Nerve Activity Analysis Using Matrix Pencil Method

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1.Abstract

The electrically evoked compound action potential (CAP) is an electric measure of neural tissue's response. CAP is the result the sum of elementary action potential from activated neural fibers. Currently, CAP analysis is only based on its amplitude. In our study, we have opted to use, Matrix Pencil Method (MPM) as it represents additional characteristics of CAP. Accordingly, parameters to link signal signature and physiological behavior will be extracted.

3.Method

❑ Experimental database :

Our data is composed of signals recorded in vitro on the sciatic nerve of a rat, using a Pico-scope with 1 MHz sampling frequency. Stimulations ranged from 200 mV to 1,6 V (28mV step) with a duration of 50 µs to 200 µs (3 µs step) .

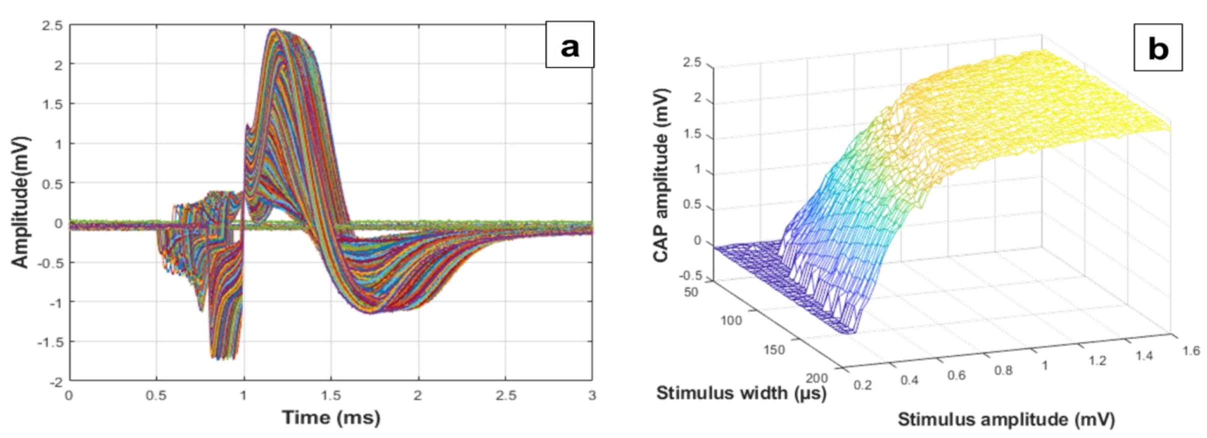


Fig.1- a:Example of recorded CAP - b: Variation of CAP amplitude in function of stimulus width and amplitude

❑ Matrix Pencil Method:

In our case, we use Matrix Pencil Method for signal identification and analysis. The signal y(t) can be written in the following form: $y(t) = x(t) + w(t) = \sum_{j=1}^{M} R_j e^{s_j t} + w(t)$

Matrix Pencil is based on the identification of the number of M significant poles, the complex value of each poles Sj and the complex value of each corresponding amplitude Rj. w(t) represents the noise measurement.

4.Results

CAP analysis is done as follow:

❑ Removal of useless information:

We have developed a software using MPM method that guarantees the removal of Stimulus artifact

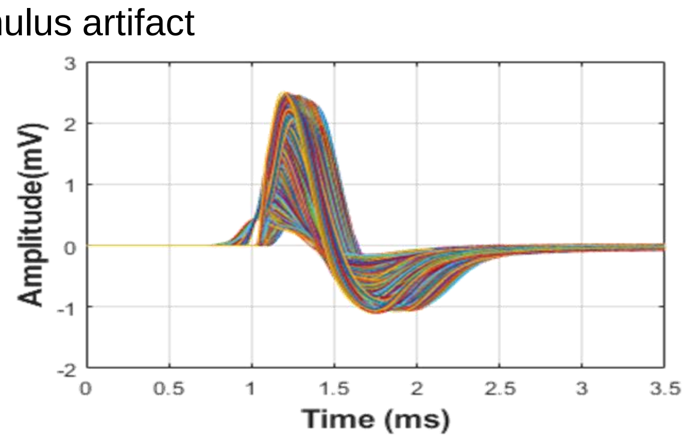


Fig.2- Free neural responses

The Fig2 shows the efficiency of our method on eliminating useless information and the contaminated data presented on the Fig1.a

❑ Identification of the number of poles M:

MPM is based on eigen values identification, that build basic functions, and curve fitting that has been assessed with normalized mean square error (NRMSE).

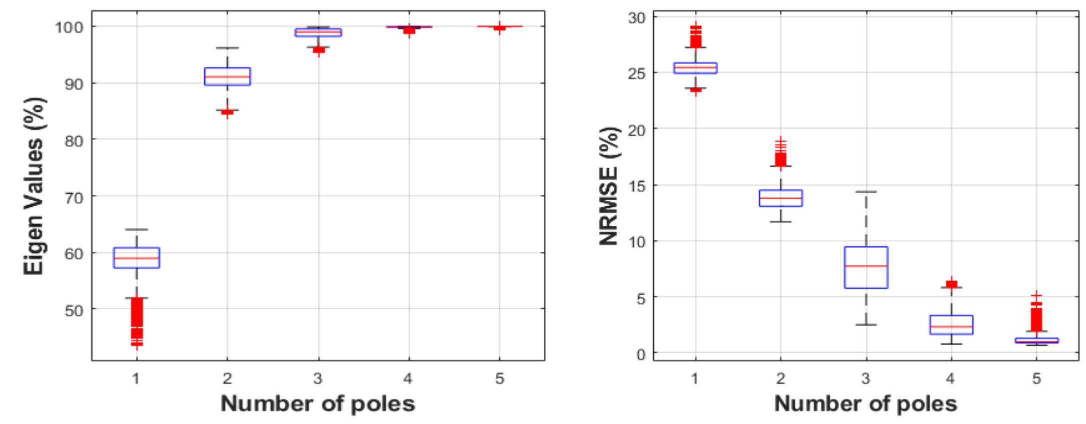


Fig.3- Identification of the number of poles M

Fig.3 shows that when we choose M =5, we guarantee a 100% energy retention (represented by eigen values) with an NRMSE mean less than 2%.

❑ CAP decomposing with MPM

For M= 5,CAP decomposing with MPM (Fig2) results in two oscillatory signals associated to complex poles and an exponential signal associated to the real pole.

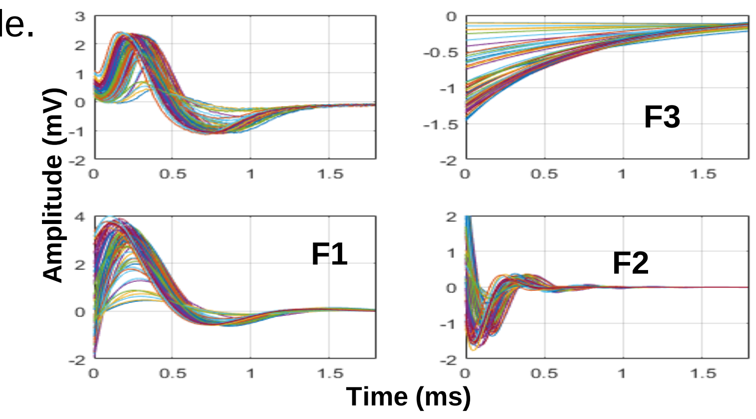
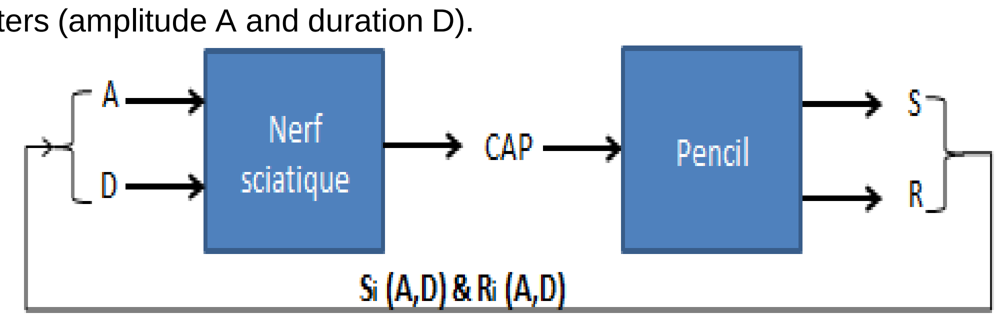


Fig.3- CAP break down using MPM

The principal function (Fig3.F1) represents the signal by an amplitude and a fundamental frequency. The second (Fig3.F2) and third (Fig3.F3) basic functions improve, respectively, the CAP depolarization and repolarization rate.

❑ Proposed model for Nerve activity :

The aim of this step is finding a model linking Pencil parameters (R and S) to stimulus parameters (amplitude A and duration D).



We Propose two models:

$$\begin{cases} S_i(A,D) = \sum_{j=1}^{N1} Rs_{i,j}(D).\, e^{Ss_{i,j}(D).(A-A_1)} \\ R_i(A,D) = \sum_{j=1}^{N2} Rr_{i,j}(D).\, e^{Sr_{i,j}(D).(A-A_1)} \end{cases} \qquad \begin{cases} S_i(A,D) = \sum_{j=1}^{N1} Ps_{ij}(D).\, Qs_{ij}(A) \\ R_i(A,D) = \sum_{j=1}^{N2} Pr_{ij}(D).\, Qr_{ij}(A) \end{cases}$$

i=1:M et j=1:51 (51stimulus width and amplitude)

The first model is based on MPM and polynomial regression the second one is based only on polynomial regression. Choosing N1 and N2 is based on two main criteria:

- ❖ Model with two input : A and D
- ❖ An error of estimation less than 5%

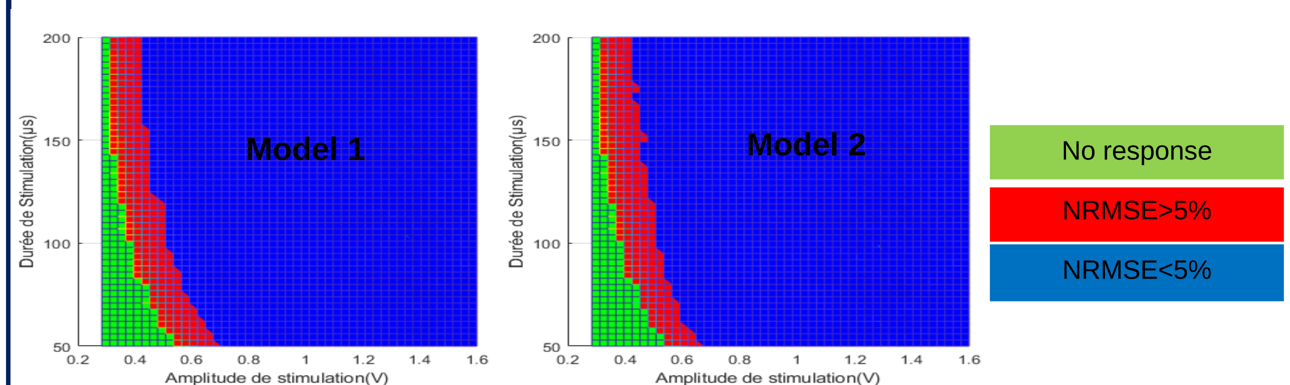


Fig.2- Models Test

5.Conclusion

Our results shows :

- MPM efficiency in CAP identification with less than 2% error.
- Two models with more than 80% of validity and less than 10% of error.
- Further work will be proposed regarding the use of proposed model in building a robust electronic control between Electrical Neuro-stimulation and CAP response for pain modulation

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