Denoising Aerial Gamma-Ray Survey Data with Non-Linear Dimensionality Reduction

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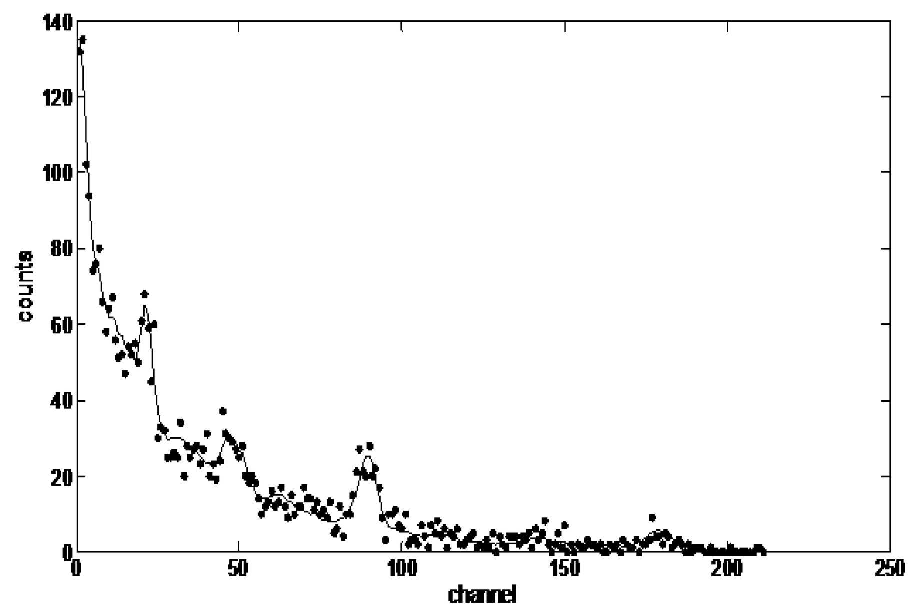
Overview

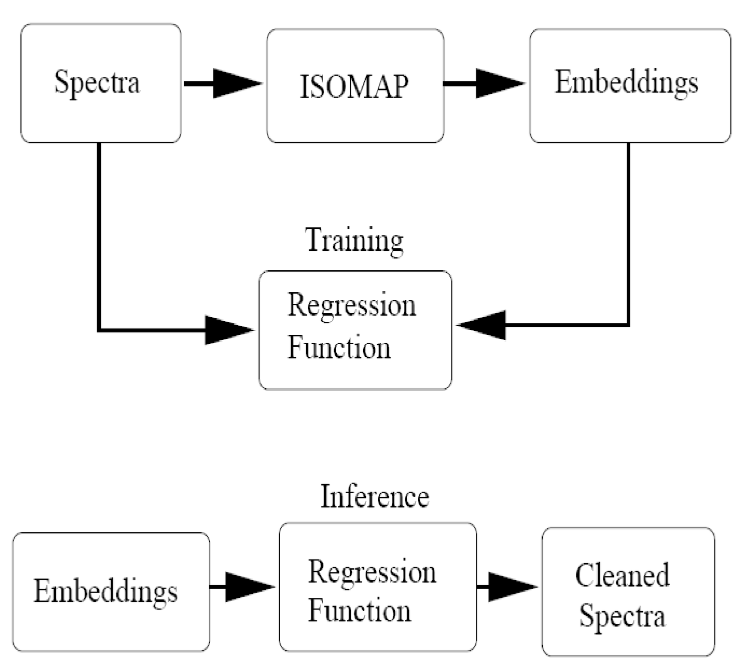
Denoising aerial gamma-ray surveying makes possible the extraction of previously hidden detail. Conventional methods for denoising spectral data make strong assumptions about the levels and type of noise which reduces their efficiency. Non-linear dimensionality reduction casts the problem as manifold learning followed by non-linear regression. The model makes no assumptions about the level and type of noise and performs significantly better than previous techniques on both synthetic and real data. The method works best on uranium channel data and can reveal previously hidden detail in surveys.



Gamma-ray spectra as recorded (.) and after NLDR denoising (--)

Non-linear dimensionality reduction (NLDR)

NLDR can be used to compute the underlying structure of the data. The steps in the process are illustrated below.



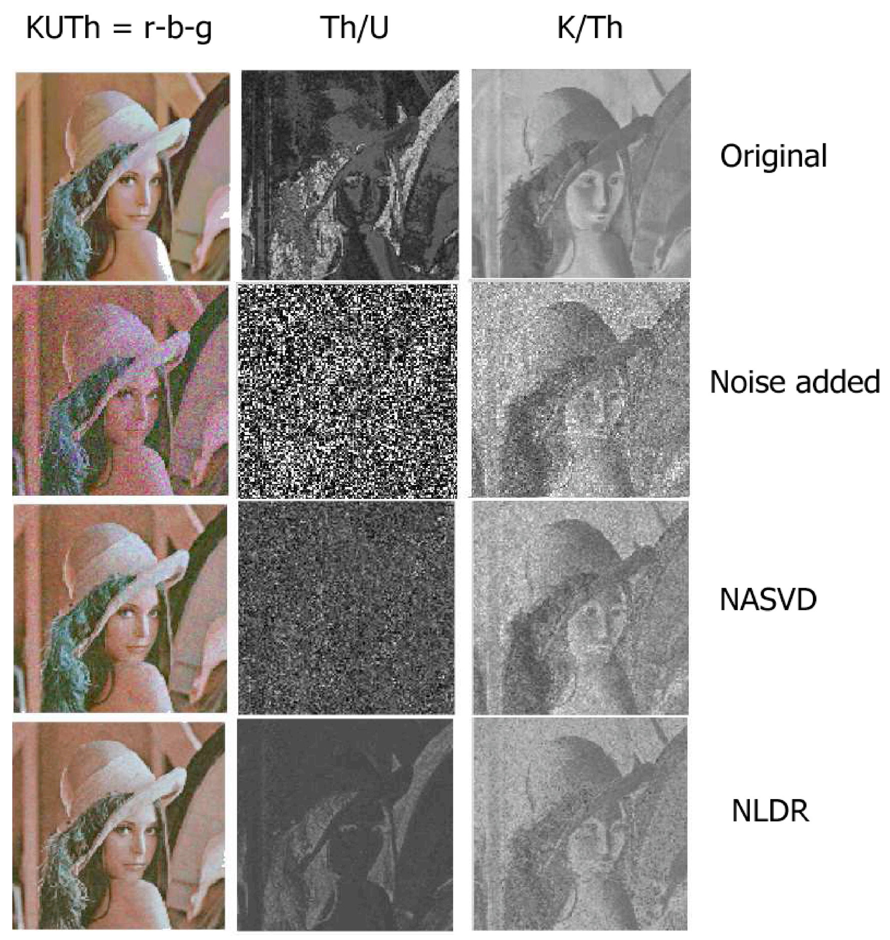
Denoising algorithm.

First, Landmark Isomap is applied to obtain low-dimensional embeddings for the spectra. The original data in conjunction with low-dimensional points is then used to train a non-linear regression model from high to low dimensional spaces. The regression model then converts the embeddings to denoised spectra.

Synthetic data

A synthetic survey for this study was prepared using nearly pure spectra of K, U and Th measured within three 200-litre calibration sources. A coloured image was used to represent the K, U and Th distributions in the survey with the red-blue-green colours taken to represent the different amounts. A stretch was applied so that Th/U ratios were in the range 3.5 to 5.5. Poisson noise was added to each data channel of each spectrum.

The images obtained by processing this data set are shown right. The ternary colour K-U-Th images obtained by either NASVD or NLDR are similar but much cleaner than those derived from the noisy data. A similar result is obtained for the K/Th ratio images. However, major difference are seen with the Th/U ratio images. The noise-added data produces a very noisy Th/U ratio image in which no detail can be seen. The NASVD method reduces the noise but fails to reveal the underlying detail in the ratio. NLDR processing brings out the major features, which results from an underlying cleaning of the U data.



Effect of NASVD and NLDR denoising on the synthetic data derived from the Lena image.

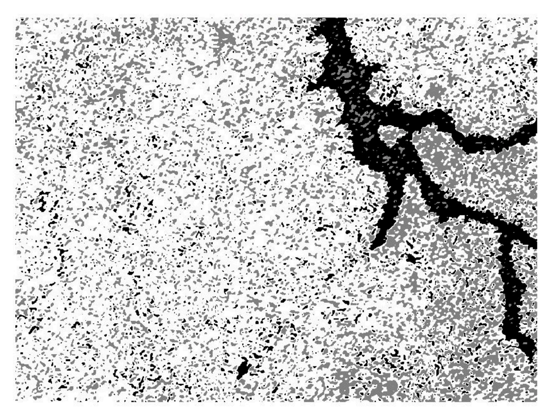
Real survey 1

A recent aerial survey was reprocessed to evaluate the effectiveness of the NLDR method. The survey used 16 liter crystal volume mounted in a helicopter and was flown with 25 m flight line spacing at a nominal ground clearance of 40 m. Total survey area amounted to 4,462 line kilometres.

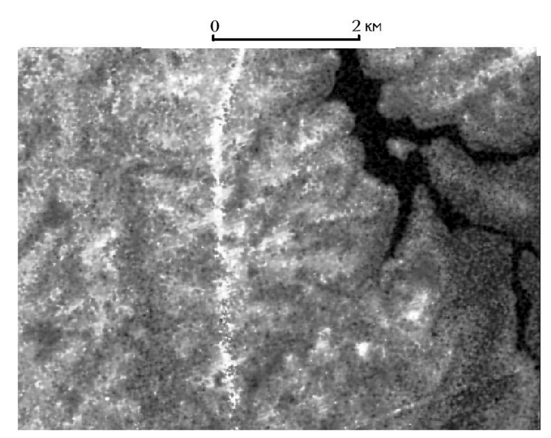
The area comprises sandstone of the Sydney Basin. The terrain over the area is moderately steep, with some heavily forested areas. Surface features of the area are some deeply incised gorges, one of which is flooded as part of a water storage dam, a track along a pipeline and a row of large power lines. All of these are oriented approximately north-south.

The NLDR processing yielded a Th/U ratio image quite different from that with NASVD (see right), mirroring the revelation of extra detail obtained with the synthetic survey above. The Th/U ratio calculated after NASVD processing shows no structure, apart from the lake which appears black, whereas that obtained after NLDR processing shows many variations including a north-south line of higher ratios.

This line is coincident with the power-line that traverses the area and appears to be an artifact, resulting from the helicopter rising to a height of 80 m from an average elevation of 40 m to clear the line. However, it illustrates the ability of NLDR-cleaned data to reveal small changes in Th/U ratios.



Th/U ratio after denoising with NASVD



Th/U ratio after denoising with NLDR

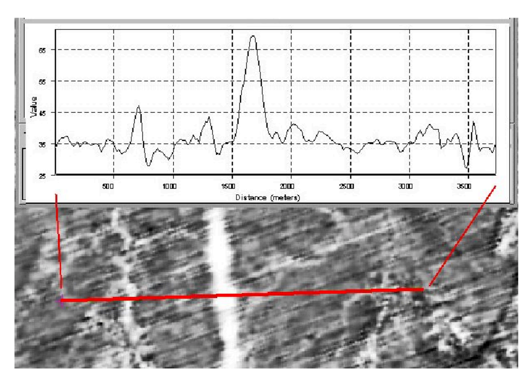
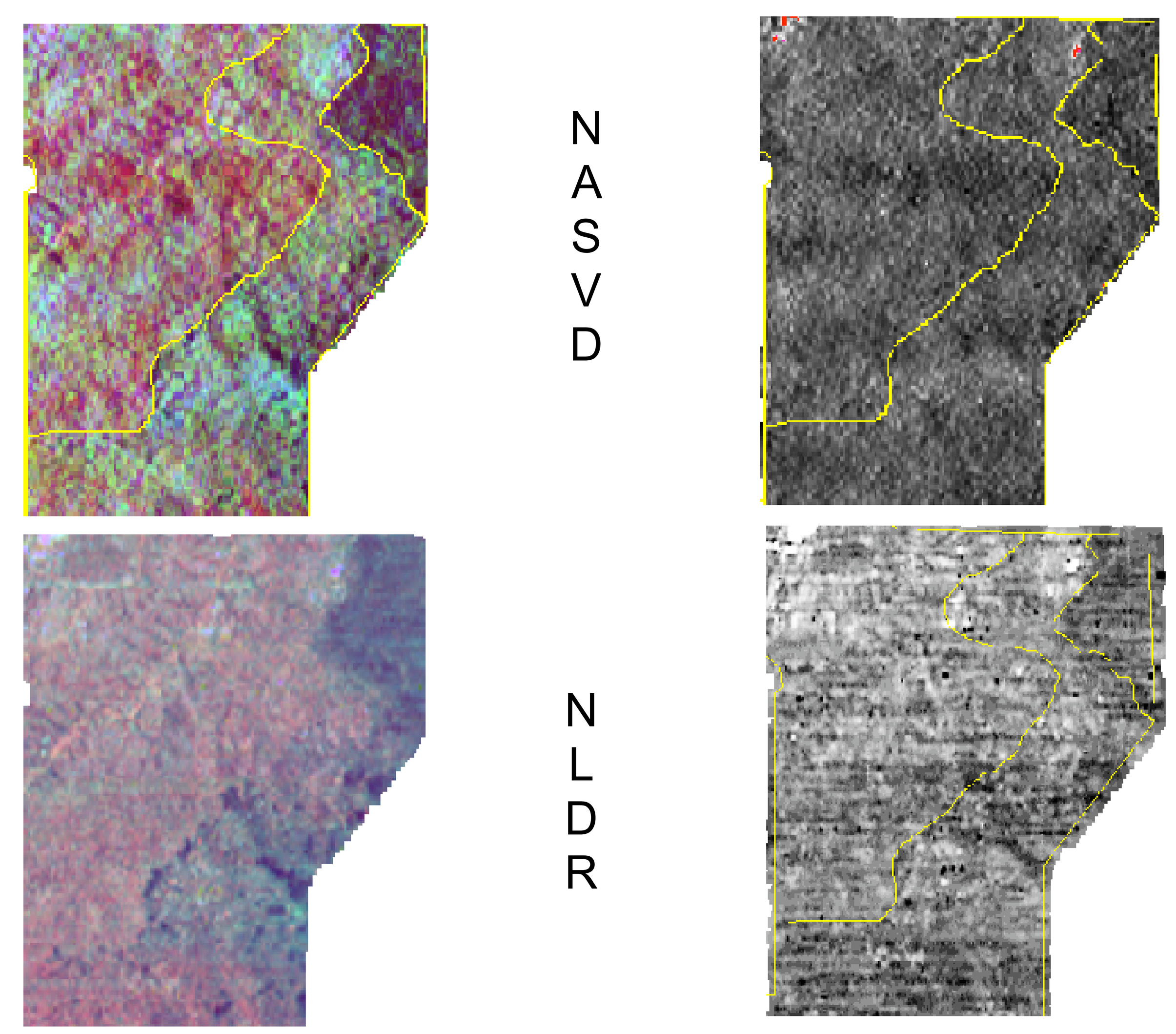


Image of radar altimeter (background) with profile across the location of the power lines

Real survey 2

Another recent survey conducted in the search for U was reprocessed using NLDR. The area consisted of scrub-covered rolling ground. The ternary image with NLDR has more subdued colours than that obtained with NASVD but shows a greater clarity for features such as a river that runs across the upper right of the images.

The U*U/Th image for NLDR shows a number of anomalies in the upper section of the illustrated area, indicative of U. This ratio emphasises areas with both high U and a high U/Th ratio. Field work has shown near-surface U to be present in both areas.



K-U-Th = r-b-g **U indicator U*U/Th**

Conclusions

NLDR processing can generated noise-reduced data for the U and Th channels revealing, in particular, more detail in the Th/U ratio images. This has been demonstrated with both synthetic and real data. The use of Th/U images is a major tool in the exploration for uranium and gold and for revealing fine detail in mapping geology, particularly around igneous bodies. The NLDR method thus should be of major benefit to users of aerial gamma-ray survey data.

Acknowledgment

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