DTU DANMARKS TEKNISKE UNIVERSITY

MASSACHUSETTS GENERAL HOSPITAL

HARVARD MEDICAL SCHOOL

NANYANG TECHNOLOGICAL UNIVERSITY

EPILEPTIFORM SPIKE DETECTION VIA CONVOLUTIONAL NEURAL NETWORKS

Alexander R. Johansen[1], Jing Jin[2], Tomasz Maszczyk[2], Justin Dauwels[2], Sydney S. Cash[3], M. Brandon Westover[3]

1. BACKGROUND

EEG recordings of epileptic patients often contains sharp waveforms called “spikes”, occurring between seizures. In current clinical practice, visual inspection and manual annotation of spikes are still gold standard for interpreting EEG, which is tedious and prone to errors. In our study, we analyzed scalp EEG recordings of five patients diagnosed with epilepsy. We applied a supervised machine learning paradigm known as “Convolutional Neural Networks” (CNNs) to learn the discriminative features of spikes, which resulted in improved performance over four standard classifiers.

2. EPILEPTIFORM EEG

Scalp EEG of five patients, from Massachusetts General Hospital, with known epilepsy were used for analysis.

- Blocks of 30 minutes of recordings from 19 scalp electrodes
- Sampling rate of 128Hz
- High-pass filter at 1Hz to remove baseline drifts
- Notch filter at 60Hz to remove power line interference
- Common average referential montage

Figure1: Illustration of (a) an interictal epileptiform spike, and (b) a background waveform.

- 1.5K spike and 150K backgrounds extracted from each patient
- Cross-annotated independently by two neurologists
- Extracted with 0.5 sec sliding windows
- Leave-one-patient-out cross-validation
- 10% of training set used for validation (stratified sampling)

3. CONVOLUTIONAL NEURAL NETWORKS (CNNs)

A convolutional neural network (CNN) is a mapping from an input domain to an output domain through multiple non-linear transformations known as layers:

$$z_{l+1} = h_l \theta_{l+1} \qquad h_{l+1} = a(z_{l+1}),$$

with h_ℓ a layer in the CNN and $a(z)$ a nonlinear activation function. To optimize the CNN, the network’s prediction is penalized with the cross entropy loss function:

$$L(x, y) = -f(x)\log(y) - (1-y)\log(1-f(x)),$$

where x is the input, y the true label and $f(x)$ a squashed CNN prediction (0-1) using a sigmoid function. The weight matrix θ was updated using *Nesterov*’s momentum:

$$v_{t+1} = \mu v_t - \varepsilon \Delta f(\theta_t + \mu v_t) \qquad \theta_{t+1} = \theta_t + v_{t+1},$$

where μ is the momentum and ε is the learning rate. The update is applied iteratively until the loss function is minimized on the validation set.

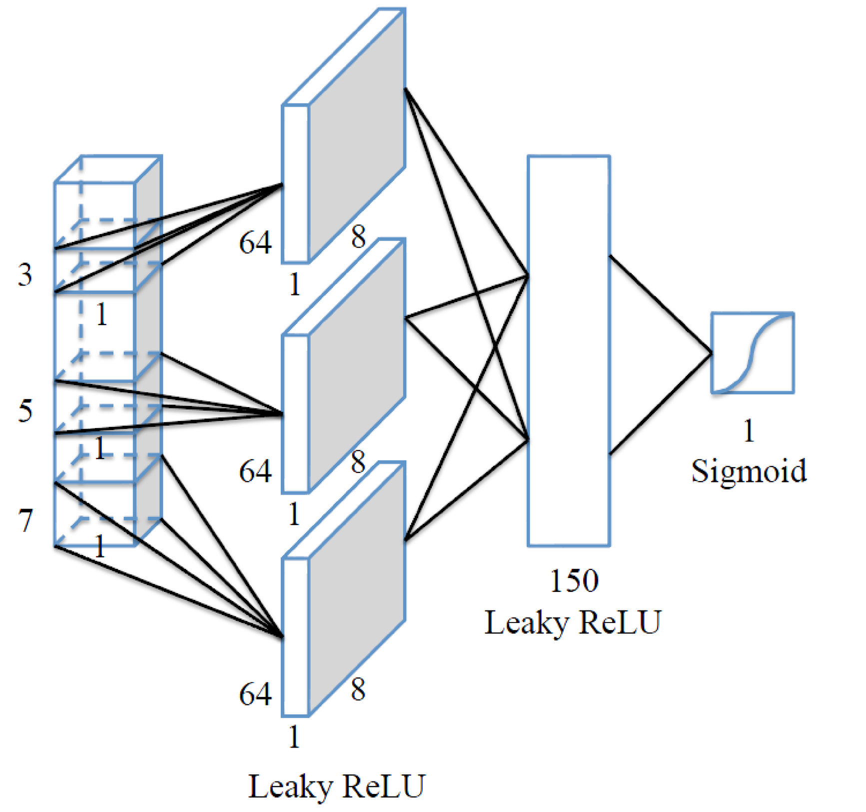
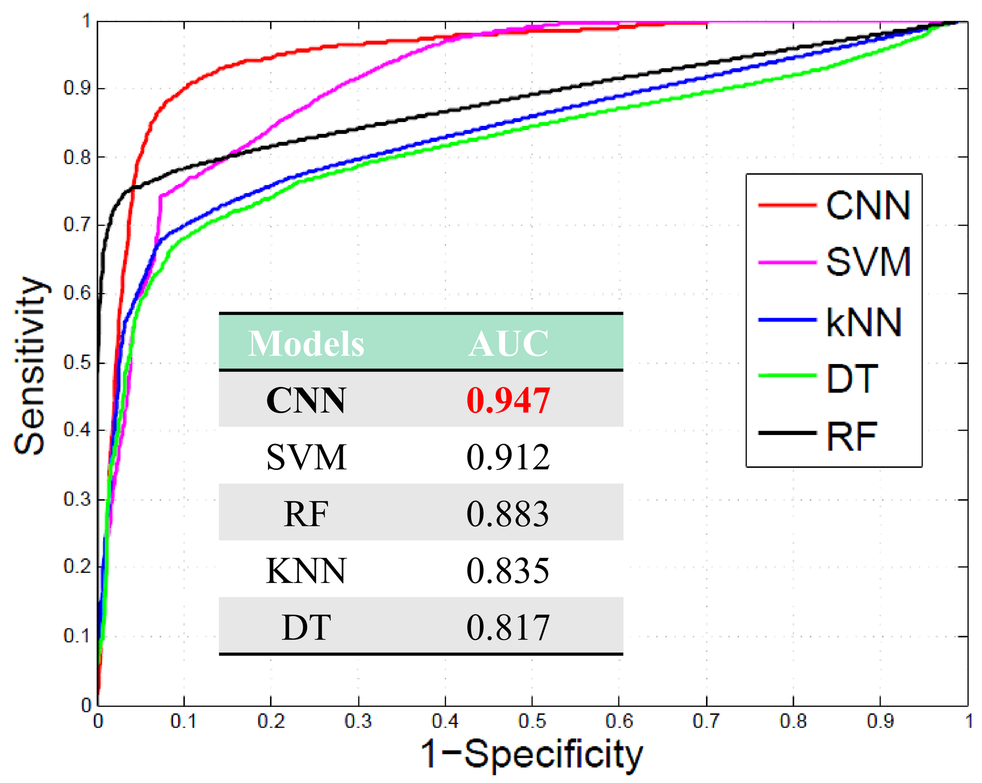


Figure 2: The architecture of a the CNN model applied.

We compared our CNN against four classic classifiers: support vector machines (SVM) with Gaussian kernel, random forest (RF), k-nearest neighbor (kNN) and C4.5 decision tree (DT).

4. RESULTS



Models	AUC
CNN	**0.947**
SVM	0.912
RF	0.883
KNN	0.835
DT	0.817

Figure 3: ROC curves for various statistical models.

5. CONCLUSION

We have developed a convolutional neural network (CNN) for detecting spikes in EEG of patients with epilepsy. Our results demonstrate that CNNs performs superior to four standard classifiers.

As further work, we will investigate larger datasets from hundreds of patients to regularize larger CNNs, which might lead to even better results.

[1] Technical University of Denmark, DTU Compute, Lyngby, Denmark.
[2] Nanyang Technological University, School of Electrical & Electronic Engineering, Singapore.
[3] Massachusetts General Hospital Neurology Department, and Harvard Medical School, Cambridge, MA, USA.