

AUTOMATIC DETECTION OF ALERTNESS LEVEL FROM  
ELECTROENCEPHALOGRAM SIGNALS AND CORTICAL AUDITORY  
EVOKED POTENTIAL RESPONSES

**by**

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# Certificate

I, Alaleh Rabie, hereby declare that this thesis titled, automatic detection of alertness level from EEG signals and its application to the assessment of hearing using the CAEP response, and the work presented is the product of my own work. I certify that:

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- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
- I have acknowledged all main sources of help.
- Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself.

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## **Dedication**

I would like to dedicate this thesis to all broken heart parents who have children with hearing loss. God bless you all for your patience.

# ABSTRACT

This research aims to identify the degree of alertness of subjects that undergo the Cortical Auditory Evoked Potential (CAEP) based hearing test. One of the important factors that influence this is the alertness state of subjects. Research has shown that for this test to be useful, subjects need to stay at a constant state of engagement. Accordingly, this thesis focuses on developing a system that will be able to classify each portion of the recorded signal into one of four states; engaged, calm, drowsy and asleep. In order to achieve this, we studied the relationship between CAEP responses and the alertness states, and we validated the existence of this relationship. We have also developed a method to search for the best channel/rhythm combination for each alertness state.

In the first study, two sets of features were considered to represent the recorded data. The first set was based on the wavelet transform of the background EEG, while the second set was obtained from the peaks of the CAEP responses. Obtained results suggest that the CAEP-based features were very comparable, in terms of classification accuracy, to the well-established wavelet-based features of EEG signals (79% compared to 80%). In the second study, the EEG rhythms of subjects were analysed. Investigation of the importance of the different EEG rhythms in terms of their capabilities in differentiating between the different alertness states was conducted. This is followed by considering subsets that contain 2, 3, 4 as well as all 5 EEG rhythms. Finally, a feature subset selection method based on differential evolution (DE) that has been proposed particularly to deal with multi-channel signals is used to search for the best subset of EEG rhythms for the various channels. It was shown that higher frequency EEG rhythms ( $\gamma$ ,  $\beta$ ) are better classifiers for the subject's alertness state than  $\alpha$ ,  $\theta$ , and  $\delta$  (lower frequency EEG rhythms). Optimal combinations of different EEG rhythms have been described. The proposed differential evolution feature selection

algorithm is shown to produce better results than the ranking and sequential forward selection approaches. Obtained results suggest that the best subsets are formed using combinations of channels and features that are influenced by high frequency rhythms.

# ABBREVIATIONS

ABR: Auditory Brainstem Response  
ANN: A Nearest Neighbour  
ANOVA: Analysis of Variance  
AP: Action Potential  
AR: Autoregressive  
BERA: Brainstem Evoked Response Audiometry  
BSS: Blind Source Separation  
CAEP: Cortical Auditory Evoked Potential  
CAP: Compound Action Potentials  
CM: Cochlear Microphonic  
CN: Cochlear Nucleus  
CNS: Central Nervous System  
CWT: Continuous Wavelet Transform  
DE: Differential Evolution  
DEFS: Differential Evolution Feature Selection  
DWT: Discrete Wavelet Transform  
EEG: Electroencephalogram  
EP: Evoked Potential  
FFT: Fast Fourier Transform  
GA: Genetic Algorithm  
ICA: Independent Component Analysis  
KNN: K-nearest Neighbour  
KSOM: Kohonen's Self-organizing Map  
LDA: Linear Discriminant Analysis  
LSD: Least Significant Difference  
MLR: Middle Latency Response  
MP: Matching Pursuit  
OAE: Otoacoustic Emissions  
PCA: Principal Component Analysis



PNS: Peripheral Nervous System  
PP: Projection Pursuit  
PS: Physiological Signals  
PSA: Particle Swarm Optimisation  
REM: Rapid Eye Movement  
SEP: Sound Evoked Potentials  
SFS: Sequential Forward Search  
SP: Summating Potential  
SPL: Sound Pressure Level  
SVM: Support Vector Machine  
SWS: Slow Wave Sleep  
TEC: Total Error of Classification  
TM: Tympanic Membrane  
TRN: Thalamic Reticular Nucleus  
uLDA: uncorrelated Linear Discriminant Analysis  
VEO: Vertical Electro-Oculogram  
VCN: Ventral Cochlear Nucleus  
WT: Wavelet Transform  
WPT: Wavelet Packet Transform

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