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Smart-EEG

a Tele-medicine System for EEG Exams

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I. INTRODUCTION

An electroencephalogram is a measurement of the electrical activity occurring in the brain over a period of time. It is used to diagnose different pathologies related to the human brain (epilepsy, anoxic or metabolic encephalopathy, brain death validation or assessment of neonate brain maturation...)

In order to diagnose those different pathologies, an acquisition of the electrical activity at the surface of the scalp for an average of 20 minutes in the laboratory to 30 minutes in the intensive care is commonly performed. The data are captured through electrodes which are placed at predefined positions all over the cortex (called international 10-20 system [1]). Those signals are interfered by artifacts coming either from other activities inside the body (namely the eyes movement, heartbeat, tremor, sudation etc.) or from outside perturbations (cellular phone, nearby elevator, door closing). To interpret correctly those signals and to be able to distinguish them from pathological brain activity, EEG signals acquisition is associated with ECG (electrocardiogram), EMG (electromyogram), EOG (electrooculogram) and an audio-video recording to provide a context of the acquisition. This extra-EEG information is mandatory to provide a more accurate interpretation of the signals.

Those exams are commonly performed by a technician and then interpreted by a neurologist, both being localized in the same hospital Department. However, considering that medical demography is dramatically decreasing, access to health care is not any more available in areas lacking neurophysiology expertise. The telemedicine system could be a solution to this problem. Several hospitals in Canada and Spain already experienced this type of services [2] [3]. In France, remote transmission of EEG recordings is currently used either in routine or for a second expertise. But, transmission is not always computer-assisted, and whenever it is, our analysis of the existing devices reveals two flaws:

- 1) The synchronization of physical values is not strictly respected.
- 2) The frame rate of acquired videos restricts the identification of abnormal movements and hence correct interpretation.

Thus, our primary goal is to solve these limitations. This paper is structured as follows: section 2 describes limitations in

the state of the art systems. Section 3 overviews Smart-EEG project which aims at overcoming those limitations. Section 4 outlines briefly what evolution could be brought to the healthcare. Last section provides a conclusion and the direction for future works.

II. CURRENT LIMITATIONS

Current generation systems have limited performances. One of those technological limitations concerns the time-synchronization of different signals. An accurate synchronization between the different physiological values and the video is mandatory to perform a good interpretation. However, current systems only reconstruct timing information once data have been received on a personal computer. This is insufficient for millisecond accuracy since operating systems cannot guaranty the expected level of precision.

A second limitation is the maximal video frame-rate that the system can acquire and transmit (most systems are limited to 30 fps maximum). This is a problem as some pathologies, where myoclonic jerks, can be elicited by the cortex up to 20 milliseconds in some extreme cases. To analyze the delay between the cortex spike and the myoclonic jerk, is essential to refer the myoclony to cerebral cortical activity and not to subcortical activity for instance. Since frames are taken every 33ms, The current frame-rate acquisition does not allow this accuracy, biasing the final diagnosis. In order to capture those activities, a 10 milliseconds interval between two frames should be required. This implies having 100 fps.

Once all acquisitions are completed, data are transmitted to a remote location to be interpreted by a neurophysiologist. Without compression, this transfer would be too heavy for any network infrastructures. In addition, medical records must be stored according to secure and standardized protocols to ensure full confidentiality and data protection for a long period of time (for instance in France, the legal duration for which hospitals are required to keep data records is 20 years after the last visit of the patient). The accumulation of data records would become overwhelming and this encourages the use of a compression algorithm.

The compression algorithm used can be either lossless or lossy depending on the criticality of the data. Lossless algorithms guarantee the restitution of the exact original data after decompression. In medical application, exact reconstruction of physiological signals is more critical than compression performance, this is why distortion due to compression should

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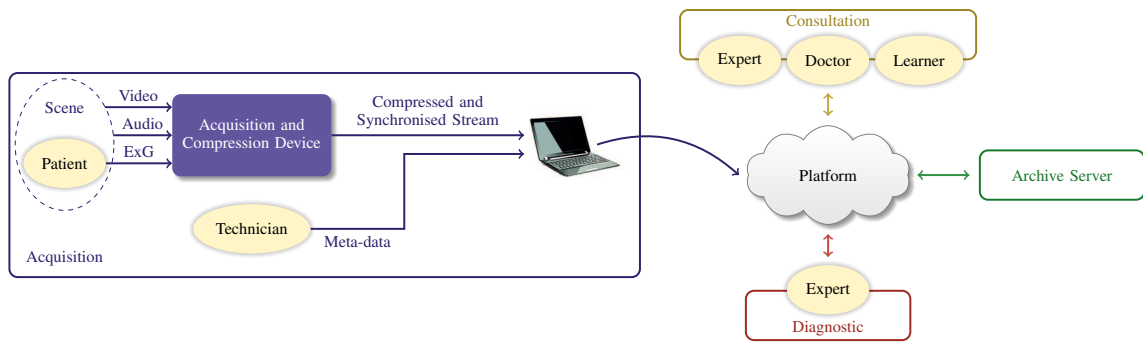


Fig. 1: Healthcare pathway of Smart-EEG

be limited. So using lossless algorithm would be a better fit in this field to reduce file size without losing information [4]. On the other hand, lossy algorithms can achieve higher compression ratio but information will suffer from distortion. Less diagnosable information can be compressed using those algorithms. This is particularly applicable to our application to compress audio or video which would be too bulky if compressed with a lossless algorithms.

III. SMART-EEG

The Smart-EEG project aims to push back those two technological barriers by offering a reliable Hardware/Software solution for EEG diagnosis. Moreover, the system is targeted for telemedicine, thus the needs of compression and transmission are therefore at the very core of this project. In order to answer the two problems, we propose a new system level architecture which integrate EEG signals, synchronized audio-video and annotations made during the acquisition and clinical data. This system is based on an acquisition device that is in charge of both synchronization and compression. Once the acquisition is finished, data are completed with the patient information and technician annotations and transferred to a remote server until the interpretation is performed by an expert.

Compression of the exams data is essential. Both video and physiological signals are compressed using a medical certified image sequences compressor [5]. Work is ongoing to modify this compression algorithm for video and physiological signals. Video is critical in term of performance as the input data rate is important (more than 2Gbit/s). This incoming stream cannot be stored before transmission as it would impose having high storage capacity on the device. Moreover, most hard drive cannot handle this writing throughput. For this reason, the video is encoded on the fly by the device. The codec is based on wavelet transform and öktem coder [6]. Previous work showed good results in using this algorithm for sequences of images [5]. Moreover, work has been carried out to speed up the computation of the algorithm using a FPGA co-design implementations [7].

IV. CLINICAL PATHWAY

The usual successive steps from EEG acquisition to interpretation is only slightly modified by the introduction of telemedicine. The figure 1 illustrate different steps of Smart-EEG. Acquisition is carried out as usual at the hospital by the technician. Video, audio and physiological signals are gradually saved in a file on the local computer. At the end of the 20 minutes acquisition, the technician is asked to upload the complete record (signals + meta data) to the platform. Once this upload is completed, the complete exam is available to the neurolophysiologist in charge of this record. He/she can

therefore read the signals and upload his/her diagnostic on the same platform. The complete record can now be stored on the archive server. The exams may be reviewed in case of tele expertise.

V. CONCLUSION AND FUTURE WORKS

In this paper, we have presented the stakes of telemedicine for EEG. We introduced the Smart-EEG project aiming to provide a complete tele-medicine system for video-EEG. This solution is based on an acquisition device capable of synchronizing and compressing ExG, video and audio signals. The base-line compression algorithm used for both lossless and lossy constrained modalities has been overviewed.

The current implementation is able to compress the test data using the described compression algorithm. However this implementation does not meet the expectation of a full-HD 100 fps video encoder. Thus, an optimized hardware version of this coder is under development to improve performance. In addition, studies are in progress for the compression of physiological signals. Work is being done to overcome the synchronization limitations of state of the art systems.

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