Towards reliable automatized state classification

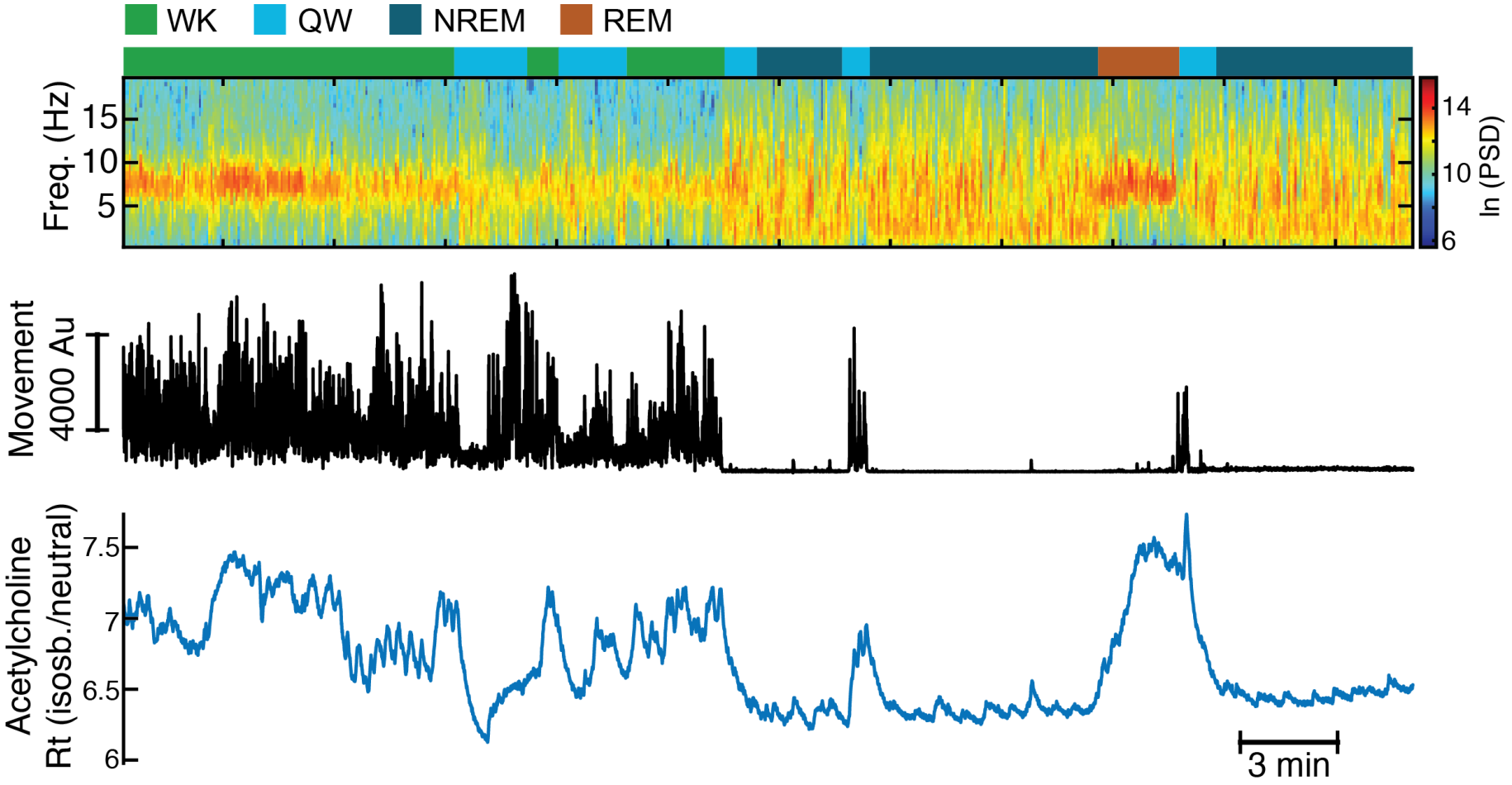
Progress Report

Ricardo Santos, October 7th, 2022

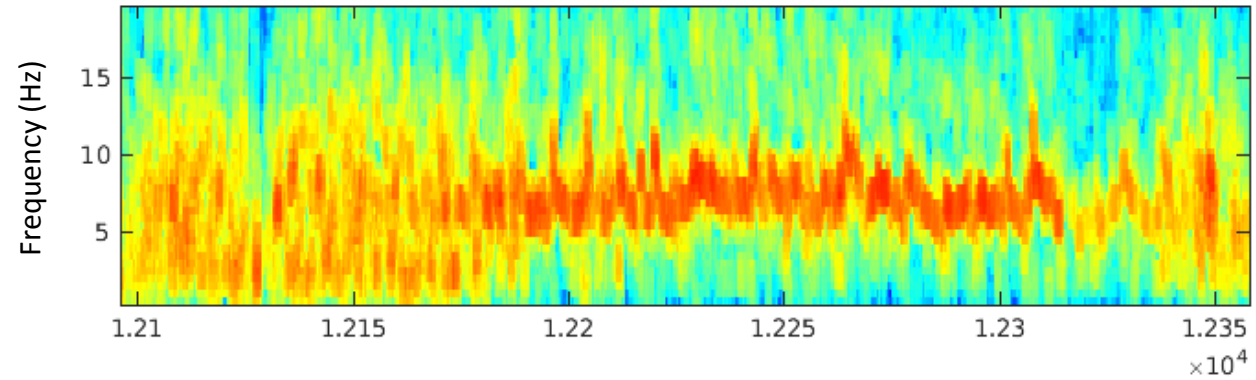
Brain states

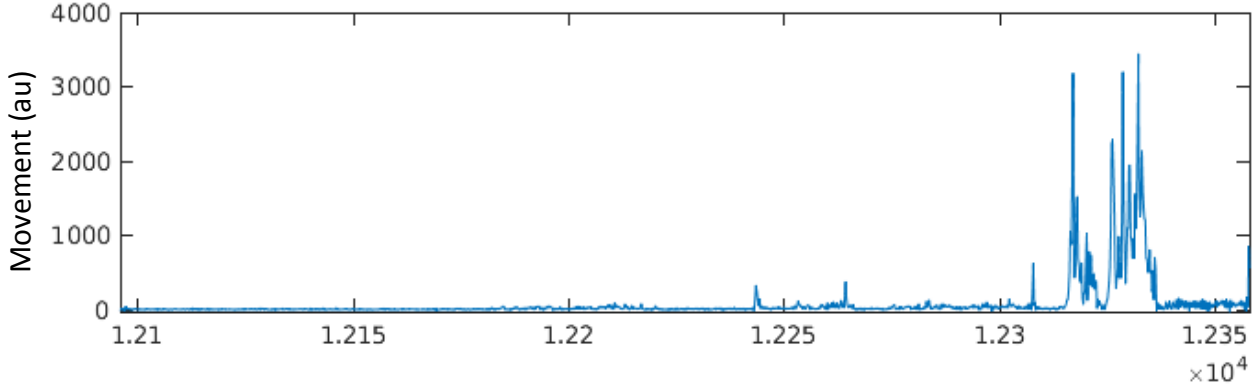
Animal's brain states can be divided into 4 main categories:

- Wake (WK), Quiet Wake (QW), non-REM sleep (NREM) and REM sleep (REM)



Classifying brain states: automatic methods





Rely on:

Ratio between frequency bands or absolute power

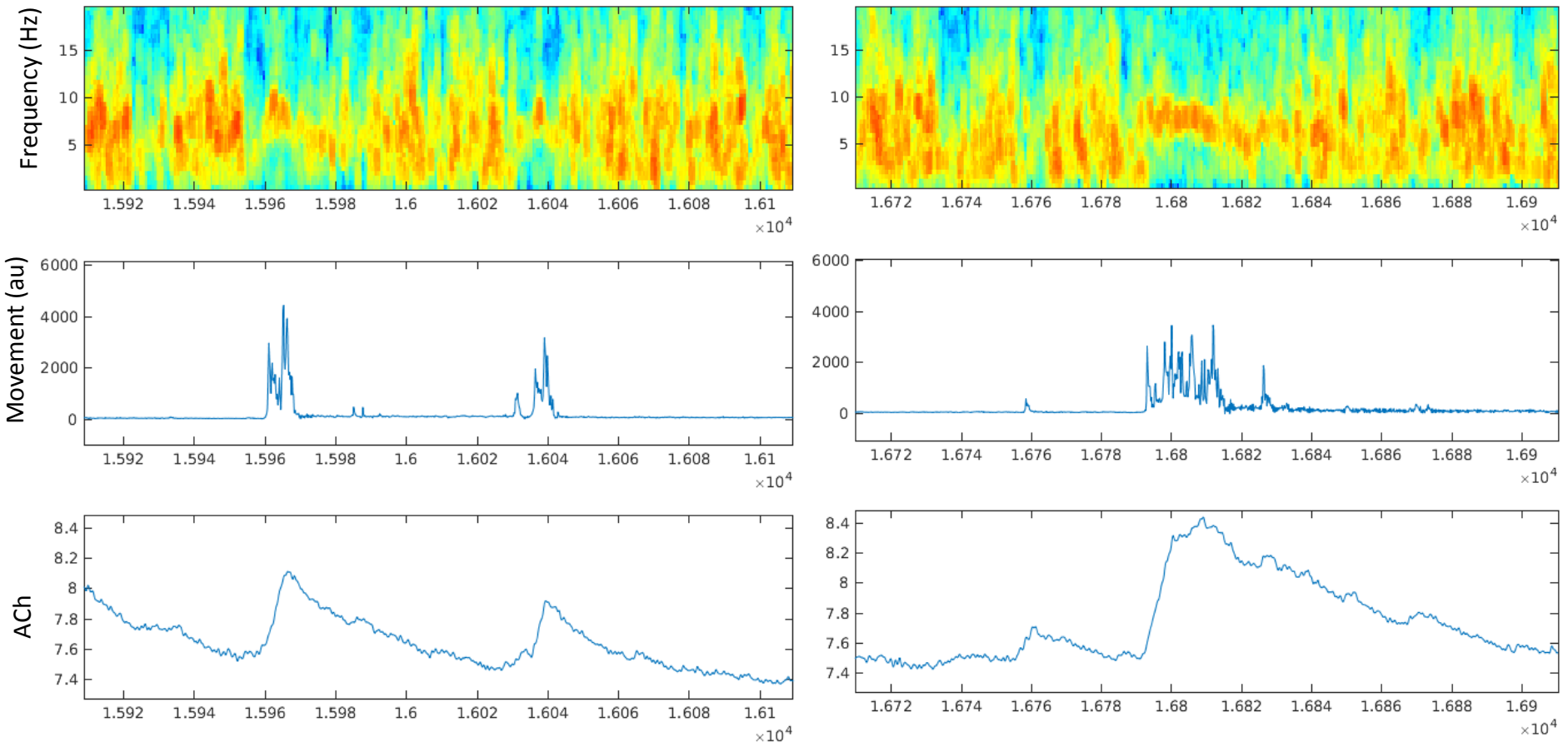
Movement magnitude (accelerometer, behavioral tracking)

Advantages: Fast to run, objective criteria not biased by user

Classifying brain states: automatic methods

Disadvantages:

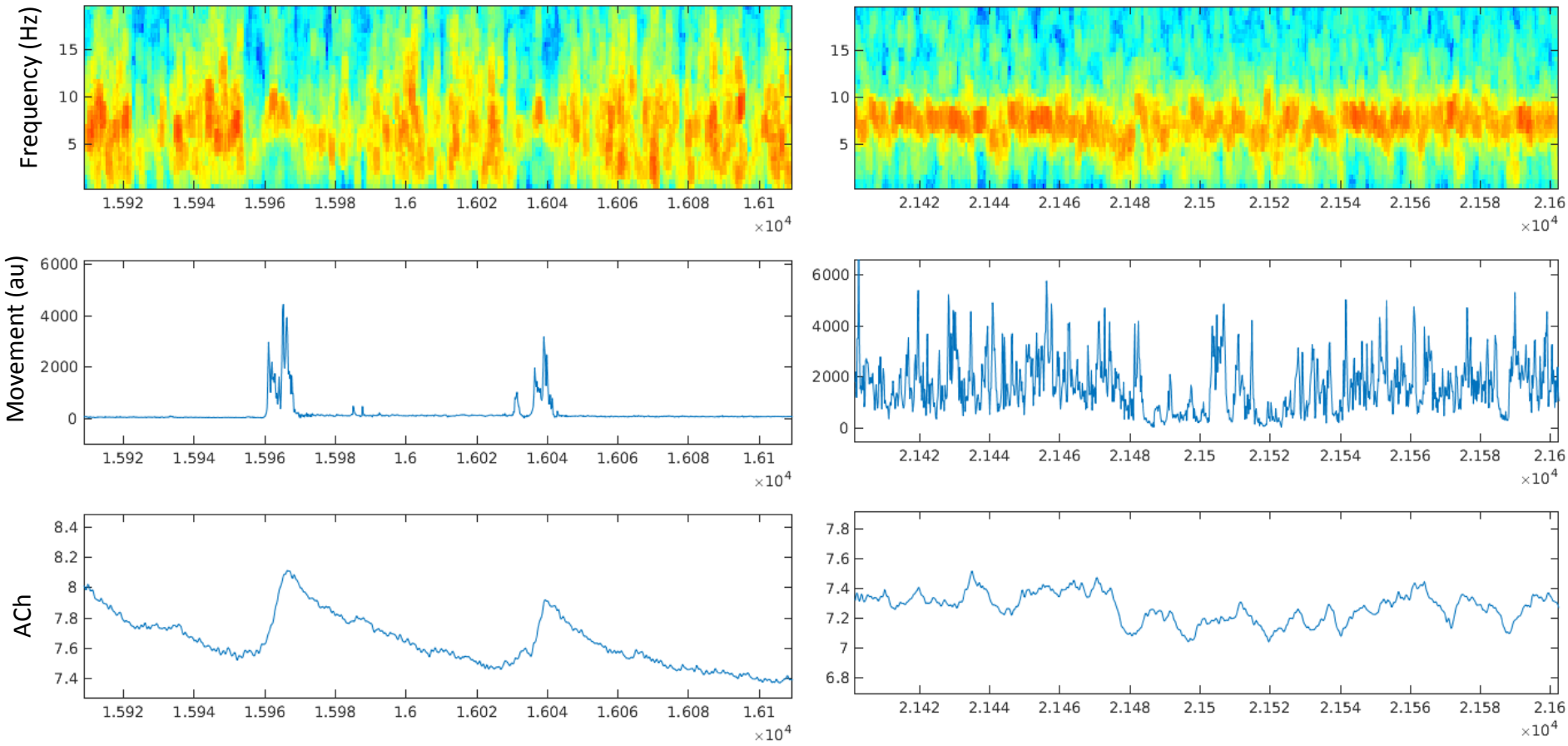
- Often requires manual adjustment of thresholds
- Usually does not take into account the context



Classifying brain states: automatic methods

Disadvantages:

- Often requires manual adjustment of thresholds
- Usually does not take into account the context



Classifying brain states: manual methods

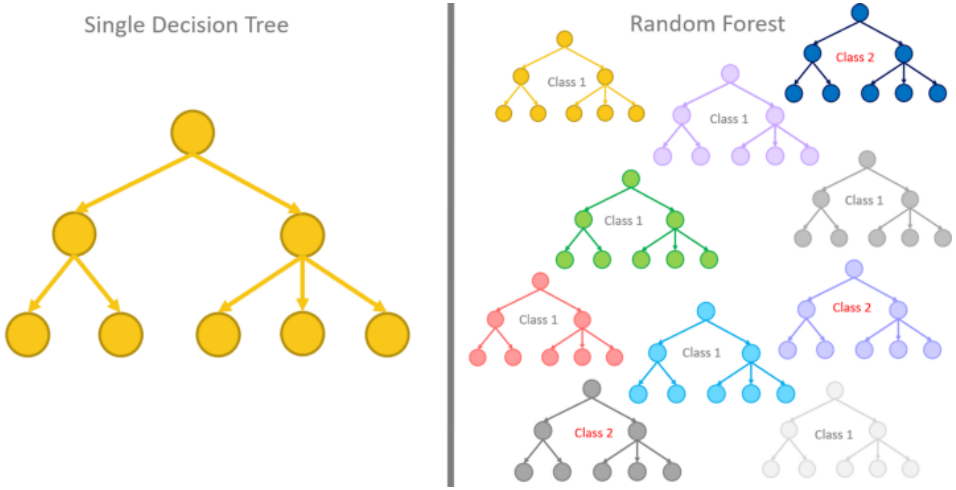
Advantages:
- Can take the context into account
- Uses domain knowledge

Disadvantages:
- Time consuming
- Can be biased by subjective judgments

Challenge:
Develop an automatic state classification method with human-like accuracy that does not require manual adjustments

Machine learning and AI-based classifiers

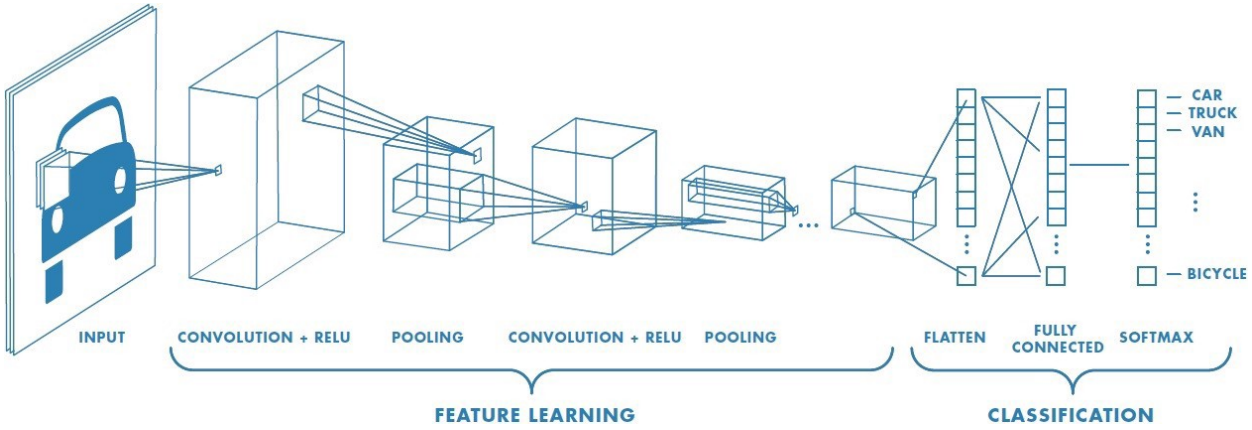
Decision tree



- Non-parametric
- Don't require data normalization
- Single trees tend to overfit
- Random forests generalize better

From: https://towardsdatascience.com/from-a-single-decision-tree-to-a-random-forest-b9523be65147

Convolutional neural network



- Apply multiple convolution filters
- Learn features in an image
- Complex computer vision problems

https://towardsdatascience.com/a-comprehensive-guide-to-convolutional-neural-networks-the-eli5-way-3bd2b1164a53

Methodological steps

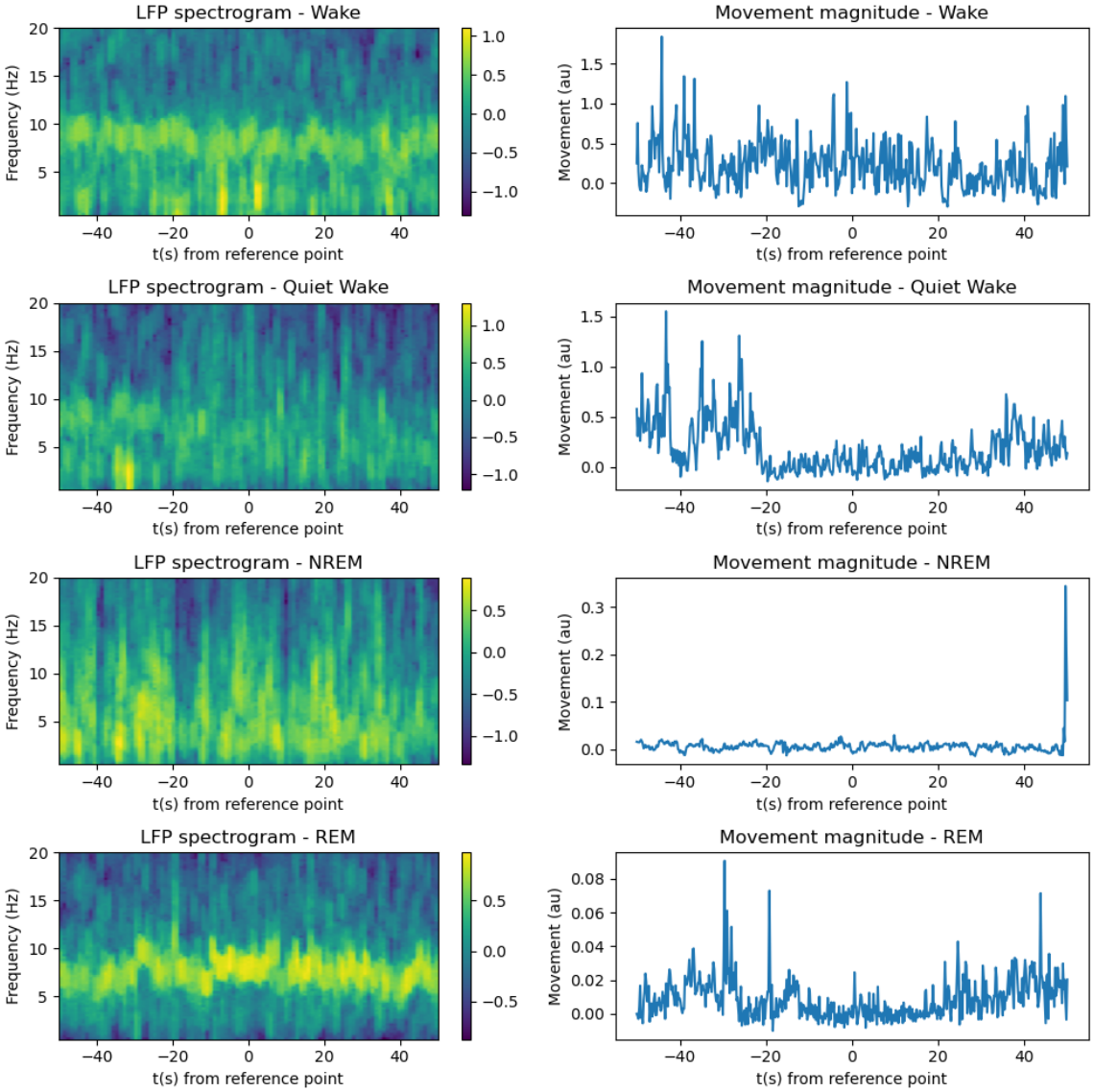
1 – Get labelled data

- Manually labelled data from recordings in 2 mice
- Each instance corresponds to a LFP power spectrogram and a movement magnitude time series (from accelerometer) in a window of +- 50 s relative to the time point to classify
- Data split into train, validation and test sets (non-overlaping sessions) at a ratio of 4/3/3.

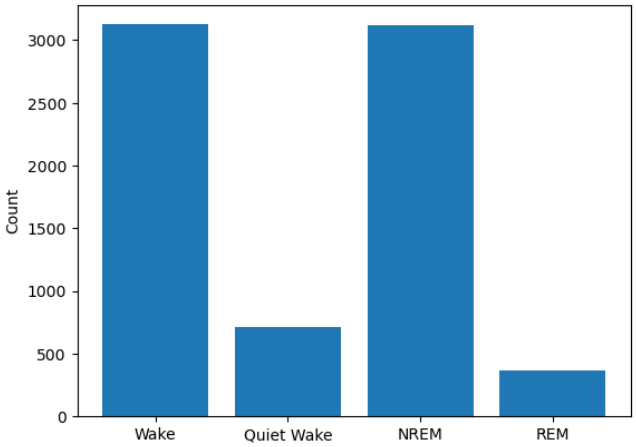
2 – Normalize data

- Data normalized to maximize generalizability
- Robust method based on percentile extremes plus centering
- Spectral data normalized at each instance
- Movement data normalized for whole training set and baseline-corrected for each instance

Methodological steps: visualizing single instances

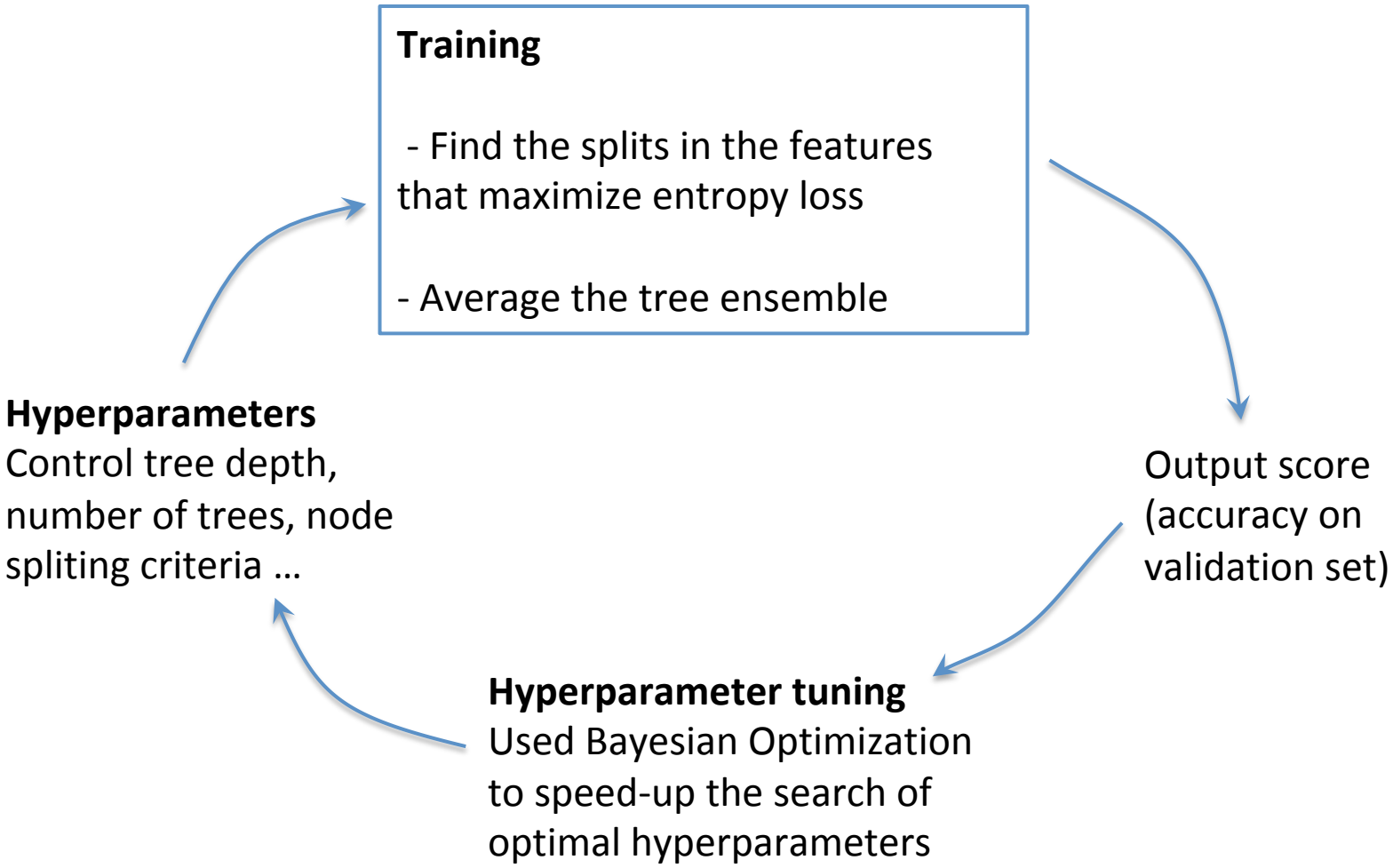


Number of instances per state (train set)



Corrected imbalanced data by undersampling

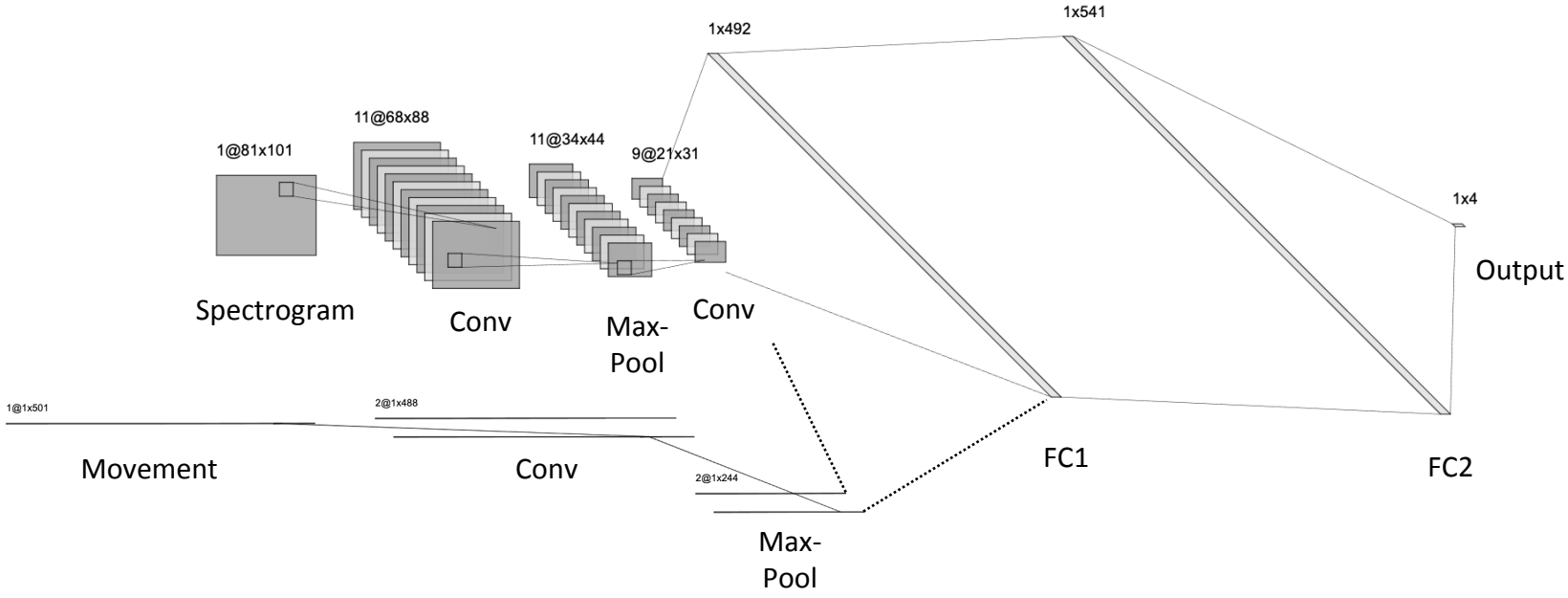
Training Random Forests



CNN design

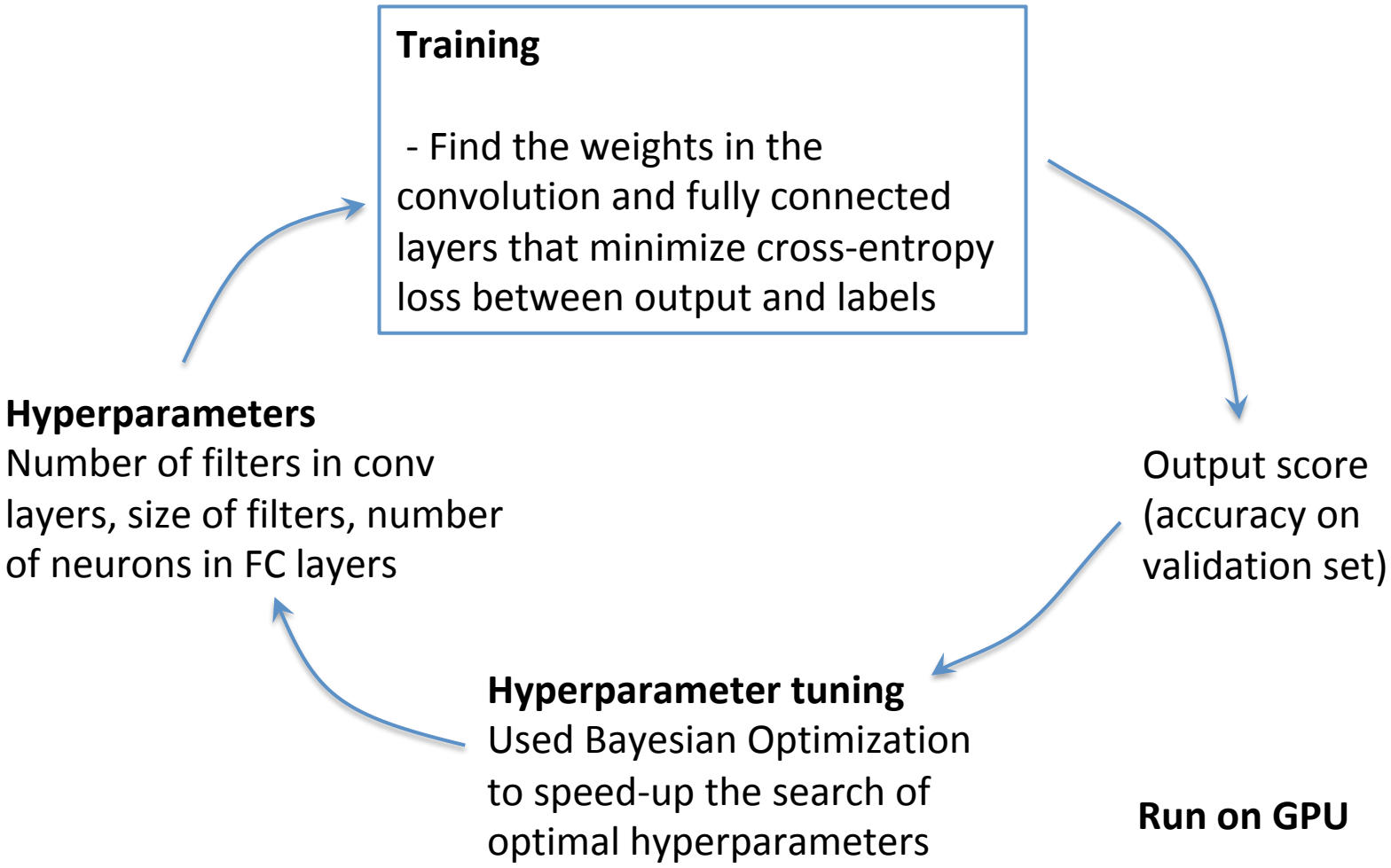
Bimodal inputs

- 2D from LFP spectrograms
- 1D from movement



Prediction is given by class with max output

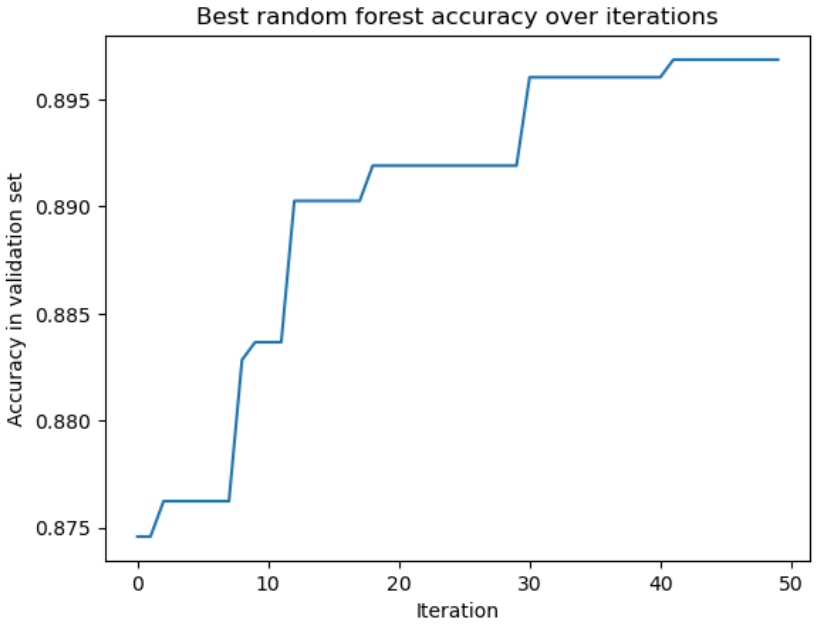
Training CNNs



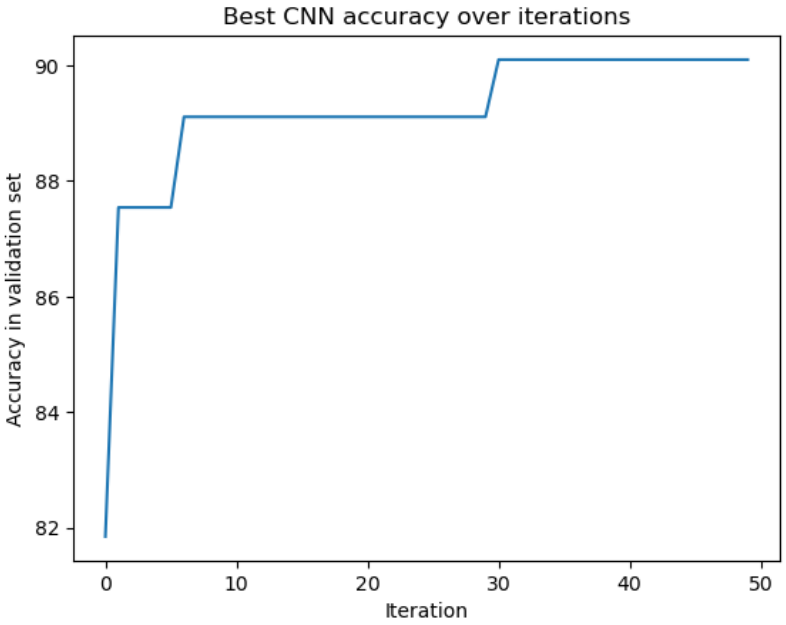
Bayesian Optimization

Run 50 iterations to collect points in the hyperparameter space

11 minutes

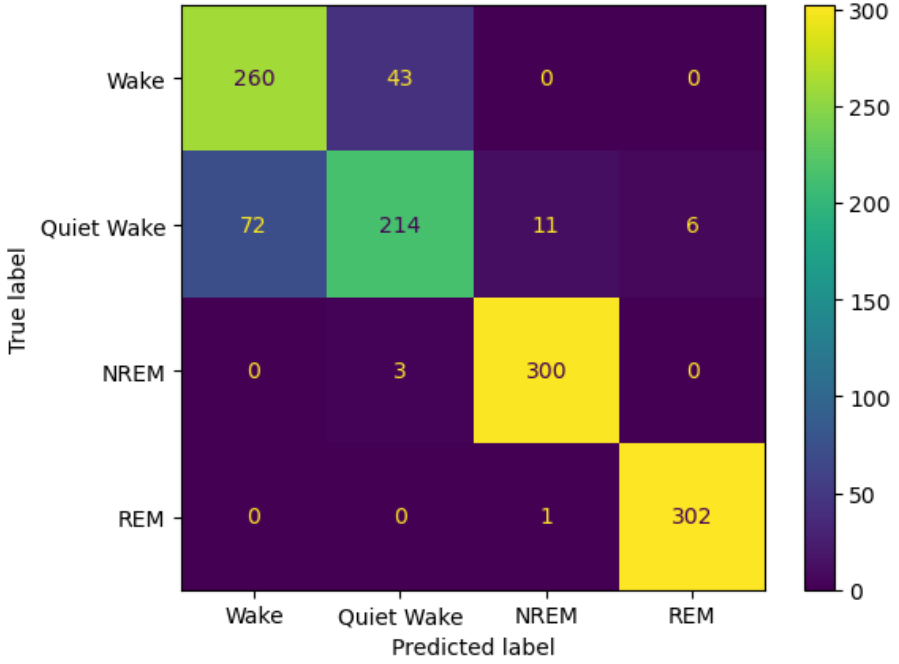


2 hours

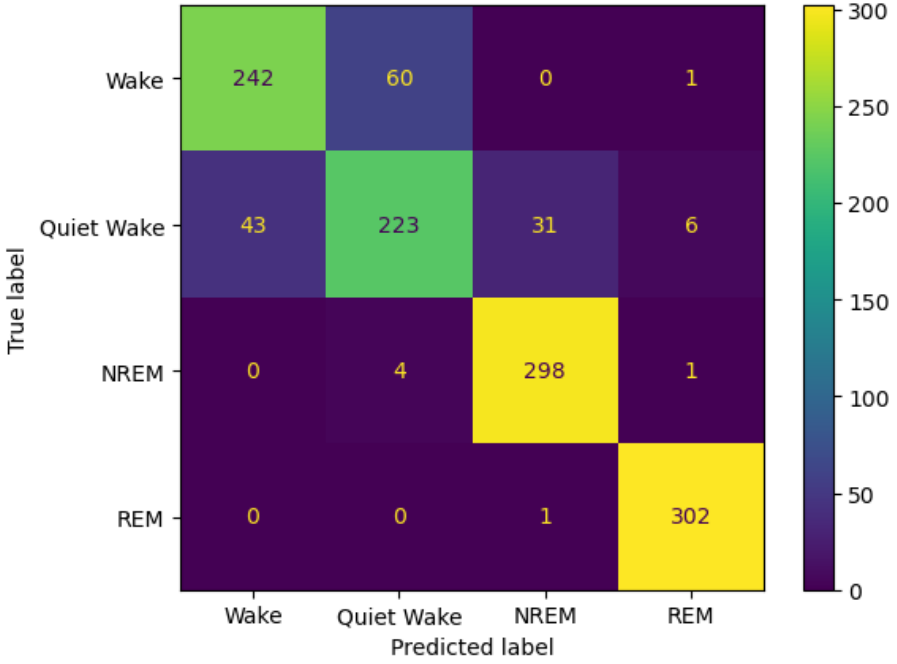


Performance on the validation set

Random Forest
Total accuracy = 88.8 %

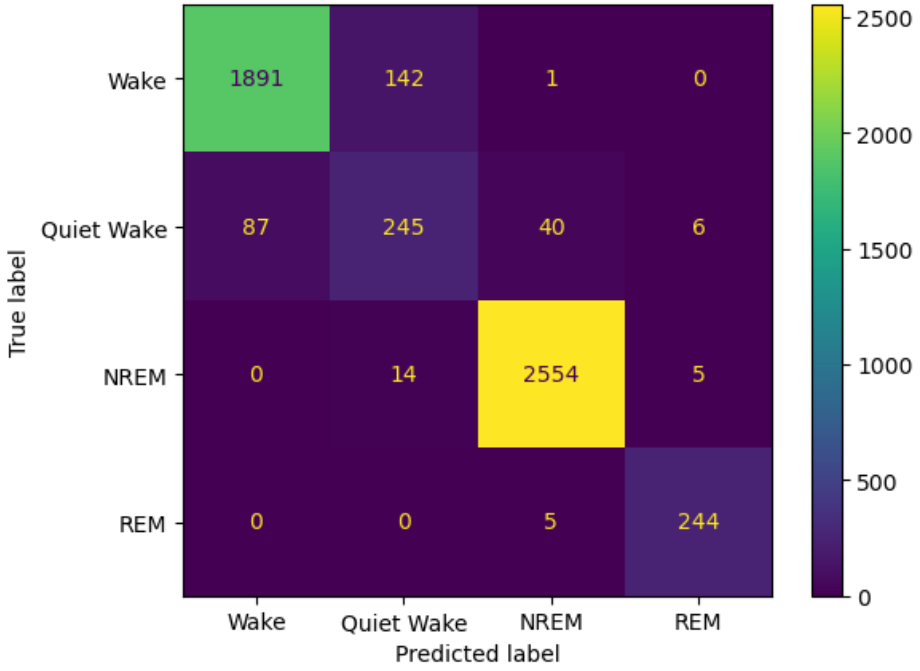


CNN
Total accuracy = 87.9 %

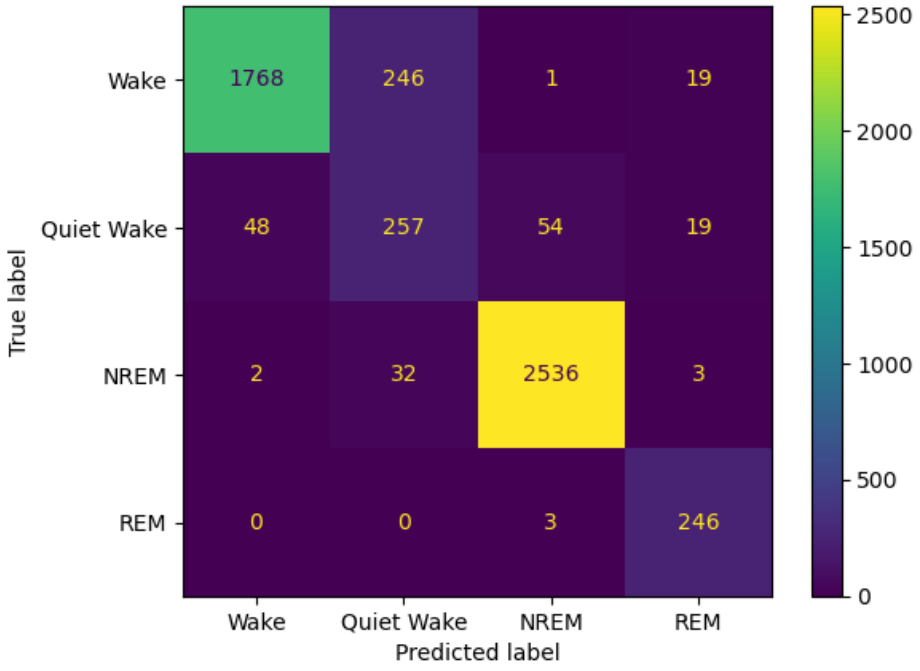


Performance on the test set

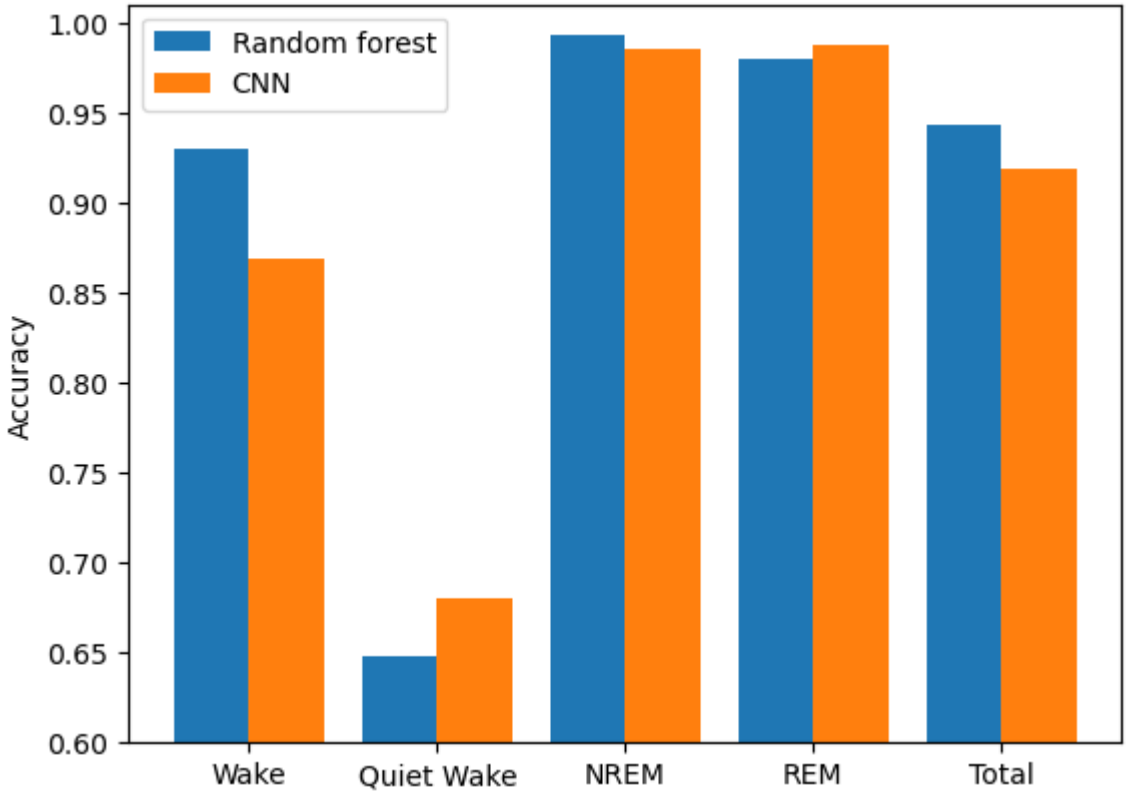
Random Forest
Total accuracy = 94.3 %



CNN
Total accuracy = 91.8 %



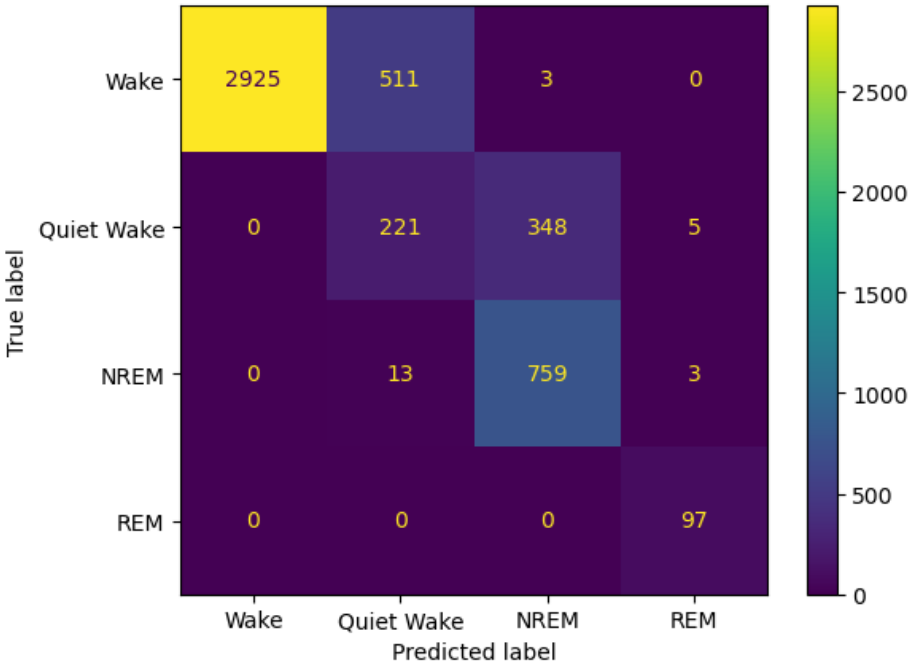
Accuracy by state on the test set



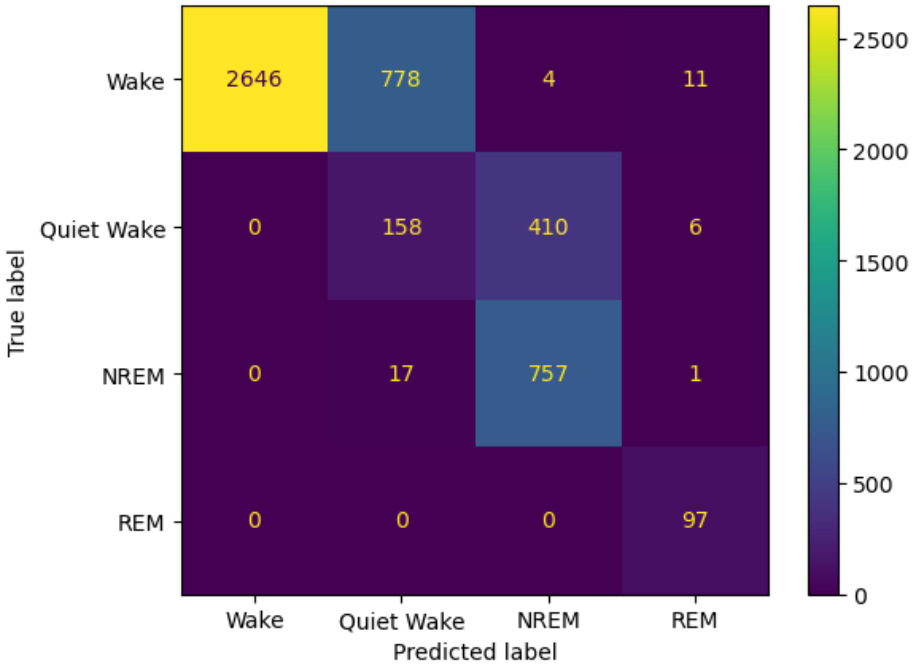
Performance on a test set from another animal

Labelling done 4 years ago

Random Forest
Total accuracy = 81.9 %



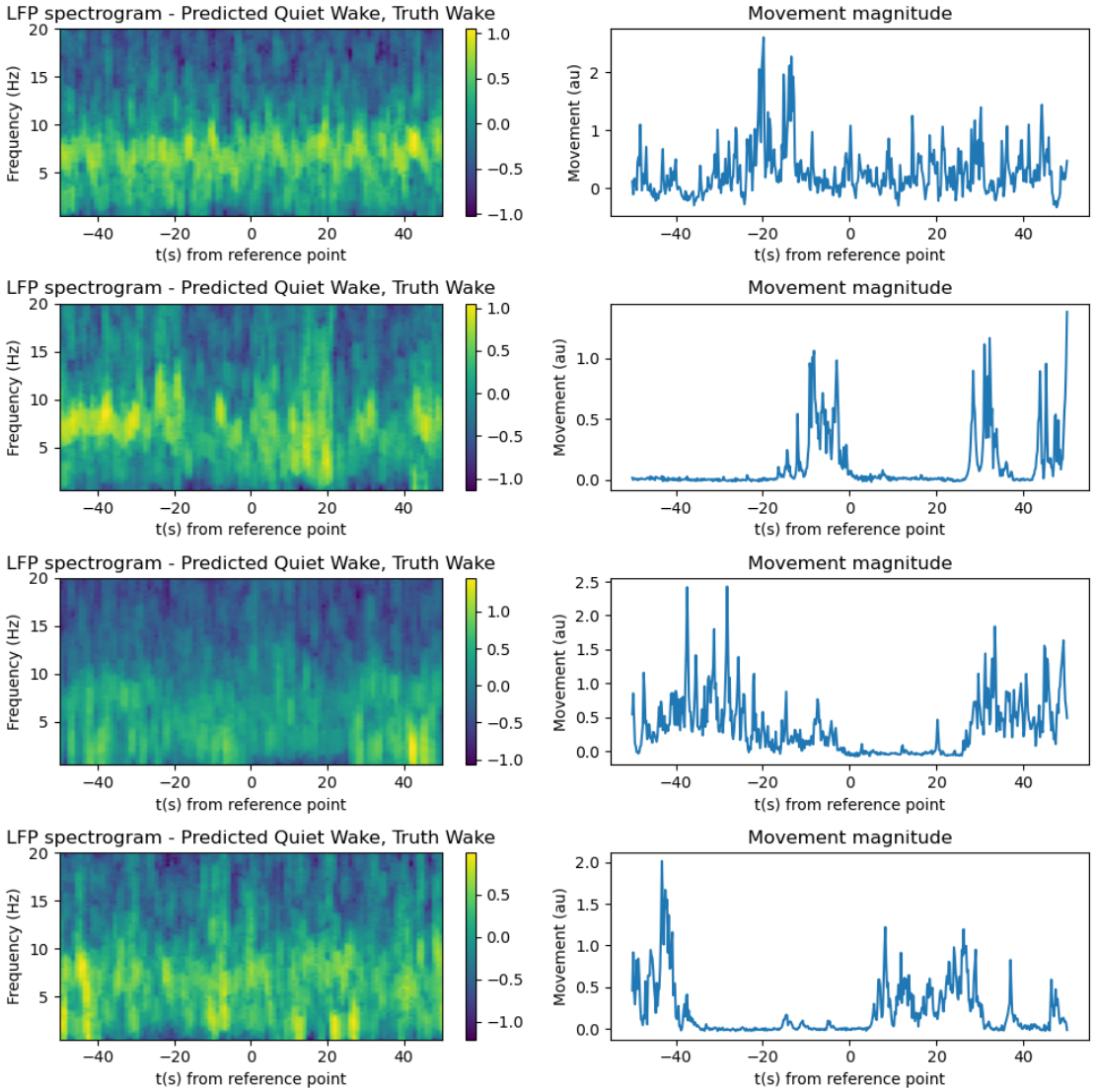
CNN
Total accuracy = 74.9 %

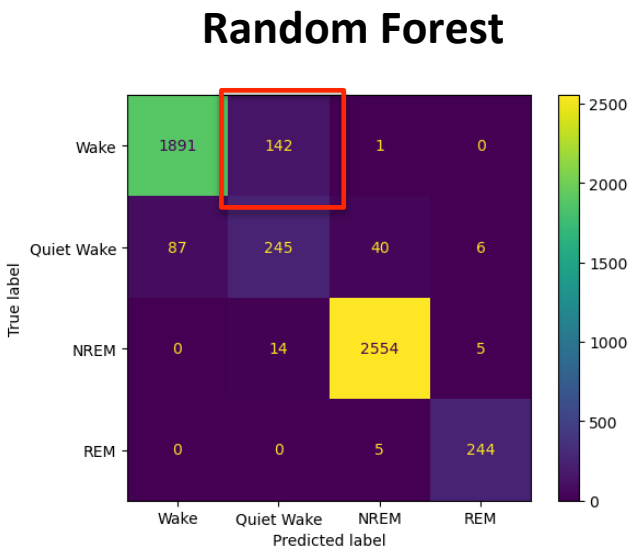


Lower accuracy may reflect bias in labelling of QW state

Check misclassified instances

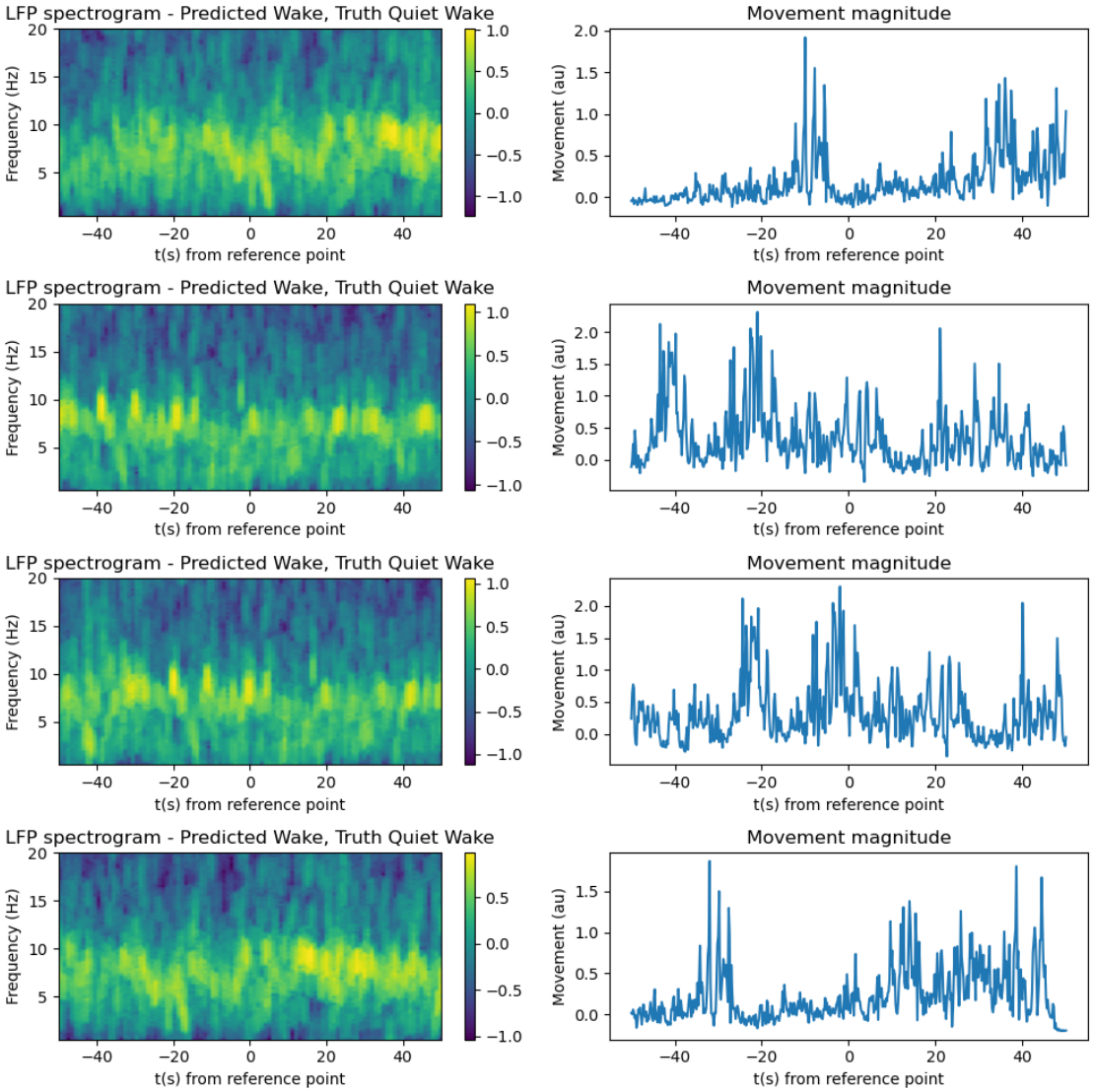
Check instances classified as QW when label was WK

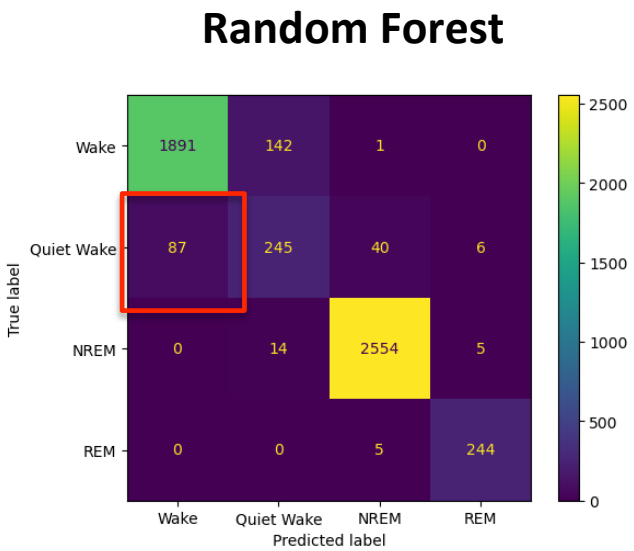




Check misclassified instances

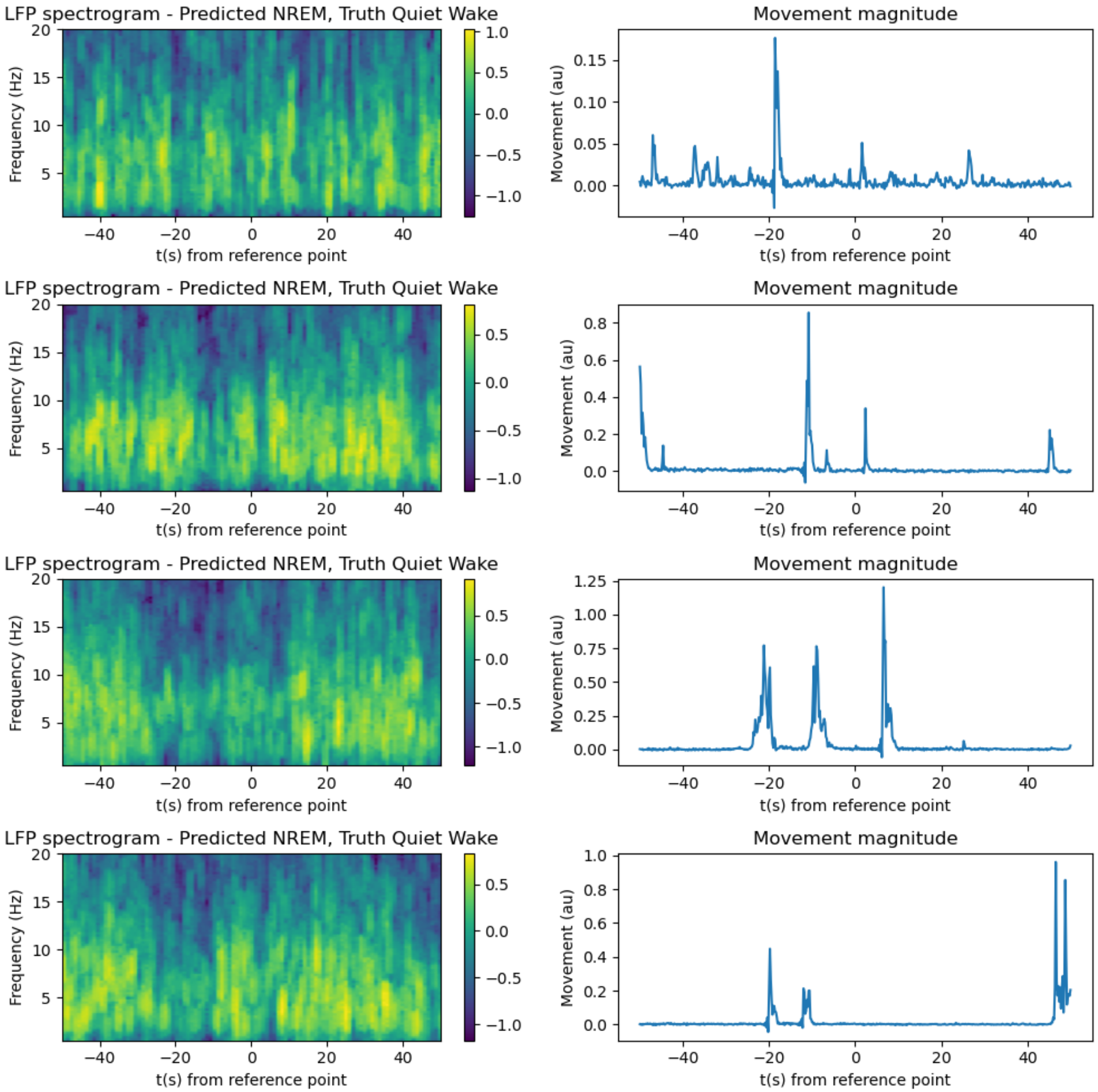
Check instances classified as WK when label was QW



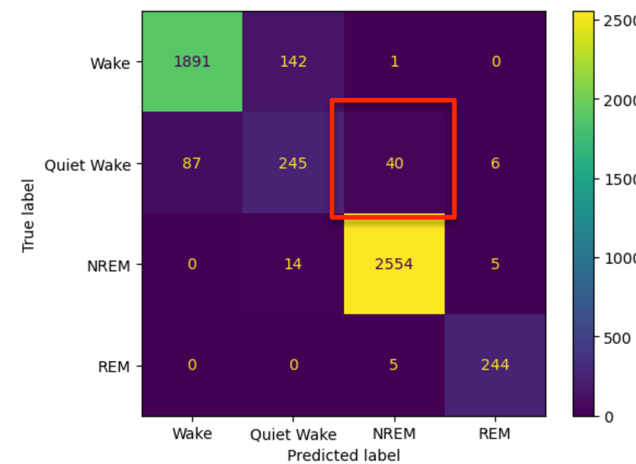


Check misclassified instances

Check instances classified as NREM when label was QW

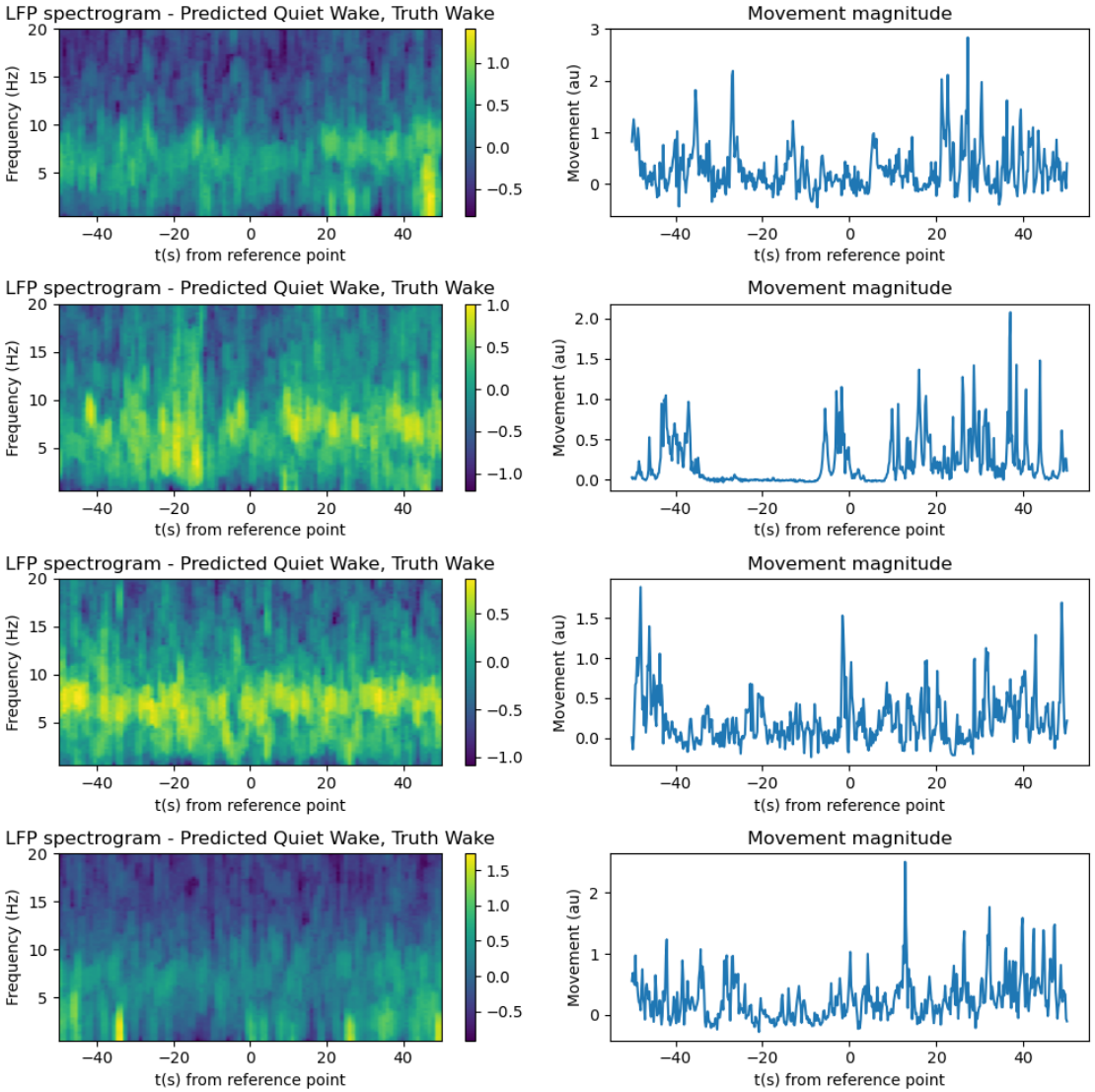


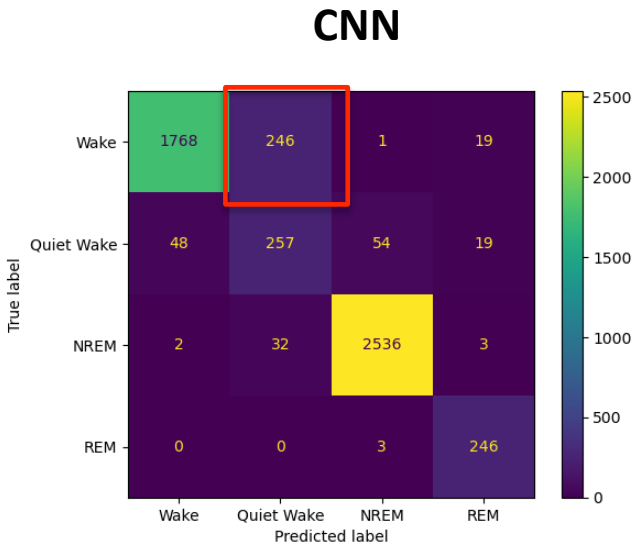
Random Forest



Check misclassified instances

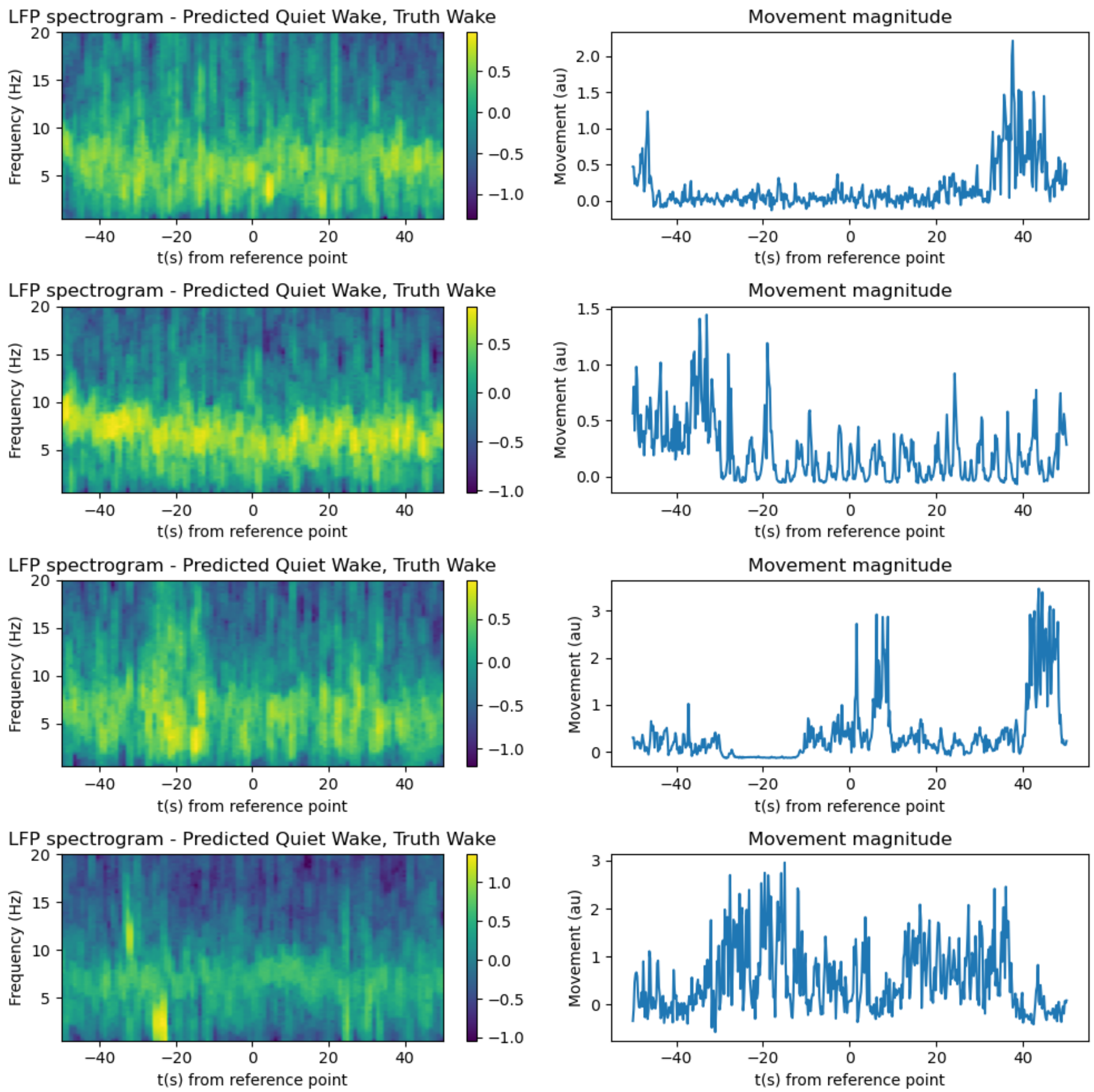
Check instances classified as QW when label was WK



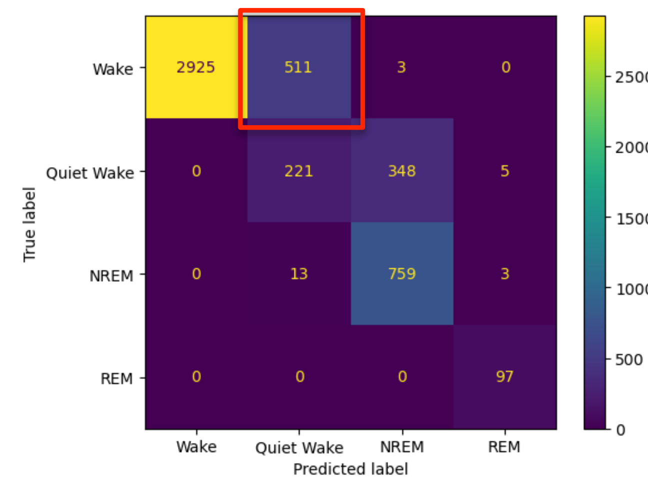


Check misclassified instances in test set from other mouse

Check instances classified as QW when label was WK

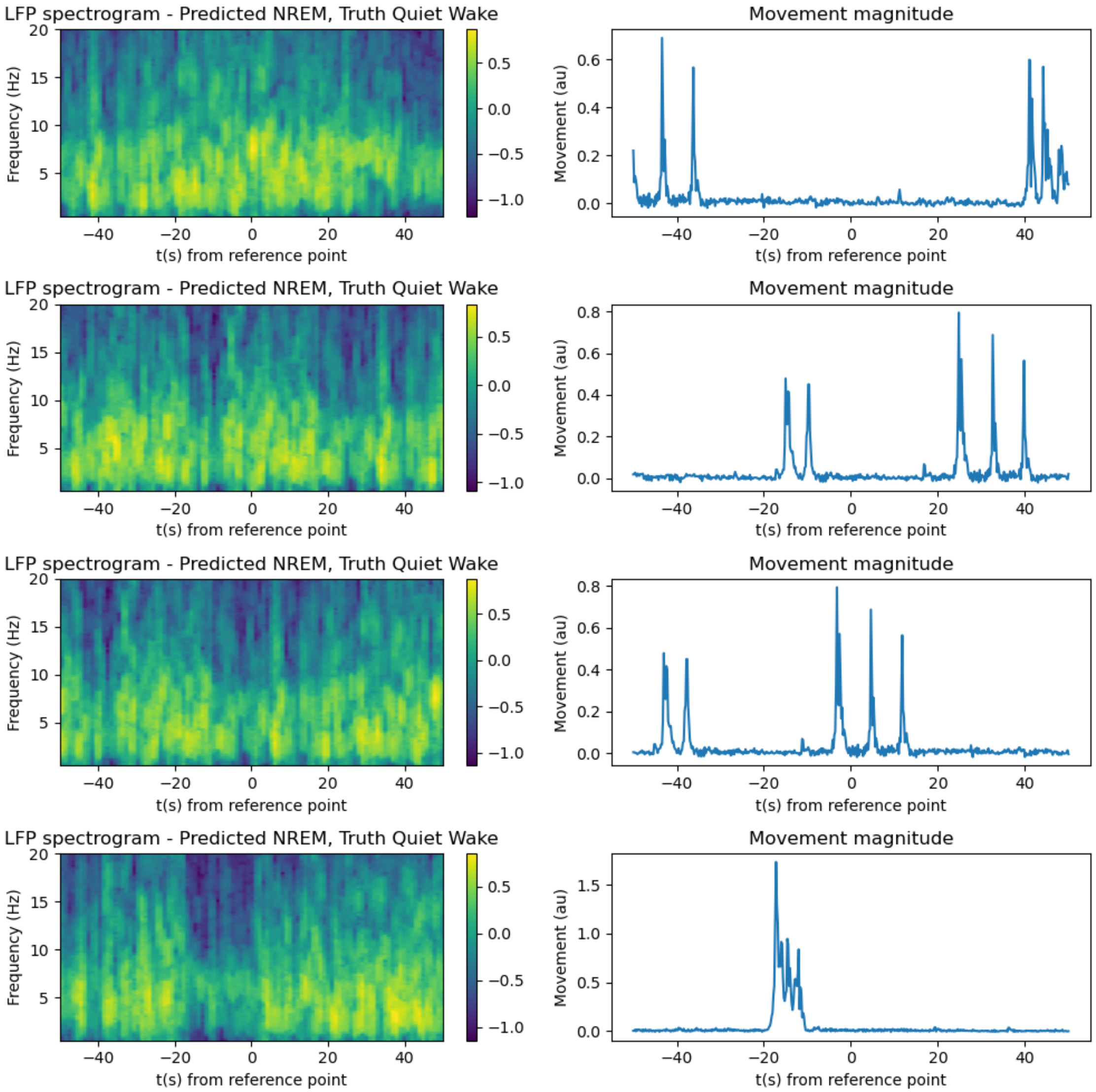


Random Forest

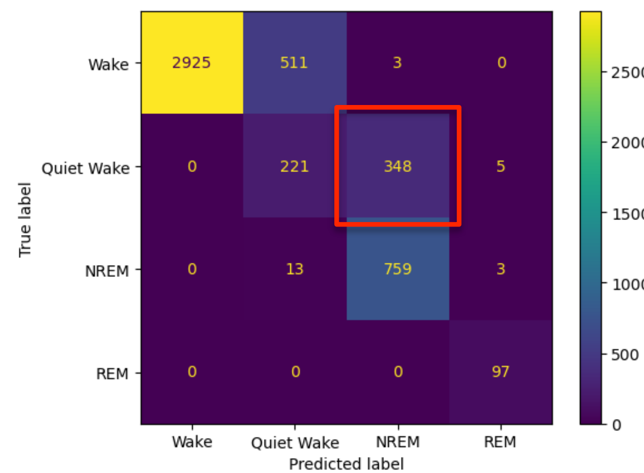


Check misclassified instances in test set from other mouse

Check instances classified as NREM when label was QW



Random Forest



Conclusions

- At this point, deep learning does not show an advantage vs a standard machine learning algorithm
- Good accuracy overall
- Labelling should be improved
- Add more animals to training set
- Improve the architecture of the CNN