasterization. A normalized raster transformation is suggested in the works of the authors [7, 8] to simplify the rasterization procedure from which a raster transformation of the required lineature is obtained relatively simply by scaling,

IntelITSIS'2021: 2nd International Workshop on Intelligent Information Technologies and Systems of Information Security, March 24–26, 2021, Khmelnytskyi, Ukraine

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CEUR Workshop Proceedings (CEUR-WS.org)

which is developed in this paper. Therefore, the task of forming a normalized raster transformation is relevant and it will simplify the rasterization procedure and increase the efficiency of the image processing.

2. Literature Review

In many areas of science and technology, the basic information about real objects or processes is presented in the form of images. When obtaining and reproducing images by printing techniques, it is necessary to ensure high quality, which is reduced in the preparation of images for printing, plate manufacturing and printing itself, which necessitates the development of simple and effective methods and technologies to improve their quality. In digital image processing, grey gradations in the range [0,255] are represented by arrays of numbers. Instead, in the raster transformation one can operate by changing the geometric dimensions and areas of raster elements, and in plate manufacturing and printing one can operate by changing the printing elements that are the carrier of information. Therefore, the existing methods of digital image processing [1, 6, 12] cannot be directly applied to the analysis and synthesis of the raster transformation.

The monographs [1, 5, 7] provide the general information about raster technology, raster tone transfer, coordination of tone transfer ranges. Mathematical models of raster transformation are presented in publications [3, 4], rasterization characteristics for elements of different shapes and lines are constructed, their analysis is carried out. The paper [4] suggests an integrated indicator of quality assessment of the rasterization process, which gives a quantitative assessment of rasterization. In the dissertation thesis [13] mathematical models of raster transformation are developed and natural characteristics of rasterization are constructed, their properties for elements of different lineature are assessed. It has been established that the rhombic element is the best one in terms of the linearity of the gradation characteristic of rasterization. An analytical method of raster transformation adjustment for elements of different shapes and lines has been developed.

The authors [8, 9] suggested a new more general approach to raster analysis based on normalized raster transformation. Mathematical models of normalized raster transformation for square and round elements, structural models for simulation modelling are developed. The natural characteristics of the normalized raster transformation are calculated and constructed and their properties are analysed.

3. Results and Discussion

Rasterization is the basis for reproducing images in printing industry. The information carrier is the area of raster elements that corresponds to the optical density of the original, or the number of levels of brightness of the digital image. To generalize the analysis, a mathematical model of normalized raster transformation in the form of a double function with a domain as a closed single square and a set of relative areas with a limited interval [0,1] is suggested. In general, the normalized raster transformation, in which the control effect is the normalized geometric size of the raster element, and the result is a normalized area of the element, which corresponds to the optical density of the original or the number of levels of grey image, is given by the expression:

$$S_H = F(X_H, L_P, D) , \quad (1)$$

where X_H is a normalized size of a raster element, which is located in a single square, L_P is a number of grey levels, D is the optical density of the original image.

The geometric representation of the suggested normalized raster transformation for the rhombic element, located in the centre of the square of single dimensions is presented in Figure 1.

The raster square (cell) ABCD has constant single dimensions. The rhombic element is located in the centre of square O. In the process of raster transformation, the size of the raster element changes, which is represented by a quarter of the diagonal of the square, which varies within [0, L_0]. According to Figure.1, one can write the function of raster transformation for the first interval:

$$S_{1H} = 4X_H^2, \text{ if } 0 \leq X_H \leq L_0 = 0,3538, \quad (2)$$

where X_H is an argument (space variable), L_0 is a quarter of the diagonal of the raster square ABCD.

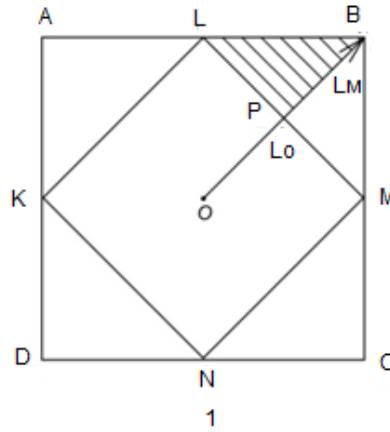


Figure 1 : Scheme of geometry of a rhombic element normalized for raster transformation

With a further increase of the geometric dimensions of the rhombic element from point P to point B, the surface of the rhombus is gradually limited by a raster square, its shape, as a result, is distorted and turns into an octagon, and the area increment gradually decreases and approaches to zero. Let's define their area as an integral bounded by the expression PL [5, 14]

$$S2_H = 8 \int_{L_0}^{L_H} (L_H - X_H) dX_H, \text{ if } L_0 \leq X_H \leq L_M \quad (3)$$

Based on the diagram of Figure.2, we determine necessary parameters for calculating the area:

$$BS = \sqrt{1 + 1} = 1,414, X_M = L_H = \frac{BD}{2} = 0,7071; L_0 = \frac{BD}{4} = 0,3538 \quad (4)$$

Then, the function of the normalized raster transformation is

$$S_H = S1_H + S2_H, \quad (5)$$

If in expressions (3) and (4) the spatial variable is linearly changed, then they can be used to calculate and construct the characteristic of the normalized raster transformation. Since the characteristic of raster transformation is nonlinear, it is suggested to determine the deviation of the characteristic from the linear one to assess the nonlinearity

$$E = [S_H - S_0] * 100\%, \quad (6)$$

where S_0 – is a linear characteristic

To simplify the solution of problems and construction of the raster transformation characteristic and its linearization, we use simulation modeling. Based on the above information and the paradigm of object-oriented programming, a block diagram of the model of the normalized raster transformation is designed in the Matlab:Simulink package [15, 16, 17, 18] (Figure 2).

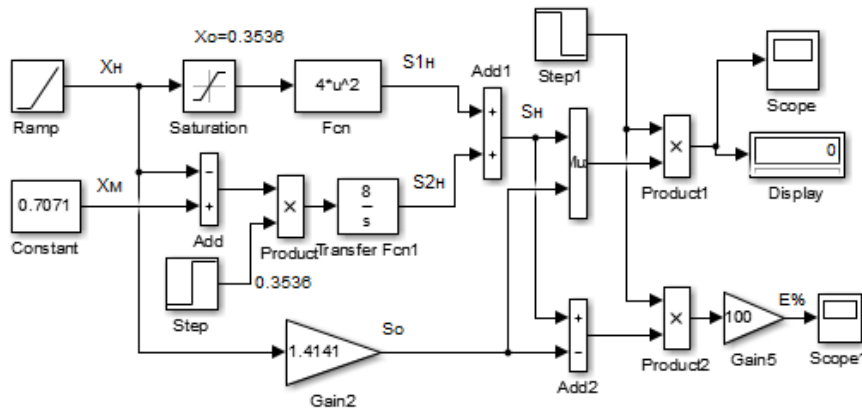


Figure 2 : Block diagram of the model of the normalized raster transformation

In the upper part there is a diagram of the model to calculate the area by the first interval $[0 \leq X_H \leq 0,3538]$. The Ramp block generates a linear normalized size X_H which is limited by the Saturation block to the level of 0,3536. Mathematical functions block Fcn calculates the area S_{1H} according to the expression (2). There is a diagram in each part for calculating the area of the raster element on the second range $[0,3536 \leq X_H \leq 0,7071]$. The $TransferFcn$ unit performs the integration operation according to expression (3).

The Step unit switches the specified ranges. At the output of the summation unit, the result of calculating the normalized raster transformation is obtained. Scope and Display units are used to visualize the simulation results. At the bottom there is a diagram that determines the deviation of the characteristics of the normalized raster transformation from the linear. Let's adjust the model to certain parameters. Figure 3 presents the results of simulation modeling of the graphic characteristics of the normalized raster transformation for raster elements of rhombic shape.

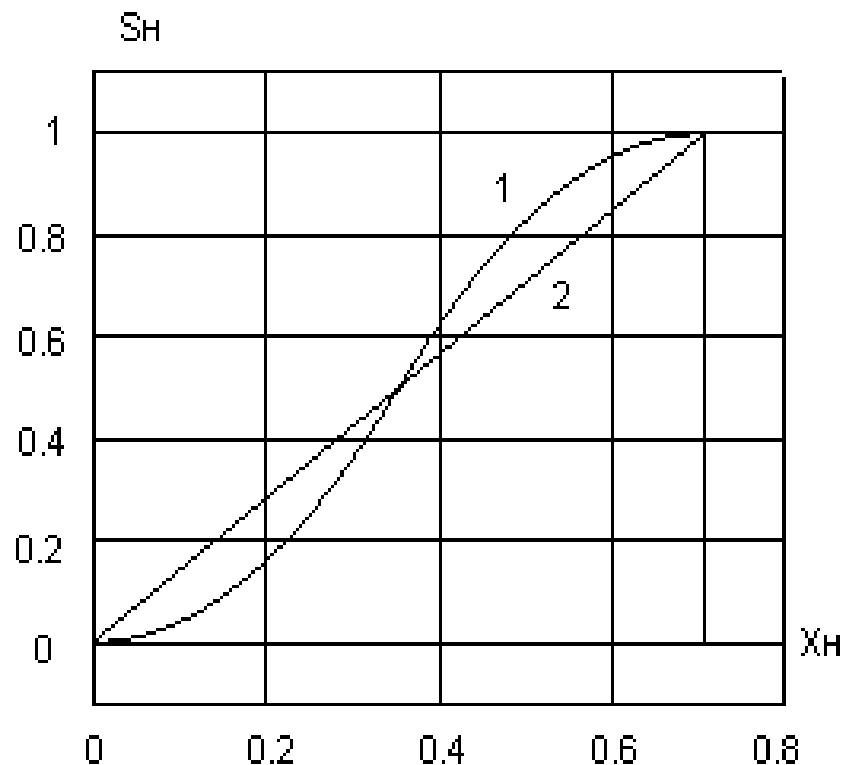


Figure 3 : Characteristics of the normalized raster transformation: 1 – physical characteristics, 2 – linear transformation

Linear characteristics is presented in the Figure 3 for comparison. The normalized raster transformation characteristic is a nonlinear S-shaped curve. At the beginning of the range, the characteristic is placed below the linear, intersects it, rises higher and at the end of the range approaches figure one. Therefore, normalized raster transformation will cause image distortion: lightening of the image in light areas and darkening of gray areas, that is why, the characteristic must be linearized. The results of the characteristic deviation modeling of the normalized raster transformation from the linear one are presented in Figure 4.

The deviation characteristic is a negative sinusoidal curve. At the beginning of the range, the deviation is negative, then it gradually increases, reaches a maximum value of -12.5% , passes through zero, gradually increases, reaches a maximum value of $+12.5\%$ and at the end of the interval approaches to zero. The nonlinearity of the normalized raster transformation characteristic causes distortion of the tone transfer and worsens the quality of the raster image, so it must be adjusted. The function for linearization of the normalized raster transformation is offered for this purpose

$$F_n = 0,599X_H^{0,5}, \text{ if } 0 \leq X_H \leq 0,7071 \quad (7)$$

which precedes the raster transformation function (2).

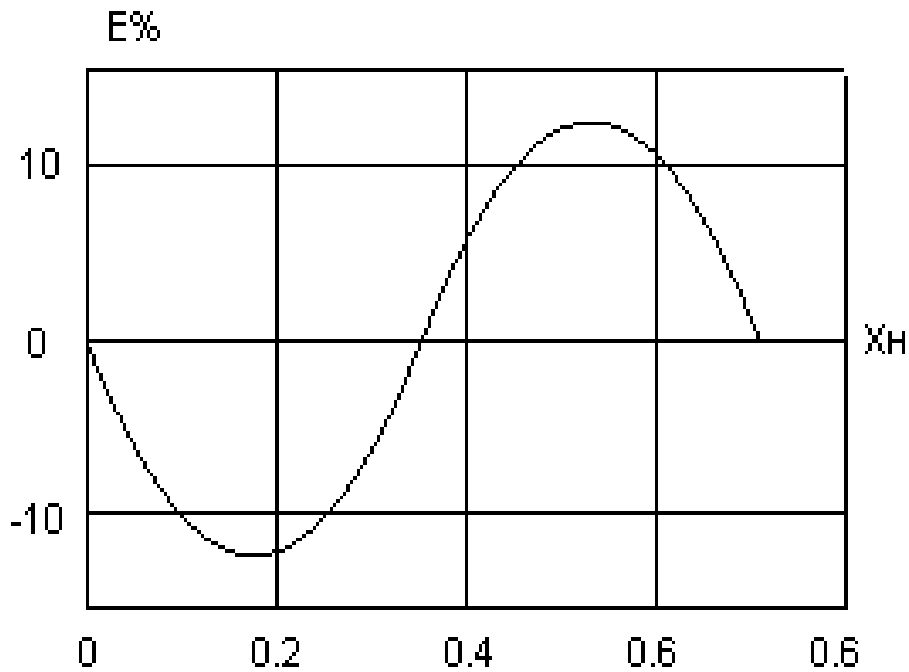


Figure 4: Graphic chart of deviation of the rasterization characteristic from the linear one

On the basis of the above information and Figure 2, a block diagram of the model of linear characteristic forming of the normalized raster transformation for rhombic elements with sequential inclusion of the adjustment unit (Figure 5) implemented using a block of mathematical functions.

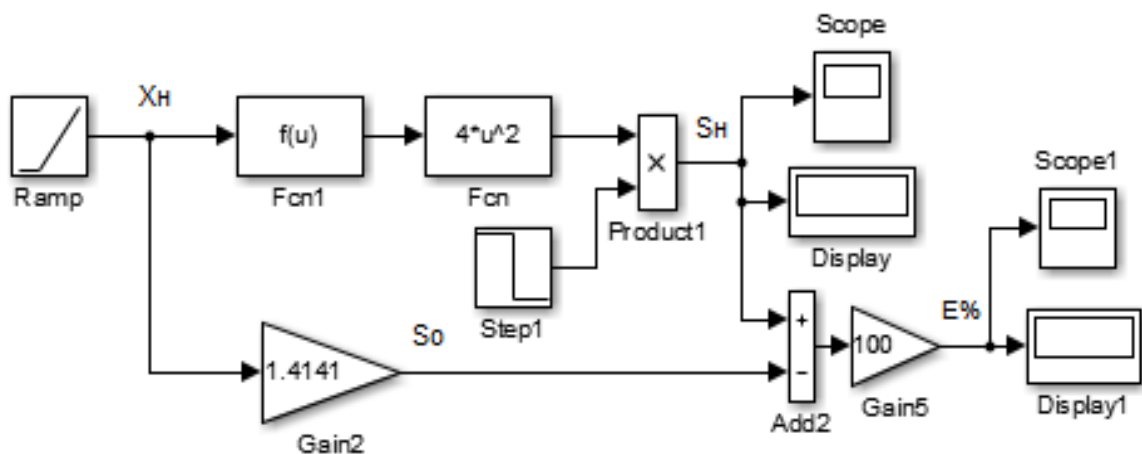


Figure 5: Block diagram of the model of linear characteristic forming of the normalized raster transformation

The *Ramp* block generates a linearly increasing normalized size of the X_H raster element, which is provided at the input of the *Fcn1* mathematical functions block in the dialogue box of which the equation (7) is recorded for linearization, the output of which is transferred to the next block of mathematical functions *Fcn1* where the expression (2) is recorded of the normalized raster

transformation, the calculated area is obtained at its output. The *Scope* unit is used to visualize the simulation results.

At the bottom there is a diagram that determines the deviation of the characteristic from the linear according to the expression (6), which is visualized by the second unit *Scope1*. Figure 6 shows the results of linearization of the normalized raster transformation characteristic.

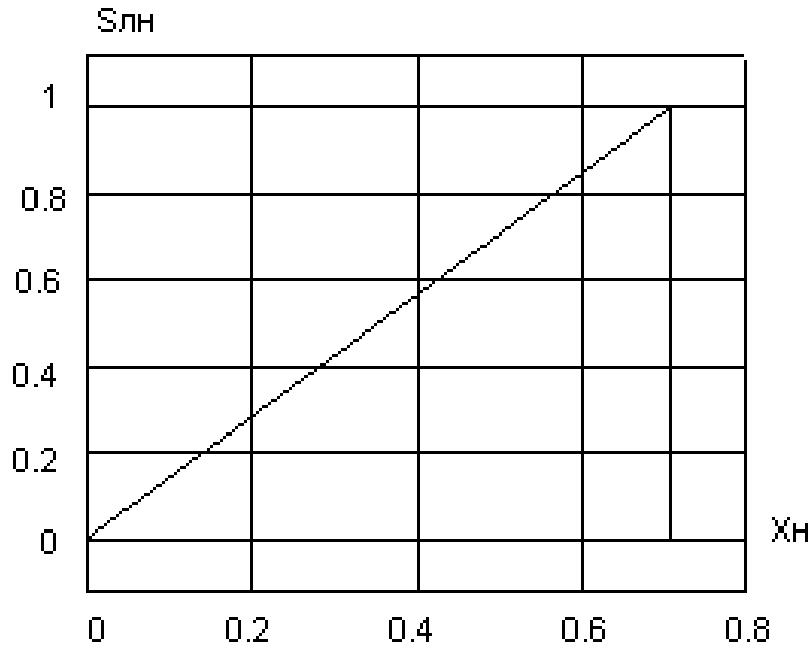


Figure 6: Linearized characteristic of the normalized raster transformation

For comparison, the figure shows linear characteristic that is quite close to the normalized raster transformation characteristic, and the difference between them is barely noticeable. Figure 7 shows the results of simulation of the deviation of the linearized characteristic from the linear one.

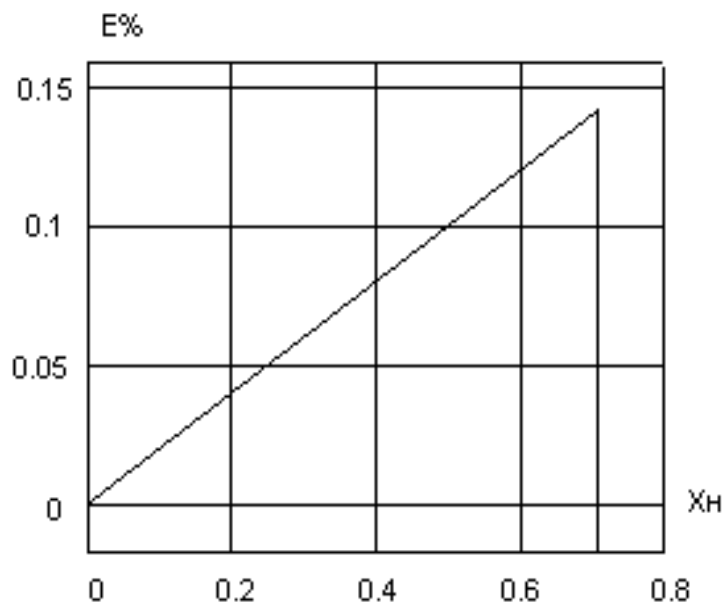


Figure 7 : Graphic chart of deviation of the adjusted characteristic from the linear one

The deviation characteristic is almost linear and varies from zero to 0.141%. Therefore, the suggested sequential adjustment is simple and provides sufficient accuracy of linearization of the normalized raster transformation characteristic for raster elements of rhombic shape, which is an advantage.

4. Conclusions.

Analytical method of linear characteristic forming of the normalized raster transformation for rhombic raster elements with a normalized relative area that changes linearly within [0,1], which is an information carrier, is worked out, and the parameters of the adjustment unit are determined. The block diagram of the model for linearization in the Matlab:Simulink package for calculation, construction, and analysis of the normalized raster transformation characteristics is designed.

The results of simulation modeling of gradation characteristics, deviation from the linear one are presented, the parameters of the adjustment unit are determined, that provides the formation of the linear characteristic of the normalized raster transformation for rhombic elements. It is defined, that the suggested method of linearization of the natural characteristic of the normalized raster transformation provides a linearization error of not more than 0.141%. The results of this work can be used for further research with the aim to compensate the impact of dot gain of raster elements while making a plate, and in the process of printing.

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