Estimation of copper grade from the flotation froth using image analysis and machine vision

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ABSTRACT

By observing froth surface, operators can usually determine the metallurgical parameters (grade and recovery) of flotation process but it is associated with many problems such as inability to continuously monitor, significant differences with operation results, and various observations by different persons. In this study, the physical and structure properties of flotation froth images have been investigated to determine the metallurgical parameters of copper oxide ore. Pre-processing and processing of images obtained from the flotation froth was studied using artificial neural networks in MATLAB program. The estimated grade was compared with the actual grade to check the accuracy of the system. Studies show that when the three color characteristics (red, green, and blue colors) of images are used to determine the grade of froth, these three characteristics alone are not sufficient to estimate the grade, and the amount of error rate is 21.7%. When factors of the three color characteristics, and their standard deviation was studied for estimating the grade, the error rate reached 8.7%. Finally, the simultaneous studies of 11 characteristics including color channels, their standard deviation and haralic characteristics (entropy, contrast, energy, correlation, and gradient-density) showed that a very good similarity between the actual grade and their predicted grade. The calculated error rate greatly reduced to 2.3%. The method of work was including of the picture taking of froth flotation, pre-processing and processing of images, characteristics extraction, system training, testing and validation, and finally the results showed that the amount of froth grade in the online form.

KEYWORDS:

Flotation, Machine Vision, Image Analysis, Color Channels, Online Froth Grade

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1. Introduction

Flotation froth grade is a metallurgical parameter. Froth grade is measured by atomic absorption, titration and user observations of the froth surface, which are time consuming, costly and less accurate[1, 2]. Properties that can be extracted from the flotation froth of image include froth color, bubble size distribution, froth velocity, bubble collapse rate, bubble shape, and froth stability. Texture or haralic characteristics of the image are used for image processing (formula 1), these characteristics have a special matrix (Gray level co-occurrence matrix (GLCM))[3, 4].

$$P(i,j)=\{((r,s),(t,v)):I(r,s)=I(T,V) \quad (1)$$

The important parameters of the GLCM matrix including are entropy, contrast, energy, correlation, and gradient-density [4-6].

Energy parameter: The energy of an image indicates its homogeneity and is a good criterion for estimating image turbulence. Less homogeneity of the image indicates its energy is low.

Entropy Characteristics: The entropy or irregularity of an image indicates how complex it is. In fact, images with more complexity have higher entropy.

Correlation Characteristics: Correlation is an indicator that indicates the degree of linear correlation between two neighboring pixels.

Contrast Characteristics: Contrast is a measure of the variety and spatial difference of an image.

Density Variation Characteristics: The Gradient-Density Characteristics is an important parameter in image analysis that identifies the edges of an image. Edging is more important in flotation froth images. In fact, the sides of the bubbles are the edges of the images that determine bubbles dimensions and shapes.

The image processing system includes a camera, lighting and a computer. In this system, images with the camera are taken from the floor of the flotation process at different speeds (for example, 25 frames per second) and transmitted to a computer processor. With various software such as MATLAB and Python, the processor measures metallurgical parameters such as carat and recovery (based on visual and textural properties extracted from the flotation floor)[2, 7]. The purpose of this study is to determine the metallurgical grade of copper oxide ore flotation, with image properties of the froth.

2. Preparation of sample and its properties

Copper ore is prepared from Rashidabad copper mine in Zanjan and has a chemical composition according to Table 1.

Table 1: Chemical composition of ore (%)

SiO_2	Al_2O_3	Fe_2O_3	CaO	Na_2O	K_2O	MgO	TiO_2	MnO	P_2O_5	SO_3	L.O.I
62.26	15.44	5.33	2.68	0.39	4.73	1.05	0.792	0.076	0.245	0.01	5.01

Malachite, quartz, albite, orthoclase, muscovite, illite, chlorite, calcite and hematite ores that have formed the sample.

3- Method of performing experiments and imaging

Froth images were taken during flotation experiments to measure the appearance properties of the froth to determine its grade. The captured images were transferred to the computer for image analysis. The pre-processing and processing was done on the images by MATLAB program and MLP multilayer nervous system (with 5 hidden layers).

4. Discussion and results

4.1. Using color parameters in training and accuracy of system

In this method, the average properties of three colors (blue, green and red) per pixel and finally the total image is calculated for 64 samples. After the training was given to the system using 64 samples, the system testing and comparison of actual grade with predicted grade is carried with some information from the flotation froth images (10 images).The diagram in Figure 1 shows that there is no proper match between the actual grade and their predicted grade of flotation froths.

Using the three image properties to determine the froth grade alone is not enough to estimate the grade and more parameters should be used to evaluate this system to determine the grade.

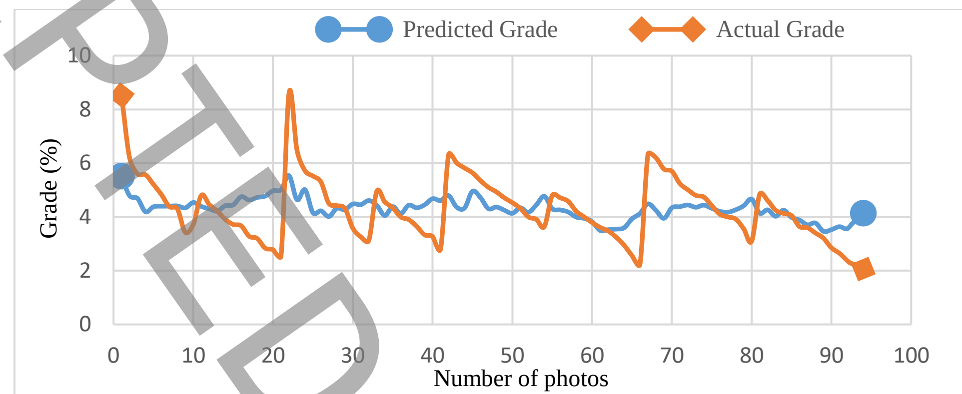

Figure 1: Diagram of comparison between actual grade and predicted grade in the first method

4.2. Using color parameters and their standard deviation in training and accuracy of system

In this method, the average characteristics of the three colors blue, green and red as well as their standard deviation are used. The diagram in Figure 2 shows a comparison between actual and predicted grade.

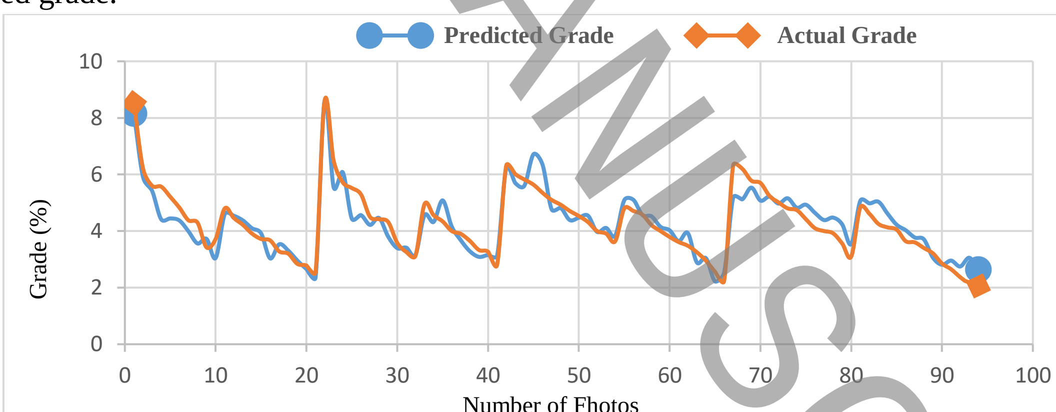

Figure 2: Diagram of comparison between actual and predicted grade in the second method

Figure 2 shows that there is still no proper correlation between the actual grade and the predicted grade. The predicted error rate of the actual grade is calculated to be about 8.7%, which is somewhat high and the amount should be minimized. Therefore, it is necessary to use more parameters to evaluate this system to determine the grade.

4.3. Using 11 parameters (color and haralic) in training and accuracy of system

In this method, color characteristics (red, green and blue and their standard deviation) and haralic characteristics (entropy, contrast, energy, correlation and gradient-density) are used. The diagram in Figure 3 shows that the correspondence between the real and predicted curves is much greater. The calculated error rate is about 2.3%, which is much less than previous methods. The predicted titer of the smart app is much closer to the actual titer. Therefore, it can be concluded that this method is the best method in evaluating the flotation froth grade.

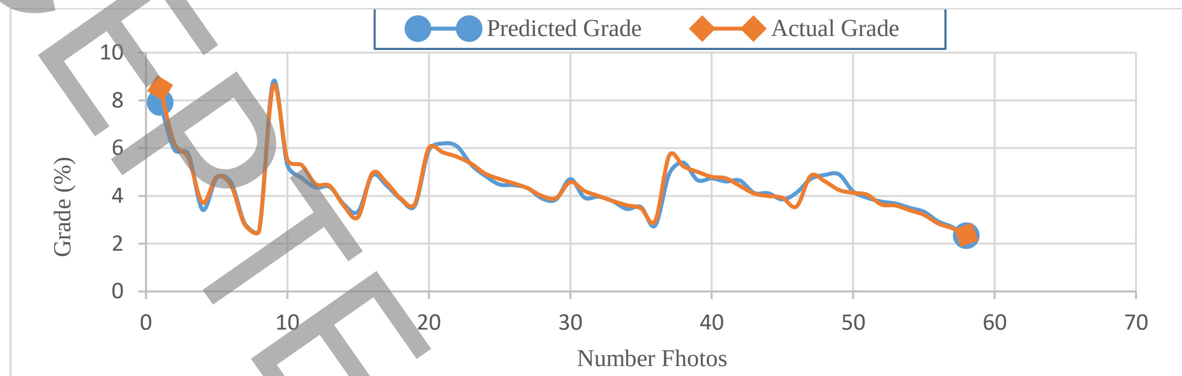

Diagram of comparison between actual and predicted grade in the third method

6. Conclusions

- Research has shown that the more haralic and visual parameters used, the error rate will be less between the actual grade and the predicted grade.
- When the three color properties (red, green, and blue) of images are used to determine the froth grade, these properties alone are not sufficient to estimate the grade. The error rate reaches 21.7% in this method.
- The error rate when using the three color characteristics and their standard deviation reached 8.7%, which indicated that more parameters should be used.
- The use of 11 parameters (color and haralic) indicates a very good match between the actual grade and the predicted grade. The calculated error rate has been greatly reduced to 2.3%.

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