Automation of drilling and blasting passport formation with intelligent algorithms

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Abstract: This article is devoted to the problem of a passport for drilling and blasting operations formation, taking into account the main characteristics. At most mining enterprises, this process is a manual calculation that leads to errors due to human factor and increases the time it takes to generate drilling and blasting passport, and, as a consequence, the time for drilling and blasting. The proposed solution is an automated complex that bases its calculations on the data of the cross-section mines shape, the dimensions of the height and width of the mine and the cross-sectional area in the tunnel, the fortress on the scale of prof. M.M. Protodyakonov and the thickness of the host rocks. All geometrical parameters of tunnel face are obtained automatically based on laser scanning. For further calculations, intelligent algorithms are used, implemented using deep learning neural networks (with python tensorflow library). It is worth noting that the final decision on the acceptance of the drilling and blasting passport is made by the person in charge. The result of using the proposed system is automatically generated passport of drilling and blasting operations, including its alternative variations (due to the passport chosen by the person in charge, the system will receive feedback to further improvement of the system algorithm).

KEYWORDS: MINE, UNDERGROUND MINING, DRILLING AND BLASTING, NEURAL NETWORK, PYTHON, TENSORFLOW, CALCULATION OF DRILLING AND BLASTING

1. Introduction

At present, in the mining industry a tendency for a colossal increase in the automation of certain technological processes through the introduction of modern equipment and the usage of innovative technologies can be noticed. But it should be noted that this trend bypasses some mining processes, due to the complexity of their automation in general, the lack of efficiency of existing solutions, or the high cost of equipment. One of these processes is the drilling and blasting passport development.

A large percentage of enterprises engaged in the development of underground deposits use the drilling and blasting method for rock excavation. And these enterprises are obliged to carry out blasting operations using the appropriate documentation, namely, according to the drilling and blasting passport. The efficiency factor of high-quality and modern equipment, when drilling and blasting, directly depends on the correct parameters of the drilling and blasting passport. The drilling and blasting passport must include such parameters as: the layout of the blastholes, the depth of the blastholes, the diameter of the blastholes, the type of cut hole, the consumption of the explosive, the type of explosive, the volume of the blasted rock mass, etc.

A large number of calculated parameters of the drilling and blasting passport, the calculation of which at many enterprises is often performed manually using universal methods, which can lead to errors in the drilling and blasting passport, as well as an increase in the time of its formation for the developed face, due to which there is an increase in the production time and the loss of production pace.

2. Prerequisites and means for solving the problem

The prerequisites for the automation of the process of designing a drilling and blasting passport are many factors. First of all, the wrong, non-optimal drilling and blasting passport development leads to large production losses. For example: non-optimal waste of explosives in excess of the design norm or insufficient level of blasting of the face and, as a consequence, the rework necessity the face by manual methods, which in turn leads to a decrease in production rates, and as a result, failure to fulfill the mining plan. Also, one of the most important prerequisites for the system development is the lack of a unified optimal method for the location of holes, and the consequence of its absence is an increase in the time for building the drilling and blasting passport itself. Often, due to the expenditure of a large amount of time on the design of the blasthole drill, mining enterprises design passports in advance before starting mining operations, and do not change them during the execution of the entire plan, regardless of various changes during the excavation, which is an extremely sub-optimal and costly factor.

The existing digital solutions for a drilling and blasting passport development have an insufficient level of automation, often represent desktop software, where the parameters for generating a passport are entered manually, and it is also a serious disadvantage to cancel the application of intelligent algorithms for determining suitable methods for generating a drilling and blasting passport. Also, in this type of software there is no feedback from the real object so the parameters of drilling and blasting passport cannot be recalculated based on changed input data in accordance with real values. Thus, the automation of the process of a drilling and blasting passport formation and development is an extremely important problem for many enterprises, which will increase the speed and accuracy of formation of a drilling and blasting passport and the speed of tunnelling.

The current automated systems, as mentioned earlier, are software with no intelligent algorithms and feedback to improve them.[1-3] This is due to the fact that often the specialists of mining enterprises do not have the skills to design intelligent data processing systems, and the data scientists do not have the skills to design drilling and blasting passports and understand the specifics of many processes in mining.

Nowadays, the creation of an automated system for the design of blast-hole passports based on intelligent algorithms has become possible thanks to the development of modern technologies: a reduction in the amount of resources for deploying systems based on intelligent algorithms (the ability to deploy systems of this kind directly in the enterprise infrastructure itself)[4], the rapid growth of the general trend of digitalization of mining operations and the emergence of more specialists in related fields of mining.

3. Solution of the examined problem

The authors of this work propose the following method for constructing the drilling and blasting passport automation:

1. Geometric and working area parameters determination by laser scanning with an automated complex.
2. Type of cut hole determination by geometrical and mining-geological parameters according to the project plan.
4. Methods and module for determining the coordinates of cut holes, contouring and auxiliary holes placement development.
5. Drilling grid method development. Consider the steps in more detail.

3.1. Geometric and working area parameters determination

Laser scanning technology (LiDaR) is widely used in the construction of digital 3D objects in medicine, architecture, and mechanical engineering. The hardware component of these scanners includes the necessary geodetic instruments such as theodolite and a...
high-speed and accurate laser rangefinder. These scanners are used to create 3D models of both complex and simple objects. The measurement speed of this type of scanners is high and can reach up to a million iterations per second, and the accuracy reaches up to hundreds of a millimeter.

Laser scanning in this complex is applicable to determine the type of cut hole and geometric parameters of the holes placement surface in the automatic mode. The laser scanners themselves are divided into types depending on the measurement method: pulsed, phase and triangulation. Despite the fact that triangulation scanners have the highest accuracy, scanners using pulsed and phase measurement methods are suitable for scanning incisions, due to the limited effective distance of the triangulation scanner. Regardless of the type of lidar, after scanning the mining face, the coordinates of the points will be obtained at the output - the so-called point cloud, with the help of which an accurate model of the cut will be built, for its further use in calculations for the placement of blastholes. [5]

But lidars have one small drawback, despite measurements, calculations, building a model in automatic mode, this type of device, with each new scan of the face, requires initial orientation in space relative to the required coordinate system, which leads to the intervention of a person placing control points, coordinates which are determined by geodetic methods. Despite this, this type of scanning can significantly speed up the work on measuring the geometric parameters of a face by quickly building an accurate model of it.

3.2. Type of cut hole determination by geometrical and mining-geological parameters.

The location of the holes in the face, the explosion rates, as well as the amount of entry are largely determined by the type of cut hole that used. The choice of the type of cut itself is determined by such indicators as: section of production, rock strength and the type of drilling equipment of a mining enterprise.

By the nature of the action, the cuts are divided into two types: into inclined cuts (cuts with boreholes directed obliquely to the working axis) and cylinder cuts (cuts with boreholes directed parallel to the mine working). Of the inclined cuts, the most common is the wedge cut. Of the cylinder cuts, the most common are: prismatic symmetric, slotted, spiral and double spiral.

Further in the article, the cylinder type of cut will be considered, in particular, the prismatic symmetric cut (Fig. 1) as the basis for further research on this topic, since high efficiency of cuts with the use of inclined holes and the advantages of their usage in comparison with straight ones are achieved only with a certain section of the working and a limited depth of holes.

![Image 1](https://example.com/fig1.png)

**Fig.1. The prismatic symmetric cut example**

Also, the cylinder type of cut is used both on faces with a cross section of less than 6m2 and more than 6m2, in contrast to the inclined type of cut. Thus, we can say that the most common type of cut is a cylinder cut. Cylinder cut parameters are determined by the following values: the cut construction, the compensating cavity diameter and rocks strength. These parameters are always set initially when designing the production plan, and it can be argued that, in the future, the parameters of the selected cut hole will be entered into the database of the automated complex after creating the project production plan.

3.3. Module for automatic calculation of explosives development.

The amount of explosive required to destroy a unit of rock, or the amount of explosive consumption, depends on such parameters as: the mine rock section strength, the explosive type and the blasting conditions. All calculations are carried out according to formalized formulas. The specific charge when using cylinder cut is recommended to be determined by the modified formula of N.M. Pokrovsky (1):

\[
q = (0,1\cdot f\cdot v)e, \tag{1}
\]

Where \( q \) is the specific charge of the explosive, kg/m3; \( f \) — rock strength coefficient according to M.M. Protodyakonov; \( f \) — rock structure coefficient; \( v \) — rock clamping coefficient; \( e \) — explosive charge efficiency coefficient.

Cylinder cut require an increased specific explosive charge, and it is calculated only for cut and delineating holes with a rock clamping coefficient \( v = 1.1 - 1.4 \).

The amount of explosive per cycle using cylinder cut hole is calculated by the formula (2):

\[
Q = Q_{bh}\cdot q\cdot (S_{bh}-S_{ah})\cdot h_{bh}, \tag{2}
\]

Where \( Q_{bh} \) is the amount of explosive in the cut holes, taken as the sum of the charges of the cut holes. The amount of charge in kg in the cut hole is calculated by the formula (3):

\[
q_{bh} = 0,785\cdot d^2\cdot \rho \cdot \alpha \cdot l_{bh} \tag{3}
\]

where \( d \) is the diameter of an explosive cartridge or a borehole, depending on the loading method, m; \( \rho \) is the density of the explosive in the charge, kg / m3; \( \alpha \) — filling factor of the cut hole; \( l_{bh} \) is the cut holes length.

All these calculations are immediately carried out when designing a drilling and blasting passport, and as practice shows, they do not change in the future, which in turn, under certain conditions of work, leads to overspending and irrational use of explosives. In turn, this can be avoided just by the introduction of an automated system for drilling and blasting passport generating based on laser scanning and intelligent algorithms. Laser scanning after drilling the blastholes using a high-precision point cloud allows determining the actual diameter and length of the blasthole, which may change due to the grinding of the bit and changes in the rock hardness during mining[6].

The intelligent algorithms usage, based on the changed data after scanning, and already existing unchanged coefficients for calculating the amount of explosive, just the same allow to calculate the actual amount of explosive for each cycle.

3.4. Methods and module for determining the coordinates of cut holes, contouring and auxiliary holes placement development.

For the optimal location of auxiliary and cut holes, we propose to use a neural network algorithm, implemented using tensorflow in the python language [7], and based on the solution of the so-called circle packing into an arbitrary area problem [8]. Circle packing problems are a category of geometric problems that consists in placing circles of the same or different diameters in a certain two-dimensional region, touching but not intersecting each other. There are a large number of well-known algorithms for solving this class of problems - from homogeneous mosaics to intelligent algorithms. It should be borne in mind that the zones of influence in the geometric construction of the drilling grid, as a rule, intersect (provided that the radius of the circles is equal to a as zone of influence), but when using the radius equal to a/2, the problem is reduced to the circle packing problem.
One of the algorithms that gives the most qualitative result of mesh generation is the “shaking” method, which consists in the following: each point of the hole placement is shifted in different directions by some randomly selected (and after training the neural network - by a certain) amount (Fig. 2). Further, from the options after the shifts, the most optimal is selected, after which the “shaking” is carried out again - until the circles are packed in the most efficient way. In this case, an option is considered to be effective in which there are no or minimized areas that do not fall into the zone of influence of any blasthole, and the number of blastholes also tends to the minimum of the possible number.

### 3.5. Drilling grid method development.

After each cycle of drilling and blasting operations in the mine can be so-called bootleg - technological holes formed after blasting, and located in places of cut holes and auxiliary holes. It is prohibited to carry out further drilling operations in these holes, because they may contain explosives. And as practice shows, redesigning of the drilling and blasting passport or making changes to during work is not carried out, drilling continues with an arbitrary displacement of the holes from the bootlegs by 1-2 cm, thus the zones of influence of the holes do not correspond to the initial calculations, which can lead to resource costs and loss of production rates due to insufficient efficiency of further drilling and blasting operations. Repeated laser scanning can avoid this.

The technique is as follows: repeated laser scanning is carried out, as a result of which, using a high-precision point cloud, we can obtain an actual face model, with all the bootlegs located on it. Further, the processing of this model by intelligent algorithms comes into play [9], which displace the cut relative to the axis by a sufficiently effective distance for further drilling operations. After the displacement of the cut on the project of the drilling and blasting passport, the task of circle packing comes is solved, for the subsequent placement of the minimum number of auxiliary holes, corresponding to their zones of influence, without their overlays on the remaining bootlegs but providing full face coverage without spaces free from zones of influence.

Thus, you can quickly and accurately make changes to the current drilling and blasting passport model. Moreover, depending on the displacement of the cut relative to the axis and the bootlegs, you can get several effective drilling and blasting passport models, but the choice of the most effective option is accepted by the person in charge, which in turn will allow further training of neural network algorithms.

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**Fig. 2.** The “shaking” algorithm for drilling net design.

**Fig. 3.** Drilling and blasting passport designed manually.

**Fig. 4.** Bootlegs model

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### 4. Results and discussion

As an object for carrying out an experiment using intelligent algorithms, a drilling and blasting passport, already designed for a specific face with a cylinder cut type (prismatic symmetric), was taken. (Fig. 3)

In the course of the experimental study, markers were imposed on the model of the drilling and blasting passport, indicating the bootlegs remaining after drilling: from cut holes, since they remain always, and randomly located from the auxiliary holes. (Fig. 4)

Further, using the data from the already designed drilling and blasting passport, with the tensorflow-based neural network, the problem of placing cut and auxiliary holes and constructing their influence zones was solved by displacing the cut relative to the markers of the cutting bootlegs and the most efficient placement of auxiliary holes relative to the bootleg markers of auxiliary holes. (Fig. 5)
Also, for the design and displacement of the elements of the new passport, algorithms were used to solve the problem of circle packing. (Fig. 6) When solving the problem of circle packing, the circle radius was taken as the zone of influence divided by two ($a/2$), since the zones of influence must intersect to ensure a high-quality explosion, while the circles during packing do not.

The data obtained is not accurate, due to the initially incorrect design plan of the drilling and blasting passport, the absence of a large dataset for training the neural network, and as a consequence the lack of training, there is a large inaccuracy in providing models with this neural network.

5. Conclusion

Based on the provided models, it can be said that the method of using intelligent and neural algorithms solving circle packing problem are applicable for the automated design of drilling and blasting passports, despite the inaccuracy of the data obtained from the primary experiment, with further training of the neural network on datasets of correctly designed drilling and blasting passports, and also scanned by laser scanning of shaft face models at different work cycles, will allow to train the neural network as efficiently as possible and achieve high accuracy and efficiency in designing drilling and blasting passports.

References:


