Epileptic seizures and deep learning

Chronic diseases are growing exponentially. Today, there are over 900 million individuals suffering with some chronic diseases around the world. For this reason, e-health systems are being developed to design a better quality of life for patients. For instance, we have systems for detection of epilepsy, monitoring of vital signs, control of diabetes, among others. Deep learning has being an important technique embedded in these systems to predict and sort the data without the need of a 24-hour monitoring specialist. However, by combining e-health systems and deep learning techniques also brings several challenges that need to be overcome.

Epilepsy is one of the most common neurological diseases in the world, with approximately 50 million people around the world. This disease is a chronic brain disorder that affects people of all ages[1] and also influences the people's quality of life, because they need to live with the possibility of a seizure occurring at any time. The World Health Organization (WHO) recognizes that epilepsy is a public health concern and encourages projects aimed at reducing the impact of the disorder[2].

A system for automatic crisis detection can help people quality of life. If the system can safely predict periods that are more likely to occur seizures, it would be possible to develop some mechanisms to warn patients and then they can avoid dangerous activities[3].

In recent years, the brain-computer interface (BCI) has been developed to allow the acquisition of the patient's brain data using electrodes on the scalp, capturing spontaneous electrical activities of the brain based on electroencephalograms (EEG)[4], making it a standard technique for monitoring brain activity.

A specialized physician is usually used to analyze the data and predict possible seizures. One method that is currently being found in the projects is deep learning (DL). The DL is a robust solution that uses algorithms to find patterns in complex data, and has its consolidation in the field of computer vision and speech recognition[5].

For the development of a system for epileptic seizures detection, there are several challenges [6]. The first one is the EEG data; it is a non-stationary signal, so normal patterns and seizures may change from patient to patient[3]. The volume of data generated by an EEG is also other challenge due to complexity to handle it; on the one hand, due to the high-resolution space-time, it helps for prediction. Due to the big data, one needs a secure location to store the patient data continuously[3]. As a consequence, the network bandwidth for sending data is also a challenge[7], but both, network and data storage, can be covered by a cloud based solution. Last, the application for real-time epileptic crisis detection requires a rapid diagnosis to prevent the patient from performing dangerous activities[4].

Several papers have proposed systems for detecting epileptic seizures [3] [4] [7], however none of them have used fog and cloud computing to improve the availability or performance. In [3], only cloud computing was used. In [8], the authors used only IoT in their system. Finally, in [4], the system proposed works with cloud and edge computing, which although it is similar to fog, but has different concepts based on NIST definition.

We propose an e-health system for predicting epileptic seizures with real-time analysis, using the advantages of cloud and fog computing, as shown in Figure 1. We use the cloud due its large storage and processing capacities. We store data from existing generic databases and also new data collected from individual patients, and train the DL model at cloud, since it requires high computation.

Figure 1. E-health system for predicting epileptic seizures with real-time analysis[9].

In the data collection layer, we have the sensors that are in direct contact with the patient, collecting their vital signs, such as spontaneous electrical activities of the brain, heart rate and movement. Once collected, the data is sent to the fog computing layer.

The fog computing layer is responsible for diagnosing and alerting the patient or his/her family. It receives the patient's data, performs the pre-processing of the data, executes the DL model for classification and, if necessary, generates an alert. The fog layer is also responsible for sending the pre-processed data and its classification results to the cloud computing layer. The fog computing layer is deployed close to the client, so we can avoid issues with network bandwidth and achieve response with low latency.

The cloud computing layer performs the DL training, patient data storage and long-term monitoring. The DL training process is performed by the cloud, because it requires high computation, so one can take advantages of the cloud, such as its high processing capacity and high availability. Initially, the DL model is trained with existent generic data. Additionally, we can generate a specific DL for each patient, feeding the DL model with data from the monitored patient.

Our proposed e-health system is able to generalize the DL model in order to achieve satisfactory predictions in new patients. Considering that the EEG does not have a defined standard for all patients, it is important that DL models learn and become a specialist in that patient by decreasing the false positives. This goal is accomplished through the data stored in the cloud and its continuous monitoring. As any research proposal, this system development faces several challenges.

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References

1. Megiddo, Itamar; Colson, Abigail; Chisholm, Dan; Dua, Tarun; Nandi, Arindam; Laxminarayan, Ramanan. Health and economic benefits of public financing of epilepsy treatment in India: An agent-based simulation model; Wiley Online Library: Wiley Online Library, 2016; pp. 464.

2. World Health Organization, Epilepsy . World Health Organization, Epilepsy. Retrieved 2020-12-25

3. M. P. Hosseini, H. Soltanian-Zadeh, K. Elisevich, and D. Pompili, "Cloud-based deep learning of big eeg data for epileptic seizure prediction," in 2016 IEEE Global Conference on Signal and Information Processing (GlobalSIP). IEEE, 2016, pp. 1151–1155.

4. M. P. Hosseini, T. X. Tran, D. Pompili, K. Elisevich, and H. SoltanianZadeh, "Deep learning with edge computing for localization of epileptogenicity using multimodal rs-fmri and eeg big data," in Autonomic Computing (ICAC), 2017 IEEE International Conference on. IEEE, 2017, pp. 83–92.

5. R. Miotto, F. Wang, S. Wang, X. Jiang, and J. T. Dudley, "Deep learning for healthcare: review, opportunities and challenges," Briefings in bioinformatics, 2017.

6. J. Prasanna; M. S. P. Subathra; Mazin Abed Mohammed; Robertas Damaševičius; Nanjappan Jothiraj Sairamya; S. Thomas George; Automated Epileptic Seizure Detection in Pediatric Subjects of CHB-MIT EEG Database—A Survey. *Journal of Personalized Medicine* **2021**, *11*, 1028, 10.3390/jpm11101028.

7. M. P. Hosseini, D. Pompili, K. Elisevich, and H. Soltanian-Zadeh, "Optimized deep learning for eeg big data and seizure prediction bci via internet of things," IEEE Transactions on Big Data, vol. 3, no. 4, pp. 392–404, 2017.

8. Mohammad-Parsa Hosseini; Dario Pompili; Kost Elisevich; Hamid Soltanian-Zadeh; Optimized Deep Learning for EEG Big Data and Seizure Prediction BCI via Internet of Things. *IEEE Transactions on Big Data* **2017**, *3*, 392-404, 10.1109/tbdata.2017.2769670.

9. Rocha, E., Monteiro, K., Silva, E., Santos, G.L., Santos, W. and Endo, P.T., 2018, December. Detecting epileptic seizures using deep learning with cloud and fog computing. In 2018 IEEE/ACM International Conference on Utility and Cloud Computing Companion (UCC Companion) (pp. 19-20). IEEE.