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Research Paper

Ultimate Pit Limit Optimization Using Keshtel Algorithm

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Abstract: To design an open pit mine, geological operations must be conducted, followed by the preparation of a three-dimensional model and mineral block model. The ultimate pit limit can be determined through accurate methods and artificial intelligence techniques. The problem of determining the ultimate pit limit is considered to be NP-hard, making it challenging to solve. While exact methods provide better and optimal results, they may require significant time to answer the problem due to the large number of blocks involved. In such cases, it is more suitable to use collective algorithms or a planned approach to determine the final range. Optimizing the determination of the ultimate pit limit is similar to other optimization problems that can be addressed using logical algorithms in MATLAB software. In this study, Keshtel algorithm, implemented in MATLAB, is utilized to optimize the final range. Initially, Keshtel algorithm is employed to solve the problem. Subsequently, the Songun copper mine is chosen as a case study for the two-dimensional and three-dimensional implementation, and the results of determining the ultimate pit limit are compared with both Keshtel algorithm and NPV Scheduler software. The findings reveal that Keshtel algorithm, used to determine the final limits of the Songun copper mine, differs by only 0.47% compared to the NPV Scheduler software. Moreover, the comparison of Keshtel algorithm with the results of Lerch Grossman in determining the two-dimensional final range, as well as the comparison with NPV Scheduler software in three-dimensional problems, demonstrates its efficiency in solving these issues effectively.

Keywords: Optimization, Keshtel Algorithm, 3D ultimate pit limit.

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INTRODUCTION

The problem of determining the final limit of a mine is thoroughly examined after the design of the 3D and block models. This problem is classified as one of the NP-hard problems. To address the issue of determining the final limit, various mathematical (exact) and artificial intelligence methods are employed. Exact methods typically yield better and optimal results, but for complex problems with a large number of blocks, they may require a significant amount of time to solve. Due to uncertainties such as grade and price uncertainties in the field of mining engineering, mining companies are compelled to find ways to reduce costs and increase revenue. Optimization methods can be categorized into exact methods and search methods. Exact methods provide optimal solutions but require substantial time and powerful computers for larger problems. On the other hand, search methods may not yield the optimal solution, but can provide reasonably accurate solutions within a reasonable time frame. The problem of determining the final limit of a mine is classified as an NP-hard problem. The objective of this article is to investigate the optimization of the final limit using Keshtel algorithm and to compare it with Lerch and Grossman's algorithm (mathematically). To achieve this, the Keshtel algorithm is deemed feasible and will be utilized for optimization. One of the future goals of this article is to evaluate the algorithm and its applications in various mining problems. While many meta-exploration algorithms, such as ant algorithms, colonial competition algorithms, bee algorithms, and genetic algorithms, have been employed to determine the ultimate pit limit in mines, many of these studies have limitations (e.g., slope limitations) and fail to address uncertainties (e.g., price and grade uncertainties). Therefore, researchers are seeking flexible methods or algorithms that can handle all of these cases and even adapt to future changes in the field. In this research, the theory of Keshtel algorithm and its implementation for determining the final limits of mines are initially discussed. Subsequently, it is applied to a hypothetical block model in a two-dimensional form, and the resulting value is compared to the Lerch and Grossman algorithm. The performance of Keshtel algorithm and the final value obtained demonstrate its success in solving the problem.

METHODS

Keshtel, a place in Mazandaran, derives its name from the Ghazsanan family who migrated to this location from Mazandaran. The scientific name of the duck found in this area is Anas Claipita, known as the Northern Shawler in North America, which signifies "Northern paddler". The term "paddler" is attributed to the shape of the duck's beak, and this bird predominantly resides in the northern regions of the world, particularly Eurasia (Europe-Asia). During the winter season, it migrates to southern areas of the Arctic, including North America, Europe, southern Russia, and the south of the Mazandaran Sea. The breeding algorithm of this duck exploits its feeding behavior in the pond. Kestel's algorithm, inspired by a natural process, is an innovative meta-exploratory algorithm. The behavior of this type of duck involves submerging its head and rotating its entire body, resembling a feather, with the center of its beak when it discovers a favorable food source. This movement creates a moving circle with a mobile center, exhibiting both positional and translational motion. As soon as this hypothetical circle is formed by the duck, other ducks in close proximity gradually approach the target duck, which found the food source first. Then, they rotate around it in the same direction. The initial keshtel occupies the center, while others rotate around it harmoniously. This hypothetical circle, dictated by the movement of the keshtels, combines both positional and translational rotational motions. This collective movement, as depicted in Figure 1, revolves around the food source and consistently gravitates towards more abundant and superior sources of food. The keshtels consume and rotate until no other food source remains in the area. At this point, the keshtels disperse.

FINDINGS AND ARGUMENT

The implementation of Keshtel algorithm in the problem of determining the final two-dimensional range is discussed after the formation of the block model and the determination of the value of each block [2]. Figure 2 illustrates the values of hypothetical blocks in different positions of the block model, represented as a 4*10 matrix.

Once the block model is selected, the implementation of Keshtel algorithm is then addressed in the problem of determining the final two-dimensional range.

After finalizing the calculations and determining the ultimate pit limit using Keshtel algorithm, the optimal is shown in Figure 3,4.

Figure 1. Movement of the group of keshtels around the food [1]

-1	6	2	5	6	-4	2	-2	4	-2
-1	1	3	8	-4	10	3	1	-3	1
1	2	-3	10	-3	-2	-10	-2	-1	-2
-1	1	-3	4	10	10	6	-1	2	-1

Figure 2. The values of hypothetical blocks in different positions of the block model [2]

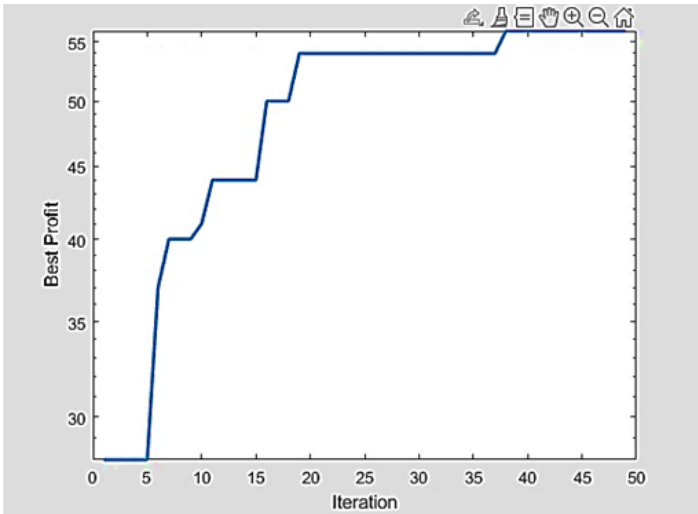

Figure 3. The answer obtained by solving the problem with 50 repetitions

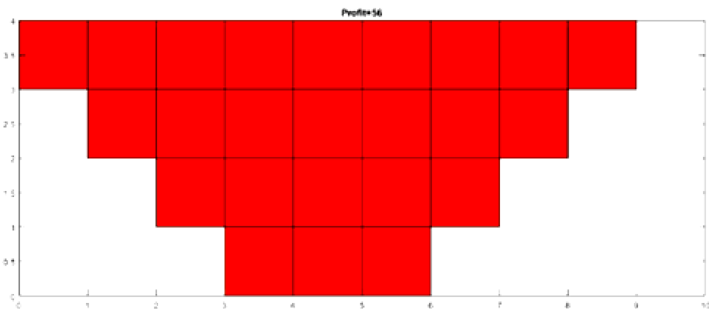

Figure 4. The result of solving the problem of determining the optimal ultimate pit limit using Keshtel algorithm

To implement Keshtel algorithm in determining the 3D ultimate pit limit, a hypothetical block model with specific dimensions is used. Figure 5 shows a block model with dimensions of 4*8*8 and the results of using Keshtel Algorithm.

-2	-2	-2	5	14	8	-2	1
-2	-2	9	-2	6	12	-2	-2
3	10	10	5	-2	-2	-2	-2
-2	-2	9	1	-2	-2	5	1
-2	-2	-2	-2	-2	13	-2	-2
-2	-2	8	-2	7	-2	-2	-2
-2	-2	7	-2	-2	9	-2	-2
4	-2	-2	-2	-2	-2	-2	-2

-2	-2	-2	14	9	3	-2	3
-2	-2	11	-2	14	9	-2	-2
1	11	9	5	-2	-2	-2	-2
-2	-2	5	2	-2	-2	5	7
-2	-2	-2	-2	-2	7	-2	-2
-2	-2	8	-2	8	-2	-2	-2
-2	-2	8	-2	-2	7	-2	-2
3	-2	-2	-2	-2	-2	-2	-2

-2	-2	-2	12	5	7	-2	1
-2	-2	9	-2	7	12	-2	-2
2	6	6	5	-2	-2	-2	-2
-2	-2	9	5	-2	-2	5	3
-2	-2	-2	-2	-2	11	-2	-2
-2	-2	9	-2	8	-2	-2	-2
-2	-2	12	-2	-2	13	-2	-2
2	-2	-2	-2	-2	-2	-2	-2

-2	-2	-2	5	7	5	-2	5
-2	-2	10	-2	12	11	-2	-2
3	9	6	5	-2	-2	-2	-2
-2	-2	9	8	-2	-2	7	3
-2	-2	-2	-2	-2	11	-2	-2
-2	-2	6	-2	7	-2	-2	-2
-2	-2	7	-2	-2	8	-2	-2
1	-2	-2	-2	-2	-2	-2	-2

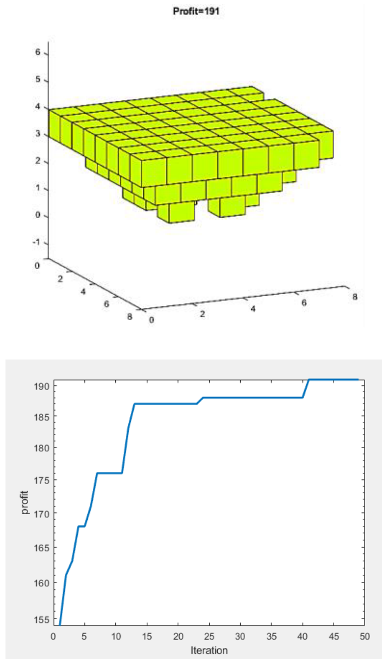

Figure 5. A block model with dimensions of 4*8*8 and the results of using Keshtel Algorithm

CONCLUSIONS

Nowadays, in light of scientific and technological advancements, the optimization of mining activities to achieve maximum income and metal extraction at minimal cost has become crucial. Various uncertainties, such as geological conditions, market price fluctuations, and technical requirements, have prompted mining companies to continuously develop technical improvements in order to enhance profitability, optimize exploitation, and meet investor goals. In this research, the problem of determining the final two-dimensional range was addressed using a set of hypothetical blocks measuring 4*10. Additionally, to determine the final three-dimensional range, a set of hypothetical blocks measuring 4*8*8 was utilized. The response obtained from applying Keshtel algorithm to these hypothetical two-dimensional and three-dimensional datasets (with smaller dimensions) was found to be equivalent to the response generated by NPV Scheduler software. Furthermore, the Keshtel algorithm was evaluated using data from the Songon copper mine, resulting in an ultimate pit limit value of 14501 million dollars. Comparatively, the NPV Scheduler software yielded an ultimate pit limit value of 14570 million dollars for the same mine. The difference between the final answers obtained through these two methods was less than one percent.

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