Image Analysis of Salt Deposits.

Dane Lee with Prof. Robert Todd

A Problem from Kaggle.com

Kaggle.com is a website that hosts machine learning competitions. Large data sets are posted and a question about the data set is posed. The contest is to provide the best possible answer to the question. This particular project is about identifying salt deposits from seismic images. Salt deposits are important to identify as they are associated with deposits of oil and gas.

As the website describes:

> *A seismic image is produced from imaging the reflection coming from rock boundaries. The seismic image shows the boundaries between different rock types. In theory, the strength of reflection is directly proportional to the difference in the physical properties on either sides of the interface. While seismic images show rock boundaries, they don't say much about the rock themselves; some rocks are easy to identify while some are difficult. There are several areas of the world where there are vast quantities of salt in the subsurface. One of the challenges of seismic imaging is to identify the part of subsurface which is salt. Salt has characteristics that makes it both simple and hard to identify. Salt density is usually 2.14 g/cc which is lower than most surrounding rocks. The seismic velocity of salt is 4.5 km/sec, which is usually faster than its surrounding rocks. This difference creates a sharp reflection at the salt-sediment interface. Usually salt is an amorphous rock without much internal structure. This means that there is typically not much reflectively inside the salt, unless there are sediments trapped inside it. The unusually high seismic velocity of salt can create problems with seismic imaging.*

The Data

The data for this project is a collection of grey-scale images. The data is further partitioned into two groups: A training data set and a test data set. The goal is to build a mathematical model using the training data set to answer a question and then test your model by applying it's methods to the test data set. Our data set contains around 4000 images each one with a mask identifying the salt regions.

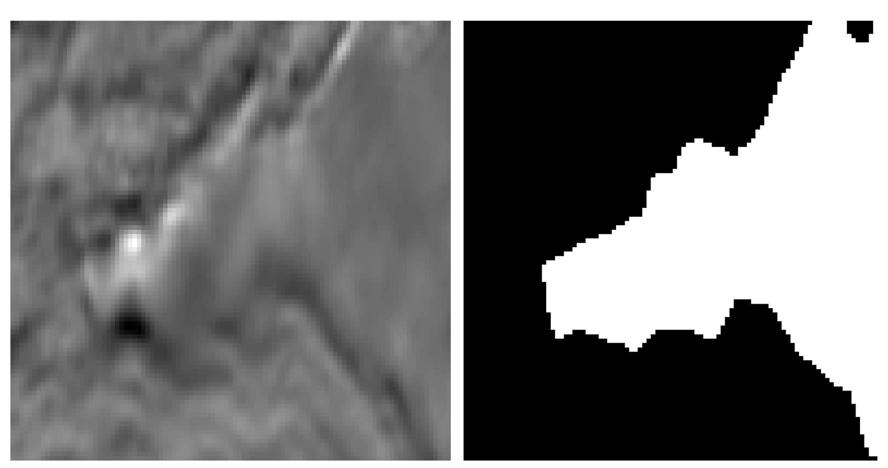

Fig. 1: A sesimc image and it's mask identifying the salt

Here's the questions: *can you identify the regions of salt?*

The Math (mostly hidden)

In order to perform the analysis we attempted to analyze the images according to the *contrast metric*. The contrast metric attempts to measure in a meaningful way the "length" of a group of pixels. In particular the length squared of a 4x4 collection of pixels is given by the following:

$$|v|^2 = \begin{pmatrix} v_1 & v_2 & v_3 & v_4 \end{pmatrix} \begin{pmatrix} 2 & -1 & 0 & -1 \\ -1 & 2 & -1 & 0 \\ 0 & -1 & 2 & -1 \\ -1 & 0 & -1 & 2 \end{pmatrix} \begin{pmatrix} v_1 \\ v_2 \\ v_3 \\ v_4 \end{pmatrix}$$

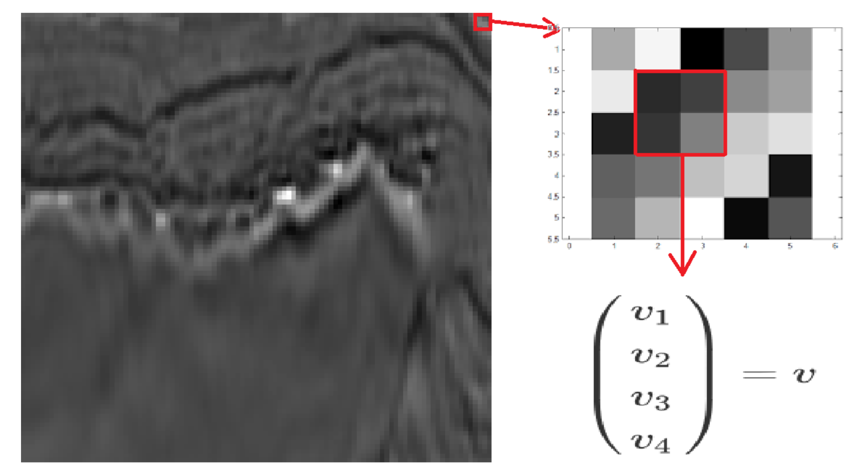

Fig. 2: converting and image to a collection of vectors

However the contrast metric has a peculiar property: it can be diagonalized.

$$\begin{pmatrix} 2 & -1 & 0 & -1 \\ -1 & 2 & -1 & 0 \\ 0 & -1 & 2 & -1 \\ -1 & 0 & -1 & 2 \end{pmatrix} = M^{-1} \begin{pmatrix} 4 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 2 \end{pmatrix} M$$

Further analysis proves that there is a way of mapping 4x4 grid of pixels to a vector of length 1 and then to a *a point on the unit sphere* [1]. Then we convert points on the unit sphere in Cartesian coordinates to spherical coordinates and plot the Euler angles. The result is that every grey-scale image can be converted to points on a plane.

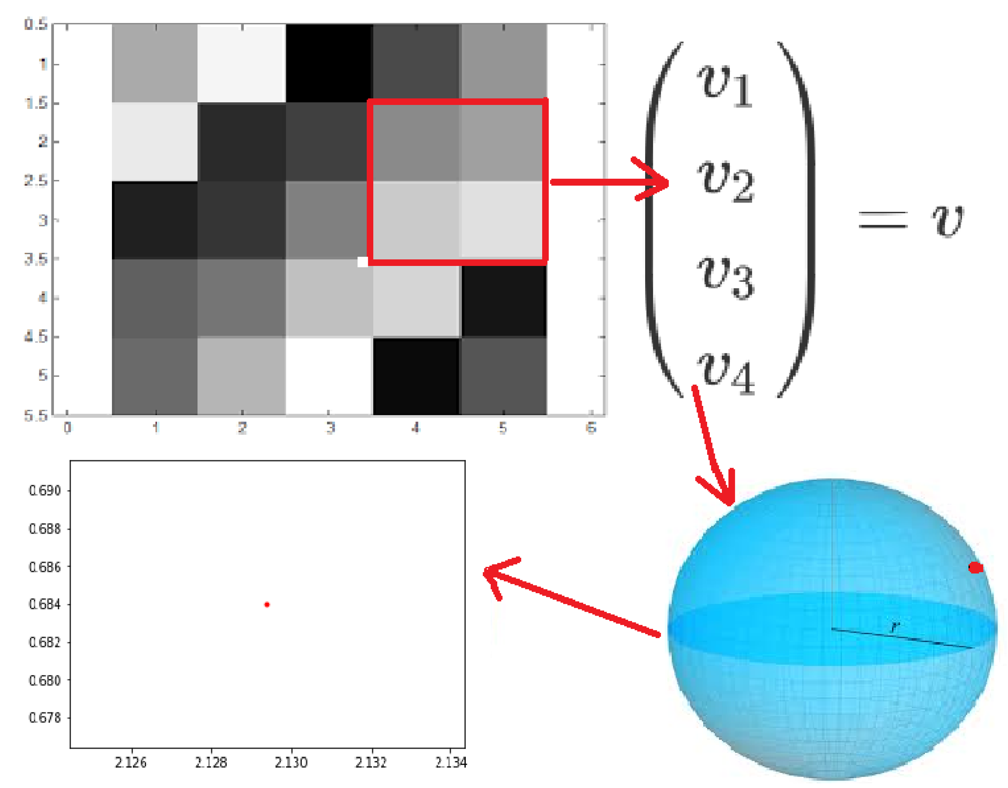

Fig. 3: converting a pixel grid to a point in the plane

Results

We wrote code to render each grey-scale image as a collection of points in the plane.

Fig. 4: A small snippet of the code

Each point represents a 4x4 grid of pixels. The points are color coded according to whether the grid was identified as being composed of all salt (red), no slat (blue), and boundary (black).

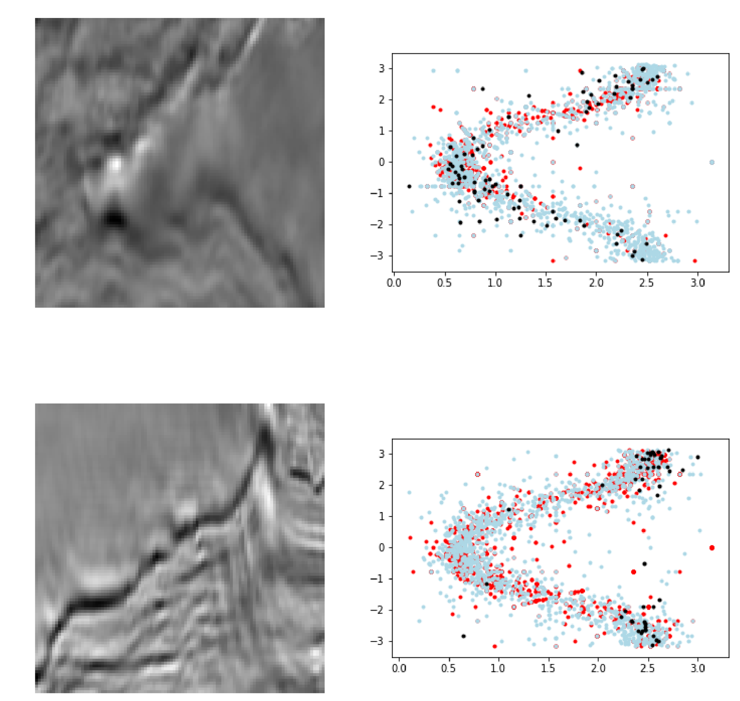

Fig. 6: A pair of seismic images with their computed planar points

Analysis

It was our hope that by looking at the color coded images we could be able to distinguish between the three types of pixel grids: salt, non-salt, and boundary. This didn't happen. Were it not for the color coding one would not be able distinguish any groups of points. However we hope to continue our analysis to perhaps find a solution or to apply our techniques to other data sets.

Acknowledgements

Thanks to the Pathways to Scholarship program for supporting this work

References

[1] Ann B Lee, Kim S Pedersen, and David Mumford. "The nonlinear statistics of high-contrast patches in natural images". In: *International Journal of Computer Vision* 54.1-3 (2003), pp. 83–103.