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## SOFTWARE APPLICATION FOR DETERMINING THE SURFACE ROUGHNESS USING IMAGE PROCESSING WITH PARTICLE CLASSIFICATION

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**Abstract:** This paper will present a method developed to automatically inspect and monitor the roughness parameters of different parts through image processing and vision. The designed system is developed based on a non-contact method that uses a smart camera, LabVIEW and NI Vision Assistant programming. Through a particle classification methodology, the application identifies an object in an image and by comparing some meaningful features with characteristics which define classes of samples. The software application will determine the value of the roughness and the type of processing used. The experimental results obtained show that the proposed system is able to perform an accurate control in automatic mode while ensuring flexibility for distinct types of mechanical components with different profiles.

**Key words:** surface roughness, image processing, particle classification, LabVIEW.

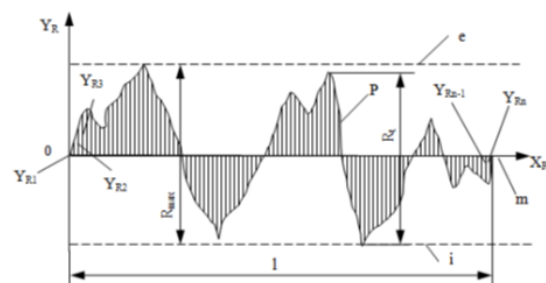
### 1. INTRODUCTION

The set of irregularities that form the relief of the real surface and which are by convention defined within the limits of a section without shape deviations, represents the surface roughness. These imperfections may occur as a result of the oscillating movement of the tool top, the friction of the tool edge on the workpiece surface, the high frequency vibrations of the tool or the machine [1].

Cutting process reliability is one of the parameters that define the machinability of a material and it can be characterized by effective surface quality, chip breaking and tool durability. Due to low intensity vibration, surface roughness decreases when high feed and depth of cut are used [2]. In a roughing machining phase, high values are required for depth and feed. In a finishing phase, among the parameters of the cutting regime a high speed is necessary to obtain the appropriate roughness.

The surface roughness of machined parts is influenced by numerous factors, such as material characteristics, cutting data (depth of cut, feed rate, cutting speed), tool geometry, tool wear or

cutting fluids. The principal statistical parameter used to evaluate the surface roughness of a machined surface is the average roughness ( $R_a$ ) having the profile represented in the figure 1. The arithmetic mean deviation of the roughness represents the average value of the ordinates  $Y_{R1}, Y_{R2} \dots Y_{Rn}$  of the effective profile "P", up to the average line "m" considered within the limits of the reference length "l" [1].



$$R_a = \frac{1}{l} \int_0^l |f(x)| dx$$

Fig.1. Roughness parameter  $R_a$  [1]

The standard samples for the surface roughness contains some specimens, each created according to a manufacturing process

and a roughness parameter. The results were collected and analyzed through the LabVIEW and NI Vision Assistant programs. There are six different workpieces obtained by different manufacturing processes and then utilized in this experiment. With the help of the model trained in the NI Vision Assistant, the surface condition could be properly identified for the various parts used.

The created application can be used for measurement, monitoring and control. In the quality control of the parts, through image processing, the software will give data in a form of boolean indicators elements that will be bright if the roughness of an analyzed workpiece is the same with the sample with which it was compared. The application is suitable for surface roughness measurement directly on the machine immediately after the cutting process.

## 2. FUNDAMENTAL CONCEPTS

In his paper, Chiou [3] developed a system that uses LabVIEW software and a camera for establishing the roughness on the correlation of optical parameters and the average roughness. In image processing field, Gosciowska [4] presented a shape feature algorithm for action recognition that could be applied in a human recognition process related to the Ambient Assisted Living concept, aiding people increasing their daily activity. In his research, Yu [5] proposed an approach based on multiple scale sampling for the matching of small objects. Different samples establish thresholds and are adopted to improve the probability of matching the small object area with the aim that as few small objects as possible are not ignored from the analysis.

In graphical programming environment LabVIEW with different installed modules (Vision Acquisition, Vision Assistant), a digital image can be acquired in various methods like a sequence of images or image at a particular time. A digital image becomes a bidimensional array of light intensity values. It can be explained as a mathematic function  $f(x_p, y_p)$ , where  $f$  represents the brightness of the point  $(x_p, y_p)$  [6]. This point is a pixel, the minimum element of an image that can be processed in a video system [6]. These pixels are enumerated by his position towards a

Cartesian system, which, through a convention, has the origin at the left top corner of the image. For each pixel, a value that represents the brightness of the light or the color that the video device collects is assigned.

The image acquired in real-time by using Vision Acquisition module is extracted to a single-color plane. A proper plane is selected based on how good the roughness standard is being highlighted from the image to differentiate it easier with respect to the background. After the extraction of a plane, the image is used for other process like basic morphology or particle classification.

Image acquisition is the most important step for this type of the non-contact analysis. The most important factor that influences the acquisition process is making an environment with proper lighting. The images are purchased through a smart vision camera that digitizes the images and process them in a real-time manner. The camera used is ESP32, a system-on-chip microcontrollers with integrated Wi-Fi. This camera could be placed in working position over the processed surface or can be used to take an image after the part was processed. Thereby for red, yellow and blue planes, there are values between 0 and 255 (0 = black, 255 = white). On a histogram, to the right of the graphical representation, the light intensity of the color increases. If the graph is flattened to the left, there is a small probability that there are dark areas in the selected image.

The LabVIEW program is applied for monitoring the application data. The quality inspection algorithm is also incorporated and will determine the unviable pieces. In image processing tasks following the classification functions, objects with several shapes can be recognized, characterized and in some cases sorted. Binary particle classification performs the classification on the basis of identifying an object by comparing a group of its meaningful features to a set of characteristics of some samples [6].

In order to achieve that, the software needs to be trained using object images with meaningful features to create classes during the process. The particle classification is based on particle analysis of binary images [7]. The geometric and pattern matching are based on extraction of

information on the boundary of objects and on the light intensity of the pixels in the image.

### 3. NI VISION ASSISTANT AND LABVIEW APPLICATIONS

The merits for each of the image processing methods need be considered before choosing the suitable algorithm for measuring or inspecting of the objects [7]. Binary particle classification is a rapid method in which the objects that will be used in this analysis will be sorted. This method will not find some occluded objects that can be considered as one object of a different shape.

Any grayscale image will need to have adequate contrast towards the background whilst the limits of the object are represented as a result of the binary conversion [8]. The algorithm of the training process is shown in the following figure.

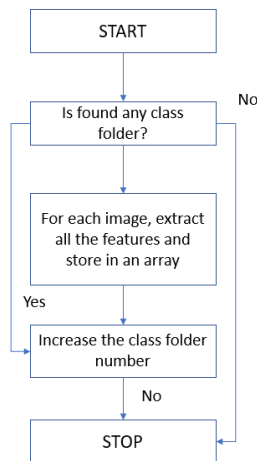


Fig.2. The flowchart of training process

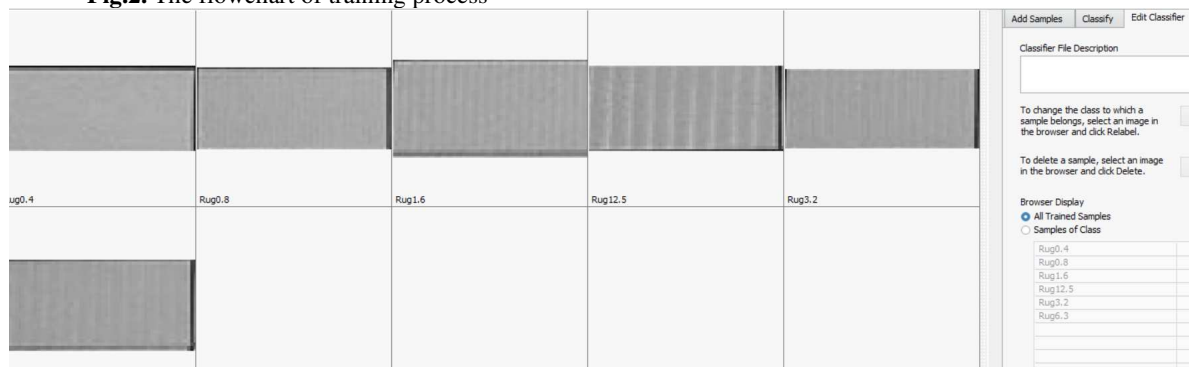


Fig.3. NI Vision Assistant – particle classification setup

By using a classification method, the monitoring process is realized. Any problems of the classified object can be analyzed by the comparison with referenced features [7]. To classify the surface roughness, the NI Vision software is used. The first stage is to load all images with the roughness standards. Then any required plan can be selected through the Color Plane Extraction function.

A region of interest (ROI) is drawn around the samples from the roughness standard and later a class is formed. The next step is to use the option of threshold to transform the grayscale ROI to binary image. The feature Dark Objects is chosen because the objects are darker than the background. Through the option Reject Objects Touching ROI, the object that cuts the ROI boundary is excluded [7]. Some elements touching the required region are not taken into account in the training.

If more samples are added to the class, the training results will be improved significantly. In this software application, six classes of surface roughness are used: Ra 0.4; Ra 0.8; Ra 1.6; Ra 3.2; Ra 6.3; Ra 12.5. Two samples are added for each type of roughness researched. After finishing populating the classes, the classifier model must be trained. If the classification score has the value 1000, it denotes that is fully matched with the trained class. The interface from NI Vision Assistant and the obtained results are displayed in the following figure.

By drawing a rectangular in the processing window, the classified results of the objects within the ROI are obtained [7]. Also, can be

evaluated the accuracy of the classification total of the selection made. If the object's classification score is determined below a

threshold value, the object should be ignored. In NI Vision Assistant the option Advanced Morphology using Remove Small Objects was

used in order to eliminate noises and particles that may be left over from the previous processes.

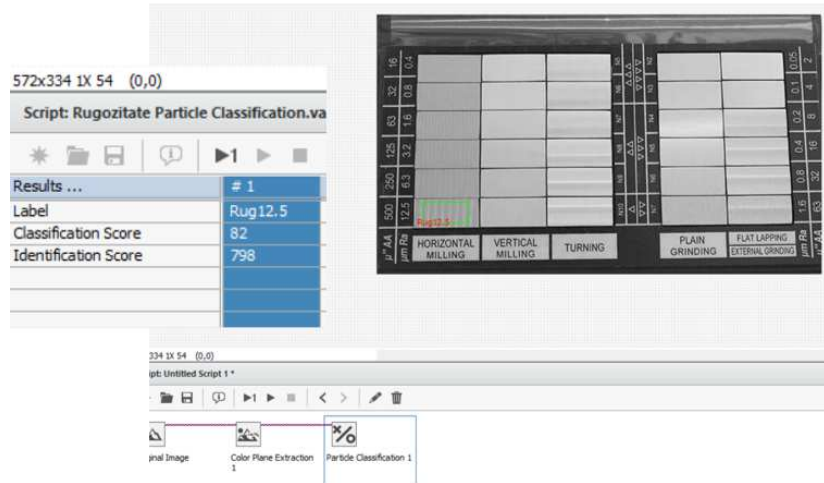


Fig.4. Results from NI Vision Assistant application

The inputs and outputs of the created LabVIEW VI were connected. Following this

stage, the classification results will be obtained by executing the VI (figure 5).

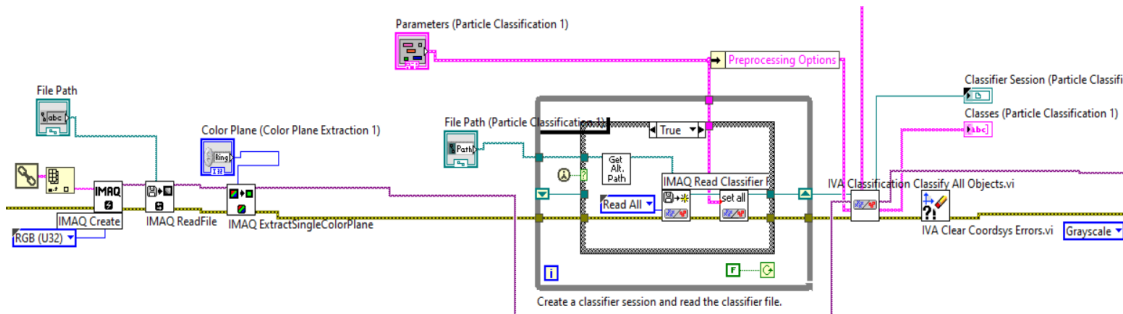


Fig.5. Block diagram of the developed LabVIEW application

A binary image template is handled to classify each object and find the particles. Each found particle will correspond to a ROI, which identifies the location of the classified objects. The output element ROI Descriptors are an array of clusters with the locations of the classified particles. The size of the output is equal to the number of particles found [7]. Analyzing the scores, it was evaluated the degree of fulfillment with whom the algorithm classified the objects. The classification score highlights how an object fits into each individual class, being able to draw clear conclusions about which component complies with the imposed conditions. The graphic user interface for this LabVIEW program is designed as in figure 6.

To verify the image processing results, there are shown on the image display from the front panel. This method enables to add text and different geometric features without damaging the image. The location of the region of interest from the original image was added to overlay the output on the original image in the correct position.

The monitoring action of the parts roughness will imply that the control action will generate a feed-back to the machining process. The particle results and ROI data are required to determine the overlay location on original image. The Front Panel of the overlay VI created in LabVIEW is shown in the following figure 7.

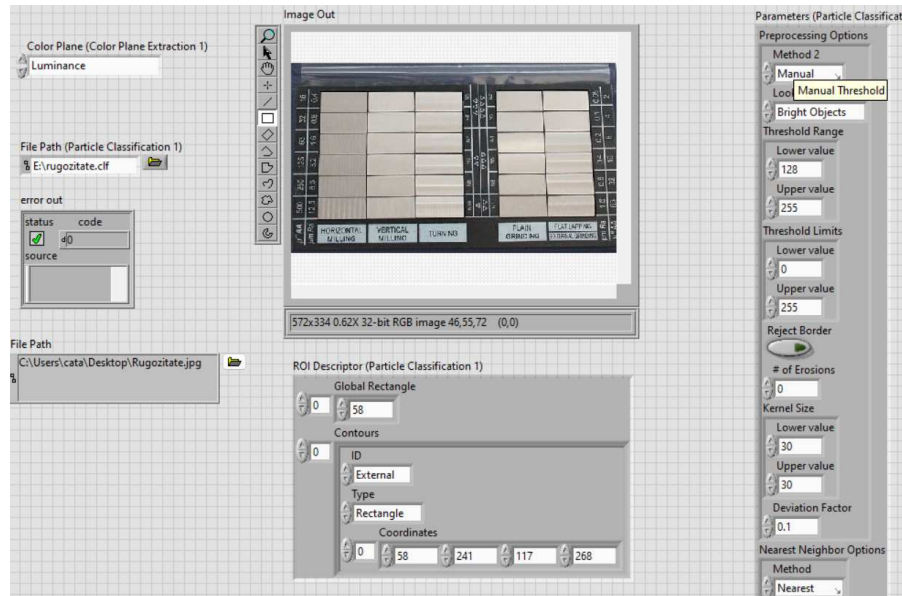


Fig.6. Front panel (interface) of the LabVIEW application

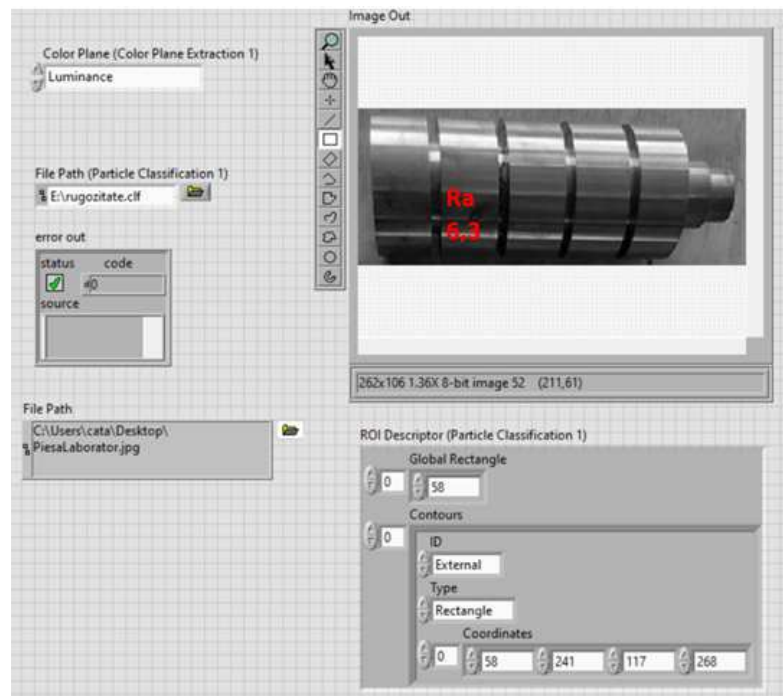


Fig.7. Front Panel of the VI for the overlaying action

## 7. CONCLUSION

Through specific algorithms for the analysis and processing of images with different processed surfaces of machined parts, an application was created to determine the roughness of parts. The concept of particle classification was used for categorizing and

labeling groups of pixels within images of different machined parts based on established rules. After identifying the roughness of a surface, the application created in LabVIEW will be able, depending on the type of surface that the user will enter, to identify the possible types of processing used, the number of processing steps (roughing, semi-finishing,

finishing) based on the specialized standards and then the corresponding precision and roughness coefficients will be calculated. The presented software is used in the educational process for students that applies computer science concepts in industrial engineering, but also can be used in the manufacturing industry.

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## APLICAȚIE SOFTWARE PENTRU DETERMINAREA RUGOZITĂȚII SUPRAFETELOR FOLOSIND PRELUCRAREA IMAGINILOR PRIN CLASIFICAREA PARTICULELOR

Această lucrare va prezenta o metodă dezvoltată pentru inspectarea și monitorizarea automată a parametrilor de rugozitate a diferitelor piese prin procesarea de imagini și inteligență artificială. Sistemul proiectat este dezvoltat pe baza unei metode fără contact care utilizează o cameră inteligentă, partea de programare realizându-se în LabVIEW și NI Vision Assistant. Printr-o metodologie de clasificare a particulelor, aplicația identifică un obiect dintr-o imagine și compară unele caracteristici semnificative cu altele care definesc unele clase. Aplicația software va determina valoarea rugozității și metoda de prelucrare utilizată. Rezultatele experimentale obținute arată că sistemul propus este capabil să efectueze un control precis în mod automat, asigurând în același timp flexibilitate pentru tipuri distincte de componente mecanice cu profiluri diferite.

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