ABSTRACT: Detection of size and shape of minerals are important for the information about minerals. Different size and shape of same mineral can be effective in classification of them. Therefore it is necessary to know the size and shape of mineral exactly. In this study, using possibilities of image processing techniques in the detection of shape and size of mineral was discussed and a sample study was carried out. According to this, successful results can be obtained about size and shape features of minerals by using image processing techniques especially in thin section images whose third dimension effect was decreased.

Keywords: Image processing, thin section, minerals size, minerals shape

1. INTRODUCTION

With the development of technology image taking technology has also developed and image processing methods have taken their place in many disciplines as standard measurement and evaluation method. Fast taking of images, detection of color and physical size over image, advantage of analysis in short time made image processing methods superior over conventional analysis methods. Parallel to this, being adherent to common image processing terminology studies were carried out in different disciplines. Especially in the fields in which measurement is difficult such as physical and engineering characteristics of rocks, researchers evaluated image analysis methods alternatively. Studies were carried out under microscope on the identification of minerals, detection of void ratio (porosity) of rocks, analysis of discontinuity, detection of mineral boundary, detection of grain boundary, grain size distribution and formal analysis.

With the development of image taking technology with electron microscope and polarized microscopes studies about identification of minerals, detection of texture characteristics were carried out.

In their study carried out in 1991, Clelland and Fens did element assignment with the images taken from electron microscope in a short time (1). Tovey and Krinsley (1991) searched the analysis and classification of structural analysis of minerals by developing same methods (2). Later on, image analysis methods were especially used in quality control of industrial minerals. For example, the relationship of potassium control with the texture and degree of freedom of minerals in the production of iron was observed by Stirling (1989) (3).

Image processing techniques were also used in the detection of void ratio of rocks. In these studies micro sized researches were carried out and spaces were detected on the images taken from optic and electron microscope. Studies on images taken by electron microscope from the surface of polished rock was observed by Bodziozy et al., (1993) and Tovey and Huslow (1995), this method was used on many rocks and surfaces (4,5). Meng (1996) have done analysis between spaces in marbles and fractal size by using image processing techniques (6). With these studies approaches have been carried out on the gas absorption of marbles.

The analysis of micro cracks on rocks with image processing techniques was carried out with the principle in porosity studies. Cracks on rocks can be seen under microscope and images can be taken. Especially filled and empty cracks are seen as black and analysis can be carried out. Studies with this technique was carried out by Zheng (1989), especially development of micro cracks on rocks under load was detected by image processing techniques (7). Although these studies were limited by the two-dimensional analysis of three-dimensional cracks; this problem was solved with the application of streonet models.

With image processing, studies on detection of grain boundary were carried out. In order to do this, image passes through preprocessing and segmentation processes and grain boundaries become evident. In their study (1998) Goodchild and Fueten expressed and analyzed grain boundaries of grained rock image taken from electron microscope in line by using image processing techniques (8). With the same principle, Jenkins et al., (1991) studied industrial practice of image processing method, and studied the effect of grain sizes in refractor magnesite production (9).

In the studies about grain size distribution, two-dimensional effect of image was tried to be resolved...
with high-resolution images. It was expressed that even in this condition grain shape has effect on grain size distribution. Comparison of grain size distribution with image processing techniques with sieve analysis values was carried out by Friedman for the first time (1962). In his study Friedman did statistical studies in sandstone thin sections and obtained high correlation coefficients. Particle-size distribution found a utilization place especially in aggregate production (10).


In the science and engineering of geology, mineral particles are important elements for analysis. To obtain quantitative information about particle size and shape from mineral, it is common that optical microscopy and image technique were used in the characterization of the surface roughness and microstructure of the minerals (15, 16, 17).

1.1 Image Processing

Image is a two-dimensional sign record. It can be either visible like photograph or a record on magnetic band or numerical values in computer memory. Images can be continuous-discrete, analog-numerical or continuous-numerical. Luminance on an image is a variable that changes continuously both as level and as location (18). Detection of boundaries of different substances and objects of luminance values in image as pixels in computer enabled usability of image processing methods. In this sense producing data with analysis of images obtained by imaging devices especially in the field of medicine has been pioneer studies and later on found a utilization field for itself being a fast and easy measurement technique in many disciplines.

Application of image analysis methods in geology were carried out for the first time in the field of measurement and identification of spaces. Parallel to this, analysis of discontinuity and grain sizes on rocks were carried out by using different features of image that can be identified such as color.

In addition to many commercial programs that perform numerical image analysis, processes of the analysis common in all of them are given by and large in Figure 1.

2. MATERIAL AND METHODS

2.1 Material

In the study, size and shape analysis of minerals were carried out with image analysis method. Many studies were carried out on thin section images for petrographic description.

Examples involve quantifying quartz micro crack patterns to analyze stone deterioration, conducting porosimetric studies of stone, examining grain-size distribution and grain shape in stone, comprehensively evaluating deterioration mechanisms of stone, studying conservation treatments of stone, characterizing cementitious materials, analyzing ceramic materials, and measuring layer thickness on a variety of materials. Background issues that must be understood before undertaking or evaluating image analysis include experimental design and statistical validity, calibration, image quality, and image enhancement (preprocessing of images). Early work often required in-house computer programs; recent studies make use of new comprehensive image analysis packages. With the emergence of these packages that provide fast preprocessing and measurement of a wide range parameters (20)

Here, application on thin section with image analysis method was presented and a sample was carried out.
about the detection of size and shape analysis of minerals.

2.2. Experimental Methods

Thin section image to be used was taken and prepared from a marble sample. Image enrichment processes were done on thin section image first of all and image was edged.

In this process, contrast enrichment and histogram equalization treatments were applied.

Linear Contrast Enhancement, luminance values between 0-255 in grey level image is narrow in some of the images. For example minimum luminance value of an image can be 50 and maximum 100. In such condition, recognizing the details in the image is difficult. By contrast enhancement, luminance value of the image is withdrawn between 0-255 and point of image is enriched.

Contrast improving is about how far does the object histogram to be displayed is widened. In other words it is the minimum and maximum size of ranges to be displayed. While this range is better displayed, values above and below this range would not be displayed.

In linear contrast improving method, a linear relationship is carried out between original image values and values displayed. Linear contrast improving gives the best result in Gauss distribution of image histogram. An ideal gauss histogram is a histogram in which values are places in single-mod range and mod is distributed symmetrically at both sides. If there are materials which give close reflection values in the image, histogram will be gauss or close to gauss. Values to be obtained in linear contrast improving method are detected according to Equation 2.

\[
g(x, y) = \left( \frac{f(x, y) - f(x, y)_{\text{min}}}{f(x, y)_{\text{max}} - f(x, y)_{\text{min}}} \right) \times 255
\]

- \( g(x, y) \): Pixel value to be displayed
- \( f(x, y) \): Original image pixel value
- \( f(x, y)_{\text{min}} \): Original image minimum pixel value
- \( f(x, y)_{\text{max}} \): Original image maximum pixel value

Histogram equalization is a suitable image enrichment method for the images whose color values were not distributed uniform. It can either be applied all through the image or only on a specific part. It is called global histogram equalization if applied all through the image and called local histogram equalization if applied on a specific part of image.

In histogram equalization method, equalization algorithm is applied on original image and equal pixel is provided per ton. With this algorithm it is ideally expected from the histogram graphic to have linear level that gives close values. In histogram equalization, first of all cumulative histogram is found by making use of the histogram of original image. Cumulative histogram is the graphic that includes the values obtained by the addition of each luminance value with the ones previous of it and itself (Figure 2). Cumulative histogram values are normalized by multiplying maximum luminance value we want in enriched image and dividing the total pixel number in the image. If normalized histogram values and luminance values of the image is updated we have succeeded in applying histogram equalization method on that image.

![Figure 2. Histogram equalization method](image)

Applying contrast enhancement and histogram equalization method on the original image, the image is prepared for segmentation process. In this process which is called image enrichment, boundaries in the image are edged and the success of segmentation process is enhanced.

In Figure 3, sample image application of contrast enhancement and histogram equalization is given.
Figure 3. Image enhancement of sample image, (a) Original Image, (b) Contrast Enhancement, (c) Histogram Equalization

After pre-processes are carried out, segmentation treatment begins. Segmentation is the process of separating an object and background in an image or different parts studied in the image from themselves. Segmentation is the most difficult application of image processing and a specific error ratio may occur at the end of segmentation techniques. Image segmentation produces raw information such as the boundaries, shape and area of the object in the image. If we are concerned about the shape of objects, we expect segmentation to give us information about the sides, edges and boundaries of that object. But if we are concerned about the internal features such as surface cover, area, colors and frame of the object local segmentation must be used. For the solution of very complex problems such as identification of characteristics or generally pattern, both segmentation methods can be used (21). Edge detect application for the thin section image after enrichment process is given in Figure 4.

Figure 4. Segmentation of sample image, (a) enhancement image, (b) edge detect application of sample image

3. RESULTS AND DISCUSSIONS

3.1. Size Analysis of Mineral Particles

The most common measurement used for the sizes of irregular grains under microscope is Ferret diameters of grains. Ferret diameter limits can be
defined as the farthest distance in the boundaries of a grain. In Figure 5 ferret diameter of a grain is given.

As a result of image enrichment and segmentation processes of different minerals in sample thin section image, edges are detected. While detecting the edges, shape features of all the grains in the image are presented regardless of the type of minerals. However it is possible to do optional grain analysis according to image type by using image processing methods.

With image analysis program, grains in the image are assigned to the variables according to their boundaries. The image located according to their boundaries is given in Figure 6. Following this process, size analysis can be carried out by making use of each grain and located boundary of that grain in computer memory.

![Figure 6. Image located with its boundaries](image6)

Ferret diameters of the grain in the image are detected. According to this, average ferret diameter of 151 mineral grains in sample image is 808.0 micronmeter. Distribution graphics according to ferret diameter is given in Figure 7.

![Figure 7. Distribution graphics according to ferret diameters](image7)

3.2. Shape Analysis of Mineral Particles

Dozens of size parameters are possible; therefore, they can be combined in hundreds of ways into a formally dimensionless expression that might be used as a shape descriptor. In fact, only a few relatively common combinations are possible, but even these are plagued by total inconsistency in naming conventions. Table 1 summarizes some of the most widely used shape parameters calculated as combinations of size measurements.

<table>
<thead>
<tr>
<th>Table 1. Representative shape descriptors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Form factor: ( \frac{4\pi}{\text{perimeter}^2} )</td>
</tr>
<tr>
<td>Roundness: ( \frac{4\cdot \text{Area}}{\pi \cdot \text{maximum diameter}^2} )</td>
</tr>
<tr>
<td>Compactness: ( \frac{\left( \frac{\text{Area}}{\text{Maximum diameter}} \right)^2}{\text{Area}} )</td>
</tr>
<tr>
<td>Aspect ratio: ( \frac{\text{Maximum diameter}}{\text{Minimum diameter}} )</td>
</tr>
<tr>
<td>Solidity: ( \frac{\text{Area}}{\text{Convex area}} )</td>
</tr>
</tbody>
</table>
Formal features of grains described as ratio generally aims to produce numerical data about the forms of them by using diameter, perimeter and area information of grains. Formal features of 151 mineral grains described in sample image and identifies in Ferret diameters are calculated according to the equations given in Table 2. According to this, form factor, roundness, compactness, aspect ratio and solidity normal distribution graphics are given in Figure 8.

With the formula described in Table 1, an approach can be presented for the shape of grains in the image. When the statistical evaluation of data as a result of analysis is done, numerical data can be produced about the form, roundness, compactness ratio with average values and solution offers can be suggested for the other mechanical features in which the shape of grain is important. Statistical evaluation of data obtained as a result of sample image shape analysis is given in Table 2.

Figure 8. Normal distribution graphics: (a) form factor, (b) roundness, (c) compactness, (d) aspect ratio, (e) solidity
Table 2. Statistical evaluation of shape parameters

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total Count</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Minimum Value</th>
<th>Maximum Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Form Factor</td>
<td>151</td>
<td>0.59</td>
<td>0.15</td>
<td>0.16</td>
<td>1</td>
</tr>
<tr>
<td>Roundness</td>
<td>151</td>
<td>0.58</td>
<td>0.18</td>
<td>0.08</td>
<td>0.97</td>
</tr>
<tr>
<td>Compactness</td>
<td>151</td>
<td>0.75</td>
<td>0.12</td>
<td>0.29</td>
<td>0.99</td>
</tr>
<tr>
<td>Aspect Ratio</td>
<td>151</td>
<td>1.97</td>
<td>1.10</td>
<td>1.03</td>
<td>12.31</td>
</tr>
<tr>
<td>Solidity</td>
<td>151</td>
<td>0.84</td>
<td>0.09</td>
<td>0.34</td>
<td>1</td>
</tr>
</tbody>
</table>

5. CONCLUSIONS

Results obtained in this paper in which the utilization possibilities of image processing techniques in mineral size and shape analysis are given in articles below:

- Image processing used commonly in different disciplines and has commercial aspect can be used in mineral identification, size and shape analysis as well. According to the academic studies about the issue, mineral size and shape analysis of image processing methods are in the way of forming and using commercial products.

- Restrictive side of image processing methods in application is their third-dimension effect. Therefore in this study thin section image on which the third-dimension effect is not determining was detailed and size and shape analysis of grains in the image are presented. Ferret diameters of grains in the sample image are calculated by using image processing methods. Formal features of grains in the same image; such as the ratio of long diameter by short diameter, form roundness are calculated.

- Apart from the disadvantage of third-dimension effect of image processing techniques, there is sampling disadvantage as well. While image processing techniques that enable two-dimensional analysis in the image area are applied, sampling size must be detected well. Size of masses must be regarded during sample taking, and if required numerical data must be produced by taking many images among recurrent ranges.

REFERENCES


