EVALUATION OF PERSPECTIVE ERROR IN DIGITAL IMAGE PROCESSING METHOD FOR SZE DISTRIBUTION OF BLASTED MUCK-PILE

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Abstract: Achieving the optimal size distribution and fragmentation of blasted muck-pile has an important role in controlling mining processes and mineral processing as well as reducing production costs, including: transportation, loading, crushing, and milling. In order to optimize the production process and to have rapid and reliable evaluation of size distribution and rock fragmentation, image processing method is one of the most common methods. Despite of numerous advantages of this method, the associated inherent limitations and errors affect precision, accuracy, and reproducibility of measured results. Understanding such limitations and errors thus decreasing their effectiveness will improve the results of image processing. Current study, while introducing different types of image processing errors, analyzes errors of inappropriate imaging angle (perspective) and suggests procedures to decrease this error. Results of studies on 240 digital images of blasted rocks, showed an average of 97% accuracy and standard deviation of 4.5% in eliminating perspective errors. Also, it was found that when the distance factor is between 0.8 and 1.5 the results are more reliable. Moreover, with a smaller particle size, optimal results can be achieved when the distance factor is reduced to a value between 0.2 and 0.4. Furthermore, when data is normally distributed, the frequency of distance factor in the range of 0.5 to 1.5 with the average of 1.48 has a range of frequency error with an average of 3%. Comparing sieve size distribution curve of muck-piles with the size distribution curve of images taken before and after perspective error elimination using Split Desktop software, showed that after perspective error elimination, mean value of size distribution error depending on the amount of perspective distortion, were decreased from 5 to 25%.

Keywords: Digital image processing, particles size distribution, muck-pile, perspective error, fragmentation by blasting

INTRODUCTION

Knowing the size distribution of fragmented rock particles in the process of mining operations and mineral processing has significant results such as improving the efficiency of mining operations and minimizing production costs. Digital image analysis method is known as an indirect, fast and reliable method, to evaluate the results of blasting and to determine the particle size distribution of blasted rocks (Eghtesadi 2011, Jahani 2013). The advantages of this method are being cheap and easy to use, enabling fast measurements on site, not interfering with production, saving time and money (especially in large muck-piles), saving images taken, providing a good history of blasting with various fragmentations, and also being non-destructive for weak rocks and ores (Eghtesadi 2011, Jahani 2013). Despite numerous advantages of this method, the associated inherent limitations and errors affect the precision, accuracy, and reproducibility of measured results. Understanding such limitations and errors and decreasing their effectiveness will improve the results of image processing. Considering the variety of errors and the increasing use of image processing methods, errors and their causes should be recognized and then decreased in order to achieve results closer to reality. In this study, image pre-processing and quality improving methods are reviewed. Also, image processing errors are

introduced and then perspective distortions are studied as one of the most important errors with some solutions suggested to reduce them.

METHOD

During the imaging process, errors occur in captured images due to some reasons such as dust, environmental contamination, failure to adjust the brightness and intensity of light, incorrect angle of imaging, and shades; therefore, pre-processing of images are necessary. Among the methods of pre-processing and image enhancement it can be used noise removal, smoothing or sharpening filters, and also filters for increasing the contrast or improving details. In muck-piles imaging, due to safety requirements and the necessity of not interfering with production cycle, some limitations are imposed. Therefore, the above mentioned errors exist, and to prevent the occurrence of subsequent errors in the algorithm, it is necessary to remove or decrease these errors. Errors that may occur in the process of image analysis, can be divided into four categories: a) errors related to image processing technique, b) errors related to morphological characteristics of the sample, c) errors associated with sampling, and d) errors associated with the process of imaging such as perspective distortion. The effects of perspective distortion appear in the image when the camera is not perpendicular to the surface of the muck-pile. In this case, the particle sizes in the image are different from actual sizes and particles far from camera are shown smaller than their actual size.

In this study, the method proposed is perspective distortion of muck-pile images; first two identical scale objects (like two balls) are placed on the muck-pile surface and the image is taken. After transferring the images to a computer, the first pre-processing is carried out using image processing algorithms and Matlab software. Then, the scale objects are removed, their diameter and area is calculated, and the perspective distortion is reduced or removed using a geometric transformation. The algorithm is shown in Figure 1.

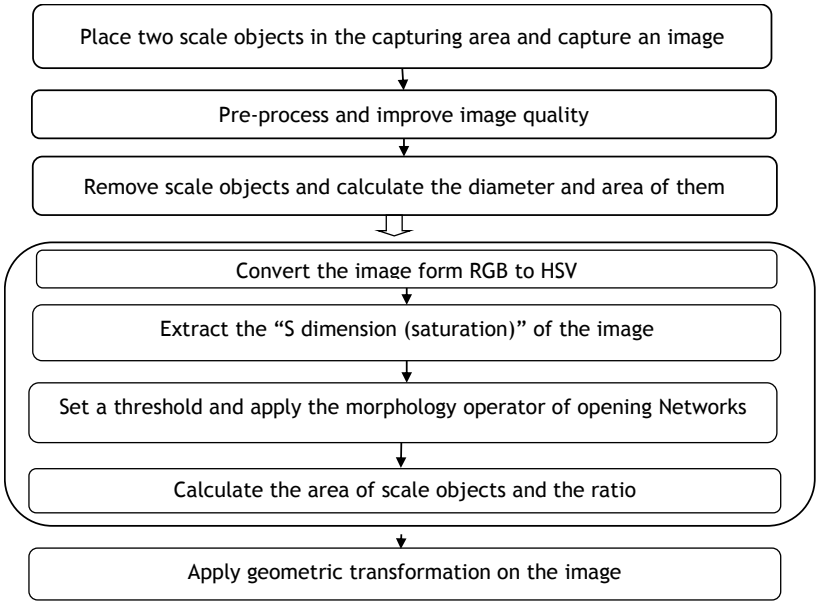


Fig 1. Pre-processing steps and elimination of perspective distortion in digital image of muck-pile

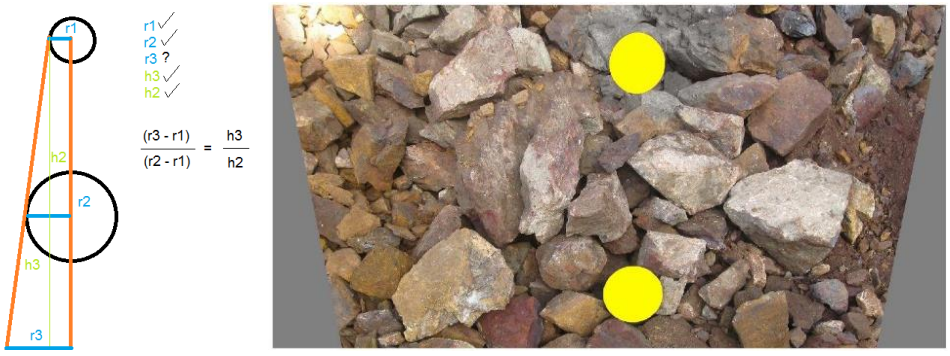
The process of extracting the scale objects is carried out based on the following steps:

Convert image from RGB to HSV system,
Extract the "S dimension (saturation)" of image,
Convert the image to a binary image,
Opening the resulting image from the previous (Gonzalez 2004),
Calculate the area of extracted scale objects.
After removing the scale object, geometric transformation is performed. There are various geometric transformations such as transitional transformations, Euclidean, isotropic, Affine, and perspective. In this section, due to the characteristics of these geometric transformations and their accordance with images of fragmented rocks, perspective transformation is used to eliminate the error. This geometric transformation is known as perspective, projective or homograph. Under this transformation, parallel lines do not remain parallel, but straight lines are preserved and are not distorted. The process of correcting capturing angle error is based on geometric transformations as shown in Fig 2a. Depending on the accuracy of scale objects removing and determination of their sizes in the previous step, elimination of errors is done more accurately. Fig 2b shows an image after elimination of error of capturing angle (perspective).

FINDINGS AND ARGUMENT

In this study, the different stages of the proposed method were tested on database images and the ratio of scale object areas were calculated before and after eliminating the perspective error. For this purpose, 240 images of fragmented rock particles of different blasting operations and at different times were captured at Gol-e-Gohar iron ore mine, and the above-mentioned steps were taken on them. Then, to evaluate the accuracy of the proposed method, the mean relative error (MRE) was calculated (Eq. 1).

$$\mathrm{MRE} = \left(\frac{100}{n}\right)\sum_{t=1}^{n}\left(\frac{At-Ft}{At}\right) \qquad \text{Eq. (1)}$$



(a) (b)

Fig. 2 (a) Geometric transformations, (b) An image after elimination of error perspective

In this equation, n is the number of images, At and Ft are the actual size of the scale objects and the scale object size after eliminating the perspective error, respectively. Results showed an average accuracy of 97% and standard deviation of 4.5% for size equalization of scale objects

and elimination of the perspective distortion of images. Also, findings showed that in order to achieve better results, following points must be considered:

1- For a proper separation and removal of the scale objects in an image, it is recommended to use scale objects that are monochromatic, of the same color, and also separable in HSV color space.
2- Results showed that if the two scale objects are placed at a distance that the calculated diameter ratio of them is less than 0.53, then on average, the accuracy of eliminating perspective distortion error is reduced about 13%.
3- Since, in the majority of mining operations, the distance between camera and surface of muck-piles cannot be measured, therefore, the distance factor was used instead of distance. The distance factor (DF) is defined as the ratio of scale object actual size, to the size of scale object in an image. Generally, too far or too close capturing do not bring satisfactory results.
4- The particle size distribution curve of muck-piles were compared with the particle size distribution curves of captured images, before and after eliminating perspective error using Split-Desktop software, and it was concluded that after perspective error elimination, the mean value of size distribution error, were decreased from 5 to 25%, depending on the amount of perspective distortion.

CONCLUSIONS

In this study, a method was proposed to eliminate the error associated with improper capturing angles (distortion). Results showed an average of 97% accuracy in eliminating distortion error of the 240 digital images of muck-piles at Gol-e-Gohar iron ore mine. Also, investigations showed that the mean errors of estimating particle size distribution of muck-piles were decreased from 5 to 25%, depending on the amount of perspective distortion.

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