

Segmentation Approaches for Analysis of Size Distribution of Rocks in Open Cast Mines

Jayendra Kumar¹, Vasanth Subramanyam², Sourabh Kumar³ and Siva Rama Krishna⁴

Department of Electronics and Communication Engineering

National Institute of Technology, Jamshedpur, India

E-mail:- sourabhk104@gmail.com¹, sivagade666@gmail.com², jkumar.ece@nitjsr.ac.in³,
v.subramanyam@tatasteel.com⁴

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Abstract

In open-pit mines, blasting is common, and it will be optimal if there are rock fragments that can be easily transported and moved without any further blasting or crushing. Optimal blasting is of quite an importance for reducing the production cost, hence size analysis of blast fragmentation needs to be done. In this paper, the indirect method is discussed, i.e., an optical method that uses image analysis using MATLAB to analyze grain size and to find parameters like average grain radius and average standard deviation of grain radius. A brief discussion of all topics related to the algorithms and their implementation in MATLAB are discussed thoroughly. Image segmentation plays a major role in scene understanding and further in many applications. Since segmentation is the primary step for getting the size analysis, hereby, in this paper, the development of suitable and appropriate trailing of all the applicable segmentation algorithms to get better results of rock segmentation outputs is discussed. Extracting regions information from the segmented images and calculating certain parameters for size analysis of rock fragments are done to achieve optimal blasting and reduce production cost.

Keywords: - Segmentation, Blob detection, Binary image, Watershed Algorithm.

INTRODUCTION

A large number of processes in open-pit mining and related industries are affected by rock fragment or particle size obtained after blasting. Generally, stones from the blasted mines have vast usage, such as the construction of roads, railway tracks etc. In open-pit mines, blasting, drilling, processing and transportation of blast fragments are the most common processes that are carried out almost every day. The rock fragments after blasting are moved from the mines by wagons or dumpers to an ore pass or to plants. Due to constraints in transportation and ease of transportation, the rock fragments after blasting needs to be of a specific size, i.e. neither too large nor too fine. The primary and foremost step in the process is blasting. Later on, crushing, loading, hauling comes into the process line before the blasted fragments get transported. Many factors are responsible for the cost of production [1]. For minimal production cost, the overall blasting process should be optimal so that the rock fragments produced after blasting are of uniform size. If the rock fragments have large size

variation, then the cost of production will increase, and that will be a time-taking process as the large stones need to be further drilled, crushed and maybe there is a need for re-blasting, which will eventually increase the cost to the company. Hence the parameters, basically the size of fragments, exactly decides all these things after blasting. Size distribution of blasted rocks is done to approximate the quantity of blasting material and wagons etc., to be used for production. The continuous study on the variation of the size of blasted fragments helps the concerned people to develop new methods and to reduce the production cost in the future.

Hence for the analysis of the size of rocks, several methods are adopted. Direct and indirect methods are two general categories for the size estimation of fragments [2]. Sieve analysis which falls under the direct method is a perfect one but can't be used since production is of large scale. Indirect methods are more preferable in such cases. All the empirical, visual and digital methods come under the indirect method of analysis. Several difficulties are encountered during the size

estimation of the rock fragments size such as the fragments have to be properly delineated by using indirect methods, or else estimation of the sizes of rock fragments properly is not possible. Also, the presence of shadows, noise, uniform lighting, and different size ranges of fragment cause great difficulty during edge detection. Another problem which is three dimension information extraction from an image in two dimension which requires assuming the fragment size approximately. Due to the overlapping of rocks in real-time, proper correction has to be made in the rock fragments sizes. In this paper, the popularly used digital technology, which is known as Digital Image Processing, is discussed with certain specific applications. Using Digital Image Processing, the results can be more accurate and rapid size analysis of rocks is possible. The process of analyzing the size distribution of fragments using digital image Processing is done generally in three steps [3].

Image Acquisition is the first step for analyzing the size distribution by digital image processing [4]. Then the second and third steps are Image delineation [5] and Image segmentation, respectively [6]. Finally, by calculating the average grain radius based on the results obtained from the above steps, the total size distribution analysis will be done successfully. Image acquisition refers to the collection of good quality photos of the muck-pile for further implementation of all delineation and segmentation techniques. High-resolution digital cameras are used for image acquisition from mines-site. After proper image acquisition is made, the very next step is checking different parameters of the image like scale, contrast etc. which are later discussed in detail in this paper. The second step, which is the most important step, is image delineation, where all the fragments in the image are delineated. Delineation means that an RGB image is converted into a binary image showing the fragments, boundaries as well gaps between the fragments. Then different techniques like watershed-based, partial differential based and then clustering-based techniques can be implemented, which are chosen appropriately.

RELATED WORKS

In mines, accomplishing effective fragmentation is the main objective of blasting. The fragments in the muck-pile must be analyzed, and this is essential for reducing costs by optimizing all blasting parameters, such as the use of different types of explosives and selecting suitable blast designs [7].

Mainly two methods are used for size distribution measurement, i.e., direct and indirect [2]. The direct method is inconvenient as it takes much time and also is costly [7]. Sieving is an example of a direct method. Indirect methods use Image analysis techniques and use images to get an outline of every fragment by automatic netting by CPU and then to determine the shape and size parameters by computer [8], but the only limitation in this method is that errors may creep in the processing stage when rock-fragments are misidentified [9]. The larger fragments may be divided into smaller particles after analysis, and smaller particles can be grouped together into larger particles [10].

Image analysis methods give accurate results under certain conditions where the distance between the camera and rock fragments is fixed, and the camera angle is also fixed with sufficient lighting [11,12]. Practically, these are impossible in large mines.

The morphological Edge detection technique is used for detecting boundaries of limestone fragments on a conveyer belt. Thurley first implemented this method in 2011. 3-D data was generated and was used to analyse the size distribution and for further implementation of automatic rock size management, which involves process like crushing etc., automatically [16].

A machine vision-based procedure was introduced by Jemwa and Aldrich [17]. The procedure was based on textual characterization of images, and it was proposed to solve the problem in the prediction of coal particles size and their class. Later on, Chimi et al., in 2014, proposed a segmentation algorithm known as the Water-shed algorithm for detecting chunks in soil. Followed by chimi, in the same year, Al-Thyabt et al. has done image analysis for finding the boundaries of coal fragments manually [18].

PROCESS WORK-FLOW

The process workflow is shown in Fig.1. To get the size analysis of rocks, there are various procedures that need to be followed up. For the first step, there is a need for a high-resolution digital camera to take the pictures [jk]. The pictures are taken at mine sites. After blasting, there is lots of debris of rocks and fines around the blasting site. The debris is termed as Muckpile. All the pictures of the muck pile are captured at different locations and must have some scaling objects in it. The pictures which are being used in this paper has cardboard and a football of known dimensions as scaling object. The dimension of

the cardboard is 200mm x 200mm. The dimension of football is of diameter 26 cm. These scales are used as a reference to scale up the size of rocks to its actual dimension. The important step is to delineate the rock particles by using any suitable algorithm available. Our focus will be on developing a universal algorithm that is applicable to all sorts of images. There are various approaches to the delineation of rock particles by different segmentation algorithms. This paper focuses on trying on with most suitable algorithms which serve the purpose, be it using Deep Learning or Matlab or OpenCV. Various segmentation algorithms are to be used to try on with the images to get the desired accuracy.

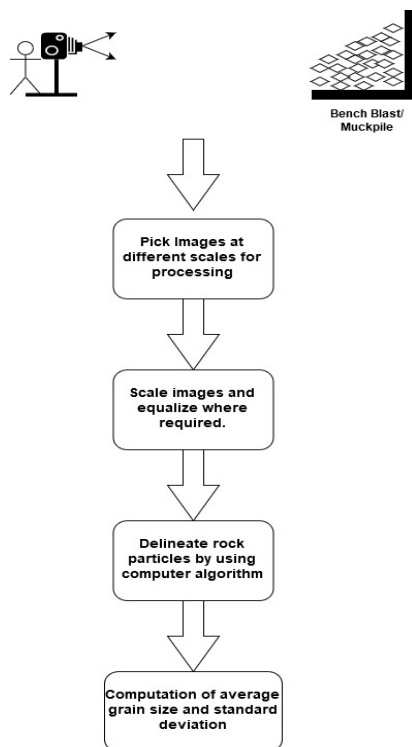


Fig. 1: Flowchart depicting Process Workflow

Upon proper segmentation, i.e., clear delineation of rocks, further analysis is done to get the exact size of the rocks, and average grain size of rocks and the standard deviation is calculated, which will further be used to improvise the blasting parameters to ensure an optimum blast which will eventually lead to cost-cutting and reduced expenditure and hence will prove more profitable.

METHODOLOGY

In this paper, the segmentation and size analysis of rock fragments in the images is done using Matlab. There are lots of methods involved in getting the size analysis, starting from image acquisition to blob detection. Acquisition of images of muck-pile after blasting for size distribution analysis is one of the critical phases of

the analysis. Consideration of the location of the image is a must for obtaining good quality images. In the ideal case, the camera lens is to be kept perpendicular to the surface. Images of blasted muck are captured using a high-resolution digital camera. In the mine-field area, successive images were randomly taken with cardboard of size 200mm x 200 mm in some images and a football of diameter 26cm in other sets of images were used in the field in order to provide scale in the images. The successive step after image acquisition is the production of binary images, which depict the outlines of the fragments observable in the acquired digital images. There are 3 most significant delineation parameters, which are Gradient Ratio, Watershed Ratio and Noise Ratio.

The process of image binarization is used to convert any image of up to 256 gray levels to a black and white image. Image binarization is simply done by choosing a threshold value and substituting all the pixels with values above this threshold as white and all other pixels as black.

In many cases, it is almost impossible to find threshold value using a direct process. Hence, to choose an optimal threshold value for different image areas, adaptive image binarization is used.

A number of defectiveness can creep in binary images like binary regions in an image are easily distorted by noise when binary regions are generated by simple thresholding.

These imperfections are further removed by morphological image processing, which accounts for the form and structure of the image. Hence, such a technique can be used with grayscale images. A set of non-linear operations done in order to identify the shapes or morphology of features in an image is termed as morphological image processing.

The watershed algorithm is used for distinguishing between different objects in an image. It is a classical algorithm used for segmentation [15].

A watershed is defined as a region of land that assists in draining water (usually rainwater) into a river or a creek. It is an area of high ground through which water flows into the river or creek. Grayscale or binary images are transformed using Watershed transformation.

This transformation technique basically segments the image when two edges touch each other, i.e., regions of interest are close to one another.

The intensity of each pixel represents the height as the watershed transformation technique considers

the image as a topographic map like lower height areas are considered as troughs and dark in color while higher areas are considered as mountain ridge or hills and are brighter.



Fig. 2: Input Image



Fig.3: Image after Binary conversion via thresholding



Fig. 4: Image after morphological operation

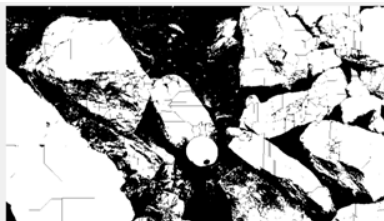


Fig. 5: Image after Watershed algorithm application

Graythresh calculates a global threshold level which is normalized [] in between the range [0,1], and converts any intensity image to binary image by using Otsu’s method. This method is used to isolate two related data, like background and foreground, in an image. It is an adaptive thresholding way for binarization in the image. It selects the threshold value in such a way that the intra-class variance of the high contrast pixels is minimum. Im2bw is used to change over the grayscale picture to the binary image by substituting the pixels in the input image with intensity greater than the threshold level with white (i.e., pixel value in image matrix is set to 1) and replacing all other pixels as black (i.e., pixel value in image matrix is set to zero). The intensity value exactly in between the extreme value of the image’s class is represented by 0.5 as this range is

standardized (normalized). Bwmorph is used to apply a specific morphological operation to the binary image. A structuring element is applied to the image taken as input, and the output is another image of the same size after applying morphological operations.

The difference is only that each pixel value in the morphed image depends on the corresponding pixels comparisons in the input image with its neighbors. Bwdist calculates the Euclidean distance transform of the binary image. The distance transform assigns a value for each element in the image matrix, i.e., each and every pixel in the image, which is calculated as the distance between that pixel and the nearest non-zero pixel of the image. Here, ‘city block is a method which calculates the distance between (x1,y1) and (x2,y2) as [abs(x1-x2) + abs(y1-y2)]. Medfilt2 command is used for 2-D median filtering. The pixels value in the output image is the median value calculated in a 3 x 3 matrix/pixel elements around the corresponding pixel in the input image. Points within half the width in the vicinity of the edges may look distorted as medfilt2 pads image with 0s on the edges.

The watershed transform finds watershed ridgelines in an image by treating it as a surface where light pixels represent high elevations, and dark pixels represent low elevations. Watershed returns a label matrix that identifies the watershed regions of the input matrix. It uses 8-connected neighborhoods for 2-D input. Elements labeled 1 belongs to the first watershed region; elements labeled 2 belongs to the second watershed region, and so on.

Bwareaopen command is used for Area Opening operation i.e. to remove all linked components which have lesser than nine pixels from the binary image, therefore constructing a different binary image. Connectivity is fixed for 8; hence, it removes all connected components with connectivity eight. And then, the final pore radius, PR, is calculated as per the formula. It is assumed that the rock fragments are circular in shape. This is done in order to get the radius of the rock fragments and to ease the calculation process.

$$PR = Resolution \times \left(\frac{V}{\pi}\right)^{0.5}$$

And the average grain radius in microns is calculated as the mean of pore radius, PR. The mean of grain radius is calculated by using the mean command. The standard deviation of grain radius is also calculated by thestd command. The

median of grain radius in microns is calculated by the median command.

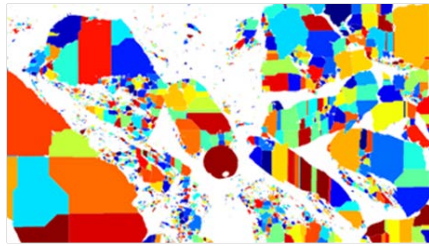


Fig. 6: Segmented image after Blob Detection

The final output for the input image after blob detection is as shown in Fig.6. Here, it is clearly seen that due to over-segmentation, the size analysis of rocks is not accurate. This problem needs to be solved, and the algorithm needs to be improvised in order to get more accurate results. While looking for new ways to solve the over-segmentation problem faced in the previous segmented images, we decided to try different edge detection techniques combined with different sorts of filters like range filter and Gaussian filter.

By going through various methods, which included canny edge detection with 'bothat' morphing, the edges of the rocks were successfully removed. But these images, when subtracted from the previous ones, the edges obtained aren't smooth at all. In other cases, the smooth edges are obtained by range-filtering the binary image, but there is lots of salt and pepper noise present in the image, which isn't removed by a 3x3 median filter. Choosing a filter of larger size removes significant portions of the image. Hence, this, too, is discarded. The conventional edge detection methods fail as there is lots of noise present in the image, and also, there is no particular background. Noisy images have large frequency components, which decrease the performance of edge detection. If noiseless images are processed for edge detection, then these edge detection techniques give a better result.

To remove this problem, when tried with changing some parameters of the code and modified some part of the previous code and tried using some new filters. Range filter is a texture filter function that is used to detect regions of texture in the image. Since the surface contours of the rocks exhibit more texture, hence range-filtering makes the edges and contours of the rocks more visible. Range filter returns the local range of the image in a 3x3 neighborhood around all pixels where every output pixel contains the range value (maximum value – minimum value). Imdilte and Imerode morphological functions are used internally during Range filter operation in order to get the minimum

and maximum values in the concerned neighborhood.

Bwmorph is used to apply a specific morphological operation to the binary image A. Majority operator is used while morphing the image as it sets a pixel value to 1 if, in its neighborhood, 5 or more pixels have values 1, else it sets the corresponding pixel value to zero. The watershed transform finds watershed ridgelines in an image by treating it as a surface where light pixels represent high elevations, and dark pixels represent low elevations. Watershed returns a label matrix that identifies the watershed regions of the input matrix. It uses 8-connected neighborhoods for 2-D input.

Elements labeled 1 belongs to the first watershed region, elements labeled 2 belongs to the second watershed region and so on. The output image, which is segmented in different regions, is then filled with different colours in different regions.



Fig.7: Improved Segmented image

From the above image, it is clearly seen that the over-segmentation problem which was present there in the previous approach was resolved in this case. Now, the segmentation is more prominent and clear and the results are better than the previous one.

But, amidst all these improvements achieved by this approach, there is loss of one significant information which is the loss of ability to distinguish different rocks as most of the rocks are coloured in same colour and they'll be counted as a single region while going for size analysis. This will result in inaccurate results. Hence, for size analysis, there needs to be some sort of trade-off between the quality of segmentation and distinction of different rocks.

RESULTS AND DISCUSSION

When the watershed algorithm is applied with a range filter and changing some parameters from the previous algorithm, the results are more prominent segmented images. The edges of the rocks are more clear and prominent, and the over-segmentation problem is also removed up to a significant extent. But the only drawback while

using this approach is that though the images are properly segmented, there cannot be the distinction between different rocks and boulders present in the image as many rocks are filled with the same color and hence signifies to one region.

The real problem that arises, in this case, is that some groups of rocks are considered as a single region, and hence size analysis of the rocks is not possible for this segmentation as it will give inaccurate results. For the size analysis of rocks via this method, a trade-off needs to be done between the quality of segmentation and the distinction of different rocks. This is more like a hit-and-trial method, and the parameters need to be changed according to each and every individual image. Hence, this approach is not used for further analysis. After all conversions and morphological operations continued by the application of the watershed algorithm, the result is the blob detection of fragments.

Along with blob detection as a part of size analysis, a histogram is plotted, which shows the variation of relative frequency, which keeps on changing with respect to equivalent grain radius. The grain radius calculation is based on the approximation that all the regions or fragments are assumed to be circular.

Output images showing the blobs of the input images and histograms are as shown below.



Fig. 8.a: Input image

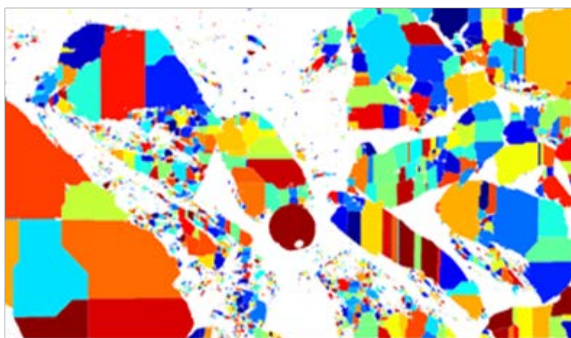


Fig. 8.b: Segmented image

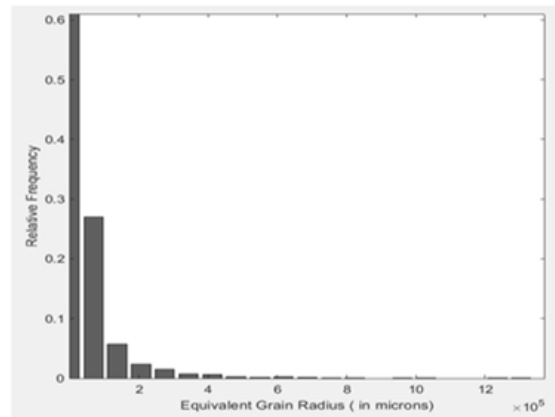


Fig.8.c: Histogram Plot of Eqvt. Grain Radius v/s. Relative Frequency



Fig.9.a: Input image

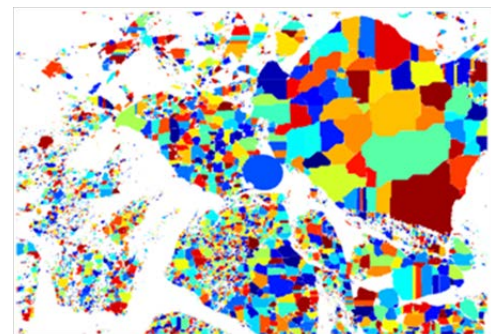


Fig.9.b: Segmented image

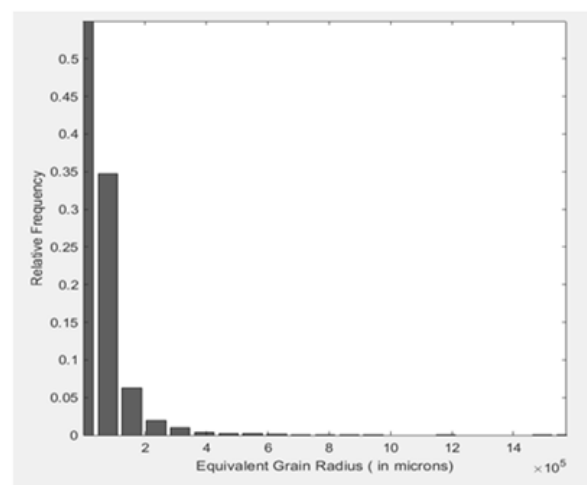


Fig.9.c: Histogram Plot of Eqvt. Grain Radius v/s. Relative Frequency

This is the only method which is the most appropriate and most suitable of all. This method has its disadvantages in the form of over-segmentation, but of all the approaches tried till date, this is closest to reality and the only possible solution universally applicable to almost all of the images. Since this paper is focused on developing a universal approach that will be applicable to the majority of images without changing the codes and the parameters, this approach suits perfectly. A table comparing all the different parameters calculated from blob detection for some significant images from the set of images on which the analysis was done as shown below.

Table 1: Calculated Value of Various Parameters

Input Image	Average grain Radius (in micron)	Standard Deviation of grain radius (in micron)	Median of grain radius (in micron)
Image 1	5.5537e+04	6.0393e+04	3.8057e+04
Image 2	5.6423e+04	6.2951e+04	3.7104e+04
Image 3	5.1537e+04	5.9578e+04	3.2837e+04
Image 4	4.5003e+04	4.8437e+04	3.0773e+04
Image 5	5.5537e+04	6.0393e+04	3.8057e+04

CONCLUSION

The main conclusion of this paper is the development of an operating procedure for computing the distribution of the size of rock fragments using images procured from the mining sites. The process involves using a high-resolution camera for capturing in the mine area and computer algorithms in MATLAB for processing images. Thus from the size analysis of the rock fragments, the corresponding values of average grain radius and average standard deviation of grain radius are calculated. The average grain radius is found to be 5.53e4 microns which is a scaled value and can get the exact value in meters by multiplying it by 10⁻⁶. The standard deviation of grain radius in micron after the calculation is 6.0393e4 for the same input image, and the median is 3.8057e4.

The size analysis and the results of this paper can be used to know the exact conditions for optimal blasting, and further, this analysis can be applied in future blasts for getting better results. This helps the concerned officials estimate the exact quantity of explosives, land conditions and blast patterns of future blasting surfaces to get the optimized results. The results of this paper are quite useful in optimizing the blasting process and therefore minimize the total cost of production.

FUTURE WORK

Since there was a need to develop a universal approach for analysis of rocks in different images,

the Blob detection method using Watershed algorithm in Matlab gives the most prominent results among all the approaches tried in this paper. Though it too has certain limitations, this is a simple and fast method of calculating the size distribution of blasted rock fragments in the field. It consumes lesser time and also is cheaper than the traditional sieving methods. There is a lot more scope to improvise the results, and more research needs to be done in devising more suitable approach to segmentation of rocks and to plot the actual size distribution curve as accurate as possible. This is in the future scope of this paper.

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