



VNIVERSITAT
E Q̄ VALÈNCIA

**La inteligencia computacional como herramienta
de apoyo en la cirugía de estimulación cerebral
profunda para la enfermedad de Parkinson**

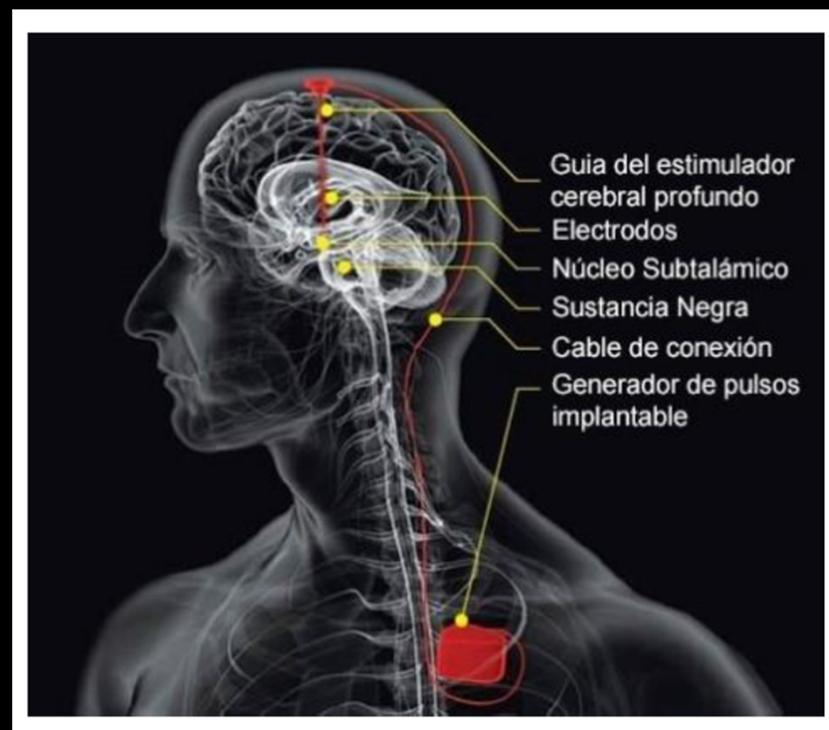
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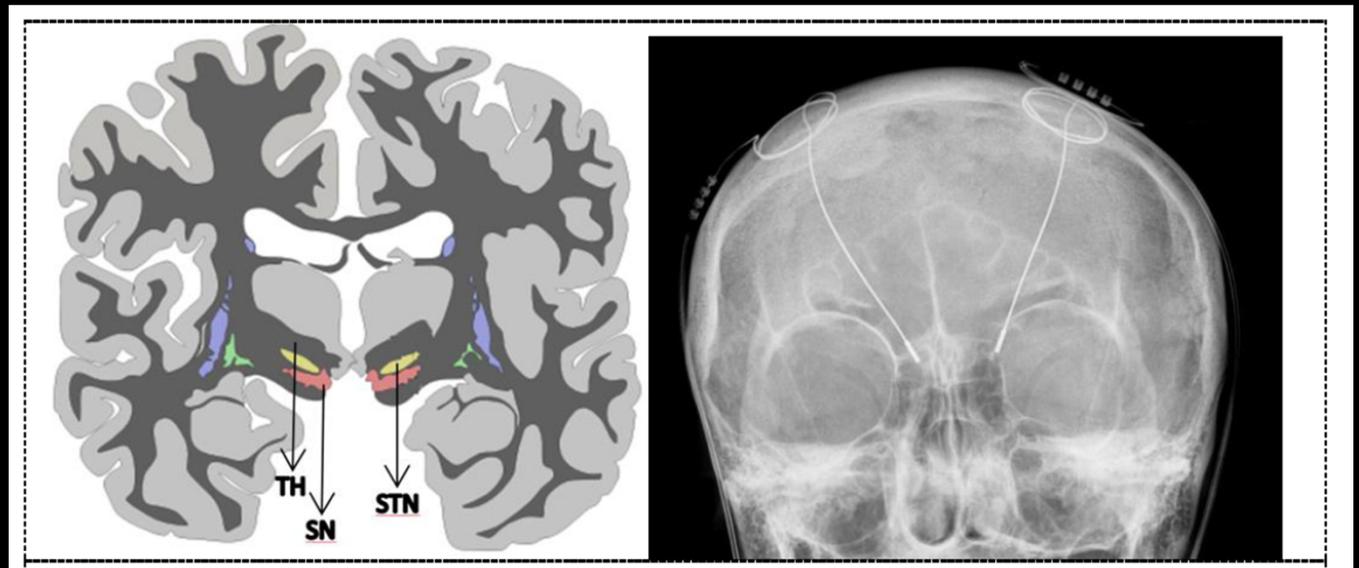
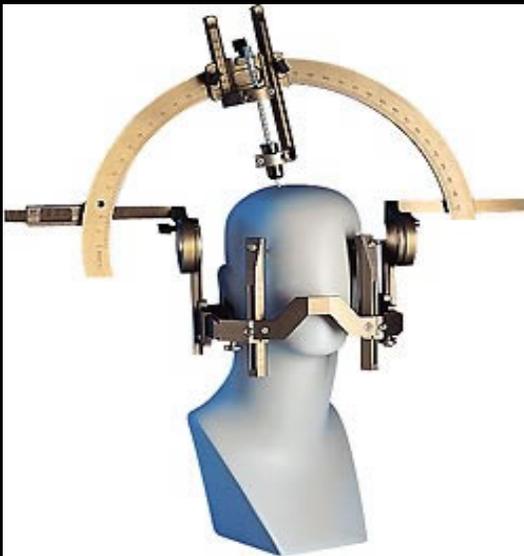
¿Qué es un estimulador cerebral profundo?

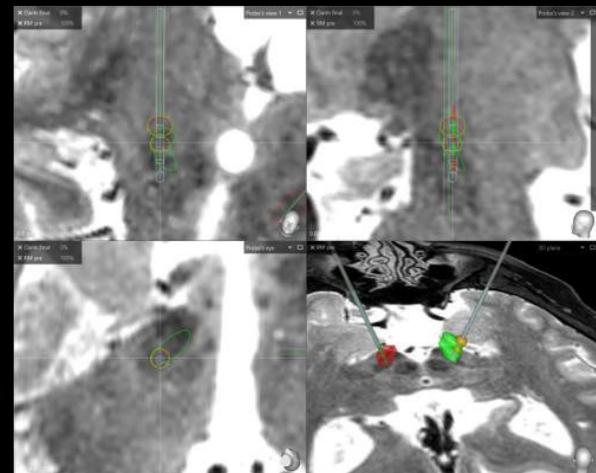
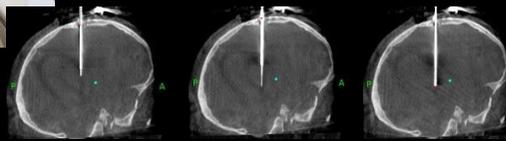
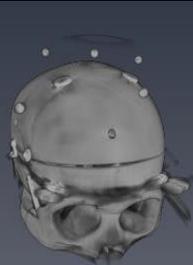
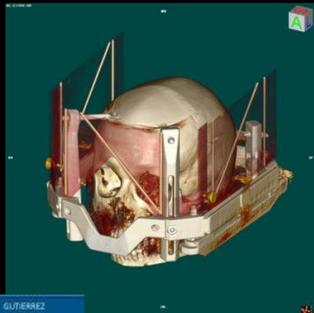
[The Effects of Turning a Deep Brain Stimulation Device Off and On - YouTube](#)



¿Cómo es la cirugía?

- Sólo pacientes con patología Parkinson muy concreta
- Estudio previo mediante imagen (Resonancia Magnética) → objetivo: localizar Hipotálamo (STN)
- Planificación de trayectorias (ambos hemisferios)





MR-3D: 3T T2

TAC 3D/OARM

O-ARM
Intraoperatorio

TAC 3D final

Planificación de trayectorias MR T2
Trayectorias rectilíneas

Fusión CT/ OARM
para puntos
fiduciales
(trépanos)

O-ARM-preMER
O-ARM-Track
O-ARM DBS

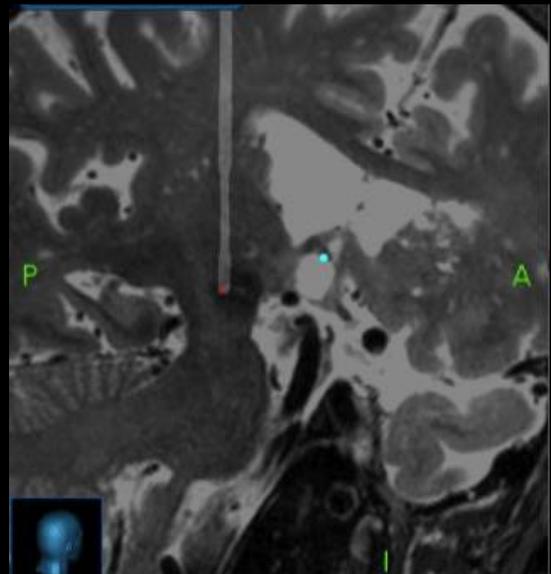
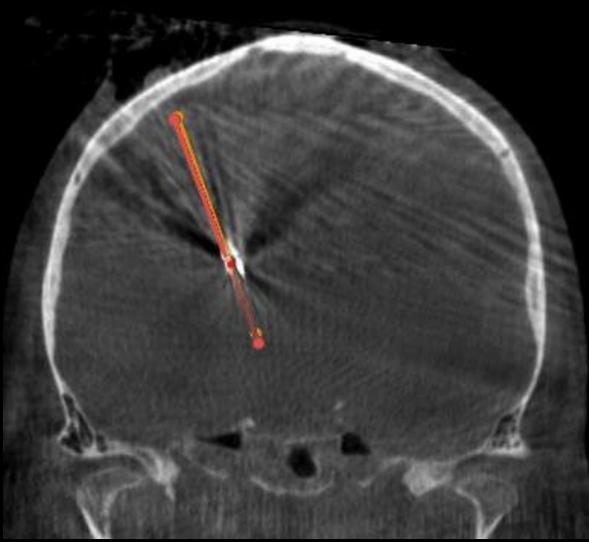
Control por imagen CT 3D



O-ARM1 preMER
(cánula)

O-ARM2 Track
(MER)

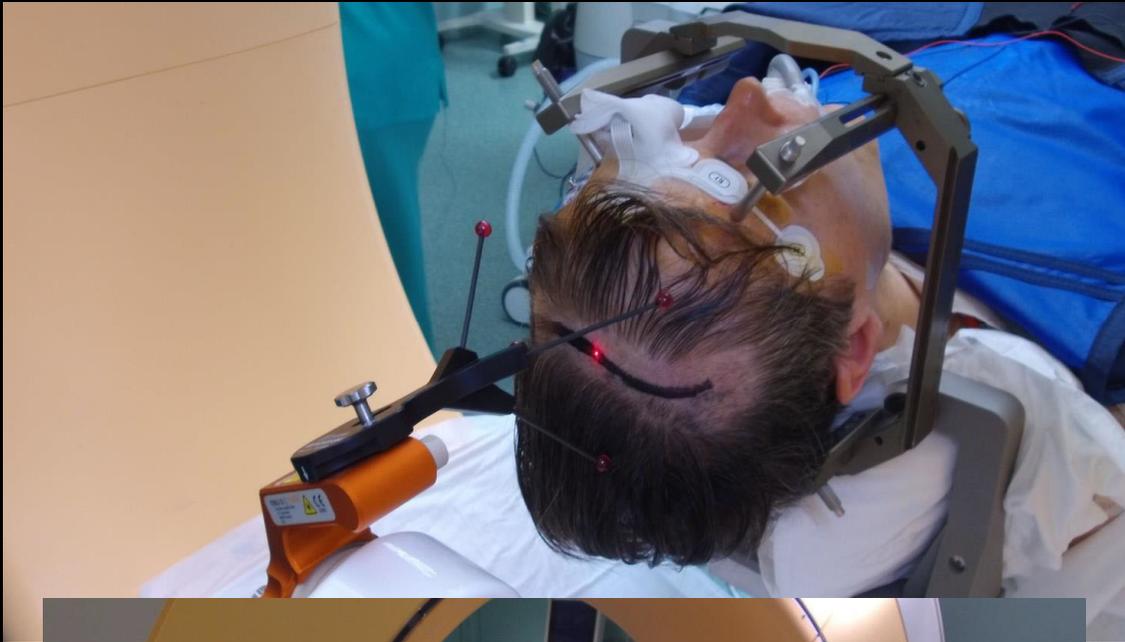
O-ARM3
(DBS)

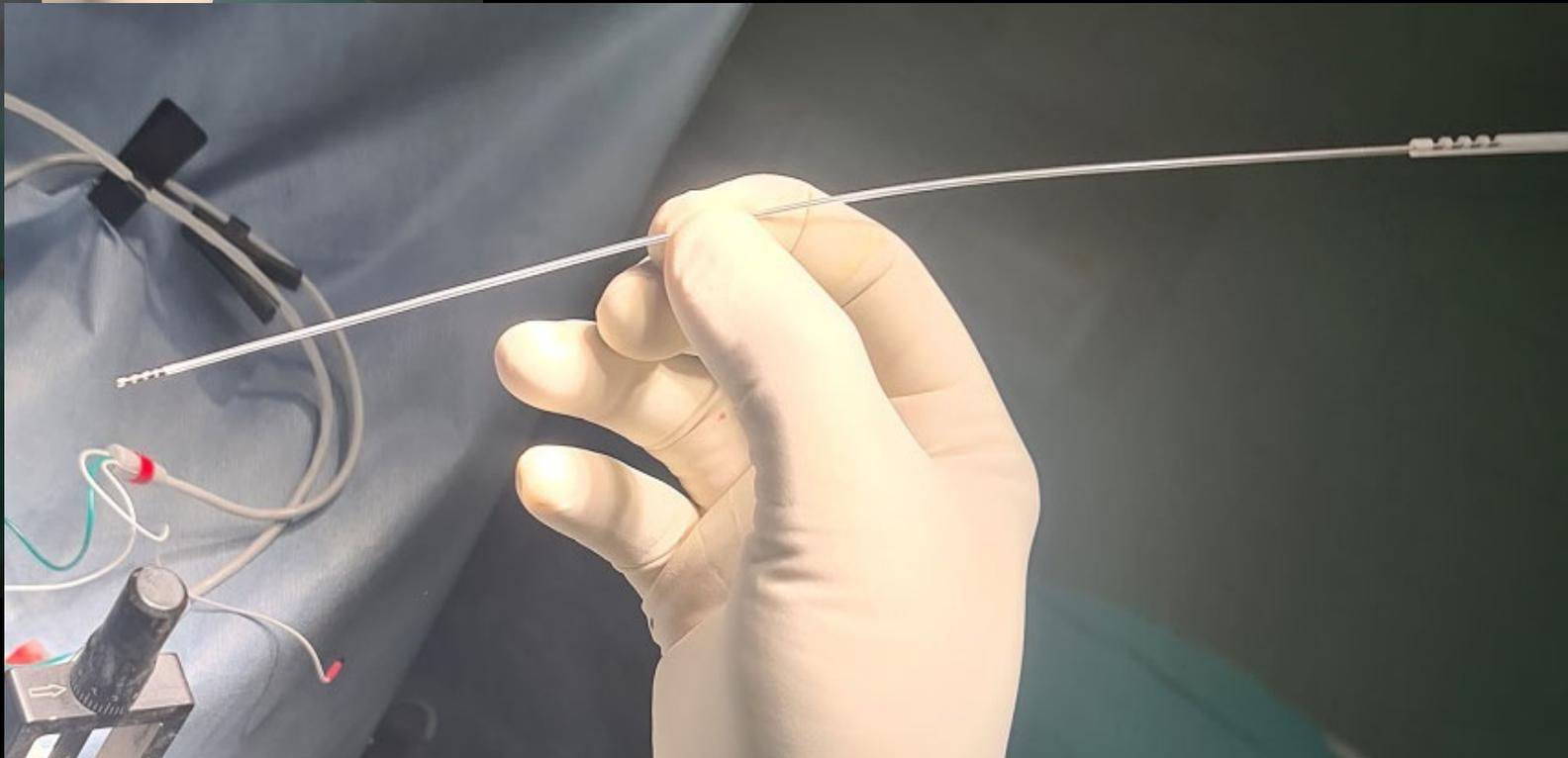
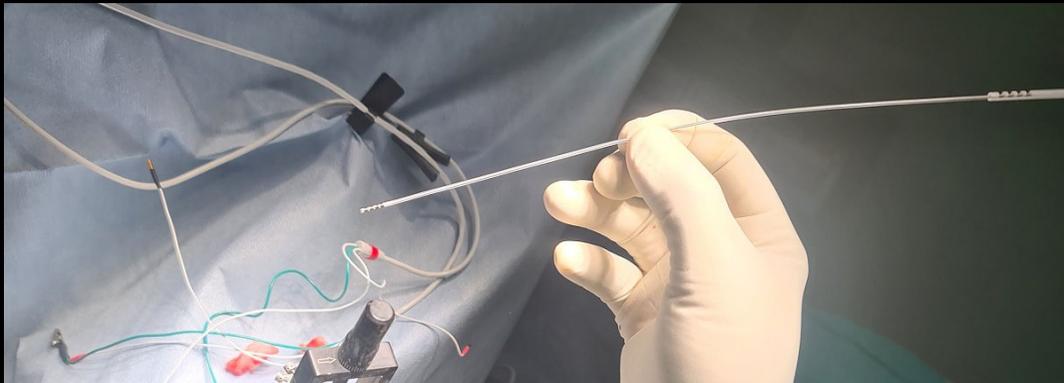


Prolong cannula trajectory
± Plan extra-track

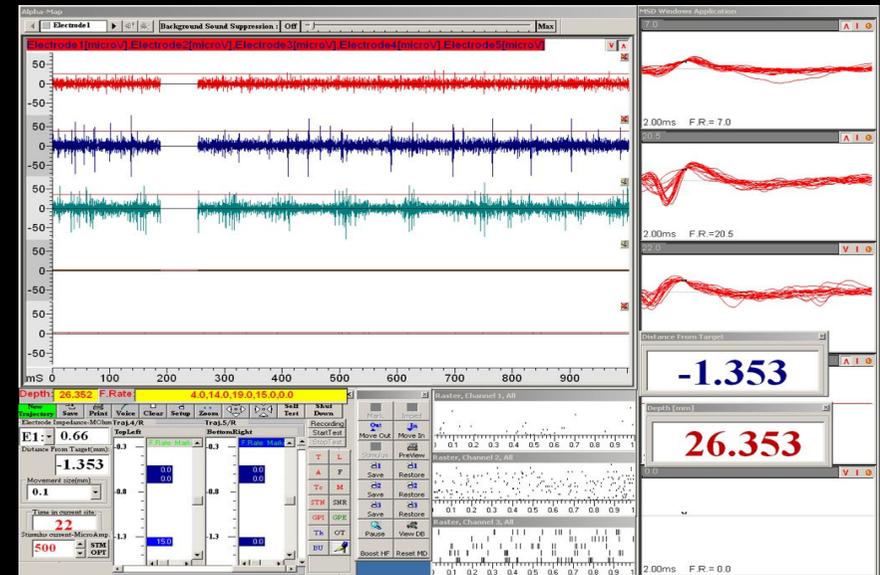
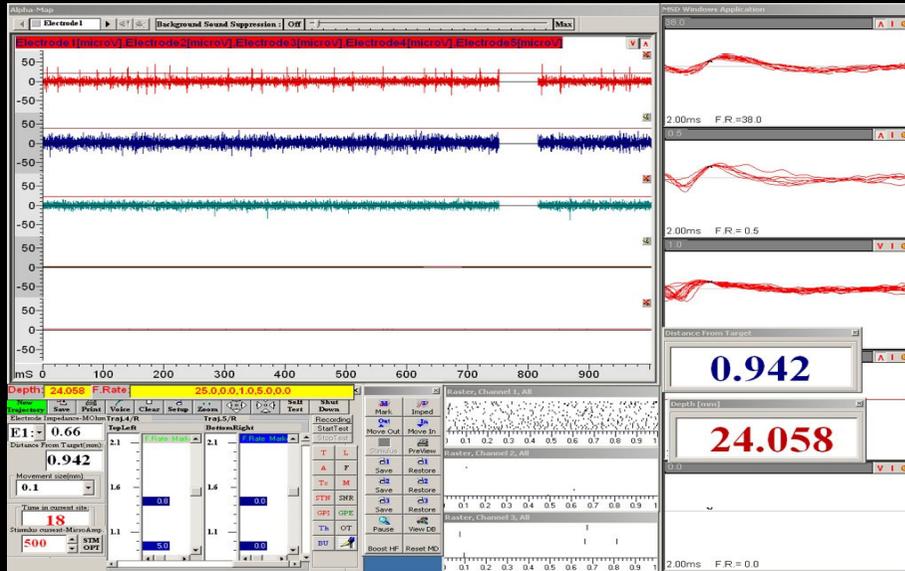
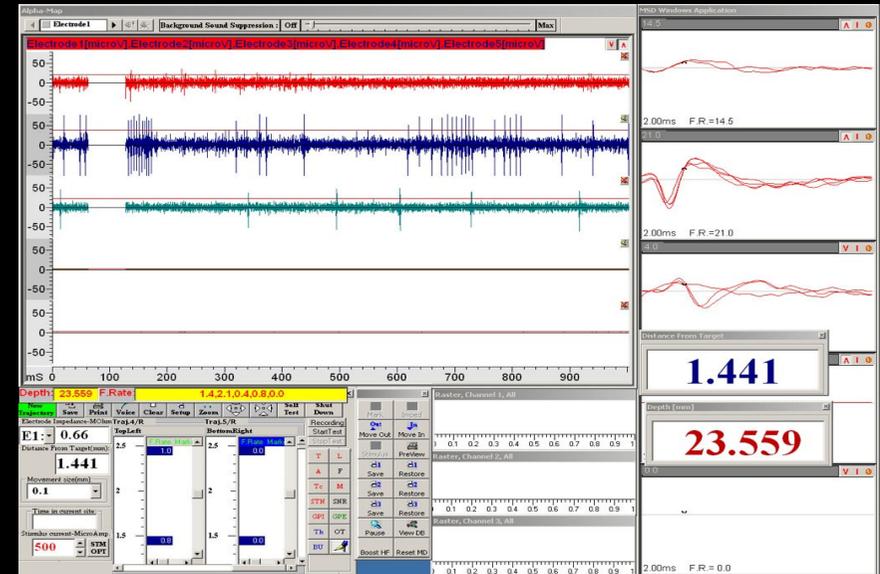
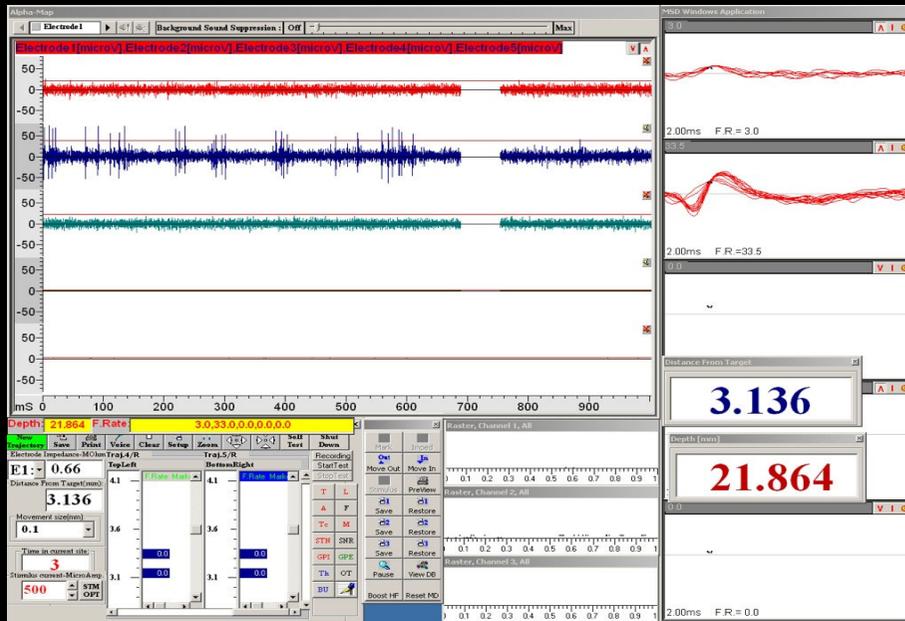
Posición MER

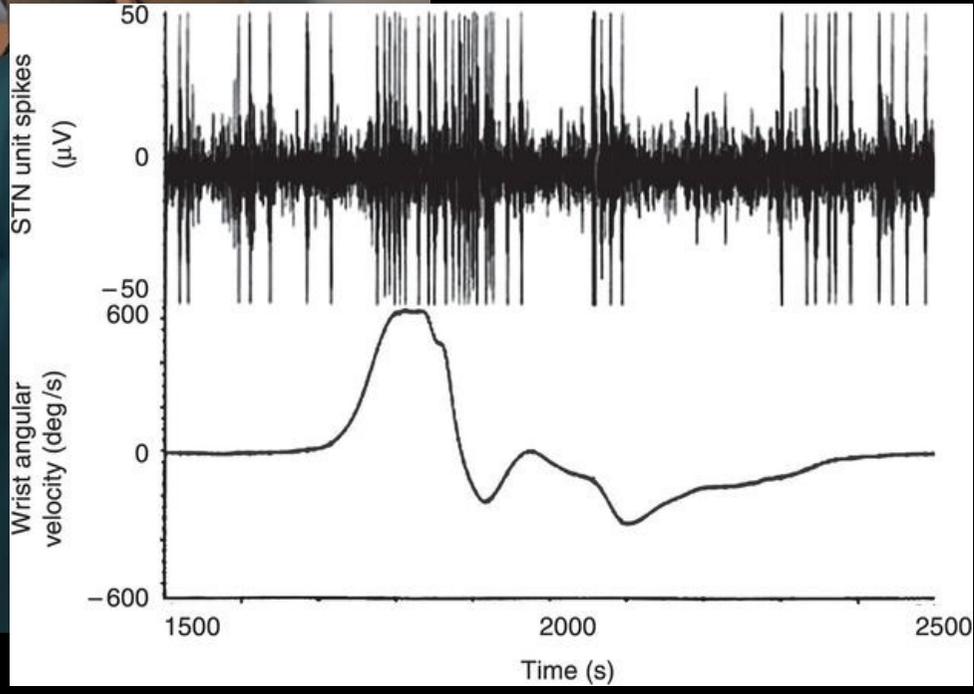
Posición DBS
Corrección de posición

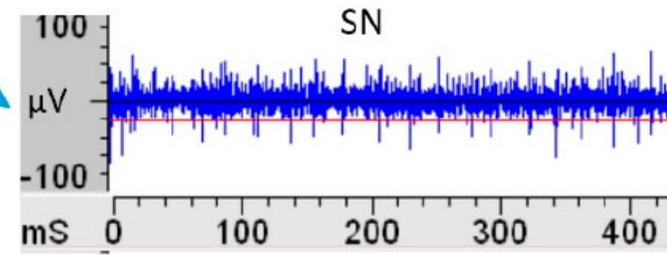
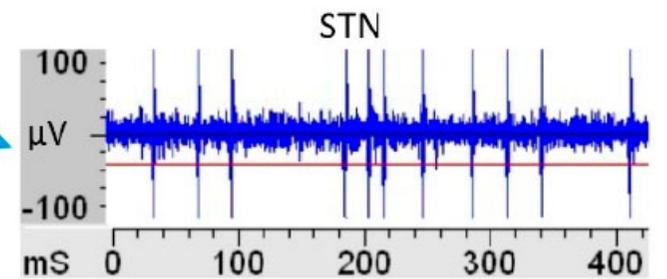
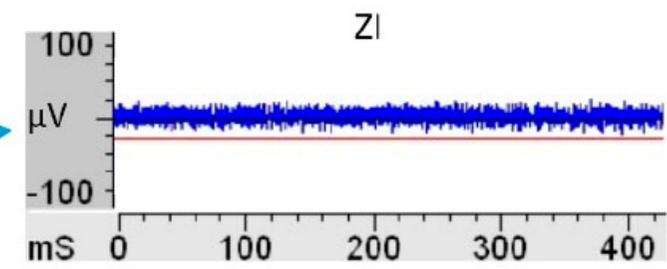
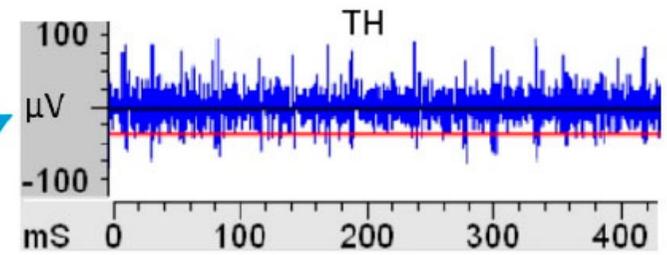
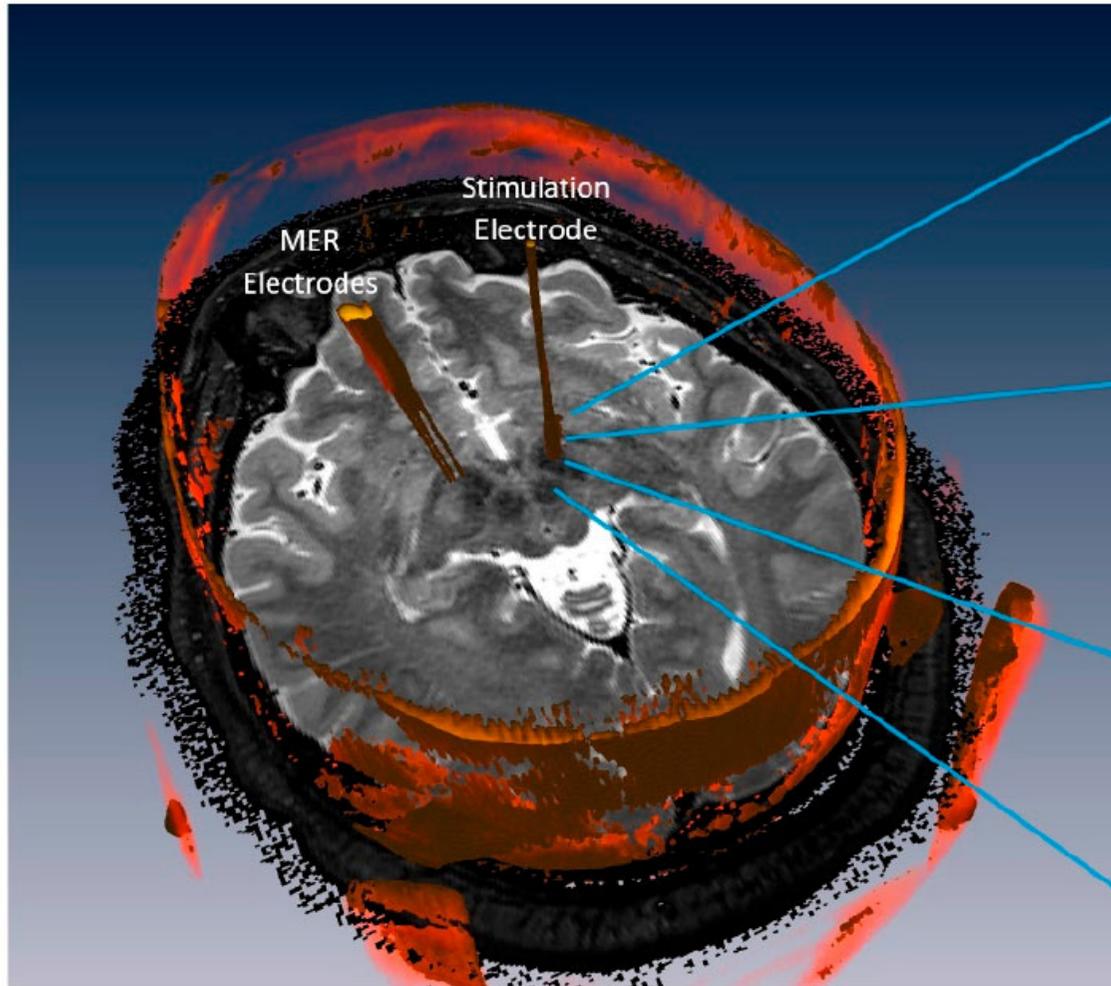




AlphaOmega[®]







¿Estamos en la diana (terapéutica)?

1. Frecuencia y amplitud de las señales de campo
 - alfa, beta, gamma, delta, theta, kappa
2. Potencial de campo (LFP-Local Field Potential)
3. Análisis de espigas (pulsos, 'spikes')
 - ráfagas, amplitud, etc.

Procesado y análisis de señales MER

- Empleo de Inteligencia Artificial
- Obtención del mejor algoritmo
 - Proceso habitual para el aprendizaje máquina

DBScan

Ayuda

Seleccionar trayectoria

Analizar trayectoria

Datos trayectoria

Trayectoria seleccionada: 1

Coordenada inicial: 8.137 mm

Coordenada final: 0.001 mm

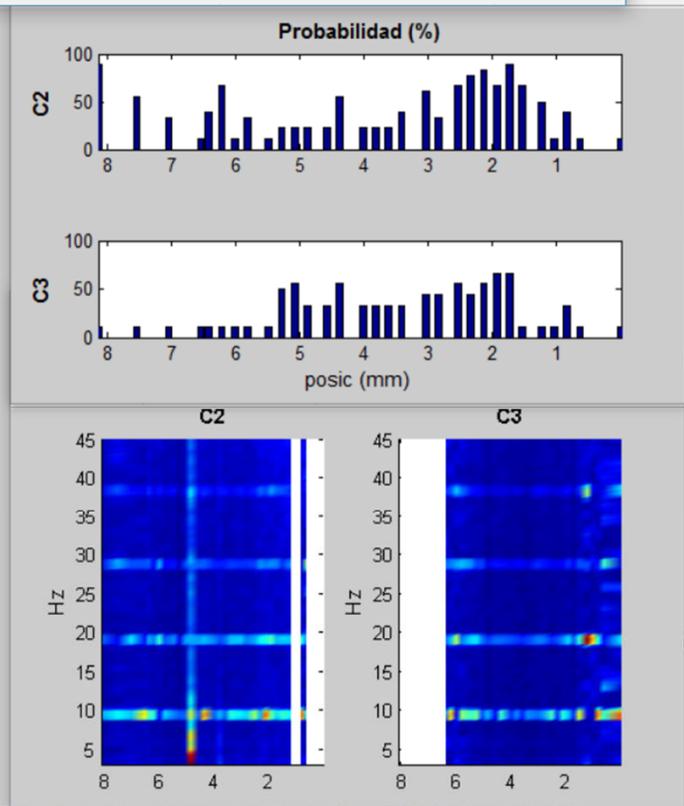
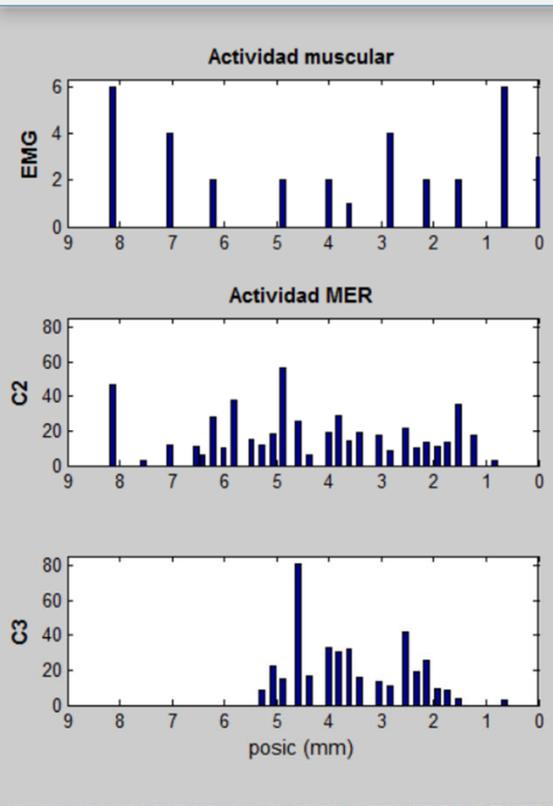
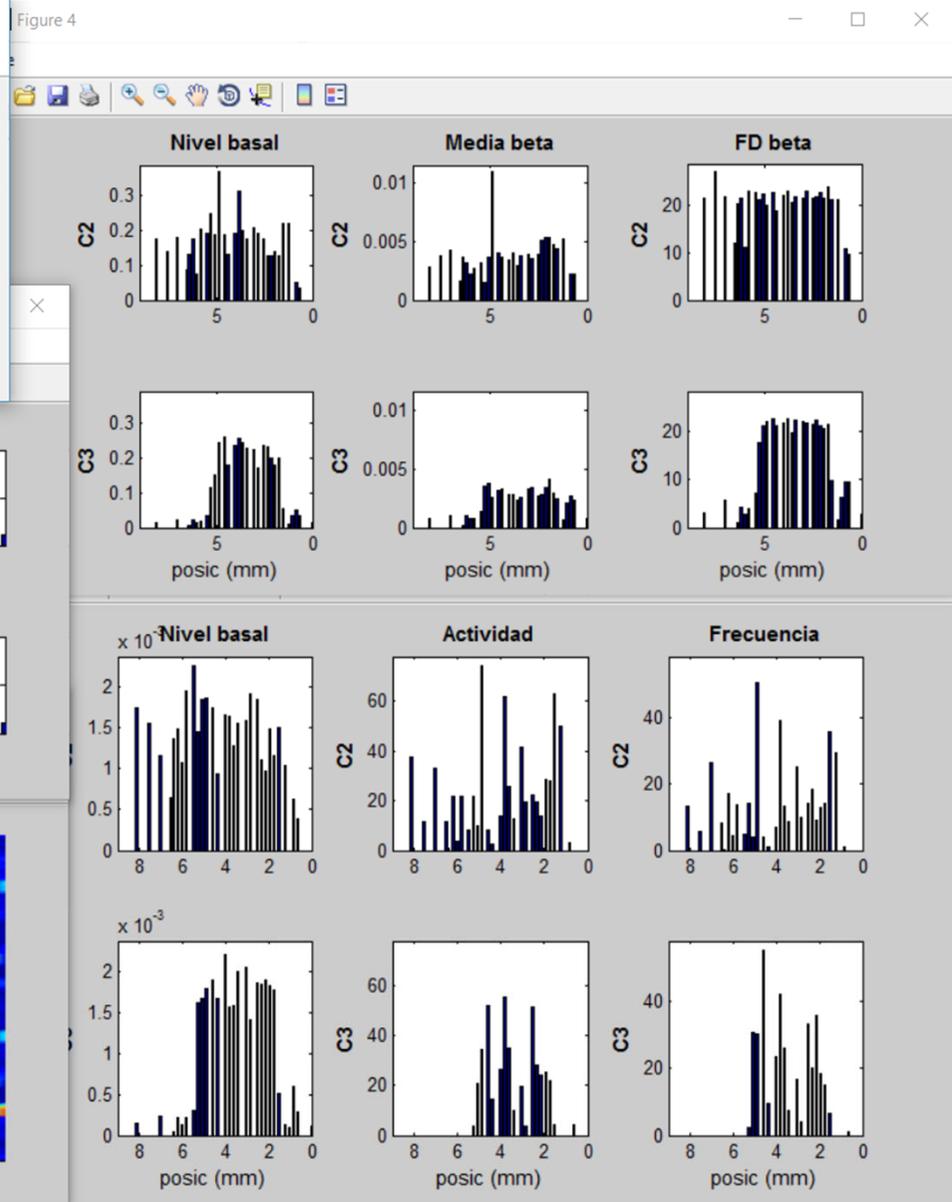
Canales MER: 3

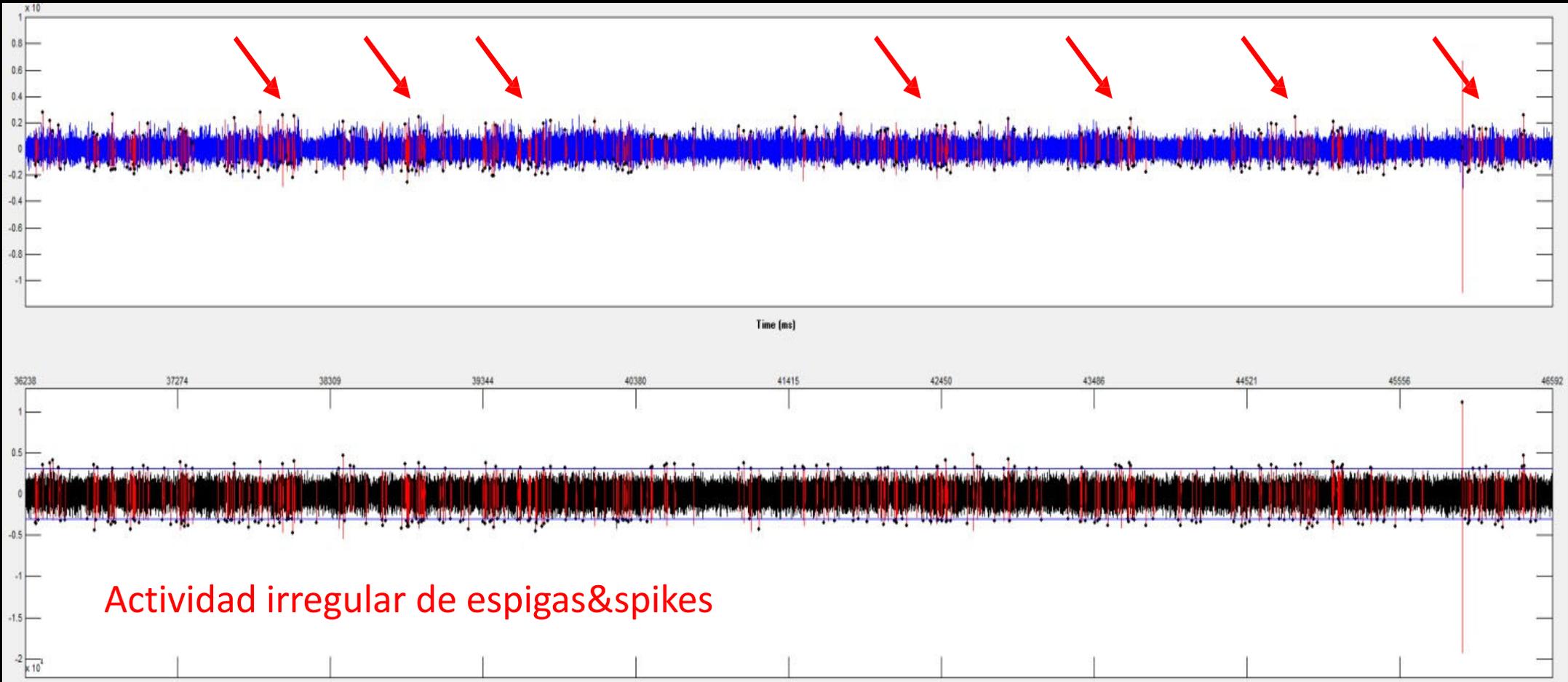
Canales EMG: 5

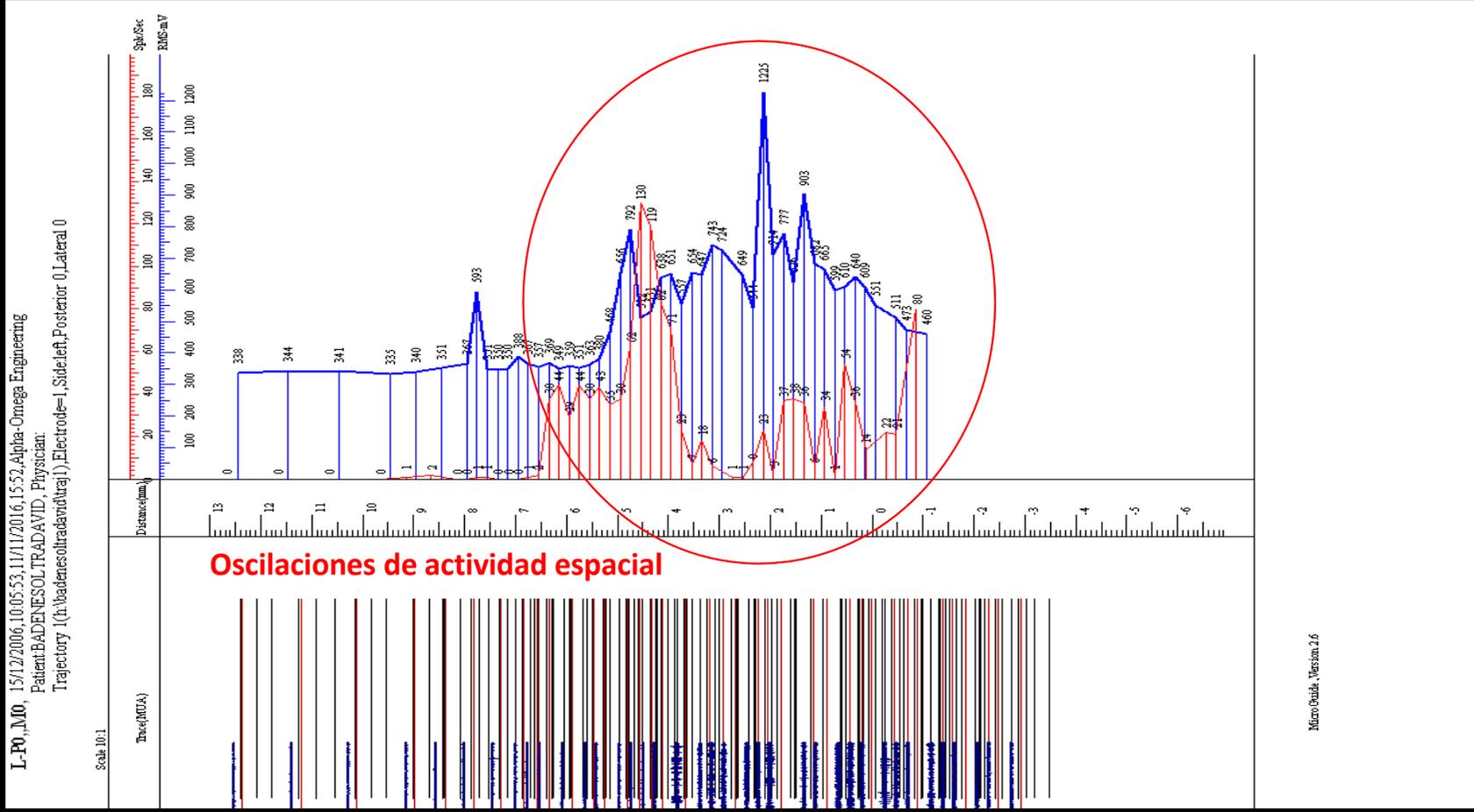
Procesado

- Determinar zona
- Driving
- Tiempo
- Frecuencia: beta

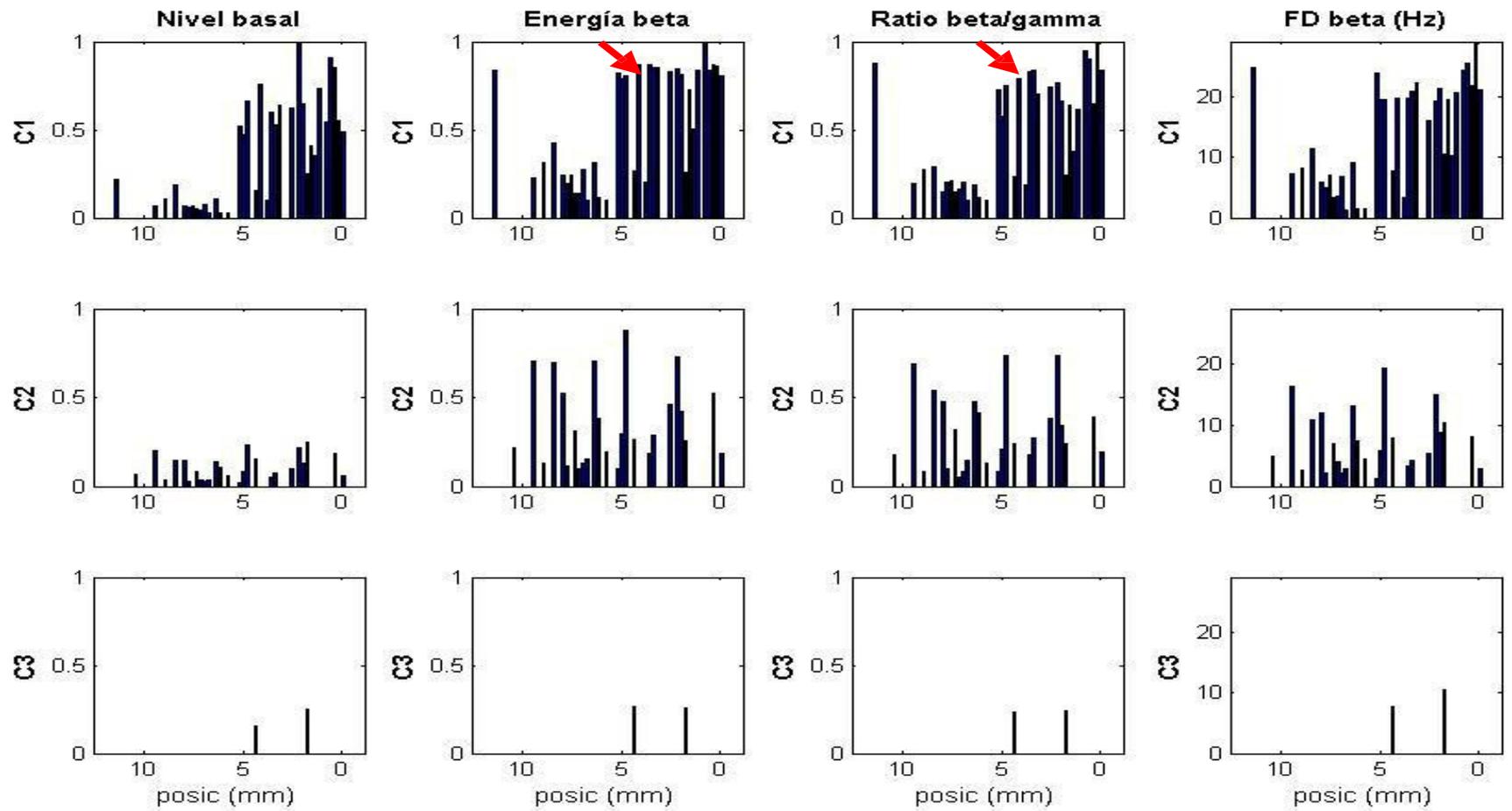
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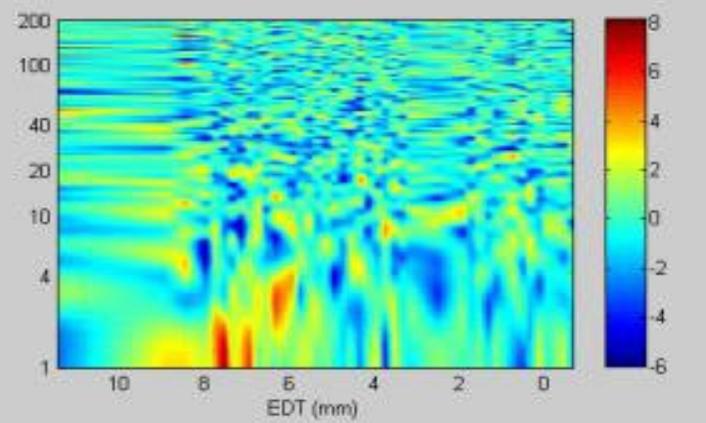
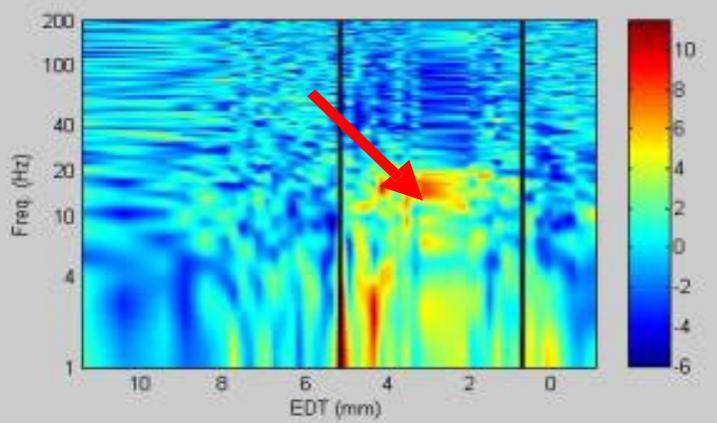
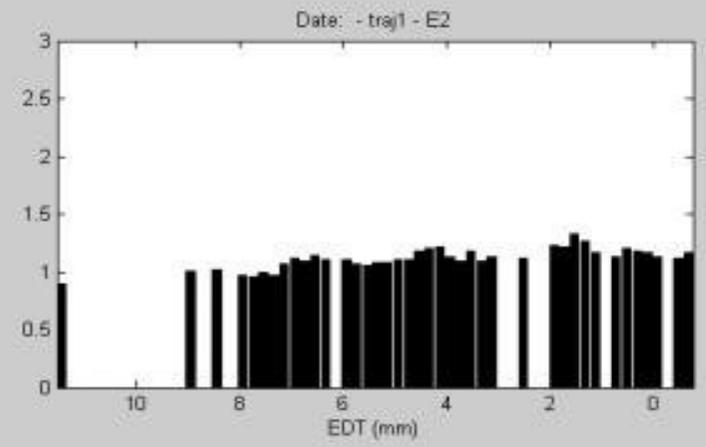
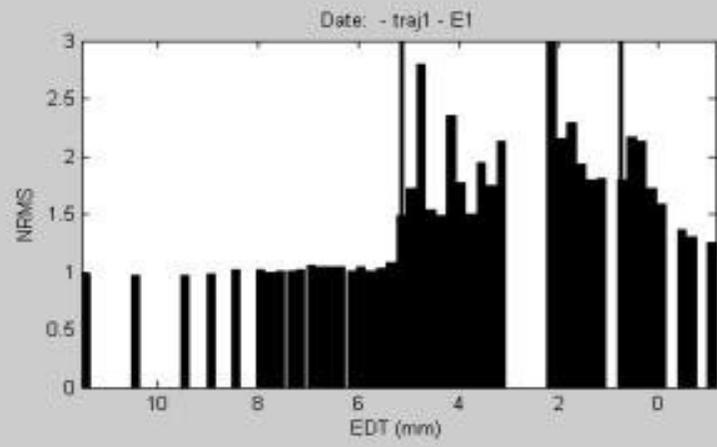




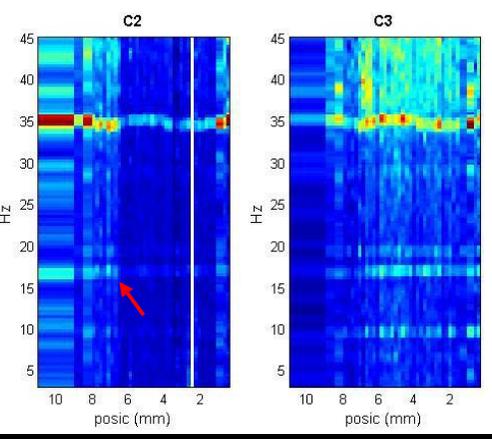
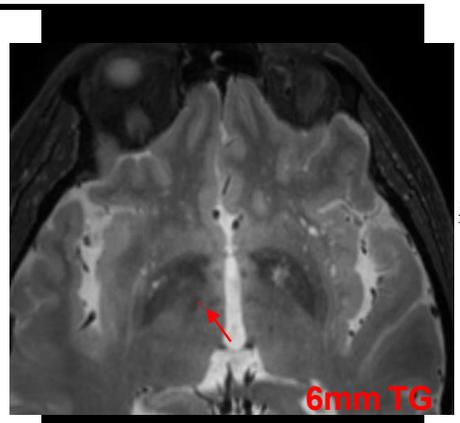
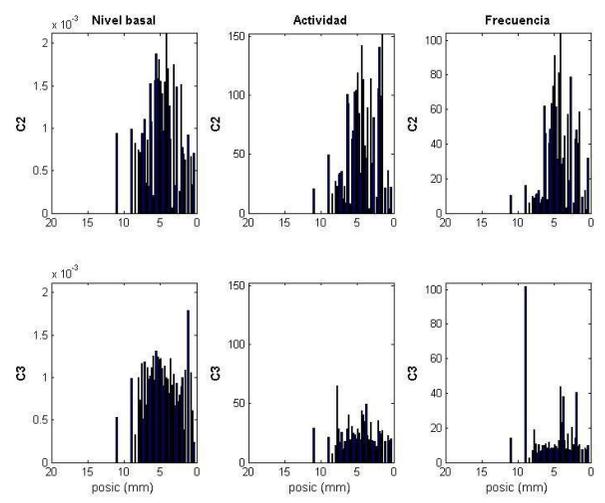


Beta rate as biological marker of the Parkinson Disease . Irregular neuronal activity of frequency / Energy Beta that we can register by the unitary neuronal analysis (Model Hidden Markov Of Alpha Omega) Fig. 3 Or the method MTM Spectrum Of the program DBScan Fig. 4

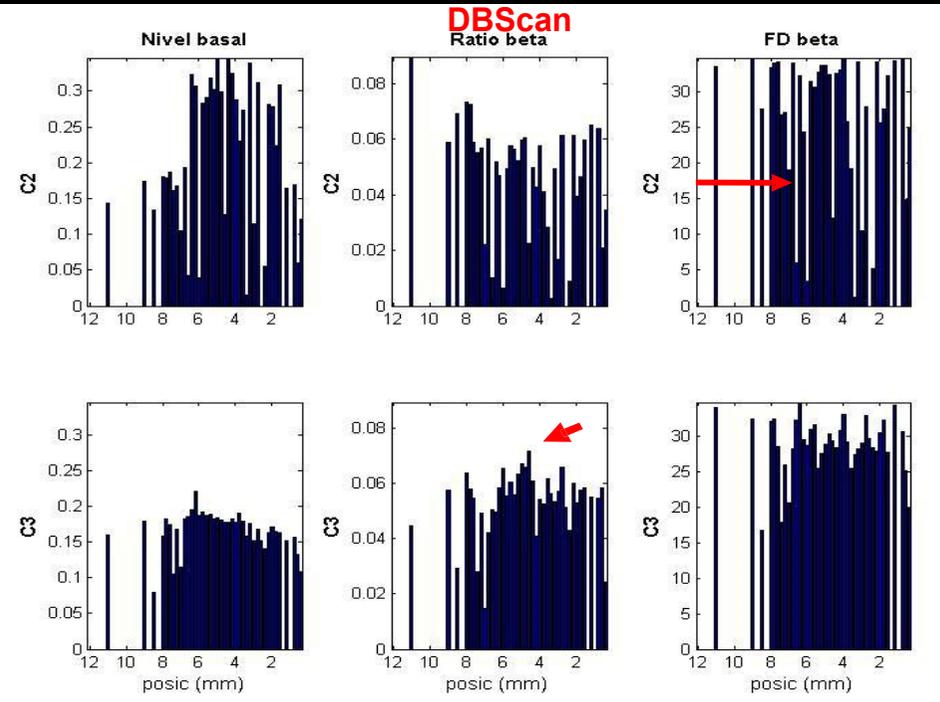
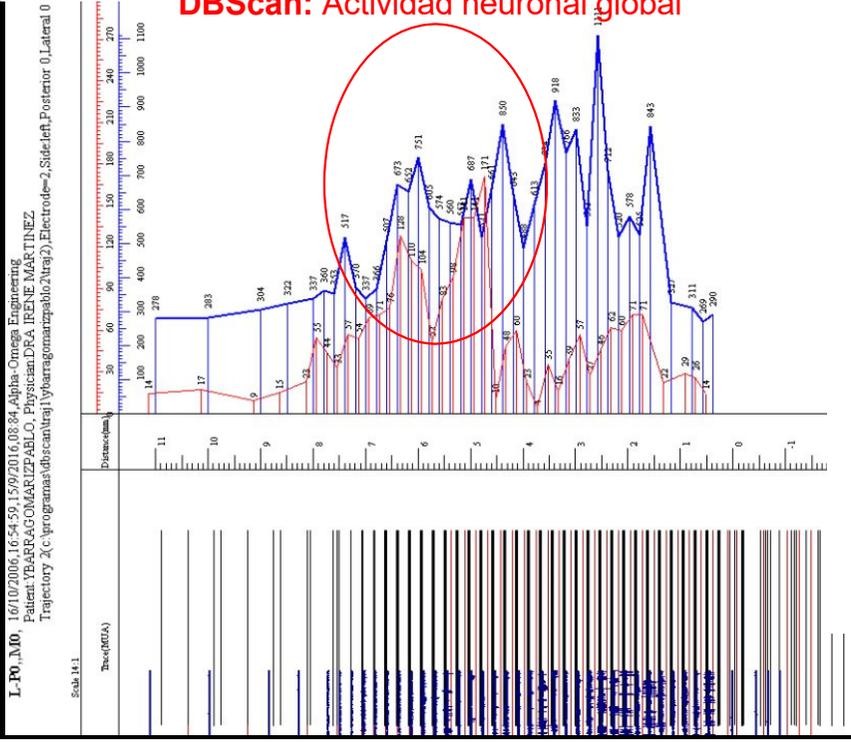




DBScan: Actividad neuronal



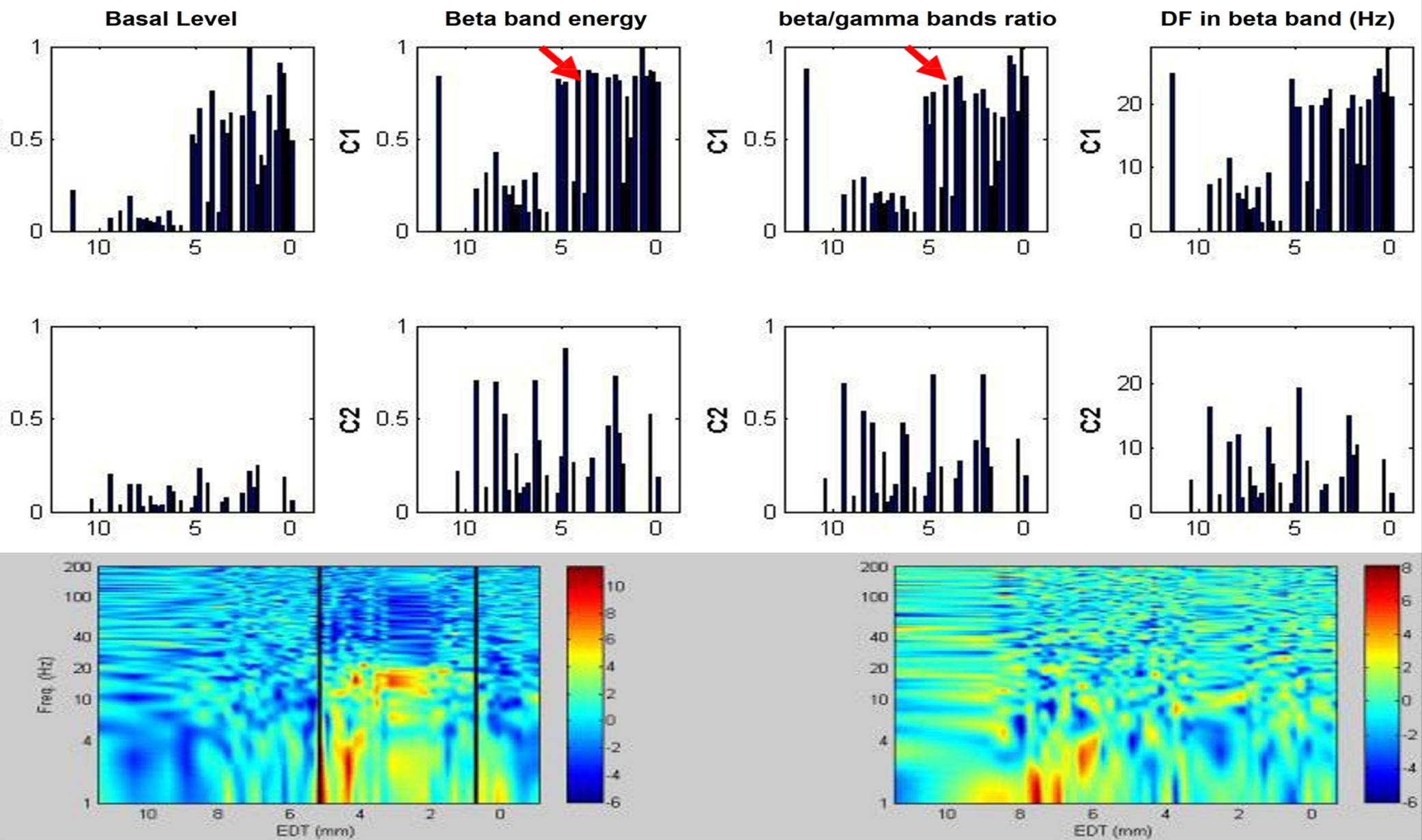
DBScan: Actividad neuronal global



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software

L_P0_M0: 16/10/2006,16:54:59,15/9/2016,08:84,Alpha-Omega Engineering
 Patent:YBARRAGOMAR,IZPABLO, PhysicanDRA IRENE MAR, TINEZ
 Trajectory: Xc:\programas\subscan\traj\YbarraGomazpablo\Zuraj\,Electrode=2,Side:left,Posterior:0,Lateral:0

DBScan: banda beta



Datos

- 9 varones, 5 mujeres. Edad: $65,1 \pm 5,6$ años
- Segmentos categorizados (etiquetados) por cirujanos

- 12kHz

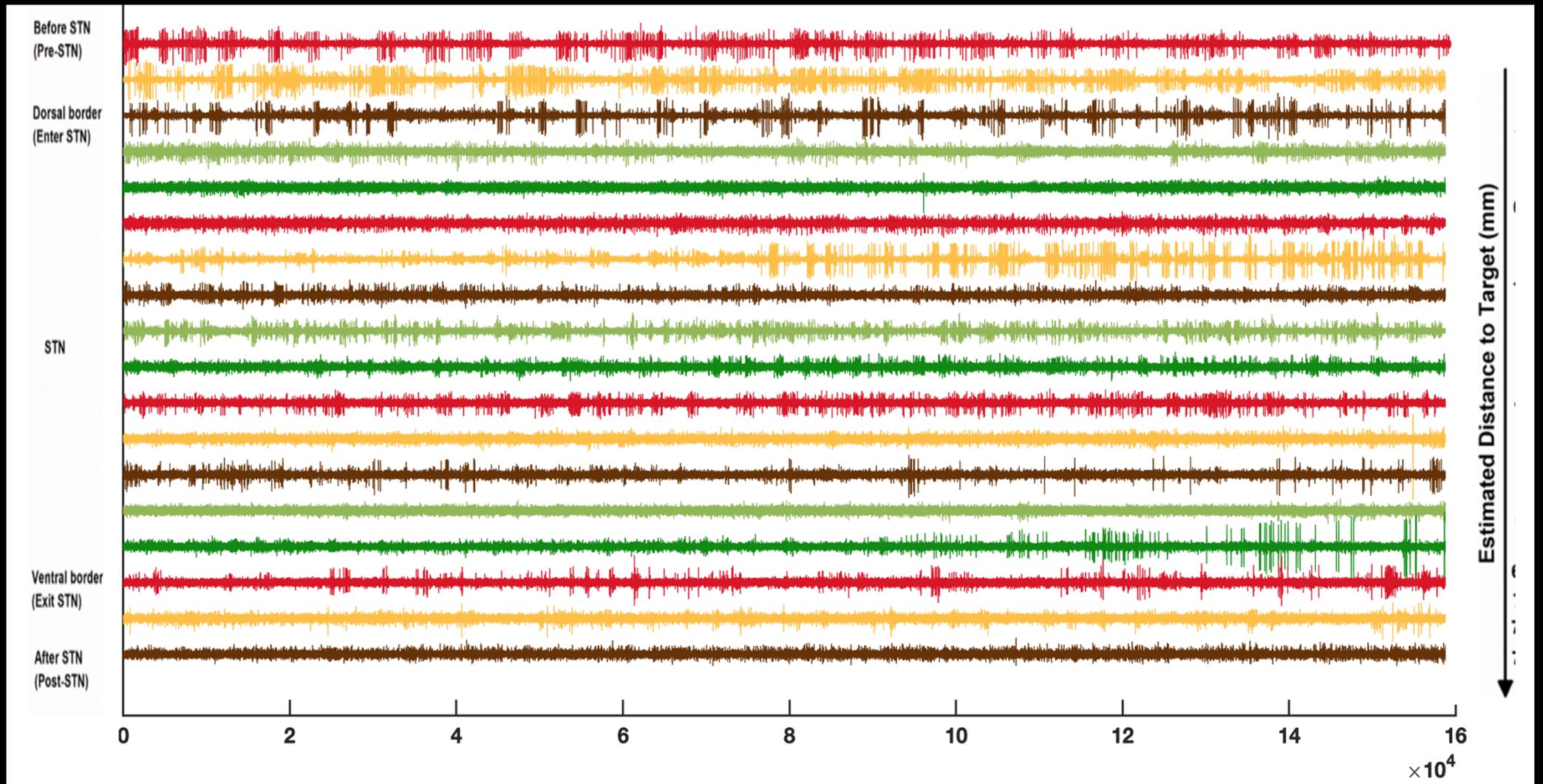
- Ventana 1s

- Solape 50%

- Pre-filtrado

Patient number	STN-IN(L+R) #steps	STN-OUT(L+R) #steps	STN-IN(L+R) seconds	STN-OUT(L+R) seconds	Total seconds
1	20+NA	4+NA	959+NA	134+NA	1093
2	18+31	14+3	1354+1855	591+199	3999
3	13+27	27+12	626+993	923+434	2976
4	21+21	11+9	946+1114	629+421	3110
5	26+NA	15+NA	1200+NA	497+NA	1697
6	15+NA	25+NA	941+NA	1528+NA	2469
7	23+NA	7+NA	1632+NA	731+NA	2363
8	22+17	11+26	1229+1041	454+1141	3865
9	30+37	8+4	1248+1322	285+114	2969
10	32+32	15+13	1147+1852	921+557	4477
11	18+NA	19+NA	1024+NA	939+NA	1963
12	30+30	11+12	1415+995	380+416	3206
13	29+25	18+14	1429+1119	548+640	3736
14	NA+24	NA+11	NA+1129	NA+461	1590
TOTAL	297+244	185+104	15150+11420	8560+4383	39513

Datos



Extracción de características

- Espigas

Features	Description
Spike Firing Rate (SFR)	Count of spikes per second.
Inter Spike Interval (ISI)	Time intervals between consecutive spikes in the spike sequence [23].
Standard deviation of <i>ISI</i> (SISI)	Standard deviation of inter-spike intervals <i>ISI</i> .
Pause Ratio (PR)	Ratio of cumulative time of <i>ISI</i> greater than 50 ms to the cumulative time of <i>ISI</i> less than 50 ms.
Pause Index (PI)	Ratio of the number of <i>ISI</i> greater than 50 ms to the number of <i>ISI</i> less than 50 ms.
Bursting Rate (BR)	Number of bursts per second.
Modified Burst Index (MBI)	Ratio of the number of <i>ISI</i> less than 10 ms to the number of <i>ISI</i> greater than 10 ms.

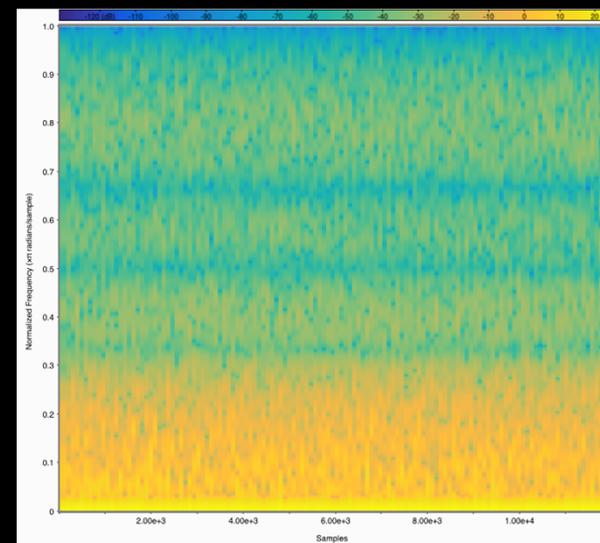
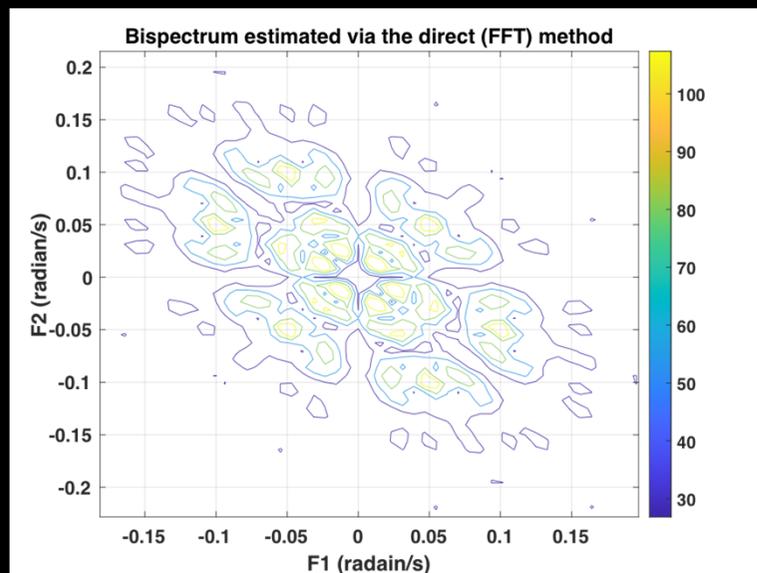
Extracción de características

Potencial de campo

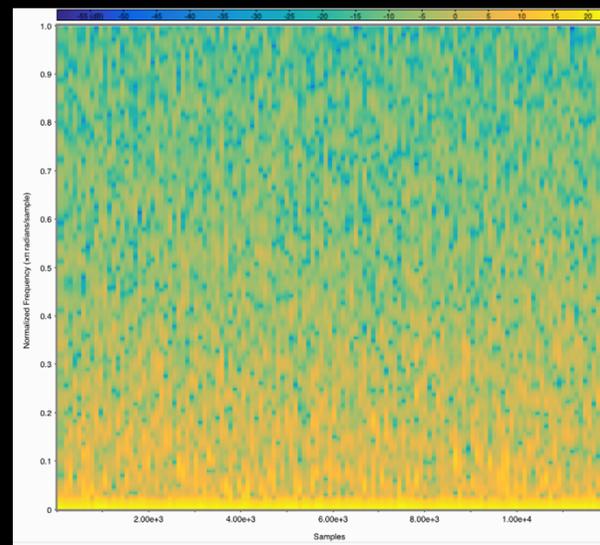
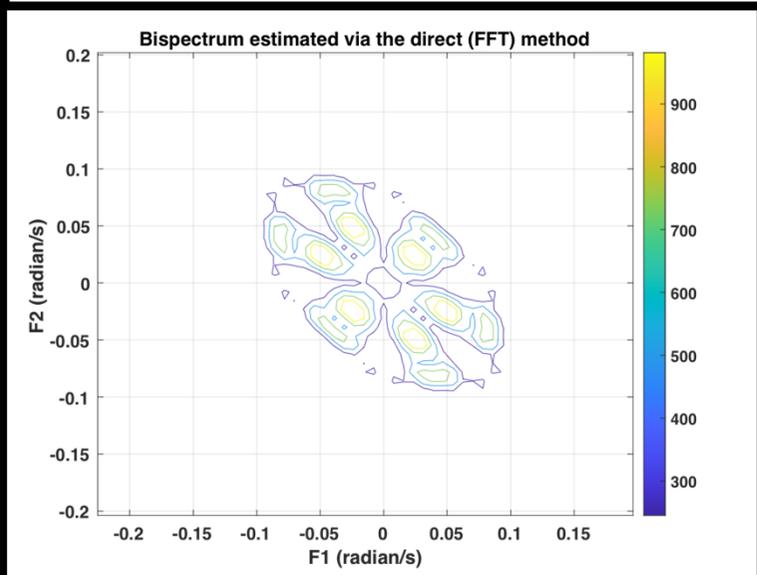
Features	Description
Bispectrum (Bs)	The Fourier transform of the third-order cumulant spectrum [25].
Zero crossing (Zc)	Number of zero crossings in the temporal domain [24].
Curve length (Cl)	Sum of the difference of consecutive samples [27].
Integrator (In)	Sum of absolute value [24].
Root Mean Square (RMS)	Root mean square [24].
Kurtosis (Ku)	Peakiness coefficient variation [28].
Cumulative bispectrum (Cb)	Cumulative relationship between the higher order moments [25].
Average Amplitude Change (AAc)	Average value of all amplitudes [24].
Short Term Fourier Transform (STFT)	Spectrum energy from each MER segment [29].
Teager Energy (Te)	Energy rate induced from the second order differential derivative of the amplitude and frequency variation [30].
Average First Amplitude difference (AFa)	Average of first amplitude difference [24].
Second Amplitude difference (SAd)	Average of second amplitude difference [24].
Standard deviation (SD)	Standard deviation [24].
Skewness (Sk)	Measure to quantify the presence of assymetry in the shape of the distribution [31].
Slope Sign change (SSc)	Number of times that the slope of the MER curve changes sign in the segment [24].
Variance (Va)	The signal's averaged power [24].
1D-Local Binary Pattern (LBP1)	Having the central segment as threshold, it is compared with its neighborhood to generate binary code [[32], [33]].

Extracción de características

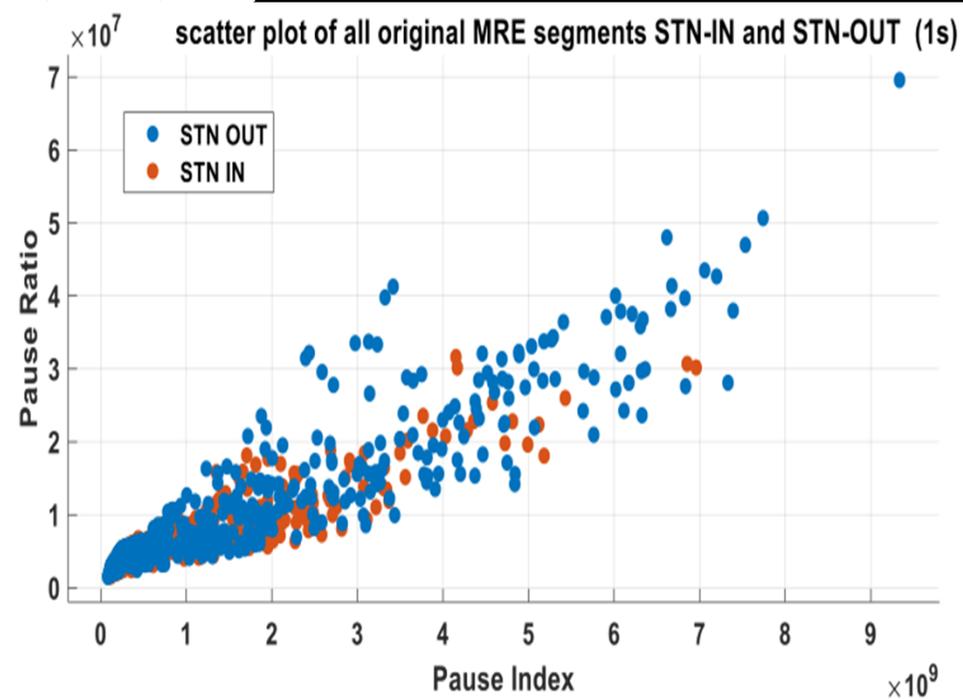
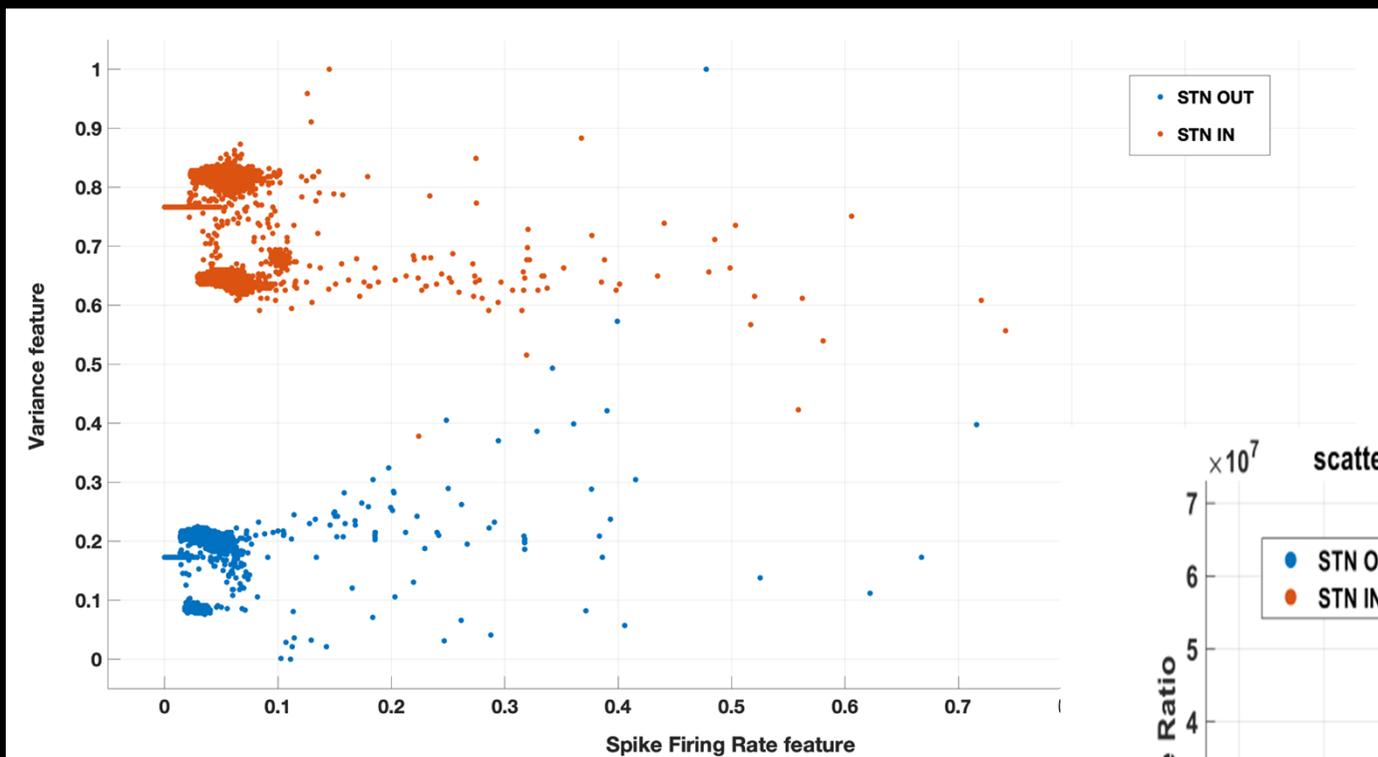
STN-IN



STN-OUT



Extracción de características



Reducción de características

- Método NCA (Neighborhood Component Analysis)
- Inicialmente 24 características, se toman 11
- En este caso, principalmente, características de campo

Entrenamiento de IA

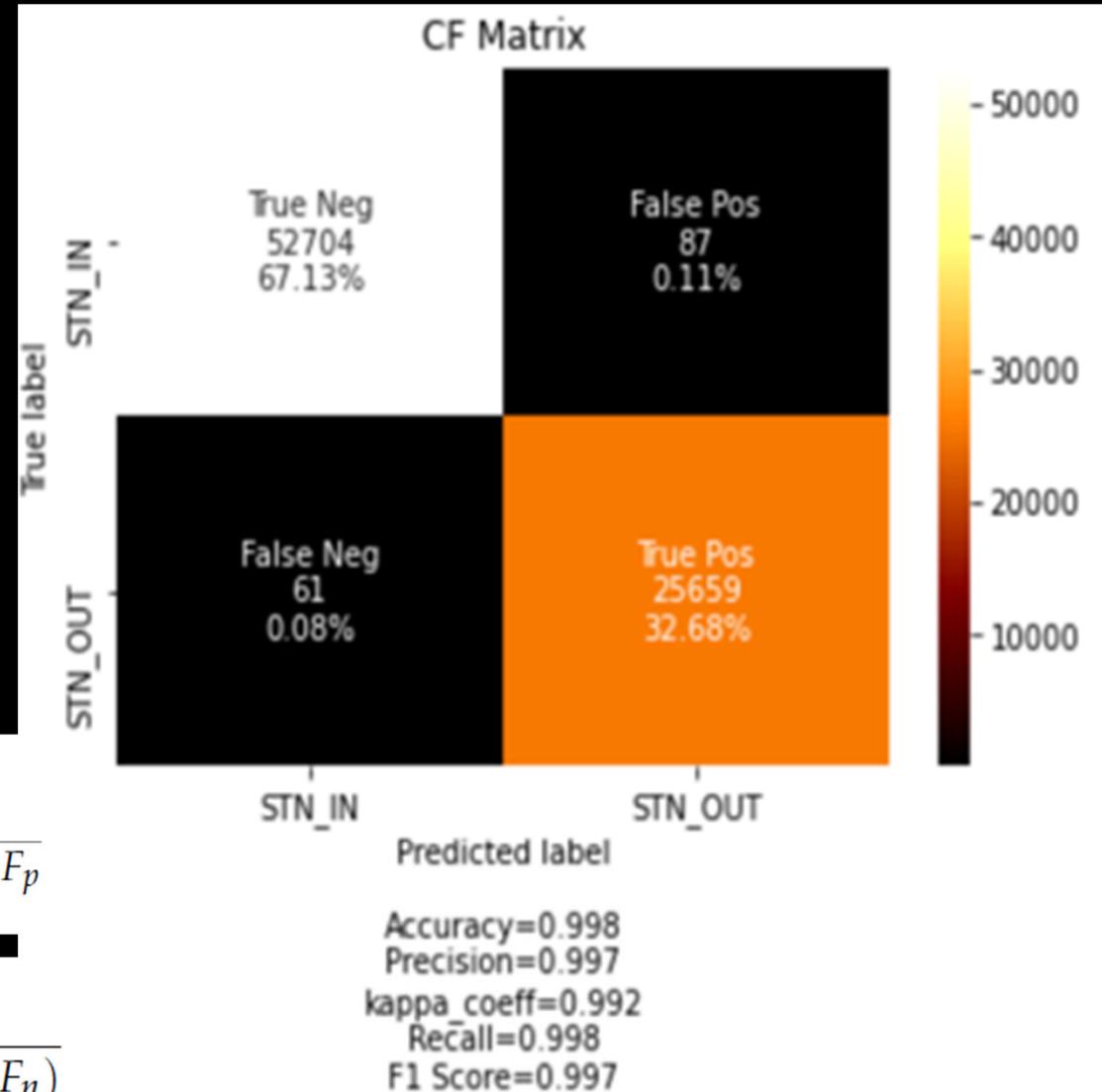
- Entrenamiento supervisado
 - ‘Dejar uno fuera’ -> ‘Leave one-out’
- Clasificadores analizados
 - Máquinas Vectores Soporte - Support Vector Machine (SVM)
 - K vecinos más cercanos – K Nearest Neighbors (KNN)
 - Bosque aleatorio - Random Forest (RF)
 - Árbol de decisión - Decision Tree (DT)
 - Análisis discriminante - Discriminant Analysis (DA)
 - Redes neuronales - Neural Network (NN)
 - Probabilistic neural network (PNN)
 - Feed-forward neural network (FNN)
 - Back-Propagation neural network (BNN)

KNN

$$F_{measure} = \frac{2 * (precision * recall)}{(precision + recall)}$$

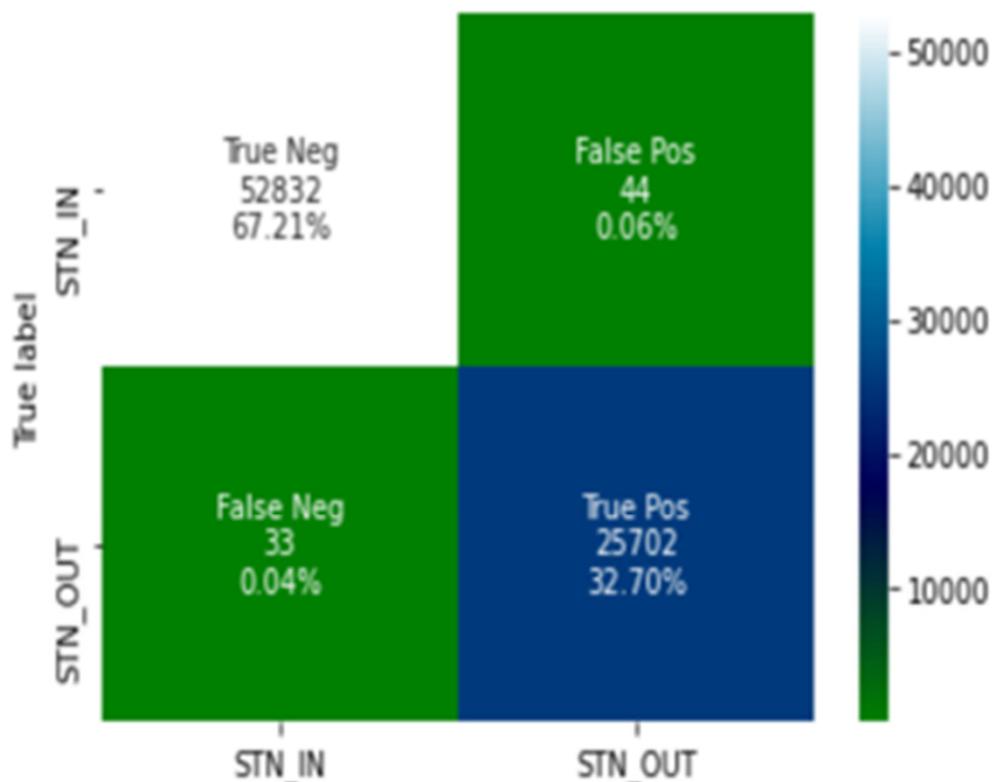
$$accuracy = \frac{T_p + T_n}{T} ; recall = \frac{T_p}{P} ; precision = \frac{T_p}{T_n + F_p}$$

$$Kappa = \frac{2 * (T_p + T_n - F_n * F_p)}{(T_p + F_p) * (T_n + F_p) + (T_p + F_n) * (T_n + F_n)}$$



SVM

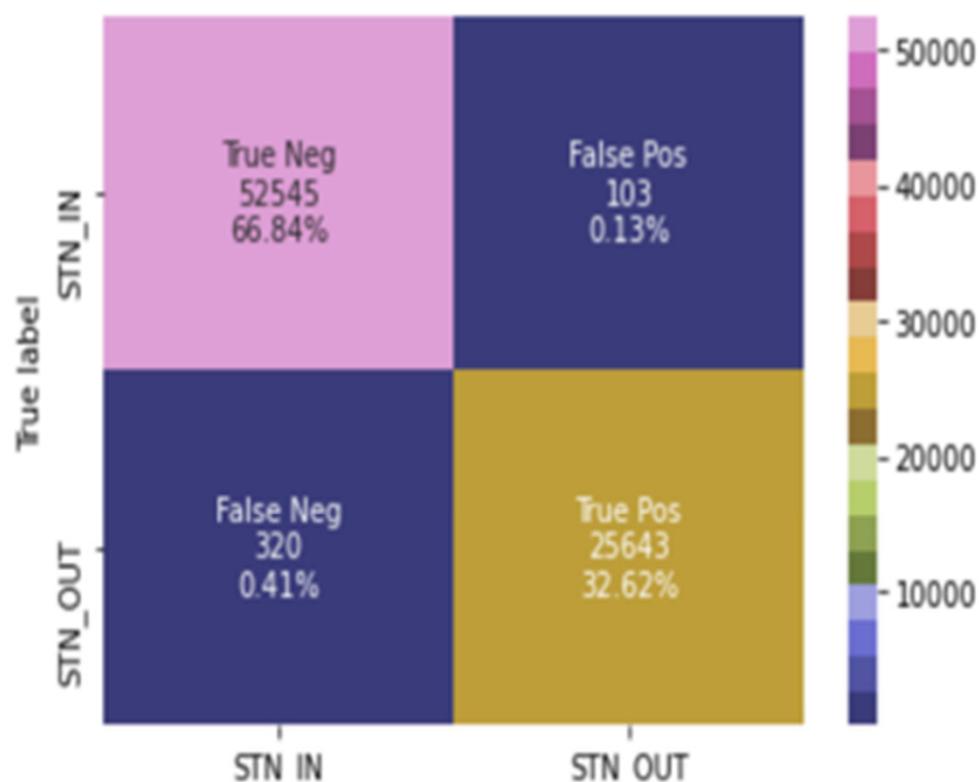
CF Matrix



Accuracy=0.999
Precision=0.998
kappa_coeff=0.992
Recall=0.999
F1 Score=0.999

RF

CF Matrix



Accuracy=0.995
Precision=0.996
kappa_coeff=0.992
Recall=0.988
F1 Score=0.992

Resultados

Exactitud
/ Accuracy

ML classifier	KNN	SVM	RF	DT	DA
The 11 features selected	99.9	100.0	99.9	99.8	100.0
All 24 features selected	99.8	99.9	99.5	99.9	99.8

PNN

Patient	Precision	Recall	Kappa	F1-score	Accuracy
P1	100	100	86.8	100	100
P2	100	100	87.0	100	100
P3	86.9	95.1	87.7	90.1	96.3
P4	100	99.9	84.9	99.9	100
P5	96.6	99.6	87.9	98.00	99.5
P6	99.8	99.8	84.4	99.8	99.9
P7	99.8	99.8	84.8	99.8	99.9
P8	99.8	99.9	88.4	99.3	99.6
P9	98.8	99.9	88.4	99.3	99.6
P10	99.6	99.5	81.2	99.5	99.6
P11	99.8	99.8	80.8	99.8	99.8
P12	99.7	100	86.1	99.8	99.9
P13	99.7	100	86.1	99.8	99.9
P14	99.5	99.9	87.0	99.6	99.7

Proyectos

- Focos de epilepsia
- 'presencia'
- Daño cerebral

Bibliografía

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Selection of the optimal algorithm for real time estimation of beta band power during DBS surgeries in patients with Parkinson's disease. Ángeles Tepper, Mauricio Carlos Henrich, Luciano Schiaffino, Alfredo Rosado, Antonio Gutiérrez, Juan Guerrero Martínez. Computational Intelligence and Neuroscience. Issue: Recent Advances in Brain Signal Analysis: Methods and Applications. December 2017, Volume 2017, Article ID 1512504. DOI: 10.1155/2017/1512504.

Optimización del algoritmo de clasificación supervisada KNN como herramienta de soporte para la implantación de estimuladores cerebrales profundos en pacientes con Parkinson. G. Bellino, M. Battisti, L. Schiaffino, J. Guerrero, A. Rosado-Muñoz. XXXVI Congreso Anual de la Sociedad Española de ingeniería Biomédica. Ciudad Real. España. 11-13 de Noviembre de 2018.

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Gracias por su atención

... ¿PREGUNTAS? ...