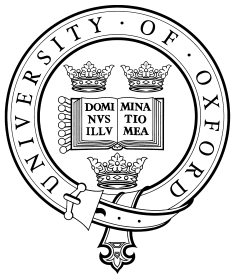
Signal Processing Methods For Cerebral Autoregulation

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This thesis is submitted to the University of Oxford, for the degree of Doctor of Philosophy. This thesis is entirely my own work, and, except where otherwise indicated, describes my own research.

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Abstract

Cerebral autoregulation describes the clinically observed phenomenon that cerebral blood flow remains relatively constant in healthy human subjects despite large systemic changes in blood pressure, dissolved blood gas concentrations, heart rate and other systemic variables. Cerebral autoregulation is known to be impaired post ischaemic stroke, after severe head injury, in patients suffering from autonomic dysfunction and under the action of various drugs.

Cerebral auto-regulation is a dynamic, multivariate phenomenon. Sensitive techniques are required to monitor cerebral auto-regulation in a clinical setting. This thesis presents 4 related signal processing studies of cerebral autoregulation.

The first study shows how consideration of changes in blood gas concentrations simultaneously with changes in blood pressure can improve the accuracy of an existing frequency domain technique for monitoring cerebral autoregulation from spontaneous fluctuations in blood pressure and a transcranial doppler measure of cerebral blood flow velocity. The second study shows how the continuous wavelet transform can be used to investigate coupling between blood pressure and near infrared spectroscopy measures of cerebral haemodynamics in patients with autonomic failure. This introduces time information into the frequency based assesment, however neglects the contribution of blood gas concentrations. The third study shows how this limitation can be resolved by introducing a new time-varying multivariate system identification algorithm based around the dual tree undecimated wavelet transform. All frequency and time-frequency domain methods of monitoring cerebral autoregulation assume linear coupling between the variables under consideration. The fourth study therefore considers nonlinear techniques of monitoring cerebral autoregulation, and illustrates some of the difficulties inherent in this form of analysis.

The general approach taken in this thesis is to formulate a simple system model; usually in the form of an ODE or a stochastic process. The form of the model is adapted to encapsulate a hypothesis about features of cerebral autoregulation, paticularly those features that may be difficult to recover using existing methods of analysis. The performance of the proposed method of analysis is then evaluated under these conditions. After this testing, the techniques are then applied to data provided by the Laboratory of Human Cerebrovascular Physiology in Alberta, Canada, and the National Hospital for Neurology and Neurosurgery in London, UK.

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