Machine Learning and Neural Networks for Automatic Sleep Stage Scoring

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Introduction

The motivation behind this project is to efficiently score EKG data from mice and determine the sleep stage of each epoch. Currently, in sleep analysis and neuroscience research, most of the sleep scoring process is done manually using Fast Fourier analysis of the EEG and EMG data. However, this process creates a huge bottleneck for the advancement of this field since the process is very time-consuming and tedious. Using machine learning and neural network to create a method to automatically score this data will optimize efficiency and save many hours of manual labor. The work done in the lab is analyzing and using a MATLAB program called AccuSleep in order to train a neural network in order to recognize patterns in EKG data and determine which stage of sleep (REM, NREM, or Wake) the animal is in. In doing so, we can hope to help members in the lab, and researchers in the sleep science field, to quickly score data for further analysis.

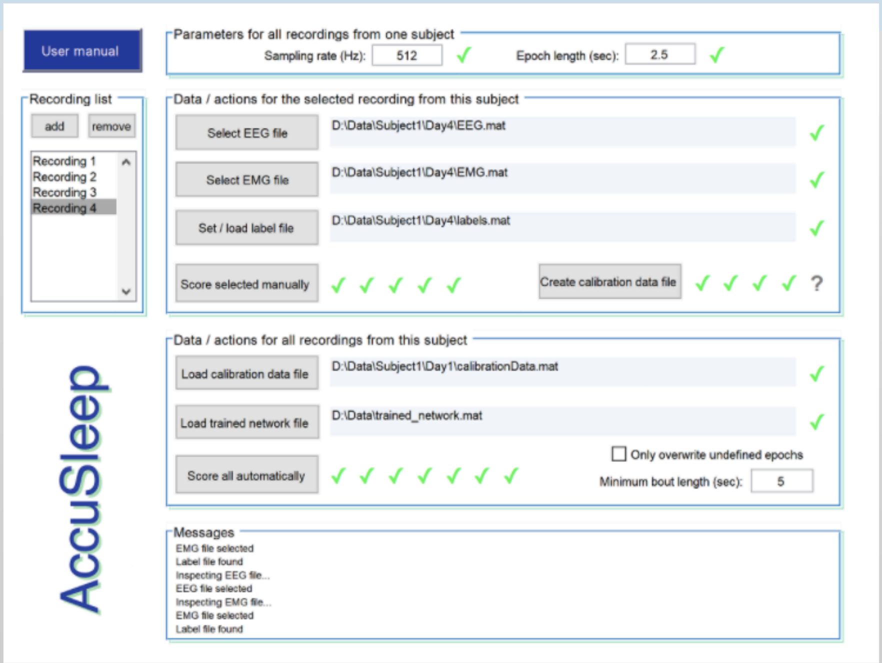

Figure 1: The interface of the AccuSleep program when run

Procedures

The work on my UROP research project was mostly contributed by myself, with guidance and advice from my lab mentor and data sets generated by my peers in the lab. The project mostly focused on the accuracy of the machine learning program so most of the data that I was generating was the accuracy results of my trials which are given in percentages and are unitless. The other tools needed in my project were MATLAB, the AccuSleep software developed by Zeke Barger at the University of Berkeley, and EKG devices that are used to record the brain wave patterns in mice. To accomplish the goals in my project, we wanted to find a reliable way to implement the software in the lab, so the procedures mostly consisted of acquiring data sets from my partners that were already labeled and creating unique calibration and network files to create varied trials with different amount of given data that was already labeled. After that, I calculated confusion matrices for each of the individual labels and analyzed the accuracy.

Results

After testing for different parameters within data sets and the data analysis, including minimum bout length, training our own neural network, and quality and quantity of testing data, we were able to automatically score data sets of over 24-hour hours with about 10-30 min of training data and produce relatively high accuracies (~80-90%).

Trained Network #	**Animal 888 (accuracy, R/W/NR)**	**Animal 882 (accuracy, R/W/NR)**	**Animal 830 (accuracy, R/W/NR)**	**Animal 775 (accuracy, R/W/NR)**
1 (~10 minutes)	0.953 0.949 0.958	0.990 0.977 0.982	1.000 0.989 0.947	0.986 0.964 0.982
1 (~ 30 minutes)	0.943 0.944 0.967		0.998 0.987 0.961	0.986 0.977 0.973
2 (~10 minutes)	0.962 0.943 0.961	0.990 0.977 0.988	0.999 0.992 0.948	0.973 0.964 0.989
2 (~ 30 minutes)	0.951 0.938 0.968		1.000 0.987 0.970	0.992 0.976 0.980
3 (~10 minutes)	0.979 0.951 0.894	0.539 0.824 0.872	0.459 0.965 0.768	0.925 0.972 0.900
3 (~ 30 minutes)	0.984 0.957 0.845	0.414 0.885 0.837	0.556 0.958 0.667	0.937 0.973 0.912
4 (~10 minutes)	0.946 0.940 0.961	0.990 0.973 0.992	0.940 0.978 0.927	0.974 0.970 0.990
4 (~30 minutes)	0.946 0.938 0.962		0.939 0.975 0.938	
5 (~10 minutes)	0.957 0.936 0.975	0.960 0.969 0.989	0.998 0.986 0.950	0.965 0.950 0.987
5 (~30 minutes)	0.953 0.932 0.978	0.970 0.973 0.986	0.997 0.980 0.968	0.983 0.965 0.981
6 (~10 minutes)	0.935 0.939 0.967	0.979 0.979 0.986	1.000 0.990 0.944	0.967 0.967 0.987
6 (~30 minutes)	0.941 0.934 0.972		0.999 0.985 0.967	
7 (~10 minutes)	0.955 0.945 0.965	0.985 0.980 0.987	1.000 0.989 0.951	0.970 0.968 0.986
7 (~30 minutes)	0.942 0.942 0.971		0.999 0.984 0.971	

Trained Network #1	Trained a neural network with 882, 830, and 775 Called net = Accusleep_train(fileList, 256, 4, 25)
Trained Network #2	Trained a neural network with 882, 830, and 775 Called net = Accusleep_train(fileList, 256, 4, 19)
Trained Network #3	Trained a neural network with 888, 887, and 775 Called net = Accusleep_train(fileList, 256, 4, 19)
Trained Network #4	Trained a neural network with 882 and 775 Called net = Accusleep_train(fileList, 256, 4, 25)
Trained Network #5	Trained a neural network with 882, 830, and 775 Called net = Accusleep_train(fileList, 256, 4, 9)
Trained Network #6	Trained a neural network with 882, 830, and 775 Called net = Accusleep_train(fileList, 256, 4, 13)
Trained Network #7	Trained a neural network with 882, 830, and 775 Called net = Accusleep_train(fileList, 256, 4, 15)

Table 1: Example of recorded data of accuracies of different trained networks with green cells hitting target accuracies of >0.97, with legend

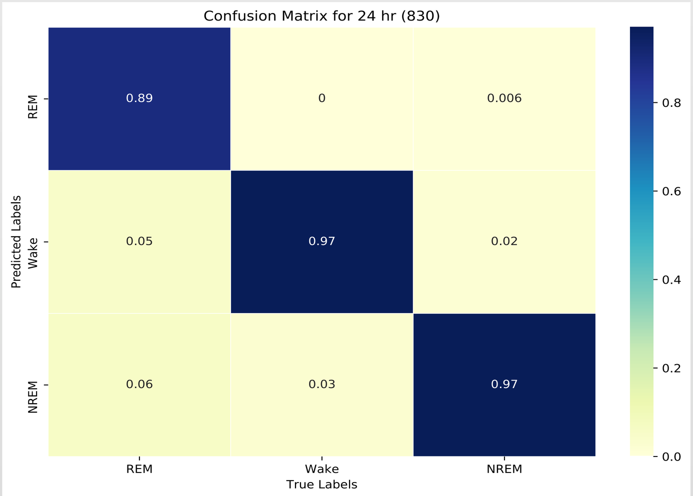

Figure 2: Confusion Matrix for a 24-hour data set after analysis showing relatively high accuracies

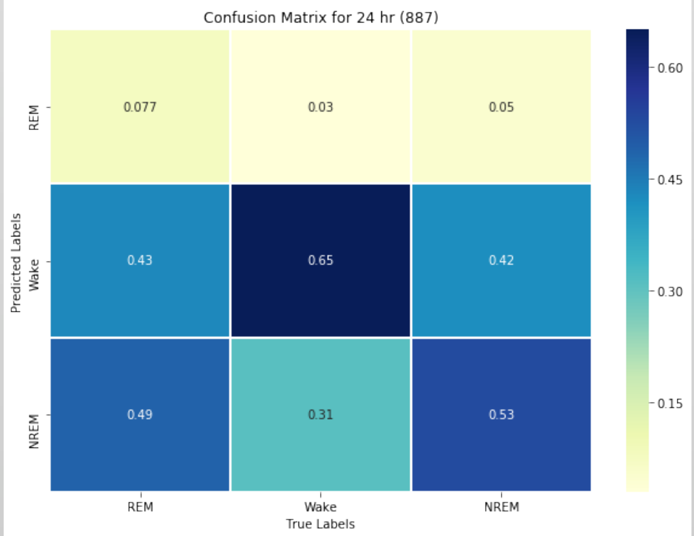

Figure 3: Confusion Matrix for a 24-hour data set after analysis showing poor results and low accuracies

Conclusion

In conclusion, the AccuSleep program, developed by Zeke Barger at the University of Berkeley can automatically score high volumes of EKG data with high accuracy. The procedures for producing accurate analysis are training your own neural network. In the case of the Eban-Rothschild Lab and our 4 second epoch recordings, using a parameter of 15 epochs to consider when training a neural network is most efficient. In addition, the program can be given around 10 minutes of training data for 24 hours and still produce accurate results, however, it is beneficial to have around 20 or 30 of those epochs should be labelled REM sleep, since the program usually has the most difficulty identifying these stages. In addition, it is also beneficial to include epochs from the light and dark phase of the recordings. Increasing the minimum bout length may have a positive effect on the accuracy but not reliably and not across all three stages.

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References

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2. http://www.scholarpedia.org/article/Neurobiology_of_sleep_and_wakefulness