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METHODS FOR EVALUATING THE QUALITY OF EDGE DETECTORS OPERATION IN MATHCAD SOFTWARE PACKAGE

A technique is developed for evaluating the quality of edge detector operation in Mathcad package, which makes it possible to estimate effectiveness of edge detectors in their work with various types of images and to use the obtained research results for elaboration of scientific and educational materials for image processing-related disciplines.

Key words: *quality, detector, edge, criterion, images.*

Introduction

One of the main tasks of digital image processing is image edge detection, as edges are the most informative structural elements of objects. Therefore, presence of this subject in the education process while studying different disciplines related to image processing, particularly, "Electronic systems", "Computer graphics", for students of such knowledge branches as 15 - "Automation and instrumentation" and 17 - " Electronics and telecommunications", is relevant.

Image processing is performed with the application of various software packages, which are widely used in educational process, namely, Mathcad and Matlab.

At present Matlab, in particular, Image Processing Toolbox, is the most powerful tool for simulation and studyingimage processing techniques. These techniques, however, are not considered in-depth or only for general familiarization. More complex image processing tasks are solved while doing qualification works. Besides, the price of basic commercial version of Matlab without the tools is about $ 2000 and $ 100 with minimal set of tools for educational institutions. All this complicates wide application of Matlabin educational process.

At the same time Mathcad, particularly, Image Processing Extension Pack,includes many built-in functions, which realize the most common image processing techniques. Besides, portable version is free. Therefore, sufficient level of functional capabilities and availability enable wide use of Mathcad in educational process.

At present, there is a large number of edge detection techniques, which are implemented both in software environments and by hardware means [1].

One of the ways to realize edge detection techniques is application of corresponding detectors. Edges, recognized in defocused images by known detectors, usually have breaks, contour lines may be absent or there could be false ones, which do not belong to the object under study. Contour lines may be thick, blurred and fuzzy, which makes their recognition impossible [1]. Depending on the detector, these disadvantages could be manifested in greater or lesser degree, which results in different edge detection quality levels. In order to provide estimation of this parameter, development of a special procedure is required.

Thus, the research aims at the development of a procedure for evaluating quality of edge detector operation in Mathcad software package, which could be used for elaboration of the tasks for practical and laboratory lessons of the disciplines related to image processing.

Main part

In order to evaluate the quality of edge detector operation a number of studies were conducted with the application of synthesized images of objects. The detected edges were compared using two methods:

- a subjective method, using visual evaluation of the obtained object edge quality;
- quantitative method, using known criteria [2 – 6].

For this, special images with various degrees of blurring and noise levels, synthesized in Mathcad, were used.

One of the most common noise types, considered in the learning process, is Gaussian noise. Mathcad package allows working with it.

Gaussian noise is characterized by adding values from the corresponding normal distribution with zero mean value to each pixel of the image. Such noise appears in the devices of digital image formation [7].

The most common object edge detectors, used in the learning process, are Canny, Roberts, Prewitt and Sobel operators. Mathcad makes it possible to work with them.

Canny operator is distinguished by high accuracy of detecting object image edges, particularly, their position [8].

Roberts and Sobel detectors are user-friendly [9, 10]. However, they do not give adequate results in the case of defocused images. The obtained contour lines are thick, blurred and fuzzy, which makes them impossible to be recognized by automatic systems.

Prewitt operator [11] is characterized by highly accurate edge detection and noise resistance, but its disadvantages include computational complexity, long-time image processing and low efficiency in processing blurred images.

For quantitative evaluation of edge detector operation various criteria are used. In education process PSNR and RMSE criteria are the most common ones.

PSNR is the criterion of peak signal-to-noise ratio, which is determined by the formula

$$PSNR(n,m) = 20Lg\frac{255}{\sqrt{\frac{1}{N}\sum_{i=1}^{N} d(n_i, m_i)^2}}, \quad (1)$$

where N– total number of pixels in each image; n_i, m_i - pixels of two images are compared; $d(n_i, mi)$ – difference in the colors of corresponding pixels.

Image of the edge, obtained from a noiseless one, which was determined as an ideal, as well as images of edges, obtained with the above detectors from noisy ones, were used. In accordance with the criterion, the higher PSNR value, the better detector operation quality is [12].

In addition, the edge detection results were evaluated using the filtering error criterion–*RMSE* (root mean square error):

$$RMSE = \sqrt{\frac{\sum_i \sum_j (n(i,j) - m(i,j))^2}{N}}, \quad (2)$$

where N – number of pixels processed; $m(i, j)$ – filtered image; $n(i, j)$ – Initial image.

For RMSE, the lower filtering error value, the higher quality of filter operation [13, 14].

Thus, a procedure, using Mathcad capabilities, could be proposed for evaluating the quality of edge detector operation. It includes the following steps:

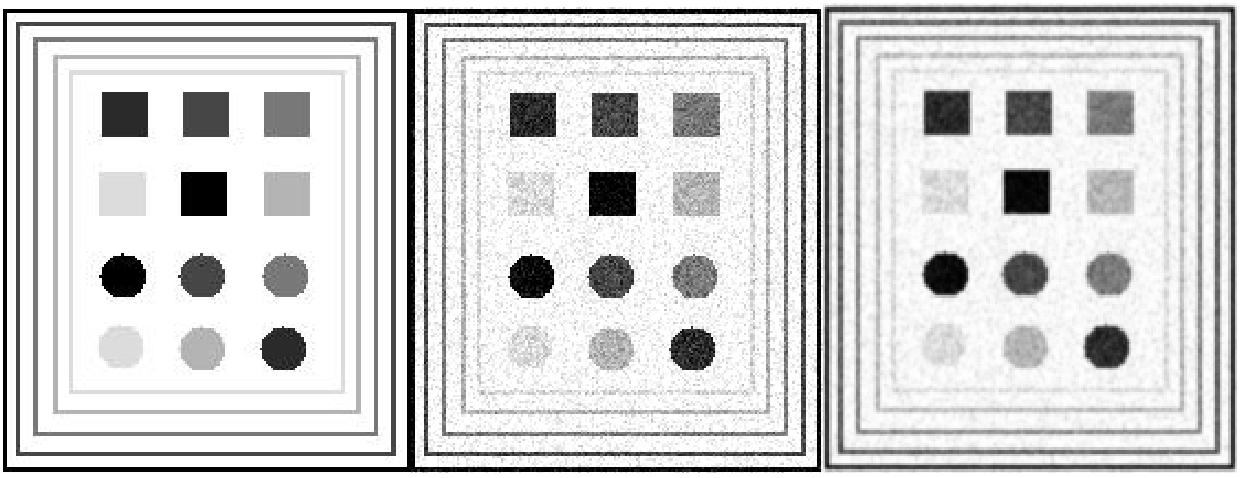
1. Entering and displaying the reference image in Mathcad
2. Displaying the table of pixel intensity in the reference image
3. Displaying the reference image with superimposed Gaussian noise
4. Blurring the reference image
5. Adding Gaussian noise to the blurred image
6. Detecting edges of the reference, noisy and blurred images using Canny, Roberts, Sobel and Prewitt detectors
7. Computation of *PSNR*and *RMSE*criteria
8. Entering the obtained criteria values into the Table
9. Analyzing the obtained results and evaluating quality of the edge detectors operation.

The procedure of implementation is illustrated by the following example.

A reference image, that is image with known parameters, is entered into Mathcad using *Image*: = "*Image.bmp*" operation. Pixel intensity table for this image is generated by performing *M* = *READBMP* (*Image*) operation.

Blurring and adding noise to the image in Mathcad are performed using known operations and functions, which are given in the references to the Image Processing Extension Pack, namely, in the sections Gaussian Kernel Filtering and Addition and Measurement of Noise, respectively.

The synthesized object images, which include several regions of different intensities and contain edges of different contrast, are presented in Fig. 1.



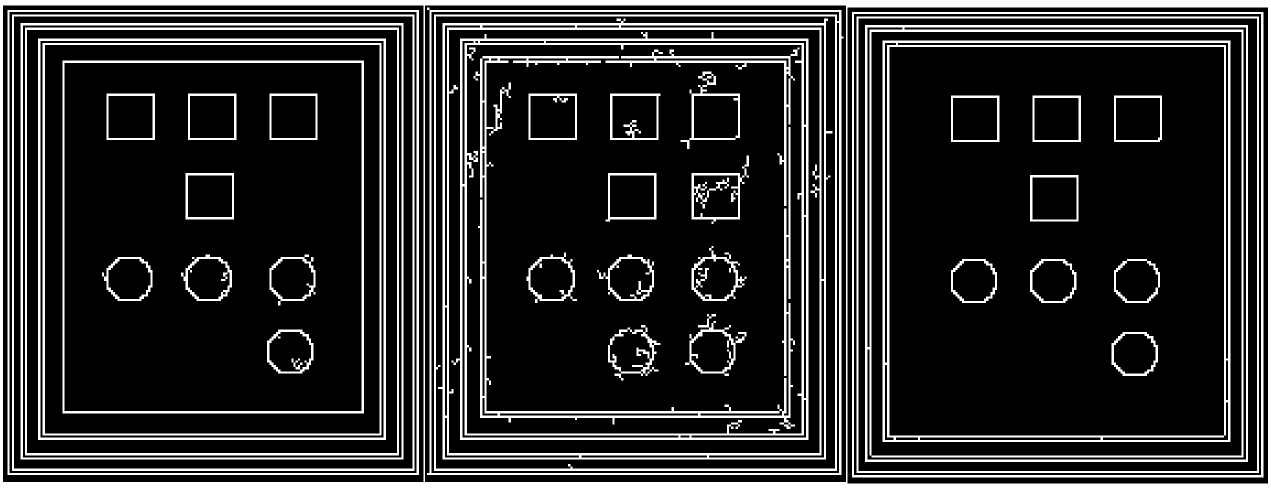
a b c

Fig. 1. Synthesized images: a – reference image; b – with 100% Gaussian noise; c – blurred image with superimposed100 % Gaussian noise

100% Gaussian noise was superimposed on the reference image (Fig. 1, a; 1, b). Additionally, this image was subjected to 75 % Gaussian blurring, followed by 100% addition of Gaussian noise (Fig. 1, c).

Object edge detection in Mathcad is performed using known operations and functions given in the reference to Image Processing Extension Pack, namely, in Edge Finders section.

Fig. 2 shows image object edge detection using Canny detector.

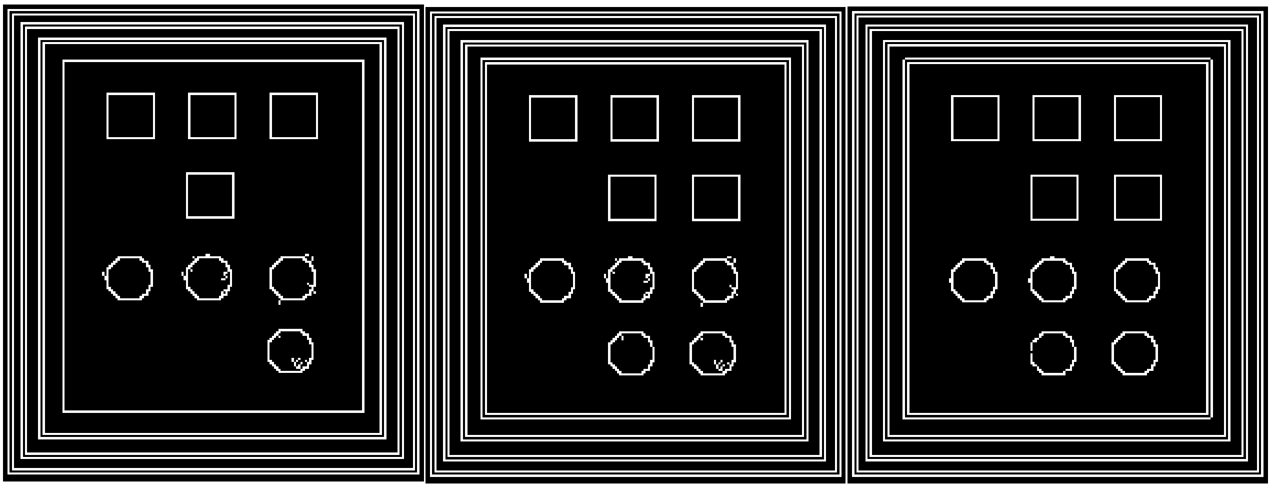


a b c

Fig. 2. Object edge detection using Canny detector: a – reference image; b – image with 100% Gaussian noise; c – blurred image with superimposed 100 % Gaussian noise

As it is evident from Fig. 2, Canny operator provides distinct image object edge detection, which is its indisputable advantage. However, it is apparently sensitive to noise, which forms false contours. Low-intensity objects could also be imperceptible for this detector.

Besides, image object edge detection with Canny operator is characterized by such parameters as upper and lower thresholds. Fig. 3 presents examples of image object edge detection for various values of upper and lower thresholds.

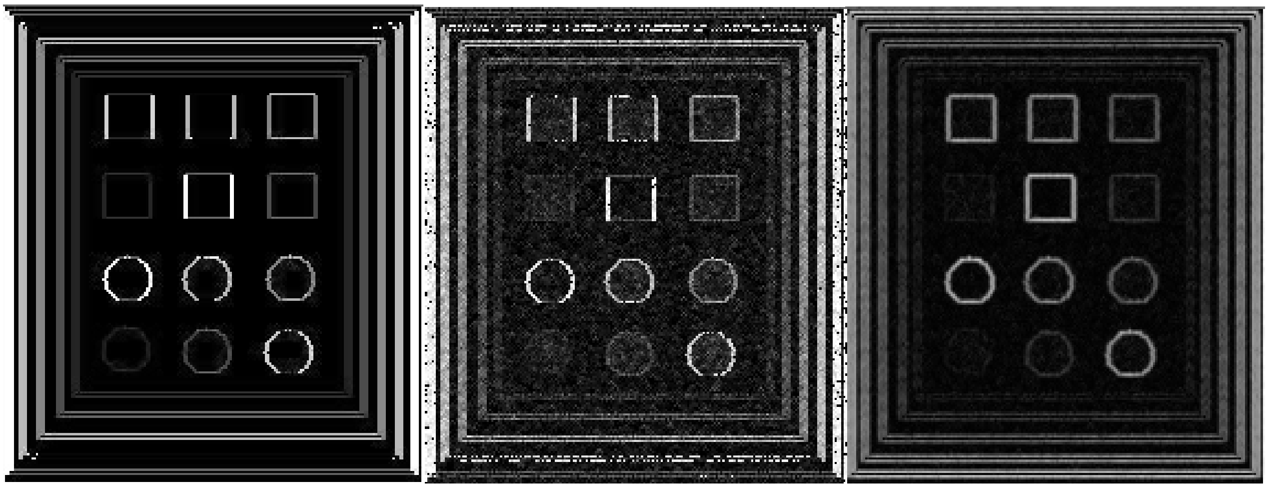


a b c

Fig. 3. Object edge detection with Canny operator: a – upper threshold is 80, lower threshold – 10; b – upper threshold is 50, lower threshold – 10; c – upper threshold is 45, lower threshold – 45

As it is evident from Fig. 3, changes in the values of the upper and lower thresholds of Canny detector make it possible to identify low-intensity objects in the image and to remove false contours.

Fig. 4 presents examples of image object edge detection using Roberts operator.

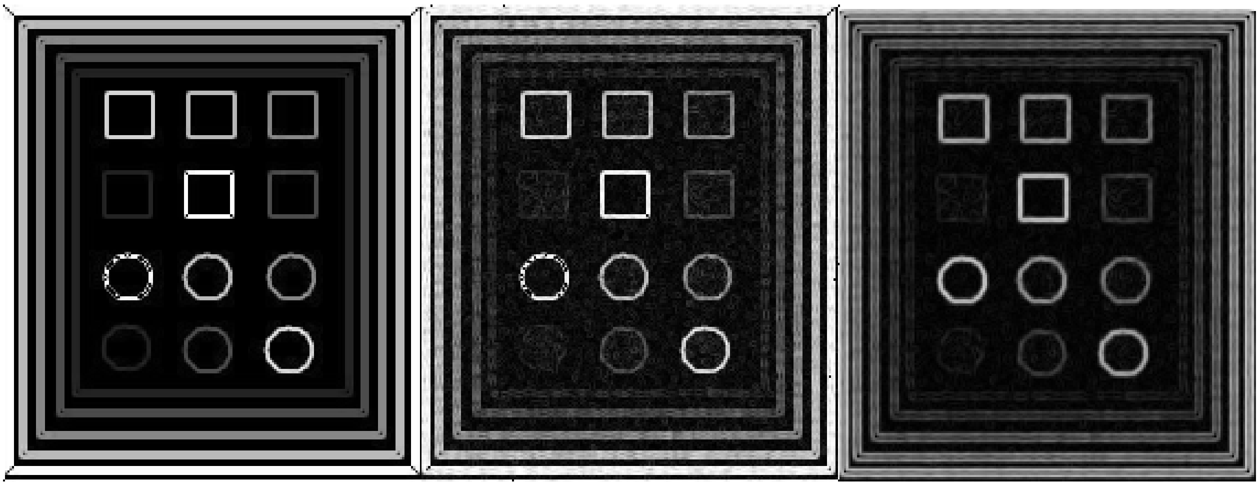


a b c

Fig. 4. Object edge detection using Roberts operator: a – the reference image; b – image with 100 % Gaussian noise; c – blurred object with a superimposed 100 % Gaussian noise

As it can be seen from Fig. 4, edge lines are wide, blurred and fuzzy, which complicates their detection with automatic systems. However, in the case of edge detection of the image objects with superimposed 100 % Gaussian noise, edge lines without breaks can be obtained.

Fig. 5 shows examples of image object edge detection using Sobel operator.

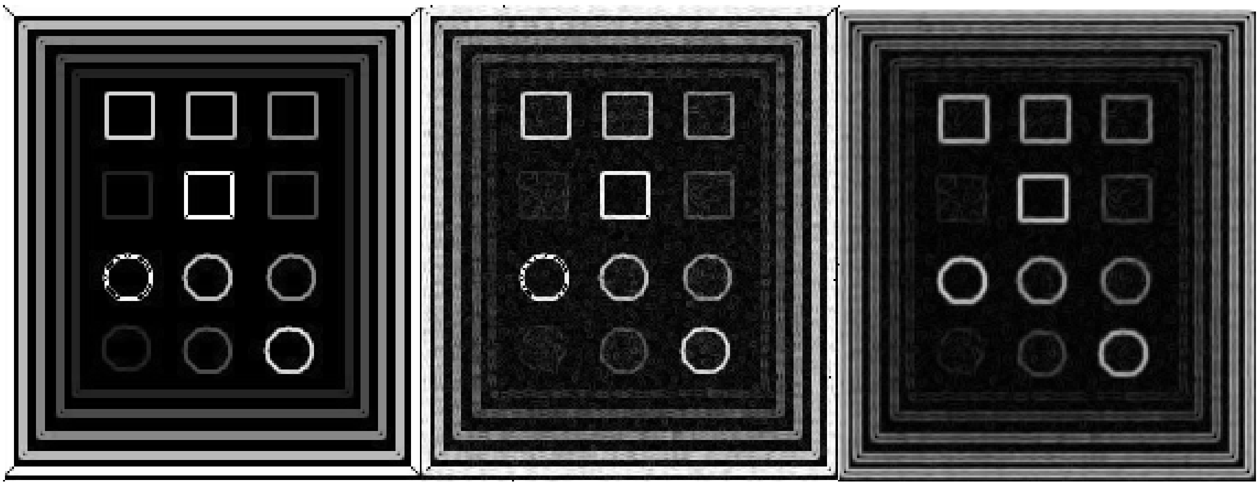


a b c

Fig. 5. Object edge detection with Sobel detector: a - reference image; b - image with 100 % Gaussian noise; c - blurred image with superimposed 100 % Gaussian noise

As it is evident from Fig. 5, Sobel detector gives results for images, which are difficult to be recognized by automatic systems. Among the obtained edge lines there are wide, blurred and fuzzy ones and those with breaks. Only in the case of edge detection of image objects with superimposed 100 % Gaussian noise, edge lines without breaks can be obtained.

Fig. 6 presents the results of object edge detection using Prewitt operator.



a b c

Fig. 6. Object edge detection using Prewitt operator: a – the reference image; b – image with 100 % Gaussian noise; c – blurred image with superimposed 100 % Gaussian noise

As it can be seen from Fig. 6, Prewitt detector is characterized by highly accurate edge detection and noise resistance. However, it has low efficiency in working with blurred images.

PSNR- and *RMSE*-criteria calculation in Mathcad package is performed in accordance with the above formulas (1), (2). The criteria values, obtained with each detector for noisy and blurred images, are entered into the Table.

Table 1 presents the results of studying operation of each detector using the above criteria.

Table 1

The results of studying operation of the detectors

	PSNR		*RMSE*	
	Image with 100 % noise	Blurred image with 100 % noise	Image with 100 % noise	Blurred image with 100 % noise
Cannydetector	5.05	34.79	0.32	4.64
Robertsdetector	3.39	21.36	3.87	2,8
Sobeldetector	3.49	22.18	3.82	1,85
Prewittdetector	3.61	22.19	3.77	1.83

Analysis of the results shows that Canny detector is, on the whole, the most efficient among all of the image object edge detectors considered. The rest of the detectors demonstrate almost equivalent operation as to the edge detection quality.

Conclusions

In this paper a procedure has been developed for evaluating the quality of operation of image object edge detectors with the application of Mathcad package. The procedure could be used in elaboration of laboratory and practical tasks for disciplines related to image processing, in particular "Electronic systems", "Computer graphics", for the students of such knowledge branches as 15 - "Automation and instrumentation" and 17 - "Electronics and telecommunications".

Besides, operation of Canny, Roberts, Sobel and Prewitt detectors has been analyzed. Canny detector has been recognized as the most efficient as to image object edge detection among all of the detectors considered. Other detectors demonstrate almost equivalent performance as to the edge detection quality.

REFERENCES

1. Detector of defocused images edge extraction [Electronic resource] / Y. Y. Bilynskyi, K. V. Ogorodnik, I. V. Mykylka // Scientific Works of Vinnytsia National Technical University. – 2012. – №3. Access mode to journal: https://works.vntu.edu.ua/index.php/works/article/view/345/343.
2. Zukerman I. I. Digital coding of TV images / I. I. Zukerman, B. M. Katz, D. S. Lebedev. – M. : Radio and communication, 1981. – 240 p. (Rus).
3. Bilynskyi Y. Y. Method of light shade boundary determination of refractometric measuring tools / Y. Y. Bilynskyi // Bulletin of Khmelnitski National University. – 2006. – № 2. – P. 62 – 66. (Ukr).
4. Belikova T. P. Certain methods of digital preparation of images. Digital processing of signals and its application / T. P. Belikova. – M. : Nauka, 1981. – P. 280. (Rus).
5. Coleman G. Image Segmentation by Clustering / G. Coleman, H. Andrew // In Proceedings of IEEE. – 1979. – Vol. 67. – P. 773 – 785.
6. Online fast measurement of section sizes of three-dimensional objects using binary image analysis / W. Ren, Y. Wang, H. Zhu, P. Sun [et al] // Opt. Eng. – 1998. – Vol. 37, № 6. – P. 1740 – 1745.
7. Filtration of biomedical images by OpenCV methods [Electronic resource]. – Access mode: http://ki.tneu.edu.ua/view/showResearch/imageFiltration.php (Ukr).
8. A computational approach to edge detection [Electronic resource] / J. Canny // IEEE Transactions on pattern analysis and machine intelligence. – 1986. – Vol. PAMI-8, № 6. – . Access mode: https://perso.limsi.fr/vezien/PAPIERS_ACS/canny1986.pdf.
9. Gonsales R. Digital processing of images / Gonsales R., Woods R. ; Translated from English by P. A. Chochia. – M. : Technosphere. – 2006. – 1070 p. (Rus).
10. Rusyn B. P. Systems of synthesis, processing and recognition of complex-constructed images / B. P. Rusyn. – L. : Vertical. – 1997. – P. 264. (Rus).
11. Pratt W. Digital processing of images. Books 1, 2 / Pratt W. ; Translated from English by D. S. Lebedev . – M. : Mir, 1982. – P.790. (Rus).
12. Wezerl W. Assessment of image quality. Design of optical systems / Wezerl W. ; Under editorship of R. Shennon, J. Viante. – M. : Mir, 1983. – P. 398. (Rus).
13. Bilynskyi Y. Y. Noise attenuation in the problems of object edge detection on the image / Y. Y. Bilynskyi // Eastern-European journal of advanced technologies. – 2008. – № 3/2 (33). – P. 9 – 13. (Ukr).

14. Bilynskyi Y. Y. Methods of images processing in computer-based opto-electronic systems : Monograph / Y. Y. Bilynskyi. – Vinnytsia : VNTU, 2010. – P.272. (Ukr).

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