Chapter 1

INTRODUCTION

1.1.Background

Underground pillars play a crucial role in the excavation of minerals in underground mining. They are often formed of undamaged ores with no extra reinforcements. However, underground pillars provide interim or permanent support to the weight of the heavy loads acting between the adjacent underground spaces and the roofs of the pit during the excavation of the metaliferrous ores and coal (Salamon,1970; Kostak,1971; Deng, et al. 2003; Brandy and Brown,2003; Tesarik et al. 2009; and Najafi et al. 2011). Every generation of rock engineers has been attempting to find the best methods for effective designs of pillars. However, pillar designs continue to elude perfect solutions that incorporate all the significant factors contributing to the stability mechanics of the pillars. Even interplay of these factors affecting mines pillars mechanics has received constant revision. Recently, mathematical tools and associated software are being successfully deployed in multi-parametric phenomena for assessing their relative impact. Because of the significant increase in ambient loads as mining progresses deeper, the occurrence of the pillar failure becomes more critically frequent. Most of the researchers (Brandy and Brown, 2003; and Deng et al., 2003) have looked and has been given various theories regarding underground mine pillars and their design because of their safety importance in efficient extraction of underground ores. Deterministic (such as empirical, statistical, or analytical) approaches for determinations of the mine pillar stability has been developed over the last few decades. (Salamon,1970; Kostak,1971; and Cauvin et al., 2009).

Typically, pillar design entails predicting the pillars' strength and stress, and then measuring the pillars to ensure that an appropriate margin exists between the predicted pillar strength and stress. By computing the factor of safety (FoS), which is the ratio of the pillar's strength to its stress, the pillar stability can be determined, because the rock's UCS which plays a key role in the pillar instability. Theoretically, a FoS greater than one indicates that the pillar is stable, but a FoS value less than one indicates that the pillar is unstable, (Cauvin et al. 2009). However, these procedures are sometimes questioned because pillar failures have occurred even when the pillars were thought to be stable., i.e., FoS >1. Furthermore, the failure mechanism is not properly explored in current techniques due to nonlinear pillar behaviour under high-stress conditions associated with deep mining.

In the past few years, engineers and researchers have been attracted to machine learning algorithms and statistical tools such as PCA, SSE ANN, etc. These machine learning algorithms, artificial intelligence, and statistical tools have provided lots of positive ideas to researchers in the field of engineering and sciences**.** Machine Learning is an artificial intelligence application in which a computer/machine learns from previous experiences (input data) and prediction of the future has been done. Flow chart diagram of the Machine learning process is shown in figure 1.1. The experiment or learning starts with acquiring or gathering the data and, then it is followed by preprocessing part. After the second step, the model is selected and trained. Further, testing and tuning of the model are done and the last step is prediction or forecast. Basically, Machine learning is categorized into three parts which have been represented as follows. The main types of machine learning are presented in fig 1.2.

a. Supervised learning

b. Unsupervised learning

c. Reinforcement learning,

Supervised learning entails the existence of a supervisor as a teacher. It teaches or trains the machine using well-categorized data, which indicates some of the data has been already marked correctly. Furthermore, the machine has been trained with new data sets, in order to analyze and produce correct results from well-categorized data.

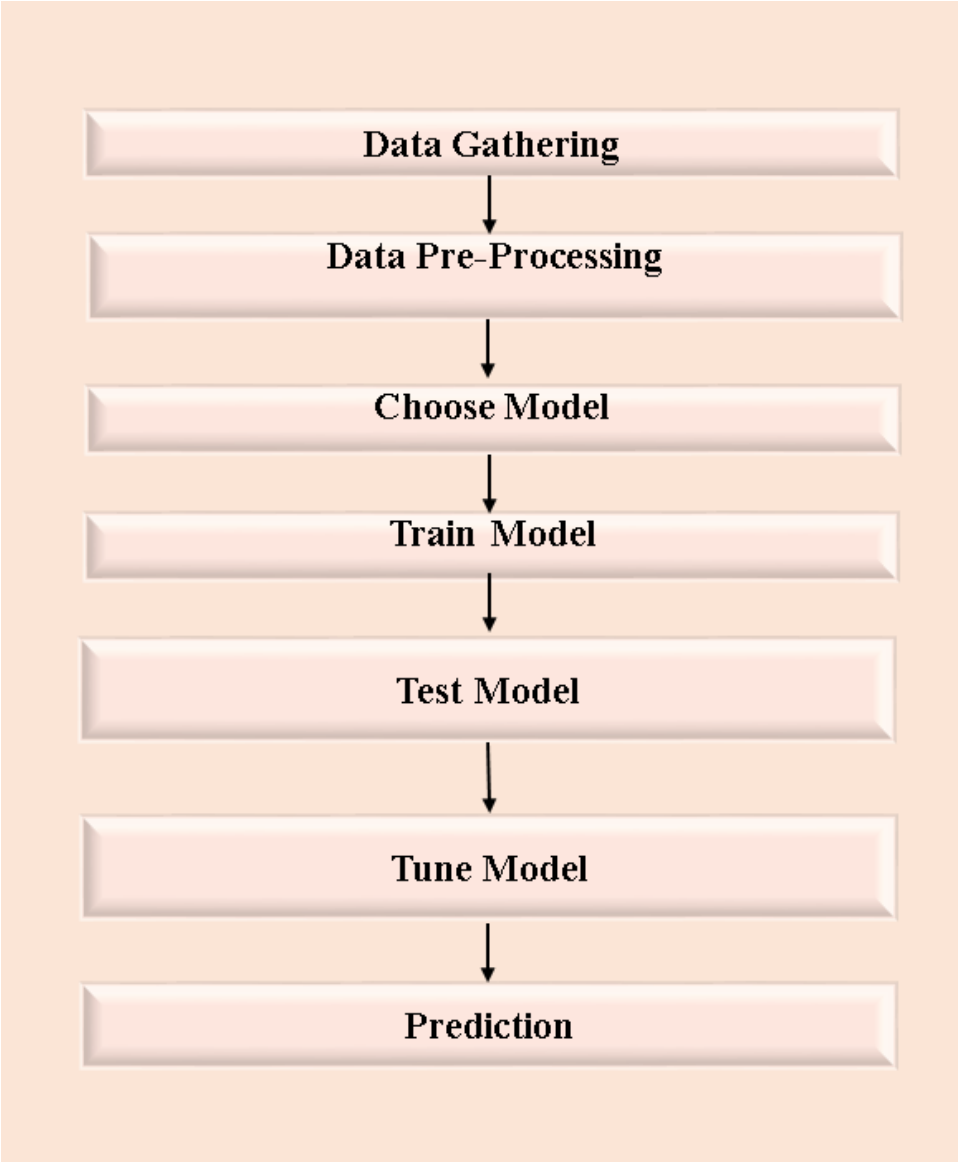

Figure 1.1 Flow Chart of Machine Learning

Supervised learning is divided into two categories of algorithms:

1. Classification: It deals with the separation of data and helps in classification of variables such as black or white, blue or red, coal or wood.
2. Regression: It occurs when output of variable is a real value like rupees or weight.

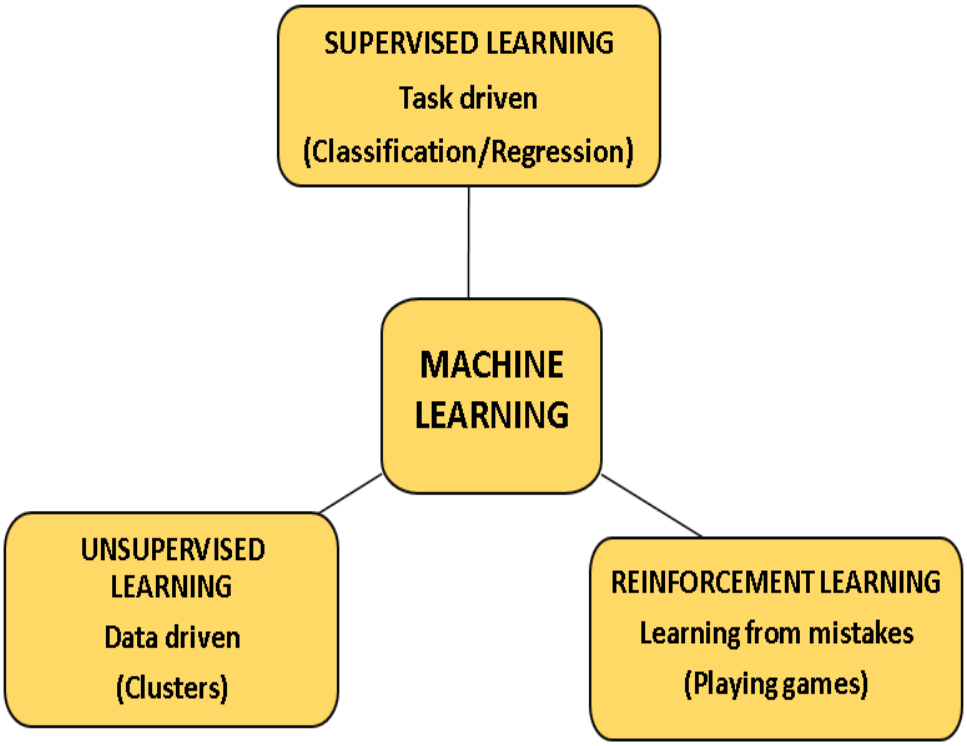

Figure 1.2 Main types of Machine learning

This learning method interacts and learn with categorized data. Supervised reading allows data collection and generating data output from previous experiences. It helps to solve various types of real-world calculation problems. The main disadvantages of this learning are separation of big data sets which requires a lot of calculation and hence takes a lot of time to perform.

Unsupervised learning does not need any supervision. Its algorithm uses that information which is not segmented or categorized .Main function of this learning is to

collect the information based on patterns, similarities and differences without any prior training of datasets. This method is therefore restricted from accessing the hidden structure to data without the labels themselves. It enables the model to work independently to identify previously unseen patterns. Unsupervised learning is divided into two categories:

1. Clustering: Clustering is an unsupervised machine learning approach for discovering and grouping similar data points in huge datasets without regard for the outcome. Clustering (also known as cluster analysis) is extensively used to organize data into structures that are easier to understand and manipulate.
2. Association: Association models allow you to anticipate which elements are most likely to occur together and the strength of their association.

Reinforcement learning explains about taking the essential steps to boost the reward in a particular condition using different software tools and equipment to provide the best solution in a given situation. This learning method is different from supervised learning, as the model in supervised learning has the answer key to training with the correct answer, while in reinforcement learning, reinforcement tools choose what to do for a given task. If datasets are not available it is bound to learn from past experiences.

Key points in strengthening learning -

- Input: It should be the initial state in which the model will start
- Output: Variety of solutions are available for a particular problem.
- Training: Model restores its status and helps user to penalize or give rewards to the model depending on its output.
- Best solution is adopted based on the output.

1.2. Objectives of the study

The primary objective of this study was to determine the applicability of several Machine Learning (ML) methods for predicting pillar stability in underground mining. The collateral objectives were:

- To create a research approach for comparing the performance of several SL algorithms.
- Feature ranking to obtain the discriminating ability of different features in the prediction of pillar stability,
- To investigate the relative importance of influencing variables affecting pillar stability in underground mining,
- To select pillar stability parameters affecting factor of safety by Principle Component Analysis **(**PCA**)** and Step**-**wise Selection and Elimination **(**SSE**)** techniques in underground mines, and
- To develop a suitable model using PCA and SSE for statistical analysis
- Finally, the validation of the obtained equation or model with the remaining data.

1.3. Significance of study

This study attains significance in the light of newer challenges being posed to underground mining. As underground mining is getting deeper, the risk and cost of production are at high risk. To handle these risks, we need to study the challenges posed by the pillars in underground mining and reduce risk factors and increase production. As we are moving into the new digital era, the rise of novel approaches, Artificial intelligence, PCA and soft computing has been entered in every field of research. The

findings of this study through these methods will give valuable ideas in improving the performances of pillar stability in understanding the pillar stability in underground mining, which will further reduce the factor of risk and increase the production of ores.

1.4.Organization of the Thesis

The whole work of this thesis has been divided into six major chapters whose a brief summary has been described below.

Chapter 1 contains the introduction to the problem of pillar stability in underground mines as well as the significance of the study, objectives of the work, and the structure of the thesis.

Chapter 2 of the thesis has a literature review under the broader headings of the factor affecting the pillar stability and pillar design and contemporary issues in pillar design, pillar mechanics involving empirical, numerical, and statistical approaches.

Chapter 3 describes the research methodology, which includes the novel approaches of machine learning for assessment of pillar strength, software used, Artificial intelligence, PCA, and feature selection and elimination parts are also described. The various formula for eestimation of pillar strength and pillar load used in this work are also included.

Chapter 4 of the thesis describes the results obtained through the method applied to the database and its validations.

Chapter 5 contains the discussion of the result, which includes performances prediction of machine learning tools and graphical representation of the ROC curve

obtained, followed by the details of pillar strength model developed through PCA and SSE tools.

Chapter 6 of the thesis provides the conclusions of the work and suggestions for future work.

Further,the thesis has been compiled by references and appendix.