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A heuristic approach to optimal design of an underground mine stope layout

Don Suneth Sameera Sandanayake[a,*], Erkan Topal[b,1], Mohammad Waqar Ali Asad[b,2]

[a] Western Australian School of Mines, Locked Bag 30, Kalgoorlie, WA 6433, Australia
[b] Mining Engineering, Western Australian School of Mines, Locked Bag 30, Kalgoorlie, WA 6433, Australia

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ABSTRACT

The optimal layout or geometry of the production area (stope) in an underground mining operation maximises the undiscounted value subject to the inherent physical, geotechnical, and geological constraints. Numerous approaches to develop possible stope layouts have been introduced. However, owing to the size and complexity of the problem, these approaches do not guarantee an optimal solution in three-dimensional space. This article proposes a new heuristic algorithm that incorporates stope size variation for solving this complex and challenging optimisation problem. A case study demonstrates the implementation of the algorithm on an actual ore body model. In a validation study, the proposed algorithm generates 10.7% more profitable solution than the commercially available Maximum Value Neighbourhood (MVN) algorithm.

1. Introduction

The prerequisite to inception of a successful mining operation rests in the existence of adequate supply of ore (valuable raw material) or economic reserves. A decent supply of ore guides the selection of the appropriate production scale of an operation and assists in reducing the corresponding costs of producing ore [1]. Mineral exploration sampling and consequent geological interpretation in conjunction with spatial statistical modelling techniques delineate the ore body [2]. This process not only defines the size, shape, depth, geology, and geotechnical characteristics of the available ore reserves, but also divides the volume of these reserves into thousands of fixed size mining blocks in three-dimensional space and assigns qualitative (grade or metal content) and quantitative (t) data to each mining block [3]. Given the available grade and tonnage in a mining block and economic parameters such as commodity price, mining cost, and ore processing cost, the economic value of a mining block is calculated, which becomes basic input to the subsequent mine planning process [4,5].

The foremost step in mine planning process resolves the question on mining a particular ore body through a surface or an underground operation. While, spatial (size, shape, depth, location) characteristics of the ore body facilitate the solution to this question, the economy remains the driving force that guides this selection between surface or underground mining operation. If this strategic decision is made in favour of an underground mining operation, then, at the same time, among a few available options, the most appropriate underground mining method may be selected. The selection of an optimal stope layout is the core to mine planning process in the majority of underground mining methods, because, it dictates the net present value maximisation in subsequent production scheduling [6]. Given the selection of an optimal stope layout is based on analysing all possible combinations of thousands of mining blocks, achieving the optimal solution to this complex problem is a challenge, and this article contributes an innovative as well as efficient algorithm to solve this stope layout problem.

Fig. 1 depicts a series of important technical stages and primary activities which belongs to these stages of a typical underground mining project. Stope layout optimisation lies within mine planning stage, and it is the most pivotal activity as the optimal stope layout impacts the value maximisation in the subsequent stope production scheduling step, and guides the productivity of the mine development and mine production stages.

Fig. 2 presents the general layout of an underground mine [7]. As indicated in Fig. 2, a stope in an underground mine is the production area, where ore is extracted using an appropriate underground mining method.

Fig. 3 demonstrates a three-dimensional view of the possible layout of stopes available/accessible for extraction in a section of an underground mine.

* Corresponding author. Tel.: +61 8 90886162.
E-mail addresses: Donsuneth.Sandanayake@curtin.edu.au (D.S.S. Sandanayake), E.Topal@curtin.edu.au (E. Topal), waqar.asad@curtin.edu.au (M.W. Ali Asad).
[1] Tel.: +61 8 9088 6156.
[2] Tel.: +61 8 9088 6139.

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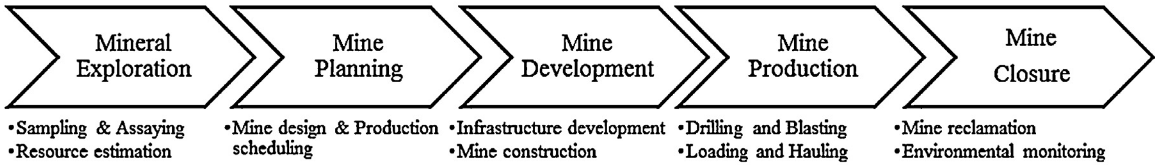

Fig. 1. The overall technical road map of an underground mining project.

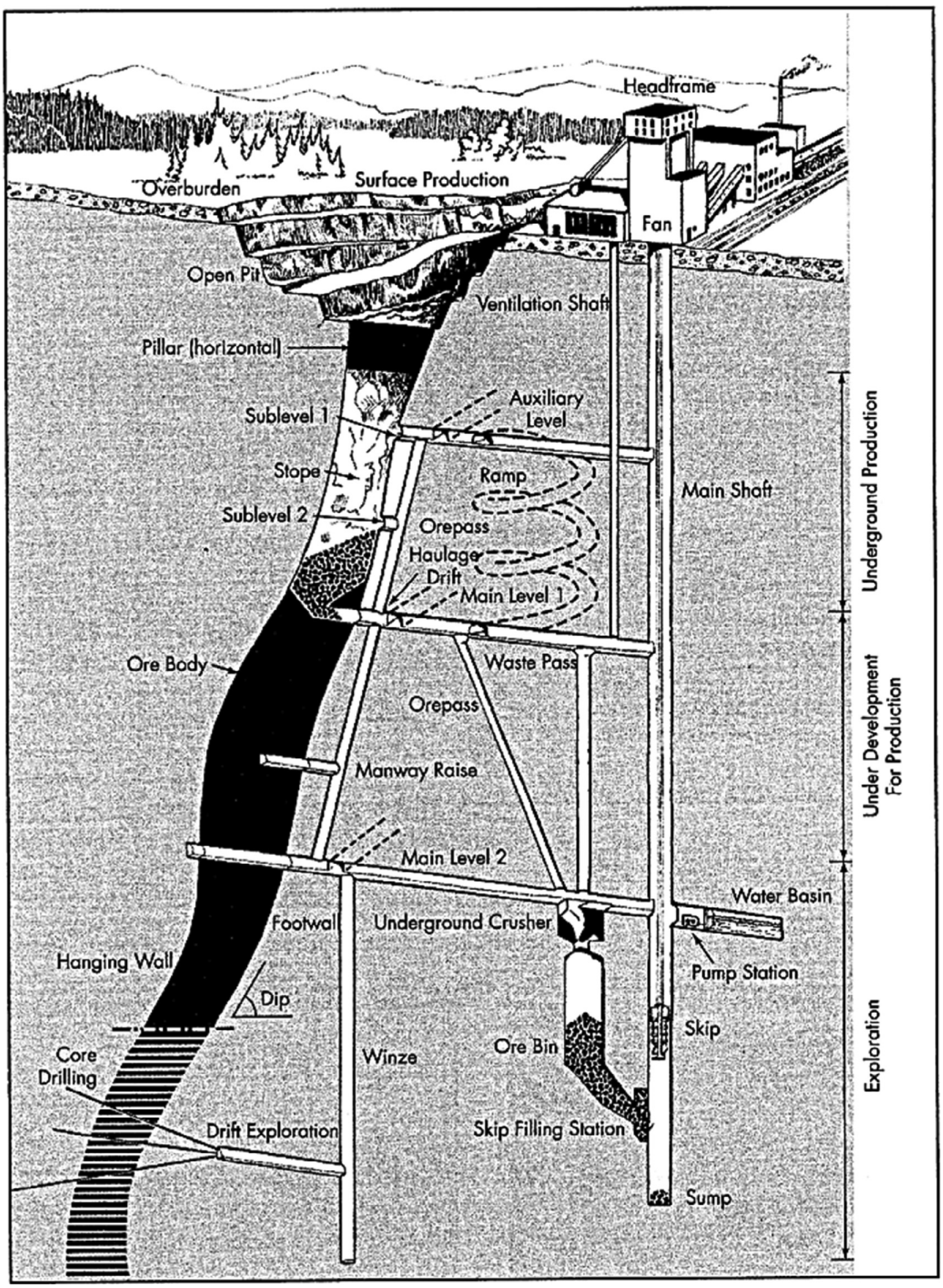

Fig. 2. A general layout of an underground mine [7].