



## AREAS Y PROYECTOS DE INVESTIGACIÓN 2023

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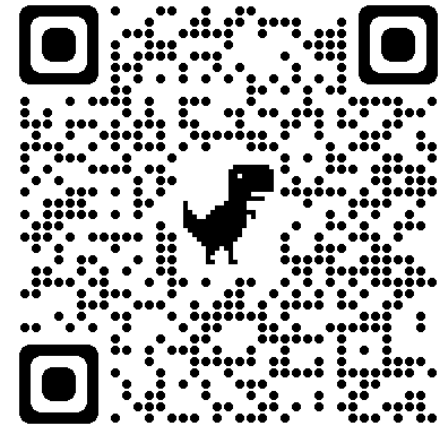
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*Presentación disponible en:*

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V: 19-Oct-2023

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INSTITUTO NACIONAL DE ASTROFÍSICA, ÓPTICA Y  
ELECTRÓNICA (INAOE)



Coordinación de  
Ciencias Computacionales

Updated : October 26, 2017 by P. Gómez-Gil

## Dra. María del Pilar Gómez Gil

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- ▶ Cursos y Tutoriales (Spanish)
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- ▶ Semblanza profesional (Spanish)

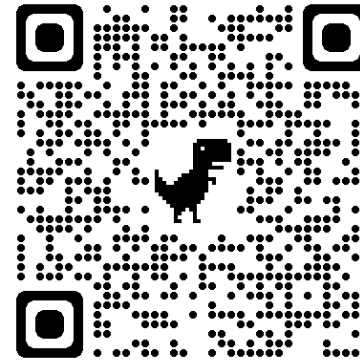
Consulta aquí  
propuestas de tesis  
de Maestría

I am interested in basic and applied research in artificial neural networks and other learning machines, when used for temporal classification and prediction. Our research group currently works in projects that tackle problems related to Brain Computer Interfaces, forecasting for finances, data mining and classification of brain signals



# Google scholar

[https://scholar.google.com/citations?hl=en&user=M3yVI1oAAAAJ&view\\_op=list\\_works&sortby=pubdate](https://scholar.google.com/citations?hl=en&user=M3yVI1oAAAAJ&view_op=list_works&sortby=pubdate)



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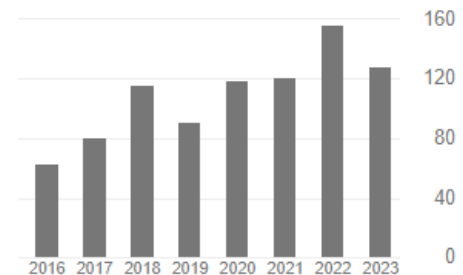
Neural networks Artificial Neural Networks time series forecasting brain-computer interfaces

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TITLE	CITED BY	YEAR
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<a href="#">Self-Organizing Clustering by Growing-SOM for EEG-based Biometrics</a> Z Sandoval-Lara, P Gómez-Gil, JC Moreno-Rodríguez, M Ramírez-Cortés 2023 International Conference on Artificial Intelligence and Applications ...		2023
<a href="#">Quantification of glycated hemoglobin and glucose in vivo using Raman spectroscopy and artificial neural networks</a> N González-Viveros, J Castro-Ramos, P Gómez-Gil, HH Cerecedo-Núñez, ... Lasers in Medical Science 37 (9), 3537-3549	3	2022
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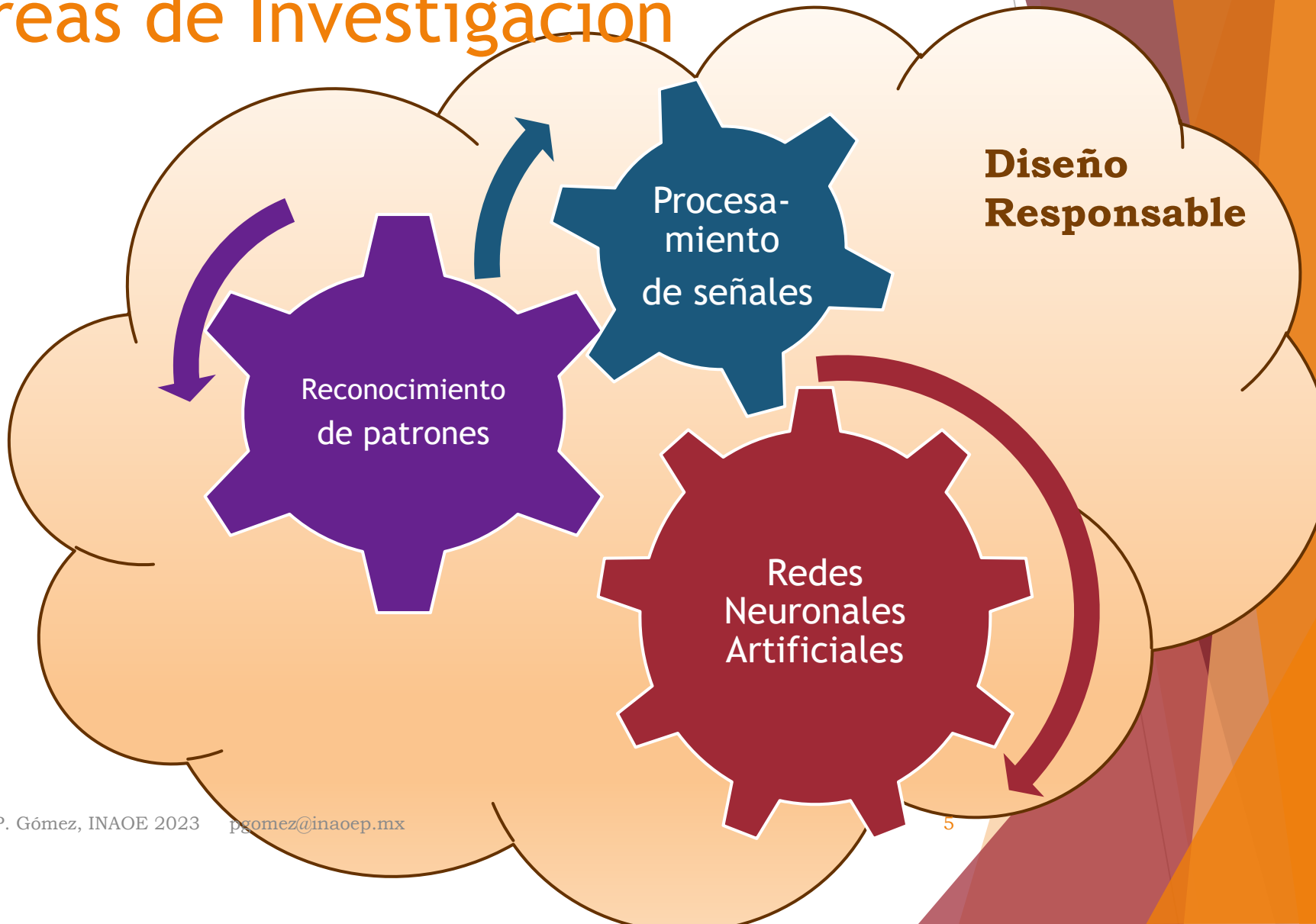
	All	Since 2018
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i10-index	38	21



# Área de trabajo

- ▶ Formo parte de las línea de investigación **“Aprendizaje computacional y reconocimiento de patrones”** y **“Procesamiento de Señales y Computación Médica”**
- ▶ Mi investigación se lleva a cabo en la intersección del procesamiento de señales, el reconocimiento de patrones y las redes neuronales artificiales
- ▶ El objetivo fundamental es encontrar nuevos y mejores algoritmos para resolver problemas de clasificación y predicción, que tienen como entrada señales temporales no estacionarias, complejas, ruidosas

# Áreas de Investigación



**Diseño  
Responsable**

Reconocimiento  
de patrones

Procesa-  
miento  
de señales

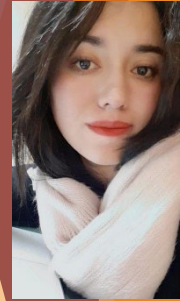
Redes  
Neuronales  
Artificiales

# Retos a atacar

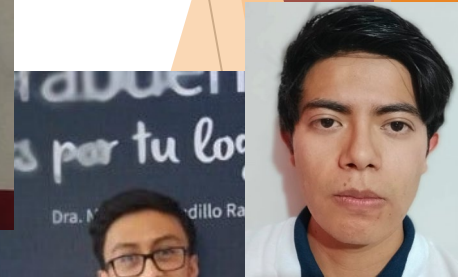
- ▶ Manejo de datos ruidosos
- ▶ Clases sobrepuestas
- ▶ Pocos datos disponibles
- ▶ Datos difíciles de caracterizar
- ▶ Situaciones que requieren fusionar características para obtener desempeños de clasificación aceptables
- ▶ Encontrar las mejores arquitecturas de modelos neuronales para el problema de clasificación/regresión bajo estudio
- ▶ Identificar información contextual que ayude a mejorar desempeños

# Colaboraciones recientes

- ▶ Con la Coordinación de Electrónica del INAOE, a través del Grupo de procesamiento de señales e Inteligencia Computacional (PSIC)
- ▶ Con la Coordinación de Óptica del INAOE y la Universidad Veracruzana, a través del Grupo de Instrumentación y Óptica Biomédica (**GIOB**) y con el grupo de Biofonética y Óptica Médica
- ▶ Con la coordinación de Astrofísica del INAOE, con el grupo de cosmología milimétrica
- ▶ Con la Universidad Iberoamericana de la Cd. De México a través del desarrollo de un proyecto de clasificación de BCI basada en EEG asociado a cálculo mental
- ▶ Con el departamento de Mecatrónica de la Benemérita Universidad Autónoma de Puebla a través de un proyecto de Inteligencia Artificial Explicable (AIX).



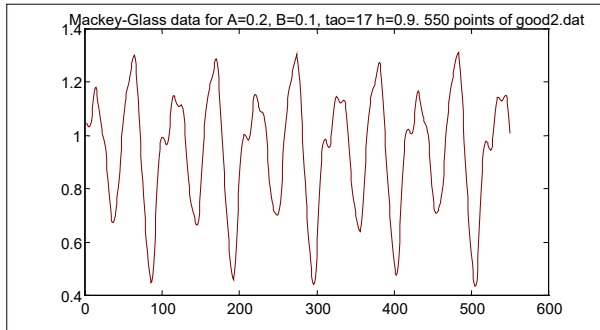
# Grupo PSIC, algunos colaboradores y amigos



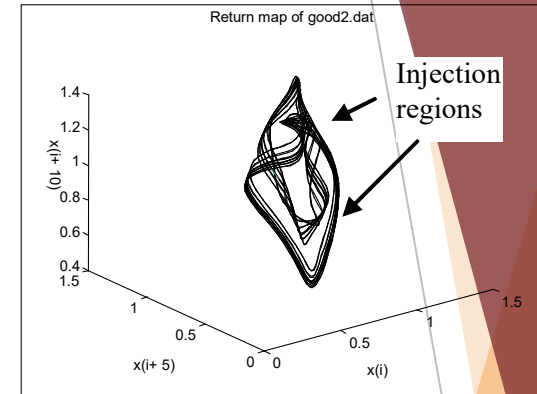
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# Ejemplos de señales complejas

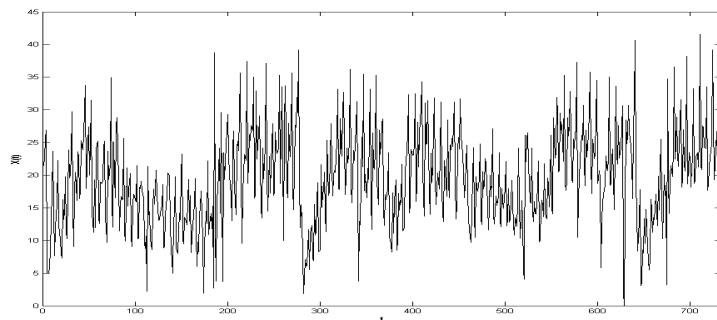


$$\frac{dx(t)}{dt} = \frac{ax(t-\tau)}{1+x^{10}(t-\tau)} - bx(t)$$

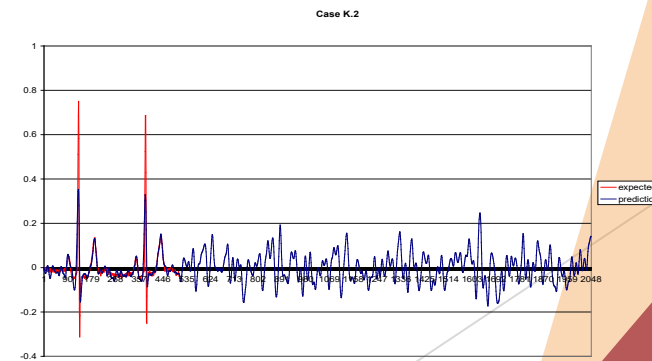


Mackey-Glass time series (Glass 1987)

Return map of a Mackey-Glass time series



ATM withdraws (NN5-001) (Crone 2006)



Long-term prediction of an ECG (Gomez et al., 2019)

# Mapa curricular de la maestría en CC



## PLAN DE ESTUDIOS

Código: INAOE-PNPC-MA-002

Referencia normativa: ISO 9001:2015PNPC MARCO DE REFERENCIA  
PARA LA EVALUACIÓN Y SEGUIMIENTO DE PROGRAMAS DE  
POSGRADO

Revisión: 0  
Página: 9 de 12

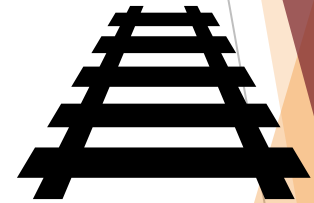
### 1.1. Mapa curricular

PRIMERO	SEGUNDO	TERCERO	CUARTO	QUINTO	SEXTO
<p><b>C</b> 45 <b>100</b> <b>8</b></p> <p>Matemáticas para Computación MCC5002</p>	<p><b>O</b> 45 <b>100</b> <b>8</b></p> <p>Optativa</p>	<p><b>O</b> 45 <b>100</b> <b>8</b></p> <p>Optativa</p>	<p><b>T</b> 0 <b>600</b> <b>30</b></p> <p>Desarrollo de Tesis MCT5002</p>	<p><b>T</b> 0 <b>600</b> <b>30</b></p> <p>Evaluación de Avances de Tesis MCT5003</p>	<p><b>T</b> 0 <b>280</b> <b>14</b></p> <p>Escritura y Defensa de Tesis MCT5004</p>
<p><b>C</b> 45 <b>100</b> <b>8</b></p> <p>Diseño y Análisis de Algoritmos MCC5003</p>	<p><b>O</b> 45 <b>100</b> <b>8</b></p> <p>Optativa</p>	<p><b>A</b> 45 <b>100</b> <b>8</b></p> <p>Tópicos Avanzados</p>			
<p><b>O</b> 45 <b>100</b> <b>8</b></p> <p>Optativa</p>	<p><b>O</b> 45 <b>100</b> <b>8</b></p> <p>Optativa</p>	<p><b>S</b> 5 <b>0</b> <b>2</b></p> <p>Seminario de Investigación II MCS5004</p>			
<p><b>O</b> 45 <b>100</b> <b>8</b></p> <p>Optativa</p>	<p><b>A</b> 45 <b>100</b> <b>8</b></p> <p>Tópicos Avanzados</p>				
<p><b>S</b> 45 <b>0</b> <b>2</b></p> <p>Seminario de Metodología MCS5002</p>	<p><b>S</b> 45 <b>0</b> <b>2</b></p> <p>Seminario de Investigación I MCS5003</p>				

<https://posgrados.inaoep.mx/oferta-academica/posgrado-en-ciencias-computacionales/maestria/plan-de-estudios>

# Ver plan de estudios completo en:

<https://posgrados.inaoep.mx/oferta-academica/posgrado-en-ciencias-computacionales/maestria/plan-de-estudios>



# Cursos/conocimiento deseable para trabajar en mis proyectos

1. Procesamiento digital de señales
2. Inteligencia Computacional I / Redes Neuronales Artificiales
3. Reconocimiento de patrones
4. Inteligencia Computacional II (una vez elegido un proyecto conmigo)

## Algunos proyectos de tesis de maestría recientes o asociados a intereses vigentes

- ▶ Hernández González Edgar (2020) “Clasificación de Señales de Electroencefalograma con Aprendizaje Profundo para Interfaces Cerebro Computadora.” Tesis de Maestría en Ciencias Computacionales, Instituto Nacional de Astrofísica, Óptica y Electrónica.  
<http://inaoe.repositorioinstitucional.mx/jspui/handle/1009/2001>
- ▶ Sandoval Lara Zurisadai (2020), “Self-organizing clustering by Growing-SOM for EEG Biometrics”, Tesis de Maestría en Ciencias Computacionales, Instituto Nacional de Astrofísica, Óptica y Electrónica.
- ▶ Reynoso Armenta Daniela Michelle (2017). “Diagnosis of breast cancer through the processing of thermographic images and neural networks.” Tesis de Maestría en Óptica, Instituto Nacional de Astrofísica, Óptica y Electrónica.  
<http://inaoe.repositorioinstitucional.mx/jspui/handle/1009/856>
- ▶ Cárdenas Carballo J. Francisco (a partir de 2022). Algoritmos de Inteligencia Artificial Explicable en la Detección Automática de Cáncer” Tesis de Maestría en Ciencias Computacionales, Instituto Nacional de Astrofísica, Óptica y Electrónica.
- ▶ Daniel Lima López (a partir de 2023). Clasificación de imágenes con arquitecturas ligeras de redes neuronales en el espacio de Fourier Tesis de Maestría en Ciencias Computacionales, Instituto Nacional de Astrofísica, Óptica y Electrónica.

## Algunos proyectos de tesis doctorales recientes o asociados a intereses vigentes (1/2)

- ▶ Silva Silverio, Analuz (a partir de 2022), “A Deep Learning Framework for the Detection of Baryon Acoustic Oscillations in the Sub-millimetre Galaxy Population” Tesis de Doctorado en Ciencias Computacionales, Instituto Nacional de Astrofísica, Óptica y Electrónica. (en progreso)

[https://www.researchgate.net/publication/363088021\\_A\\_Deep\\_Learning\\_Framework\\_for\\_the\\_Detection\\_of\\_Baryon\\_Acoustic\\_Oscillations\\_in\\_the\\_Sub-millimetre\\_Galaxy\\_Population\\_-\\_PhD\\_Progress\\_Report\\_first-half\\_year](https://www.researchgate.net/publication/363088021_A_Deep_Learning_Framework_for_the_Detection_of_Baryon_Acoustic_Oscillations_in_the_Sub-millimetre_Galaxy_Population_-_PhD_Progress_Report_first-half_year)

- ▶ González Viveros, Naara, (2021), Cuantificación de hemoglobina glicosilada y glucosa in vivo usando espectroscopia Raman y redes neuronales artificiales, Tesis de Doctorado en Óptica, Instituto Nacional de Astrofísica, Óptica y Electrónica.

<https://inaoe.repositorioinstitucional.mx/jspui/handle/1009/2419>

- ▶ Grande Barreto, J., (2020), Partial Volume Segmentation in Magnetic Resonance Imaging (MRI), Tesis de Doctorado en Ciencias Computacionales, Instituto Nacional de Astrofísica, Óptica y Electrónica.

<https://inaoe.repositorioinstitucional.mx/jspui/handle/1009/2113>

## Algunos proyectos de tesis doctorales recientes o asociados a intereses vigentes (2/2)

- ▶ Jiménez Guarneros, M. (2020) Classifiers based on Deep unsupervised domain adaptation for cross-subject EEG-based signal recognition, Tesis de Doctorado en Ciencias Computacionales, Instituto Nacional de Astrofísica, Óptica y Electrónica.

<https://ccc.inaoep.mx/archivos/CCC-17-002.pdf>

- ▶ Julián M. Luis Echeverri (a partir de 2023) Algoritmos para detectar anomalías en las mamas y en los miembros inferiores mediante imágenes térmicas , Tesis de Doctorado en Ciencias y Tecnologías Biomédicas, Instituto Nacional de Astrofísica, Óptica y Electrónica.

# Artículos del grupo relacionados a proyectos recientes



# Segmentación de MRI del cerebro

Med Biol Eng Comput

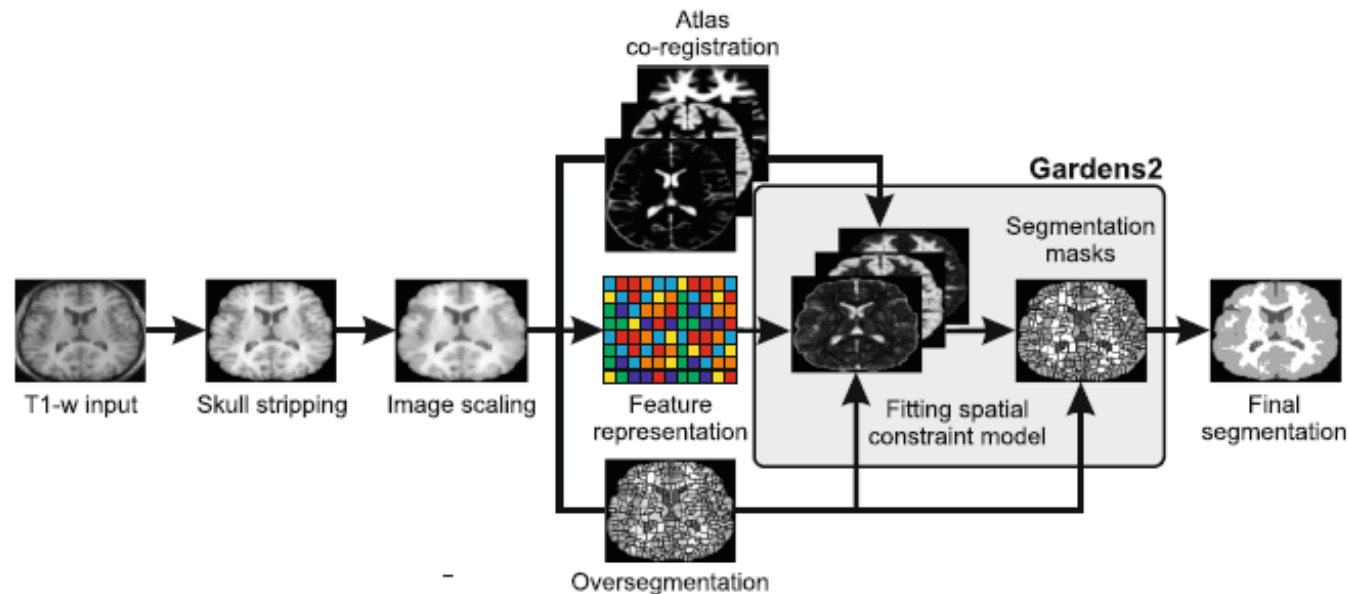


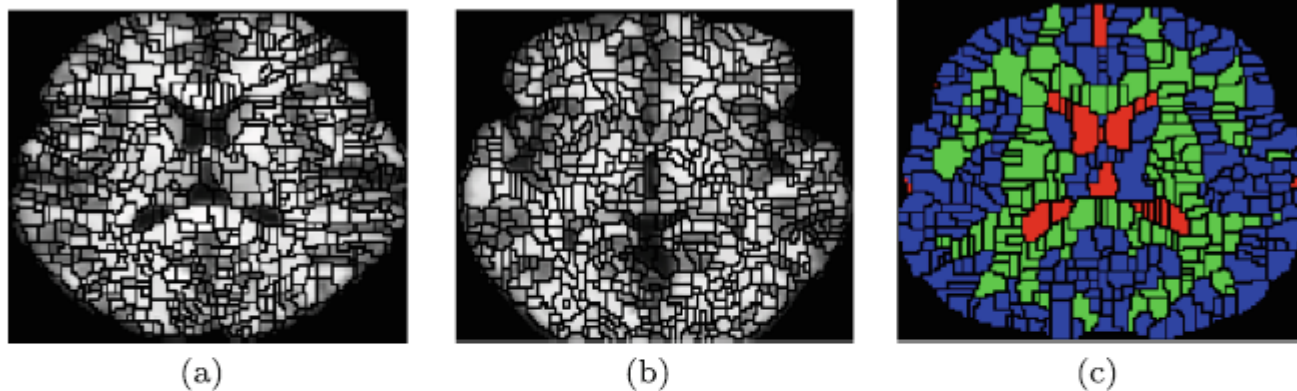
Fig. 1 Segmentation pipeline using Gardens2

Grande-Barreto, J., Gómez-Gil, P. Segmentation of MRI brain scans using spatial constraints and 3D features. *Med Biol Eng Comput* **58**, 3101–3112 (2020).

<https://doi.org/10.1007/s11517-020-02270-1>

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# Segmentación de MRI del cerebro



**Fig. 2** An example of segmentation using Garden2. **a** Input image: A brain MRI scan on grayscale. **b** Subregions generated by the oversegmentation (see Section 2.1.4); each subregion is drawn in a different false color. **c** Output image: segmentation of classes CSF (red), GM (blue), and WM (green)

# Base de datos biométricos producida en INAOE

Received June 23, 2021, accepted July 13, 2021, date of publication July 26, 2021, date of current version August 16, 2021.

Digital Object Identifier 10.1109/ACCESS.2021.3100035

## BIOMEX-DB: A Cognitive Audiovisual Dataset for Unimodal and Multimodal Biometric Systems

**JUAN CARLOS MORENO-RODRIGUEZ<sup>1</sup>**, (Graduate Student Member, IEEE),  
**JUAN CARLOS ATENCO-VAZQUEZ<sup>1</sup>**,  
**JUAN MANUEL RAMIREZ-CORTES<sup>1</sup>**, (Senior Member, IEEE),  
**RENE ARECHIGA-MARTINEZ<sup>2</sup>**, **PILAR GOMEZ-GIL<sup>3</sup>**,  
**AND RIGOBERTO FONSECA-DELGADO<sup>4</sup>**

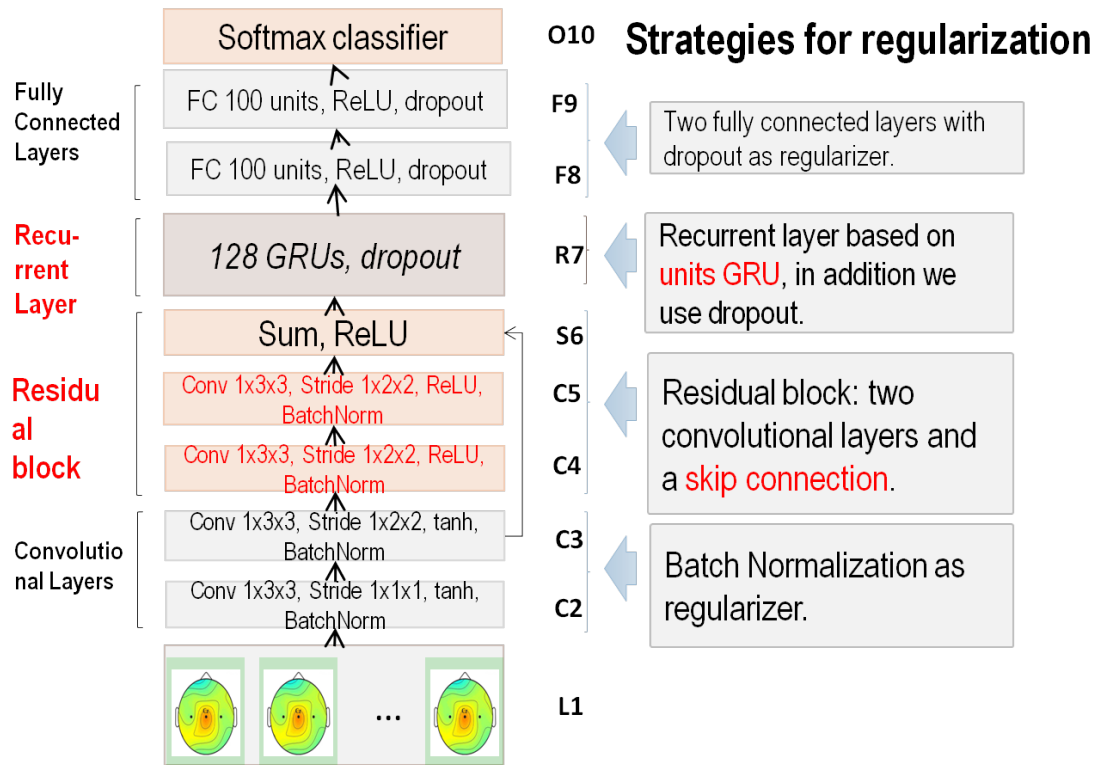
<sup>1</sup>Department of Electronics, National Institute of Astrophysics, Optics and Electronics, San Andrés Cholula 72840, Mexico

<sup>2</sup>Department of Electrical Engineering, New Mexico Tech, Socorro, NM 87801, USA

<sup>3</sup>Department of Computer Science, National Institute of Astrophysics, Optics and Electronics, San Andrés Cholula 72840, Mexico

# Uso de modelos profundos y adaptación de dominio para detección y retroalimentación basada en EEG

(C) Pilar Gómez-Gil, INAOE 2019



M. Jiménez-Guarneros and P. Gómez-Gil, "Cross-subject classification of cognitive loads using a recurrent-residual deep network," *2017 IEEE Symposium Series on Computational Intelligence (SSCI)*, 2017, pp. 1-7, doi: 10.1109/SSCI.2017.8280897.

# Adaptación de Dominio: reciclando EEG's para construir clasificadores de diferentes sujetos

752

---

## Algorithm 1: Training Algorithm.

---

**Inputs:**  $(\mathbf{X}_s, \mathbf{Y}_s)$  - a source labeled dataset;  $(\mathbf{X}_t)$  - a target unlabeled dataset;  $\lambda$  - a weighted factor.

**Output:**  $G(\cdot; \theta_t)$  - a trained CDA neural network model

- 1: Initialize  $\theta_s$  with random values.
- 2: **repeat**
- 3: Update  $\theta_s$  using gradient descent:

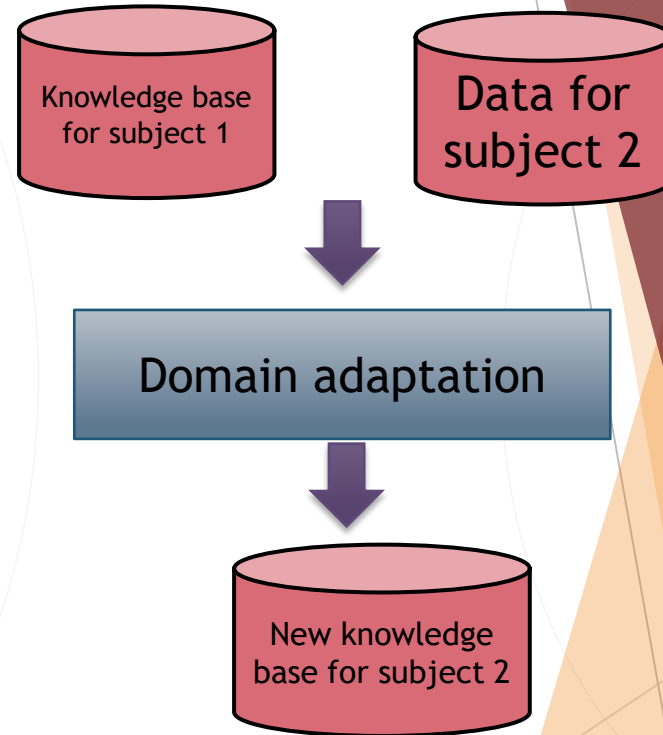
$$\nabla_{\theta_s} [-\mathbb{E}_{(\mathbf{X}_s, \mathbf{Y}_s)} \sum_{k=1}^K \mathbf{1}_{k=\mathbf{Y}_s} \log G_S(\mathbf{X}_s)] \quad (4)$$

- 4: **until** convergence
- 5: Set  $\theta_t = \theta_s$ .
- 6: **repeat**
- 7: Update  $\theta_t$  using the gradient descent:

$$\nabla_{\theta_t} [\lambda \cdot \mathbb{E}_{\mathbf{X}_s, \mathbf{X}_t} \mathcal{L}_{\text{MMD}}(G_s(\mathbf{X}_s), G_t(\mathbf{X}_t))] \quad (5)$$

where  $\mathcal{L}_{\text{MMD}}$  is defined in Eq. (2).

- 8: **until** convergence
  - 10: **return**  $G_t(\cdot; \theta_t)$
- 



M. Jiménez-Guarneros and P. Gómez-Gil, "Custom Domain Adaptation: A New Method for Cross-Subject, EEG-Based Cognitive Load Recognition," in *IEEE Signal Processing Letters*, vol. 27, pp. 750-754, 2020, doi: 10.1109/LSP.2020.2989663.

# Redes recurrentes wavelets para clasificacion de estados cerebrales asociados a epilepsia

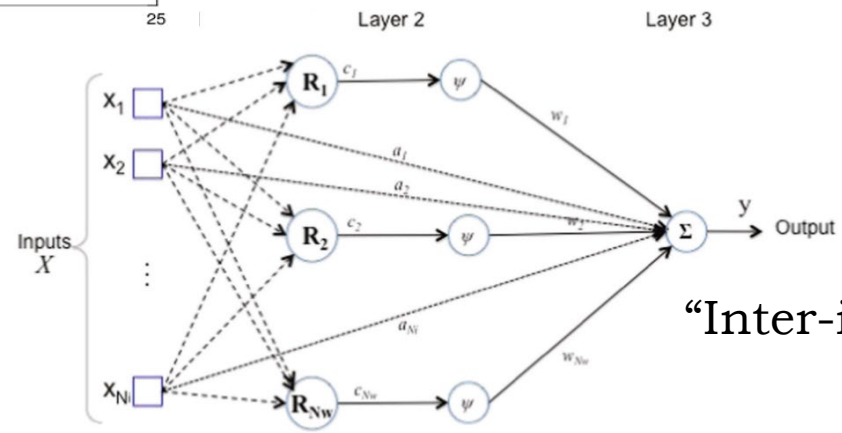
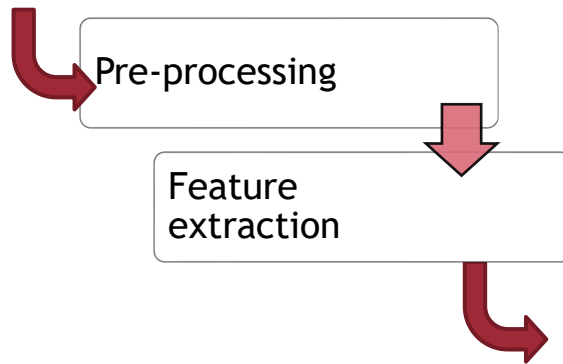
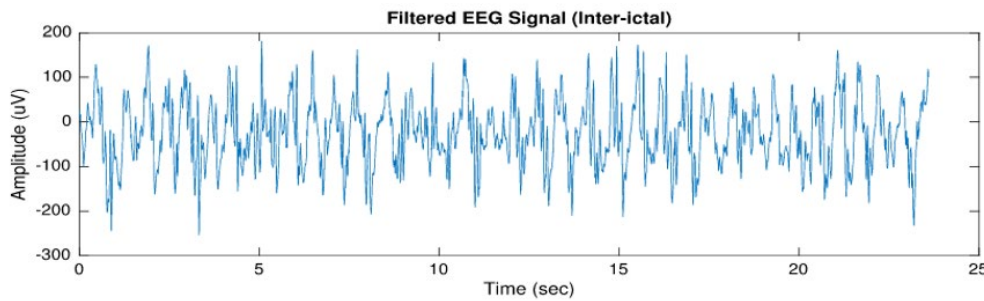


Figure 9 Proposed MRW-FFWNN structure [31].


Springer

“Inter-ictal sta

Juárez-Guerra, E., Alarcon-Aquino, V., Gómez-Gil, P. *et al.* A New Wavelet-Based Neural Network for Classification of Epileptic-Related States using EEG. *J Sign Process Syst* **92**, 187–211 (2020). <https://doi.org/10.1007/s11265-019-01456-7>



# Quantification of glycated hemoglobin and glucose in vivo using Raman spectroscopy and artificial neural networks

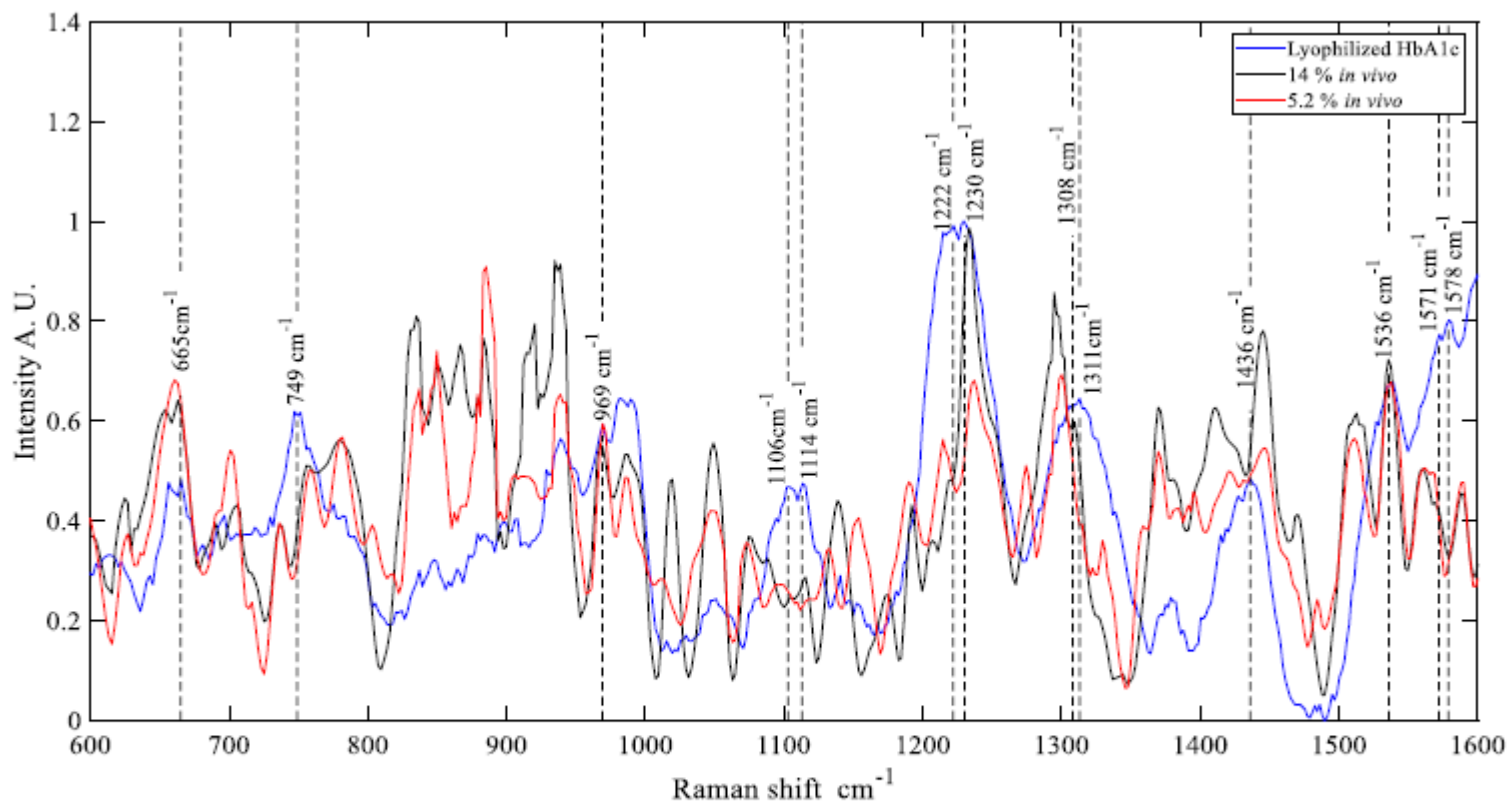
Naara González-Viveros<sup>1</sup> · Jorge Castro-Ramos<sup>1</sup> · Pilar Gómez-Gil<sup>2</sup> · Hector Humberto Cerecedo-Núñez<sup>3</sup> · Francisco Gutiérrez-Delgado<sup>4</sup> · Enrique Torres-Rasgado<sup>5</sup> · Ricardo Pérez-Fuentes<sup>6</sup> · Jose L. Flores-Guerrero<sup>7</sup> 

Received: 23 June 2022 / Accepted: 14 August 2022  
© The Author(s) 2022

## Abstract

Undiagnosed type 2 diabetes (T2D) remains a major public health concern. The global estimation of undiagnosed diabetes is about 46%, being this situation more critical in developing countries. Therefore, we proposed a non-invasive method to quantify glycated hemoglobin (HbA1c) and glucose in vivo. We developed a technique based on Raman spectroscopy, RReliefF as a feature selection method, and regression based on feed-forward artificial neural networks (FFNN). The spectra were obtained from the forearm, wrist, and index finger of 46 individuals. The use of FFNN allowed us to achieve an error in the predictive model of 0.69% for HbA1c and 30.12 mg/dL for glucose. Patients were classified according to HbA1c values into three categories: healthy, prediabetes, and T2D. The proposed method obtained a specificity and sensitivity of 87.50% and 80.77%, respectively. This work demonstrates the benefit of using artificial neural networks and feature selection techniques to enhance Raman spectra processing to determine glycated hemoglobin and glucose in patients with undiagnosed T2D.

<https://rdcu.be/c6fSu>



**Fig. 1** Raman spectra of lyophilized human HbA1c compared with the highest and lowest percentage of HbA1c in vivo measurements in the region of the wrist and their respective peaks



## Bi-dimensional representation of EEGs for BCI classification using CNN architectures

Edgar Hernández-González<sup>1</sup>, Pilar Gómez-Gil<sup>1</sup>, Erik Bojorges-Valdez<sup>2</sup>, Manuel Ramírez-Cortés<sup>3</sup>

**Abstract**—An important challenge when designing Brain Computer Interfaces (BCI) is to create a pipeline (signal conditioning, feature extraction and classification) requiring minimal parameter adjustments for each subject and each run. On the other hand, Convolutional Neural Networks (CNN) have shown outstanding to automatically extract features from images, which may help when distribution of input data is unknown and irregular. To obtain full benefits of a CNN, we propose two meaningful image representations built from multi-channel EEG signals. Images are built from spectrograms and scalograms. We evaluated two kinds of classifiers: one based on a CNN-2D and the other built using a CNN-2D combined with a LSTM. Our experiments showed that this pipeline allows to use the same channels and architectures for all subjects, getting competitive accuracy using different datasets:  $71.3 \pm 11.9\%$  for BCI IV-2a (four classes);  $80.7 \pm 11.8\%$  for BCI IV-2a (two classes);  $73.8 \pm 12.1\%$  for BCI IV-2b;  $83.6 \pm 1.0\%$  for BCI II-III and  $82.10\% \pm 6.9\%$  for a private database based on mental calculation.

**Keywords:** 2D signal representation, Convolutional Neural Networks (CNN), Long Short Term Memory (LSTM), Short Time Fourier Transform (STFT), Continuous Wavelet Trans.

called Discriminative Filter Bank Common Spatial Pattern (DFBCSP), which is a modification of the Filter Bank Common Spatial Pattern (FBCSP). This model looks for enhancing those frequency bands that most discriminate among mental activities; features were classified using two CNNs, with monolithic and modular structures respectively. Xu and collaborators [5] presented a model based on scalogram estimation of EEG, using Wavelet transforms at the C3 and C4 channels and combining them in a single image as input for a CNN. Tabar and Halici [6] used *STFT* to extract features from EEG signals classified with a CNN-1D followed by a Stacked Auto Encoder (SAE). However, all of these models required to define the CNN's hyper-parameters for each new set of data subjects being used.

In this paper, we present a simple but robust design of an image representation of EEG segments, using a combination of a CNN layer with a long-short term memory network (LSTM) and a fully connected (FC) network. The main

<https://ieeexplore.ieee.org/abstract/document/9629958>

TABLE V: Hyper-parameters of the *CNN-2D* and *CNN-2D + LSTM* networks.

Dataset	<i>IV-2a</i>	<i>IV-2a</i>	<i>IV-2b</i>	<i>IV-2b</i>	<i>II-III</i>	<i>II-III</i>	<i>MC</i>	<i>MC</i>
Repre	<i>STFT</i>	<i>CWT</i>	<i>STFT</i>	<i>CWT</i>	<i>STFT</i>	<i>CWT</i>	<i>STFT</i>	<i>CWT</i>
Input (a)	990x31	495x500	135x31	67x500	90x17	90x384	1440x27	720x672
<i>CNN-2D</i> (b)	16@3x3	16@3x3	4@3x3	8@3x3	64@3x3	8@3x3	2@3x3	8@15x3
Dense ( <i>CNN-2D</i> ) (d)	128	128	32	16	256	128	16	32
LSTM (c)	8	32	4	8	32	16	4	8
Dense (LSTM) (d)	128	256	32	16	256	128	16	32

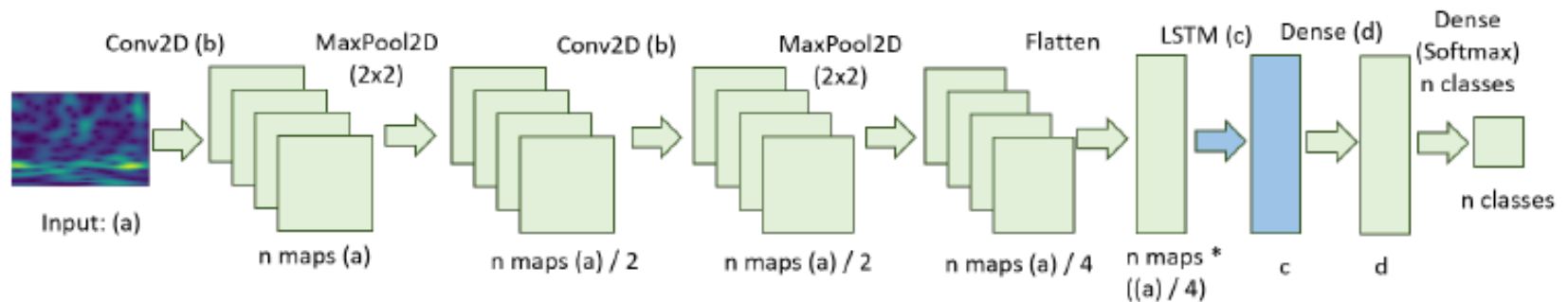


Fig. 1: Proposed architecture, *CNN-2D* (green network) and *CNN-2D + LSTM* (green network plus blue network).

Hernández-González, Edgar, et al. "Bi-dimensional representation of EEGs for BCI classification using CNN architectures." *2021 43rd Annual International Conference of the IEEE Engineering in Medicine & Biology Society (EMBC)*. IEEE, 2021.

# Estimación de concentraciones de azúcar

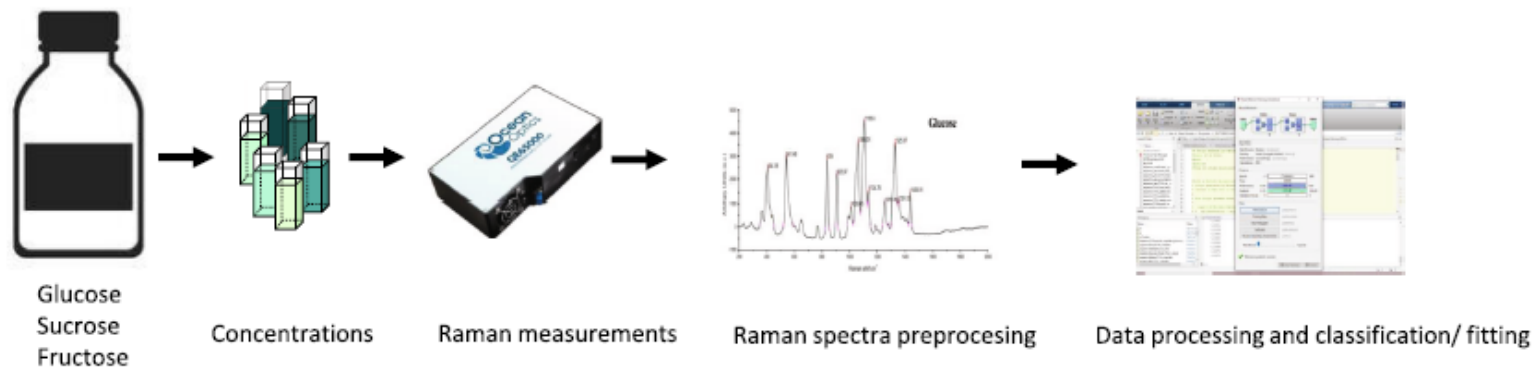
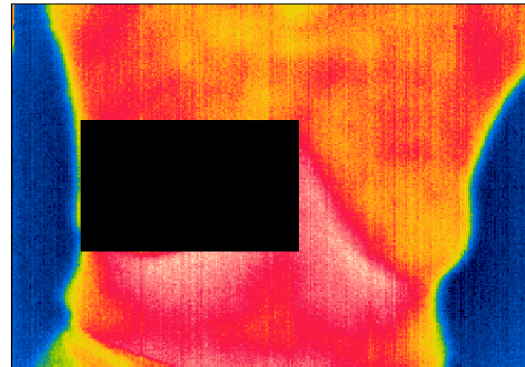
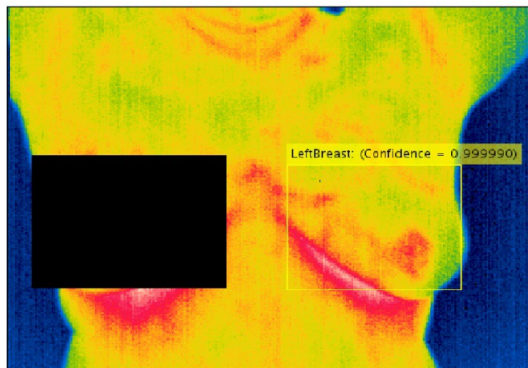
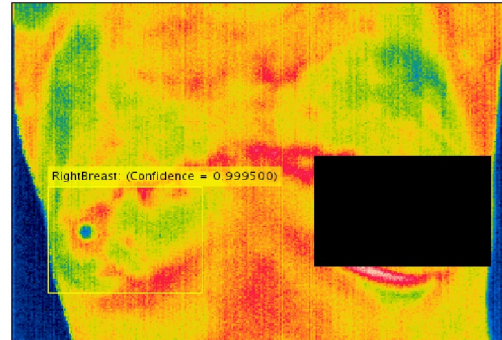
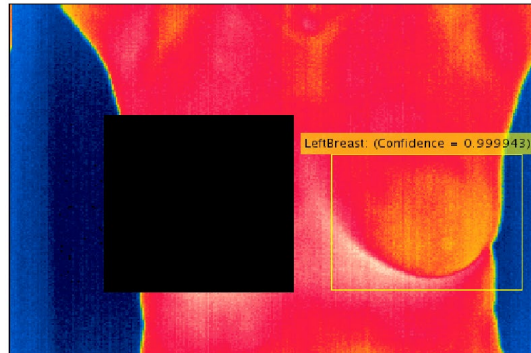


Fig. 1. Experimental setup and data analysis.

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N. González-Viveros, P. Gómez-Gil, J. Castro-Ramos, H.H. Cerecedo-Núñez, "On the estimation of sugars concentrations using Raman spectroscopy and artificial neural networks" *Food Chemistry*, (352), 129375, 2021, <https://doi.org/10.1016/j.foodchem.2021.129375>.

# Ejemplos de detección automática de la región mamaria en tomografías usando R-CNN



\\Eval\_Pru\_Frontal\_L2Regularization(0004)\\Eval\_Pru\_Frontal2C1

Gomez-Gil P., Reynoso-Armenta D., Castro-Ramos J., Ramirez-Cortes J.M., Alarcon-Aquino V. (2020) Segmentation and Classification of Noisy Thermographic Images as an Aid for Identifying Risk Levels of Breast Cancer. In: Castillo O., Melin P., Kacprzyk J. (eds) Studies in Computational Intelligence, vol 862. Springer, Cham. [https://doi.org/10.1007/978-3-030-35445-9\\_21](https://doi.org/10.1007/978-3-030-35445-9_21)

Si te interesa hacer tesis de licenciatura, maestría o doctorado relacionada a alguno de estos proyectos, manda un correo a [pgomez@inaoep.mx](mailto:pgomez@inaoep.mx) para mayor información...



# GRACIAS POR SU ATENCIÓN!!

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