Scientific Approach to Reduce Ground Vibration in Mines due to Blasting

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Abstract

With more and more people coming out of poverty every year, the number of consumers for industrial goods is rapidly increasing. This increase in demand directly affects the source of the industrial goods. The mining sector is showing a slower growth rate than earlier because of various environmental concerns and restrictions coming from governments. This puts impact on the production rate though demand keeps increasing. The easiest and cheapest way of extracting minerals from ground is blasting. Blasting has been in use as a practice of extraction ever since industrialization started. Although it is an easier method, the energy from blasting does cause a number of damage to the environment. As much as 80% of the blast energy goes to waste in the form of heat, noise etc. With such a small fraction of energy only being used, the rest damages the surrounding living and non-living creatures. This is why there have been rigorous researches all over the world dedicated to optimization of the blast designs so as to use the maximum power of blasting in fragmentation and waste the to be minimum. Therefore, it is essential to predict the vibration considering parameters of a blasting operation. There have been many strides in predicting the ground vibration using various regression methods and empirical methods. The empirical methods have become a standard for easy prediction of the ground vibration and design of benches. But the limitation of these empirical methods is that it has been calculated from the blast vibration studies conducted in a particular condition, which may not be suitable for all kind of strata conditions. The ground vibration changes with local strata conditions. Therefore, this paper aims to establish a stringent and novel method to predict the ground vibration using neural networks with the help of various blasting parameters. This paper further show that even with a small sample of data, the accuracy of the ANN is much more reliable than the prediction done with the empirical/conventional predictors currently in use.

Keywords: Ground vibrations, mine environment, artificial neural network

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Introduction

- Blasting is perhaps one of the easiest way of extraction of minerals from the ground
- Easiest doesn’t always mean the cheapest or the most environmentally friendly
- It only uses 20% of it’s energy (at max) for actual fragmentation[2]
- The blast vibration causes the surrounding structures damage and interferes with the wildlife in the surrounding area[3]

- PPV is one of the determining and quantitative factors for measuring the ground vibration.
- There were several input parameters that were responsible for the PPV (Peak Particle Velocity) to vary (like explosive amount, depth of the blast hole, distance of measuring device, stemming length etc.)

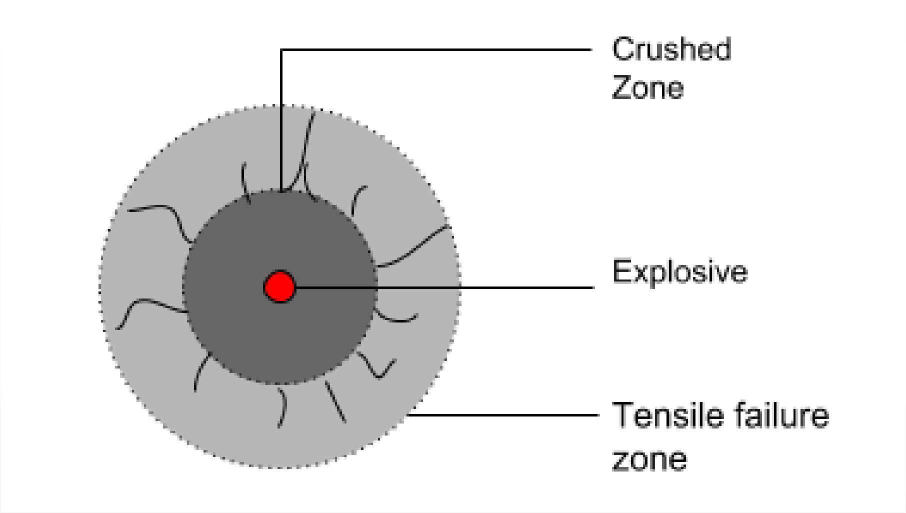

Figure 1: Cross-sectional view of a blast hole

Empirical Predictors

Since blasting is a very complicated procedure and uses extensive amount of energy for little work, there has been many attempts with regards to predict the blast vibration caused given the input parameters

Table 1: Empirical Predictors

Predictor Name	PPV Computation Formula
USBM [11]	$\mathbf{k}\left(\frac{\mathbf{D}}{\sqrt{\mathbf{Q}_{\mathbf{max}}}}\right)^{\mathbf{n}}$
Ambraseys-Hendron [19]	$\mathbf{k}\left(\frac{\mathbf{D}}{\sqrt[3]{\mathbf{Q}_{\mathbf{max}}}}\right)^{\mathbf{n}}$
Langefors-Kilhstrom (Langefors & Kilhström, 1978)	$\mathbf{k}\left(\sqrt{\frac{\mathbf{Q}_{\mathbf{max}}}{\mathbf{D}^{2/3}}}\right)^{\mathbf{n}}$
Indian Standard [20]	$\mathbf{k}\left(\frac{\mathbf{Q}_{\mathbf{max}}}{\mathbf{D}^{2/3}}\right)^{\mathbf{n}}$
Roy/CMRI [12]	$\mathbf{n}+\mathbf{k}\left(\frac{\mathbf{D}}{\sqrt{\mathbf{Q}_{\mathbf{max}}}}\right)^{-\mathbf{1}}$

Artificial Neural Networks

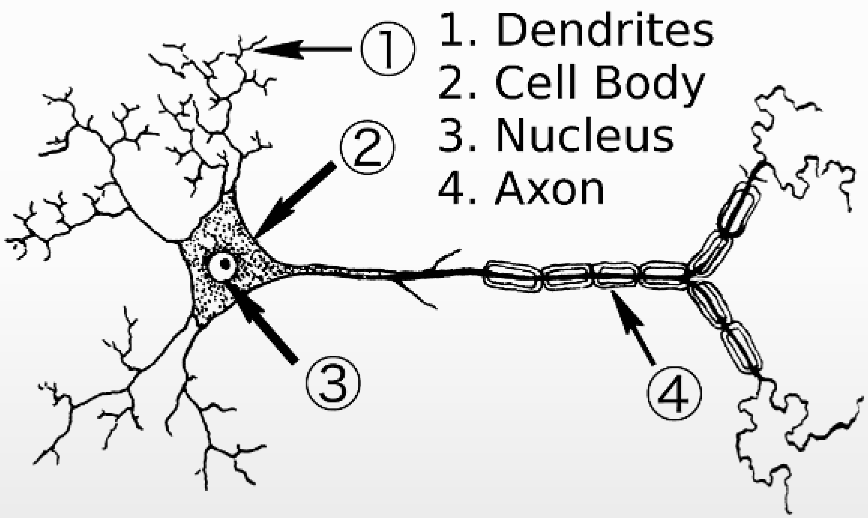

Figure 2: Schematic of a neuron

- It follows the architecture of human brain by connecting different nodes through neurons for computation
- The nodes replicate the dendrites of a neuron and the neuron itself is replicated by the connection between the nodes

- Out of several input parameters from the investigations, nine input parameters were chosen in order to predict the PPV
- The PPV was predicted using different number of nodes in the hidden layer and the hidden layer with 12 nodes gave the best and most accurate result

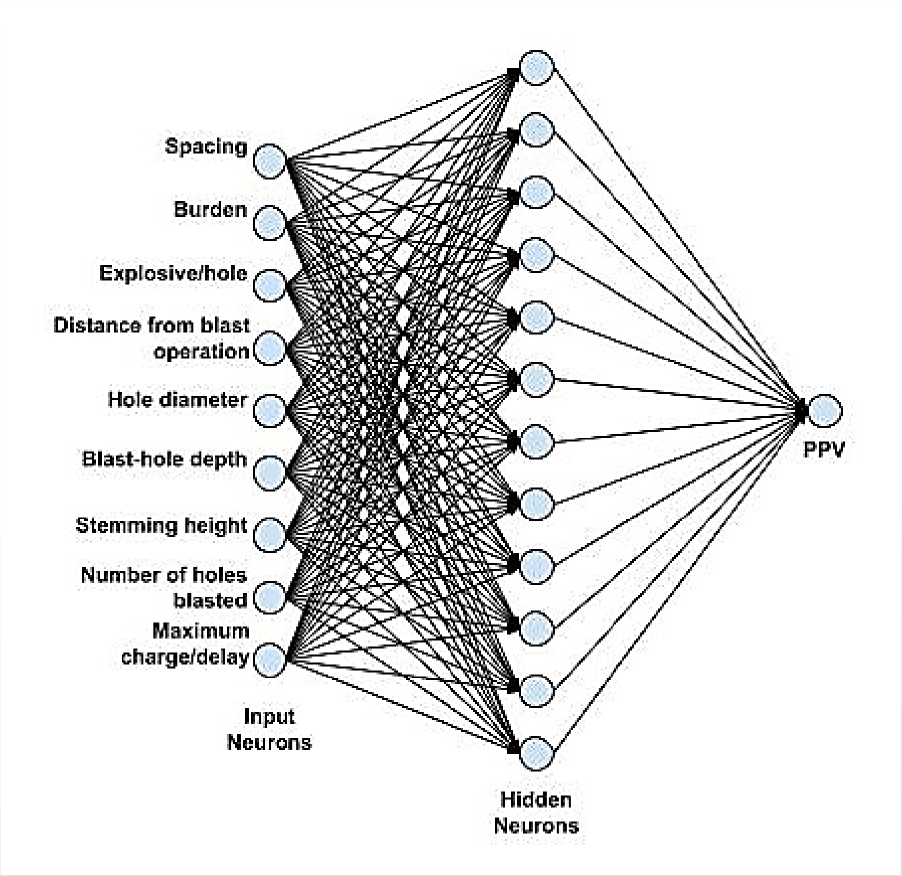

Figure 3: Neural network architecture used in the study

Observation

Table 2: Parameters chosen and their ranges

Parameters		**Range**
Input Parameters	Spacing (m)	2.5-3
	Burden (m)	3-3.5
	Explosive per blast-hole (kgs)	15-34
	Distance from blast site (m)	65-220
	Blast hole diameter (mm)	110
	Blast hole depth (m)	6-10
	Stemming height (m)	2-4
	Number of holes	30-140
	Maximum charge/delay (kgs)	450-4760
Output Parameter	PPV (mm/s)	0.02-17.47

- The ANN has shown a very good fit for the PPV
- Even with a very small sample data, ANN has proved to be a much capable predictor

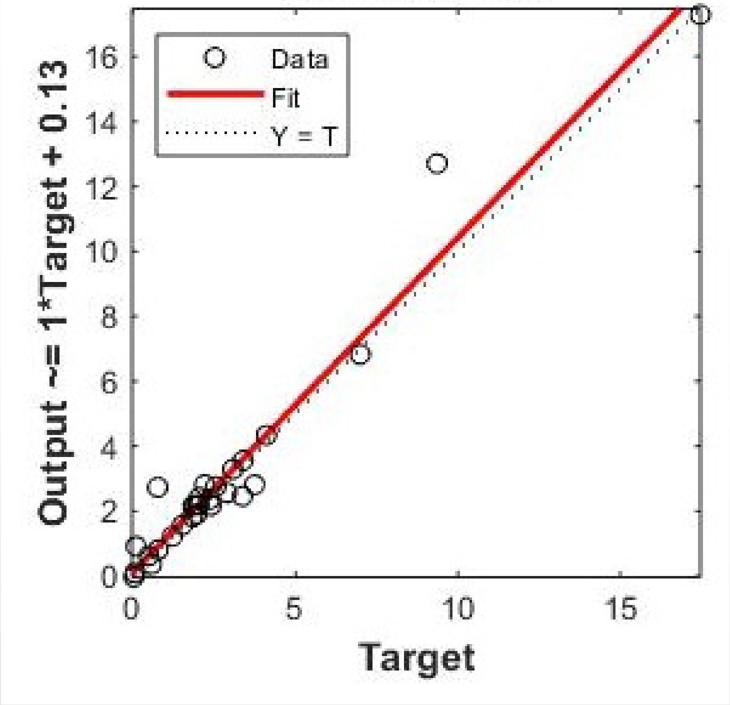

Figure 4: Neural network prediction results

Table 4: Comparison of prediction results from empirical formulae and ANN

Predictors		R^2	**MAE**
Empirical Predictors	USBM	0.67	0.65
	Langefors-Kilhstrom	0.73	0.85
	Ambraseys-Hendron	0.62	0.83
	Indian Standards	0.74	0.85
	Roy/CMRI	0.56	0.77
ANN	Bayesian Regularization	**0.94**	**0.34**

Conclusion

- The limitation of the empirical predictors is that they depend only on two parameters
- These traditional predictors vary with different sites/locations
- The neural network has performed with a much better accuracy with an R^2 value of 0.94
- The ANNs are versatile and can perform in a variety of problems

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Thank you