Claims

1. A method for measuring a non-stationary brain signal, comprising:

receiving brain signals;

extracting one or more features from the brain signals;

determine, based on the extracted one or more features, a super feature set describing dynamic behaviour of the brain signals;

forming a cluster-recurrent-neural-network (CRNN)from samples taken from the super feature set, by building a clustering model from the samples, clustering the samples into a plurality of clusters based on features in the super feature set, building a recursive-neural-network (cluster-RNN) over each cluster, a number of cluster-RNNs being equal to a number of clusters derived from the super feature set;

using a stochastic sampling Monte Carlo approach to estimate a posteriori probability density function of the brain state of interest by applying the CRNN to each sample and evaluating a probability that a particular sample of the samples belongs to each cluster; and

determining the brain state of interest from the estimated density function.

2. A method according to claim 1, wherein using a stochastic sampling Monte Carlo approach to estimate a posterior probability density function comprises applying a stochastic sampling Monte Carlo approach to estimate one of a continuous, bivariate or multi-variate probability density function.

3. A method according to claim 1, wherein receiving brain signals comprises receiving electroencephalogram (EEG) signals.

4. A method according to claim 1, wherein each feature of the one or more features is continuous, occurring over a period of time.

5. A method according to claim 4, wherein the super feature set is

determined by calculating one or more of:

- averages values in the recent time frames;
- linear trends in the recent time frames;
- variances in the recent time frames;
- frequency components that describes rhythmic fluctuations;
- super-fluctuations of the frequency components, i.e. the fluctuations of the rhythmic activities in the raw scores; and
- complexity of the raw scores.

6. A method according to claim 1, wherein determining a super feature set comprises forming a super feature set by applying at least one of principal component analysis and independent component analysis to the one or more features.

7. A method according to claim 6, wherein applying at least one of principal component analysis and independent component analysis comprises determining a fluctuation of at least one said feature.

8. A method according to claim 1, wherein clustering the samples comprises grouping the samples based on the dynamic behaviour of at least one feature of the one or more features, each cluster hypothetically corresponding to a particular class of the plurality of classes of brain signal.

9. A method according to claim 1, wherein the samples are clustered by grouping the samples based on the dynamic behaviour.

10.A method according to claim 9, wherein grouping the samples comprises grouping the samples based on spectra of the dynamic behaviour of at least one feature of the one or more features.

11. A method according to claim 9 or 10, wherein grouping the samples based on the dynamic behaviour of at least one of the one or more features

comprises grouping the samples using k-means clustering based on the dynamic behaviour of at least one feature of the one or more features.

12. A method for cross-correlating N concurrent brain states, comprising:

performing the method of claim 1, wherein receiving brain signals comprises receiving brain signals corresponding to trials designed to elicit N-variate responses in the brain signals, each variable of the N-variate responses corresponding to a presence or absence of a respective one of the N concurrent brain states, wherein forming a CRNN comprises clustering the samples into 2^N clusters, each cluster being a unique combination of the variables; and

determining a combination of brain states indicated by the further brain signal by applying the CRNN and Monte Carlo approach to estimate an a posteriori probability density function of the combination of brain states using the CRNN and the Monte Carlo approach.

13. A method according to claim 12, wherein each brain state corresponds to an emotional state.

14. A method according to claim 13, wherein N is 2, and the emotional states are stress/non-stress and happiness/sadness.

15. A system for measuring a non-stationary brain signal, comprising:

memory; and

at least one processor,

wherein the memory stores instructions that, when executed by the at least one processor, cause the at least one processor to:

receive brain signals;

extract one or more features from the brain signals;

determine, based on the extracted one or more features, a super feature set describing dynamic behaviour of the brain signals;

form a cluster-recurrent-neural-network (CRNN)from samples taken from the super feature set, by building a clustering model from the

samples, clustering the samples into a plurality of clusters based on features in the super feature set, building a recursive-neural-network (cluster-RNN) over each cluster, a number of cluster-RNNs being equal to a number of clusters derived from the super feature set;

use a stochastic sampling Monte Carlo approach to estimate a posteriori probability density function of the brain state of interest by applying the CRNN to each sample and evaluating a probability that a particular sample of the samples belongs to each cluster; and

determining the brain state of interest from the estimated density function.

16. A system according to claim 15, wherein the at least one processor uses a stochastic sampling Monte Carlo approach to estimate a posterior probability density function by applying a stochastic sampling Monte Carlo approach to estimate one of a continuous, bivariate or multi-variate probability density function.

17. A system according to claim 15, wherein the at least one processor forms the CRNN by taking one or more samples of the super feature set and forming at least one cluster by grouping the one or more samples based on the dynamic behaviour of at least one feature of the one or more features, each cluster hypothetically corresponding to a particular class of the plurality of classes of brain signal, and evaluating a probability that a particular sample of the one or more samples belongs to every cluster.

18. A system according to claim 17, wherein the at least one processor groups the one or more samples based on the dynamic behaviour of at least one of the one or more features by grouping the one or more samples based on spectra of the dynamic behaviour of at least one feature of the one or more features.

19. A system according to claim 17, wherein the at least one processor groups the one or more samples based on the dynamic behaviour of at least one of the one or more features by grouping the one or more samples using k-means clustering based on the dynamic behaviour of at least one feature of the one or more features.

20. A system according to claim 15, wherein the at least one processor receives brain signals by receiving brain signals corresponding to trials designed to elicit N-variate responses in the brain signals, each variable of the N-variate responses corresponding to a presence or absence of a respective one of the N concurrent brain states, wherein the at least one processor forms a CRNN by clustering the samples into 2^N clusters, each cluster being a unique combination of the variables, the at least one processor being configured, by the instructions stored in the memory, to determine a combination of brain states indicated by the further brain signal by classifying the further brain signal as being representative of one of the plurality of classes.