Improving MRS Classification of Children's Brain Tumours Through Wavelet De-Noising

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Background and Objectives Magnetic resonance spectroscopy (MRS) provides useful diagnostic information for children's brain tumours. However, low signal-to-noise ratios (SNR) continue to be a severe limitation for this technique particularly for paucicellular tumours which are common in children. Wavelet de-noising has met with success in improving SNR for a range of signals but its use in this field of MRS has not yet been reported.

Materials and Methods As true metabolite concentrations are unknown for clinical data, the initial assessment of wavelet de-noising was carried out using simulated spectra. MRS was initially simulated using the Versatile Simulation, Pulses, and Analysis (VeSPA), mimicking clinically acquired MRS of three tumour types including ependymomas (EP), medulloblastomas (MB) and pilocytic astrocytomas (PA). Eight levels of Gaussian white noise with a SNR ranging from 5 to 20 were added to simulated spectra. Clinical MRS was acquired using Siemens 1.5 T scanners with the SVS PRESS (TE=30ms, TR=1500ms) at Birmingham Children's Hospital. Scans acquired up until Jun 2017 with a total of 57 cases including 15 EP, 20 MB, and 22 PA. All datasets have been previously implemented and validated. Both the continuous wavelet transform (CWT) and the continuous wavelet packet transform (CWPT) with thresholding as global and level dependent were implemented to MRS in the time domain (FID) data. Evaluation was achieved through quantification using TARQUIN 4.3.10, which provides metabolite concentrations, SNR, absolute and percent standard deviations, residual SNR and full width half maximum (FWHM). Metabolites were assessed using the bias between true and estimated concentrations for simulated data. Classification was achieved through the combination of principal component analysis for dimension reduction and linear discriminant analysis on the whole MRS spectra. Classification accuracy was obtained by a leave one out cross validation.

Results Application of wavelet de-noising to simulated data shows significant improvement on signal quality using CWT instead of CWPT, and demonstrates that level-dependent thresholding achieves noise removal with uniform distribution on the frequency. Results of simulated experiments showed an increase in SNR, given by Table 1. These results were mirrored in the clinically acquired MRS data. As is shown in Figure 1, classification of clinical MRS data without wavelet de-noising gave an error of misdiagnosis of 15.8% when all metabolites and 14 principal components were included. Error of misdiagnosis for the de-noised MRS was decreased to 12.3% with the first or second level of decomposition although increased to 17.5% for the third level.

Conclusion The CWT significantly improves the accuracy of quantification for clinically acquired MRS. The findings of this research demonstrate the potential of functional imaging in paediatric brain cancer diagnosis with the assistance of machine learning.

	Noisy	LoD=1	LoD=2	LoD=3
EP	18.43	18.92	21.12	26.87
MB	14.93	14.31	16.31	20.76
PA	29.83	29.51	33.47	39.91

Table 1 Averages signal-to-noise ratios of noisy and de-noised MRS based on all cases involved in this study. LoD=level of decomposition, EP=ependymomas, MB=medulloblastomas, PA=pilocytic astrocytomas.

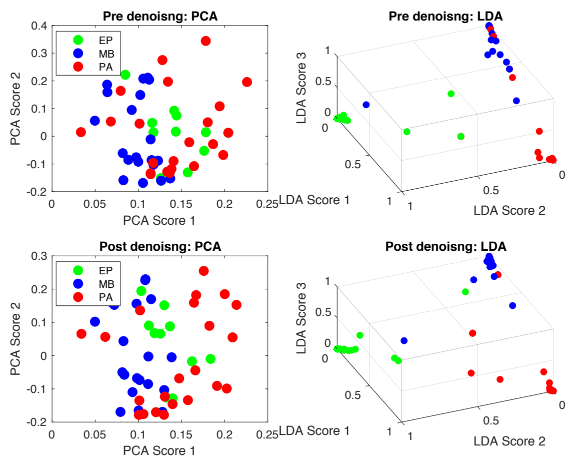

Figure 1 Classification performance of de-nosing using principal component analysis and linear discriminant analysis, employing 14 principal components and 2nd level of decomposition.