Article

Development of a software module using computer vision for the analysis of diseases of grape seedlings

Marina Rudenko 1, Yurij Plugatar 2, Anatoliy Kazak 3,\*, Nadezhda Gallini 3 and Andrey Rudenko 1

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1 Institute of Physics and Technology, V.I., Vernadsky Crimean Federal University, Simferopol 295007, Russia; maridigit@gmail.com (M.R.); rudenkoandre@gmail.com (A.R.)

2 Nikitsky Botanical Gardens - National Scientific Center of Russian Academy of Sciences, Yalta; [priemnaya-nbs-nnc@ya.ru](mailto:priemnaya-nbs-nnc@ya.ru) (Y.P.)

3 Humanitarian Pedagogical Academy, V.I. Vernadsky Crimean Federal University, Simferopol 295007, Russia; gallini.nadi@yandex.ru (N.G.);

**\*** Correspondence: kazak@cfuv.ru or kazak\_a@mail.ru

**Abstract:** The paper substantiates the mathematical modeling of a fuzzy model classification of damage to grape seedlings, containing clusters of diagnostics of lesions of diseases or pests of grapes, obtained in the process of analyzing detected images. An algorithm for contour analysis of the image of a grape seedling is proposed. A software module for the analysis of grape seedlings is presented and an analysis of the results obtained is carried out.

**Keywords:** neural networks, computer vision, viticulture, grape diseases, artificial intelligence, environmental engineering

1. Introduction

The relevance of the study is based on the need to analyze grapevine seedlings using computer vision to establish disease or frost infestation. The appearance of the seedling is determined visually. On examination, a person may not notice the damage to the seedling, so the authors of the article proposed a solution based on computer vision.

The purpose of this study is to develop a software module for the analysis of grape seedlings for the presence of diseases.

The objectives of this study are:

1. Carry out mathematical modeling of a fuzzy model for the classification of damage to grapes.
2. Substantiate the algorithm for contour analysis of images of grape seedlings.
3. Develop a software module for the analysis of grape seedlings

2. Fuzzy classification model for vine damage

The main expected result of the system for diagnosing damage to grapes is a list of diseases or pests obtained during the analysis of detected images. The vector of results should be supported by metrics that characterize the significance and proximity of the condition of the affected grapes to the set of symptoms of a particular class of damage. In practice, as one of the methods of confirmation, a comparison with some similar conclusions made earlier by specialists can be used. To do this, a database of "reference" classes of vine lesions, characteristic for a particular localization of agricultural production, can be formed, containing the characteristics and description of objects in the image. Analyzing on the basis of comparison, a specialist or artificial intelligence will be able to draw reasonable conclusions based on their proximity to the standards according to some rules. The formulation of the problem of fuzzy classification of grape lesions based on image analysis can be reduced to the classical problem of classifying the elements of a set of grape diseases by a tuple of fuzzy variables using an additional fuzzy classification neural network [1; 6-11].

The FuzzyClassificator software modules were developed and distributed under the MIT license. However, we decided to build our own fuzzy classifier, which allowed us to enter and take into account information and expert assessments of specialists with given membership functions. The proposed mechanism made it possible to more accurately and flexibly tune the classifier, taking into account the complexity of formalizing knowledge and expert opinions, as well as to retrain or retrain the fuzzy model. Under these conditions, the method of convolution of tuples of image objects by classes with the formation of a fuzzy estimate of their form factors, such as the fill factor (the share of the area occupied by class objects), the presence factor (the share of class objects in the tuple), the degree of severity of the class structure (assessment of the degree assigning an object to a class). Also, the estimates of the SNA of the entire image, the estimate of informativeness (the share of the area occupied by all objects), and the uniformity of the distribution of objects were also converted to fuzzy variables [2-4].

The study uses fuzzy classification rules, each of which describes one of the types of damage to grapes in the data set. The a priori rule is a fuzzy description in the n-dimensional property space and the sequence of rules is a fuzzy class label from the given set (1):

(1)

Here n denotes the number of properties, x is the input vector, A ij are fuzzy sets, represented by fuzzy ratios of the output of the i -th rule and the input vector or the previous fuzzy rule. The degree of activation of the i -th rule from the set (2) M is calculated as:

(2)

The classifier output is determined by rule (3), which has the highest degree of activation α i :

(3)

At this stage, we have implemented only 21 rules for making a conclusion regarding the type of lesion and its degree. The degree of confidence in the solution is given by the normalized degree of rule triggering (4):

(4)

However, a feature of grape damage is its combination in several classes, which requires information about all reliable lesions found in the image in accordance with a fuzzy assessment of confidence. Therefore, the result is supported by the vector (5)

(5)

For which , Dm is the threshold value for a given class of damage to grapes. It also provides for combining estimates and conclusions obtained after the detection of several images of the same source location. The union is a convolution by the maximum and average value of the metrics, activated classes. The output of the classifier activates the score gain among the set L of images acquired at the selected location (6).

(6)

The complex lesion vector collapses the estimates by the maximum weighted one from the set L relative to the threshold Dm (7).

(7)

In the future, the rules are reinforced by tracking the dynamics of the development of the process when using certain factors in the processing and protection of grapes. This a posteriori information forms a set of meta-rules or reflex patterns that are evaluated and ranked by disease, proven potency, and grape variety. Given the variety of drugs and technologies for combating grape diseases, we have chosen the path of accumulating the proposed templates and technologies as rules that have their own fuzzy assessment of effectiveness µ.

3. The use of Computer Vision to Analyze Vine Seedlings

3.1. Search subject by bloom

Color is the property of bodies to reflect or emit visible radiation of a certain spectral composition and intensity. Everywhere and everywhere we are surrounded by color indicators. Traffic lights, white and yellow road marking lines, corporate product colors, road signs and various indicators. For example, for visually impaired people, yellow circles are glued on the doors of shops (yellow is the last color they see) so as not to confuse, for example, a glass showcase with a glass door. There are also yellow stripes on the steps of pedestrian crossings. The borders are covered with yellow paint. This color is one of the brightest and it becomes easier for people with poor eyesight to navigate the city. One of the important problems of searching by color is the influence of many factors. For example, illumination. We must also not forget that the visible color is the result of the interaction of the spectrum of the emitted light and the surface. Those. If a white sheet is illuminated by the light of a red bulb, then the sheet will also appear red.

The main difficulty of object localization is the most difficult part of object de-tection. We use many ways to search for objects in an image, one of the methods is to use a sliding window of different sizes to search for objects in an image. This method is called "exhaustive search". The "exhaustive search" method consumes enormous computing resources, since it is necessary to detect an object in thousands of windows, given the small size of the image. To improve the operation of the method and increase the speed of data processing, we optimized the processing algo-rithm, namely: we changed the window sizes in different ratios (instead of 23 mag-nification by several pixels). The result of such optimization is an increase in the speed of the algorithm, but the efficiency leaves much to be desired. This paper dis-cusses a selective search algorithm that uses both an exhaustive method and segmen-tation (a method of separating objects of different shapes in an image by assigning different colors to them). To determine the color characteristics, a program was written that helps to highlight the contours in the image. To determine these parame-ters, a program was written for the RGB color of an image from video camera No. 1. The results of the provided program are shown in Figures 2.1.1 through 2.1.8. The resulting images were obtained by coloring the original image in red, green and blue colors and defining the mask [21-24].

Applying the output information, it is possible to find the pixels of the required color using the function to select image pixels that fall within the specified range of colors, which examines the array elements (pixels) element by element and checks if the colors are in the list of values of 2 different matrices.

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| **Figure.** 2.1.1. Initial picture | **Figure.** 2.1.2. Applying a mask by color to the original image |
| **Figure.** 2.1.3. Colorized original picture | **Figure.** 2.1.4. Selecting colors in the image (mask 1) |
| **Figure.** 2.1.5. Selecting colors in the image (mask 2) | **Figure.** 2.1.6. Selecting colors in the image (mask 3) |
| **Figure.** 2.1.7. Selecting colors in the image (mask 4) | **Figure.** 2.1.8. Selecting colors in the image (mask 5) |

3.2. Algorithm for contour analysis of an image of a grape seedling

The contour analysis algorithm is one of the important and very useful methods for describing, recognizing, comparing and searching for graphic images (objects). A contour is the outer outline of an object. When carrying out contour analysis: it is assumed that the contour contains sufficient information about the shape of the ob-ject; due to the same brightness with the background, the object may not have a clear border, or it may be noisy with interference, which makes it impossible to select the contour (successful use only with a clearly defined object against a contrasting background and no interference); overlapping of objects or their grouping leads to the fact that the contour is selected incorrectly and does not correspond to the border of the object; internal points of the object are not taken into account. Therefore, a number of restrictions are imposed on the scope of contour analysis, which are mainly related to the problems of contour detection in images.

Among the methods for obtaining a binary image, one can single out, for exam-ple, thresholding or selecting an object by color. The OpenCV library implements convenient methods for detecting and manipulating image edges. The findContours function is used to find contours in a binary image . This function can find outer and nested contours and determine their nesting hierarchy. There are also other functions that are often used, such as minAreaRect2(), which returns the smallest possible rectangle that can wrap around the path, but that can be rotated relative to the image coordinate system by a certain angle. An example of how contour analysis works is shown in Figure 2.2.1. When the algorithm is running with the cv.CHAIN\_APPROX\_SIMPLE parameter (Figure 2.2.2), all boundary points are preserved. It removes all unnecessary points and compresses the contour, and also saves memory [12-14; 15-20; 25].

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| **Figure**. 2.2.1. Contour analysis example | **Figure.** 2.2.2. Contour analysis |

3.3. Development of a software module for the analysis of grape seedlings

To find the radii of the selected contours with the support of 2 cameras, a method was developed for the program. The essence is correct: the object moves along the assembly flow and when it enters the frame of video camera No. 2, its contour is located by subtracting the snow-white background. As soon as the middle of the plant reaches the center of the frame, the assembly flow stops and focuses on the prevailing paint of the resulting contour. Subsequently, it starts processing the image from video camera No. 1. With a given color, a specific color palette is used to de-termine the contour of the ellipse and find its center [5].

Before use, the camera must be calibrated. Calibration allows you to take into ac-count the distortion introduced by the optical system. Camera calibration comes down to obtaining the internal and external parameters of the camera from the avail-able photos or videos obtained with its help. Camera calibration is usually per-formed at the initial stage of solving many computer vision problems [26-30]. In addition, this procedure allows you to correct distortion in photos and videos.

Before the sensor is embedded, the image is converted to shades of grayish to re-duce computational costs. First, the image is smoothed to remove useless noise from the image, in this case a Gaussian filter is applied. To do this, we use a filter that can be approximated by 1 Gaussian derivative. Then comes the calculation of the gradients. object contours are marked where the image gradient contains the largest values. After that, non-maximums are removed and only local maxima are marked as boundaries. This is followed by double threshold filtering. The output is more clear contours on a black and white binary image. Figure 2.3.1 shows open an image of grape cuttings end the contour selection algorithm. Figure 2.3.2. shows Contour selection algorithm and Calculation of the difference in plant contours. Results of analysis of current image of grape cuttings is shown in Figure 2.3.3.

# open an image to find grapes contour

img\_orig = cv2.imread('ch11.jpg')

frameSize = (200, 200) # set size of frame

# find contours of grape cuttings

img\_rgb = cv2.cvtColor(img\_orig, cv2.COLOR\_BGR2RGB)

grey = cv2.cvtColor(img\_orig, cv2.COLOR\_BGR2GRAY)

ret, thresh = cv2.threshold(grey, 185, 250, 3)

contours0, hierarchy = cv2.findContours(thresh, cv2.RETR\_LIST, cv2.CHAIN\_APPROX\_SIMPLE)

mask = np.zeros(img\_orig.shape, np.uint8)

mask = cv2.drawContours(mask, contours0, -2, (255,255,255), 4)

result = cv2.bitwise\_and(img\_orig, mask)

**Figure**. 2.3.1. Contour selection algorithm

Ellipses = []

x = []

y = []

a\_min = []

a\_max = []

angle = []

for cnt in contours0:

        if len(cnt)>200:

            ellipse = cv2.fitEllipse(cnt)

            ellipses.append(ellipse)

            x.append(ellipse[0][0]) # center x

            y.append(ellipse[0][1]) # center y

            angle.append(ellipse[2]) # angle

            a\_min.append(ellipse[1][0])

            a\_max.append(ellipse[1][1])

            cv2.ellipse(thresh, ellipse,(255,0,0),2)

            cv2.drawContours(img\_rgb, cnt, -3, (255,0,0), 2)

ratio1 = 0

ratio2 = 0

if len(ellipses) == 2:

    if a\_min[0] > a\_min[1]:

        ratio1 = a\_min[0]/a\_min[1]

        ratio2 = a\_max[0]/a\_max[1]

    else:

        ratio1 = a\_min[1]/a\_min[0]

        ratio2 = a\_max[1]/a\_max[0]

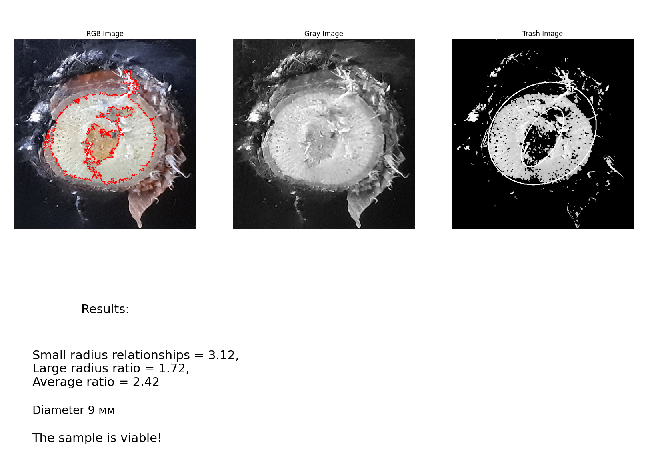
if len(ellipses)>=2:

    print(ratio1)

    print(ratio2)

    print((ratio1+ratio2)/2)

**Figure**. 2.3.2. Contour selection algorithm and Calculation of the difference in plant contours



**Figure**. 2.3.3. Show of results of analysis

3.4. Analysis of the results

Consider the results obtained during the testing of the plant contour analysis algo-rithm, and also present the comparative results of the algorithm for 5 different seed-lings. Each sapling has two multi-colored circles in the section (Figure 2.4.1), which are needed to assess the quality of the sapling and together form a two-dimensional representation of the internal structure of the sapling. The selection of the contour on the seedling is displayed as a red connecting line (Figure 2.4.2), but the program also highlights unnecessary parts due to excess material in the images (such as the film that is visible in the picture), which is why the algorithm does not perfectly deter-mine the contour [31].

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| **Figure.** 2.4.1. original image | **Figure.** 2.4.2. Selection of the contour on the seedling |

The next step is to convert the image to black and white format (Figure 2.4.3). Af-ter that, we use a mask to select contours with cutting off extra points (Figure 2.4.4) [32-35].

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| **Figure.** 2.4.3. Converted image in black and white | **Figure.** 2.4.4. Using an algorithm to extract contours |

As you can see in image 2.4.4, the contour from above, the algorithm selected an extra part of the seedling due to an incorrect source code (it captured a part of the film in which the seedling was wrapped).

Next, we calculate the radii of the ellipses and find how much space the inner el-lipse takes relative to the outer one (Figure 2.4.5), if it occupies more than half of the seedling, then it can be considered unsuitable. But the visual processing of the program in this case is incorrect and a 1st order error occurs, since we use incorrect image data. On this account, it is possible to increase the error in the calculation of ellipses (Figure 2.4.6), but this will only be suitable for such unique cases when seedlings with external physical interference are used.

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| **Figure.** 2.4.5. Calculation of the radii of ellipses without taking into account the error for images with noise | **Figure.** 2.4.6. Calculation with error |

Let's move on to the second test. This seedling turned out to be illuminated by a flash (Figure 2.4.7), which is why the white background strongly predominates on the left side, which can lead to incorrect operation of the algorithm. We use image processing based on information about the color of the object. First, the algorithm colors the original picture in red, green, blue (Figure 2.4.8). Next comes the calcula-tion of the mask of all three colors: red, green and blue (Figure 2.4.9). Then comes testing for a set of HSV colors (Figure 2.4.10). The next step is to calculate the mask of all three colors: red, green, blue (Figure 2.4.11).

As you can see in the images, too much noise is obtained during the determina-tion, which does not allow making a qualitative assessment of the seedling. The next step is to use the contour analysis algorithm (Figure 2.4.12), but due to the image being overexposed by the flash, the algorithm could not highlight the center. Next, we convert the image to black and white format (Figure 2.4.13). After that, we use a mask to select contours with cutting off extra points (Figure 2.4.14). It turns out a very small part in the center and the algorithm does not highlight it, but visually it is considered to be of high quality, since the fact that the center is quite light indicates that the dead part occupies a small space and the seedling is of high quality [36-38].

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| **Figure.** 2.4.7. Original image | **Figure.** 2.4.8. colorized original picture RGB |
| **Figure.** 2.4.9. Masked image | **Figure.** 2.4.10. Colorized original HSV picture |
| **Figure.** 2.4.11. Applying a mask | **Figure.** 2.4.12. Applying the Contour Analysis Algorithm |
| **Figure.** 2.4.13. Converted image in black and white | **Figure.** 2.4.14. Using an algorithm to extract contours |

The next photo of the seedling for testing is shown in Figure 2.4.15, the seedling turned out well and without unnecessary defects and noise. The next step uses the contour analysis algorithm (Figure 2.4.16). After that, we use a mask to select con-tours with cutting off extra points (Figure 2.4.17). Further, the use of the algorithm for selecting contours is shown in Figure 2.4.18. It turns out to ideally highlight the contours of the seedling clearly along the edges, the center in this experiment, which means that the dead part occupies a small space and the seedling is of high quality.

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| **Figure.** 2.4.15. original image | **Figure.** 2.4.16. Path selection |
| **Figure.** 2.4.17. Converted image in black and white | **Figure.** 2.4.18. Using an algorithm to extract contours |

The fourth seedling has damage in the very center in the form of a fault (Figure 2.4.19). The next step uses the contour analysis algorithm (Figure 2.4.20). After that, we use a mask to select contours with cutting off extra points (Figure 2.4.21). Fur-ther, the use of the algorithm for selecting contours is shown in Figure 2.4.22. It is not possible to qualitatively highlight the contours of the seedling, there are too many changes in this picture and the algorithm does not cope with its task of evalu-ating the dead part relative to the center of the healthy part, but due to pronounced defects, it can be considered of poor quality.

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| **Figure**. 2.4.19. Original image | **Figure**. 2.4.20. Path selection |
| **Figure.** 2.4.21. Converted image in black and white | **Figure.** 2.4.22. Using an algorithm to extract contours |

Let's do one last test. This seedling (figure 2.4.23) looks without visible damage, but the image is slightly blurry. The next step uses the contour analysis algorithm (Figure 2.4.24). Then we use a mask to select contours with cutting off extra points (Figure 2.4.25-2.4.26). It turns out to qualitatively highlight the contours of the seed-ling, in this picture there is a small black area that did not fall under the selection and it is not very clear how critical this is, perhaps the problem is due to the fuzzy image as a whole. The algorithm coped with its task and determined the seedling as a quality one [39-42].

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| **Figure.** 2.4.23. Original image | **Figure.** 2.4.24. Path selection |
| **Figure.** 2.4.25. Converted image in black and white | **Figure.** 2.4.26. Using an algorithm to extract contours |

4. Conclusions

The results of the study showed the high efficiency of using artificial neural networks to classify grape lesions in images. The solution of these problems is impossible without the widespread use of convolutional neural networks. However, the most valuable are the conclusions based on a comprehensive assessment of the results of recognition of both the entire image and individual objects using detection. The apparatus of fuzzy logic with the help of linguistic and fuzzy variables allows presenting the obtained conclusions in the form of a full-fledged conclusion.

Developed system By localization areas manages With delivered task, but also has its disadvantages. Background noise is accepted in attention. Bias dressed contours, relatively edges images, affects on result. Algorithms computer vision work Not Always correctly, at hit on image superfluous materials like crumpled cut film images seedling, or when strongly illuminated data And strongly damaged.

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