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INTERACTIVE RESOURCE FOR IMAGE PROCESSING IN SCILAB

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Abstract

The engineering field "Image Processing and Computer Vision" is extremely relevant nowadays, because with the development of techniques and technologies, digital image processing is applied in many fields, such as medicine, astronomy, the food industry, remote sensing, industry, security, etc., and there is a need for trained specialists to solve emerging problems. With the development of computer technologies, image processing methods, and algorithms are being developed and applied to an increasing number of food quality indicators. This requires food quality specialists and computer engineers to work together, which assumes, to ensure good communication between them, that each knows key aspects of the other's field. This paper discusses the capabilities of the open-source software Scilab for image processing and for creating graphical user interfaces.

For educational purposes, many existing specialized image processing software products that contain built-in functions such as ImageJ can be used, also specialized software platforms contain built-in image processing modules such as LabView, Matlab, Scilab, etc. Computer technologies are also increasingly entering the field of education, leading to changes in teaching methods and tools, including those for students. The use of e-learning results allows for diversifying the form of learning and improving motivation and knowledge acquisition. An interactive programming resource with user-friendly graphical user interface is developed. The developed resource is implemented in the programming environment Scilab and contains an array of buttons and drop-down menus for applying well-known image processing techniques such as binarization, morphological operations, filtering, etc.

The application has been used in the training of computer engineers and has been discussed in terms of its development and capabilities for food analysis. A specially designed survey was used to explore the opinions of the learners and assess their perceptions of the usefulness and motivation in learning and the ease of use of the developed interactive resource. The statistical analysis of the results shows a positive attitude of the learners towards the interactive resource in terms of its performance and effectiveness in knowledge acquisition.

***Key words**: Computer vision, Image processing, Education, Scilab, Interactive tool.*

1. Introduction

With the development of computer systems and technologies, digitization is entering all areas of life, and one of the main aspects is the application of image processing and computer vision to solve specific problems based on primary information obtained from a digital image. Some examples are diagnostic imaging in medicine and biology; access control of persons or vehicles; scene analysis in industry, such as control by location, shape, and other characteristics of objects; acquisition and processing of aerial and satellite images, etc. Trends in the use of computer systems are also reflected in the analysis of food products, which is essential for ensuring the quality of life of people. One of the directions is the use of digital image processing methods and algorithms to determine food and product characteristics. Examples include the evaluation of quality indicators of food products both in finished form such as different types of cheese, bread and bakery products, meat and meat products, etc., and in the course of production such as the analysis of lactic acid bacterial colonies [1 - 6]. This defines the field of "Image processing and computer vision" as particularly relevant and perspective, which leads to the need for training of computer specialists in this field. The training would also be suitable for specialists in other fields, where specific tasks can be solved using digital image processing methods and algorithms. The development of a specific project in a given field requires teamwork between experts in that field and computer specialists, and the

basis for success is good competent communication between them.

With the development of technology, the means of learning are also changing, and computer-based learning modules are now increasingly used. They need to be simple, concise, flexible, educational, and engaging to effectively complement traditional teaching tools. Computer-based modules need to clarify problem concepts, improve problem-solving skills, and perhaps most importantly manage to hold the learner's attention. It is also important to explore feedback between the educator and the learners to improve the interactivity and scope of the modules [7, 8].

Interactive learning tools and technologies can be used by a large number of learners, thus saving time and effort [9]. E-learning tools play a very important role in bringing about a change in teaching methods and in providing quality education. Many learning software products have been developed through which the learner can get the opportunity to learn in an interactive environment. Some application software and open-source software that help learning to be more effective are Course Management System, Modular Object-Oriented Dynamic Learning Environment, JOOMLA, and DRUPAL [10].

Several software products contain a wide range of tools to enable you to create your own interactive learning resource. For example, Kroumov *et al.*, [11], present in their paper a set of interactive learning tools that are aimed at improving understanding and skills for the analysis and design of management systems. The tools are implemented in MATLAB and have detailed help and advice information. They can be used by students for seminar problem-solving and individual study and can be applied as a teaching aid during lectures on classical automatic control.

In this paper, the capabilities of the open-source software Scilab to create a graphical user interface are discussed and an interactive image processing resource including basic operations is developed.

2. Interactive resource for image processing in Scilab

Image processing is the process of transforming an image into digital form and performing certain operations on it to improve its quality or extract useful information, using various methods and techniques to manipulate digital images using computers.

The image processing procedure can be divided into two main tasks. The first is image preprocessing and image information reduction. At this stage, image contrast enhancement, filtering, binarization, performing arithmetic and logical operations between more images, and others are performed. The second main task is image analysis. At this stage, certain features are extracted from the image (edge detection, spatial features of the captured objects, edges, etc.), and image segmentation, recognition, or classification of certain objects are performed [12].

In many industrial applications, computer vision is used for object recognition, image segmentation, and defect detection. Some image processing functions can only be applied to grayscale images, and with primary color data it is necessary to make a conversion to grayscale format. This defines binarization as one of the main preprocessing operations, and it can be performed using various methods to automatically determine the binarization threshold or set manually. The extraction of different features about the shape of objects such as edges, cracks, and holes can be realized by applying morphological processing to the images using structuring elements of different shapes, which defines morphological operations as basic.

Digital image processing is performed using algorithms from discrete mathematics and involves elementary arithmetic operations of addition/subtraction, multiplication/division, and shifting on two-dimensional or three-dimensional arrays of data depending on the type of image, whether planar or spatial. These algorithms can be implemented in any programming language, but there are also various software products, both purely specialized in image processing, providing ready-made functions, such as ImageJ, or software platforms containing built-in image processing modules, such as LabView, Matlab, Scilab, etc. When solving a specific task, the most appropriate way should be chosen depending on the developer's preferences, the compatibility of the software with the computer system used, the type of license - paid or free, etc.

Scilab is a free and open-source software for engineers and scientists and a high-level, numerically oriented programming language. It can be used for numerical analysis, data visualization, algorithm development, application development, signal processing, statistical analysis, image processing, and others [13]. Scilab allows one to perform operations in the mathematical field or to create a program that is saved as a separate file. The Scilab language allows dynamic compilation and linking with other languages such as Fortran and C. Thus, external libraries can be used as part of Scilab's built-in functions. The programming environment has a rich set of libraries that are divided into groups according to their application and it is necessary to install additionally the desired library. Scilab users can develop their own module to solve specific engineering

and mathematical problems that will be compatible with different operating systems (Windows, Linux, and MacOS X) [14]. To create their own graphical user interface (GUI), it is necessary to first install the GUI Builder library [13]. It contains a rich palette of fields, buttons, sliders, and menus that can be placed on the interface under development (Figure 1).

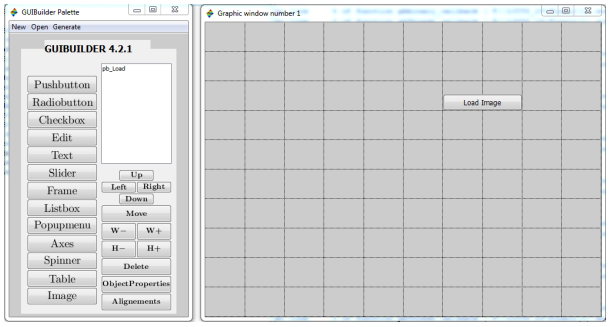

Figure 1. Opportunities for GUI creation

Each element is placed in the desired position on the graphic window, and it must be assigned a "name" (string), which will be displayed, and a "tag" (tag), which is the name of the function controlling the button. Scilab allows multiple settings for each button, such as color, alignment, text font, color of the button itself, and more. Once the user interface is created in the desired form with all the required fields and buttons, a command is executed to generate the GUI project itself in the form of program code (Generate/ Generate GUI Code). This program contains all the properties of each created element and an empty function created for it, in which to program the corresponding actions to be implemented through it.

2.1 Studying image processing and computer vision

In the professional field 5.3 Communication and Computer Engineering at the University of Food Technologies students study the discipline „Image Processing and Computer Vision". In this discipline the software product Scilab is used, given its advantages of being free, running robustly, containing many different libraries, and being similar to other similar paid software products.

An interactive learning resource was developed with a graphical user interface (Figure 2) that contains a set of buttons and drop-down menus to apply basic image processing. The developed interactive module enables:
- image conversion to different color systems;
- conversion of a color image to grayscale;
- binarization using automatic or manually set binarization threshold;
- applying morphological operations on a color or binary image;
- image noising with the possibility to select the type of noise;
- filtering the image with a choice of filter type;
- create a histogram of a color and binary image, and display the result in a separate window;
- distance measurement in pixels.

The user can choose the sequence in which to perform the conversions and has the option to save the result to a file.

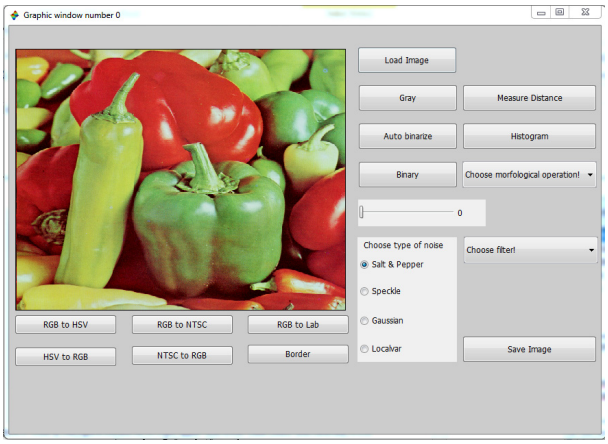

Figure 2. Interactive learning resource

Users have the ability to apply multiple treatments to an image of their choice. When binarizing an image with a manually set threshold, a slider is used. Each time the slider is moved, the result is immediately displayed and thus the user can visually decide which is the most appropriate threshold to binarize the image. Two drop-down menus have also been added to the created graphical user interface. The first one gives the possibility to apply basic (dilation and erosion) and additional (image opening and closing) morphological operations applied on a color or binary image. The second drop-down menu contains 7 different types of filters that can be applied when processing the image (Figure 3).

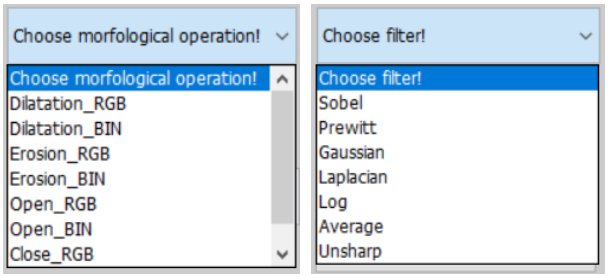

Figure 3. Possible options for the two created drop-down menus

Figure 4 shows the result of the Histogram button to draw the histogram of the color and grayscale image, which is implemented in the application by opening a new graphic window.

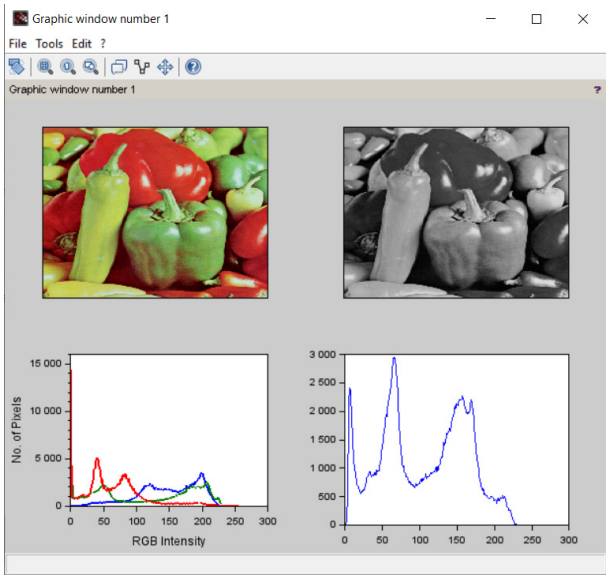

Figure 4. Result of Histogram button selection

The interactive image processing resource is designed for educational purposes to facilitate and motivate the acquisition and consolidation of theoretical and practical knowledge and to encourage creative thinking. The implementation of multiple basic image processing operations is a prerequisite for the possibility of using the application for other purposes, such as research and development. As an example, the capabilities of the breadcrumb distribution analysis application, one of the thematic areas of the author team's work concerning the University of Food Technologies core area, are presented (Figure 5).

The developed interactive module was used to train 35 students in the 4th year, majoring in computer systems and technologies in the discipline "Image Processing and Computer Vision" during the winter semester of the academic year 2022 - 2023. As users, they were able to evaluate perceptions regarding the usefulness and ease of use of the training resource. For this purpose, students completed a prepared survey (survey) containing 5 questions (Table 1) with response options on a 4-point Likert scale: 'No'; 'Rather No'; 'Rather Yes'; 'Yes', therefor the type of the results is ordinal data. For four of the questions (1st, 2nd, 4th, and 5th) the target responses are in the positive levels - "Yes" and "Rather Yes", while for one of them (3rd) the target responses are in the negative levels - "No" and "Rather No". Table 1 shows the frequency distribution of responses and their percentages for each question of the survey.

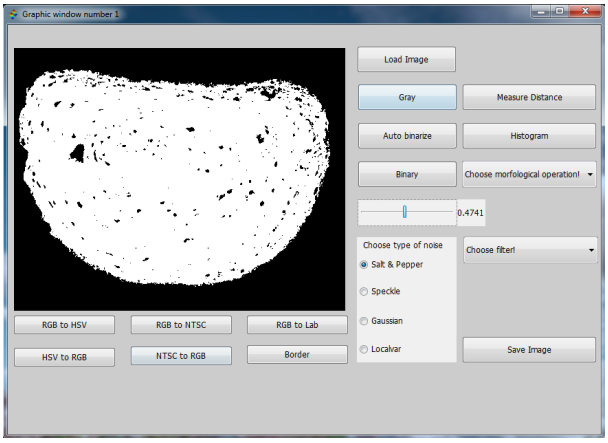

Figure 5. Result from the breadcrumb distribution analysis

For the statistical analysis of the results for each survey question are determined [15]:
- Measures of central tendency - Median (Me) - the middle value in a list ordered from smallest to largest; Mode (Mo) - most frequently occurring value on the list (the largest rectangle when representing the data using a bar graph);
- Percentile (P) and Percentile rank (PR) - Percentiles show how a value compares to other values and they indicate the percentage of scores that fall below a particular value. If the value X is at the kth percentile, then X is greater than K% of the values, where X is the score of percentile and k is the percentile rank;
- Quartile (Q) - cut points dividing the number of data points into four parts. The second quartile Q2 is the

Table 1. Distribution of students' responses

Question	No, Number (%)	Rather No, Number (%)	Rather Yes, Number (%)	Yes, Number (%)
1. Do you think the interactive resource is stable and working well?	0 (0)	3 (8.6)	8 (22.8)	24 (68.6)
2. Do you find the interactive resource easy to use?	0 (0)	1 (2.8)	3 (8.6)	31 (88.6)
3. Did you encounter any difficulties when working with the presented interactive resource?	24 (68.6)	7 (20)	2 (5.7)	2 (5.7)
4. Do you find using the interactive resource useful for understanding the learning material?	2 (5.7)	6 (20.0)	7 (17.2)	20 (57.1)
5. Does working with the interactive resource motivate you to learn the discipline?	0 (0)	3 (8.6)	4 (11.4)	28 (80)

Median, respectively the 50th percentile, meaning that 50% of the data falls below their values. Q1 and Q3 are the first (lower) and third (upper) quartiles, respectively the 25th and 75th percentiles, meaning that 25% and 75% of the data fall below their values;
- Interquartile range (IQR) - it is a measure of dispersion in statistics for ordinal data and IQR = Q3 - Q1. A relatively small IQR indicates a consensus and a larger IQR indicates that the data are more spread out.

The statistical results for each survey question are shown in the cumulative frequency graph (Figure 6), answers are arranged in ascending order according to the purpose of the question - where for the third question the target answers are negative ones and for the other four questions the target answers are the positive ones.

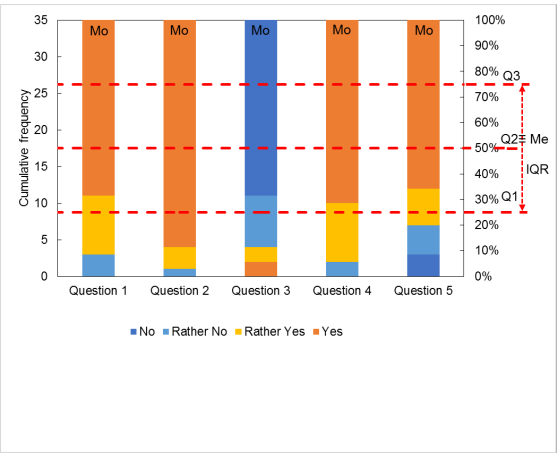

Figure 6. Cumulative frequencies and response statistics for each survey question

Figure 7 presents the commutative frequencies of the negative ("No" and "Rather No") and positive ("Rather Yes" and "Yes") response groups for each survey question and the corresponding percentile ranks (PR) for the negative response groups.

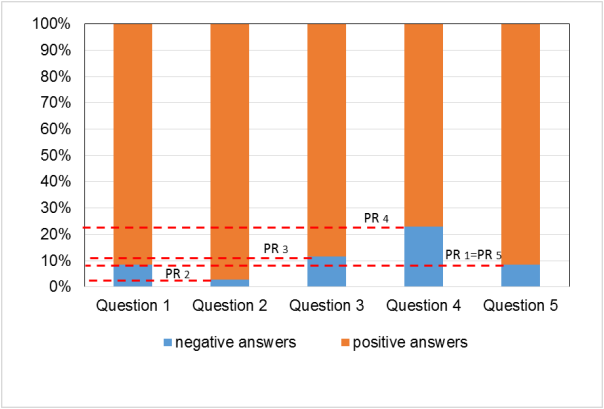

Figure 7. Cumulative frequencies of groups of negative („No" and „Rather No") and positive („Rather Yes" and „Yes") responses and percentile ranks (PR) for groups of negative responses to each survey question

The analysis of the results of the first three questions of the survey shows a positive opinion of the students regarding the performance of the interactive resource. For all three questions, the median and mode have the highest target positive value for the respective question. The percentile rank for the negative responses has low values ($PR_1 = 9$, $PR_2 = 3$, $PR_3 = 11$), indicating that a small percentage of respondents express negative opinions, and the majority believe that the application is easy to use, works stable, and they have not encountered any difficulties. The interquartile ranged values show little dispersion and consensus of opinions, for question two and IQR is 0, and for questions one and three the difference between Q3 and Q1 is expressed in one level.

The results of the fourth and fifth questions of the survey show a positive evaluation of the students regarding the impact of the interactive resource on their understanding of the educational material and on their motivation to learn the discipline. For both questions, the median and mode have the highest target positive value for the respective question. The percentile rank for negative responses to question four has a value of 23 ($PR_4 = 23$) and for question five has a value of 9 ($PR_5 = 9$). These results show that 77% of the students believe that the application helps them to understand the study material and 91% of the students give positive answers, which is very high in terms of motivating them to study. The interquartile range values show little dispersion and consensus of opinions, with a one-level difference between Q3 and Q1 for both questions

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3. Conclusions

- In the learning process, it is important to look for ways to better motivate learners and learning. The advent of computer technology in education has enabled the use of computer-based learning modules, which effectively complement traditional teaching methods to increase learner interest and involvement in the learning process.
In this regard, an interactive image processing module including multiple basic operations has been developed and used for teaching. Students' opinion about the impact of the application on the learning process was investigated through a specially designed survey. The statistical analysis of the results shows a positive attitude of the learners towards the interactive resource in both aspects of the objectives set for its development - Firstly in terms of its operation, such as

stability, ease, and lack of difficulties in operation, and secondly in terms of improving knowledge acquisition and increasing motivation.
- The developed application can also be used for purposes other than training, such as research and development, given the availability of multiple basic image processing operations and the easy-to-use graphical user interface.

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