Quantitative Continuity Feature for Preterm Neonatal EEG Signal Analysis

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ABSTRACT

Electroencephalography (EEG) is an electrical signal recorded from a person's scalp, and is used to monitor the neurological state of the patient. This thesis proposes a quantified continuity feature to aid preterm neonatal EEG analysis. The continuity of EEG signals for preterm infants refers to the variation of the EEG amplitude, and is affected by the conceptional age of the infants. Currently, the continuity of the signal is determined largely by visual examination of the raw EEG signal, or by using general guidelines on amplitude-integrated EEG (aEEG), which is a compressed plot of the estimated signal envelope.

The proposed parametric feature embodies the statistical distribution parameters of the signal amplitudes. The signal is first segmented into pseudo-stationary segments using Generalized Likelihood Ratio (GLR). These segments are used to construct a vector of amplitude, the distribution of which can be modelled using a log-normal distribution. The mean and standard deviation of the log-normal distribution are used as the continuity feature. This feature is less prone to the effects of local transient activities than the aEEG.

This investigation has demonstrated that the degree of continuity corresponds to the major axis of the feature distribution in the feature space, and the minor axis roughly corresponds to the age of the infants in healthy files. Principal component analysis was performed on the feature, with the first coefficient used as a continuity index and the second coefficient as a maturation index. In this research, classifiers were developed to use the continuity feature to produce a qualitative continuity label. It was found that using a linear discriminant analysis based classifier, labelled data can be used as training data to produce labels consistent across all recordings. It was also found that unsupervised classifiers can assist in identifying the intrinsic clusters occurring in the recordings.

It was concluded that the proposed continuity feature can be used to aid further research in neonatal EEG analysis. Further work should focus on using the continuity information to provide a context for further feature extraction and analysis.

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List of Acronyms

aEEG	Amplitude Integrated Electroencephalogram
ANN	Artificial Neural Network
AP	Absolute Power
AR	Autoregressive
ARMA	Autoregressive Moving Average
BMU	Best Matched Unit
CA	Conceptional Age
CFM	Cerebral Function Monitoring
CT	Computed Tomography
CUS	Cranial Ultrasound
CWD	Choi-Williams Distribution
ECG	Electrocardiogram
ED	Exponential Distribution
EEG	Electroencephalogram
EMG	Electromyography
EOG	Electrooculography
FAR	False Alarm Rate
FFT	Fast Fourier Transform
FM	Frequency Modulation
FWE	Frequency-Weighted Energy
GA	Gestational Age
GLR	Generalized Likelihood Ratio
GMM	Gaussian Mixture Model
HIE	Hypoxic Ischaemic Encephalopathy
IBI	Inter-Burst Interval
ICU	Intensive Care Unit
IF	Instantaneous Frequency
LDA	Linear Discriminant Analysis

MBD	Modified B-Distribution
MIEF	Mutual Information Evaluation Function
MRI	Magnetic Resonance Imaging
NLEO	Nonlinear Energy Operator
PCA	Principal Component Analysis
PRSW	Positive Rolandic Sharp Waves
rEEG	Range-Electroencephalogram
REM	Rapid Eye Movement
RID	Reduced Interference Distribution
RP	Relative Power
SDR	Seizure Detection Rate
SEM	Spectral Error Measurement
SOM	Self Organising Map
STFT	Short Time Fourier Transform
TFD	Time Frequency Distribution
TS	Temporal Sawtooth
TSE	Total Square Error
VIBeS	Victoria Infant Brain Study
w-NLEO	Windowed Nonlinear Energy Operator
WVD	Wigner-Ville Distribution

Glossary

10-20 Electrode Placement

An international standard for electrode placement in EEG recordings.

Artificial Neural Network

A mathematical model based on the biological model of neurons, used in machine learning systems.

Burst Suppresion

An EEG signal with short periods of very high amplitude activities and very low amplitude inactivities in-between.

Cerebral Palsy

An umbrella term for motor disablities caused by brain defect or lesion.

Computed Tomography (CT)

Method for constructing 3D biomedical images using rotating beams of x-rays.

Conceptional Age (CA)

Age of an infant, measured from time of conception

Continuity

The variation of amplitude in an EEG recording.

Continuous Signal

An EEG signal with a relatively constant envelope.

Cortex

Outer layer of the brain, formed by neurons. Also known as Grey Matter.

Cortical EEG

An invasive form of EEG where the electrodes are placed surgically on the cortex of the brain.

Cranial Ultrasound (CUS)

Medical imaging technique that uses ultrasound to visualise the brain area.

Discontinuous Signal

An EEG signal with regions of high amplitude activities with low ampltiude activities in-between

Dysmature EEG

EEG signals that do not show expected maturation signs, and exhibit the behaviour expected in a younger patient's EEG.

Electrocardiogram (ECG)

An electrical signal originating in the muscular movements of the heart.

Electroencephalogram (EEG)

An electrical signal originating in the brain, measured from the scalp, and used for brain function monitoring.

Electrooculogram (EOG)

An electrical signal originating in movements of the eye.

Gestational Age (GA)

Age of infant at birth, measured from time of conception.

Grey Matter

See **Cortex**

Hypoxia

A lack of oxygen supply.

Hypoxic-Ischaemic Encephalopathy (HIE)

Damages to brain cells due to lack of blood flow and oxygen.

Inter-Burst Interval (IBI)

Periods of inactivity between bursts in burst suppression EEG.

Magnetic Resonance Imaging(MRI)

Method of biomedical imaging that utilises a powerful magnetic field to visualise the internal structure of the body.

Non-REM Sleep

A stage of sleep where no rapid eye movement occurs, also known as Quiet Sleep in infants.

Positive Rolandic Sharp Wave (PRSW)

An EEG pattern on full channel EEG that is associated with brain injuries.

Preterm

A term used to describe infants born before 37 weeks GA.

Rapid Eye Movement (REM) Sleep

A stage of sleep where rapid eye movement occurs, also known as Active Sleep in infants.

Sleep-Wake Cycle

The alternating periods of sleep and wakefulness, as shown by alternating continuous and discontinuous signals in an EEG recording.

Symmetry

The similarity in EEG behaviour between the two hemispheres of the brain.

Synchrony

The similarity of EEG recordings from both hemispheres of the brain.

Temporal Sawtooth (TS)

A "sawtooth" pattern in EEG that occurs in temporal channels.

Time-Frequency Distribution

A 3D distribution of energy as expressed in the joint time-frequency domain.

Tracé Alternant

See **Discontinuous Signal**

Tracé Discontinu

See **Burst Suppression**

White Matter

Solid components of the brain, located under the brain surface, used for connecting the grey matter (on the brain surface) and and carrying the electrical signals that connect neurons.