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Evidence-Based Filters for Signal Detection: Application to Evoked Brain Responses

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Template-based signal detection most often relies on computing a correlation, or a dot product, between an incoming data stream and a signal template. Such a correlation results in an ongoing estimate of the magnitude of the signal in the data stream. However, it does not directly indicate the presence or absence of the signal. The problem is really one of model-testing, and the relevant quantity is the Bayesian evidence (marginal likelihood) of the signal model. Given a signal template and an ongoing data stream, we have developed an evidence-based filter that computes the Bayesian evidence that a signal is present in the data. We demonstrate this algorithm by applying it to brain-machine interface (BMI) data obtained by recording human brain electrical activity, or electroencephalography (EEG). A very popular and effective paradigm in EEG-based BMI is based on the detection of the P300 evoked brain response which is generated in response to particular sensory stimuli. The goal is to detect the presence of a P300 signal in ongoing EEG activity as accurately and as fast as possible. Our algorithm uses a subject-specific P300 template to compute the Bayesian evidence that a applying window of EEG data contains the signal. The efficacy of this algorithm is demonstrated by comparing receiver operating characteristic (ROC) curves of the evidence-based filter to the usual correlation method. Our results show a significant improvement in single-trial P300 detection. The evidence-based filter promises to improve the accuracy and speed of the detection of evoked brain responses in BMI applications as well the detection of template signals in more general signal processing applications

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