New Mathematical Methods for Mineral Resources Estimations

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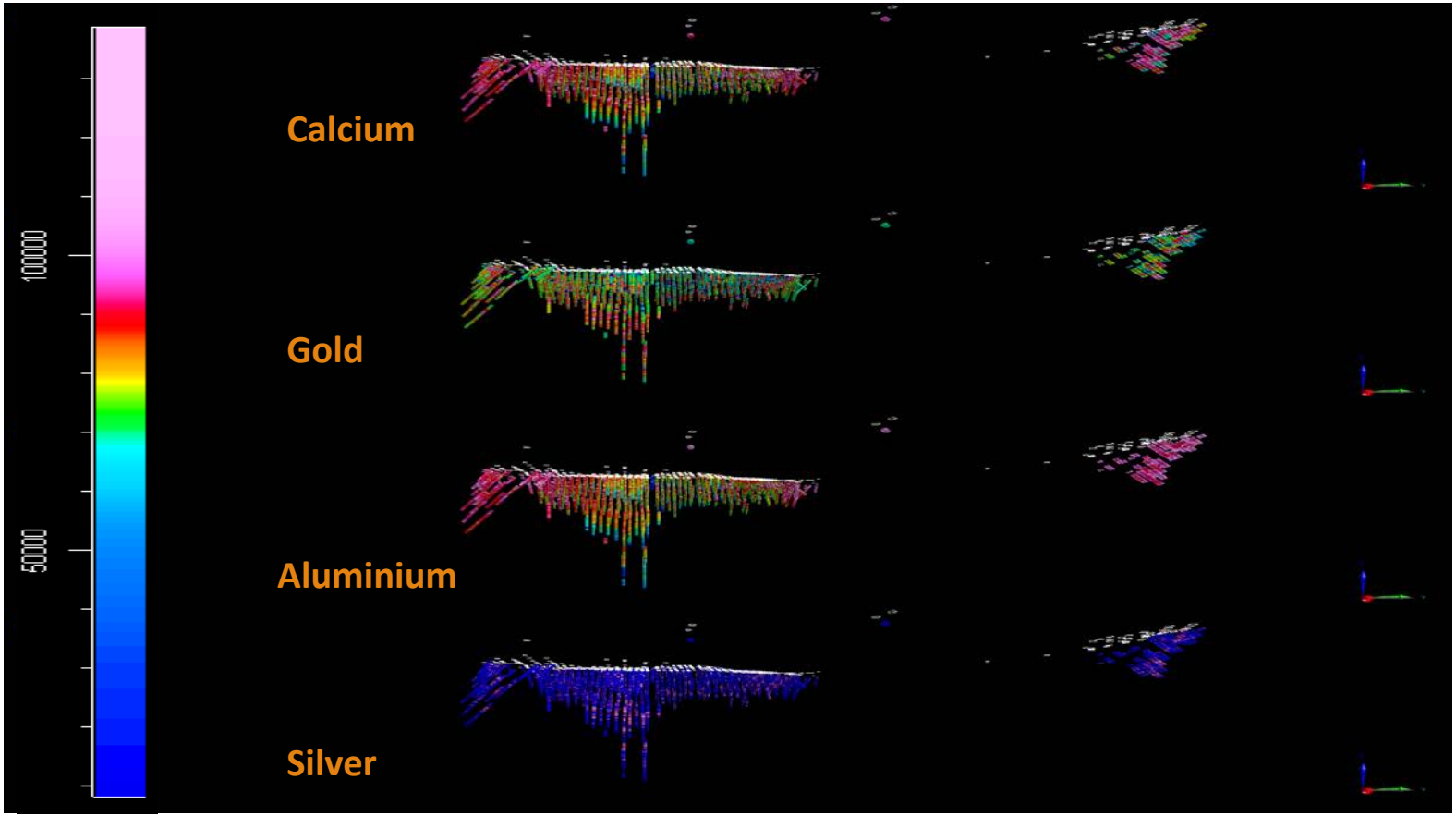
Motivation and Introduction

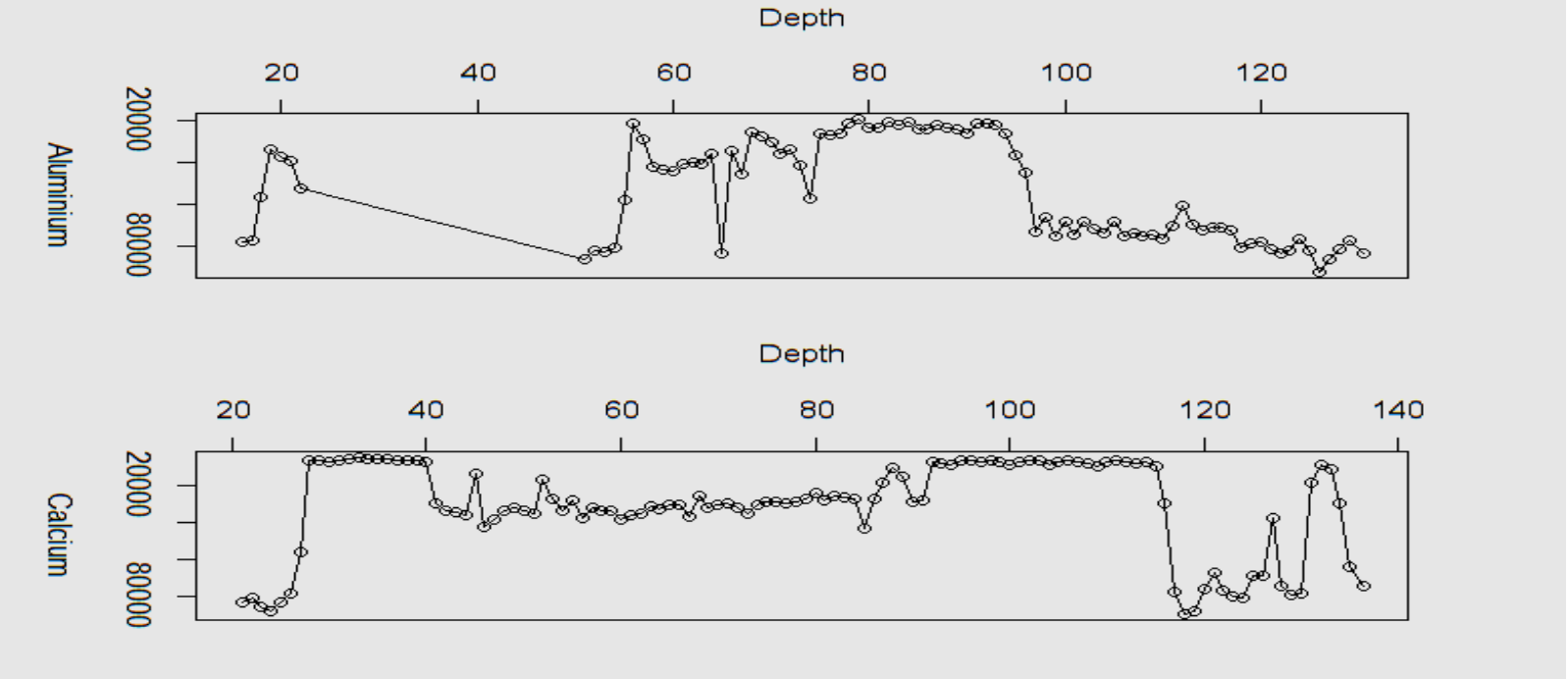
Mineral resources estimations can be divided into two tasks:

1. Assignment of domains: We employ nonlinear time series change-point detection techniques to detect transitions between different geophysical regions within a single drill hole record.
2. Grade estimation and interpolation: We aim to develop a novel ore body model from drill hole data based on minimum description length and radial basis models. This is intended to provide an alternative, parametric, approach to the existing ones (such as Kriging).

DATA



Single Drill Hole Data ("*Time-Series*")



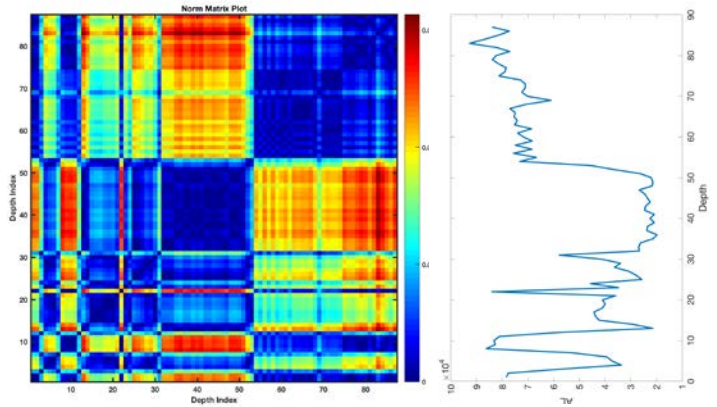
Recurrence plots

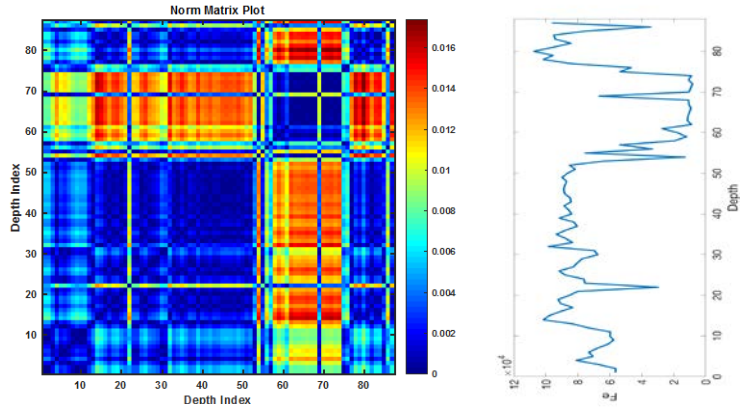
Let $x_t \in \mathbb{R}^m$ be the state of the system at depth (time) $t = 1, 2, \ldots, N$. Construct an $N \times N$ binary matrix A with $a_{ij} = 1$ iff $d(x_i, x_j) < \epsilon$. Here $d(.,.)$ is some norm. If $m > 1$, it probably require to perform some sort of normalisation.

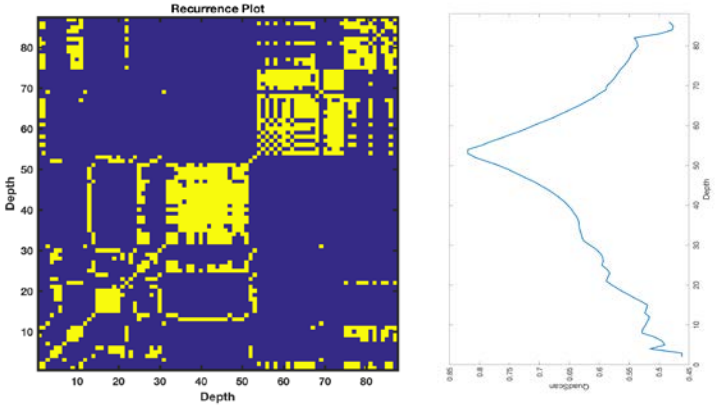
Quadrant Scan

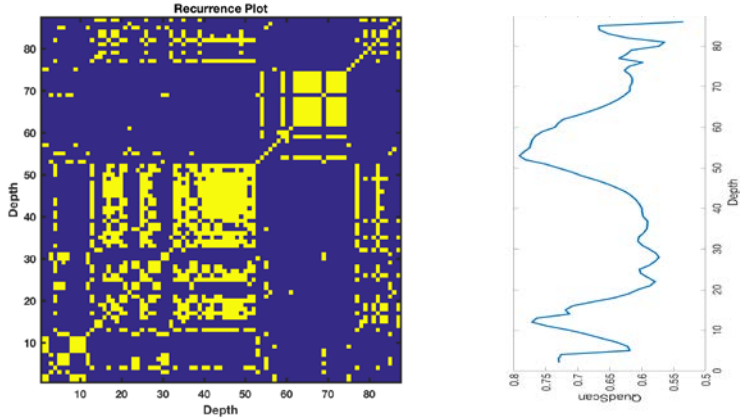
Construct a time series $q(t)$ from the recurrence plot by count the number (fraction) of points that are in the same quadrant (i.e. $d(x_i, x_j) < \epsilon$ and either $i, j < t$ or $i, j > t$) versus those are not (i.e. $i < t$ and $j > t$ or vice versa). Maximum (peaks) of $q(t)$ correspond to shifts/changes in the dynamics (in our case: changes in depth hole characterisation).

Single-variable application

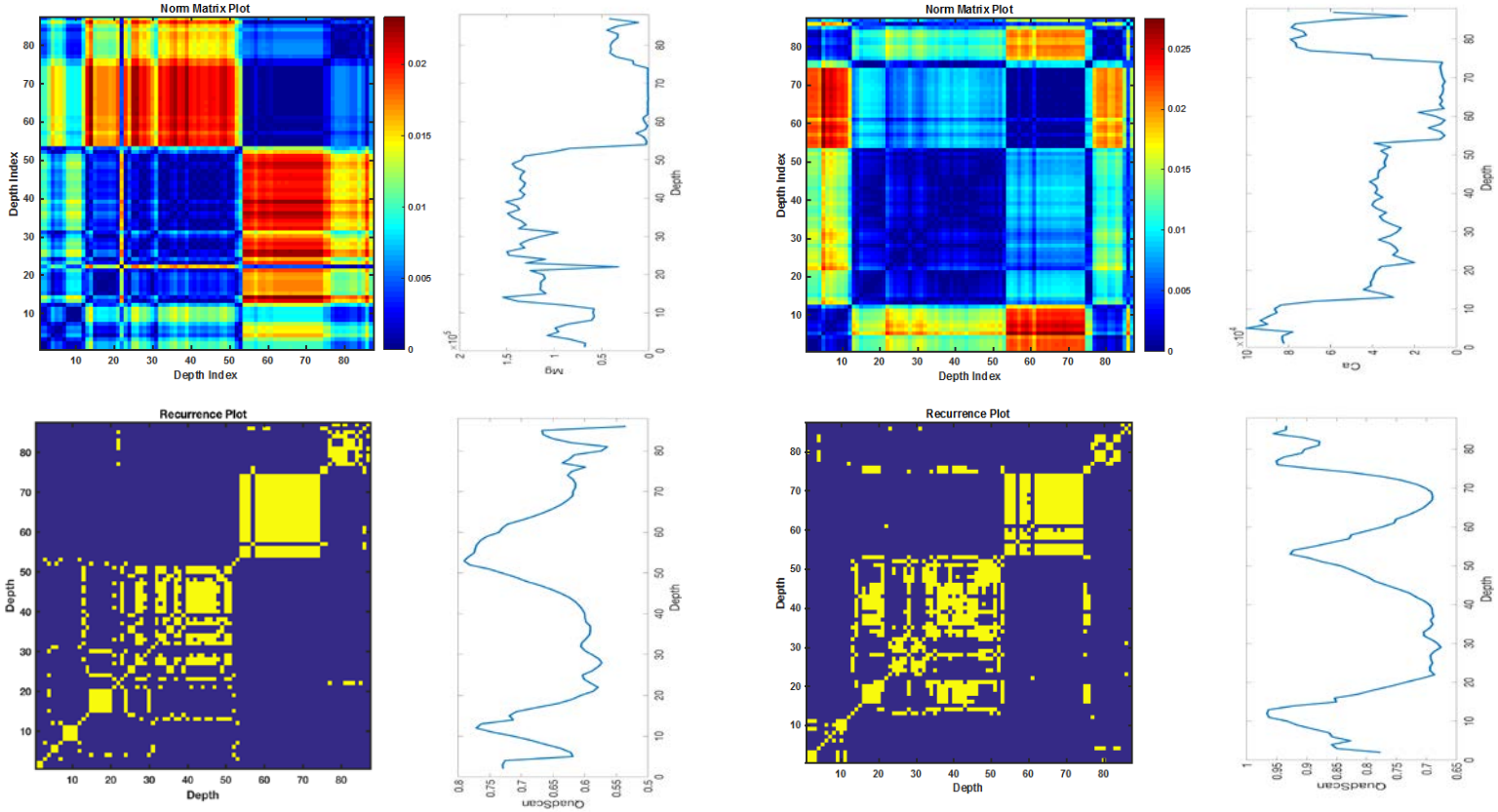








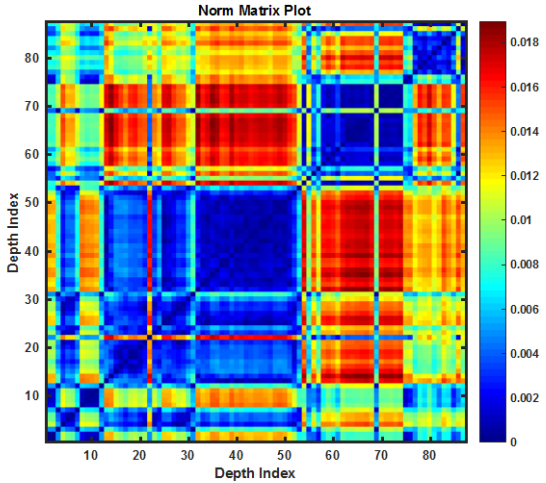
Single-variable application

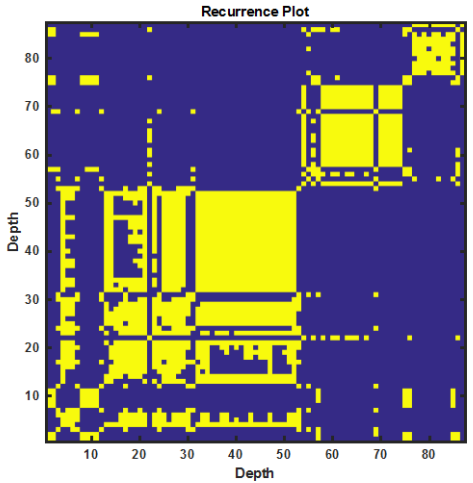


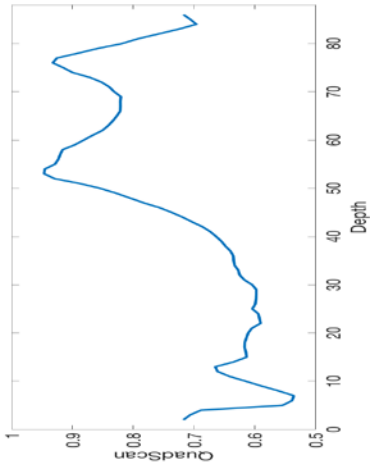
Single-variable application

- Interesting, but is it sufficient?
- Is it an accurate characterisation of the different geophysical regions (layers)?
- Can we do better?
- What if we consider multiple variables?

Multi-variable application

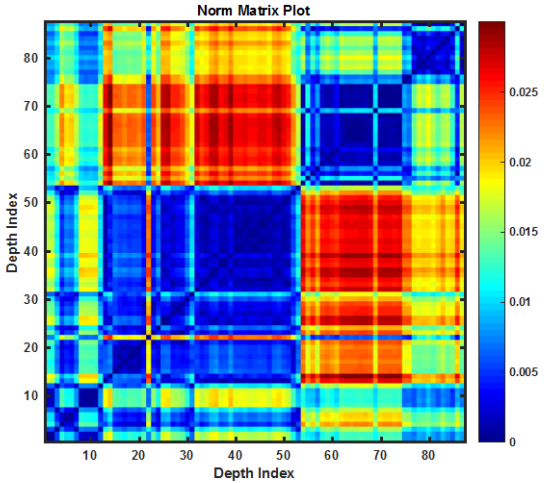


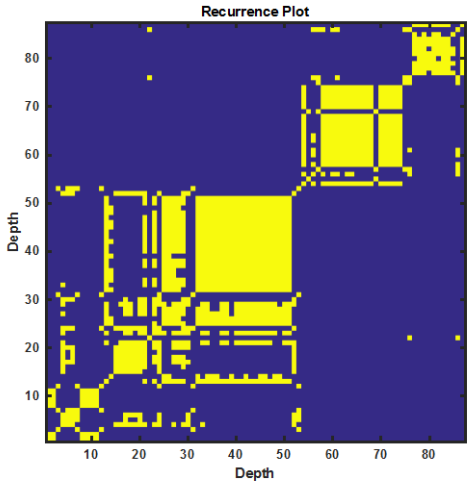


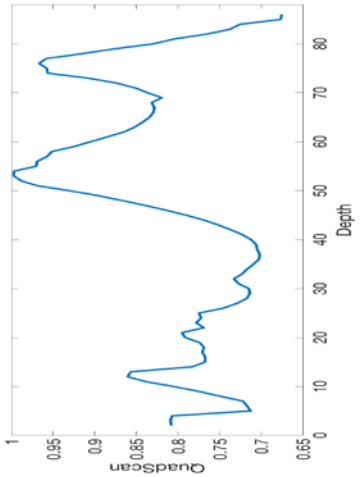


AL + Fe

Multi-variable application

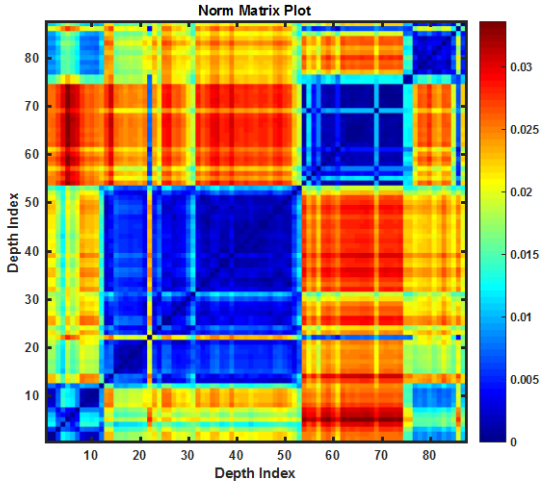


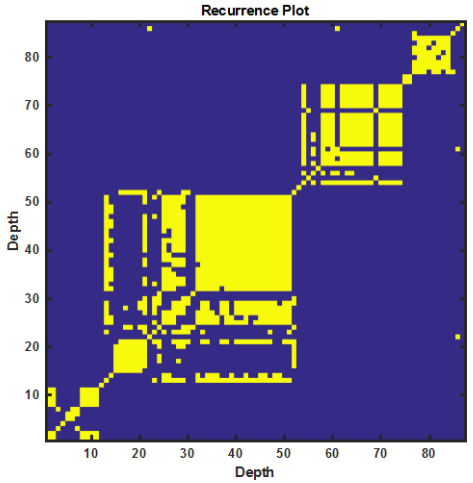


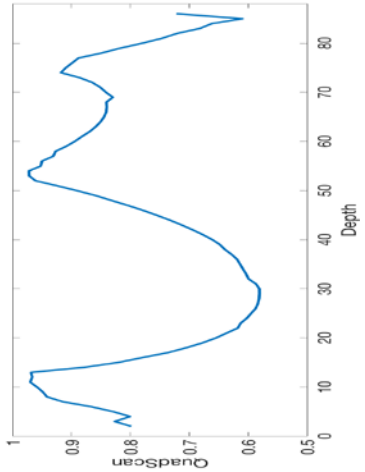


AL + Fe + Mg

Multi-variable application







AL + Fe + Mg + Ca

Conclusion

To Do:

- More analysis on this
- Optimise over choice of metric and embedding and compare to other methods
- Characterise cross-channel relationships via cross recurrence plots
- Build nonlinear models of inter-dependence of variables, within a single characterisation.
- Use these characterisation analysis for the second task (grade estimation and interpolation) to build a “3D” model.
- Apply this to infer structure undercover and extend this to determine optimum hole placement.

Conclusion

Thanks;

- CSIRO team
- UWA team

References

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