Predicting Geological Material Types Using Ground Penetrating Radar

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Abstract

This paper presents a new machine learning feature extraction methodology for the identification of material transitions in a lateritic bauxite deposit using ground penetrating radar (GPR). Our feature, Gaussian Ridge Extraction (GRE), quantitatively outperforms typical feature extraction processes whilst providing qualitatively useful results.

Introduction

Mineral reserve location and estimation are vital processes in mining operations. As an alternative to the destructive, and expensive exploratory drilling, we seek to use Ground Penetrating Radar (GPR) to assess bauxite mineral reserves.

In normal GPR applications, bauxite reserves are estimated by identifying the signal amplitude spike that occurs at the boundary between bauxite and a lower ironstone waste material. The amplitude of this spike is a function of boundary starkness. At this paper's site the transition line is unusually indistinct and intermixed (Figure 1) resulting in a largely absent amplitude spike, rendering current methods unreliable.

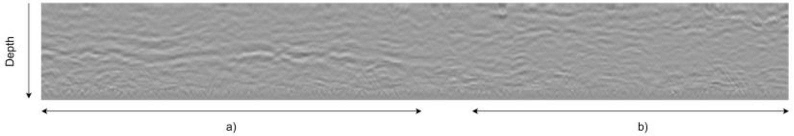

Figure 1: An example of GPR signal data, a) highlights a rare area of GPR data with a somewhat clear transition line with visual amplitude spikes, and b) depicts a more common area where there is no obvious transition line.

Methodology

In this paper we seek to overcome the problems with this site through the implementation of a novel feature extraction algorithm, the GRE, and compare the results with more common feature extraction processes, such as RMS, wavelet decomposition and multi-signal feature fusion.

To test feature performance each GPR signal is divided into segments, features are extracted and classification models to identify whether each segment is either Ironstone or bauxite, with a transition line identified as a by-product.

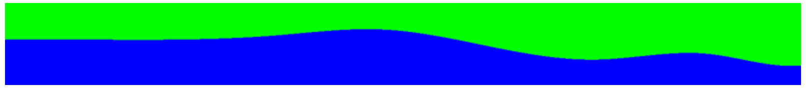

Figure 2: Identified ground truth created using exploratory hole data, blue is ironstone and green is bauxite..

Gaussian Ridge Extraction

The GRE algorithm operates by identifying clusters of small, non-visual amplitude spikes which occur near the transition zone. These spikes can be identified and chained together to form an approximated transition line. This process takes place over three steps, seen in Figure 3. The output of the algorithm is then converted into features and fed to models for training and testing.

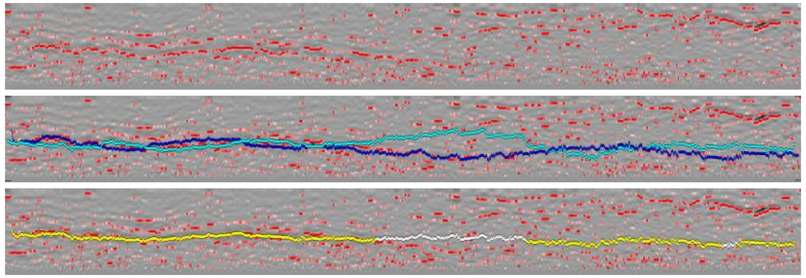

Figure 3: The three steps of the GRE algorithm. First, non-visual peaks are identified and ordered via prominence. Second, forwards and backwards passes are used to chain peaks together using a gaussian distributed weighted voting system creating an approximated transition line. Finally, the two approximated transition line are compared, with different features being generated based upon if the two lines differ greatly at a specific point (white), or if they are similar (yellow).

Results

Figure 4 shows the results of models trained on some common feature extraction processes. Each of these processes achieved similar performance levels, with each having close to 50% accuracy. Qualitatively these models were not effective at identifying a transition line with outputs being little more than white noise.

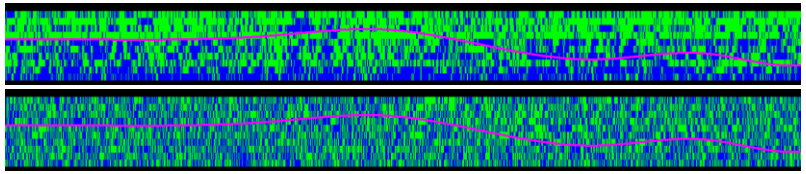

Figure 4: Qualitative output of the common Wavelet and RMS feature extraction processes, which show no evidence of transition line identification. The ground truth transition line is shown in purple.

Figure 5 shows the qualitative output of the GRE algorithm, and other features selected by a DEFS algorithm. This feature resulted in models with an average accuracy of 87% accuracy, a significant increase over the 50% achieved by previous feature extractions. Qualitatively it is clear that the GRE algorithm can predict a transition line to an acceptable degree. This shows that the GRE algorithm can identify transition line where other extraction processes cannot, likely due to the chaining together of subsequent non-visual amplitude spikes.

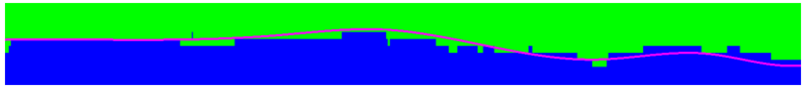

Figure 5: Qualitative output of the GRE algorithm, combined with other features, showing strong evidence of transition line identification.

Conclusion

In this paper we have presented a novel feature extraction method which is qualitatively and quantitatively superior to existing extraction processes. Future work may involve further developing the GRE and applying it into regression algorithms.