Research on Fragmentation Distribution of Rock Based on Digital Image Processing Technology

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Abstract. Accurate measurement of the distribution of rock fragmentation is helpful to improve the blasting technology and bring more economic benefits for mine production. Therefore, it is one of the research focuses and hot topics in the field of mine application. Based on this, this paper first studies the theory and method of rock mechanics, then analyses the application of digital image processing technology, and finally gives the specific research on the distribution of rock fragmentation based on digital image processing technology.

Keywords: Fragmentation Distribution, Digital Image Processing Technology, Rock

1. Introduction

With the development of social economy, various infrastructure projects are being carried out in full swing, especially the infrastructure projects represented by tunnels and bridges have become an important cornerstone to ensure the sustainable development of social economy. China as a mountainous country, these large-scale foundation projects inevitably involve the blasting of mountains, especially rocks. As a kind of complex discontinuous and heterogeneous body, its mechanical properties are relatively special. Therefore, it is necessary to carry out stability evaluation and research in engineering construction, so as to ensure the smooth development of the project.

It is of great value to carry out the research on the distribution of rock fragmentation for the parameter optimization of rock blasting, which is mainly reflected in the significant reduction of the mining cost of rock mines through parameter optimization, so as to significantly improve its production efficiency and efficiency[1]. At present, the blasting effect of open-pit mine is mainly measured and calculated by the indexes of rock accumulation position, cost, and vibration and rock fragmentation distribution. As an important index, the distribution of rock fragmentation plays an important role in the management of rock blasting quality and parameter optimization.

There are several methods to analyze and statistics the distribution of rock fragmentation as shown in Figure 1. However, there are some typical defects in the statistics of rock fragmentation distribution in the existing statistical analysis methods, so it is urgent to apply and explore new technologies and methods. In recent years, with the rapid development of artificial intelligence technology, the application of the new technology represented by digital image processing technology in the statistics of rock fragmentation size distribution has been gradually promoted and deepened, and it provides a
new research idea and direction for the research on the distribution law of fragmentation degree of blasting rock.

Figure 1. Methods to analyze and statistics the distribution of rock fragmentation.

Efficient and accurate identification of rock fragmentation distribution is helpful to promote the design optimization of rock blasting parameters, which can significantly reduce the workload, improve the utilization efficiency of resources, and play a greater economic value. And the accurate measurement of rock fragmentation distribution is also helpful to improve and improve the blasting technology and bring greater economic benefits for mine production. Therefore, it is one of the research focuses and hot topics in the field of mine application.

In addition, as an important index to evaluate the mining efficiency, the research on the distribution law of rock fragmentation is helpful to optimize the crushing process, thus significantly reducing the mining cost, and there is a significant corresponding relationship between the process efficiency and the cost of rock fragmentation, as shown in Figure 2 below. It can be seen that the fragmentation distribution of rock in blasting pile is closely related to blasting parameters. Only reasonable and optimized blasting parameters can obtain better mining benefits. With the application of digital image processing technology in the distribution of rock fragmentation, it will play a greater role in the optimization of blasting parameters\[2\]. Therefore, it is of great practical value to carry out the research on the fragmentation distribution of rocks and rocks based on digital image processing technology.

Figure 2. Relationship between the process efficiency and the cost of rock fragmentation.

2. The Theory and method of rock mechanics
The strength and deformation characteristics of rock are closely related to the stress, deformation state, stress history, loading rate, water content and occurrence state, which are based on the theory of
continuum mechanics\textsuperscript{[3]}. The rock mechanics model becomes more and more complex with the development of the research, and has been widely and deeply applied in the engineering field.

2.1. The fractal rock mechanics
As a complex product of natural evolution, rock materials have more complex distribution of pores, cavities and cracks, which make the rock like a high-strength natural sponge. The research on Fractal mechanics of rock mainly focuses on the irregular curves with self-similarity and horizontal evolution, fractal transformation with self squareness and fractal set with self-affine. Among them, in the linear fractal level, the analytical geometry of rock has high self-similarity and continuous variable dimension\textsuperscript{[4]}. In addition, the irregular curve of self-similarity is based on the overall scale reduction, so it has the characteristics of constant scale. The fractal model of micro fracture of fractal fracture of stone is shown in Figure 3 below.

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{fractal_model.png}
\caption{The fractal model of micro fracture of fractal fracture of stone.}
\end{figure}

2.2. Fractal dimension of rock fragmentation distribution
In the process of rock being broken, fragments of different sizes will be produced. With the gradual decrease of fragmentation, more new surfaces will be produced, so more energy is needed to be dissipated\textsuperscript{[5]}. Therefore, the process of rock fragmentation can also be regarded as a process of energy dissipation. In addition, the process of rock fragmentation is also a fractal process, so a fractal fracture model can be established to analyze the relationship between fragmentation and energy dissipation. The fractal crushing model is shown in the following equation 1below.

\begin{equation}
E = C_f \left( r_2^{D-3} - r_1^{D-3} \right)
\end{equation}

The fractal characteristics of damage evolution and fractal fracture model of rock materials are shown in Figure 4 below.

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{damage_evolution.png}
\caption{The damage evolution and fractal fracture model of rock materials.}
\end{figure}

2.3. Damage mechanics of rock
In rock damage mechanics, there are the following assumptions: rock mass is composed of matrix and damage body, in which the matrix is isotropic elastic medium, and the deformation of matrix and
damage part is harmonious, and the damage body is rigid plastic without yield strength. Elastic deformation and purified water pressure will not cause damage to rock mass. Then the effective stress under uniaxial tension is expressed as follows in equation 2:

$$\sigma_{ef} = \frac{P}{A_0(1-D)} = \frac{\sigma'}{\psi}$$

In which, $\sigma_{ef}$ is the effective stress, that is, the stress on the undamaged section, $\sigma'$ is the net stress, $D$ is the damage variable, $\psi$ is the ratio of the actual area to the apparent area of the loaded specimen, $P$ is the axial pressure or tension, $A_0$ is the area of the undamaged section. In addition, the strain produced by the effective stress is equivalent to that of the same kind of material without damage. Therefore, the constitutive relation of damaged rock can be changed into effective one by changing the stress into the effective one.

3. Application of digital image processing technology

3.1. Focusing algorithm for rock image of blasting pile

The imaging of rock materials requires both higher resolution and sufficient depth of field. However, with the increase of magnification and resolution, it is difficult for an object to be fully focused in one image. Therefore, it is necessary to use digital image fusion technology to synthesize sequence images. The image fusion operator is shown in the following formula:

$$ML(x, y) = |2f(x, y) - f(x - step, y) - f(x + step, y)| + |2f(x, y) - f(x, y - step) - f(x, y + step)|$$

$$F(i, j) = \sum_{x=i-N}^{i+N} \sum_{y=j-N}^{j+N} ML(x, y)$$

In which, $N$ is the size of the window, and $F(i, j)$ is the measure of the focus clarity of points $(i, j)$, thus, the fusion problem of reflected light microscopic image can be solved effectively.

3.2. Spatial fusion algorithm

Simple region fusion methods include maximum and minimum contrast, gray average method and so on. By extracting the direction information, 3D reconstruction can be realized by 2D image sequence. Instead of laser confocal imaging of reflected light, three-dimensional surface imaging is realized by calculation\[6\]. The focus evaluation function curve has a Gaussian distribution at the peak. The symmetry is not obvious at the edge, which is mainly caused by the initial position of the microscope during image acquisition.

$$I_0 = \max \sum_{x} \sum_{y} ML(x, y)$$

3.3. The level of social insurance information management needs to be further improved

Rock image sampling is to divide a continuous image into several grids in space; each grid is represented by a luminance value\[7\]. The result of lattice sampling is an array of sample values. Rock image sampling makes the continuous image discretized in space, but the brightness value of the image on the sampling point is still a continuous distribution in a certain amplitude range. In addition, the gray values in the small squares sampled are the same. The process of converting the continuous variation range of brightness on the sampling point into a limited number of specific numbers, that is,
the discretization of sample brightness, the value of each point should also reflect the color change, and the maximum gray level of each pixel should be determined by the digitized matrix.

4. Rock fragmentation distribution based on digital image processing technology

4.1. Statistics and mathematical description of rock fragmentation distribution
The distribution of rock fragmentation actually refers to the particle size of ore and rock fragments. The research on the distribution of rock fragmentation needs to confirm that it is more convenient, simple and effective to use a specific geometric feature of rock block to measure the size of rock fragment size. As a three-dimensional solid, the volume of rock block can be used as a standard geometric characteristic parameter to measure the distribution of rock fragmentation. In addition, based on statistical theory, there is a linear relationship between the projected area, chord length and volume of rock fragmentation, and the linear ratio of volume to projected area and chord length will be gradually fixed with the increase of the number of rock blocks of this size.

Based on statistical theory, the plane area of rock block can be used as an important geometric characteristic parameter to measure the fragmentation degree of rock, and its one-dimensional or two-dimensional parameter is linearly related to its volume. Therefore, the rock image analysis can be transformed into the rock volume fragmentation size distribution which takes the rock volume as the grain size characteristic quantity, so as to make a more accurate description of the ore rock fragmentation distribution.

4.2. Statistical analysis of rock fragmentation based on image processing technology
Based on computer image processing technology for statistical analysis of rock fragmentation, it is necessary to locate the edge of rock image and measure the image size. Then, the volume or weight of rock block can be obtained based on computer statistical algorithm. Classification data list or fragmentation distribution function is often used to describe the size and composition of the fragmentation of ore and rock blasting, and the fragmentation distribution has statistical regularity, that is, there is a quantitative relationship between the size of rock block and the corresponding accumulation rate under the screen, which can be expressed by G-M distribution function.

In addition, the confirmation of the final distribution function is mainly based on the nature of rock fragmentation distribution, such as the proportion of coarse particles. The probability density and probability distribution of rock fragmentation can be calculated based on the linear relationship between the plane projection size and the rock block volume and the plane area to volume modeling. Finally, based on the statistical distribution of rock fragmentation, the area and quality of rock block can be corrected.

5. Conclusion
In summary, efficient and accurate identification of rock fragmentation distribution is helpful to promote the design and optimization of rock blasting parameters, which can significantly reduce the workload, improve the utilization efficiency of resources, and play a greater economic value. Only reasonable and optimized blasting parameters can get better mining benefits. With the application of digital image processing technology in the distribution of rock fragmentation, it will play a greater role in the optimization of blasting parameters. In this paper, through the study of rock mechanics theory and method, the fractal and damage theory of rock fragmentation distribution are analyzed. Through the analysis of the application of digital image processing technology, the sampling of rock block is studied. And through the research on the distribution of rock fragmentation based on digital image processing technology, the specific application of image processing technology in statistical analysis of rock fragmentation is analyzed.

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