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Design and Fabrication of a Rock-Cutting Tracker using a Laser Relay Transceiver in a Novel Drilling Approach based on an AVR Microcontroller

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Abstract

Various extraction methods including wire saw machines, chain saw machines, diamond blade saws, water jet cutting machines, flame jet cutters, and hydraulic stone cutters have been employed in construction rock mining. The most common techniques used in rock mines are high-pressure waterjet cutting and diamond wire cutting, which are more advanced than classical techniques such as controlled blasting, katrock, and frackt-expanded materials, and plug and feather techniques. The most widely used method to cut marble and granite is diamond wire cutting. In this method, the wire is passed through three mutually perpendicular holes, ensuring efficient rock extraction. The hole locations are determined based on some traditional spot-finding methods, such as a level hose or sometimes theodolite. Due to the low accuracy of conventional drilling techniques, a novel Laser Transceiver System (LTS) is proposed in this work to accurately determine the locations of three mutually perpendicular and intersecting holes on three spatial planes in three-dimensional cartesian coordinates. The work suggests a technique using an AVR microcontroller and a laser tracker installed on a level rod to enhance tracking accuracy and speed in mining operations. This method reduces noise and air pollution, lowers equipment transportation costs, and improves overall efficiency. Experiments conducted in a mine demonstrate that the system significantly reduces errors even without skilled surveyors, outperforming previous methods. Moreover, according to the Analytical Hierarchy Process (AHP) method, LTS has the highest score of 46.8%, followed by the theodolite and leveling hose techniques with 28.8% and 24.9%, respectively.

1. Introduction

The rock mining relies heavily on precise and efficient drilling techniques to optimize extraction and minimize operational costs. However, traditional drilling methods, although widely used, often suffer from significant accuracy limitations. This results in material waste, increased operating costs, and reduced productivity. These inefficiencies are especially pronounced in the extraction of decorative rocks like marble and granite, where precision is crucial for ensuring the quality and usability of the extracted blocks. In rock mining, the diamond wire-cutting method has become a preferred technique due to its ability to reduce noise and air pollution, as well as its higher efficiency compared to classical methods such as controlled blasting or plug-and-feather techniques [1]. However, the success of

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diamond wire cutting relies on the accurate drilling of three mutually perpendicular holes that intersect at a single point within the rock block. Traditional methods for determining the locations of these holes, such as using leveling hoses and theodolites, are prone to high levels of error, mainly when performed by less experienced operators. These errors can lead to misaligned holes, resulting in incomplete or irregular cuts, which not only waste valuable material, but also increase extraction time and costs. Furthermore, reliance on skilled surveyors for traditional drilling methods introduces additional challenges including higher labor costs and the potential for human error. In many mining operations, especially in remote or resource-constrained areas, access to skilled personnel may be limited, exacerbating these issues [2].

As a result, there is a pressing need for a more accurate, automated, and cost-effective solution to improve the precision of drilling operations in the rock mining industry. This work addresses these challenges by proposing a novel LTS integrated with an AVR microcontroller. The system is designed to accurately determine the locations of drilling points in three-dimensional Cartesian coordinates, thereby reducing errors and enhancing drilling efficiency. By leveraging advanced laser tracking techniques, LTS eliminates the need for manual measurements and significantly reduces the reliance on skilled labor. The integration of the AVR microcontroller further enhances the system's capabilities by enabling real-time tracking and automated adjustments, ensuring that drilling points are precisely aligned according to the desired specifications. Theoretically, this research contributes to the ongoing development of automated drilling systems by introducing a new approach that combines laser technology with microcontroller-based control. This integration represents a significant advancement in mining technology, offering a more reliable and efficient alternative to traditional drilling methods. The proposed system not only improves drilling accuracy but also provides a scalable solution that can be adapted to various mining environments and conditions. By minimizing drilling errors, the system ensures that rock blocks are extracted with greater precision, leading to higher-quality end products and reduced processing time. Additionally, the reduction in labor costs and the elimination of human error further enhance the economic viability of mining operations, making them more sustainable and competitive in the global market. In conclusion, this study is motivated by the critical need to improve the accuracy and efficiency of drilling operations in the rock mining industry.

The paper's organization is as follows: Section 2 provides the background and motivation for the study. Section 3 introduces the proposed Laser Tracking System (LTS) integrated with an AVR microcontroller. Section 4 compares traditional methods and LTS using AHP and GA, and discusses the experimental results and advantages of LTS. Finally, Section 5 concludes the paper by summarizing the findings and suggesting future research directions.

2. Background and Motivation

Rocks are solid collections of minerals with specific and relatively stable chemical compounds [3, 4]. Building rocks have been mined for thousands of years since humans started constructing substantial houses [5-7]. Various extraction methods including laser cutting, flame jet, disk cutting, and the Havazh machinet have been studied by researchers such as Raether [8], Ozcelik [9, 10], Morrison [11], Boshkov [12], Hartman [13, 14], Laubscher [15], and Miller [16]. Each rock extraction method has advantages and disadvantages, so the suitable method should be chosen through detailed examinations. Accordingly, to compare different rock extraction methods, the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) was investigated by Aryafar et al. [5]. The methods of the Analytical Hierarchy Process (AHP), Fuzzy Analytical Hierarchy Process (FAHP), and Genetic Algorithm (GA) were proposed in Refs. [17-19] and [6]. The results indicated that the diamond wire-cutting method is more appropriate than other methods [7].

In Refs. [20, 21], diamond wire cutting was studied in small-scale applications. In 2011, this method was studied for the first time to reduce vibration effects in tunnel excavation [22]. In 2015, diamond wire cutting was patented and used on the full scale [23]. Some of the essential aspects of this method are the reduction in noise pollution, less air pollution, and higher efficiency [24]. In a diamond cutting system, using circular diamond saw blades significantly reduces the operation time and improves product quality [25]. Therefore, the ability of rock cutting by drilling machines, diamond wire, or saw can be estimated as an essential measure to evaluate the operation costs [26]. Reference [27] discussed the superiority of the diamond wire-cutting method in increasing efficiency.

Briefly, the first step in extracting decorative rock blocks by diamond wire cutting is to drill three mutually perpendicular holes (at an angle of 90 degrees concerning each other), like the spatial coordinate system. In this case, the three holes intersect at one point. After drilling the holes, the side, rear, and bottom faces of the rock block are cut using a diamond wire cutting machine. Finally, the cut block is separated from the quarry and toppled over by hydraulic bags or lever jacks [28]. Figure 1 shows the two-dimensional diamond wire cutting operation in a mine [29], and Figure 2 shows a one-dimensional diamond wire cutting operation in a tunnel [30].

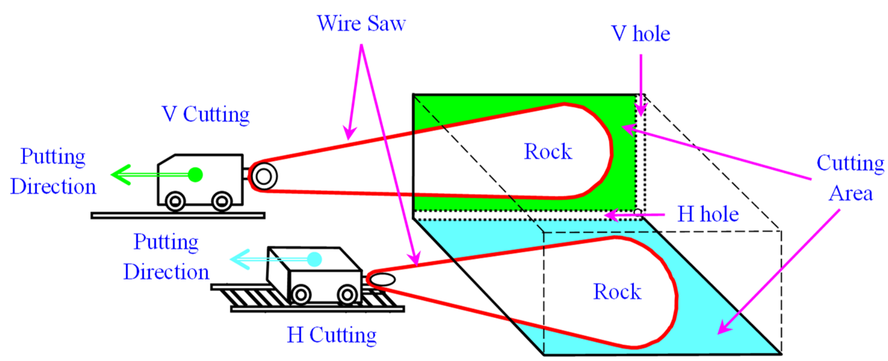


Figure 1. Schematics of two-dimensional rock cutting by diamond wire [29] (V= vertical; H = horizontal).

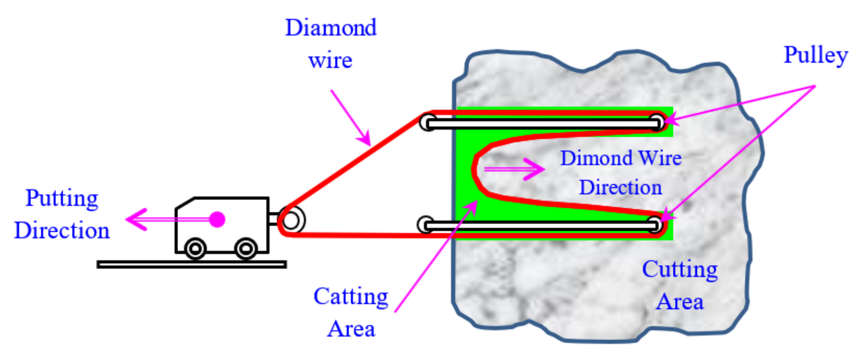


Figure 2. One-dimensional rock cutting by diamond wire cutting in a tunnel [30].

2.1. Traditional drilling

Hardness and abrasion are key factors in rock drilling and cutting [31]. Abrasion significantly affects the drilling speed in rocks. Rock abrasion can be defined as the erosion or removal of surface particles due to contact and friction [32, 33].

Today, the diamond wire-cutting is widely used to grind, cut, and shape rocks in mines in many countries. An increase in the efficiency of cutting wire reduces the total cost of rock extraction, so researchers in the rock industry always try to identify the factors affecting the cutting process and improve the efficiency of cutting tools [27, 29, 34]. The steps of the diamond wire-cutting process are introduced as follows. After deciding on the size of the desired block, an essential step in the cutting process is to select the hole locations. In the first step, vertical holes are drilled. The depth of the vertical hole has to be equal to the step height (4-5 meters). Then two mutually perpendicular horizontal holes are drilled such that the three holes (one vertical hole and two horizontal holes) intersect at the same point, as shown in Figure 3-a. After drilling the holes, the diamond wire is passed through the horizontal holes. The cutting process is started using a cutting machine in the horizontal direction to perform the horizontal cutting, as shown in Figure 3-b.

Subsequently, the same process is used for the vertical cut from the top and right open faces, as shown in Figures 3-c and 3-d. Next, the rock block is separated from the quarry using hydraulic bags or lever jacks (Figure 3-e). Moreover, to prevent cracks in the block, soil mounds are used where the block falls (Figure 3-f). After the necessary sizing, the rock blocks are transported to the factory for cutting and sawing [29, 35-37].

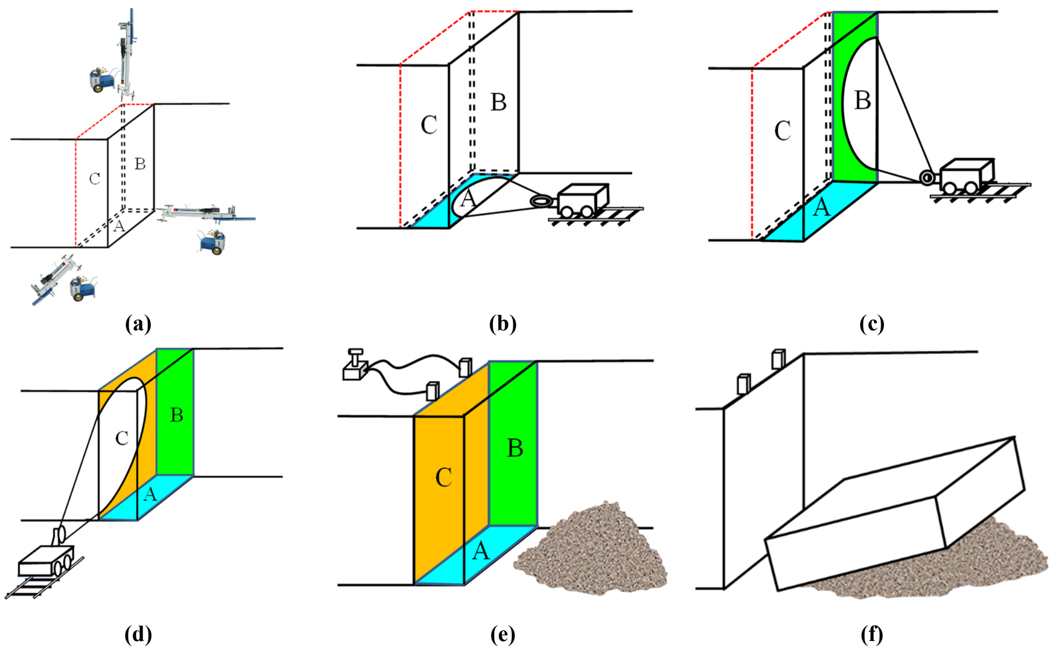


Figure 3. Steps of cutting and extracting rocks: (a) drilling a vertical hole and two horizontal holes, (b) horizontal cutting from the bottom face, (c) vertical cutting from the right face, (d) vertical cutting from the top face, (e) separation using hydraulic bags or lever jacks, and (f) toppling the block over onto a soil mound.

Leveling hose and theodolite techniques are conventionally used to determine the hole locations. The error in the leveling hose technique, traditionally performed by an expert, is very high. Furthermore, the drilling cost is high in this method. The theodolite method also requires a considerable cost and skilled workforce.

3. Proposed Method

In the proposed LTS, an ATMEGA8A microcontroller and a laser rangefinder are used. The laser rangefinder operates based on two techniques: measuring the time of flight of an intense laser pulse from the source to the target and interferometry. According to Figure 4, to design the circuit, the proteus simulator is used, and the clock frequency of AVR is set to 1 MHz. When the light from the laser diode arrives at the surface of the receiver, the program calls the interrupt subroutine, and the timer is activated for three seconds. After three seconds, the buzzer of the device and the second laser are simultaneously triggered, so the operator realizes the proper operation of the device. This circuit uses a PD438C laser receiver, which is biased by a BC547B transistor. The prototype of the circuit is shown in Figure 5.

For spot finding according to Figure 6-A, a laser diode box is assumed at a certain distance from the rock block as the origin of the Cartesian coordinates, so that the box has a direct line-of-sight on both faces of the rock block. Two lasers at the origin can apply mutually perpendicular beams to both the right and left faces at a certain height. According to Figure 6-a, the laser beam is emitted on the right (or left) open face. On the right (or left) open face, a box contains a photodiode and a laser diode; this box is also attached to the level rod on the right (or left) face. Accordingly, once the laser signal is received and the photodiode is activated, the laser diode perpendicular to this laser is activated and shows the desired spot on the rock surface. The spot of the other face can also be determined in the same way. So far, two spots were found on a plane in three-dimensional space so that the drilled holes corresponding to these spots intersect perpendicularly somewhere inside the quarry. The third hole has to be drilled perpendicularly to these two holes such that all three holes meet at the previously determined intersection point inside the quarry with the help of the laser that is directed upward. The desired spot in Cartesian coordinates is obtained, as shown in Figure 6-b.

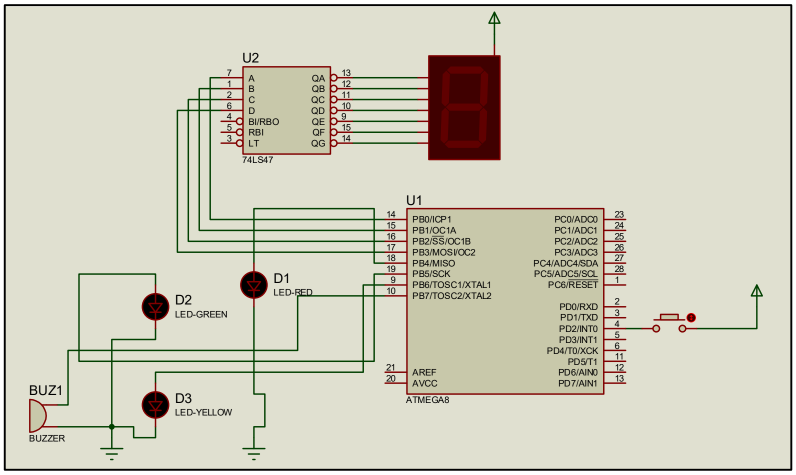


Figure 4. Design of the proposed LTS circuit.

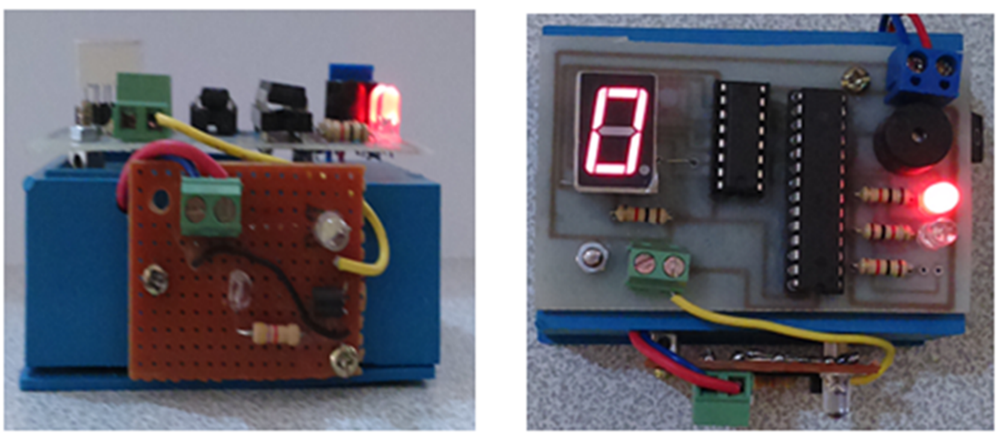
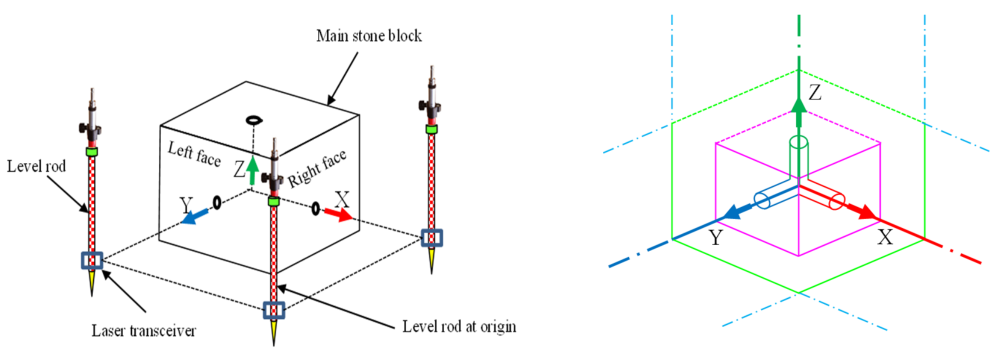


Figure 5. Hardware implementation of the proposed LTS circuit.



(a) **(b)**

Figure 6. Cutting cube generated by the laser beam; (a) laser radiation on the right and left faces, and (b) spot-finding in Cartesian coordinates

4. Comparison of Spot-Finding Techniques and Discussion

The leveling hose and theodolite techniques are commonly used to determine the hole locations. In the present study, the proposed LTS is compared with leveling hose and theodolite techniques (see Figure 7) statistically and experimentally in the Yahya-Abad travertine mine (Natanz county, Isfahan province, central Iran). This study is conducted on rock blocks with dimensions of 10x10x15 m^3 under the same conditions. In the following, AHP and GA are used to compare these three techniques.

(a) (b) (c)

Figure 7. (a) leveling hose, (b) theodolite, and (c) using LTS for spot-finding.

4.1. Analytical hierarchy process

The fuzzy theory provides a basis for logic, control, and decision-making under ambiguous or imprecise conditions and represents qualitative judgments as quantitative values [38, 39]. The fuzzy AHP (FAHP) that was based on the logarithmic least squares method has not become popular due to its computational complexity [40]. In 1996, a comprehensive analysis method was developed [41], and it was recently used in various projects for multi-criteria decision-making. Moreover, the FAHP analysis for mine extraction is presented in Ref. [7] in Refs. [42, 43], AHP is used, and a comparison is made based on TOPSIS to select the best environmental protection method for the reclamation of the Sarcheshmeh copper mine in Iran.

These studies are cross-sectional descriptive surveys with practical feasibility. The data in these studies are initially collected using the survey method, and then field data are collected experimentally. Therefore, AHP is used to investigate leveling hose, theodolite, and LTS as three alternative candidates for spot finding in mines based on nine criteria. These criteria are examined by testing the rock blocks under the same conditions. Then according to the suggestion of experts, the nine criteria are categorized in terms of costs (Table 1), time (Table 2), and accuracy (Table 3). After determining the goal, which is to locate hole positions, the nine criteria influencing the three mentioned techniques are incorporated into the decision tree or hierarchical structure (Figure 8).

The AHP process begins by forming a decision hierarchy that defines the objective of the decision-making process, which in this study is selecting the most suitable drilling method for stone mining. The hierarchy includes three main criteria: cost, time, and accuracy, which are chosen based on expert opinions, empirical data, and the operational requirements of the mining project. These criteria are critical in determining the best drilling method, as they directly impact the efficiency, cost-effectiveness, and precision of the drilling process. The available options for comparison are the leveling hose method, theodolite method, and the proposed LTS. The next step in the AHP process involves conducting pairwise comparisons between the criteria and the available options. For instance, the accuracy of LTS is compared with the accuracy of the theodolite method, and the corresponding weights are calculated. The weight calculation process employs mathematical techniques such as the geometric mean or eigenvector method, which derive the final weights for each criterion and option. These weights reflect the relative importance of each factor in the decision-making process and guide the selection of the most appropriate drilling method. In this study, the accuracy criterion was assigned the highest weight (0.288), followed by device cost and time to implement the top hole, indicating that precision is the most critical factor in selecting a drilling method.

An essential aspect of the AHP method is the inconsistency ratio analysis, which measures the level of compatibility or consistency in the pairwise comparisons. If the inconsistency ratio exceeds a certain threshold, the comparisons are considered unreliable, and the decision-making process may need revisited. The inconsistency ratio is calculated to ensure that it remains below the accepted threshold of 0.1, which indicates that the comparisons are consistent and reliable. In the present study, the inconsistency ratio obtained using the Expert Choice software is less than 0.043, confirming that the pairwise comparisons are consistent and the results are reliable. This low inconsistency ratio validates the robustness of the AHP analysis and supports the conclusion that LTS is the most suitable method for drilling in stone mining applications.

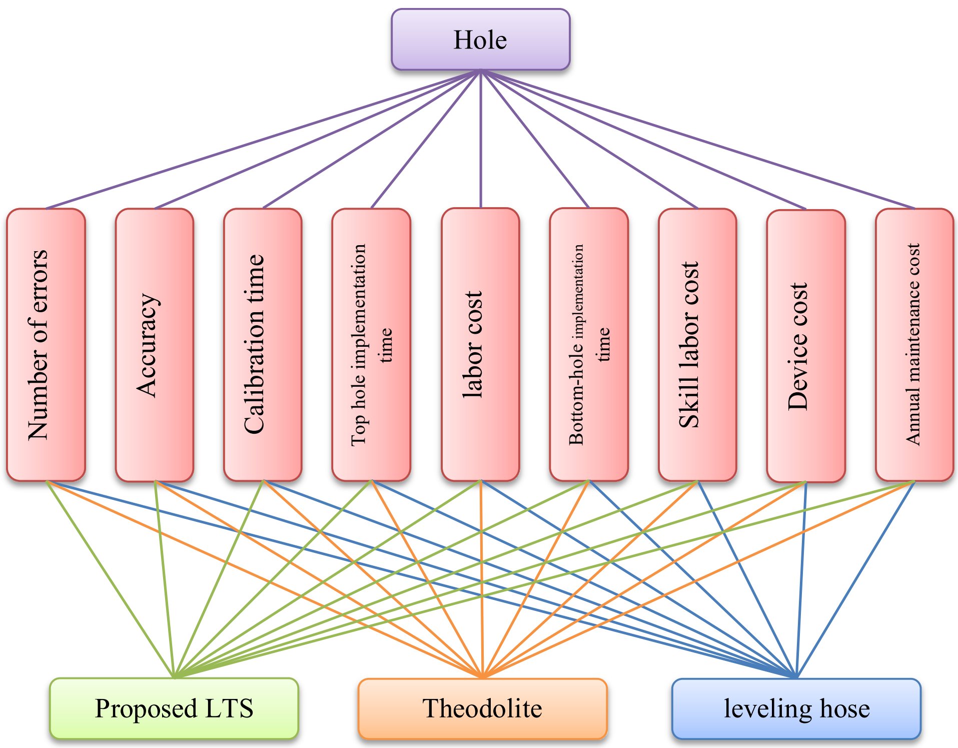


Figure 8. Decision Tree or Hierarchical Scheme for Spot-Finding.

Table 1. Costs.

Proposed LTS	Theodolite	Leveling hose	Parameters	No.
14-20	Not required	3-5	Annual maintenance cost (in dollars)	1
140-195	560-1395	3-5	Device cost (in dollars)	2
Not required	140	Not required	Cost of skilled labor (in dollars)	3
Two people (725)	One person (365)	Two people (725)	Cost and number of workers (in dollars)	4

Table 2. Required time.

Proposed LTS	Theodolite	leveling hose	Parameters	No.
8-13	10-16	25-35	Approximate time to implement the bottom hole (minutes)	1
13-16	16-22	35-45	Approximate time to implement the top hole (minutes)	2
5-10	5-10	5-10	Calibration time (minutes)	3

Table 3. Accuracy.

Proposed LTS	Theodolite	Leveling hose	Parameters	No.
1-2	1-2	50-60	Accuracy (mm)	1
0	0	5-7	Approximate error count per 100 holes	2

The AHP method makes proper decisions for complex problems based on simplification and pairwise comparisons to guide decisions. Therefore, in the present study, the nine criteria are simplified, and the geometric mean, normalized weight, or eigenvector techniques are used for each criterion as shown in Figure 9. According to this Fig, the accuracy criterion has an L of 0.288 with the highest priority, while the annual maintenance cost criterion has an L of 0.026 with the lowest priority weight. After determining the weight of each criterion, the proposed options have to be compared pairwise based on each criterion. Additionally, the inconsistency coefficient is assumed to be less than 0.1 in all stages of pairwise comparisons. After analyzing the Expert Choice software, the sensitivity and contribution of each option are determined based on the measurement of each criterion in Figure 10. Finally, according to Figure 11, LTS, and the leveling hose technique ranks the worst with a total score of 24.9%. Some of the advantages of the proposed LTS for spot finding are as follows: significant cost reduction, prevention of time loss, higher accuracy/sensitivity, requiring fewer workforce, and less human error.

The proposed spot-finding approach enables simpler tracking operations with enhanced accuracy and speed. The results indicate that with a slight increase in cost, there is a significant improvement in speed, accuracy, and overall performance. Compared to other methods, the proposed approach offers low complexity, while maintaining high quality. Experimental results further demonstrate that after implementing the proposed system in a rock quarry, the error approaches zero even without the assistance of an expert surveyor, and the efficiency nearly doubles compared to previously reported techniques.

4.2. Genetic algorithm

The GA method is an eficient algorithm that performs searches based on the natural structure and genetics of living organisms [44]. In this work, GA is applied to evaluate three drilling leveling hose methods, theodolite, and laser, based on cost, time, and accuracy criteria. The goal is to determine the method that provides the best balance among these factors, ensuring optimal efficiency and precision in stone mining operations. GA is particularly well-suited for this task due to its ability to handle multiple constraints and objectives simultaneously, making it an effective decision-making tool for mining applications. The GA process begins by generating an initial population, where each chromosome represents a potential solution that incorporates cost, time, and accuracy parameters for the three drilling methods. The fitness of each chromosome is assessed using a fitness function derived from the weight values assigned by the Analytical Hierarchy Process (AHP). Selection operators such as tournament or roulette wheel selection, are employed to choose the best-performing chromosomes for reproduction. Crossover operators, like single-point or multi-point crossover, recombine genetic material from parent chromosomes to generate new solutions. In contrast, mutation operators introduce random changes to maintain population diversity and prevent premature convergence. The algorithm terminates once predefined criteria-such as reaching a maximum number of generations or achieving an acceptable fitness level-are met.

The results of the GA optimization, as illustrated in Figure 12, confirm that LTS outperforms both the leveling hose and theodolite methods, achieving the best balance between cost, time, and accuracy. This conclusion is further validated by the AHP analysis, reinforcing the superiority of LTS. The integration of GA with AHP in this study not only enhances the decision-making process but also demonstrates the effectiveness of evolutionary algorithms in solving complex optimization problems within the mining industry. By adopting this approach, the research establishes a robust framework for selecting the most efficient drilling method, ultimately improving productivity and reducing operational costs in stone mining operations.

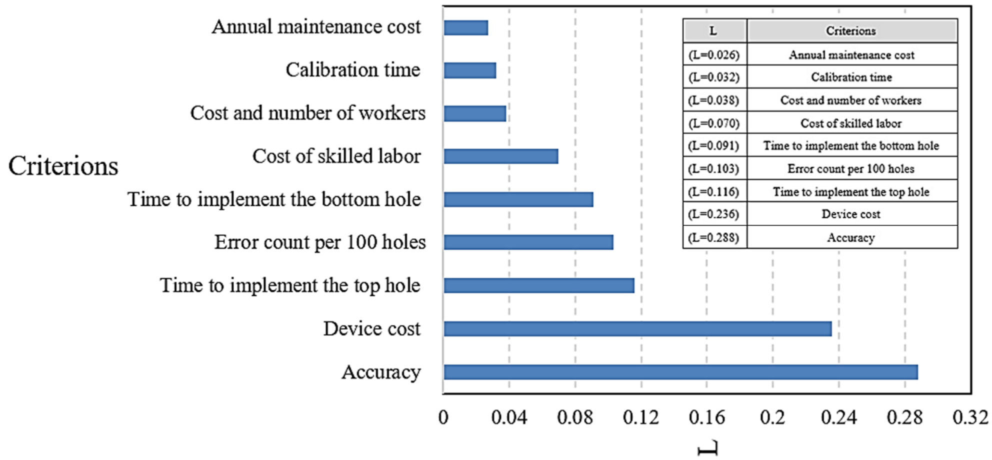


Figure 9. Normalized weights of nine criteria.

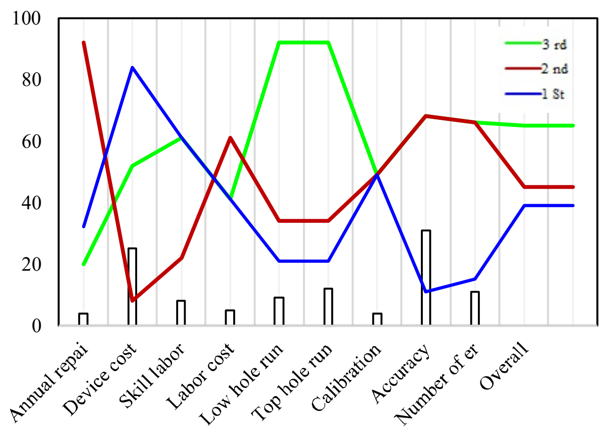


Figure 10. Analysis of the individual and overall scores of alternatives among the nine criteria. The labels 1st, 2nd, and 3rd denote leveling hose, theodolite, and LTS, respectively.

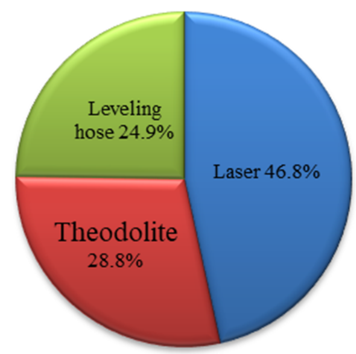


Figure 11. Overall scores of the three evaluated approaches using AHP.

In this work, the input and output data from Tables 1, 2, and 3 were used to generate five figures based on GA analysis in MATLAB software. Figure 12-a illustrates that the leveling hose technique has the highest number of errors per 100 holes, based on field examinations. Figure 12-b and Figure 12-c display the time required to locate the top and bottom hole spots using the leveling hose technique, revealing that this method takes longer than both the theodolite and LTS. Calibration time, another critical parameter, is shown in Figure 12-d, indicating that the calibration times for the theodolite and leveling hose techniques are nearly identical. In contrast, LTS requires significantly less calibration time. Accuracy is the most critical parameter in spot finding due to the high operational costs associated with Russell machines and diamond drills. In AHP, accuracy is assigned the highest weight compared to other criteria. As depicted in Figure 12-e, the accuracy of LTS and theodolite techniques is similar, while the leveling hose technique scores the lowest. The annual maintenance cost analysis, shown in Figure 12-f, indicates that LTS incurs the highest maintenance costs, followed by the leveling hose technique. Notably, the theodolite technique has no annual maintenance costs. Ultimately, based on GA analysis in MATLAB, LTS emerges as the most cost-effective option compared to the leveling hose and theodolite techniques while delivering the highest performance and efficiency. This makes it the optimal choice for precision drilling in stone mining operations.

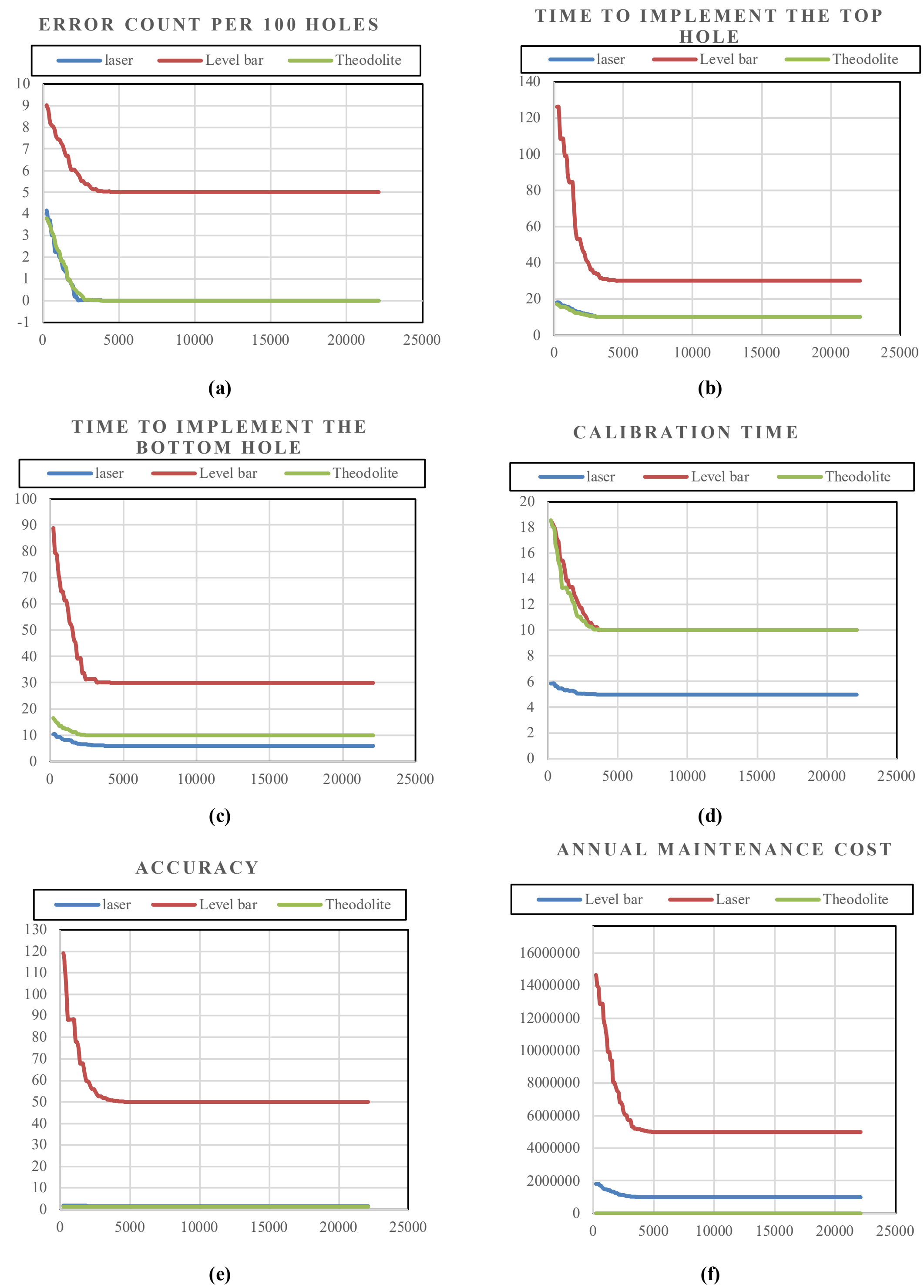


Figure 12. Implementing the three evaluated techniques in GA.

5. Conclusions

In this work, a novel LTS integrated with an AVR microcontroller was proposed to enhance the accuracy and efficiency of drilling operations in rock mining. The system was designed to precisely determine the locations of drilling points in three-dimensional Cartesian coordinates, significantly reducing errors and improving productivity. Experimental results demonstrated that the proposed LTS outperformed traditional methods such as the leveling hose and theodolite, in terms of accuracy, speed, and cost-effectiveness. LTS achieved the highest score (46.8%) in the Analytical Hierarchy Process (AHP) analysis, followed by the theodolite (28.8%) and leveling hose (24.9%) methods. Additionally, Genetic Algorithm (GA) optimization further validated the superiority of LTS, confirming its ability to balance cost, time, and accuracy effectively. The findings of this study align with previous research highlighting the advantages of laser-based technologies in improving precision and reducing operational costs in mining applications. However, unlike earlier studies that focused primarily on theoretical models or small-scale implementations, this research provides a practical, scalable solution that can be readily adopted in real-world mining environments. Integrating AHP and GA in the decision-making process represents a significant methodological contribution, offering a robust framework for evaluating and selecting optimal drilling techniques. Despite these advancements, the study acknowledges certain limitations, such as the initial cost of implementing LTS and the need for further testing in diverse mining conditions to ensure its universal applicability. This research contributes to the growing body of knowledge in automated drilling systems by introducing a cost-effective, high-precision solution that addresses the limitations of traditional methods. By reducing reliance on skilled labor and minimizing human error, the proposed system has the potential to revolutionize rock mining operations, making them more sustainable and economically viable. Future work should focus on optimizing the system for different types of rocks and exploring its integration with other advanced technologies, such as artificial intelligence and IoT, to further enhance its performance and applicability in the mining industry.

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طراحی و ساخت ردیاب برش سنگ با استفاده از فرستنده و گیرنده لیزری در یک روش حفاری نوین مبتنی بر میکروکنترلر AVR

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چکیده:

روش‌های مختلفی برای استخراج سنگ در معادن سنگ ساختمانی به کار گرفته شده‌اند که شامل ماشین‌های برش با سیم، اره‌های زنجیری، اره‌های تیغه الماس، ماشین‌های برش با آب فشار بالا یا واترجت، برش‌دهنده‌های شعله‌ای و دستگاه‌های برش هیدرولیکی هستند. رایج‌ترین تکنیک‌های مورد استفاده در معادن سنگ، برش با آب فشار بالا و برش با سیم الماس هستند که نسبت به روش‌های کلاسیک مانند انفجار کنترل‌شده، مواد منبسط‌شونده مانند کتراک و فرکت، و روش‌های گوه و پتک، پیشرفته‌تر محسوب می‌شوند. پرکاربردترین روش برای برش سنگ‌های مرمر و گرانیت، روش برش با سیم الماس است. در این روش، سیم از میان سه سوراخ متعامد عبور داده می‌شود تا استخراج سنگ به‌صورت بهینه انجام گیرد. موقعیت این سوراخ‌ها معمولاً با استفاده از روش‌های سنتی مانند شلنگ تراز یا گاهی اوقات دوربین نقشه برداری (تئودولیت) تعیین می‌شود. با توجه به دقت پایین روش‌های حفاری متداول، این پژوهش یک سیستم فرستنده و گیرنده لیزری (LTS) نوین را برای تعیین دقیق محل سه سوراخ متعامد و متقاطع در سه صفحه فضایی در مختصات سه‌بعدی پیشنهاد می‌دهد. این روش از یک میکروکنترلر AVR و یک ردیاب لیزری نصب‌شده روی میله تراز برای افزایش دقت و سرعت در عملیات استخراج معادن استفاده می‌کند. این تکنیک باعث کاهش آلودگی صوتی و محیط زیستی، کاهش هزینه‌های حمل‌ونقل تجهیزات و بهبود کلی بهره‌وری می‌شود. آزمایش‌های انجام‌شده در یک معدن نشان می‌دهند که این سیستم حتی بدون نیاز به نقشه‌برداران حرفه‌ای، به‌طور قابل‌توجهی میزان خطاها را کاهش داده و عملکرد بهتری نسبت به روش‌های قبلی ارائه می‌دهد. علاوه بر این، مطابق روش فرآیند تحلیل سلسله مراتبی (AHP)، سیستم LTS بالاترین امتیاز ۴۶/۸٪ را کسب کرده است، در حالی که روش‌های تئودولیت و شلنگ تراز به‌ترتیب امتیازات ۲۸/۸٪ و ۲۴/۹٪ را به دست آورده‌اند.

کلمات کلیدی: حفاری نوین، سیستم فرستنده و گیرنده لیزری (LTS)، سوراخ حفاری، برش با سیم الماس، میکروکنترلر.