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To cite this version:

Ludovic Gardy, Emmanuel Barbeau, Christophe Hurter. Epileptic Spikes Detection and Visualization in Intracerebral EEG with Convolutional Kernel Density Estimation. WIRED: Workshop on Intracranial Recordings in humans: Epilepsy, Nov 2019, Paris, France. hal-02396485

HAL Id: hal-02396485
https://hal-enac.archives-ouvertes.fr/hal-02396485

Epileptic Spikes Detection and Visualization in Intracerebral EEG with Convolutional Kernel Density Estimation

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Introduction

The intracerebral electroencephalographic (EEG) signal of drug-resistant epileptic patients can be recorded 24/7 for a duration ranging from 7 to 15 days. This signal, recorded on more than a hundred channels simultaneously, represents a huge amount of data. Electrophysiological markers of the epileptogenic zone are concealed within this mass of data and are both difficult and time consuming to identify. Current pattern recognition techniques such as dynamic time wrapping [2], frequency analysis [3], or machine learning [1], are challenged by the size of the data and by their noisiness as electrophysiological markers are usually subtle. We propose an effective and noise-resistant way to identify Interictal Epileptic Spikes (IES). This novel technique, called Convolutional Kernel Density Estimation (CKDE), could provide a new alternative for detecting IES and in the future, other pathological markers.

Methods

Two-dimensional convolution is a technique commonly used in image processing to apply effects such as blurring, sharpening, or edge detection. We used this technique on imaged-converted EEG signal to highlight density fields that could mark the occurrence of pathological events. Sharp amplitude variations during IES have the effect of spacing points from each other, and therefore the pixels representing the signal on the image. It is this notion of spacing between points that we can exploit to identify IES in EEG. When convolution is applied, non-pathological variations appear under the form of high densities and IES under the form of low densities because of the increased spacing between the points in the same amount of time.

Results

We have identified several interesting or novel aspects of CKDE that are worth assessing in future work:

- Unlike other event detection methods, density changes are neither affected by signal orientation (positive or negative) nor by prominent but slow changes in amplitude, nor by unwanted oscillations.
- Only very abrupt variations can be detected, like those caused by IES, thus avoiding false detections driven by rise or fall of slow and non-pathological amplitudes.
- No training of the algorithm on the data is necessary, and only a few or no preprocessing at all has to be done.
- The representation of densities in EEG is straightforward for the user to understand given that the data look a lot like a line graph.

Discussion

This method could be used in the development and improvement of automatic detectors. Our first tests show a good identification of IES but the computation time is still long and other pathological events such as fast oscillations can not yet be detected.

Figures 1 and 2 describe the process used from raw signal to CKDE.

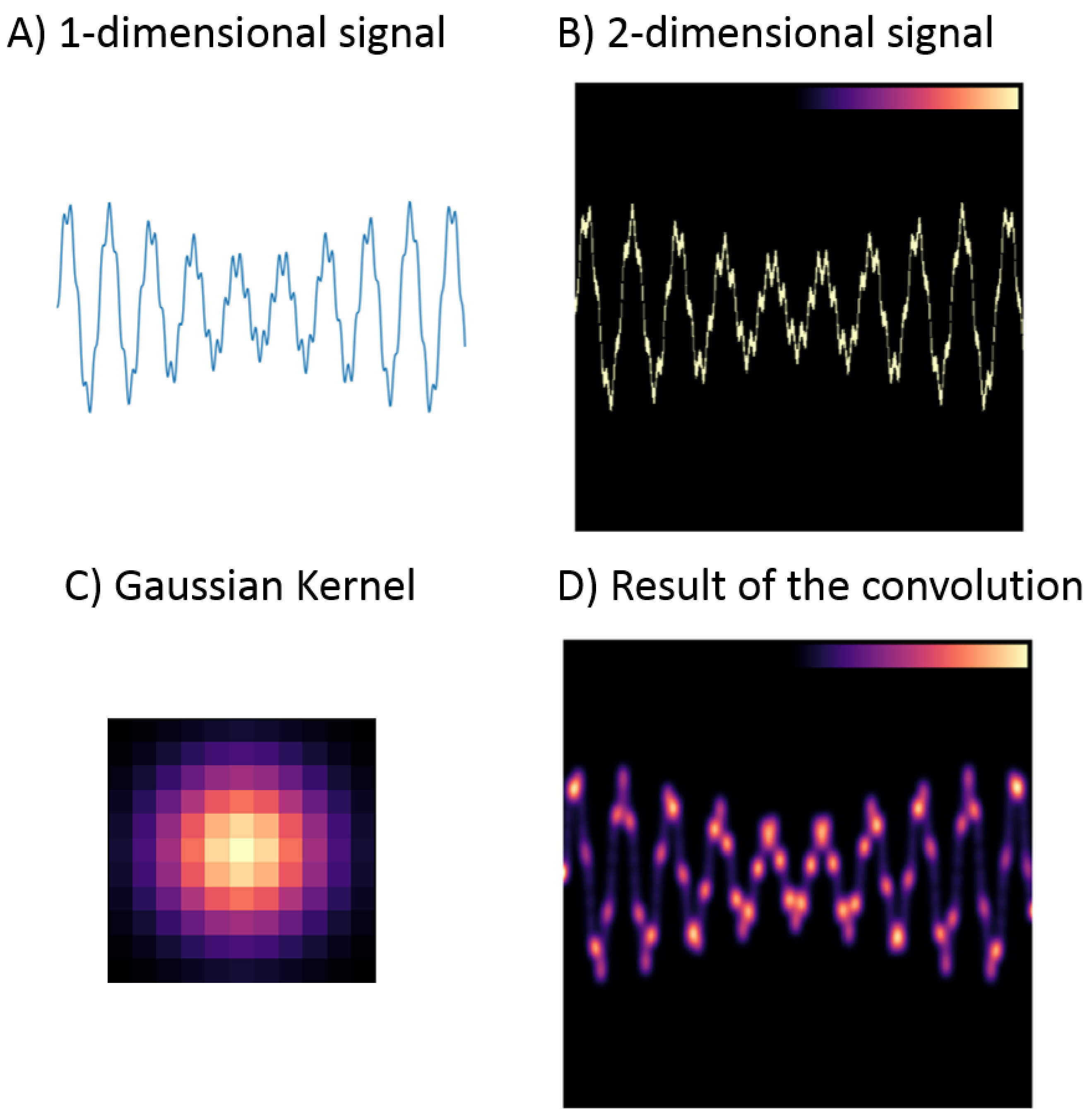

Figure 1: A) Simulated 1D sine time-series. B) The time series was transformed into a 2D image. C) The gaussian kernel used for convolution. D) Result of the CKDE.

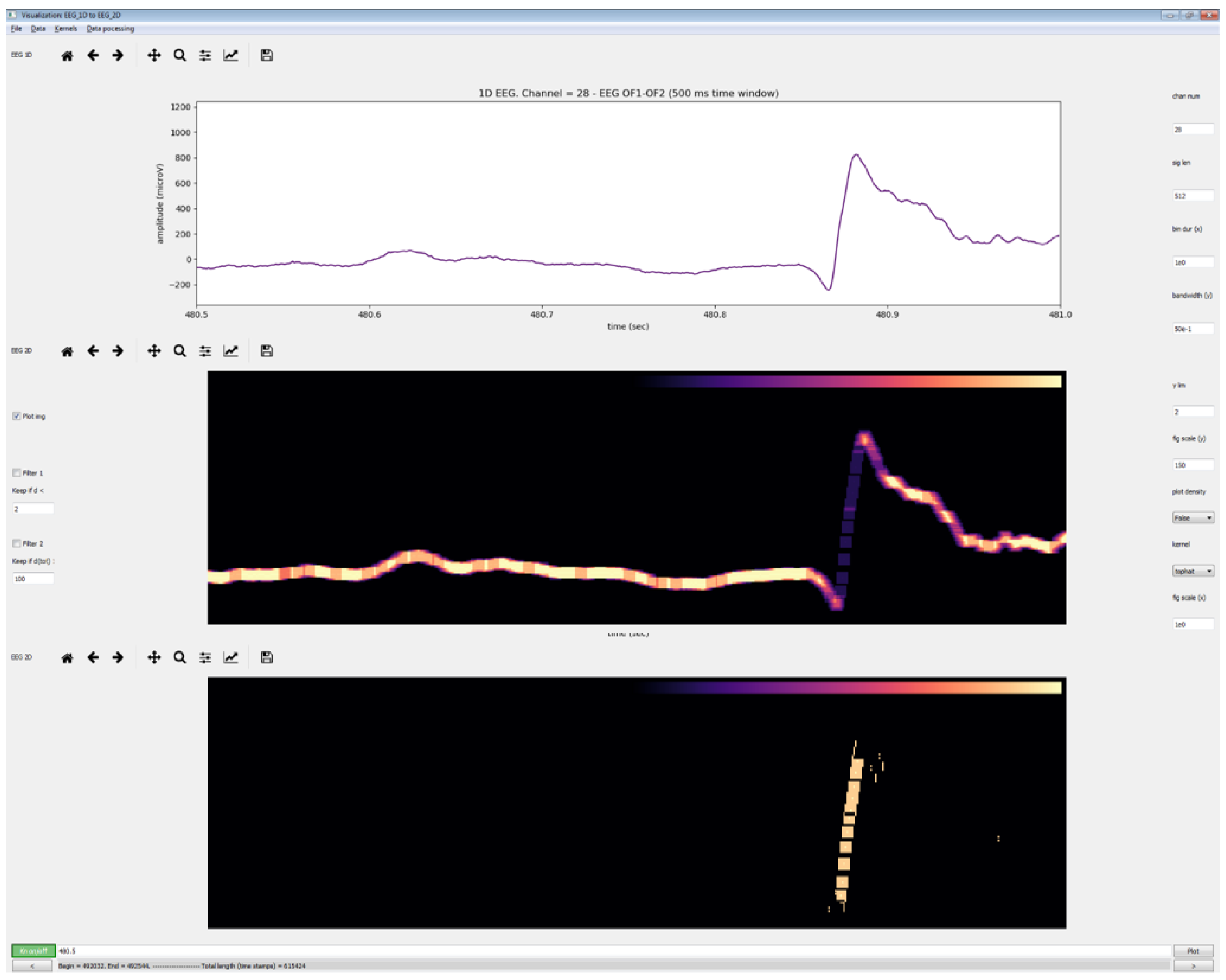

Figure 2: Top graph: One second of raw signal showing an IES. Middle: Signal after application of CKDE. Bottom: A low-pass filter was applied on densities to isolate the IES.

Acknowledgements

This project has received funding from the Université Fédérale of Toulouse Midi-Pyrénées and the Région Occitanie.

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